SECTION 2

Physical and Chemical Data

PERRY'S CHEMICAL ENGINEERS' HANDBOOK

8TH EDITION

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Section 2

Physical and Chemical Data*

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GENERAL REFERENCES

Considerations of reader interest, space availability, the system or systems of units employed, copyright considerations, etc., have all influenced the revision of material in previous editions for the present edition. Reference is made at numerous places to various specialized works and, when appropriate, to more general works. A listing of general works may be useful to readers in need of further information.

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PHYSICAL PROPERTIES OF PURE SUBSTANCES

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds*

Abbreviations Used in the Table

a., acid
A., specific gravity with reference to air = 1
abs., absolute
ac., acetic acid
act., acetone
al., 95 percent ethyl alcohol
alk, alkali (*i.e.,* aq. NaOH or KOH)
am., amyl (C_5H_{11})
amor., amorphous
anh., anhydrous
aq., aqueous or water
aq. reg., aqua regia
atm., atmosphere or 760 mm. of mercury pressure
bk., black
brn., brown
bz., benzene
c., cold
cb., cubic
cc, cubic centimeter
chl., chloroform
col., colorless or white
conc., concentrated
cr., crystals or crystalline
d., decomposes
D., specific gravity with reference to hydrogen = 1
d. 50, decomposes at 50°C; 50 d., melts at 50°C with decomposition
delq., deliquescent
dil., dilute
dk., dark
eff., effloresces or efflorescent
et., ethyl ether
expl., explodes
gel., gelatinous
gly., glycerol (glycerin)
gn., green
h., hot
hex., hexagonal
hyg., hygroscopic
i., insoluble
ign., ignites
lq., liquid
lt., light
m. al., methyl alcohol
mn., monoclinic
nd., needles
NH_3, liquid ammonia
NH_4OH, ammonium hydroxide solution
oct., octahedral
or., orange
pd., powder
pl., plates
pr., prisms or prismatic
pyr., pyridine
rhb., rhombic (orthorhombic)
s., soluble
satd., saturated
sl., slightly
soln., solution
subl., sublimes
sulf., sulfides
tart. a., tartaric acid
tet., tetragonal
tr., transition
tri., triclinic
trig., trigonal
v., very
vac., in vacuo
vl., violet
volt., volatile or volatilizes
wh., white
yel., yellow
∞, soluble in all proportions
<, less than
>, greater than
42±, about or near 42
$-3H_2O$, 100, loses 3 moles of water per formula weight at 100°C

Formula weights are based upon the International Atomic Weights in "Atomic Weights of the Elements 2001," *Pure Appl. Chem.,* **75,** 1107, 2003, and are computed to the nearest hundredth.

Refractive index, where given for a uniaxial crystal, is for the ordinary (ω) ray; where given for a biaxial crystal, the index given is for the median (β) value. Unless otherwise specified, the index is given for the sodium D-line (λ = 589.3 mμ).

Specific gravity values are given at room temperatures (15 to 20 °C) unless otherwise indicated by the small figures which follow the value: thus, "5.6 $^{18°}_{4}$" indicates a specific gravity of 5.6 for the substance at 18 °C referred to water at 4 °C. In this table the values for the specific gravity of gases are given with reference to air (A) = 1, or hydrogen (D) = 1.

Melting point is recorded in a certain case as "82 d." and in some other case as "d. 82," the distinction being made in this manner to indicate that the former is a melting point with decomposition at 82°C, while in the latter decomposition only occurs at 82 °C. Where a value such as "$-2H_2O$, 82" is given it indicates loss of 2 moles of water per formula weight of the compound at a temperature of 82 °C.

Boiling point is given at atmospheric pressure (760 mm. of mercury) unless otherwise indicated; thus, "$82^{15\ mm.}$" indicates the boiling point is 82°C when the pressure is 15 mm.

Solubility is given in parts by weight (of the formula shown at the extreme left) per 100 parts by weight of the solvent; the small superscript indicates the temperature. In the case of gases the solubility is often expressed in some manner as "5^{10} cc" which indicates that at 10 °C, 5 cc. of the gas are soluble in 100 g of the solvent. The symbols of the common mineral acids: H_2SO_4, HNO_3, HCl, etc., represent dilute aqueous solutions of these acids. See also special tables on Solubility.

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Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Aluminum	Al	26.98	silv., cb.	$2.70^{20°}$	660	2056	i.	i.	s. HCl, H_2SO_4, alk.
acetate, normal	$Al(C_2H_3O_2)_3$	204.11	wh. pd.		d. 200		s.	d.	
acetate, basic	$Al(OH)(C_2H_3O_2)_2$	162.08	wh., amor.		d.		i.		s.a.; i. NH_4 salts
bromide	$AlBr_3$	266.69	trig.	$3.01^{\frac{25°}{4}}$	97.5	268	s.		s.al., act., CS_2
bromide	$AlBr_3 \cdot 6H_2O$	374.78	col., delq. cr.		d. 100		s.	s.	s. al., CS_2
carbide	Al_4C_3	143.96	yel., hex., 2.70	2.95	d. >2200		d. to CH_4		s. a.; i. act.
chloride	$AlCl_3$	133.34	wh., delq., hex.	$2.44^{\frac{25°}{4}}$	$194^{5.2atm.}$	182.7^{752mm}; subl. 178	$69.87^{15°}$	s. d.	s. et., chl., CCl_4; i. bz.
chloride	$AlCl_3 \cdot 6H_2O$	241.43	col., delq., trig., 1.560				400	v. s.	50 al.; s. et.
fluoride (fluellite)	$AlF_3 \cdot H_2O$	101.99	col., rhb., 1.490	2.17	d.		sl. s.		
fluoride	$Al_2F_6 \cdot 7H_2O$	294.06	wh., cr. pd.		$-4H_2O$, 120	$-6H_2O$, 250	i.	sl. s.	
hydroxide	$Al(OH)_3$	78.00	wh., mn.	2.42	$-2H_2O$, 300		$0.000104^{18°}$	i.	s. a., alk.; i. a.
nitrate	$Al(NO_3)_3 \cdot 9H_2O$	375.13	rhb., delq.		73	d. 134	v. s.	v. s. d.	s. al., CS_2
nitride	Al_2N_2	81.98	yel., hex.	$3.05^{\frac{25°}{4}}$	$2150^{4atm.}$	d. >1400	d. slowly		s. alk. d.
oxide	Al_2O_3	101.96	col., hex., 1.67–8	3.99	1999 to 2032		i.	i.	v. sl. s. a., alk.
oxide (corundum)	Al_2O_3	101.96	wh., trig., 1.768	4.00	1999 to 2032	2210	i.	i.	v. sl. s. a., alk.
phosphate	$AlPO_4$	121.95	col., hex.	2.59			i.	i.	s. a., alk.; i. ac.

*By N. A. Lange, Ph.D., Handbook Publishers, Inc., Sandusky, Ohio. Abridged from table of Physical Constants of Inorganic Compounds in *Lange's Handbook of Chemistry.*

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds (*Continued*)

Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Aluminum (*Cont.*)									
potassium silicate (muscovite)	$3Al_2O_3 \cdot K_2O \cdot 6SiO_2 \cdot 2H_2O$	796.61	mn., 1.590	2.9	d.		i.		
potassium silicate (orthoclase)	$Al_2O_3 \cdot K_2O \cdot 6SiO_2$	556.66	col., mn., 1.524	2.56	1450 (1150)		i.		
Aluminum potassium tartrate	$AlK(C_4H_4O_6)_2$	362.22	col.				s.	s.	
sodium fluoride (cryolite)	$AlF_3 \cdot 3NaF$	209.94	wh., mn., 1.3389	2.90	1000		sl. s.		i. HCl
sodium silicate	$Al_2O_3 \cdot Na_2O \cdot 6SiO_2$	524.44	col., tri., 1.529	2.61	1100		i.	i.	d. a.
sulfate	$Al_2(SO_4)_3$	342.15	wh. cr.	2.71	d. 770		$31.3^{0°}$	$89^{100°}$	
Alum, ammonium (tschermigite)	$Al_2(SO_4)_3 \cdot (NH_4)_2SO_4 \cdot 24H_2O$	906.66	col., oct., 1.4594	$1.64\ \frac{20°}{4}$	93.5	$-20H_2O$, 120; $-24H_2O$, 200	$3.9^{0°}$	∞ 100°	i. al.
ammonium chrome	$Cr_2(SO_4)_3 \cdot (NH_4)_2SO_4 \cdot 24H_2O$	956.69	gn. or vl., oct., 1.4842	1.72	100 d.		$21.2^{25°}$		s. al.
ammonium iron	$Fe_2(SO_4)_3 \cdot (NH_4)_2SO_4 \cdot 24H_2O$	964.38	vl., oct., 1.485	1.71	40		$124^{25°}$		i. al.
potassium (kalinite)	$Al_2(SO_4)_3 \cdot K_2SO_4 \cdot 24H_2O$	948.78	col., mn., 1.4564	$1.76\ \frac{26°}{4}$	92	$-18H_2O$, 64.5	$5.7^{0°}$	$\infty^{93°}$	
potassium chrome	$Cr_2(SO_4)_3 \cdot K_2SO_4 \cdot 24H_2O$	998.81	red or gn., cb., 1.4814	1.83	89		20	50	i. al.
sodium	$Al_2(SO_4)_3 \cdot Na_2SO_4 \cdot 24H_2O$	916.56	col., oct., 1.4388	$1.675\ \frac{20°}{4}$	61		$106.4^{0°}$	$121.7^{45°}$	i. al.
Ammonia†	NH_3	17.03	col. gas, 1.325 (lq.)	$0.817^{-79°}$ 0.5971 (A)	−77.7	−33.4	$89.9^{0°}$	$7.4^{96°}$	$14.8^{20°}$ al.; s. et.
Ammonium acetate	$NH_4C_2H_3O_2$	77.08	wh., hyg. cr.	1.073	114	d.	$148^{4°}$		s. al.; sl. s. act.
auricyanide	$NH_4CN \cdot Au(CN)_3 \cdot H_2O$	337.09	pl.		d. 200		s.	v. s.	i. al.
bicarbonate	NH_4HCO_3	79.06	mn. or rhb., 1.5358	1.573	d. 35–60		$11.9^{0°}$	$27^{30°}$	i. al.
bromide	NH_4Br	97.94	col., cb., 1.7108	$2.327\ \frac{15°}{4}$	subl. 542		$68^{10°}$	$145.6^{100°}$	s. al., et., act.
carbonate	$(NH_4)_2CO_3 \cdot H_2O$	114.10	col. pl.		d. 58		$100^{15°}$		i. al., CS_2, NH_3
carbonate, carbamate	$NH_4HCO_3 \cdot NH_2CO_2NH_4$‡	157.13	wh. cr.		subl.		$25^{15°}$	$67^{65°}$	
carbonate, sesqui-	$(NH_4)_2CO_3 \cdot 2NH_4HCO_3 \cdot H_2O$	272.21	wh.		d.		$20^{15°}$	$50^{49°}$	
chloride (salammoniac)	NH_4Cl	53.49	wh., cb., 1.639, 1.6426	$1.53^{17°}$	d. 350	subl. 520	$29.4^{0°}$	$77.3^{100°}$	s. NH_3; sl. s. al., m. al.
chloroplatinate	$(NH_4)_2PtCl_6$	443.87	yel., cb.	3.065	d.		$0.7^{15°}$	$1.25^{100°}$	0.005 al.
chloroplatinite	$(NH_4)_2PtCl_4$	372.97	tet.		d.		s.	v. s.	
chlorostannate	$(NH_4)_2SnCl_6$	367.50	pink., cb.	2.4			$33.3^{15°}$		
chromate	$(NH_4)_2CrO_4$	152.07	yel., mn.	$1.917^{12°}$	d. 180		$40.5^{30°}$	d.	sl. s. act., NH_3; i. al.
cyanide	NH_4CN	44.06	col., cb.	$0.79^{100°}$ (A)	36		s.	v. s.	s. al.
dichromate	$(NH_4)_2Cr_2O_7$	252.06	or., mn.	2.15	d. 185		$47.2^{30°}$	v. s.	s. al.; i. act.
ferrocyanide	$(NH_4)_4Fe(CN)_6 \cdot 6H_2O$	392.19	mn.		d.		s.		i. al.
fluoride	NH_4F	37.04	wh., hex.				v. s.	d.	s. al.; i. NH_3
fluoride, acid	$NH_4F \cdot HF$	57.04	wh., rhb., 1.390	$2.21\ \frac{12°}{12}$			v. s.		
formate	HCO_2NH_4	63.06	col., mn., delq.	1.266	114–116	d. 180; subl. in vac.	$102^{0°}$	$531^{80°}$	s. al.
hydrosulfide	NH_4HS	51.11	col., rhb.		d.	subl. 120	v. s.		s. al.
hydroxide	NH_4OH	35.05	in soln. only				s.		
molybdate	$(NH_4)_2MoO_4$	196.01	mn.	2.27	d.		d.	d.	i. al., NH_3
molybdate, hepta-	$(NH_4)_6Mo_7O_{24} \cdot 4H_2O$‡	1235.86	col., mn.				$44^{25°}$		i. al.
nitrate (α), stable −16° to 32°	NH_4NO_3	80.04	col., tet., 1.611	$1.66\ \frac{25°}{4}$	169.6	d. 210	$118.3^{0°}$	$241.8^{30°}$	
nitrate (β), stable 32° to 84°	NH_4NO_3	80.04	col., rhb. or mn.	$1.725\ \frac{25°}{4}$		d. 210	$365.8^{35°}$	$580^{80°}$	$3.8^{20°}$ al., $17.1^{20°}$ m. al.; v. s. NH_3
nitrite	NH_4NO_2	64.04	wh. nd.	1.69	expl.		s.	d.	s. al.
osmochloride	$(NH_4)_2OsCl_6$	439.02	cb.	$2.93\ \frac{20°}{4}$					
oxalate	$(NH_4)_2C_2O_4 \cdot H_2O$	142.11	col., rhb.	1.501			$2.5^{0°}$	$11.8^{50°}$	sl. s. al.; i. NH_3
oxalate, acid	$NH_4HC_2O_4 \cdot H_2O$	125.08	col., trimetric	1.556	d.		s.		
perchlorate	NH_4ClO_4	117.49	col., rhb., 1.4833	1.95	d.		$10.9^{0°}$	$46.9^{100°}$	$2^{20°}$ al.; s. act.; i. et.
persulfate	$(NH_4)_2S_2O_8$	228.20	wh., mn., 1.5016	1.98	d. 120		$58.2^{0°}$	d.	
phosphate, monobasic	$NH_4H_2PO_4$	115.03	col., tet., 1.5246	$1.803\ \frac{19°}{4}$			$22.7^{0°}$	$173.2^{100°}$	i. ac.

phosphate, dibasic	$(NH_4)_2HPO_4$	132.06	col., mn., 1.53	1.619			$131^{15°}$		i. act.
phosphate, meta-	$(NH_4)_4P_4O_{12}$	388.04	col., mn.	2.21			s.		
Ammonium phosphomolybdate	$(NH_4)_3PO_4 \cdot 12MoO_3 \cdot 3H_2O$ (?)	1930.39	yel.		d.		$0.03^{15°}$	i.	s. alk.; i. al., HNO_3
silicofluoride	$(NH_4)_2SiF_6$	178.15	cb., 1.3696	2.01		subl.	$18.5^{17.5°}$	55.5	s. al.; i. act.
sulfamate	$NH_4 \cdot SO_3NH_2$	114.12	col. pl.		132	d. 160	$134^{0°}$	$357^{50°}$	
sulfate (mascagnite)	$(NH_4)_2SO_4$	132.14	col., rhb., 1.5230	$1.769\frac{20°}{4}$	235 d.		$70.6^{0°}$	$103.3^{100°}$	i. al., act., CS_2
sulfate, acid	NH_4HSO_4	115.11	col., rhb., 1.480	1.78	146.9	490	100		v. sl. s. al.; i. act.
sulfide	$(NH_4)_2S$	68.14	yel.-wh.		d.		v. s.		$120^{25°}$ NH_3
sulfide, penta-	$(NH_4)_2S_5$	196.40	or.-red pr.				s.		
sulfite	$(NH_4)_2SO_3 \cdot H_2O$	134.16	col., mn.	1.41	d.		$100^{12°}$		i. al., act.
sulfite, acid	NH_4HSO_3	99.11	rhb.	$2.03\frac{12°}{4}$	d.		s.		
tartrate	$(NH_4)_2C_4H_4O_6$	184.15	col., mn.	1.60	d.		$45^{0°}$	$87^{60°}$	sl. s. al.
thiocyanate	NH_4CNS	76.12	col., mn., 1.685±	1.305	149.6	d. 170	$120^{0°}$	$170^{20°}$	s. al., act., NH_3, SO_2
vanadate, meta-	NH_4VO_3	116.98	col. cr.	2.326	d.		$0.44^{18°}$	$3.05^{70°}$	i. al., NH_4Cl
Antimony	Sb	121.76	tin wh., trig.	$6.684^{25°}$	630.5	1380	i.	i.	s. aq. reg., h. conc. H_2SO_4
chloride, tri- (butter of antimony)*	$SbCl_3$	228.12	col., rhb., delq.	$3.14\frac{20°}{4}$	73.4	220.2	$601.6^{0°}$	$\infty^{72°}$	s. al., HCl, HBr, $H_3C_4H_4O_6$
oxide, tri- (valentinite)	Sb_2O_3	291.52	rhb., 2.35	5.67	656	1570	v. sl. s.	sl. s.	s. HCl, KOH, $H_2C_4H_4O_6$
oxide, tri- (senarmontite)	Sb_2O_3	291.52	cb., 2.087	5.2	652				
sulfide, tri- (stibnite)	Sb_2S_3	339.72	bk., rhb., 4.046	4.64	550		$0.00017^{18°}$	d.	s. HCl; alk., NH_4HS, K_2S; i. ac.
sulfide, penta-	Sb_2S_5	403.85	golden	$4.120^{0°}$	–2S, 135		i.	i.	s. HCl, alk., NH_4HS
telluride, tri-	Sb_2Te_3	626.32	gray		629				
Antimonyl potassium tartrate (tartar emetic)	$(SbO)KC_4H_4O_6 \cdot ½H_2O$	333.94	wh., rhb.	2.60	$–½H_2O$, 100		$5.26^{8.7°}$	$35.7^{100°}$	s. gly.; i. al.
sulfate, normal	$(SbO)_2SO_4$	371.58	wh. pd.	4.89			d.	d.	
sulfate, basic	$(SbO)_2SO_4 \cdot Sb_2(OH)_4$	683.20	wh. pd.				i.	d.	$5.15^{15°}$ gly.
Argon	Ar	39.95	col. gas	$1.65^{-288°}$; $1.402^{-185.7°}$; 1.38 (A)	–189.2	–185.7	$5.6^{0°}$ cc	$2.23^{50°}$ cc	$24^{25°}$ cc al.
Arsenic (crystalline) (α)	As_4	299.69	met., hex.	$5.727^{14°}$	$814^{36atm.}$	subl. 615	i.	i.	s. HNO_3
Arsenic (black) (β)	As_4	299.69	bk., amor.	$4.7^{20°}$			i.	i.	s. HNO_3, aq. reg., aq. Cl_2, h. alk.
Arsenic (yellow)(γ)	As_4	299.69	yel., cb.	$2.0^{20°}$	d. 358				
acid, ortho-	$H_3AsO_4 \cdot ½H_2O$	150.95	col., hyg.	2.0–2.5	35.5	$–H_2O$, 160	16.7	50	s. alk.
acid, meta-	$HAsO_3$	123.93	wh., hyg.		d.		d. to form H_3AsO_4		
acid, pyro-	$H_4As_2O_7$	265.87	col.		d. 206		d. to form H_3AsO_4		
pentoxide	As_2O_5	229.84	wh., amor.	4.086		d.	$59.5^{0°}$	$76.7^{100°}$	s. alk., al.
sulfide, di- (realgar)	As_2S_2	213.97	red, mn., 2.68	(α)$3.506^{19°}$; (β)$3.254^{19°}$	(α)tr. 267; (β)307	565	i.	d.	s. K_2S, $NaHCO_3$
sulfide, penta-	As_2S_5	310.17	yel.			d. 500	$0.000136^{0°}$	i.	s. HNO_3, alk.
Arsenious chloride (butter of arsenic)	$AsCl_3$	181.28	oily lq.	lq. 2.163	–18	130	d.	d.	s. HCl, HBr, PCl_3
hydride (arsine)	AsH_3	77.95	col. gas	2.695 (A)	–113.5	–55; d. 230	20 cc	sl. s.	sl. s. alk.
oxide (arsenolite)	As_2O_3	197.84	col., cb., fibrous, 1.755	$3.865\frac{25°}{4}$	subl.		sl. s.	sl. s.	i. al., et.
oxide (claudetite)	As_2O_3	197.84	col., mn., 1.92	3.85	subl.		sl. s.	sl. s.	i. al., et.
oxide	As_2O_3	197.84	amor. or vitreous	3.738	315		$1.21^{0°}$	$2.93^{40°}$	s. HCl, alk., Na_2CO_3; i. al., et.
Auric chloride	$AuCl_3 \cdot 2H_2O$	339.36	or. cr.		d.		v. s.	v. s.	s. HCl, al., et.; sl. s. NH_3
cyanide	$Au(CN)_3 \cdot 6H_2O$	383.11			d. 50		v. s.	v. s.	s. al.
Aurous chloride	AuCl	232.42	yel. cr.	7.4	$AuCl_3$, 170	d. 290	d.	d.	s. HCl, HBr; d. al.
cyanide	AuCN	222.98	yel. cr.		d.		i.	i.	s. KCN; i. al., et.
Cf. also under *Gold*									
Barium	Ba	137.33	silv. met.	3.5	850	1140	d.	d.	s. a.; d. al.
acetate	$Ba(C_2H_3O_2)_2$	255.42	col.	2.468			$58.8^{0°}$	$75.0^{100°}$	
acetate	$Ba(C_2H_3O_2)_2 \cdot H_2O$	273.43	wh., tri. pr., 1.517	2.19	$–H_2O$, 41		$75^{30°}$(anh.)	$79^{40°}$(anh.)	i. al.
bromide	$BaBr_2$	297.14	col.	$4.781\frac{24°}{4}$	847	d.	$98^{0°}$	$149^{100°}$	v. s. m. al.; v. sl. s. act.

*Usually the solution.
†See special tables.
‡Usual commercial form.

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds (*Continued*)

Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Barium (*Cont.*)									
bromide	$BaBr_2 \cdot 2H_2O$	333.17	col., mn., 1.7266	3.69	$-2H_2O$, 100	d.	v. s.	v. s.	s. al.
carbonate (witherite)	$BaCO_3$	197.34	wh., rhb., 1.676	4.29	tr. 811 to α	d. 1450	$0.0022^{18°}$	$0.0065^{100°}$	s. a.; i. al.
carbonate (α)	$BaCO_3$	197.34	wh., hex.		tr. 982 to β				
carbonate (β)	$BaCO_3$	197.34	wh.		1740^{90atm}		$0.0022^{18°}$	$0.0065^{100°}$	s. a.; i. al.
Barium chlorate	$Ba(ClO_3)_2$	304.23	col.		414		$20.35^{0°}$	$84.8^{80°}$	
chlorate	$Ba(ClO_3)_2 \cdot H_2O$*	322.24	col., mn., 1.577	3.179	d. 120		s.	s.	sl. s. al., act.
chloride	$BaCl_2$	208.23	col., mn., 1.7361	$3.856\,\frac{24°}{4}$	tr. 925	1560	$31^{0°}$	$59^{100°}$	sl. s. HCl, HNO_3; i. al.
chloride	$BaCl_2$	208.23	col., cb.		962	1560			
chloride	$BaCl_2 \cdot 2H_2O$†	244.26	col., mn., 1.646	$3.097\,\frac{24°}{4}$	$-2H_2O$, 100		$39.3^{0°}$	$76.8^{100°}$	sl. s. HCl, HNO_3; i. al.
hydroxide	$Ba(OH)_2$	171.34	col., mn.	4.495			$1.67^{0°}$	$101.4^{80°}$	
hydroxide	$Ba(OH)_2 \cdot 8H_2O$	315.46	col., mn., 1.5017	$2.188^{16°}$	77.9	$-8H_2O$, 550	$5.6^{15°}$		v. sl. s. al.; i. et.
nitrate (nitrobarite)	$Ba(NO_3)_2$	261.34	col., cb., 1.572	$3.244^{28°}$	592	d.	$5.0^{0°}$	$34.2^{100°}$	sl. s. a.; i. al.
oxalate	BaC_2O_4	225.35	wh. cr.	2.658			$0.0016^{8°}$	$0.0024^{24°}$	s. a., NH_4Cl; i. al.
oxide	BaO	153.33	col., cb., 1.98	5.72	1923	2000±	$1.5^{0°}$	$90.8^{80°}$	s. HCl, HNO_3, abs. al.; i. NH_3, act.
peroxide	BaO_2*	169.33	gray or wh. pd.	4.958	–O, 800		v. sl. s.	d.	s. dil. a.; i. act.
peroxide	$BaO_2 \cdot 8H_2O$	313.45	pearly sc.		$-8H_2O$, 100		0.168	d.	s. dil. a.; i. al., et., act.
phosphate, monobasic	$BaH_4(PO_4)_2$	331.30	tri.	$2.9^{4°}$			d.	d.	s. a.
phosphate, dibasic	$BaHPO_4$	233.31	wh., rhb. nd., 1.635	$4.165^{15°}$			0.015		s. a., NH_4 salts
phosphate, tribasic	$Ba_3(PO_4)_2$	601.92	wh., cb.	$4.1^{16°}$			i.		s. a.
phosphate, pyro-	$Ba_2P_2O_7$	448.60	wh., rhb.	$3.9^{20°}$			0.01		s. a., NH_4 salts
silicofluoride	$BaSiF_6$	279.40	pr.	$4.279^{15°}$			$0.026^{17°}$	$0.09^{100°}$	sl. s. HCl, NH_4Cl; i. al.
sulfate (barite, barytes)	$BaSO_4$	233.39	col., rhb., 1.636	$4.499^{15°}$	1580 d.	tr. to mn. 1149	$0.000115^{0°}$	$0.000285^{30°}$	s. conc. H_2SO_4; 0.006, 3% HCl
sulfide, mono-	BaS	169.39	col., cb., 2.155	$4.25^{15°}$			d.	d.	d. HCl; i. al.
sulfide, tri-	BaS_3	233.52	yel.-gn.		d. 400		s.	s.	
sulfide, tetra-	$BaS_4 \cdot 2H_2O$	301.62	red, rhb.	$2.988^{20°}$	d. 200		$41^{15°}$	v. s.	i. al., CS_2
Beryllium (glucinum)	Be(Gl)	9.01	gray, met., hex.	1.816	1284	2767	i.	sl. s. d.	s. dil. a., alk.
Bismuth	Bi	208.98	silv. wh. or reddish, hex.	$9.80^{20°}$	271	1450	i.	i.	s. aq. reg., conc. H_2SO_4, HNO_3
carbonate, sub-	$Bi_2O_3 \cdot CO_2 \cdot H_2O$	527.98	wh. pd.	6.86	d.		i.	i.	s. a.
chloride, di-	$BiCl_2$(?)	279.89	bk. nd.	4.86	163	d. 300	d.		
chloride, tri-	$BiCl_3$*	315.34	wh. cr.	4.75	230	447	d.		s. al.
nitrate	$Bi(NO_3)_3 \cdot 5H_2O$	485.07	col., tri.	2.82	d. 30	$-5H_2O$, 80	d.		$42^{19°}$ act.; s. a.; i. al.
nitrate, sub-	$BiONO_3 \cdot H_2O$	305.00	hex. pl.	$4.928^{15°}$	d. 260		i.	i.	s. a.
oxide, tri-	Bi_2O_3	465.96	yel., rhb.	8.9	820	1900±	i.	i.	s. a.
oxide, tri-	Bi_2O_3	465.96	yel., tet.	8.55	860		i.	i.	s. a.
oxide, tri-	Bi_2O_3	465.96	yel., cb.	8.20	tr. 704		i.	i.	s. a.
oxychloride	BiOCl	260.43	wh., amor.	$7.72^{15°}$			sl. s.	sl. s.	s. a.; i. act., NH_3, $H_2C_4H_4O_6$
Boric acid	H_3BO_3	61.83	wh., tri.	$1.435^{15°}$	185 d.		$2.66^{0°}$	$40.2^{100°}$	$22.2^{20°}$ gly., $0.24^{25°}$ et.; s. al.
Boron	B	10.81	gray or bk., amor. or mn.	2.32	2300	2550	i.	i.	s. HNO_3; i. al.
carbide	B_4C	55.25	bk. cr.	2.54	2450	>3500	i.	i.	i. a.
oxide	B_2O_3	69.62	col. glass, 1.459	1.85	577	>1500	$1.1^{0°}$	$15.7^{100°}$	s. a., al., gly.
oxide (sassolite)	$B_2O_3 \cdot 3H_2O$	123.67	tri., 1.456	1.49	d.		sl. s.	s.	
Bromic acid	$HBrO_3$	128.91	col.; in soln. only		d. 100		v. s.	d.	
Bromine	Br_2	159.81	rhb., or red lq.	$3.119^{20°}$; 5.87 (A)	–7.2	58.78	$4.22^{0°}$	$3.13^{30°}$	s. al., et., alk., CS_2
hydrate	$Br_2 \cdot 10H_2O$	339.96	red, oct.		d. 6.8		s.		
Cadmium	Cd	112.41	silv. met., hex.	$8.65^{20°}$	320.9	767	i.	i.	s. a., NH_4NO_3
acetate	$Cd(C_2H_3O_2)_2$	230.50	col.	2.341	256	d.	v. s.		s. m. al.
acetate	$Cd(C_2H_3O_2)_2 \cdot 2H_2O$*	266.53	col., mn.	2.01	$-H_2O$, 130		v. s.		s. al.
carbonate	$CdCO_3$	172.42	wh., trig.	$4.258^{4°}$	d. <500		i.	i.	s. a., KCN, NH_4 salts; i. NH_3
chloride	$CdCl_2$	183.32	wh., cb.	$4.047\,\frac{25°}{4}$	568	960	$90^{0°}$	$147^{100°}$	$1.52^{15°}$ al.; i. et., act.

chloride	$CdCl_2 \cdot 2\frac{1}{2}H_2O$	228.36	col., mn., 1.6513	3.327	tr. 34		$168^{20°}$	$180^{100°}$	$2.05^{15°}$ m. al.
cyanide	$Cd(CN)_2$	164.45			d. >200		$0.0247^{18°}$		s. a.; NH_4OH, KCN
hydroxide	$Cd(OH)_2$	146.43	wh., trig.	$4.79\frac{15°}{4}$	d. 300		$0.00026^{25°}$		s. a., NH_4 salts; i. alk.
nitrate	$Cd(NO_3)_2$	236.42	col.		350		$109.7^{0°}$	$326^{59.5°}$	v. s. a.
nitrate	$Cd(NO_3)_2 \cdot 4H_2O$*	308.48	col. nd.	$2.455\frac{17°}{4}$	59.4	132	$215^{0°}$		s. al., NH_3; i. HNO_3
oxide	CdO	128.41	brn., cb.	8.15			i.	i.	s. a., NH_4 salts; i. alk.
oxide	CdO	128.41	brn., amor, 2.49	6.95	d. 900–1000		i.	i.	s. a., NH_4 salts; i. alk.
oxide, sub-	Cd_2O	240.82	gn., amor.	$8.192\frac{18°}{4}$	d.				d. a., alk.
Cadmium sulfate	$CdSO_4$	208.47	rhb.	$4.691\frac{24°}{4}$	1000		$76.5^{0°}$	$60.8^{100°}$	i.act., NH_3
sulfate	$CdSO_4 \cdot H_2O$	226.49	mn.	$3.786^{20°}$	tr. 108		s.	s.	
sulfate	$3CdSO_4 \cdot 8H_2O$*	769.54	col., mn., 1.565	3.09	tr. 41.5		$114.2^{0°}$	$127.6^{60°}$	i. al.
sulfate	$CdSO_4 \cdot 4H_2O$	280.53	col.	3.05			s.	s.	i. al.
sulfate	$CdSO_4 \cdot 7H_2O$	334.58	mn.	$2.48\frac{20°}{4}$	tr. 4		$350^{-5°}$		i. al.
sulfide (greenockite)	CdS	144.48	yel.-or., hex., 2.506	4.58	1750^{100atm}	subl. in N_2, 980	0.000001	Colloidal	s. a.; v. s. NH_4OH
Calcium	Ca	40.08	silv. met., cb.	$1.55^{20°}$	810	1200 ± 30	d.	d.	s, a.; sl. s. al.
acetate	$Ca(C_2H_2O_2)_2 \cdot H_2O$	176.18	wh. nd.		d.		$52^{0°}$	$45.5^{80°}$	sl. s. al.
aluminate	$Ca(AlO_2)_2$	158.04	col., rhb. or mn.	$3.67^{20°}$	1600		d.		s. HCl
aluminum silicate (anorthite)	$CaO \cdot Al_2O_3 \cdot 2SiO_2$	278.21	tri., 1.5832	2.765	1551				
arsenate	$Ca_3(AsO_4)_2$	398.07	wh. pd.				$0.013^{25°}$	i.	s. dil. a.
bromide	$CaBr_2$	199.89	delq. nd.	$3.353\frac{25°}{4}$	760	1810	$125^{0°}$	$312^{105°}$	s. al., act.; sl. s. NH_3
carbonate (aragonite)	$CaCO_3$	100.09	col., rhb., 1.6809	2.93	d. 825		$0.0012^{20°}$†	$0.002^{100°}$	s. a., NH_4Cl
carbonate (calcite)	$CaCO_3$	100.09	col., hex., 1.550	$2.711\frac{25°}{4}$	$1339^{103atm.}$		$0.0014^{25°}$	$0.002^{100°}$	s. a., NH_4Cl
chloride (hydrophilite)	$CaCl_2$*	110.98	wh., delq., cb, 1.52	$2.152\frac{15°}{4}$	772	>1600	$59.5^{0°}$	$347^{260°}$	s. al.
chloride	$CaCl_2 \cdot H_2O$	129.00	col., delq.				s.	s.	s. al.
chloride	$CaCl_2 \cdot 6H_2O$	219.08	col., trig., 1.417	$1.68^{17°}$	29.92	$-6H_2O$, 200	v. s.	v. s.	s. al.
citrate	$Ca_3(C_6H_5O_7)_2 \cdot 4H_2O$	570.49	col. nd.		$-2H_2O$, 130	$-4H_2O$, 185	$0.085^{18°}$	$0.096^{26°}$	$0.0065^{18°}$ al.
cyanamide	$CaCN_2$	80.10	col., rhombohedral				s. d.	d.	
ferrocyanide	$Ca_2Fe(CN)_6 \cdot 12H_2O$	508.29	yel., tri., 1.5818	1.7			s.	$150^{90°}$	i. al.
fluoride (fluorite)	CaF_2	78.07	wh., cb., 1.4339	$3.180^{20°}$	1330		$0.0016^{18°}$	$0.0017^{26°}$	sl. s. a.
formate	$Ca(HCO_2)_2$	130.11	col., rhb.	2.015	d.		$16.1^{0°}$	18.4^{100}	i. al., et.
hydride	CaH_2	42.09	wh. cr. or pd.	1.7	d. 675		d.		d. a.; i. bz.
hydroxide	$Ca(OH)_2$	74.09	col., hex., 1.574	2.2	$-H_2O$, 580		$0.185^{0°}$	$0.077^{100°}$	s. NH_4Cl
hypochlorite	$Ca(ClO)_2 \cdot 4H_2O$	215.04	wh., feathery cr.		d.		delq.; d.	d.	d. a.
hypophosphate	$Ca_2P_2O_6 \cdot 2H_2O$	274.13	granular		$-2H_2O$, 200		i.		s. HCl, $H_4P_2O_6$
lactate	$Ca(C_3H_5O_3)_2 \cdot 5H_2O$	308.29	col., eff.		$-3H_2O$, 100		10.5	∞	∞h. al.; i. et.
magnesium carbonate (dolomite)	$CaO \cdot MgO \cdot 2CO_2$	184.40	trig., 1.68174	2.872	d. 730–760		$0.032^{18°}$		
magnesium silicate (diopside)	$CaO \cdot MgO \cdot 2SiO_2$	216.55	wh., mn.	3.3	1391		i.	i.	
nitrate (nitrocalcite)	$Ca(NO_3)_2$	164.09	col., cb.	2.36	561		$102^{0°}$	$376^{151°}$	$14^{15°}$ al.; s. amyl al., NH_3
nitrate	$Ca(NO_3)_2 \cdot 4H_2O$*	236.15	col., mn., 1.498	1.82	42.7		$266^{0°}$	v. s.	
nitride	Ca_3N_2	148.25	brn. cr.	$2.63^{17°}$	900		d.	d.	s. dil. a.; i. abs. al.
nitrite	$Ca(NO_2)_2 \cdot H_2O$	150.10	delq., hex.	$2.23^{34°}$			$77^{0°}$	$417^{90°}$	s. 90% al.
oxalate	CaC_2O_4	128.10	col., cb.	$2.2^{4°}$	d.		$0.00067^{13°}$	$0.0014^{95°}$	s. a.; i. ac.
oxalate	$CaC_2O_4 \cdot H_2O$	146.11	col.	2.2	$-H_2O$, 200		i.	i.	s. a.; i. ac
oxide	CaO	56.08	col., cb., 1.837	3.32	2570	2850	Forms $Ca(OH)_2$		s. a.; i. al.
peroxide	$CaO_2 \cdot 8H_2O$	216.20	pearly, tet.		$-8H_2O$, 100	expl. 275	sl. s.	d.	s. a. d.; i. al., et.
phosphate, monobasic	$CaH_4(PO_4)_2 \cdot H_2O$	252.07	wh., tri.	$2.220\frac{16°}{4}$	$-H_2O$, 100	d. 200	d.	d.	
phosphate, dibasic	$CaHPO_4 \cdot 2H_2O$	172.09	wh., mn. pl.	$2.306\frac{16°}{4}$	d.		$0.02^{24.5°}$	$0.075^{100°}$	
phosphate, tribasic	$Ca_3(PO_4)_2$	310.18	wh., amor.	3.14	1670		0.0025	d.	s. a.; i. al., ac.
phosphate, meta-	$Ca(PO_3)_2$	198.02	wh., tet., 1.588	2.82	975		i.	i.	i. a.
phosphate, pyro-	$Ca_2P_2O_7$	254.10	col., biaxial, 1.60	3.09	1230		i.		s. a.
phosphate, pyro- (brushite)	$Ca_2P_2O_7 \cdot 5H_2O$	344.18	wh., mn.	2.25			sl. s.		s. a.; i. NH_4Cl
phosphide	Ca_3P_2	182.18	red cr.	$2.51^{15°}$	>1600		d.		s. dil. a.; i. al., et.
silicate (α) (pseudowollastonite)	$CaSiO_3$	116.16	col., pseudo hex., 1.6150 or mn.(?)	2.905	1540		$0.0095^{17°}$		s. HCl
silicate (β) (wollastonite)	$CaSiO_3$	116.16	col., mn., 1.610	2.915	tr. 1190 to α				
sulfate (anhydrite)	$CaSO_4$	136.14	col., rhb., 1.576, or mn, 1.50	2.96	1450(mn.)	tr. 1193 to rhb.	$0.298^{20°}$	$0.1619^{100°}$	s. a., $Na_2S_2O_3$, NH_4 salts

*Usual commercial form.

†The solubility of $CaCO_3$ in H_2O is greatly increased by increasing the amount of CO_2 in the H_2O.

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds (*Continued*)

Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Calcium (*Cont.*)									
sulfate (gypsum)	$CaSO_4 \cdot 2H_2O$	172.17	col., mn., 1.5226	2.32	$-1\frac{1}{2}H_2O$, 128	$-2H_2O$, 163	$0.223^{0°}$	$0.257^{50°}$	s. a., gly., $Na_2S_2O_3$, NH_4 salts
sulfhydrate	$Ca(SH)_2 \cdot 6H_2O$	214.32	col. pr.		d. 15		v. s.	v. s.	s. al.
sulfide (oldhamite)	CaS	72.14	col., cb.	$2.8^{15°}$			d.	d.	s. a.
sulfite	$CaSO_3 \cdot 2H_2O$	156.17	wh., cr., 1.595		$-2H_2O$, 100	d. 650	$0.0043^{18°}$	$0.0027^{90°}$	s. H_2SO_3
tartrate	$CaC_4H_4O_6 \cdot 4H_2O$	260.21	col., rhb.		d.		$0.037^{0°}$	$0.22^{85°}$	sl. s. al.
thiocyanate	$Ca(CNS)_2 \cdot 3H_2O$	210.29	wh., delq. cr.				s.	v. s.	v. s. al.
thiosulfate	$CaS_2O_3 \cdot 6H_2O$	260.30	col., tri., 1.56	$1.873^{16°}$	d.		$71.2^{9°}$	d.	i. al.
tungstate (scheelite)	$CaWO_4$	287.92	wh., tet., 1.9200	6.06			0.2		s. NH_4Cl; i. a.
Carbon, *cf.* table of organic compounds									
Carbon, amorphous	C	12.01	bk., amor.	1.8–2.1	>3500	4200	i.	i.	i. a., alk.
Carbon, diamond	C	12.01	col., cb., 2.4195	$3.51^{20°}$	>3500	4200	i.	i.	i. a., alk.
Carbon, graphite	C	12.01	bk., hex.	$2.26^{20°}$	>3500	4200	i.	i.	i. a., alk.
dioxide	CO_2	44.01	col. gas	lq. $1.101^{-87°}$; 1.53 (A); solid $1.56^{-79°}$	$-56.6^{5.2atm.}$	subl. −78.5	$179.7^{0°}$ cc	$90.1^{20°}$ cc	s. a., alk.
disulfide	CS_2	76.14	col. lq.	lq. $1.261\frac{22°}{20°}$; 2.63 (A)	−108.6	46.3	$0.2^{0°}$	$0.014^{50°}$	s. al.; et.
monoxide	CO	28.01	col., poisonous, odorless gas	lq. $0.814\frac{-195°}{4}$; 0.968 (A)	−207	−192	$0.0044^{0°}$; $3.5^{0°}$ cc	$0.0018^{50°}$ $2.32^{20°}$ cc	s. al., Cu_2Cl_2
oxychloride (phosgene)	$COCl_2$	98.92	poisonous gas	$1.392\frac{19°}{4}$	−104	8.2^{756mm}	v. s. sl. d.	d.	s. ac., CCl_4, bs.; d.a.
oxysulfide	COS	60.08	gas	lq. $1.24^{-87°}$; 2.10 (A)	−138.2	-50.2^{760mm}	$133^{0°}$ cc	$40.3^{30°}$ cc	v. s. alk., al.
suboxide	C_3O_2	68.03	gas	lq. $1.114^{0°}$	−107	7^{761mm}	d.		s. et.
thionyl chloride	$CSCl_2$	114.98	yel.-red lq.	$1.509^{15°}$		73.5			
Ceric hydroxide	$2CeO_2 \cdot 3H_2O$	398.28	yel., gelatinous						s. a.; sl. s. alk. carb.; i. alk
hydroxynitrate	$Ce(OH)(NO_3)_3 \cdot 3H_2O$	397.18	red, mn.				d.		
oxide	CeO_2	172.11	wh. or pa. yel., cb.	7.3	1950		i.	i.	s. H_2SO_4, HCl
sulfate	$Ce(SO_4)_2 \cdot 4H_2O$	404.30	yel., rhb.	3.91			s. d.		s. dil. H_2SO_4
Cerium	Ce	140.12	steel gray, cb. or hex.	$6.9^{20°}$ cb.; 6.7 hex.	645	1400	i.	Slowly oxidized	s. dil. a.; i. al.
Cerous sulfate	$Ce_2(SO_4)_3$	568.42	wh., mn. or rhb.	3.91			$18.98^{0°}$	$0.4^{100°}$	
sulfate	$Ce_2(SO_4)_3 \cdot 8H_2O$	712.54	tri.	$2.886^{17°}$	$-8H_2O$, 630		$25^{0°}$	$7.6^{40°}$	
Cesium	Cs	132.91	silv. met., hex.	$1.90^{20°}$	28.5	670	d.		s. a., al., NH_3
Chloric acid	$HClO_3 \cdot 7H_2O$	210.57	lq.	$1.282^{14.2°}$	<−20	d. 40	v. s.		
Chlorine	Cl_2	70.91	rhb., or gn.-yel. gas	lq. $1.56^{-33.6°}$; $2.49^{0°}$ (A)	−101.6	−34.6	$1.46^{0°}$; $310^{10°}$ cc	$0.57^{30°}$; $177^{30°}$ cc	s. alk.
hydrate	$Cl_2 \cdot 8H_2O$	215.03	rhb.	1.23	d. 9.6		s.		s. alk.
Chloroplatinic acid	$H_2PtCl_6 \cdot 6H_2O$	517.90	red-brn., delq.	2.431	60		v. s.	v. s.	s. al., et.
Chlorostannic acid	$H_2SnCl_6 \cdot 6H_2O$	441.54	delq.	$1.971^{28°}$	19.2		s.		
Chlorosulfonic acid	$HO \cdot SO_2 \cdot Cl$	116.52	col. lq.	$1.787^{25°}$	−80	151.5^{765mm}	d.		d. al.; i. CS_2
Chromic acetate	$Cr_2(C_2H_3O_2)_6 \cdot 2H_2O$	494.29	gn.				s.		$4.76^{15°}$ m. al.
chloride	$CrCl_3$	158.36	pink, trig.	$2.757^{15°}$		1200–1500 d.	i.§	sl. s.	i. a., act., CS_2
chloride	$CrCl_3 \cdot 6H_2O$*	266.45	vl. or gn., hex. pl.	$1.835\frac{25°}{4}$	subl. 83		v. s. d.		s. al.; i. et.
fluoride	CrF_3	108.99	gn., rhb.	3.8	>1000	d.	i.		sl. s. a.; i. al., NH_3
hydroxide	$Cr(OH)_3$	103.02	gn. or blue, gelatinous				i.		s. a., alk.; sl. s. NH_3
hydroxide	$Cr(OH)_3 \cdot 2H_2O$	139.05	gn.		$-2H_2O$, 100		i.	i.	s. a., alk.
nitrate	$Cr(NO_3)_3 \cdot 9H_2O$*	400.15	purple pr.		36.5	d. 100	s.	s.	s. a., alk., al., act.
nitrate	$Cr(NO_3)_3 \cdot 7\frac{1}{2}H_2O$	373.13	purple, mn.		100	d.	s.	s.	
oxide	Cr_2O_3	151.99	dark gn., hex.	5.21	1900		i.	i.	sl. s. a.
sulfate	$Cr_2(SO_4)_3$	392.18	rose pd.	3.012			i.†		i. a.
sulfate	$Cr_2(SO_4)_3 \cdot 5H_2O$	482.26	gn.				s.		s. al., H_2SO_4
sulfate	$Cr_2(SO_4)_3 \cdot 15H_2O$	662.41	vl.	$1.867^{17°}$	100	$-10H_2O$, 100	s.	d. 67°	sl. s. al.
sulfate	$Cr_2(SO_4)_3 \cdot 18H_2O$	716.46	vl., cb., 1.564	$1.7^{22°}$		$-12H_2O$, 100	$120^{20°}$	d.	s. al.
sulfide	Cr_2S_3	200.19	brn.-bk. pd.	$3.77^{19°}$	−S, 1350		i.	d.	s. h. HNO_3

Chromium	Cr	52.00	gray, met., cb.	7.1	1615	2200	i.	i.	s. HCl, dil. H_2SO_4; i. HNO_3
trioxide (chromic acid)	CrO_3	99.99	red, rhb.	2.70	197 d.		$164.9^{0°}$	$206.7^{100°}$	s. H_2SO_4, al., et.
Chromous chloride	$CrCl_2$	122.90	wh., delq.	2.75			v. s.	v. s.	sl. s. al.; i. et.
hydroxide	$Cr(OH)_2$	86.01	yel.-brn.		d.		d.		s. conc. a.
oxide	CrO	68.00	bk. pd.				i.	i.	i. dil. HNO_3
sulfate	$CrSO_4 \cdot 7H_2O$	274.17	blue				12.35^{0}		sl. s. al.
sulfide (daubrelite)	CrS	84.06	bk. pd.	3.97	1550		i.		v. s. a.
Chromyl chloride	CrO_2Cl_2	154.90	dark red lq.	1.92	–96.5	117.6	d.		s. et.
Cobalt	Co	58.93	silv. met., cb.	$8.9^{20°}$	1480	2900	i.	i.	s. a.
carbonyl	$Co(CO)_4$	170.97	or. cr.	$1.73^{18°}$	51	d. 52	i.	d.	s. al., et., CS_2
sulfide, di-	CoS_2	123.06	bk., cb.	4.269			i.		s. HNO_3, aq. reg.
Cobaltic chloride	$CoCl_3$	165.29	red cr.	2.94	subl.		s.	s.	
chloride, dichro	$Co(NH_3)_3Cl_3 \cdot H_2O$	234.40					s.		s. a.; al.
chloride, luteo	$Co(NH_3)_6Cl_3$	267.48	or., mn.	$1.7016^{20°}$			$4.26^{0°}$	$12.74^{46.5°}$	i. al., NH_4OH
chloride, praseo	$Co(NH_3)_4Cl_3 \cdot H_2O$	251.43	gn., rhb.	1.847			v. s.		s. a.; i. al.
Cobaltic chloride, purpureo	$Co(NH_3)_5Cl_3$	250.44	rhb.	$1.819\frac{25°}{25}$			$0.232^{0°}$	$1.031^{46.5°}$	i. al.
chloride, roseo	$Co(NH_3)_5Cl_3 \cdot H_2O$	268.46	brick red		d. 100		$16.12^{0°}$	$24.87^{16°}$	sl. s. HCl
hydroxide	$Co(OH)_3$	109.96	bk.		$-1\frac{1}{2}H_2O$, 100		i.	i.	s. a.; i. al.
oxide	Co_2O_3	165.86	bk.	5.18	d. 900		i.	i.	s. a.
sulfate	$Co_2(SO_4)_3$	406.05	blue cr.				d.		s. H_2SO_4
sulfide	Co_2S_3	214.06	bk. cr.	4.8			i.		d. a.
Cobalto-cobaltic oxide	Co_3O_4	240.80	bk., cb.	6.07			i.	i.	s. H_2SO_4; i. HCl, HNO_3
Cobaltous acetate	$Co(C_2H_3O_2)_2 \cdot 4H_2O$	249.08	red-vl., mn., 1.542	$1.7053^{18.7°}$	$-4H_2O$, 140		s.	s.	s. a., al.
chloride	$CoCl_2$	129.84	blue cr.	3.356	subl.	1049	$45^{7°}$	$105^{96°}$	31 al.; 8.6 act.
chloride	$CoCl_2 \cdot 6H_2O$*	237.93	red, mn.	$1.924\frac{25°}{25}$	86	$-6H_2O$, 110	$116.5^{0°}$	$177^{80°}$	v. s. et., act.
nitrate	$Co(NO_3)_2 \cdot 6H_2O$	291.03	red, mn., 1.4	$1.883\frac{35°}{25}$	<100	d.	$84.03^{0°}$(anh.)	$334.9^{90°}$ (anh.)	$100^{12.5°}$ al.; s. act.; sl. s. NH_3
oxide	CoO	74.93	brn., cb.	5.68	d. 1800		i.	i.	s. a., NH_4OH; i. al.
sulfate	$CoSO_4$	155.00	red pd.	$3.710^{25°}$	d. 880		$25.6^{0°}$	$83^{100°}$	$1.04^{18°}$ m. al.; i. NH_3
sulfate	$CoSO_4 \cdot H_2O$	173.01	red pd., mn.(?), 1.639	3.13	d.		s.	s.	
sulfate (biebeorite)	$CoSO_4 \cdot 7H_2O$*	281.10	red, mn., 1.483	$1.948\frac{25°}{25}$	96.8	$-7H_2O$, 420	$33^{80°}$	s.	$2.5^{8°}$ al.
sulfide (syeporite)	CoS	91.00	brn. nd.	$5.45^{18°}$	>1100		$0.00038^{18°}$		s. a., aq. reg.
Copper	Cu	63.55	yel.-red met., cb.	$8.92^{20°}$	1083	2300	i.	i.	s. HNO_3, h. H_2SO_4
Cupric acetate	$Cu(C_2H_3O_2)_2$	181.63		$1.930\frac{20°}{4}$			s.		
acetate	$Cu(C_2H_3O_2)_2 \cdot H_2O$	199.65	dark gn., mn.	1.882	115	240 d.	7.2	20	7 al.; s. et.; gly.
aceto-arsenite (Paris green)	$(CuOAs_2O_3)_3 \cdot Cu(C_2H_3O_2)_2$*	1013.79	gn.				i.		s. a., NH_4OH
ammonium chloride	$CuCl_2 \cdot 2NH_4Cl \cdot 2H_2O$	277.47	blue, tet., 1.670, 1.744	1.98	d. 110		$33.8^{0°}$	$99.3^{80°}$	s. a.
ammonium sulfate	$CuSO_4 \cdot 4NH_3 \cdot H_2O$	245.75	blue, rhb.	1.81	d. 150		$18.05^{21.5°}$	d.	i. al.
carbonate, basic (azurite)	$2CuCO_3 \cdot Cu(OH)_2$	344.67	blue, mn., 1.758	3.88	d. 220		i.	d.	s. NH_4OH, h. aq. $NaHCO_3$
carbonate, basic (malachite)	$CuCO_3 \cdot Cu(OH)_2$	221.12	dark gn., mn., 1.875	3.9	d.		i.	d.	s. KCN; 0.03 aq. CO
chloride (eriochalcite)	$CuCl_2$	134.45	brn.-yel. pd.	3.054	498	Forms Cu_2Cl_2 993	$70.7^{0°}$	$107.9^{100°}$	$53^{15°}$ al.; $68^{15°}$ m. al.
chloride	$CuCl_2 \cdot 2H_2O$	170.48	gn., rhb., 1.684	$2.39^{22.4°}$	$-2H_2O$, 110	d.	$110.4^{0°}$	$192.4^{100°}$	s. al.; et., NH_4Cl
chromate, basic	$CuCrO_4 \cdot 2CuO \cdot 2H_2O$	374.66	yel.-brn.		$-2H_2O$, 260		i.		s. HNO_3, NH_4OH
cyanide	$Cu(CN)_2$	115.58	yel.-gn.		d.		i.		s. KCN, C_5H_5N
dichromate	$CuCr_2O_7 \cdot 2H_2O$	315.56	bk., tri.	$2.286^{18°}$	$-2H_2O$, 100		sl. s.	d.	s. a.; NH_4OH
ferricyanide	$Cu_3[Fe(CN)_6]_2$	614.54	yel.-gn.				i.		s. NH_4OH; i. HCl
ferrocyanide	$Cu_2Fe(CN)_6 \cdot 7H_2O$	465.15	red-brn.				i.	i.	s. NH_4OH; i. a., NH_3
formate	$Cu(HCO_2)_2$	153.58	blue, mn.	1.831			12.5	d.	0.25 al.
hydroxide	$Cu(OH)_2$	97.56	blue, gelatinous	3.368	$-H_2O$		i.	d.	s. a., NH_4OH, KCN, al.
lactate	$Cu(C_3H_5O_3)_2 \cdot 2H_2O$	277.72	dark blue, mn.				16.7	$45^{100°}$	sl. s. al.
nitrate	$Cu(NO_3)_2 \cdot 3H_2O$*	241.60	blue, delq.	$2.047^{3.9°}$	114.5	$-HNO_3$, 170	$381^{40°}$	$666^{80°}$	$100^{12.5°}$ al.
nitrate	$Cu(NO_3)_2 \cdot 6H_2O$	295.65	blue, rhb.	2.074	$-3H_2O$, 26.4		$243.7^{0°}$	∞	s. al.

*Usual commercial form.
†Also a soluble modification.

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds (*Continued*)

Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Cupric acetate (*Cont.*)									
oxide (paramelaconite)	CuO	79.55	bk., cb.	6.40	d. 1026		i.	i.	s. a.; KCN, NH_4Cl
oxide (tenorite)	CuO	79.55	bk., tri., 2.63	6.45	d. 1026		i.	i.	s. a., KCN, NH_4Cl
oxychloride	$CuCl_2 \cdot 2CuO \cdot 4H_2O$	365.60	blue-gn.		$-3H_2O$, 140		i.		s. a.
phosphide	Cu_3P_2	252.59	bk.	6.35	d.		i.		s. HNO_3; i. HCl
sulfate (hydrocyanite)	$CuSO_4$	159.61	gn.-wh., rhb., 1.733	$3.606^{15°}$	d. >600	Forms CuO, 650	$14.3^{0°}$	$75.4^{100°}$	i. al.
sulfate (blue vitriol or chalcanthite)	$CuSO_4 \cdot 5H_2O$*	249.69	blue, tri., 1.5368	$2.286\ \frac{15.6°}{4}$	$-4H_2O$, 110	$-5H_2O$, 250	$24.3^{0°}$	$205^{100°}$	$1.1^{8°}$ al.
sulfide (covellite)	CuS	95.61	blue, hex. or mn., 1.45	4.6	tr. 103	d. 220	$0.000033^{18°}$		s. HNO_3, KCN
tartate	$CuC_4H_4O_6 \cdot 3H_2O$	265.66	1 gn. pd.		d.		$0.02^{15°}$	$0.14^{85°}$	s. a., KOH
Cuprous ammonium iodide	$CuI \cdot NH_4I \cdot H_2O$	353.41	rhb. pl.				d.		s. NH_4I
carbonate	Cu_2CO_3	187.10	yel.	4.4	d.		i.	i.	s. a., NH_4OH
chloride (nantokite)	Cu_2Cl_2	198.00	wh., cb., 1.973	3.53	422	1366	$1.52^{25°}$		s. HCl, NH_4OH, al.
cyanide	$Cu_2(CN)_2$	179.13	wh., mn.	2.9	474.5	d.	i.	i.	s. KCN, HCl, NH_4OH; sl. s. NH_3
ferricyanide	$Cu_3Fe(CN)_6$	402.59	brn.-red				i.		s. NH_4OH; i. HCl
ferrocyanide	$Cu_4Fe(CN)_6$	466.13	brn.-red				i.		s. NH_4OH; i. NH_4Cl
fluoride	Cu_2F_2	165.09	red cr.		908	subl. 1100	i.		s. HF, HCl, HNO_3; i. al.
hydroxide	CuOH	80.55	yel.	3.4	$-½H_2O$, 360		i.	i.	s. a., NH_4OH
oxide (cuprite)	Cu_2O	143.09	red, cb., 2.705	6.0	1235	$-O$, 1800	i.	i.	s. HCl, NH_4Cl, NH_4OH
Cuprous phosphide	Cu_6P_2	443.22	gray-bk.	6.4 to 6.8			i.		s. HNO_3; i. HCl
sulfide (chalcocite)	Cu_2S	159.16	bk., rhb.	5.6	1100		$0.0005^{18°}$		s. HNO_3, NH_4OH; i. act.
sulfide	Cu_2S	159.16	bk., cb.	5.80	1130		$0.0005^{18°}$		s. HNO_3, NH_4OH; i. act.
Cyanogen	C_2N_2	52.03	poisonous gas	lq. $0.866^{-17.2°}$; 1.806 (A)	−34.4	−20.5	$450^{20°}$ cc		$2300^{20°}$ cc al.; $500^{18°}$ cc et.
Cyanogen compounds, *cf.* table of organic compounds									
Ferric acetate, basic	$Fe(OH)(C_2H_3O_2)_2$	190.94	brn., amor.				i.		s. a.; al.
ammonium sulfate, *cf.* Alum									
chloride (molysite)	$FeCl_3$	162.20	bk.-brn., hex. delq.	$2.804^{11°}$	282	315	$74.4^{0°}$	$535.8^{100°}$	v. s. al.; et. +HCl
chloride	$FeCl_3 \cdot 6H_2O$*	270.30	red-yel., delq.		37	280	$246^{0°}$	∞	s. al., act., gly.
ferrocyanide (Prussian blue)	$Fe_4[Fe(CN)_6]_3$	859.23	dark blue		d.		i.	d.	s. HCl, conc. H_2SO_4; i. al., et.
hydroxide	$Fe(OH)_3$	106.87	red-brn.	3.4 to 3.9	$-1½H_2O$, 500		i.	i.	s. a.; i. al., et.
lactate	$Fe(C_3H_5O_3)_3$	323.06	brn., amor., delq.				v. s.	v. s.	i. et.
nitrate	$Fe(NO_3)_3 \cdot 6H_2O$	349.95	rhb., delq.	$1.684^{20°}$	35	d.	$150^{0°}$	∞	s. al., act.
oxide (hematite)	Fe_2O_3	159.69	red or bk., trig., 3.042	5.12	1560 d.		i.		s. HCl
sulfate	$Fe_2(SO_4)_3$	399.88	rhb., 1.814	$3.097^{18°}$	d. 480		sl. s.	d.	i. H_2SO_4, NH_3
sulfate (coquimbite)	$Fe_2(SO_4)_3 \cdot 9H_2O$	562.02	yel., trig.	2.1			440	d.	s. abs. al.
Ferroso-ferric chloride	$FeCl_2 \cdot 2FeCl_3 \cdot 18H_2O$	775.43	yel., delq.		d. 50		s.	s.	
ferricyanide (Prussian green)	$Fe''_4Fe''_3[Fe(CN)_6]_6$	1662.61	gn.		d. 180		i.		s. d. h. HCl
oxide (magnetite; magnetic iron oxide)	Fe_3O_4	231.53	bk., cb., 2.42	5.2	1538 d.		i.	i.	i. al.
oxide, hydrated	$Fe_3O_4 \cdot 4H_2O$	303.59	bk.		d.		i.	i.	s. a.
Ferrous ammonium sulfate	$FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$	392.14	blue-gn., mn., 1.4915	1.864	d.		$18^{0°}$	$100^{75°}$	i. al.
chloride (lawrencite)	$FeCl_2$	126.75	gn.-yel., hex., 1.567	2.7		delq.	$64.4^{10°}$	$105.7^{100°}$	100 al.; s. act.; i. et.
chloroplatinate	$FePtCl_6 \cdot 6H_2O$	571.73	yel., hex.	2.714			v. s.	v. s.	
ferricyanide (Turnbull's blue)	$Fe_3[Fe(CN)_6]_2$	591.43	dark blue		d.		i.		i. dil. a., al.
ferrocyanide	$Fe_2Fe(CN)_6$	323.64	blue-wh., amor.				i.		
formate	$Fe(HCO_2)_2 \cdot 2H_2O$	181.91			d.		sl. s.		
hydroxide	$Fe(OH)_2$	89.86	lt. gn.	3.4			0.00067		s. a., NH_4Cl
nitrate	$Fe(NO_3)_2 \cdot 6H_2O$	287.95	cr.		60.5		$200^{0°}$	$300^{25°}$	
oxide	FeO	71.84	bk.	5.7	1420		i.	i.	s. a.; i. alk.

phosphate (vivianite)	$Fe_3(PO_4)_2 \cdot 8H_2O$	501.60	blue, mn., 1.592, 1.603	2.58			i.	i.	s. a.; i. ac.
silicate	$FeSiO_3$	131.93	mn.	3.5	1550				
sulfate (siderotilate)	$FeSO_4 \cdot 5H_2O$	241.98	gn., tri., 1.536	2.2		$-5H_2O$, 300	s.	s.	i. al.
sulfate (copperas)	$FeSO_4 \cdot 7H_2O$*	278.01	blue-gn., mn.	$1.899^{14.8°}$	64	$-7H_2O$, 300	$32.8^{0°}$	$149^{50°}$	i. al.
sulfide	FeS	87.91	bk., hex.	4.84	1193	d.	$0.000616^{18°}$		s. a.; i. NH_3
cf. also under iron									
Fluoboric acid	HBF_4	87.81	col. lq.			130 d.	∞	∞	s. al.
Fluorine	F_2	38.00	gn.-yel. gas	lq. $1.51^{-187°}$; $1.31^{15°}$ (A)	−223	−187	d.		
Fluosilicic acid	H_2SiF_6	144.09					s.	s.	
Gadolinium	Gd	157.25							
Gallium bromide	$GaBr_3$	309.44	delq. cr.				s.	s.	
Glucinum *cf.* Beryllium									
Gold	Au	196.97	yel. met., cb.	$19.3^{20°}$	1063	2600	i.	i.	s. aq. reg., KCN; i. a.
Gold, colloidal	Au	196.97	blue to vl.				s.		s. aq. reg., KCN; i. a.
Gold salts *cf.* under Auric and Aurous									
Hafnium	Hf	178.49	hex.	12.1	>1700	>3200(?)			
Helium	He	4.00	col. gas	0.1368 (A)	<−272.2	−268.9	$0.97^{0°}$ cc	$1.08^{50°}$ cc	Absorbed by Pt
Hydrazine	N_2H_4	32.05	col. lq.	$1.011\,\frac{15°}{4}$	1.4	113.5	∞	∞	s. al.
formate	$N_2H_4 \cdot 2HCO_2H$	124.10	cb.		128		s.		
hydrate	$N_2H_4 \cdot H_2O$	50.06	col.	$1.03^{21°}$	−40	$118.5^{739.5mm}$	∞	∞	∞ al.; i. et.
hydrochloride	$N_2H_4 \cdot HCl$	68.51	yel. lq.				v. s.	v. s.	sl. s. al.
hydrochloride, di-	$N_2H_4 \cdot 2HCl$	104.97	wh., cb.	1.42	198		s.	v. s.	s. al.
nitrate	$N_2H_4 \cdot HNO_3$	95.06	cr.		70.7	subl. 140	$174.9^{10°}$	v. s.	
nitrate, di-	$N_2H_4 \cdot 2HNO_3$	158.07	nd.		104	d.	v. s.		
sulfate	$N_2H_4 \cdot \frac{1}{2}H_2SO_4$	81.08	delq. pl.		85		v. s.		i. al.
sulfate	$N_2H_4 \cdot H_2SO_4$	130.12	rhb.	1.378	254		$3.055^{22°}$	$27.65^{60°}$	v. sl. s. abs. al.
Hydrazoic acid (azoimide)	HN_3	43.03	col. lq.		−80	37	∞	∞	∞ al.
Hydriodic acid	HI	127.91	col. gas	$4.4^{0°}$ (A)	−50.8	−35.5	$42500^{10°}$ cc	v. s.	s. al.
Hydriodic acid	$HI \cdot H_2O$	145.93	col. lq.	$1.7^{15°}$		127^{774mm}	∞		∞ al.
Hydriodic acid	$HI \cdot 2H_2O$	163.94	col. lq.		−43		∞		s. al.
Hydriodic acid	$HI \cdot 3H_2O$	181.96	col. lq.		−48		∞		s. al.
Hydriodic acid	$HI \cdot 4H_2O$	199.97	col. lq.		−36.5		∞		s. al.
Hydrobromic acid	HBr	80.91	col. gas; 1.325 (lq.)	$2.71^{0°}$ (A)	−86	−67	$221^{0°}$	$130^{100°}$	s. al.
Hydrobromic acid	$HBr \cdot H_2O$	98.93	col. lq.	1.78					Stable at −15.5° and 1 atm., and at −11.3° and 2.5 atm.
Hydrobromic acid	HBr (47.8% in H_2O)	80.91	col. lq.	1.486		126	∞		s. al.
Hydrobromic acid	$HBr \cdot 2H_2O$	118.96	wh. cr.	$2.11^{-15°}$	−11		s.	s.	
Hydrochloric acid	HCl†	36.46	col. gas; 1.256 (lq.)	$1.268^{0°}$ (A)	−111	−85	$82.3^{0°}$	$56.1^{60°}$	s. al., et.
Hydrochloric acid	HCl (45.2% in H_2O)	36.46	col. lq.	1.48	−15.35		∞		s. al.
Hydrochloric acid	$HCl \cdot 2H_2O$	72.49	col. lq.	$1.46\,\frac{-18.3°}{4}$	0	d.	∞		s. al.
Hydrochloric acid	$HCl \cdot 3H_2O$	90.51	col. lq.		−24.4	d.	∞		s. al.
Hydrocyanic acid (prussic acid)	HCN	27.03	poisonous gas or col. lq., 1.254	$0.697^{18°}$	−14	26	∞		∞ al., et.
Hydrofluoric acid	HF	20.01	gas or col. lq.	$0.988^{13.6°}$	−83	19.4	∞ 0° to 19.4°	v. s.	
Hydrofluoric acid	HF (35.35% in H_2O)	20.01	col. lq.	1.15	−35	120	v. s.		
Hydrogen	H_2	2.02	col. gas or cb.	lq. 0.0709$^{-252.7°}$ 0.06948 (A)	−259.1	−252.7	$2.1^{0°}$ cc	$0.85^{80°}$ cc	sl. s. Fe, Pd, Pt
peroxide	H_2O_2‡	34.01	col. lq., 1.333	$1.438\,\frac{20°}{4}$	−0.89	151.4^{760mm}	∞		s. a., et.; i. petr. et
selenide	H_2Se	80.98	col. gas	$2.12^{-42°}$	−64	−42	$377^{4°}$ cc	$270^{22.5°}$ cc	s. CS_2, $COCl_2$
sulfide	H_2S	34.08	col. gas	1.1895 (A)	−82.9	−59.6	$437^{0°}$ cc	$186^{40°}$ cc	$9.54^{15°}$ cc al.; s. CS_2
Hydroxylamine	NH_2OH	33.03	rhb., delq.	$1.35^{18°}$	34	56.5^{22mm}	s.	d.	s. a., al.
hydrochloride	$NH_2OH \cdot HCl$	69.49	col., mn.	$1.67^{17°}$	151	d.	$83.3^{17°}$	v. s.	s. al.; i. et.
nitrate	$NH_2OH \cdot HNO_3$	96.04	col. cr.		48	d. <100	v. s.	d.	v. s. abs. al.
sulfate	$NH_2OH \cdot \frac{1}{2}H_2SO_4$	82.07	col., mn.		170 d.		$32.9^{0°}$	$68.5^{90°}$	v. sl. s. al.; i. et., abs. al.

*Usual commercial form.
†Usual commercial form about 31 percent.
‡Usual commercial forms 3 or 30 percent.

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds (*Continued*)

Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Hypobromous acid	HBrO	96.91	yel.			40^{50mm}	s.	d.	
Indium	In	114.82	soft, tet. met.	$7.3^{20°}$	155	1450	i.	i.	s. a.
Iodic acid	HIO_3	175.91	col., rhb.	$4.629^{0°}$	110 d.		$286^{0°}$	$576^{101°}$	v. s. 87% al.; i. abs. al. et., chl.
Iodine	I_2	253.81	blue-bk., rhb.	$4.93^{20°}$	113.5	184.35	$0.0162^{0°}$	$0.09566^{60°}$	s. al., KI, et.
oxide, penta-	I_2O_5	333.81	wh., trimetric	$4.799\frac{25°}{4}$	d. 300		$187.4^{12°}$		i. abs. al., et., chl.
Iodoplatinic acid	$H_2PtI_6 \cdot 9H_2O$	1120.66	brn., delq. mn.				s. d.		
Iridium	Ir	192.22	wh. met., cb.	$22.4^{20°}$	2350	>4800	i.	i.	sl. s. aq. reg., aq. Cl_2
Iron, cast†	Fe	55.85	gray	7.03	1275		i.	i.	s. a.; i. alk.
pure	Fe	55.85	silv. met., cb.	$7.86^{20°}$	1535	3000	i.	i.	s. a.; i. alk.
steel	Fe	55.85	silv. gray	7.6 to 7.8	1375		i.	i.	s. a.; i. alk.
white pig	Fe	55.85	gray	7.6 to 7.8	1075		i.	i.	s. a.; i. alk.
wrought	Fe	55.85	gray	7.86	1505		i.	i.	s. a.; i. alk.
carbide (cementite)	Fe_3C	179.55	pseudo hex.	7.4	1837		i.	i.	s. a.
carbonyl	$Fe(CO)_5$	195.90	pa. yel. lq.	$1.457^{21°}$	–21	102.5^{760mm}	i.		s. al., H_2SO_4, alk.
nitride	Fe_2N	125.70	gray	6.35	d. >560		d.		s. HCl, H_2SO_4
silicide	FeSi	83.93	yel.-gray, oct.	$6.1\frac{20°}{4}$			i.	i.	i. aq. reg.
sulfide, di- (marcasite)	FeS_2	119.98	yel., rhb.	4.87	tr. 450	d.	0.00049		i. dil. a.
sulfide, di- (pyrite)	FeS_2	119.98	yel., cb.	5.0	1171	d.	0.0005		i. dil. a.
sulfide (pyrrhotite)	Fe_7S_8	647.44	hex.	$4.6\frac{20°}{4}$	d. >700		i.		
Cf. also under ferric and ferrous									
Krypton	Kr	83.80	col. gas	2.818 (A)	–169	–151.8	$11.05^{0°}$ cc	$3.57^{60°}$ cc	sl. s. al., bz.
Lanthanum	La	138.91	lead gray	$6.15^{20°}$	826	1800	d.		s. a.
Lead	Pb	207.20	silv. met., cb.	$11.337\frac{20°}{20°}$	327.5	1620	i.	i.	s. HNO_3; i. c. HCl, H_2SO_4
acetate	$Pb(C_2H_3O_2)_2$	325.29	wh. cr.	$3.251\frac{20°}{4}$	280		$19.7^{0°}$	$221^{50°}$	s. gly.; v. sl. s. al.
acetate (sugar of lead)	$Pb(C_2H_3O_2)_2 \cdot 3H_2O$†	379.33	wh., mn.	2.55	$-3H_2O$, 75		$45.64^{15°}$	$200^{100°}$	s. gly.; sl. s. al.
acetate	$Pb(C_2H_3O_2)_2 \cdot 10H_2O$	505.44	wh., rhb.	1.689	22		s.	s.	
acetate, basic	$Pb_2(C_2H_3O_2)_3OH$	608.54	wh.				v. s.		sl. s. al.
acetate, basic	$Pb(C_2H_3O_2)_2 \cdot Pb(OH)_2 \cdot H_2O$	584.52	wh. nd.				v. s.		s. al.
acetate, basic	$Pb(C_2H_3O_2)_2 \cdot 2Pb(OH)_2$	807.72	wh. nd.				5.55	18.2	s. al.
arsenate, monobasic	$PbH_4(AsO_4)_2$	489.07	tri., 1.82	$4.46^{15°}$	d. 140		d.		s. HNO_3
arsenate, dibasic (schultenite)	$PbHAsO_4$	347.13	wh., mn., 1.9097	5.94	d. >200	$-H_2O$, 280	i.	sl. s.	s. HNO_3, NaOH
arsenate, meta-	$Pb(AsO_3)_2$	453.04	hex.	$6.42^{15°}$			d.		s. HNO_3
arsenate, pyro-	$Pb_2As_2O_7$	676.24	rhb., 2.03	$6.85\frac{15°}{15°}$	802		i.	d.	s. HCl, HNO_3; i. sc.
Lead azide	PbN_6	291.24	col. nd.		expl. 350		i.	$0.05^{100°}$	v. s. ac.; i. NH_4OH
bromide	$PbBr_2$	367.01	col., rhb.	6.66	373	918	$0.4554^{0°}$	$4.75^{100°}$	s. a., KBr.; sl. s. NH_3; i. al.
carbonate (cerussite)	$PbCO_3$	267.21	wh., rhb., 2.0763	6.6	d. 315		$0.00011^{20°}$	d.	s. a., alk.; i. NH_3, al.
carbonate, basic (hydrocerussite; white lead)	$2PbCO_3 \cdot Pb(OH)_2$†	775.63	wh., hex.	6.14	d. 400		i.	i.	s. ac.; sl. s. aq. CO_2
chloride (cotunnite)	$PbCl_2$	278.11	wh., rhb., 2.2172	5.80	501	954^{760mm}	$0.673^{0°}$	$3.34^{100°}$	sl. s. dil. HCl, NH_3, i. al.
chromate (crocoite)	$PbCrO_4$	323.19	yel., mn., 2.42	6.12	844	d.	$0.000007^{20°}$	i.	s. a., alk.; i. NH_3, ac.
chromate, basic	$PbCrO_4 \cdot PbO$	546.39	or.-yel. nd.				i.	i.	s. a., alk.
formate	$Pb(HCO_2)_2$	297.23	wh., rhb.	4.56	d. 190		$1.6^{16°}$	$18^{100°}$ d.	i. al.
hydroxide	$3PbO \cdot H_2O$	687.61	cb.	7.592	$-H_2O$, 130		0.014		s. a., alk.
nitrate	$Pb(NO_3)_2$	331.21	col., cb. or mn., 1.7815	4.53	d. 470		$38.8^{0°}$	$138.8^{100°}$	$8.8^{22°}$ al.
oxide, sub-	Pb_2O	430.40	bk., amor.	8.34	d. red heat		i.	i.	s. a., alk.
oxide, mono- (litharge)	PbO	223.20	yel., tet.	9.53	888		$0.0068^{18°}$		s. alk., PbAc, NH_4Cl, $CaCl_2$
oxide, mono (massicotite)	PbO	223.20	yel., rhb., 2.61	8.0					

oxide, mono-	PbO	223.20	amor.	9.2 to 9.5			i.	i.	s. alk., PbAc, NH_4Cl, $CaCl_2$
oxide, red (minium)	Pb_3O_4	685.60	red, amor.	9.1	d. 500		i.	i.	s. ac., h. HCl
oxide, sesqui-	Pb_2O_3	462.40	red-yel., amor.		d. 360		i.	i.	s. a., alk.
oxide, di- (plattnerite)	PbO_2	239.20	brn., tet., 2.229	9.375	d. 290		i.	i.	s. ac., h. alk.; i. al.
silicate	$PbSiO_3$	283.28	col., mn., 1.961	6.49	766		i.		s. a.
sulfate (anglesite)	$PbSO_4$	303.26	wh., mn. or rhb., 1.8823	6.2	1170		$0.0028^{0°}$	$0.0056^{40°}$	s. conc. a., NH_4 salts; i. al.
sulfate, acid	$Pb(HSO_4)_2 \cdot H_2O$	419.36	cr.		d.		$0.0001^{18°}$		sl. s. H_2SO_4
sulfate, basic (lanarkite)	$PbSO_4 \cdot PbO$	526.46	col., mn.	6.92	977		$0.0044^{18°}$		sl. s. H_2SO_4
sulfide (galena)	PbS	239.27	lead gray, cb., 3.912	7.5	1120		$0.00009^{18°}$	i.	s. a.; i. alk.
thiocyanate	$Pb(CNS)_2$	323.36	col., mn.	3.82	d. 190		$0.05^{20°}$	s.	s. KCNS, HNO_3
Lithium	Li	6.94	silv. met. cb.	$0.53^{20°}$	186	1336 ± 5	d.	d.	s. a., NH_3
benzoate	$LiC_7H_5O_2$	128.05	wh. leaflets				$33^{25°}$	$40^{100°}$	$7.7^{25°}$, $10^{78°}$ al.
bromide	LiBr	86.85	wh., delq., cb., 1.784	$3.464\frac{25°}{4}$	547	1265	$143^{0°}$ ($2H_2O$)	$266^{100°}$ ($1H_2O$)	s. al., act.
bromide	$LiBr \cdot 2H_2O$	122.88	wh. pr.		44		$246^{20°}$		s. al.
carbonate	Li_2CO_3	73.89	col., mn., 1.567	$2.11^{0°}$	618	d.	$1.54^{0°}$	$0.72^{100°}$	s. dil. a.; i. al., act., NH_3
chloride	LiCl	42.39	wh., delq., cb., 1.662	$2.068\frac{25°}{4}$	614	1360	$67^{0°}$	$127.5^{100°}$	$2.48^{15°}$ al.; s. et.
citrate	$Li_3C_6H_5O_7 \cdot 4H_2O$	281.98	wh. cr.		d.		$61.2^{15°}$	$66.7^{100°}$	sl. s. al., et.
fluoride	LiF	25.94	wh., cb., 1.3915	$2.295^{21.5°}$	870	1670	$0.27^{18°}$	$0.135^{35°}$	s. HF; i. act.
formate	$LiHCO_2 \cdot H_2O$	69.97	col., rhb.	1.46	$-H_2O$, 94		$49.2^{0°}$	$346.6^{104°}$	sl. s. al., et.
hydride	LiH	7.95	wh., cb.	0.820	680		d.		i. et.
hydroxide	LiOH	23.95	wh. cr.	2.54	445	925±	$12.7^{0°}$	$17.5^{100°}$	sl. s. al.
hydroxide	$LiOH \cdot H_2O$	41.96	col., mn.	1.83		d.	$22.3^{10°}$	$26.8^{80°}$	sl. s. al.
nitrate	$LiNO_3$	68.95	col., trig., 1.735	2.38	261		$53.4^{0°}$	$194^{70°}$	s. al., NH_3
nitrate	$LiNO_3 \cdot 3H_2O$	122.99	col.		29.88		v. s.	∞	
oxide	Li_2O	29.88	col., 1.644	$2.013\frac{25°}{4}$		subl. <1000	forms LiOH		
phosphate, monobasic	LiH_2PO_4	103.93	col.	2.461	>100				
phosphate, tribasic	Li_3PO_4	115.79	wh., rhb.	$2.537^{17.5°}$	837		$0.034^{18°}$	v. sl. s.	s. a., NH_4Cl; i. act.
phosphate, tribasic	$Li_3PO_4 \cdot 12H_2O$	331.98	wh., trig.	1.645	100		v. sl. s.	v. sl. s.	
salicylate	$LiC_7H_5O_3$	144.05	col.		d.		$128^{26°}$		v. s. al.
sulfate	Li_2SO_4	109.94	col., mn., 1.465	2.22	860		$35.34^{0°}$	$29.9^{100°}$	i. act., 80% al.
sulfate	$Li_2SO_4 \cdot H_2O$†	127.96	col., mn., 1.477	2.06	$-H_2O$, 130		$43.6^{0°}$	$35^{100°}$	i. 80% al.
sulfate, acid	$LiHSO_4$	104.01	pr.	$2.123^{13°}$	170.5		d.		
Lutecium	Lu	174.97							
Magnesium	Mg	24.31	silv. met., hex.	$1.74^{20°}$	651	1110	i.	sl. s. d.	s. a., NH_4 salts
acetate	$Mg(C_2H_3O_2)_2$	142.39	wh.	1.42	323		v. s.	v. s.	$5.25^{15°}$ m. al.
acetate	$Mg(C_2H_3O_2)_2 \cdot 4H_2O$†	214.45	wh., mn. pr., 1.491	1.454	80		v. s.	v. s.	v. s. al.
aluminate (spinel)	$MgO \cdot Al_2O_3$	142.26	col. cb., 1.718–23	3.6	2135		i.		v. sl. s. dil. HCl; i. dil. HNO_3
ammonium chloride	$MgCl_2 \cdot NH_4Cl \cdot 6H_2O$	256.79	wh., rhb., delq.	1.456	$-4H_2O$, 195		16.7	s.	
ammonium phosphate (struvite)	$MgNH_4PO_4 \cdot 6H_2O$	245.41	col., rhb., 1.496	1.715	d. 100		$0.0231^{0°}$	$0.0195^{80°}$	s. a.; i. al.
ammonium sulfate (boussingaultite)	$MgSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$	360.60	col., mn.	1.72	>120		$16.86^{0°}$	$130^{100°}$	
benzoate	$Mg(C_7H_5O_2)_2 \cdot 3H_2O$	320.58	wh. pd.		$-3H_2O$, 110		$4.5^{25°}$ (anh.)	s.	s. act.
carbonate (magnesite)	$MgCO_3$	84.31	wh., trig. 1.700	3.037	d. 350		0.0106		s. a., aq. CO_2; i. act., NH_3
carbonate (nesquehonite)	$MgCO_3 \cdot 3H_2O$	138.36	col., rhb., 1.501	1.852	$-H_2O$, 100		$0.1518^{19°}$	d.	s. a., aq. CO_2
carbonate, basic (hydromagnesite)	$3MgCO_3 \cdot Mg(OH)_2 \cdot 3H_2O$	365.31	wh., rhb., 1.530	2.16	d.		0.04	0.011	s. a., NH_4 salts; i. al.
Magnesium chloride (chloromagnesite)	$MgCl_2$	95.21	col., hex., 1.675	$2.325^{25°}$	712	1412	$52.8^{0°}$	$73^{100°}$	50 al.
chloride (bischofite)	$MgCl_2 \cdot 6H_2O$†	203.30	wh., delq., mn., 1.507	1.56	118 d.	d.	$281^{0°}$	$918^{100°}$	50 al.
hydroxide (brucite)	$Mg(OH)_2$	58.32	wh., trig., 1.5617	2.4	d.		$0.0009^{18°}$		s. NH_4 salts, dil. a.
nitride	Mg_3N_2	100.93	gn.-yel., amor.		d.		i.	d.	s. a.; i. al.
oxide (magnesia; periclase)	MgO	40.30	col., cb., 1.7364	3.65	2800	3600	0.00062		s. a., NH_4 salts; i. al.
perchlorate	$Mg(ClO_4)_2$†	223.21	wh., delq.	$2.60^{25°}$	d.		$99.6^{25°}$	v. s.	24^{25} al., $51.8^{25°}$ m. al.; 0.29 et.

*See also a table of alloys.
†Usual commercial form.

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds (*Continued*)

Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Magnesium chloride (*Cont.*)									
peroxide	MgO_2	56.30	wh. pd.		expl. 275		i.	i.	s. a.
phosphate, pyro-	$Mg_2P_2O_7$	222.55	col., mn., 1.604	$2.598^{22°}$	1383		i.	i.	s. a.; i. alk.
phosphate, pyro-	$Mg_2P_2O_7 \cdot 3H_2O$	276.60	wh., amor.	2.56	$-3H_2O$, 100		i.	sl. s.	s. a.; i. al.
potassium chloride (carnallite)	$MgCl_2 \cdot KCl \cdot 6H_2O$	277.85	delq., rhb., 1.475	$1.60\,\frac{19.4°}{4}$	265		$64.5^{19°}$ d.	d.	d. al.
potassium sulfate (picromerite)	$MgSO_4 \cdot K_2SO_4 \cdot 6H_2O$	402.72	mn., 1.4629	2.15	d. 72		$19.26^{0°}$	$81.7^{75°}$	
silicofluoride	$MgSiF_6 \cdot 6H_2O$	274.47	col., trig., 1.3439	$1.788\,\frac{17.5°}{4}$	d.		$64.8^{17.5°}$	s.	d. HF
sodium chloride	$MgCl_2 \cdot NaCl \cdot H_2O$	171.67	col.				s.	s.	
sulfate	$MgSO_4$	120.37	col.	2.66	1185		$26.9^{0°}$	$68.3^{100°}$	s. al.
sulfate (epsom salt; epsomite)	$MgSO_4 \cdot 7H_2O$*	246.47	col., rhb., 1.4554	1.68	70 d.		$72.4^{0°}$	$178^{40°}$	s. al.
Manganese	Mn	54.94	gray-pink met.	$7.2^{20°}$	1260	1900	d.		s. dil. a.
acetate	$Mn(C_2H_3O_2)_2$	173.03		$1.74\,\frac{20°}{4}$			s.	s.	
acetate	$Mn(C_2H_3O_2)_2 \cdot 4H_2O$*	245.09	pa. pink, mn.	1.589			s.	$64.5^{50°}$	s. al., m. al.
carbonate (rhodocrosite)	$MnCO_3$	114.95	rose, trig., 1.817	3.125	d.		$0.0065^{25°}$		s. aq. CO_2, dil. a.; l. NH_3, al.
chloride (scacchite)	$MnCl_2$	125.84	rose, delq., cb.	$2.977\,\frac{25°}{4}$	650	1190	$63.4^{0°}$	$123.8^{100°}$	s. al.; i. et., NH_3
chloride	$MnCl_2 \cdot 4H_2O$*	197.91	rose red, delq., mn. 1.575	2.01	58.0	$-H_2O$, 106; $-4H_2O$, 200	$151^{8°}$	∞	s. al.; i. et.
chloride, per-	$MnCl_4$	196.75	gn.				s.	s.	s. al., et.
hydroxide (ous) (pyrochroite)	$Mn(OH)_2$	88.95	wh., trig.	$3.258^{18°}$	d.		$0.002^{20°}$	i.	s. a., NH_4 salts; i. alk.
hydroxide (ic) (manganite)	$Mn_2O_3 \cdot H_2O$	175.89	brn., rhb., 2.24	3.258	d.		i.	i.	s. h. H_2SO_4
nitrate	$Mn(NO_3)_2 \cdot 6H_2O$	287.04	rose red, mn.	$1.82^{21°}$	25.8	129.5	$426^{0°}$	∞	v. s. al.
oxide (ous) (manganosite)	MnO	70.94	gray-gn., cb., 2.16	5.18	1650		i.	i.	s. a., NH_4Cl
oxide (ic)	Mn_2O_3	157.87	brn.-bk., cb.	4.81	–0, 1080		i.	i.	s. a.; i. act.
oxide, di- (pyrolusite; polianite)	MnO_2*	86.94	bk., rhb.	5.026	–0, >230		i.	i.	s. HCl; i. HNO_3, act.
sulfate (ous)	$MnSO_4$	151.00	red-wh.	3.235	700	d. 850	$53^{0°}$	$73^{50°}$	s. al.; i. et.
sulfate (ous) (szmikite)	$MnSO_4 \cdot H_2O$	169.02	pa. pink, mn., 1.595	2.87	Stable 57 to 117		$98.47^{48°}$	$79.77^{100°}$	
sulfate (ous)	$MnSO_4 \cdot 2H_2O$	187.03		$2.526^{15°}$	Stable 40 to 57		$85.27^{35°}$	$106.8^{55°}$	
sulfate (ous)	$MnSO_4 \cdot 3H_2O$	205.05		$2.356^{15°}$	Stable 30 to 40		$74.22^{5°}$	$99.31^{57°}$	
sulfate (ous)	$MnSO_4 \cdot 4H_2O$*	223.06	pink, rhb. or mn., 1.518	2.107	Stable 18 to 30	$-4H_2O$, 450	$136^{16°}$	$169^{50°}$	i. al.
sulfate (ous)	$MnSO_4 \cdot 5H_2O$	241.08	pink, tri., 1.508	$2.103^{15°}$	Stable 8 to 18		$142^{5°}$	$200^{35°}$	
sulfate (ous)	$MnSO_4 \cdot 6H_2O$	259.09			Stable –5 to +8		$204^{0°}$	$247^{9°}$	
sulfate (ous)	$MnSO_4 \cdot 7H_2O$	277.11	pink, mn. or rhb.	2.092	Stable –10 to –5; 19 d.	$-7H_2O$, 280	$176^{0°}$	$251^{14°}$	
sulfate (ic)	$Mn_2(SO_4)_3$	398.06	gn., delq. cr.	3.24	d. 160		v. s.	d.	s. HCl, dil. H_2SO_4; l. conc. H_2SO_4, HNO_3
Mercuric acetate	$Hg(C_2H_3O_2)_2$	318.68	wh. pl.	3.270	d.		$25^{10°}$	$100^{100°}$	s. al. sl. d.
bromide	$HgBr_2$	360.40	wh., rhb.	6.053	237	322	$0.5^{20°}$	$25^{100°}$	$25.2^{0°}$ al.; v. sl. s. et.
carbonate, basic	$HgCO_3 \cdot 2HgO$	693.78	brn.-red				i.		s. aq. CO_2, NH_4Cl
chloride (corrosive sublimate)	$HgCl_2$	271.50	wh., rhb., 1.859	5.44	277	304	$3.6^{0°}$	$61.3^{100°}$	$33^{25°}$ 99% al.; 33 et.
fulminate	$Hg(CNO)_2$	284.62	cb.	4.42	expl.		sl. s.		s. NH_4OH, al.
hydroxide	$Hg(OH)_2$	234.60			$-H_2O$, 175		i.	i.	s. a.
oxide (montroydite)	HgO	216.59	yel. or red, rhb., 2.5	11.14	d. 100		$0.0052^{25°}$	$0.041^{100°}$	s. a.; i. al.
oxychloride (kleinite)	$HgCl_2 \cdot 3HgO$	921.26	yel., hex.	7.93	d. 260		i.	d.	s. HCl
silicofluoride, basic	$HgSiF_6 \cdot HgO \cdot 3H_2O$	613.30	yel. nd.				d.		s. a.
sulfate	$HgSO_4$	296.65	wh., rhb.	6.47	d.		d.		s. a.; i. al., act., NH_8
sulfate, basic (turpeth)	$HgSO_4 \cdot 2HgO$	729.83	yel., tet.	6.44			0.005	$0.167^{100°}$	s. a.; i. al.
Mercurous acetate	$HgC_2H_3O_2$	259.63	wh. sc.		d.		$0.75^{13°}$	d.	s. H_2SO_4, HNO_3; i. al.
bromide	HgBr	280.49	wh., tet.	7.307	subl. 345		7×10^{-9}	i.	s. a.; i. al., act.
carbonate	Hg_2CO_3	461.19	yel. pd.		d. 130		i.	d.	s. NH_4Cl

chloride (calomel)	$HgCl$	236.04	wh., tet., 1.9733	7.150	302	383.7	$0.0014^{0°}$	$0.0007^{43°}$	s. aq. reg., $Hg(NO_3)_2$; sl. s. HNO_3, HCl; i. al., etc.
iodide	HgI	327.49	yel., tet.	7.70	290 d.	subl. 140; 310d.	2×10^{-8}	v. sl. s.	s. KI; i. al.
nitrate	$HgNO_3 \cdot H_2O$	280.61	wh. mn.	$4.785^{3.9°}$	70	expl.	v. s.	d.	s. HNO_3; i. al., et.
Mercurous oxide	Hg_2O	417.18	bk.	9.8	d. 100		i.	0.0007	s. h. ac.; i. alk., dil. HCl, NH_3
sulfate	Hg_2SO_4	497.24	wh., mn.	7.56	d.		$0.055^{16.5°}$	$0.092^{100°}$	s. H_2SO_4, HNO_3
Mercury†	Hg	200.59	silv. lq. or hex.(?)	$13.546^{20°}$	−38.87	356.9	i.	i.	s. HNO_3; i. HCl
Molybdenum	Mo	95.94	gray, cb.	10.2	2620 ± 10	3700	i.	i.	s. h. conc. H_2SO_4; i. HCl, HF, NH_3, dil. H_2SO_4, Hg
chloride, di-	$MoCl_2$	166.85	yel., amor.	$3.714\,\frac{25°}{4}$	d.		i.	i.	s. HCl, H_2SO_4, NH_4OH, al., et.
chloride, tri-	$MoCl_3$	202.30	dark red pd.	$3.578\,\frac{25°}{4}$	d.		i.	d.	s. HNO_3, H_2SO_4; v. sl. s. al., et.
chloride, tetra-	$MoCl_4$	237.75	brn., delq.		volt.	d.	s.	d.	s. HNO_3, H_2SO_4; sl. s. al., et.
chloride, penta-	$MoCl_5$	273.21	bk. cr.	$2.928\,\frac{25°}{4}$	194	268	s.	d.	s. HNO_3, H_2SO_4; i. abs. al., et.
oxide, tri- (molybdite)	MoO_3	143.94	col., rhb.	$4.50^{19.5°}$	795	subl.	$0.107^{18°}$	$2.106^{79°}$	s. a., NH_4OH
sulfide, di- (molybdenite)	MoS_2	160.07	bk., hex., 4.7	$4.801^{14°}$	1185		i.	i.	s. H_2SO_4, aq. reg.
sulfide, tri-	MoS_3	192.14	red-brn.		d.		sl. s.	s.	s. alk. sulfides
sulfide, tetra-	MoS_4	224.20	brn. pd.		d.		i.	i.	s. alk. sulfides; i. NH_3
Molybdic acid	H_2MoO_4	161.95	yel-wh., hex.		d. 115		v. sl. s.	sl. s.	s. NH_4OH, H_2SO_4; i. NH
Molybdic acid	$H_2MoO_4 \cdot H_2O$	161.95	yel., mn.	$3.124^{15°}$	$-H_2O$, 70	$-2H_2O$, 200	$0.133^{18°}$	$2.13^{70°}$	s. a., NH_4OH, NH_4, salts
Neodymium	Nd	144.24	yellowish	$6.9^{20°}$	840		d.		
Neon	Ne	20.18	col. gas	lq. $1.204^{-245.9°}$ 0.674 (A)	−248.67	−245.9	$2.6^{0°}$ cc	$1.1^{45°}$ cc	s. lq. O_2, al., act., bz.
Neptunium	Np^{239}	239.05		Produced by Neutron bombardment of U^{238}					
Nickel	Ni	58.69	silv. met., cb.	8.90^{20}	1452	2900	i.	i.	s. dil. HNO_3; sl. s. H_2SO_4, HCl; i. NH_3
acetate	$Ni(C_2H_3O_2)_2$	176.78	gn. pr.	1.798	d.		16.6		i. al.
ammonium chloride	$NiCl_2 \cdot NH_4Cl \cdot 6H_2O$	291.18	gn., delq., mn.	1.645			$150^{25°}$	v. s.	
ammonium sulfate	$NiSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$	394.99	blue-gn., mn., 1.5007	1.923			$2.5^{3.5°}$	$39.2^{88°}$	v. sl. s. $(NH_4)_2SO_4$
bromate	$Ni(BrO_3)_2 \cdot 6H_2O$	422.59	gn., cb.	2.575	d.		28		s. NH_4OH
bromide	$NiBr_2$	218.50	yel., delq.	$4.64\,\frac{28°}{4}$	d.		$112.8^{0°}$	$156^{100°}$	s. al., et., NH_4OH
bromide	$NiBr_2 \cdot 3H_2O$	272.55	gn., delq.		$-3H_2O$, 200		$199^{9°}$	$316^{100°}$	s. al., et., NH_4OH
bromide, ammonia	$NiBr_2 \cdot 6NH_3$	320.68	vl. pd.	1.837			v. s.	d.	i. c. NH_4OH
bromoplatinate	$NiPtBr_6 \cdot 6H_2O$	841.29	trig.	3.715					
carbonate	$NiCO_3$	118.70	lt. gn., rhb.		d.		$0.0093^{25°}$	i.	s. a.
carbonate, basic	$2NiCO_3 \cdot 3Ni(OH)_2 \cdot 4H_2O$	587.59	lt. gn.		d.		i.	d.	s. a., NH_4 salts
carbonyl	$Ni(CO)_4$	170.73	lq.	$1.31^{17°}$	−25	43^{751mm}	$0.018^{9.8°}$	i.	s. aq. reg., HNO_3, al., et.
chloride	$NiCl_2$	129.60	yel., delq.	3.544	subl.	973	$53.8^{0°}$	$87.6^{100°}$	s. NH_4OH, al.; i. NH_3
chloride	$NiCl_2 \cdot 6H_2O$*	237.69	gn., delq., mn., 1.57±				180	v. s.	v. s. al.
chloride, ammonia	$NiCl_2 \cdot 6NH_3$	231.78					s.	d.	s. NH_4OH; i. al.
cyanide	$Ni(CN)_2 \cdot 4H_2O$	182.79	gn. pl.		$-4H_2O$, 200	d.	i.	i.	s. KCN; i. dil. KCl
dimethylglyoxime	$NiC_8H_{14}O_4N_4$	288.91	scarlet red cr.		subl. 250		i.	i.	s. abs. al., a.; i. ac., NH_4OH
formate	$Ni(HCO_2)_2 \cdot 2H_2O$	184.76	gn. cr.	2.154	d.		s.		
hydroxide (ic)	$Ni(OH)_3$	109.72	bk.		d.		i.	i.	s. a., NH_4OH, NH_4Cl
hydroxide (ous)	$Ni(OH)_2 \cdot \frac{1}{4}H_2O$	97.21	lt. gn.	4.36	d.		v. sl. s.	v. sl. s.	s. a., NH_4OH; i. alk.
nitrate	$Ni(NO_3)_2 \cdot 6H_2O$	290.79	gn., mn.	2.05	56.7	136.7	$243.0^{0°}$	$\infty^{56.7°}$	s. NH_4OH; i. abs. al.
nitrate, ammonia	$Ni(NO_3)_2 \cdot 4NH_3 \cdot 2H_2O$	286.86					v. s.		i. al.
oxide, mono- (bunsenite)	NiO	74.69	gn.-bk., cb., 2.37	7.45	Forms Ni_2O_3 at 400		i.	i.	s. a., NH_4OH
potassium cyanide	$Ni(CN)_2 \cdot 2KCN \cdot H_2O$	258.97	red yel., mn.	$1.875^{11°}$	$-H_2O$, 100		s.		d. a.
sulfate	$NiSO_4$	154.76	yel., cb.	3.68	$-SO_3$, 840		$27.2^{0°}$	$76.7^{100°}$	i. al., et., act.

*Usual commercial form.
†See also Tables 2-28 and 2-280.

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds (*Continued*)

Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Nickel (*Cont.*)									
sulfate	$NiSO_4 \cdot 6H_2O$*	262.85	gn. mn. or blue, tet., 1.5109	2.07	tr. 53.3	$-6H_2O$, 280	$131^{50°}$	$280^{100°}$	v. s. NH_4OH, al.
sulfate (morenosite)	$NiSO_4 \cdot 7H_2O$	280.86	gn., rhb., 1.4893	1.948	98–100	$-6H_2O$, 103	$63.5^{0°}$	$117.8^{30°}$	s. al.
Nitric acid	HNO_3	63.01	col. lq.	1.502	–42	86	∞	∞	expl. with al.
Nitric acid	$HNO_3 \cdot H_2O$	81.03	col. lq.		–38		∞	∞	d. al.
Nitric acid	$HNO_3 \cdot 3H_2O$	117.06	col. lq.		–18.5		$263^{-20°}$	∞	d. al.
Nitro acid sulfite	NO_2HSO_3	127.08	col., rhb.		73 d.		d.		s. H_2SO_4
Nitrogen	N_2	28.01	col. gas or cb. cr.	$1.026^{-252.5°}$ $0.808^{-195.8°}$ $12.5^{0°}$ (D)	–209.86	–195.8	$2.35^{0°}$ cc	$1.55^{20°}$ cc	sl. s. al.
Nitrogen oxide, mono- (ous)	N_2O	44.01	col. gas	lq. $1.226^{-89°}$ 1.530 (A)	–102.3	–90.7	$130.52^{0°}$ cc	$60.82^{24°}$ cc	s. H_2SO_4, al.
oxide, di- (ic)	NO or $(NO)_2$	30.01 60.01	col. gas	lq. $1.269^{-150.2°}$ 1.0367 (A)	–161	–151	$7.34^{0°}$ cc	$0.0^{100°}$	26.6 cc al.; 3.5 cc H_2SO_4; s. aq. $FeSO_4$
oxide, tri-	N_2O_3	76.01	red-brn. gas or blue lq. or solid	$1.447^{2°}$	–102	3.5	s.		s. a., et.
oxide, tetra- (per- or di-)	NO_2 or $(NO_2)_2$	46.01 92.01	yel. lq., col. solid, red-brn. gas	$1.448^{20°}$	–9.3	21.3	d.		s. HNO_3, H_2SO_4, chl., CS_2
oxide, penta-	N_2O_5	108.01	wh., rhb.	$1.63^{18°}$	30	47	s.	Forms HNO_3	
oxybromide	NOBr	109.91	brn. lq.	>1.0	–55.5	–2	d.		
oxychloride	NOCl	65.46	red-yel. lq. or gas	$1.417^{-12°}$ 2.31 (A)	–64.5	–5.5	d.		s. fuming H_2SO_4
Nitroxyl chloride	NO_2Cl	81.46	yel.-brn. gas	lq. $1.32^{14°}$	<–30	5	d		
Osmium	Os	190.23	blue, hex.	$22.48^{20°}$	2700	>5300	i.	i.	sl. s. aq. reg., HNO_3; i. NH_3
chloride, di-	$OsCl_2$	261.14	gn., delq.				s. d.		s. NaCl, al., et.
chloride, tri-	$OsCl_3$	296.59	brn., cb.		d. 560–600		sl. s.		s. a., alk., al.; sl. s. et.
chloride, tetra-	$OsCl_4$	332.04	red-yel. nd.				s. d.		s. HCl, al.
Oxygen	O_2	32.00	col. gas or hex. solid	$1.14^{-188°}$ $1.426^{-252.5°}$ 1.1053 (A)	–218.4	–183	$4.89^{0°}$ cc	$2.6^{30°}$ cc $1.7^{100°}$ cc	sl. s. al., s. fused Ag
Ozone	O_3	48.00	col. gas	$1.71^{-183°}$ $3.03^{-80°}$ 1.658 (A)	–251	–112	$0.494^{0°}$ cc	$0^{60°}$ cc	s. oil turp., oil cinn.
Palladium	Pd	106.42	silv. met., cb.	$12.0^{20°}$ $11^{1550°}$	1555	2200	i.	i.	s. aq. reg., h. H_2SO_4; i. NH_3
bromide (ous)	$PdBr_2$	266.23	brn.				i.	i.	s. HBr
chloride	$PdCl_2$	177.33	brn., cb.		500 d.		s.	s.	s. HCl, act., al.
chloride	$PdCl_2 \cdot 2H_2O$	213.36	brn. pr.				s.	s.	s. HCl, act., al.
cyanide	$Pd(CN)_2$	158.45	yel.		d.		i.	i.	s. HCN, KCN, NH_4OH; i. dil. a.
hydride	Pd_2H	213.85	met.	11.06	d.				
Palladous dichlorodiammine	$Pd(NH_3)_2Cl_2$	211.39	red or yel., tet.	2.5			s.		s. a., NH_4OH
Perchloric acid	$HClO_4$	100.46	unstable, col. lq	$1.768\ \frac{22°}{4}$	–112	16^{18mm}	s.		
Perchloric acid	$HClO_4 \cdot H_2O$	118.47	fairly stable nd.	1.88	50	d.	s.		
Perchloric acid	$HClO_4 \cdot 2H_2O$* 73.6% anh.	136.49	stable lq., col.	$1.71\ \frac{25°}{4}$	–17.8	200	v. s.		s. al.
Periodic acid	HIO_4	191.91	wh. cr.		d. 138	subl. 110	s.		
Periodic acid	$HIO_4 \cdot 2H_2O$	227.94	delq., mn.		d. 110		v. s.	v. s.	sl. s. al., et.
Permanganic acid	$HMnO_4$	119.94	exists only in solution				v. s.	d.	d. al.
Permolybdic acid	$HMoO_4 \cdot 2H_2O$	196.98	wh. cr.				v. s.	v. s.	
Persulfuric acid	$H_2S_2O_8$	194.14	hyg. cr.		<60		v. s.	d.	
Phosphamic acid	$PONH_2 \cdot (OH)_2$	97.01	cb.		d.		v. s.	v. s. d.	i. al.
Phosphatomolybdic acid	$H_7P(Mo_2O_7)_6 \cdot 28H_2O$	2365.71	yel. cb.		78	$-25H_2O$, 140	s.		s. HNO_3
Phosphine	PH_3	34.00	col. gas	lq. $0.746^{-90°}$ 1.146 (A)	–132.5	–85	$26^{17°}$ cc	$i.^{100°}$	s. Cu_2Cl_2, al., et.
Phosphonium chloride	PH_4Cl	70.46	wh., cb.		28^{46atm}	subl.	d.		

Phosphoric acid, hypo-	$H_4P_2O_6$	161.98	cr.		55	d. 70	s.	$450^{62°}$	
Phosphoric acid, meta-	HPO_3	79.98	vitreous, delq.	2.2–2.5	subl.		s.	Forms H_3PO_4	i. lq. CO_2
Phosphoric acid, ortho-	H_3PO_4†	98.00	col., rhb.	$1.834^{18.2°}$	42.35	$-½H_2O$, 213	$2340^{26°}$	v. s.	s. al.
Phosphoric acid, pyro-	$H_4P_2O_7$	177.98	wh. nd.		61		$800^{25°}$	Forms H_3PO_4	v. s. al., et.
Phosphorous acid, hypo-	H_3PO_2	66.00	syrupy	$1.493^{18.8°}$	26.5	d.	∞	∞	
Phosphorous acid, ortho-	H_3PO_3	82.00	col.	$1.651^{21.2°}$	74	d. 200	$307.3^{0°}$	$730^{40°}$	
Phosphorous acid, pyro-	$H_4P_2O_5$	145.98	nd.		38	d. 130	d.		
Phosphorus, black	P_4	123.90	rhombohedral	2.69		ign. in air, 400	i.	i.	i. CS_2
Phosphorus, red	P_4	123.90	red, cb.	$2.20^{20°}$	590^{43atm}	ign. in air, 725	i.	i.	s. alk.; i. CS_2, NH_3, et.
Phosphorus, yellow	P_4	123.90	yel., hex., 2.1168	$1.82^{20°}$; lq. $1.745^{44.5°}$	44.1; ign. 34	280	0.0003	sl. s.	0.4 al.; $1000^{10°}$ CS_2; $1.5^{0°}$, $10^{81°}$ bs.; s. NH_3
chloride, tri-	PCl_3	137.33	col., fuming lq.	$1.574\,\frac{20.8°}{4}$	−111.8	75.95^{760mm}	d.		s. et., chl., CS_2
chloride, penta-	PCl_5	208.24	delq., tet.	solid 1.6; $3.60^{295°}$ (A)	148 under pressure	subl. 160	d.		s. CS_2, C_6H_5COCl
oxide, penta-	P_2O_5	141.94	wh., delq., amor.	2.387	subl. 250		Forms H_3PO_4	v. s.	s. H_2SO_4; i. NH_3, act.
oxychloride	$POCl_3$	153.33	col., fuming lq.	1.675	2	107.2^{760mm}	d.		d. al.
Phosphotungstic acid	$H_3PO_4 \cdot 12WO_3 \cdot xH_2O$	2880.05	yel.-gn. cr.				s.		s. al., et.
Platinum	Pt	195.08	silv. met., cb.	$21.45^{20°}$ lq. $19^{1755°}$	1755	4300	i.	i.	s. aq. reg., fused alk.
chloride (ic)	$PtCl_4$	336.89	brn.		d. 370		$140^{25°}$	v. s.	s. al., act.; sl. s. NH_3; i. et.
chloride (ous)	$PtCl_2$	265.98	brn.	$5.87^{11°}$	d. 581		i.	i.	s. HCl, NH_4OH; sl. s. NH_3; i. al., et.
chloride (ic)	$PtCl_4 \cdot 8H_2O$	481.01	red, mn.	2.43	$-4H_2O$, 100		v. s.	v. s.	s. al., et.
cyanide (ous)	$Pt(CN)_2$	247.11	yel.-brn.				i.	i.	i. alk.
Plutonium	Pu	238.05		Produced by deuteron bombardment on U^{238}					
Plutonium	Pu	239.05		Produced by neutron bombardment on U^{238}					
Potassium	K	39.10	silv. met., cb.	$0.86^{20°}$ lq. $0.83^{42°}$	62.3	760	d.	Forms KOH	s. a., al., Hg
acetate	$KC_2H_3O_2$	98.14	wh. pd.	1.8	292		$217^{0°}$	$396^{90°}$	33 al.; i. et.
acetate, acid	$KH(C_2H_3O_2)_2$	158.19	delq. nd. or pl.		148	d. 200	d.		s. ac.
aluminate	$K_2(AlO_2)_2 \cdot 3H_2O$	250.20	cr.				s.	d.	s. alk.; i al.
amide	KNH_2	55.12	yel.-grn.		338	subl. 400	d.		d. al.; $3.6^{25°}$ NH_3
arsenate (monobasic)	KH_2AsO_4	180.03	col., tet., 1.5674	2.867	288		$18.87^{6°}$	v. s.	i. al.
auricyanide	$KAu(CN)_4 \cdot 1 \cdot 5H_2O$	367.16	pl.		d. 200		s.	v. s.	s. al.
aurocyanide	$KAu(CN)_2$	288.10	rhb.				14.3	$200^{100°}$	sl. s. al.; i. et.
bicarbonate	$KHCO_3$	100.12	mn., 1.482	2.17	d. 100–200		$22.4^{0°}$	$60^{60°}$	i. satd. K_2CO_3, al.
bisulfate	$KHSO_4$	136.17	rhb., or mn., 1.480	2.35	210	d.	$36.3^{0°}$	$121.6^{100°}$	d. al.
bromate	$KBrO_3$	167.00	trig.	$3.27^{17.5°}$	370 d.		$3.11^{0°}$	$49.75^{100°}$	sl. s. al.; i. act.
bromide	KBr	119.00	col., cb., 1.5594	$2.75^{25°}$	730	1380	$53.5^{0°}$	$104^{100°}$	sl. s. al., et.
carbonate	K_2CO_3	138.21	wh., delq. pd., 1.531	2.29	891	d.	$105.5^{0°}$	$156^{100°}$	i. al.
carbonate	$K_2CO_3 \cdot 2H_2O$	174.24	rhb.	2.043			$183^{0°}$	$331^{100°}$	
carbonate	$2K_2CO_3 \cdot 3H_3O$	330.46	mn.	2.13			$129.4^{0°}$	$268^{100°}$	
chlorate	$KClO_3$	122.55	col., mn., 1.5167	2.32	368	d. 400	$3.3^{0°}$	$57^{100°}$	0.83 al.; s. alk.
chloride (sylvite)	KCl	74.55	col., cb., 1.4904	1.988	790	1500	$27.6^{0°}$	$56.7^{100°}$	s. al., alk.
chloroplatinate	K_2PtCl_6	485.99	yel., cb., 1.825±	3.499	d. 250		$0.74^{0°}$	$5.2^{100°}$	i. al., et.
chromate (tarapacaite)	K_2CrO_4	194.19	yel., rhb., 1.7261	$2.732^{18°}$	975		$58.0^{0°}$	$75.6^{100°}$	i. al.
cyanate	KCNO	81.12	wh., tet.	2.048			s.	d.	v. sl. s. al.
cyanide	KCN	65.12	wh., cb., delq., 1.410	$1.52^{16°}$	634.5		s.	$122.2^{108.8°}$	s. gly.; $0.9^{19.5°}$ al.; 1.3 h. al.
dichromate	$K_2Cr_2O_7$	294.18	red, tri.	2.69	398	d.	$4.9^{0°}$	$80^{100°}$	i. al.
ferricyanide	$K_3Fe(CN)_6$	329.24	red, mn. pr., 1.5689	1.84	d.		$33^{4.4°}$	$77.5^{100°}$	s. act.; sl. s. al.; i. NH_3
ferrocyanide	$K_4Fe(CN)_6 \cdot 3H_2O$	422.39	yel., mn., 1.5772	$1.853^{17°}$	$-3HO_2$, 70		$27.8^{12.2°}$	$90.6^{96.8°}$	s. act.; i. NH_3, al., et.
formate	$KHCO_2$	84.12	col., rhb.	1.91	167.5	d.	$331^{18°}$	$657^{90°}$	sl. s. al.; i. et.
hydride	KH	40.11	cb., 1.453	0.80	d.		d.		i. et., bz., CS_2
hydrosulfide	KHS	72.17	wh., delq., rhb.	2.0	455		s.	s. d.	s. al.
hydroxide	KOH	56.11	wh., delq., rhb.	2.044	380	1320	$97^{0°}$	$178^{100°}$	v. s. al., et.; i. NH_3
iodate	KIO_3	214.00	col., mn.	3.89	560		$4.73^{0°}$	$32.2^{100°}$	s. KI; i. al., NH_3
iodide	KI	166.00	wh., cb., 1.6670	3.13	723	1330	$127.5^{0°}$	$208^{100°}$	$4^{20°}$ al.; s. NH_3; sl. s. et.

*One commercial form 70 to 72 per cent.
†Common commercial form 85 per cent H_3PO_4 in aqueous solution.

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds (*Continued*)

Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Potassium (*Cont.*)									
iodide, tri-	KI_3	419.81	dark blue, delq., mn.	3.498	45	d. 225	v. s.		s. KI, al.
iodoplatinate	K_2PtI_6	1034.70	cb.	5.18			s.		
manganate	K_2MnO_4	197.13	gn., rhb.		d. 190		d.		s. KOH
metabisulfite	$K_2S_2O_5$	222.32	mn., pl.		d. 150		$25^{0°}$	$120^{94°}$	sl. s. al.; i. et.
nitrate (saltpeter)	KNO_3	101.10	col., rhb., 1.5038	$2.11^{10.6°}$	tr. 129; 333	d. 400	$13.3^{0°}$	$246^{100°}$	$0.1^{30°}$ al.; i. et.
nitrite	KNO_2	85.10	pr.	1.915	297	d. 350	$281^{0°}$	$413^{100°}$	v. s. NH_3; sl. s. al.
oxalate	$K_2C_2O_4 \cdot H_2O$	184.23	wh., mn.	2.13	d.		$28.7^{0°}$	$83.2^{100°}$	
oxalate, acid	KHC_2O_4*	128.13	mn., 1.545	2.0	d.		$14.3^{50°}$	$48.1^{100°}$	
oxalate, acid	$KHC_2O_4 \cdot \frac{1}{2}H_2O$	137.13	trimetric		d.		$2.2^{0°}$	$51.5^{100°}$	
oxide	K_2O	94.20	wh., cb.	$2.32\,\frac{20°}{4}$			Forms KOH	v. s.	s. al., et.
perchlorate	$KClO_4$	138.55	col., rhb., 1.4737	$2.524\,\frac{11°}{4}$	d. 400		$0.75^{0°}$	$21.8^{100°}$	$0.105^{20°}$ m. al.; i. et.
permanganate	$KMnO_4$	158.03	purple, rhb.	2.703	d. <240		$2.83^{0°}$	$32.35^{75°}$	s. H_2SO_4; d. al.
persulfate	$K_2S_2O_3$	190.32	wh., tri., 1.4669		d. <100		$1.77^{0°}$	$10^{40°}$	i. al.
phosphate, monobasic	KH_2PO_4	136.09	col., delq., tet., 1.5095	2.338	256		$14.8^{0°}$	$83.5^{90°}$	i. al.
phosphate, dibasic	K_2HPO_4	174.18	wh., delq.		d.		$33^{25°}$	v. s.	sl. s. al.
phosphate, tribasic	K_3PO_4	212.27	wh., rhb.	$2.564^{17°}$	1340		$193.1^{25°}$	v. s.	i. al.
phosphate, meta-	KPO_3	118.07	wh. pd.	$2.258^{14.5°}$	tr. 450; 798	1320	s.	s.	
phosphate, meta-	$K_4P_4O_{12} \cdot 2H_2O$	508.31	amor.	$2.264^{14.5°}$	$-2H_2O$, 100	d.	s.	83	s. a.
phosphate, pyro-	$K_4P_2O_7 \cdot 3H_2O$	384.38	delq.	2.33	$-2H_2O$, 180	$-3H_2O$, 300	s.	v. s.	i. al.
phthalate, acid	$KHC_8H_4O_4$	204.22	wh. cr.	1.63	d.		$10.2^{25°}$	36	
platinocyanide	$K_2Pt(CN)_4 \cdot 3H_2O$	431.39	yel., rhb., 1.62±	$2.45^{16°}$			sl. s.	v. s.	s. al., et.
silicate	K_2SiO_3	154.28	hyg. 1.521±		976		s.	s.	i. al.
silicate, tetra-	$K_2Si_4O_9 \cdot H_2O$	352.55	rhb., 1.530	2.417	d. 400		s.	s.	i. al.
sulfate (arcanite)	K_2SO_4	174.26	col., rhb., 1.4947	2.662	tr. 588		$7.35^{0°}$	$24.1^{100°}$	i. al., act., CS_2
Potassium sulfate, pyro-	$K_2S_2O_7$	254.32	col.	2.277	300		s.	d.	
sulfide, mono-	$K_2S \cdot 5H_2O$	200.34	rhb., delq.		60	$-3H_2O$, 150	s.		s. al., gly.; i. et.
sulfite	$K_2SO_3 \cdot 2H_2O$	194.29	wh., rhb.		d.		100	>100	sl. s. al.; i. NH_3
sulfite, acid	$KHSO_3$	120.17	wh., mn.		d. 190		$45.5^{15°}$	$91.5^{75°}$	i. abs. al.
tartrate	$K_2C_4H_4O_6 \cdot \frac{1}{2}H_2O$	235.28	col., mn., 1.526	1.98		d.	$12.5^{17.5°}$	$278^{100°}$	sl. s. al.
tartrate, acid	$KHC_4H_4O_6$*	188.18	col., rhb.	1.956			$0.37^{0°}$	$6.1^{100°}$	s. a., alk.; i. al., ac.
thiocyanate	KCNS	97.18	col., delq., mn., 1.660±	1.886	172.3	d. 500	$177^{0°}$	$217^{20°}$	$20.8^{22°}$ act.; s. al.
thiosulfate	$K_2S_2O_3$	190.32	col., cb.		d. 400		$96.1^{0°}$	$311.2^{90°}$	
thiosulfate	$3K_2S_2O_3 \cdot H_2O$	588.99	delq., mn.	2.23	$-H_2O$, 180	d.			i. al.
Praseodymium	Pr	140.91	yel.	$6.5^{20°}$	940		d.		
Radium	Ra	226.03	wh., met.	5?	960	1140	d. $+H_2$		d. a.
bromide	$RaBr_2$	385.83	wh., mn.	5.79	728	subl. 900	$70^{20°}$	s.	s. al.
Radon (Niton)	Rn	222.02	gas	lq. 5.5; 111 (D)	−71	−62	$51^{0°}$ cc	$8.5^{60°}$ cc	
Rhenium	Re	186.21	hex.		3440				i. HF, HCl; s. H_2SO_4; HNO_3
Rhodium	Rh	102.91	gray-wh., cb.	12.5	1955	>2500	i.	i.	sl. s. aq. reg., a.
chloride	$RhCl_3$	209.26	red		d. 450	subl. 800±	i.	i.	v. sl. s. alk.; i. aq. reg., a.
chloride	$RhCl_3 \cdot 4H_2O$	281.33	dark red				v. s.		s. HCl, al.; i. et.
Rubidium	Rb	85.47	silv. wh.	lq. $1.475^{88.5}$; $1.53^{20°}$	38.5	700	d.		s. a., al.
Ruthenium	Ru	101.07	bk., porous	8.6	>1950		i.	i.	sl. s. aq. reg., a.
Ruthenium	Ru	101.07	gray, hex.	$12.2^{20°}$	2450	>2700	i.	i.	
Samarium	Sm (also Sa)	150.36		7.7	>1300				
Scandium	Sc	44.96		2.5?	1200	2400			
Selenic acid	H_2SeO_4	144.97	hex. pr.	$2.950\,\frac{15°}{4}$	58	260	$1300^{30°}$	$\infty^{60°}$	s. H_2SO_4; d. al.; i. NH_3
Selenic acid	$H_2SeO_4 \cdot H_2O$	162.99	nd.	$2.627\,\frac{15°}{4}$	26	205	v. s.		
Selenium	Se_8	631.68	red pd., amor., 2.92	$4.26^{25°}$	50	688	i.	i.	s. CS_2, H_2SO_4, CH_2I_2
Selenium	Se_8	631.68	gray, trig., 3.00; red, hex.	4.80; 4.50	220	688	i.	i.	s. CS_2, H_2SO_4

Selenium	Se_8	631.68	steel gray	$4.8^{25°}$	217	688	i.	i.	i. CS_2; s. H_2SO_4
Selenous acid	H_2SeO_3	128.97	hex.	$3.004\,\frac{15°}{4}$	d.		$90^{0°}$	$400^{90°}$	v. s. al.; i. NH_3
Silicic acid, meta-	H_2SiO_3	78.10	amor., 1.41	2.1–2.3			i.	i.	s. alk.; i. NH_4Cl
Silicic acid, ortho-	H_4SiO_4	96.11	amor.	$1.576^{17°}$			sl. s.	sl. s.	s. alk.; i. NH_4Cl
Silicon, crystalline	Si	28.09	gray, cb., 3.736	$2.4^{20°}$	1420	2600	i.	i.	s. HNO_3 + HF, Ag; sl. s. Pb, Zn; i. HF
Silicon, graphitic	Si	28.09	cr.	2.0–2.5		2600	i.	i.	s. HNO_3 + HF, fused alk.; i. HF.
Silicon, amorphous	Si	28.09	brn., amor.	2		2600	i.	i.	s. HF, KOH
carbide	SiC	40.10	blue-bk., trig., 2.654	3.17	>2700	subl. 2200	i.	i.	s. fused alk.; i. a.
chloride, tri-	Si_2Cl_6	268.89	lf. or lq.	$1.58^{0°}$	–1	144^{760mm}	d.		d. alk.
chloride, tetra-	$SiCl_4$	169.90	col., fuming lq., 1.412	1.50	–70	57.6	d.		d. conc. H_2SO_4, al.
fluoride	SiF_4	104.08	gas	3.57 (A)	–95.7	-65^{1810mm}	v. s. d.		s. HNO_3, al., et.
hydride (silane)	SiH_4	32.12	col. gas	lq. $0.68^{-185°}$	–185	-112^{760mm}	i.		i. al., et.; d. KOH
oxide, di- (opal)	$SiO_2{\cdot}xH_2O$		iridescent, amor.	2.2	1600–1750	subl. 1750	i.	i.	s. HF, h. alk., fused $CaCl_2$
oxide, di- (cristobalite)	SiO_2	60.08	col., cb. or tet., 1.487	2.32	1710	2230	i.	i.	s. HF; i. alk.
oxide, di- (lechatelierite)	SiO_2	60.08		2.20		2230	i.	i.	s. HF; i. alk.
oxide, di- (quartz)	SiO_2	60.08	hex., 1.5442	$2.650^{20°}$	tr. <1425	2230	i.	i.	s. HF; i. alk.
oxide, di- (tridymite)	SiO_2	60.08	trig., rhb., 1.469	2.26	tr. 1670	2230	i.		s. HF; i. alk.
Silver	Ag	107.87	silv. met., cb.	$10.5^{20°}$	960.5	1950	i.	i.	s. HNO_3, h. H_2SO_4; i. alk.
bromide (bromyrite)	AgBr	187.77	pa. yel., cb., 2.252	$6.473\,\frac{25°}{4}$	434	d. 700	$0.00002^{20°}$	$0.00037^{100°}$	$0.51^{18°}$ NH_4OH; s. KCN, $Na_2S_2O_3$
carbonate	Ag_2CO_3	275.75	yel. pd.	6.077	218 d.		$0.003^{20°}$	$0.05^{100°}$	s. NH_4OH, $Na_2S_2O_3$; i. al.
chloride (cerargyrite)	AgCl	143.32	wh., cb., 2.071	5.56	455	1550	$0.000089^{10°}$	$0.00217^{100°}$	s. NH_4OH, KCN; sl. s. HCl
cyanide	AgCN	133.89	wh., 1.685±	3.95	$-(CN)_2$, 320		$0.000022^{20°}$		s. NH_4OH, KCN, HNO_3
nitrate (lunar caustic)	$AgNO_3$	169.87	col., rhb., 1.744	$4.352\,\frac{19°}{4}$	212	444 d.	$122^{0°}$	$952^{100°}$	s. gly.; v. sl. s. al.
Sodium	Na	22.99	silv. met, cb.	$0.97^{20°}$	97.5	880	d., forms NaOH		i. bz.; d. al.
acetate	$NaC_2H_3O_2$	82.03	wh., mn., 1.464	1.528	324		$46.5^{20°}$	$170^{100°}$	$2.1^{18°}$ al.
acetate	$NaC_2H_3O_2{\cdot}3H_2O$	136.08	wh., mn.	1.45	58	$-3H_2O$, 120	v. s.	v. s.	$7.8^{25°}$ abs. al.
aluminate	$NaAlO_2$	81.97	amor.		1650		s.	v. s.	i. al.
amide	$NaNH_2$	39.01	olive gn.		210	400	d.		d. al.
Sodium ammonium phosphate	$NaNH_4HPO_4{\cdot}4H_2O$	209.07	col., mn.	1.574	79 d.		16.7	100	i. al.
antimonate, meta-	$2NaSbO_3{\cdot}7H_2O$	511.60	cb.				$0.031^{12.8°}$		sl. s. al., NH_4 salts; i. ac.
arsenate	$Na_3AsO_4{\cdot}12H_2O$	424.07	hex., 1.4589	1.759	86.3		$26.7^{17°}$		1.67 al., $50^{15°}$ gly.
arsenate, acid (monobasic)	$NaH_2AsO_4{\cdot}H_2O$	181.94	rhb., 1.5535	2.535	d. 100		s.		
arsenate, acid (dibasic)	$Na_2HAsO_4{\cdot}7H_2O$*	312.01	col., mn., 1.4658	1.871	125	$-7H_2O$, 100	$61^{15°}$	v. s.	sl. s. al.
arsenate, acid (dibasic)	$Na_2HAsO_4{\cdot}12H_2O$	402.09	mn., 1.4496	1.72	28	$-12H_2O$, 100	$5.59^{0.1°}$	$140.7^{30°}$	sl. s. al.
arsenite, acid	Na_2HAsO_3	169.91	col.	1.87			v. s.		
benzoate	$NaC_7H_5O_2$	144.10	col. cr.				$62.5^{25°}$	$76.9^{100°}$	$2.3^{25°}$, $8.3^{78°}$ al.
bicarbonate	$NaHCO_3$	84.01	wh., mn., 1.500	2.20	$-CO_2$, 270		$6.9^{0°}$	$16.4^{60°}$	i. al.
bifluoride	$NaHF_2$	61.99	col. cr.		d.		$3.7^{20°}$	s.	
bisulfate	$NaHSO_4$	120.06	col., tri.	2.742	>315	d., $-H_2O$	$50^{0°}$	$100^{100°}$	d. al.; i. NH_3
bisulfite	$NaHSO_3$	104.06	col., mn., 1.526	1.48	d.		sl. s.	s.	i. al., act.
borate, tetra-	$Na_2B_4O_7$	201.22		2.367	741		$1.3^{0°}$	$8.79^{40°}$	i. al.
borate, tetra	$Na_2B_4O_7{\cdot}5H_2O$	291.30	col., rhb., 1.461	1.815			$22^{62°}$ (anh.)	$52.3^{100°}$ (anh.)	
borate, tetra- (borax)	$Na_2B_4O_7{\cdot}10H_2O$*	381.37	wh., mn., 1.4694	1.73	75	$-10H_2O$, 200	$1.3^{0.5}$ (anh).	$20.3^{80°}$ (anh.)	s. gly.; i. abs. al.
bromate	$NaBrO_3$	150.89	col., cb.	$3.339^{17.5°}$	381		$27.5^{0°}$	$90.9^{100°}$	i. al.
bromide	NaBr	102.89	col., cb., 1.6412	$3.205^{17.5°}$	755	1390	$90^{20°}$	$121^{100°}$	sl. s. al.
bromide	$NaBr{\cdot}2H_2O$	138.92	col., mn.	2.176	50.7		$79.5^{0°}$ (anh.)	$118.3^{80°}$ (anh.)	sl. s. al.
carbonate (soda ash)	Na_2CO_3	105.99	wh. pd., 1.535	2.533	851	d.	$7.1^{0°}$	$48.5^{104°}$	i. al., et.
carbonate	$Na_2CO_3{\cdot}H_2O$	124.00	wh., rhb., 1.506–1.509	1.55	$-H_2O$, 100		s.	s.	s. gly.; i. al., et.
carbonate	$Na_2CO_3{\cdot}7H_2O$	232.10	rhb. or trig.	1.51	d. 35.1		s.	s.	
carbonate (sal soda)	$Na_2CO_3{\cdot}10H_2O$	286.14	wh., mn., 1.425	1.46			$21.5^{0°}$	$238^{30°}$	i. al.

*Usual commercial form.

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds (*Continued*)

Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Sodium ammonium phosphate (*Cont.*)									
carbonate, sesqui- (trona)	$Na_3H(CO_3)_2 \cdot 2H_2O$	226.03	wh., mn., 1.5073	2.112	d.		$13^{0°}$	$42^{100°}$	
chlorate	$NaClO_3$	106.44	wh., cb., or trig., 1.5151	$2.490^{15°}$	248	d.	$79^{0°}$	$230^{100°}$	s. al.
chloride	NaCl	58.44	col., cb., 1.5443	2.163	800.4	1413	$35.7^{0°}$	$39.8^{100°}$	sl. s. al.; i. conc. HCl
chromate	Na_2CrO_4	161.97	yel., rhb.	2.723	392		$32^{0°}$	$126^{100°}$	
chromate	$Na_2CrO_4 \cdot 10H_2O$	342.13	yel., delq., mn.	1.483	19.9		v. s.	∞	sl. s. al.
citrate	$2Na_3C_6H_5O_7 \cdot 11H_2O$	714.31	wh., rhb.	$1.857\ \frac{23.5°}{4}$	$-11H_2O$, 150	d.	$91^{25°}$	$250^{100°}$	i. al.
cyanide	NaCN	49.01	wh., cb., 1.452		563.7	1496	$48^{10°}$	$82^{35°}$	s. NH_3; sl. s. al.
dichromate	$Na_2Cr_2O_7 \cdot 2H_2O$	298.00	red, mn., 1.6994	$2.52^{18°}$	$-2H_2O$, 84.6; 356 (anh.)	d. 400	$238^{0°}$	$508^{80°}$	
ferricyanide	$Na_3Fe(CN)_6 \cdot H_2O$	298.93	red, delq.				$18.9^{0°}$	$67^{100°}$	i. al.
ferrocyanide	$Na_4Fe(CN)_6 \cdot 10H_2O$	484.06	yel., mn.	1.458			$17.9^{20°}$ (anh.)	$63^{98.5°}$ (anh.)	i. al.
fluoride (villiaumite)	NaF	41.99	tet., 1.3258	2.79	992		$4^{0°}$	$5^{100°}$	v. sl. s. al.
formate	$NaHCO_2$	68.01	wh., mn.	1.919	253		$44^{0°}$	$160^{100°}$	sl. s. al.; i. et.
hydride	NaH	24.00	silv. nd., 1.470	0.92	d. 800		d.		i. bz., CS_2, CCl_4, NH_3; s. molten metal
hydrosulfide	$NaSH \cdot 2H_2O$	92.09	col., delq., nd.		d.		s.	s.	s. al.; d. a.
hydrosulfide	$NaSH \cdot 3H_2O$	110.11	rhb.		22	d.	s.	s.	s. al.; d. a.
hydrosulfite	$Na_2S_2O_4 \cdot 2H_2O$	210.14	col. cr.		d.		$22^{20°}$	d.	i. al.
hydroxide	NaOH	40.00	wh., delq.	2.130	318.4	1390	$42^{0°}$	$347^{100°}$	v. s. al., et., gly.; i. act.
hydroxide	$NaOH \cdot 3½H_2O$	103.05	mn.		15.5		s.	v. s.	
hypochlorite	NaOCl	74.44	pa. yel., in soln. only		d.		$26^{0°}$	$158^{56°}$	
iodide	NaI°	149.89	col., cb., 1.7745	$3.667^{0°}$	651	1300	$158.7^{0°}$	$302^{100°}$	v. s. al., act.
iodide	$NaI \cdot 2H_2O$	185.92	col., mn.	2.448			v. s.	v. s.	v. s. NH_3
lactate	$NaC_3H_5O_3$	112.06	col., amor.		d.		v. s.	v. s.	s. al.; i. et.
nitrate (soda niter)	$NaNO_3$	84.99	col., trig., 1.5874	2.257	308	d. 380	$73^{0°}$	$180^{100°}$	s. NH_3; sl. s. gly., al.
nitrite	$NaNO_2$	69.00	pa. yel., rhb.	$2.168^{0°}$	271	d. 320	$72.1^{0°}$	$163.2^{100°}$	$0.3^{20°}$ et.; 0.3 abs. al.; $4.4^{20°}$ m. al.; v. s. NH_3
oxide	Na_2O	61.98	wh., delq.	2.27	subl.		Forms NaOH		d. al.
perborate	$NaBO_3 \cdot H_2O$	99.81	wh. pd.		d. 40		sl. s.	d.	s. gly., alk.
perchlorate	$NaClO_4$	122.44	rhb., 1.4617		482 d.		$170^{0°}$	$320^{100°}$	s. al.; 51 m. al.; 52 act.; i. et.
perchlorate	$NaClO_4 \cdot H_2O$	140.46	hex.	2.02	d. 130		$209^{15°}$	$284^{50°}$	s. al.
peroxide	Na_2O_2°	77.98	yel.-wh. pd.	2.805	d.		s. d.	d.	s. dil. a.
peroxide	$Na_2O_2 \cdot 8H_2O$	222.10	wh., hex.		d. 30		s. d.	d.	
phosphate, monobasic	$NaH_2PO_4 \cdot H_2O$°	137.99	col., rhb., 1.4852	2.040	$-H_2O$, 100	d. 200	$71^{0°}$	$390^{83°}$	i. al.
phosphate, monobasic	$NaH_2PO_4 \cdot 2H_2O$	156.01	col., rhb., 1.4629	1.91	60		$91.1^{0°}$	$308^{40°}$	
phosphate, dibasic	$Na_2HPO_4 \cdot 7H_2O$	268.07	col., mn., 1.4424	1.679	d.		$185^{40°}$	$2000^{100°}$	
phosphate, dibasic	$Na_2HPO_4 \cdot 12H_2O$	358.14	col., mn., 1.4361	1.52	34.6	$-12H_2O$, 180	$4.3^{0°}$	$76.7^{30°}$	i. al.
phosphate, tribasic	Na_3PO_4	163.94	wh.	$2.537^{17.5°}$	1340		$4.5^{0°}$	$77^{100°}$	
phosphate, tribasic	$Na_3PO_4 \cdot 12H_2O$°	380.12	wh., trig., 1.4458	1.62	73.4	$-11H_2O$, 100	$28.3^{15°}$	∞	i. CS_2
phosphate, meta-	$Na_4P_4O_{12}$	407.85	col.	2.476	616 d.		s.	s.	s. a., alk.
phosphate, pyro-	$Na_4P_2O_7$°	265.90	wh.	2.45	988		$2.26^{0°}$	$45^{96°}$	d. a.
phosphate, pyro-	$Na_4P_2O_7 \cdot 10H_2O$	446.06	mn., 1.4525	1.82	d.		$5.4^{0°}$	$93^{100°}$	i. al., NH_3
phosphate (pyrodisodium)	$Na_2H_2P_2O_7$	221.94	col., mn., 1.510	1.862	d. 220		$4.5^{0°}$	$21^{40°}$	
phosphate (pyrodisodium)	$Na_2H_2P_2O_7 \cdot 6H_2O$	330.03	col., mn., 1.4645	1.848			$6.9^{0°}$	$36^{40°}$	
potassium tartrate	$NaKC_4H_4O_6 \cdot 4H_2O$	282.22	rhb., 1.493	1.790	70 to 80	$-4H_2O$, 215	$26^{0°}$	$66^{26°}$	sl. s. al.
silicate, meta-	Na_2SiO_3	122.06	col., rhb., 1.520		1088		s.	s. d.	i. Na or K salts, al.
Sodium silicate, meta-	$Na_2SiO_3 \cdot 9H_2O$	284.20	rhb.		47	$-6H_2O$, 100	v. s.	v. s.	$29^{18°}$, ½N NaOH
silicate, ortho-	Na_4SiO_4	184.04	col., hex., 1.530		1018		s.	s.	
silicofluoride	Na_2SiF_6	188.06	wh., hex., 1.312	2.679	d.		$0.44^{0°}$	$2.45^{100°}$	i. al.
stannate	$Na_2SnO_3 \cdot 3H_2O$	266.73	hex. tablets		d. 140		$50^{0°}$	$67^{50°}$	i. al., act.
sulfate (thenardite)	Na_2SO_4	142.04	col., rhb., 1.477	2.698	tr. 100 to mn.		$5^{0°}$	$42^{100°}$	i. al.
sulfate	Na_2SO_4	142.04	col., mn.		tr. 500 to hex.		$48.8^{40°}$	$42.5^{100°}$	d. HI; s. H_2SO_4

sulfate	Na_2SO_4	142.04	col., hex.		884		$19.4^{20°}$	$45.3^{60°}$	
sulfate	$Na_2SO_4·7H_2O$	268.15	tet.				$44.9^{0°}$	$202.6^{26°}$	
sulfate (Glauber's salt)	$Na_2SO_4·10H_2O$	322.19	col., mn., 1.396	1.464	32.4	$-10H_2O$, 100	$36^{15°}$	$412^{34°}$	i. al.
sulfide, mono-	Na_2S	78.04	pink or wh., amor.	1.856			$15.4^{10°}$	$57.3^{90°}$	sl. s. al.; i. et.
sulfide, tetra-	Na_2S_4	174.24	yel., cb.		275		s.	s.	s. al.
sulfide, penta-	Na_2S_5	206.30	yel.		251.8		s.	s.	s. al.
sulfite	Na_2SO_3	126.04	hex. pr., 1.565	$2.633\,\frac{15°}{4}$	d.		$13.9^{0°}$	$28.3^{84°}$	i. al., NH
sulfite	$Na_2SO_3·7H_2O$	252.15	mn.	1.561	$-7H_2O$, 150	d.	$34.7^{2°}$	$67.8^{18°}$	i. al.
tartrate	$Na_2C_4H_4O_6·2H_2O$	230.08	rhb.	1.818			$29^{6°}$	$66^{43°}$	i. al.
thiocyanate	NaCNS	81.07	delq., rhb., 1.625±		287		$110^{10°}$	$225^{100°}$	v. s. al.
thiosulfate	$Na_2S_2O_3$	158.11	mn.	1.667			$50^{0°}$	$231^{80°}$	
thiosulfate (hypo)	$Na_2S_2O_3·5H_2O$°	248.18	mn. pr., 1.5079	1.685	d. 48.0		$74.7^{0°}$	$301.8^{60°}$	s. NH_3; v. sl. s. al.
tungstate	Na_2WO_4	293.82	wh., rhb.	4.179	692		$57.58^{0°}$	$97^{100°}$	
tungstate	$Na_2WO_4·2H_2O$°	329.85	wh., rhb.	3.245	$-2H_2O$, 100		$88^{0°}$	$123.5^{100°}$	sl. s. NH_3; i. a., al.
tungstate, para-	$Na_6W_7O_{24}·16H_2O$	2097.05	wh., tri.	3.987[14°]	$-16H_2O$, 300		8	d.	
uranate	Na_2UO_4	348.01	yel.				i.	i.	s. alk. carb., dil. a.
vanadate	$Na_3VO_4·16H_2O$	472.15	col. nd.		866 (anh.)		v. s.	d.	i. al.
vanadate, pyro-	$Na_4V_2O_7$	305.84	hex.		654		s.		i. al.
Stannic chloride	$SnCl_4$	260.52	col., fuming lq.	2.226	−30.2	114.1	s.	d.	s. abs. al., act., NH_3; s. ∞ CS_2
oxide (cassiterite)	SnO_2	150.71	wh., tet., 1.9968	7.0	1127		i.	i.	s. conc. H_2SO_4; i. alk.; NH_4OH, NH_3
sulfate	$Sn(SO_4)_2·2H_2O$	346.87	col., delq., hex.				v. s.	d.	s. dil. H_2SO_4, HCl; d. abs. al.
Stannous bromide	$SnBr_2$	278.52	yel., rhb.	5.12[17°]	215.5	620	s.	d.	s. C_6H_5N
chloride	$SnCl_2$	189.62	wh., rhb.		246.8	623	$83.9^{0°}$	$269.8^{15°}$	s. alk., abs. al., et.
chloride (tin salt)	$SnCl_2·2H_2O$°	225.65	wh., tri.	2.71[15.5°]	37.7	d.	$118.7^{0°}$	∞	s. tart. a., alk., al.
sulfate	$SnSO_4$	214.77	wh. cr.		$-SO_2$, 360		$19^{19°}$	$18^{100°}$	s. H_2SO_4
Strontium	Sr	87.62	silv. met.	2.6	800	1150	d.	Forms $Sr(OH)_2$	s. al., a.
acetate	$Sr(C_2H_3O_2)_2$	205.71	wh. cr.	2.099		d.	$36.9^{0°}$	$36.4^{97°}$	$0.26^{15°}$ m. al.
carbonate (strontianite)	$SrCO_3$	147.63	wh., rhb., 1.664	3.70	1497[60atm]	$-CO_2$, 1350	$0.0011^{18°}$	$0.065^{100°}$	s. a., NH_4 salts, aq. CO_2
chloride	$SrCl_2$	158.53	wh., cb., 1.6499	3.052	873		$43.5^{0°}$	$100.8^{100°}$	v. sl. s. act., abs. al.; i. NH_3
chloride	$SrCl_2·6H_2O$°	266.62	wh., rhb., 1.5364	1.933[17°]	$-4H_2O$, 61	$-6H_2O$, 100	$104^{0°}$	$198^{40°}$	
hydroxide	$Sr(OH)_2$	121.63	wh., delq.	3.625	375		$0.41^{0°}$	$21.83^{100°}$	s. NH_4Cl
hydroxide	$Sr(OH)_2·8H_2O$°	265.76	col., tet., 1.499	1.90	$-7H_2O$ in dry air		$0.90^{0°}$	$47.7^{100°}$	s. NH_4Cl; i. act.
nitrate	$Sr(NO_3)_2$°	211.63	col., cb., 1.5878	2.986	570		$40^{0°}$	$100^{89°}$	s. NH_3; 0.012 abs. al.
nitrate	$Sr(NO_3)_2·4H_2O$	283.69	wh., mn.	2.2			$62.2^{0°}$	$124^{20°}$	i. HNO_3
oxide (strontia)	SrO	103.62	col., cb., 1.870	4.7	2430		Forms $Sr(OH)_2$		sl. s. al.; i. et.
peroxide	SrO_2	119.62	wh. pd.		d.		$0.008^{20°}$	d.	s. al., NH_4Cl; i. act.
peroxide	$SrO_2·8H_2O$	263.74	wh. cr.		$-8H_2O$, 100	d.	$0.018^{20°}$	d.	s. al.; i. NH_4OH
sulfate (celestite)	$SrSO_4$	183.68	col., rhb., 1.6237	3.96	1580 d.		$0.0113^{0°}$	$0.0114^{32°}$	sl. s. a.; i. dil. H_2SO_4, al.
sulfate, acid	$Sr(HSO_4)_2$	281.76	col., granular		d.		d.		$14^{70°}$ H_2SO_4
Sulfamic acid	NH_2SO_3H	97.09	wh., rhb.	$2.03\,\frac{12°}{4}$	205 d.		$20^{0°}$	$40^{70°}$	sl. s. al., act.; i. et.
Sulfur, amorphous	S	32.07	pa. yel. pd., 2.0–2.9	2.046	120	444.6	i.	i.	sl. s. CS_2
Sulfur, monoclinic	S_8	256.52	pa. yel., mn.	1.96	119.0	444.6	i.	i.	s. CS_2, al.
Sulfur, rhombic	S_8	256.52	pa. yel., rhb.	2.07	112.8	444.6	i.	i.	$24^{0°}$, $181^{55°}$ CS_2
Sulfur bromide, mono-	S_2Br_2	223.94	red, fuming lq.	2.635	−46	$54^{0.18mm}$	d.		
chloride, mono-	S_2Cl_2	135.04	red-yel. lq.	1.687	−80	138	d.		s. CS_2, et., bz.
chloride, di-	SCl_2	102.97	dark red fuming lq.	$1.621\,\frac{15°}{15}$	−78	59	d.		d. al.
chloride, tetra-	SCl_4	173.88	yel.-brn. lq.		−30	d. > −20	d.		
oxide, di-	SO_2	64.06	col. gas	lq., $1.434^{0°}$; 2.264 (A)	−75.5	−10.0	$22.8^{0°}$	$4.5^{50°}$	s. H_2SO_4; al., ac.
oxide, tri-(α)	SO_3	80.06	col. pr.	lq., 1.923; 2.75 (A)	16.83	44.6	d.		s. H_2SO_4
oxide, tri-(β)	$(SO_3)_2$	160.13	col., silky, nd.	$1.97^{20°}$	50		Forms H_2SO_4		s. H_2SO_4
Sulfuric acid	H2SO4°	98.08	col., viscous lq.	$1.834\,\frac{18°}{4}$	10.49	d. 340	∞	∞	d. al.
Sulfuric acid	$H_2SO_4·H_2O$	116.09	pr. or lq.	$1.842\,\frac{15°}{4}$	8.62	290	∞	∞	d. al.

°Usual commercial form.

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds (*Concluded*)

Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Sulfuric acid	$H_2SO_4 \cdot 2H_2O$	134.11	col. lq.	$1.650^{\frac{0°}{4}}$	–38.9	167	∞	∞	d. al.
Sulfuric acid, pyro-	$H_2S_2O_7$	178.14	cr.	$1.9^{20°}$	35	d.	d.		d. al.
Sulfuric oxychloride	SO_2Cl_2	134.97	col. lq.	$1.667^{\frac{20°}{4}}$	–54.1	69.1^{760mm}	d.		s. ac.; d. al.
Sulfurous oxybromide	$SOBr_2$	207.87	or.-yel. lq.	$2.68^{18°}$	–50	68^{40mm}	d.		s. bz., CS_2, CCl_4; d. act.
oxychloride	$SOCl_2$	118.97	col. lq.	1.638	–104.5	78.8	d.		s. bz., chl.
Tantalum	Ta	180.95	bk.-gray, cb.	16.6	2850	>4100	i.	i.	s. fused alk., HF; i. HCl, HNO_3, H_2SO_4
Tellurium	Te	127.60	met., hex.	(α) 6.24; (β) 6.00	452	1390	i.	i.	s. H_2SO_4, HNO_3, KCN, KOH, aq. reg.; i. CS_2
Terbium	Tb	158.93							
Thallium	Tl	204.38	blue-wh., tet.	11.85	303.5	1650	i.	i.	s. HNO_3, H_2SO_4; i. NH_3
acetate	$TlC_2H_3O_2$	263.43	silky nd.	3.68	110		v. s.		v. s. al.
chloride, mono-	TlCl	239.84	wh., cb.	7.00	430	806	$0.21^{0°}$	$1.8^{100°}$	sl. s. HCl; i. al., NH_4OH
chloride, sesqui-	Tl_2Cl_3	515.13	yel., hex.	5.9	400–500	d.	$0.26^{15°}$	$1.9^{100°}$	
chloride, tri-	$TlCl_3$	310.74	hex. pl.		25	d.	v. s.		s. al., et.
chloride, tri-	$TlCl_3 \cdot 4H_2O$	382.80	nd.		37	$-4H_2O$, 100	$86.2^{17°}$	d.	s. al., et.
sulfate (ic)	$Tl_2(SO_4)_3 \cdot 7H_2O$	823.06	lf.		$-6H_2O$, 200	d.	d.	d.	s. dil. H_2SO_4
sulfate (ous)	Tl_2SO_4	504.83	col., rhb., 1.8671	6.77	632	d.	$2.70^{0°}$	$18.45^{100°}$	
sulfate, acid	$TlHSO_4$	301.45	trimorphous		115 d.				v. sl. s. dil. H_2SO_4
Thio, *cf.* sulfo or sulfur									
Thorium	Th	232.04	cb.	11.2	1845	>3000	i.	i.	s. HCl, H_2SO; sl. s. HNO_3; i. HF, alk.
oxide, di- (thorianite)	ThO_2	264.04	wh., cb.	9.69	>2800	4400	i.		s. h. H_2SO_4; i. alk.
sulfate	$Th(SO_4)_2$	424.16		$4.225^{17°}$			$0.74^{0°}$	$5.22^{50°}$	
sulfate	$Th(SO_4)_2 \cdot 9H_2O$	586.30	mn. pr.	2.77	$-9H_2O$, 400		sl. s.	sl. s.	
Thulium	Tm	168.93					i.	i.	
Tin	Sn	118.71	silv. met., tet.	7.31	231.85	2260	i.	i.	s. HCl, H_2SO_4, dil. HNO_3 h. aq KOH
Tin	Sn	118.71	gray, cb.	5.750	Stable –163 to +18	2260	i.	i.	s. a., h. alk. solns.
Tin salts, *cf.* stannic and stannous									
Titanic acid	H_2TiO_3	97.88	wh. pd.				i.	i.	s. alk.; v. sl. s. dil. a.; i. al.
Titanium	Ti	47.87	dark gray, cb.	$4.50^{17.5°}$	1800	>3000	i.	d.	s. a.
chloride, di-	$TiCl_2$	118.77	bk., delq.		Unstable in air		d.		i. CS_2, et., chl.
chloride, tri-	$TiCl_3$	154.23	vl., delq.		d. 440		s.	s.	
chloride, tetra-	$TiCl_4$*	189.68	col. lq.	lq., 1.726	–30	136.4	s.	d.	s. dil. HCl
oxide, di- (anatase)	TiO_2	79.87	brn. or bk., tet., 2.534–2.564	3.84			i.	i.	sl. s. alk.
oxide, di- (brookite)	TiO_2	79.87	brn. or bk., rhb., 2.586	4.17			i.	i.	
oxide, di- (rutile)	TiO_2	79.87	col. if pure, tet., 2.615	4.26	1640 d.	<3000	i.	i.	s. H_2SO_4, alk.
Tungsten	W	183.84	gray-bk., cb.	19.3	3370	5900	i.	i.	s. h. conc. KOH; sl. s. NH_3, HNO_3, aq. reg.
carbide	WC	195.85	gray pd., cb.	$15.7^{18°}$	2777	6000	i.	i.	s. F_2; i. a.
carbide	W_2C	379.69	iron gray	$16.06^{18°}$	2877	6000	i.	i.	s. h. HNO_3; sl. s. HCl, H_2SO_4
oxide, tri-	WO_3	231.84	yel., rhb.	7.16	>2130		i.	i.	s. alk.; i. a.
Tungstic acid (tungstite)	H_2WO_4	249.85	yel., rhb. 2.24	5.5	$-½H_2O$, 100; 1473		i.	sl. s.	s. HF, alk., NH_3
Uranic acid	H_2UO_4	304.04	yel. pd.	$5.926^{15°}$	$-H_2O$, 250 to 300		i.	i.	s. a., alk. carb.; i. alk.
Uranium	U	238.03	wh. cr.	$18.485^{\frac{13°}{4}}$	1133	3500	i.	i.	s. a.; i. alk.
carbide	U_2C_3	512.09	cr.	11.28	2400		d.		d. a.
oxide, di- (uraninite)	UO_2	270.03	bk., rhb.	10.9	2176		i.	i.	s. HNO_3, conc. H_2SO_4

oxide (pitchblende)	U_3O_8	842.08	olive gn.	7.31	d.		i.	i.	s. HNO_3, H_2SO_4
sulfate (ous)	$U(SO_4)_2 \cdot 4H_2O$	502.22	gn., rhb.		$-4H_2O$, 300		$23^{11°}$	$9^{63°}$	s. dil. a.
Uranyl acetate	$UO_2(C_2H_3O_2)_2 \cdot 2H_2O$	424.15	yel., rhb.	$2.89^{15°}$	$-2H_2O$, 110		$9.2^{17°}$	d.	s. al., act.
carbonate (rutherfordine)	UO_2CO_3	330.04	tet.	5.6					
nitrate	$UO_2(NO_3)_2 \cdot 6H_2O$	502.13	yel., rhb., 1.4967	2.807	60.2	118	$170.3^{0°}$	$\infty^{60°}$	v. s. ac., al., et.; i. dil., alk.
sulfate	$UO_2SO_4 \cdot 3H_2O$	420.14	yel. cr.	$3.28^{16.5°}$	d. 100		$18.9^{13.2°}$	$230^{25°}$	4 al.; s. a.
Vanadic acid, meta-	HVO_3	99.95	yel. scales				i.		s. a., alk.; i. NH_3
Vanadic acid, pyro-	$H_4V_2O_7$	217.91	pa. yel., amor.				i.		s. a., alk., NH_4OH
Vanadium	V	50.94	lt. gray, cb.	5.96	1710	3000	i.	i.	s. HNO_3, H_2SO_4; i. aq., alk.
chloride, di-	VCl_2	121.85	gn., hex., delq.	$3.23^{18°}$			s.	d.	s. al., et.
chloride, tri-	VCl_3	157.30	pink, tabular, delq.	$3.00^{18°}$	d.		s.	d.	s. abs. al., et.
chloride, tetra-	VCl_4	192.75	red lq.	$1.816^{30°}$	−109	148.5^{755mm}	s. d.		s. abs. al., et., chl., ac.
oxide, di-	V_2O_2	133.88	lt. gray cr.	3.64	ign.		i.	i.	s. a.
oxide, tri-	V_2O_3	149.88	bk. cr.	$4.87\ \frac{18°}{4}$	1970		sl. s.	s.	s. HNO_3, HF, alk.
oxide, tetra-	V_2O_4	165.88	blue cr.	4.399	1967		i.	i.	s. a., alk.
oxide, penta-	V_2O_5	181.88	red-yel., rhb.	$3.357\ \frac{18°}{4}$	800	d. 1750	$0.8^{20°}$		s. a., alk.; i. abs. al.
oxychloride, mono-	VOCl	86.39	brn. pd.	2.824			i.		v. s. HNO_3
Vanadyl chloride	$(VO)_2Cl$	169.33	yel. cr.	3.64	d. in air		i.		s. HNO_3
chloride, di-	$VOCl_2$	137.85	gn., delq.	$2.88^{13°}$			d.		s. abs. al., dil. HNO_3
chloride, tri-	$VOCl_3$	173.30	yel. lq.	1.829	<−15	127.19	s. d.		s. al., et., ∞Br_2
Water†	H_2O	18.02	col. lq., $1.33300^{20°}$; hex. solid, 1.309	$1.00^{4°}$ (lq.); $0.915^{0°}$ (ice)	0	100			∞ al.; sl. s. et.
Water, heavy	D_2O	20.029	col. lq., $1.32844^{20°}$	$1.107^{20°}$	3.82	101.42	∞	∞	∞ al.; sl. s. et.
Xenon	Xe	131.29	col. gas	lq., $3.06^{-109.1}$ $2.7^{-140°}$ 4.53 (A)	−140	−109.1	$24.2^{0°}$ cc	$7.3^{50°}$ cc	
Ytterbium	Yb	173.04							
Yttrium	Y	88.91	dark gray, hex.	5.51	1490	2500	sl. d.	d.	v. s. dil. a., h. KOH
Zinc	Zn	65.41	silv. met., hex.	7.140	419.4	907	i.	i.	s. a., ac., alk.
acetate	$Zn(C_2H_3O_2)_2$	183.50	mn.	1.840	242	subl. in vac.	$30^{25°}$	$44.6^{100°}$	$2.8^{25°}$, $166^{79°}$ al.
acetate	$Zn(C_2H_3O_2)_2 \cdot 2H_2O$*	219.53	wh., mn., 1.494	1.735	237	$-2H_2O$, 100	$40^{25°}$	$66.6^{100°}$	v. s. al.
bromide	$ZnBr_2$	225.22	rhb.	$4.219^{4°}$	394	650	$390^{0°}$	$670^{100°}$	v. s. NH_4OH, al., et.
carbonate	$ZnCO_3$	125.42	wh., trig., 1.818	4.42	$-CO_2$, 300		$0.001^{15°}$		s. a., alk., NH_4 salts; i. act., NH_3
chloride	$ZnCl_2$	136.32	wh., delq., 1.687, uniaxial	$2.91\ \frac{25°}{4}$	283	732	$432^{25°}$	$615^{100°}$	$100^{12.5°}$ al.; v. s. et.; i. NH_3
cyanide	$Zn(CN)_2$	117.44	col., rhb.		d. 80		$0.0005^{18°}$	sl. s.	s. KCN, NH_3, alk.; i. al.
hydroxide	$Zn(OH)_2$	99.42	col., rhb.	3.053	d. 125		$0.00052^{18°}$		s. a., alk., NH_4OH
iodide	ZnI_2	319.22	cb.	$4.666\ \frac{14.2°}{4}$	446	624	$430^{0°}$	$510^{100°}$	s. a., al., NH_3, aq. $(NH_4)_2CO_3$
nitrate	$Zn(NO_3)_2 \cdot 6H_2O$	297.51	col., tet.	$2.065\ \frac{14°}{4}$	36.4	$-6H_2O$, 105	324.5	$\infty^{36.4°}$	v. s. al.
oxide (zincite)	ZnO	81.41	wh., hex., 2.004	5.606	>1800		$0.00042^{18°}$		s. a., alk., NH_4Cl; i. NH_3
oxide	ZnO	81.41	wh., amor.	5.47	>1800		$0.00042^{18°}$		
peroxide	ZnO_2	97.41	yel.	1.571	expl. 212		0.0022		i. NH_4OH; d. a.
phosphide	Zn_3P_2	258.17	steel gray, cb.	$4.55\ \frac{13°}{4}$	>420	1100	i.		s. dil. a.
silicate	$ZnSiO_3$	141.49	hex. or rhb.; glass, 1.650	3.52	1437		i.		
sulfate (zincosite)	$ZnSO_4$	161.47	wh., rhb., 1.669	$3.74\ \frac{15°}{4}$	d. 740		$42^{0°}$	$61^{100°}$	sl. s. al.; s. gly.
sulfate	$ZnSO_4 \cdot H_2O$	179.49	col.	$3.28\ \frac{15°}{4}$	d. 238		s.	$89.5^{100°}$	
sulfate	$ZnSO_4 \cdot 6H_2O$	269.56	mn.	$2.072\ \frac{15°}{4}$	$-5H_2O$, 70		s.	s.	sl. s. al.; i. act.; NH_3
sulfate (goslarite)	$ZnSO_4 \cdot 7H_2O$*	287.58	rhb., 1.4801	$1.966^{16.5°}$	tr. 39	$-7H_2O$, 280	$115.2^{0°}$	$653.6^{100°}$	sl. s. al.; i. act.; NH_3
sulfide (α) (wurzite)	ZnS	97.47	wh., hex., 2.356	4.087	1850^{150atm}	subl. 1185	$0.00069^{18°}$	i.	v. s. a.; i. ac.
sulfide (β) (sphalerite)	ZnS	97.47	wh., cb.; glass (?) 2.18–2.25	$4.102\ \frac{25°}{4}$	tr. 1020		i.	i.	s. a.
sulfide (blende)	ZnS	97.47	wh., granular	4.04			i.	i.	v. s. a.; i. ac.
sulfite	$ZnSO_3 \cdot 2½H_2O$	190.51	mn.		$-2½H_2O$, 100	d. 200	0.16	d.	s. H_2SO_3, NH_4OH; i. al.
Zirconium	Zr	91.22	cb., pd. ign. easily	6.4	1700	>2900	i.	i.	s. HF, aq. reg.; sl. s. a.
oxide, di- (baddeleyite)	ZrO_2	123.22	yel. or brn., mn., 2.19	5.49	2700		i.	i.	s. H_2SO_4, HF
oxide, di- (free from Hf)	ZrO_2	123.22	wh., mn.	5.73		4300	i.	i.	s. H_2SO_4, HF

*Usual commercial form.
†*Cf.* special tables on water and steam, Tables 2-3, 2-4, 2-5, 2-185, 2-186 and 2-351 through 2-357.
NOTE: °F = ⅘ °C + 32.

TABLE 2-2 Physical Properties of Organic Compounds*

Abbreviations Used in the Table

(A), density referred to air
al., ethyl alcohol
amor., amorphous
aq., aqua, water
brn., brown
bz., benzene
c., cubic
cc., cubic centimeter
chl., chloroform
col., colorless
cr., crystalline
d., decomposes
d-, dextrorotatory
dl-, dextro-laevorotatory
et., ethyl ether
expl., explodes
gn., green
h., hot
hex., hexagonal
i-, iso-, containing the group $(CH_3)_2CH$-
i., insoluble
ign., ignites
l-, laevorotatory
lf., leaflets
lq., liquid
m-, meta
mn., monoclinic
n-, normal
nd., needles
o-, ortho
or., orange
p-, para
pd., powder
pet., petroleum ether
pl., plates
pr., prisms
rhb., rhombic
s., soluble
s-, sec-, secondary
silv., silvery
sl., slightly
subl., sublimes
sym., symmetrical
t-, tertiary
tet., tetragonal
tri., triclinic
uns., unsymmetrical
v., very
v. s., very soluble
v. sl. s., very slightly soluble
wh., white
yel., yellow
(+), right rotation
>, greater than
<, less than
∞, infinitely

This table of the physical properties includes the organic compounds of most general interest. For the properties of other organic compounds, reference must be made to larger tables in Lange's *Handbook of Chemistry* (Handbook Publishers), *Handbook of Chemistry and Physics* (Chemical Rubber Publishing Co.), Van Nostrand's *Chemical Annual, International Critical Tables* (McGraw-Hill), and similar works.

The **molecular weights** are based on the atomic weight values in "Atomic weights of the Elements 2001," *PURE Appl. Chem.*, **75,** 1107, 2003. The **densities** are given for the temperature indicated and are usually referred to water at 4°C, *e.g.,* $1.028^{95/4}$ a density of 1.028 at 95° C referred to water at 4° C, the 4 being omitted when it is not clear whether the reference is to water at 4°C or at the temperature indicated by the upper figure. The melting and boiling points given have been selected from available data as probably the most accurate. The **solubility** is given in grams of the substance in 100 of the solvent. In the case of gases, the solubility is often expressed in some manner as "5^{10} cc." which indicates that, at 10°C, 5 cc. of the gas are soluble in 100 of the solvent.

Name	Synonym	Formula	Formula weight	Form and color	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
								Water	Alcohol	Ether
Abietic acid	sylvic acid, abietinic acid	$C_{20}H_{30}O_2$	302.45	lf.		182		i.	v. s.	v. s.
Acenaphthene	naphthylene ethylene	$C_{10}H_6(CH_2)_2$	154.21	rhb./al.	$1.069^{95/95}$	95	278–9	i.	s. h.	s. chl.
Acetal	acetaldehyde diethylacetal	$CH_3CH(OC_2H_5)_2$	118.17	lq.	$0.821^{22/4}$		102.2	6^{25}	∞	∞
Acet-aldehyde	ethanal	CH_3CHO	44.05	col. lq.	$0.783^{18/4}$	–123.5	20.2	∞	∞	∞
-aldehyde, par-	paraldehyde	$(C_2H_4O)_3$	132.16	col. cr.	$0.994^{20/4}$	10.5–12	124.4^{752}	12^{13}	∞	∞
-aldehyde ammonia		$CH_3CHOHNH_2$	61.08	col. cr.		97	100–10 d.	v. s.	v. s.	sl. s.
-amide	ethanamide	CH_3CONH_2	59.07	col. cr.	1.159	81(69.4)	222	s.	s.	v. sl. s.
-anilide	antifebrin	$C_6H_5NHCOCH_3$	135.16	rhb./al.	1.21^4	113–4	305	0.5^6	21^{20}	7^{25}
-phenetidide (*o-*)	*o*-ethoxyacetanilide	$CH_3CONHC_6H_4OC_2H_5$	179.22	lf./al.		79	>250	i.	s.	
(*m-*)	acetyl-*m*-phenetidine	$CH_3CONHC_6H_4OC_2H_5$	179.22	lf./al.		96–7		sl. s.	s.	
-toluidide (*o-*)	N-tolylacetamide	$CH_3C_6H_4NHCOCH_3$	149.19	rhb.	1.168^{15}	110	296	0.86^{19}	s.	s.
(*p-*)	N-tolylacetamide	$CH_3C_6H_4NHCOCH_3$	149.19	rhb. or mn.	1.212^{15}	153	306–7	0.09^{22}	10^{25}	s.
Acetic acid	ethanoic acid, vinegar acid	CH_3CO_2H	60.05	col. lq.	$1.049^{20/4}$	16.7	118.1	∞	∞	∞
anhydride	acetyl oxide, acetic oxide	$(CH_3CO)_2O$	102.09	col. lq.	$1.082^{20/4}$	–73	139.6	12 c.	∞	∞
nitrile	methyl cyanide	CH_3CN	41.05	col. lq.	$0.783^{20/4}$	–41	81.6–2.0	∞	∞	∞
Acetone	propanone, dimethyl ketone	CH_3COCH_3	58.08	col. lq.	$0.792^{20/4}$	–94.6	56.5	∞	∞	∞
Acetonyl urea	dimethyl hydantoin	<NHCONHCOC>$(CH_3)_2$	128.13	tri./al.		175	subl.	s.	s.	s.
Acetophenone benzoyl hydride	methyl-phenyl ketone	$CH_3COC_6H_5$	120.15	lf.	$1.033^{15/15}$	20.5	202.3^{749}	i.	s.	s.
Acetyl-chloride	ethanoyl chloride	CH_3COCl	78.50	col. lq.	$1.105^{20/4}$	–112.0	51–2	d.	d.	∞
-phenylenediamine (-*p*)	amino-acetanilide (*p*)	$C_2H_3ONHC_6H_4NH_2$	150.18	nd./aq.		162		s. h.	v. s.	v. s.
Acetylene	ethyne; ethine	HC:CH	26.04	col. gas	(A) 0.906	$–81.5^{891}$	$–84^{760}$	100 cc.[18]	600 cc.[18]	
dichloride (*cis*)	1,2-dichloroethene	CHCl:CHCl	96.94	col. lq.	$1.291^{15/4}$	–80.5	60.3	0.35^{20}	∞	∞
(*trans*)	dioform	CHCl:CHCl	96.94	col. lq.	$1.265^{15/4}$	–50	48.4	0.63^{20}	∞	∞
Aconitic acid	equisetic acid; citridic acid	$C_3H_3(CO_2H)_3$	174.11	cr./aq.		192 d.		33^{15}	sl. s.	v. sl. s.
Acridine		$C_6H_4 < (CH)(N) > C_6H_4$	179.22	rhb./aq. al.		110–1	346	sl. s. h.	s.	s.
Acrolein ethylene aldehyde	acrylic aldehyde, propenal	$CH_2{:}CH{\cdot}CHO$	56.06	col. lq.	$0.841^{20/4}$	–87.7	52.5	40	s.	s.
Acrylic acid	propenoic acid	$CH_2{:}CH{\cdot}CO_2H$	72.06	col. lq.	$1.062^{16/4}$	12–13	141–2	∞	∞	
nitrile	vinyl cyanide	$CH_2{:}CH{\cdot}CN$	53.06	col. lq.	0.811^{20}	–82	78–9	s.		
Adipic acid	hexandioc acid, adipinic acid	$(CH_2CH_2CO_2H)_2$	146.14	mn. pr.	$1.360^{25/4}$	151–3	265^{10}	1.4^{15}	v. s.	0.6^{15}
amide		$(CH_2CH_2CONH_2)_2$	144.17	cr. pd.		226–7		0.4^{12}		
nitrile	tetramethylene	$(CH_2CH_2CN)_2$	108.14	col. oil	$0.951^{19/19}$	1	295	v. sl. s.	s.	v. sl. s.
Adrenaline (1-) (3,4,1)	1-suprarenine	$C_6H_3(OH)_2(CHOHCH_2NHCH_3)$	183.20	col. pd.		d. 207–11		0.03^{20}	v. sl. s.	i.
Alanine (α) (*dl-*)		$CH_3CH(NH_2)CO_2H$	89.09	nd./aq.		295 d.	subl. >200	22^{17}	v. sl. s.	i.
Aldol acetaldol	2-hydroxybutyraldehyde	$CH_3CH(OH)CH_2COH$	88.11	col. lq.	$1.103^{20/4}$		83^{20}	∞	∞	s.
Alizarin	Anthraquinoic acid	$C_6H_4(CO)_2C_6H_2(OH)_2$	240.21	red rhb.		289–90	430	0.03^{100}	v. s.	v. s.
Allyl alcohol	propen-1-ol-3,propenyl alcohol	$CH_2{:}CH{\cdot}CH_2OH$	58.08	col. lq.	$0.854^{20/4}$	–129	96.6	∞	∞	∞
bromide	3-bromo-propene-1	$CH_2{:}CH{\cdot}CH_2Br$	120.98	lq.	$1.398^{20/4}$	–119.4	$70–1^{753}$	i.	∞	∞
chloride	3-chloro-propene-1	$CH_2{:}CH{\cdot}CH_2Cl$	76.52	col. lq.	$0.938^{20/4}$	–136.4	44.6	<0.1	∞	∞
thiocyanate (*i*)	mustard oil	$CH_2{:}CH{\cdot}CH_2NCS$	99.15	col. oil	$1.013^{20/4}$	–80	152	0.2	∞	∞
thiourea	thiosinamide	$CH_2{:}CH{\cdot}CH_2NHCSNH_2$	116.18	col. pr.	$1.219^{20/20}$	77–8		3^0	s.	v. sl. s.
Aluminum ethoxide		$Al(OCH_2CH_3)_3$	162.16	pd.	$1.142^{20/0}$	150–60	$200–5^{10}$	d.	i.	v. sl. s.
Amino-anthraquinone (α)		$C_6H_4(CO)_2C_6H_3NH_2$	223.23	red nd.		256	subl.	i.	s.	s.
(β)		$C_6H_4(CO)_2C_6H_3NH_2$	223.23	red nd.		302	subl.	i.	s.	i.
-azobenzene		$C_6H_5{\cdot}N{:}N{\cdot}C_6H_4NH_2$	197.24	yel. mn.		126–7	225^{120}	sl. s. h.	s. h.	s.
-benzoic acid (*m-*)		$H_2N{\cdot}C_6H_4CO_2H$	137.14	nd./aq.	$1.511^{4°}$	173–4		v. sl. s.	2^{10}	1.8^6
(*p-*)	aminodracylic acid	$H_2N{\cdot}C_6H_4CO_2H$	137.14	mn. pr.		187–8		0.3^{13}	11^{10}	8.2^6

Amino-diphenylamine (*p*-)		$H_2N{\cdot}C_6H_4NH{\cdot}C_6H_5$	184.24	nd./aq. al.		67	354	sl. s.	s.	s.
-G-acid (2-)(6-,8-), Na_2 salt		$C_{10}H_5(NH_2)(SO_3Na)_2$	347.28					v. sl. s.		
-mono-potassium salt		$C_{10}H_5(NH_2)S_2O_6HK$	341.40					12.8^{20}		
-sodium salt		$C_{10}H_5(NH_2)S_2O_6HNa$	325.29					2.7^{18}		
-J-acid (2-)(5-,7-)		$C_{10}H_5(NH_2)(SO_3H)_2$	303.31					10.0^{20}		
-mono-potassium salt		$C_{10}H_5(NH_2)S_2O_6HK$	341.40					3.4^{18}		
-naphthol sulfonic (1-,2-,4-)(α-)		$C_{10}H_5OHNH_2SO_3H{\cdot}½H_2O$	248.26					v. s.		
(1-,8-,4-)		$NH_2(OH)C_{10}H_5SO_3H$	239.25					v. sl. s.		
-phenol (*o*-)	2-aminophenol	$H_2N{\cdot}C_6H_4{\cdot}OH$	109.13	col. nd.		173	subl.	1.7^{0}	4.3^{0}	v. s.
(*m*-)	3-aminophenol	$H_2N{\cdot}C_6H_4{\cdot}OH$	109.13	pr.		122–3		2.6^{0}	s.	sl. s.
(*p*-)	*p*-hydroxyaniline	$H_2N{\cdot}C_6H_4{\cdot}OH$	109.13	lf.		184–6 d.	subl.	1.1^{0}	4^{0}	i. bz.
-toluene sulfonic acid (1-,2-,3-)		$C_6H_3(CH_3)(NH_2)SO_3H$	187.22	nd.				0.97^{11}		
(1-,4-,2-)		$C_6H_3(CH_3)(NH_2)SO_3H{\cdot}H_2O$	205.23	mn.		d.		0.5^{20}	i.	
(1-,4-,3-)		$C_6H_3(CH_3)(NH_2)SO_3H{\cdot}½H_2O$	196.22	nd.				0.47		
(1-,2-,5-)		$C_6H_3(CH_3)(NH_2)SO_3H{\cdot}H_2O$	205.23	tri./aq.		$-H_2O$, 120		3^{11}	i.	
Amyl acetate (*n*-)		$CH_3CO_2CH_2(CH_2)_3CH_3$	130.18	col. lq.	$0.879^{30/20}$	−70.8	148.4^{737}	v. sl. s.	∞	∞
(*i*-)	common amyl acetate	$CH_3CO_2CH_2CH_2CH(CH_3)_2$	130.18	col. lq.	$0.876^{15/4}$		142^{757}	0.3^{15}	∞	∞
		$CH_3CO_2CH_2CH(CH_3)C_2H_5$	130.18	col. lq.	0.880^{13}		141–2	v. sl. s.	∞	∞
(*s*-)	α-Me-Bu-acetate	$CH_3CO_2CH(CH_3)CH_2C_2H_5$	130.18	col. lq.	0.922^{0}		133.5	sl. s.	∞	∞
(*s*-)	di Et-carbinol acetate	$CH_3CO_2CH(C_2H_5)_2$	130.18	col. lq.	$0.871^{20/4}$		133	sl. s.	∞	∞
(*t*-)		$CH_3CO_2C(CH_3)_2C_2H_5$	130.18	col. lq.	0.874^{19}		124.5^{749}	v. sl. s.	∞	∞
alcohol (*n*-) fusel oil,	pentanol-1	$CH_3(CH_2)_3CH_2OH$	88.15	col. lq.	$0.817^{20/20}$	−78.5	137.9	2.7^{22}	∞	∞
(*s*-,*n*-) methyl-propyl carbinol,	pentanol-2	$C_2H_5CH_2CH(OH)CH_3$	88.15	col. lq.	$0.810^{20/20}$		119.5	4^{20}	∞	∞
(prim.-,*i*-) isobutyl carbinol,	2-methyl-butanol-4	$(CH_3)_2CHCH_2CH_2OH$	88.15	col. lq.	$0.813^{15/4}$	−117.2	132.0	2^{14}	∞	∞
		$(C_2H_5)_2CHOH$	88.15	col. lq.	$0.815^{25/4}$		115.6	5.5^{30}	∞	∞
(*s*-,*i*-)	2-methyl-butanol-3	$(CH_3)_2CHCH(OH)CH_3$	88.15	col. lq.	0.819^{19}		113–4	2.8^{30}	∞	∞
(*t*-)	2-methyl-butanol-2	$(CH_3)_2C(OH)C_2H_5$	88.15	col. lq.	$0.809^{20/4}$	−11.9	102	sl. s.	s.	s.
		$(CH_3)_3CCH_2OH$	88.15	cr.		52–3	113–4	sl. s.	∞	∞
(*d*-)	active amyl alcohol	$C_2H_5CH(CH_3)CH_2OH$	88.15	col. lq.	$0.816^{20/4}$		128	3.6^{30}	∞	∞
-amine (*n*-)		$CH_3(CH_2)_4NH_2$	87.16	col. lq.	0.766^{19}	−55	103–4	s.	s.	s.
(*s*-,*n*-)		$(C_3H_7)(CH_3)CHNH_2$	87.16	col. lq.	$0.749^{20/4}$		91–2	∞	∞	∞
(*i*-)		$(CH_3)_2CH(CH_2)_2NH_2$	87.16	col. lq.	$0.751^{18/4}$		95	∞	∞	∞
(*t*-)		$(C_2H_5)(CH_3)_2CNH_2$	87.16	col. lq.	$0.731^{25/4}$	−105	77–8	∞	∞	∞
	1-NH_2-2-Me-butane	$C_2H_5CH(CH_3)CH_2NH_2$	87.16	col. lq.	0.755^{18}		95–6	∞	∞	∞
	3-amino pentane	$(C_2H_5)_2CHNH_2$	87.16	col. lq.	$0.749^{20/4}$		90–1	∞	∞	∞
	3-NH_2-2-Me-butane	$(CH_3)_2CHCH(CH_3)NH_2$	87.16	col. lq.	0.757^{18}		83–4	∞	∞	∞
aniline (*i*-)		$C_6H_5NHC_5H_{11}$	163.26	lq.	$0.928^{15/4}$		254.5	i.		
benzoate (*i*-)		$C_6H_5CO_2C_5H_{11}$	192.25	col. lq.	$0.992^{14/14}$		261^{746}	i.	∞	∞
bromide (*n*-)	1-bromopentane	$CH_3(CH_2)_3CH_2Br$	151.04	col. lq.	$1.218^{20/4}$	−95	129.7	i.	s.	
(*i*-)	4-Br-2-Me-butane	$(CH_3)_2CH(CH_2)_2Br$	151.04	col. lq.	$1.220^{17/15}$		120^{745}	0.02^{16}	s.	s.
(*t*-)	2-Br-2-Me-butane	$(CH_3)_2C(Br)C_2H_5$	151.04	lq.	$1.216^{19/0}$		108^{765}	i.	s.	s.
n-butyrate (*n*-)		$C_2H_5CH_2CO_2(CH_2)_4CH_3$	158.24	col. lq.	$0.871^{15/4}$	−73.2	186.4	0.05^{50}	∞	∞
(*i*-)		$C_2H_5CH_2CO_2{\cdot}C_5H_{11}$	158.24	col. lq.	$0.866^{19/15}$		178.6	i.	∞	∞
(*t*-)		$C_3H_7CO_2C(CH_3)_2C_2H_5$	158.24	col. lq.	$0.865^{15/0}$		164	sl. s.	∞	∞
i-butyrate (*i*-)		$(CH_3)_2CHCO_2C_5H_{11}$	158.24	lq.	$0.876^{0/4}$		168.8	i.	s.	s.
chloride (*n*-)	1-chloropentane	$CH_3(CH_2)_3CH_2Cl$	106.59	col. lq.	$0.878^{20/4}$	−99	108.4	i.	s.	s.
(*s*-)	2-chloropentane	$C_2H_5CH_2CHClCH_3$	106.59	lq.	$0.870^{20/4}$		96.7	i.	s.	s.
(*s*-)	3-chloropentane	$(C_2H_5)_2CHCl$	106.59	col. lq.	0.895^{21}		97.3	i.	∞	∞
(*i*-)	4-Cl-2-Me-butane	$(CH_3)_2CH(CH_2)_2Cl$	106.59	col. lq.	$0.893^{20/4}$		99.7^{758}	i.	s.	∞
(*s*-,*i*-)	3-Cl-2-Me-butane	$(CH_3)CHCHClCH_3$	106.59	lq.	0.883^{0}		91^{753}	i.	s.	s.
(*t*-)	2-Cl-2-Me-butane	$(CH_3)_2CClC_2H_5$	106.59	lq.	$0.871^{20/4}$	−72.9	85.7	i.	s.	s.
	1-Cl-2-Me-butane	$(CH_3)(C_2H_5)CHCH_2Cl$	106.59	lq.	$0.881^{17.5}$		98–9	i.	s.	s.
i-cyanide (*i*-)	iso-caproic iso-nitrile	$(CH_3)_2CH(CH_2)_2NC$	97.16	lq.			137–9	i.	s.	s.
formate (*n*-)		$HCO_2CH_2(CH_2)_3CH_3$	116.16	lq.	0.902^{0}	−73.5	132	v. sl. s.	∞	∞
(*i*-)		$HCO_2CH_2CH_2CH(CH_3)_2$	116.16	lq.	$0.882^{20/4}$	−93.5	123.5	0.3^{22}	∞	∞
iodide (*n*-)	1-iodopentane	$CH_3(CH_2)_3CH_2I$	198.05	lq.	$1.510^{20/4}$	−86	157.0	i.	s.	∞
(*i*-)	4-I-2-Me-butane	$(CH_3)_2CHCH_2CH_2I$	198.05	lq.	$1.515^{18/4}$		147^{765}	i.	∞	∞
(*s*-,*n*-)	2-iodopentane	$C_2H_5CH_2CHICH_3$	198.05	lq.	$1.507^{17/4}$		144–5	i.	∞	∞
(*t*-)	2-I-2-Me-butane	$(CH_3)_2CIC_2H_5$	198.05	lq.	$1.471^{19/15}$		127^{765}	i.	∞	∞
		$C_2H_5CH(CH_3)CH_2I$	198.05	lq.	$1.524^{20/4}$		148	i.	∞	∞
mercaptan (*n*-)	pentanthiol-1	$CH_3(CH_2)_3CH_2SH$	104.21	lq.	0.857^{20}		126^{767}	i.	∞	∞
(*n*-)	pentanthiol-3	$(C_2H_5)_2CHSH$	104.21	col. lq.			105	i.	∞	∞
(*i*-)	2-Me-butanthiol-4	$(CH_3)_2CH(CH_2)_2SH$	104.21	lq.	$0.835^{20/4}$		120	i.	∞	∞
phenol (*t*-)(*p*-)	pentaphen	$C_5H_{11}{\cdot}C_6H_4OH$	164.24	cr.		93	265–7	sl. s.	s.	s.
propionate (*n*-)		$C_2H_5CO_2(CH_2)_4CH_3$	144.21	lq.	$0.876^{15/4}$	−73.1	168.7	i.	∞	∞
(*i*-)		$C_2H_5CO_2(CH_2)_2CH(CH_3)_2$	144.21	col. lq.	$0.870^{20/4}$		160.2	0.1^{25}	∞	∞
(act.)		$C_2H_5CO_2C_5H_{11}$	144.21	col. lq.	$0.866^{20/4}$		58^{16}	v. sl. s.	∞	∞
salicylate (*n*-)		$HOC_6H_4CO_2C_5H_{11}$	208.25	lq.	1.065^{15}		265	i.	∞	∞
Amyl *i*-valerate (*i*)		$C_4H_9CO_2C_5H_{11}$	172.26	col. lq.	$0.858^{20/15}$		194	v. sl. s.	∞	∞
(*t*-)		$C_4H_9CO_2C_5H_{11}$	172.26	col. lq.	$0.861^{14/0}$		173–4	sl. s.	s.	s.

*By N. A. Lange, Ph.D., Handbook Publishers, Inc., Sandusky, Ohio. Abridged from table of Physical Constants of Organic Compounds in *Lange's Handbook of Chemistry.*

TABLE 2-2 Physical Properties of Organic Compounds (*Continued*)

Name	Synonym	Formula	Formula weight	Form and color	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
								Water	Alcohol	Ether
Amylene (*n*-)(α-)	pentene-1	$C_2H_5CH_2CH{:}CH_2$	70.13	lq.	0.644^{20}		30–1	i.	∞	∞
(*i*-)	2-methyl-butene-3	$(CH_3)_2CHCH{:}CH_2$	70.13	col. lq.	0.632^{15}	–135	20.5^{771}	i.	∞	∞
(α-)	2-methyl-butene-1	$(C_2H_5)(CH_3)C{:}CH_2$	70.13	col. lq.	$0.667^{0/0}$		$31–2^{758}$	i.	∞	∞
(*n*-)(β-)	pentene-2	$C_2H_5CH{:}CHCH_3$	70.13	col. lq.	$0.650^{20/4}$	–139	36.4	v. sl. s.	∞	∞
(*i*-)(β-)	2-methyl-butene-2	$(CH_3)_2C{:}CHCH_3$	70.13	col. lq.	$0.663^{19/4}$	–124	37–8	i.	s.	∞
Anethole (*p*-)	*p*-propenyl anisole	$CH_3CH{:}CH{\cdot}C_6H_4OCH_3$	148.20	lf./al.	$0.991^{20/20}$	22.5	235.3	v. sl. s.	s.	∞
Anhydroformald-aniline	methylene aniline	$(CH_2NC_6H_5)_3$	315.41	pr./al.		143	185	i.	sl. s.	s.
Aniline	amino benzene, phenyl amine, cyanol	$C_6H_5NH_2$	93.13	col. oil	$1.022^{20/4}$	–6.2	184.4	3.6^{18}	∞	∞
hydrochloride	aniline salt, aniline chloride	$C_6H_5NH_2{\cdot}HCl$	129.59	cr.	1.222^{4}	198	245	18^{15}	s.	i.
nitrate		$C_6H_5NH_2{\cdot}HNO_3$	156.14	rhb.	1.356^{4}	d. 190		s.	s.	sl. s.
sulfate		$(C_6H_5NH_2)_2{\cdot}H_2SO_4$	284.33	lf./al.	1.377^{4}	d.		5^{14}	sl. s.	i.
Anisal-acetone (*p*-)	MeO-benzalacetone	$CH_3OC_6H_4CH{:}CHCOCH_3$	176.21	lf./et.		73–4		i.	v. s.	v. s.
Anisic acid (*p*-)		$CH_3OC_6H_4CO_2H$	152.15	mn./aq.	1.385^{4}	184.2	275–80	0.03^{19}	v. s.	v. s.
aldehyde (*p*-)		$CH_3OC_6H_4CHO$	136.15	col. oil	$1.123^{20/4}$	2.5	247–8	v. sl. s.	∞	∞
Anisidine (*o*-)	2-amino-anisole	$CH_3OC_6H_4NH_2$	123.15	col. lq.	$1.098^{15/15}$	5.2	225	v. sl. s.	∞	∞
(*m*-)	MeO-aniline(*m*)	$CH_3OC_6H_4NH_2$	123.15	oil	$1.096^{20/4}$	<–12	251	v. sl. s.	s.	s.
(*p*-)	4-amino anisole	$CH_3OC_6H_4NH_2$	123.15	pl./aq.	$1.089^{55/55}$	57.2	243	s. h.	s.	s.
Anisole	methyl phenyl ether	$CH_3OC_6H_5$	108.14	col. lq.	$0.990^{22/4}$	–37.3	154–5	i.	s.	s.
Anthracene	paranaphthalene, anthracin green oil	$C_6H_4{:}(CH)_2{:}C_6H_4$	178.23	col. mn.	$1.25^{27/4}$	217–8	340–2	i.	1.5^{20}	
Anthramine (α)	α-amino-anthracene	$C_6H_4{:}(CH)_2{:}C_6H_3NH_2$	193.24	yel./al.		130±		i.	s.	
(β)	β-amino-anthracene	$C_6H_4{:}(CH)_2{:}C_6H_3NH_2$	193.24	yel./al.		238	subl.	i.	sl. s.	sl. s.
Anthranil		$C_6H_4{:}(NH)CO$	119.12	col. oil	$1.187^{15/4}$	<–18	d. >215	sl. s. h.	s.	s.
Anthranilic acid (*o*-)		$H_2NC_6H_4CO_2H$	137.14	col. rhb.		144–5	subl.	0.35^{14}	11^{10}	16^{7}
Anthrapurpurin (1-,2-,7-)		$C_{14}H_5O_2(OH)_3$	256.21	or. nd./al.		369	462	sl. s. h.	v. s. h.	sl. s.
Anthraquinone	diphenyleneketone, dihydrodiketoanthracene	$C_6H_4{:}(CO)_2{:}C_6H_4$	208.21	yel. rhb.	$1.438^{20/4}$	286	379–81	i.	0.05^{18}	v. sl. s.
disulfonate Na_2 (1-,5-)	ρ-anthraquinone disulfonate	$C_{14}H_6O_2(SO_3Na)_2{\cdot}5H_2O$	502.38	yel. lf.				v. s.	i.	i.
(1-,8-)	*x*-anthraquinone disulfonate	$C_{14}H_6O_2(SO_3Na)_2{\cdot}4H_2O$	484.36	yel. pr.				sl. s.		
(2-,6-)		$C_{14}H_6O_2(SO_3Na)_2{\cdot}7H_2O$	538.41	col. cr.				3.9^{20}		
(2-,7-)		$C_{14}H_6O_2(SO_3Na)_2{\cdot}4H_2O$	484.36	cr.				30.5^{20}	v. sl. s.	i.
sulfonate Na (1-)		$C_{14}H_7O_2SO_3Na$	310.26	yel. lf.				0.53^{20}	i.	i.
(2-)		$C_{14}H_7O_2SO_3Na$	310.26	silv. lf.				0.84^{25}	i.	i.
Anthrarufin (1-,5-)		$C_{14}H_6O_2(OH)_2$	240.21	yel. lf.		280	subl.	i.	sl. s.	s.
Antipyrene	1-ph-2,3-diMepyrazolone-5	$C_{11}H_{12}ON_2$	188.23	mn./aq.	$1.088^{113/4}$	113(109)	319^{174}	100^{25}	100	sl. s.
Apiole	1-allyl-2, 5-diMeO-3,4 methylenedioxybenzene	$C_{12}H_{14}O_4$	222.24	col. nd.	$1.02^{20/4}$	30	294	i	s.	s.
Arabinose (α)(*d*- or *l*-)		$CH_2OH(CHOH)_3CHO$	150.13	rhb. pr.	$1.585^{20/4}$	159.5		46^{0}	$0.5^{9°}$	i.
(*dl*-)		$CH_2OH(CHOH)_3CHO$	150.13			164.5		16.9^{10}		
Arachidic acid	eicosanoic acid	$CH_3(CH_2)_{18}CO_2H$	312.53	col. lf.		77	328	i.	s. h.	v. s.
Arsanilic acid (*p*-)		$H_2N{\cdot}C_6H_4.AsO_3H_2$	217.05	nd./aq.		232		v. s. h.	v. s. h.	i.
Asparagine (*l*-)		$HO_2C{\cdot}C_2H_3(NH_2){\cdot}CONH_2$	132.12	rhb.	$1.543^{15/4}$	227–35	d. 235	3.1^{28}	i. c.	
Aspirin (*o*-)		$CH_3CO_2{\cdot}C_6H_4{\cdot}CO_2H$	180.16	nd./aq.		135–6		1^{37}	s.	5^{20}
Atropic acid	α-phenyl acrylic acid	$C_6H_5C(:CH_2){\cdot}CO_2H$	148.16	nd./aq.		106–7	267 d.	0.1 c.	s.	s.
Auramine	4,4′-dimethylaminobenzophenomide	$[(CH_3)_2NC_6H_4]_2C{:}NH$	267.37	col./al.		136		i.	7^{20}	2.3^{20}
Aurine, coralline (4-,4′-)		$(HOC_6H_4)_2C{:}C_6H_4{:}O$	290.31	red		310 d.		i.	s.	s.
Azo-anisole (2-,2′-)	diMeO-azobenzene	$(CH_3O{\cdot}C_6H_4N{:})_2$	242.27	or. pr.		153		i.	s.	s.
benzene	diphenyldiimide	$C_6H_5N{:}N{\cdot}C_6H_5$	182.22	or. mn.	$1.203^{20/4}$	68	297	i.	4.2^{20}	
Azoxybenzene		$(C_6H_5)_2N_2O$	198.22	yel. rhb.	$1.248^{20/20}$	36	d.	i.	11.4^{15}	
Barbituric acid	malonyl urea	$CO{:}(NHCO)_2{:}CH_2{\cdot}2H_2O$	164.12	col./aq.		d. 245		s. h.	sl. s.	s.
Benzal acetone	Me-cinnamyl ketone	$C_6H_5CH{:}CHCOCH_3$	146.19	pl.	$1.035^{20/20}$	41–2	260–2	i.	s.	s.
Benzaldehyde	artificial almond oil	C_6H_5CHO	106.12	col. lq.	$1.046^{20/4}$	–26	179	0.3	∞	∞
Benzamide		$C_6H_5CONH_2$	121.14	col. pr.	1.341	130	290	1.35^{25}	17^{25}	sl. s.
Benzanilide		$C_6H_5CONHC_6H_5$	197.23	lf./al.	1.31^{4}	163	$117–9^{10}$	i.	4^{30}	sl. s.
Benzene	benzol, phenyl hydride, cyclohexatriene	C_6H_6	78.11	col. lq.	$0.879^{20/4}$	5.5	80.1	0.07^{22}	s.	∞
sulfinic acid		$C_6H_5SO_2H$	142.18	pr./aq.		83–4	d. > 100	v. s. h.	v. s.	v. s.
sulfonic acid		$C_6H_5SO_3H$	158.18	col. nd.		65–6	d.	v. s.	v. s.	i.
sulfonic amide	benzene sulfonamide	$C_6H_5SO_2NH_2$	157.19	mn./aq.		156		0.43^{16}	v. s.	v. s.
sulfonic chloride	benzene sulfonyl chloride	$C_6H_5SO_2Cl$	176.62	cr.	$1.384^{15/15}$	14.5	251.5	i.	v. s.	s.
Benzidine (4-,4′-)		$NH_2{\cdot}C_6H_4{\cdot}C_6H_4{\cdot}NH_2$	184.24	cr./aq.		128–9	400^{740}	1 h.	1 h.	2
disulfonic acid (2-,2′-)		$(\cdot C_6H_3(NH_2)SO_3H)_2{\cdot}3H_2O$	398.41	pr./aq.		d. >175		0.09^{25}	i.	i.
(3-,3′-)		$(\cdot C_6H_3(NH_2)SO_3H)_2$	344.36					v. sl. s.		
Benzil	dibenzoyl	$C_6H_5CO{\cdot}COC_6H_5$	210.23	pr.	1.23^{15}	95	348 d.	i.	v. s.	v. s.
Benzoic acid		$C_6H_5CO_2H$	122.12	mn. pr.	$1.266^{15/4}$	121.7	249.2	0.2^{17}	46^{15}	66^{15}
anhydride		$(C_6H_5CO)_2O$	226.23	rhb./et.	$1.199^{15/4}$	42	360	i.	s.	s.
nitrile	phenyl cyanide	C_6H_5CN	103.12	col. lq.	$1.001^{25/6}$	–12.9	190.7	1^{100}	∞	∞

Benzoin (*dl-*)		$C_6H_5CO{\cdot}CHOHC_6H_5$	212.24	mn.		133–7	344^{768}	v. sl. s.	s. h.	sl. s.
Benzophenone	diphenyl ketone	$C_6H_5COC_6H_5$	182.22	col. rhb.	1.083^{54}	48.5	305.4	i.	6.5^{15}	15^{13}
Benzotrichloride	phenyl chloroform	$C_6H_5CCl_3$	195.47	col. lq.	1.380^{14}	−4.75	220.7	i.	s.	s.
Benzoyl-benzoic acid (*o-*)		$C_6H_5COC_6H_4CO_2H{\cdot}H_2O$	244.24	tri./aq.		93(128)		sl. s.		
-chloride		C_6H_5COCl	140.57	col. lq.	$1.212^{20/4}$	−0.5	197.2	d.	d. h.	∞
-peroxide		$(C_6H_5CO)_2O_2$	242.23	rhb./et.		108 d.	expl.	i.	s. h.	s.
Benzyl acetate		$CH_3CO_2CH_2C_6H_5$	150.17	col. lq.	1.057^{17}	−51.5	213.5	i.	∞	∞
alcohol	phenyl carbinol	$C_6H_5CH_2OH$	108.14	col. lq.	$1.043^{20/4}$	−15.3	204.7	4^{17}	∞	∞
amine	ω-amino toluene	$C_6H_5CH_2NH_2$	107.15	lq.	$0.982^{20/4}$		184.5	∞	∞	∞
aniline	phenyl-benzylamine	$C_6H_5CH_2NHC_6H_5$	183.25	mn. pr.	$1.065^{25/25}$	37–8	306^{750}	i.		s.
benzoate		$C_6H_5CO_2CH_2C_6H_5$	212.24	nd.	$1.12^{20/4}$	21	323–4	i.	∞	∞
butyrate		$C_2H_5CH_2CO_2CH_2C_6H_5$	178.23	col. lq.	$1.016^{16/18}$	238–40	i.	v. s.	v. s.	
chloride	ω-chlorotoluene	$C_6H_5CH_2Cl$	126.58	col. lq.	$1.100^{20/20}$	−39	179.4	i.	∞	∞
ether	dibenzyl ether	$(C_6H_5CH_2)_2O$	198.26	lq.	1.036^{16}		295–8	i.	s. h.	s.
formate		$HCO_2CH_2C_6H_5$	136.15	col. lq.	1.081^{23}	3.6	$202–3^{747}$	i.	s.	∞
propionate		$C_2H_5CO_2CH_2C_6H_5$	164.20	lq.	$1.036^{16/17}$		220–2	i.		
Berberonic acid (2-,4-,5-)		$C_5H_2N(CO_2H)_3{\cdot}2H_2O$	247.16	tri.		243		v. sl. s.	sl. s. h.	i.
Biuret	allophanamide	$NH(CONH_2)_2$	103.08	nd./al.		192–3 d.		1.3^0	s.	
Borneol (*dl-*)		$C_{10}H_{17}OH$	154.25	col. cr.	$1.011^{20/4}$	210.5	subl.	v. sl. s.		
(*d-* or *l-*)		$C_{10}H_{17}OH$	154.25	col. cr.	$1.011^{20/4}$	208–9	212–3	v. sl. s.	v. s.	v. s.
(iso-)		$C_{10}H_{17}OH$	154.25	col. cr.		212		i.		
Bornyl acetate (*d-*)		$CH_3CO_2C_{10}H_{17}$	196.29	rhb./pet.	0.991^{15}	29	226–7	i.	s.	s.
Bromo-aniline (*p-*)		$BrC_6H_4NH_2$	172.02	rhb.	1.8^{20}	63–4		i. c.	v. s.	v. s.
-benzene	phenyl bromide	C_6H_5Br	157.01	col. lq.	$1.495^{20/4}$	−30.6	156.2	i.	s.	∞
-camphor (3-)(*d-*)	α-bromocamphor	$BrC_{10}H_{15}O$	231.13	cr.	$1.449^{20/4}$	77–8	274	i.	20^{26}	v. s.
-diphenyl (*p-*)		$BrC_6H_4{\cdot}C_6H_5$	233.10	cr./al.		90–1	310	i.	s.	34^{25}
-naphthalene (α-)	α-naphthyl bromide	$C_{10}H_7Br$	207.07	col. oil	$1.482^{20/4}$	5–6	281.1	i.	s.	∞
(β-)	β-naphthyl bromide	$C_{10}H_7Br$	207.07	lf./al.	1.605^0	59	281–2	i.	6^{20}	v. s.
-phenol (*o-*)		BrC_6H_4OH	173.01	col. lq.	1.553^{80}	5.6	194–5	s.	s.	∞
(*m-*)		BrC_6H_4OH	173.01	cr.		32–3	236–7		s.	s.
(*p-*)		BrC_6H_4OH	173.01	tet. cr.	1.588^{80}	63.5	238	1.4^{15}	v. s.	v. s.
-styrene (ω)(1)		$C_6H_5CH{:}CHBr$	183.05	lq.	$1.422^{20/4}$	7	221	i.	∞	∞
(2)		$C_6H_5CH{:}CHBr$	183.05	lq.	$1.427^{20/4}$	−7.5	108^{26}	i.	∞	∞
-toluene (*o-*)	*o*-tolyl bromide	$CH_3{\cdot}C_6H_4Br$	171.03	col. lq.	$1.422^{20/4}$	−28	181.8	i.	s.	$∞^{25}$
(*m-*)		$CH_3{\cdot}C_6H_4Br$	171.03	col. lq.	$1.410^{20/4}$	−39.8	183.7	i.	s.	s.
(*p-*)		$CH_3{\cdot}C_6H_4Br$	171.03	cr./al.	$1.390^{20/4}$	28.5	184–5	i.	s.	$∞^{25}$
Bromoform	tribromo-methane	$CHBr_3$	252.73	col. lq.	$2.890^{20/4}$	8–9	150.5	0.1 c.	∞	∞
Butadiene (1-,2-)	methyl-allene	$CH_3CH{:}C{:}CH_2$	54.09	lq.			18–9	i.	∞	∞
(1-,3-)	erythrene	$CH_2{:}CHCH{:}CH_2$	54.09	col. gas	$0.621^{20/4}$	−108.9	−4.41	i.	∞	∞
Butadienyl acetylene		$CH_2{:}(CH)_2{:}CH{\cdot}C{\equiv}CH$	78.11	col. lq.	$0.773^{20/4}$		83–6	i.		
Butane	diethyl	$CH_3CH_2CH_2CH_3$	58.12	col. gas	0.60^0	−135	−0.6	i.	s.	s.
(*i-*)	trimethyl-methane	$(CH_3)_2CHCH_3$	58.12	col. gas	0.60^0	−145	−10	i.	s.	s.
Butyl acetate (*n-*)		$CH_3CO_2(CH_2)_2C_2H_5$	116.16	col. lq.	0.882^{20}	−76.3	125^{740}	0.7	∞	∞
(*s-*)		$CH_3CO_2CH(CH_3)C_2H_5$	116.16	col. lq.	$0.865^{25/4}$		112^{744}	i.	∞	∞
(*i-*)		$CH_3CO_2CH_2CH(CH_3)_2$	116.16	col. lq.	$0.871^{20/4}$	−98.9	118	0.6^{25}	∞	∞
(*tert-*)		$CH_3CO_2C(CH_3)_3$	116.16	col. lq.	$0.866^{20/4}$		$95–6^{760}$	i.	∞	∞
alcohol (*n-*)	butanol-1	$C_2H_5CH_2CH_2OH$	74.12	col. lq.	$0.810^{20/4}$	−79.9	117	9^{15}	∞	∞
(*s-*)	butanol-2	$C_2H_5CH(OH)CH_3$	74.12	col. lq.	$0.808^{20/4}$	−114.7	99.5	12.5^{20}	∞	∞
(*i-*)	2-methyl-propanol-1	$(CH_3)_2CHCH_2OH$	74.12	col. lq.	$0.805^{17.5}$	−108	107–8	10^{15}	∞	∞
(*tert-*)	2-methyl-propanol-2	$(CH_3)_2COH$	74.12	lq.	0.779^{26}	25.5	82.9	∞	∞	∞
amine (*n-*)		$C_2H_5CH_2CH_2NH_2$	73.14	col. lq.	$0.739^{25/4}$	−50	77.8	∞	∞	∞
(*s-*)		$C_2H_5CH(NH_2)CH_3$	73.14	col. lq.	$0.724^{20/4}$	−104	66^{772}	∞	∞	∞
(*i-*)		$(CH_3)_2CHCH_2NH_2$	73.14	col. lq.	$0.732^{20/20}$	−85	68–9	∞	∞	∞
(*t-*)		$(CH_3)_2CNH_2$	73.14	col. lq.	$0.698^{18/4}$	−67.5	45.2		∞	
p-aminophenol (*N*)(*n*)		$C_4H_9NH{\cdot}C_6H_4{\cdot}OH$	165.23			71		i.		
(*N*)(*i-*)		$C_4H_9NH{\cdot}C_6H_4{\cdot}OH$	165.23			79		i.		
aniline (*n-*)		$C_4H_9NHC_6H_5$	149.23	lq.			235^{720}	i.	v. s.	v. s.
(*i-*)		$C_4H_9NHC_6H_5$	149.23	oil	$0.940^{20/4}$		231–2	0.01^{15}	v. s.	v. s.
arsonic acid (*n-*)		$C_4H_9AsO(OH)_2$	182.05	col. lf.		158–9		s.	s.	i.
benzoate (*n-*)		$C_6H_5CO_2C_4H_9$	178.23	col. oil	$1.005^{25/25}$	−22	249–50	i.	s.	s.
(*i-*)		$C_6H_5CO_2C_4H_9$	178.23	col. oil	$0.997^{25/25}$		241.5	i.	∞	∞
bromide (*n-*)	1-bromo-butane	$C_2H_5CH_2CH_2Br$	137.02	lq.	$1.277^{20/4}$	−112.4	101.6	0.06^{16}	∞	∞
(*s-*)	2-bromo-butane	$C_2H_5CH(Br)CH_3$	137.02	lq.	$1.251^{25/4}$	−112	91.3	i.		
(*i-*)	1-Br-2-Me-propane	$(CH_3)_2CHCH_2Br$	137.02	lq.	$1.258^{25/4}$	−118.5	91.5	0.06^{18}	∞	∞
(*t-*)	2-Br-2-Me-propane	$(CH_3)_3CBr$	137.02	lq.	$1.211^{20/4}$	−16.2	73.3	i.	∞	∞
butyrate (*n-*)(*n-*)		$C_2H_5CH_2CO_2CH_2CH_2C_2H_5$	144.21	col. lq.	$0.872^{20/20}$		165.7^{736}	i.	∞	∞
(*n-*)(*i-*)		$C_2H_5CH_2CO_2CH_2CH(CH_3)_2$	144.21	col. lq.	$0.863^{18/4}$		156.9	i.	∞	∞
(*i-*)(*i-*)		$(CH_3)_2CHCO_2CH_2CH(CH_3)_2$	144.21	col. lq.	$0.875^{0/4}$	−80.7	148–9	i.	∞	∞
caproate		$CH_3(CH_2)_4CO_2C_4H_9$	172.26	col. lq.	$0.882^{0/0}$		204.3	i.		
carbamate (*i-*)		$NH_2CO_2CH_2CH(CH_3)_2$	117.15	col. lf.	$0.956^{76/4}$	65	206–7	i.	s.	s.
cellosolve (*n-*)	2-BuO-ethanol-1	$C_4H_9OCH_2CH_2OH$	118.17	col. lq.	$0.903^{20/4}$		171.2	∞	∞	∞

TABLE 2-2 Physical Properties of Organic Compounds (*Continued*)

Name	Synonym	Formula	Formula weight	Form and color	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
								Water	Alcohol	Ether
chloride (*n-*)	1-chloro-butane	$C_2H_5CH_2CH_2Cl$	92.57	col. lq.	0.887^{20}	–123.1	77.9^{763}	0.07^{18}	∞	∞
(*s-*)	2-chloro-butane	$C_2H_5{\cdot}CHCl{\cdot}CH_3$	92.57	col. lq.	$0.871^{20/4}$	–131	67.8^{767}	i.	∞	∞
(*i-*)	1-Cl_2-2-Me-propane	$(CH_3)_2CHCH_2Cl$	92.57	col. lq.	0.884^{15}	–131.2	68.9	i.	∞	∞
(*t-*)	2-Cl_2-2-Me-propane	$(CH_3)_3CCl$	92.57	col. lq.	0.847^{15}	–26.5	51–2	i.	∞	∞
dimethylbenzene (*t-*)(1-,3-,5-)		$(CH_3)_3C{\cdot}C_6H_3{\cdot}(CH_3)_2$	162.27	col. lq.			$200–2^{147}$	i.		
formate (*n-*)		$HCO_2CH_2CH_2C_2H_5$	102.13	lq.	0.911^{0}		106.9	v. sl. s.	∞	∞
(*s-*)		$HCO_2CH(CH_3)C_2H_5$	102.13	lq.	$0.882^{20/4}$		97	sl. s.	∞	∞
(*i-*)		$HCO_2CH_2CH(CH_3)_2$	102.13	lq.	$0.885^{20/4}$	–95.3	98.2	1.1^{22}	∞	∞
furoate (*n-*)		$OC_4H_3CO_2C_4H_9$	168.19	col. lq.	$1.056^{20/4}$		$118–20^{25}$	i.	∞	∞
iodide (*n-*)	1-iodo-butane	$C_2H_5CH_2CH_2I$	184.02	lq.	$1.617^{20/4}$	–103.5	129.9	i.	∞	∞
(*s-*)	2-iodo-butane	$C_2H_5CHICH_3$	184.02	lq.	1.595^{20}	–104	118–9	i.	∞	∞
(*i-*)	1-iodo-2-Me-propane	$(CH_3)_2CHCH_2I$	184.02	lq.	$1.606^{20/4}$	–90.7	120	i.	∞	∞
(*t-*)	2-iodo-2-Me-propane	$(CH_3)_3CI$	184.02	lq.	$1.370^{19/15}$	–34	99	i.	∞	∞
lactate (*n-*)		$CH_3CH(OH)CO_2C_4H_9$	146.18	col. lq.	0.968		$75–6^{6}$	sl. s.	∞	∞
mercaptan (*n-*)	butanthiol-1	$C_2H_5CH_2CH_2SH$	90.19	col. lq.	$0.837^{25/4}$	–116	97–8	sl. s.	v. s.	v. s.
(*i-*)	2-Me-propanthiol-1	$(CH_3)_2CHCH_2SH$	90.19	lq.	$0.836^{20/4}$	<–79	88	v. sl. s.	s.	s.
(*t-*)		$(CH_3)_3CSH$	90.19	lq.			65–7			
methacrylate (*n-*)		$CH_2{:}C(CH_3)CO_2C_4H_9$	142.20	lq.	$0.889^{15.6}$		155	i.		
(*i-*)		$CH_2{:}C(CH_3)CO_2C_4H_9$	142.20	lq.	$0.889^{15.6}$		155	i.		
phenol (*p-*)(*t-*)		$(CH_3)_3C{\cdot}C_6H_4{\cdot}OH$	150.22	nd./aq.	$0.908^{112/4}$	99	236–8	sl. s.	s.	s.
propionate (*n-*)		$C_2H_5CO_2C_4H_9$	130.18	col. lq.	0.883^{15}	–89.55	146	i.	∞	∞
(*s-*)		$C_2H_5CO_2C_4H_9$	130.18	col. lq.	$0.866^{20/4}$		132.5	i.	∞	∞
(*i-*)		$C_2H_5CO_2C_4H_9$	130.18	col. lq.	$0.888^{0/4}$	–71.4	136.8	i.	∞	∞
stearate (*n-*)		$CH_3(CH_2)_{16}CO_2C_4H_9$	340.58	col. lq.	$0.855^{25/25}$	27.5	$220–5^{25}$	0.3^{25}	s.	s.
(*i-*)		$CH_3(CH_2)_{16}CO_2C_4H_9$	340.58	wax		25		i.		
iso-thiocyanate (*n-*)	butyl mustard oil	$C_2H_5CH_2CH_2{\cdot}N{:}CS$	115.20	lq.	0.956^{11}		165^{724}	i.	s.	s.
(*i-*)	iso-Bu mustard oil	$(CH_3)_2CHCH_2{\cdot}N{:}CS$	115.20	lq.	$0.964^{14/4}$		162	i.	s.	s.
(*s-*)(*d-*)		$C_4H_9{\cdot}N{:}CS$	115.20	lq.	$0.943^{20/4}$		159–63	i.	s.	s.
(*t-*)		$(CH_3)_3C{\cdot}N{:}CS$	115.20	lq.	0.919^{10}	10.5	140^{770}	i.	s.	s.
valerate (*n-*)(*n-*)		$CH_3(CH_2)_3CO_2(CH_2)_3CH_3$	158.24	lq.	$0.870^{15/4}$	–93	186	v. sl. s.	∞	∞
(*i-*)(*n-*)		$(CH_3)_2CHCH_2CO_2(CH_2)_3CH_3$	158.24	lq.	$0.862^{25/4}$		168.8	i.	∞	∞
(*i-*)(*s-*)		$(CH_3)_2CHCH_2CO_2C_4H_9$	158.24	col. lq.	$0.848^{20/4}$		$163–4^{752}$	i.	∞	∞
(*i-*)(*i-*)		$C_4H_9CO_2C_4H_9$	158.24	col. lq.	$0.874^{0/4}$		168.7	i.	∞	∞
Butylene (α-)	butene-1	$C_2H_5CH{:}CH_2$	56.11	col. gas	0.6^{9}	–130	$–5^{758}$	i.	v. s.	v. s.
(β-)	butene-2	$CH_3CH{:}CHCH_3$	56.11	col. gas		–127	3^{746}			
Butyraldehyde (*n-*)		$CH_3CH_2CH_2CHO$	72.11	col. lq.	$0.817^{20/4}$	–99	75.7	4	∞	∞
(*i-*)	2-Me-propanol	$(CH_3)_2CHCHO$	72.11	col. lq.	$0.794^{20/4}$	–65.9	64^{757}	11^{20}	∞	∞
Butyric acid (*n-*)	butanoic acid	$C_2H_5CH_2CO_2H$	88.11	col. lq.	$0.964^{20/4}$	–4.7	163.5^{757}	∞	∞	∞
(*i-*)	2-Me-propanoic acid	$(CH_3)_2CHCO_2H$	88.11	col. lq.	$0.949^{20/4}$	–47	154.5	20^{20}	∞	∞
amide (*n-*)	*n*-butyramide	$C_2H_5CH_2CONH_2$	87.12	rhb.	1.032	115–6	216	16.3^{15}	s.	sl. s.
(*i-*)	iso-butyramide	$(CH_3)_2CHCONH_2$	87.12	mn. pl.	1.013	129–30	216–20	v. s.	s.	sl. s.
anhydride (*n-*)		$(C_2H_5CH_2CO)_2O$	158.19	col. lq.	$0.968^{20/20}$	–75	199.5	d.	d	∞
(*i-*)		$[(CH_3)_2CHCO]_2O$	158.19	col. lq.	$0.950^{25/4}$	–53.5	181.5^{734}	d.	d	∞
anilide (*n-*)	*n*-butyranilide	$C_3H_7CONHC_6H_5$	163.22	mn. pr.	1.134	92	189^{15}	i.	s.	s.
Caffeic acid (3-,4-)		$(HO)_2C_6H_3C_2H_2CO_2H$	180.16	yel./aq.		195–213	d.	s. h.	s.	sl. s.
Caffeine		$C_8H_{10}O_2N_4{\cdot}H_2O$	212.21	nd./al.	1.23^{19}	237	subl.	2	2	0.3
Camphene (*dl-*)		$C_{10}H_{16}$	136.23	cr.	0.822^{78}	50	160	i.	s.	s.
(*d-* or *l-*)		$C_{10}H_{16}$	136.23	cr.	$0.845^{50/4}$	42.7	159.6	i.	s.	s.
Camphor (*d-*)		$C_{10}H_{16}O$	152.23	trig.	$0.999^{9/9}$	178–9	209.1^{759}	0.1	120^{12}	v. s.
Camphoric acid (*d-*)		$C_8H_{14}(CO_2H)_2$	200.23	mn.	1.186	187		0.6^{12}	s.	
Cantharidine		$C_{10}H_{12}O_4$	196.20	cr.		212		0.003		
Capric acid	decanoic acid	$CH_3(CH_2)_8CO_2H$	172.26	col. nd.	0.889^{87}	31.5	268–70	0.003	s.	s.
Caproic acid (*n-*)	hexanoic acid	$CH_3(CH_2)_4CO_2H$	116.16	oily lq.	$0.922^{20/4}$	–1.5	202^{761}	1.1^{20}	s.	s.
(*i-*)	2-Me-pentanoic-5 acid	$(CH_3)_2CH(CH_2)_2{\cdot}CO_2H$	116.16	col. oil	$0.925^{20/4}$	–35	207.7	v. sl. s.	s.	s.
Caprylic acid (*n-*)	octanoic acid	$CH_3(CH_2)_6CO_2H$	144.21	col. lf.	$0.910^{20/4}$	16	237.5	0.07^{15}	s.	s.
Carbazole	diphenylenelimine, dibenzopyrrole	$(C_6H_4)_2NH$	167.21	lf.		244.8	354.8	i.	0.92^{14}	sl. s.
Carbitol	diethylene glycol mono-Et ether	$C_2H_5O(CH_2)_2O(CH_2)_2OH$	134.17	col. lq.	$0.990^{20/20}$		201.9	∞	v. s.	s.
Carbon disulfide		CS_2	76.14	col. lq.	$1.263^{20/4}$	–108.6	46.3	0.2^{0}	∞	∞
monoxide		CO	28.01	col. gas	$0.81^{-195/4}$	–207	–192	3.5^{0} cc.	s.	
suboxide		OC:C:CO	68.03	gas	1.114^{0}	–107	7^{761}	d.	s.	
tetrabromide	tetrabromomethane	CBr_4	331.63	col. mn.	3.42	90.1(48)	189.5	0.02^{30}	s.	s.
tetrachloride	tetrachloromethane	CCl_4	153.82	col. lq.	$1.595^{20/4}$	–22.6	76.8	0.08^{20}	∞	∞
tetrafluoride	tetrafluoromethane	CF_4	88.00	gas			–128	sl. s.		
Carbonyl sulfide		COS	60.08	col. gas	1.24^{-87}	–138.2	$–50.2^{760}$	80^{14} cc.	s.	s.
Carminic acid		$C_{22}H_{20}O_{13}$	492.39	red pd.		d. 136		s.	s.	v. sl. s.
Carvacrol (1-,2-,4-)		$CH_3C_6H_3(OH)CH(CH_3)_2$	150.22	col. lq.	$0.977^{20/4}$	0.5	238	v. sl. s.	∞	∞

Carvacrylamine (2-,1-,4-)	$H_2NC_6H_3(CH_3)C_3H_7$	149.23	oil	0.994^{20}	−16	241	v. sl. s.	s.	s.
Carvone (*d*-)	$C_{10}H_{14}O$	150.22	col. lq.	$0.961^{20/4}$		230^{766}	i.	∞	∞
Cellosolve	$C_2H_5O(CH_2)_2OH$	90.12	col. lq.	$0.931^{20/4}$	−70	135.1	∞	∞	∞
acetate	$CH_3CO_2CH_2CH_2OC_2H_5$	132.16	col. lq.	$0.975^{20/4}$		156.3	22	∞	∞
Cellulose	$(C_6H_{10}O_5)x$	162.14	amor.	1.3–1.4		i.	i.	i.	
Cetyl acetate	$CH_3CO_2(CH_2)_{15}CH_3$	284.48	nd.	0.858^{20}	22–3	200^{15}	i.	v. sl. s. c.	
alcohol	$CH_3(CH_2)_{14}CH_2OH$	242.44	lf.	$0.818^{50/4}$	49–50	189.5^{15}	i.	s.	s.
Chloral	$CCl_3{\cdot}CHO$	147.39	col. lq.	$1.505^{25/4}$	−57	97.6^{768}	v. s.	∞	∞
hydrate	$CCl_3{\cdot}CH(OH)_2$	165.40	mn. pr.	$1.619^{50/4}$	51.7	d. 98	474^{17}	v. s.	s.
Chloranil	$OC:(CCl{\cdot}CCl)_2{:}CO$	245.88	yel./bz.		290	subl.	i.	i. c.	i. c.
Chloretone	$Cl_3C{\cdot}C(OH)(CH_3)_2$	177.46	col. cr.		97	167	0.8 c.	111	s.
Chloro-acetanilide (*p*-)	$CH_3CONHC_6H_4CI$	169.61	rhb.	1.385^{22}	175–6		sl. s.	s.	v. s.
-acetic acid	$ClCH_2CO_2H$	94.50	col. cr.	$1.58^{20/20}$	61.2	189.5	v. s.	s.	s.
-acetone	CH_3COCH_2Cl	92.52	col. lq.	1.162^{16}	−44.5	121	∞	∞	∞
-acetophenone (ω-)	$C_6H_5COCH_2Cl$	154.59	rhb.	1.324^{15}	58–9	245–7	0.11	v. s.	v. s.
-acetyl chloride	$ClCH_2COCl$	112.94	col. lq.	$1.498^{20/20}$		105	d.	d.	
-aniline (*o*-)	$ClC_6H_4NH_2$	127.57	lq.	$1.213^{20/4}$	0	210.5	i.		s.
(*m*-)	$ClC_6H_4NH_2$	127.57	lq.	$1.216^{20/4}$	−10.4	230^{767}	i.		s.
(*p*-)	$ClC_6H_4NH_2$	127.57	rhb.	1.427^{19}	70–1	230–1	s. h.	s.	s.
-anthraquinone (1-)	$C_6H_4(CO)_2C_6H_3Cl$	242.66	yel. nd.		162	subl.	i.	sl. s. h.	
(2-)	$C_6H_4(CO)_2C_6H_3Cl$	242.66	nd./al.		208–9		i.		
-benzaldehyde (*o*-)	ClC_6H_4CHO	140.57	nd.	1.29^{8}	11	208^{748}	v. sl. s.	v. s.	v. s.
(*m*-)	ClC_6H_4CHO	140.57	pr.	1.250^{15}	17–8	213–4	v. sl. s.	v. s.	v. s.
(*p*-)	ClC_6H_4CHO	140.57	pr.	1.196^{61}	47.8	213^{748}	s. h.	v. s.	v. s.
-benzene	C_6H_5Cl	112.56	col. lq.	$1.107^{20/4}$	−45.2	132.1	0.049^{20}	∞	∞
-benzoic acid (*o*-)	$ClC_6H_4CO_2H$	156.57	mn./aq.	$1.544^{25/4}$	141–2		0.208^{25}	s.	s.
(*m*-)	$ClC_6H_4CO_2H$	156.57	pr.	$1.496^{25/4}$	158		0.041^{25}	s.	s.
(*p*-)	$ClC_6H_4CO_2H$	156.57	tri.	1.541^{24}	242–3	subl.	0.008^{25}	s.	s.
-buta-1,3-diene (2-)	$CH_2{:}CCl{\cdot}CH{:}CH_2$	88.54	col. lq.	$0.958^{20/20}$		59.4	v. sl. s.	∞	∞
(1-)	$CH_2{:}CH{\cdot}CH{:}CHCl$	88.54	col. lq.	$0.965^{20/20}$		69	v. sl. s.	∞	∞
-buta-1,2-diene (4-)	$CH_2{:}C{:}CH{\cdot}CH_2Cl$	88.54	col. lq.	$0.991^{20/20}$		88	d.		
-dimethylhydantoin	$—C(CH_3)_2N(Cl)CON(Cl)CO—$	197.02		$1.5^{20/20}$	130		0.21^{25}		
-dinitrobenzene (α)(1-,2-)(4-)	$ClC_6H_3(NO_2)_2$	202.55	cr./et.		39(36)	315 d.	i.	v. s. h.	v. s.
(α)(1-,3-)(4-)	$ClC_6H_3(NO_2)_2$	202.55	rhb./et.	1.697^{22}	53(43)	315 d.	i.	s. h.	s.
-diphenyl (*o*-)	$C_6H_5{\cdot}C_6H_4Cl$	188.65	cr.		34	267–8	i.		
(*m*-)	$C_6H_5{\cdot}C_6H_4Cl$	188.65	cr.		89	284–5	i.		
(*p*-)	$C_6H_5{\cdot}C_6H_4Cl$	188.65	lf.		77.5	282	i.		
-hydroquinone	$ClC_6H_3(OH)_2$	144.56	mn.		106	263 sl. d.	v. s.	v. s.	v. s.
-naphthalene (α-)	$C_{10}H_7Cl$	162.62	col. lq.	$1.194^{20/4}$	−20	259.3	i.	s.	∞
(β-)	$C_{10}H_7Cl$	162.62	lf./al.	1.266^{16}	56–7	264^{751}	i.	v. s.	v. s.
-nitrobenzene (*o*-)	$ClC_6H_4NO_2$	157.55	mn. nd.	$1.305^{50/4}$	32.5	245.5^{753}	i.	s. h.	s.
(*m*-)	$ClC_6H_4NO_2$	157.55	yel./al.	$1.343^{50/4}$	44.4(24)	235.6	i.	v. s. h.	v. s.
(*p*-)	$ClC_6H_4NO_2$	157.55	mn. pr.	1.298^{91}	83–4	242^{761}	i.	v. s. h.	v. s.
-nitrotoluene (2-,4-)	$CH_3C_6H_3(NO_2)(Cl)$	171.58	cr.	1.256^{80}	38.2	240^{718}	i.		
(2-,6-)	$CH_3C_6H_3(NO_2)(Cl)$	171.58	cr.		37.5	238	i.		
-phenol (*o*-)	ClC_6H_4OH	128.56	col. lq.	$1.241^{18/15}$	7(0)	175–6	2.85^{20}	s.	s.
(*m*-)	ClC_6H_4OH	128.56	nd.	1.268^{25}	32–3	214	2.60^{20}	s.	s.
(*p*-)	ClC_6H_4OH	128.56	nd.	$1.306^{20/4}$	41–3	217	2.71^{20}	v. s.	v. s.
-propionic acid (α)(dl-)	$CH_3{\cdot}CHCl{\cdot}CO_2H$	108.52	col. lq.	1.306^{9}	<−20	186	∞	∞	∞
-toluene (*o*-)	$CH_3{\cdot}C_6H_4Cl$	126.58	col. lq.	$1.082^{20/4}$	−34	159.5	i.	s.	∞
(*m*-)	$CH_3{\cdot}C_6H_4Cl$	126.58	col. lq.	$1.072^{20/4}$	−47.8	161.6	i.	s.	∞
(*p*-)	$CH_3{\cdot}C_6H_4Cl$	126.58	col. lq.	$1.070^{20/4}$	7.5	162.2	i.	s.	∞
Chloroform	$CHCl_3$	119.38	col. lq.	1.489^{20}	−63.5	61.2	0.82^{20}	∞	∞
Chlorophyll (α-)	$C_{55}H_{72}O_5N_4Mg$	893.49			d.	i.	s.		
Chloropicrin	Cl_3CNO_2	164.38	lq.	$1.651^{23/4}$	−64	112.3^{766}	0.17^{18}	s.	s.
Cholesterol	$C_{27}H_{45}OH{\cdot}H_2O$	404.67	rhb./al.	1.067	149–51	subl.	0.26^{20}	1.1^{17}	18
Chrysene	$C_{18}H_{12}$	228.29	col. rhb.		253–4	448	i.	0.1^{16}	v. sl. s.
Chrysoidine (2-,4-)	$C_6H_5{\cdot}N{:}N{\cdot}C_6H_3(NH_2)_2$	212.25	yel. cr.		117.5		sl. s. h.	s.	s.
Chrysophanic acid	$C_{14}H_5(OH)_2(CH_3)O_2$	254.24	yel./al.		195	subl.	i. c.	s. h.	sl. s.
Cinchomeronic acid (3-,4-)	$C_5H_3N(CO_2H)_2$	167.12	cr./HCl		258–9 d.	subl. d.	v. sl. s.	sl. s.	i.
Cineole, eucalyptole	$C_{10}H_{18}O$	154.25	col. oil	0.927^{20}	1.5	176–7	1.9^{15}	∞	∞
Cinnamic acid (*cis*-)	$C_6H_5CH{:}CHCO_2H$	148.16	mn. pr.	1.284^{4}	68	125^{19}			
(*trans*-)	$C_6H_5CH{:}CHCO_2H$	148.16	mn. pr.	1.245	133	300	0.04^{18}	24^{20}	v. s.
aldehyde	$C_6H_5CH{:}CHCHO$	132.16	lq.	$1.110^{20/20}$	−7.5	252 sl. d.	v. sl. s.	s.	∞
Cinnamyl alcohol	$C_6H_5CH{:}CHCH_2OH$	134.18	nd.	$1.040^{35/35}$	33	257.5	sl. s.	v. s.	v. s.
cinnamate	$C_8H_7CO_2C_9H_9$	264.32	nd. or pr.	$1.085^{16.5}$	44		i.	4 c.	33
Citraconic acid (*cis*-)	$CH_3C(CO_2H){:}CHCO_2H$	130.10	nd.	1.617	92–3		360^{25}	s.	s.
Citral (α)	$C_9H_{15}CHO$	152.23	col. oil	$0.890^{17/4}$		229	i.	∞	∞
Citric acid	$C_3H_4(OH)(CO_2H)_3$	192.12	cr.	$1.542^{20/4}$	153	d.	207.7^{25}	76^{15}	2^{15}
Citronellal (*d*-)	$C_9H_{17}{\cdot}CHO$	154.25	col. oil	$0.855^{17.5}$		204–8	v. sl. s.	∞	∞
Citronellol (*d*-)	$C_{10}H_{20}O$	156.27	col. oil	$0.848^{20/4}$		224–5	v. sl. s.	∞	∞
Coniine (*d*-)(2-)	$C_3H_7{\cdot}C_5H_{10}N$	127.23	col. lq.	0.847^{17}	−2	166–7	1.1	v. s.	v. s.

TABLE 2-2 Physical Properties of Organic Compounds (*Continued*)

Name	Formula	Formula weight	Form and color	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Water	Alcohol	Ether
Coumaric acid (*o*-)	$HOC_6H_4CH{:}CHCO_2H$	164.16	nd./aq.		207–8	subl.	sl. s. c.	s.	v. sl. s.
(*p*-)	$HOC_6H_4CH{:}CHCO_2H$	164.16	cr./aq.		206–7 d.		s. h.	v. s. h.	v. s.
Coumarin	$C_9H_6O_2$	146.14	rhb./et.	$0.935^{20/4}$	70	290–1	0.3 c.	v. s.	s.
Coumarone	C_8H_6O	118.13	oil	$1.078^{15/15}$	<–18	173–4	i.		s.
Creatine	$C_4H_9N_3O_2{\cdot}H_2O$	149.15	mn./aq.		295		1.4^{18}	0.01^{17}	i.
Creatinine	$C_4H_7N_3O$	113.12	mn.		260 d.		8.7^{16}	1^{16}	
Creosol (3-,1-,4-)	$CH_3O{\cdot}C_6H_3(CH_3)OH$	138.16	pr.	$1.092^{20/20}$	5.5	$221–2^{765}$	v. sl. s.	∞	∞
Cresidine (1-,2-,4-)	$CH_3(NH_2)C_6H_3{\cdot}OCH_3$	137.18	nd./pet.		93–4	235	v. sl. s.	s.	s.
Cresol (*o*-)	$CH_3C_6H_4OH$	108.14	cr.	$1.048^{20/4}$	30.8	190.8	2.5	∞^{30}	∞^{30}
(*m*-)	$CH_3C_6H_4OH$	108.14	lq.	$1.034^{20/4}$	10.9	202.8	0.5	∞	∞
(*p*-)	$CH_3C_6H_4OH$	108.14	pr.	$1.035^{20/4}$	35–6	202	1.8	∞^{36}	∞^{36}
Cresyl benzoate (*o*-)	$C_6H_5CO_2C_6H_4CH_3$	212.24	lq.			308	i.		
(*m*-)	$C_6H_5CO_2C_6H_4CH_3$	212.24	cr.		55	314	i.		
(*p*-)	$C_6H_5CO_2C_6H_4CH_3$	212.24	cr.		71.5	316	i.		
Crotonic acid (α-)	$CH_3CH{:}CHCO_2H$	86.09	col. mn.	$0.964^{79.7}$	72	189	8.3^{15}		
acid (β-)(*cis*-)	$CH_3CH{:}CHCO_2H$	86.09	nd.	$1.031^{15/4}$	15.5	170–1 d.	∞^{25}	s.	
aldehyde (α)	$CH_3CH{:}CHCHO$	70.09	col. lq.	$0.853^{20/20}$	–69	102.2	18	∞	∞
Cumene	$C_6H_5CH(CH_3)_2$	120.19	col. lq.	$0.862^{20/4}$	–96.9	152.5	i.	∞	∞
Cumic acid (*p*-)	$(CH_3)_2CH{\cdot}C_6H_4CO_2H$	164.20	tri.	1.162^{4}	116–7	subl.	0.02^{25}	s.	s.
Cumidine (*p*-)	$(CH_3)_2CH{\cdot}C_6H_4NH_2$	135.21	lq.	0.953	<–20	225^{761}	i.		
Cyanamide	$H_2N{\cdot}CN$	42.04	col. nd.	$1.073^{48/4}$	44–5	140^{19}	v. s.	v. s.	v. s.
Cyanic acid	HOCN or HNCO	43.02	gas	1.140^{9}	–80	$–64^{0}$	sl. s.		s.
Cyanoacetic acid	$CH_2(CN)CO_2H$	85.06	col. lq.		65–6	$108^{0.2}$	s.	s.	s.
Cyanogen	$(CN)_2$	52.03	col. gas	0.866^{17}	–34.4	–21	450^{20} cc.	2300^{20} cc.	500^{20} cc.
bromide	BrCN	105.92	nd.	$2.015^{20/4}$	52	61.3^{750}	s.	s.	s.
chloride	ClCN	61.47	gas	1.222^{9}	–6.5	12.5–13	2500^{20} cc.	v. s.	5000^{20} cc.
Cyanuric acid	$C_3H_3O_3N_3{\cdot}2H_2O$	165.10	mn./aq.	$1.768^{0/4}$	>360	d.	0.27^{17}	0.1^{22}	
Cyclo-butane	$CH_2<(CH_2)_2>CH_2$	56.11	col. gas	$0.703^{0/4}$	–50	$11–12^{726}$	i.	v. s.	
-heptane	$CH_2<(CH_2CH_2CH_2)_2>$	98.19	oil	$0.810^{20/4}$	–12	118–20	i.		
-hexane	$CH_2<(CH_2CH_2)_2>CH_2$	84.16	col. lq.	$0.779^{20/4}$	6.5	80–1	i.	∞	∞
-hexanol	$CH_2<(CH_2CH_2)_2>CHOH$	100.16	col. nd.	$0.962^{20/4}$	23.9	160–1	3.6^{20}	s.	s.
-hexanone	$CH_2<(CH_2CH_2)_2>CO$	98.14	col. oil	$0.947^{19/4}$	–45	155–6	s.	s.	s.
-hexene	$(\cdot CH_2{\cdot}CH_2CH{:})_2$	82.14	lq.	$0.810^{20/4}$	–103.7	83.3	v. sl. s.	v. s.	v. s.
-hexyl acetate	$CH_3CO_2C_6H_{11}$	142.20	oil	$0.985^{0/4}$		174^{750}	i.	∞	∞
amine	$CH_2<(CH_2CH_2)_2>CHNH_2$	99.17	col. lq.	$0.865^{20/0}$		134	i.	s.	
bromide	$CH_2<(CH_2CH_2)_2>CHBr$	163.06	col. lq.	$1.324^{20/20}$		165^{714}	i.	s.	s.
chloride	$CH_2<(CH_2CH_2)_2>CHCl$	118.60	col. lq.	$0.977^{18/4}$	–43.9	142	i.		∞
-pentadiene (1-,3-)	$CH_2<(CH{:}CH)_2>$	66.10	col. lq.	$0.805^{19/4}$	–85	41–2	i.	∞	∞
-pentane	$CH_2<(CH_2CH_2)_2>$	70.13	col. oil	$0.745^{20/4}$	–93.3	49–50	i.		
-pentanone	$<(CH_2CH_2)_2>CO$	84.12	col. oil	0.948^{20}	–58.2	129–30	v. sl. s.		
-propane	$<CH_2CH_2CH_2>$	42.08	col. gas	0.720^{-79}	–126.6	$–34^{749}$	i.	s.	s.
Cymene (*o*-)	$CH_3{\cdot}C_6H_4CH(CH_3)_2$	134.22	col. lq.	$0.875^{20/4}$		177	i.	s.	s.
(*m*-)	$CH_3{\cdot}C_6H_4CH(CH_3)_2$	134.22	col. lq.	0.862^{20}	<–25	175–6	i.	s.	s.
(*p*-)	$CH_3{\cdot}C_6H_4CH(CH_3)_2$	134.22	col. lq.	$0.857^{20/4}$	–73.5	176–7	i.	s.	s.
Cystine (*l*-)	$[\cdot SCH_2CH(NH_2)CO_2H]_2$	240.30	pl.		d. 258–61		0.01^{19}	i.	
Dambose	$C_6H_6(OH)_6$	180.16	mn./aq.	1.752	253	319^{15}	2^{12}	i.	i.
Decahydronaphthalene (*cis*-)	$C_{10}H_{18}$	138.25	lq.	$0.895^{18/4}$	–51	193.3	i.	s.	s.
(*trans*-)	$C_{10}H_{18}$	138.25	lq.	$0.872^{20/4}$	–32	185.3	i.	s.	s.
Decane (*n*-)	$CH_3(CH_2)_8CH_3$	142.28	col. lq.	0.730^{2}	–29.7	174.0	i.	∞	∞
Decyl alcohol	$CH_3(CH_2)_8CH_2OH$	158.28	col. oil	$0.830^{20/4}$	7	232.9	i.	s.	
Dextrin	$(C_6H_{10}O_5)x$	162.14	amor.	1.038			s.	i.	i.
Diacetone alcohol	$(CH_3)_2C(OH){\cdot}CH_2COCH_3$	116.16	lq.	0.931^{25}	–47	167.9	∞	∞	∞
Diamino-benzophenone (4-,4′-)	$H_2NC_6H_4COC_6H_4NH_2$	212.25	yel. nd.		237–9		sl. s. h.	s.	s.
-diphenylamine (4-,4′-)	$H_2NC_6H_4NHC_6H_4NH_2$	199.25	lf./aq.		158	d.	sl. s.	s.	s.
-diphenylmethane (4-,4′-)	$H_2NC_6H_4CH_2C_6H_4NH_2$	198.26	nd./aq.		93–4	$249–53^{15}$	sl. s. c.	s.	s.
-diphenylurea (4-,4′-)	$(H_2NC_6H_4NH)_2CO$	242.28	cr.		subl. 310		v. sl. s.		
Diamyl-amine (*i*-)	$[(CH_3)_2CHCH_2CH_2]_2NH$	157.30	col. lq.	$0.767^{21/4}$	–44	188–90	sl. s.	s.	∞
ether (*n*-)	$(C_2H_5CH_2CH_2CH_2)_2O$	158.28	col. lq.	$0.774^{20/4}$	–69	190	i.	∞	∞
(*i*-)	$[(CH_3)_2CH(CH_2)_2]_2O$	158.28	col. lq.	$0.777^{20/4}$		173.4	i.	∞	∞
Diamyl ketone (*i*-)	$[(CH_3)_2CHCH_2CH_2]_2CO$	170.29	yel. oil	$0.821^{25/4}$	14.6	228	i.	s.	s.
phthalate (*n*-)	$C_6H_4(CO_2C_5H_{11})_2$	306.40	col. lq.			$204–6^{11}$			
(*i*-)	$C_6H_4(CO_2C_5H_{11})_2$	306.40	col. lq.	1.03		225^{40}	i.	s.	s.
tartrate (*i*-)	$(HOCH{\cdot}CO_2C_5H_{11})_2$	290.35	lq.	$1.063^{15/4}$		195^{16}	i.		
Dianisidine (*o*-)(4-,3-)$_2$	$[NH_2(OCH_3)C_6H_3{\cdot}]_2$	244.29	col. lf.		131.5		i.	s.	s.
Diazo-aminobenzene	$C_6H_5N{:}N{\cdot}NHC_6H_5$	197.24	yel. lf.		96–8	expl.	i.	s. h.	v. s.
-aminotoluene (2-,2′-)	$C_7H_7N{:}N{\cdot}NHC_7H_7$	225.29	or. cr.		51		0.05		
-methane	$CH_2{:}N_2$	42.04	gas		–145	–23	d.		s.

Dibenzothiazyl-disulfide (2-,2′-)	$(C_6H_4NSC)_2S_2$	332.49	cr.	1.50	180	d.	i.		
Dibensoyl methane	$(C_6H_5CO)_2CH_2$	224.25	rhb./al.		78	219–21[18]	i.	4.4^{20}	s.
Dibensyl-amine	$(C_6H_5CH_2)_2NH$	197.28	col. oil	$1.028^{25/25}$	–26	268–71[250]	i.	s.	s.
-aniline	$C_6H_5N(CH_2C_6H_5)_2$	273.37	pr./al.		70–1	>300	i.	v. s. h.	s.
ketone	$(C_6H_5CH_2)_2CO$	210.27	cr.		34–5	330.6	i.		
phthalate (*o*-)	$C_6H_4(CO_2CH_2C_6H_5)_2$	346.38	pr./al.		42–3	274^{12}	v. sl. s.	s.	s.
succinate	$(\cdot CH_2CO_2CH_2C_6H_5)_2$	298.33	lf./al.		45–6	238^{14}	i.	s.	s.
Dibromo-benzene (*o*-)	$C_6H_4Br_2$	235.90	col. lq.	$1.956^{20/4}$	1.8	221–2	i.	s.	s.
(*m*-)	$C_6H_4Br_2$	235.90	col. lq.	$1.952^{20/4}$	–6.9	219^{755}	i.	s.	s.
(*p*-)	$C_6H_4Br_2$	235.90	pl./al.	2.261^{18}	87–8	218.6^{758}	i.	1.6	71^{25}
-diphenyl (4-,4′-)	$BrC_6H_4{\cdot}C_6H_4Br$	312.00	mn. pr.	1.897	164–5	355–60	i.	v. sl. s. h.	
Dibutyl-adipate (*n*-)	$(\cdot CH_2CH_2CO_2C_4H_9)_2$	258.35	col. lq.	$0.965^{20/4}$	–38	183^{14}	i.	∞	∞
(*i*-)	$(\cdot CH_2CH_2CO_2C_4H_9)_2$	258.35	col. lq.	0.950^{25}	–20	278–80	i.		
-amine (*n*-)	$(C_2H_5CH_2CH_2)_2NH$	129.24	col. lq.	$0.768^{20/20}$		159^{761}	∞	∞	∞
(*i*-)	$[(CH_3)_2CHCH_2]_2NH$	129.24	col. lq.	$0.741^{25/4}$	–70	139–40	v. sl. s.	s.	s.
-*p*-aminophenol (*s*-)	$(C_4H_9)_2N{\cdot}C_6H_4OH$	221.34	lq.			170^{10}	i.		
-aniline (*n*-)	$C_6H_5N(C_4H_9)_2$	205.34	lq.			262.8	i.	∞	∞
carbonate (*n*-)	$CO(OC_4H_9)_2$	174.24	col. lq.	$0.924^{20/4}$		207^{740}	i.	s.	
(*i*-)	$CO(OC_4H_9)_2$	174.24	col. lq.	0.919^{15}		190	i.		
(*s*-)	$CO(OC_4H_9)_2$	174.24	col. lq.			178–80			
ether (*n*-)	$(C_2H_5CH_2CH_2)_2O$	130.23	lq.	$0.769^{20/20}$	–98	142.4	<0.05	∞	∞
(*i*-)	$[(CH_3)_2CHCH_2]_2O$	130.23	lq.	0.762^{15}		122.5	i.	∞	∞
(*s*-)	$[C_2H_5(CH_3)CH]_2O$	130.23	lq.	0.756^{21}		121	i.	∞	∞
ketone (*n*-)	$(C_2H_5CH_2CH_2)_2CO$	142.24	lq.	$0.827^{18/4}$	–5.9	187.7	i.	s.	v. s.
(*i*-)	$[(CH_3)_2CHCH_2]_2CO$	142.24	oil	$0.805^{21/4}$		168.1	<0.06	∞	∞
malate (*l*-)(*n*-)	$C_2H_4O(CO_2C_4H_9)_2$	246.30	lq.	$1.038^{20/4}$		$170–1^{18}$	v. sl. s.		
oxalate (*n*-)	$(\cdot CO_2C_4H_9)_2$	202.25	col. lq.	$0.986^{20/4}$	–29.6	245.5	i.	s.	s.
phthalate (*n*-)	$C_6H_4(CO_2C_4H_9)_2$	278.34	col. lq.	1.045^{21}		340	0.04^{25}	∞	∞
tartrate (*d*-)(*n*-)	$(CHOHCO_2C_4H_9)_2$	262.30	pr.	1.098^{15}	22–2.5	$200–3^{18}$	i.		
(*d*-)(*i*-)	$(CHOHCO_2C_4H_9)_2$	262.30	cr.	$1.031^{75/4}$	73–4	323–5	v. sl. s.		
Dichloro-acetic acid	$Cl_2CH{\cdot}CO_2H$	128.94	lq.	$1.560^{25/25}$	9.7(–4)	194.4	∞	∞	∞
-acetone (αα-)	$Cl_2CHCOCH_3$	126.97	lq.	1.234^{15}		120	v. sl. s.	s.	s.
-aniline (2-,5-)	$Cl_2C_6H_3NH_2$	162.02	nd.		50	251	v. sl. s.	s.	s.
-anthraquinone (1-,3-)	$C_6H_4{:}(CO)_2{:}C_6H_2Cl_2$	277.10	yel. nd.		208–9		i.	i.	
(1-,4-)	$C_6H_4{:}(CO)_2{:}C_6H_2Cl_2$	277.10	yel. nd.		187.5		i.	v. sl. s.	v. sl. s.
(1-,5-)	$C_6H_3Cl{:}(CO)_2{:}C_6H_3Cl$	277.10	yel. nd.		251		i.	sl. s.	
(1-,6-)	$C_6H_3Cl{:}(CO)_2{:}C_6H_3Cl$	277.10	yel. nd.		203–4		i.		
(1-,8-)	$C_6H_3Cl{:}(CO)_2{:}C_6H_3Cl$	277.10	yel. nd.		202–3		i.	sl. s.	
(2-,3-)	$C_6H_4{:}(CO)_2{:}C_6H_2Cl_2$	277.10	yel. nd.		268–70		i.	sl. s.	
(2-,6-)	$C_6H_3Cl{:}(CO)_2{:}C_6H_3Cl$	277.10	yel. nd.		282		i.		
(2-,7-)	$C_6H_3Cl{:}(CO)_2{:}C_6H_3Cl$	277.10	yel. nd.		210–11		i.		
-benzene (*o*-)	$C_6H_4Cl_2$	147.00	col. lq.	$1.305^{20/4}$	–17.6	179	i.	∞	∞
(*m*-)	$C_6H_4Cl_2$	147.00	col. lq.	$1.288^{20/4}$	–24.8	172^{766}	i.	s.	s.
(*p*-)	$C_6H_4Cl_2$	147.00	col. mn.	1.458^{21}	53	174^{764}	i.	v. s.	v. s.
-butane (*n*-)(1-,4-)	$ClCH_2(CH_2)_2CH_2Cl$	127.01	lq.		–38.7	161–3			
-diphenyl (4-,4′-)	$ClC_6H_4{\cdot}C_6H_4Cl$	223.10	pr.	$1.442^{0/4}$	148	315–9	i.	v. sl. s.	4^{25}
-ethane (1-,2-)	$ClCH_2{\cdot}CH_2Cl$	98.96	col. lq.	$1.256^{20/20}$	–35.3	83.7	0.9^{0}	∞	∞
-naphthalene (β-)(1-,4-)	$C_{10}H_6Cl_2$	197.06	nd./al.	$1.300^{76/4}$	67–8	286–7[740]	i.	v. sl. s.	
(γ-)(1-,5-)	$C_{10}H_6Cl_2$	197.06	lf./al.		107	subl.	i.	s.	s.
-nitrobenzene (2-,5-)	$Cl_2C_6H_3NO_2$	192.00	tri./al.	1.669^{22}	54.6	266	i.	v. s. h.	
-pentane (1-,5-)	$ClCH_2(CH_2)_3CH_2Cl$	141.04	col. lq.	$1.094^{25/4}$		180–1	i.	s.	s.
-phenol (2-,4-)	$Cl_2C_6H_3OH$	163.00	nd.	$1.383^{60/25}$	45	209–10	0.45^{20}	v. s.	v. s.
Dichloramine T (*p*-)	$CH_3C_6H_4SO_2NCl_2$	240.11	cr.		83		sl. s.		
Dicyandiamide	$H_2N{\cdot}C(:NH){\cdot}NH{\cdot}CN$	84.08	mn. pl.	1.40^{14}	207–8	d.	2.3^{18}	1.3^{18}	0.01^{18}
Diethanolamine	$HN(CH_2CH_2OH)_2$	105.14	pr.	$1.097^{20/4}$	28	270^{748}	∞	∞	v. sl. s.
Diethyl adipate	$(\cdot CH_2CH_2CO_2C_2H_5)_2$	202.25	col. lq.	$1.009^{20/4}$	–21	239–41[761]	0.43^{80}	s.	s.
-amine	$(C_2H_5)_2NH$	73.14	col. lq.	$0.712^{15/15}$	–38.9	55.5^{759}	v. s.	∞	∞
-aminophenol (*m*-)	$(C_2H_5)_2N{\cdot}C_6H_4{\cdot}OH$	165.23	rhb.		78	276–80	s.		
-aniline	$(C_2H_5)_2NC_6H_5$	149.23	oil	$0.934^{20/4}$	–34.4	216	1.4^{12}	s.	s.
sulfonic acid (*m*-)	$(C_2H_5)_2NC_6H_4SO_3H$	229.30	cr.		270 d.		s.		
carbonate	$OC(OC_2H_5)_2$	118.13	col. lq.	$0.975^{20/4}$	–43	126^{759}	i.	∞	∞
diethyl malonate	$(C_2H_5)_2C(CO_2C_2H_5)_2$	216.27	col. lq.	$0.985^{20/4}$		230	i.	∞	∞
Diethyl dimethyl malonate	$(CH_3)_2C(CO_2C_2H_5)_2$	188.22	col. lq.	$0.994^{25/25}$		196.7	i.	∞	∞
glutarate	$CH_2(CH_2CO_2C_2H_5)_2$	188.22	syrup	1.025^{21}	–24	237	0.88^{20}	v. s.	s.
ketone	$(C_2H_5)_2CO$	86.13	col. lq.	$0.816^{19/4}$	–42	101.7	4.7^{20}	∞	∞
malonate	$CH_2(CO_2C_2H_5)_2$	160.17	col. lq.	$1.055^{20/4}$	–49.8	198.9	2.08^{20}	∞	∞
-malonic acid	$(C_2H_5)_2C(CO_2H)_2$	160.17	pr./aq.		125	d. 170–80	65^{16}	v. s.	v. s.
-naphthylamine (α-)	$C_{10}H_7N(C_2H_5)_2$	199.29	col. oil	1.005		285–90	i.	∞	∞
(β-)	$C_{10}H_7N(C_2H_5)_2$	199.29	col. oil	1.026		318	i.	∞	∞
oxalate	$(\cdot CO_2C_2H_5)_2$	146.14	col. lq.	$1.079^{20/4}$	–40.6	186	v. sl. s.	∞	∞
phthalate (*o*-)	$C_6H_4(CO_2C_2H_5)_2$	222.24	col. lq.	$1.121^{25/25}$		298–9	i.	∞	∞
sulfate	$O_2S(OC_2H_5)_2$	154.18	col. lq.	$1.172^{25/4}$	–25	210	i.	s.	∞
sulfide	$(C_2H_5)_2S$	90.19	col. lq.	$0.837^{20/4}$	–99.5	$92–3^{754}$	0.31^{20}	∞	∞

TABLE 2-2 Physical Properties of Organic Compounds (*Continued*)

Name	Formula	Formula weight	Form and color	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Water	Alcohol	Ether
tartrate (*d*-)	$(CHOH{\cdot}CO_2C_2H_5)_2$	206.19	lq.	$1.204^{20/4}$	17	280	sl. s.	∞	∞
-toluidine (*o*-)	$CH_3{\cdot}C_6H_4{\cdot}N(C_2H_5)_2$	163.26	lq.			208–9[755]	i.	s.	s.
(*m*-)	$CH_3{\cdot}C_6H_4{\cdot}N(C_2H_5)_2$	163.26	lq.			231–2	i.	s.	s.
(*p*-)	$CH_3{\cdot}C_6H_4{\cdot}N(C_2H_5)_2$	163.26	lq.	$0.924^{15.5}$		228–9	i.		
Diethyleneglycol dinitrate	$O(CH_2CH_2ONO_2)_2$	196.12	lq.	$1.377^{25/4}$	–11.3		i.		
Difluorodichloromethane	F_2CCl_2	120.91	gas	1.486^{-30}	–155	–29.2	5.7 cc.[26]	s.	s.
Diglycerol	$[(HO)_2C_3H_5]_2O$	166.17	lq.			220–30[10]	s. h.		i.
Dihydroxy-dinaphthyl (α-)	$(HO{\cdot}C_{10}H_6{\cdot})_2$	286.32	pl./al.		300		i.	s.	v. s.
(-2,-2′,-1,-1′)	$(HO{\cdot}C_{10}H_6{\cdot})_2$	286.32	nd./al.		218	subl.	i.	s.	v. s.
-diphenyl (4-,4′-)	$(HO{\cdot}C_6H_4{\cdot})_2$	186.21	rhb./al.	1.25	270–2	subl.	sl. s.	v. s.	v. s.
-ethyl formal (β-)	$CH_2(OCH_2CH_2OH)_2$	136.15	lq.	1.154^{25}	–5.3	264	∞		
-naphthalene (1-,5-)	$C_{10}H_6(OH)_2$	160.17	pr./aq.		258–60	d.	sl. s.	s.	v. s.
(1-,8-)	$C_{10}H_6(OH)_2$	160.17	nd.		140		sl. s. h.		v. s.
Dimethoxy-benzene (*p*-)	$(CH_3O)_2C_6H_4$	138.16	lf.	$1.053^{55/55}$	56	212.6	v. sl. s.	v. s.	v. s.
-diphenylamine (4-,4′-)	$HN(C_6H_4OCH_3)_2$	229.27	cr.		103		i.		
-ethyl adipate	$(CH_2)_4(CO_2C_2H_4OCH_3)_2$	262.30	lq.	$1.075^{15.6}$		145–50[2]	5		
Dimethyl adipate	$[(CH_2)_2CO_2CH_3]_2$	174.19	col. lq.	$1.063^{20/4}$	10–1	115[18]	i.		
-amine	$(CH_3)_2NH$	45.08	col. lq.	$0.680^{0/4}$	–96	7.4	v. s.	s.	s.
-aminoasobenzene (*p*-)	$C_6H_5N{:}N{\cdot}C_6H_4N(CH_3)_2$	225.29	yel./al.		116–7	d.	i.	s.	s.
-aminoethanol	$(CH_3)_2NCH_2CH_2OH$	89.14	col. lq.	$0.887^{20/4}$		135[756]	∞		
-aminophenol (*m*-)	$(CH_3)_2NC_6H_4OH$	137.18	nd.		85	265–8	sl. s. h.	s.	s.
-aniline	$(CH_3)_2NC_6H_5$	121.18	yel. lq.	$0.956^{20/4}$	2.5	193	i.	s.	s.
sulfonic acid (*m*-)	$(CH_3)_2NC_6H_4SO_3H$	201.24	cr.		d. 266		s.		
(*p*-)	$(CH_3)_2NC_6H_4SO_3H{\cdot}H_2O$	219.26	pr.		257		s. h.	v. sl. s.	v. sl. s.
carbonate	$OC(OCH_3)_2$	90.08	col. lq.	$1.070^{20/4}$	0.5	89–90	i.	∞	∞
ether	CH_3OCH_3	46.07	gas		–138.5	–23.7	3700 cc.[18]	s.	s.
-formamide	$HCON(CH_3)_2$	73.09	lq.	0.945^{25}	–58.3	152.8	∞		
fumarate	$(:CHCO_2CH_3)_2$	144.13	col. tri.		102	192	i.	sl. s.	sl. s.
glutarate	$(CH_2)_3(CO_2CH_3)_2$	160.17	lq.	$1.089^{15.6}$	–37	130[50]			
glyoxime	$(CH_3{\cdot}C{:}NOH)_2$	116.12	col. cr.		240–6		0.06^{20}	v. s.	v. s.
-naphthalene (1-,4-)	$C_{10}H_6(CH_3)_2$	156.22	lq.	$1.016^{20/4}$	<–18	264–6	i.		
(2-,3-)	$C_{10}H_6(CH_3)_2$	156.22	lf./al.		104	265[767]	i.	sl. s.	
-naphthylamine (α-)	$C_{10}H_7N(CH_3)_2$	171.24	col. oil	1.042^{20}		274.5[711]	i.	s.	s.
(β-)	$C_{10}H_7N(CH_3)_2$	171.24	col. cr.	$1.039^{70/70}$	46	304–5	i.	s.	s.
oxalate	$(\cdot CO_2CH_3)_2$	118.09	col. mn.	1.148^{54}	54	163.3	6	s.	s.
phthalate (*o*-)	$C_6H_4(CO_2CH_3)_2$	194.18	col. lq.	$1.189^{25/25}$		280[734]	0.43		
sulfate	$(CH_3O)_2SO_2$	126.13	col. oil	$1.352^{0/4}$	–26.8	188.3	v. sl. s.	∞	∞
sulfide	$(CH_3)_2S$	62.13	oil	$0.846^{21/4}$	–83.2	37.3	i.	s.	s.
tartrate (*d*-)	$(CHOH{\cdot}CO_2CH_3)_2$	178.14	cr.	$1.328^{20/4}$	61.5	280	s.	200^{15}	
-vinyl-ethenyl carbinol	$(CH_3)_2COH{\cdot}C{:}C{\cdot}CH{:}CH_2$	110.15	lq.	$0.887^{20/4}$		150	6^{20}		
Dinaphthyl (αα-)	$C_{10}H_7{\cdot}C_{10}H_7$	254.33	lf./al.		160	240–4[12]	i.	s. h.	s.
-methane (αα′-)	$(C_{10}H_7)_2CH_2$	268.35	pr./al.		109	>360	i.	0.8 c.	v. s.
(β,β′-)	$(C_{10}H_7)_2CH_2$	268.35	nd./al.		92		i.	s.	
Dinitro-anisole (1-)(2-,4-)	$CH_3OC_6H_3(NO_2)_2$	198.13	col. mn.	1.341^{20}	94–5		sl. s. h.	1.5^{20}	
-benzene (*o*-)	$C_6H_4(NO_2)_2$	168.11	col. mn.	1.59^{18}	117–8	319[774]	0.01 c.	1.9^{21}	
(*m*-)	$C_6H_4(NO_2)_2$	168.11	col. rhb.	$1.575^{20/4}$	89.8	300–2	0.3^{99}	3^{20}	
(*p*-)	$C_6H_4(NO_2)_2$	168.11	col. mn.	1.625^{18}	173–4	299[777]	0.18^{100}	0.18^{21}	
sulfonic acid (2-,4-)(1-)	$(NO_2)_2C_6H_3SO_3H{\cdot}3H_2O$	302.22	pr.		106–8		s.	s.	v. sl. s.
-benzoic acid (2-,4-)	$(NO_2)_2C_6H_3CO_2H$	212.12	cr./aq.		179–80		1.85^{25}	s.	
(3-,5-)	$(NO_2)_2C_6H_3CO_2H$	212.12	mn. pr.		204–5	subl.	s h.	v. s.	sl. s.
-benzophenone (4-,4′-)	$(NO_2C_6H_4)_2CO$	272.21	col. nd.		189		i.		
-diphenyl (4-,4′-)	$(NO_2C_6H_4)_2$	244.20	nd./al.	1.445	233		i.	1.5^{20}	
(2-,4′-)	$(NO_2C_6H_4)_2$	244.20	mn.	1.474	93.5		i.	v. s. h.	
-naphthalene (1-,5-)	$C_{10}H_6(NO_2)_2$	218.17	nd.		216	subl.	i.		
(1-,8-)	$C_{10}H_6(NO_2)_2$	218.17	rhb.		170–2	d.	i.	0.2 c.	
Dinitro-phenol (2-,3-)	$(NO_2)_2C_6H_3OH$	184.11	yel. mn.	1.681^{20}	144–5		sl. s.	v. s. h.	v. s.
(2-,4-)	$(NO_2)_2C_6H_3OH$	184.11	yel. rhb.	1.683^{24}	114–5	subl.	0.5 c.	4^{20}	v. s. h.
(2-,6-)	$(NO_2)_2C_6H_3OH$	184.11	yel. rhb.		63–4		s. h.	s. h.	s.
-salicylic acid (3-,5-)	$(NO_2)_2C_6H_2(OH)CO_2H{\cdot}H_2O$	246.13	pl./aq.		173 d.		s. c.	v. s.	v. s.
-stilbene (4-,4′-)	$(NO_2C_6H_4CH{:})_2$	270.24	yel. lf.		210–6		i.	v. sl. s.	v. sl. s.
-toluene (2-,4-)	$(NO_2)_2C_6H_3CH_3$	182.13	nd.	1.321^{71}	70	300	0.03^{22}	1.2^{15}	9^{16}
(3-,4-)	$(NO_2)_2C_6H_3CH_3$	182.13	nd.	1.259^{111}	60–1		i.		
(3-,5-)	$(NO_2)_2C_6H_3CH_3$	182.13	mn. pr.	1.277^{111}	92–3	subl.	sl. s.	s. h.	s.
Dioxane	$O<(CH_2{\cdot}CH_2)_2>O$	88.11	col. lq.	$1.033^{20/4}$	9.5–10.5	101.1	∞	s.	s.
Dipentene	$C_{10}H_{16}$	136.23	col. lq.	0.865^{18}		178	i.		

Diphenyl	$C_6H_5{\cdot}C_6H_5$	154.21	col. mn.	$0.992^{73/4}$	69–70	254.9	i.	10^{20}	6.6^{20}
-amine	$C_6H_5NHC_6H_5$	169.22	col. mn.	$1.160^{20/20}$	52.9	302	0.03^{25}	$56^{19.5}$	s.
carbonate	$CO(OC_6H_5)_2$	214.22	nd./al.	1.272^{14}	80	302–6	i.	v. s.	s.
-chloroarsine	$(C_6H_5)_2AsCl$	264.58	rhb.	1.583^{40}	43–4	d. 327	0.2 d.	20	s.
-ethane	$(C_6H_5CH_2{\cdot})_2$	182.26	col. pr.	$0.978^{50/50}$	52–3	284	i.	s.	v. s.
ether	$C_6H_5OC_6H_5$	170.21	col. rhb.	1.073^{30}	27	259	v. sl. s.	s.	∞
guanidine	$(C_6H_5NH)_2C{:}NH$	211.26	mn./al.		147–8	d. > 170	v. sl. s.	9^{20}	sl. s.
-methane	$(C_6H_5)_2CH_2$	168.23	col. pr.	$1.001^{26/4}$	26–7	265	i.	v. s.	v. s.
phenylenediamine (*p*-)	$(C_6H_5NH)_2C_6H_4$	260.33	cr.		152		i.		
succinate	$(\cdot CH_2CO_2C_6H_5)_2$	270.28	lf./al.		122–3	330	i.		s.
sulfide	$(C_6H_5)_2S$	186.27	col. lq.	$1.119^{15/15}$	<–40	296–7	i.	s. h.	∞
sulfone	$(C_6H_5)_2SO_2$	218.27	nd./aq.	$1.248^{25/4}$	128–9	379	sl. s. h.	s. h.	
urea (uns.)	$(C_6H_5)_2NCONH_2$	212.25	rhb.	1.276	189		v. sl. s.	s.	s.
Diphenylene oxide	$<(C_6H_4)_2O$	168.19	lf./al.		86–7	287–8	i.	s. h.	v. s.
Dipropyl adipate (*n*-)	$(\cdot CH_2CH_2CO_2C_3H_7)_2$	230.30	col. lq.	$0.979^{20/4}$	–20.3	$143–5^{10}$	i.	s.	s.
-amine (*n*-)	$(C_2H_5CH_2)_2NH$	101.19	col. lq.	$0.739^{20/4}$	–39.6	110–1	s.	∞	∞
(*i*-)	$[(CH_3)_2CH]_2NH$	101.19	col. lq.	0.722^{22}	–61	83.5^{743}	s.	s.	
aniline (*n*-)	$C_6H_5N(C_3H_7)_2$	177.29	yel. oil	0.910^{20}		245.4	i.	s.	s.
carbonate (*n*-)	$CO(OCH_2C_2H_5)_2$	146.18	col. lq.	0.968^{22}		168.2	v. sl. s.		
ether (*n*-)	$(C_2H_5CH_2)_2O$	102.17	col. lq.	$0.744^{21/0}$	–122	91	sl. s.	∞	∞
(*i*-)	$[(CH_3)_2CH]_2O$	102.17	col. lq.	$0.725^{21/0}$	–60	69	0.2	∞	∞
ketone (*n*-)	$(C_2H_5CH_2)_2CO$	114.19	col. lq.	$0.822^{20/4}$	–32.6	144.2	0.43	∞	∞
(*i*-)	$[(CH_3)_2CH]_2CO$	114.19	col. lq.	$0.806^{20/4}$		123.7	v. sl. s.	∞	∞
oxalate (*n*-)	$(CO_2CH_2C_2H_5)_2$	174.19	col. lq.	$1.038^{0/0}$	–51.7	213.5	d. h.		
(*i*-)	$[CO_2CH(CH_3)_2]_2$	174.19	col. lq.			190			
Disalicylal ethylenediamine	$[HOC_6H_4CH{:}NCH_2{\cdot}]_2$	268.31	cr.	1.34	125–6		0.03^{28}		
Ditolyl guanidine (*o*-)	$(C_7H_7NH)_2C{:}NH$	239.32	cr.	$1.10^{20/4}$	178–9		v. sl. s.	s. h.	s.
Divinyl acetylene	$(H_2C{:}CH{\cdot}C{:})_2$	78.11	lq.	$0.776^{20/4}$		85	i.		
Docosane (*n*-)	$CH_3(CH_2)_{20}CH_3$	310.60	cr.	$0.778^{44/4}$	44.5	224.5^{15}	i.	4 h.	v. s.
Dodecane (*n*-)	$CH_3(CH_2)_{10}CH_3$	170.33	lq.	$0.751^{20/4}$	–9.6	214.5	i.	v. s.	v. s.
Dulcitol	$CH_2OH(CHOH)_4CH_2OH$	182.17	mn.	1.466^{15}	189	$290–5^{3}$	3.2^{15}	v. sl. s.	i.
Durene (1-,2-,4-,5-)	$(CH_3)_4C_6H_2$	134.22	mn.	$0.838^{81/4}$	79–80	193–5	i.	s.	s.
Elaidic acid	$C_8H_{17}CH{:}CH(CH_2)_7CO_2H$	282.46	lf./al.	$0.851^{79/4}$	51–2	288^{100}	i.	v. s.	v. s.
Eosine	$C_{20}H_8O_5Br_4$	647.89	col. cr.				i.	s.	
Ephedrine (*l*-)	$C_6H_5CHOHCH(CH_3)NHCH_3$	165.23	cr./et.		40	255	5	500	s.
Epichlorhydrin (α-)	$C_3H_5O{\cdot}CH_2Cl$	92.52	lq.	$1.183^{25/25}$	–25.6	117^{756}	<5	∞	∞
Epidichlorohydrin (α-)	$CH_2{:}CCl{\cdot}CH_2Cl$	110.97	col. lq.	1.204^{25}		94	i.	∞	∞
Erythritol (*dl*-)	$CH_2OH(CHOH)_2CH_2OH$	122.12	tet. pr.	$1.451^{20/4}$	126	329–31	60	sl. s. c.	i.
tetranitrate	$C_4H_6(ONO_2)_4$	302.11	lf./al.		61	expl.	i. c.	s.	s.
Ethane	CH_3CH_3	30.07	col. gas	0.546^{-88}	–172	–88.6	4.7 cc.^{20}	150 cc.	
Ethanol-amine	$HOCH_2CH_2NH_2$	61.08	col. oil	1.022^{20}	10.5	171^{757}	∞	∞	1
formamide	$HCONHCH_2CH_2OH$	89.09	lq.	1.169^{25}	<–40	d.	∞		
Ether	$(CH_3CH_2)_2O$	74.12	col. lq.	$0.708^{25/4}$	–116.3	34.6	7.5^{30}	∞	
Ethyl abietate	$C_{19}H_{29}CO_2C_2H_5$	330.50	lq.	$1.020^{20/20}$		200^{4}	i.		
acetate	$CH_3CO_2C_2H_5$	88.11	col. lq.	$0.901^{20/4}$	–82.4	77.1	8.5^{15}	∞	∞
acetoacetate	$CH_3COCH_2CO_2C_2H_5$	130.14	col. lq.	$1.025^{20/4}$	–45	180^{755}	13^{17}	∞	∞
alcohol	CH_3CH_2OH	46.07	col. lq.	$0.789^{20/4}$	–112	78.4	∞		∞
-amine	$C_2H_5NH_2$	45.08	col. lq.	$0.689^{15/15}$	–80.6	16.6	∞	∞	∞
hydrochloride	$C_2H_5NH_2{\cdot}HCl$	81.54	mn.	1.216	108–9		240^{17}	v. s.	i.
aniline	$C_6H_5NHC_2H_5$	121.18	lq.	$0.963^{20/4}$	–63.5	204	i.	∞	∞
sulfonic acid (*m*-)	$C_2H_5NHC_6H_4SO_3H$	201.24	nd./aq.		d. 294		2.15^{15}		
anisate (*p*-)	$CH_3OC_6H_4CO_2C_2H_5$	180.20	lq.	$1.103^{25/25}$	7–8	269–70	i.	s.	s.
anthranilate (*o*-)	$NH_2C_6H_4CO_2C_2H_5$	165.19	cr.	$1.117^{20/4}$	13	266–8	v. sl. s.	s.	s.
benzene	$C_6H_5{\cdot}C_2H_5$	106.17	col. lq.	$0.867^{20/4}$	–94.4	136.2	0.01^{15}	∞	∞
benzoate	$C_6H_5CO_2C_2H_5$	150.17	col. lq.	$1.052^{15/15}$	–34.6	211–2	0.08^{20}	∞	∞
-benzyl-aniline	$C_6H_5N(C_2H_5)CH_2C_6H_5$	211.30	yel. oil	$1.034^{18.5}$		285^{10}	i.	18	∞
bromide	C_2H_5Br	108.97	col. lq.	$1.431^{20/4}$	–117.8	38.4	1.06^{0}	∞	∞
butyrate (*n*-)	$C_2H_5CH_2CO_2C_2H_5$	116.16	col. lq.	$0.879^{20/4}$	–93.3	120–1	0.68^{25}	∞	∞
(*i*-)	$(CH_3)_2CHCO_2C_2H_5$	116.16	col. lq.	$0.871^{20/4}$	–88.2	110–1	sl. s.	∞	∞
caprate (*n*-)	$CH_3(CH_2)_8CO_2C_2H_5$	200.32	lq.	0.859^{28}	–20	244.6^{758}	0.002^{20}	∞	∞
Ethyl caproate (*n*-)	$CH_3(CH_2)_4CO_2C_2H_5$	144.21	col. lq.	$0.873^{20/20}$	–67.5	$165–6^{736}$	i.	∞	∞
caprylate (*n*-)	$CH_3(CH_2)_6CO_2C_2H_5$	172.26	col. lq.	0.878^{17}	–45	$207–8^{753}$	i.	∞	∞
chloride	CH_3CH_2Cl	64.51	col. lq.	$0.917^{6/6}$	–139	13	0.45^{0}	∞	∞
chloroacetate	$ClCH_2CO_2C_2H_5$	122.55	col. lq.	$1.159^{20/4}$	–26	144	i.	∞	∞
chlorocarbonate	$ClCO_2CH_2CH_3$	108.52	col. lq.	$1.138^{20/4}$	–80.6	94–5	d.	∞	∞
cinnamate (*trans*-)	$C_6H_5CH{:}CHCO_2C_2H_5$	176.21	col. lq.	$1.049^{20/4}$	12	271	i.	∞	∞
cyanoacetate	$CH_2(CN)CO_2C_2H_5$	113.11	col. lq.	$1.062^{20/4}$	–22.5	208^{753}	2^{25}	∞	∞
formate	$HCO_2CH_2CH_3$	74.08	col. lq.	$0.923^{20/4}$	–79	54^{760}	11^{18}	∞	∞
furoate (α)	$OC_4H_3CO_2C_2H_5$	140.14	lf.	$1.117^{21/4}$	34	195^{766}	i.	∞	∞
heptoate	$CH_3(CH_2)_5CO_2C_2H_5$	158.24	col. lq.	$0.872^{20/20}$	–66.1	187–8	0.029^{20}	∞	∞
hypochlorite	$ClOCH_2CH_3$	80.51	yel. lq.	$1.013^{-6/4}$	expl.	36^{752}			∞
iodide	CH_3CH_2I	155.97	col. lq.	$1.933^{20/4}$	–105	72.4	0.4^{20}	∞	∞
lactate	$CH_3CH(OH)CO_2C_2H_5$	118.13	oil	$1.030^{25/4}$		155	∞	∞	∞

TABLE 2-2 Physical Properties of Organic Compounds (*Continued*)

Name	Formula	Formula weight	Form and color	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Water	Alcohol	Ether
laurate	$CH_3(CH_2)_{10}CO_2C_2H_5$	228.37	oil	$0.868^{13/4}$	−10.7	269	i.	s.	∞
mercaptan	CH_3CH_2SH	62.13	lq.	$0.839^{20/4}$	−121	36–7	1.5	s.	s.
methacrylate	$CH_2{:}C(CH_3)CO_2C_2H_5$	114.14	col. lq.	$0.913^{15.6}$		118	i.	s.	s.
naphthylamine (α-)	$C_{10}H_7NHC_2H_5$	171.24	oil	$1.060^{20/4}$		303^{723}	i.	s.	s.
naphthyl ether (α-)	$C_{10}H_7OC_2H_5$	172.22	cr.	$1.061^{20/20}$	5.5	276.4	i.	s.	s.
nitrate	$C_2H_5ONO_2$	91.07	col. lq.	$1.100^{25/4}$	−102	87–8	1.3^{55}	∞	∞
nitrite	C_2H_5ONO	75.07	lq.	$0.900^{15.5}$		17	v. sl. s.	∞	∞
oleate	$C_{17}H_{33}CO_2C_2H_5$	310.51	oil	0.867^{25}	<−15	$216–8^{15}$	i.	∞	∞
palmitate	$CH_3(CH_2)_{14}CO_2C_2H_5$	284.48	col. nd.	$0.858^{25/4}$	24–5	191^{10}	i.	s.	s.
pelargonate	$CH_3(CH_2)_7CO_2C_2H_5$	186.29	col. lq.	$0.866^{17.5}$	−44.5	$227–8^{757}$	i.	∞	∞
propionate	$CH_3CH_2CO_2C_2H_5$	102.13	col. lq.	$0.891^{20/4}$	−72.6	99.1	2.4^{20}	∞	∞
salicylate (*o*-)	$HOC_6H_4CO_2C_2H_5$	166.17	col. lq.	$1.136^{15/4}$	1.3	233–4	i.	∞	∞
stearate	$CH_3(CH_2)_{16}CO_2C_2H_5$	312.53	col. cr.	$0.848^{36.3}$	33.4(31)	201^{10}	i.	s.	s.
toluate (*o*-)	$CH_3{\cdot}C_6H_4CO_2C_2H_5$	164.20	lq.	$1.032^{25/25}$	<−10	227	i.	∞	∞
(*m*-)	$CH_3{\cdot}C_6H_4CO_2C_2H_5$	164.20	lq.	$1.030^{20/20}$		231^{750}	i.	∞	∞
toluene sulfonate (*p*-)	$CH_3{\cdot}C_6H_4SO_3C_2H_5$	200.25	pr./al.	$1.166^{48/4}$	33–4	221.3	i.	s.	s.
toluidine (*o*-)	$CH_3{\cdot}C_6H_4NHC_2H_5$	135.21	lq.	$0.948^{25/4}$	<−15	215–6	i.		
(*p*-)	$CH_3{\cdot}C_6H_4NHC_2H_5$	135.21	lq.	$0.942^{25/4}$		217	i.		
urea	$C_2H_5NH{\cdot}CO{\cdot}NH_2$	88.11	nd.	1.213^{18}	92		v. s.	80	i.
valerate (*n*-)	$CH_3(CH_2)_3CO_2C_2H_5$	130.18	col. lq.	0.877^{20}	−91.2	145.5	0.24^{25}	∞	∞
(*i*-)	$(CH_3)_2CH(CH_2)CO_2C_2H_5$	130.18	col. lq.	$0.867^{20/4}$	−99.3	135	0.17^{20}	∞	∞
Ethylal	$CH_2(OC_2H_5)_2$	104.15	lq.	$0.824^{25/4}$	−66.5	89	9^{18}	∞	∞
Ethylene	$H_2C{:}CH_2$	28.05	col. gas	$0.57^{-102/4}$	−169	−103.9	26 cc.[0]	360 cc.	s.
bromide	$BrCH_2{\cdot}CH_2Br$	187.86	col. lq.	$2.180^{20/4}$	10	131.5	0.43^{80}	∞	∞
bromohydrin	$BrCH_2{\cdot}CH_2OH$	124.96	col. lq.	$1.772^{20/4}$		150.3	sl. s.	s.	
chlorobromide	$ClCH_2{\cdot}CH_2Br$	143.41	lq.	1.689^{19}	−16.6	106.7	0.69^{80}		
chlorohydrin	$ClCH_2{\cdot}CH_2OH$	80.51	col. lq.	$1.213^{20/4}$	−69	128.8	∞	∞	∞
diamine	$H_2NCH_2{\cdot}CH_2NH_2$	60.10	col. lq.	$0.900^{20/20}$	8.5	117.2	∞	∞	0.3
oxide	$<(CH_2)_2>O$	44.05	lq.	$0.887^{7/4}$	−111.3	13.5^{747}	∞	∞	v. s.
Ethylidene diacetate	$CH_3CH(O_2CCH_3)_2$	146.14	col. lq.	1.061^{12}	18.85	168^{740}	sl. s.	∞	
Eugenol (1-,4-,3-)	$C_3H_5{\cdot}C_6H_3(OH)OCH_3$	164.20	oil	$1.070^{15/15}$	10.3	253.5	v. sl. s.	∞	∞
(*i*-)(1-,3-,4-)	$C_3H_5{\cdot}C_6H_3(OCH_3)OH$	164.20	oil	$1.091^{15/15}$	−10	267.5	v. sl. s.	∞	∞
Fenchyl alcohol (*dl*-)	$C_{10}H_{17}OH$	154.25	col. cr.	0.935^{40}	35	201	sl. s.		
(*d*-)(α-)	$C_{10}H_{17}OH$	154.25	col. pr.	$0.964^{20/4}$	45–7	201–2	sl. s.	s.	s.
(*i*-)(*l*-)	$C_{10}H_{17}OH$	154.25	col. cr.	0.961	61–2	201–2	i.		
Ferric dimethyl-dithiocarbamate	$Fe[SSCN(CH_3)_2]_3$	416.49	cr.		d. 100–30	ign. >150	v. sl. s.		
Fluorene	$(C_6H_4)_2>CH_2$	166.22	cr./al.	$1.203^{0/4}$	115–6	293–5	i.	s. h.	s.
Fluorescein	$C_{20}H_{12}O_5$	332.31	yel. red		d. > 290		v. sl. s. h.	s. h.	
Fluoro-dichloromethane	$FCHCl_2$	102.92	gas	1.426^{0}	−127	14.5	i.	s.	s.
-trichloromethane	Cl_3CF	137.37	col. lq.	$1.494^{17.2}$		24.9	i.	∞	∞
Formaldehyde	$HCHO$	30.03	gas	0.815^{-20}	−92	−21	v. s.	v. s.	v. s.
(*m*-)	$(CH_2O)_3$	90.08	wh.	1.17^{65}	64	114.5^{759}	21^{25}	s.	s.
(*p*-)	$(CH_2O)_x{\cdot}xH_2O$	(30.03)	amor.		150–60	subl.	$20–30^{18}$	i.	i.
Formamide	$HCONH_2$	45.04	lq.	$1.139^{20/4}$	2	193	∞	∞	v. sl. s.
Formanilide	$HCONHC_6H_5$	121.14	mn.	$1.147^{15/15}$	47	216^{120}	sl. s.	v. s.	s.
Formic acid	HCO_2H	46.03	col. lq.	$1.220^{20/4}$	8.6	100.8	∞	∞	
Fructose	$CH_2OH(CHOH)_3COCH_2OH$	180.16	nd./aq.	$1.669^{17.5}$	95–105		v. s.	8^{18}	
Fuchsin	$C_{20}H_{19}N_3HCl$	337.85	red	1.22	d. >200		0.3	s.	i.
Fulminic acid	C:NOH	43.02							
Fumaric acid (*trans*-)	$HO_2CCH{:}CHCO_2H$	116.07	col. pr.	$1.635^{20/4}$	286–7	290	0.7^{17}	5.8^{30}	0.7^{25}
Furfural	$C_4H_3O{\cdot}CHO$	96.08	lq.	$1.159^{20/4}$	−38.7	161.7^{760}	9.1^{13}	∞	∞
Furfuran	C_4H_4O	68.07	col. lq.	$0.937^{20/4}$		$31–2^{756}$	i.	s.	s.
Furfuryl acetate	$CH_3CO_2CH_2C_4H_3O$	140.14	col. oil	$1.118^{20/4}$		175–7	i.	s.	s.
alcohol	$C_4H_3O{\cdot}CH_2OH$	98.10	oil	$1.129^{25/4}$		169.5^{752}	∞	s.	s.
butyrate	$C_3H_7CO_2CH_2{\cdot}C_4H_3O$	168.19	col. lq.	$1.053^{20/4}$		212–3	v. sl. s.	s.	∞
propionate	$C_2H_5CO_2CH_2{\cdot}C_4H_3O$	154.16	col. lq.	$1.109^{20/4}$		195–6	v. sl. s.	s.	∞
Furoic acid	$C_4H_3O{\cdot}CO_2H$	112.08	mn. pr.		133–4	230–2	3.6^{15}	s.	s.
G-acid, K salt (2-)(6-,8-)	$HOC_{10}H_5(SO_3K)_2$	380.48	cr.				8^{25}		
Na salt (2-)(6-,8-)	$HOC_{10}H_5(SO_3Na)_2$	348.26	cr.				34^{20}		
Galactose (*d*-)(α-)	$C_5H_{11}O_5{\cdot}CHO$	180.16	pr.		165.5		10.3^{0}	0.6^{40}	
Gallic acid (3-,4-,5-)	$(HO)_3C_6H_2CO_2H{\cdot}H_2O$	188.13	mn./aq.	$1.694^{4/4}$	d. 220		1^{13}	28^{15}	2.5^{15}
Gamma acid (2-,8-,6-)	$C_{10}H_5(NH_2)(OH)SO_3H$	239.25	cr.						
Geraniol	$C_9H_{15}CH_2OH$	154.25	col. lq.	0.883^{15}	<−15	230	i.	∞	∞
Glucose (*d*-)(α-)	$C_5H_{11}O_5{\cdot}CHO$	180.16	rhb.	1.544^{25}	146		$82^{17.5}$	sl. s.	i.
(*d*-)(β-)	$C_6H_{12}O_6{\cdot}H_2O$	198.17	cr.	$1.562^{18/4}$	150		154^{15}		
Glucuronic acid	$CHO(CHOH)_4CO_2H$	194.14	cr.		154	d.	v. s.		
Glutam(in)ic acid (*dl*-)	$[{\cdot}CHNH_2(CH_2)_2{\cdot}](CO_2H)_2$	147.13	cr./aq.	1.460	199 d.		1.5^{20}	v. sl. s.	v. sl. s.

Glutaric acid	$CH_2(CH_2CO_2H)_2$	132.11	col. cr.	1.429^{15}	97.5	200^{20}	63.9^{20}	v. s.	v. s.
Glycerol	$CH_2OH{\cdot}CHOH{\cdot}CH_2OH$	92.09	col. lq.	$1.260^{50/4}$	17.9	290	∞	∞	i.
acetate (mono-)	$C_5H_{10}O_4$	134.13	col. oil	$1.20^{20/4}$		158^{165}	v. s.	v. s.	sl. s.
(di-)	$(CH_3CO_2)_2C_3H_5OH$	176.17	col. lq.	$1.178^{15/15}$	40	$175–6^{40}$	s.	s.	sl. s.
nitrate (mono-) (α-)	$CH_2OH{\cdot}CHOH{\cdot}CH_2NO_3$	137.09	col. pr.	1.40^{15}	58–9	155–60	70^{15}	v. s.	v. sl. s.
(β-)	$CH_2OH{\cdot}CHNO_3{\cdot}CH_2OH$	137.09	lf.	1.40^{15}	54	155–60		v. s.	sl. s.
dinitrate (1-,3-)	$CHOH(CH_2ONO_2)_2$	182.09	oil	1.47^{15}	<–30	$146–8^{15}$		v. s.	v. s.
Glyceryl triacetate	$(CH_3CO_2)_3C_3H_5$	218.20	col. lq.	$1.161^{17/4}$	–78	258–9	7.17^{15}	∞	∞
tribenzoate	$(C_6H_5CO_2)_3C_3H_5$	404.41	nd.	1.228^{12}	75–6	d.	i.	s. h.	s.
tributyrate	$(C_2H_5CH_2CO_2)_3C_3H_5$	302.36	col. lq.	$1.032^{20/4}$	<–75	305–9	i.	s.	s.
tricaprate	$[CH_3(CH_2)_8CO_2]_3C_3H_5$	554.84	col. cr.	$0.921^{40/4}$	31(25)		i.	s. h.	v. s.
tricaproate	$[CH_3(CH_2)_4CO_2]_3C_3H_5$	386.52	col. lq.	$0.987^{20/4}$	–25		i.	s.	s.
tricaprylate	$[CH_3(CH_2)_6CO_2]_3C_3H_5$	470.68	col. lq.	$0.954^{20/4}$	8.3(–21)		i.	s.	s.
trilaurate	$[CH_3(CH_2)_{10}CO_2]_3C_3H_5$	639.00	col. nd.	$0.894^{60/4}$	45–6		i.	sl. s. c.	v. s.
trimyristate	$[CH_3(CH_2)_{12}CO_2]_3C_3H_5$	723.16	lf.	$0.885^{60/6}$	56.5		i.	s.	
trinitrate	$CH_2NO_3{\cdot}CHNO_3{\cdot}CH_2NO_3$	227.09	yel. oil	1.601^{15}	13.3(2)	160^{15}	0.18^{20}	50^{20}	∞
trinitrite	$CH_2NO_2{\cdot}CHNO_2{\cdot}CH_2NO_2$	179.09	yel. lq.	$1.291^{10/16}$		150 sl. d.	d.	d.	s.
trioleate	$(C_{17}H_{33}CO_2)_3C_3H_5$	885.43	col. oil	0.915^{15}	–4	240^{18}	i.	sl. s.	v. s.
tripalmitate	$[CH_3(CH_2)_{14}CO_2]_3C_3H_5$	807.32	col. nd.	$0.866^{80/4}$	65.1	$310–20^{0.1}$	i.	0.004^{21}	v. s.
tristearate	$[CH_3(CH_2)_{16}CO_2]_3C_3H_5$	891.48	col. pr.	$0.862^{80/4}$	70.8(55)		i.	s. h.	s. h.
Glycide	$C_2H_3O{\cdot}CH_2OH$	74.08	col. lq.	$1.114^{16/16}$		166 sl. d.	∞	∞	∞
Glycine, Glycocoll	$NH_2CH_2{\cdot}CO_2H$	75.07	mn.	1.161	232–6 d.		23 c.	0.1 c.	i.
Glycol	$CH_2OH{\cdot}CH_2OH$	62.07	col. lq.	$1.113^{19/4}$	–15.6	197.4	∞	∞	1.0
diacetate	$(CH_3CO_2CH_2{\cdot})_2$	146.14	col. lq.	$1.109^{14/4}$	–31	190.5	14.3^{22}	∞	∞
dibenzoate	$(C_6H_5CO_2CH_2{\cdot})_2$	270.28	rhb./et.		73–4	>360	i.		s.
dibutyrate	$(C_3H_7CO_2CH_2{\cdot})_2$	202.25	col. lq.	1.024^{0}		240	i.	v. s.	v. s.
dicaprylate	$(C_7H_{15}CO_2CH_2{\cdot})_2$	314.46	lq.		22		i.		
diformate	$(HCO_2CH_2{\cdot})_2$	118.09	lq.			174	v. sl. s.		
dilaurate	$(C_{11}H_{25}CO_2CH_2{\cdot})_2$	426.67	amor.		52–4	188^{20}	i.	v. s.	v. s.
dinitrate	$(O_2NO{\cdot}CH_2{\cdot})_2$	152.06	yel. lq.	$1.482^{21/2}$	–20	expl. 114	0.92^{25}	s.	∞
dinitrite	$(ONO{\cdot}CH_2{\cdot})_2$	120.06	lq.	1.216^{0}	<–15	96–8	i.	s. d.	s.
dipalmitate	$(C_{15}H_{31}CO_2CH_2{\cdot})_2$	538.89	nd.		71–2	$260^{0.1}$	i.	s.	s.
dipropionate	$(C_2H_5CO_2CH_2{\cdot})_2$	174.19	lq.	1.045^{25}		211–2	sl. s.	∞	∞
ether	$(HO{\cdot}CH_2CH_2)_2O$	106.12	lq.	$1.118^{20/20}$	–10.5	244.8	∞	∞	i.
formal	$<O{\cdot}CH_2CH_2OCH_2>$	74.08	lq.	$1.060^{20/4}$		75–6	∞		
formate (mono-)	$HCO_2CH_2CH_2OH$	90.08	lq.	$1.199^{15/4}$		180	∞		
Glycolic acid	$HOCH_2CO_2H$	76.05	nd./aq.		79(63)	d.	∞	90^{25}	v. s.
Guaiacol (*o*-)	$CH_3O{\cdot}C_6H_4OH$	124.14	pr.	$1.140^{15/15}$	28.3	205	1.7^{15}	v. s.	v. s.
Guanidine	$NH{:}C(NH_2)_2$	59.07	col. cr.		50		v. s.	s.	
H-acid, Na salt (1-,8-,3-,6-)	$C_{10}H_8O_7NS_2Na{\cdot}1½H_2O$	368.32	cr.				0.17^{20}		
Heptacosane (*n*-)	$CH_3(CH_2)_{25}CH_3$	380.73	col. cr.	$0.780^{60/4}$	59.5	270^{15}	i.		
Heptane (*n*-)	$CH_3(CH_2)_5CH_3$	100.20	col. lq.	$0.684^{20/4}$	–90.6	98.4^{760}	0.005^{15}	sl. s.	∞
(*i*-)	$(CH_3)_2CH(CH_2)_3CH_3$	100.20	col. lq.	$0.679^{20/4}$	–118.2	90.0	i.	s.	∞
	$C_3H_7{\cdot}CH(CH_3){\cdot}C_2H_5$	100.20	col. lq.	$0.687^{20/4}$	–119.4	91.8	i.	s.	∞
	$(CH_3)_3C{\cdot}CH_2{\cdot}C_2H_5$	100.20	col. lq.	$0.674^{20/4}$	–125	79.1	i.	s.	∞
	$[(CH_3)_2CH]_2CH_2$	100.20	col. lq.	$0.675^{20/4}$	–119.4	80.8	i.	s.	∞
	$(CH_3)_2C(C_2H_5)_2$	100.20	col. lq.	$0.693^{20/4}$	–135.0	86.0	i.	s.	∞
	$(C_2H_5)_3CH$	100.20	col. lq.	$0.698^{20/4}$	–118.7	93.5	i.	s.	∞
	$(CH_3)_3C{\cdot}CH(CH_3)_2$	100.20	col. lq.	$0.690^{20/4}$	–25	80.8	i.	s.	∞
Heptoic acid	$CH_3(CH_2)_5CO_2H$	130.18	col. lq.	0.918^{20}	–10	221–2	0.25^{15}	s.	s.
aldehyde	$CH_3(CH_2)_5CHO$	114.19	col. lq.	$0.850^{20/\ell}$	–42	155	0.02^{20}	∞	∞
Heptyl acetate (*n*-)	$CH_3CO_2CH_2(CH_2)_5CH_3$	158.24	col. lq.	$0.874^{16/16}$		191.5^{759}	i.	s.	s.
alcohol (*n*-)	$CH_3(CH_2)_5CH_2OH$	116.20	col. lq.	$0.824^{20/4}$	–34	175^{756}	0.18^{25}	∞	∞
	$[(CH_3)_2CH]_2CHOH$	116.20	col. lq.	$0.829^{20/4}$		140	v. sl. s.	∞	∞
	$(C_2H_5{\cdot}CH_2)_2CHOH$	116.20	lq.	$0.820^{20/4}$	–37	156	i.	s.	s.
mercaptan	$CH_3CH(SH){\cdot}C_5H_{11}$	132.27	lq.	0.835^{20}		$174–5^{765}$	i.		
Hexachloro-benzene	C_6Cl_6	284.78	mn.	2.044^{24}	228–31	309^{742}	i.	v. sl. s. h.	s. h.
-ethane	$CCl_3{\cdot}CCl_3$	236.74	rhb.	$2.091^{20/4}$	186–7	186^{777}	0.005^{22}	v. s.	v. s.
Hexacosane (*n*-)	$CH_3(CH_2)_{24}CH_3$	366.71	cr.	$0.779^{57/4}$	56.6	262^{15}	i.	v. sl. s.	
Hexadecane (*n*-)	$CH_3(CH_2)_{14}CH_3$	226.44	lf.	$0.774^{20/4}$	18.5	287.5	i.	∞	∞
Hexaethylbenzene	$C_6(C_2H_5)_6$	246.43	pr./al.	$0.831^{130/4}$	130	298.3	i.	0.75^{25}	8^{25}
Hexamethylbenzene	$C_6(CH_3)_6$	162.27	pl./al.		166	265	i.	0.2^{0}	v. s.
Hexamethylene-diamine	$NH_2(CH_2)_6NH_2$	116.20	lf.		42	204–5	v. s.	s.	
-diisocyanate	$OCN(CH_2)_6NCO$	168.19	lq.	1.04^{28}		143–4[20]	d.	d.	
-glycol	$HO(CH_2)_6OH$	118.17	nd./aq.		42	250	s.	s.	sl. s. h.
tetramine	$(CH_2)_6N_4$	140.19	col. rhb.		subl.		81^{12}	3	v. sl. s.
Hexane (*n*-)	$CH_3(CH_2)_4CH_3$	86.18	col. lq.	$0.659^{20/4}$	–94	69	0.014^{15}	50^{33}	∞
(*i*-)	$(CH_3)_2CH(CH_2)_2CH_3$	86.18	lq.	$0.654^{20/4}$	–153.7	60.2	i.		s.
(neo-)	$(CH_3)_3C{\cdot}C_2H_5$	86.18	lq.	$0.649^{20/20}$	–98.2	49.7	i.		s.
	$(CH_3)_2CH{\cdot}CH(CH_3)_2$	86.18	lq.	$0.662^{20/4}$	–129.8	58.0^{760}	i.		s.
	$(C_2H_5)_2CHCH_3$	86.18	lq.	$0.664^{20/4}$	–118	63.2	i.		s.

TABLE 2-2 Physical Properties of Organic Compounds (*Continued*)

Name	Formula	Formula weight	Form and color	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Water	Alcohol	Ether
Hexyl acetate (*n*-)	$CH_3CO_2(CH_2)_5CH_3$	144.21	col. lq.	$0.890^{0/0}$		169.2	i.	v. s.	v. s.
alcohol (*n*-)	$CH_3(CH_2)_4CH_2OH$	102.17	col. lq.	$0.820^{20/20}$	–51.6	157.2	0.6^{20}	∞	∞
	$(CH_3)_2CH{\cdot}C(CH_3)_2OH$	102.17	lq.	$0.821^{20/0}$	–14	120–1	v. sl. s.	∞	∞
	$(CH_3)_2COH{\cdot}CH_2C_2H_5$	102.17	lq.	$0.809^{20/4}$	–107	123^{762}	v. sl. s.	∞	∞
formate (*n*-)	$HCO_2CH_2(CH_2)_4CH_3$	130.18	lq.	0.895^{0}		153.6		∞	∞
resorcinol (2-,4-)	$CH_3(CH_2)_5C_6H_3(OH)_2$	194.27	col. nd.		68–70	179^{7}	0.05	v. s.	s.
Hippuric acid	$C_6H_5CONHCH_2CO_2H$	179.17	rhb.	$1.371^{20/4}$	187–8	d.	0.4^{20}	s. h.	0.25^{18}
Histidine (*l*-)	$C_6H_9O_2N_3$	155.15	lf./aq.		d. 287		s.	v. sl. s.	i.
Homophthalic acid (*o*-)	$HO_2C{\cdot}C_6H_4{\cdot}CH_2CO_2H$	180.16	cr./aq.		175–80		s. h.	v. s.	sl. s.
Hydracrylic acid	$HOCH_2CH_2CO_2H$	90.08	syrup			d.			
Hydro-cyanic acid	HCN	27.03	lq.	0.697^{18}	–12	25–6	∞	∞	∞
-quinone (*p*-)	$C_6H_4(OH)_2$	110.11	cr.	1.332^{15}	170.3	285^{730}	6^{15}	v. s.	v. s.
Hydroxy-benzaldehyde (*p*-)	$HO{\cdot}C_6H_4{\cdot}CHO$	122.12	nd./aq.	1.129^{130}	116–7	subl.	1.38^{31}		
-benzanilide (*o*-)	$HO{\cdot}C_6H_4{\cdot}CONHC_6H_5$	213.23	pr./al.		135	d.	v. sl. s. h.	s.	s.
-quinoline (2-)(α-)	$C_9H_6N{\cdot}OH$	145.16	pr./al.		199–200	subl.	s. h.	v. s.	v. s.
(8-)(*o*-)	$C_9H_6N{\cdot}OH$	145.16	pr.		75–6	266.6^{752}	v. sl. s. c.	s.	sl. s.
Indigo	$[C_6H_4(CO)(NH)C{:}]_2$	262.26	cr.	1.35	390–2	subl.	i.	i.	i.
White	$C_{16}H_{12}O_2N_2$	264.28	gray				i.	s.	s.
Indole	C_8H_7N	117.15	lf./aq.		52	253–4	s. h.	s. h.	s.
Indoxyl	C_8H_6NOH	133.15	yel. pr.		85	110	s.	s.	s.
Iodo-benzene	C_6H_5I	204.01	col. lq.	$1.824^{25/4}$	–28.5	188.6	0.034^{20}	s.	∞
-phenol (*p*-)	IC_6H_4OH	220.01	nd./aq.	1.857^{112}	93–4	d.	sl. s.	v. s.	v. s.
Iodoform	HCI_3	393.73	yel. hex.	4.008^{17}	119	subl.	0.01^{25}	1.5^{17}	13.6^{25}
Ionone (α-)	$C_{10}H_{16}{:}CHCOCH_3$	192.30	col. oil	0.930^{20}		136.1^{17}	sl. s.	∞	∞
(β-)	$C_{10}H_{16}{:}CHCOCH_3$	192.30	col. oil	0.944^{20}		140^{18}	sl. s.	∞	∞
Irone (β-)	$C_{14}H_{22}O$	206.32	col. oil	0.939^{20}		144^{16}	v. sl. s.	v. s.	v. s.
Isatin	$C_6H_4 < (CO)(N) > COH$	147.13	yel. red		200–1	subl.	s. h.	v. s. h.	sl. s.
Isoprene	$CH_2{:}CH{\cdot}C(CH_3){:}CH_2$	68.12	col. lq.	$0.681^{20/4}$	–120	34	i.	∞	∞
Ketene	$H_2C{:}CO$	42.04	col. gas		–151	–56	d.	d.	s.
Koch acid (1-)(3-,6-,8-)	$C_{10}H_4(NH_2)S_3O_9HNa_2$	427.34	cr.				7.2^{20}		
Lactic acid (*dl*-)	$CH_3CH(OH)CO_2H$	90.08	hyg.	$1.249^{15/4}$	16.8	122^{14}	∞	∞	∞
anhydride	$C_6H_{10}O_5$	162.14	yel. oil			d. 250	v. sl. s.	s.	s.
Lactide (*dl*-)	$C_6H_8O_4$	144.13	tri./al.	$0.862^{10/4}$	124.5	255^{757}	v. sl. s.	v. sl. s. c.	
Lactose	$C_{12}H_{22}O_{11}{\cdot}H_2O$	360.31	col. rhb.	1.525^{20}	202	d.	17^{10}	i.	i.
Lauric acid	$CH_3(CH_2)_{10}CO_2H$	200.32	col. nd.	$0.869^{50/4}$	48(44)	225^{100}	i.	s.	s.
Laurone	$[CH_3(CH_2)_{10}]_2CO$	338.61	pl.	$0.809^{69/4}$	69–70		i.	i. c.	
Lauryl alcohol	$CH_3(CH_2)_{10}CH_2OH$	186.33	lf.	$0.831^{24/4}$	24	255–9	i.	s.	s.
Lead tetraethyl	$Pb(CH_2CH_3)_4$	323.44	col. lq.	$1.659^{18/4}$	–136	152^{291}	i.	sl. s.	∞
tetramethyl	$Pb(CH_3)_4$	267.34	col. lq.	$1.995^{20/4}$	–27.5	110^{760}	i.	∞	∞
Lepidine (*py*-4)	$C_9H_6N{\cdot}CH_3$	143.19	lq.	1.086^{20}	9–10	261–3	sl. s.	∞	∞
Leucine (*l*-)	$(CH_3)_2CHCH_2CH(NH_2)CO_2H$	131.17	cr.	1.293^{18}	295	subl.	2.2^{18}		
Levulinic acid	$CH_3CO(CH_2)_2CO_2H$	116.12	lf.	$1.140^{20/20}$	33.5	245–6	v. s.	v. s.	v. s.
Limonene (*d*- or *l*-)	$C_{10}H_{16}$	136.23	lq.	$0.842^{20/4}$	–96.9	177	i.	∞	∞
Linalool (*d*- or *l*-)	$C_{10}H_{17}OH$	154.25	col. oil	0.868^{20}		198–200	v. sl. s.	s.	∞
Linalyl acetate	$CH_3CO_2C_{10}H_{17}$	196.29	col. lq.	0.895^{20}		220^{762} d.	v. sl. s.	∞	∞
Linoleic acid	$C_{17}H_{31}CO_2H$	280.45	yel. oil	$0.903^{18/4}$	–9.5	$229–30^{16}$	i.	∞	∞
Maleic acid	$HO_2C{\cdot}CH{:}CH{\cdot}CO_2H$	116.07	mn.	1.609	130.5	135 d.	79^{25}	70^{30}	8^{25}
anhydride	$< (\cdot CHCO)_2 > O$	98.06	cr.	1.5	57–60	202	16.3^{80}		
Malic acid (*dl*-)	$HO_2CCH_2CH(OH)CO_2H$	134.09	col. cr.	$1.601^{20/4}$	128–9	150 d.	144^{26}	v. s.	v. s.
(*d*- or *l*-)	$HO_2CCH_2CH(OH)CO_2H$	134.09	col. cr.	$1.595^{20/4}$	99–100	140 d.	v. s.	v. s.	8.4^{15}
Malonic acid	$H_2C(CO_2H)_2$	104.06	col. tri.	1.631^{15}	130–5 d.		138^{16}	42^{25}	8^{15}
Maltose	$C_{12}H_{22}O_{11}{\cdot}H_2O$	360.31	col. nd.	1.540^{17}	d.		108^{25}	v. sl. s. c.	i.
Mandelic acid (*dl*-)	$C_6H_5CH(OH)CO_2H$	152.15	rhb./aq.	$1.300^{20/4}$	118.1	d.	16^{20}	s.	s.
Mannitol (*d*-)	$CH_2OH(CHOH)_4CH_2OH$	182.17	col. rhb.	$1.489^{20/4}$	166	290–5^{3}	13^{14}	0.01^{14}	i.
Mannose (*d*-)	$CH_2OH(CHOH)_4CHO$	180.16	rhb.	$1.539^{20/4}$	132		248^{17}	v. sl. s.	i.
Margaric acid	$CH_3(CH_2)_{15}CO_2H$	270.45	col. pl.	0.853^{60}	60–1	227^{100}	i.	32^{28}	v. s.
Mellitic acid	$C_6(CO_2H)_6$	342.17	nd./al.		286–8	d.	v. s.	v. s.	
Menthol (l-)(α-)	$C_{10}H_{19}OH$	156.27	col. cr.	$0.890^{15/15}$	42–3	212	0.04 c.	v. s.	v. s.
Mercapto-benzothiazole (2-)	$< C_6H_4N{:}C(SH)S >$	167.25	nd.	$1.42^{20/4}$	179	d.	i.	s.	sl. s.
-thiazoline (2-)	$< CH_2N{:}C(SH)SCH_2 >$	119.21	cr.	1.50	106		1.6^{60}		
Mercuric cyanide	$Hg(CN)_2$	252.62	cr.	4.003^{22}	d. 320		12.5^{15}		
fulminate	$Hg(ONC)_2{\cdot}½H_2O$	293.63	cr./aq.	4.4	expl.		0.07^{12}	s.	
Mesityl oxide	$(CH_3)_2C{:}CHCOCH_3$	98.14	lq.	$0.858^{20/4}$	–59	130^{750}	3^{20}	∞	∞
Mesitylene (1-,3-,5-)	$C_6H_3(CH_3)_3$	120.19	col. lq.	$0.865^{20/4}$	–45(–52)	164.8	i.	s.	∞
Metanilic acid (*m*-)	$H_2NC_6H_4SO_3H$	173.19	col. nd.		d.		2^{15}	v. sl. s.	v. sl. s.
Methane	CH_4	16.04	gas	0.415^{-164}	–182.6	–161.4	0.4^{20} cc.	47^{20} cc.	104^{10} cc.

Methoxy-methoxyethanol	$CH_3(OCH_2)_2CH_2OH$	106.12	lq.	1.038^{25}	<–70	167.5	∞		
Methyl acetate	$CH_3CO_2CH_3$	74.08	col. lq.	$0.924^{20/4}$	–98.7	57.1	33^{22}	∞	∞
acrylic acid (α-)	$CH_2{:}C(CH_3)CO_2H$	86.09	pr.	$1.015^{20/4}$	15–16	161–3	s. h.	∞	∞
alcohol	CH_3OH	32.04	col. lq.	$0.792^{20/4}$	–97–8	64.7	∞	∞	∞
-amine	CH_3NH_2	31.06	col. gas	0.699^{-11}	–92.5	-6.7^{758}	v. s.	v. s.	
-amine hydrochloride	$CH_3NH_2{\cdot}HCl$	67.52	pl./al.	1.23	226–8	230^{15}	v. s.	23 h.	i.
aniline	$C_6H_5NHCH_3$	107.15	lq.	$0.989^{20/4}$	–57	195.5	0.01^{25}	s.	∞
anthracene (α-)	$C_6H_4{:}(CH)_2{:}C_6H_3CH_3$	192.26	lf./al.	$1.047^{99.4}$	86		i.		
(β-)	$C_6H_4{:}(CH)_2{:}C_6H_3CH_3$	192.26	col. lf.	$1.181^{0/4}$	207		i.	v. sl. s.	v. sl. s.
anthranilate (*o*-)	$NH_2C_6H_4CO_2CH_3$	151.16	col. lq.	$1.168^{19/4}$	24	135.5^{15}	sl. s.	s.	s.
anthraquinone (2-)	$C_6H_4{:}(CO)_2{:}C_6H_3CH_3$	222.24	col. nd.		176–7	subl.	i.	s.	s.
benzoate	$C_6H_5CO_2CH_3$	136.15	col. lq.	$1.087^{25/25}$	–12.5	198–9	0.02^{30}	∞	∞
benzylaniline	$C_6H_5N(CH_3)CH_2C_6H_5$	197.28	lq.		9.2	305–6	i.	s.	s.
bromide	CH_3Br	94.94	gas	$1.732^{0/0}$	–93	4.5^{758}	v. sl. s.	s.	s.
butyrate (*n*-)	$CH_3(CH_2)_2CO_2CH_3$	102.13	col. lq.	$0.898^{20/4}$	<–95	102.3	1.7	∞	∞
(*i*-)	$(CH_3)_2CHCO_2CH_3$	102.13	col. lq.	$0.891^{20/4}$	–84.7	92.6	v. sl. s.	∞	∞
caprate	$CH_3(CH_2)_8CO_2CH_3$	186.29	lq.		–18	223–4	i.	∞	∞
caproate (*n*-)	$CH_3(CH_2)_4CO_2CH_3$	130.18	col. lq.	$0.904^{0/0}$		149.5	i.	∞	∞
caprylate	$CH_3(CH_2)_6CO_2CH_3$	158.24	col. lq.	0.887^{18}	–40	192–4	i.	∞	∞
cellosolve	$CH_3OCH_2CH_2OH$	76.09	col. lq.	$0.965^{20/4}$		124–5	∞	∞	∞
chloride	CH_3Cl	50.49	gas	0.952^{0}	–97.7	–24	280^{16} cc.	v. s.	v. s.
chloroacetate	$ClCH_2CO_2CH_3$	108.52	col. lq.	$1.236^{20/4}$	–32.7	130^{740}	v. sl. s.	∞	∞
chloroformate	$ClCO_2CH_3$	94.50	col. lq.	1.236^{15}		71–2	d.	∞	∞
cinnamate	$C_6H_5CH{:}CHCO_2CH_3$	162.19	cr.	$1.042^{36/0}$	33.4	263	i.	v. s.	v. s.
cyclohexane	$CH_2 < (CH_2CH_2)_2 > CHCH_3$	98.19	col. lq.	$0.769^{20/4}$	–126.3	101	i.	s.	s.
ethyl carbonate	$CH_3O{\cdot}CO{\cdot}OC_2H_5$	104.10	lq.	1.002^{27}	–14.5	109.2	i.	∞	∞
ethyl ketone	$CH_3.CO{\cdot}C_2H_5$	72.11	col. lq.	$0.805^{20/4}$	–85.9	79.6	35^{10}	∞	∞
ethyl oxalate	$CH_3OCO{\cdot}CO_2C_2H_5$	132.11	lq.	$1.156^{0/0}$		173.7	i.	v. s.	v. s.
formate	HCO_2CH_3	60.05	lq.	$0.974^{20/4}$	–99.8	32	30^{20}	∞	
furoate	$C_4H_3O{\cdot}CO_2CH_3$	126.11	col. lq.	$1.179^{21/4}$		181.3	i.	∞	∞
glucamine	$CH_2OH(CHOH)_4CH_2NHCH_3$	195.21							
glycolate	$HOCH_2CO_2CH_3$	90.08	lq.	1.168^{18}		151.2			
heptoate	$CH_3(CH_2)_5CO_2CH_3$	144.21	lq.	$0.881^{15/4}$		172–3	i.		
hypochlorite	$ClOCH_3$	66.49	gas			12^{726}			
iodide	CH_3I	141.94	col. lq.	$2.279^{20/4}$	–64.4	42.4	1.8^{15}	∞	∞
lactate	$CH_3CH(OH)CO_2CH_3$	104.10	lq.	1.090^{19}		144.8	∞	s.	s.
laurate	$CH_3(CH_2)_{10}CO_2CH_3$	214.34	lq.		5	148^{18}	i.		
mercaptan	CH_3SH	48.11	gas	0.896^{0}	–121	5.8^{752}	s.	v. s.	v. s.
methacrylate	$CH_2{:}C(CH_3)CO_2CH_3$	100.12	lq.	$0.950^{15.6}$	–48	100.3	i.		
myristate	$CH_3(CH_2)_{12}CO_2CH_3$	242.40	cr./al.		18–9	295^{715}	i.		
naphthalene (α-)	$C_{10}H_7CH_3$	142.20	oil	$1.025^{14/4}$	–19	244.6	i.	v. s.	v. s.
(β-)	$C_{10}H_7CH_3$	142.20	mn.	$0.994^{40/4}$	35–6	241–2	i.	v. s.	v. s.
nitrate	CH_3ONO_2	77.04	lq.	1.203^{25}	expl.	65	sl. s.	s.	s.
nitrite	CH_3ONO	61.04	gas	0.991^{15}		–12		s.	s.
nonyl ketone (*n*-)	$CH_3(CH_2)_8COCH_3$	170.29	col. oil	$0.828^{20/20}$	13.5	228	i.	s.	s.
oleate	$C_{17}H_{33}CO_2CH_3$	296.49	oil	0.879^{18}		190–1^{10}	i.	∞	∞
orange	$(CH_3)_2NC_6H_4N_2C_6H_4SO_3Na$	327.33	red pd.				0.2 c.		
palmitate	$CH_3(CH_2)_{14}CO_2CH_3$	270.45	col. cr.		30–1	196^{15}	i.	s.	s.
phosphine	CH_3PH_2	48.02	gas			-14^{759}	i.	sl. s.	
propionate	$CH_3CH_2CO_2CH_3$	88.11	col. lq.	$0.915^{20/4}$	–87.5	79.7	0.5^{20}	∞	∞
propyl ketone (*n*-)	$CH_3COCH_2CH_2CH_3$	86.13	col. lq.	$0.812^{15/15}$	–77.8	102	v. sl. s.	∞	∞
salicylate (*o*-)	$HO{\cdot}C_6H_4CO_2CH_3$	152.15	col. lq.	$1.182^{25/25}$	–8.3	222.2	0.07^{30}	∞	∞
stearate	$CH_3(CH_2)_{16}CO_2CH_3$	298.50	col. cr.		38–9	215^{15}	i.	s.	s.
toluate (*o*-)	$CH_3{\cdot}C_6H_4CO_2CH_3$	150.17	col. lq.	1.073^{15}	<–50	213	i.	∞	∞
(*m*-)	$CH_3{\cdot}C_6H_4CO_2CH_3$	150.17	col. lq.	1.066^{15}		215	i.		
(*p*-)	$CH_3{\cdot}C_6H_4CO_2CH_3$	150.17	cr.		33–4	217	i.	v. s.	v. s.
Methyl toluidine (*o*-)	$CH_3{\cdot}C_6H_4NHCH_3$	121.18	lq.	0.973^{15}		206–7	i.	∞	∞
(*m*-)	$CH_3{\cdot}C_6H_4NHCH_3$	121.18	lq.			206–7	i.	∞	∞
(*p*-)	$CH_3{\cdot}C_6H_4NHCH_3$	121.18	lq.	$0.935^{55/4}$		211^{761}	i.	∞	∞
valerate (*n*-)	$CH_3(CH_2)_3CO_2CH_3$	116.16	lq.	$0.895^{15/4}$	–91	127.3	v. sl. s.	∞	∞
(*i*-)	$(CH_3)_2CHCH_2CO_2CH_3$	116.16	col. lq.	$0.881^{20/4}$		116.7^{764}	v. sl. s.	∞	∞
vinyl ketone	$CH_3COCH{:}CH_2$	70.09	lq.	$0.836^{20/4}$		81	>85		
Methylal	$HCH(OCH_3)_2$	76.09	col. lq.	$0.866^{15/4}$	–104.8	42–3	33	∞	∞
Methylene-bis-(phenyl-4-isocyanate)	$(OCN{\cdot}C_6H_4)_2CH_2$	250.25	lq.	1.222^{30}		210–2^{13}	d.	d.	
bromide	CH_2Br_2	173.83	col. lq.	$2.495^{20/4}$	–52.8	98.5^{756}	1.17^{0}	∞	∞
chloride	CH_2Cl_2	84.93	col. lq.	$1.336^{20/4}$	–96.7	40–1	2^{20}	∞	∞
dianiline	$(C_6H_5NH)_2CH_2$	198.26	cr.		65	208–9 d.	i.	s.	s.
iodide	CH_2I_2	267.84	col. lq.	$3.325^{20/4}$	5.7	180 d.	1.4^{20}	∞	∞
Michler's hydrol (*p*-,*p'*-)	$[(CH_3)_2NC_6H_4]_2CHOH$	270.37	gn.		96–7		i.	s. h.	s.
ketone	$[(CH_3)_2NC_6H_4]_2CO$	268.35	lf./al.		174	>360 d.	i.	sl. s.	v. sl. s.
Morphine	$C_{17}H_{19}O_3N{\cdot}H_2O$	303.35	pr./al.	1.317	254 d.		0.02^{20}	sl. s.	s.
Mucic acid	$(\cdot CHOHCHOHCO_2H)_2$	210.14	pd.		206–14		0.33^{14}	i.	i.

TABLE 2-2 Physical Properties of Organic Compounds (*Continued*)

Name	Formula	Formula weight	Form and color	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Water	Alcohol	Ether
Mustard gas	$(ClCH_2{\cdot}CH_2)_2S$	159.08	oil	$1.275^{20/4}$	13–4	217	0.07^{25}	s.	s.
Myricyl alcohol	$C_{31}H_{63}OH$(?)	452.84	cr.	0.777^{95}	88		i.	v. sl. s.	v. s.
Myristic acid	$CH_3(CH_2)_{12}CO_2H$	228.37	col. lf.	$0.853^{70/4}$	57–8	250.5^{100}	i.	v. s.	v. s.
Myristyl alcohol	$CH_3(CH_2)_{12}CH_2OH$	214.39	cr.	$0.824^{38/4}$	38	167^{15}	<0.02	sl. s.	s.
Naphthalene	$C_{10}H_8$	128.17	pl./al.	$1.145^{20/4}$	80.2	217.9	0.003^{25}	9.5^{20}	v. s.
disulfonic acid (1-,5-)	$C_{10}H_6(SO_3H)_2$	288.30	lf.		d.		102^{20}	s.	i.
(1-,6-)	$C_{10}H_6(SO_3H)_2$	288.30	cr.		d. 125		164^{20}	s.	i.
sulfonic acid (α-)	$C_{10}H_7SO_3H{\cdot}2H_2O$	244.26	cr.		90		v. s.	v. s.	sl. s.
(β-)	$C_{10}H_7SO_3H{\cdot}H_2O$	226.25	cr.		125		77^{30}		
Naphthasultam (1-,8-)	$C_{10}H_7O_2NS$	205.23	nd.		177–8		s. h.	sl. s.	s.
disulfonate Na (1-,8-)	$C_{10}H_5O_8NS_3Na_2{\cdot}2H_2O$	445.35	cr.				v. s.		
(2-,4-)	$C_{10}H_4O_8NS_3Na_3{\cdot}8½H_2O$	584.43	lf.				v. s.	sl. s.	
Naphthoic acid (α-)	$C_{10}H_7CO_2H$	172.18	nd.		160–1	300	v. sl. s. h.	s. h.	s.
(β-)	$C_{10}H_7CO_2H$	172.18	mn.	$1.077^{100/4}$	184	>300	0.007^{25}	s.	s.
Naphthol (α-)	$C_{10}H_7OH$	144.17	mn.	1.224^{4}	96	278–80	sl. s. h.	v. s.	v. s.
(β-)	$C_{10}H_7OH$	144.17	mn.	1.217^{4}	122–3	285–6	0.074^{25}	v. s.	v. s.
sulfonic acid (α-)(1-,2-)	$HO{\cdot}C_{10}H_6SO_3H$	224.23	pl./aq.		>250		v. s. h.		i.
(β-)(2-,6-)	$HO{\cdot}C_{10}H_6SO_3H$	224.23	lf.		125		v. s.	v. s.	
Naphthyl acetate (α-)	$CH_3CO_2C_{10}H_7$	186.21	nd./al.		46–9		sl. s. h.	s.	s.
(β-)	$CH_3CO_2C_{10}H_7$	186.21	nd./al.		69–70		i.	s.	s.
amine (α-)	$C_{10}H_7NH_2$	143.19	rhb.	$1.123^{25/25}$	50	300.8	0.17 c.	v. s.	v. s.
(β-)	$C_{10}H_7NH_2$	143.19	lf./aq.	$1.061^{98/4}$	111–2	306.1	v. s. h.	s.	s.
amine hydrochloride (α-)	$C_{10}H_7NH_2{\cdot}HCl$	179.65	nd.			subl.	3.8^{20}	s.	s.
(β-)	$C_{10}H_7NH_2{\cdot}HCl$	179.65	lf.				v. s.	v. s.	
amine sulfonic acid (1-,4-)	$NH_2{\cdot}C_{10}H_6{\cdot}SO_3H$	223.25	nd.		d.		0.2^{100}	i.	i.
(1-,5-)	$NH_2{\cdot}C_{10}H_6{\cdot}SO_3H{\cdot}H_2O$	241.26	cr.				sl. s.		
(1-,7-)	$NH_2{\cdot}C_{10}H_6{\cdot}SO_3H{\cdot}H_2O$	241.26	cr.				0.46^{25}		
(1-,8-)	$NH_2{\cdot}C_{10}H_6{\cdot}SO_3H{\cdot}H_2O$	241.26	cr.				0.42^{100}		
(2-,5-)	$NH_2{\cdot}C_{10}H_6{\cdot}SO_3H$	223.25	cr.				0.08		
(2-,6-)	$NH_2{\cdot}C_{10}H_6{\cdot}.SO_3H{\cdot}H_2O$	241.26	cr.				0.38^{100}		
(2-,7-)	$NH_2{\cdot}C_{10}H_6{\cdot}SO_3H{\cdot}H_2O$	241.26	cr.				0.28^{100}		
isocyanate (α-)	$C_{10}H_7N{:}CO$	169.18	col. lq.	1.18		269–70	d.	s.	s.
Nicotine	$C_{10}H_{14}N_2$	162.23	oil	$1.009^{20/4}$	<–80	246^{730}	s.	∞	∞
Nicotinic acid (3-)	$C_5H_4NCO_2H$	123.11	nd./al.		235.2	subl.	s. h.	s. h.	v. sl. s.
(*i*-)(4-)	$C_5H_4NCO_2H$	123.11	nd./aq.		317	d.	s. h.	sl. s. h.	v. sl. s.
Nitro-acetanilide (*p*-)	$CH_3CONHC_6H_4NO_2$	180.16	rhb.		215–6		s. h.	s.	s.
-acetophenone (*m*-)	$CH_3COC_6H_4NO_2$	165.15	nd.		80–1	202	i.	s.	
-aminoanisole (4-,1-,2-)	$NO_2{\cdot}C_6H_3(OCH_3)NH_2$	168.15	red nd.	1.207^{156}	118		i.	s.	
(5-,1-,2-)	$NO_2{\cdot}C_6H_3(OCH_3)NH_2$	168.15	yel. nd.	1.211^{156}	139–40				
(3-,1-,4-)	$NO_2{\cdot}C_6H_3(OCH_3)NH_2$	168.15	red		123		sl. s.	s.	s.
-aminophenol (4-,2-,1-)	$NO_2{\cdot}C_6H_3(NH_2)OH$	154.12	or. pr.		142–3		sl. s. c.	v. s.	v. s.
-aniline (*o*-)	$NO_2{\cdot}C_6H_4NH_2$	138.12	yel. rhb.	1.442^{15}	71.5	284.1	s. h.	v. s.	v. s.
(*m*-)	$NO_2{\cdot}C_6H_4NH_2$	138.12	yel. rhb.	1.43	114	306.4	0.11^{20}	7.1^{20}	7.9^{20}
(*p*-)	$NO_2{\cdot}C_6H_4NH_2$	138.12	yel. mn.	1.437^{14}	146–7	331.7	0.08^{19}	5.8^{20}	6.1^{20}
-anisole (*o*-)	$CH_3OC_6H_4NO_2$	153.14	col. cr.	$1.254^{20/4}$	9.4	272–3	0.17^{30}	∞	∞
(*p*-)	$CH_3OC_6H_4NO_2$	153.14	pr./al.	1.233^{20}	54	274	0.06^{30}	v. s.	v. s.
-anthraquinone (α-)	$C_6H_4{:}(CO)_2{:}C_6H_3NO_2$	253.21	nd.		230	270^{7}	i.	sl. s.	v. sl. s.
-anthraquinone sulfonic acid (1-,5-)	$NO_2{\cdot}C_{14}H_6O_2{\cdot}SO_3H$	333.27	yel. cr.				s.	i.	i.
-benzal chloride (*m*-)	$NO_2{\cdot}C_6H_4{\cdot}CHCl_2$	206.03	mn.		65		i.	v. s. h.	v. s.
-benzaldehyde (*m*-)	$NO_2{\cdot}C_6H_4CHO$	151.12	nd./aq.		58	164^{23}	1.95^{112}	v. s. h.	v. s.
Nitro-benzene	$C_6H_5NO_2$	123.11	yel. lq.	$1.205^{18/4}$	5.7	210.9	0.19^{20}	v. s.	∞
-benzidine (2-)	$NH_2C_6H_4C_6H_3(NH_2)NO_2$	229.23	red nd.		143		sl. s. h.		
-benzoic acid (*o*-)	$NO_2{\cdot}C_6H_4{\cdot}CO_2H$	167.12	tri./aq.	$1.575^{4/4}$	147.5		0.65^{20}	28^{11}	22^{11}
(*m*-)	$NO_2{\cdot}C_6H_4{\cdot}CO_2H$	167.12	mn.	$1.494^{4/4}$	140–1		0.24^{165}	31^{12}	25^{10}
(*p*-)	$NO_2{\cdot}C_6H_4{\cdot}CO_2H$	167.12	yel. mn.	$1.550^{22/4}$	240–2	subl.	0.02^{15}	0.9^{10}	2.2^{18}
-benzyl alcohol (*m*-)	$NO_2{\cdot}C_6H_4{\cdot}CH_2OH$	153.14	cr.		27	$175–80^{3}$			
-benzyl bromide (*p*-)	$NO_2{\cdot}C_6H_4CH_2Br$	216.03	nd./al.		99–100		i.	2^{19}	v. s.
-chlorotoluene (1-,2-,6-)	$CH_3{\cdot}C_6H_3(NO_2)Cl$	171.58	cr.		37.5	238	i.		
-cresol (1-,3-,4-)	$CH_3{\cdot}C_6H_3(NO_2)OH$	153.14	yel.	$1.240^{89/4}$	32	125^{22}	v. sl. s.	v. s.	v. s.
-cymene (1-,2-,4-)	$CH_3{\cdot}C_6H_3(NO_2)CH(CH_3)_2$	179.22	oil	$1.067^{20/4}$		152^{15}	i.		
-dimethylaniline (*o*-)	$NO_2{\cdot}C_6N_4N(CH_3)_2$	166.18	yel. oil	$1.179^{20/4}$		$151–3^{80}$	v. sl. s.	v. s.	v. s.
(*m*-)	$NO_2{\cdot}C_6H_4N(CH_3)_2$	166.18	red mn.	1.313^{17}	60–1	280–5	i.	s.	s.
(*p*-)	$NO_2{\cdot}C_6H_4N(CH_3)_2$	166.18	yel. nd.		163–4		i.	s. h.	
-diphenyl (*o*-)	$C_6H_5{\cdot}C_6H_4NO_2$	199.21	rhb.	1.44	37	320	i.	s.	v. s.
(*p*-)	$C_6H_5{\cdot}C_6H_4NO_2$	199.21	nd./al.		113–4	340	i.	sl. s. c.	v. s.
-diphenylamine (*o*-)	$C_6H_5{\cdot}NH{\cdot}C_6H_4NO_2$	214.22	or. cr.		75–6				
-guanidine	$H_2NC(NH)NHNO_2$	104.07	nd./aq.		246–7		9^{100}	sl. s.	v. sl. s.

-naphthalene (α-)	$C_{10}H_7NO_2$	173.17	yel./al.	1.223^{62}	59–60	304	i.	s.	s.
(β-)	$C_{10}H_7NO_2$	173.17	col./al.		79	165^{15}	i.	v. s.	v. s.
-phenol (*o*-)	$NO_2{\cdot}C_6H_4{\cdot}OH$	139.11	yel. mn.	1.295^{45}	44–5	214.5	1.08^{100}	v. s.	v. s.
(*m*-)	$NO_2{\cdot}C_6H_4{\cdot}OH$	139.11	col. mn.	1.485^{20}	96–7	194^{70}	1.35^{20}	v. s.	s.
(*p*-)	$NO_2{\cdot}C_6H_4{\cdot}OH$	139.11	yel. pr.	1.479^{20}	113–4	subl.	1.6^{25}	v. s.	v. s.
-phenol sulfonic acid (1-,4-,2-)	$HO{\cdot}C_6H_3(NO_2)SO_3H{\cdot}3H_2O$	273.22	nd.		d. 110		v. s.	v. s.	sl. s.
(1-,2-,4-)	$HO{\cdot}C_6H_3(NO_2)SO_3H{\cdot}3H_2O$	273.22	nd./aq.		51.5		v. s.	v. s.	
-phthalic acid (3-)	$NO_2{\cdot}C_6H_3(CO_2H)_2$	211.13	yel./aq.		222		2.05^{25}	v. s. h.	sl. s.
(4-)	$NO_2{\cdot}C_6H_3(CO_2H)_2$	211.13	yel. cr.		164–5		v. s.	v. s.	s.
-toluene (*o*-)	$CH_3{\cdot}C_6H_4NO_2$	137.14	yel. lq.	$1.163^{20/4}$	–4.1	222.3	0.07^{80}	∞	∞
(*m*-)	$CH_3{\cdot}C_6H_4NO_2$	137.14	lq.	$1.160^{18/4}$	15–16	230–1	0.05^{80}	∞	∞
(*p*-)	$CH_3{\cdot}C_6H_4NO_2$	137.14	rhb.	$1.139^{55/55}$	51.9	237.7	0.04^{80}	8.6^{15}	80.8^{15}
-toluene sulfonic acid (1-,4-,2-)	$CH_3{\cdot}C_6H_3(NO_2)SO_3H{\cdot}2H_2O$	253.23	pl./aq.		130		47.7^{28}	v. s.	v. s.
-toluidine (4-,1-,2-)	$NO_2{\cdot}C_6H_3(CH_3)NH_2$	152.15	yel. mn.	1.365^{15}	105–7		v. sl. s.	s.	s.
(3-,1-,4-)	$NO_2{\cdot}C_6H_3(CH_3)NH_2$	152.15	red mn.	1.312^{17}	116–7		sl. s. h.	s.	
Nitron	$C_{20}H_{16}N_4$	312.37	yel. lf.		189–90 d.		i.	s. h.	v. sl. s.
Nitroso-dimethylaniline (*p*-)	$ON{\cdot}C_6H_4N(CH_3)_2$	150.18	gn. tri.		86–7		i.	s.	s.
-naphthol (β-)(1-)	$ON{\cdot}C_{10}H_6OH$	173.17	brn. pr.		109.5		0.1^{20}	2.4^{18}	
Nonadecane (*n*-)	$CH_3(CH_2)_{17}CH_3$	268.52	cr.	$0.777^{32/4}$	32	330	i.	sl. s.	s.
Nonane (*n*-)	$CH_3(CH_2)_7CH_3$	128.26	col. lq.	$0.718^{20/4}$	–53.7	150.5^{759}	i.	sl. s.	s.
Octadecane (*n*-)	$CH_3(CH_2)_{16}CH_3$	254.49	cr.	$0.775^{28/4}$	28	317	i.	sl. s.	s.
Octane (*n*-)	$CH_3(CH_2)_6CH_3$	114.23	col. lq.	$0.703^{20/4}$	–56.5	125.7	0.002^{16}	sl. s.	s.
(iso-)	$(CH_3)_3CCH_2CH(CH_3)_2$	114.23	col. lq.	$0.692^{20/4}$	–107.4	99.3^{760}	i.	sl. s.	s.
Octyl acetate (*n*-)	$CH_3CO_2CH_2(CH_2)_6CH_3$	172.26	col. lq.	$0.885^{0/4}$	–38.5	210	i.	s.	s.
(*sec*-)	$CH_3CO_2CH(CH_3)C_6H_{13}$	172.26	col. lq.	$0.863^{14/4}$		195	i.	s.	s.
alcohol (*n*-)	$CH_3(CH_2)_6CH_2OH$	130.23	col. lq.	$0.827^{20/4}$	–16	194–5	0.054^{25}	∞	∞
(*sec*-)	$CH_3(CH_2)_5CH(OH)CH_3$	130.23	col. lq.	$0.822^{20/4}$	–38.6	179–80	0.096^{25}	∞	∞
Octylene (*n*-)	$CH_3(CH_2)_5CH{:}CH_2$	112.21	lq.	$0.721^{18/4}$		126	i.	∞	∞
Oleic acid	$C_8H_{17}CH{:}CH(CH_2)_7CO_2H$	282.46	col. nd.	$0.854^{75/4}$	14	$285–6^{100}$	i.	∞	∞
Orcinol (1-,3-,5-)	$(HO)_2C_6H_3{\cdot}CH_3$	124.14	pr./bz.	1.290^{4}	107–8	287–90	v. s.	v. s.	v. s.
Oxalic acid	$HO_2C{\cdot}CO_2H{\cdot}2H_2O$	126.07	col. mn.	$1.653^{19/4}$	101.5	subl.	s.	s.	1.3
Palmitic acid	$CH_3(CH_2)_{14}CO_2H$	256.42	col. pl.	$0.849^{70/4}$	63–4	271.5^{100}	i.	9^{20}	s.
Pelargonic acid	$CH_3(CH_2)_7CO_2H$	158.24	col. oil	$0.906^{20/4}$	12.5	253–4	v. sl. s.	s.	s.
Penta-chloroethane	$CHCl_2{\cdot}CCl_3$	202.29	col. lq.	$1.671^{25/4}$	–22	162	0.05^{20}	∞	∞
-decane (*n*-)	$CH_3(CH_2)_{13}CH_3$	212.41	col. lq.	$0.770^{20/4}$	10	270.5	i.	v. s.	v. s.
-erythritol	$C(CH_2OH)_4$	136.15	cr.		262	276^{30}	5.6^{15}	v. sl. s.	i.
Pentandiol	$HOCH_2(CH_2)_3CH_2OH$	104.15	lq.	$0.994^{20/4}$		239.4	∞		
Pentane (*n*-)	$CH_3(CH_2)_3CH_3$	72.15	col. lq.	$0.630^{18/4}$	–129.7	36.3	0.036^{16}	∞	∞
(*i*-)	$(CH_3)_2CHCH_2CH_3$	72.15	col. lq.	0.621^{19}	–160.0	27.95	i.	∞	∞
(neo-)	$(CH_3)_2C(CH_3)_2$	72.15	col. lq.	$0.613^{20/4}$	–20	9.5	i.	s.	s.
Phenacetin	$C_2H_5OC_6H_4NHCOCH_3$	179.22	col. mn.		134–5	d.	0.7^{20}	40 h.	1.6^{25}
Phenanthrene	$<(C_6H_4CH)_2>$	178.23	pl./al.	1.179^{25}	99–100	340	i.	10 h.	v. s.
Phenetidine (*o*-)	$C_2H_5O{\cdot}C_6H_4{\cdot}NH_2$	137.18	oil		<–21	228–9	i.	s.	s.
(*p*-)	$C_2H_5O{\cdot}C_6H_4{\cdot}NH_2$	137.18	lq.	1.061^{15}	3–4	254–5	i.	s.	s.
Phenetole	$C_2H_5O{\cdot}C_6H_5$	122.16	col. lq.	$0.967^{20/4}$	–30.2	172	i.	∞	∞
Phenol	C_6H_5OH	94.11	col. nd.	$1.071^{25/4}$	42–3	181.4	8.2^{15}	∞	∞
-phthalein	$C_{20}H_{14}O_4$	318.32	col. rhb.	$1.299^{25/4}$	261–2		0.2^{20}	10^{25}	5.9 c.
-sulfonic acid (*o*-)	$HO{\cdot}C_6H_4SO_3H{\cdot}¾H_2O$	187.69	cr.		50 d.		v. s.	v. s.	
Phenyl acetaldehyde	$C_6H_5CH_2CHO$	120.15	lq.	1.025^{20}		193–4	v. sl. s.	∞	∞
acetic acid	$C_6H_5CH_2CO_2H$	136.15	lf.	$1.081^{80/4}$	76–7	265.5	1.66^{20}	v. s.	v. s.
-acetylene	$C_6H_5C{:}CH$	102.13	col. lq.	$0.930^{20/4}$	–43	142–3	i.	∞	∞
aniline (*o*-)	$C_6H_5{\cdot}C_6H_4{\cdot}NH_2$	169.22	cr.		45–6	299^{760}	v. sl. s.	s.	s.
(*p*-)	$C_6H_5{\cdot}C_6H_4{\cdot}NH_2$	169.22	lf.		50–2	302	s. h.	s.	s.
Phenyl-ethyl alcohol	$C_6H_5CH_2CH_2OH$	122.16	col. oil	$1.023^{18/4}$		$219–21^{750}$	1.6^{20}	s.	∞
-glycine	$C_6H_5NHCH_2CO_2H$	151.16	cr.		127		s.	s.	sl. s.
-hydrazine	$C_6H_5NH{\cdot}NH_2$	108.14	yel. oil	$1.097^{23/4}$	19.6	243.5	sl. s. h.	∞	∞
-hydrazine sulfonic acid (*p*-)	$H_2NNHC_6H_4SO_3H$	188.20	cr./al.		286		0.6^{12}	sl. s.	
isocyanate	$C_6H_5N{:}CO$	119.12	lq.	$1.096^{20/4}$		166^{769}	d.	d.	v. s.
-methylpyrazolone (3-)(*N*-)	$C_4H_5ON_2{\cdot}C_6H_5$	174.20	pr./aq.		128	191^{17}	1^{20}	v. s. h.	v. sl. s.
-mustard oil	$C_6H_5N{:}CS$	135.19	col. lq.	$1.138^{15/15}$	–21	219–20	i.	s.	s.
naphthalene (α-)	$C_{10}H_7{\cdot}C_6H_5$	204.27	waxy		45	336–7	i.	v. s.	v. s.
(β-)	$C_{10}H_7{\cdot}C_6H_5$	204.27	lf./al.		102.5	345–6	i.	sl. s.	sl. s.
naphthylamine (α-)	$C_{10}H_7NHC_6H_5$	219.28	pr./al.	1.17	62	335^{258}	0.08^{60}	s.	s.
(β-)	$C_{10}H_7NHC_6H_5$	219.28	rhb.	1.18	107–8	399.5	0.4^{60}	v. s. h.	v. s. h.
phenol (*o*-)	$C_6H_5{\cdot}C_6H_4OH$	170.21	nd.		56–7	275	i.	s.	s.
(*p*-)	$C_6H_5{\cdot}C_6H_4OH$	170.21	nd.		164–5	305–8	i.	s.	s.
propyl alcohol (γ-)	$C_6H_5(CH_2)_3OH$	136.19	oil	$1.008^{20/4}$	<–18	235–7	sl. s.	∞	∞
quinoline (2-)(α-)	$C_6H_5{\cdot}C_9H_6N$	205.25	nd.		86	363	sl. s.	s. h.	s.
(8-)(0-)	$C_6H_5{\cdot}C_9H_6N$	205.25	lq.			283^{187}	sl. s.	s.	s.
salicylate, salol	$HO{\cdot}C_6H_4CO_2C_6H_5$	214.22	rhb./al.	$1.250^{20/4}$	42–3	$172–3^{12}$	0.015^{25}	v. s.	s.
stearate	$CH_3(CH_2)_{16}CO_2C_6H_5$	360.57	cr.		52	267^{15}	i.		
urethane	$C_6H_5NHCO_2C_2H_5$	165.19	pl./al.	$1.106^{30/4}$	52–3	237–8	i. c.	s.	s.

TABLE 2-2 Physical Properties of Organic Compounds (*Continued*)

Name	Formula	Formula weight	Form and color	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Water	Alcohol	Ether
Phenylene-diamine (*o-*)	$C_6H_4(NH_2)_2$	108.14	lf./aq.		103–4	256–8	733^{81}	v. s.	v. s.
(*m-*)	$C_6H_4(NH_2)_2$	108.14	rhb.	$1.139^{15/15}$	62.8	284–7	35.1^{25}	v. s.	s.
(*p-*)	$C_6H_4(NH_2)_2$	108.14	mn.		140	267	669^{107}	s.	s.
Phloroglucinol (1-,3-,5-)	$C_6H_3(OH)_3{\cdot}2H_2O$	162.14	rhb.		117	subl.	1.13^{25}	v. s.	v. s.
Phorone	$[(CH_3)_2C{:}CH]_2CO$	138.21	yel. pr.	$0.885^{20/4}$	28	197.2^{743}	0.1^{50}	s.	s.
Phosgene	$OCCl_2$	98.92	gas	$1.392^{19/4}$	−104	8.2^{756}	v. sl. s.		
Phthalic acid (*o-*)	$C_6H_4(CO_2H)_2$	166.13	mn./aq.	$1.593^{20/4}$	208	d.	0.70^{25}	12^{18}	0.68^{15}
(*m-*)(iso-)	$C_6H_4(CO_2H)_2$	166.13	nd./aq.		330	subl.	0.2^{100}	s.	
anhydride (*o-*)	$C_6H_4{<}(CO)_2{>}O$	148.12	rhb.	1.527^{4}	130.8	284.5	v. sl. s.	s.	sl. s.
nitrile (*o-*)	$C_6H_4(CN)_2$	128.13	cr.		141		sl. s. c.		
Phthalide	$C_6H_4(CH_2)(CO){>}O$	134.13	nd./aq.	$1.164^{99/4}$	73(65)	290	v. sl. s.	s.	
Phthalimide (*o-*)	$C_6H_4{<}(CO)_2{>}NH$	147.13	cr./et.		238	subl.	0.04^{25}	5	s. h.
Picoline (α-)	$C_5H_4N{\cdot}CH_3$	93.13	col. lq.	$0.950^{15/4}$	−70	128.8	v. s.	∞	∞
(β-)	$C_5H_4N{\cdot}CH_3$	93.13	col. lq.	$0.961^{15/4}$		143.5	∞	∞	∞
(γ-)	$C_5H_4N{\cdot}CH_3$	93.13	lq.	$0.957^{15/4}$		143.1	∞	∞	∞
Picramic acid (1-,2-,4-,6-)	$HO{\cdot}C_6H_2(NH_2)(NO_2)_2$	199.12	red nd.		169		0.14^{22}	s.	sl. s.
Picric acid (2-,4-,6-)	$HO{\cdot}C_6H_2(NO_2)_3$	229.10	yel. rhb.	$1.763^{20/4}$	121.8	expl.	1.23^{20}	6^{20}	1^{13}
Picryl chloride (2-,4-,6-)	$ClC_6H_2(NO_2)_3$	247.55	yel. mn.	1.797^{20}	83	d.	0.018^{15}	4.8^{17}	7^{17}
Pinacol	$[(CH_3)_2C{\cdot}OH]_2$	118.17	col. nd.	0.967^{15}	43(38)	$171–2^{789}$	sl. s. c.	v. s.	v. s.
Pinacoline	$CH_3COC(CH_3)_3$	100.16	col. lq.	0.800^{16}	−52.5	106.2	2.5^{15}	s.	s.
Pinene (α-)(*dl-*)	$C_{10}H_{16}$	136.23	col. lq.	$0.878^{20/4}$	−55	154–6	v. sl. s.	s.	∞
hydrochloride	$C_{10}H_{17}Cl$	172.69	lf.		131–2	207–8	i.	33	s.
Pinol (*dl-*)	$C_{10}H_{16}O$	152.23	lq.	$0.953^{20/20}$		183–4		s.	s.
Piperidine	$CH_2{<}(CH_2CH_2)_2{>}NH$	85.15	lq.	$0.860^{20/4}$	−9	106	∞	∞	
carboxylic acid (α-)(*dl-*)	$HO_2C{\cdot}CH{<}(CH_2CH_2)_2{>}NH$	129.16	cr.		264		s.		
Piperidinium pentamethylene dithiocarbamate	$(CH_2)_5CS_2H{\cdot}HN(CH_2)_5$	232.43	cr.	1.13	175		6^{28}		
Propane	$CH_3CH_2CH_3$	44.10	gas	$0.585^{-45/4}$	−187.1	−42.2	6.5^{18} cc.	s.	v. s.
Propionic acid	$CH_3CH_2CO_2H$	74.08	col. lq.	$0.992^{20/4}$	−22	141.1	∞	∞	∞
aldehyde	CH_3CH_2CHO	58.08	col. lq.	$0.807^{20/4}$	−81	49.5^{740}	20^{20}	∞	∞
anhydride	$(CH_3CH_2CO)_2O$	130.14	col. lq.	$1.012^{20/4}$	−45	168.8^{780}	d.	d.	
Propyl acetate (*n-*)	$CH_3CO_2CH_2CH_2CH_3$	102.13	col. lq.	$0.886^{20/4}$	−92.5	101.6	1.6^{16}	∞	∞
(*i-*)	$CH_3CO_2CH(CH_3)_2$	102.13	col. lq.	$0.874^{20/20}$	−73.4	88.4	3^{20}	∞	∞
alcohol (*n-*)	$CH_3CH_2CH_2OH$	60.10	col. lq.	$0.804^{20/4}$	−127	97.8	∞	∞	∞
(*i-*)	$(CH_3)_2CHOH$	60.10	col. lq.	$0.789^{20/4}$	−85.8	82.5	∞	∞	∞
amine (*n-*)	$CH_3CH_2CH_2NH_2$	59.11	col. lq.	$0.718^{20/20}$	−83	$49–50^{761}$	∞	∞	∞
(*i-*)	$(CH_3)_2CHNH_2$	59.11	col. lq.	$0.694^{15/4}$	−101	33–4	∞	∞	∞
aniline (*n-*)	$C_6H_5NHCH_2CH_2CH_3$	135.21	lq.	0.949^{18}		222	i.	v. s.	v. s.
benzoate (*n-*)	$C_6H_5CO_2CH_2CH_2CH_3$	164.20	col. lq.	$1.021^{25/25}$	−51.6	231	i.	s.	s.
(*i-*)	$C_6H_5CO_2CH(CH_3)_2$	164.20	col. lq.	$1.010^{25/25}$		218.5	i.	s.	s.
bromide (*n-*)	$CH_3CH_2CH_2Br$	122.99	col. lq.	$1.353^{20/4}$	−109.9	70.8	0.25^{20}	∞	∞
(*i-*)	$(CH_3)_2CHBr$	122.99	col. lq.	$1.310^{20/4}$	−89	60	0.32^{20}	∞	∞
n-butyrate (*n-*)	$C_2H_5CH_2CO_2CH_2C_2H_5$	130.18	col. lq.	0.879^{15}	−95.2	142.7	0.17^{17}	∞	∞
i-butyrate (*n-*)	$(CH_3)_2CHCO_2CH_2C_2H_5$	130.18	col. lq.	$0.884^{0/4}$		134–5	v. sl. s.		
n-butyrate (*i-*)	$C_2H_5CH_2CO_2CH(CH_3)_2$	130.18	col. lq.	0.865^{18}		128	v. sl. s.		
i-butyrate (*i-*)	$(CH_3)_2CHCO_2CH(CH_3)_2$	130.18	col. lq.	$0.869^{0/4}$		120.8	v. sl. s.		
chloride (*n-*)	$CH_3CH_2CH_2Cl$	78.54	col. lq.	$0.890^{20/4}$	−122.8	46.4	0.27^{20}	∞	∞
(*i-*)	$(CH_3)_2CHCl$	78.54	col. lq.	0.859^{20}	−117	36.5	0.31^{20}	∞	∞
Propyl formate (*n-*)	$HCO_2CH_2CH_2CH_3$	88.11	col. lq.	$0.901^{20/4}$	−92.9	81.3	12.2^{22}	∞	∞
(*i-*)	$HCO_2CH(CH_3)_2$	88.11	col. lq.	$0.873^{20/4}$		$68–71^{751}$	2.1^{22}	∞	∞
furoate (*n-*)	$C_4H_3O{\cdot}CO_2C_3H_7$	154.16	col. lq.	$1.075^{26/4}$		211	v. sl. s.	s.	∞
lactate (*n-*)	$CH_3CH(OH)CO_2CH_2C_2H_5$	132.16	col. lq.			$122–3^{150}$	s.	s.	s.
(*i-*)	$CH_3CH(OH)CO_2CH(CH_3)_2$	132.16	col. lq.			167.5	s.	s.	s.
mercaptan (*n-*)	$CH_3CH_2CH_2SH$	76.16	lq.	$0.836^{25/4}$	−112	67-8	v. sl. s.	s.	s.
(*i-*)	$(CH_3)_2CHSH$	76.16	lq.	$0.809^{25/4}$	−130.7	58-60	v. sl. s.	∞	∞
propionate (*n-*)	$C_2H_5CO_2CH_2C_2H_5$	116.16	col. lq.	$0.883^{20/4}$	−76	122-3	0.56^{25}	∞	∞
(*i-*)	$C_2H_5CO_2CH(CH_3)_2$	116.16	col. lq.	0.893^{0}		$109–11^{750}$	0.6^{25}	∞	∞
thiocyanate (*i-*)	$(CH_3)_2CH{\cdot}CNS$	101.17	lq.	0.963^{20}		$152–3^{754}$	i.	∞	∞
n-valerate (*n-*)	$CH_3(CH_2)_3CO_2CH_2C_2H_5$	144.21	lq.	0.874^{15}	−70.7	67.5	i.	∞	∞
i-valerate (*n-*)	$(CH_3)_2CHCH_2CO_2C_3H_7$	144.21	col. lq.	$0.863^{20/4}$		155.9	i.	∞	∞
i-valerate (*i-*)	$(CH_3)_2CHCH_2CO_2C_3H_7$	144.21	col. lq.	0.854^{17}		142^{756}			
Propylene	$CH_3CH{:}CH_2$	42.08	gas	$0.609^{-47/4}$	−185	-48^{749}	44.6 cc.	1200 cc.	
bromide	$CH_3CHBrCH_2Br$	201.89	col. lq.	$1.933^{20/4}$	−55.5	141.6	0.25^{20}	s.	v. s.
chlorohydrin	$CH_3CHClCH_2OH$	94.54	col. lq.	1.103^{20}		133-4	s.	s.	s.
chloride	$CH_3CHClCH_2Cl$	112.99	col. lq.	$1.159^{20/20}$	<−70	96.8	0.27^{20}	v. s.	v. s.
glycol	$CH_3CH(OH)CH_2OH$	76.09	col. oil	$1.040^{19.4}$		188-9	∞	∞	8
oxide	$CH_3(CHCH_2)O$	58.08	col. lq.	$0.831^{20/20}$		35	33^{20}	∞	∞
Protocatechuic acid (3-,4-)	$(HO)_2C_6H_3CO_2H{\cdot}H_2O$	172.14	nd./aq.	$1.542^{4/4}$	199 d.		1.82^{14}	v. s.	s.

Pulegol (iso-)(*d*-)	$C_{10}H_{17}OH$	154.25	col. lq.	$0.911^{20/4}$		86-9[10]	v. sl. s.		
Pulegone	$C_{10}H_{16}O$	152.23	col. lq.	$0.932^{20/20}$		224[754]	i.	∞	∞
Pyrazole	——NH·N:CH·CH:CH——	68.08	nd./et.		70	186-8	s.	s.	s.
Pyrazoline	——NH·N:CH·CH_2CH_2——	70.09	lq.			144	∞	∞	sl. s.
Pyrazolone	——NH·CO·CH_2CH:N——	84.08	nd.		165	subl. d.	s.	v. s.	v. sl. s.
Pyrene	$C_{16}H_{10}$	202.25	yel. pr.	$1.277^{0/4}$	149-50	>360	i.	3 h.	v. s.
Pyridazine	N_2 < $(CHCH)_2$ >	80.09	lq.	$1.107^{20/4}$	–8	208	∞	s.	s.
Pyridine	CH < $(CHCH)_2$ > N	79.10	col. lq.	$0.982^{20/4}$	–42	115-6	∞	∞	s.
Pyrocatechol (*o*-)	$C_6H_4(OH)_2$	110.11	nd./aq.	1.344^{4}	104-5	240-5	45.1^{20}	v. s.	v. s.
Pyrogallol (1-,2-,3-)	$C_6H_3(OH)_3$	126.11	nd.	1.453^{4}	133-4	309	40^{13}	s.	s.
Pyrone	CO < $(CHCH)_2$ > O	96.08	cr.	$1.190^{40.3}$	32.5	215-7	v. sl. s.	s.	v. s.
Pyrrole	< $(CH:CH)_2$ > NH	67.09	lq.	$0.948^{20/4}$		131	i.	s.	s.
Pyrrolidine	< $(CH_2·CH_2)_2$ > NH	71.12	lq.	$0.852^{22.5}$		87-8	∞	∞	∞
Pyrroline	< (CH·CH_2)$_2$ > NH	69.11	lq.	$0.910^{20/4}$		90-1	v. s.	∞	∞
Pyruvic acid	CH_3COCO_2H	88.06	col. lq.	$1.267^{20/4}$	13.6	165	∞	∞	∞
Quercitrin	$C_{21}H_{20}O_{11}·2H_2O$	484.41	yel. nd.		182-5		0.04^{20}	s.	sl. s.
Quinaldine (p*y*-2)	$CH_3·C_9H_6N$	143.19	lq.	$1.059^{20/4}$	–1	244-5[750]	v. sl. s.		s.
Quinoline	C_9H_7N	129.16	lq.	1.095^{20}	–15	237.1[747]	6	∞	∞
(iso-)	C_9H_7N	129.16	pl.	$1.099^{21/4}$	24.6	240.5[763]	sl. s.		s.
-diol (1-,3-)	——C_6H_4CH:C(OH)N:C(OH)——	161.16	cr.		237		v. sl. s.		
Quinone (*p*-)	CO < $(CHCH)_2$ > CO	108.09	yel. mn.	$1.318^{20/4}$	115.7	subl.	sl. s. h.	s.	s.
R-acid Ca salt (2-)(3-,6-)	$HOC_{10}H_5(SO_3)_2Ca$	342.36	cr.				30.6^{25}		
K salt	$HOC_{10}H_5(SO_3K)_2$	380.48	cr.				29.5^{25}		
Na salt	$HOC_{10}H_5(SO_3Na)_2$	348.26	cr.				25.2^{25}		
Raffinose	$C_{18}H_{32}O_{16}·5H_2O$	594.51	cr./aq.	1.465^{0}	119	d. 130	14.3^{20}	0.1^{20}	
Resorcinol (*m*-)	$C_6H_4(OH)_2$	110.11	col. rhb.	1.272^{15}	110.7	276.5	147^{12}	v. s.	v. s.
Retene	$C_{18}H_{18}$	234.34	lf./al.	1.13^{16}	98-9	390-4	i.	69 h.	v. s. h.
Rhamnose (β-)	$CH_3(CHOH)_4CHO·H_2O$	182.17	col. mn.	$1.471^{20/4}$	126		60.8^{21}		i.
Ricinoleic acid	$C_{17}H_{32}(OH)CO_2H$	298.46	lq.	0.954^{16}	4-5	226-8[10]	i.	∞	∞
Rosaniline	$C_{20}H_{21}ON_3$	319.40	col. nd.		186 d.		v. sl. s.	sl. s.	i.
Rosolic acid	$C_{20}H_{16}O_3$	304.34	red lf.		308-10 d.		0.12^{25}	v. s. h.	sl. s.
Saccharin	$C_6H_4(CO)(SO_2)$ > NH	183.18	mn.		225-8	subl.	0.4^{25}	3.1 c.	1.05 c.
Safrole (1-,3-,4-)	CH_2:CHCH$_2$·C_6H_3:O_2CH_2	162.19	col. mn.	$1.100^{20/4}$	11.2	233-4	i.	s.	∞
(iso-)(1-,3-,4-)	CH_3·CH:CH·C_6H_3:O_2CH_2	162.19	col. lq.	$1.122^{20/4}$	6-7	252-3	i.	∞	∞
Salicylic acid (*o*-)	HO·C_6H_4·CO_2H	138.12	mn.	$1.443^{20/4}$	159	211[20]	0.2^{23}	49^{15}	51^{15}
aldehyde (*o*-)	HO·C_6H_4·CHO	122.12	col. oil	$1.153^{25/4}$	-7	196.5	1.7^{96}	∞	∞
Saligenin	HO·C_6H_4·CH_2OH	124.14	rhb./aq.	1.161^{25}	86-7	subl.	6.6^{15}	v. s.	v. s.
Schaeffer's salt, Ca	$(HOC_{10}H_6SO_3)_2Ca·5H_2O$	576.60	cr.				4.76^{20}		
K	$HOC_{10}H_6SO_3K$	262.32	cr.				3.46^{25}		
Na	$HOC_{10}H_6SO_3Na$	246.21	cr.				6.29^{25}		
Semicarbazide	$NH_2·CO·NH·NH_2$	75.07	pr./al.		96		v. s.	v. s.	i.
hydrochloride	$NH_2·CO·NH·NH_3Cl$	111.53	pr.		173 d.		v. s.	sl. s.	i.
Skatole (3-)	$CH_3·C_8H_6N$	131.17	lf.		95	265-6[755]	0.05 c.	s.	s.
Sodium methylate	CH_3ONa	54.02	pd.		d. 300		d.		
Sorbitol	$[CH_2OH(CHOH)_2]_2$	182.17	cr.		110-2		v. s.	v. s. h.	
Sorbose (*d*- or *l*-)	$C_6H_{12}O_6$	180.16	rhb.	1.654^{15}	165		55^{17}	sl. s.	
Starch	$(C_6H_{10}O_5)x$	162.14	amor.	1.50^{21}	d.		i.	i.	i.
Stearic acid	$CH_3(CH_2)_{16}CO_2H$	284.48	mn.	$0.847^{69.3}$	70-1	291[110]	0.03^{25}	2^{20}	6[g]
amide	$CH_3(CH_2)_{16}CONH_2$	283.49	col. cr.		108-9	251[12]	i.	s. h.	s. h:
Styrene	$C_6H_5CH:CH_2$	104.15	col. lq.	$0.903^{20/4}$	–31	145-6	v. sl. s.	∞	∞
Suberic acid	$HO_2C(CH_2)_6CO_2H$	174.19	nd./aq.	$1.266^{25/4}$	140-4	279[100]	0.14^{16}	s.	0.8^{15}
Succinic acid	$HO_2C(CH_2)_2CO_2H$	118.09	col. mn.	$1.572^{25/4}$	189-90	235 d.	6.8^{20}	9.9^{15}	1.2^{15}
Sucrose	$C_{12}H_{22}O_{11}$	342.30	col. mn.	1.588^{15}	170-86 d.		179^{0}	0.9	i.
Sulfanilic acid (*p*-)	$H_2N·C_6H_4·SO_3H$	173.19	col. cr.		d. > 280		0.8^{10}	v. sl. s.	v. sl. s.
Sylvestrene (*d*-)	$C_{10}H_{16}$	136.23	lq.	$0.863^{20/4}$		176-7			
Tartaric acid (meso-)	$(CHOHCO_2H)_2$	150.09	cr.	1.737	159-60		120^{15}		
(racemic)	$(CHOHCO_2H)_2·H_2O$	168.10	tri.	$1.697^{20/4}$	205-6		20.6^{20}	2^{0}	0.09
(*d*- or *l*-)	$(CHOHCO_2H)_2$	150.09	mn.	$1.760^{20/4}$	168-70	d.	139^{20}	25^{15}	0.4^{15}
Tartronic acid	$CH(OH)(CO_2H)_2·½H_2O$	129.07	pr./aq.		d. 155-8	subl.	v. s.	v. s.	i.
Terephthalic acid (*p*-)	$C_6H_4(CO_2H)_2$	166.13	cr.	1.510	subl.		0.001 c.	sl. s. h.	i.
Terpin hydrate (*cis*-)	$C_{10}H_{20}O_2·H_2O$	190.28	rhb.		117	d.	0.4^{15}	10^{15}	1^{15}
Terpineol (α-)(*d*- or *l*-)	$C_{10}H_{18}O$	154.25	col. cr.	0.935^{15}	38-40	219-21	i.	v. s.	v. s.
(*dl*-)	$C_{10}H_{18}O$	154.25	col. cr.	$0.935^{20/20}$	35	218-9[752]	i.	v. s.	v. s.
Terpinyl acetate (α-)(*dl*-)	$CH_3CO_2·C_{10}H_{17}$	196.29	lq.	$0.966^{20/4}$	< –50	220 d.	i.	20	
Tetrabromo-ethane (sym)	$Br_2CH·CHBr_2$	345.65	col. lq.	$2.964^{20/4}$	–1.0	151[54]	i.	∞	∞
(uns)	$Br_3C·CH_2Br$	345.65	col. lq.	$2.875^{20/4}$	0	104[13]		s.	
Tetrachloro-ethane (sym)	$Cl_2CH·CHCl_2$	167.85	col. lq.	$1.600^{20/4}$	–36	146.3	0.29^{20}	∞	∞
(uns)	$Cl_3C·CH_2Cl$	167.85	lq.	$1.588^{20/4}$		129-30	i.	∞	∞
-ethylene	$Cl_2C:CCl_2$	165.83	col. lq.	$1.624^{15/4}$	–19	120.8	0.02^{20}	∞	∞
Tetracosane (*n*-)	$CH_3(CH_2)_{22}CH_3$	338.65	cr.	$0.779^{51/4}$	51.1	324			s.
Tetradecane (*n*-)	$CH_3(CH_2)_{12}CH_3$	198.39	col. lq.	$0.765^{20/4}$	5.5	252.5	i.	v. s.	v. s.
Tetraethyl-thiuram disulfide	$[(C_2H_5)_2NCS]_2S_2$	296.54	cr.	1.17	70		i.		

TABLE 2-2 Physical Properties of Organic Compounds (*Concluded*)

Name	Formula	Formula weight	Form and color	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Water	Alcohol	Ether
Tetrafluoro-ethylene	$F_2C{:}CF_2$	100.02	gas	1.58^{-78}	−142.5	−76.3	0.01^{30}		
Tetrahydro-furan	$—CH_2(CH_2)_2CH_2{\cdot}O—$	72.11	col. lq.	$0.888^{21/4}$	−65	65-6	s.	s.	s.
-furfuryl alcohol	$C_4H_7O{\cdot}CH_2OH$	102.13	col. lq.	$1.050^{20/4}$		177-8^{743}	∞	∞	∞
-pyran	$—CH_2(CH_2)_3CH_3{\cdot}O—$	86.13	lq.	$0.881^{20/4}$		88	s.		
Tetralin	$—C_6H_4CH_2(CH_2)_2CH_2—$	132.20	col. lq.	$0.973^{18/4}$	−31	206^{764}	i.	s.	s.
Tetramethyl-thiuram disulfide	$[(CH_3)_2NCS]_2S_2$	240.43	cr.	1.29	155-6		i.		
Tetryl (2-,4-,6-)	$(NO_2)_3C_6H_2{\cdot}N(CH_3)NO_2$	287.14	yel. mn.	1.57^{19}	130.5	expl.	i.	s. h.	s.
Theobromine	$C_7H_8O_2N_4$	180.16	rhb.		330		0.06^{15}	0.06 c.	0.03 h.
Thio-acetic acid	$CH_3{\cdot}CO{\cdot}SH$	76.12	yel. lq.	1.074^{10}	< −17	93	s.	∞	∞
-aniline (4-, 4′-)	$(NH_2{\cdot}C_6H_4)_2S$	216.30	nd./aq.		108		sl. s. h.	s.	s.
-carbanilide	$(C_6H_5{\cdot}NH)_2CS$	228.31	rhb./al.	1.3^{24}	154	d.	i.	v. s.	v. s.
-naphthol (β-)	$C_{10}H_7{\cdot}SH$	160.24	cr./al.		81	286-8	v. sl. s.	v. s.	v. s.
-phenol	$C_6H_5{\cdot}SH$	110.18	col. lq.	$1.074^{23/4}$		168-9	v. sl. s.	v. s.	∞
-salicylic acid (*o*-)	$HS{\cdot}C_6H_4{\cdot}CO_2H$	154.19	yel. nd.		164	subl.	sl. s. h.	s.	
-urea	$NH_2{\cdot}CS{\cdot}NH_2$	76.12	rhb./al.	$1.405^{20/4}$	180-2	d.	9.2^{13}	s.	sl. s.
Thiophene	$<(CH{:}CH)_2>S$	84.14	col. lq.	$1.070^{15/4}$	−30	84	i.	s.	
Thymol (5-,2-,1-)	$(CH_3)(C_3H_7)C_6H_3OH$	150.22	cr.	$0.972^{25/25}$	51.5	232^{752}	0.09^{19}	v. s.	v. s.
Tolidine (0-)(3-,3′-,4-,4′-)	$[CH_3(NH_2)C_6H_3]_2$	212.29	lf.		128-9		v. sl. s.	s.	s.
Toluene	$C_6H_5{\cdot}CH_3$	92.14	col. lq.	$0.866^{20/4}$	−95	110.8	0.05^{16}	s.	∞
sulfonic acid (*o*-)	$CH_3{\cdot}C_6H_4SO_3H{\cdot}2H_2O$	208.23	cr.		d.	128.8^{0}	v. s.	s.	
(*p*-)	$CH_3{\cdot}C_6H_4SO_3H{\cdot}H_2O$	190.22	mn.		104-5	$146\text{-}7^{0}$	v. s.	s.	
sulfonic amide (*p*-)	$CH_3{\cdot}C_6H_4SO_2NH_2$	171.22	mn.		137		0.2^{9}	7.4^{5}	
sulfonic chloride (*p*-)	$CH_3{\cdot}C_6H_4{\cdot}SO_2Cl$	190.65	tri.		69	134.5^{10}	i.	s.	s.
Toluic acid (*o*-)	$CH_3{\cdot}C_6H_4{\cdot}CO_2H$	136.15	cr./aq.	$1.062^{115/4}$	104-5	259^{751}	2.17^{100}	v. s.	
(*m*-)	$CH_3{\cdot}C_6H_4{\cdot}CO_2H$	136.15	pr./aq.	$1.054^{112/4}$	110-1	263	1.6^{100}	v. s.	v. s.
(*p*-)	$CH_3{\cdot}C_6H_4{\cdot}CO_2H$	136.15	cr./aq.		179-80	274-5	1.3^{100}	v. s.	v. s.
Toluidine (*o*-)	$CH_3{\cdot}C_6H_4{\cdot}NH_2$	107.15	col. lq.	$0.999^{20/4}$	−16.3	199.7	1.5^{25}	∞	∞
(*m*-)	$CH_3{\cdot}C_6H_4{\cdot}NH_2$	107.15	col. lq.	$0.989^{20/4}$	−31.5	203.3	sl. s.	∞	∞
(*p*-)	$CH_3{\cdot}C_6H_4{\cdot}NH_2$	107.15	cr.	$1.046^{20/4}$	44-5	200.3	0.74^{21}	v. s.	v. s.
hydrochloride (*o*-)	$CH_3{\cdot}C_6H_4{\cdot}NH_3Cl$	143.61	mn. pr.		218-20	242	s.	sl. s.	
sulfonic acid (1-,2-,3-)	$CH_3(NH_2)C_6H_3SO_3H$	187.22	cr.				0.97^{11}		
Toluylenediamine (1-,2-,4-)	$CH_3{\cdot}C_6H_3(NH_2)_2$	122.17	rhb.		99	283-5	s. h.	s.	s.
Tolylene diisocyanate (1-,2-,4-)	$CH_3{\cdot}C_6H_3(NCO)_2$	174.16	lq.	1.23^{28}		134.5^{20}	d.	d.	
Trehalose	$C_{12}H_{22}O_{11}{\cdot}2H_2O$	378.33	rhb./al.		97		s. h.	sl. s. h.	i.
Triamylamine (*n*-)	$[CH_3(CH_2)_3CH_2]_3N$	227.43	lq.			240-5	i.		
(*i*-)	$[(CH_3)_2CH(CH_2)_2]_3N$	227.43	col. lq.	$0.786^{20/4}$		235	i.		
Tributyl-amine (*n*-)	$[CH_3(CH_2)_2CH_2]_3N$	185.35	col. lq.	$0.778^{20/20}$		216.5^{761}	i.	s.	∞
phosphite	$[CH_3(CH_2)_3O]_3P$	250.31	lq.	$0.925^{20/4}$		122-3^{12}	i.		
Trichloro-acetic acid	$Cl_3C{\cdot}CO_2H$	163.39	cr.	$1.617^{46/15}$	58	195.5^{754}	120^{25}	s.	s.
-benzene (*s*-)(1-,3-,5-)	$C_6H_3Cl_3$	181.45	nd.		63.5	208.5^{764}	i.	sl. s.	
-ethane (1-,1-,1-)	$Cl_3C{\cdot}CH_3$	133.40	lq.	$1.325^{26/4}$		74.1	i.	∞	∞
-ethylene	$Cl_2C{:}CHCl$	131.39	col. lq.	$1.466^{20/20}$	−73	87.2	0.1^{25}	∞	∞
-phenol	$Cl_3C_6H_2OH$	197.45	nd.	$1.490^{75/4}$	68-9	246	0.09^{25}	v. s.	v. s.
Tricosane (*n*-)	$CH_3(CH_2)_{21}CH_3$	324.63	lf.	$0.779^{48/4}$	47.7	234^{15}	i.		
Tricresyl phosphate (*o*-)	$OP(OC_6H_4CH_3)_3$	368.36	lq.				i.		
Tridecane (*n*-)	$CH_3(CH_2)_{11}CH_3$	184.36	col. lq.	$0.757^{20/4}$	−6.2	234	i.	v. s.	v. s.
Triethanol amine	$(HOCH_2CH_2)_3N$	149.19	col. lq.	$1.126^{20/20}$	20-1	$277\text{-}9^{150}$	∞	∞	sl. s.
Triethyl-amine	$(CH_3CH_2)_3N$	101.19	col. oil	$0.729^{20/20}$	−114.8	89.4	$\infty > 19^{0}$	∞	∞
-benzene (1-,3-,5-)	$(C_2H_5)_3C_6H_3$	162.27	lq.	$0.861^{20/4}$		215	i.	s.	s.
(1-,2-,4-)	$(C_2H_5)_3C_6H_3$	162.27	lq.	$0.882^{17/4}$		$217\text{-}8^{755}$	i.	s.	s.
borate	$B(OCH_2CH_3)_3$	145.99	lq.	$0.864^{20/20}$		120	d.		
citrate	$HOC_3H_4(CO_2C_2H_5)_3$	276.28	oil	$1.137^{20/4}$		294	i.	∞	∞
Triethylene glycol	$(\cdot CH_2OCH_2CH_2OH)_2$	150.17	col. lq.	$1.125^{20/20}$	−5	290	∞	∞	v. sl. s.
Trifluoro-chloromethane	CF_3Cl	104.46	gas	1.726^{-130}	−182	−80			
-chloroethylene	$F_2C{:}CFCl$	116.47	gas		−157.5	−27.9	d.		
-trichloroethane	$Cl_2CF{\cdot}CClF_2$	187.38	lq.	$1.576^{20/4}$	−35	47.6	i.	∞	∞
Trimethoxybutane (1-,3-,3-)	$CH_2(OCH_3)CH_2C(OCH_3)_2CH_3$	148.20	lq.	0.932		$63\text{-}5^{25}$	d.		
Trimethylamine	$(CH_3)_3N$	59.11	gas	0.662^{-5}	−124	3.5	41^{19}	s.	s.
Trimethylene bromide	$BrCH_2CH_2CH_2Br$	201.89	lq.	$1.987^{15/4}$	−34.4	167.5	0.17^{30}	s.	s.
chloride	$ClCH_2CH_2CH_2Cl$	112.99	lq.	1.201^{15}		123-5	0.27^{25}	s.	s.
glycol	$HOCH_2CH_2CH_2OH$	76.09	oil	$1.060^{20/4}$		214	∞	∞	
Trinitro-benzene (1-,3-,5-)	$C_6H_3(NO_2)_3$	213.10	col. rhb.	$1.688^{20/4}$	121	d.	0.03^{15}	1.9^{18}	1.5^{18}
-benzoic acid (2-,4-,6-)	$(NO_2)_3C_6H_2CO_2H$	257.11	rhb./aq.		210-20 d.		2.05^{24}		
-tert-butylxylene	$(NO_2)_3C_6(CH_3)_2C_4H_9$	297.26	nd./al.		110		i.	sl. s.	s.
-naphthalene (α-)(1-,3-,5-)	$C_{10}H_5(NO_2)_3$	263.16	rhb.		122-3		i.	s.	
(β-)(1-,3-,8-)	$C_{10}H_5(NO_2)_3$	263.16	cr./al.		218-9		0.02^{100}	0.05^{23}	0.13^{15}
(γ-)(1-,4-,5-)	$C_{10}H_5(NO_2)_3$	263.16	yel. cr.		148-9		i.	0.11^{19}	0.4^{19}

-phenol (2-,3-,6-)	$(NO_2)_3C_6H_2OH$	229.10	nd.		117-8		s. h.	v. s.	v. s.
-toluene (β-)(2-,3-,4-)	$CH_3C_6H_2(NO_2)_3$	227.13	cr.	$1.620^{20/4}$	112	expl.	i.	sl. s. c.	s.
(γ-)(2-,4-,5-)	$CH_3C_6H_2(NO_2)_3$	227.13	yel. pl.	$1.620^{20/4}$	104	expl.	i.	s. h.	v. s.
(α-)(2-,4-,6-)	$CH_3C_6H_3(NO_2)_3$	227.13	cr./al.	1.654	80.8	expl.	0.01^{20}	1.5^{22}	5^{33}
Trional	$(C_2H_5SO_2C_2H_4)_2$	242.36	pl./al.	$1.199^{85/4}$	76	d.	0.3^{15}	5^{0}	6.6^{15}
Triphenyl-arsine	$(C_6H_5)_3As$	306.23	pl.	1.306	59-60	>360	i.	s.	v. s.
carbinol	$(C_6H_5)_3COH$	260.33	cr.	$1.188^{20/4}$	162.5	>360	i.	v. s.	v. s.
guanidine (α-)	$C_6H_5N{:}C(NHC_6H_5)_2$	287.36	rhb./al.	1.13	144-5	d.	i.	4^{0}	
methane	$(C_6H_5)_3CH$	244.33	cr.	$1.014^{99/4}$	93.4	359^{754}	i.	v. s. h.	v. s.
methyl	$(C_6H_5)_3C\ldots$	243.32	col. cr.		145-7	d.	i.	sl. s. h.	
phosphate	$OP(OC_6H_5)_3$	326.28	pr./al.	$1.206^{58/4}$	49-50	245^{11}	i.	155^{25}	v. s.
Tripropylamine (*n*-)	$(CH_3CH_2CH_2)_3N$	143.27	col. lq.	$0.757^{20/4}$	–93.5	156.5	v. sl. s.	∞	∞
Undecane (*n*-)	$CH_3(CH_2)_9CH_3$	156.31	col. lq.	$0.741^{20/4}$	–25.6	194.5	i.	∞	∞
Urea	$H_2N{\cdot}CO{\cdot}NH_2$	60.06	col. pr.	$1.335^{30/4}$	132.7	d.	100^{17}	20^{20}	sl. s.
nitrate	$CO(NH_2)_2{\cdot}HNO_3$	123.07	col. mn.		152 d.		v. s. h.	s.	
Uric acid	$C_5H_4O_3N_4$	168.11	cr.	1.893^{20}	d.		0.06 h.	i.	i.
Valeric acid (*n*-)	$C_2H_5CH_2CH_2CO_2H$	102.13	col. lq.	$0.939^{20/4}$	–34.5	187	3.3^{16}	∞	∞
(*i*-)	$(CH_3)_2CHCH_2CO_2H$	102.13	col. lq.	$0.931^{20/20}$	–37.6	176	4.2^{20}	∞	∞
aldehyde (*n*-)	$C_2H_5CH_2CH_2CHO$	86.13	lq.	0.819^{11}	–92	103.4	v. sl. s.	s.	s.
(*i*-)	$(CH_3)_2CHCH_2CHO$	86.13	col. lq.	0.803^{17}	–51	92.5	sl. s.	s.	s.
amide (*n*-)	$C_2H_5CH_2CH_2CONH_2$	101.15	mn. pl.	1.023	106		v. s.	v. s.	v. s.
(*i*-)	$(CH_3)_2CHCH_2CONH_2$	101.15	mn.	$0.965^{20/4}$	135-7	232	s.	s.	s.
Vanillic acid (3-,4-,1-)	$CH_3O(OH)C_6H_3CO_2H$	168.15	nd./aq.		207	subl.	0.12^{14}	v. s.	v. s.
alcohol (3-,4-,1-)	$CH_3O(OH)C_6H_3CH_2OH$	154.16	mn./aq.		115	d.	v. s. h.	v. s.	v. s.
hyl-thiuram disulfide	$[(C_2H_5)_2NCS]_2S_2$	296.54	cr.	1.17	70		i.		
Vanillin (3-,4-,1-)	$CH_3O(OH)C_6H_3CHO$	152.15	mn.	1.056	81-2	285	1^{14}	v. s.	v. s.
Veratrole (*o*-)	$C_6H_4(OCH_3)_2$	138.16	cr.	$1.091^{15/15}$	22.5	207.1	v. sl. s.	s.	s.
Vinyl acetate	$CH_3CO_2CH{:}CH_2$	86.09	col. lq.	$0.932^{20/4}$	< –60	72-3	2^{20}	∞	∞
(poly-)	$(CH_3CO_2CH{:}CH_2)x$	(86.09)		1.19^{20}	100-25		i.		
acetic acid	$CH_2{:}CH{\cdot}CH_3CO_2H$	86.09	col. lq.	$1.013^{15/15}$	–39	163	s.	∞	∞
acetylene	$CH_2{:}CH{\cdot}C{:}CH$	52.07	gas	$0.705^{1.5}$		5.5	$0.67^{0.6}$		
alcohol	$CH_2{:}CHOH$	44.05							
(poly-)	$(CH_2{:}CHOH)x$	(44.05)		1.3^{20}	d. >200		s.		
chloride	$CH_2{:}CHCl$	62.50	gas	$0.908^{25/25}$	–160	–12	sl. s.	s.	v. s.
propionate	$C_2H_5CO_2CH{:}CH_2$	100.12	lq.			93-5	v. sl. s.		
Xylene (*o*-)	$C_6H_4(CH_3)_2$	106.17	col. lq.	$0.881^{20/4}$	–25	144	i.	s.	∞
(*m*-)	$C_6H_4(CH_3)_2$	106.17	col. lq.	$0.867^{17/4}$	–47.4	139.3	i.	s.	∞
(*p*-)	$C_6H_4(CH_3)_2$	106.17	col. lq.	$0.861^{20/4}$	13.2	138.5	i.	s.	v. s.
sulfonic acid (1-,4-,2-)	$(CH_3)_2C_6H_3SO_3H{\cdot}2H_2O$	222.26	col. lf.		86	$149^{0.1}$	s.		
Xylidine (1:2)(3-)	$(CH_3)_2C_6H_3NH_2$	121.18	lq.	0.991^{15}	< –15	223	v. sl. s.	s.	s.
(1:2)(4-)	$(CH_3)_2C_6H_3NH_2$	121.18	pr.	$1.076^{17.5}$	49-50	224-6	v. sl. s.		
(1:3)(2-)	$(CH_3)_2C_6H_3NH_2$	121.18	lq.	0.980^{15}		216-7	v. sl. s.		
(1:3)(4-)	$(CH_3)_2C_6H_3NH_2$	121.18	lq.	$0.978^{20/4}$		213-4	v. sl. s.		
(1:3)(5-)	$(CH_3)_2C_6H_3NH_2$	121.18	oil	$0.972^{20/4}$		221-2	v. sl. s.		
(1:4)(2-)	$(CH_3)_2C_6H_3NH_2$	121.18	oil	$0.979^{21/4}$	15.5	215^{789}	v. sl. s.		
Xylose (*l*-)(+)	$CH_2OH(CHOH)_3CHO$	150.13	nd.	1.535^{0}	153-4		117^{20}	v. sl. s.	i.
Xylylene dichloride (*p*-)	$C_6H_4(CH_2Cl)_2$	175.06	mn.	1.417^{0}	100.5	240-5 d.	i.	s.	v. sl. s.
Zinc diethyl	$Zn(CH_2CH_3)_2$	123.53	col. lq.	1.182^{18}	–28	118	d.	d.	
dimethyl	$Zn(CH_3)_2$	95.48	col. lq.	1.386^{11}	–40	46	d.	d.	
dimethyl-dithiocarbamate	$Zn[S_2CN(CH_3)_2]_2$	305.84		$2.00^{40/4}$	248-50		i.		

NOTE: °F = ⅘ °C + 32.

VAPOR PRESSURES OF PURE SUBSTANCES

TABLE 2-3 Vapor Pressure of Water Ice from 0 to –40 °C

	Vapor pressure			Vapor pressure			Vapor pressure	
t, °C	mmHg	kPa	t, °C	mmHg	kPa	t, °C	mmHg	kPa
0	4.584	0.6112	–13.5	1.423	0.1897	–27.0	0.3881	0.05174
–0.5	4.399	0.5865	–14.0	1.359	0.1812	–27.5	0.3688	0.04918
–1.0	4.220	0.5627	–14.5	1.298	0.1731	–28.0	0.3505	0.04673
–1.5	4.049	0.5398	–15.0	1.240	0.1653	–28.5	0.3330	0.04439
–2.0	3.883	0.5177	–15.5	1.184	0.1578	–29.0	0.3162	0.04216
–2.5	3.724	0.4965	–16.0	1.130	0.1507	–29.5	0.3003	0.04004
–3.0	3.571	0.4761	–16.5	1.079	0.1438	–30.0	0.2851	0.03801
–3.5	3.423	0.4564	–17.0	1.029	0.1372	–30.5	0.2706	0.03608
–4.0	3.281	0.4375	–17.5	0.9822	0.1310	–31.0	0.2568	0.03424
–4.5	3.145	0.4193	–18.0	0.9370	0.1249	–31.5	0.2437	0.03249
–5.0	3.013	0.4018	–18.5	0.8937	0.1191	–32.0	0.2311	0.03082
–5.5	2.887	0.3849	–19.0	0.8522	0.1136	–32.5	0.2192	0.02923
–6.0	2.766	0.3687	–19.5	0.8125	0.1083	–33.0	0.2078	0.02771
–6.5	2.649	0.3532	–20.0	0.7745	0.1033	–33.5	0.1970	0.02627
–7.0	2.537	0.3382	–20.5	0.7381	0.09841	–34.0	0.1867	0.02490
–7.5	2.429	0.3238	–21.0	0.7034	0.09377	–34.5	0.1769	0.02359
–8.0	2.325	0.3100	–21.5	0.6701	0.08934	–35.0	0.1676	0.02235
–8.5	2.225	0.2967	–22.0	0.6383	0.08510	–35.5	0.1587	0.02116
–9.0	2.130	0.2839	–22.5	0.6078	0.08104	–36.0	0.1503	0.02004
–9.5	2.038	0.2717	–23.0	0.5787	0.07716	–36.5	0.1423	0.01897
–10.0	1.949	0.2599	–23.5	0.5509	0.07345	–37.0	0.1347	0.01796
–10.5	1.865	0.2486	–24.0	0.5243	0.06991	–37.5	0.1274	0.01699
–11.0	1.783	0.2377	–24.5	0.4989	0.06652	–38.0	0.1206	0.01607
–11.5	1.705	0.2273	–25.0	0.4747	0.06329	–38.5	0.1140	0.01520
–12.0	1.630	0.2173	–25.5	0.4515	0.06020	–39.0	0.1078	0.01437
–12.5	1.558	0.2077	–26.0	0.4294	0.05725	–39.5	0.1019	0.01359
–13.0	1.489	0.1985	–26.5	0.4083	0.05443	–40.0	0.0963	0.01284

SOURCE: Formulation of Wagner, Saul, and Pruss, *J. Phys. Chem. Ref. Data*, **23**, 515 (1994), implemented in Harvey, Peskin, and Klein, *NIST/ASME Steam Properties*, NIST Standard Reference Database 10, Version 2.2, National Institute of Standards and Technology, Gaithersburg, Md., 2000. This source provides data down to 190 K (–83.15 °C). A formula extending to 110 K may be found in Murphy and Koop, *Q. J. R. Meteorol. Soc.*, **131**, 1539 (2005).

TABLE 2-4 Vapor Pressure of Supercooled Liquid Water from 0 to –40 °C*

	Vapor pressure			Vapor pressure			Vapor pressure	
t, °C	mmHg	kPa	t, °C	mmHg	kPa	t, °C	mmHg	kPa
0	4.584	0.6112	–13.5	1.623	0.2163	–27.0	0.5051	0.06734
–0.5	4.421	0.5894	–14.0	1.558	0.2077	–27.5	0.4824	0.06431
–1.0	4.262	0.5682	–14.5	1.495	0.1993	–28.0	0.4606	0.06141
–1.5	4.108	0.5477	–15.0	1.435	0.1913	–28.5	0.4397	0.05862
–2.0	3.959	0.5279	–15.5	1.377	0.1836	–29.0	0.4197	0.05595
–2.5	3.816	0.5087	–16.0	1.321	0.1761	–29.5	0.4005	0.05339
–3.0	3.676	0.4901	–16.5	1.267	0.1689	–30.0	0.3820	0.05094
–3.5	3.542	0.4722	–17.0	1.215	0.1620	–30.5	0.3644	0.04858
–4.0	3.411	0.4548	–17.5	1.165	0.1553	–31.0	0.3475	0.04633
–4.5	3.285	0.4380	–18.0	1.117	0.1489	–31.5	0.3313	0.04417
–5.0	3.163	0.4218	–18.5	1.070	0.1427	–32.0	0.3158	0.04210
–5.5	3.046	0.4061	–19.0	1.026	0.1367	–32.5	0.3009	0.04012
–6.0	2.932	0.3909	–19.5	0.9827	0.1310	–33.0	0.2867	0.03822
–6.5	2.822	0.3762	–20.0	0.9414	0.1255	–33.5	0.2731	0.03640
–7.0	2.715	0.3620	–20.5	0.9016	0.1202	–34.0	0.2600	0.03467
–7.5	2.612	0.3483	–21.0	0.8633	0.1151	–34.5	0.2476	0.03300
–8.0	2.513	0.3351	–21.5	0.8265	0.1102	–35.0	0.2356	0.03141
–8.5	2.417	0.3223	–22.0	0.7911	0.1055	–35.5	0.2242	0.02989
–9.0	2.324	0.3099	–22.5	0.7571	0.1009	–36.0	0.2133	0.02844
–9.5	2.235	0.2980	–23.0	0.7244	0.0965	–36.5	0.2029	0.02705
–10.0	2.149	0.2865	–23.5	0.6930	0.0923	–37.0	0.1929	0.02572
–10.5	2.065	0.2753	–24.0	0.6628	0.08836	–37.5	0.1834	0.02445
–11.0	1.985	0.2646	–24.5	0.6337	0.08449	–38.0	0.1743	0.02324
–11.5	1.907	0.2542	–25.0	0.6059	0.08078	–38.5	0.1656	0.02208
–12.0	1.832	0.2442	–25.5	0.5791	0.07721	–39.0	0.1573	0.02098
–12.5	1.760	0.2346	–26.0	0.5534	0.07379	–39.5	0.1494	0.01992
–13.0	1.690	0.2253	–26.5	0.5288	0.07050	–40.0	0.1419	0.01891

*SOURCE: Murphy and Koop, *Q. J. R. Meteorol. Soc.*, **131**, 1539 (2005). The formula in the reference extends down to 123 K (-150.15 °C), although in practice pure liquid water cannot be supercooled below about 235 K.

UNITS CONVERSIONS

For this subsection, the following units conversions are applicable:

$$°F = \tfrac{9}{5}\,°C + 32.$$

To convert millimeters of mercury to pounds-force per square inch, multiply by 0.01934.

ADDITIONAL REFERENCES

Additional vapor-pressure data may be found in major thermodynamic property databases, such as those produced by the AIChE's DIPPER program (www.aiche.org/dippr/), NIST's Thermodynamics Research Center (trc.nist.gov), the Dortmund Databank (www.ddbst.de), and the Physical Property Data Service (www.ppds.co.uk). Additional sources include the *NIST Chemistry Webbook* (webbook.nist.gov/chemistry/); Boublik, Fried, and Hala, *The Vapor Pressures of Pure Substances*, 2d ed., Elsevier, Amsterdam, 1984; Poling, Prausnitz, and O'Connell, *The Properties of Gases and Liquids*, 5th ed., McGraw-Hill, New York, 2001; *Vapor Pressure of Chemicals* (Subvolumes A, B, and C), vol. IV/20 in Landolt-Bornstein: *Numerical Data nad Functional Relationships in Science and Technology—New Series*, Springer-Verlag, Berlin, 1999–2001. The most recent work on water may be found at The International Association for the Properties of Water and Steam website http://iapws.org.

TABLE 2-5 Vapor Pressure (MPa) of Liquid Water from 0 to 100°C

t, °C	P_{vp}, MPa	t, °C	P_{vp}, MPa	t, °C	P_{vp}, MPa
0.01	0.00061165	34	0.0053251	68	0.028599
1	0.00065709	35	0.0056290	69	0.029876
2	0.00070599	36	0.0059479	70	0.031201
3	0.00075808	37	0.0062823	71	0.032575
4	0.00081355	38	0.0066328	72	0.034000
5	0.00087258	39	0.0070002	73	0.035478
6	0.00093536	40	0.0073849	74	0.037009
7	0.0010021	41	0.0077878	75	0.038595
8	0.0010730	42	0.0082096	76	0.040239
9	0.0011483	43	0.0086508	77	0.041941
10	0.0012282	44	0.0091124	78	0.043703
11	0.0013130	45	0.0095950	79	0.045527
12	0.0014028	46	0.010099	80	0.047414
13	0.0014981	47	0.010627	81	0.049367
14	0.0015990	48	0.011177	82	0.051387
15	0.0017058	49	0.011752	83	0.053476
16	0.0018188	50	0.012352	84	0.055635
17	0.0019384	51	0.012978	85	0.057867
18	0.0020647	52	0.013631	86	0.060173
19	0.0021983	53	0.014312	87	0.062556
20	0.0023393	54	0.015022	88	0.065017
21	0.0024882	55	0.015762	89	0.067558
22	0.0026453	56	0.016533	90	0.070182
23	0.0028111	57	0.017336	91	0.072890
24	0.0029858	58	0.018171	92	0.075684
25	0.0031699	59	0.019041	93	0.078568
26	0.0033639	60	0.019946	94	0.081541
27	0.0035681	61	0.020888	95	0.084608
28	0.0037831	62	0.021867	96	0.087771
29	0.0040092	63	0.022885	97	0.091030
30	0.0042470	64	0.023943	98	0.094390
31	0.0044969	65	0.025042	99	0.097852
32	0.0047596	66	0.026183	100	0.10142
33	0.0050354	67	0.027368		

From E. W. Lemmon, M. O. McLinden, and D. G. Friend, "Thermophysical Properties of Fluid Systems" in *NIST Chemistry WebBook*, NIST Standard Reference Database Number 69, Eds. P. J. Linstrom and W. G. Mallard, June 2005, National Institute of Standards and Technology, Gaithersburg, Md. (http://webbook.nist.gov) and Wagner, W., and A., Pruss, "The IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use," *J. Phys. Chem. Ref. Data* **31**(2):387–535, 2002.

The website mentioned above allows users to generate their own tables of thermodynamic properties. The user can select the units as well as the temperatures and/or pressures for which properties are to be generated. The results can be then be copied into spreadsheets or other files.

TABLE 2-6 Substances in Tables 2-8, 2-32, 2-141, 2-150, 2-153, 2-155, 2-156, 2-179, 2-312, 2-313, 2-314, and 2-315 Sorted by Chemical Family

Name	Cmpd. No.	Formula
Paraffins		
Methane	193	CH_4
Ethane	125	C_2H_6
Propane	295	C_3H_8
Butane	31	C_4H_{10}
Pentane	279	C_5H_{12}
Hexane	171	C_6H_{14}
Heptane	160	C_7H_{16}
Octane	265	C_8H_{18}
Nonane	256	C_9H_{20}
Decane	74	$C_{10}H_{22}$
Undecane	336	$C_{11}H_{24}$
Dodecane	123	$C_{12}H_{26}$
Tridecane	327	$C_{13}H_{28}$
Tetradecane	319	$C_{14}H_{30}$
Pentadecane	277	$C_{15}H_{32}$
Hexadecane	169	$C_{16}H_{34}$
Heptadecane	158	$C_{17}H_{36}$
Octadecane	263	$C_{18}H_{38}$
Nonadecane	254	$C_{19}H_{40}$
Eicosane	124	$C_{20}H_{42}$
2-Methylpropane	236	C_4H_{10}
2-Methylbutane	202	C_5H_{12}
2,3-Dimethylbutane	107	C_6H_{14}
2-Methylpentane	234	C_6H_{14}
2,3-Dimethylpentane	114	C_7H_{16}
2,2,3,3-Tetramethylbutane	323	C_8H_{18}
2,2,4-Trimethylpentane	332	C_8H_{18}
2,3,3-Trimethylpentane	333	C_8H_{18}
Cyclopropane	71	C_3H_6
Cyclobutane	64	C_4H_8
Cyclopentane	69	C_5H_{10}
Cyclohexane	65	C_6H_{12}
Methylcyclopentane	217	C_6H_{12}
Ethylcyclopentane	134	C_7H_{14}
Methylcyclohexane	213	C_7H_{14}
1,1-Dimethylcyclohexane	108	C_8H_{16}
cis-1,2-Dimethylcyclohexane	109	C_8H_{16}
trans-1,2-Dimethylcyclohexane	110	C_8H_{16}
Ethylcyclohexane	133	C_8H_{16}
Olefins		
Ethylene	135	C_2H_4
Propylene	305	C_3H_6
1-Butene	36	C_4H_8
cis-2-Butene	37	C_4H_8
trans-2-Butene	38	C_4H_8
Cyclopentene	70	C_5H_8
1-Pentene	285	C_5H_{10}
Cyclohexene	68	C_6H_{10}
1-Hexene	177	C_6H_{12}
1-Heptene	166	C_7H_{14}
1-Octene	271	C_8H_{16}
1-Nonene	260	C_9H_{18}
1-Decene	77	$C_{10}H_{20}$
2-Methyl propene	238	C_4H_8
2-Methyl-1-butene	205	C_5H_{10}
2-Methyl-2-butene	206	C_5H_{10}
1-Methylcyclopentene	218	C_6H_{10}
3-Methylcyclopentene	219	C_6H_{10}
Propenylcyclohexene	298	C_9H_{14}
Propadiene	294	C_3H_4
1,2-Butadiene	29	C_4H_6
1,3-Butadiene	30	C_4H_6
3-Methyl-1,2-butadiene	201	C_5H_8
Acetylenes		
Acetylene	7	C_2H_2
1-Butyne	43	C_4H_6
1-Pentyne	288	C_5H_8
2-Pentyne	289	C_5H_8
3-Hexyne	178	C_6H_{10}
1-Hexyne	180	C_6H_{10}
2-Hexyne	181	C_6H_{10}
1-Heptyne	168	C_7H_{12}

Name	Cmpd. No.	Formula
Acetylenes		
1-Octyne	273	C_8H_{14}
1-Nonyne	262	C_9H_{16}
1-Decyne	79	$C_{10}H_{18}$
Methyl acetylene	197	C_3H_4
Vinyl acetylene	339	C_4H_4
Dimethyl acetylene	105	C_4H_6
2-Methyl -1-butene-3-yne	207	C_5H_6
3-Methyl-1-butyne	210	C_5H_8
Aromatics		
Benzene	16	C_6H_6
Toluene	325	C_7H_8
Styrene	312	C_8H_8
Ethylbenzene	129	C_8H_{10}
m-Xylene	343	C_8H_{10}
o-Xylene	344	C_8H_{10}
p-Xylene	345	C_8H_{10}
alpha-Methyl styrene	243	C_9H_{10}
Cumene	62	C_9H_{12}
Propylbenzene	304	C_9H_{12}
1,2,3-Trimethylbenzene	330	C_9H_{12}
1,2,4-Trimethylbenzene	331	C_9H_{12}
Naphthalene	246	$C_{10}H_8$
1,2,3,4-Tetrahydronaphthalene	321	$C_{10}H_{12}$
Butylbenzene	40	$C_{10}H_{14}$
Biphenyl	24	$C_{12}H_{10}$
Phenanthrene	290	$C_{14}H_{10}$
o-Terphenyl	318	$C_{18}H_{14}$
Aldehydes		
Formaldehyde	153	CH_2O
Acetaldehyde	1	C_2H_4O
Propionaldehyde	299	C_3H_6O
Butyraldehyde	44	C_4H_8O
Pentanal	278	$C_5H_{10}O$
Hexanal	170	$C_6H_{12}O$
Heptanal	159	$C_7H_{14}O$
Octanal	264	$C_8H_{16}O$
Nonanal	255	$C_9H_{18}O$
Decanal	73	$C_{10}H_{20}O$
Ketones		
Acrolein	8	C_3H_4O
Acetone	5	C_3H_6O
Methylethyl ketone	222	C_4H_8O
Methylisopropyl ketone	229	$C_5H_{10}O$
2-Pentanone	283	$C_5H_{10}O$
3-Pentanone	284	$C_5H_{10}O$
Quinone	310	$C_6H_4O_2$
Cyclohexanone	67	$C_6H_{10}O$
Ethylisopropyl ketone	144	$C_6H_{12}O$
2-Hexanone	175	$C_6H_{12}O$
3-Hexanone	176	$C_6H_{12}O$
Methylisobutyl ketone	226	$C_6H_{12}O$
Diisopropyl ketone	102	$C_7H_{14}O$
3-Heptanone	164	$C_7H_{14}O$
2-Heptanone	165	$C_7H_{14}O$
2-Octanone	269	$C_8H_{16}O$
3-Octanone	270	$C_8H_{16}O$
Benzophenone	20	$C_{13}H_{10}O$
Heterocyclics		
Furan	156	C_4H_4O
Thiophene	324	C_4H_4S
Tetrahydrofuran	320	C_4H_8O
Tetrahydrothiophene	322	C_4H_8S
Elements		
Argon	14	Ar
Bromine	25	Br_2
Chlorine	52	Cl_2
Deuterium	80	D_2
Fluorine	149	F_2

TABLE 2-6 Substances in Tables 2-8, 2-32, 2-141, 2-150, 2-153, 2-155, 2-156, 2-179, 2-312, 2-313, 2-314, and 2-315 Sorted by Chemical Family (*Continued*)

Name	Cmpd. No.	Formula
Elements		
Hydrogen	183	H_2
Helium-4	157	He
Nitrogen	249	N_2
Neon	247	Ne
Oxygen	275	O_2
Alcohols		
Methanol	194	CH_4O
Ethanol	126	C_2H_6O
1-Propanol	296	C_3H_8O
2-Propanol	297	C_3H_8O
1-Butanol	34	$C_4H_{10}O$
2-Butanol	35	$C_4H_{10}O$
1-Pentanol	281	$C_5H_{12}O$
2-Pentanol	282	$C_5H_{12}O$
Cyclohexanol	66	$C_6H_{12}O$
1-Hexanol	173	$C_6H_{14}O$
2-Hexanol	174	$C_6H_{14}O$
1-Heptanol	162	$C_7H_{16}O$
2-Heptanol	163	$C_7H_{16}O$
1-Octanol	267	$C_8H_{18}O$
2-Octanol	268	$C_8H_{18}O$
1-Nonanol	258	$C_9H_{20}O$
2-Nonanol	259	$C_9H_{20}O$
1-Decanol	76	$C_{10}H_{22}O$
1-Undecanol	337	$C_{11}H_{24}O$
2-Methyl-2-propanol	237	$C_4H_{10}O$
3-Methyl-1-butanol	204	$C_5H_{12}O$
Benzyl alcohol	21	C_7H_8O
1-Methylcyclohexanol	214	$C_7H_{14}O$
cis-2-Methylcyclohexanol	215	$C_7H_{14}O$
trans-2-Methylcyclohexanol	216	$C_7H_{14}O$
Ethylene glycol	137	$C_2H_6O_2$
1,2-Propylene glycol	309	$C_3H_8O_2$
1,2-Butanediol	32	$C_4H_{10}O_2$
1,3-Butanediol	33	$C_4H_{10}O_2$
Phenols		
Phenol	291	C_6H_6O
m-Cresol	59	C_7H_8O
o-Cresol	60	C_7H_8O
p-Cresol	61	C_7H_8O
Ethers		
Dimethyl ether	112	C_2H_6O
Methyl vinyl ether	245	C_3H_6O
Methylethyl ether	221	C_3H_8O
1,4-Dioxane	120	$C_4H_8O_2$
Diethyl ether	95	$C_4H_{10}O$
Methylpropyl ether	240	$C_4H_{10}O$
Methylisopropyl ether	228	$C_4H_{10}O$
1,1-Dimethoxyethane	103	$C_4H_{10}O_2$
Methylbutyl ether	208	$C_5H_{12}O$
Methylisobutyl ether	225	$C_5H_{12}O$
Methyl *tert*-butyl ether	244	$C_5H_{12}O$
Ethylpropyl ether	147	$C_5H_{12}O$
Ethylisopropyl ether	143	$C_5H_{12}O$
1,2-Dimethoxypropane	104	$C_5H_{12}O_2$
Di-isopropyl ether	101	$C_6H_{14}O$
Methyl pentyl ether	235	$C_6H_{14}O$
Anisole	13	C_7H_8O
Dibutyl ether	84	$C_8H_{18}O$
Ethylhexyl ether	142	$C_8H_{18}O$
Benzyl ethyl ether	22	$C_9H_{12}O$
Diphenyl ether	121	$C_{12}H_{10}O$
Acids		
Formic acid	155	CH_2O_2
Oxalic acid	274	$C_2H_2O_4$
Acetic acid	3	$C_2H_4O_2$
Acrylic acid	9	$C_3H_4O_2$
Malonic acid	191	$C_3H_4O_4$
Propionic acid	300	$C_3H_6O_2$

Name	Cmpd. No.	Formula
Acids		
Methacrylic acid	192	$C_4H_6O_2$
Acetic anhydride	4	$C_4H_6O_3$
Succinic acid	313	$C_4H_6O_4$
Butyric acid	45	$C_4H_8O_2$
Isobutyric acid	189	$C_4H_8O_2$
2-Methylbutanoic acid	203	$C_5H_{10}O_2$
Pentanoic acid	280	$C_5H_{10}O_2$
2-Ethyl butanoic acid	131	$C_6H_{12}O_2$
Hexanoic acid	172	$C_6H_{12}O_2$
Benzoic acid	18	$C_7H_6O_2$
Heptanoic acid	161	$C_7H_{14}O_2$
Phthalic anhydride	293	$C_8H_4O_3$
Terephthalic acid	317	$C_8H_6O_4$
2-Ethyl hexanoic acid	141	$C_8H_{16}O_2$
Octanoic acid	266	$C_8H_{16}O_2$
2-Methyloctanoic acid	233	$C_9H_{18}O_2$
Nonanoic acid	257	$C_9H_{18}O_2$
Decanoic acid	75	$C_{10}H_{20}O_2$
Esters		
Methyl formate	224	$C_2H_4O_2$
Ethyl formate	140	$C_3H_6O_2$
Methyl acetate	196	$C_3H_6O_2$
Methyl acrylate	198	$C_4H_6O_2$
Vinyl acetate	338	$C_4H_6O_2$
Ethyl acetate	127	$C_4H_8O_2$
Methyl propionate	239	$C_4H_8O_2$
Propyl formate	306	$C_4H_8O_2$
Methyl methacrylate	232	$C_5H_8O_2$
Ethyl propionate	146	$C_5H_{10}O_2$
Methyl butyrate	211	$C_5H_{10}O_2$
Propyl acetate	302	$C_5H_{10}O_2$
Butyl acetate	39	$C_6H_{12}O_2$
Ethyl butyrate	132	$C_6H_{12}O_2$
Methyl benzoate	200	$C_8H_8O_2$
Ethyl benzoate	130	$C_9H_{10}O_2$
Dimethyl phthalate	115	$C_{10}H_{10}O_4$
Dimethyl terephthalate	119	$C_{10}H_{10}O_4$
Amines		
Methyl amine	199	CH_5N
Ethyleneimine	138	C_2H_5N
Dimethyl amine	106	C_2H_7N
Ethyl amine	128	C_2H_7N
Ethylenediamine	136	$C_2H_8N_2$
Isopropyl amine	190	C_3H_9N
Propyl amine	303	C_3H_9N
Trimethyl amine	329	C_3H_9N
Diethyl amine	94	$C_4H_{11}N$
Diethanol amine	93	$C_4H_{11}NO_2$
Di-isopropyl amine	100	$C_6H_{15}N$
Dipropyl amine	122	$C_6H_{15}N$
Triethyl amine	328	$C_6H_{15}N$
Amides		
Formamide	154	CH_3NO
Acetamide	2	C_2H_5NO
N,N-Dimethyl formamide	113	C_3H_7NO
N-Methyl acetamide	195	C_3H_7NO
Benzamide	15	C_7H_7NO
Nitriles		
Acetonitrile	6	C_2H_3N
Cyanogen	63	C_2N_2
Acrylonitrile	10	C_3H_3N
Propionitrile	301	C_3H_5N
Butyronitrile	46	C_4H_7N
Benzonitrile	19	C_7H_5N
Nitro Compounds		
Nitromethane	251	CH_3NO_2
Nitroethane	248	$C_2H_5NO_2$

TABLE 2-6 Substances in Tables 2-8, 2-32, 2-141, 2-150, 2-153, 2-155, 2-156, 2-179, 2-312, 2-313, 2-314, and 2-315 Sorted by Chemical Family (*Concluded*)

Name	Cmpd. No.	Formula
Nitro Compounds		
1,3,5-Trinitrobenzene	334	$C_6H_3N_3O_6$
2,4,6-Trinitrotoluene	335	$C_7H_5N_3O_6$
Isocyanates		
Methyl isocyanate	227	C_2H_3NO
Phenyl isocyanate	292	C_7H_5NO
Mercaptans		
Methyl mercaptan	231	CH_4S
Ethyl mercaptan	145	C_2H_6S
Propyl mercaptan	308	C_3H_8S
2-Propyl mercaptan	307	C_3H_8S
Butyl mercaptan	41	$C_4H_{10}S$
sec-Butyl mercaptan	42	$C_4H_{10}S$
Pentyl mercaptan	287	$C_5H_{12}S$
2-Pentyl mercaptan	286	$C_5H_{12}S$
Benzenethiol	17	C_6H_6S
Cyclohexyl mercaptan	72	$C_6H_{12}S$
Hexyl mercaptan	179	$C_6H_{14}S$
Benzyl mercaptan	23	C_7H_8S
Heptyl mercaptan	167	$C_7H_{16}S$
Octyl mercaptan	272	$C_8H_{18}S$
Nonyl mercaptan	261	$C_9H_{20}S$
Decyl mercaptan	78	$C_{10}H_{22}S$
Sulfides		
Dimethyl sulfide	117	C_2H_6S
Dimethyl disulfide	111	$C_2H_6S_2$
Methylethyl sulfide	223	C_3H_8S
Diethyl sulfide	96	$C_4H_{10}S$
Methylisopropyl sulfide	230	$C_4H_{10}S$
Methylpropyl sulfide	241	$C_4H_{10}S$
Methylbutyl sulfide	209	$C_5H_{12}S$
Halogenated Hydrocarbons		
Carbon tetrachloride	50	CCl_4
Carbon tetrafluoride	51	CF_4
Chloroform	55	$CHCl_3$
Dibromomethane	83	CH_2Br_2
Dichloromethane	90	CH_2Cl_2
Difluoromethane	99	CH_2F_2
Bromomethane	28	CH_3Br
Chloromethane	56	CH_3Cl
Fluoromethane	152	CH_3F
Vinyl chloride	340	C_2H_3Cl
1,1,2-Trichloroethane	326	$C_2H_3Cl_3$
1,1-Dibromoethane	81	$C_2H_4Br_2$
1,2-Dibromoethane	82	$C_2H_4Br_2$
1,1-Dichloroethane	88	$C_2H_4Cl_2$

Name	Cmpd. No.	Formula
Halogenated Hydrocarbons		
1,2-Dichloroethane	89	$C_2H_4Cl_2$
1,1-Difluoroethane	97	$C_2H_4F_2$
1,2-Difluoroethane	98	$C_2H_4F_2$
Bromoethane	27	C_2H_5Br
Chloroethane	54	C_2H_5Cl
Fluoroethane	151	C_2H_5F
1,1-Dichloropropane	91	$C_3H_6Cl_2$
1,2-Dichloropropane	92	$C_3H_6Cl_2$
1-Chloropropane	57	C_3H_7Cl
2-Chloropropane	58	C_3H_7Cl
m-Dichlorobenzene	85	$C_6H_4Cl_2$
o-Dichlorobenzene	86	$C_6H_4Cl_2$
p-Dichlorobenzene	87	$C_6H_4Cl_2$
Bromobenzene	26	C_6H_5Br
Chlorobenzene	53	C_6H_5Cl
Fluorobenzene	150	C_6H_5F
Silanes		
Methylsilane	242	CH_6Si
Methylchlorosilane	212	CH_5ClSi
Methyldichlorosilane	220	CH_4Cl_2Si
Vinyl trichlorosilane	341	$C_2H_3Cl_3Si$
Ethyltrichlorosilane	148	$C_2H_5Cl_3Si$
Dimethylsilane	116	C_2H_8Si
Silicon tetrafluoride	311	F_4Si
Light Gases		
Hydrogen cyanide	186	CHN
Carbon monoxide	49	CO
Carbon dioxide	47	CO2
Carbon disulfide	48	CS_2
Nitrogen trifluoride	250	F_3N
Sulfur hexafluoride	315	F_6S
Hydrogen bromide	184	HBr
Hydrogen chloride	185	HCl
Hydrogen fluoride	187	HF
Hydrogen sulfide	188	H_2S
Ammonia	12	H_3N
Hydrazine	182	H_4N_2
Nitric oxide	253	NO
Nitrous oxide	252	N_2O
Sulfur dioxide	314	O_2S
Ozone	276	O_3
Sulfur trioxide	316	O_3S
Others		
Air	11	Mixture
Ethylene oxide	139	C_2H_4O
Dimethyl sulfoxide	118	C_2H_6OS
Water	342	H_2O

TABLE 2-7 Formula Index of Substances in Tables 2-8, 2-32, 2-141, 2-150, 2-153, 2-155, 2-156, 2-179, 2-312, 2-313, 2-314, and 2-315

Formula	No.	Name	Formula	No.	Name
	11	Air	$C_3H_6Cl_2$	92	1,2-Dichloropropane
Ar	14	Argon	C_3H_6O	5	Acetone
Br_2	25	Bromine	C_3H_6O	245	Methyl vinyl ether
CCl_4	50	Carbon tetrachloride	C_3H_6O	299	Propionaldehyde
CF_4	51	Carbon tetrafluoride	$C_3H_6O_2$	140	Ethyl formate
$CHCl_3$	55	Chloroform	$C_3H_6O_2$	196	Methyl acetate
CHN	186	Hydrogen cyanide	$C_3H_6O_2$	300	Propionic acid
CH_2Br_2	83	Dibromomethane	C_3H_7Cl	57	1-Chloropropane
CH_2Cl_2	90	Dichloromethane	C_3H_7Cl	58	2-Chloropropane
CH_2F_2	99	Difluoromethane	C_3H_7NO	113	*N,N*-Dimethyl formamide
CH_2O	153	Formaldehyde	C_3H_7NO	195	*N*-Methyl acetamide
CH_2O_2	155	Formic acid	C_3H_8	295	Propane
CH_3Br	28	Bromomethane	C_3H_8O	221	Methylethyl ether
CH_3Cl	56	Chloromethane	C_3H_8O	296	1-Propanol
CH_3F	152	Fluoromethane	C_3H_8O	297	2-Propanol
CH_3NO	154	Formamide	$C_3H_8O_2$	309	1,2-Propylene glycol
CH_3NO_2	251	Nitromethane	C_3H_8S	223	Methylethyl sulfide
CH_4	193	Methane	C_3H_8S	308	Propyl mercaptan
CH_4Cl_2Si	220	Methyldichlorosilane	C_3H_8S	307	2-Propyl mercaptan
CH_4O	194	Methanol	C_3H_9N	190	Isopropyl amine
CH_4S	231	Methyl mercaptan	C_3H_9N	303	Propyl amine
CH_5ClSi	212	Methylchlorosilane	C_3H_9N	329	Trimethyl amine
CH_5N	199	Methyl amine	C_4H_4	339	Vinyl acetylene
CH_6Si	242	Methylsilane	C_4H_4O	156	Furan
CO	49	Carbon monoxide	C_4H_4S	324	Thiophene
CO_2	47	Carbon dioxide	C_4H_6	29	1,2-Butadiene
CS_2	48	Carbon disulfide	C_4H_6	30	1,3-Butadiene
C_2H_2	7	Acetylene	C_4H_6	43	1-Butyne
$C_2H_2O_4$	274	Oxalic acid	C_4H_6	105	Dimethyl acetylene
C_2H_3Cl	340	Vinyl chloride	$C_4H_6O_2$	192	Methacrylic acid
$C_2H_3Cl_3$	326	1,1,2-Trichloroethane	$C_4H_6O_2$	198	Methyl acrylate
$C_2H_3Cl_3Si$	341	Vinyl trichlorosilane	$C_4H_6O_2$	338	Vinyl acetate
C_2H_3N	6	Acetonitrile	$C_4H_6O_3$	4	Acetic anhydride
C_2H_3NO	227	Methyl Isocyanate	$C_4H_6O_4$	313	Succinic acid
C_2H_4	135	Ethylene	C_4H_7N	46	Butyronitrile
$C_2H_4Br_2$	81	1,1-Dibromoethane	C_4H_8	36	1-Butene
$C_2H_4Br_2$	82	1,2-Dibromoethane	C_4H_8	37	*cis*-2-Butene
$C_2H_4Cl_2$	88	1,1-Dichloroethane	C_4H_8	38	*trans*-2-Butene
$C_2H_4Cl_2$	89	1,2-Dichloroethane	C_4H_8	64	Cyclobutane
$C_2H_4F_2$	97	1,1-Difluoroethane	C_4H_8	238	2-Methyl propene
$C_2H_4F_2$	98	1,2-Difluoroethane	C_4H_8O	44	Butyraldehyde
C_2H_4O	1	Acetaldehyde	C_4H_8O	222	Methylethyl ketone
C_2H_4O	139	Ethylene oxide	C_4H_8O	320	Tetrahydrofuran
$C_2H_4O_2$	3	Acetic acid	$C_4H_8O_2$	45	Butyric acid
$C_2H_4O_2$	224	Methyl formate	$C_4H_8O_2$	120	1,4-Dioxane
C_2H_5Br	27	Bromoethane	$C_4H_8O_2$	127	Ethyl acetate
C_2H_5Cl	54	Chloroethane	$C_4H_8O_2$	189	Isobutyric acid
$C_2H_5Cl_3Si$	148	Ethyltrichlorosilane	$C_4H_8O_2$	239	Methyl propionate
C_2H_5F	151	Fluoroethane	$C_4H_8O_2$	306	Propyl formate
C_2H_5N	138	Ethyleneimine	C_4H_8S	322	Tetrahydrothiophene
C_2H_5NO	2	Acetamide	C_4H_{10}	31	Butane
$C_2H_5NO_2$	248	Nitroethane	C_4H_{10}	236	2-Methylpropane
C_2H_6	125	Ethane	$C_4H_{10}O$	34	1-Butanol
C_2H_6O	112	Dimethyl ether	$C_4H_{10}O$	35	2-Butanol
C_2H_6O	126	Ethanol	$C_4H_{10}O$	95	Diethyl ether
$C_2H_6O_2$	137	Ethylene glycol	$C_4H_{10}O$	237	2-Methyl-2-propanol
C_2H_6OS	118	Dimethyl sulfoxide	$C_4H_{10}O$	240	Methylpropyl ether
C_2H_6S	117	Dimethyl sulfide	$C_4H_{10}O$	228	Methylisopropyl ether
C_2H_6S	145	Ethyl mercaptan	$C_4H_{10}O_2$	32	1,2-Butanediol
$C_2H_6S_2$	111	Dimethyl disulfide	$C_4H_{10}O_2$	33	1,3-Butanediol
C_2H_7N	106	Dimethyl amine	$C_4H_{10}O_2$	103	1,1-Dimethoxyethane
C_2H_7N	128	Ethyl amine	$C_4H_{10}S$	41	Butyl mercaptan
$C_2H_8N_2$	136	Ethylenediamine	$C_4H_{10}S$	42	*sec*-Butyl mercaptan
C_2H_8Si	116	Dimethylsilane	$C_4H_{10}S$	96	Diethyl sulfide
C_2N_2	63	Cyanogen	$C_4H_{10}S$	230	Methylisopropyl sulfide
C_3H_3N	10	Acrylonitrile	$C_4H_{10}S$	241	Methylpropyl sulfide
C_3H_4	197	Methyl acetylene	$C_4H_{11}N$	94	Diethyl amine
C_3H_4	294	Propadiene	$C_4H_{11}NO_2$	93	Diethanol amine
C_3H_4O	8	Acrolein	C_5H_6	207	2-Methyl-1-butene-3-yne
$C_3H_4O_2$	9	Acrylic acid	C_5H_8	70	Cyclopentene
$C_3H_4O_4$	191	Malonic acid	C_5H_8	201	3-Methyl-1,2-butadiene
C_3H_5N	301	Propionitrile	C_5H_8	210	3-Methyl-1-butyne
C_3H_6	71	Cyclopropane	C_5H_8	288	1-Pentyne
C_3H_6	305	Propylene	C_5H_8	289	2-Pentyne
$C_3H_6Cl_2$	91	1,1-Dichloropropane	$C_5H_8O_2$	232	Methyl methacrylate

TABLE 2-7 Formula Index of Substances in Tables 2-8, 2-32, 2-141, 2-150, 2-153, 2-155, 2-156, 2-179, 2-312, 2-313, 2-314, and 2-315 (*Continued*)

Formula	No.	Name	Formula	No.	Name
C_5H_{10}	69	Cyclopentane	C_7H_8	325	Toluene
C_5H_{10}	205	2-Methyl-1-butene	C_7H_8O	13	Anisole
C_5H_{10}	206	2-Methyl-2-butene	C_7H_8O	21	Benzyl alcohol
C_5H_{10}	285	1-Pentene	C_7H_8O	59	*m*-Cresol
$C_5H_{10}O$	229	Methylisopropyl ketone	C_7H_8O	60	*o*-Cresol
$C_5H_{10}O$	278	Pentanal	C_7H_8O	61	*p*-Cresol
$C_5H_{10}O$	283	2-Pentanone	C_7H_8S	23	Benzyl mercaptan
$C_5H_{10}O$	284	3-Pentanone	C_7H_{12}	168	1-Heptyne
$C_5H_{10}O_2$	146	Ethyl propionate	C_7H_{14}	134	Ethylcyclopentane
$C_5H_{10}O_2$	203	2-Methylbutanoic acid	C_7H_{14}	166	1-Heptene
$C_5H_{10}O_2$	211	Methyl butyrate	C_7H_{14}	213	Methylcyclohexane
$C_5H_{10}O_2$	280	Pentanoic acid	$C_7H_{14}O$	102	Di-isopropyl ketone
$C_5H_{10}O_2$	302	Propyl acetate	$C_7H_{14}O$	159	Heptanal
C_5H_{12}	202	2-Methylbutane	$C_7H_{14}O$	164	3-Heptanone
C_5H_{12}	279	Pentane	$C_7H_{14}O$	165	2-Heptanone
$C_5H_{12}O$	143	Ethylisopropyl ether	$C_7H_{14}O$	214	1-Methylcyclohexanol
$C_5H_{12}O$	147	Ethylpropyl ether	$C_7H_{14}O$	215	*cis*-2-Methylcyclohexanol
$C_5H_{12}O$	204	3-Methyl-1-butanol	$C_7H_{14}O$	216	*trans*-2-Methylcyclohexanol
$C_5H_{12}O$	208	Methylbutyl ether	$C_7H_{14}O_2$	161	Heptanoic acid
$C_5H_{12}O$	225	Methylisobutyl ether	C_7H_{16}	114	2,3-Dimethylpentane
$C_5H_{12}O$	244	Methyl *tert*-butyl ether	C_7H_{16}	160	Heptane
$C_5H_{12}O$	281	1-Pentanol	$C_7H_{16}O$	162	1-Heptanol
$C_5H_{12}O$	282	2-Pentanol	$C_7H_{16}O$	163	2-Heptanol
$C_5H_{12}O_2$	104	1,2-Dimethoxypropane	$C_7H_{16}S$	167	Heptyl mercaptan
$C_5H_{12}S$	209	Methylbutyl sulfide	$C_8H_4O_3$	293	Phthalic anhydride
$C_5H_{12}S$	286	2-Pentyl mercaptan	$C_8H_6O_4$	317	Terephthalic acid
$C_5H_{12}S$	287	Pentyl mercaptan	C_8H_8	312	Styrene
$C_6H_3N_3O_6$	334	1,3,5-Trinitrobenzene	$C_8H_8O_2$	200	Methyl benzoate
$C_6H_4Cl_2$	85	*m*-Dichlorobenzene	C_8H_{10}	129	Ethylbenzene
$C_6H_4Cl_2$	86	*o*-Dichlorobenzene	C_8H_{10}	343	*m*-Xylene
$C_6H_4Cl_2$	87	*p*-Dichlorobenzene	C_8H_{10}	344	*o*-Xylene
$C_6H_4O_2$	310	Quinone	C_8H_{10}	345	*p*-Xylene
C_6H_5Br	26	Bromobenzene	C_8H_{14}	273	1-Octyne
C_6H_5Cl	53	Chlorobenzene	C_8H_{16}	108	1,1-Dimethylcyclohexane
C_6H_5F	150	Fluorobenzene	C_8H_{16}	109	*cis*-1,2-Dimethylcyclohexane
C_6H_6	16	Benzene	C_8H_{16}	110	*trans*-1,2-Dimethylcyclohexane
C_6H_6O	291	Phenol	C_8H_{16}	133	Ethylcyclohexane
C_6H_6S	17	Benzenethiol	C_8H_{16}	271	1-Octene
C_6H_{10}	218	1-Methylcyclopentene	$C_8H_{16}O$	264	Octanal
C_6H_{10}	68	Cyclohexene	$C_8H_{16}O$	269	2-Octanone
C_6H_{10}	178	3-Hexyne	$C_8H_{16}O$	270	3-Octanone
C_6H_{10}	180	1-Hexyne	$C_8H_{16}O_2$	141	2-Ethyl hexanoic acid
C_6H_{10}	181	2-Hexyne	$C_8H_{16}O_2$	266	Octanoic acid
C_6H_{10}	219	3-Methylcyclopentene	C_8H_{18}	265	Octane
$C_6H_{10}O$	67	Cyclohexanone	C_8H_{18}	323	2,2,3,3-Tetramethylbutane
C_6H_{12}	65	Cyclohexane	C_8H_{18}	332	2,2,4-Trimethylpentane
C_6H_{12}	177	1-Hexene	C_8H_{18}	333	2,3,3-Trimethylpentane
C_6H_{12}	217	Methylcyclopentane	$C_8H_{18}O$	84	Dibutyl ether
$C_6H_{12}O$	66	Cyclohexanol	$C_8H_{18}O$	142	Ethylhexyl ether
$C_6H_{12}O$	144	Ethylisopropyl ketone	$C_8H_{18}O$	267	1-Octanol
$C_6H_{12}O$	170	Hexanal	$C_8H_{18}O$	268	2-Octanol
$C_6H_{12}O$	175	2-Hexanone	$C_8H_{18}S$	272	Octyl mercaptan
$C_6H_{12}O$	176	3-Hexanone	C_9H_{10}	243	alpha-Methyl styrene
$C_6H_{12}O$	226	Methylisobutyl ketone	$C_9H_{10}O_2$	130	Ethyl benzoate
$C_6H_{12}O_2$	39	Butyl acetate	C_9H_{12}	62	Cumene
$C_6H_{12}O_2$	131	2-Ethyl butanoic acid	C_9H_{12}	304	Propylbenzene
$C_6H_{12}O_2$	132	Ethyl butyrate	C_9H_{12}	330	1,2,3-Trimethylbenzene
$C_6H_{12}O_2$	172	Hexanoic acid	C_9H_{12}	331	1,2,4-Trimethylbenzene
$C_6H_{12}S$	72	Cyclohexyl mercaptan	$C_9H_{12}O$	22	Benzyl ethyl ether
C_6H_{14}	107	2,3-Dimethylbutane	C_9H_{14}	298	Propenylcyclohexene
C_6H_{14}	171	Hexane	C_9H_{16}	262	1-Nonyne
C_6H_{14}	234	2-Methylpentane	C_9H_{18}	260	1-Nonene
$C_6H_{14}O$	101	Di-isopropyl ether	$C_9H_{18}O$	255	Nonanal
$C_6H_{14}O$	173	1-Hexanol	$C_9H_{18}O_2$	233	2-Methyloctanoic acid
$C_6H_{14}O$	174	2-Hexanol	$C_9H_{18}O_2$	257	Nonanoic acid
$C_6H_{14}O$	235	Methyl pentyl ether	C_9H_{20}	256	Nonane
$C_6H_{14}S$	179	Hexyl mercaptan	$C_9H_{20}O$	258	1-Nonanol
$C_6H_{15}N$	100	Di-isopropyl amine	$C_9H_{20}O$	259	2-Nonanol
$C_6H_{15}N$	122	Dipropyl amine	$C_9H_{20}S$	261	Nonyl mercaptan
$C_6H_{15}N$	328	Triethyl amine	$C_{10}H_8$	246	Naphthalene
C_7H_5N	19	Benzonitrile	$C_{10}H_{10}O_4$	115	Dimethyl phthalate
$C_7H_5N_3O_6$	335	2,4,6-Trinitrotoluene	$C_{10}H_{10}O_4$	119	Dimethyl terephthalate
C_7H_5NO	292	Phenyl isocyanate	$C_{10}H_{12}$	321	1,2,3,4-Tetrahydronaphthalene
$C_7H_6O_2$	18	Benzoic acid	$C_{10}H_{14}$	40	Butylbenzene
C_7H_7NO	15	Benzamide	$C_{10}H_{18}$	79	1-Decyne

TABLE 2-7 Formula Index of Substances in Tables 2-8, 2-32, 2-141, 2-150, 2-153, 2-155, 2-156, 2-179, 2-312, 2-313, 2-314, and 2-315 (*Concluded*)

Formula	No.	Name	Formula	No.	Name
$C_{10}H_{20}$	77	1-Decene	D_2	80	Deuterium
$C_{10}H_{20}O$	73	Decanal	F_2	149	Fluorine
$C_{10}H_{20}O_2$	75	Decanoic acid	F_3N	250	Nitrogen trifluoride
$C_{10}H_{22}$	74	Decane	F_4Si	311	Silicon tetrafluoride
$C_{10}H_{22}O$	76	1-Decanol	F_6S	315	Sulfur hexafluoride
$C_{10}H_{22}S$	78	Decyl mercaptan	HBr	184	Hydrogen bromide
$C_{11}H_{24}$	336	Undecane	HCl	185	Hydrogen chloride
$C_{11}H_{24}O$	337	1-Undecanol	HF	187	Hydrogen fluoride
$C_{12}H_{10}$	24	Biphenyl	H_2	183	Hydrogen
$C_{12}H_{10}O$	121	Diphenyl ether	H_2O	342	Water
$C_{12}H_{26}$	123	Dodecane	H_2S	188	Hydrogen sulfide
$C_{13}H_{10}O$	20	Benzophenone	H_3N	12	Ammonia
$C_{13}H_{28}$	327	Tridecane	H_4N_2	182	Hydrazine
$C_{14}H_{10}$	290	Phenanthrene	He	157	Helium-4
$C_{14}H_{30}$	319	Tetradecane	NO	253	Nitric oxide
$C_{15}H_{32}$	277	Pentadecane	N_2	249	Nitrogen
$C_{16}H_{34}$	169	Hexadecane	N_2O	252	Nitrous oxide
$C_{17}H_{36}$	158	Heptadecane	Ne	247	Neon
$C_{18}H_{14}$	318	*o*-Terphenyl	O_2	275	Oxygen
$C_{18}H_{38}$	263	Octadecane	O_2S	314	Sulfur dioxide
$C_{19}H_{40}$	254	Nonadecane	O_3	276	Ozone
$C_{20}H_{42}$	124	Eicosane	O_3S	316	Sulfur trioxide
Cl_2	52	Chlorine			

TABLE 2-8 Vapor Pressure of Inorganic and Organic Liquids, ln P = C1 + C2/T + C3 ln T + C4 T^{C5}, P in Pa

No.	Name	Formula	CAS no.	C1	C2	C3	C4	C5	T_{min}, K	P at T_{min}	T_{max}, K	P at T_{max}
1	Acetaldehyde	C_2H_4O	75-07-0	193.69	–8,036.7	–29.502	4.3678E-02	1	150.15	3.23E–01	466	5.565E+06
2	Acetamide	C_2H_5NO	60-35-5	125.81	–12,376	–14.589	5.0824E-06	2	353.33	3.36E+02	761	6.569E+06
3	Acetic acid	$C_2H_4O_2$	64-19-7	53.27	–6,304.5	–4.2985	8.8865E-18	6	289.81	1.28E+03	591.95	5.739E+06
4	Acetic anhydride	$C_4H_6O_3$	108-24-7	100.95	–8,873.2	–11.451	6.1316E-06	2	200.15	2.20E–02	606	3.970E+06
5	Acetone	C_3H_6O	67-64-1	69.006	–5,599.6	–7.0985	6.2237E-06	2	178.45	2.79E+00	508.2	4.709E+06
6	Acetonitrile	C_2H_3N	75-05-8	58.302	–5,385.6	–5.4954	5.3634E-06	2	229.32	1.87E+02	545.5	4.852E+06
7	Acetylene	C_2H_2	74-86-2	39.63	–2,552.2	–2.78	2.3930E-16	6	192.4	1.27E+05	308.3	6.106E+06
8	Acrolein	C_3H_4O	107-02-8	138.4	–7,122.7	–19.638	2.6447E-02	1	185.45	1.03E+01	506	5.020E+06
9	Acrylic acid	$C_3H_4O_2$	79-10-7	46.745	–6,587.1	–3.2208	5.2253E-07	2	286.15	2.57E+02	615	5.661E+06
10	Acrylonitrile	C_3H_3N	107-13-1	87.604	–6,392.7	–10.101	1.0891E-05	2	189.63	3.68E+00	535	4.480E+06
11	Air	Mixture	132259-10-0	21.662	–692.39	–0.392	4.7574E-03	1	59.15	5.64E+03	132.45	3.793E+06
12	Ammonia	H_3N	7664-41-7	90.483	–4,669.7	–11.607	1.7194E-02	1	195.41	6.11E+03	405.65	1.130E+07
13	Anisole	C_7H_8O	100-66-3	128.06	–9,307.7	–16.693	1.4919E-02	1	235.65	2.45E+00	645.6	4.273E+06
14	Argon	Ar	7440-37-1	42.127	–1,093.1	–4.1425	5.7254E-05	2	83.78	6.87E+04	150.86	4.896E+06
15	Benzamide	C_7H_7NO	55-21-0	85.474	–11,932	–8.3348	1.2850E-18	6	403	3.55E+02	824	5.047E+06
16	Benzene	C_6H_6	71-43-2	83.107	–6,486.2	–9.2194	6.9844E-06	2	278.68	4.76E+03	562.05	4.875E+06
17	Benzenethiol	C_6H_6S	108-98-5	77.765	–8,455.1	–7.7404	4.3089E-18	6	258.27	7.68E+00	689	4.728E+06
18	Benzoic acid	$C_7H_6O_2$	65-85-0	88.513	–11,829	–8.6826	2.3248E-19	6	395.45	7.96E+02	751	4.469E+06
19	Benzonitrile	C_7H_5N	100-47-0	138.5	–11,195	–17.085	9.5641E-06	2	260.4	3.08E+00	699.35	4.243E+06
20	Benzophenone	$C_{13}H_{10}O$	119-61-9	88.404	–11,769	–8.9014	1.9334E-18	6	321.35	1.49E+00	830	3.357E+06
21	Benzyl alcohol	C_7H_8O	100-51-6	100.68	–11,059	–10.709	3.0582E-18	6	257.85	1.88E–01	720.15	4.372E+06
22	Benzyl ethyl ether	$C_9H_{12}O$	539-30-0	68.541	–7,886.2	–6.5804	2.4285E-06	2	275.65	2.31E+01	662	3.113E+06
23	Benzyl mercaptan	C_7H_8S	100-53-8	118.02	–10,527	–13.91	6.4794E-06	2	243.95	2.98E–01	718	4.074E+06
24	Biphenyl	$C_{12}H_{10}$	92-52-4	77.314	–9,910.4	–7.5079	2.2385E-18	6	342.2	9.42E+01	773	3.407E+06
25	Bromine	Br_2	7726-95-6	108.26	–6,592	–14.16	1.6043E-02	1	265.85	5.85E+03	584.15	1.028E+07
26	Bromobenzene	C_6H_5Br	108-86-1	63.749	–7,130.2	–5.879	5.2136E-18	6	242.43	7.84E+00	670.15	4.520E+06
27	Bromoethane	C_2H_5Br	74-96-4	62.217	–5,113.3	–5.9761	4.7174E-17	6	154.55	3.72E–01	503.8	6.290E+06
28	Bromomethane	CH_3Br	74-83-9	72.586	–4,698.6	–7.9966	1.1553E-05	2	179.47	1.95E+02	467	7.997E+06
29	1,2-Butadiene	C_4H_6	590-19-2	39.714	–3,769.9	–2.6407	6.9379E-18	6	136.95	4.47E–01	452	4.361E+06
30	1,3-Butadiene	C_4H_6	106-99-0	75.572	–4,621.9	–8.5323	1.2269E-05	2	164.25	6.92E+01	425	4.303E+06
31	Butane	C_4H_{10}	106-97-8	66.343	–4,363.2	–7.046	9.4509E-06	2	134.86	6.74E–01	425.12	3.770E+06
32	1,2-Butanediol	$C_4H_{10}O_2$	584-03-2	103.28	–11,548	–10.925	4.2560E-18	6	220	2.93E–04	680	5.202E+06
33	1,3-Butanediol	$C_4H_{10}O_2$	107-88-0	123.22	–12,620	–13.986	3.9260E-06	2	196.15	3.74E–07	676	4.033E+06
34	1-Butanol	$C_4H_{10}O$	71-36-3	106.295	–9,866.4	–11.655	1.0832E-17	6	183.85	2.90E–04	563.1	4.401E+06
35	2-Butanol	$C_4H_{10}O$	78-92-2	114.68	–9,850.2	–12.963	1.8738E-17	6	158.45	1.95E–06	535.9	4.182E+06
36	1-Butene	C_4H_8	106-98-9	51.836	–4,019.2	–4.5229	4.8833E-17	6	87.8	6.94E–07	419.5	4.021E+06
37	*cis*-2-Butene	C_4H_8	590-18-1	72.541	–4,691.2	–7.9776	1.0368E-05	2	134.26	2.72E–01	435.5	4.238E+06
38	*trans*-2-Butene	C_4H_8	624-64-6	71.704	–4,563.1	–7.9053	1.1319E-05	2	167.62	7.45E+01	428.6	4.100E+06
39	Butyl acetate	$C_6H_{12}O_2$	123-86-4	122.82	–9,253.2	–14.99	1.0470E-05	2	199.65	8.17E–02	575.4	3.087E+06
40	Butylbenzene	$C_{10}H_{14}$	104-51-8	101.22	–9,255.4	–11.538	5.9208E-06	2	185.3	1.54E–04	660.5	2.882E+06
41	Butyl mercaptan	$C_4H_{10}S$	109-79-5	65.382	–6,262.4	–6.2585	1.4943E-17	6	157.46	2.35E–03	570.1	3.973E+06
42	*sec*-Butyl mercaptan	$C_4H_{10}S$	513-53-1	60.649	–5,785.9	–5.6113	1.5877E-17	6	133.02	3.40E–05	554	4.060E+06
43	1-Butyne	C_4H_6	107-00-6	77.004	–5,054.5	–8.5665	1.0161E-05	2	147.43	1.18E+00	440	4.599E+06
44	Butyraldehyde	C_4H_8O	123-72-8	99.33	–7,083.6	–11.733	1.0027E-05	2	176.75	3.17E–01	537.2	4.323E+06
45	Butyric acid	$C_4H_8O_2$	107-92-6	93.815	–9,942.2	–9.8019	9.3124E-18	6	267.95	6.78E+00	615.7	4.071E+06
46	Butyronitrile	C_4H_7N	109-74-0	66.32	–6,714.9	–6.3087	1.3516E-17	6	161.25	6.18E–04	582.25	3.787E+06
47	Carbon dioxide	CO_2	124-38-9	140.54	–4,735	–21.268	4.0909E-02	1	216.58	5.19E+05	304.21	7.390E+06
48	Carbon disulfide	CS_2	75-15-0	67.114	–4,820.4	–7.5303	9.1695E-03	1	161.11	1.49E+00	552	8.041E+06
49	Carbon monoxide	CO	630-08-0	45.698	–1,076.6	–4.8814	7.5673E-05	2	68.15	1.54E+04	132.92	3.494E+06
50	Carbon tetrachloride	CCl_4	56-23-5	78.441	–6,128.1	–8.5766	6.8465E-06	2	250.33	1.12E+03	556.35	4.544E+06
51	Carbon tetrafluoride	CF_4	75-73-0	61.89	–2,296.3	–7.086	3.4687E-05	2	89.56	1.08E+02	227.51	3.742E+06
52	Chlorine	Cl_2	7782-50-5	71.334	–3,855	–8.5171	1.2378E-02	1	172.12	1.37E+03	417.15	7.793E+06
53	Chlorobenzene	C_6H_5Cl	108-90-7	54.144	–6,244.4	–4.5343	4.7030E-18	6	227.95	8.45E+00	632.35	4.529E+06
54	Chloroethane	C_2H_5Cl	75-00-3	65.988	–4,661.3	–6.8586	7.9404E-06	2	134.8	1.25E–01	460.35	5.327E+06
55	Chloroform	$CHCl_3$	67-66-3	146.43	–7,792.3	–20.614	2.4578E-02	1	207.15	5.25E+01	536.4	5.554E+06
56	Chloromethane	CH_3Cl	74-87-3	64.697	–4,048.1	–6.8066	1.0371E-05	2	175.43	8.71E+02	416.25	6.691E+06
57	1-Chloropropane	C_3H_7Cl	540-54-5	79.24	–5,718.8	–8.789	8.4486E-06	2	150.35	6.96E–02	503.15	4.581E+06
58	2-Chloropropane	C_3H_7Cl	75-29-6	46.854	–4,445.5	–3.6533	1.3260E-17	6	155.97	9.08E–01	489	4.510E+06
59	*m*-Cresol	C_7H_8O	108-39-4	95.403	–10,581	–10.004	4.3032E-18	6	285.39	5.86E+00	705.85	4.522E+06
60	*o*-Cresol	C_7H_8O	95-48-7	210.88	–13,928	–29.483	2.5182E-02	1	304.19	6.53E+01	697.55	5.058E+06

TABLE 2-8 Vapor Pressure of Inorganic and Organic Liquids, ln P = C1 + C2/T + C3 ln T + C4 T^{C5}, P in Pa (*Continued*)

No.	Name	Formula	CAS no.	C1	C2	C3	C4	C5	T_{min}, K	P at T_{min}	T_{max}, K	P at T_{max}
61	*p*-Cresol	C_7H_8O	106-44-5	118.53	−11,957	−13.293	8.6988E-18	6	307.93	3.45E+01	704.65	5.151E+06
62	Cumene	C_9H_{12}	98-82-8	102.81	−8,674.6	−11.922	7.0048E-06	2	177.14	4.71E−04	631	3.226E+06
63	Cyanogen	C_2N_2	460-19-5	81.565	−4,808.9	−9.3748	1.3901E-05	2	245.25	7.39E+04	400.15	5.961E+06
64	Cyclobutane	C_4H_8	287-23-0	85.899	−4,884.4	−10.883	1.4934E-02	1	182.48	1.80E+02	459.93	4.991E+06
65	Cyclohexane	C_6H_{12}	110-82-7	51.087	−5,226.4	−4.2278	9.7554E-18	6	279.69	5.36E+03	553.8	4.094E+06
66	Cyclohexanol	$C_6H_{12}O$	108-93-0	189.19	−14,337	−24.148	1.0740E-05	2	296.6	7.65E+01	650.1	4.265E+06
67	Cyclohexanone	$C_6H_{10}O$	108-94-1	85.424	−7,944.4	−9.2862	4.9957E-06	2	242	6.80E+00	653	3.989E+06
68	Cyclohexene	C_6H_{10}	110-83-8	88.184	−6,624.9	−10.059	8.2566E-06	2	169.67	1.04E−01	560.4	4.392E+06
69	Cyclopentane	C_5H_{10}	287-92-3	66.341	−5,198.5	−6.8103	6.1930E-06	2	179.28	9.07E+00	511.7	4.513E+06
70	Cyclopentene	C_5H_8	142-29-0	67.952	−5,187.5	−7.0785	6.8165E-06	2	138.13	1.28E−02	507	4.799E+06
71	Cyclopropane	C_3H_6	75-19-4	40.608	−3,179.6	−2.8937	5.6131E-17	6	145.59	7.80E+01	398	5.494E+06
72	Cyclohexyl mercaptan	$C_6H_{12}S$	1569-69-3	85.146	−7,843.7	−9.2982	5.1788E-06	2	189.64	8.24E−03	664	3.970E+06
73	Decanal	$C_{10}H_{20}O$	112-31-2	201.64	−15,133	−26.264	1.4625E-05	2	267.15	4.86E−01	674.2	2.599E+06
74	Decane	$C_{10}H_{22}$	124-18-5	112.73	−9,749.6	−13.245	7.1266E-06	2	243.51	1.39E+00	617.7	2.091E+06
75	Decanoic acid	$C_{10}H_{20}O_2$	334-48-5	123.36	−14,680	−13.474	1.9491E-18	6	304.55	1.50E−01	722.1	2.233E+06
76	1-Decanol	$C_{10}H_{22}O$	112-30-1	156.239	−15,212	−18.424	8.5006E-18	6	280.05	1.51E−01	688	2.309E+06
77	1-Decene	$C_{10}H_{20}$	872-05-9	68.401	−7,776.9	−6.4637	6.3750E-18	6	206.89	2.59E−02	616.6	2.223E+06
78	Decyl mercaptan	$C_{10}H_{22}S$	143-10-2	91.91	−10,565	−9.5957	5.7028E-18	6	247.56	2.59E−02	696	2.130E+06
79	1-Decyne	$C_{10}H_{18}$	764-93-2	142.94	−11,119	−17.818	1.1020E-05	2	229.15	1.60E−01	619.85	2.363E+06
80	Deuterium	D_2	7782-39-0	18.947	−154.47	−0.5723	3.8899E-02	1	18.73	1.72E+04	38.35	1.663E+06
81	1,1-Dibromoethane	$C_2H_4Br_2$	557-91-5	62.711	−6,503.5	−5.7669	1.0427E-06	2	210.15	2.64E+00	628	6.034E+06
82	1,2-Dibromoethane	$C_2H_4Br_2$	106-93-4	43.751	−5,587.7	−3.0891	8.2664E-07	2	282.85	7.53E+02	650.15	5.375E+06
83	Dibromomethane	CH_2Br_2	74-95-3	86.295	−7,010.3	−9.5972	6.7794E-06	2	220.6	2.13E+01	611	7.170E+06
84	Dibutyl ether	$C_8H_{18}O$	142-96-1	72.227	−7,537.6	−7.0596	9.1442E-18	6	175.3	7.14E−04	584.1	2.459E+06
85	*m*-Dichlorobenzene	$C_6H_4Cl_2$	541-73-1	53.187	−6,827.5	−4.3233	2.3112E-18	6	248.39	6.41E+00	683.95	4.070E+06
86	*o*-Dichlorobenzene	$C_6H_4Cl_2$	95-50-1	77.105	−8,111.1	−7.8886	2.7267E-06	2	256.15	6.49E+00	705	4.074E+06
87	*p*-Dichlorobenzene	$C_6H_4Cl_2$	106-46-7	88.31	−8,463.4	−9.6308	4.5833E-06	2	326.14	1.23E+03	684.75	4.070E+06
88	1,1-Dichloroethane	$C_2H_4Cl_2$	75-34-3	66.611	−5,493.1	−6.7301	5.3579E-06	2	176.19	2.21E+00	523	5.106E+06
89	1,2-Dichloroethane	$C_2H_4Cl_2$	107-06-2	92.355	−6,920.4	−10.651	9.1426E-06	2	237.49	2.37E+02	561.6	5.318E+06
90	Dichloromethane	CH_2Cl_2	75-09-2	101.6	−6,541.6	−12.247	1.2311E-05	2	178.01	5.93E+00	510	6.093E+06
91	1,1-Dichloropropane	$C_3H_6Cl_2$	78-99-9	83.495	−6,661.4	−9.2386	6.7652E-06	2	200	4.52E+00	560	4.239E+06
92	1,2-Dichloropropane	$C_3H_6Cl_2$	78-87-5	65.955	−6,015.6	−6.5509	4.3172E-06	2	172.71	8.25E−02	572	4.232E+06
93	Diethanol amine	$C_4H_{11}NO_2$	111-42-2	106.38	−13,714	−11.06	3.2645E-18	6	301.15	1.02E−01	736.6	4.260E+06
94	Diethyl amine	$C_4H_{11}N$	109-89-7	49.314	−4,949	−3.9256	9.1978E-18	6	223.35	3.74E+02	496.6	3.674E+06
95	Diethyl ether	$C_4H_{10}O$	60-29-7	136.9	−6,954.3	−19.254	2.4508E-02	1	156.85	3.95E−01	466.7	3.641E+06
96	Diethyl sulfide	$C_4H_{10}S$	352-93-2	46.705	−5,177.4	−3.5985	1.7147E-06	2	169.20	9.93E−02	557.15	3.961E+06
97	1,1-Difluoroethane	$C_2H_4F_2$	75-37-6	73.491	−4,385.9	−8.1851	1.2978E-05	2	154.56	6.45E+01	386.44	4.507E+06
98	1,2-Difluoroethane	$C_2H_4F_2$	624-72-6	84.625	−5,217.4	−9.871	1.3050E-05	2	215	2.83E+03	445	4.372E+06
99	Difluoromethane	CH_2F_2	75-10-5	69.132	−3,847.7	−7.5868	1.5065E-05	2	136.95	5.43E+01	351.255	5.760E+06
100	Di-isopropyl amine	$C_6H_{15}N$	108-18-9	462.84	−18,227	−73.734	9.2794E-02	1	176.85	4.47E−03	523.1	3.199E+06
101	Di-isopropyl ether	$C_6H_{14}O$	108-20-3	41.631	−4,668.7	−2.8551	6.3693E-04	1	187.65	6.86E+00	500.05	2.869E+06
102	Di-isopropyl ketone	$C_7H_{14}O$	565-80-0	50.868	−6,036.5	−4.066	1.1326E-06	2	204.81	8.21E−01	576	3.017E+06
103	1,1-Dimethoxyethane	$C_4H_{10}O_2$	534-15-6	53.637	−5,251.2	−4.5649	1.6754E-17	6	159.95	9.45E−02	507.8	3.773E+06
104	1,2-Dimethoxypropane	$C_5H_{12}O_2$	7778-85-0	62.097	−6,174.9	−5.715	1.2323E-17	6	226.1	4.50E+01	543	3.447E+06
105	Dimethyl acetylene	C_4H_6	503-17-3	66.592	−4,999.8	−6.8387	6.6793E-06	2	240.91	6.12E+03	473.2	4.870E+06
106	Dimethyl amine	C_2H_7N	124-40-3	71.738	−5,302	−7.3324	6.4200E-17	6	180.96	7.56E+01	437.2	5.258E+06
107	2,3-Dimethylbutane	C_6H_{14}	79-29-8	77.161	−5,691.1	−8.501	8.0325E-06	2	145.19	1.52E−02	500	3.130E+06
108	1,1-Dimethylcyclohexane	C_8H_{16}	590-66-9	81.184	−6,927	−8.8498	5.4580E-06	2	239.66	6.06E+01	591.15	2.939E+06
109	*cis*-1,2-Dimethylcyclohexane	C_8H_{16}	2207-01-4	78.952	−7,075.4	−8.4344	4.5035E-06	2	223.16	6.41E+00	606.15	2.939E+06
110	*trans*-1,2-Dimethylcyclohexane	C_8H_{16}	6876-23-9	78.429	−6,882.1	−8.4129	4.9831E-06	2	184.99	8.04E−02	596.15	2.938E+06
111	Dimethyl disulfide	$C_2H_6S_2$	624-92-0	81.045	−6,941.3	−8.777	5.5501E-06	2	188.44	2.07E−01	615	5.363E+06
112	Dimethyl ether	C_2H_6O	115-10-6	44.704	−3,525.6	−3.4444	5.4574E-17	6	131.65	3.05E+00	400.1	5.274E+06
113	*N,N*-Dimethyl formamide	C_3H_7NO	68-12-2	82.762	−7,955.5	−8.8038	4.2431E-06	2	212.72	1.95E−01	649.6	4.365E+06
114	2,3-Dimethylpentane	C_7H_{16}	565-59-3	78.335	−6,348.7	−8.5105	6.4311E-06	2	160	1.26E−02	537.3	2.882E+06
115	Dimethyl phthalate	$C_{10}H_{10}O_4$	131-11-3	72.517	−10,415	−6.755	1.3269E-06	2	274.18	3.72E−02	766	2.780E+06
116	Dimethylsilane	C_2H_8Si	1111-74-6	63.08	−4,062.3	−6.425	1.5115E-16	6	122.93	4.15E−01	402	3.561E+06
117	Dimethyl sulfide	C_2H_6S	75-18-3	84.39	−5,740.6	−9.6454	1.0073E-05	2	174.88	7.86E+00	503.04	5.533E+06
118	Dimethyl sulfoxide	C_2H_6OS	67-68-5	56.273	−7,620.6	−4.6279	4.3819E-07	2	291.67	5.02E+01	729	5.648E+06
119	Dimethyl terephthalate	$C_{10}H_{10}O_4$	120-61-6	43.541	−8,204.8	−2.7519	1.0466E-18	6	413.8	1.26E+03	772	2.778E+06
120	1,4-Dioxane	$C_4H_8O_2$	123-91-1	44.494	−5,406.7	−3.1287	2.8913E-18	6	284.95	2.53E+03	587	5.158E+06

121	Diphenyl ether	$C_{12}H_{10}O$	101-84-8	59.969	−8,585.5	−5.1538	1.9983E-18	6	300.03	7.09E+00	766.8	3.097E+06
122	Dipropyl amine	$C_6H_{15}N$	142-84-7	54	−6,018.5	−4.4981	9.9684E-18	6	210.15	3.69E+00	550	3.111E+06
123	Dodecane	$C_{12}H_{26}$	112-40-3	137.47	−11,976	−16.698	8.0906E-06	2	263.57	6.15E−01	658	1.822E+06
124	Eicosane	$C_{20}H_{42}$	112-95-8	203.66	−19,441	−25.525	8.8382E-06	2	309.58	9.26E−03	768	1.175E+06
125	Ethane	C_2H_6	74-84-0	51.857	−2,598.7	−5.1283	1.4913E-05	2	90.35	1.13E+00	305.32	4.852E+06
126	Ethanol	C_2H_6O	64-17-5	73.304	−7,122.3	−7.1424	2.8853E-06	2	159.05	4.96E−04	514	6.109E+06
127	Ethyl acetate	$C_4H_8O_2$	141-78-6	66.824	−6,227.6	−6.41	1.7914E-17	6	189.6	1.43E+00	523.3	3.850E+06
128	Ethyl amine	C_2H_7N	75-04-7	81.56	−5,596.9	−9.0779	8.7920E-06	2	192.15	1.52E+02	456.15	5.594E+06
129	Ethylbenzene	C_8H_{10}	100-41-4	89.063	−7,733.7	−9.917	5.9860E-06	2	178.2	3.91E−03	617.15	3.590E+06
130	Ethyl benzoate	$C_9H_{10}O_2$	93-89-0	52.923	−7,531.7	−4.2347	1.1835E-06	2	238.45	1.69E−01	698	3.203E+06
131	2-Ethyl butanoic acid	$C_6H_{12}O_2$	88-09-5	90.464	−10,243	−9.2836	5.2573E-18	6	258.15	4.63E−01	655	3.403E+06
132	Ethyl butyrate	$C_6H_{12}O_2$	105-54-4	57.661	−6,346.5	−5.032	8.2534E-18	6	175.15	1.04E−02	571	2.935E+06
133	Ethylcyclohexane	C_8H_{16}	1678-91-7	80.208	−7,203.2	−8.6023	4.5901E-06	2	161.84	3.57E−04	609.15	3.041E+06
134	Ethylcyclopentane	C_7H_{14}	1640-89-7	88.671	−7,012.7	−10.045	7.4578E-06	2	134.71	3.71E−06	569.5	3.412E+06
135	Ethylene	C_2H_4	74-85-1	53.963	−2,443	−5.5643	1.9079E-05	2	104	1.26E+02	282.34	5.032E+06
136	Ethylenediamine	$C_2H_8N_2$	107-15-3	73.51	−7,572.7	−7.1435	1.2124E-17	6	284.29	6.78E+02	593	6.290E+06
137	Ethylene glycol	$C_2H_6O_2$	107-21-1	84.09	−10,411	−8.1976	1.6536E-18	6	260.15	2.19E−01	720	8.257E+06
138	Ethyleneimine	C_2H_5N	151-56-4	66.51	−6,019.2	−6.3332	1.0394E-17	6	195.2	9.71E+00	537	6.850E+06
139	Ethylene oxide	C_2H_4O	75-21-8	91.944	−5,293.4	−11.682	1.4902E-02	1	160.65	7.79E+00	469.15	7.255E+06
140	Ethyl formate	$C_3H_6O_2$	109-94-4	73.833	−5,817	−7.809	6.3200E-06	2	193.55	1.81E+01	508.4	4.708E+06
141	2-Ethyl hexanoic acid	$C_8H_{16}O_2$	149-57-5	117.52	−12,991	−12.895	6.1306E-18	6	235	2.86E−04	674.6	2.788E+06
142	Ethylhexyl ether	$C_8H_{18}O$	5756-43-4	77.523	−7,978.8	−7.7757	1.0076E-17	6	180	7.60E−04	583	2.460E+06
143	Ethylisopropyl ether	$C_5H_{12}O$	625-54-7	57.723	−5,236.9	−5.2136	2.2998E-17	6	140	4.31E−03	489	3.415E+06
144	Ethylisopropyl ketone	$C_6H_{12}O$	565-69-5	57.459	−6,356.8	−4.9545	5.2015E-18	6	204.15	9.70E−01	567	3.293E+06
145	Ethyl mercaptan	C_2H_6S	75-08-1	65.551	−5,027.4	−6.6853	6.3208E-06	2	125.26	1.14E−03	499.15	5.492E+06
146	Ethyl propionate	$C_5H_{10}O_2$	105-37-3	105.64	−8,007	−12.477	9.0000E-06	2	199.25	7.80E−01	546	3.337E+06
147	Ethylpropyl ether	$C_5H_{12}O$	628-32-0	86.898	−6,646.4	−9.5758	5.9615E-17	6	145.65	1.61E−03	500.23	3.372E+06
148	Ethyltrichlorosilane	$C_2H_5Cl_3Si$	115-21-9	62.614	−6,148.2	−5.84	1.0900E-17	6	167.55	1.85E−02	559.95	3.320E+06
149	Fluorine	F_2	7782-41-4	42.393	−1,103.3	−4.1203	5.7815E-05	2	53.48	2.53E+02	144.12	5.167E+06
150	Fluorobenzene	C_6H_5F	462-06-6	51.915	−5,439	−4.2896	8.7527E-18	6	230.94	1.51E+02	560.09	4.544E+06
151	Fluoroethane	C_2H_5F	353-36-6	56.639	−3,576.5	−5.5801	9.8969E-06	2	129.95	8.37E+00	375.31	5.006E+06
152	Fluoromethane	CH_3F	593-53-3	59.123	−3,043.7	−6.1845	1.6637E-05	2	131.35	4.33E+02	317.42	5.875E+06
153	Formaldehyde	CH_2O	50-00-0	101.51	−4,917.2	−13.765	2.2031E-02	1	181.15	8.87E+02	408	6.594E+06
154	Formamide	CH_3NO	75-12-7	100.3	−10,763	−10.946	3.8503E-06	2	275.6	1.04E+00	771	7.751E+06
155	Formic acid	CH_2O_2	64-18-6	50.323	−5,378.2	−4.203	3.4697E-06	2	281.45	2.40E+03	588	5.807E+06
156	Furan	C_4H_4O	110-00-9	74.738	−5,417	−8.0636	7.4700E-06	2	187.55	5.00E+01	490.15	5.550E+06
157	Helium-4	He	7440-59-7	11.533	−8.99	0.6724	2.7430E-01	1	1.76	1.46E+03	5.2	2.285E+05
158	Heptadecane	$C_{17}H_{36}$	629-78-7	156.95	−15,557	−18.966	6.4559E-06	2	295.13	4.65E−02	736	1.344E+06
159	Heptanal	$C_7H_{14}O$	111-71-7	92.252	−8,349	−10.274	5.9252E-06	2	229.8	1.45E+00	616.8	3.155E+06
160	Heptane	C_7H_{16}	142-82-5	87.829	−6,996.4	−9.8802	7.2099E-06	2	182.57	1.83E−01	540.2	2.719E+06
161	Heptanoic acid	$C_7H_{14}O_2$	111-14-8	120.47	−13,106	−13.31	5.8384E-18	6	265.83	4.34E−02	677.3	3.039E+06
162	1-Heptanol	$C_7H_{16}O$	111-70-6	147.41	−13,466	−17.353	1.1284E-17	6	239.15	1.95E−02	632.3	3.013E+06
163	2-Heptanol	$C_7H_{16}O$	543-49-7	124.23	−11,637	−14.148	6.9486E-17	5.7	230	3.68E−02	608.3	2.995E+06
164	3-Heptanone	$C_7H_{14}O$	106-35-4	78.463	−8,077.2	−7.9062	8.0521E-18	6	234.15	2.30E+00	606.6	2.919E+06
165	2-Heptanone	$C_7H_{14}O$	110-43-0	75.494	−7,896.5	−7.5047	8.9130E-18	6	238.15	3.54E+00	611.4	2.946E+06
166	1-Heptene	C_7H_{14}	592-76-7	65.922	−6,189	−6.3629	2.0091E-17	6	154.12	1.86E−03	537.4	2.921E+06
167	Heptyl mercaptan	$C_7H_{16}S$	1639-09-4	79.858	−8,501.8	−8.1043	8.1501E-18	6	229.92	3.05E−01	645	2.772E+06
168	1-Heptyne	C_7H_{12}	628-71-7	59.083	−6,031.8	−5.3072	1.4357E-17	6	192.22	8.15E−01	547	3.209E+06
169	Hexadecane	$C_{16}H_{34}$	544-76-3	156.06	−15,015	−18.941	6.8172E-06	2	291.31	9.23E−02	723	1.411E+06
170	Hexanal	$C_6H_{12}O$	66-25-1	81.507	−7,776.8	−8.4516	1.5143E-17	6	217.15	1.25E+00	591	3.461E+06
171	Hexane	C_6H_{14}	110-54-3	104.65	−6,995.5	−12.702	1.2381E-05	2	177.83	9.02E−01	507.6	3.045E+06
172	Hexanoic acid	$C_6H_{12}O_2$	142-62-1	114.05	−12,332	−12.45	5.6253E-18	6	269.25	2.43E−01	660.2	3.284E+06
173	1-Hexanol	$C_6H_{14}O$	111-27-3	135.421	−12,288	−15.732	1.2701E-17	6	228.55	2.25E−02	611.3	3.441E+06
174	2-Hexanol	$C_6H_{14}O$	626-93-7	109.42	−10,449	−12.051	2.6122E-46	16	223	7.44E−02	585.3	3.298E+06
175	2-Hexanone	$C_6H_{12}O$	591-78-6	107.44	−8,528.6	−12.679	8.4606E-06	2	217.35	1.45E+00	587.61	3.286E+06
176	3-Hexanone	$C_6H_{12}O$	589-38-8	73.155	−7,242.9	−7.2569	1.2741E-17	6	217.5	2.22E+00	582.82	3.322E+06
177	1-Hexene	C_6H_{12}	592-41-6	51.024	−4,986.4	−4.2463	1.6768E-17	6	133.39	7.96E−04	504	3.212E+06
178	3-Hexyne	C_6H_{10}	928-49-4	47.091	−5,104	−3.6371	5.1621E-04	1	170.05	2.20E−01	544	3.540E+06
179	Hexyl mercaptan	$C_6H_{14}S$	111-31-9	68.467	−7,390.5	−6.5456	7.7611E-18	6	192.62	1.31E−02	623	3.079E+06
180	1-Hexyne	C_6H_{10}	693-02-7	133.2	−7,492.9	−18.405	2.2062E-02	1	141.25	3.92E−04	516.2	3.635E+06
181	2-Hexyne	C_6H_{10}	764-35-2	123.71	−7,639	−16.451	1.6495E-02	1	183.65	5.40E−01	549	3.530E+06
182	Hydrazine	H_4N_2	302-01-2	76.858	−7,245.2	−8.22	6.1557E-03	1	274.69	4.08E+02	653.15	1.473E+07
183	Hydrogen	H_2	1333-74-0	12.69	−94.896	1.1125	3.2915E-04	2	13.95	7.21E+03	33.19	1.315E+06

TABLE 2-8 Vapor Pressure of Inorganic and Organic Liquids, ln P = C1 + C2/T + C3 ln T + C4 T^{C5}, P in Pa (*Continued*)

No.	Name	Formula	CAS no.	C1	C2	C3	C4	C5	T_{min}, K	P at T_{min}	T_{max}, K	P at T_{max}
184	Hydrogen bromide	HBr	10035-10-6	29.315	−2,424.5	−1.1354	2.3806E-18	6	185.15	2.95E+04	363.15	8.463E+06
185	Hydrogen chloride	HCl	7647-01-0	104.27	−3,731.2	−15.047	3.1340E-02	1	158.97	1.35E+04	324.65	8.356E+06
186	Hydrogen cyanide	CHN	74-90-8	36.75	−3,927.1	−2.1245	3.8948E-17	6	259.83	1.87E+04	456.65	5.353E+06
187	Hydrogen fluoride	HF	7664-39-3	59.544	−4,143.8	−6.1764	1.4161E-05	2	189.79	3.37E+02	461.15	6.487E+06
188	Hydrogen sulfide	H_2S	7783-06-4	85.584	−3,839.9	−11.199	1.8848E-02	1	187.68	2.29E+04	373.53	8.999E+06
189	Isobutyric acid	$C_4H_8O_2$	79-31-2	110.38	−10,540	−12.262	1.4310E-17	6	227.15	7.82E−02	605	3.683E+06
190	Isopropyl amine	C_3H_9N	75-31-0	136.66	−7,201.5	−18.934	2.2255E-02	1	177.95	7.73E+00	471.85	4.540E+06
191	Malonic acid	$C_3H_4O_4$	141-82-2	122.92	−16,258	−13.113	2.0609E-18	6	407.95	7.03E+01	805	5.652E+06
192	Methacrylic acid	$C_4H_6O_2$	79-41-4	109.53	−10,410	−12.289	3.1990E-06	2	288.15	5.86E+01	662	4.812E+06
193	Methane	CH_4	74-82-8	39.205	−1,324.4	−3.4366	3.1019E-05	2	90.69	1.17E+04	190.56	4.590E+06
194	Methanol	CH_4O	67-56-1	82.718	−6,904.5	−8.8622	7.4664E-06	2	175.47	1.11E−01	512.5	8.146E+06
195	*N*-Methyl acetamide	C_3H_7NO	79-16-3	79.128	−9,523.9	−7.7355	3.1616E-18	6	301.15	2.86E+01	718	4.997E+06
196	Methyl acetate	$C_3H_6O_2$	79-20-9	61.267	−5,618.6	−5.6473	2.1080E-17	6	175.15	1.02E+00	506.55	4.695E+06
197	Methyl acetylene	C_3H_4	74-99-7	50.242	−3,811.9	−4.2526	6.5326E-17	6	170.45	4.15E+02	402.4	5.619E+06
198	Methyl acrylate	$C_4H_6O_2$	96-33-3	107.69	−7,027.2	−13.916	1.5185E-02	1	196.32	4.07E+00	536	4.277E+06
199	Methyl amine	CH_5N	74-89-5	75.206	−5,082.8	−8.0919	8.1130E-06	2	179.69	1.77E+02	430.05	7.414E+06
200	Methyl benzoate	$C_8H_8O_2$	93-58-3	84.828	−9,334.7	−8.7063	6.1723E-18	6	260.75	1.81E+00	693	3.590E+06
201	3-Methyl-1,2-butadiene	C_5H_8	598-25-4	66.575	−5,213.4	−6.7693	4.8106E-06	2	159.53	7.28E−01	490	3.831E+06
202	2-Methylbutane	C_5H_{12}	78-78-4	71.308	−4,976	−7.7169	8.7271E-06	2	113.25	1.21E−04	460.4	3.366E+06
203	2-Methylbutanoic acid	$C_5H_{10}O_2$	116-53-0	85.383	−9,575.4	−8.6164	5.6124E-18	6	193	6.94E−05	643	3.887E+06
204	3-Methyl-1-butanol	$C_5H_{12}O$	123-51-3	121.85	−10,976	−13.869	1.4283E-17	6	155.95	8.67E−09	577.2	3.916E+06
205	2-Methyl-1-butene	C_5H_{10}	563-46-2	93.131	−5,525.4	−11.852	1.4205E-02	1	135.58	2.05E−02	465	3.465E+06
206	2-Methyl-2-butene	C_5H_{10}	513-35-9	83.927	−5,640.5	−9.6453	1.1121E-05	2	139.39	1.94E−02	470	3.394E+06
207	2-Methyl-1-butene-3-yne	C_5H_6	78-80-8	95.453	−5,448.8	−12.384	1.5643E-02	1	160.15	2.92E+00	492	4.469E+06
208	Methylbutyl ether	$C_5H_{12}O$	628-28-4	60.164	−5,621.7	−5.53	1.8629E-17	6	157.48	2.99E−02	512.74	3.377E+06
209	Methylbutyl sulfide	$C_5H_{12}S$	628-29-5	96.344	−7,856.3	−11.058	7.3080E-06	2	175.3	4.61E−03	593	3.464E+06
210	3-Methyl-1-butyne	C_5H_8	598-23-2	69.459	−5,250	−7.1125	7.9289E-17	6	183.45	4.36E+01	463.2	4.199E+06
211	Methyl butyrate	$C_5H_{10}O_2$	623-42-7	71.87	−6,885.7	−7.0944	1.4903E-17	6	187.35	1.34E−01	554.5	3.480E+06
212	Methylchlorosilane	CH_5ClSi	993-00-0	95.984	−5,401.7	−11.829	1.8092E-05	2	139.05	4.12E−01	442	4.170E+06
213	Methylcyclohexane	C_7H_{14}	108-87-2	92.684	−7,080.8	−10.695	8.1366E-06	2	146.58	1.52E−04	572.1	3.486E+06
214	1-Methylcyclohexanol	$C_7H_{14}O$	590-67-0	134.63	−10,682	−16.511	8.4427E-06	2	299.15	2.57E+02	686	3.994E+06
215	*cis*-2-Methylcyclohexanol	$C_7H_{14}O$	7443-70-1	125.1	−10,288	−15.157	1.0918E-05	2	280.15	4.56E+01	614	3.808E+06
216	*trans*-2-Methylcyclohexanol	$C_7H_{14}O$	7443-52-9	54.179	−7,477.2	−4.22	3.5225E-18	6	269.15	1.62E+01	617	3.767E+06
217	Methylcyclopentane	C_6H_{12}	96-37-7	55.368	−5,149.8	−5.0136	3.2220E-06	2	130.73	2.25E−04	532.7	3.759E+06
218	1-Methylcyclopentene	C_6H_{10}	693-89-0	52.732	−5,286.9	−4.4509	1.0883E-17	6	146.62	3.98E−03	542	4.130E+06
219	3-Methylcyclopentene	C_6H_{10}	1120-62-3	52.601	−5,120.3	−4.4554	1.3288E-17	6	115	2.12E−06	526	4.129E+06
220	Methyldichlorosilane	CH_4Cl_2Si	75-54-7	79.788	−5,420	−9.0702	1.1489E-05	2	182.55	2.58E+01	483	3.964E+06
221	Methylethyl ether	C_3H_8O	540-67-0	78.586	−5,176.3	−8.7501	9.1727E-06	2	160	7.85E+00	437.8	4.433E+06
222	Methylethyl ketone	C_4H_8O	78-93-3	72.698	−6,143.6	−7.5779	5.6476E-06	2	186.48	1.39E+00	535.5	4.120E+06
223	Methylethyl sulfide	C_3H_8S	624-89-5	79.07	−6,114.1	−8.631	6.5333E-06	2	167.23	2.25E−01	533	4.261E+06
224	Methyl formate	$C_2H_4O_2$	107-31-3	77.184	−5,606.1	−8.392	7.8468E-06	2	174.15	6.88E+00	487.2	5.983E+06
225	Methylisobutyl ether	$C_5H_{12}O$	625-44-5	57.984	−5,339.6	−5.2362	2.0767E-17	6	150	2.13E−02	497	3.416E+06
226	Methylisobutyl ketone	$C_6H_{12}O$	108-10-1	80.503	−7,421.8	−8.379	1.8114E-17	6	189.15	6.99E−02	574.6	3.272E+06
227	Methyl Isocyanate	C_2H_3NO	624-83-9	57.612	−5,197.9	−5.1269	2.1702E-17	6	256.15	7.28E+03	488	5.480E+06
228	Methylisopropyl ether	$C_4H_{10}O$	598-53-8	53.867	−4,701	−4.7052	2.8791E-17	6	127.93	3.32E−03	464.48	3.764E+06
229	Methylisopropyl ketone	$C_5H_{10}O$	563-80-4	45.242	−5,324.4	−3.2551	3.0363E-18	6	180.15	2.95E−01	553.4	3.792E+06
230	Methylisopropyl sulfide	$C_4H_{10}S$	1551-21-9	52.82	−5,437.7	−4.442	9.5103E-18	6	171.64	1.80E−01	553.1	4.022E+06
231	Methyl mercaptan	CH_4S	74-93-1	54.15	−4,337.7	−4.8127	4.5000E-17	6	150.18	3.15E+00	469.95	7.231E+06
232	Methyl methacrylate	$C_5H_8O_2$	80-62-6	107.36	−8,085.3	−12.72	8.3307E-06	2	224.95	1.91E+01	566	3.674E+06
233	2-Methyloctanoic acid	$C_9H_{18}O_2$	3004-93-1	105.7	−12,458	−11.234	4.4629E-18	6	240	4.19E−04	694	2.545E+06
234	2-Methylpentane	C_6H_{14}	107-83-5	53.579	−5,041.2	−4.6404	1.9443E-17	6	119.55	2.07E−05	497.7	3.044E+06
235	Methyl pentyl ether	$C_6H_{14}O$	628-80-8	61.907	−6,188.9	−5.706	1.1767E-17	6	176	6.33E−02	546.49	3.041E+06
236	2-Methylpropane	C_4H_{10}	75-28-5	108.43	−5,039.9	−15.012	2.2725E-02	1	113.54	1.21E−02	407.8	3.630E+06
237	2-Methyl-2-propanol	$C_4H_{10}O$	75-65-0	172.27	−11,589	−22.113	1.3703E-05	2	298.97	5.88E+03	506.2	3.957E+06
238	2-Methyl propene	C_4H_8	115-11-7	78.01	−4,634.1	−8.9575	1.3413E-05	2	132.81	6.45E−01	417.9	4.004E+06
239	Methyl propionate	$C_4H_8O_2$	554-12-1	70.717	−6,439.7	−6.9845	2.0129E-17	6	185.65	6.34E−01	530.6	4.028E+06
240	Methylpropyl ether	$C_4H_{10}O$	557-17-5	67.942	−5,419.1	−6.8067	4.7778E-17	6	133.97	2.90E−03	476.25	3.802E+06
241	Methylpropyl sulfide	$C_4H_{10}S$	3877-15-4	83.711	−6,786.9	−9.2526	6.6666E-06	2	160.17	4.26E−03	565	3.972E+06
242	Methylsilane	CH_6Si	992-94-9	37.205	−2,590.3	−2.5993	6.0508E-06	2	116.34	1.43E+01	352.5	4.702E+06

243	α-Methyl styrene	C_9H_{10}	98-83-9	56.485	−6,954.2	−4.7889	2.7753E-18	6	249.95	9.23E+00	654	3.341E+06
244	Methyl *tert*-butyl ether	$C_5H_{12}O$	1634-04-4	57.1511	−5,201.7	−5.1429	1.6529E-17	6	164.55	4.93E−01	497.1	3.285E+06
245	Methyl vinyl ether	C_3H_6O	107-25-5	51.085	−4,271	−4.307	3.0530E-17	6	151.15	3.37E+00	437	4.583E+06
246	Naphthalene	$C_{10}H_8$	91-20-3	62.964	−8,137.5	−5.6317	2.2675E-18	6	353.43	9.91E+02	748.4	4.069E+06
247	Neon	Ne	7440-01-9	29.755	−271.06	−2.6081	5.2700E-04	2	24.56	4.38E+04	44.4	2.665E+06
248	Nitroethane	$C_2H_5NO_2$	79-24-3	75.632	−7,202.3	−7.6464	1.8250E-17	6	183.63	3.18E-02	593	5.159E+06
249	Nitrogen	N_2	7727-37-9	58.282	−1,084.1	−8.3144	4.4127E-02	1	63.15	1.25E+04	126.2	3.391E+06
250	Nitrogen trifluoride	F_3N	7783-54-2	68.149	−2,257.9	−8.9118	2.3233E-02	1	66.46	1.86E−01	234	4.500E+06
251	Nitromethane	CH_3NO_2	75-52-5	57.278	−6,089	−4.9821	1.2154E-17	6	244.6	1.47E+02	588.15	6.309E+06
252	Nitrous oxide	N_2O	10024-97-2	96.512	−4,045	−12.277	2.8860E-05	2	182.3	8.69E+04	309.57	7.278E+06
253	Nitric oxide	NO	10102-43-9	72.974	−2,650	−8.261	9.7000E-15	6	109.5	2.20E+04	180.15	6.516E+06
254	Nonadecane	$C_{19}H_{40}$	629-92-5	182.54	−17,897	−22.498	7.4008E-06	2	305.04	1.59E−02	758	1.208E+06
255	Nonanal	$C_9H_{18}O$	124-19-6	337.71	−18,506	−50.224	4.7345E-02	1	255.15	3.42E−01	658	2.743E+06
256	Nonane	C_9H_{20}	111-84-2	109.35	−9,030.4	−12.882	7.8544E-06	2	219.66	4.31E−01	594.6	2.305E+06
257	Nonanoic acid	$C_9H_{18}O_2$	112-05-0	137.6	−14,948	−15.618	5.5660E-18	6	285.55	4.71E−02	710.7	2.502E+06
258	1-Nonanol	$C_9H_{20}O$	143-08-8	162.854	−15,205	−19.424	1.0722E-17	6	268.15	8.55E−02	670.9	2.522E+06
259	2-Nonanol	$C_9H_{20}O$	628-99-9	146.46	−13,813	−17.158	8.6279E-40	14	238.15	4.32E−03	649.5	2.551E+06
260	1-Nonene	C_9H_{18}	124-11-8	63.313	−7,040.4	−5.8055	7.5753E-18	6	191.91	2.04E−02	593.1	2.427E+06
261	Nonyl mercaptan	$C_9H_{20}S$	1455-21-6	106.2	−10,982	−11.696	8.8955E-18	6	253.05	1.47E−01	681	2.330E+06
262	1-Nonyne	C_9H_{16}	3452-09-3	114.77	−9,430.8	−13.631	8.1918E-06	2	223.15	4.50E−01	598.05	2.620E+06
263	Octadecane	$C_{18}H_{38}$	593-45-3	157.68	−16,093	−18.954	5.9272E-06	2	301.31	3.39E−02	747	1.256E+06
264	Octanal	$C_8H_{16}O$	124-13-0	83.601	−8,865.8	−8.5711	7.9446E-18	6	246	1.46E+00	638.9	2.951E+06
265	Octane	C_8H_{18}	111-65-9	96.084	−7,900.2	−11.003	7.1802E-06	2	216.38	2.11E+00	568.7	2.467E+06
266	Octanoic acid	$C_8H_{16}O_2$	124-07-2	140.16	−14,813	−16.004	6.4239E-18	6	289.65	1.83E−01	694.26	2.761E+06
267	1-Octanol	$C_8H_{18}O$	111-87-5	144.111	−13,667	−16.826	9.3666E-18	6	257.65	9.60E−02	652.3	2.782E+06
268	2-Octanol	$C_8H_{18}O$	123-96-6	133.41	−12,630	−15.369	2.9939E-41	14	241.55	4.04E−02	629.8	2.754E+06
269	2-Octanone	$C_8H_{16}O$	111-13-7	63.775	−7,711.3	−5.7359	3.0902E-18	6	252.85	4.68E+00	632.7	2.647E+06
270	3-Octanone	$C_8H_{16}O$	106-68-3	72.382	−8,054.8	−7.0002	5.8276E-18	6	255.55	7.84E+00	627.7	2.705E+06
271	1-Octene	C_8H_{16}	111-66-0	74.936	−7,155.9	−7.5843	1.7106E-17	6	171.45	2.98E−03	566.9	2.663E+06
272	Octyl mercaptan	$C_8H_{18}S$	111-88-6	78.368	−8,855.4	−7.8202	5.6629E-18	6	223.95	3.05E−02	667.3	2.523E+06
273	1-Octyne	C_8H_{14}	629-05-0	64.612	−6,802.5	−6.0261	1.1013E-17	6	193.55	1.04E−01	574	2.880E+06
274	Oxalic acid	$C_2H_2O_4$	144-62-7	122.04	−16,050	−12.986	2.0871E-18	6	462.65	2.15E+03	804	7.060E+06
275	Oxygen	O_2	7782-44-7	51.245	−1,200.2	−6.4361	2.8405E-02	1	54.36	1.48E+02	154.58	5.021E+06
276	Ozone	O_3	10028-15-6	40.067	−2,204.8	−2.9351	7.7520E-16	6	80.15	7.35E−01	261	5.566E+06
277	Pentadecane	$C_{15}H_{32}$	629-62-9	135.57	−13,478	−16.022	5.6136E-06	2	283.07	1.29E−01	708	1.474E+06
278	Pentanal	$C_5H_{10}O$	110-62-3	149.58	−8,890	−20.697	2.2101E-02	1	182	5.23E−02	566.1	3.969E+06
279	Pentane	C_5H_{12}	109-66-0	78.741	−5,420.3	−8.8253	9.6171E-06	2	143.42	6.86E−02	469.7	3.364E+06
280	Pentanoic acid	$C_5H_{10}O_2$	109-52-4	101.7	−10,955	−10.829	7.1880E-18	6	239.15	3.28E−02	639.16	3.589E+06
281	1-Pentanol	$C_5H_{12}O$	71-41-0	114.748	−10,643	−12.858	1.2491E-17	6	195.56	5.48E−04	588.1	3.896E+06
282	2-Pentanol	$C_5H_{12}O$	6032-29-7	122.26	−10,774	−13.943	1.0700E-42	15	200	4.15E−03	561	3.709E+06
283	2-Pentanone	$C_5H_{10}O$	107-87-9	84.635	−7,078.4	−9.3	6.2702E-06	2	196.29	7.52E−01	561.08	3.706E+06
284	3-Pentanone	$C_5H_{10}O$	96-22-0	44.286	−5,415.1	−3.0913	1.8580E-18	6	234.18	7.34E+01	560.95	3.699E+06
285	1-Pentene	C_5H_{10}	109-67-1	46.994	−4,289.5	−3.7345	2.5424E-17	6	108.02	3.70E−05	464.8	3.562E+06
286	2-Pentyl mercaptan	$C_5H_{12}S$	2084-19-7	58.985	−6,193.1	−5.2746	7.3986E-18	6	160.75	1.77E−03	584.3	3.537E+06
287	Pentyl mercaptan	$C_5H_{12}S$	110-66-7	67.309	−6,880.8	−6.4449	1.0148E-17	6	197.45	2.01E−01	598	3.474E+06
288	1-Pentyne	C_5H_8	627-19-0	82.805	−5,683.8	−9.4301	1.0767E-05	2	167.45	2.40E+00	481.2	4.170E+06
289	2-Pentyne	C_5H_8	627-21-4	137.29	−7,447.1	−19.01	2.1415E-02	1	163.83	2.05E−01	519	4.020E+06
290	Phenanthrene	$C_{14}H_{10}$	85-01-8	72.958	−10,943	−6.7902	1.0850E-18	6	372.38	2.93E+01	869	2.902E+06
291	Phenol	C_6H_6O	108-95-2	95.444	−10,113	−10.09	6.7603E-18	6	314.06	1.88E+02	694.25	6.059E+06
292	Phenyl isocyanate	C_7H_5NO	103-71-9	86.779	−8,101.8	−9.5303	6.1367E-06	2	243.15	4.33E+00	653	4.063E+06
293	Phthalic anhydride	$C_8H_4O_3$	85-44-9	126.5	−12,551	−15.002	7.7521E-06	2	404.15	7.90E+02	791	4.734E+06
294	Propadiene	C_3H_4	463-49-0	57.069	−3,682.7	−5.5662	6.5133E-06	2	136.87	1.83E+01	394	5.218E+06
295	Propane	C_3H_8	74-98-6	59.078	−3,492.6	−6.0669	1.0919E-05	2	85.47	1.68E−04	369.83	4.214E+06
296	1-Propanol	C_3H_8O	71-23-8	84.6642	−8,307.2	−8.5767	7.5091E-18	6	146.95	4.28E−07	536.8	5.170E+06
297	2-Propanol	C_3H_8O	67-63-0	96.094	−8,575.4	−10.292	1.6665E-17	6	185.26	1.95E−02	508.3	4.783E+06
298	Propenylcyclohexene	C_9H_{14}	13511-13-2	64.268	−7,298.9	−5.9109	4.8482E-18	6	199	2.48E−02	636	3.130E+06
299	Propionaldehyde	C_3H_6O	123-38-6	80.581	−5,896.1	−8.9301	8.2236E-06	2	170	1.31E+00	504.4	4.919E+06
300	Propionic acid	$C_3H_6O_2$	79-09-4	54.552	−7,149.4	−4.2769	1.1843E-18	6	252.45	1.31E+01	600.81	4.608E+06
301	Propionitrile	C_3H_5N	107-12-0	82.699	−6,703.5	−9.1506	7.5424E-06	2	180.26	1.69E−01	564.4	4.191E+06
302	Propyl acetate	$C_5H_{10}O_2$	109-60-4	115.16	−8,433.9	−13.934	1.0346E-05	2	178.15	1.71E−02	549.73	3.366E+06
303	Propyl amine	C_3H_9N	107-10-8	58.398	−5,312.7	−5.2876	1.9913E-06	2	188.36	1.30E+01	496.95	4.738E+06
304	Propylbenzene	C_9H_{12}	103-65-1	91.379	−8,276.8	−10.176	5.6240E-06	2	173.55	1.81E−04	638.35	3.202E+06
305	Propylene	C_3H_6	115-07-1	43.905	−3,097.8	−3.4425	9.9989E-17	6	87.89	1.17E−03	364.85	4.599E+06

TABLE 2-8 Vapor Pressure of Inorganic and Organic Liquids, ln P = C1 + C2/T + C3 ln T + C4 T^{C5}, P in Pa (*Concluded*)

No.	Name	Formula	CAS no.	C1	C2	C3	C4	C5	T_{min}, K	P at T_{min}	T_{max}, K	P at T_{max}
306	Propyl formate	$C_4H_8O_2$	110-74-7	104.08	−7,535.9	−12.348	9.6020E−06	2	180.25	2.11E−01	538	4.031E+06
307	2-Propyl mercaptan	C_3H_8S	75-33-2	60.43	−5,276.9	−5.6572	2.6039E−17	6	142.61	9.73E−03	517	4.752E+06
308	Propyl mercaptan	C_3H_8S	107-03-9	62.165	−5,624	−5.8595	2.0597E−17	6	159.95	6.51E−02	536.6	4.627E+06
309	1,2-Propylene glycol	$C_3H_8O_2$	57-55-6	212.8	−15,420	−28.109	2.1564E−05	2	213.15	9.29E−05	626	6.041E+06
310	Quinone	$C_6H_4O_2$	106-51-4	48.651	−7,289.5	−3.4453	1.0068E−18	6	388.85	1.17E+04	683	5.925E+06
311	Silicon tetrafluoride	F_4Si	7783-61-1	272.85	−9,548.9	−40.089	6.3699E−15	6	186.35	2.21E+05	259	3.748E+06
312	Styrene	C_8H_8	100-42-5	105.93	−8,685.9	−12.42	7.5583E−06	2	242.54	1.06E+01	636	3.823E+06
313	Succinic acid	$C_4H_6O_4$	110-15-6	128.65	−16,958	−13.872	2.1559E−18	6	460.65	8.85E+02	806	4.727E+06
314	Sulfur dioxide	O_2S	7446-09-5	47.365	−4,084.5	−3.6469	1.7990E−17	6	197.67	1.67E+03	430.75	7.860E+06
315	Sulfur hexafluoride	F_6S	2551-62-4	29.16	−2,383.6	−1.1342			223.15	2.30E+05	318.69	3.771E+06
316	Sulfur trioxide	O_3S	7446-11-9	180.99	−12,060	−22.839	7.2350E−17	6	289.95	2.09E+04	490.85	8.192E+06
317	Terephthalic acid	$C_8H_6O_4$	100-21-0	248.72	−32,238	−30.009	4.7950E−06	2	700.15	4.57E+03	1113	3.943E+06
318	*o*-Terphenyl	$C_{18}H_{14}$	84-15-1	110.52	−14,045	−11.861	2.2121E−18	6	329.35	4.14E−01	857	2.974E+06
319	Tetradecane	$C_{14}H_{30}$	629-59-4	140.47	−13,231	−16.859	6.5877E−06	2	279.01	2.53E−01	693	1.569E+06
320	Tetrahydrofuran	C_4H_8O	109-99-9	54.898	−5,305.4	−4.7627	1.4291E−17	6	164.65	1.96E−01	540.15	5.203E+06
321	1,2,3,4-Tetrahydronaphthalene	$C_{10}H_{12}$	119-64-2	137.23	−10,620	−17.908	1.4506E−02	1	237.38	1.33E−01	720	3.624E+06
322	Tetrahydrothiophene	C_4H_8S	110-01-0	75.881	−6,910.6	−7.9499	4.4315E−06	2	176.99	1.54E−02	631.95	5.117E+06
323	2,2,3,3-Tetramethylbutane	C_8H_{18}	594-82-1	57.963	−5,901.5	−5.2048	9.1301E−18	6	373.96	8.69E+04	568	2.871E+06
324	Thiophene	C_4H_4S	110-02-1	93.193	−7,001.5	−10.738	8.2308E−06	2	234.94	1.86E+02	579.35	5.702E+06
325	Toluene	C_7H_8	108-88-3	76.945	−6,729.8	−8.179	5.3017E−06	2	178.18	4.75E−02	591.75	4.080E+06
326	1,1,2-Trichloroethane	$C_2H_3Cl_3$	79-00-5	54.153	−6,041.8	−4.5383	4.9833E−18	6	236.5	4.47E+01	602	4.447E+06
327	Tridecane	$C_{13}H_{28}$	629-50-5	137.45	−12,549	−16.543	7.1275E−06	2	267.76	2.51E−01	675	1.679E+06
328	Triethyl amine	$C_6H_{15}N$	121-44-8	56.55	−5,681.9	−4.9815	1.2363E−17	6	158.45	1.06E−02	535.15	3.037E+06
329	Trimethyl amine	C_3H_9N	75-50-3	134.68	−6,055.8	−19.415	2.8619E−02	1	156.08	9.92E+00	433.25	4.102E+06
330	1,2,3-Trimethylbenzene	C_9H_{12}	526-73-8	78.341	−8,019.8	−8.1458	3.8971E−06	2	247.79	3.71E+00	664.5	3.447E+06
331	1,2,4-Trimethylbenzene	C_9H_{12}	95-63-6	85.301	−8,215.9	−9.2166	4.7979E−06	2	229.33	6.93E−01	649.1	3.212E+06
332	2,2,4-Trimethylpentane	C_8H_{18}	540-84-1	84.912	−6,722.2	−9.5157	7.2244E−06	2	165.78	1.71E−02	543.8	2.550E+06
333	2,3,3-Trimethylpentane	C_8H_{18}	560-21-4	83.105	−6,903.7	−9.1858	6.4703E−06	2	172.22	1.68E−02	573.5	2.812E+06
334	1,3,5-Trinitrobenzene	$C_6H_3N_3O_6$	99-35-4	506.33	−37,483	−69.22	2.7381E−05	2	398.4	8.50E+00	846	3.410E+06
335	2,4,6-Trinitrotoluene	$C_7H_5N_3O_6$	118-96-7	302	−24,324	−40.13	1.7403E−05	2	354	9.36E−01	828	3.019E+06
336	Undecane	$C_{11}H_{24}$	1120-21-4	131	−11,143	−15.855	8.1871E−06	2	247.57	4.08E−01	639	1.949E+06
337	1-Undecanol	$C_{11}H_{24}O$	112-42-5	182.571	−17,112	−22.125	1.12835E−17	6	288.45	1.26E−01	703.9	2.120E+06
338	Vinyl acetate	$C_4H_6O_2$	108-05-4	57.406	−5,702.8	−5.0307	1.1042E−17	6	180.35	7.06E−01	519.13	3.930E+06
339	Vinyl acetylene	C_4H_4	689-97-4	55.682	−4,439.3	−5.0136	1.9650E−17	6	173.15	6.69E+01	454	4.887E+06
340	Vinyl chloride	C_2H_3Cl	75-01-4	91.432	−5,141.7	−10.981	1.4318E−05	2	119.36	1.92E−02	432	5.750E+06
341	Vinyl trichlorosilane	$C_2H_3Cl_3Si$	75-94-5	54.571	−5,561.5	−4.712	1.0702E−17	6	178.35	3.54E−01	543.15	3.058E+06
342	Water	H_2O	7732-18-5	73.649	−7,258.2	−7.3037	4.1653E−06	2	273.16	6.11E+02	647.096	2.193E+07
343	*m*-Xylene	C_8H_{10}	108-38-3	85.099	−7,615.9	−9.3072	5.5643E−06	2	225.3	3.18E+00	617	3.528E+06
344	*o*-Xylene	C_8H_{10}	95-47-6	90.405	−7,955.2	−10.086	5.9594E−06	2	247.98	2.18E+01	630.3	3.741E+06
345	*p*-Xylene	C_8H_{10}	106-42-3	88.72	−7,741.2	−9.8693	6.0770E−06	2	286.41	5.76E+02	616.2	3.501E+06

Vapor pressure P_s is calculated by

$$P_s = \exp(C1 + C2/T + C3 \ln T + C4T^{C5})$$

where P_s is in Pa and T is in K. All substances are listed by chemical family in Table 2-6 and by formula in Table 2-7.

Values in this table were taken from the Design Institute for Physical Properties (DIPPR) of the American Institute of Chemical Engineers (AIChE), copyright 2007 AIChE and reproduced with permission of AIChE and of the DIPPR Evaluated Process Design Data Project Steering Committee. Their source should be cited as R. L. Rowley, W. V. Wilding, J. L. Oscarson, Y. Yang, N. A. Zundel, T. E. Daubert, R. P. Danner, DIPPR® Data Compilation of Pure Chemical Properties, Design Institute for Physical Properties, AIChE, New York (2007).

The number of digits provided for values at T_{min} and T_{max} was chosen for uniformity of appearance and formatting; these do not represent the uncertainties of the physical quantities, but are the result of calculations from the standard thermophysical property formulations within a fixed format.

TABLE 2-9 Vapor Pressures of Inorganic Compounds, up to 1 atm*

Compound		Pressure, mmHg										Melting point, °C
		1	5	10	20	40	60	100	200	400	760	
Name	Formula	Temperature, °C										
Aluminum	Al	1284	1421	1487	1555	1635	1684	1749	1844	1947	2056	660
borohydride	$Al(BH_4)_3$		–52.2	–42.9	–32.5	–20.9	–13.4	–3.9	+11.2	28.1	45.9	–64.
bromide	$AlBr_3$	81.3	103.8	118.0	134.0	150.6	161.7	176.1	199.8	227.0	256.3	97.
chloride	Al_2Cl_6	100.0	116.4	123.8	131.8	139.9	145.4	152.0	161.8	171.6	180.2	192.4
fluoride	AlF_3	1238	1298	1324	1350	1378	1398	1422	1457	1496	1537	1040
iodide	AlI_3	178.0	207.7	225.8	244.2	265.0	277.8	294.5	322.0	354.0	385.5	
oxide	Al_2O_3	2148	2306	2385	2465	2549	2599	2665	2766	2874	2977	2050
Ammonia	NH_3	–109.1	–97.5	–91.9	–85.8	–79.2	–74.3	–68.4	–57.0	–45.4	–33.6	–77.7
heavy	ND_3						–74.0	–67.4	–57.0	–45.4	–33.4	–74.0
Ammonium bromide	NH_4Br	198.3	234.5	252.0	270.6	290.0	303.8	320.0	345.3	370.8	396.0	
carbamate	$N_2H_6CO_2$	–26.1	–10.4	–2.9	+5.3	14.0	19.6	26.7	37.2	48.0	58.3	
chloride	NH_4Cl	160.4	193.8	209.8	226.1	245.0	256.2	271.5	293.2	316.5	337.8	520
cyanide	NH_4CN	–50.6	–35.7	–28.6	–20.9	–12.6	–7.4	–0.5	+9.6	20.5	31.7	36
hydrogen sulfide	NH_4HS	–51.1	–36.0	–28.7	–20.8	–12.3	–7.0	0.0	+10.5	21.8	33.3	
iodide	NH_4I	210.9	247.0	263.5	282.8	302.8	316.0	331.8	355.8	381.0	404.9	
Antimony	Sb	886	984	1033	1084	1141	1176	1223	1288	1364	1440	630.5
tribromide	$SbBr_3$	93.9	126.0	142.7	158.3	177.4	188.1	203.5	225.7	250.2	275.0	96.6
trichloride	$SbCl_3$	49.2	71.4	85.2	100.6	117.8	128.3	143.3	165.9	192.2	219.0	73.4
pentachloride	$SbCl_5$	22.7	48.6	61.8	75.8	91.0	101.0	114.1				2.8
triiodide	SbI_3	163.6	203.8	223.5	244.8	267.8	282.5	303.5	333.8	368.5	401.0	167
trioxide	Sb_4O_6	574	626	666	729	812	873	957	1085	1242	1425	656
Argon	A	–218.2	–213.9	–210.9	–207.9	–204.9	–202.9	–200.5	–195.6	–190.6	–185.6	–189.2
Arsenic	As	372	416	437	459	483	498	518	548	579	610	814
Arsenic tribromide	$AsBr_3$	41.8	70.6	85.2	101.3	118.7	130.0	145.2	167.7	193.6	220.0	
trichloride	$AsCl_3$	–11.4	+11.7	+23.5	36.0	50.0	58.7	70.9	89.2	109.7	130.4	–18
trifluoride	AsF_3					–2.5	+4.2	13.2	26.7	41.4	56.3	–5.9
pentafluoride	AsF_5	–117.9	–108.0	–103.1	–98.0	–92.4	–88.5	–84.3	–75.5	–64.0	–52.8	–79.8
trioxide	As_2O_3	212.5	242.6	259.7	279.2	299.2	310.3	332.5	370.0	412.2	457.2	312.8
Arsine	AsH_3	–142.6	–130.8	–124.7	–117.7	–110.2	–104.8	–98.0	–87.2	–75.2	–62.1	–116.3
Barium	Ba		984	1049	1120	1195	1240	1301	1403	1518	1638	850
Beryllium borohydride	$Be(BH_4)_2$	+1.0	19.8	28.1	36.8	46.2	51.7	58.6	69.0	79.7	90.0	123
bromide	$BeBr_2$	289	325	342	361	379	390	405	427	451	474	490
chloride	$BeCl_2$	291	328	346	365	384	395	411	435	461	487	405
iodide	BeI_2	283	322	341	361	382	394	411	435	461	487	488
Bismuth	Bi	1021	1099	1136	1177	1217	1240	1271	1319	1370	1420	271
tribromide	$BiBr_3$		261	282	305	327	340	360	392	425	461	218
trichloride	$BiCl_3$		242	264	287	311	324	343	372	405	441	230
Diborane hydrobromide	B_2H_5Br	–93.3	–75.3	–66.3	–56.4	–45.4	–38.2	–29.0	–15.4	0.0	+16.3	–104.2
Borine carbonyl	BH_3CO	–139.2	–127.3	–121.1	–114.1	–106.6	–101.9	–95.3	–85.5	–74.8	–64.0	–137.0
triamine	$B_3N_3H_6$	–63.0	–45.0	–35.3	–25.0	–13.2	–5.8	+4.0	18.5	34.3	50.6	–58.2
Boron hydrides												
dihydrodecaborane	$B_{10}H_{14}$	60.0	80.8	90.2	100.0	117.4	127.8	142.3	163.8			99.6
dihydrodiborane	B_2H_6	–159.7	–149.5	–144.3	–138.5	–131.6	–127.2	–120.9	–111.2	–99.6	–86.5	–169
dihydropentaborane	B_5H_9		–40.4	–30.7	–20.0	–8.0	–0.4	+9.6	24.6	40.8	58.1	–47.0
tetrahydropentaborane	B_5H_{11}	–50.2	–29.9	–19.9	–9.2	+2.7	10.2	20.1	34.8	51.2	67.0	
tetrahydrotetraborane	B_4H_{10}	–90.9	–73.1	–64.3	–54.8	–44.3	–37.4	–28.1	–14.0	+0.8	16.1	–119.9
Boron tribromide	BBr_3	–41.4	–20.4	–10.1	+1.5	14.0	22.1	33.5	50.3	70.0	91.7	–45
trichloride	BCl_3	–91.5	–75.2	–66.9	–57.9	–47.8	–41.2	–32.4	–18.9	–3.6	+12.7	–107
trifluoride	BF_3	–154.6	–145.4	–141.3	–136.4	–131.0	–127.6	–123.0	–115.9	–108.3	–100.7	–126.8
Bromine	Br_2	–48.7	–32.8	–25.0	–16.8	–8.0	–0.6	+9.3	24.3	41.0	58.2	–7.3
pentafluoride	BrF_5	–69.3	–51.0	–41.9	–32.0	–21.0	–14.0	–4.5	+9.9	25.7	40.4	–61.4
Cadmium	Cd	394	455	484	516	553	578	611	658	711	765	320.9
chloride	$CdCl_2$		618	656	695	736	762	797	847	908	967	568
fluoride	CdF_2	1112	1231	1286	1344	1400	1436	1486	1561	1651	1751	520
iodide	CdI_2	416	481	512	546	584	608	640	688	742	796	385
oxide	CdO	1000	1100	1149	1200	1257	1295	1341	1409	1484	1559	
Calcium	Ca		926	983	1046	1111	1152	1207	1288	1388	1487	851
Carbon (graphite)	C	3586	3828	3946	4069	4196	4273	4373	4516	4660	4827	
dioxide	CO_2	–134.3	–124.4	–119.5	–114.4	–108.6	–104.8	–100.2	–93.0	–85.7	–78.2	–57.5
disulfide	CS_2	–73.8	–54.3	–44.7	–34.3	–22.5	–15.3	–5.1	+10.4	28.0	46.5	–110.8
monoxide	CO	–222.0	–217.2	–215.0	–212.8	–210.0	–208.1	–205.7	–201.3	–196.3	–191.3	–205.0
oxyselenide	COSe	–117.1	–102.3	–95.0	–86.3	–76.4	–70.2	–61.7	–49.8	–35.6	–21.9	
oxysulfide	COS	–132.4	–119.8	–113.3	–106.0	–98.3	–93.0	–85.9	–75.0	–62.7	–49.9	–138.8
selenosulfide	CSeS	–47.3	–26.5	–16.0	–4.4	+8.6	17.0	28.3	45.7	65.2	85.6	–75.2
subsulfide	C_3S_2	14.0	41.2	54.9	69.3	85.6	96.0	109.9	130.8			+0.4
tetrabromide	CBr_4					96.3	106.3	119.7	139.7	163.5	189.5	90.1
tetrachloride	CCl_4	–50.0	–30.0	–19.6	–8.2	+4.3	12.3	23.0	38.3	57.8	76.7	–22.6
tetrafluoride	CF_4	–184.6	–174.1	–169.3	–164.3	–158.8	–155.4	–150.7	–143.6	–135.5	–127.7	–183.7
Cesium	Cs	279	341	375	409	449	474	509	561	624	690	28.5
bromide	CsBr	748	838	887	938	993	1026	1072	1140	1221	1300	636
chloride	CsCl	744	837	884	934	989	1023	1069	1139	1217	1300	646
fluoride	CsF	712	798	844	893	947	980	1025	1092	1170	1251	683
iodide	CsI	738	828	873	923	976	1009	1055	1124	1200	1280	621

*Compiled from the extended tables published by D. R. Stull in *Ind. Eng. Chem.,* **39,** 517 (1947).

TABLE 2-9 Vapor Pressures of Inorganic Compounds, up to 1 atm (*Continued*)

Compound		Pressure, mmHg										Melting point, °C
		1	5	10	20	40	60	100	200	400	760	
Name	Formula	Temperature, °C										
Chlorine	Cl_2	−118.0	−106.7	−101.6	−93.3	−84.5	−79.0	−71.7	−60.2	−47.3	−33.8	−100.7
fluoride	ClF		−143.4	−139.0	−134.3	−128.8	−125.3	−120.8	−114.4	−107.0	−100.5	−145
trifluoride	ClF_3		−80.4	−71.8	−62.3	−51.3	−44.1	−34.7	−20.7	−4.9	+11.5	−83
monoxide	Cl_2O	−98.5	−81.6	−73.1	−64.3	−54.3	−48.0	−39.4	−26.5	−12.5	+2.2	−116
dioxide	ClO_2			−59.0	−51.2	−42.8	−37.2	−29.4	−17.8	−4.0	+11.1	−59
heptoxide	Cl_2O_7	−45.3	−23.8	−13.2	−2.1	+10.3	+18.2	29.1	44.6	62.2	78.8	−91
Chlorosulfonic acid	HSO_3Cl	32.0	53.5	64.0	75.3	87.6	95.2	105.3	120.0	136.1	151.0	−80
Chromium	Cr	1616	1768	1845	1928	2013	2067	2139	2243	2361	2482	1615
carbonyl	$Cr(CO)_6$	36.0	58.0	68.3	79.5	91.2	98.3	108.0	121.8	137.2	151.0	
oxychloride	CrO_2Cl_2	−18.4	+3.2	13.8	25.7	38.5	46.7	58.0	75.2	95.2	117.1	
Cobalt chloride	$CoCl_2$					770	801	843	904	974	1050	735
nitrosyl tricarbonyl	$Co(CO)_3NO$				−1.3	+11.0	18.5	29.0	44.4	62.0	80.0	−11
Columbium fluoride	CbF_5			86.3	103.0	121.5	133.2	148.5	172.2	198.0	225.0	75.5
Copper	Cu	1628	1795	1879	1970	2067	2127	2207	2325	2465	2595	1083
Cuprous bromide	Cu_2Br_2	572	666	718	777	844	887	951	1052	1189	1355	504
chloride	Cu_2Cl_2	546	645	702	766	838	886	960	1077	1249	1490	422
iodide	Cu_2I_2		610	656	716	786	836	907	1018	1158	1336	605
Cyanogen	C_2N_2	−95.8	−83.2	−76.8	−70.1	−62.7	−57.9	−51.8	−42.6	−33.0	−21.0	−34.4
bromide	CNBr	−35.7	−18.3	−10.0	−1.0	+8.6	14.7	22.6	33.8	46.0	61.5	58
chloride	CNCl	−76.7	−61.4	−53.8	−46.1	−37.5	−32.1	−24.9	−14.1	−2.3	+13.1	−6.5
fluoride	CNF	−134.4	−123.8	−118.5	−112.8	−106.4	−102.3	−97.0	−89.2	−80.5	−72.6	
Deuterium cyanide	DCN	−68.9	−54.0	−46.7	−38.8	−30.1	−24.7	−17.5	−5.4	+10.0	26.2	−12
Fluorine	F_2	−223.0	−216.9	−214.1	−211.0	−207.7	−205.6	−202.7	−198.3	−193.2	−187.9	−223
oxide	F_2O	−196.1	−186.6	−182.3	−177.8	−173.0	−170.0	−165.8	−159.0	−151.9	−144.6	−223.9
Germanium bromide	$GeBr_4$		43.3	56.8	71.8	88.1	98.8	113.2	135.4	161.6	189.0	26.1
chloride	$GeCl_4$	−45.0	−24.9	−15.0	−4.1	+8.0	16.2	27.5	44.4	63.8	84.0	−49.5
hydride	GeH_4	−163.0	−151.0	−145.3	−139.2	−131.6	−126.7	−120.3	−111.2	−100.2	−88.9	−165
Trichlorogermane	$GeHCl_3$	−41.3	−22.3	−13.0	−3.0	+8.8	16.2	26.5	41.6	58.3	75.0	−71.1
Tetramethylgermane	$Ge(CH_3)_4$	−73.2	−54.6	−45.2	−35.0	−23.4	−16.2	−6.3	+8.8	26.0	44.0	−88
Digermane	Ge_2H_6	−88.7	−69.8	−60.1	−49.9	−38.2	−30.7	−20.3	−4.7	+13.3	31.5	−109
Trigermane	Ge_3H_8	−36.9	−12.8	−0.9	+11.8	26.3	35.5	47.9	67.0	88.6	110.8	−105.6
Gold	Au	1869	2059	2154	2256	2363	2431	2521	2657	2807	2966	1063
Helium	He	−271.7	−271.5	−271.3	−271.1	−270.7	−270.6	−270.3	−269.8	−269.3	−268.6	
para-Hydrogen	H_2	−263.3	−261.9	−261.3	−260.4	−259.6	−258.9	−257.9	−256.3	−254.5	−252.5	−259.1
Hydrogen bromide	HBr	−138.8	−127.4	−121.8	−115.4	−108.3	−103.8	−97.7	−88.1	−78.0	−66.5	−87.0
chloride	HCl	−150.8	−140.7	−135.6	−130.0	−123.8	−119.6	−114.0	−105.2	−95.3	−84.8	−114.3
cyanide	HCN	−71.0	−55.3	−47.7	−39.7	−30.9	−25.1	−17.8	−5.3	+10.2	25.9	−13.2
fluoride	H_2F_2		−74.7	−65.8	−56.0	−45.0	−37.9	−28.2	−13.2	+2.5	19.7	−83.7
iodide	HI	−123.3	−109.6	−102.3	−94.5	−85.6	−79.8	−72.1	−60.3	−48.3	−35.1	−50.9
oxide (water)	H_2O	−17.3	+1.2	11.2	22.1	34.0	41.5	51.6	66.5	83.0	100.0	0.0
sulfide	H_2S	−134.3	−122.4	−116.3	−109.7	−102.3	−97.9	−91.6	−82.3	−71.8	−60.4	−85.5
disulfide	HSSH	−43.2	−24.4	−15.2	−5.1	+6.0	12.8	22.0	35.3	49.6	64.0	−89.7
selenide	H_2Se	−115.3	−103.4	−97.9	−91.8	−84.7	−80.2	−74.2	−65.2	−53.6	−41.1	−64
telluride	H_2Te	−96.4	−82.4	−75.4	−67.8	−59.1	−53.7	−45.7	−32.4	−17.2	−2.0	−49.0
Iodine	I_2	38.7	62.2	73.2	84.7	97.5	105.4	116.5	137.3	159.8	183.0	112.9
heptafluoride	IF_7	−87.0	−70.7	−63.0	−54.5	−45.3	−39.4	−31.9	−20.7	−8.3	+4.0	5.5
Iron	Fe	1787	1957	2039	2128	2224	2283	2360	2475	2605	2735	1535
pentacarbonyl	$Fe(CO)_5$		−6.5	+4.6	16.7	30.3	39.1	50.3	68.0	86.1	105.0	−21
Ferric chloride	Fe_2Cl_6	194.0	221.8	235.5	246.0	256.8	263.7	272.5	285.0	298.0	319.0	304
Ferrous chloride	$FeCl_2$			700	737	779	805	842	897	961	1026	
Krypton	Kr	−199.3	−191.3	−187.2	−182.9	−178.4	−175.7	−171.8	−165.9	−159.0	−152.0	−156.7
Lead	Pb	973	1099	1162	1234	1309	1358	1421	1519	1630	1744	327.5
bromide	$PbBr_2$	513	578	610	646	686	711	745	796	856	914	373
chloride	$PbCl_2$	547	615	648	684	725	750	784	833	893	954	501
fluoride	PbF_2		861	904	950	1003	1036	1080	1144	1219	1293	855
iodide	PbI_2	479	540	571	605	644	668	701	750	807	872	402
oxide	PbO	943	1039	1085	1134	1189	1222	1265	1330	1402	1472	890
sulfide	PbS	852	928	975	1005	1048	1074	1108	1160	1221	1281	1114
Lithium	Li	723	838	881	940	1003	1042	1097	1178	1273	1372	186
bromide	LiBr	748	840	888	939	994	1028	1076	1147	1226	1310	547
chloride	LiCl	783	880	932	987	1045	1081	1129	1203	1290	1382	614
fluoride	LiF	1047	1156	1211	1270	1333	1372	1425	1503	1591	1681	870
iodide	LiI	723	802	841	883	927	955	993	1049	1110	1171	446
Magnesium	Mg	621	702	743	789	838	868	909	967	1034	1107	651
chloride	$MgCl_2$	778	877	930	988	1050	1088	1142	1223	1316	1418	712
Manganese	Mn	1292	1434	1505	1583	1666	1720	1792	1900	2029	2151	1260
chloride	$MnCl_2$		736	778	825	879	913	960	1028	1108	1190	650
Mercury	Hg	126.2	164.8	184.0	204.6	228.8	242.0	261.7	290.7	323.0	357.0	−38.9
Mercuric bromide	$HgBr_2$	136.5	165.3	179.8	194.3	211.5	221.0	237.8	262.7	290.0	319.0	237
chloride	$HgCl_2$	136.2	166.0	180.2	195.8	212.5	222.2	237.0	256.5	275.5	304.0	277
iodide	HgI_2	157.5	189.2	204.5	220.0	238.2	249.0	261.8	291.0	324.2	354.0	259
Molybdenum	Mo	3102	3393	3535	3690	3859	3964	4109	4322	4553	4804	2622
hexafluoride	MoF_6	−65.5	−49.0	−40.8	−32.0	−22.1	−16.2	−8.0	+4.1	17.2	36.0	17
oxide	MoO_3	734	785	814	851	892	917	955	1014	1082	1151	795

TABLE 2-9 Vapor Pressures of Inorganic Compounds, up to 1 atm (*Continued*)

Compound		Pressure, mmHg										Melting point, °C
		1	5	10	20	40	60	100	200	400	760	
Name	Formula	Temperature, °C										
Neon	Ne	–257.3	–255.5	–254.6	–253.7	–252.6	–251.9	–251.0	–249.7	–248.1	–246.0	–248.7
Nickel	Ni	1810	1979	2057	2143	2234	2289	2364	2473	2603	2732	1452
carbonyl	$Ni(CO)_4$					–23.0	–15.9	–6.0	+8.8	25.8	42.5	–25
chloride	$NiCl_2$	671	731	759	789	821	840	866	904	945	987	1001
Nitrogen	N_2	–226.1	–221.3	–219.1	–216.8	–214.0	–212.3	–209.7	–205.6	–200.9	–195.8	–210.0
Nitric oxide	NO	–184.5	–180.6	–178.2	–175.3	–171.7	–168.9	–166.0	–162.3	–156.8	–151.7	–161
Nitrogen dioxide	NO_2	–55.6	–42.7	–36.7	–30.4	–23.9	–19.9	–14.7	–5.0	+8.0	21.0	–9.3
Nitrogen pentoxide	N_2O_5	–36.8	–23.0	–16.7	–10.0	–2.9	+1.8	7.4	15.6	24.4	32.4	30
Nitrous oxide	N_2O	–143.4	–133.4	–128.7	–124.0	–118.3	–114.9	–110.3	–103.6	–96.2	–85.5	–90.9
Nitrosyl chloride	NOCl					–60.2	–54.2	–46.3	–34.0	–20.3	–6.4	–64.5
fluoride	NOF	–132.0	–120.3	–114.3	–107.8	–100.3	–95.7	–88.8	–79.2	–68.2	–56.0	–134
Osmium tetroxide (yellow)	OsO_4	3.2	22.0	31.3	41.0	51.7	59.4	71.5	89.5	109.3	130.0	56
(white)	OsO_4	–5.6	+15.6	26.0	37.4	50.5	59.4	71.5	89.5	109.3	130.0	42
Oxygen	O_2	–219.1	–213.4	–210.6	–207.5	–204.1	–201.9	–198.8	–194.0	–188.8	–183.1	–218.7
Ozone	O_3	–180.4	–168.6	–163.2	–157.2	–150.7	–146.7	–141.0	–132.6	–122.5	–111.1	–251
Phosgene	$COCl_2$	–92.9	–77.0	–69.3	–60.3	–50.3	–44.0	–35.6	–22.3	–7.6	+8.3	–104
Phosphorus (yellow)	P	76.6	111.2	128.0	146.2	166.7	179.8	197.3	222.7	251.0	280.0	44.1
(violet)	P	237	271	287	306	323	334	349	370	391	417	590
tribromide	PBr_3	7.8	34.4	47.8	62.4	79.0	89.8	103.6	125.2	149.7	175.3	–40
trichloride	PCl_3	–51.6	–31.5	–21.3	–10.2	+2.3	10.2	21.0	37.6	56.9	74.2	–111.8
pentachloride	PCl_5	55.5	74.0	83.2	92.5	102.5	108.3	117.0	131.3	147.2	162.0	
Phosphine	PH_3					–129.4	–125.0	–118.8	–109.4	–98.3	–87.5	–132.5
Phosphonium bromide	PH_4Br	–43.7	–28.5	–21.2	–13.3	–5.0	+0.3	7.4	17.6	28.0	38.3	
chloride	PH_4Cl	–91.0	–79.6	–74.0	–68.0	–61.5	–57.3	–52.0	–44.0	–35.4	–27.0	–28.5
iodide	PH_4I	–25.2	–9.0	–1.1	+7.3	16.1	21.9	29.3	39.9	51.6	62.3	
Phosphorus trioxide	P_4O_6		39.7	53.0	67.8	84.0	94.2	108.3	129.0	150.3	173.1	22.5
pentoxide	P_4O_{10}	384	424	442	462	481	493	510	532	556	591	569
oxychloride	$POCl_3$			2.0	13.6	27.3	35.8	47.4	65.0	84.3	105.1	2
thiobromide	$PSBr_3$	50.0	72.4	83.6	95.5	108.0	116.0	126.3	141.8	157.8	175.0	38
thiochloride	$PSCl_3$	–18.3	+4.6	16.1	29.0	42.7	51.8	63.8	82.0	102.3	124.0	–36.2
Platinum	Pt	2730	3007	3146	3302	3469	3574	3714	3923	4169	4407	1755
Potassium	K	341	408	443	483	524	550	586	643	708	774	62.3
bromide	KBr	795	892	940	994	1050	1087	1137	1212	1297	1383	730
chloride	KCl	821	919	968	1020	1078	1115	1164	1239	1322	1407	790
fluoride	KF	885	988	1039	1096	1156	1193	1245	1323	1411	1502	880
hydroxide	KOH	719	814	863	918	976	1013	1064	1142	1233	1327	380
iodide	KI	745	840	887	938	995	1030	1080	1152	1238	1324	723
Radon	Rn	–144.2	–132.4	–126.3	–119.2	–111.3	–106.2	–99.0	–87.7	–75.0	–61.8	–71
Rhenium heptoxide	Re_2O_7	212.5	237.5	248.0	261.0	272.0	280.0	289.0	307.0	336.0	362.4	296
Rubidium	Rb	297	358	389	422	459	482	514	563	620	679	38.5
bromide	RbBr	781	876	923	975	1031	1066	1114	1186	1267	1352	682
chloride	RbCl	792	887	937	990	1047	1084	1133	1207	1294	1381	715
fluoride	RbF	921	982	1016	1052	1096	1123	1168	1239	1322	1408	760
iodide	RbI	748	839	884	935	991	1026	1072	1141	1223	1304	642
Selenium	Se	356	413	442	473	506	527	554	594	637	680	217
dioxide	SeO_2	157.0	187.7	202.5	217.5	234.1	244.6	258.0	277.0	297.7	317.0	340
hexafluoride	SeF_6	–118.6	–105.2	–98.9	–92.3	–84.7	–80.0	–73.9	–64.8	–55.2	–45.8	–34.7
oxychloride	$SeOCl_2$	34.8	59.8	71.9	84.2	98.0	106.5	118.0	134.6	151.7	168.0	8.5
tetrachloride	$SeCl_4$	74.0	96.3	107.4	118.1	130.1	137.8	147.5	161.0	176.4	191.5	
Silicon	Si	1724	1835	1888	1942	2000	2036	2083	2151	2220	2287	1420
dioxide	SiO_2			1732	1798	1867	1911	1969	2053	2141	2227	1710
tetrachloride	$SiCl_4$	–63.4	–44.1	–34.4	–24.0	–12.1	–4.8	+5.4	21.0	38.4	56.8	–68.8
tetrafluoride	SiF_4	–144.0	–134.8	–130.4	–125.9	–120.8	–117.5	–113.3	–170.2	–100.7	–94.8	–90
Trichlorofluorosilane	$SiFCl_3$	–92.6	–76.4	–68.3	–59.0	–48.8	–42.2	–33.2	–19.3	–4.0	+12.2	–120.8
Iodosilane	SiH_3I		–53.0	–47.7	–33.4	–21.8	–14.3	–4.4	+10.7	27.9	45.4	–57.0
Diiodosilane	SiH_2I_2		3.8	18.0	34.1	52.6	64.0	79.4	101.8	125.5	149.5	–1.0
Disiloxan	$(SiH_3)_2O$	–112.5	–95.8	–88.2	–79.8	–70.4	–64.2	–55.9	–43.5	–29.3	–15.4	–144.2
Trisilane	Si_3H_8	–68.9	–49.7	–40.0	–29.0	–16.9	–9.0	+1.6	17.8	35.5	53.1	–117.2
Trisilazane	$(SiH_3)_3N$	–68.7	–49.9	–40.4	–30.0	–18.5	–11.0	–1.1	+14.0	31.0	48.7	–105.7
Tetrasilane	Si_4H_{10}	–27.7	–6.2	+4.3	15.8	28.4	36.6	47.4	63.6	81.7	100.0	–93.6
Octachlorotrisilane	Si_3Cl_8	46.3	74.7	89.3	104.2	121.5	132.0	146.0	166.2	189.5	211.4	
Hexachlorodisiloxane	$(SiCl_3)_2O$	–5.0	17.8	29.4	41.5	55.2	63.8	75.4	92.5	113.6	135.6	–33.2
Hexachlorodisilane	Si_2Cl_6	+4.0	27.4	38.8	51.5	65.3	73.9	85.4	102.2	120.6	139.0	–1.2
Tribromosilane	$SiHBr_3$	–30.5	–8.0	+3.4	16.0	30.0	39.2	51.6	70.2	90.2	111.8	–73.5
Trichlorosilane	$SiHCl_3$	–80.7	–62.6	–53.4	–43.8	–32.9	–25.8	–16.4	–1.8	+14.5	31.8	–126.6
Trifluorosilane	$SiHF_3$	–152.0	–142.7	–138.2	–132.9	–127.3	–123.7	–118.7	–111.3	–102.8	–95.0	–131.4
Dibromosilane	SiH_2Br_2	–60.9	–40.0	–29.4	–18.0	–5.2	+3.2	14.1	31.6	50.7	70.5	–70.2
Difluorosilane	SiH_2F_2	–146.7	–136.0	–130.4	–124.3	–117.6	–113.3	–107.3	–98.3	–87.6	–77.8	
Monobromosilane	SiH_3Br		–85.7	–77.3	–68.3	–57.8	–51.1	–42.3	–28.6	–13.3	+2.4	–93.9
Monochlorosilane	SiH_3Cl	–117.8	–104.3	–97.7	–90.1	–81.8	–76.0	–68.5	–57.0	–44.5	–30.4	
Monofluorosilane	SiH_3F	–153.0	–145.5	–141.2	–136.3	–130.8	–127.2	–122.4	–115.2	–106.8	–98.0	
Tribromofluorosilane	$SiFBr_3$	–46.1	–25.4	–15.1	–3.7	+9.2	17.4	28.6	45.7	64.6	83.8	–82.5
Dichlorodifluorosilane	SiF_2Cl_2	–124.7	–110.5	–102.9	–94.5	–85.0	–78.6	–70.3	–58.0	–45.0	–31.8	–139.7
Trifluorobromosilane	SiF_3Br								–69.8	–55.9	–41.7	–70.5

TABLE 2-9 Vapor Pressures of Inorganic Compounds, up to 1 atm (*Concluded*)

Compound		Pressure, mmHg										Melting point, °C
		1	5	10	20	40	60	100	200	400	760	
Name	Formula	Temperature, °C										
Trifluorochlorosilane	SiF_3Cl	−144.0	−133.0	−127.0	−120.5	−112.8	−108.2	−101.7	−91.7	−81.0	−70.0	−142
Hexafluorodisilane	Si_2F_6	−81.0	−68.8	−63.1	−57.0	−50.6	−46.7	−41.7	−34.2	−26.4	−18.9	−18.6
Dichlorofluorobromosilane	$SiFCl_2Br$	−86.5	−68.4	−59.0	−48.8	−37.0	−29.0	−19.5	−3.2	+15.4	35.4	−112.3
Dibromochlorofluorosilane	$SiFClBr_2$	−65.2	−45.5	−35.6	−24.5	−12.0	−4.7	+6.3	23.0	43.0	59.5	−99.3
Silane	SiH_4	−179.3	−168.6	−163.0	−156.9	−150.3	−146.3	−140.5	−131.6	−122.0	−111.5	−185
Disilane	Si_2H_6	−114.8	−99.3	−91.4	−82.7	−72.8	−66.4	−57.5	−44.6	−29.0	−14.3	−132.6
Silver	Ag	1357	1500	1575	1658	1743	1795	1865	1971	2090	2212	960.5
chloride	AgCl	912	1019	1074	1134	1200	1242	1297	1379	1467	1564	455
iodide	AgI	820	927	983	1045	1111	1152	1210	1297	1400	1506	552
Sodium	Na	439	511	549	589	633	662	701	758	823	892	97.5
bromide	NaBr	806	903	952	1005	1063	1099	1148	1220	1304	1392	755
chloride	NaCl	865	967	1017	1072	1131	1169	1220	1296	1379	1465	800
cyanide	NaCN	817	928	983	1046	1115	1156	1214	1302	1401	1497	564
fluoride	NaF	1077	1186	1240	1300	1363	1403	1455	1531	1617	1704	992
hydroxide	NaOH	739	843	897	953	1017	1057	1111	1192	1286	1378	318
iodide	NaI	767	857	903	952	1005	1039	1083	1150	1225	1304	651
Strontium	Sr		847	898	953	1018	1057	1111	1192	1285	1384	800
Strontium oxide	SrO	2068	2198	2262	2333	2410						2430
Sulfur	S	183.8	223.0	243.8	264.7	288.3	305.5	327.2	359.7	399.6	444.6	112.8
monochloride	S_2Cl_2	−7.4	+15.7	27.5	40.0	54.1	63.2	75.3	93.5	115.4	138.0	−80
hexafluoride	SF_6	−132.7	−120.6	−114.7	−108.4	−101.5	−96.8	−90.9	−82.3	−72.6	−63.5	−50.2
Sulfuryl chloride	SO_2Cl_2		−35.1	−24.8	−13.4	−1.0	+7.2	17.8	33.7	51.3	69.2	−54.1
Sulfur dioxide	SO_2	−95.5	−83.0	−76.8	−69.7	−60.5	−54.6	−46.9	−35.4	−23.0	−10.0	−73.2
trioxide (α)	SO_3	−39.0	−23.7	−16.5	−9.1	−1.0	+4.0	10.5	20.5	32.6	44.8	16.8
trioxide (β)	SO_3	−34.0	−19.2	−12.3	−4.9	+3.2	8.0	14.3	23.7	32.6	44.8	32.3
trioxide (γ)	SO_3	−15.3	−2.0	+4.3	11.1	17.9	21.4	28.0	35.8	44.0	51.6	62.1
Tellurium	Te	520	605	650	697	753	789	838	910	997	1087	452
chloride	$TeCl_4$			233	253	273	287	304	330	360	392	224
fluoride	TeF_6	−111.3	−98.8	−92.4	−86.0	−78.4	−73.8	−67.9	−57.3	−48.2	−38.6	−37.8
Thallium	Tl	825	931	983	1040	1103	1143	1196	1274	1364	1457	3035
Thallous bromide	TlBr		490	522	559	598	621	653	703	759	819	460
chloride	TlCl		487	517	550	589	612	645	694	748	807	430
iodide	TlI	440	502	531	567	607	631	663	712	763	823	440
Thionyl bromide	$SOBr_2$	−6.7	+18.4	31.0	44.1	58.8	68.3	80.6	99.0	119.2	139.5	−52.2
Thionyl chloride	$SOCl_2$	−52.9	−32.4	−21.9	−10.5	+2.2	10.4	21.4	37.9	56.5	75.4	−104.5
Tin	Sn	1492	1634	1703	1777	1855	1903	1968	2063	2169	2270	231.9
Stannic bromide	$SnBr_4$		58.3	72.7	88.1	105.5	116.2	131.0	152.8	177.7	204.7	31.0
Stannous chloride	$SnCl_2$	316	366	391	420	450	467	493	533	577	623	246.8
Stannic chloride	$SnCl_4$	−22.7	−1.0	+10.0	22.0	35.2	43.5	54.7	72.0	92.1	113.0	−30.2
iodide	SnI_4		156.0	175.8	196.2	218.8	234.2	254.2	283.5	315.5	348.0	144.5
hydride	SnH_4	−140.0	−125.8	−118.5	−111.2	−102.3	−96.6	−89.2	−78.0	−65.2	−52.3	−149.9
Tin tetramethyl	$Sn(CH_3)_4$	−51.3	−31.0	−20.6	−9.3	+3.5	11.7	22.8	39.8	58.5	78.0	
trimethyl-ethyl	$Sn(CH_3)_3{\cdot}C_2H_5$	−30.0	−7.6	+3.8	16.1	30.0	38.4	50.0	67.3	87.6	108.8	
trimethyl-propyl	$Sn(CH_3)_3{\cdot}C_3H_7$	−12.0	+10.7	21.8	34.0	48.5	57.5	69.8	88.0	109.6	131.7	
Titanium chloride	$TiCl_4$	−13.9	+9.4	21.3	34.2	48.4	58.0	71.0	90.5	112.7	136.0	−30
Tungsten	W	3990	4337	4507	4690	4886	5007	5168	5403	5666	5927	3370
Tungsten hexafluoride	WF_6	−71.4	−56.5	−49.2	−41.5	−33.0	−27.5	−20.3	−10.0	+1.2	17.3	−0.5
Uranium hexafluoride	UF_6	−38.8	−22.0	−13.8	−5.2	+4.4	10.4	18.2	30.0	42.7	55.7	69.2
Vanadyl trichloride	$VOCl_3$	−23.2	+0.2	12.2	26.6	40.0	49.8	62.5	82.0	103.5	127.2	
Xenon	Xe	−168.5	−158.2	−152.8	−147.1	−141.2	−137.7	−132.8	−125.4	−117.1	−108.0	−111.6
Zinc	Zn	487	558	593	632	673	700	736	788	844	907	419.4
chloride	$ZnCl_2$	428	481	508	536	566	584	610	648	689	732	365
fluoride	ZnF_2	970	1055	1086	1129	1175	1207	1254	1329	1417	1497	872
diethyl	$Zn(C_2H_5)_2$	−22.4	0.0	+11.7	24.2	38.0	47.2	59.1	77.0	97.3	118.0	−28
Zirconium bromide	$ZrBr_4$	207	237	250	266	281	289	301	318	337	357	450
chloride	$ZrCl_4$	190	217	230	243	259	268	279	295	312	331	437
iodide	ZrI_4	264	297	311	329	344	355	369	389	409	431	499

TABLE 2-10 Vapor Pressures of Organic Compounds, up to 1 atm*

Compound		Pressure, mmHg										Melting point, °C
		1	5	10	20	40	60	100	200	400	760	
Name	Formula	Temperature, °C										
Acenaphthalene	$C_{12}H_{10}$		114.8	131.2	148.7	168.2	181.2	197.5	222.1	250.0	277.5	95
Acetal	$C_6H_{14}O_2$	−23.0	−2.3	+8.0	19.6	31.9	39.8	50.1	66.3	84.0	102.2	
Acetaldehyde	C_2H_4O	−81.5	−65.1	−56.8	−47.8	−37.8	−31.4	−22.6	−10.0	+4.9	20.2	−123.5
Acetamide	C_2H_5NO	65.0	92.0	105.0	120.0	135.8	145.8	158.0	178.3	200.0	222.0	81
Acetanilide	C_8H_9NO	114.0	146.6	162.0	180.0	199.6	211.8	227.2	250.5	277.0	303.8	113.5
Acetic acid	$C_2H_4O_2$	−17.2	+6.3	17.5	29.9	43.0	51.7	63.0	80.0	99.0	118.1	16.7
anhydride	$C_4H_6O_3$	1.7	24.8	36.0	48.3	62.1	70.8	82.2	100.0	119.8	139.6	−73
Acetone	C_3H_6O	−59.4	−40.5	−31.1	−20.8	−9.4	−2.0	+7.7	22.7	39.5	56.5	−94.6
Acetonitrile	C_2H_3N	−47.0	−26.6	−16.3	−5.0	+7.7	15.9	27.0	43.7	62.5	81.8	−41
Acetophenone	C_8H_8O	37.1	64.0	78.0	92.4	109.4	119.8	133.6	154.2	178.0	202.4	20.5
Acetyl chloride	C_2H_3OCl	−50.0	−35.0	−27.6	−19.6	−10.4	−4.5	+3.2	16.1	32.0	50.8	−112.0
Acetylene	C_2H_2	−142.9	−133.0	−128.2	−122.8	−116.7	−112.8	−107.9	−100.3	−92.0	−84.0	−81.5
Acridine	$C_{13}H_9N$	129.4	165.8	184.0	203.5	224.2	238.7	256.0	284.0	314.3	346.0	110.5
Acrolein (2-propenal)	C_3H_4O	−64.5	−46.0	−36.7	−26.3	−15.0	−7.5	+2.5	17.5	34.5	52.5	−87.7
Acrylic acid	$C_3H_4O_2$	+3.5	27.3	39.0	52.0	66.2	75.0	86.1	103.3	122.0	141.0	14
Adipic acid	$C_6H_{10}O_4$	159.5	191.0	205.5	222.0	240.5	251.0	265.0	287.8	312.5	337.5	152
Allene (propadiene)	C_3H_4	−120.6	−108.0	−101.0	−93.4	−85.2	−78.8	−72.5	−61.3	−48.5	−35.0	−136
Allyl alcohol (propen-1-ol-3)	C_3H_6O	−20.0	+0.2	10.5	21.7	33.4	40.3	50.0	64.5	80.2	96.6	−129
chloride (3-chloropropene)	C_3H_5Cl	−70.0	−52.0	−42.9	−32.8	−21.2	−14.1	−4.5	10.4	27.5	44.6	−136.4
isopropyl ether	$C_6H_{12}O$	−43.7	−23.1	−12.9	−1.8	+10.9	18.7	29.0	44.3	61.7	79.5	
isothiocyanate	C_4H_5NS	−2.0	+25.3	38.3	52.1	67.4	76.2	89.5	108.0	129.8	150.7	−80
n-propyl ether	$C_6H_{12}O$	−39.0	−18.2	−7.9	+3.7	16.4	25.0	35.8	52.6	71.4	90.5	
4-Allylveratrole	$C_{11}H_{14}O_2$	85.0	113.9	127.0	142.8	158.3	169.6	183.7	204.0	226.2	248.0	
iso-Amyl acetate	$C_7H_{14}O_2$	0.0	+23.7	35.2	47.8	62.1	71.0	83.2	101.3	121.5	142.0	
n-Amyl alcohol	$C_5H_{12}O$	+13.6	34.7	44.9	55.8	68.0	75.5	85.8	102.0	119.8	137.8	
iso-Amyl alcohol	$C_5H_{12}O$	+10.0	30.9	40.8	51.7	63.4	71.0	80.7	95.8	113.7	130.6	−117.2
sec-Amyl alcohol (2-pentanol)	$C_5H_{12}O$	+1.5	22.1	32.2	42.6	54.1	61.5	70.7	85.7	102.3	119.7	
tert-Amyl alcohol	$C_5H_{12}O$	−12.9	+7.2	17.2	27.9	38.8	46.0	55.3	69.7	85.7	101.7	−11.9
sec-Amylbenzene	$C_{11}H_{16}$	29.0	55.8	69.2	83.8	100.0	110.4	124.1	145.2	168.0	193.0	
iso-Amyl benzoate	$C_{12}H_{16}O_2$	72.0	104.5	121.6	139.7	158.3	171.4	186.8	210.2	235.8	262.0	
bromide (1-bromo-3-methylbutane)	$C_5H_{11}Br$	−20.4	+2.1	13.6	26.1	39.8	48.7	60.4	78.7	99.4	120.4	
n-butyrate	$C_9H_{18}O_2$	21.2	47.1	59.9	74.0	90.0	99.8	113.1	133.2	155.3	178.6	
formate	$C_6H_{12}O_2$	−17.5	+5.4	17.1	30.0	44.0	53.3	65.4	83.2	102.7	123.3	
iodide (1-iodo-3-methylbutane)	$C_5H_{11}I$	−2.5	+21.9	34.1	47.6	62.3	71.9	84.4	103.8	125.8	148.2	
isobutyrate	$C_9H_{18}O_2$	14.8	40.1	52.8	66.6	81.8	91.7	104.4	124.2	146.0	168.8	
Amyl isopropionate	$C_8H_{16}O_2$	+8.5	33.7	46.3	60.0	75.5	85.2	97.6	117.3	138.4	160.2	
iso-Amyl isovalerate	$C_{10}H_{20}O_2$	27.0	54.4	68.6	83.8	100.6	110.3	125.1	146.1	169.5	194.0	
n-Amyl levulinate	$C_{10}H_{18}O_3$	81.3	110.0	124.0	139.7	155.8	165.2	180.5	203.1	227.4	253.2	
iso-Amyl levulinate	$C_{10}H_{18}O_3$	75.6	104.0	118.8	134.4	151.7	162.6	177.0	198.1	222.7	247.9	
nitrate	$C_5H_{11}NO_3$	+5.2	28.8	40.3	53.5	67.6	76.3	88.6	106.7	126.5	147.5	
4-*tert*-Amylphenol	$C_{11}H_{16}O$		109.8	125.5	142.3	160.3	172.6	189.0	213.0	239.5	266.0	93
Anethole	$C_{10}H_{12}O$	62.6	91.6	106.0	121.8	139.3	149.8	164.2	186.1	210.5	235.3	22.5
Angelonitrile	C_5H_7N	−8.0	+15.0	28.0	41.0	55.8	65.2	77.5	96.3	117.7	140.0	
Aniline	C_6H_7N	34.8	57.9	69.4	82.0	96.7	106.0	119.9	140.1	161.9	184.4	−6.2
2-Anilinoethanol	$C_8H_{11}NO$	104.0	134.3	149.6	165.7	183.7	194.0	209.5	230.6	254.5	279.6	
Anisaldehyde	$C_8H_8O_2$	73.2	102.6	117.8	133.5	150.5	161.7	176.7	199.0	223.0	248.0	2.5
o-Anisidine (2-methoxyaniline)	C_7H_9NO	61.0	88.0	101.7	116.1	132.0	142.1	155.2	175.3	197.3	218.5	5.2
Anthracene	$C_{14}H_{10}$	145.0	173.5	187.2	201.9	217.5	231.8	250.0	279.0	310.2	342.0	217.5
Anthraquinone	$C_{14}H_8O_2$	190.0	219.4	234.2	248.3	264.3	273.3	285.0	314.6	346.2	379.9	286
Azelaic acid	$C_9H_{16}O_4$	178.3	210.4	225.5	242.4	260.0	271.8	286.5	309.6	332.8	356.5	106.5
Azelaldehyde	$C_9H_{18}O$	33.3	58.4	71.6	85.0	100.2	110.0	123.0	142.1	163.4	185.0	
Azobenzene	$C_{12}H_{10}N_2$	103.5	135.7	151.5	168.3	187.9	199.8	216.0	240.0	266.1	293.0	68
Benzal chloride (α,α-Dichlorotoluene)	$C_7H_6Cl_2$	35.4	64.0	78.7	94.3	112.1	123.4	138.3	160.7	187.0	214.0	−16.1
Benzaldehyde	C_7H_6O	26.2	50.1	62.0	75.0	90.1	99.6	112.5	131.7	154.1	179.0	−26
Benzanthrone	$C_{17}H_{10}O$	225.0	274.5	297.2	322.5	350.0	368.8	390.0	426.5			174
Benzene	C_6H_6	−36.7	−19.6	−11.5	−2.6	+7.6	15.4	26.1	42.2	60.6	80.1	+5.5
Benzenesulfonylchloride	$C_6H_5ClO_2S$	65.9	96.5	112.0	129.0	147.7	158.2	174.5	198.0	224.0	251.5	14.5
Benzil	$C_{14}H_{10}O_2$	128.4	165.2	183.0	202.8	224.5	238.2	255.8	283.5	314.3	347.0	95
Benzoic acid	$C_7H_6O_2$	96.0	119.5	132.1	146.7	162.6	172.8	186.2	205.8	227.0	249.2	121.7
anhydride	$C_{14}H_{10}O_3$	143.8	180.0	198.0	218.0	239.8	252.7	270.4	299.1	328.8	360.0	42
Benzoin	$C_{14}H_{12}O_2$	135.6	170.2	188.1	207.0	227.6	241.7	258.0	284.4	313.5	343.0	132
Benzonitrile	C_7H_5N	28.2	55.3	69.2	83.4	99.6	109.8	123.5	144.1	166.7	190.6	−12.9
Benzophenone	$C_{13}H_{10}O$	108.2	141.7	157.6	175.8	195.7	208.2	224.4	249.8	276.8	305.4	48.5
Benzotrichloride (α,α,α-Trichlorotoluene)	$C_7H_5Cl_3$	45.8	73.7	87.6	102.7	119.8	130.0	144.3	165.6	189.2	213.5	−21.2
Benzotrifluoride (α,α,α-Trifluorotoluene)	$C_7H_5F_3$	−32.0	−10.3	−0.4	12.2	25.7	34.0	45.3	62.5	82.0	102.2	−29.3
Benzoyl bromide	C_7H_5BrO	47.0	75.4	89.8	105.4	122.6	133.4	147.7	169.2	193.7	218.5	0
chloride	C_7H_5ClO	32.1	59.1	73.0	87.6	103.8	114.7	128.0	149.5	172.8	197.2	−0.5
nitrile	C_8H_5NO	44.5	71.7	85.5	100.2	116.6	127.0	141.0	161.3	185.0	208.0	33.5
Benzyl acetate	$C_9H_{10}O_2$	45.0	73.4	87.6	102.3	119.6	129.8	144.0	165.5	189.0	213.5	−51.5
alcohol	C_7H_8O	58.0	80.8	92.6	105.8	119.8	129.3	141.7	160.0	183.0	204.7	−15.3

*Compiled from the extended tables published by D. R. Stull in *Ind. Eng. Chem.*, **39,** 517 (1947). For information on fuels see Hibbard, N.A.C.A. Research Mem. E56I21, 1956. For methane see Johnson (ed.), WADD-TR-60-56, 1960.

TABLE 2-10 Vapor Pressures of Organic Compounds, up to 1 atm (*Continued*)

Compound		Pressure, mmHg										Melting point, °C
		1	5	10	20	40	60	100	200	400	760	
Name	Formula	Temperature, °C										
Benzylamine	C_7H_9N	29.0	54.8	67.7	81.8	97.3	107.3	120.0	140.0	161.3	184.5	
Benzyl bromide (α-bromotoluene)	C_7H_7Br	32.2	59.6	73.4	88.3	104.8	115.6	129.8	150.8	175.2	198.5	–4
chloride (α-chlorotoluene)	C_7H_7Cl	22.0	47.8	60.8	75.0	90.7	100.5	114.2	134.0	155.8	179.4	–39
cinnamate	$C_{16}H_{14}O_2$	173.8	206.3	221.5	239.3	255.8	267.0	281.5	303.8	326.7	350.0	39
Benzyldichlorosilane	$C_7H_8Cl_2Si$	45.3	70.2	83.2	96.7	111.8	121.3	133.5	152.0	173.0	194.3	
Benzyl ethyl ether	$C_9H_{12}O$	26.0	52.0	65.0	79.6	95.4	105.5	118.9	139.6	161.5	185.0	
phenyl ether	$C_{13}H_{12}O$	95.4	127.7	144.0	160.7	180.1	192.6	209.2	233.2	259.8	287.0	
isothiocyanate	C_8H_7NS	79.5	107.8	121.8	137.0	153.0	163.8	177.7	198.0	220.4	243.0	
Biphenyl	$C_{12}H_{10}$	70.6	101.8	117.0	134.2	152.5	165.2	180.7	204.2	229.4	254.9	69.5
1-Biphenyloxy-2,3-epoxypropane	$C_{15}H_{14}O_2$	135.3	169.9	187.2	205.8	226.3	239.7	255.0	280.4	309.8	340.0	
d-Bornyl acetate	$C_{12}H_{20}O_2$	46.9	75.7	90.2	106.0	123.7	135.7	149.8	172.0	197.5	223.0	29
Bornyl *n*-butyrate	$C_{14}H_{24}O_2$	74.0	103.4	118.0	133.8	150.7	161.8	176.4	198.0	222.2	247.0	
formate	$C_{11}H_{18}O_2$	47.0	74.8	89.3	104.0	121.2	131.7	145.8	166.4	190.2	214.0	
isobutyrate	$C_{14}H_{24}O_2$	70.0	99.8	114.0	130.0	147.2	157.6	172.2	194.2	218.2	243.0	
propionate	$C_{13}H_{22}O_2$	64.6	93.7	108.0	123.7	140.4	151.2	165.7	187.5	211.2	235.0	
Brassidic acid	$C_{22}H_{42}O_2$	209.6	241.7	256.0	272.9	290.0	301.5	316.2	336.8	359.6	382.5	61.5
Bromoacetic acid	$C_2H_3BrO_2$	54.7	81.6	94.1	108.2	124.0	133.8	146.3	165.8	186.7	208.0	49.5
4-Bromoanisole	C_7H_7BrO	48.8	77.8	91.9	107.8	125.0	136.0	150.1	172.7	197.5	223.0	12.5
Bromobenzene	C_6H_5Br	+2.9	27.8	40.0	53.8	68.6	78.1	90.8	110.1	132.3	156.2	–30.7
4-Bromobiphenyl	$C_{12}H_9Br$	98.0	133.7	150.6	169.8	190.8	204.5	221.8	248.2	277.7	310.0	90.5
1-Bromo-2-butanol	C_4H_9BrO	23.7	45.4	55.8	67.2	79.5	87.0	97.6	112.1	128.3	145.0	
1-Bromo-2-butanone	C_4H_7BrO	+6.2	30.0	41.8	54.2	68.2	77.3	89.2	107.0	126.3	147.0	
cis-1-Bromo-1-butene	C_4H_7Br	–44.0	–23.2	–12.8	–1.4	+11.5	19.8	30.8	47.8	66.8	86.2	
trans-1-Bromo-1-butene	C_4H_7Br	–38.4	–17.0	–6.4	+5.4	18.4	27.2	38.1	55.7	75.0	94.7	–100.3
2-Bromo-1-butene	C_4H_7Br	–47.3	–27.0	–16.8	–5.3	+7.2	15.4	26.3	42.8	61.9	81.0	–133.4
cis-2-Bromo-2-butene	C_4H_7Br	–39.0	–17.9	–7.2	+4.6	17.7	26.2	37.5	54.5	74.0	93.9	–111.2
trans-2-Bromo-2-butene	C_4H_7Br	–45.0	–24.1	–13.8	–2.4	+10.5	18.7	29.9	46.5	66.0	85.5	–114.6
1,4-Bromochlorobenzene	C_6H_4BrCl	32.0	59.5	72.7	87.8	103.8	114.8	128.0	149.5	172.6	196.9	
1-Bromo-1-chloroethane	C_2H_4BrCl	–36.0	–18.0	–9.4	0.0	+10.4	17.0	28.0	44.7	63.4	82.7	16.6
1-Bromo-2-chloroethane	C_2H_4BrCl	–28.8	–7.0	+4.1	16.0	29.7	38.0	49.5	66.8	86.0	106.7	–16.6
2-Bromo-4,6-dichlorophenol	$C_6H_3BrCl_2O$	84.0	115.6	130.8	147.7	165.8	177.6	193.2	216.5	242.0	268.0	68
1-Bromo-4-ethyl benzene	C_8H_9Br	30.4	42.5	74.0	90.2	108.5	121.0	135.5	156.5	182.0	206.0	–45.0
(2-Bromoethyl)-benzene	C_8H_9Br	48.0	76.2	90.5	105.8	123.2	133.8	148.2	169.8	194.0	219.0	
2-Bromoethyl 2-chloroethyl ether	C_4H_8BrClO	36.5	63.2	76.3	90.8	106.6	116.4	129.8	150.0	172.3	195.8	
(2-Bromoethyl)-cyclohexane	$C_8H_{15}Br$	38.7	66.6	80.5	95.8	113.0	123.7	138.0	160.0	186.2	213.0	
1-Bromoethylene	C_2H_3Br	–95.4	–77.8	–68.8	–58.8	–48.1	–41.2	–31.9	–17.2	–1.1	+15.8	–138
Bromoform (tribromomethane)	$CHBr_3$		22.0	34.0	48.0	63.6	73.4	85.9	106.1	127.9	150.5	8.5
1-Bromonaphthalene	$C_{10}H_7Br$	84.2	117.5	133.6	150.2	170.2	183.5	198.8	224.2	252.0	281.1	5.5
2-Bromo-4-phenylphenol	$C_{12}H_9BrO$	100.0	135.4	152.3	171.8	193.8	207.0	224.5	251.0	280.2	311.0	95
3-Bromopyridine	C_5H_4BrN	16.8	42.0	55.2	69.1	84.1	94.1	107.8	127.7	150.0	173.4	
2-Bromotoluene	C_7H_7Br	24.4	49.7	62.3	76.0	91.0	100.0	112.0	133.6	157.3	181.8	–28
3-Bromotoluene	C_7H_7Br	14.8	50.8	64.0	78.1	93.9	104.1	117.8	138.0	160.0	183.7	39.8
4-Bromotoluene	C_7H_7Br	10.3	47.5	61.1	75.2	91.8	102.3	116.4	137.4	160.2	184.5	28.5
3-Bromo-2,4,6-trichlorophenol	$C_6H_2BrCl_3O$	112.4	146.2	163.2	181.8	200.5	213.0	229.3	253.0	278.0	305.8	
2-Bromo-1,4-xylene	C_8H_9Br	37.5	65.0	78.8	94.0	110.6	121.6	135.7	156.4	181.0	206.7	+9.5
1,2-Butadiene (methyl allene)	C_4H_6	–89.0	–72.7	–64.2	–54.9	–44.3	–37.5	–28.3	–14.2	+1.8	18.5	
1,3-Butadiene	C_4H_6	–102.8	–87.6	–79.7	–71.0	–61.3	–55.1	–46.8	–33.9	–19.3	–4.5	–108.9
n-Butane	C_4H_{10}	–101.5	–85.7	–77.8	–68.9	–59.1	–52.8	–44.2	–31.2	–16.3	–0.5	–135
iso-Butane (2-methylpropane)	C_4H_{10}	–109.2	–94.1	–86.4	–77.9	–68.4	–62.4	–54.1	–41.5	–27.1	–11.7	–145
1,3-Butanediol	$C_4H_{10}O_2$	22.2	67.5	85.3	100.0	117.4	127.5	141.2	161.0	183.8	206.5	77
1,2,3-Butanetriol	$C_4H_{10}O_3$	102.0	132.0	146.0	161.0	178.0	188.0	202.5	222.0	243.5	264.0	
1-Butene	C_4H_8	–104.8	–89.4	–81.6	–73.0	–63.4	–57.2	–48.9	–36.2	–21.7	–6.3	–130
cis-2-Butene	C_4H_8	–96.4	–81.1	–73.4	–64.6	–54.7	–48.4	–39.8	–26.8	–12.0	+3.7	–138.9
trans-2-Butene	C_4H_8	–99.4	–84.0	–76.3	–67.5	–57.6	–51.3	–42.7	–29.7	–14.8	+0.9	–105.4
3-Butenenitrile	C_4H_5N	–19.6	+2.9	14.1	26.6	40.0	48.8	60.2	78.0	98.0	119.0	
iso-Butyl acetate	$C_6H_{12}O_2$	–21.2	+1.4	12.8	25.5	39.2	48.0	59.7	77.6	97.5	118.0	–98.9
n-Butyl acrylate	$C_7H_{12}O_2$	–0.5	+23.5	35.5	48.6	63.4	72.6	85.1	104.0	125.2	147.4	–64.6
alcohol	$C_4H_{10}O$	–1.2	+20.0	30.2	41.5	53.4	60.3	70.1	84.3	100.8	117.5	–79.9
iso-Butyl alcohol	$C_4H_{10}O$	–9.0	+11.6	21.7	32.4	44.1	51.7	61.5	75.9	91.4	108.0	–108
sec-Butyl alcohol	$C_4H_{10}O$	–12.2	+7.2	16.9	27.3	38.1	45.2	54.1	67.9	83.9	99.5	–114.7
tert-Butyl alcohol	$C_4H_{10}O$	–20.4	–3.0	+5.5	14.3	24.5	31.0	39.8	52.7	68.0	82.9	25.3
iso-Butyl amine	$C_4H_{11}N$	–50.0	–31.0	–21.0	–10.3	+1.3	8.8	18.8	32.0	50.7	68.6	–85.0
n-Butylbenzene	$C_{10}H_{14}$	22.7	48.8	62.0	76.3	92.4	102.6	116.2	136.9	159.2	183.1	–88.0
iso-Butylbenzene	$C_{10}H_{14}$	14.1	40.5	53.7	67.8	83.3	93.3	107.0	127.2	149.6	172.8	–51.5
sec-Butylbenzene	$C_{10}H_{14}$	18.6	44.2	57.0	70.6	86.2	96.0	109.5	128.8	150.3	173.5	–75.5
tert-Butylbenzene	$C_{10}H_{14}$	13.0	39.0	51.7	65.6	80.8	90.6	103.8	123.7	145.8	168.5	–58
iso-Butyl benzoate	$C_{11}H_{14}O_2$	64.0	93.6	108.6	124.2	141.8	152.0	166.4	188.2	212.8	237.0	
n-Butyl bromide (1-bromobutane)	C_4H_9Br	–33.0	–11.2	–0.3	+11.6	24.8	33.4	44.7	62.0	81.7	101.6	–112.4
iso-Butyl *n*-butyrate	$C_8H_{16}O_2$	+4.6	30.0	42.2	56.1	71.7	81.3	94.0	113.9	135.7	156.9	
carbamate	$C_5H_{11}NO_2$		83.7	96.4	110.1	125.3	134.6	147.2	165.7	186.0	206.5	65
Butyl carbitol (diethylene glycol butyl ether)	$C_8H_{18}O_3$	70.0	95.7	107.8	120.5	135.5	146.0	159.8	181.2	205.0	231.2	
n-Butyl chloride (1-chlorobutane)	C_4H_9Cl	–49.0	–28.9	–18.6	–7.4	+5.0	13.0	24.0	40.0	58.8	77.8	–123.1
iso-Butyl chloride	C_4H_9Cl	–53.8	–34.3	–24.5	–13.8	–1.9	+5.9	16.0	32.0	50.0	68.9	–131.2

TABLE 2-10 Vapor Pressures of Organic Compounds, up to 1 atm (*Continued*)

Compound		Pressure, mmHg										Melting point, °C
		1	5	10	20	40	60	100	200	400	760	
Name	Formula	Temperature, °C										
sec-Butyl chloride (2-Chlorobutane)	C_4H_9Cl	–60.2	–39.8	–29.2	–17.7	–5.0	+3.4	14.2	31.5	50.0	68.0	–131.3
tert-Butyl chloride	C_4H_9Cl					–19.0	–11.4	–1.0	+14.6	32.6	51.0	–26.5
sec-Butyl chloroacetate	$C_6H_{11}ClO_2$	17.0	41.8	54.6	68.2	83.6	93.0	105.5	124.1	146.0	167.8	
2-*tert*-Butyl-4-cresol	$C_{11}H_{16}O$	70.0	98.0	112.0	127.2	143.9	153.7	167.0	187.8	210.0	232.6	
4-*tert*-Butyl-2-cresol	$C_{11}H_{16}O$	74.3	103.7	118.0	134.0	150.8	161.7	176.2	197.8	221.8	247.0	
iso-Butyl dichloroacetate	$C_6H_{10}Cl_2O_2$	28.6	54.3	67.5	81.4	96.7	106.6	119.8	139.2	160.0	183.0	
2,3-Butylene glycol (2,3-butanediol)	$C_4H_{10}O_2$	44.0	68.4	80.3	93.4	107.8	116.3	127.8	145.6	164.0	182.0	22.5
2-Butyl-2-ethylbutane-1,3-diol	$C_{10}H_{22}O_2$	94.1	122.6	136.8	151.2	167.8	178.0	191.9	212.0	233.5	255.0	
2-*tert*-Butyl-4-ethylphenol	$C_{12}H_{15}O$	76.3	106.2	121.0	137.0	154.0	165.4	179.0	200.3	223.8	247.8	
n-Butyl formate	$C_5H_{10}O_2$	–26.4	–4.7	+6.1	18.0	31.6	39.8	51.0	67.9	86.2	106.0	
iso-Butyl formate	$C_5H_{10}O_2$	–32.7	–11.4	–0.8	+11.0	24.1	32.4	43.4	60.0	79.0	98.2	–95.3
sec-Butyl formate	$C_5H_{10}O_2$	–34.4	–13.3	–3.1	+8.4	21.3	29.6	40.2	56.8	75.2	93.6	
sec-Butyl glycolate	$C_6H_{12}O_3$	28.3	53.6	66.0	79.8	94.2	104.0	116.4	135.5	155.6	177.5	
iso-Butyl iodide (1-iodo-2-methylpropane)	C_4H_9I	–17.0	+5.8	17.0	29.8	42.8	51.8	63.5	81.0	100.3	120.4	–90.7
isobutyrate	$C_8H_{16}O_2$	+4.1	28.0	39.9	52.4	67.2	75.9	88.0	106.3	126.3	147.5	–80.7
isovalerate	$C_9H_{18}O_2$	16.0	41.2	53.8	67.7	82.7	92.4	105.2	124.8	146.4	168.7	
levulinate	$C_9H_{16}O_3$	65.0	92.1	105.9	120.2	136.2	147.0	160.2	181.8	205.5	229.9	
naphthylketone (1-isovaleronaphthone)	$C_{15}H_{16}O$	136.0	167.9	184.0	201.6	219.7	231.5	246.7	269.7	294.0	320.0	
2-*sec*-Butylphenol	$C_{10}H_{14}O$	57.4	86.0	100.8	116.1	133.4	143.9	157.3	179.7	203.8	228.0	
2-*tert*-Butylphenol	$C_{10}H_{14}O$	56.6	84.2	98.1	113.0	129.2	140.0	153.5	173.8	196.3	219.5	
4-iso-Butylphenol	$C_{10}H_{14}O$	72.1	100.9	115.5	130.3	147.2	157.0	171.2	192.1	214.7	237.0	
4-*sec*-Butylphenol	$C_{10}H_{14}O$	71.4	100.5	114.8	130.3	147.8	157.9	172.4	194.3	217.6	242.1	
4-*tert*-Butylphenol	$C_{10}H_{14}O$	70.0	99.2	114.0	129.5	146.0	156.0	170.2	191.5	214.0	238.0	99
2-(4-*tert*-Butylphenoxy)ethyl acetate	$C_{14}H_{20}O_3$	118.0	150.0	165.8	183.3	201.5	212.8	228.0	250.3	277.6	304.4	
4-*tert*-Butylphenyl dichlorophosphate	$C_{10}H_{13}Cl_2O_2P$	96.0	129.6	146.0	164.0	184.3	197.2	214.3	240.0	268.2	299.0	
tert-Butyl phenyl ketone (pivalophenone)	$C_{11}H_{14}O$	57.8	85.7	99.0	114.3	130.4	140.8	154.0	175.0	197.7	220.0	
iso-Butyl propionate	$C_7H_{14}O_2$	–2.3	+20.9	32.3	44.8	58.5	67.6	79.5	97.0	116.4	136.8	–71
4-*tert*-Butyl-2,5-xylenol	$C_{12}H_{18}O$	88.2	119.8	135.0	151.0	169.8	180.3	195.0	217.5	241.3	265.3	
4-*tert*-Butyl-2,6-xylenol	$C_{12}H_{18}O$	74.0	103.9	119.0	135.0	152.2	163.6	176.0	196.0	217.8	239.8	
6-*tert*-Butyl-2,4-xylenol	$C_{12}H_{18}O$	70.3	100.2	115.0	131.0	148.5	158.2	172.0	192.3	214.2	236.5	
6-*tert*-Butyl-3,4-xylenol	$C_{12}H_{18}O$	83.9	113.6	127.0	143.0	159.7	170.0	184.0	204.5	226.7	249.5	
Butyric acid	$C_4H_8O_2$	25.5	49.8	61.5	74.0	88.0	96.5	108.0	125.5	144.5	163.5	–74
iso-Butyric acid	$C_4H_8O_2$	14.7	39.3	51.2	64.0	77.8	86.3	98.0	115.8	134.5	154.5	–47
Butyronitrile	C_4H_7N	–20.0	+2.1	13.4	25.7	38.4	47.3	59.0	76.7	96.8	117.5	
iso-Valerophenone	$C_{11}H_{14}O$	58.3	87.0	101.4	116.8	133.8	144.6	158.0	180.1	204.2	228.0	
Camphene	$C_{10}H_{16}$			47.2	60.4	75.7	85.0	97.9	117.5	138.7	160.5	50
Campholenic acid	$C_{10}H_{16}O_2$	97.6	125.7	139.8	153.9	170.0	180.0	193.7	212.7	234.0	256.0	
d-Camphor	$C_{10}H_{16}O$	41.5	68.6	82.3	97.5	114.0	124.0	138.0	157.9	182.0	209.2	178.5
Camphylamine	$C_{10}H_{19}N$	45.3	74.0	83.7	97.6	112.5	122.0	134.6	153.0	173.8	195.0	
Capraldehyde	$C_{10}H_{20}O$	51.9	78.8	92.0	106.3	122.2	132.0	145.3	164.8	186.3	208.5	
Capric acid	$C_{10}H_{20}O_2$	125.0	142.0	152.2	165.0	179.9	189.8	200.0	217.1	240.3	268.4	31.5
n-Caproic acid	$C_6H_{12}O_2$	71.4	89.5	99.5	111.8	125.0	133.3	144.0	160.8	181.0	202.0	–1.5
iso-Caproic acid	$C_6H_{12}O_2$	66.2	83.0	94.0	107.0	120.4	129.6	141.4	158.3	181.0	207.7	–35
iso-Caprolactone	$C_6H_{10}O_2$	38.3	66.4	80.3	95.7	112.3	123.2	137.2	157.8	182.1	207.0	
Capronitrile	$C_6H_{11}N$	9.2	34.6	47.5	61.7	76.9	86.8	99.8	119.7	141.0	163.7	
Capryl alcohol (2-octanol)	$C_8H_{18}O$	32.8	57.6	70.0	83.3	98.0	107.4	119.8	138.0	157.5	178.5	–38.6
Caprylaldehyde	$C_8H_{16}O$	73.4	92.0	101.2	110.2	120.0	126.0	133.9	145.4	156.5	168.5	
Caprylic acid (octanoic acid)	$C_8H_{16}O_2$	92.3	114.1	124.0	136.4	150.6	160.0	172.2	190.3	213.9	237.5	16
Caprylonitrile	$C_8H_{15}N$	43.0	67.6	80.4	94.6	110.6	121.2	134.8	155.2	179.5	204.5	
Carbazole	$C_{12}H_9N$						248.2	265.0	292.5	323.0	354.8	244.8
Carbon dioxide	CO_2	–134.3	–124.4	–119.5	–114.4	–108.6	–104.8	–100.2	–93.0	–85.7	–78.2	–57.5
disulfide	CS_2	–73.8	–54.3	–44.7	–34.3	–22.5	–15.3	–5.1	+10.4	28.0	46.5	–110.8
monoxide	CO	–222.0	–217.2	–215.0	–212.8	–210.0	–208.1	–205.7	–201.3	–196.3	–191.3	–205.0
oxyselenide (carbonyl selenide)	COSe	–117.1	–102.3	–95.0	–86.3	–76.4	–70.2	–61.7	–49.8	–35.6	–21.9	
oxysulfide (carbonyl sulfide)	COS	–132.4	–119.8	–113.3	–106.0	–98.3	–93.0	–85.9	–75.0	–62.7	–49.9	–138.8
tetrabromide	CBr_4					96.3	106.3	119.7	139.7	163.5	189.5	90.1
tetrachloride	CCl_4	–50.0	–30.0	–19.6	–8.2	+4.3	12.3	23.0	38.3	57.8	76.7	–22.6
tetrafluoride	CF_4	–184.6	–174.1	–169.3	–164.3	–158.8	–155.4	–150.7	–143.6	–135.5	–127.7	–183.7
Carvacrol	$C_{10}H_{14}O$	70.0	98.4	113.2	127.9	145.2	155.3	169.7	191.2	213.8	237.0	+0.5
Carvone	$C_{10}H_{14}O$	57.4	86.1	100.4	116.1	133.0	143.8	157.3	179.6	203.5	227.5	
Chavibetol	$C_{10}H_{12}O_2$	83.6	113.3	127.0	143.2	159.8	170.7	185.5	206.8	229.8	254.0	
Chloral (trichloroacetaldehyde)	C_2HCl_3O	–37.8	–16.0	–5.0	+7.2	20.2	29.1	40.2	57.8	77.5	97.7	–57
hydrate (trichloroacetaldehyde hydrate)	$C_2H_3Cl_3O_2$	–9.8	+10.0	19.5	29.2	39.7	46.2	55.0	68.0	82.1	96.2	51.7
Chloranil	$C_6Cl_4O_2$	70.7	89.3	97.8	106.4	116.1	122.0	129.5	140.3	151.3	162.6	290
Chloroacetic acid	$C_2H_3ClO_2$	43.0	68.3	81.0	94.2	109.2	118.3	130.7	149.0	169.0	189.5	61.2
anhydride	$C_4H_4Cl_2O_3$	67.2	94.1	108.0	122.4	138.2	148.0	159.8	177.8	197.0	217.0	46
2-Chloroaniline	C_6H_6ClN	46.3	72.3	84.8	99.2	115.6	125.7	139.5	160.0	183.7	208.8	0
3-Chloroaniline	C_6H_6ClN	63.5	89.8	102.0	116.7	133.6	144.1	158.0	179.5	203.5	228.5	–10.4
4-Chloroaniline	C_6H_6ClN	59.3	87.9	102.1	117.8	135.0	145.8	159.9	182.3	206.6	230.5	70.5
Chlorobenzene	C_6H_5Cl	–13.0	+10.6	22.2	35.3	49.7	58.3	70.7	89.4	110.0	132.2	–45.2
2-Chlorobenzotrichloride (2-α,α,α-tetrachlorotoluene)	$C_7H_4Cl_4$	69.0	101.8	117.9	135.8	155.0	167.8	185.0	208.0	233.0	262.1	28.7

TABLE 2-10 Vapor Pressures of Organic Compounds, up to 1 atm (*Continued*)

Compound		Pressure, mmHg										Melting point, °C
		1	5	10	20	40	60	100	200	400	760	
Name	Formula	Temperature, °C										
2-Chlorobenzotrifluoride (2-chloro-α,α,α-trifluorotoluene)	$C_7H_4ClF_3$	0.0	24.7	37.1	50.6	65.9	75.4	88.3	108.3	130.0	152.2	–6.0
2-Chlorobiphenyl	$C_{12}H_9Cl$	89.3	109.8	134.7	151.2	169.9	182.1	197.0	219.6	243.8	267.5	34
4-Chlorobiphenyl	$C_{12}H_9Cl$	96.4	129.8	146.0	164.0	183.8	196.0	212.5	237.8	264.5	292.9	75.5
α-Chlorocrotonic acid	$C_4H_5ClO_2$	70.0	95.6	108.0	121.2	135.6	144.4	155.9	173.8	193.2	212.0	
Chlorodifluoromethane	$CHClF_2$	–122.8	–110.2	–103.7	–96.5	–88.6	–83.4	–76.4	–65.8	–53.6	–40.8	–160
Chlorodimethylphenylsilane	$C_8H_{11}ClSi$	29.8	56.7	70.0	84.7	101.2	111.5	124.7	145.5	168.6	193.5	
1-Chloro-2-ethoxybenzene	C_8H_9ClO	45.8	72.8	86.5	101.5	117.8	127.8	141.8	162.0	185.5	208.0	
2-(2-Chloroethoxy) ethanol	$C_4H_9ClO_2$	53.0	78.3	90.7	104.1	118.4	127.5	139.5	157.2	176.5	196.0	
bis-2-Chloroethyl acetacetal	$C_6H_{12}Cl_2O_2$	56.2	83.7	97.6	112.2	127.8	138.0	150.7	169.8	190.5	212.6	
1-Chloro-2-ethylbenzene	C_8H_9Cl	17.2	43.0	56.1	70.3	86.2	96.4	110.0	130.2	152.2	177.6	–80.2
1-Chloro-3-ethylbenzene	C_8H_9Cl	18.6	45.2	58.1	73.0	89.2	99.6	113.6	133.8	156.7	181.1	–53.3
1-Chloro-4-ethylbenzene	C_8H_9Cl	19.2	46.4	60.0	75.5	91.8	102.0	116.0	137.0	159.8	184.3	–62.6
2-Chloroethyl chloroacetate	$C_4H_6Cl_2O_2$	46.0	72.1	86.0	100.0	116.0	126.2	140.0	159.8	182.2	205.0	
2-Chloroethyl 2-chloroisopropyl ether	$C_5H_{10}Cl_2O$	24.7	50.1	63.0	77.2	92.4	102.2	115.8	135.7	156.5	180.0	
2-Chloroethyl 2-chloropropyl ether	$C_5H_{10}Cl_2O$	29.8	56.5	70.0	84.8	101.5	111.8	125.6	146.3	169.8	194.1	
2-Chloroethyl α-methylbenzyl ether	$C_{10}H_{13}ClO$	62.3	91.4	106.0	121.8	139.6	150.0	164.8	186.3	210.8	235.0	
Chloroform (trichloromethane)	$CHCl_3$	–58.0	–39.1	–29.7	–19.0	–7.1	+0.5	10.4	25.9	42.7	61.3	–63.5
1-Chloronaphthalene	$C_{10}H_7Cl$	80.6	104.8	118.6	134.4	153.2	165.6	180.4	204.2	230.8	259.3	–20
4-Chlorophenethyl alcohol	C_8H_9ClO	84.0	114.3	129.0	145.0	162.0	173.5	188.1	210.0	234.5	259.3	
2-Chlorophenol	C_6H_5ClO	12.1	38.2	51.2	65.9	82.0	92.0	106.0	126.4	149.8	174.5	7
3-Chlorophenol	C_6H_5ClO	44.2	72.0	86.1	101.7	118.0	129.4	143.0	164.8	188.7	214.0	32.5
4-Chlorophenol	C_6H_5ClO	49.8	78.2	92.2	108.1	125.0	136.1	150.0	172.0	196.0	220.0	42
2-Chloro-3-phenylphenol	$C_{12}H_9ClO$	118.0	152.2	169.7	186.7	207.4	219.6	237.0	261.3	289.4	317.5	+6
2-Chloro-6-phenylphenol	$C_{12}H_9ClO$	119.8	153.7	170.7	189.8	208.2	220.0	237.1	261.6	289.5	317.0	
Chloropicrin (trichloronitromethane)	CCl_3NO_2	–25.5	–3.3	+7.8	20.0	33.8	42.3	53.8	71.8	91.8	111.9	–64
1-Chloropropene	C_3H_5Cl	–81.3	–63.4	–54.1	–44.0	–32.7	–25.1	–15.1	+1.3	18.0	37.0	–99.0
2-Chloropyridine	C_5H_4ClN	13.3	38.8	51.7	65.8	81.7	91.6	104.6	125.0	147.7	170.2	
3-Chlorostyrene	C_8H_7Cl	25.3	51.3	65.2	80.0	96.5	107.2	121.2	142.2	165.7	190.0	
4-Chlorostyrene	C_8H_7Cl	28.0	54.5	67.5	82.0	98.0	108.5	122.0	143.5	166.0	191.0	–15.0
1-Chlorotetradecane	$C_{14}H_{29}Cl$	98.5	131.8	148.2	166.2	187.0	199.8	215.5	240.3	267.5	296.0	+0.9
2-Chlorotoluene	C_7H_7Cl	+5.4	30.6	43.2	56.9	72.0	81.8	94.7	115.0	137.1	159.3	
3-Chlorotoluene	C_7H_7Cl	+4.8	30.3	43.2	57.4	73.0	83.2	96.3	116.6	139.7	162.3	
4-Chlorotoluene	C_7H_7Cl	+5.5	31.0	43.8	57.8	73.5	83.3	96.6	117.1	139.8	162.3	+7.3
Chlorotriethylsilane	$C_6H_{15}ClSi$	–4.9	+19.8	32.0	45.5	60.2	69.5	82.3	101.6	123.6	146.3	
1-Chloro-1,2,2-trifluoroethylene	C_2ClF_3	–116.0	–102.5	–95.9	–88.2	–79.7	–74.1	–66.7	–55.0	–41.7	–27.9	–157.5
Chlorotrifluoromethane	$CClF_3$	–149.5	–139.2	–134.1	–128.5	–121.9	–117.3	–111.7	–102.5	–92.7	–81.2	
Chlorotrimethylsilane	C_3H_9ClSi	–62.8	–43.6	–34.0	–23.2	–11.4	–4.0	+6.0	21.9	39.4	57.9	
trans-Cinnamic acid	$C_9H_8O_2$	127.5	157.8	173.0	189.5	207.1	217.8	232.4	253.3	276.7	300.0	133
Cinnamyl alcohol	$C_9H_{10}O$	72.6	102.5	117.8	133.7	151.0	162.0	177.8	199.8	224.6	250.0	33
Cinnamylaldehyde	C_9H_8O	76.1	105.8	120.0	135.7	152.2	163.7	177.7	199.3	222.4	246.0	–7.5
Citraconic anhydride	$C_5H_4O_3$	47.1	74.8	88.9	103.8	120.3	131.3	145.4	165.8	189.8	213.5	
cis-α-Citral	$C_{10}H_{16}O$	61.7	90.0	103.9	119.4	135.9	146.3	160.0	181.8	205.0	228.0	
d-Citronellal	$C_{10}H_{18}O$	44.0	71.4	84.8	99.8	116.1	126.2	140.1	160.0	183.8	206.5	
Citronellic acid	$C_{10}H_{18}O_2$	99.5	127.3	141.4	155.6	171.9	182.1	195.4	214.5	236.6	257.0	
Citronellol	$C_{10}H_{20}O$	66.4	93.6	107.0	121.5	137.2	147.2	159.8	179.8	201.0	221.5	
Citronellyl acetate	$C_{12}H_{22}O_2$	74.7	100.2	113.0	126.0	140.5	149.7	161.0	178.8	197.8	217.0	
Coumarin	$C_9H_6O_2$	106.0	137.8	153.4	170.0	189.0	200.5	216.5	240.0	264.7	291.0	70
o-Cresol (2-cresol; 2-methylphenol)	C_7H_8O	38.2	64.0	76.7	90.5	105.8	115.5	127.4	146.7	168.4	190.8	30.8
m-Cresol (3-cresol; 3-methylphenol)	C_7H_8O	52.0	76.0	87.8	101.4	116.0	125.8	138.0	157.3	179.0	202.8	10.9
p-Cresol (4-cresol; 4-methylphenol)	C_7H_8O	53.0	76.5	88.6	102.3	117.7	127.0	140.0	157.3	179.4	201.8	35.5
cis-Crotonic acid	$C_4H_6O_2$	33.5	57.4	69.0	82.0	96.0	104.5	116.3	133.9	152.2	171.9	15.5
trans-Crotonic acid	$C_4H_6O_2$			80.0	93.0	107.8	116.7	128.0	146.0	165.5	185.0	72
cis-Crotononitrile	C_4H_5N	–29.0	–7.1	+4.0	16.4	30.0	38.5	50.1	68.0	88.0	108.0	
trans-Crotononitrile	C_4H_5N	–19.5	+3.5	15.0	27.8	41.8	50.9	62.8	81.1	101.5	122.8	
Cumene	C_9H_{12}	+2.9	26.8	38.3	51.5	66.1	75.4	88.1	107.3	129.2	152.4	–96.0
4-Cumidene	$C_9H_{13}N$	60.0	88.2	102.2	117.8	134.2	145.0	158.0	180.0	203.2	227.0	
Cuminal	$C_{10}H_{12}O$	58.0	87.3	102.0	117.9	135.2	146.0	160.0	182.8	206.7	232.0	
Cuminyl alcohol	$C_{10}H_{14}O$	74.2	103.7	118.0	133.8	150.3	161.7	176.2	197.9	221.7	246.6	
2-Cyano-2-*n*-butyl acetate	$C_7H_{11}NO_2$	42.0	68.7	82.0	96.2	111.8	121.5	133.8	152.2	173.4	195.2	
Cyanogen	C_2N_2	–95.8	–83.2	–76.8	–70.1	–62.7	–57.9	–51.8	–42.6	–33.0	–21.0	–34.4
bromide	CBrN	–35.7	–18.3	–10.0	–1.0	+8.6	14.7	22.6	33.8	46.0	61.5	58
chloride	CClN	–76.7	–61.4	–53.8	–46.1	–37.5	–32.1	–24.9	–14.1	–2.3	+13.1	–6.5
iodide	CIN	25.2	47.2	57.7	68.6	80.3	88.0	97.6	111.5	126.1	141.1	
Cyclobutane	C_4H_8	–92.0	–76.0	–67.9	–58.7	–48.4	–41.8	–32.8	–18.9	–3.4	+12.9	–50
Cyclobutene	C_4H_6	–99.1	–83.4	–75.4	–66.6	–56.4	–50.0	–41.2	–27.8	–12.2	+2.4	
Cyclohexane	C_6H_{12}	–45.3	–25.4	–15.9	–5.0	+6.7	14.7	25.5	42.0	60.8	80.7	+6.6
Cyclohexaneethanol	$C_8H_{16}O$	50.4	77.2	90.0	104.0	119.8	129.8	142.7	161.7	183.5	205.4	
Cyclohexanol	$C_6H_{12}O$	21.0	44.0	56.0	68.8	83.0	91.8	103.7	121.7	141.4	161.0	23.9
Cyclohexanone	$C_6H_{10}O$	+1.4	26.4	38.7	52.5	67.8	77.5	90.4	110.3	132.5	155.6	–45.0
2-Cyclohexyl-4,6-dinitrophenol	$C_{12}H_{14}N_2O_5$	132.8	161.8	175.9	191.2	206.7	216.0	229.0	248.7	269.8	291.5	
Cyclopentane	C_5H_{10}	–68.0	–49.6	–40.4	–30.1	–18.6	–11.3	–1.3	+13.8	31.0	49.3	–93.7
Cyclopropane	C_3H_6	–116.8	–104.2	–97.5	–90.3	–82.3	–77.0	–70.0	–59.1	–46.9	–33.5	–126.6
Cymene	$C_{10}H_{14}$	17.3	43.9	57.0	71.1	87.0	97.2	110.8	131.4	153.5	177.2	–68.2

TABLE 2-10 Vapor Pressures of Organic Compounds, up to 1 atm (*Continued*)

Compound		Pressure, mmHg										Melting point, °C
		1	5	10	20	40	60	100	200	400	760	
Name	Formula	Temperature, °C										
cis-Decalin	$C_{10}H_{18}$	22.5	50.1	64.2	79.8	97.2	108.0	123.2	145.4	169.9	194.6	−43.3
trans-Decalin	$C_{10}H_{18}$	−0.8	+30.6	47.2	65.3	85.7	98.4	114.6	136.2	160.1	186.7	−30.7
Decane	$C_{10}H_{22}$	16.5	42.3	55.7	69.8	85.5	95.5	108.6	128.4	150.6	174.1	−29.7
Decan-2-one	$C_{10}H_{20}O$	44.2	71.9	85.8	100.7	117.1	127.8	142.0	163.2	186.7	211.0	+3.5
1-Decene	$C_{10}H_{20}$	14.7	40.3	53.7	67.8	83.3	93.5	106.5	126.7	149.2	172.0	
Decyl alcohol	$C_{10}H_{22}O$	69.5	97.3	111.3	125.8	142.1	152.0	165.8	186.2	208.8	231.0	+7
Decyltrimethylsilane	$C_{13}H_{30}Si$	67.4	96.4	111.0	126.5	144.0	154.3	169.5	191.0	215.5	240.0	
Dehydroacetic acid	$C_8H_8O_4$	91.7	122.0	137.3	153.0	171.0	181.5	197.5	219.5	244.5	269.0	
Desoxybenzoin	$C_{14}H_{12}O$	123.3	156.2	173.5	192.0	212.0	224.5	241.3	265.2	293.0	321.0	60
Diacetamide	$C_4H_7NO_2$	70.0	95.0	108.0	122.6	138.2	148.0	160.6	180.8	202.0	223.0	78.5
Diacetylene (1,3-butadiyne)	C_4H_2	−82.5	−68.0	−61.2	−53.8	−45.9	−41.0	−34.0	−20.9	−6.1	+9.7	−34.9
Diallyldichlorosilane	$C_6H_{10}Cl_2Si$	+9.5	34.8	47.4	61.3	76.4	86.3	99.7	119.4	142.0	165.3	
Diallyl sulfide	$C_6H_{10}S$	−9.5	+14.4	26.6	39.7	54.2	63.7	75.8	94.8	116.1	138.6	−83
Diisoamyl ether	$C_{10}H_{22}O$	18.6	44.3	57.0	70.7	86.3	96.0	109.6	129.0	150.3	173.4	
oxalate	$C_{12}H_{22}O_4$	85.4	116.0	131.4	147.7	165.7	177.0	192.2	215.0	240.0	265.0	
sulfide	$C_{10}H_{22}S$	43.0	73.0	87.6	102.7	120.0	130.6	145.3	166.4	191.0	216.0	
Dibenzylamine	$C_{14}H_{15}N$	118.3	149.8	165.6	182.2	200.2	212.2	227.3	249.8	274.3	300.0	−26
Dibenzyl ketone (1,3-diphenyl-2-propanone)	$C_{15}H_{14}O$	125.5	159.8	177.6	195.7	216.6	229.4	246.6	272.3	301.7	330.5	34.5
1,4-Dibromobenzene	$C_6H_4Br_2$	61.0	79.3	87.7	103.6	120.8	131.6	146.5	168.5	192.5	218.6	87.5
1,2-Dibromobutane	$C_4H_8Br_2$	7.5	33.2	46.1	60.0	76.0	86.0	99.8	120.2	143.5	166.3	−64.5
dl-2,3-Dibromobutane	$C_4H_8Br_2$	+5.0	30.0	41.6	56.4	72.0	82.0	95.3	115.7	138.0	160.5	
meso-2,3-Dibromobutane	$C_4H_8Br_2$	+1.5	26.6	39.3	53.2	68.0	78.0	91.7	111.8	134.2	157.3	−34.5
1,2-Dibromodecane	$C_{10}H_{20}Br_2$	95.7	123.6	137.3	151.0	167.4	177.5	190.2	209.6	229.8	250.4	
Di(2-bromoethyl) ether	$C_4H_8Br_2O$	47.7	75.3	88.5	103.6	119.8	130.0	144.0	165.0	188.0	212.5	
α,β-Dibromomaleic anhydride	$C_4H_2Br_2O_3$	50.0	78.0	92.0	106.7	123.5	133.8	147.7	168.0	192.0	215.0	
1,2-Dibromo-2-methylpropane	$C_4H_8Br_2$	−28.8	−3.0	+10.5	25.7	42.3	53.7	68.8	92.1	119.8	149.0	−70.3
1,3-Dibromo-2-methylpropane	$C_4H_8Br_2$	14.0	40.0	53.0	67.5	83.5	93.7	107.4	117.8	150.6	174.6	
1,2-Dibromopentane	$C_5H_{10}Br_2$	19.8	45.4	58.0	72.0	87.4	97.4	110.1	130.2	151.8	175.0	
1,2-Dibromopropane	$C_3H_6Br_2$	−7.0	+17.3	29.4	42.3	57.2	66.4	78.7	97.8	118.5	141.6	−55.5
1,3-Dibromopropane	$C_3H_6Br_2$	+9.7	35.4	48.0	62.1	77.8	87.8	101.3	121.7	144.1	167.5	−34.4
2,3-Dibromopropene	$C_3H_4Br_2$	−6.0	+17.9	30.0	43.2	57.8	67.0	79.5	98.0	119.5	141.2	
2,3-Dibromo-1-propanol	$C_3H_6Br_2O$	57.0	84.5	98.2	113.5	129.8	140.0	153.0	173.8	196.0	219.0	
Diisobutylamine	$C_8H_{19}N$	−5.1	+18.4	30.6	43.7	57.8	67.0	79.2	97.6	118.0	139.5	−70
2,6-Ditert-butyl-4-cresol	$C_{15}H_{24}O$	85.8	116.2	131.0	147.0	164.1	175.2	190.0	212.8	237.6	262.5	
4,6-Ditert-butyl-2-cresol	$C_{15}H_{24}O$	86.2	117.3	132.4	149.0	167.4	179.0	194.0	217.5	243.4	269.3	
4,6-Ditert-butyl-3-cresol	$C_{15}H_{24}O$	103.7	135.2	150.0	167.0	185.3	196.1	211.0	233.0	257.1	282.0	
2,6-Ditert-butyl-4-ethylphenol	$C_{16}H_{26}O$	89.1	121.4	137.0	154.0	172.1	183.9	198.0	220.0	244.0	268.6	
4,6-Ditert-butyl-3-ethylphenol	$C_{16}H_{26}O$	111.5	142.6	157.4	174.0	192.3	204.4	218.0	241.7	264.6	290.0	
Diisobutyl oxalate	$C_{10}H_{18}O_4$	63.2	91.2	105.3	120.3	137.5	147.8	161.8	183.5	205.8	229.5	
2,4-Ditert-butylphenol	$C_{14}H_{22}O$	84.5	115.4	130.0	146.0	164.3	175.8	190.0	212.5	237.0	260.8	
Dibutyl phthalate	$C_{16}H_{22}O_4$	148.2	182.1	198.2	216.2	235.8	247.8	263.7	287.0	313.5	340.0	
sulfide	$C_8H_{18}S$	+21.7	51.8	66.4	80.5	96.0	105.8	118.6	138.0	159.0	182.0	−79.7
Diisobutyl *d*-tartrate	$C_{12}H_{22}O_6$	117.8	151.8	169.0	188.0	208.5	221.6	239.5	264.7	294.0	324.0	73.5
Dicarvacryl-mono-(6-chloro-2-xenyl) phosphate	$C_{32}H_{34}ClO_4P$	204.2	234.5	249.3	264.5	280.5	290.7	304.9	323.8	342.0	361.0	
Dicarvacryl-2-tolyl phosphate	$C_{27}H_{33}O_4P$	180.2	209.3	221.8	237.0	251.5	260.3	272.5	290.0	309.8	330.0	
Dichloroacetic acid	$C_2H_2Cl_2O_2$	44.0	69.8	82.6	96.3	111.8	121.5	134.0	152.3	173.7	194.4	9.7
1,2-Dichlorobenzene	$C_6H_4Cl_2$	20.0	46.0	59.1	73.4	89.4	99.5	112.9	133.4	155.8	179.0	−17.6
1,3-Dichlorobenzene	$C_6H_4Cl_2$	12.1	39.0	52.0	66.2	82.0	92.2	105.0	125.9	149.0	173.0	−24.2
1,4-Dichlorobenzene	$C_6H_4Cl_2$			54.8	69.2	84.8	95.2	108.4	128.3	150.2	173.9	53.0
1,2-Dichlorobutane	$C_4H_8Cl_2$	−23.6	−0.3	+11.5	24.5	37.7	47.8	60.2	79.7	100.8	123.5	
2,3-Dichlorobutane	$C_4H_8Cl_2$	−25.2	−3.0	+8.5	21.2	35.0	43.9	56.0	74.0	94.2	116.0	−80.4
1,2-Dichloro-1,2-difluoroethylene	$C_2Cl_2F_2$	−82.0	−65.6	−57.3	−48.3	−38.2	−31.8	−23.0	−10.0	+5.0	20.9	−112
Dichlorodifluoromethane	CCl_2F_2	−118.5	−104.6	−97.8	−90.1	−81.6	−76.1	−68.6	−57.0	−43.9	−29.8	
Dichlorodiphenyl silane	$C_{12}H_{10}Cl_2Si$	109.6	142.4	158.0	176.0	195.5	207.5	223.8	248.0	275.5	304.0	
Dichlorodiisopropyl ether	$C_6H_{12}Cl_2O$	29.6	55.2	68.2	82.2	97.3	106.9	119.7	139.0	159.8	182.7	
Di(2-chloroethoxy) methane	$C_5H_{10}Cl_2O_2$	53.0	80.4	94.0	109.5	125.5	135.8	149.6	170.0	192.0	215.0	
Dichloroethoxymethylsilane	$C_3H_8Cl_2OSi$	−33.8	−12.1	−1.3	+11.3	24.4	32.6	44.1	61.0	80.3	100.6	
1,2-Dichloro-3-ethylbenzene	$C_8H_8Cl_2$	46.0	75.0	90.0	105.9	123.8	135.0	149.8	172.0	197.0	222.1	−40.8
1,2-Dichloro-4-ethylbenzene	$C_8H_8Cl_2$	47.0	77.2	92.3	109.6	127.5	139.0	153.3	176.0	201.7	226.6	−76.4
1,4-Dichloro-2-ethylbenzene	$C_8H_8Cl_2$	38.5	68.0	83.2	99.8	118.0	129.0	144.0	166.2	191.5	216.3	−61.2
cis-1,2-Dichloroethylene	$C_2H_2Cl_2$	−58.4	−39.2	−29.9	−19.4	−7.9	−0.5	+9.5	24.6	41.0	59.0	−80.5
trans-1,2-Dichloro ethylene	$C_2H_2Cl_2$	−65.4	−47.2	−38.0	−28.0	−17.0	−10.0	−0.2	+14.3	30.8	47.8	−50.0
Di(2-chloroethyl) ether	$C_4H_8Cl_2O$	23.5	49.3	62.0	76.0	91.5	101.5	114.5	134.0	155.4	178.5	
Dichlorofluoromethane	$CHCl_2F$	−91.3	−75.5	−67.5	−58.6	−48.8	−42.6	−33.9	−20.9	−6.2	+8.9	−135
1,5-Dichlorohexamethyltrisiloxane	$C_6H_{18}Cl_2O_2Si_3$	26.0	52.0	65.1	79.0	94.8	105.0	118.2	138.3	160.2	184.0	−53.0
Dichloromethylphenylsilane	$C_7H_8Cl_2Si$	35.7	63.5	77.4	92.4	109.5	120.0	134.2	155.5	180.2	205.5	
1,1-Dichloro-2-methylpropane	$C_4H_8Cl_2$	−31.0	−8.4	+2.6	14.6	28.2	37.0	48.2	65.8	85.4	106.0	
1,2-Dichloro-2-methylpropane	$C_4H_8Cl_2$	−25.8	−4.2	+6.7	18.7	32.0	40.2	51.7	68.9	87.8	108.0	
1,3-Dichloro-2-methylpropane	$C_4H_8Cl_2$	−3.0	+20.6	32.0	44.8	58.6	67.5	78.8	96.1	115.4	135.0	
2,4-Dichlorophenol	$C_6H_4Cl_2O$	53.0	80.0	92.8	107.7	123.4	133.5	146.0	165.2	187.5	210.0	45.0
2,6-Dichlorophenol	$C_6H_4Cl_2O$	59.5	87.6	101.0	115.5	131.6	141.8	154.6	175.5	197.7	220.0	

TABLE 2-10 Vapor Pressures of Organic Compounds, up to 1 atm (*Continued*)

Compound		Pressure, mmHg										Melting point, °C
		1	5	10	20	40	60	100	200	400	760	
Name	Formula	Temperature, °C										
α,α-Dichlorophenylacetonitrile	$C_8H_5Cl_2N$	56.0	84.0	98.1	113.8	130.0	141.0	154.5	176.2	199.5	223.5	
Dichlorophenylarsine	$C_6H_5AsCl_2$	61.8	100.0	116.0	133.1	151.0	163.2	178.9	202.8	228.8	256.5	
1,2-Dichloropropane	$C_3H_6Cl_2$	−38.5	−17.0	−6.1	+6.0	19.4	28.0	39.4	57.0	76.0	96.8	
2,3-Dichlorostyrene	$C_8H_6Cl_2$	61.0	90.1	104.6	120.5	137.8	149.0	163.5	185.7	210.0	235.0	
2,4-Dichlorostyrene	$C_8H_6Cl_2$	53.5	82.2	97.4	111.8	129.2	140.0	153.8	176.0	200.0	225.0	
2,5-Dichlorostyrene	$C_8H_6Cl_2$	55.5	83.9	98.2	114.0	131.0	142.0	155.8	178.0	202.5	227.0	
2,6-Dichlorostyrene	$C_8H_6Cl_2$	47.8	75.7	90.0	105.5	122.4	133.3	147.6	169.0	193.5	217.0	
3,4-Dichlorostyrene	$C_8H_6Cl_2$	57.2	86.0	100.4	116.2	133.7	144.6	158.2	181.5	205.7	230.0	
3,5-Dichlorostyrene	$C_8H_6Cl_2$	53.5	82.2	97.4	111.8	129.2	140.0	153.8	176.0	200.0	225.0	
1,2-Dichlorotetraethylbenzene	$C_{14}H_{20}Cl_2$	105.6	138.7	155.0	172.5	192.2	204.8	220.7	245.6	272.8	302.0	
1,4-Dichlorotetraethylbenzene	$C_{14}H_{20}Cl_2$	91.7	126.1	143.8	162.0	183.2	195.8	212.0	238.5	265.8	296.5	
1,2-Dichloro-1,1,2,2-tetrafluoroethane	$C_2Cl_2F_4$	−95.4	−80.0	−72.3	−63.5	−53.7	−47.5	−39.1	−26.3	−12.0	+3.5	−94
Dichloro-4-tolylsilane	$C_7H_8Cl_2Si$	46.2	71.7	84.2	97.8	113.2	122.6	135.5	153.5	175.2	196.3	
3,4-Dichloro-α,α,α-trifluorotoluene	$C_7H_3Cl_2F_3$	11.0	38.3	52.2	67.3	84.0	95.0	109.2	129.0	150.5	172.8	−12.1
Dicyclopentadiene	$C_{10}H_8$		34.1	47.6	62.0	77.9	88.0	101.7	121.8	144.2	166.6	32.9
Diethoxydimethylsilane	$C_6H_{16}O_2Si$	−19.1	+2.4	13.3	25.3	38.0	46.3	57.6	74.2	93.2	113.5	
Diethoxydiphenylsilane	$C_{16}H_{20}O_2Si$	111.5	142.8	157.6	174.3	193.2	205.0	220.0	243.8	259.7	296.0	
Diethyl adipate	$C_{10}H_{18}O_4$	74.0	106.6	123.0	138.3	154.6	165.8	179.0	198.2	219.1	240.0	−21
Diethylamine	$C_4H_{11}N$			−33.0	−22.6	−11.3	−4.0	+6.0	21.0	38.0	55.5	−38.9
N-Diethylaniline	$C_{10}H_{15}N$	49.7	78.0	91.9	107.2	123.6	133.8	147.3	168.2	192.4	215.5	−34.4
Diethyl arsanilate	$C_{10}H_{16}AsNO_3$	38.0	62.6	74.8	88.0	102.6	111.8	123.8	141.9	161.0	181.0	
1,2-Diethylbenzene	$C_{10}H_{14}$	22.3	48.7	62.0	76.4	92.5	102.6	116.2	136.7	159.0	183.5	−31.4
1,3-Diethylbenzene	$C_{10}H_{14}$	20.7	46.8	59.9	74.5	90.4	100.7	114.4	134.8	156.9	181.1	−83.9
1,4-Diethylbenzene	$C_{10}H_{14}$	20.7	47.1	60.3	74.7	91.1	101.3	115.3	136.1	159.0	183.8	−43.2
Diethyl carbonate	$C_5H_{10}O_3$	−10.1	+12.3	23.8	36.0	49.5	57.9	69.7	86.5	105.8	125.8	−43
cis-Diethyl citraconate	$C_9H_{14}O_4$	59.8	88.3	103.0	118.2	135.7	146.2	160.0	182.3	206.5	230.3	
Diethyl dioxosuccinate	$C_8H_{10}O_6$	70.0	98.0	112.0	126.8	143.8	153.7	167.7	188.0	210.8	233.5	
Diethylene glycol	$C_4H_{10}O_3$	91.8	120.0	133.8	148.0	164.3	174.0	187.5	207.0	226.5	244.8	
Diethyleneglycol-bis-chloroacetate	$C_8H_{12}Cl_2O_5$	148.3	180.0	195.8	212.0	229.0	239.5	252.0	271.5	291.8	313.0	
Diethylene glycol dimethyl ether												
Di(2-methoxyethyl) ether	$C_6H_{14}O_3$	13.0	37.6	50.0	63.0	77.5	86.8	99.5	118.0	138.5	159.8	
glycol ethyl ether	$C_6H_{14}O_3$	45.3	72.0	85.8	100.3	116.7	126.8	140.3	159.0	180.3	201.9	
Diethyl ether	$C_4H_{10}O$	−74.3	−56.9	−48.1	−38.5	27.7	−21.8	−11.5	+2.2	17.9	34.6	−116.3
ethylmalonate	$C_9H_{16}O_4$	50.8	77.8	91.6	106.0	122.4	132.4	146.0	166.0	188.7	211.5	
fumarate	$C_8H_{12}O_4$	53.2	81.2	95.3	110.2	126.7	137.7	151.1	172.2	195.8	218.5	+0.6
glutarate	$C_9H_{16}O_4$	65.6	94.7	109.7	125.4	142.8	153.2	167.8	189.5	212.8	237.0	
Diethylhexadecylamine	$C_{20}H_{43}N$	139.8	175.8	194.0	213.5	235.0	248.5	265.5	292.8	324.6	355.0	
Diethyl itaconate	$C_9H_{14}O_4$	51.3	80.2	95.2	111.0	128.2	139.9	154.3	177.5	203.1	227.9	
ketone (3-pentanone)	$C_5H_{10}O$	−12.7	+7.5	17.2	27.9	39.4	46.7	56.2	70.6	86.3	102.7	−42
malate	$C_8H_{14}O_5$	80.7	110.4	125.3	141.2	157.8	169.0	183.9	205.3	229.5	253.4	
maleate	$C_8H_{12}O_4$	57.3	85.6	100.0	115.3	131.8	142.4	156.0	177.8	201.7	225.0	
malonate	$C_7H_{12}O_4$	40.0	67.5	81.3	95.9	113.3	123.0	136.2	155.5	176.8	198.9	−49.8
mesaconate	$C_9H_{14}O_4$	62.8	91.0	105.3	120.3	137.3	147.9	161.6	183.2	205.8	229.0	
oxalate	$C_6H_{10}O_4$	47.4	71.8	83.8	96.8	110.6	119.7	130.8	147.9	166.2	185.7	−40.6
phthalate	$C_{12}H_{14}O_4$	108.8	140.7	156.0	173.6	192.1	204.1	219.5	243.0	267.5	294.0	
sebacate	$C_{14}H_{26}O_4$	125.3	156.2	172.1	189.8	207.5	218.4	234.4	255.8	280.3	305.5	1.3
2,5-Diethylstyrene	$C_{12}H_{16}$	49.7	78.4	92.6	108.5	125.8	136.8	151.0	173.2	198.0	223.0	
Diethyl succinate	$C_8H_{14}O_4$	54.6	83.0	96.6	111.7	127.8	138.2	151.1	171.7	193.8	216.5	−20.8
isosuccinate	$C_8H_{14}O_4$	39.8	66.7	80.0	94.7	111.0	121.4	134.8	155.1	177.7	201.3	
sulfate	$C_4H_{10}O_4S$	47.0	74.0	87.7	102.1	118.0	128.6	142.5	162.5	185.5	209.5	−25.0
sulfide	$C_4H_{10}S$	−39.6	−18.6	−8.0	+3.5	16.1	24.2	35.0	51.3	69.7	88.0	−99.5
sulfite	$C_4H_{10}O_3S$	10.0	34.2	46.4	59.7	74.2	83.8	96.3	115.8	137.0	159.0	
d-Diethyl tartrate	$C_8H_{14}O_6$	102.0	133.0	148.0	164.2	182.3	194.0	208.5	230.4	254.8	280.0	17
dl-Diethyl tartrate	$C_8H_{14}O_6$	100.0	131.7	147.2	163.8	181.7	193.2	208.0	230.0	254.3	280.0	
3,5-Diethyltoluene	$C_{11}H_{16}$	34.0	61.5	75.3	90.2	107.0	117.7	131.7	152.4	176.5	200.7	
Diethylzinc	$C_4H_{10}Zn$	−22.4	0.0	+11.7	24.2	38.0	47.2	59.1	77.0	97.3	118.0	−28
1-Dihydrocarvone	$C_{10}H_{16}O$	46.6	75.5	90.0	106.0	123.7	134.7	149.7	171.8	197.0	223.0	
Dihydrocitronellol	$C_{10}H_{22}O$	68.0	91.7	103.0	115.0	127.6	136.7	145.9	160.2	176.8	193.5	
1,4-Dihydroxyanthraquinone	$C_{14}H_8O_4$	196.7	239.8	259.8	282.0	307.4	323.3	344.5	377.8	413.0	450.0	194
Dimethylacetylene (2-butyne)	C_4H_6	−73.0	−57.9	−50.5	−42.5	−33.9	−27.8	−18.8	−5.0	+10.6	27.2	−32.5
Dimethylamine	C_2H_7N	−87.7	−72.2	−64.6	−56.0	−46.7	−40.7	−32.6	−20.4	−7.1	+7.4	−96
N,*N*-Dimethylaniline	$C_8H_{11}N$	29.5	56.3	70.0	84.8	101.6	111.9	125.8	146.5	169.2	193.1	+2.5
Dimethyl arsanilate	$C_8H_{12}AsNO_3$	15.0	39.6	51.8	65.0	79.7	88.6	101.0	119.8	140.3	160.5	
Di(α-methylbenzyl) ether	$C_{16}H_{18}O$	96.7	128.3	144.0	160.3	179.6	191.5	206.8	229.7	254.8	281.0	
2,2-Dimethylbutane	C_6H_{14}	−69.3	−50.7	−41.5	−31.1	−19.5	−12.1	−2.0	+13.4	31.0	49.7	−99.8
2,3-Dimethylbutane	C_6H_{14}	−63.6	−44.5	−34.9	−24.1	−12.4	−4.9	+5.4	21.1	39.0	58.0	−128.2
Dimethyl citraconate	$C_7H_{10}O_4$	50.8	78.2	91.8	106.5	122.6	132.7	145.8	165.8	188.0	210.5	
1,1-Dimethylcyclohexane	C_8H_{16}	−24.4	−1.4	+10.3	23.0	37.3	45.7	57.9	76.2	97.2	119.5	−34
cis-1,2-Dimethylcyclohexane	C_8H_{16}	−15.9	+7.3	18.4	31.1	45.3	54.4	66.8	85.6	107.0	129.7	−50.0
trans-1,2-Dimethylcyclohexane	C_8H_{16}	−21.1	+1.7	13.0	25.6	39.7	48.7	61.0	79.6	100.9	123.4	−88.0
trans-1,3-Dimethylcyclohexane	C_8H_{16}	−19.4	+3.4	14.9	27.4	41.4	50.4	62.5	81.0	102.1	124.4	−92.0
cis-1,3-Dimethylcyclohexane	C_8H_{16}	−22.7	0.0	+11.2	23.6	37.5	46.4	58.5	76.9	97.8	120.1	−76.2
cis-1,4-Dimethylcyclohexane	C_8H_{16}	−20.0	+3.2	14.5	27.1	41.1	50.1	62.3	80.8	101.9	124.3	−87.4
trans-1,4-Dimethylcyclohexane	C_8H_{16}	−24.3	−1.7	+10.1	22.6	36.5	45.4	57.6	76.0	97.0	119.3	−36.9

TABLE 2-10 Vapor Pressures of Organic Compounds, up to 1 atm (*Continued*)

Compound		Pressure, mmHg										Melting point, °C
		1	5	10	20	40	60	100	200	400	760	
Name	Formula	Temperature, °C										
Dimethyl ether	C_2H_6O	−115.7	−101.1	−93.3	−85.2	−76.2	−70.4	−62.7	−50.9	−37.8	−23.7	−138.5
2,2-Dimethylhexane	C_8H_{18}	−29.7	−7.9	+3.1	15.0	28.2	36.7	48.2	65.7	85.6	106.8	
2,3-Dimethylhexane	C_8H_{18}	−23.0	−1.1	+9.9	22.1	35.6	44.2	56.0	73.8	94.1	115.6	
2,4-Dimethylhexane	C_8H_{18}	−26.9	−5.3	+5.2	17.2	30.5	39.0	50.6	68.1	88.2	109.4	
2,5-Dimethylhexane	C_8H_{18}	−26.7	−5.5	+5.3	17.2	30.4	38.9	50.5	68.0	87.9	109.1	−90.7
3,3-Dimethylhexane	C_8H_{18}	−25.8	−4.4	+6.1	18.2	31.7	40.4	52.5	70.0	90.4	112.0	
3,4-Dimethylhexane	C_8H_{18}	−22.1	+0.2	11.3	23.5	37.1	45.8	57.7	75.6	96.0	117.7	
Dimethyl itaconate	$C_7H_{10}O_4$	69.3	94.0	106.6	119.7	133.7	142.6	153.7	171.0	189.8	208.0	38
1-Dimethyl malate	$C_6H_{10}O_5$	75.4	104.0	118.3	133.8	150.1	160.4	175.1	196.3	219.5	242.6	
Dimethyl maleate	$C_6H_8O_4$	45.7	73.0	86.4	101.3	117.2	127.1	140.4	160.0	182.2	205.0	
malonate	$C_5H_8O_4$	35.0	59.8	72.0	85.0	100.0	109.7	121.9	140.0	159.8	180.7	−62
trans-Dimethyl mesaconate	$C_7H_{10}O_4$	46.8	74.0	87.8	102.1	118.0	127.8	141.5	161.0	183.5	206.0	
2,7-Dimethyloctane	$C_{10}H_{22}$	+6.3	30.5	42.3	55.8	71.2	80.8	93.9	114.0	136.0	159.7	−52.8
Dimethyl oxalate	$C_4H_6O_4$	20.0	44.0	56.0	69.4	83.6	92.8	104.8	123.3	143.3	163.3	
2,2-Dimethylpentane	C_7H_{16}	−49.0	−28.7	−18.7	−7.5	+5.0	13.0	23.9	40.3	59.2	79.2	−123.7
2,3-Dimethylpentane	C_7H_{16}	−42.0	−20.8	−10.3	+1.1	13.9	22.1	33.3	50.1	69.4	89.8	−135
2,4-Dimethylpentane	C_7H_{16}	−48.0	−27.4	−17.1	−5.9	+6.5	14.5	25.4	41.8	60.6	80.5	−119.5
3,3-Dimethylpentane	C_7H_{16}	−45.9	−25.0	−14.4	−2.9	+9.9	18.1	29.3	46.2	65.5	86.1	−135.0
2,3-Dimethylphenol (2,3-xylenol)	$C_8H_{10}O$	56.0	83.8	97.6	112.0	129.2	139.5	152.2	173.0	196.0	218.0	75
2,4-Dimethylphenol (2,4-xylenol)	$C_8H_{10}O$	51.8	78.0	91.3	105.0	121.5	131.0	143.0	161.5	184.2	211.5	25.5
2,5-Dimethylphenol (2,5-xylenol)	$C_8H_{10}O$	51.8	78.0	91.3	105.0	121.5	131.0	143.0	161.5	184.2	211.5	74.5
3,4-Dimethylphenol (3,4-xylenol)	$C_8H_{10}O$	66.2	93.8	107.7	122.0	138.0	148.0	161.0	181.5	203.6	225.2	62.5
3,5-Dimethylphenol (3,5-xylenol)	$C_8H_{10}O$	62.0	89.2	102.4	117.0	133.3	143.5	156.0	176.2	197.8	219.5	68
Dimethylphenylsilane	$C_8H_{12}Si$	+5.3	30.3	42.6	56.2	71.4	81.3	94.2	114.2	136.4	159.3	
Dimethyl phthalate	$C_{10}H_{10}O_4$	100.3	131.8	147.6	164.0	182.8	194.0	210.0	232.7	257.8	283.7	
3,5-Dimethyl-1,2-pyrone	$C_7H_8O_2$	78.6	107.6	122.0	136.4	152.7	163.8	177.5	198.0	221.0	245.0	51.5
4,6-Dimethylresorcinol	$C_8H_{10}O_2$	49.0	76.8	90.7	105.8	122.5	133.2	147.3	167.8	192.0	215.0	
Dimethyl sebacate	$C_{12}H_{22}O_4$	104.0	139.8	156.2	175.8	196.0	208.0	222.6	245.0	269.6	293.5	38
2,4-Dimethylstyrene	$C_{10}H_{12}$	34.2	61.9	75.8	90.8	107.7	118.0	132.3	153.2	177.5	202.0	
2,5-Dimethylstyrene	$C_{10}H_{12}$	29.0	55.9	69.0	84.0	100.2	110.7	124.7	145.6	168.7	193.0	
α,α-Dimethylsuccinic anhydride	$C_6H_8O_3$	61.4	88.1	102.0	116.3	132.3	142.4	155.3	175.8	197.5	219.5	
Dimethyl sulfide	C_2H_6S	−75.6	−58.0	−49.2	−39.4	−28.4	−21.4	−12.0	+2.6	18.7	36.0	−83.2
d-Dimethyl tartrate	$C_6H_{10}O_6$	102.1	133.2	148.2	164.3	182.4	193.8	208.8	230.5	255.0	280.0	61.5
dl-Dimethyl tartrate	$C_6H_{10}O_6$	100.4	131.8	147.5	164.0	182.4	193.8	209.5	232.3	257.4	282.0	89
N,*N*-Dimethyl-2-toluidine	$C_9H_{13}N$	28.8	54.1	66.2	80.2	95.0	105.2	118.1	138.3	161.5	184.8	−61
N,*N*-Dimethyl-4-toluidine	$C_9H_{13}N$	50.1	74.3	86.7	100.0	116.3	126.4	140.3	161.6	185.4	209.5	
Di(nitrosomethyl) amine	$C_2H_5N_3O_2$	+3.2	27.8	40.0	53.7	68.2	77.7	90.3	110.0	131.3	153.0	
Diosphenol	$C_{10}H_{16}O_2$	66.7	95.4	109.0	124.0	141.2	151.3	165.6	186.2	209.5	232.0	
1,4-Dioxane	$C_4H_8O_2$	−35.8	−12.8	−1.2	+12.0	25.2	33.8	45.1	62.3	81.8	101.1	10
Dipentene	$C_{10}H_{16}$	14.0	40.4	53.8	68.2	84.3	94.6	108.3	128.2	150.5	174.6	
Diphenylamine	$C_{12}H_{11}N$	108.3	141.7	157.0	175.2	194.3	206.9	222.8	247.5	274.1	302.0	52.9
Diphenyl carbinol (benzhydrol)	$C_{13}H_{12}O$	110.0	145.0	162.0	180.9	200.0	212.0	227.5	250.0	275.6	301.0	68.5
chlorophosphate	$C_{12}H_{10}ClPO_3$	121.5	160.5	182.0	203.8	227.9	244.2	265.0	299.5	337.2	378.0	
disulfide	$C_{12}H_{10}S_2$	131.6	164.0	180.0	197.0	214.8	226.2	241.3	262.6	285.8	310.0	61
1,2-Diphenylethane (dibenzyl)	$C_{14}H_{14}$	86.8	119.8	136.0	153.7	173.7	186.0	202.8	227.8	255.0	284.0	51.5
Diphenyl ether	$C_{12}H_{10}O$	66.1	97.8	114.0	130.8	150.0	162.0	178.8	203.3	230.7	258.5	27
1,1-Diphenylethylene	$C_{14}H_{12}$	87.4	119.6	135.0	151.8	170.8	183.4	198.6	222.8	249.8	277.0	
trans-Diphenylethylene	$C_{14}H_{12}$	113.2	145.8	161.0	179.8	199.0	211.5	227.4	251.7	278.3	306.5	124
1,1-Diphenylhydrazine	$C_{12}H_{12}N_2$	126.0	159.3	176.1	194.0	213.5	225.9	242.5	267.2	294.0	322.2	44
Diphenylmethane	$C_{13}H_{12}$	76.0	107.4	122.8	139.8	157.8	170.2	186.3	210.7	237.5	264.5	26.5
Diphenyl sulfide	$C_{12}H_{10}S$	96.1	129.0	145.0	162.0	182.8	194.8	211.8	236.8	263.9	292.5	
Diphenyl-2-tolyl thiophosphate	$C_{18}H_{17}O_3PS$	159.7	179.8	201.6	215.5	230.6	240.4	252.5	270.3	290.0	310.0	
1,2-Dipropoxyethane	$C_8H_{18}O_2$	−38.8	−10.3	+5.0	22.3	42.3	55.8	74.2	103.8	140.0	180.0	
1,2-Diisopropylbenzene	$C_{12}H_{18}$	40.0	67.8	81.8	96.8	114.0	124.3	138.7	159.8	184.3	209.0	
1,3-Diisopropylbenzene	$C_{12}H_{18}$	34.7	62.3	76.0	91.2	107.9	118.2	132.3	153.7	177.6	202.0	−105
Dipropylene glycol	$C_6H_{14}O_3$	73.8	102.1	116.2	131.3	147.4	156.5	169.9	189.9	210.5	231.8	
Dipropyleneglycol monobutyl ether	$C_{10}H_{22}O_3$	64.7	92.0	106.0	120.4	136.3	146.3	159.8	180.0	203.8	227.0	
isopropyl ether	$C_9H_{20}O_3$	46.0	72.8	86.2	100.8	117.0	126.8	140.3	160.0	183.1	205.6	
Di-*n*-propyl ether	$C_6H_{14}O$	−43.3	−22.3	−11.8	0.0	+13.2	21.6	33.0	50.3	69.5	89.5	−122
Diisopropyl ether	$C_6H_{14}O$	−57.0	−37.4	−27.4	−16.7	−4.5	+3.4	13.7	30.0	48.2	67.5	−60
Di-*n*-propyl ketone (4-heptanone)	$C_7H_{14}O$	23.0	44.4	55.0	66.2	78.1	85.8	96.0	111.2	127.3	143.7	−32.6
Di-*n*-propyl oxalate	$C_8H_{14}O_4$	53.4	80.2	93.9	108.6	124.6	134.8	148.1	168.0	190.3	213.5	
Diisopropyl oxalate	$C_8H_{14}O_4$	43.2	69.0	81.9	95.6	110.5	120.0	132.6	151.2	171.8	193.5	
Di-*n*-propyl succinate	$C_{10}H_{18}O_4$	77.5	107.6	122.2	138.0	154.8	166.0	180.3	202.5	226.5	250.8	
Di-*n*-propyl *d*-tartrate	$C_{10}H_{18}O_6$	115.6	147.7	163.5	180.4	199.7	211.7	227.0	250.1	275.6	303.0	
Diisopropyl *d*-tartrate	$C_{10}H_{18}O_6$	103.7	133.7	148.2	164.0	181.8	192.6	207.3	228.2	251.8	275.0	
Divinyl acetylene (1,5-hexadiene-3-yne)	C_6H_6	−45.1	−24.4	−14.0	−2.8	+10.0	18.1	29.5	46.0	64.4	84.0	
1,3-Divinylbenzene	$C_{10}H_{10}$	32.7	60.0	73.8	88.7	105.5	116.0	130.0	151.4	175.2	199.5	−66.9
Docosane	$C_{22}H_{46}$	157.8	195.4	213.0	233.5	254.5	268.3	286.0	314.2	343.5	376.0	44.5
n-Dodecane	$C_{12}H_{26}$	47.8	75.8	90.0	104.6	121.7	132.1	146.2	167.2	191.0	216.2	−9.6
1-Dodecene	$C_{12}H_{24}$	47.2	74.0	87.8	102.4	118.6	128.5	142.3	162.2	185.5	208.0	−31.5
n-Dodecyl alcohol	$C_{12}H_{26}O$	91.0	120.2	134.7	150.0	167.2	177.8	192.0	213.0	235.7	259.0	24
Dodecylamine	$C_{12}H_{27}N$	82.8	111.8	127.8	141.6	157.4	168.0	182.1	203.0	225.0	248.0	
Dodecyltrimethylsilane	$C_{15}H_{34}Si$	91.2	122.1	137.7	153.8	172.1	184.2	199.5	222.0	248.0	273.0	
Elaidic acid	$C_{18}H_{34}O_2$	171.3	206.7	223.5	242.3	260.8	273.0	288.0	312.4	337.0	362.0	51.5

TABLE 2-10 Vapor Pressures of Organic Compounds, up to 1 atm (*Continued*)

Compound		Pressure, mmHg										Melting point, °C
		1	5	10	20	40	60	100	200	400	760	
Name	Formula	Temperature, °C										
Epichlorohydrin	C_3H_5ClO	−16.5	+5.6	16.6	29.0	42.0	50.6	62.0	79.3	98.0	117.9	−25.6
1,2-Epoxy-2-methylpropane	C_4H_8O	−69.0	−50.0	−40.3	−29.5	−17.3	−9.7	+1.2	17.5	36.0	55.5	
Erucic acid	$C_{22}H_{42}O_2$	206.7	239.7	254.5	270.6	289.1	300.2	314.4	336.5	358.8	381.5	33.5
Estragole (*p*-methoxy allyl benzene)	$C_{10}H_{12}O$	52.6	80.0	93.7	108.4	124.6	135.2	148.5	168.7	192.0	215.0	
Ethane	C_2H_6	−159.5	−148.5	−142.9	−136.7	−129.8	−125.4	−119.3	−110.2	−99.7	−88.6	−183.2
Ethoxydimethylphenylsilane	$C_{10}H_{16}OSi$	36.3	63.1	76.2	91.0	107.2	127.5	131.4	151.5	175.0	199.5	
Ethoxytrimethylsilane	$C_5H_{14}OSi$	−50.9	−31.0	−20.7	−9.8	+3.7	11.5	22.1	38.1	56.3	75.7	
Ethoxytriphenylsilane	$C_{20}H_{20}OSi$	167.0	198.2	213.5	230.0	247.0	258.3	273.5	295.0	319.5	344.0	
Ethyl acetate	$C_4H_8O_2$	−43.4	−23.5	−13.5	−3.0	+9.1	16.6	27.0	42.0	59.3	77.1	−82.4
acetoacetate	$C_6H_{10}O_3$	28.5	54.0	67.3	81.1	96.2	106.0	118.5	138.0	158.2	180.8	−45
Ethylacetylene (1-butyne)	C_4H_6	−92.5	−76.7	−68.7	−59.9	−50.0	−43.4	−34.9	−21.6	−6.9	+8.7	−130
Ethyl acrylate	$C_5H_8O_2$	−29.5	−8.7	+2.0	13.0	26.0	33.5	44.5	61.5	80.0	99.5	−71.2
α-Ethylacrylic acid	$C_5H_8O_2$	47.0	70.7	82.0	94.4	108.1	116.7	127.5	144.0	160.7	179.2	
α-Ethylacrylonitrile	C_5H_7N	−29.0	−6.4	+5.0	17.7	31.8	40.6	53.0	71.6	92.2	114.0	
Ethyl alcohol (ethanol)	C_2H_6O	−31.3	−12.0	−2.3	+8.0	19.0	26.0	34.9	48.4	63.5	78.4	−112
Ethylamine	C_2H_7N	−82.3	−66.4	−58.3	−48.6	−39.8	−33.4	−25.1	−12.3	+2.0	16.6	−80.6
4-Ethylaniline	$C_8H_{11}N$	52.0	80.0	93.8	109.0	125.7	136.0	149.8	170.6	194.2	217.4	−4
N-Ethylaniline	$C_8H_{11}N$	38.5	66.4	80.6	96.0	113.2	123.6	137.3	156.9	180.8	204.0	−63.5
2-Ethylanisole	$C_9H_{12}O$	29.7	55.9	69.0	83.1	98.8	109.0	122.3	142.1	164.2	187.1	
3-Ethylanisole	$C_9H_{12}O$	33.7	60.3	73.9	88.5	104.8	115.5	129.2	149.7	172.8	196.5	
4-Ethylanisole	$C_9H_{12}O$	33.5	60.2	73.9	88.5	104.7	115.4	128.4	149.2	172.3	196.5	
Ethylbenzene	C_8H_{10}	−9.8	+13.9	25.9	38.6	52.8	61.8	74.1	92.7	113.8	136.2	−94.9
Ethyl benzoate	$C_9H_{10}O_2$	44.0	72.0	86.0	101.4	118.2	129.0	143.2	164.8	188.4	213.4	−34.6
benzoylacetate	$C_{11}H_{12}O_3$	107.6	136.4	150.3	166.8	181.8	191.9	205.0	223.8	244.7	265.0	
bromide	C_2H_5Br	−74.3	−56.4	−47.5	−37.8	−26.7	−19.5	−10.0	+4.5	21.0	38.4	−117.8
α-bromoisobutyrate	$C_6H_{11}BrO_2$	10.6	35.8	48.0	61.8	77.0	86.7	99.8	119.7	141.2	163.6	
n-butyrate	$C_6H_{12}O_2$	−18.4	+4.0	15.3	27.8	41.5	50.1	62.0	79.8	100.0	121.0	−93.3
isobutyrate	$C_6H_{12}O_2$	−24.3	−2.4	+8.4	20.6	33.8	42.3	53.5	71.0	90.0	110.0	−88.2
Ethylcamphoronic anhydride	$C_{11}H_{16}O_5$	118.2	149.8	165.0	181.8	199.8	211.5	226.6	248.5	272.8	298.0	
Ethyl isocaproate	$C_8H_{16}O_2$	11.0	35.8	48.0	61.7	76.3	85.8	98.4	117.8	139.2	160.4	
carbamate	$C_3H_7NO_2$		65.8	77.8	91.0	105.6	114.8	126.2	144.2	164.0	184.0	49
carbanilate	$C_9H_{11}NO_2$	107.8	131.8	143.7	155.5	168.8	177.3	187.9	203.8	220.0	237.0	52.5
Ethylcetylamine	$C_{18}H_{39}N$	133.2	168.2	186.0	205.5	226.5	239.8	256.8	283.3	313.0	342.0	
Ethyl chloride	C_2H_5Cl	−89.8	−73.9	−65.8	−56.8	−47.0	−40.6	−32.0	−18.6	−3.9	+12.3	−139
chloroacetate	$C_4H_7ClO_2$	+1.0	25.4	37.5	50.4	65.2	74.0	86.0	103.8	123.8	144.2	−26
chloroglyoxylate	$C_4H_5ClO_3$	−5.1	+18.0	29.9	42.0	56.0	65.2	76.6	94.5	114.7	135.0	
α-chloropropionate	$C_5H_9ClO_2$	+6.6	30.2	41.9	54.3	68.2	77.3	89.3	107.2	126.2	146.5	
trans-cinnamate	$C_{11}H_{12}O_2$	87.6	108.5	134.0	150.3	169.2	181.2	196.0	219.3	245.0	271.0	12
3-Ethylcumene	$C_{11}H_{16}$	28.3	55.5	68.8	83.6	99.9	110.2	124.3	145.4	168.2	193.0	
4-Ethylcumene	$C_{11}H_{16}$	31.5	58.4	72.0	86.7	103.3	113.8	127.2	148.3	171.8	195.8	
Ethyl cyanoacetate	$C_5H_7NO_2$	67.8	93.5	106.0	119.8	133.8	142.1	152.8	169.8	187.8	206.0	
Ethylcyclohexane	C_8H_{16}	−14.5	+9.2	20.6	33.4	47.6	56.7	69.0	87.8	109.1	131.8	−111.3
Ethylcyclopentane	C_7H_{14}	−32.2	−10.8	−0.1	+11.7	25.0	33.4	45.0	62.4	82.3	103.4	−138.6
Ethyl dichloroacetate	$C_4H_6Cl_2O_2$	9.6	34.0	46.3	59.5	74.0	83.6	96.1	115.2	135.9	156.5	
N,*N*-diethyloxamate	$C_8H_{15}NO_3$	76.0	106.3	121.7	137.7	154.4	166.0	180.3	202.8	226.5	252.0	
N-Ethyldiphenylamine	$C_{14}H_{15}N$	98.3	130.2	146.0	162.8	182.0	193.7	209.8	233.0	258.8	286.0	
Ethylene	C_2H_4	−168.3	−158.3	−153.2	−147.6	−141.3	−137.3	−131.8	−123.4	−113.9	−103.7	−169
Ethylene-bis-(chloroacetate)	$C_6H_8Cl_2O_4$	112.0	142.4	158.0	173.5	191.0	201.8	215.0	237.3	259.5	283.5	
Ethylene chlorohydrin (2-chloroethanol)	C_2H_5ClO	−4.0	+19.0	30.3	42.5	56.0	64.1	75.0	91.8	110.0	128.8	−69
diamine (1,2-ethanediamine)	$C_2H_8N_2$	−11.0	+10.5	21.5	33.0	45.8	53.8	62.5	81.0	99.0	117.2	8.5
dibromide (1,2-dibromethane)	$C_2H_4Br_2$	−27.0	+4.7	18.6	32.7	48.0	57.9	70.4	89.8	110.1	131.5	10
dichloride (1,2-dichloroethane)	$C_2H_4Cl_2$	−44.5	−24.0	−13.6	−2.4	+10.0	18.1	29.4	45.7	64.0	82.4	−35.3
glycol (1,2-ethanediol)	$C_2H_6O_2$	53.0	79.7	92.1	105.8	120.0	129.5	141.8	158.5	178.5	197.3	−15.6
glycol diethyl ether (1,2-diethoxyethane)	$C_6H_{14}O_2$	−33.5	−10.2	+1.6	14.7	29.7	39.0	51.8	71.8	94.1	119.5	
glycol dimethyl ether (1,2-dimethoxyethane)	$C_4H_{10}O_2$	−48.0	−26.2	−15.3	−3.0	+10.7	19.7	31.8	50.0	70.8	93.0	
glycol monomethyl ether (2-methoxyethanol)	$C_3H_8O_2$	−13.5	+10.2	22.0	34.3	47.8	56.4	68.0	85.3	104.3	124.4	
oxide	C_2H_4O	−89.7	−73.8	−65.7	−56.6	−46.9	−40.7	−32.1	−19.5	−4.9	+10.7	−111.3
Ethyl α-ethylacetoacetate	$C_8H_{14}O_3$	40.5	67.3	80.2	94.6	110.3	120.6	133.8	153.2	175.6	198.0	
fluoride	C_2H_5F	−117.0	−103.8	−97.7	−90.0	−81.8	−76.4	−69.3	−58.0	−45.5	−32.0	
formate	$C_3H_6O_2$	−60.5	−42.2	−33.0	−22.7	−11.5	−4.3	−5.4	20.0	37.1	54.3	−79
2-furoate	$C_7H_8O_3$	37.6	63.8	77.1	91.5	107.5	117.5	130.4	150.1	172.5	195.0	34
glycolate	$C_4H_8O_3$	14.3	38.8	50.5	63.9	78.1	87.6	99.8	117.8	138.0	158.2	
3-Ethylhexane	C_8H_{18}	−20.0	+2.1	12.8	25.0	38.5	47.1	58.9	76.7	97.0	118.5	
2-Ethylhexyl acrylate	$C_{11}H_{20}O_2$	50.0	77.7	91.8	106.3	123.7	134.0	147.9	168.2	192.2	216.0	
Ethylidene chloride (1,1-dichloroethane)	$C_2H_4Cl_2$	−60.7	−41.9	−32.3	−21.9	−10.2	−2.9	+7.2	22.4	39.8	57.4	−96.7
fluoride (1,1-difluoroethane)	$C_2H_4F_2$	−112.5	−98.4	−91.7	−84.1	−75.8	−70.4	−63.2	−52.0	−39.5	−26.5	−117
Ethyl iodide	C_2H_5I	−54.4	−34.3	−24.3	−13.1	−0.9	+7.2	18.0	34.1	52.3	72.4	−105
Ethyl *l*-leucinate	$C_8H_{17}NO_2$	27.8	57.3	72.1	88.0	106.0	117.8	131.8	149.8	167.3	184.0	
Ethyl levulinate	$C_7H_{12}O_3$	47.3	74.0	87.3	101.8	117.7	127.6	141.3	160.2	183.0	206.2	
Ethyl mercaptan (ethanethiol)	C_2H_6S	−76.7	−59.1	−50.2	−40.7	−29.8	−22.4	−13.0	+1.5	17.7	35.0	−121
Ethyl methylcarbamate	$C_4H_9NO_2$	26.5	51.0	63.2	76.1	91.0	100.0	112.0	130.0	149.8	170.0	
Ethyl methyl ether	C_3H_8O	−91.0	−75.6	−67.8	−59.1	−49.4	−43.3	−34.8	−22.0	−7.8	+7.5	

TABLE 2-10 Vapor Pressures of Organic Compounds, up to 1 atm (*Continued*)

Compound		Pressure, mmHg										Melting point, °C
		1	5	10	20	40	60	100	200	400	760	
Name	Formula	Temperature, °C										
1-Ethylnaphthalene	$C_{12}H_{12}$	70.0	101.4	116.8	133.8	152.0	164.1	180.0	204.6	230.8	258.1	–27
Ethyl α-naphthyl ketone (1-propionaphthone)	$C_{13}H_{12}O$	124.0	155.5	171.0	188.1	206.9	218.2	233.5	255.5	280.2	306.0	
Ethyl 3-nitrobenzoate	$C_9H_9NO_4$	108.1	140.2	155.0	173.6	192.6	205.0	220.3	244.6	270.6	298.0	47
3-Ethylpentane	C_7H_{16}	–37.8	–17.0	–6.8	+4.7	17.5	25.7	36.9	53.8	73.0	93.5	–118.6
4-Ethylphenetole	$C_{10}H_{14}O$	48.5	75.7	89.5	103.8	119.8	129.8	143.5	163.2	185.7	208.0	
2-Ethylphenol	$C_8H_{10}O$	46.2	73.4	87.0	101.5	117.9	127.9	141.8	161.6	184.5	207.5	–45
3-Ethylphenol	$C_8H_{10}O$	60.0	86.8	100.2	114.5	130.0	139.8	152.0	171.8	193.3	214.0	–4
4-Ethylphenol	$C_8H_{10}O$	59.3	86.5	100.2	115.0	131.3	141.7	154.2	175.0	197.4	219.0	46.5
Ethyl phenyl ether (phenetole)	$C_8H_{10}O$	18.1	43.7	56.4	70.3	86.6	95.4	108.4	127.9	149.8	172.0	–30.2
Ethyl propionate	$C_5H_{10}O_2$	–28.0	–7.2	+3.4	14.3	27.2	35.1	45.2	61.7	79.8	99.1	–72.6
Ethyl propyl ether	$C_5H_{12}O$	–64.3	–45.0	–35.0	–24.0	–12.0	–4.0	+6.8	23.3	41.6	61.7	
Ethyl salicylate	$C_9H_{10}O_3$	61.2	90.0	104.2	119.3	136.7	147.6	161.5	183.7	207.0	231.5	1.3
3-Ethylstyrene	$C_{10}H_{12}$	28.3	55.0	68.3	82.8	99.2	109.6	123.2	144.0	167.2	191.5	
4-Ethylstyrene	$C_{10}H_{12}$	26.0	52.7	66.3	80.8	97.3	107.6	121.5	142.0	165.0	189.0	
Ethylisothiocyanate	C_3H_5NS	–13.2	+10.6	22.8	36.1	50.8	59.8	71.9	90.0	110.1	131.0	–5.9
2-Ethyltoluene	C_9H_{12}	9.4	34.8	47.6	61.2	76.4	86.0	99.0	119.0	141.4	165.1	
3-Ethyltoluene	C_9H_{12}	7.2	32.3	44.7	58.2	73.3	82.9	95.9	115.5	137.8	161.3	–95.5
4-Ethyltoluene	C_9H_{12}	7.6	32.7	44.9	58.5	73.6	83.2	96.3	116.1	136.4	162.0	
Ethyl trichloroacetate	$C_4H_5Cl_3O_2$	20.7	45.5	57.7	70.6	85.5	94.4	107.4	125.8	146.0	167.0	
Ethyltrimethylsilane	$C_5H_{14}Si$	–60.6	–41.4	–31.8	–21.0	–9.0	–1.2	+9.2	25.0	42.8	62.0	
Ethyltrimethyltin	$C_5H_{14}Sn$	–30.0	–7.6	+3.8	16.1	30.0	38.4	50.0	67.3	87.6	108.8	
Ethyl isovalerate	$C_7H_{14}O_2$	–6.1	+17.0	28.7	41.3	55.2	64.0	75.9	93.8	114.0	134.3	–99.3
2-Ethyl-1,4-xylene	$C_{10}H_{14}$	25.7	52.0	65.6	79.8	96.0	106.2	120.0	140.2	163.1	186.9	
4-Ethyl-1,3-xylene	$C_{10}H_{14}$	26.3	53.0	66.4	80.6	97.2	107.4	121.2	141.8	164.4	188.4	
5-Ethyl-1,3-xylene	$C_{10}H_{14}$	22.1	48.8	62.1	76.5	92.6	103.0	116.5	137.4	159.6	183.7	
Eugenol	$C_{10}H_{12}O_2$	78.4	108.1	123.0	138.7	155.8	167.3	182.2	204.7	228.3	253.5	
iso-Eugenol	$C_{10}H_{12}O_2$	86.3	117.0	132.4	149.0	167.0	178.2	194.0	217.2	242.3	267.5	–10
Eugenyl acetate	$C_{12}H_{14}O_3$	101.6	132.3	148.0	164.2	183.0	194.0	209.7	232.5	257.4	282.0	295
Fencholic acid	$C_{10}H_{16}O_2$	101.7	128.7	142.3	155.8	171.8	181.5	194.0	215.0	237.8	264.1	19
d-Fenchone	$C_{10}H_{16}O$	28.0	54.7	68.3	83.0	99.5	109.8	123.6	144.0	166.8	191.0	5
dl-Fenchyl alcohol	$C_{10}H_{18}O$	45.8	70.3	82.1	95.6	110.8	120.2	132.3	150.0	173.2	201.0	35
Fluorene	$C_{13}H_{10}$		129.3	146.0	164.2	185.2	197.8	214.7	240.3	268.6	295.0	113
Fluorobenzene	C_6H_5F	–43.4	–22.8	–12.4	–1.2	+11.5	19.6	30.4	47.2	65.7	84.7	–42.1
2-Fluorotoluene	C_7H_7F	–24.2	–2.2	+8.9	21.4	34.7	43.7	55.3	73.0	92.8	114.0	–80
3-Fluorotoluene	C_7H_7F	–22.4	–0.3	+11.0	23.4	37.0	45.8	57.5	75.4	95.4	116.0	–110.8
4-Fluorotoluene	C_7H_7F	–21.8	+0.3	11.8	24.0	37.8	46.5	58.1	76.0	96.1	117.0	
Formaldehyde	CH_2O			–88.0	–79.6	–70.6	–65.0	–57.3	–46.0	–33.0	–19.5	–92
Formamide	CH_3NO	70.5	96.3	109.5	122.5	137.5	147.0	157.5	175.5	193.5	210.5	
Formic acid	CH_2O_2	–20.0	–5.0	+2.1	10.3	24.0	32.4	43.8	61.4	80.3	100.6	8.2
trans-Fumaryl chloride	$C_4H_2Cl_2O_2$	+15.0	38.5	51.8	65.0	79.5	89.0	101.0	120.0	140.0	160.0	
Furfural (2-furaldehyde)	$C_5H_4O_2$	18.5	42.6	54.8	67.8	82.1	91.5	103.4	121.8	141.8	161.8	
Furfuryl alcohol	$C_5H_6O_2$	31.8	56.0	68.0	81.0	95.7	104.0	115.9	133.1	151.8	170.0	
Geraniol	$C_{10}H_{18}O$	69.2	96.8	110.0	125.6	141.8	151.5	165.3	185.6	207.8	230.0	
Geranyl acetate	$C_{12}H_{20}O_2$	73.5	102.7	117.9	133.0	150.0	160.3	175.2	196.3	219.8	243.3	
Geranyl *n*-butyrate	$C_{14}H_{24}O_2$	96.8	125.2	139.0	153.8	170.1	180.2	193.8	214.0	235.0	257.4	
Geranyl isobutyrate	$C_{14}H_{24}O_2$	90.9	119.6	133.0	147.9	164.0	174.0	187.7	207.6	228.5	251.0	
Geranyl formate	$C_{11}H_{18}O_2$	61.8	90.3	104.3	119.8	136.2	147.2	160.7	182.6	205.8	230.0	
Glutaric acid	$C_5H_8O_4$	155.5	183.8	196.0	210.5	226.3	235.5	247.0	265.0	283.5	303.0	97.5
Glutaric anhydride	$C_5H_6O_3$	100.8	133.3	149.5	166.0	185.5	196.2	212.5	236.5	261.0	287.0	
Glutaronitrile	$C_5H_6N_2$	91.3	123.7	140.0	156.5	176.4	189.5	205.5	230.0	257.3	286.2	
Glutaryl chloride	$C_5H_6Cl_2O_2$	56.1	84.0	97.8	112.3	128.3	139.1	151.8	172.4	195.3	217.0	
Glycerol	$C_3H_8O_3$	125.5	153.8	167.2	182.2	198.0	208.0	220.1	240.0	263.0	290.0	17.9
Glycerol dichlorohydrin (1,3-dichloro-2-propanol)	$C_3H_6Cl_2O$	28.0	52.2	64.7	78.0	93.0	102.0	114.8	133.3	153.5	174.3	
Glycol diacetate	$C_6H_{10}O_4$	38.3	64.1	77.1	90.8	106.1	115.8	128.0	147.8	168.3	190.5	–31
Glycolide (1,4-dioxane-2,6-dione)	$C_4H_4O_4$		103.0	116.6	132.0	148.6	158.2	173.2	194.0	217.0	240.0	97
Guaicol (2-methoxyphenol)	$C_7H_8O_2$	52.4	79.1	92.0	106.0	121.6	131.0	144.0	162.7	184.1	205.0	28.3
Heneicosane	$C_{21}H_{44}$	152.6	188.0	205.4	223.2	243.4	255.3	272.0	296.5	323.8	350.5	40.4
Heptacosane	$C_{27}H_{56}$	211.7	248.6	266.8	284.6	305.7	318.3	333.5	359.4	385.0	410.6	59.5
Heptadecane	$C_{17}H_{36}$	115.0	145.2	160.0	177.7	195.8	207.3	223.0	247.8	274.5	303.0	22.5
Heptaldehyde (enanthaldehyde)	$C_7H_{14}O$	12.0	32.7	43.0	54.0	66.3	74.0	84.0	102.0	125.5	155.0	–42
n-Heptane	C_7H_{16}	–34.0	–12.7	–2.1	+9.5	22.3	30.6	41.8	58.7	78.0	98.4	–90.6
Heptanoic acid (enanthic acid)	$C_7H_{14}O_2$	78.0	101.3	113.2	125.6	139.5	148.5	160.0	179.5	199.6	221.5	–10
1-Heptanol	$C_7H_{16}O$	42.4	64.3	74.7	85.8	99.8	108.0	119.5	136.6	155.6	175.8	34.6
Heptanoyl chloride (enanthyl chloride)	$C_7H_{13}ClO$	34.2	54.6	64.6	75.0	86.4	93.5	102.7	116.3	130.7	145.0	
2-Heptene	C_7H_{14}	–35.8	–14.1	–3.5	+8.3	21.5	30.0	41.3	58.6	78.1	98.5	
Heptylbenzene	$C_{13}H_{20}$	64.0	94.6	110.0	126.0	144.0	154.8	170.2	193.3	217.8	244.0	
Heptyl cyanide (enanthonitrile)	$C_7H_{13}N$	21.0	47.8	61.6	76.3	92.6	103.0	116.8	137.7	160.0	184.6	
Hexachlorobenzene	C_6Cl_6	114.4	149.3	166.4	185.7	206.0	219.0	235.5	258.5	283.5	309.4	230
Hexachloroethane	C_2Cl_6	32.7	49.8	73.5	87.6	102.3	112.0	124.2	143.1	163.8	185.6	186.6
Hexacosane	$C_{26}H_{54}$	204.0	240.0	257.4	275.8	295.2	307.8	323.2	348.4	374.6	399.8	56.6
Hexadecane	$C_{16}H_{34}$	105.3	135.2	149.8	164.7	181.3	193.2	208.5	231.7	258.3	287.5	18.5
1-Hexadecene	$C_{16}H_{32}$	101.6	131.7	146.2	162.0	178.8	190.8	205.3	226.8	250.0	274.0	4
n-Hexadecyl alcohol (cetyl alcohol)	$C_{16}H_{34}O$	122.7	158.3	177.8	197.8	219.8	234.3	251.7	280.2	312.7	344.0	49.3

TABLE 2-10 Vapor Pressures of Organic Compounds, up to 1 atm (*Continued*)

Compound		Pressure, mmHg										Melting point, °C
		1	5	10	20	40	60	100	200	400	760	
Name	Formula	Temperature, °C										
n-Hexadecylamine (cetylamine)	$C_{16}H_{35}N$	123.6	157.8	176.0	195.7	215.7	228.8	245.8	272.2	300.4	330.0	
Hexaethylbenzene	$C_{18}H_{30}$		134.3	150.3	168.0	187.7	199.7	216.0	241.7	268.5	298.3	130
n-Hexane	C_6H_{14}	−53.9	−34.5	−25.0	−14.1	−2.3	+5.4	15.8	31.6	49.6	68.7	−95.3
1-Hexanol	$C_6H_{14}O$	24.4	47.2	58.2	70.3	83.7	92.0	102.8	119.6	138.0	157.0	−51.6
2-Hexanol	$C_6H_{14}O$	14.6	34.8	45.0	55.9	67.9	76.0	87.3	103.7	121.8	139.9	
3-Hexanol	$C_6H_{14}O$	+2.5	25.7	36.7	49.0	62.2	70.7	81.8	98.3	117.0	135.5	
1-Hexene	C_6H_{12}	−57.5	−38.0	−28.1	−17.2	−5.0	+2.8	13.0	29.0	46.8	66.0	−98.5
n-Hexyl levulinate	$C_{11}H_{20}O_3$	90.0	120.0	134.7	150.2	167.8	179.0	193.6	215.7	241.0	266.8	
n-Hexyl phenyl ketone (enanthophenone)	$C_{13}H_{18}O$	100.0	130.3	145.5	161.0	178.9	189.8	204.2	225.0	248.3	271.3	
Hydrocinnamic acid	$C_9H_{10}O_2$	102.2	133.5	148.7	165.0	183.3	194.0	209.0	230.8	255.0	279.8	48.5
Hydrogen cyanide (hydrocyanic acid)	CHN	−71.0	−55.3	−47.7	−39.7	−30.9	−25.1	−17.8	−5.3	+10.2	25.9	−13.2
Hydroquinone	$C_6H_6O_2$	132.4	153.3	163.5	174.6	192.0	203.0	216.5	238.0	262.5	286.2	170.3
4-Hydroxybenzaldehyde	$C_7H_6O_2$	121.2	153.2	169.7	186.8	206.0	217.5	233.5	256.8	282.6	310.0	115.5
α-Hydroxyisobutyric acid	$C_4H_8O_3$	73.5	98.5	110.5	123.8	138.0	146.4	157.7	175.2	193.8	212.0	79
α-Hydroxybutyronitrile	C_5H_9NO	41.0	65.8	77.8	90.7	104.8	113.9	125.0	142.0	159.8	178.8	
4-Hydroxy-3-methyl-2-butanone	$C_5H_{10}O_2$	44.6	69.3	81.0	94.0	108.2	117.4	129.0	146.5	165.5	185.0	
4-Hydroxy-4-methyl-2-pentanone	$C_6H_{12}O_2$	22.0	46.7	58.8	72.0	86.7	96.0	108.2	126.8	147.5	167.9	−47
3-Hydroxypropionitrile	C_3H_5NO	58.7	87.8	102.0	117.9	134.1	144.7	157.7	178.0	200.0	221.0	
Indene	C_9H_8	16.4	44.3	58.5	73.9	90.7	100.8	114.7	135.6	157.8	181.6	−2
Iodobenzene	C_6H_5I	24.1	50.6	64.0	78.3	94.4	105.0	118.3	139.8	163.9	188.6	−28.5
Iodononane	$C_9H_{19}I$	70.0	96.2	109.0	123.0	138.1	147.7	159.8	179.0	199.3	219.5	
2-Iodotoluene	C_7H_7I	37.2	65.9	79.8	95.6	112.4	123.8	138.1	160.0	185.7	211.0	
α-Ionone	$C_{13}H_{20}O$	79.5	108.8	123.0	139.0	155.6	166.3	181.2	202.5	225.2	250.0	
Isoprene	C_5H_8	−79.8	−62.3	−53.3	−43.5	−32.6	−25.4	−16.0	−1.2	+15.4	32.6	−146.7
Lauraldehyde	$C_{12}H_{24}O$	77.7	108.4	123.7	140.2	157.8	168.7	184.5	207.8	231.8	257.0	44.5
Lauric acid	$C_{12}H_{24}O_2$	121.0	150.6	166.0	183.6	201.4	212.7	227.5	249.8	273.8	299.2	48
Levulinaldehyde	$C_5H_8O_2$	28.1	54.9	68.0	82.7	98.3	108.4	121.8	142.0	164.0	187.0	
Levulinic acid	$C_5H_8O_3$	102.0	128.1	141.8	154.1	169.5	178.0	190.2	208.3	227.4	245.8	33.5
d-Limonene	$C_{10}H_{16}$	14.0	40.4	53.8	68.2	84.3	94.6	108.3	128.5	151.4	175.0	−96.9
Linalyl acetate	$C_{12}H_{20}O_2$	55.4	82.5	96.0	111.4	127.7	138.1	151.8	173.3	196.2	220.0	
Maleic anhydride	$C_4H_2O_3$	44.0	63.4	78.7	95.0	111.8	122.0	135.8	155.9	179.5	202.0	58
Menthane	$C_{10}H_{20}$	+9.7	35.7	48.3	62.7	78.3	88.6	102.1	122.7	146.0	169.5	
1-Menthol	$C_{10}H_{20}O$	56.0	83.2	96.0	110.3	126.1	136.1	149.4	168.3	190.2	212.0	42.5
Menthyl acetate	$C_{12}H_{22}O_2$	57.4	85.8	100.0	115.4	132.1	143.2	156.7	178.8	202.8	227.0	
benzoate	$C_{17}H_{24}O_2$	123.2	154.2	170.0	186.3	204.3	215.8	230.4	253.2	277.1	301.0	54.5
formate	$C_{11}H_{20}O_2$	47.3	75.8	90.0	105.8	123.0	133.8	148.0	169.8	194.2	219.0	
Mesityl oxide	$C_6H_{10}O$	−8.7	+14.1	26.0	37.9	51.7	60.4	72.1	90.0	109.8	130.0	−59
Methacrylic acid	$C_4H_6O_2$	25.5	48.5	60.0	72.7	86.4	95.3	106.6	123.9	142.5	161.0	15
Methacrylonitrile	C_4H_5N	−44.5	−23.3	−12.5	−0.6	+12.8	21.5	32.8	50.0	70.3	90.3	
Methane	CH_4	−205.9	−199.0	−195.5	−191.8	−187.7	−185.1	−181.4	−175.5	−168.8	−161.5	−182.5
Methanethiol	CH_4S	−90.7	−75.3	−67.5	−58.8	−49.2	−43.1	−34.8	−22.1	−7.9	+6.8	−121
Methoxyacetic acid	$C_3H_6O_3$	52.5	79.3	92.0	106.5	122.0	131.8	144.5	163.5	184.2	204.0	
N-Methylacetanilide	$C_9H_{11}NO$		103.8	118.6	135.1	152.2	164.2	179.8	202.3	227.4	253.0	102
Methyl acetate	$C_3H_6O_2$	−57.2	−38.6	−29.3	−19.1	−7.9	−0.5	+9.4	24.0	40.0	57.8	−98.7
acetylene (propyne)	C_3H_4	−111.0	−97.5	−90.5	−82.9	−74.3	−68.8	−61.3	−49.8	−37.2	−23.3	−102.7
acrylate	$C_4H_6O_2$	−43.7	−23.6	−13.5	−2.7	+9.2	17.3	28.0	43.9	61.8	80.2	
alcohol (methanol)	CH_4O	−44.0	−25.3	−16.2	−6.0	+5.0	12.1	21.2	34.8	49.9	64.7	−97.8
Methylamine	CH_5N	−95.8	−81.3	−73.8	−65.9	−56.9	−51.3	−43.7	−32.4	−19.7	−6.3	−93.5
N-Methylaniline	C_7H_9N	36.0	62.8	76.2	90.5	106.0	115.8	129.8	149.3	172.0	195.5	−57
Methyl anthranilate	$C_8H_9NO_2$	77.6	109.0	124.2	141.5	159.7	172.0	187.8	212.4	238.5	266.5	24
benzoate	$C_8H_8O_2$	39.0	64.4	77.3	91.8	107.8	117.4	130.8	151.4	174.7	199.5	−12.5
2-Methylbenzothiazole	C_8H_7NS	70.0	97.5	111.2	125.5	141.2	150.4	163.9	183.2	204.5	225.5	15.4
α-Methylbenzyl alcohol	$C_8H_{10}O$	49.0	75.2	88.0	102.1	117.8	127.4	140.3	159.0	180.7	204.0	
Methyl bromide	CH_3Br	−96.3	−80.6	−72.8	−64.0	−54.2	−48.0	−39.4	−26.5	−11.9	+3.6	−93
2-Methyl-1-butene	C_5H_{10}	−89.1	−72.8	−64.3	−54.8	−44.1	−37.3	−28.0	−13.8	+2.5	20.2	−135
2-Methyl-2-butene	C_5H_{10}	−75.4	−57.0	−47.9	−37.9	−26.7	−19.4	−9.9	+4.9	21.6	38.5	−133
Methyl isobutyl carbinol (2-methyl-4-pentanol)	$C_6H_{14}O$	−0.3	+22.1	33.3	45.4	58.2	67.0	78.0	94.9	113.5	131.7	
n-butyl ketone (2-hexanone)	$C_6H_{12}O$	+7.7	28.8	38.8	50.0	62.0	69.8	79.8	94.3	111.0	127.5	−56.9
isobutyl ketone (4-methyl-2-pentanone)	$C_6H_{12}O$	−1.4	+19.7	30.0	40.8	52.8	60.4	70.4	85.6	102.0	119.0	−84.7
n-butyrate	$C_5H_{10}O_2$	−26.8	−5.5	+5.0	16.7	29.6	37.4	48.0	64.3	83.1	102.3	
isobutyrate	$C_5H_{10}O_2$	−34.1	−13.0	−2.9	+8.4	21.0	28.9	39.6	55.7	73.6	92.6	−84.7
caprate	$C_{11}H_{22}O_2$	63.7	93.5	108.0	123.0	139.0	148.6	161.5	181.6	202.9	224.0	−18
caproate	$C_7H_{14}O_2$	+5.0	30.0	42.0	55.4	70.0	79.7	91.4	109.8	129.8	150	
caprylate	$C_9H_{18}O_2$	34.2	61.7	74.9	89.0	105.3	115.3	128.0	148.1	170.0	193.0	−40
chloride	CH_3Cl		−99.5	−92.4	−84.8	−76.0	−70.4	−63.0	−51.2	−38.0	−24.0	−97.7
chloroacetate	$C_3H_5ClO_2$	−2.9	19.0	30.0	41.5	54.5	63.0	73.5	90.5	109.5	130.3	−31.9
cinnamate	$C_{10}H_{10}O_2$	77.4	108.1	123.0	140.0	157.9	170.0	185.8	209.6	235.0	263.0	33.4
α-Methylcinnamic acid	$C_{10}H_{10}O_2$	125.7	155.0	169.8	185.2	201.8	212.0	224.8	245.0	266.8	288.0	
Methylcyclohexane	C_7H_{14}	−35.9	−14.0	−3.2	+8.7	22.0	30.5	42.1	59.6	79.6	100.9	−126.4
Methylcyclopentane	C_6H_{12}	−53.7	−33.8	−23.7	−12.8	−0.6	+7.2	17.9	34.0	52.3	71.8	−142.4
Methylcyclopropane	C_4H_8	−96.0	−80.6	−72.8	−64.0	−54.2	−48.0	−39.3	−26.0	−11.3	+4.5	
Methyl *n*-decyl ketone (*n*-dodecan-2-one)	$C_{12}H_{24}O$	77.1	106.0	120.4	136.0	152.4	163.8	177.5	199.0	222.5	246.5	
dichloroacetate	$C_3H_4Cl_2O_2$	3.2	26.7	38.1	50.7	64.7	73.6	85.4	103.2	122.6	143.0	
N-Methyldiphenylamine	$C_{13}H_{13}N$	103.5	134.0	149.7	165.8	184.0	195.4	210.1	232.8	257.0	282.0	−7.6

TABLE 2-10 Vapor Pressures of Organic Compounds, up to 1 atm* (*Continued*)

Compound		Pressure, mmHg										Melting point, °C
		1	5	10	20	40	60	100	200	400	760	
Name	Formula	Temperature, °C										
Methyl *n*-dodecyl ketone (2-tetradecanone)	$C_{14}H_{28}O$	99.3	130.0	145.5	161.3	179.8	191.4	206.0	228.2	253.3	278.0	
Methylene bromide (dibromomethane)	CH_2Br_2	–35.1	–13.2	–2.4	+9.7	23.3	31.6	42.3	58.5	79.0	98.6	–52.8
chloride (dichloromethane)	CH_2Cl_2	–70.0	–52.1	–43.3	–33.4	–22.3	–15.7	–6.3	+8.0	24.1	40.7	–96.7
Methyl ethyl ketone (2-butanone)	C_4H_8O	–48.3	–28.0	–17.7	–6.5	+6.0	14.0	25.0	41.6	60.0	79.6	–85.9
2-Methyl-3-ethylpentane	C_8H_{18}	–24.0	–1.8	+9.5	21.7	35.2	43.9	55.7	73.6	94.0	115.6	–114.5
3-Methyl-3-ethylpentane	C_8H_{18}	–23.9	–1.4	+9.9	22.3	36.2	45.0	57.1	75.3	96.2	118.3	–90
Methyl fluoride	CH_3F	–147.3	–137.0	–131.6	–125.9	–119.1	–115.0	–109.0	–99.9	–89.5	–78.2	
formate	$C_2H_4O_2$	–74.2	–57.0	–48.6	–39.2	–28.7	–21.9	–12.9	+0.8	16.0	32.0	–99.8
α-Methylglutaric anhydride	$C_6H_8O_3$	93.8	125.4	141.8	157.7	177.5	189.9	205.0	229.1	255.5	282.5	
Methyl glycolate	$C_3H_6O_3$	+9.6	33.7	45.3	58.1	72.3	81.8	93.7	111.8	131.7	151.5	
2-Methylheptadecane	$C_{18}H_{38}$	119.8	152.0	168.7	186.0	204.8	216.3	231.5	254.5	279.8	306.5	
2-Methylheptane	C_8H_{18}	–21.0	+1.3	12.3	24.4	37.9	46.6	58.3	76.0	96.2	117.6	–109.5
3-Methylheptane	C_8H_{18}	–19.8	+2.6	13.3	25.4	38.9	47.6	59.4	77.1	97.4	118.9	–120.8
4-Methylheptane	C_8H_{18}	–20.4	+1.5	12.4	24.5	38.0	46.6	58.3	76.1	96.3	117.7	–121.1
2-Methyl-2-heptene	C_8H_{16}	–16.1	+6.7	17.8	30.4	44.0	52.8	64.6	82.3	102.2	122.5	
6-Methyl-3-hepten-2-ol	$C_8H_{16}O$	41.6	65.0	76.7	89.3	102.7	111.5	122.6	139.5	156.6	175.5	
6-Methyl-5-hepten-2-ol	$C_8H_{16}O$	41.9	66.0	77.8	90.4	104.0	112.8	123.8	140.0	156.6	174.3	
2-Methylhexane	C_7H_{16}	–40.4	–19.5	–9.1	+2.3	14.9	23.0	34.1	50.8	69.8	90.0	–118.2
3-Methylhexane	C_7H_{16}	–39.0	–18.1	–7.8	+3.6	16.4	24.5	35.6	52.4	71.6	91.9	
Methyl iodide	CH_3I		–55.0	–45.8	–35.6	–24.2	–16.9	–7.0	+8.0	25.3	42.4	–64.4
laurate	$C_{13}H_{26}O_2$	87.8	117.9	133.2	149.0	166.0	176.8	190.8				5
levulinate	$C_6H_{10}O_3$	39.8	66.4	79.7	93.7	109.5	119.3	133.0	153.4	175.8	197.7	
methacrylate	$C_5H_8O_2$	–30.5	–10.0	+1.0	11.0	25.5	34.5	47.0	63.0	82.0	101.0	
myristate	$C_{15}H_{30}O_2$	115.0	145.7	160.8	177.8	195.8	207.5	222.6	245.3	269.8	295.8	18.5
α-naphthyl ketone (1-acetonaphthone)	$C_{12}H_{10}O$	115.6	146.3	161.5	178.4	196.8	208.6	223.8	246.7	270.5	295.5	
β-naphthyl ketone (2-acetonaphthone)	$C_{12}H_{10}O$	120.2	152.3	168.5	185.7	203.8	214.7	229.8	251.6	275.8	301.0	55.5
n-nonyl ketone (undecan-2-one)	$C_{11}H_{22}O$	68.2	95.5	108.9	123.1	139.0	148.6	161.0	181.2	202.3	224.0	15
palmitate	$C_{17}H_{34}O_2$	134.3	166.8	184.3	202.0							30
n-pentadecyl ketone (2-heptdecanone)	$C_{17}H_{34}O$	129.6	161.6	178.0	196.4	214.3	226.7	242.0	265.8	291.7	319.5	
2-Methylpentane	C_6H_{14}	–60.9	–41.7	–32.1	–21.4	–9.7	–1.9	+8.1	24.1	41.6	60.3	–154
3-Methylpentane	C_6H_{14}	–59.0	–39.8	–30.1	–19.4	–7.3	+0.1	10.5	26.5	44.2	63.3	–118
2-Methyl-1-pentanol	$C_6H_{14}O$	15.4	38.0	49.6	61.6	74.7	83.4	94.2	111.3	129.8	147.9	
2-Methyl-2-pentanol	$C_6H_{14}O$	–4.5	+16.8	27.6	38.8	51.3	58.8	69.2	85.0	102.6	121.2	–103
Methyl *n*-pentyl ketone (2-heptanone)	$C_7H_{14}O$	19.3	43.6	55.5	67.7	81.2	89.8	100.0	116.1	133.2	150.2	
phenyl ether (anisole)	C_7H_8O	+5.4	30.0	42.2	55.8	70.7	80.1	93.0	112.3	133.8	155.5	–37.3
2-Methylpropene	C_4H_8	–105.1	–96.5	–81.9	–73.4	–63.8	–57.7	–49.3	–36.7	–22.2	–6.9	–140.3
Methyl propionate	$C_4H_8O_2$	–42.0	–21.5	–11.8	–1.0	+11.0	18.7	29.0	44.2	61.8	79.8	–87.5
4-Methylpropiophenone	$C_{10}H_{12}O$	59.6	89.3	103.8	120.2	138.0	149.3	164.2	187.4	212.7	238.5	
2-Methylpropionyl bromide	C_4H_7BrO	13.5	38.4	50.6	64.1	79.4	88.8	101.6	120.5	141.7	163.0	
Methyl propyl ether	$C_4H_{10}O$	–72.2	–54.3	–45.4	–35.4	–24.3	–17.4	–8.1	+6.0	22.5	39.1	
n-propyl ketone (2-pentanone)	$C_5H_{10}O$	–12.0	+8.0	17.9	28.5	39.8	47.3	56.8	71.0	86.8	103.3	–77.8
isopropyl ketone (3-Methyl-2-butanone)	$C_5H_{10}O$	–19.9	–1.0	+8.3	18.3	29.6	36.2	45.5	59.0	73.8	88.9	–92
2-Methylquinoline	$C_{10}H_9N$	75.3	104.0	119.0	134.0	150.8	161.7	176.2	197.8	211.7	246.5	–1
Methyl salicylate	$C_8H_8O_3$	54.0	81.6	95.3	110.0	126.2	136.7	150.0	172.6	197.5	223.2	–8.3
α-Methyl styrene	C_9H_{10}	7.4	34.0	47.1	61.8	77.8	88.3	102.2	121.8	143.0	165.4	–23.2
4-Methyl styrene	C_9H_{10}	16.0	42.0	55.1	69.2	85.0	95.0	108.6	128.7	151.2	175.0	
Methyl *n*-tetradecyl ketone (2-hexadecanone)	$C_{16}H_{32}O$	109.8	151.5	167.3	184.6	203.7	215.0	230.5	254.4	279.8	307.0	
thiocyanate	C_2H_3NS	–14.0	+9.8	21.6	34.5	49.0	58.1	70.4	89.8	110.8	132.9	–51
isothiocyanate	C_2H_3NS	–34.7	–8.3	+5.4	20.4	38.2	47.5	59.3	77.5	97.8	119.0	35.5
undecyl ketone (2-tridecanone)	$C_{13}H_{26}O$	86.8	117.0	131.8	147.8	165.7	176.6	191.5	214.0	238.3	262.5	28.5
isovalerate	$C_6H_{12}O_2$	–19.2	+2.9	14.0	26.4	39.8	48.2	59.8	77.3	96.7	116.7	
Monovinylacetylene (butenyne)	C_4H_4	–93.2	–77.7	–70.0	–61.3	–51.7	–45.3	–37.1	–24.1	–10.1	+5.3	
Myrcene	$C_{10}H_{16}$	14.5	40.0	53.2	67.0	82.6	92.6	106.0	126.0	148.3	171.5	
Myristaldehyde	$C_{14}H_{28}O$	99.0	132.0	148.3	166.2	186.0	198.3	214.5	240.4	267.9	297.8	23.5
Myristic acid (tetradecanoic acid)	$C_{14}H_{28}O_2$	142.0	174.1	190.8	207.6	223.5	237.2	250.5	272.3	294.6	318.0	57.5
Naphthalene	$C_{10}H_8$	52.6	74.2	85.8	101.7	119.3	130.2	145.5	167.7	193.2	217.9	80.2
1-Naphthoic acid	$C_{11}H_8O_2$	156.0	184.0	196.8	211.2	225.0	234.5	245.8	263.5	281.4	300.0	160.5
2-Naphthoic acid	$C_{11}H_8O_2$	160.8	189.7	202.8	216.9	231.5	241.3	252.7	270.3	289.5	308.5	184
1-Naphthol	$C_{10}H_8O$	94.0	125.5	142.0	158.0	177.8	190.0	206.0	229.6	255.8	282.5	96
2-Naphthol	$C_{10}H_8O$		128.6	145.5	161.8	181.7	193.7	209.8	234.0	260.6	288.0	122.5
1-Naphthylamine	$C_{10}H_9N$	104.3	137.7	153.8	171.6	191.5	203.8	220.0	244.9	272.2	300.8	50
2-Naphthylamine	$C_{10}H_9N$	108.0	141.6	157.6	175.8	195.7	208.1	224.3	249.7	277.4	306.1	111.5
Nicotine	$C_{10}H_{14}N_2$	61.8	91.8	107.2	123.7	142.1	154.7	169.5	193.8	219.8	247.3	
2-Nitroaniline	$C_6H_6N_2O_2$	104.0	135.7	150.4	167.7	186.0	197.8	213.0	236.3	260.0	284.5	71.5
3-Nitroaniline	$C_6H_6N_2O_2$	119.3	151.5	167.8	185.5	204.2	216.5	232.1	255.3	280.2	305.7	114
4-Nitroaniline	$C_6H_6N_2O_2$	142.4	177.6	194.4	213.2	234.2	245.9	261.8	284.5	310.2	336.0	146.5
2-Nitrobenzaldehyde	$C_7H_5NO_3$	85.8	117.7	133.4	150.0	168.8	180.7	196.2	220.0	246.8	273.5	40.9
3-Nitrobenzaldehyde	$C_7H_5NO_3$	96.2	127.4	142.8	159.0	177.7	189.5	204.3	227.4	252.1	278.3	58
Nitrobenzene	$C_6H_5NO_2$	44.4	71.6	84.9	99.3	115.4	125.8	139.9	161.2	185.8	210.6	+5.7
Nitroethane	$C_2H_5NO_2$	–21.0	+1.5	12.5	24.8	38.0	46.5	57.8	74.8	94.0	114.0	–90
Nitroglycerin	$C_3H_5N_3O_9$	127	167	188	210	235	251					11
Nitromethane	CH_3NO_2	–29.0	–7.9	+2.8	14.1	27.5	35.5	46.6	63.5	82.0	101.2	–29
2-Nitrophenol	$C_6H_5NO_3$	49.3	76.8	90.4	105.8	122.1	132.6	146.4	167.6	191.0	214.5	45
2-Nitrophenyl acetate	$C_8H_7NO_4$	100.0	128.0	142.0	155.8	172.8	181.7	194.1	213.0	233.5	253.0	

TABLE 2-10 Vapor Pressures of Organic Compounds, up to 1 atm (*Continued*)

Compound		Pressure, mmHg										Melting point, °C
		1	5	10	20	40	60	100	200	400	760	
Name	Formula	Temperature, °C										
1-Nitropropane	$C_3H_7NO_2$	−9.6	+13.5	25.3	37.9	51.8	60.5	72.3	90.2	110.6	131.6	−108
2-Nitropropane	$C_3H_7NO_2$	−18.8	+4.1	15.8	28.2	41.8	50.3	62.0	80.0	99.8	120.3	−93
2-Nitrotoluene	$C_7H_7NO_2$	50.0	79.1	93.8	109.6	126.3	137.6	151.5	173.7	197.7	222.3	−4.1
3-Nitrotoluene	$C_7H_7NO_2$	50.2	81.0	96.0	112.8	130.7	142.5	156.9	180.3	206.8	231.9	15.5
4-Nitrotoluene	$C_7H_7NO_2$	53.7	85.0	100.5	117.7	136.0	147.9	163.0	186.7	212.5	238.3	51.9
4-Nitro-1,3-xylene (4-nitro-*m*-xylene)	$C_8H_9NO_2$	65.6	95.0	109.8	125.8	143.3	153.8	168.5	191.7	217.5	244.0	+2
Nonacosane	$C_{29}H_{60}$	234.2	269.8	286.4	303.6	323.2	334.8	350.0	373.2	397.2	421.8	63.8
Nonadecane	$C_{19}H_{40}$	133.2	166.3	183.5	200.8	220.0	232.8	248.0	271.8	299.8	330.0	32
n-Nonane	C_9H_{20}	+1.4	25.8	38.0	51.2	66.0	75.5	88.1	107.5	128.2	150.8	−53.7
1-Nonanol	$C_9H_{20}O$	59.5	86.1	99.7	113.8	129.0	139.0	151.3	170.5	192.1	213.5	−5
2-Nonanone	$C_9H_{18}O$	32.1	59.0	72.3	87.2	103.4	113.8	127.4	148.2	171.2	195.0	−19
Octacosane	$C_{28}H_{58}$	226.5	260.3	277.4	295.4	314.2	326.8	341.8	364.8	388.9	412.5	61.6
Octadecane	$C_{18}H_{38}$	119.6	152.1	169.6	187.5	207.4	219.7	236.0	260.6	288.0	317.0	28
n-Octane	C_8H_{18}	−14.0	+8.3	19.2	31.5	45.1	53.8	65.7	83.6	104.0	125.6	−56.8
n-Octanol (1-octanol)	$C_8H_{18}O$	54.0	76.5	88.3	101.0	115.2	123.8	135.2	152.0	173.8	195.2	−15.4
2-Octanone	$C_8H_{16}O$	23.6	48.4	60.9	74.3	89.8	99.0	111.7	130.4	151.0	172.9	−16
n-Octyl acrylate	$C_{11}H_{20}O_2$	58.5	87.7	102.0	117.8	135.6	145.6	159.1	180.2	204.0	227.0	
iodide (1-Iodooctane)	$C_8H_{17}I$	45.8	74.8	90.0	105.9	123.8	135.4	150.0	173.3	199.3	225.5	−45.9
Oleic acid	$C_{18}H_{34}O_2$	176.5	208.5	223.0	240.0	257.2	269.8	286.0	309.8	334.7	360.0	14
Palmitaldehyde	$C_{16}H_{32}O$	121.6	154.6	171.8	190.0	210.0	222.6	239.5	264.1	292.3	321.0	34
Palmitic acid	$C_{16}H_{32}O_2$	153.6	188.1	205.8	223.8	244.4	256.0	271.5	298.7	326.0	353.8	64.0
Palmitonitrile	$C_{16}H_{31}N$	134.3	168.3	185.8	204.2	223.8	236.6	251.5	277.1	304.5	332.0	31
Pelargonic acid	$C_9H_{18}O_2$	108.2	126.0	137.4	149.8	163.7	172.3	184.4	203.1	227.5	253.5	12.5
Pentachlorobenzene	C_6HCl_5	98.6	129.7	144.3	160.0	178.5	190.1	205.5	227.0	251.6	276.0	85.5
Pentachloroethane	C_2HCl_5	+1.0	27.2	39.8	53.9	69.9	80.0	93.5	114.0	137.2	160.5	−22
Pentachloroethylbenzene	$C_8H_5Cl_5$	96.2	130.0	148.0	166.0	186.2	199.0	216.0	241.8	269.3	299.0	
Pentachlorophenol	C_6HCl_5O				192.2	211.2	223.4	239.6	261.8	285.0	309.3	188.5
Pentacosane	$C_{25}H_{52}$	194.2	230.0	248.2	266.1	285.6	298.4	314.0	339.0	365.4	390.3	53.3
Pentadecane	$C_{15}H_{32}$	91.6	121.0	135.4	150.2	167.7	178.4	194.0	216.1	242.8	270.5	10
1,3-Pentadiene	C_5H_8	−71.8	−53.8	−45.0	−34.8	−23.4	−16.5	−6.7	+8.0	24.7	42.1	
1,4-Pentadiene	C_5H_8	−83.5	−66.2	−57.1	−47.7	−37.0	−30.0	−20.6	−6.7	+8.3	26.1	
Pentaethylbenzene	$C_{16}H_{26}$	86.0	120.0	135.8	152.4	171.9	184.2	200.0	224.1	250.2	277.0	
Pentaethylchlorobenzene	$C_{16}H_{25}Cl$	90.0	123.8	140.7	158.1	178.2	191.0	208.0	230.3	257.2	285.0	
n-Pentane	C_5H_{12}	−76.6	−62.5	−50.1	−40.2	−29.2	−22.2	−12.6	+1.9	18.5	36.1	−129.7
iso-Pentane (2-methylbutane)	C_5H_{12}	−82.9	−65.8	−57.0	−47.3	−36.5	−29.6	−20.2	−5.9	+10.5	27.8	−159.7
neo-Pentane (2,2-dimethylpropane)	C_5H_{12}	−102.0	−85.4	−76.7	−67.2	−56.1	−49.0	−39.1	−23.7	−7.1	+9.5	−16.6
2,3,4-Pentanetriol	$C_5H_{12}O_3$	155.0	189.3	204.5	220.5	239.6	249.8	263.5	284.5	307.0	327.2	
1-Pentene	C_5H_{10}	−80.4	−63.3	−54.5	−46.0	−34.1	−27.1	−17.7	−3.4	+12.8	30.1	
α-Phellandrene	$C_{10}H_{16}$	20.0	45.7	58.0	72.1	87.8	97.6	110.6	130.6	152.0	175.0	
Phenanthrene	$C_{14}H_{10}$	118.2	154.3	173.0	193.7	215.8	229.9	249.0	277.1	308.0	340.2	99.5
Phenethyl alcohol (phenyl cellosolve)	$C_8H_{10}O_2$	58.2	85.9	100.0	114.8	130.5	141.2	154.0	175.0	197.5	219.5	
2-Phenetidine	$C_8H_{11}NO$	67.0	94.7	108.6	123.7	139.9	149.8	163.5	184.0	207.0	228.0	
Phenol	C_6H_6O	40.1	62.5	73.8	86.0	100.1	108.4	121.4	139.0	160.0	181.9	40.6
2-Phenoxyethanol	$C_8H_{10}O_2$	78.0	106.6	121.2	136.0	152.2	163.2	176.5	197.6	221.0	245.3	11.6
2-Phenoxyethyl acetate	$C_{10}H_{12}O_3$	82.6	113.5	128.0	144.5	162.3	174.0	189.2	211.3	235.0	259.7	−6.7
Phenyl acetate	$C_8H_8O_2$	38.2	64.8	78.0	92.3	108.1	118.1	131.6	151.2	173.5	195.9	
Phenylacetic acid	$C_8H_8O_2$	97.0	127.0	141.3	156.0	173.6	184.5	198.2	219.5	243.0	265.5	76.5
Phenylacetonitrile	C_8H_7N	60.0	89.0	103.5	119.4	136.3	147.7	161.8	184.2	208.5	233.5	−23.8
Phenylacetyl chloride	C_8H_7ClO	48.0	75.3	89.0	103.6	119.8	129.8	143.5	163.8	186.0	210.0	
Phenyl benzoate	$C_{13}H_{10}O_2$	106.8	141.5	157.8	177.0	197.6	210.8	227.8	254.0	283.5	314.0	70.5
4-Phenyl-3-buten-2-one	$C_{10}H_{10}O$	81.7	112.2	127.4	143.8	161.3	172.6	187.8	211.0	235.4	261.0	41.5
Phenyl isocyanate	C_7H_5NO	10.6	36.0	48.5	62.5	77.7	87.7	100.6	120.8	142.7	165.6	
isocyanide	C_7H_5N	12.0	37.0	49.7	63.4	78.3	88.0	101.0	120.8	142.3	165.0	
Phenylcyclohexane	$C_{12}H_{16}$	67.5	96.5	111.3	126.4	144.0	154.2	169.3	191.3	214.6	240.0	+7.5
Phenyl dichlorophosphate	$C_6H_5Cl_2O_2P$	66.7	95.9	110.0	125.9	143.4	153.6	168.0	189.8	213.0	239.5	
m-Phenylene diamine (1,3-phenylenediamine)	$C_6H_8N_2$	99.8	131.2	147.0	163.8	182.5	194.0	209.9	233.0	259.0	285.5	62.8
Phenylglyoxal	$C_8H_6O_2$		75.0	87.8	100.7	115.5	124.2	136.2	153.8	173.5	193.5	73
Phenylhydrazine	$C_6H_8N_2$	71.8	101.6	115.8	131.5	148.2	158.7	173.5	195.4	218.2	243.5	19.5
N-Phenyliminodiethanol	$C_{10}H_{15}NO_2$	145.0	179.2	195.8	213.4	233.0	245.3	260.6	284.5	311.3	337.8	
1-Phenyl-1,3-pentanedione	$C_{11}H_{12}O_2$	98.0	128.5	144.0	159.9	178.0	189.8	204.5	226.7	251.2	276.5	
2-Phenylphenol	$C_{12}H_{10}O$	100.0	131.6	146.2	163.3	180.3	192.2	205.9	227.9	251.8	275.0	56.5
4-Phenylphenol	$C_{12}H_{10}O$			176.2	193.8	213.0	225.3	240.9	263.2	285.5	308.0	164.5
3-Phenyl-1-propanol	$C_9H_{12}O$	74.7	102.4	116.0	131.2	147.4	156.8	170.3	191.2	212.8	235.0	
Phenyl isothiocyanate	C_7H_5NS	47.2	75.6	89.8	115.5	122.5	133.3	147.7	169.6	194.0	218.5	−21.0
Phorone	$C_9H_{14}O$	42.0	68.3	81.5	95.6	111.3	121.4	134.0	153.5	175.3	197.2	28
iso-Phorone	$C_9H_{14}O$	38.0	66.7	81.2	96.8	114.5	125.6	140.6	163.3	188.7	215.2	
Phosgene (carbonyl chloride)	CCl_2O	−92.9	−77.0	−69.3	−60.3	−50.3	−44.0	−35.6	−22.3	−7.6	+8.3	−104
Phthalic anhydride	$C_8H_4O_3$	96.5	121.3	134.0	151.7	172.0	185.3	202.3	228.0	256.8	284.5	130.8
Phthalide	$C_8H_6O_2$	95.5	127.7	144.0	161.3	181.0	193.5	210.0	234.5	261.8	290.0	73
Phthaloyl chloride	$C_8H_4Cl_2O_2$	86.3	118.3	134.2	151.0	170.0	182.2	197.8	222.0	248.3	275.8	88.5
2-Picoline	C_6H_7N	−11.1	+12.6	24.4	37.4	51.2	59.9	71.4	89.0	108.4	128.8	−70
Pimelic acid	$C_7H_{12}O_4$	163.4	196.2	212.0	229.3	247.0	258.2	272.0	294.5	318.5	342.1	103
α-Pinene	$C_{10}H_{16}$	−1.0	+24.6	37.3	51.4	66.8	76.8	90.1	110.2	132.3	155.0	−55
β-Pinene	$C_{10}H_{16}$	+4.2	30.0	42.3	58.1	71.5	81.2	94.0	114.1	136.1	158.3	

TABLE 2-10 Vapor Pressures of Organic Compounds, up to 1 atm (*Continued*)

Compound		Pressure, mmHg										Melting point, °C
		1	5	10	20	40	60	100	200	400	760	
Name	Formula	Temperature, °C										
Piperidine	$C_5H_{11}N$		−7.0	+3.9	15.8	29.2	37.7	49.0	66.2	85.7	106.0	−9
Piperonal	$C_8H_6O_3$	87.0	117.4	132.0	148.0	165.7	177.0	191.7	214.3	238.5	263.0	37
Propane	C_3H_8	−128.9	−115.4	−108.5	−100.9	−92.4	−87.0	−79.6	−68.4	−55.6	−42.1	−187.1
Propenylbenzene	C_9H_{10}	17.5	43.8	57.0	71.5	87.7	97.8	111.7	132.0	154.7	179.0	−30.1
Propionamide	C_3H_7NO	65.0	91.0	105.0	119.0	134.8	144.3	156.0	174.2	194.0	213.0	79
Propionic acid	$C_3H_6O_2$	4.6	28.0	39.7	52.0	65.8	74.1	85.8	102.5	122.0	141.1	−22
anhydride	$C_6H_{10}O_3$	20.6	45.3	57.7	70.4	85.6	94.5	107.2	127.8	146.0	167.0	−45
Propionitrile	C_3H_5N	−35.0	−13.6	−3.0	+8.8	22.0	30.1	41.4	58.2	77.7	97.1	−91.9
Propiophenone	$C_9H_{10}O$	50.0	77.9	92.2	107.6	124.3	135.0	149.3	170.2	194.2	218.0	21
n-Propyl acetate	$C_5H_{10}O_2$	−26.7	−5.4	+5.0	16.0	28.8	37.0	47.8	64.0	82.0	101.8	−92.5
iso-Propyl acetate	$C_5H_{10}O_2$	−38.3	−17.4	−7.2	+4.2	17.0	25.1	35.7	51.7	69.8	89.0	
n-Propyl alcohol (1-propanol)	C_3H_8O	−15.0	+5.0	14.7	25.3	36.4	43.5	52.8	66.8	82.0	97.8	−127
iso-Propyl alcohol (2-propanol)	C_3H_8O	−26.1	−7.0	+2.4	12.7	23.8	30.5	39.5	53.0	67.8	82.5	−85.8
n-Propylamine	C_3H_9N	−64.4	−46.3	−37.2	−27.1	−16.0	−9.0	+0.5	15.0	31.5	48.5	−83
Propylbenzene	C_9H_{12}	6.3	31.3	43.4	56.8	71.6	81.1	94.0	113.5	135.7	159.2	−99.5
Propyl benzoate	$C_{10}H_{12}O_2$	54.6	83.8	98.0	114.3	131.8	143.3	157.4	180.1	205.2	231.0	−51.6
n-Propyl bromide (1-bromopropane)	C_3H_7Br	−53.0	−33.4	−23.3	−12.4	−0.3	+7.5	18.0	34.0	52.0	71.0	−109.9
iso-Propyl bromide (2-bromopropane)	C_3H_7Br	−61.8	−42.5	−32.8	−22.0	−10.1	−2.5	+8.0	23.8	41.5	60.0	−89.0
n-Propyl n-butyrate	$C_7H_{14}O_2$	−1.6	+22.1	34.0	47.0	61.5	70.3	82.6	101.0	121.7	142.7	−95.2
isobutyrate	$C_7H_{14}O_2$	−6.2	+16.8	28.3	40.6	54.3	63.0	73.9	91.8	112.0	133.9	
iso-Propyl isobutyrate	$C_7H_{14}O_2$	−16.3	+5.8	17.0	29.0	42.4	51.4	62.3	80.2	100.0	120.5	
Propyl carbamate	$C_4H_9NO_2$	52.4	77.6	90.0	103.2	117.7	126.5	138.3	155.8	175.8	195.0	
n-Propyl chloride (1-chloropropane)	C_3H_7Cl	−68.3	−50.0	−41.0	−31.0	−19.5	−12.1	−2.5	+12.2	29.4	46.4	−122.8
iso-Propyl chloride (2-chloropropane)	C_3H_7Cl	−78.8	−61.1	−52.0	−42.0	−31.0	−23.5	−13.7	+1.3	18.1	36.5	−117
iso-Propyl chloroacetate	$C_5H_9ClO_2$	+3.8	28.1	40.2	53.9	68.7	78.0	90.3	108.8	128.0	148.6	
Propyl chloroglyoxylate	$C_5H_7ClO_3$	9.7	32.3	43.5	55.6	68.8	77.2	88.0	104.7	123.0	150.0	
Propylene	C_3H_6	−131.9	−120.7	−112.1	−104.7	−96.5	−91.3	−84.1	−73.3	−60.9	−47.7	−185
Propylene glycol (1,2-Propanediol)	$C_3H_8O_2$	45.5	70.8	83.2	96.4	111.2	119.9	132.0	149.7	168.1	188.2	
Propylene oxide	C_3H_6O	−75.0	−57.8	−49.0	−39.3	−28.4	−21.3	−12.0	+2.1	17.8	34.5	−112.1
n-Propyl formate	$C_4H_8O_2$	−43.0	−22.7	−12.6	−1.7	+10.8	18.8	29.5	45.3	62.6	81.3	−92.9
iso-Propyl formate	$C_4H_8O_2$	−52.0	−32.7	−22.7	−12.1	−0.2	+7.5	17.8	33.6	50.5	68.3	
4,4′-iso-Propylidenebisphenol	$C_{15}H_{16}O_2$	193.0	224.2	240.8	255.5	273.0	282.9	297.0	317.5	339.0	360.5	
n-Propyl iodide (1-iodopropane)	C_3H_7I	−36.0	−13.5	−2.4	+10.0	23.6	32.1	43.8	61.8	81.8	102.5	−98.8
iso-Propyl iodide (2-iodopropane)	C_3H_7I	−43.3	−22.1	−11.7	0.0	+13.2	21.6	32.8	50.0	69.5	89.5	−90
n-Propyl levulinate	$C_8H_{14}O_3$	59.7	86.3	99.9	114.0	130.1	140.6	154.0	175.6	198.0	221.2	
iso-Propyl levulinate	$C_8H_{14}O_3$	48.0	74.5	88.0	102.4	118.1	127.8	141.8	161.6	185.2	208.2	
Propyl mercaptan (1-propanethiol)	C_3H_8S	−56.0	−36.3	−26.3	−15.4	−3.2	+4.6	15.3	31.5	49.2	67.4	−112
2-iso-Propylnaphthalene	$C_{13}H_{14}$	76.0	107.9	123.4	140.3	159.0	171.4	187.6	211.8	238.5	266.0	
iso-Propyl β-naphthyl ketone (2-isobutyronaphthone)	$C_{14}H_{14}O$	133.2	165.4	181.0	197.7	215.6	227.0	242.3	264.0	288.2	313.0	
2-iso-Propylphenol	$C_9H_{12}O$	56.6	83.8	97.0	111.7	127.5	137.7	150.3	170.1	192.6	214.5	15.5
3-iso-Propylphenol	$C_9H_{12}O$	62.0	90.3	104.1	119.8	136.2	146.6	160.2	182.0	205.0	228.0	26
4-iso-Propylphenol	$C_9H_{12}O$	67.0	94.7	108.0	123.4	139.8	149.7	163.3	184.0	206.1	228.2	61
Propyl propionate	$C_6H_{12}O_2$	−14.2	+8.0	19.4	31.6	45.0	53.8	65.2	82.7	102.0	122.4	−76
4-iso-Propylstyrene	$C_{11}H_{14}$	34.7	62.3	76.0	91.2	108.0	118.4	132.8	153.9	178.0	202.5	
Propyl isovalerate	$C_8H_{16}O_2$	+8.0	32.8	45.1	58.0	72.8	82.3	95.0	113.9	135.0	155.9	
Pulegone	$C_{10}H_{16}O$	58.3	82.5	94.0	106.8	121.7	130.2	143.1	162.5	189.8	221.0	
Pyridine	C_5H_5N	−18.9	+2.5	13.2	24.8	38.0	46.8	57.8	75.0	95.6	115.4	−42
Pyrocatechol	$C_6H_6O_2$		104.0	118.3	134.0	150.6	161.7	176.0	197.7	221.5	245.5	105
Pyrocaltechol diacetate (1,2-phenylene diacetate)	$C_{10}H_{10}O_4$	98.0	129.8	145.7	161.8	179.8	191.6	206.5	228.7	253.3	278.0	
Pyrogallol	$C_6H_6O_3$		151.7	167.7	185.3	204.2	216.3	232.0	255.3	281.5	309.0	133
Pyrotartaric anhydride	$C_5H_6O_3$	69.7	99.7	114.2	130.0	147.8	158.6	173.8	196.1	221.0	247.4	
Pyruvic acid	$C_3H_4O_3$	21.4	45.8	57.9	70.8	85.3	94.1	106.5	124.7	144.7	165.0	13.6
Quinoline	C_9H_7N	59.7	89.6	103.8	119.8	136.7	148.1	163.2	186.2	212.3	237.7	−15
iso-Quinoline	C_9H_7N	63.5	92.7	107.8	123.7	141.6	152.0	167.6	190.0	214.5	240.5	24.6
Resorcinol	$C_6H_6O_2$	108.4	138.0	152.1	168.0	185.3	195.8	209.8	230.8	253.4	276.5	110.7
Safrole	$C_{10}H_{10}O_2$	63.8	93.0	107.6	123.0	140.1	150.3	165.1	186.2	210.0	233.0	11.2
Salicylaldehyde	$C_7H_6O_2$	33.0	60.1	73.8	88.7	105.2	115.7	129.4	150.0	173.7	196.5	−7
Salicylic acid	$C_7H_6O_3$	113.7	136.0	146.2	156.8	172.2	182.0	193.4	210.0	230.5	256.0	159
Sebacic acid	$C_{10}H_{18}O_4$	183.0	215.7	232.0	250.0	268.2	279.8	294.5	313.2	332.8	352.3	134.5
Selenophene	C_4H_4Se	−39.0	−16.0	−4.0	+9.1	24.1	33.8	47.0	66.7	89.8	114.3	
Skatole	C_9H_9N	95.0	124.2	139.6	154.3	171.9	183.6	197.4	218.8	242.5	266.2	95
Stearaldehyde	$C_{18}H_{36}O$	140.0	174.6	192.1	210.6	230.8	244.2	260.0	285.0	313.8	342.5	63.5
Stearic acid	$C_{18}H_{36}O_2$	173.7	209.0	225.0	243.4	263.3	275.5	291.0	316.5	343.0	370.0	69.3
Stearyl alcohol (1-octadecanol)	$C_{18}H_{36}O$	150.3	185.6	202.0	220.0	240.4	252.7	269.4	293.5	320.3	349.5	58.5
Styrene	C_8H_8	−7.0	+18.0	30.8	44.6	59.8	69.5	82.0	101.3	122.5	145.2	−30.6
Styrene dibromide [(1,2-dibromoethyl) benzene]	$C_8H_8Br_2$	86.0	115.6	129.8	145.2	161.8	172.2	186.3	207.8	230.0	254.0	
Suberic acid	$C_8H_{14}O_4$	172.8	205.5	219.5	238.2	254.6	265.4	279.8	300.5	322.8	345.5	142
Succinic anhydride	$C_4H_4O_3$	92.0	115.0	128.2	145.3	163.0	174.0	189.0	212.0	237.0	261.0	119.6
Succinimide	$C_4H_5NO_2$	115.0	143.2	157.0	174.0	192.0	203.0	217.4	240.0	263.5	287.5	125.5
Succinyl chloride	$C_4H_4Cl_2O_2$	39.0	65.0	78.0	91.8	107.5	117.2	130.0	149.3	170.0	192.5	17
α-Terpineol	$C_{10}H_{18}O$	52.8	80.4	94.3	109.8	126.0	136.3	150.1	171.2	194.3	217.5	35
Terpenoline	$C_{10}H_{16}$	32.3	58.0	70.6	84.8	100.0	109.8	122.7	142.0	163.5	185.0	

TABLE 2-10 Vapor Pressures of Organic Compounds, up to 1 atm (*Continued*)

Compound		Pressure, mmHg										Melting point, °C
		1	5	10	20	40	60	100	200	400	760	
Name	Formula	Temperature, °C										
1,1,1,2-Tetrabromoethane	$C_2H_2Br_4$	58.0	83.3	95.7	108.5	123.2	132.0	144.0	161.5	181.0	200.0	
1,1,2,2-Tetrabromoethane	$C_2H_2Br_4$	65.0	95.5	110.0	126.0	144.0	155.1	170.0	192.5	217.5	243.5	
Tetraisobutylene	$C_{16}H_{32}$	63.8	93.7	108.5	124.5	142.2	152.6	167.5	190.0	214.6	240.0	
Tetracosane	$C_{24}H_{50}$	183.8	219.6	237.6	255.3	276.3	288.4	305.2	330.5	358.0	386.4	51.1
1,2,3,4-Tetrachlorobenzene	$C_6H_2Cl_4$	68.5	99.6	114.7	131.2	149.2	160.0	175.7	198.0	225.5	254.0	46.5
1,2,3,5-Tetrachlorobenzene	$C_6H_2Cl_4$	58.2	89.0	104.1	121.6	140.0	152.0	168.0	193.7	220.0	246.0	54.5
1,2,4,5-Tetrachlorobenzene	$C_6H_2Cl_4$					146.0	157.7	173.5	196.0	220.5	245.0	139
1,1,2,2-Tetrachloro-1,2-difluoroethane	$C_2Cl_4F_2$	−37.5	−16.0	−5.0	+6.7	19.8	28.1	38.6	55.0	73.1	92.0	26.5
1,1,1,2-Tetrachloroethane	$C_2H_2Cl_4$	−16.3	+7.4	19.3	32.1	46.7	56.0	68.0	87.2	108.2	130.5	−68.7
1,1,2,2-Tetrachloroethane	$C_2H_2Cl_4$	−3.8	+20.7	33.0	46.2	60.8	70.0	83.2	102.2	124.0	145.9	−36
1,2,3,5-Tetrachloro-4-ethylbenzene	$C_8H_6Cl_4$	77.0	110.0	126.0	143.7	162.1	175.0	191.6	215.3	243.0	270.0	
Tetrachloroethylene	C_2Cl_4	−20.6	+2.4	13.8	26.3	40.1	49.2	61.3	79.8	100.0	120.8	−19.0
2,3,4,6-Tetrachlorophenol	$C_6H_2Cl_4O$	100.0	130.3	145.3	161.0	179.1	190.0	205.2	227.2	250.4	275.0	69.5
3,4,5,6-Tetrachloro-1,2-xylene	$C_8H_6Cl_4$	94.4	125.0	140.3	156.0	174.2	185.8	200.5	223.0	248.3	273.5	
Tetradecane	$C_{14}H_{30}$	76.4	106.0	120.7	135.6	152.7	164.0	178.5	201.8	226.8	252.5	5.5
Tetradecylamine	$C_{14}H_{31}N$	102.6	135.8	152.0	170.0	189.0	200.2	215.7	239.8	264.6	291.2	
Tetradecyltrimethylsilane	$C_{17}H_{38}Si$	120.0	150.7	166.2	183.5	201.5	213.3	227.8	250.0	275.0	300.0	
Tetraethoxysilane	$C_8H_{20}O_4Si$	16.0	40.3	52.6	65.8	81.1	90.7	103.6	123.5	146.2	168.5	
1,2,3,4-Tetraethylbenzene	$C_{14}H_{22}$	65.7	96.2	111.6	127.7	145.8	156.7	172.4	196.0	221.4	248.0	11.6
Tetraethylene glycol	$C_8H_{18}O_5$	153.9	183.7	197.1	212.3	228.0	237.8	250.0	268.4	288.0	307.8	
Tetraethylene glycol chlorohydrin	$C_8H_{17}ClO_4$	110.1	141.8	156.1	172.6	190.0	200.5	214.7	236.5	258.2	281.5	
Tetraethyllead	$C_8H_{20}Pb$	38.4	63.6	74.8	88.0	102.4	111.7	123.8	142.0	161.8	183.0	−136
Tetraethylsilane	$C_8H_{20}Si$	−1.0	+23.9	36.3	50.0	65.3	74.8	88.0	108.0	130.2	153.0	
Tetralin	$C_{10}H_{12}$	38.0	65.3	79.0	93.8	110.4	121.3	135.3	157.2	181.8	207.2	−31.0
1,2,3,4-Tetramethylbenzene	$C_{10}H_{14}$	42.6	68.7	81.8	95.8	111.5	121.8	135.7	155.7	180.0	204.4	−6.2
1,2,3,5-Tetramethylbenzene	$C_{10}H_{14}$	40.6	65.8	77.8	91.0	105.8	115.4	128.3	149.9	173.7	197.9	−24.0
1,2,4,5-Tetramethylbenzene	$C_{10}H_{14}$	45.0	65.0	74.6	88.0	104.2	114.8	128.1	149.5	172.1	195.9	79.5
2,2,3,3-Tetramethylbutane	C_8H_{18}	−17.4	+3.2	13.5	24.6	36.8	44.5	54.8	70.2	87.4	106.3	−102.2
Tetramethylene dibromide (1,4-dibromobutane)	$C_4H_8Br_2$	32.0	58.8	72.4	87.6	104.0	115.1	128.7	149.8	173.8	197.5	−20
Tetramethyllead	$C_4H_{12}Pb$	−29.0	−6.8	+4.4	16.6	30.3	39.2	50.8	68.8	89.0	110.0	−27.5
Tetramethyltin	$C_4H_{12}Sn$	−51.3	−31.0	−20.6	−9.3	+3.5	11.7	22.8	39.8	58.5	78.0	
Tetrapropylene glycol monoisopropyl ether	$C_{15}H_{32}O_5$	116.6	147.8	163.0	179.8	197.7	209.0	223.3	245.0	268.3	292.7	
Thioacetic acid (mercaptoacetic acid)	$C_2H_4O_2S$	60.0	87.7	101.5	115.8	131.8	142.0	154.0				−16.5
Thiodiglycol (2,2′-thiodiethanol)	$C_4H_{10}O_2S$	42.0	96.0	128.0	165.0	210.0	240.5	285				
Thiophene	C_4H_4S	−40.7	−20.8	−10.9	0.0	+12.5	20.1	30.5	46.5	64.7	84.4	−38.3
Thiophenol (benzenethiol)	C_6H_6S	18.6	43.7	56.0	69.7	84.2	93.9	106.6	125.8	146.7	168.0	
α-Thujone	$C_{10}H_{16}O$	38.3	65.7	79.3	93.7	110.0	120.2	134.0	154.2	177.8	201.0	
Thymol	$C_{10}H_{14}O$	64.3	92.8	107.4	122.6	139.8	149.8	164.1	185.5	209.2	231.8	51.5
Tiglaldehyde	C_5H_8O	−25.0	−1.6	+10.0	23.2	37.0	45.8	57.7	75.4	95.5	116.4	
Tiglic acid	$C_5H_8O_2$	52.0	77.8	90.2	103.8	119.0	127.8	140.5	158.0	179.2	198.5	64.5
Tiglonitrile	C_5H_7N	−25.5	−2.4	+9.2	22.1	36.7	46.0	58.2	77.8	99.7	122.0	
Toluene	C_7H_8	−26.7	−4.4	+6.4	18.4	31.8	40.3	51.9	69.5	89.5	110.6	−95.0
Toluene-2,4-diamine	$C_7H_{10}N_2$	106.5	137.2	151.7	167.9	185.7	196.2	211.5	232.8	256.0	280.0	99
2-Toluic nitrile (2-tolunitrile)	C_8H_7N	36.7	64.0	77.9	93.0	110.0	120.8	135.0	156.0	180.0	205.2	−13
4-Toluic nitrile (4-tolunitrile)	C_8H_7N	42.5	71.3	85.8	101.7	109.5	130.0	145.2	167.3	193.0	217.6	29.5
2-Toluidine	C_7H_9N	44.0	69.3	81.4	95.1	110.0	119.8	133.0	153.0	176.2	199.7	−16.3
3-Toluidine	C_7H_9N	41.0	68.0	82.0	96.7	113.5	123.8	136.7	157.6	180.6	203.3	−31.5
4-Toluidine	C_7H_9N	42.0	68.2	81.8	95.8	111.5	121.5	133.7	154.0	176.9	200.4	44.5
2-Tolyl isocyanide	C_8H_7N	25.2	51.0	64.0	78.2	94.0	104.0	117.7	137.8	159.9	183.5	
4-Tolylhydrazine	$C_7H_{10}N_2$	82.4	110.0	123.8	138.6	154.1	165.0	178.0	198.0	219.5	242.0	65.5
Tribromoacetaldehyde	C_2HBr_3O	18.5	45.0	58.0	72.1	87.8	97.5	110.2	130.0	151.6	174.0	
1,1,2-Tribromobutane	$C_4H_7Br_3$	45.0	73.5	87.8	103.2	120.2	131.6	146.0	167.8	192.0	216.2	
1,2,2-Tribromobutane	$C_4H_7Br_3$	41.0	69.0	83.2	98.6	116.0	127.0	141.8	163.5	188.0	213.8	
2,2,3-Tribromobutane	$C_4H_7Br_3$	38.2	66.0	79.8	94.6	111.8	122.2	136.3	157.8	182.2	206.5	
1,1,2-Tribromoethane	$C_2H_3Br_3$	32.6	58.0	70.6	84.2	100.0	110.0	123.5	143.5	165.4	188.4	−26
1,2,3-Tribromopropane	$C_3H_5Br_3$	47.5	75.8	90.0	105.8	122.8	134.0	148.0	170.0	195.0	220.0	16.5
Triisobutylamine	$C_{12}H_{27}N$	32.3	57.4	69.8	83.0	97.8	107.3	119.7	138.0	157.8	179.0	−22
Triisobutylene	$C_{12}H_{24}$	18.0	44.0	56.5	70.0	86.7	96.7	110.0	130.2	153.0	179.0	
2,4,6-Tritertbutylphenol	$C_{18}H_{30}O$	95.2	126.1	142.0	158.0	177.4	188.0	203.0	226.2	250.6	276.3	
Trichloroacetic acid	$C_2HCl_3O_2$	51.0	76.0	88.2	101.8	116.3	125.9	137.8	155.4	175.2	195.6	57
Trichloroacetic anhydride	$C_4Cl_6O_3$	56.2	85.3	99.6	114.3	131.2	141.8	155.2	176.2	199.8	223.0	
Trichloroacetyl bromide	C_2BrCl_3O	−7.4	+16.7	29.3	42.1	57.2	66.7	79.5	98.4	120.2	143.0	
2,4,6-Trichloroaniline	$C_6H_4Cl_3N$	134.0	157.8	170.0	182.6	195.8	204.5	214.6	229.8	246.4	262.0	78
1,2,3-Trichlorobenzene	$C_6H_3Cl_3$	40.0	70.0	85.6	101.8	119.8	131.5	146.0	168.2	193.5	218.5	52.5
1,2,4-Trichlorobenzene	$C_6H_3Cl_3$	38.4	67.3	81.7	97.2	114.8	125.7	140.0	162.0	187.7	213.0	17
1,3,5-Trichlorobenzene	$C_6H_3Cl_3$		63.8	78.0	93.7	110.8	121.8	136.0	157.7	183.0	208.4	63.5
1,2,3-Trichlorobutane	$C_4H_7Cl_3$	+0.5	27.2	40.0	55.0	71.5	82.0	96.2	118.0	143.0	169.0	
1,1,1-Trichloroethane	$C_2H_3Cl_3$	−52.0	−32.0	−21.9	−10.8	+1.6	9.5	20.0	36.2	54.6	74.1	−30.6
1,1,2-Trichloroethane	$C_2H_3Cl_3$	−24.0	−2.0	+8.3	21.6	35.2	44.0	55.7	73.3	93.0	113.9	−36.7
Trichloroethylene	C_2HCl_3	−43.8	−22.8	−12.4	−1.0	+11.9	20.0	31.4	48.0	67.0	86.7	−73
Trichlorofluoromethane	CCl_3F	−84.3	−67.6	−59.0	−49.7	−39.0	−32.3	−23.0	−9.1	+6.8	23.7	
2,4,5-Trichlorophenol	$C_6H_3Cl_3O$	72.0	102.1	117.3	134.0	151.5	162.5	178.0	201.5	226.5	251.8	62
2,4,6-Trichlorophenol	$C_6H_3Cl_3O$	76.5	105.9	120.2	135.8	152.2	163.5	177.8	199.0	222.5	246.0	68.5

TABLE 2-10 Vapor Pressures of Organic Compounds, up to 1 atm (*Concluded*)

Compound		Pressure, mmHg										Melting point, °C
		1	5	10	20	40	60	100	200	400	760	
Name	Formula	Temperature, °C										
Tri-2-chlorophenylthiophosphate	$C_{18}H_{12}Cl_3O_3PS$	188.2	217.2	231.2	246.7	261.7	271.5	283.8	302.8	322.0	341.3	
1,1,1-Trichloropropane	$C_3H_5Cl_3$	−28.8	−7.0	+4.2	16.2	29.9	38.3	50.0	67.7	87.5	108.2	−77.7
1,2,3-Trichloropropane	$C_3H_5Cl_3$	+9.0	33.7	46.0	59.3	74.0	83.6	96.1	115.6	137.0	158.0	−14.7
1,1,2-Trichloro-1,2,2-trifluoroethane	$C_2Cl_3F_3$	−68.0	−49.4	−40.3	−30.0	−18.5	−11.2	−1.7	+13.5	30.2	47.6	−35
Tricosane	$C_{23}H_{48}$	170.0	206.3	223.0	242.0	261.3	273.8	289.8	313.5	339.8	366.5	47.7
Tridecane	$C_{13}H_{28}$	59.4	98.3	104.0	120.2	137.7	148.2	162.5	185.0	209.4	234.0	−6.2
Tridecanoic acid	$C_{13}H_{26}O_2$	137.8	166.3	181.0	195.8	212.4	222.0	236.0	255.2	276.5	299.0	41
Triethoxymethylsilane	$C_7H_{18}O_3Si$	−1.5	+22.8	34.6	47.2	61.7	70.4	82.7	101.0	121.8	143.5	
Triethoxyphenylsilane	$C_{12}H_{20}O_3Si$	71.0	98.8	112.6	127.2	143.5	153.2	167.5	188.0	210.5	233.5	
1,2,4-Triethylbenzene	$C_{12}H_{18}$	46.0	74.2	88.5	104.0	121.7	132.2	146.8	168.3	193.7	218.0	
1,3,4-Triethylbenzene	$C_{12}H_{18}$	47.9	76.0	90.2	105.8	122.6	133.4	147.7	168.3	193.2	217.5	
Triethylborine	$C_6H_{15}B$			−148.0	−140.6	−131.4	−125.2	−116.0	−101.0	−81.0	−56.2	
Triethyl camphoronate	$C_{15}H_{26}O_6$		150.2	166.0	183.6	201.8	213.5	228.6	250.8	276.0	301.0	135
citrate	$C_{12}H_{20}O_7$	107.0	138.7	144.0	171.1	190.4	202.5	217.8	242.2	267.5	294.0	
Triethyleneglycol	$C_6H_{14}O_4$	114.0	144.0	158.1	174.0	191.3	201.5	214.6	235.2	256.6	278.3	
Triethylheptylsilane	$C_{13}H_{30}Si$	70.0	99.8	114.6	130.3	148.0	158.2	174.0	196.0	221.0	247.0	
Triethyloctylsilane	$C_{14}H_{32}Si$	73.7	104.8	120.6	137.7	155.7	168.0	184.3	208.0	235.0	262.0	
Triethyl orthoformate	$C_7H_{16}O_3$	+5.5	29.2	40.5	53.4	67.5	76.0	88.0	106.0	125.7	146.0	
phosphate	$C_6H_{15}O_4P$	39.6	67.8	82.1	97.8	115.7	126.3	141.6	163.7	187.0	211.0	
Triethylthallium	$C_6H_{15}Tl$	+9.3	37.6	51.7	67.7	85.4	95.7	112.1	136.0	163.5	192.1	−63.0
Trifluorophenylsilane	$C_6H_5F_3Si$	−31.0	−9.7	+0.8	12.3	25.4	33.2	44.2	60.1	78.7	98.3	
Trimethallyl phosphate	$C_{12}H_{21}PO_4$	93.7	131.0	149.8	169.8	192.0	207.0	225.7	255.0	288.5	324.0	
2,3,5-Trimethylacetophenone	$C_{11}H_{14}O$	79.0	108.0	122.3	137.5	154.2	165.7	179.7	201.3	224.3	247.5	
Trimethylamine	C_3H_9N	−97.1	−81.7	−73.8	−65.0	−55.2	−48.8	−40.3	−27.0	−12.5	+2.9	−117.1
2,4,5-Trimethylaniline	$C_9H_{13}N$	68.4	95.9	109.0	123.7	139.8	149.5	162.0	182.3	203.7	234.5	67
1,2,3-Trimethylbenzene	C_9H_{12}	16.8	42.9	55.9	69.9	85.4	95.3	108.8	129.0	152.0	176.1	−25.5
1,2,4-Trimethylbenzene	C_9H_{12}	13.6	38.3	50.7	64.5	79.8	89.5	102.8	122.7	145.4	169.2	−44.1
1,3,5-Trimethylbenzene	C_9H_{12}	9.6	34.7	47.4	61.0	76.1	85.8	98.9	118.6	141.0	164.7	−44.8
2,2,3-Trimethylbutane	C_7H_{16}			−18.8	−7.5	+5.2	13.3	24.4	41.2	60.4	80.9	−25.0
Trimethyl citrate	$C_9H_{14}O_7$	106.2	146.2	160.4	177.2	194.2	205.5	219.6	241.3	264.2	287.0	78.5
Trimethyleneglycol (1,3-propanediol)	$C_3H_8O_2$	59.4	87.2	100.6	115.5	131.0	141.1	153.4	172.8	193.8	214.2	
1,2,4-Trimethyl-5-ethylbenzene	$C_{11}H_{16}$	43.7	71.2	84.6	99.7	106.0	126.3	140.3	160.3	184.5	208.1	
1,3,5-Trimethyl-2-ethylbenzene	$C_{11}H_{16}$	38.8	67.0	80.5	96.0	113.2	123.8	137.9	158.4	183.5	208.0	
2,2,3-Trimethylpentane	C_8H_{18}	−29.0	−7.1	+3.9	16.0	29.5	38.1	49.9	67.8	88.2	109.8	−112.3
2,2,4-Trimethylpentane	C_8H_{18}	−36.5	−15.0	−4.3	+7.5	20.7	29.1	40.7	58.1	78.0	99.2	−107.3
2,3,3-Trimethylpentane	C_8H_{18}	−25.8	−3.9	+6.9	19.2	33.0	41.8	53.8	72.0	92.7	114.8	−101.5
2,3,4-Trimethylpentane	C_8H_{18}	−26.3	−4.1	+7.1	19.3	32.9	41.6	53.4	71.3	91.8	113.5	−109.2
2,2,4-Trimethyl-3-pentanone	$C_8H_{16}O$	14.7	36.0	46.4	57.6	69.8	77.3	87.6	102.2	118.4	135.0	
Trimethyl phosphate	$C_3H_9O_4P$	26.0	53.7	67.8	83.0	100.0	110.0	124.0	145.0	167.8	192.7	
2,4,5-Trimethylstyrene	$C_{11}H_{14}$	48.1	77.0	91.6	107.1	124.2	135.5	149.8	171.8	196.1	221.2	
2,4,6-Trimethylstyrene	$C_{11}H_{14}$	37.5	65.7	79.7	94.8	111.8	122.3	136.8	157.8	182.3	207.0	
Trimethylsuccinic anhydride	$C_7H_{10}O_3$	53.5	82.6	97.4	113.8	131.0	142.2	156.5	179.8	205.5	231.0	
Triphenylmethane	$C_{19}H_{16}$	169.7	188.4	197.0	206.8	215.5	221.2	228.4	239.7	249.8	259.2	93.4
Triphenylphosphate	$C_{18}H_{15}O_4P$	193.5	230.4	249.8	269.7	290.3	305.2	322.5	349.8	379.2	413.5	49.4
Tripropyleneglycol	$C_9H_{20}O_4$	96.0	125.7	140.5	155.8	173.7	184.6	199.0	220.2	244.3	267.2	
Tripropyleneglycol monobutyl ether	$C_{13}H_{28}O_4$	101.5	131.6	147.0	161.8	179.8	190.2	204.4	224.4	247.0	269.5	
Tripropyleneglycol monoisopropyl ether	$C_{12}H_{26}O_4$	82.4	112.4	127.3	143.7	161.4	173.2	187.8	209.7	232.8	256.6	
Tritolyl phosphate	$C_{21}H_{21}O_4P$	154.6	184.2	198.0	213.2	229.7	239.8	252.2	271.8	292.7	313.0	
Undecane	$C_{11}H_{24}$	32.7	59.7	73.9	85.6	104.4	115.2	128.1	149.3	171.9	195.8	−25.6
Undecanoic acid	$C_{11}H_{22}O_2$	101.4	133.1	149.0	166.0	185.6	197.2	212.5	237.8	262.8	290.0	29.5
10-Undecenoic acid	$C_{11}H_{20}O_2$	114.0	142.8	156.3	172.0	188.7	199.5	213.5	232.8	254.0	275.0	24.5
Undecan-2-ol	$C_{11}H_{24}O$	71.1	99.0	112.8	127.5	143.7	153.7	167.2	187.7	209.8	232.0	
n-Valeric acid	$C_5H_{10}O_2$	42.2	67.7	79.8	93.1	107.8	116.6	128.3	146.0	165.0	184.4	−34.5
iso-Valeric acid	$C_5H_{10}O_2$	34.5	59.6	71.3	84.0	98.0	107.3	118.9	136.2	155.2	175.1	−37.6
γ-Valerolactone	$C_5H_8O_2$	37.5	65.8	79.8	95.2	101.9	122.4	136.5	157.7	182.3	207.5	
Valeronitrile	C_5H_9N	−6.0	+18.1	30.0	43.3	57.8	66.9	78.6	97.7	118.7	140.8	
Vanillin	$C_8H_8O_3$	107.0	138.4	154.0	170.5	188.7	199.8	214.5	237.3	260.0	285.0	81.5
Vinyl acetate	$C_4H_6O_2$	−48.0	−28.0	−18.0	−7.0	+5.3	13.0	23.3	38.4	55.5	72.5	
2-Vinylanisole	$C_9H_{10}O$	41.9	68.0	81.0	94.7	110.0	119.8	132.3	151.0	172.1	194.0	
3-Vinylanisole	$C_9H_{10}O$	43.4	69.9	83.0	97.2	112.5	122.3	135.3	154.0	175.8	197.5	
4-Vinylanisole	$C_9H_{10}O$	45.2	72.0	85.7	100.0	116.0	126.1	139.7	159.0	182.0	204.5	
Vinyl chloride (1-chloroethylene)	C_2H_3Cl	−105.6	−90.8	−83.7	−75.7	−66.8	−61.1	−53.2	−41.3	−28.0	−13.8	−153.7
cyanide (acrylonitrile)	C_3H_3N	−51.0	−30.7	−20.3	−9.0	+3.8	11.8	22.8	38.7	58.3	78.5	−82
fluoride (1-fluoroethylene)	C_2H_3F	−149.3	−138.0	−132.2	−125.4	−118.0	−113.0	−106.2	−95.4	−84.0	−72.2	−160.5
Vinylidene chloride (1,1-dichloroethene)	$C_2H_2Cl_2$	−77.2	−60.0	−51.2	−41.7	−31.1	−24.0	−15.0	−1.0	+14.8	31.7	−122.5
4-Vinylphenetole	$C_{10}H_{12}O$	64.0	91.7	105.6	120.3	136.3	146.4	159.8	180.0	202.8	225.0	
2-Xenyl dichlorophosphate	$C_{12}H_9Cl_2PO$	138.2	171.1	187.0	205.0	223.8	236.0	251.5	275.3	301.5	328.5	
2,4-Xyaldehyde	$C_9H_{10}O$	59.0	85.9	99.0	114.0	129.7	139.8	152.2	172.3	194.1	215.5	75
2-Xylene (2-xylene)	C_8H_{10}	−3.8	+20.2	32.1	45.1	59.5	68.8	81.3	100.2	121.7	144.4	−25.2
3-Xylene (3-xylene)	C_8H_{10}	−6.9	+16.8	28.3	41.1	55.3	64.4	76.8	95.5	116.7	139.1	−47.9
4-Xylene (4-xylene)	C_8H_{10}	−8.1	+15.5	27.3	40.1	54.4	63.5	75.9	94.6	115.9	138.3	+13.3
2,4-Xylidine	$C_8H_{11}N$	52.6	79.8	93.0	107.6	123.8	133.7	146.8	166.4	188.3	211.5	
2,6-Xylidine	$C_8H_{11}N$	44.0	72.6	87.0	102.7	120.2	131.5	146.0	168.0	193.7	217.9	

VAPOR PRESSURES OF SOLUTIONS

UNITS CONVERSIONS

For this subsection, the following units conversions are applicable:

$$°F = \tfrac{9}{5}°C + 32$$

To convert millimeters of mercury to pounds-force per square inch, multiply by 0.01934.

To convert cubic feet to cubic meters, multiply by 0.02832.

To convert bars to pounds-force per square inch, multiply by 14.504.

To convert bars to kilopascals, multiply by 1×10^2.

TABLE 2-11 Partial Pressures of Water over Aqueous Solutions of HCl*

$\log_{10} p\text{mm} = A - B/T$, ($T$ in K), which, however, agrees only approximately with the table. The table is more nearly correct.

Partial pressure of H_2O, mmHg, °C

% HCl	A	B	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	60°	70°	80°	90°	100°	110°
6	8.99156	2282	4.18	6.04	8.45	11.7	15.9	21.8	29.1	39.4	50.6	66.2	86.0	139	220	333	492	715	
10	8.99864	2295	3.84	5.52	7.70	10.7	14.6	20.0	26.8	35.5	47.0	61.5	80.0	130	204	310	463	677	960
14	8.97075	2300	3.39	4.91	6.95	9.65	13.1	18.0	24.1	31.9	42.1	55.3	72.0	116	185	273	425	625	892
18	8.98014	2323	2.87	4.21	5.92	8.26	11.3	15.4	20.6	27.5	36.4	47.9	62.5	102	162	248	374	550	783
20	8.97877	2334	2.62	3.83	5.40	7.50	10.3	14.1	19.0	25.1	33.3	43.6	57.0	93.5	150	230	345	510	729
22	9.02708	2363	2.33	3.40	4.82	6.75	9.30	12.6	17.1	22.8	30.2	39.8	52.0	85.6	138	211	317	467	670
24	8.96022	2356	2.05	3.04	4.31	6.03	8.30	11.4	15.4	20.4	27.1	35.7	46.7	77.0	124	194	290	426	611
26	9.01511	2390	1.76	2.60	3.71	5.21	7.21	9.95	13.5	18.0	24.0	31.7	41.5	69.0	112	173	261	387	555
28	8.97611	2395	1.50	2.24	3.21	4.54	6.32	8.75	11.8	15.8	21.1	27.9	36.5	60.7	99.0	154	234	349	499
30	9.00117	2422	1.26	1.90	2.73	3.88	5.41	7.52	10.2	13.7	18.4	24.3	32.0	53.5	87.5	136	207	310	444
32	9.03317	2453	1.04	1.57	2.27	3.25	4.55	6.37	8.70	11.7	15.7	21.0	27.7	46.5	76.5	120	184	275	396
34	9.07143	2487	0.85	1.29	1.87	2.70	3.81	5.35	7.32	9.95	13.5	18.1	24.0	40.5	66.5	104	161	243	355
36	9.11815	2526	0.68	1.03	1.50	2.19	3.10	4.41	6.08	8.33	11.4	15.4	20.4	34.8	57.0	90.0	140	212	311
38	9.20783	2579	0.53	0.81	1.20	1.75	2.51	3.60	5.03	6.92	9.52	13.0	17.4	29.6	49.1	77.5	120	182	266
40	9.33923	2647	0.41	0.63	0.94	1.37	2.00	2.88	4.09	5.68	7.85	10.7	14.5	25.0	42.1	67.3	105	158	230
42	9.44953	2709	0.31	0.48	0.72	1.06	1.56	2.30	3.28	4.60	6.45	8.90	12.1	21.2	35.8	57.2	89.2	135	195

*Uncertainty, ca. 2 percent for solutions of 15 to 30 percent HCl between 0 and 100°; for solutions of > 30 percent HCl the accuracy is ca. 5 percent at the lower temperatures and ca. 15 percent at the higher temperatures. Below 15 percent HCl, the uncertainty is ca. 5 percent at the lower temperatures and higher strengths to ca. 15 to 20 percent at the lower strengths and perhaps 15 to 20 percent at the higher temperatures and lower strengths.

International Critical Tables, vol. 3, p. 301.

TABLE 2-12 Partial Pressures of HCl over Aqueous Solutions of HCl*

$\log_{10} p\text{mm} = A - B/T$, ($T$ in K), which, however, agrees only approximately with the table. The table is more nearly correct. mmHg, °C

% HCl	A	B	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	60°	70°	80°	90°	100°	110°
2	11.8037	4736			0.0000117	0.000023	0.000044	0.000084	0.000151	0.000275	0.00047	0.00083	0.00140	0.00380	0.0100	0.0245	0.058	0.132	0.280
4	11.6400	4471	0.000018	0.000036	.000069	.000131	.00024	.00044	.00077	.00134	.0023	.00385	.0064	.0165	.0405	.095	.21	.46	.93
6	11.2144	4202	.000066	.000125	.000234	.000425	.00076	.00131	.00225	.0038	.0062	.0102	.0163	.040	.094	.206	.44	.92	1.78
8	11.0406	4042	.000118	.000323	.000583	.00104	.00178	.0031	.00515	.0085	.0136	.022	.0344	.081	.183	.39	.82	1.64	3.10
10	10.9311	3908	.00042	.00075	.00134	.00232	.00395	.0067	.0111	.0178	.0282	.045	.069	.157	.35	.73	1.48	2.9	5.4
12	10.7900	3765	.00099	.00175	.00305	.0052	.0088	.0145	.0234	.037	.058	.091	.136	.305	.66	1.34	2.65	5.1	9.3
14	10.6954	3636	.0024	.00415	.0071	.0118	.0196	.0316	.050	.078	.121	.185	.275	.60	1.25	2.50	4.8	9.0	16.0
16	10.6261	3516	.0056	.0095	.016	.0265	.0428	.0685	.106	.163	.247	.375	.55	1.17	2.40	4.66	8.8	16.1	28
18	10.4957	3376	.0135	.0225	.037	.060	.095	.148	.228	.345	.515	.77	1.11	2.3	4.55	8.6	15.7	28	48
20	10.3833	3245	.0316	.052	.084	.132	.205	.32	.48	.72	1.06	1.55	2.21	4.4	8.5	15.6	28.1	49	83
22	10.3172	3125	.0734	.119	.187	.294	.45	.68	1.02	1.50	2.18	3.14	4.42	8.6	16.3	29.3	52	90	146
24	10.2185	2995	.175	.277	.43	.66	1.00	1.49	2.17	3.14	4.5	6.4	8.9	16.9	31.0	54.5	94	157	253
26	10.1303	2870	.41	.64	.98	1.47	2.17	3.20	4.56	6.50	9.2	12.7	17.5	32.5	58.5	100	169	276	436
28	10.0115	2732	1.0	1.52	2.27	3.36	4.90	7.05	9.90	13.8	19.1	26.4	35.7	64	112	188	309	493	760
30	9.8763	2593	2.4	3.57	5.23	7.60	10.6	15.1	21.0	28.6	39.4	53	71	124	208	340	542	845	
32	9.7523	2457	5.7	8.3	11.8	16.8	23.5	32.5	44.5	60.0	81	107	141	238	390	623	970		
34	9.6061	2316	13.1	18.8	26.4	36.8	50.5	68.5	92	122	161	211	273	450	720				
36	9.5262	2229	29.0	41.0	56.4	78	105.5	142	188	246	322	416	535	860					
38	9.4670	2094	63.0	87.0	117	158	210	277	360	465	598	758	955						
40	9.2156	1939	130	176	233	307	399	515	627	830									
42	8.9925	1800	253	332	430	560	709	900											
44	8.8621	1681	510	655	840														
46			940																

*Uncertainty, ca. 2 percent for solutions of 15 to 30 percent HCl between 0 and 100°; for solutions of > 30 percent HCl the accuracy is ca. 5 percent at the lower temperatures and ca. 15 percent at the higher temperatures. Below 15 percent HCl, the uncertainty is ca. 5 percent at the lower temperatures and higher strengths to ca. 15 to 20 percent at the lower strengths and perhaps 15 to 20 percent at the higher temperatures and lower strengths.

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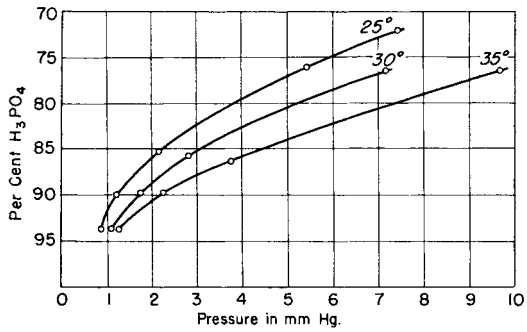

FIG. 2-1 Vapor pressures of H_3PO_4 aqueous: partial pressure of H_2O vapor. (*Courtesy of Victor Chemical Works, Stauffer Chemical Company; measurements by W. H. Woodstock.*)

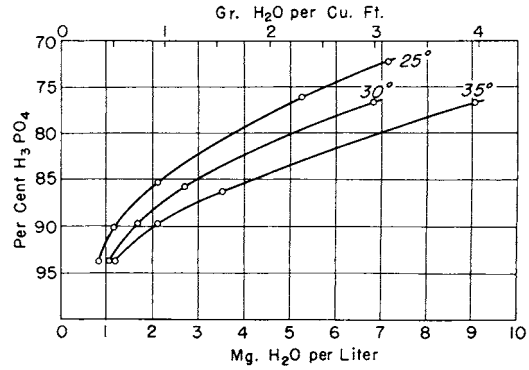

FIG. 2-2 Vapor pressures of H_3PO_4 aqueous: weight of H_2O in saturated air. (*Courtesy of Victor Chemical Works, Stauffer Chemical Company; measurements by W. H. Woodstock.*)

TABLE 2-13 Partial Pressures of H_2O and SO_2 over Aqueous Solutions of Sulfur Dioxide*

Partial pressures of H_2O and SO_2, mmHg, °C

g SO_2/ 100 g H_2O	Temperature, °C								
	0	10	20	30	40	50	60	90	120
0.01	0.02	0.04	0.07	0.12	0.19	0.29	0.43	1.21	2.82
0.05	0.38	0.66	1.07	1.68	2.53	3.69	5.24	12.9	27.0
0.10	1.15	1.91	3.03	4.62	6.80	9.71	13.5	31.7	63.9
0.15	2.10	3.44	5.37	8.07	11.7	16.5	22.7	52.2	104
0.20	3.17	5.13	7.93	11.8	17.0	23.8	32.6	73.7	145
0.25	4.34	6.93	10.6	15.7	22.5	31.4	42.8	95.8	186
0.30	5.57	8.84	13.5	19.8	28.2	39.2	53.3	118	229
0.40	8.17	12.8	19.4	28.3	40.1	55.3	74.7	164	316
0.50	10.9	17.0	25.6	37.1	52.3	72.0	96.8	211	404
1.00	25.8	39.5	58.4	83.7	117	159	212	454	856
2.00	58.6	88.5	129	183	253	342	453	955	
3.00	93.2	139	202	285	393	530	700		
4.00	129	192	277	389	535	720			
5.00	165	245	353	496	679				
6.00	202	299	430	602	824				
8.00	275	407	585	818					
10.00	351	517	741						
15.00	542	796							
20.00	735								

*Extracted with permission from *J. Chem Eng. Data* **8,** 1963: 333–336. Copyright 1963 American Chemical Society.

TABLE 2-14 Water Partial Pressure, bar, over Aqueous Sulfuric Acid Solutions*

Weight percent, H_2SO_4

°C	10.0	20.0	30.0	40.0	50.0	60.0	70.0	75.0	80.0	85.0
0	.582E–02	.534E–02	.448E–02	.326E–02	.193E–02	.836E–03	.207E–03	.747E–04	.197E–04	.343E–05
10	.117E–01	.107E–01	.909E–02	.670E–02	.405E–02	.180E–02	.467E–03	.175E–03	.490E–04	.952E–05
20	.223E–01	.205E–01	.174E–01	.130E–01	.802E–02	.367E–02	.995E–03	.388E–03	.115E–04	.245E–04
30	.404E–01	.373E–01	.319E–01	.241E–01	.151E–01	.710E–02	.201E–02	.811E–03	.253E–03	.589E–04
40	.703E–01	.649E–01	.558E–01	.427E–01	.272E–01	.131E–01	.387E–02	.162E–02	.531E–03	.133E–03
50	.117	.109	.939E–01	.725E–01	.470E–01	.232E–01	.715E–02	.309E–02	.106E–02	.286E–03
60	.189	.175	.152	.119	.782E–01	.395E–01	.127E–01	.565E–02	.204E–02	.584E–03
70	.296	.275	.239	.188	.126	.651E–01	.217E–01	.997E–02	.376E–02	.114E–02
80	.449	.417	.365	.290	.196	.104	.360E–01	.170E–01	.668E–02	.213E–02
90	.664	.617	.542	.434	.298	.161	.578E–01	.281E–01	.115E–01	.383E–02
100	.957	.891	.786	.634	.441	.244	.905E–01	.452E–01	.192E–01	.666E–02
110	1.349	1.258	1.113	.904	.638	.360	.138	.708E–01	.312E–01	.112E–01
120	1.863	1.740	1.544	1.264	.903	.519	.206	.108	.493E–01	.183E–01
130	2.524	2.361	2.101	1.732	1.253	.734	.301	.162	.760E–01	.291E–01
140	3.361	3.149	2.810	2.333	1.708	1.020	.481	.236	.115	.451E–01
150	4.404	4.132	3.697	3.090	2.289	1.392	.605	.339	.170	.682E–01
160	5.685	5.342	4.793	4.031	3.021	1.870	.837	.478	.246	.101
170	7.236	6.810	6.127	5.185	3.930	2.475	1.138	.662	.350	.147
180	9.093	8.571	7.731	6.584	5.045	3.233	1.525	.902	.489	.208
190	11.289	10.658	9.640	8.259	6.397	4.169	2.017	1.212	.673	.291
200	13.861	13.107	11.887	10.245	8.020	5.312	2.632	1.606	.913	.401
210	16.841	15.951	14.505	12.576	9.948	6.696	3.395	2.101	1.220	.542
220	20.264	19.225	17.529	15.287	12.217	8.354	4.331	2.714	1.609	.724
230	24.160	22.960	20.992	18.414	14.864	10.322	5.466	3.467	2.096	.952
240	28.561	27.188	24.927	21.992	17.929	12.641	6.831	4.381	2.699	1.237
250	33.494	31.939	29.364	26.056	21.452	15.351	8.458	5.480	3.435	1.587
260	38.984	37.240	34.334	30.642	25.472	18.496	10.382	6.788	4.326	2.012
270	45.055	43.116	39.865	35.784	30.030	22.121	12.640	8.333	5.395	2.525
280	51.726	49.590	45.984	41.514	35.168	26.274	15.269	10.142	6.663	3.136
290	59.015	56.681	52.715	47.865	40.926	31.003	18.311	12.242	8.155	3.857
300	66.934	64.407	60.081	54.868	47.346	36.360	21.808	14.665	9.897	4.701
310	75.495	72.781	68.100	62.553	54.470	42.395	25.804	17.438	11.912	5.680
320	84.705	81.816	76.792	70.947	62.337	49.164	30.343	20.591	14.227	6.806
330	94.567	91.518	86.172	80.077	70.988	56.721	35.473	24.153	16.867	8.093
340	105.083	101.894	96.252	89.969	80.463	65.123	41.240	28.154	19.855	9.551
350	116.251	112.946	107.043	100.646	90.802	74.426	47.692	32.622	23.217	11.193

*Vermeulen, Dong, Robinson, Nguyen, and Gmitro, AIChE meeting, Anaheim, Calif., 1982; and private communication from Prof. Theodore Vermeulen, Chemical Engineering Dept., University of California, Berkeley.

TABLE 2-14 Water Partial Pressure, bar, over Aqueous Sulfuric Acid Solutions (*Concluded*)

Weight percent, H_2SO_4

°C	90.0	92.0	94.0	96.0	97.0	98.0	98.5	99.0	99.5	100.0
0	.518E–06	.242E–06	.107E–06	.401E–07	.218E–07	.980E–08	.569E–08	.268E–08	.775E–09	.196E–09
10	.159E–05	.762E–06	.344E–06	.130E–06	.713E–07	.323E–07	.188E–07	.888E–08	.258E–08	.655E–09
20	.448E–05	.220E–05	.101E–05	.390E–06	.215E–06	.978E–07	.572E–07	.271E–07	.789E–08	.201E–08
30	.117E–04	.587E–05	.275E–05	.108E–05	.598E–06	.275E–06	.161E–06	.766E–07	.224E–07	.575E–08
40	.285E–04	.146E–04	.696E–05	.278E–05	.155E–05	.720E–06	.424E–06	.202E–06	.595E–07	.153E–07
50	.652E–04	.341E–04	.166E–04	.672E–05	.379E–05	.177E–05	.105E–05	.503E–06	.149E–06	.384E–07
60	.141E–03	.754E–04	.372E–04	.154E–04	.875E–05	.413E–05	.245E–05	.118E–05	.350E–06	.910E–07
70	.290E–03	.158E–03	.795E–04	.334E–04	.192E–04	.912E–05	.544E–05	.263E–05	.784E–06	.205E–06
80	.569E–03	.316E–03	.162E–03	.691E–04	.400E–04	.192E–04	.115E–04	.559E–05	.168E–05	.439E–06
90	.107E–02	.606E–03	.315E–03	.137E–03	.801E–04	.388E–04	.234E–04	.114E–04	.343E–05	.903E–06
100	.194E–02	.112E–02	.590E–03	.261E–03	.154E–03	.752E–04	.455E–04	.223E–04	.674E–05	.178E–05
110	.338E–02	.198E–02	.107E–02	.479E–03	.285E–03	.141E–03	.855E–04	.420E–04	.128E–04	.339E–05
120	.571E–02	.341E–02	.186E–02	.851E–03	.511E–03	.254E–03	.155E–03	.766E–04	.233E–04	.623E–05
130	.938E–02	.569E–02	.315E–02	.146E–02	.886E–03	.445E–03	.278E–03	.135E–03	.414E–04	.111E–04
140	.150E–01	.923E–02	.519E–02	.245E–02	.149E–02	.757E–03	.467E–03	.232E–03	.711E–04	.191E–04
150	.233E–01	.146E–01	.832E–02	.399E–02	.245E–02	.125E–02	.776E–03	.387E–03	.119E–03	.321E–04
160	.354E–01	.225E–01	.130E–01	.633E–02	.393E–02	.202E–02	.126E–02	.629E–03	.194E–03	.526E–04
170	.526E–01	.340E–01	.199E–01	.983E–02	.614E–02	.319E–02	.199E–02	.999E–03	.309E–03	.840E–04
180	.766E–01	.502E–01	.298E–01	.149E–01	.941E–02	.492E–02	.309E–02	.155E–02	.482E–03	.131E–03
190	.110	.729E–01	.438E–01	.222E–01	.141E–01	.744E–02	.469E–02	.236E–02	.735E–03	.201E–03
200	.154	.104	.631E–01	.325E–01	.208E–01	.110E–01	.698E–02	.352E–02	.110E–02	.300E–03
210	.213	.146	.894E–01	.467E–01	.300E–01	.161E–01	.102E–01	.516E–02	.161E–02	.442E–03
220	.290	.201	.125	.660E–01	.427E–01	.230E–01	.147E–01	.743E–02	.232E–02	.638E–03
230	.389	.273	.171	.918E–01	.598E–01	.325E–01	.208E–01	.105E–01	.329E–02	.906E–03
240	.514	.366	.232	.126	.825E–01	.451E–01	.290E–01	.147E–01	.460E–02	.127E–02
250	.673	.485	.310	.170	.112	.618E–01	.398E–01	.202E–01	.633E–02	.174E–02
260	.870	.635	.409	.227	.151	.835E–01	.540E–01	.274E–01	.858E–02	.237E–02
270	1.112	.822	.534	.300	.200	.111	.723E–01	.366E–01	.115E–01	.317E–02
280	1.407	1.052	.689	.391	.263	.147	.957E–01	.485E–01	.152E–01	.420E–02
290	1.763	1.335	.880	.505	.341	.192	.125	.634E–01	.199E–01	.548E–02
300	2.190	1.676	1.112	.646	.437	.248	.162	.820E–01	.257E–01	.708E–02
310	2.696	2.088	1.394	.817	.556	.316	.208	.105	.328E–01	.905E–02
320	3.292	2.578	1.732	1.025	.701	.400	.264	.133	.415E–01	.114E–01
330	3.990	3.159	2.133	1.274	.875	.502	.331	.167	.520E–01	.143E–01
340	4.801	3.843	2.608	1.571	1.083	.624	.413	.208	.646E–01	.178E–01
350	5.738	4.641	3.164	1.922	1.331	.770	.511	.256	.795E–01	.218E–01

TABLE 2-15 Sulfur Trioxide Partial Pressure, bar, over Aqueous Sulfuric Acid Solutions*

Weight percent, H_2SO_4

°C	10.0	20.0	30.0	40.0	50.0	60.0	70.0	75.0	80.0	85.0
0	.644E–29	.103E–27	.205E–26	.688E–25	.368E–23	.341E–21	.784E–19	.174E–17	.531E–16	.229E–14
10	.149E–27	.223E–26	.395E–25	.113E–23	.522E–22	.415E–20	.796E–18	.158E–16	.417E–15	.141E–13
20	.278E–26	.394E–25	.626E–24	.156E–22	.621E–21	.426E–19	.685E–17	.121E–15	.280E–14	.767E–13
30	.426E–25	.577E–24	.832E–23	.181E–21	.630E–20	.376E–18	.509E–16	.808E–15	.164E–13	.371E–12
40	.549E–24	.714E–23	.941E–22	.181E–20	.555E–19	.288E–17	.331E–15	.473E–14	.851E–13	.162E–11
50	.602E–23	.757E–22	.921E–21	.158E–19	.429E–18	.195E–16	.191E–14	.246E–13	.395E–12	.643E–11
60	.573E–22	.699E–21	.789E–20	.122E–18	.294E–17	.118E–15	.985E–14	.116E–12	.165E–11	.234E–10
70	.477E–21	.567E–20	.599E–19	.843E–18	.181E–16	.643E–15	.461E–13	.492E–12	.634E–11	.791E–10
80	.352E–20	.410E–19	.408E–18	.524E–17	.101E–15	.319E–14	.197E–12	.192E–11	.223E–10	.249E–09
90	.233E–19	.266E–18	.250E–17	.296E–16	.516E–15	.145E–13	.775E–12	.693E–11	.731E–10	.734E–09
100	.139E–18	.157E–17	.140E–16	.153E–15	.242E–14	.606E–13	.283E–11	.232E–10	.223E–09	.204E–08
110	.756E–18	.844E–17	.719E–16	.730E–15	.105E–13	.236E–12	.961E–11	.729E–10	.641E–09	.538E–08
120	.377E–17	.418E–16	.340E–15	.323E–14	.424E–13	.858E–12	.307E–10	.215E–09	.174E–08	.135E–07
130	.174E–16	.191E–15	.150E–14	.133E–13	.160E–12	.293E–11	.922E–10	.601E–09	.446E–08	.324E–07
140	.743E–16	.815E–15	.615E–14	.517E–13	.569E–12	.943E–11	.262E–09	.159E–08	.109E–07	.745E–07
150	.297E–15	.325E–14	.237E–13	.188E–12	.191E–11	.287E–10	.710E–09	.403E–08	.256E–07	.165E–06
160	.111E–14	.122E–13	.862E–13	.649E–12	.608E–11	.833E–10	.183E–08	.974E–08	.575E–07	.351E–06
170	.393E–14	.430E–13	.296E–12	.212E–11	.184E–10	.231E–09	.453E–08	.226E–07	.125E–06	.725E–06
180	.131E–13	.144E–12	.967E–12	.622E–11	.532E–10	.610E–09	.107E–07	.505E–07	.260E–06	.145E–05
190	.415E–13	.458E–12	.301E–11	.197E–10	.147E–09	.155E–08	.246E–07	.109E–06	.527E–06	.282E–05
200	.125E–12	.139E–11	.893E–11	.561E–10	.391E–09	.379E–08	.542E–07	.228E–06	.103E–05	.534E–05
210	.362E–12	.404E–11	.254E–10	.154E–09	.100E–08	.894E–08	.116E–06	.462E–06	.198E–05	.986E–05
220	.100E–11	.112E–10	.695E–10	.405E–09	.246E–08	.204E–07	.240E–06	.911E–06	.368E–05	.178E–04
230	.265E–11	.301E–10	.183E–09	.103E–08	.587E–08	.450E–07	.482E–06	.175E–05	.668E–05	.314E–04
240	.678E–11	.777E–10	.465E–09	.253E–08	.135E–07	.965E–07	.944E–06	.328E–05	.119E–04	.543E–04
250	.167E–10	.193E–09	.114E–08	.602E–08	.303E–07	.201E–06	.180E–05	.600E–05	.206E–04	.923E–04
260	.399E–10	.466E–09	.272E–08	.139E–07	.660E–07	.408E–06	.336E–05	.108E–04	.352E–04	.154E–03
270	.920E–10	.109E–08	.628E–08	.312E–07	.140E–06	.807E–06	.612E–05	.189E–04	.590E–04	.253E–03
280	.206E–09	.247E–08	.141E–07	.683E–07	.288E–06	.156E–05	.109E–04	.326E–04	.973E–04	.408E–03
290	.449E–09	.545E–08	.308E–07	.145E–06	.580E–06	.295E–05	.191E–04	.553E–04	.158E–03	.649E–03
300	.953E–09	.117E–07	.657E–07	.302E–06	.114E–05	.546E–05	.329E–04	.921E–04	.253E–03	.102E–02
310	.197E–08	.245E–07	.136E–06	.614E–06	.220E–05	.990E–05	.556E–04	.151E–03	.398E–03	.158E–02
320	.397E–08	.502E–07	.277E–06	.122E–05	.414E–05	.176E–04	.923E–04	.245E–03	.621E–03	.242E–02
330	.782E–08	.100E–06	.551E–06	.237E–05	.766E–05	.308E–04	.151E–03	.391E–03	.956E–03	.367E–02
340	.151E–07	.196E–06	.107E–05	.452E–05	.139E–04	.529E–04	.243E–03	.617E–03	.145E–02	.550E–02
350	.285E–07	.376E–06	.204E–05	.846E–05	.246E–04	.893E–04	.387E–03	.963E–03	.219E–02	.815E–02

*Vermeulen, Dong, Robinson, Nguyen, and Gmitro, AIChE meeting, Anaheim, Calif., 1982; and private communication from Prof. Theodore Vermeulen, Chemical Engineering Dept., University of California, Berkeley.

TABLE 2-15 Sulfur Trioxide Partial Pressure, bar, over Aqueous Sulfuric Acid Solutions (*Concluded*)

Weight percent, H_2SO_4

°C	90.0	92.0	94.0	96.0	97.0	98.0	98.5	99.0	99.5	100.0
0	.671E–13	.216E–12	.677E–12	.240E–11	.500E–11	.124E–10	.224E–10	.502E–10	.182E–09	.755E–09
10	.345E–12	.107E–11	.326E–11	.114E–10	.234E–10	.578E–10	.104E–09	.232E–09	.839E–09	.347E–08
20	.159E–11	.475E–11	.141E–10	.482E–10	.986E–10	.241E–09	.433E–09	.961E–09	.346E–08	.142E–07
30	.664E–11	.192E–10	.557E–10	.186E–09	.376E–09	.911E–09	.163E–08	.360E–08	.129E–07	.528E–07
40	.254E–10	.709E–10	.201E–09	.655E–09	.131E–08	.315E–08	.562E–08	.123E–07	.440E–07	.179E–06
50	.897E–10	.242E–09	.669E–09	.214E–08	.424E–08	.101E–07	.179E–07	.391E–07	.139E–06	.560E–06
60	.294E–09	.771E–09	.207E–08	.647E–08	.127E–07	.299E–07	.528E–07	.115E–06	.405E–06	.163E–05
70	.904E–09	.230E–08	.602E–08	.184E–07	.357E–07	.833E–07	.146E–06	.316E–06	.111E–05	.444E–05
80	.261E–08	.643E–08	.165E–07	.492E–07	.946E–07	.218E–06	.381E–06	.820E–06	.286E–05	.114E–04
90	.712E–08	.171E–07	.426E–07	.124E–06	.237E–06	.541E–06	.940E–06	.201E–05	.698E–05	.276E–04
100	.184E–07	.430E–07	.105E–06	.300E–06	.565E–06	.127E–05	.220E–05	.470E–05	.162E–04	.638E–04
110	.456E–07	.103E–06	.247E–06	.689E–06	.128E–05	.287E–05	.494E–05	.105E–04	.359E–04	.141E–03
120	.108E–06	.238E–06	.555E–06	.152E–05	.280E–05	.619E–05	.106E–04	.224E–04	.764E–04	.298E–03
130	.244E–06	.526E–06	.120E–05	.321E–05	.586E–05	.128E–04	.219E–04	.459E–04	.156E–03	.606E–03
140	.533E–06	.112E–05	.250E–05	.656E–05	.118E–04	.257E–04	.435E–04	.910E–04	.308E–03	.119E–02
150	.112E–05	.230E–05	.504E–05	.129E–04	.231E–04	.497E–04	.837E–04	.174E–03	.588E–03	.226E–02
160	.229E–05	.459E–05	.983E–05	.247E–04	.438E–04	.932E–04	.156E–03	.324E–03	.109E–02	.416E–02
170	.453E–05	.886E–05	.186E–04	.459E–04	.806E–04	.170E–03	.283E–03	.586E–03	.196E–02	.746E–02
180	.870E–05	.166E–04	.343E–04	.829E–04	.144E–03	.301E–03	.499E–03	.103E–02	.343E–02	.130E–01
190	.163E–04	.304E–04	.615E–04	.146E–03	.252E–03	.520E–03	.859E–03	.177E–02	.587E–02	.222E–01
200	.297E–04	.543E–04	.108E–03	.251E–03	.429E–03	.878E–03	.144E–02	.296E–02	.981E–02	.370E–01
210	.528E–04	.946E–04	.185E–03	.422E–03	.714E–03	.145E–02	.237E–02	.486E–02	.161E–01	.603E–01
220	.919E–04	.161E–03	.309E–03	.694E–03	.117E–02	.235E–02	.383E–02	.781E–02	.258E–01	.965E–01
230	.157E–03	.269E–03	.508E–03	.112E–02	.187E–02	.373E–02	.605E–02	.123E–01	.405E–01	.152
240	.261E–03	.441E–03	.819E–03	.178E–02	.293E–02	.582E–02	.939E–02	.191E–01	.627E–01	.234
250	.428E–03	.708E–03	.130E–02	.276E–02	.453E–02	.891E–02	.143E–01	.291E–01	.955E–01	.356
260	.690E–03	.112E–02	.202E–02	.423E–02	.688E–02	.134E–01	.215E–01	.437E–01	.143	.532
270	.109E–02	.174E–02	.309E–02	.638E–02	.103E–01	.200E–01	.319E–01	.646E–01	.212	.786
280	.170E–02	.266E–02	.466E–02	.948E–02	.152E–01	.293E–01	.465E–01	.943E–01	.309	1.144
290	.261E–02	.401E–02	.694E–02	.139E–01	.221E–01	.423E–01	.670E–01	.136	.444	1.646
300	.395E–02	.595E–02	.102E–01	.201E–01	.318E–01	.604E–01	.953E–01	.193	.632	2.339
310	.589E–02	.873E–02	.148E–01	.287E–01	.451E–01	.852E–01	.134	.272	.889	3.289
320	.868E–02	.126E–01	.211E–01	.405E–01	.632E–01	.119	.186	.378	1.236	4.575
330	.126E–01	.181E–01	.299E–01	.565E–01	.877E–01	.164	.256	.520	1.703	6.303
340	.181E–01	.255E–01	.418E–01	.780E–01	.120	.224	.348	.708	2.323	8.603
350	.258E–01	.357E–01	.578E–01	.107	.164	.303	.470	.956	3.142	11.640

TABLE 2-16 Sulfuric Acid Partial Pressure, bar, over Aqueous Sulfuric Acid*

	Weight percent, H_2SO_4									
°C	10.0	20.0	30.0	40.0	50.0	60.0	70.0	75.0	80.0	85.0
0	.576E–21	.843E–20	.141E–18	.344E–17	.109E–15	.438E–14	.249E–12	.200E–11	.161E–10	.121E–09
10	.634E–20	.874E–19	.131E–17	.276E–16	.769E–15	.273E–13	.135E–11	.101E–10	.743E–10	.490E–09
20	.588E–19	.769E–18	.104E–16	.193E–15	.474E–14	.149E–12	.649E–11	.447E–10	.305E–09	.179E–08
30	.468E–18	.584E–17	.721E–16	.119E–14	.259E–13	.725E–12	.278E–10	.178E–09	.113E–08	.594E–08
40	.324E–17	.389E–16	.441E–15	.649E–14	.127E–12	.317E–11	.108E–09	.643E–09	.379E–08	.181E–07
50	.197E–16	.229E–15	.241E–14	.320E–13	.562E–12	.126E–10	.380E–09	.212E–08	.117E–07	.513E–07
60	.107E–15	.121E–14	.119E–13	.144E–12	.228E–11	.462E–10	.124E–08	.646E–08	.334E–07	.135E–06
70	.526E–15	.581E–14	.535E–13	.592E–12	.851E–11	.156E–09	.373E–08	.183E–07	.888E–07	.336E–06
80	.235E–14	.254E–13	.221E–12	.225E–11	.295E–10	.492E–09	.105E–07	.485E–07	.222E–06	.786E–06
90	.960E–14	.102E–12	.844E–12	.798E–11	.956E–10	.145E–08	.279E–07	.121E–06	.522E–06	.175E–05
100	.353E–13	.381E–12	.300E–11	.264E–10	.291E–09	.402E–08	.698E–07	.287E–06	.117E–05	.371E–05
110	.127E–12	.132E–11	.997E–11	.824E–10	.835E–09	.106E–07	.166E–06	.644E–06	.249E–05	.752E–05
120	.418E–12	.432E–11	.312E–10	.243E–09	.227E–08	.264E–07	.375E–06	.138E–05	.508E–05	.147E–04
130	.129E–11	.132E–10	.924E–10	.678E–09	.589E–08	.631E–07	.814E–06	.285E–05	.995E–05	.277E–04
140	.375E–11	.385E–10	.259E–09	.181E–08	.146E–07	.144E–06	.169E–05	.565E–05	.188E–04	.503E–04
150	.103E–10	.106E–09	.694E–09	.460E–08	.346E–07	.316E–06	.340E–05	.108E–04	.343E–04	.889E–04
160	.272E–10	.279E–09	.178E–08	.112E–07	.789E–07	.670E–06	.659E–05	.200E–04	.608E–04	.152E–03
170	.682E–10	.702E–09	.436E–08	.264E–07	.174E–06	.137E–05	.124E–04	.359E–04	.104E–03	.255E–03
180	.164E–09	.170E–08	.103E–07	.599E–07	.369E–06	.271E–05	.225E–04	.627E–04	.175E–03	.416E–03
190	.378E–09	.394E–08	.234E–07	.131E–06	.760E–06	.521E–05	.400E–04	.107E–03	.286E–03	.663E–03
200	.842E–09	.883E–08	.514E–07	.278E–06	.152E–05	.975E–05	.691E–04	.177E–03	.457E–03	.104E–02
210	.181E–08	.191E–07	.109E–06	.573E–06	.295E–05	.178E–04	.117E–03	.288E–03	.715E–03	.159E–02
220	.376E–08	.401E–07	.226E–06	.115E–05	.559E–05	.316E–04	.193E–03	.459E–03	.110E–02	.239E–02
230	.758E–08	.817E–07	.455E–06	.224E–05	.103E–04	.549E–04	.311E–03	.717E–03	.166E–02	.354E–02
240	.148E–07	.162E–06	.889E–06	.427E–05	.186E–04	.935E–04	.494E–03	.110E–02	.245E–02	.515E–02
250	.283E–07	.312E–06	.170E–05	.793E–05	.329E–04	.156E–03	.770E–03	.166E–02	.358E–02	.740E–02
260	.526E–07	.588E–06	.316E–05	.144E–04	.569E–04	.255E–03	.118E–02	.247E–02	.516E–02	.105E–01
270	.954E–07	.108E–05	.577E–05	.257E–04	.965E–04	.411E–03	.178E–02	.362E–02	.733E–02	.147E–01
280	.169E–06	.194E–05	.103E–04	.450E–04	.161E–03	.650E–03	.265E–02	.524E–02	.103E–01	.203E–01
290	.294E–06	.342E–05	.180E–04	.771E–04	.263E–03	.101E–02	.389E–02	.750E–02	.143E–01	.278E–01
300	.500E–06	.591E–05	.309E–04	.130E–03	.424E–03	.156E–02	.563E–02	.106E–01	.196E–01	.376E–01
310	.834E–06	.100E–04	.522E–04	.215E–03	.672E–03	.236E–02	.805E–02	.148E–01	.266E–01	.504E–01
320	.137E–05	.167E–04	.865E–04	.352E–03	.105E–02	.352E–02	.114E–01	.205E–01	.359E–01	.670E–01
330	.220E–05	.273E–04	.141E–03	.565E–03	.162E–02	.519E–02	.159E–01	.281E–01	.480E–01	.883E–01
340	.349E–05	.440E–04	.227E–03	.895E–03	.246E–02	.757E–02	.221E–01	.382E–01	.636E–01	.116
350	.544E–05	.698E–04	.360E–03	.140E–02	.369E–02	.109E–01	.303E–01	.516E–01	.836E–01	.150

	Weight percent, H_2SO_4									
°C	90.0	92.0	94.0	96.0	97.0	98.0	98.5	99.0	99.5	100.0
0	.534E–09	.803E–09	.112E–08	.148E–08	.167E–08	.187E–08	.196E–08	.206E–08	.217E–08	.228E–08
10	.200E–08	.296E–08	.409E–08	.540E–08	.609E–08	.679E–08	.714E–08	.750E–08	.788E–08	.827E–08
20	.677E–08	.993E–08	.136E–07	.179E–07	.201E–07	.224E–07	.236E–07	.247E–07	.260E–07	.273E–07
30	.211E–07	.306E–07	.415E–07	.543E–07	.611E–07	.680E–07	.714E–07	.749E–07	.786E–07	.824E–07
40	.607E–07	.870E–07	.117E–06	.153E–06	.171E–06	.191E–06	.200E–06	.210E–06	.220E–06	.230E–06
50	.163E–06	.231E–06	.309E–06	.400E–06	.449E–06	.498E–06	.523E–06	.548E–06	.574E–06	.600E–06
60	.411E–06	.575E–06	.765E–06	.985E–06	.110E–05	.122E–05	.128E–05	.134E–05	.140E–05	.147E–05
70	.976E–06	.135E–05	.179E–05	.229E–05	.256E–05	.283E–05	.297E–05	.310E–05	.325E–05	.339E–05
80	.220E–05	.302E–05	.396E–05	.504E–05	.562E–05	.622E–05	.652E–05	.681E–05	.712E–05	.743E–05
90	.473E–05	.642E–05	.835E–05	.106E–04	.118E–04	.130E–04	.136E–04	.143E–04	.149E–04	.155E–04
100	.973E–05	.131E–04	.169E–04	.213E–04	.237E–04	.261E–04	.274E–04	.285E–04	.298E–04	.310E–04
110	.192E–04	.256E–04	.328E–04	.412E–04	.457E–04	.503E–04	.527E–04	.549E–04	.572E–04	.595E–04
120	.366E–04	.482E–04	.614E–04	.767E–04	.849E–04	.935E–04	.977E–04	.102E–03	.106E–03	.110E–03
130	.672E–04	.879E–04	.111E–03	.138E–03	.153E–03	.168E–03	.175E–03	.182E–03	.190E–03	.197E–03
140	.120E–03	.155E–03	.195E–03	.241E–03	.266E–03	.292E–03	.304E–03	.316E–03	.329E–03	.341E–03
150	.207E–03	.266E–03	.332E–03	.408E–03	.449E–03	.493E–03	.514E–03	.534E–03	.554E–03	.574E–03
160	.348E–03	.444E–03	.550E–03	.673E–03	.740E–03	.810E–03	.844E–03	.876E–03	.909E–03	.941E–03
170	.572E–03	.723E–03	.889E–03	.108E–02	.119E–02	.130E–02	.135E–02	.140E–02	.145E–02	.150E–02
180	.917E–03	.115E–02	.140E–02	.170E–02	.186E–02	.204E–02	.212E–02	.220E–02	.227E–02	.235E–02
190	.144E–02	.179E–02	.217E–02	.262E–02	.286E–02	.312E–02	.325E–02	.336E–02	.348E–02	.359E–02
200	.221E–02	.273E–02	.329E–02	.395E–02	.431E–02	.470E–02	.488E–02	.505E–02	.522E–02	.538E–02
210	.333E–02	.408E–02	.490E–02	.585E–02	.637E–02	.693E–02	.720E–02	.744E–02	.768E–02	.791E–02
220	.494E–02	.601E–02	.715E–02	.850E–02	.924E–02	.100E–01	.104E–01	.108E–01	.111E–01	.114E–01
230	.719E–02	.869E–02	.103E–01	.122E–01	.132E–01	.143E–01	.149E–01	.153E–01	.158E–01	.162E–01
240	.103E–01	.124E–01	.146E–01	.171E–01	.186E–01	.201E–01	.209E–01	.215E–01	.221E–01	.227E–01
250	.146E–01	.174E–01	.203E–01	.238E–01	.257E–01	.278E–01	.289E–01	.297E–01	.305E–01	.314E–01
260	.203E–01	.240E–01	.279E–01	.326E–01	.352E–01	.380E–01	.394E–01	.405E–01	.416E–01	.427E–01
270	.279E–01	.329E–01	.380E–01	.441E–01	.475E–01	.513E–01	.531E–01	.545E–01	.560E–01	.574E–01
280	.380E–01	.444E–01	.510E–01	.589E–01	.633E–01	.683E–01	.706E–01	.725E–01	.744E–01	.762E–01
290	.510E–01	.592E–01	.676E–01	.778E–01	.835E–01	.900E–01	.930E–01	.954E–01	.978E–01	.100
300	.678E–01	.782E–01	.888E–01	.102	.109	.117	.121	.124	.127	.130
310	.892E–01	.102	.115	.132	.141	.151	.156	.160	.164	.167
320	.116	.132	.149	.169	.180	.193	.199	.204	.209	.213
330	.150	.170	.190	.214	.228	.245	.252	.258	.263	.269
340	.192	.216	.240	.270	.287	.307	.317	.328	.330	.386
350	.243	.272	.301	.337	.358	.383	.394	.402	.410	.417

*Vermeulen, Dong, Robinson, Nguyen, and Gmitro, AIChE meeting, Anaheim, CA, 1982; and private communication from Prof. Theodore Vermeulen, Chemical Engineering Dept., University of California, Berkeley.

TABLE 2-17 Total Pressure, bar, of Aqueous Sulfuric Acid Solutions*

	Weight percent, H_2SO_4									
°C	10.0	20.0	30.0	40.0	50.0	60.0	70.0	75.0	80.0	85.0
0	.582E–02	.534E–02	.448E–02	.326E–02	.193E–02	.836E–03	.207E–03	.747E–04	.197E–04	.343E–05
10	.117E–01	.107E–01	.909E–02	.670E–02	.405E–02	.180E–02	.467E–03	.175E–03	.490E–04	.952E–05
20	.223E–01	.205E–01	.174E–01	.130E–01	.802E–02	.367E–02	.995E–03	.388E–03	.115E–03	.245E–04
30	.404E–01	.373E–01	.319E–01	.241E–01	.151E–01	.710E–02	.201E–02	.811E–03	.253E–03	.589E–04
40	.703E–01	.649E–01	.558E–01	.427E–01	.272E–01	.131E–01	.387E–02	.162E–02	.531E–03	.134E–03
50	.117	.109	.939E–01	.725E–01	.470E–01	.232E–01	.715E–02	.309E–02	.106E–02	.286E–03
60	.189	.175	.152	.119	.782E–01	.395E–01	.127E–01	.565E–02	.204E–02	.584E–03
70	.296	.275	.239	.188	.126	.651E–01	.217E–01	.997E–01	.376E–02	.114E–02
80	.449	.417	.365	.290	.196	.104	.360E–01	.170E–01	.668E–02	.213E–02
90	.664	.617	.542	.434	.298	.161	.578E–01	.281E–01	.115E–01	.383E–02
100	.957	.891	.786	.634	.441	.244	.905E–01	.452E–01	.192E–01	.666E–02
110	1.349	1.258	1.113	.904	.638	.360	.138	.708E–01	.312E–01	.112E–01
120	1.863	1.740	1.544	1.264	.903	.519	.206	.108	.493E–01	.183E–01
130	2.524	2.361	2.101	1.732	1.253	.734	.301	.162	.760E–01	.291E–01
140	3.361	3.149	2.810	2.333	1.708	1.020	.431	.236	.115	.451E–01
150	4.404	4.132	3.697	3.090	2.289	1.392	.605	.339	.170	.683E–01
160	5.685	5.342	4.793	4.031	3.021	1.870	.837	.478	.246	.101
170	7.236	6.810	6.127	5.185	3.930	2.475	1.138	.662	.350	.147
180	9.093	8.571	7.731	6.584	5.045	3.233	1.525	.902	.489	.209
190	11.289	10.658	9.640	8.259	6.397	4.169	2.017	1.212	.673	.292
200	13.861	13.107	11.887	10.245	8.020	5.312	2.633	1.606	.913	.402
210	16.841	15.951	14.505	12.576	9.948	6.696	3.396	2.101	1.221	.544
220	20.264	19.225	17.529	15.287	12.217	8.354	4.331	2.715	1.610	.726
230	24.160	22.960	20.992	18.414	14.864	10.322	5.466	3.468	2.098	.956
240	28.561	27.188	24.927	21.992	17.929	12.641	6.832	4.382	2.701	1.242
250	33.494	31.939	29.364	26.056	21.452	15.351	8.459	5.481	3.439	1.594
260	38.984	37.240	34.334	30.642	25.472	18.496	10.384	6.791	4.332	2.023
270	45.055	43.116	39.865	35.784	30.030	22.122	12.642	8.337	5.402	2.540
280	51.726	49.590	45.984	41.514	35.168	26.275	15.272	10.147	6.673	3.157
290	59.015	56.681	52.715	47.866	40.926	31.004	18.315	12.250	8.170	3.886
300	66.934	64.407	60.081	54.869	47.347	36.361	21.814	14.675	9.916	4.740
310	75.495	72.781	68.101	62.553	54.470	42.398	25.812	17.453	11.939	5.732
320	84.705	81.816	76.792	70.947	62.338	49.168	30.355	20.611	14.264	6.876
330	94.567	91.518	86.172	80.078	70.990	56.727	35.489	24.182	16.916	8.185
340	105.083	101.894	96.252	89.970	80.466	65.130	41.262	28.193	19.920	9.672
350	116.251	112.947	107.043	100.647	90.806	74.437	47.723	32.674	23.303	11.351

	Weight percent, H_2SO_4									
°C	90.0	92.0	94.0	96.0	97.0	98.0	98.5	99.0	99.5	100.0
0	.518E–06	.243E–06	.109E–06	.416E–07	.235E–07	.117E–07	.768E–08	.479E–08	.313E–08	.323E–08
10	.159E–05	.765E–06	.348E–06	.136E–06	.774E–07	.391E–07	.261E–07	.166E–07	.113E–07	.124E–07
20	.449E–05	.221E–05	.102E–05	.407E–06	.235E–06	.121E–06	.812E–07	.528E–07	.373E–07	.435E–07
30	.117E–04	.590E–05	.279E–05	.113E–05	.659E–06	.344E–06	.234E–06	.155E–06	.114E–06	.141E–06
40	.385E–04	.147E–04	.708E–05	.293E–05	.173E–05	.914E–06	.630E–06	.425E–06	.323E–06	.425E–06
50	.653E–04	.344E–04	.169E–04	.712E–05	.425E–05	.228E–05	.159E–05	.109E–05	.861E–06	.120E–05
60	.141E–03	.759E–04	.380E–04	.164E–04	.987E–05	.538E–05	.379E–05	.264E–05	.216E–05	.319E–05
70	.291E–03	.159E–03	.813E–04	.357E–04	.218E–04	.120E–04	.856E–05	.605E–05	.514E–05	.804E–05
80	.571E–03	.319E–03	.166E–03	.742E–04	.458E–04	.257E–04	.184E–04	.132E–04	.117E–04	.193E–04
90	.107E–02	.612E–03	.324E–03	.148E–03	.921E–04	.524E–04	.390E–04	.277E–04	.253E–04	.441E–04
100	.195E–02	.113E–02	.607E–03	.283E–03	.178E–03	.103E–03	.751E–04	.555E–04	.527E–04	.966E–04
110	.340E–02	.201E–02	.110E–02	.521E–03	.332E–03	.194E–03	.143E–03	.107E–03	.106E–03	.204E–03
120	.575E–02	.346E–02	.192E–02	.929E–03	.598E–03	.354E–03	.263E–03	.201E–03	.206E–03	.414E–03
130	.944E–02	.578E–02	.327E–02	.161E–02	.104E–02	.626E–03	.470E–03	.363E–03	.387E–03	.314E–03
140	.151E–01	.939E–02	.539E–02	.270E–02	.177E–02	.107E–02	.815E–03	.639E–03	.708E–03	.155E–02
150	.235E–01	.149E–01	.866E–02	.441E–02	.293E–02	.180E–02	.137E–02	.109E–02	.126E–02	.287E–02
160	.357E–01	.230E–01	.136E–01	.703E–02	.471E–02	.293E–02	.226E–02	.183E–02	.219E–02	.516E–02
170	.532E–01	.347E–01	.208E–01	.110E–01	.741E–02	.466E–02	.363E–02	.299E–02	.372E–02	.905E–02
180	.775E–01	.514E–01	.312E–01	.167E–01	.114E–01	.726E–02	.571E–02	.478E–02	.619E–02	.155E–01
190	.111	.747E–01	.460E–01	.250E–01	.172E–01	.111E–01	.880E–02	.749E–02	.101E–01	.260E–01
200	.156	.107	.665E–01	.367E–01	.255E–01	.166E–01	.133E–01	.115E–01	.161E–01	.427E–01
210	.216	.150	.944E–01	.530E–01	.371E–01	.245E–01	.198E–01	.175E–01	.253E–01	.687E–01
220	.295	.207	.132	.752E–01	.531E–01	.354E–01	.289E–01	.260E–01	.392E–01	.109
230	.396	.282	.182	.105	.749E–01	.505E–01	.417E–01	.382E–01	.596E–01	.169
240	.525	.379	.247	.145	.104	.710E–01	.592E–01	.553E–01	.895E–01	.258
250	.688	.503	.331	.197	.143	.985E–01	.830E–01	.790E–01	.132	.389
260	.881	.660	.439	.264	.193	.135	.115	.112	.193	.577
270	1.141	.856	.575	.351	.258	.153	.157	.156	.279	.846
280	1.447	1.099	.744	.460	.341	.245	.213	.215	.398	1.225
290	1.817	1.398	.954	.597	.446	.324	.285	.295	.562	1.751
300	2.261	1.761	1.211	.767	.578	.425	.379	.399	.785	2.476
310	2.791	2.199	1.524	.977	.742	.553	.498	.536	1.085	3.465
320	3.417	2.723	1.901	1.234	.944	.713	.649	.714	1.486	4.800
330	4.153	3.347	2.353	1.545	1.191	.911	.840	.944	2.018	6.586
340	5.011	4.084	2.889	1.919	1.491	1.156	1.078	1.239	2.718	8.957
350	6.006	4.949	3.523	2.366	1.852	1.456	1.374	1.614	3.631	12.079

*Vermeulen, Dong, Robinson, Nguyen, and Gmitro, AIChE meeting, Anaheim, Calif., 1982; and private communication from Prof. Theodore Vermeulen, Chemical Engineering Dept., University of California, Berkeley.

TABLE 2-18 Partial Pressures of HNO_3 and H_2O over Aqueous Solutions of HNO_3*

mmHg

Percentages are weight % HNO_3 in solution.

	20%		25%		30%		35%		40%		45%		50%	
°C	HNO_3	H_2O	HNO_3	H_2O	HNO_3	H_2O	HNO_3	H_2O	HNO_3	H_2O	HNO_3	H_2O	HNO_3	H_2O
0		4.1		3.8		3.6		3.3		3.0		2.6		2.1
5		5.7		5.4		5.0		4.6		4.2		3.6		3.0
10		8.0		7.6		7.1		6.5		5.8		5.0	0.12	4.2
15		10.9		10.3		9.7		8.9		8.0	0.10	6.9	.18	5.8
20		15.2		14.2		13.2		12.0		10.8	.15	9.4	.27	7.9
25		20.6		19.2		17.8		16.2	0.12	14.6	.23	12.7	.39	10.7
30		27.6		25.7		23.8	0.09	21.7	.17	19.5	.33	16.9	.56	14.4
35		36.5		33.8		31.1	.13	28.3	.25	25.5	.48	22.3	.80	19.0
40		47.5		44	0.11	41	.20	37.7	.36	33.5	.68	29.3	1.13	25.0
45		62	0.09	57.5	.17	53	.28	48	.52	43	.96	38.0	1.57	32.5
50		80	.13	75	.25	69	.42	63	.75	56	1.35	49.5	2.18	42.5
55	0.09	100	.18	94	.35	87	.59	79	1.04	71	1.83	62.5	2.95	54
60	.13	128	.28	121	.51	113	.85	102	1.48	90	2.54	80	4.05	70
65	.19	162	.40	151	.71	140	1.18	127	2.05	114	3.47	100	5.46	88
70	.27	200	.54	187	1.00	174	1.63	159	2.80	143	4.65	126	7.25	110
75	.38	250	.77	234	1.38	217	2.26	198	3.80	178	6.20	158	9.6	138
80	.53	307	1.05	287	1.87	267	3.07	243	5.10	218	8.15	195	12.5	170
85	.74	378	1.44	352	2.53	325	4.15	297	6.83	268	10.7	240	16.3	211
90	1.01	458	1.95	426	3.38	393	5.50	359	9.0	325	13.7	292	20.9	258
95	1.37	555	2.62	517	4.53	478	7.32	436	11.7	394	17.8	355	26.8	315
100	1.87	675	3.50	628	6.05	580	9.7	530	15.5	480	23.0	430	34.2	383
105	2.50	800	4.65	745	7.90	690	12.7	631	20.0	573	29.2	520	43.0	463
110							16.5	755	25.7	688	37.0	625	54.5	560
115									32.5	810	46	740	67	665
120													84	785

	55%		60%		65%		70%		80%		90%		100%
°C	HNO_3	H_2O	HNO_3	H_2O	HNO_3	H_2O	HNO_3	H_2O	HNO_3	H_2O	HNO_3	H_2O	HNO_3
0		1.8	0.19	1.5	0.41	1.3	0.79	1.1	2		5.5		11
5	0.14	2.5	.28	2.1	.60	1.8	1.12	1.6	3		8		15
10	.21	3.5	.41	3.0	.86	2.6	1.58	2.2	4	1.2	11		22
15	.31	4.9	.59	4.1	1.21	3.5	2.18	3.0	6	1.7	15		30
20	.45	6.7	.84	5.6	1.68	4.9	3.00	4.1	8	2.4	20		42
25	.66	9.1	1.21	7.7	2.32	6.6	4.10	5.5	10.5	3.2	27	1	57
30	.93	12.2	1.66	10.3	3.17	8.8	5.50	7.4	14	4	36	1.3	77
35	1.30	16.1	2.28	13.6	4.26	11.6	7.30	9.8	18.5	5.5	47	1.8	102
40	1.82	21.3	3.10	18.1	5.70	15.5	9.65	12.8	24.5	7	62	2.4	133
45	2.50	28.0	4.20	23.7	7.55	20.0	12.6	16.7	32	9.5	80	3	170
50	3.41	36.3	5.68	31	10.0	26.0	16.5	21.8	41	12	103	4	215
55	4.54	46	7.45	39	12.8	33.0	21.0	27.3	52	15	127	5	262
60	6.15	60	9.9	51	16.8	43.0	27.1	35.3	67	20	157	6.5	320
65	8.18	76	13.0	64	21.7	54.5	34.5	44.5	85	25	192	8	385
70	10.7	95	16.8	81	27.5	68	43.3	56	106	31	232	10	460
75	13.9	120	21.8	102	35.0	86	54.5	70	130	38	282	13	540
80	18.0	148	27.5	126	43.5	106	67.5	86	158	48	338	16	625
85	23.0	182	34.8	156	54.5	131	83	107	192	60	405	20	720
90	29.4	223	43.7	192	67.5	160	103	130	230	73	480	24	820
95	37.3	272	55.0	233	83.5	195	125	158	278	89	570	29	
100	47	331	69.5	285	103	238	152	192	330	108	675	35	
105	58.5	400	84.5	345	124	288	183	231	392	129	790	42	
110	73	485	103	417	152	345	221	278	465	155			
115	90	575	126	495	181	410	262	330	545	185			
120	110	685	156	590	218	490	312	393	640	219			
125			187	700	260	580	372	469					

**International Critical Tables*, vol. 3, pp. 304–305.

TABLE 2-19 Partial Pressures of H_2O and HBr over Aqueous Solutions of HBr at 20 to 55°C*

mmHg

% HBr	20 °C		25 °C		50 °C		55 °C	
	HBr	H_2O	HBr	H_2O	HBr	H_2O	HBr	H_2O
32			0.0016					
34			0.0022					
36			0.0033					
38			0.0061					
40			0.011					
42			0.023					
44			0.048					
46			0.10					
48	0.09	6.2	0.13	8.2	1.3	30.2	2.0	38
50	0.23	4.5	0.37	6.1	3.2	24.3	4.6	31
52	0.71	3.3	1.1	4.5	7.2	19.3	10.2	25
54	2.2	2.4	3.2	3.3	17	16.0	23.0	21
56	6.8	1.7	9.3	2.4	40	13.3	51	18
58	21	1.3	27	1.9	91	10.4	115	14
60							260	11.4

**International Critical Tables,* vol. 3, p. 306.

TABLE 2-20 Partial Pressures of HI over Aqueous Solutions of HI at 25°C*

mmHg

%HI	44	46	48	50	52	54	56
p_{HI}	0.00064	0.0010	0.0022	0.0050	0.013	0.035	0.10

**International Critical Tables,* vol. 3, p. 306.

TABLE 2-21 Vapor Pressures of the System: Water-Sulfuric Acid-Nitric Acid

For these data reference must be made to the graphs of *International Critical Tables,* vol. 3, pp. 306–308.

TABLE 2-22 Total Vapor Pressures of Aqueous Solutions of CH_3COOH*

Percentages of weight % acetic acid in the solution

mmHg

°C	25%	50%	75%
20	16.3	15.7	15.3
25	22.1	21.4	20.8
30	29.6	28.8	27.8
35	39.4	38.3	36.6
40	51.7	50.2	48.1
45	67.0	65.0	62.0
50	87.2	85.0	80.1
55	110	107	102
60	141	138	130
65	178	172	162
70	223	216	203
75	277	269	251
80	342	331	310
85	419	407	376
90	510	497	458
95	618	602	550
100	743	725	666

**International Critical Tables,* vol. 3, p. 306.

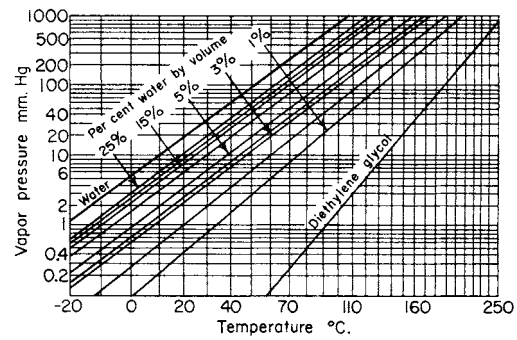

FIG. 2-3 Vapor pressure of aqueous diethylene glycol solutions. (*Courtesy of Carbide and Carbon Chemicals Corp.*)

TABLE 2-23 Partial Pressure of H_2O over Aqueous Solutions of NH_3 (psia)

	Liquid mole percent NH_3 (liquid weight percent NH_3)																			
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
t, °F	(0)	(4.74)	(9.5)	(14.29)	(19.1)	(23.94)	(28.81)	(33.71)	(38.64)	(43.59)	(48.57)	(53.58)	(58.62)	(63.69)	(68.79)	(73.91)	(79.07)	(84.26)	(89.47)	(94.72)
32	0.089	0.083	0.077	0.071	0.063	0.055	0.047	0.039	0.031	0.025	0.019	0.014	0.011	0.008	0.006	0.004	0.003	0.002	0.002	0.001
40	0.122	0.115	0.106	0.097	0.087	0.077	0.065	0.054	0.044	0.035	0.027	0.021	0.016	0.012	0.009	0.007	0.005	0.004	0.002	0.001
50	0.178	0.168	0.156	0.143	0.129	0.113	0.097	0.081	0.066	0.053	0.041	0.032	0.025	0.019	0.014	0.011	0.008	0.006	0.004	0.002
60	0.256	0.242	0.225	0.207	0.186	0.164	0.142	0.119	0.098	0.079	0.062	0.049	0.038	0.030	0.023	0.018	0.014	0.010	0.007	0.004
70	0.363	0.343	0.320	0.294	0.266	0.235	0.204	0.172	0.143	0.116	0.093	0.073	0.058	0.045	0.036	0.028	0.022	0.016	0.011	0.006
80	0.507	0.479	0.448	0.413	0.374	0.332	0.289	0.245	0.205	0.168	0.136	0.109	0.087	0.069	0.055	0.043	0.034	0.025	0.018	0.010
90	0.699	0.661	0.618	0.571	0.518	0.462	0.403	0.345	0.290	0.240	0.196	0.159	0.128	0.103	0.083	0.066	0.052	0.040	0.028	0.015
100	0.951	0.899	0.843	0.780	0.710	0.634	0.556	0.479	0.405	0.338	0.279	0.228	0.186	0.152	0.123	0.100	0.079	0.061	0.043	0.024
110	1.277	1.209	1.135	1.052	0.960	0.861	0.758	0.656	0.559	0.470	0.392	0.324	0.268	0.220	0.181	0.148	0.119	0.092	0.065	0.036
120	1.695	1.607	1.510	1.402	1.283	1.154	1.021	0.889	0.763	0.647	0.544	0.455	0.380	0.316	0.263	0.217	0.176	0.137	0.099	0.056
130	2.226	2.112	1.988	1.850	1.696	1.532	1.361	1.192	1.030	0.881	0.747	0.632	0.532	0.448	0.376	0.313	0.257	0.202	0.147	0.083
140	2.893	2.748	2.591	2.415	2.221	2.012	1.796	1.582	1.376	1.186	1.016	0.867	0.738	0.628	0.532	0.448	0.371	0.295	0.216	0.124
150	3.723	3.540	3.343	3.122	2.879	2.618	2.347	2.078	1.821	1.582	1.367	1.177	1.013	0.870	0.746	0.634	0.529	0.425	0.314	0.183
160	4.747	4.519	4.273	4.000	3.698	3.374	3.039	2.706	2.387	2.090	1.821	1.584	1.376	1.194	1.033	0.887	0.748	0.607	0.453	0.267
170	6.000	5.717	5.416	5.079	4.709	4.312	3.902	3.493	3.101	2.736	2.405	2.110	1.851	1.622	1.418	1.229	1.047	0.858	0.647	0.386
180	7.520	7.174	6.807	6.397	5.947	5.465	4.968	4.472	3.995	3.551	3.148	2.787	2.468	2.184	1.928	1.688	1.451	1.201	0.917	0.555
190	9.350	8.931	8.488	7.994	7.452	6.873	6.275	5.680	5.107	4.573	4.086	3.650	3.262	2.914	2.598	2.297	1.994	1.669	1.290	0.793
200	11.538	11.035	10.504	9.916	9.270	8.580	7.869	7.160	6.479	5.842	5.262	4.740	4.275	3.856	3.470	3.098	2.718	2.300	1.802	1.129
210	14.136	13.538	12.910	12.213	11.449	10.635	9.796	8.962	8.160	7.410	6.725	6.110	5.559	5.061	4.598	4.146	3.675	3.147	2.502	1.600
220	17.201	16.496	15.758	14.941	14.047	13.095	12.115	11.141	10.205	9.331	8.534	7.817	7.175	6.592	6.045	5.504	4.932	4.277	3.455	2.262
230	20.796	19.971	19.111	18.162	17.124	16.020	14.886	13.760	12.679	11.672	10.754	9.930	9.192	8.522	7.889	7.255	6.573	5.777	4.751	3.196
240	24.986	24.029	23.037	21.943	20.748	19.479	18.179	16.889	15.654	14.506	13.463	12.530	11.696	10.938	10.221	9.496	8.703	7.759	6.508	4.520
250	29.844	28.744	27.607	26.358	24.996	23.549	22.070	20.608	19.212	17.917	16.748	15.708	14.783	13.946	13.153	12.346	11.452	10.369	8.891	6.413

The values in Tables 2-23 to 2-26 were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002). The primary source for the properties of aqueous ammonia mixtures is R. Tillner-Roth and D. G. Friend, "A Helmholtz Free Energy Formulation of the Thermodynamic Properties of the Mixture {Water + Ammonia}," *J. Phys. Chem. Ref. Data* **27:**63–96 (1998).

TABLE 2-24 Mole Percentages of H_2O over Aqueous Solutions of NH_3

	Liquid mole percent NH_3 (liquid weight percent NH_3)																			
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
t, °F	(0)	(4.74)	(9.5)	(14.29)	(19.1)	(23.94)	(28.81)	(33.71)	(38.64)	(43.59)	(48.57)	(53.58)	(58.62)	(63.69)	(68.79)	(73.91)	(79.07)	(84.26)	(89.47)	(94.72)
32	100	32.046	14.173	7.263	3.959	2.202	1.226	0.679	0.375	0.207	0.116	0.067	0.039	0.024	0.015	0.010	0.007	0.005	0.003	0.001
40	100	33.233	15.064	7.842	4.321	2.427	1.365	0.765	0.428	0.240	0.137	0.080	0.048	0.030	0.019	0.013	0.009	0.006	0.004	0.002
50	100	34.709	16.192	8.588	4.797	2.727	1.554	0.883	0.502	0.287	0.167	0.100	0.061	0.039	0.026	0.017	0.012	0.008	0.005	0.003
60	100	36.172	17.334	9.359	5.299	3.050	1.760	1.015	0.587	0.342	0.203	0.123	0.077	0.050	0.034	0.023	0.016	0.011	0.007	0.004
70	100	37.619	18.489	10.154	5.828	3.396	1.985	1.162	0.683	0.405	0.245	0.152	0.097	0.064	0.044	0.030	0.021	0.015	0.010	0.005
80	100	39.047	19.653	10.974	6.382	3.765	2.231	1.325	0.791	0.478	0.294	0.186	0.121	0.081	0.056	0.040	0.028	0.020	0.013	0.007
90	100	40.455	20.827	11.816	6.963	4.160	2.497	1.505	0.913	0.561	0.351	0.226	0.149	0.102	0.072	0.051	0.037	0.026	0.017	0.009
100	100	41.840	22.007	12.681	7.571	4.580	2.786	1.703	1.049	0.655	0.418	0.273	0.184	0.127	0.091	0.066	0.048	0.034	0.023	0.012
110	100	43.201	23.194	13.567	8.205	5.027	3.098	1.920	1.201	0.763	0.494	0.328	0.224	0.158	0.114	0.084	0.062	0.044	0.030	0.016
120	100	44.537	24.385	14.475	8.867	5.501	3.434	2.158	1.370	0.884	0.582	0.393	0.273	0.195	0.142	0.106	0.079	0.057	0.039	0.021
130	100	45.849	25.580	15.404	9.557	6.002	3.796	2.419	1.558	1.020	0.682	0.467	0.329	0.238	0.177	0.133	0.100	0.073	0.050	0.027
140	100	47.136	26.779	16.353	10.273	6.532	4.184	2.702	1.766	1.173	0.796	0.554	0.396	0.290	0.218	0.166	0.126	0.094	0.064	0.035
150	100	48.398	27.979	17.322	11.017	7.091	4.600	3.010	1.994	1.344	0.925	0.653	0.473	0.352	0.268	0.206	0.158	0.118	0.082	0.045
160	100	49.636	29.182	18.310	11.789	7.680	5.044	3.344	2.246	1.534	1.071	0.767	0.563	0.425	0.327	0.254	0.197	0.149	0.104	0.058
170	100	50.849	30.385	19.317	12.587	8.298	5.517	3.705	2.521	1.746	1.236	0.897	0.668	0.509	0.396	0.312	0.245	0.187	0.132	0.074
180	100	52.038	31.588	20.341	13.413	8.948	6.021	4.094	2.822	1.981	1.421	1.045	0.788	0.609	0.479	0.381	0.302	0.233	0.166	0.094
190	100	53.204	32.792	21.383	14.266	9.628	6.557	4.513	3.151	2.240	1.628	1.212	0.926	0.724	0.576	0.463	0.371	0.288	0.209	0.120
200	100	54.347	33.994	22.442	15.146	10.340	7.124	4.963	3.508	2.526	1.859	1.402	1.083	0.857	0.690	0.561	0.453	0.357	0.261	0.153
210	100	55.468	35.196	23.517	16.052	11.083	7.725	5.445	3.896	2.840	2.116	1.615	1.263	1.011	0.823	0.676	0.552	0.439	0.326	0.195
220	100	56.567	36.395	24.607	16.985	11.858	8.359	5.961	4.316	3.184	2.401	1.854	1.468	1.187	0.977	0.811	0.669	0.539	0.406	0.248
230	100	57.645	37.592	25.711	17.943	12.665	9.028	6.512	4.769	3.560	2.716	2.122	1.699	1.390	1.156	0.969	0.809	0.660	0.506	0.317
240	100	58.702	38.787	26.830	18.927	13.503	9.732	7.098	5.258	3.970	3.064	2.421	1.960	1.621	1.363	1.155	0.975	0.806	0.629	0.406
250	100	59.740	39.978	27.962	19.936	14.374	10.471	7.722	5.784	4.416	3.447	2.754	2.254	1.884	1.601	1.371	1.171	0.982	0.783	0.524

The values in Tables 2-23 to 2-26 were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002). The primary source for the properties of aqueous ammonia mixtures is R. Tillner-Roth and D. G. Friend, "A Helmholtz Free Energy Formulation of the Thermodynamic Properties of the Mixture {Water + Ammonia}," *J. Phys. Chem. Ref. Data* **27:**63–96 (1998).

TABLE 2-25 Partial Pressures of NH_3 over Aqueous Solutions of NH_3 (psia)

	Liquid mole percent NH_3 (liquid weight percent NH_3)																				
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
t, °F	(0)	(4.74)	(9.5)	(14.29)	(19.1)	(23.94)	(28.81)	(33.71)	(38.64)	(43.59)	(48.57)	(53.58)	(58.62)	(63.69)	(68.79)	(73.91)	(79.07)	(84.26)	(89.47)	(94.72)	(100)
32	0	0.177	0.468	0.901	1.533	2.456	3.797	5.710	8.358	11.868	16.279	21.480	27.206	33.087	38.745	43.900	48.431	52.368	55.846	59.055	62.277
40	0	0.230	0.600	1.143	1.932	3.078	4.730	7.066	10.267	14.467	19.691	25.798	32.478	39.307	45.860	51.828	57.082	61.665	65.731	69.506	73.322
50	0	0.316	0.808	1.522	2.552	4.036	6.154	9.117	13.129	18.328	24.721	32.120	40.150	48.315	56.128	63.243	69.520	75.020	79.931	84.523	89.205
60	0	0.426	1.074	2.002	3.330	5.228	7.912	11.625	16.593	22.959	30.702	39.581	49.149	58.831	68.074	76.489	83.933	90.486	96.376	101.93	107.63
70	0	0.568	1.410	2.603	4.296	6.696	10.056	14.656	20.742	28.456	37.744	48.307	59.615	71.008	81.861	91.745	100.51	108.26	115.29	121.94	128.85
80	0	0.748	1.831	3.348	5.483	8.483	12.645	18.283	25.664	34.922	45.966	58.428	71.689	84.998	97.654	109.19	119.45	128.56	136.88	144.83	153.13
90	0	0.973	2.351	4.261	6.926	10.639	15.741	22.582	31.447	42.460	55.485	70.073	85.514	100.96	115.62	128.99	140.93	151.60	161.39	170.82	180.76
100	0	1.250	2.987	5.368	8.663	13.213	19.406	27.630	38.185	51.177	66.416	83.375	101.23	119.04	135.93	151.34	165.15	177.57	189.05	200.19	212.01
110	0	1.590	3.758	6.700	10.735	16.258	23.709	33.509	45.971	61.177	78.881	98.461	118.98	139.39	158.73	176.40	192.30	206.69	220.07	233.16	247.19
120	0	2.001	4.683	8.285	13.184	19.832	28.718	40.300	54.899	72.569	92.996	115.45	138.90	162.15	184.19	204.35	222.57	239.16	254.71	270.03	286.60
130	0	2.494	5.784	10.158	16.055	23.989	34.503	48.086	65.064	85.455	108.87	134.49	161.13	187.48	212.44	235.36	256.14	275.20	293.18	311.05	330.54
140	0	3.082	7.084	12.352	19.395	28.791	41.135	56.949	76.558	99.944	126.62	155.67	185.77	215.50	243.66	269.56	293.19	314.99	335.72	356.48	379.36
150	0	3.774	8.604	14.902	23.250	34.295	48.685	66.972	89.472	116.12	146.35	179.11	212.96	246.33	277.95	307.13	333.87	358.75	382.56	406.60	433.38
160	0	4.585	10.371	17.844	27.669	40.562	57.222	78.230	103.89	134.09	168.16	204.93	242.79	280.08	315.46	348.18	378.36	406.62	433.89	461.65	492.95
170	0	5.527	12.408	21.216	32.700	47.649	66.816	90.803	119.90	153.93	192.14	233.19	275.37	316.87	356.26	392.85	426.79	458.82	489.95	521.92	558.45
180	0	6.612	14.741	25.053	38.390	55.614	77.532	104.77	137.57	175.73	218.35	263.99	310.76	356.75	400.47	441.24	479.30	515.48	550.92	587.67	630.24
190	0	7.856	17.395	29.393	44.786	64.514	89.432	120.18	156.99	199.56	246.89	297.40	349.06	399.82	448.16	493.43	535.98	576.75	616.99	659.12	708.74
200	0	9.270	20.397	34.270	51.933	74.401	102.58	137.11	178.21	225.47	277.81	333.47	390.30	446.12	499.38	549.49	596.94	642.74	688.31	736.52	794.38
210	0	10.869	23.769	39.721	59.876	85.326	117.02	155.62	201.28	253.53	311.15	372.25	434.50	495.68	554.15	609.47	662.22	713.55	765.01	820.08	887.64
220	0	12.666	27.538	45.779	68.655	97.335	132.82	175.75	226.25	283.77	346.95	413.74	481.70	548.49	612.50	673.37	731.88	789.23	847.19	909.98	989.03
230	0	14.673	31.727	52.477	78.310	110.47	150.00	197.54	253.17	316.23	385.23	457.98	531.89	604.55	674.39	741.21	805.90	869.79	934.86	1006.3	1099.1
240	0	16.905	36.356	59.843	88.872	124.78	168.62	221.04	282.06	350.91	425.98	504.92	585.01	663.80	739.77	812.89	884.22	955.18	1028.0	1109.2	1218.7
250	0	19.371	41.449	67.906	100.38	140.28	188.70	246.26	312.93	387.82	469.20	554.55	641.05	726.18	808.55	888.35	966.78	1045.3	1126.5	1218.3	1348.5

The values in Tables 2-23 to 2-26 were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002). The primary source for the properties of aqueous ammonia mixtures is R. Tillner-Roth and D. G. Friend, "A Helmholtz Free Energy Formulation of the Thermodynamic Properties of the Mixture {Water + Ammonia}," *J. Phys. Chem. Ref. Data* **27:**63–96 (1998).

TABLE 2-26 Total Vapor Pressures of Aqueous Solutions of NH_3 (psia)

	Liquid mole percent NH_3 (liquid weight percent NH_3)																				
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
t, °F	(0)	(4.74)	(9.5)	(14.29)	(19.1)	(23.94)	(28.81)	(33.71)	(38.64)	(43.59)	(48.57)	(53.58)	(58.62)	(63.69)	(68.79)	(73.91)	(79.07)	(84.26)	(89.47)	(94.72)	(100)
32	0.089	0.260	0.545	0.971	1.596	2.512	3.844	5.749	8.389	11.893	16.298	21.494	27.217	33.095	38.751	43.904	48.434	52.371	55.848	59.056	62.277
40	0.122	0.345	0.706	1.240	2.020	3.155	4.795	7.120	10.311	14.502	19.718	25.819	32.494	39.319	45.869	51.835	57.087	61.669	65.734	69.507	73.322
50	0.178	0.483	0.964	1.665	2.680	4.149	6.251	9.198	13.195	18.381	24.762	32.152	40.175	48.334	56.143	63.254	69.528	75.026	79.935	84.526	89.205
60	0.256	0.668	1.299	2.209	3.516	5.392	8.053	11.744	16.691	23.038	30.764	39.630	49.187	58.860	68.097	76.507	83.946	90.496	96.383	101.93	107.63
70	0.363	0.911	1.730	2.898	4.562	6.931	10.260	14.828	20.885	28.572	37.837	48.381	59.673	71.053	81.897	91.773	100.53	108.28	115.30	121.95	128.85
80	0.507	1.227	2.279	3.761	5.857	8.815	12.934	18.528	25.869	35.090	46.102	58.537	71.776	85.067	97.709	109.23	119.48	128.59	136.90	144.84	153.13
90	0.699	1.633	2.969	4.832	7.445	11.101	16.144	22.927	31.737	42.700	55.680	70.232	85.642	101.06	115.70	129.06	140.98	151.64	161.42	170.84	180.76
100	0.951	2.149	3.830	6.148	9.373	13.847	19.962	28.109	38.590	51.514	66.695	83.603	101.42	119.19	136.05	151.44	165.23	177.63	189.09	200.21	212.01
110	1.277	2.799	4.893	7.751	11.694	17.119	24.467	34.165	46.530	61.647	79.273	98.785	119.25	139.61	158.91	176.55	192.42	206.78	220.14	233.20	247.19
120	1.695	3.608	6.194	9.688	14.467	20.986	29.739	41.189	55.662	73.216	93.540	115.91	139.28	162.47	184.45	204.57	222.75	239.30	254.81	270.09	286.60
130	2.226	4.607	7.773	12.008	17.752	25.521	35.864	49.278	66.094	86.336	109.62	135.12	161.66	187.93	212.82	235.67	256.40	275.40	293.33	311.13	330.54
140	2.893	5.830	9.674	14.767	21.616	30.803	42.931	58.531	77.934	101.13	127.64	156.54	186.51	216.13	244.19	270.01	293.56	315.29	335.94	356.60	379.36
150	3.723	7.315	11.947	18.024	26.129	36.913	51.032	69.050	91.292	117.70	147.72	180.29	213.97	247.20	278.70	307.76	334.40	359.17	382.87	406.78	433.38
160	4.747	9.104	14.644	21.844	31.367	43.936	60.262	80.937	106.28	136.18	169.98	206.51	244.16	281.28	316.49	349.07	379.11	407.23	434.34	461.92	492.95
170	6.000	11.244	17.824	26.295	37.409	51.961	70.718	94.297	123.00	156.67	194.54	235.30	277.22	318.49	357.68	394.08	427.84	459.68	490.60	522.31	558.45
180	7.520	13.786	21.548	31.450	44.337	61.079	82.499	109.24	141.57	179.28	221.50	266.78	313.23	358.94	402.40	442.93	480.75	516.68	551.84	588.22	630.24
190	9.350	16.787	25.883	37.387	52.238	71.387	95.708	125.86	162.10	204.13	250.98	301.05	352.32	402.74	450.76	495.73	537.98	578.42	618.28	659.91	708.74
200	11.538	20.305	30.901	44.186	61.203	82.981	110.45	144.27	184.69	231.31	283.07	338.21	394.57	449.98	502.85	552.59	599.66	645.04	690.11	737.65	794.38
210	14.136	24.407	36.679	51.934	71.325	95.961	126.82	164.58	209.44	260.94	317.88	378.36	440.06	500.74	558.75	613.62	665.90	716.70	767.51	821.68	887.64
220	17.201	29.162	43.296	60.720	82.702	110.43	144.93	186.89	236.46	293.10	355.49	421.56	488.88	555.08	618.54	678.88	736.81	793.51	850.64	912.24	989.03
230	20.796	34.644	50.838	70.639	95.434	126.49	164.89	211.30	265.85	327.90	395.98	467.91	541.08	613.07	682.28	748.46	812.47	875.57	939.61	1009.5	1099.1
240	24.986	40.934	59.393	81.786	109.62	144.26	186.80	237.93	297.71	365.42	439.44	517.45	596.71	674.74	749.99	822.39	892.93	962.94	1034.5	1113.7	1218.7
250	29.844	48.115	69.056	94.264	125.38	163.83	210.77	266.87	332.14	405.74	485.95	570.25	655.83	740.12	821.71	900.70	978.24	1055.7	1135.4	1224.7	1348.5

The values in Tables 2-23 to 2-26 were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002). The primary source for the properties of aqueous ammonia mixtures is R. Tillner-Roth and D. G. Friend, "A Helmholtz Free Energy Formulation of the Thermodynamic Properties of the Mixture {Water + Ammonia}," *J. Phys. Chem. Ref. Data* **27:**63–96 (1998).

TABLE 2-27 Partial Pressures of H_2O over Aqueous Solutions of Sodium Carbonate*

mmHg

	%Na_2CO_3						
t, °C	0	5	10	15	20	25	30
0	4.5	4.5					
10	9.2	9.0	8.8				
20	17.5	17.2	16.8	16.3			
30	31.8	31.2	30.4	29.6	28.8	27.8	26.4
40	55.3	54.2	53.0	57.6	50.2	48.4	46.1
50	92.5	90.7	88.7	86.5	84.1	81.2	77.5
60	149.5	146.5	143.5	139.9	136.1	131.6	125.7
70	239.8	235	230.5	225	219	211.5	202.5
80	355.5	348	342	334	325	315	301
90	526.0	516	506	494	482	467	447
100	760.0	746	731	715	697	676	648

**International Critical Tables*, vol. 3, p. 372.

TABLE 2-28 Partial Pressures of H_2O and CH_3OH over Aqueous Solutions of Methyl Alcohol*

Mole fraction CH_3OH	39.9 °C		Mole fraction CH_3OH	59.4 °C	
	P_{H_2O}, mmHg	P_{CH_3OH}, mmHg		P_{H_2O}, mmHg	P_{CH_3OH}, mmHg
0	54.7	0	0	145.4	0
14.99	39.2	66.1	22.17	106.9	210.1
17.85	38.5	75.5	27.40	102.2	240.2
21.07	37.2	85.2	33.24	96.6	272.1
27.31	35.8	100.6	39.80	91.7	301.9
31.06	34.9	108.8	47.08	84.8	335.6
40.1	32.8	127.7	55.5	76.9	373.7
47.0	31.5	141.6	69.2	57.8	439.4
55.8	27.3	158.4	78.5	43.8	486.6
68.9	20.7	186.6	85.9	30.1	526.9
86.0	10.1	225.2	100.0	0	609.3
100.0	0	260.7			

**International Critical Tables*, vol. 3, p. 290.

TABLE 2-29 Partial Pressures of H_2O over Aqueous Solutions of Sodium Hydroxide*

mmHg

Conc. g NaOH/ 100 g H_2O	Temperature, °C											
	0	20	40	60	80	100	120	160	200	250	300	350
0	4.6	17.5	55.3	149.5	355.5	760.0	1,489	4,633	11,647	29,771	64,200	123,600
5	4.4	16.9	53.2	143.5	341.5	730.0	1,430	4,450	11,200	28,600	61,800	118,900
10	4.2	16.0	50.6	137.0	325.5	697.0	1,365	4,260	10,750	27,500	59,300	114,100
20	3.6	13.9	44.2	120.5	288.5	621.0	1,225	3,860	9,800	25,300	54,700	105,400
30	2.9	11.3	36.6	101.0	246.0	537.0	1,070	3,460	8,950	23,300	50,800	98,000
40	2.2	8.7	28.7	81.0	202.0	450.0	920	3,090	8,150	21,500	47,200	91,600
50		6.3	20.7	62.5	160.5	368.0	770	2,690	7,400	19,900	44,100	85,800
60		4.4	15.5	47.0	124.0	294.0	635	2,340	6,750	18,400	41,200	80,700
70		3.0	10.9	34.5	94.0	231.0	515	2,030	6,100	17,100	38,700	76,000
80		2.0	7.6	24.5	70.5	179.0	415	1,740	5,500	15,800	36,300	71,900
90		1.3	5.2	17.5	53.0	138.0	330	1,490	5,000	14,700	34,200	68,100
100		0.9	3.6	12.5	38.5	105.0	262	1,300	4,500	13,650	32,200	64,600
120			1.7	6.3	20.5	61.0	164	915	3,650	11,800	28,800	58,600
140				3.0	11.0	35.5	102	765	2,980	10,300	25,900	53,400
160				1.5	6.0	20.5	63	470	2,430	8,960	23,300	49,000
180					3.5	12.0	40	340	1,980	7,830	21,200	45,100
200					2.0	7.0	25	245	1,620	6,870	19,200	41,800
250					0.5	2.0	8	110	985	5,000	15,400	35,000
300					0.1	0.5	2.7	50	610	3,690	12,500	29,800
350							0.9	23	380	2,750	10,300	25,700
400								11	240	2,080	8,600	22,400
500									100	1,210	6,100	17,500
700										440	3,300	11,500
1000											1,470	6,800
2000											150	1,760
4000												120
8000												7

**International Critical Tables*, vol. 3, p. 370.

WATER-VAPOR CONTENT OF GASES

CHART FOR GASES AT HIGH PRESSURES

The accompanying figure is useful in determining the water-vapor content of air at high pressure in contact with liquid water.

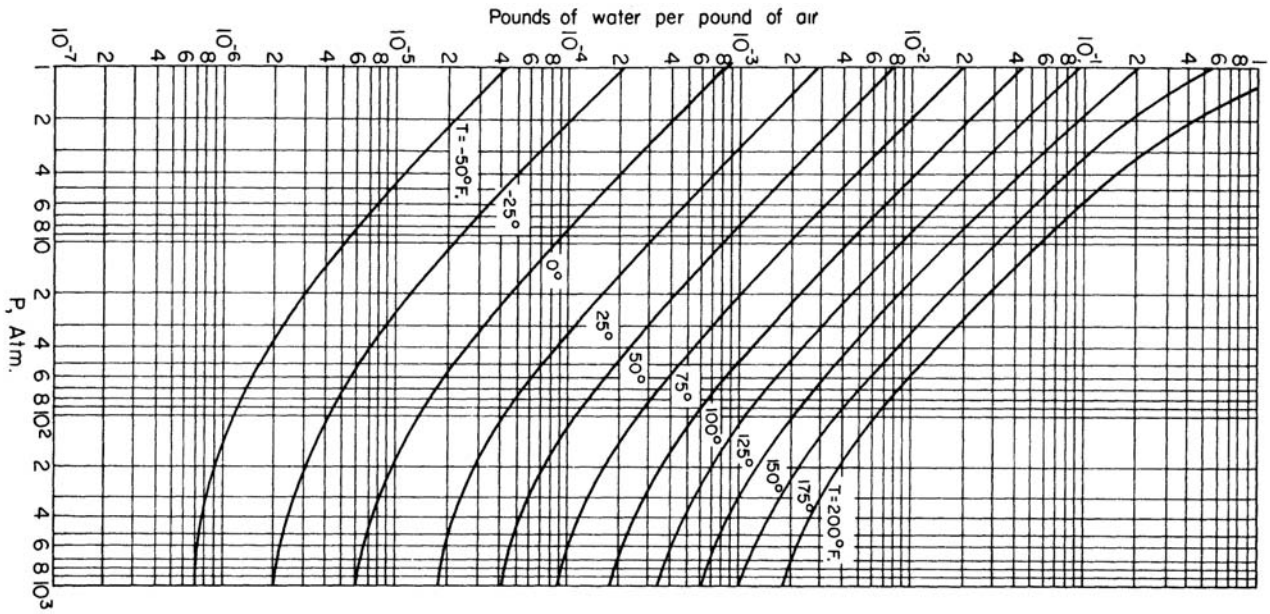

FIG. 2-4 Water content of air, °C = (°F − 32) × 5/9. (*Landsbaum, Dadds, and Stutzman. Reprinted from vol. 47, January 1955 issue of* Ind. Eng. Chem. [*p. 192*]. *Copyright 1955 by the American Chemical Society and reproduced by permission of the copyright owner.*)

DENSITIES OF PURE SUBSTANCES

TABLE 2-30 Density (kg/m³) of Saturated Liquid Water from the Triple Point to the Critical Point

T, K	ρ, kg/m³	T, K	ρ, kg/m³	T, K	ρ, kg/m³	T, K	ρ, kg/m³	T, K	ρ, kg/m³
273.160*	999.793	352	972.479	432	908.571	512	814.982	592	669.930
274	999.843	354	971.235	434	906.617	514	812.164	594	664.974
276	999.914	356	969.972	436	904.645	516	809.318	596	659.907
278	999.919	358	968.689	438	902.656	518	806.441	598	654.722
280	999.862	360	967.386	440	900.649	520	803.535	600	649.411
282	999.746	362	966.064	442	898.624	522	800.597	602	643.97
284	999.575	364	964.723	444	896.580	524	797.629	604	638.38
286	999.352	366	963.363	446	894.519	526	794.628	606	632.64
288	999.079	368	961.984	448	892.439	528	791.594	608	626.74
290	998.758	370	960.587	450	890.341	530	788.527	610	620.65
292	998.392	372	959.171	452	888.225	532	785.425	612	614.37
294	997.983	374	957.737	454	886.089	534	782.288	614	607.88
296	997.532	376	956.285	456	883.935	536	779.115	616	601.15
298	997.042	378	954.815	458	881.761	538	775.905	618	594.16
300	996.513	380	953.327	460	879.569	540	772.657	620	586.88
302	995.948	382	951.822	462	877.357	542	769.369	622	579.26
304	995.346	384	950.298	464	875.125	544	766.042	624	571.25
306	994.711	386	948.758	466	872.873	546	762.674	626	562.81
308	994.042	388	947.199	468	870.601	548	759.263	628	553.84
310	993.342	390	945.624	470	868.310	550	755.808	630	544.25
312	992.610	392	944.030	472	865.997	552	752.308	632	533.92
314	991.848	394	942.420	474	863.664	554	748.762	634	522.71
316	991.056	396	940.793	476	861.310	556	745.169	636	510.42
318	990.235	398	939.148	478	858.934	558	741.525	638	496.82
320	989.387	400	937.486	480	856.537	560	737.831	640	481.53
322	988.512	402	935.807	482	854.118	562	734.084	641	473.01
324	987.610	404	934.111	484	851.678	564	730.283	642	463.67
326	986.682	406	932.398	486	849.214	566	726.425	643	453.14
328	985.728	408	930.668	488	846.728	568	722.508	644	440.73
330	984.750	410	928.921	490	844.219	570	718.530	645	425.05
332	983.747	412	927.157	492	841.686	572	714.489	646	402.96
334	982.721	414	925.375	494	839.130	574	710.382	647	357.34
336	981.671	416	923.577	496	836.549	576	706.206	647.096†	322
338	980.599	418	921.761	498	833.944	578	701.959		
340	979.503	420	919.929	500	831.313	580	697.638		
342	978.386	422	918.079	502	828.658	582	693.238		
344	977.247	424	916.212	504	825.976	584	688.757		
346	976.086	426	914.328	506	823.269	586	684.190		
348	974.904	428	912.426	508	820.534	588	679.533		
350	973.702	430	910.507	510	817.772	590	674.781		

*Triple point
†Critical point

From Wagner, W., and Pruss, A., "The IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use," *J. Phys. Chem. Ref. Data* **31**(2):387–535, 2002.

TABLE 2-31 Density (kg/m³) of Mercury from 0 to 350°C*

	Density, kg/m³									
t, °C	0	1	2	3	4	5	6	7	8	9
0	13595.08	13592.61	13590.14	13587.68	13585.21	13582.75	13580.29	13577.82	13575.36	13572.90
10	13570.44	13567.98	13565.52	13563.06	13560.60	13558.14	13555.69	13553.23	13550.78	13548.32
20	13545.87	13543.41	13540.96	13538.51	13536.06	13533.61	13531.16	13528.71	13526.26	13523.81
30	13521.36	13518.91	13516.47	13514.02	13511.58	13509.13	13506.69	13504.25	13501.80	13499.36
40	13496.92	13494.48	13492.04	13489.60	13487.16	13484.72	13482.29	13479.85	13477.41	13474.98
50	13472.54	13470.11	13467.67	13465.24	13462.81	13460.38	13457.94	13455.51	13453.08	13450.65
60	13448.22	13445.80	13443.37	13440.94	13438.51	13436.09	13433.66	13431.23	13428.81	13426.39
70	13423.96	13421.54	13419.12	13416.69	13414.27	13411.85	13409.43	13407.01	13404.59	13402.17
80	13399.75	13397.34	13394.92	13392.50	13390.08	13387.67	13385.25	13382.84	13380.42	13378.01
90	13375.59	13373.18	13370.77	13368.36	13365.94	13363.53	13361.12	13358.71	13356.30	13353.89
100	13351.5	13349.1	13346.7	13344.3	13341.9	13339.4	13337.0	13334.6	13332.2	13329.8
110	13327.4	13325.0	13322.6	13320.2	13317.8	13315.4	13313.0	13310.6	13308.2	13305.8
120	13303.4	13301.0	13298.6	13296.2	13293.8	13291.4	13288.9	13286.6	13284.2	13281.8
130	13279.4	13277.0	13274.6	13272.2	13269.8	13267.4	13265.0	13262.6	13260.2	13257.8
140	13255.4	13253.0	13250.6	13248.2	13245.8	13243.4	13241.0	13238.7	13236.3	13233.9
150	13231.5	13229.1	13226.7	13224.3	13221.9	13219.5	13217.1	13214.7	13212.4	13210.0
160	13207.6	13205.2	13202.8	13200.4	13198.0	13195.6	13193.2	13190.8	13188.5	13186.1
170	13183.7	13181.3	13178.9	13176.5	13174.1	13171.7	13169.4	13167.0	13164.6	13162.2
180	13159.8	13157.4	13155.0	13152.6	13150.3	13147.9	13145.5	13143.1	13140.7	13138.3
190	13136.0	13133.6	13131.2	13128.3	13126.4	13124.0	13121.7	13119.3	13116.9	13114.5
200	13112.1	13109.7	13107.4	13105.0	13102.6	13100.2	13097.8	13095.4	13093.1	13090.7
210	13088.3	13085.9	13083.5	13081.1	13078.8	13076.4	13074.0	13071.6	13069.2	13066.8
220	13064.5	13062.1	13059.7	13057.3	13054.9	13052.6	13050.2	13047.8	13045.4	13043.0
230	13040.6	13038.3	13035.9	13033.5	13031.1	13028.7	13026.4	13024.0	13021.6	13019.2
240	13016.8	13014.5	13012.1	13009.7	13007.3	13004.9	13002.5	13000.2	12997.8	12995.4
250	12993.0	12990.6	12988.3	12985.9	12983.5	12981.1	12978.7	12976.3	12974.0	12971.6
260	12969.2	12966.8	12964.4	12962.0	12959.7	12957.3	12954.9	12952.5	12950.1	12947.7
270	12945.4	12943.0	12940.6	12938.2	12935.8	12933.4	12931.1	12928.7	12926.3	12923.9
280	12921.5	12919.1	12916.7	12914.4	12912.0	12909.6	12907.2	12904.8	12902.4	12900.0
290	12897.7	12895.3	12892.9	12890.5	12888.1	12885.7	12883.3	12880.9	12878.5	12876.2
300	12873.8	12871.4	12869.0	12866.6	12864.2	12861.8	12859.4	12857.0	12854.6	12852.2
310	12849.9	12847.5	12845.1	12842.7	12840.3	12837.9	12835.5	12833.1	12830.7	12828.3
320	12825.9	12823.5	12821.1	12818.7	12816.3	12813.9	12811.5	12809.1	12806.7	12804.3
330	12801.9	12799.5	12797.1	12794.7	12792.3	12789.9	12787.5	12785.1	12782.7	12780.2
340	12777.8	12775.4	12773.0	12770.6	12768.2	12765.8	12763.4	12761.0	12758.6	12756.1
350	12753.7									

*From "Mercury—Density and Thermal Expansion at Atmospheric Pressure and Temperatures from 0 to 350 °C," *Tables of Standard Handbook Data*, Standartov, Moscow, 1978. The density values obtainable from those cited for the specific volume of the saturated liquid in the "Thermodynamic Properties" subsection show minor differences. No attempt was made to adjust either set.

TABLE 2-32 Densities of Inorganic and Organic Liquids (mol/dm³)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	T_{min}, K	Density at T_{min}	T_{max}, K	Density at T_{max}
1	Acetaldehyde	C_2H_4O	75-07-0	44.053	1.6994	0.26167	466	0.2913	150.15	21.499	466.00	6.4944
2	Acetamide	C_2H_5NO	60-35-5	59.067	1.016	0.21845	761	0.26116	353.33	16.936	761.00	4.6509
3	Acetic acid	$C_2H_4O_2$	64-19-7	60.052	1.4486	0.25892	591.95	0.2529	289.81	17.492	591.95	5.5948
4	Acetic anhydride	$C_4H_6O_3$	108-24-7	102.089	0.86852	0.25187	606	0.31172	200.15	11.643	606.00	3.4483
5	Acetone	C_3H_6O	67-64-1	58.079	1.2332	0.25886	508.2	0.2913	178.45	15.683	508.20	4.7640
6	Acetonitrile	C_2H_3N	75-05-8	41.052	1.3064	0.22597	545.5	0.28678	229.32	20.628	545.50	5.7813
7	Acetylene	C_2H_2	74-86-2	26.037	2.4507	0.27448	308.3	0.28752	192.40	23.692	308.30	8.9285
8	Acrolein	C_3H_4O	107-02-8	56.063	1.3261	0.26124	506	0.2489	185.45	16.822	506.00	5.0762
9	Acrylic acid	$C_3H_4O_2$	79-10-7	72.063	1.2414	0.25822	615	0.30701	286.15	14.693	615.00	4.8075
10	Acrylonitrile	C_3H_3N	107-13-1	53.063	1.0816	0.2293	535	0.28939	189.63	17.265	535.00	4.7170
11	Air	Mixture	132259-10-0	28.960	2.8963	0.26733	132.45	0.27341	59.15	33.279	132.45	10.8340
12	Ammonia	H_3N	7664-41-7	17.031	3.5383	0.25443	405.65	0.2888	195.41	43.141	405.65	13.9070
13	Anisole	C_7H_8O	100-66-3	108.138	0.77488	0.26114	645.6	0.28234	235.65	9.668	645.60	2.9673
14	Argon	Ar	7440-37-1	39.948	3.8469	0.2881	150.86	0.29783	83.78	35.491	150.86	13.3530
15	Benzamide	C_7H_7NO	55-21-0	121.137	0.7371	0.25487	824	0.28571	403.00	8.938	824.00	2.8921
16	Benzene	C_6H_6	71-43-2	78.112	1.0259	0.26666	562.05	0.28394	278.68	11.422	562.05	3.8472
17	Benzenethiol	C_6H_6S	108-98-5	110.177	0.83573	0.26326	689	0.30798	258.27	10.074	689.00	3.1745
18	Benzoic acid	$C_7H_6O_2$	65-85-0	122.121	0.71587	0.24812	751	0.2857	395.45	8.894	751.00	2.8852
19	Benzonitrile	C_7H_5N	100-47-0	103.121	0.8552	0.26785	699.35	0.30523	260.40	10.011	699.35	3.1928
20	Benzophenone	$C_{13}H_{10}O$	119-61-9	182.218	0.43743	0.24833	830	0.27555	321.35	5.950	830.00	1.7615
21	Benzyl alcohol	C_7H_8O	100-51-6	108.138	0.59867	0.22849	720.15	0.23567	257.85	9.905	720.15	2.6201
22	Benzyl ethyl ether	$C_9H_{12}O$	539-30-0	136.191	0.60917	0.26925	662	0.2632	275.65	7.065	662.00	2.2625
23	Benzyl mercaptan	C_7H_8S	100-53-8	124.203	0.70797	0.25982	718	0.32144	243.95	8.862	718.00	2.7248
24	Biphenyl	$C_{12}H_{10}$	92-52-4	154.208	0.52257	0.25833	773	0.27026	342.20	6.425	773.00	2.0229
25	Bromine	Br_2	7726-95-6	159.808	2.1872	0.29527	584.15	0.3295	265.85	20.109	584.15	7.4075
26	Bromobenzene	C_6H_5Br	108-86-1	157.008	0.8226	0.26632	670.15	0.2821	242.43	9.909	670.15	3.0888
27	Bromoethane	C_2H_5Br	74-96-4	108.965	1.1908	0.25595	503.8	0.29152	154.55	15.833	503.80	4.6525
28	Bromomethane	CH_3Br	74-83-9	94.939	1.6762	0.26141	467	0.28402	179.47	20.640	467.00	6.4121
29	1,2-Butadiene	C_4H_6	590-19-2	54.090	1.187	0.26114	452	0.3065	136.95	15.123	452.00	4.5455
30	1,3-Butadiene	C_4H_6	106-99-0	54.090	1.2346	0.27216	425	0.28707	164.25	14.058	425.00	4.5363
31	Butane	C_4H_{10}	106-97-8	58.122	1.0677	0.27188	425.12	0.28688	134.86	12.620	425.12	3.9271
32	1,2-Butanediol	$C_4H_{10}O_2$	584-03-2	90.121	0.81696	0.24755	680	0.24535	220.00	11.734	680.00	3.3002
33	1,3-Butanediol	$C_4H_{10}O_2$	107-88-0	90.121	0.81856	0.24967	676	0.22023	196.15	11.872	676.00	3.2786
34	1-Butanol	$C_4H_{10}O$	71-36-3	74.122	0.98279	0.26830	563.1	0.25488	183.85	12.035	563.10	3.6630
35	2-Butanol	$C_4H_{10}O$	78-92-2	74.122	0.9682	0.26244	535.9	0.26749	158.45	12.471	535.90	3.6892
36	1-Butene	C_4H_8	106-98-9	56.106	1.0877	0.26454	419.5	0.2843	87.80	14.264	419.50	4.1117
37	*cis*-2-Butene	C_4H_8	590-18-1	56.106	1.1591	0.27085	435.5	0.28116	134.26	13.894	435.50	4.2795
38	*trans*-2-Butene	C_4H_8	624-64-6	56.106	1.1448	0.27154	428.6	0.28419	167.62	13.080	428.60	4.2160
39	Butyl acetate	$C_6H_{12}O_2$	123-86-4	116.158	0.67794	0.2637	575.4	0.29318	199.65	8.337	575.40	2.5709
40	Butylbenzene	$C_{10}H_{14}$	104-51-8	134.218	0.50812	0.25238	660.5	0.29373	185.30	7.026	660.50	2.0133
41	Butyl mercaptan	$C_4H_{10}S$	109-79-5	90.187	0.89458	0.27463	570.1	0.28512	157.46	10.585	570.10	3.2574
42	*sec*-Butyl mercaptan	$C_4H_{10}S$	513-53-1	90.187	0.89137	0.27365	554	0.2953	133.02	10.761	554.00	3.2573
43	1-Butyne	C_4H_6	107-00-6	54.090	1.3409	0.27892	440	0.29661	147.43	14.901	440.00	4.8075
44	Butyraldehyde	C_4H_8O	123-72-8	72.106	1.0361	0.26731	537.2	0.28397	176.75	12.589	537.20	3.8760
45	Butyric acid	$C_4H_8O_2$	107-92-6	88.105	0.88443	0.25828	615.7	0.248	267.95	11.087	615.70	3.4243
46	Butyronitrile	C_4H_7N	109-74-0	69.105	0.87533	0.24331	582.25	0.28586	161.25	13.047	582.25	3.5976
47	Carbon dioxide	CO_2	124-38-9	44.010	2.768	0.26212	304.21	0.2908	216.58	26.828	304.21	10.5600
48	Carbon disulfide	CS_2	75-15-0	76.141	1.7968	0.28749	552	0.3226	161.11	19.064	552.00	6.2500
49	Carbon monoxide	CO	630-08-0	28.010	2.897	0.27532	132.92	0.2813	68.15	30.180	132.92	10.5220
50	Carbon tetrachloride	CCl_4	56-23-5	153.823	0.99835	0.274	556.35	0.287	250.33	10.843	556.35	3.6436
51	Carbon tetrafluoride	CF_4	75-73-0	88.004	1.955	0.27884	227.51	0.28571	89.56	21.211	227.51	7.0112
52	Chlorine	Cl_2	7782-50-5	70.906	2.23	0.27645	417.15	0.2926	172.12	24.242	417.15	8.0666
53	Chlorobenzene	C_6H_5Cl	108-90-7	112.557	0.8711	0.26805	632.35	0.2799	227.95	10.385	632.35	3.2498
54	Chloroethane	C_2H_5Cl	75-00-3	64.514	1.3	0.26019	460.35	0.27155	134.80	17.016	460.35	4.9963
55	Chloroform	$CHCl_3$	67-66-3	119.378	1.0841	0.2581	536.4	0.2741	209.63	13.702	536.40	4.2003
56	Chloromethane	CH_3Cl	74-87-3	50.488	1.817	0.25877	416.25	0.2833	175.43	22.347	416.25	7.0217
57	1-Chloropropane	C_3H_7Cl	540-54-5	78.541	1.087	0.26832	503.15	0.28055	150.35	13.328	503.15	4.0511
58	2-Chloropropane	C_3H_7Cl	75-29-6	78.541	1.1202	0.27669	489	0.27646	155.97	12.855	489.00	4.0486
59	*m*-Cresol	C_7H_8O	108-39-4	108.138	0.9061	0.28268	705.85	0.2707	285.39	9.612	705.85	3.2054

60	*o*-Cresol	C_7H_8O	95-48-7	108.138	1.0861	0.30624	697.55	0.30587	304.19	9.575	697.55	3.5466
61	*p*-Cresol	C_7H_8O	106-44-5	108.138	1.1503	0.31861	704.65	0.30104	307.93	9.449	704.65	3.6104
62	Cumene	C_9H_{12}	98-82-8	120.192	0.58711	0.25583	631	0.28498	177.14	7.939	631.00	2.2949
63	Cyanogen	C_2N_2	460-19-5	52.035	1.0743	0.20948	400.15	0.20724	245.25	18.520	400.15	5.1284
64	Cyclobutane	C_4H_8	287-23-0	56.106	1.3931	0.29255	459.93	0.24913	182.48	14.074	459.93	4.7619
65	Cyclohexane	C_6H_{12}	110-82-7	84.159	0.88998	0.27376	553.8	0.28571	279.69	9.380	553.80	3.2509
66	Cyclohexanol	$C_6H_{12}O$	108-93-0	100.159	0.8243	0.26545	650.1	0.28495	296.60	9.469	650.10	3.1053
67	Cyclohexanone	$C_6H_{10}O$	108-94-1	98.143	0.86464	0.26888	653	0.29943	242.00	10.090	653.00	3.2157
68	Cyclohexene	C_6H_{10}	110-83-8	82.144	0.92997	0.27056	560.4	0.28943	169.67	11.160	560.40	3.4372
69	Cyclopentane	C_5H_{10}	287-92-3	70.133	1.0897	0.28356	511.7	0.25142	179.28	11.906	511.70	3.8429
70	Cyclopentene	C_5H_8	142-29-0	68.117	1.1035	0.27035	507	0.28699	138.13	13.470	507.00	4.0817
71	Cyclopropane	C_3H_6	75-19-4	42.080	1.7411	0.28205	398	0.29598	145.59	18.658	398.00	6.1730
72	Cyclohexyl mercaptan	$C_6H_{12}S$	1569-69-3	116.224	0.78578	0.27882	664	0.31067	189.64	8.905	664.00	2.8182
73	Decanal	$C_{10}H_{20}O$	112-31-2	156.265	0.46802	0.27146	674.2	0.26869	267.15	5.383	674.20	1.7241
74	Decane	$C_{10}H_{22}$	124-18-5	142.282	0.41084	0.25175	617.7	0.28571	243.51	5.393	617.70	1.6320
75	Decanoic acid	$C_{10}H_{20}O_2$	334-48-5	172.265	0.39348	0.2492	722.1	0.28571	304.55	5.181	722.10	1.5790
76	1-Decanol	$C_{10}H_{22}O$	112-30-1	158.281	0.38208	0.24645	688	0.26125	280.05	5.261	688.00	1.5503
77	1-Decene	$C_{10}H_{20}$	872-05-9	140.266	0.43981	0.25661	616.6	0.29148	206.89	5.733	616.60	1.7139
78	Decyl mercaptan	$C_{10}H_{22}S$	143-10-2	174.347	0.44289	0.27636	696	0.27668	247.56	5.005	696.00	1.6026
79	1-Decyne	$C_{10}H_{18}$	764-93-2	138.250	0.46877	0.25875	619.85	0.29479	229.15	5.895	619.85	1.8117
80	Deuterium	D_2	7782-39-0	4.032	5.2115	0.315	38.35	0.28571	18.73	42.945	38.35	16.5440
81	1,1-Dibromoethane	$C_2H_4Br_2$	557-91-5	187.861	0.95523	0.26364	628	0.29825	210.15	11.799	628.00	3.6232
82	1,2-Dibromoethane	$C_2H_4Br_2$	106-93-4	187.861	1.0132	0.26634	650.15	0.28571	282.85	11.704	650.15	3.8042
83	Dibromomethane	CH_2Br_2	74-95-3	173.835	1.1136	0.24834	611	0.27583	220.60	15.358	611.00	4.4842
84	Dibutyl ether	$C_8H_{18}O$	142-96-1	130.228	0.55941	0.27243	584.1	0.29932	175.30	6.607	584.10	2.0534
85	*m*-Dichlorobenzene	$C_6H_4Cl_2$	541-73-1	147.002	0.74495	0.26147	683.95	0.31526	248.39	9.121	683.95	2.8491
86	*o*-Dichlorobenzene	$C_6H_4Cl_2$	95-50-1	147.002	0.74404	0.26112	705	0.30815	256.15	9.166	705.00	2.8494
87	*p*-Dichlorobenzene	$C_6H_4Cl_2$	106-46-7	147.002	0.74858	0.26276	684.75	0.30788	326.14	8.518	684.75	2.8489
88	1,1-Dichloroethane	$C_2H_4Cl_2$	75-34-3	98.959	1.1055	0.26533	523	0.287	176.19	13.549	523.00	4.1665
89	1,2-Dichloroethane	$C_2H_4Cl_2$	107-06-2	98.959	1.2591	0.27698	561.6	0.30492	237.49	13.462	561.60	4.5458
90	Dichloromethane	CH_2Cl_2	75-09-2	84.933	1.3897	0.25678	510	0.2902	178.01	17.974	510.00	5.4120
91	1,1-Dichloropropane	$C_3H_6Cl_2$	78-99-9	112.986	0.9551	0.27794	560	0.24132	200.00	10.862	560.00	3.4364
92	1,2-Dichloropropane	$C_3H_6Cl_2$	78-87-5	112.986	0.89833	0.26142	572	0.2868	172.71	11.526	572.00	3.4363
93	Diethanol amine	$C_4H_{11}NO_2$	111-42-2	105.136	0.68184	0.23796	736.6	0.2062	301.15	10.390	736.60	2.8654
94	Diethyl amine	$C_4H_{11}N$	109-89-7	73.137	0.85379	0.25675	496.6	0.27027	223.35	10.575	496.60	3.3254
95	Diethyl ether	$C_4H_{10}O$	60-29-7	74.122	0.9554	0.26847	466.7	0.2814	156.85	11.487	466.70	3.5587
96	Diethyl sulfide	$C_4H_{10}S$	352-93-2	90.187	0.82227	0.26314	557.15	0.27369	169.20	10.470	557.15	3.1248
97	1,1-Difluoroethane	$C_2H_4F_2$	75-37-6	66.050	1.4345	0.25774	386.44	0.28178	154.56	18.006	386.44	5.5657
98	1,2-Difluoroethane	$C_2H_4F_2$	624-72-6	66.050	1.173	0.22856	445	0.28571	215.00	17.424	445.00	5.1321
99	Difluoromethane	CH_2F_2	75-10-5	52.023	1.9973	0.24653	351.26	0.28153	136.95	27.399	351.26	8.6070
100	Di-isopropyl amine	$C_6H_{15}N$	108-18-9	101.190	0.6181	0.25786	523.1	0.271	176.85	8.054	523.10	2.3970
101	Di-isopropyl ether	$C_6H_{14}O$	108-20-3	102.175	0.69213	0.26974	500.05	0.28571	187.65	8.067	500.05	2.5659
102	Di-isopropyl ketone	$C_7H_{14}O$	565-80-0	114.185	0.64619	0.26881	576	0.28036	204.81	7.680	576.00	2.4039
103	1,1-Dimethoxyethane	$C_4H_{10}O_2$	534-15-6	90.121	0.89368	0.26599	507.8	0.28571	159.95	11.029	507.80	3.3598
104	1,2-Dimethoxypropane	$C_5H_{12}O_2$	7778-85-0	104.148	0.76327	0.26742	543	0.28571	226.10	8.843	543.00	2.8542
105	Dimethyl acetylene	C_4H_6	503-17-3	54.090	1.1717	0.25895	473.2	0.27289	240.91	13.767	473.20	4.5248
106	Dimethyl amine	C_2H_7N	124-40-3	45.084	1.5436	0.27784	437.2	0.2572	180.96	16.964	437.20	5.5557
107	2,3-Dimethylbutane	C_6H_{14}	79-29-8	86.175	0.7565	0.27305	500	0.27408	145.19	9.031	500.00	2.7706
108	1,1-Dimethylcyclohexane	C_8H_{16}	590-66-9	112.213	0.55873	0.25143	591.15	0.27758	239.66	7.342	591.15	2.2222
109	*cis*-1,2-Dimethylcyclohexane	C_8H_{16}	2207-01-4	112.213	0.52953	0.24358	606.15	0.26809	223.16	7.578	606.15	2.1739
110	*trans*-1,2-Dimethylcyclohexane	C_8H_{16}	6876-23-9	112.213	0.54405	0.25026	596.15	0.2658	184.99	7.626	596.15	2.1739
111	Dimethyl disulfide	$C_2H_6S_2$	624-92-0	94.199	1.1058	0.27866	615	0.31082	188.44	12.413	615.00	3.9683
112	Dimethyl ether	C_2H_6O	115-10-6	46.068	1.5693	0.2679	400.1	0.2882	131.65	18.950	400.10	5.8578
113	*N,N*-Dimethyl formamide	C_3H_7NO	68-12-2	73.094	0.89615	0.23478	649.6	0.28091	212.72	13.954	649.60	3.8170
114	2,3-Dimethylpentane	C_7H_{16}	565-59-3	100.202	0.72352	0.28629	537.3	0.27121	160.00	7.874	537.30	2.5272
115	Dimethyl phthalate	$C_{10}H_{10}O_4$	131-11-3	194.184	0.47977	0.25428	766	0.30722	274.18	6.233	766.00	1.8868
116	Dimethylsilane	C_2H_8Si	1111-74-6	60.170	1.0214	0.26351	402	0.28421	122.93	12.898	402.00	3.8761
117	Dimethyl sulfide	C_2H_6S	75-18-3	62.134	1.4029	0.27991	503.04	0.2741	174.88	15.556	503.04	5.0120
118	Dimethyl sulfoxide	C_2H_6OS	67-68-5	78.133	1.1096	0.25189	729	0.3311	291.67	14.111	729.00	4.4051
119	Dimethyl terephthalate	$C_{10}H_{10}O_4$	120-61-6	194.184	0.50824	0.26885	772	0.2612	413.80	5.538	772.00	1.8904
120	1,4-Dioxane	$C_4H_8O_2$	123-91-1	88.105	1.1819	0.2813	587	0.3047	284.95	11.838	587.00	4.2016
121	Diphenyl ether	$C_{12}H_{10}O$	101-84-8	170.207	0.52133	0.26218	766.8	0.31033	300.03	6.265	766.80	1.9884
122	Dipropyl amine	$C_6H_{15}N$	142-84-7	101.190	0.659	0.26428	550	0.2766	210.15	7.993	550.00	2.4936

TABLE 2-32 Densities of Inorganic and Organic Liquids (mol/dm³) (*Continued*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	T_{min}, K	Density at T_{min}	T_{max}, K	Density at T_{max}
123	Dodecane	$C_{12}H_{26}$	112-40-3	170.335	0.33267	0.24664	658	0.28571	263.57	4.521	658.00	1.3490
124	Eicosane	$C_{20}H_{42}$	112-95-8	282.547	0.18166	0.23351	768	0.28571	309.58	2.729	768.00	0.7780
125	Ethane	C_2H_6	74-84-0	30.069	1.9122	0.27937	305.32	0.29187	90.35	21.640	305.32	6.8447
126	Ethanol	C_2H_6O	64-17-5	46.068	1.6288	0.27469	514	0.23178	159.05	19.410	514.00	5.9296
127	Ethyl acetate	$C_4H_8O_2$	141-78-6	88.105	0.8996	0.25856	523.3	0.278	189.60	11.478	523.30	3.4793
128	Ethyl amine	C_2H_7N	75-04-7	45.084	1.0936	0.22636	456.15	0.25522	192.15	17.588	456.15	4.8312
129	Ethylbenzene	C_8H_{10}	100-41-4	106.165	0.70041	0.26162	617.15	0.28454	178.20	9.041	617.15	2.6772
130	Ethyl benzoate	$C_9H_{10}O_2$	93-89-0	150.175	0.48864	0.23894	698	0.28421	238.45	7.291	698.00	2.0450
131	2-Ethyl butanoic acid	$C_6H_{12}O_2$	88-09-5	116.158	0.66085	0.25707	655	0.31103	258.15	8.220	655.00	2.5707
132	Ethyl butyrate	$C_6H_{12}O_2$	105-54-4	116.158	0.63566	0.25613	571	0.27829	175.15	8.491	571.00	2.4818
133	Ethylcyclohexane	C_8H_{16}	1678-91-7	112.213	0.61587	0.26477	609.15	0.28054	161.84	7.868	609.15	2.3261
134	Ethylcyclopentane	C_7H_{14}	1640-89-7	98.186	0.71751	0.26903	569.5	0.27733	134.71	9.018	569.50	2.6670
135	Ethylene	C_2H_4	74-85-1	28.053	2.0961	0.27657	282.34	0.29147	104.00	23.326	282.34	7.5789
136	Ethylenediamine	$C_2H_8N_2$	107-15-3	60.098	0.7842	0.20702	593	0.20254	284.29	15.055	593.00	3.7880
137	Ethylene glycol	$C_2H_6O_2$	107-21-1	62.068	1.315	0.25125	720	0.21868	260.15	18.310	720.00	5.2338
138	Ethyleneimine	C_2H_5N	151-56-4	43.068	1.3462	0.23289	537	0.23357	195.20	21.450	537.00	5.7804
139	Ethylene oxide	C_2H_4O	75-21-8	44.053	1.836	0.26024	469.15	0.2696	160.65	23.477	469.15	7.0550
140	Ethyl formate	$C_3H_6O_2$	109-94-4	74.079	1.1343	0.26168	508.4	0.2791	193.55	14.006	508.40	4.3347
141	2-Ethyl hexanoic acid	$C_8H_{16}O_2$	149-57-5	144.211	0.47428	0.25028	674.6	0.25442	235.00	6.563	674.60	1.8950
142	Ethylhexyl ether	$C_8H_{18}O$	5756-43-4	130.228	0.55729	0.2714	583	0.29538	180.00	6.612	583.00	2.0534
143	Ethylisopropyl ether	$C_5H_{12}O$	625-54-7	88.148	0.8185	0.26929	489	0.30621	140.00	9.924	489.00	3.0395
144	Ethylisopropyl ketone	$C_6H_{12}O$	565-69-5	100.159	0.68162	0.25152	567	0.3182	204.15	8.975	567.00	2.7100
145	Ethyl mercaptan	C_2H_6S	75-08-1	62.134	1.3047	0.2694	499.15	0.27866	125.26	16.242	499.15	4.8430
146	Ethyl propionate	$C_5H_{10}O_2$	105-37-3	102.132	0.7405	0.25563	546	0.2795	199.25	9.632	546.00	2.8968
147	Ethylpropyl ether	$C_5H_{12}O$	628-32-0	88.148	0.7908	0.266	500.23	0.292	145.65	9.847	500.23	2.9729
148	Ethyltrichlorosilane	$C_2H_5Cl_3Si$	115-21-9	163.506	0.58579	0.24246	559.95	0.29509	167.55	8.653	559.95	2.4160
149	Fluorine	F_2	7782-41-4	37.997	4.2895	0.28587	144.12	0.28776	53.48	44.888	144.12	15.0050
150	Fluorobenzene	C_6H_5F	462-06-6	96.102	1.0146	0.27277	560.09	0.28291	230.94	11.374	560.09	3.7196
151	Fluoroethane	C_2H_5F	353-36-6	48.060	1.6525	0.27099	375.31	0.2442	129.95	19.785	375.31	6.0980
152	Fluoromethane	CH_3F	593-53-3	34.033	2.1854	0.24725	317.42	0.27558	131.35	29.526	317.42	8.8388
153	Formaldehyde	CH_2O	50-00-0	30.026	1.9415	0.22309	408	0.28571	181.15	30.945	408.00	8.7028
154	Formamide	CH_3NO	75-12-7	45.041	1.2486	0.20352	771	0.25178	275.60	25.488	771.00	6.1350
155	Formic acid	CH_2O_2	64-18-6	46.026	1.938	0.24225	588	0.24435	281.45	26.806	588.00	8.0000
156	Furan	C_4H_4O	110-00-9	68.074	1.1339	0.24741	490.15	0.2612	187.55	15.702	490.15	4.5831
157	Helium-4	He	7440-59-7	4.003	7.2475	0.41865	5.2	0.24096	2.20	37.115	5.20	17.3120
158	Heptadecane	$C_{17}H_{36}$	629-78-7	240.468	0.21897	0.23642	736	0.28571	295.13	3.219	736.00	0.9262
159	Heptanal	$C_7H_{14}O$	111-71-7	114.185	0.59006	0.25609	616.8	0.28384	229.80	7.600	616.80	2.3041
160	Heptane	C_7H_{16}	142-82-5	100.202	0.61259	0.26211	540.2	0.28141	182.57	7.700	540.20	2.3371
161	Heptanoic acid	$C_7H_{14}O_2$	111-14-8	130.185	0.53066	0.24729	677.3	0.28289	265.83	7.221	677.30	2.1459
162	1-Heptanol	$C_7H_{16}O$	111-70-6	116.201	0.55687	0.24725	632.3	0.31471	239.15	7.502	632.30	2.2523
163	2-Heptanol	$C_7H_{16}O$	543-49-7	116.201	0.57114	0.25534	608.3	0.26487	230.00	7.454	608.30	2.2368
164	3-Heptanone	$C_7H_{14}O$	106-35-4	114.185	0.59268	0.25663	606.6	0.27766	234.15	7.575	606.60	2.3095
165	2-Heptanone	$C_7H_{14}O$	110-43-0	114.185	0.58247	0.25279	611.4	0.29818	238.15	7.551	611.40	2.3042
166	1-Heptene	C_7H_{14}	592-76-7	98.186	0.66016	0.26657	537.4	0.28571	154.12	8.226	537.40	2.4765
167	Heptyl mercaptan	$C_7H_{16}S$	1639-09-4	132.267	0.58622	0.2726	645	0.29644	229.92	6.728	645.00	2.1505
168	1-Heptyne	C_7H_{12}	628-71-7	96.170	0.67304	0.26045	547	0.28388	192.22	8.492	547.00	2.5841
169	Hexadecane	$C_{16}H_{34}$	544-76-3	226.441	0.23289	0.23659	723	0.28571	291.31	3.415	723.00	0.9844
170	Hexanal	$C_6H_{12}O$	66-25-1	100.159	0.71899	0.26531	591	0.27628	217.15	8.724	591.00	2.7100
171	Hexane	C_6H_{14}	110-54-3	86.175	0.70824	0.26411	507.6	0.27537	177.83	8.747	507.60	2.6816
172	Hexanoic acid	$C_6H_{12}O_2$	142-62-1	116.158	0.62833	0.25598	660.2	0.25304	269.25	8.096	660.20	2.4546
173	1-Hexanol	$C_6H_{14}O$	111-27-3	102.175	0.70093	0.26776	611.3	0.24919	228.55	8.456	611.30	2.6178
174	2-Hexanol	$C_6H_{14}O$	626-93-7	102.175	0.67393	0.25948	585.3	0.26552	223.00	8.518	585.30	2.5972
175	2-Hexanone	$C_6H_{12}O$	591-78-6	100.159	0.67816	0.25634	587.61	0.28365	217.35	8.732	587.61	2.6455
176	3-Hexanone	$C_6H_{12}O$	589-38-8	100.159	0.67666	0.25578	582.82	0.27746	217.50	8.763	582.82	2.6455
177	1-Hexene	C_6H_{12}	592-41-6	84.159	0.76925	0.26809	504	0.28571	133.39	9.581	504.00	2.8694
178	3-Hexyne	C_6H_{10}	928-49-4	82.144	0.78045	0.26065	544	0.28571	170.05	10.021	544.00	2.9942
179	Hexyl mercaptan	$C_6H_{14}S$	111-31-9	118.240	0.66372	0.27345	623	0.29185	192.62	7.773	623.00	2.4272
180	1-Hexyne	C_6H_{10}	693-02-7	82.144	0.84427	0.27185	516.2	0.2771	141.25	10.230	516.20	3.1056
181	2-Hexyne	C_6H_{10}	764-35-2	82.144	0.76277	0.25248	549	0.31611	183.65	10.133	549.00	3.0211

182	Hydrazine	H_4N_2	302-01-2	32.045	1.0516	0.16613	653.15	0.1898	274.69	31.934	653.15	6.3300
183	Hydrogen	H_2	1333-74-0	2.016	5.414	0.34893	33.19	0.2706	13.95	38.487	33.19	15.5160
184	Hydrogen bromide	HBr	10035-10-6	80.912	2.832	0.2832	363.15	0.28571	185.15	27.985	363.15	10.0000
185	Hydrogen chloride	HCl	7647-01-0	36.461	3.342	0.2729	324.65	0.3217	158.97	34.854	324.65	12.2460
186	Hydrogen cyanide	CHN	74-90-8	27.025	1.3413	0.18589	456.65	0.28206	259.83	27.202	456.65	7.2156
187	Hydrogen fluoride	HF	7664-39-3	20.006	2.5635	0.1766	461.15	0.3733	189.79	60.203	461.15	14.5160
188	Hydrogen sulfide	H_2S	7783-06-4	34.081	2.7672	0.27369	373.53	0.29015	187.68	29.130	373.53	10.1110
189	Isobutyric acid	$C_4H_8O_2$	79-31-2	88.105	0.88575	0.25736	605	0.26265	227.15	11.420	605.00	3.4417
190	Isopropyl amine	C_3H_9N	75-31-0	59.110	1.2801	0.2828	471.85	0.2972	177.95	13.561	471.85	4.5265
191	Malonic acid	$C_3H_4O_4$	141-82-2	104.061	0.84266	0.217	805	0.28571	407.95	13.533	805.00	3.8832
192	Methacrylic acid	$C_4H_6O_2$	79-41-4	86.089	0.87025	0.24383	662	0.28571	288.15	11.834	662.00	3.5691
193	Methane	CH_4	74-82-8	16.042	2.9214	0.28976	190.56	0.28881	90.69	28.180	190.56	10.0820
194	Methanol	CH_4O	67-56-1	32.042	2.3267	0.27073	512.5	0.24713	175.47	27.915	512.50	8.5942
195	*N*-Methyl acetamide	C_3H_7NO	79-16-3	73.094	0.88268	0.23568	718	0.27379	301.15	13.012	718.00	3.7452
196	Methyl acetate	$C_3H_6O_2$	79-20-9	74.079	1.13	0.2593	506.55	0.2764	175.15	14.475	506.55	4.3579
197	Methyl acetylene	C_3H_4	74-99-7	40.064	1.6085	0.26436	402.4	0.27987	170.45	19.031	402.40	6.0845
198	Methyl acrylate	$C_4H_6O_2$	96-33-3	86.089	0.97286	0.26267	536	0.2508	196.32	12.203	536.00	3.7037
199	Methyl amine	CH_5N	74-89-5	31.057	1.39	0.21405	430.05	0.2275	179.69	25.378	430.05	6.4938
200	Methyl benzoate	$C_8H_8O_2$	93-58-3	136.148	0.53382	0.23274	693	0.28147	260.75	8.220	693.00	2.2936
201	3-Methyl-1,2-butadiene	C_5H_8	598-25-4	68.117	0.84623	0.24625	490	0.29041	159.53	11.994	490.00	3.4365
202	2-Methylbutane	C_5H_{12}	78-78-4	72.149	0.91991	0.27815	460.4	0.28667	113.25	10.764	460.40	3.3072
203	2-Methylbutanoic acid	$C_5H_{10}O_2$	116-53-0	102.132	0.72762	0.25244	643	0.28571	193.00	9.992	643.00	2.8823
204	3-Methyl-1-butanol	$C_5H_{12}O$	123-51-3	88.148	0.80828	0.26783	577.2	0.23588	155.95	10.254	577.20	3.0179
205	2-Methyl-1-butene	C_5H_{10}	563-46-2	70.133	0.91619	0.26752	465	0.28164	135.58	11.332	465.00	3.4248
206	2-Methyl-2-butene	C_5H_{10}	513-35-9	70.133	0.93391	0.27275	470	0.2578	139.39	11.216	470.00	3.4241
207	2-Methyl -1-butene-3-yne	C_5H_6	78-80-8	66.101	1.1157	0.27671	492	0.30821	160.15	12.581	492.00	4.0320
208	Methylbutyl ether	$C_5H_{12}O$	628-28-4	88.148	0.8363	0.27514	512.74	0.27553	157.48	9.758	512.74	3.0395
209	Methylbutyl sulfide	$C_5H_{12}S$	628-29-5	104.214	0.75509	0.27183	593	0.29127	175.30	9.006	593.00	2.7778
210	3-Methyl-1-butyne	C_5H_8	598-23-2	68.117	0.94575	0.26008	463.2	0.30807	183.45	11.519	463.20	3.6364
211	Methyl butyrate	$C_5H_{10}O_2$	623-42-7	102.132	0.76983	0.26173	554.5	0.26879	187.35	9.764	554.50	2.9413
212	Methylchlorosilane	CH_5ClSi	993-00-0	80.589	1.0674	0.26257	442	0.26569	139.05	13.626	442.00	4.0652
213	Methylcyclohexane	C_7H_{14}	108-87-2	98.186	0.73109	0.26971	572.1	0.29185	146.58	9.017	572.10	2.7107
214	1-Methylcyclohexanol	$C_7H_{14}O$	590-67-0	114.185	0.7013	0.266	686	0.28571	285.15	8.209	686.00	2.6365
215	*cis*-2-Methylcyclohexanol	$C_7H_{14}O$	7443-70-1	114.185	0.70973	0.26544	614	0.26016	280.15	8.293	614.00	2.6738
216	*trans*-2-Methylcyclohexanol	$C_7H_{14}O$	7443-52-9	114.185	0.72836	0.27241	617	0.2478	269.15	8.263	617.00	2.6738
217	Methylcyclopentane	C_6H_{12}	96-37-7	84.159	0.84758	0.27037	532.7	0.28258	130.73	10.491	532.70	3.1349
218	1-Methylcyclopentene	C_6H_{10}	693-89-0	82.144	0.88824	0.26914	542	0.27874	146.62	10.980	542.00	3.3003
219	3-Methylcyclopentene	C_6H_{10}	1120-62-3	82.144	0.9109	0.276	526	0.26756	115.00	11.014	526.00	3.3004
220	Methyldichlorosilane	CH_4Cl_2Si	75-54-7	115.034	0.97608	0.28209	483	0.22529	182.55	10.789	483.00	3.4602
221	Methylethyl ether	C_3H_8O	540-67-0	60.095	1.2635	0.27878	437.8	0.2744	160.00	13.995	437.80	4.5322
222	Methylethyl ketone	C_4H_8O	78-93-3	72.106	0.93767	0.25035	535.5	0.29964	186.48	12.663	535.50	3.7454
223	Methylethyl sulfide	C_3H_8S	624-89-5	76.161	1.067	0.27102	533	0.29364	167.23	12.671	533.00	3.9370
224	Methyl formate	$C_2H_4O_2$	107-31-3	60.052	1.525	0.2634	487.2	0.2806	174.15	18.811	487.20	5.7897
225	Methylisobutyl ether	$C_5H_{12}O$	625-44-5	88.148	0.84005	0.27638	497	0.27645	150.00	9.738	497.00	3.0395
226	Methylisobutyl ketone	$C_6H_{12}O$	108-10-1	100.159	0.71687	0.26453	574.6	0.28918	189.15	8.862	574.60	2.7100
227	Methyl isocyanate	C_2H_3NO	624-83-9	57.051	1.0228	0.20692	488	0.28571	256.15	17.666	488.00	4.9430
228	Methylisopropyl ether	$C_4H_{10}O$	598-53-8	74.122	0.97887	0.27017	464.48	0.28998	127.93	11.933	464.48	3.6232
229	Methylisopropyl ketone	$C_5H_{10}O$	563-80-4	86.132	0.86567	0.26836	553.4	0.28364	180.15	10.460	553.40	3.2258
230	Methylisopropyl sulfide	$C_4H_{10}S$	1551-21-9	90.187	0.78912	0.25915	553.1	0.26512	171.64	10.352	553.10	3.0450
231	Methyl mercaptan	CH_4S	74-93-1	48.107	1.9323	0.28018	469.95	0.28523	150.18	21.564	469.95	6.8966
232	Methyl methacrylate	$C_5H_8O_2$	80-62-6	100.116	0.7761	0.25068	566	0.29773	224.95	10.176	566.00	3.0960
233	2-Methyloctanoic acid	$C_9H_{18}O_2$	3004-93-1	158.238	0.4416	0.2521	694	0.28532	240.00	5.938	694.00	1.7517
234	2-Methylpentane	C_6H_{14}	107-83-5	86.175	0.72701	0.26754	497.7	0.28268	119.55	9.204	497.70	2.7174
235	Methyl pentyl ether	$C_6H_{14}O$	628-80-8	102.175	0.71004	0.26981	546.49	0.29974	176.00	8.445	546.49	2.6316
236	2-Methylpropane	C_4H_{10}	75-28-5	58.122	1.0631	0.27506	407.8	0.2758	113.54	12.574	407.80	3.8650
237	2-Methyl-2-propanol	$C_4H_{10}O$	75-65-0	74.122	0.92128	0.25442	506.2	0.27586	298.97	10.556	506.20	3.6211
238	2-Methyl propene	C_4H_8	115-11-7	56.106	1.1446	0.2724	417.9	0.28172	132.81	13.507	417.90	4.2019
239	Methyl propionate	$C_4H_8O_2$	554-12-1	88.105	0.9147	0.2594	530.6	0.2774	185.65	11.678	530.60	3.5262
240	Methylpropyl ether	$C_4H_{10}O$	557-17-5	74.122	0.96145	0.26536	476.25	0.30088	133.97	12.043	476.25	3.6232
241	Methylpropyl sulfide	$C_4H_{10}S$	3877-15-4	90.187	0.87496	0.26862	565	0.30259	160.17	10.689	565.00	3.2572
242	Methylsilane	CH_6Si	992-94-9	46.144	1.3052	0.26757	352.5	0.28799	116.34	15.791	352.50	4.8780
243	alpha-Methyl styrene	C_9H_{10}	98-83-9	118.176	0.64856	0.25877	654	0.31444	249.95	8.010	654.00	2.5063
244	Methyl *tert*-butyl ether	$C_5H_{12}O$	1634-04-4	88.148	0.928	0.289	497.1	0.286	164.55	9.710	497.10	3.2111

TABLE 2-32 Densities of Inorganic and Organic Liquids (mol/dm³) (*Concluded*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	T_{min}, K	Density at T_{min}	T_{max}, K	Density at T_{max}
245	Methyl vinyl ether	C_3H_6O	107-25-5	58.079	1.2587	0.26433	437	0.25819	151.15	15.691	437.00	4.7619
246	Naphthalene	$C_{10}H_8$	91-20-3	128.171	0.6348	0.25838	748.4	0.27727	333.15	7.755	748.40	2.4568
247	Neon	Ne	7440-01-9	20.180	7.3718	0.3067	44.4	0.2786	24.56	61.796	44.40	24.0360
248	Nitroethane	$C_2H_5NO_2$	79-24-3	75.067	1.0024	0.23655	593	0.278	183.63	15.556	593.00	4.2376
249	Nitrogen	N_2	7727-37-9	28.013	3.2091	0.2861	126.2	0.2966	63.15	31.063	126.20	11.2170
250	Nitrogen trifluoride	F_3N	7783-54-2	71.002	2.3736	0.2817	234	0.29529	66.46	26.555	234.00	8.4260
251	Nitromethane	CH_3NO_2	75-52-5	61.040	1.3728	0.23793	588.15	0.29601	244.60	19.632	588.15	5.7698
252	Nitrous oxide	N_2O	10024-97-2	44.013	2.781	0.27244	309.57	0.2882	182.30	27.928	309.57	10.2080
253	Nitric oxide	NO	10102-43-9	30.006	5.246	0.3044	180.15	0.242	109.50	44.487	180.15	17.2340
254	Nonadecane	$C_{19}H_{40}$	629-92-5	268.521	0.19199	0.23337	758	0.28571	305.04	2.889	758.00	0.8227
255	Nonanal	$C_9H_{18}O$	124-19-6	142.239	0.49587	0.26135	658	0.30736	255.15	6.017	658.00	1.8973
256	Nonane	C_9H_{20}	111-84-2	128.255	0.46321	0.25444	594.6	0.28571	219.66	6.043	594.60	1.8210
257	Nonanoic acid	$C_9H_{18}O_2$	112-05-0	158.238	0.41582	0.24284	710.7	0.30036	285.55	5.759	710.70	1.7123
258	1-Nonanol	$C_9H_{20}O$	143-08-8	144.255	0.43682	0.25161	670.9	0.2498	268.15	5.850	670.90	1.7361
259	2-Nonanol	$C_9H_{20}O$	628-99-9	144.255	0.41687	0.24056	649.5	0.2916	238.15	6.031	649.50	1.7329
260	1-Nonene	C_9H_{18}	124-11-8	126.239	0.48661	0.25722	593.1	0.28571	191.91	6.372	593.10	1.8918
261	Nonyl mercaptan	$C_9H_{20}S$	1455-21-6	160.320	0.47377	0.27052	681	0.30284	253.05	5.453	681.00	1.7513
262	1-Nonyne	C_9H_{16}	3452-09-3	124.223	0.52152	0.25918	598.05	0.29177	223.15	6.537	598.05	2.0122
263	Octadecane	$C_{18}H_{38}$	593-45-3	254.494	0.20448	0.23474	747	0.28571	301.31	3.042	747.00	0.8711
264	Octanal	$C_8H_{16}O$	124-13-0	128.212	0.53636	0.26174	638.9	0.26348	246.00	6.664	638.90	2.0492
265	Octane	C_8H_{18}	111-65-9	114.229	0.5266	0.25693	568.7	0.28571	216.38	6.705	568.70	2.0500
266	Octanoic acid	$C_8H_{16}O_2$	124-07-2	144.211	0.48251	0.25196	694.26	0.26842	289.65	6.311	694.26	1.9150
267	1-Octanol	$C_8H_{18}O$	111-87-5	130.228	0.48979	0.24931	652.3	0.27824	257.65	6.574	652.30	1.9646
268	2-Octanol	$C_8H_{18}O$	123-96-6	130.228	0.50726	0.25972	629.8	0.22	241.55	6.563	629.80	1.9531
269	2-Octanone	$C_8H_{16}O$	111-13-7	128.212	0.50006	0.24851	632.7	0.29942	252.85	6.648	632.70	2.0122
270	3-Octanone	$C_8H_{16}O$	106-68-3	128.212	0.5108	0.25386	627.7	0.26735	255.55	6.628	627.70	2.0121
271	1-Octene	C_8H_{16}	111-66-0	112.213	0.55449	0.25952	566.9	0.28571	171.45	7.216	566.90	2.1366
272	Octyl mercaptan	$C_8H_{18}S$	111-88-6	146.294	0.52577	0.27234	667.3	0.30063	223.95	6.099	667.30	1.9306
273	1-Octyne	C_8H_{14}	629-05-0	110.197	0.58945	0.26052	574	0.28532	193.55	7.483	574.00	2.2626
274	Oxalic acid	$C_2H_2O_4$	144-62-7	90.035	1.0501	0.215	804	0.28571	462.65	16.271	804.00	4.8842
275	Oxygen	O_2	7782-44-7	31.999	3.9143	0.28772	154.58	0.2924	54.35	40.770	154.58	13.6050
276	Ozone	O_3	10028-15-6	47.998	3.3592	0.29884	261	0.28523	80.15	33.361	261.00	11.2410
277	Pentadecane	$C_{15}H_{32}$	629-62-9	212.415	0.25142	0.23837	708	0.28571	283.07	3.642	708.00	1.0550
278	Pentanal	$C_5H_{10}O$	110-62-3	86.132	0.83871	0.26252	566.1	0.29444	182.00	10.534	566.10	3.1948
279	Pentane	C_5H_{12}	109-66-0	72.149	0.84947	0.26726	469.7	0.27789	143.42	10.474	469.70	3.1784
280	Pentanoic acid	$C_5H_{10}O_2$	109-52-4	102.132	0.73455	0.25636	639.16	0.25522	239.15	9.587	639.16	2.8653
281	1-Pentanol	$C_5H_{12}O$	71-41-0	88.148	0.81754	0.26732	588.1	0.25348	195.56	10.061	588.10	3.0583
282	2-Pentanol	$C_5H_{12}O$	6032-29-7	88.148	0.79324	0.25806	561	0.28571	200.00	10.147	561.00	3.0739
283	2-Pentanone	$C_5H_{10}O$	107-87-9	86.132	0.90411	0.27207	561.08	0.30669	196.29	10.398	561.08	3.3231
284	3-Pentanone	$C_5H_{10}O$	96-22-0	86.132	0.71811	0.24129	560.95	0.27996	234.18	10.102	560.95	2.9761
285	1-Pentene	C_5H_{10}	109-67-1	70.133	0.89816	0.26608	464.8	0.28571	108.02	11.521	464.80	3.3755
286	2-Pentyl mercaptan	$C_5H_{12}S$	2084-19-7	104.214	0.65858	0.25367	584.3	0.28571	160.75	9.073	584.30	2.5962
287	Pentyl mercaptan	$C_5H_{12}S$	110-66-7	104.214	0.75345	0.27047	598	0.30583	197.45	8.858	598.00	2.7857
288	1-Pentyne	C_5H_8	627-19-0	68.117	0.8491	0.2352	481.2	0.353	167.45	12.532	481.20	3.6101
289	2-Pentyne	C_5H_8	627-21-4	68.117	0.92099	0.25419	519	0.31077	163.83	12.240	519.00	3.6232
290	Phenanthrene	$C_{14}H_{10}$	85-01-8	178.229	0.45554	0.2523	869	0.24841	372.38	5.985	869.00	1.8055
291	Phenol	C_6H_6O	108-95-2	94.111	1.3798	0.31598	694.25	0.32768	314.06	11.244	694.25	4.3667
292	Phenyl isocyanate	C_7H_5NO	103-71-9	119.121	0.63163	0.23373	653	0.28571	243.15	9.647	653.00	2.7024
293	Phthalic anhydride	$C_8H_4O_3$	85-44-9	148.116	0.5393	0.22704	791	0.248	404.15	8.222	791.00	2.3754
294	Propadiene	C_3H_4	463-49-0	40.064	1.6087	0.26543	394	0.29895	136.87	19.479	394.00	6.0607
295	Propane	C_3H_8	74-98-6	44.096	1.3757	0.27453	369.83	0.29359	85.47	16.583	369.83	5.0111
296	1-Propanol	C_3H_8O	71-23-8	60.095	1.2457	0.27281	536.8	0.23994	146.95	15.206	536.80	4.5662
297	2-Propanol	C_3H_8O	67-63-0	60.095	1.1799	0.2644	508.3	0.24653	185.26	14.663	508.30	4.4626
298	Propenylcyclohexene	C_9H_{14}	13511-13-2	122.207	0.61255	0.26769	636	0.28571	199.00	7.476	636.00	2.2883
299	Propionaldehyde	C_3H_6O	123-38-6	58.079	1.296	0.26439	504.4	0.29471	170.00	15.929	504.40	4.9018
300	Propionic acid	$C_3H_6O_2$	79-09-4	74.079	1.0969	0.25568	600.81	0.26857	252.45	13.935	600.81	4.2901
301	Propionitrile	C_3H_5N	107-12-0	55.079	1.0224	0.23452	564.4	0.2804	180.26	16.027	564.40	4.3595
302	Propyl acetate	$C_5H_{10}O_2$	109-60-4	102.132	0.73041	0.25456	549.73	0.27666	178.15	9.794	549.73	2.8693
303	Propyl amine	C_3H_9N	107-10-8	59.110	0.9195	0.23878	496.95	0.2461	188.36	13.764	496.95	3.8508

304	Propylbenzene	C_9H_{12}	103-65-1	120.192	0.57233	0.25171	638.35	0.29616	173.55	7.982	638.35	2.2738
305	Propylene	C_3H_6	115-07-1	42.080	1.4403	0.26852	364.85	0.28775	87.89	18.070	364.85	5.3638
306	Propyl formate	$C_4H_8O_2$	110-74-7	88.105	0.915	0.26134	538	0.28	180.25	11.590	538.00	3.5012
307	2-Propyl mercaptan	C_3H_8S	75-33-2	76.161	1.093	0.27762	517	0.29781	142.61	12.610	517.00	3.9370
308	Propyl mercaptan	C_3H_8S	107-03-9	76.161	1.0714	0.27214	536.6	0.29481	159.95	12.716	536.60	3.9369
309	1,2-Propylene glycol	$C_3H_8O_2$	57-55-6	76.094	1.0923	0.26106	626	0.20459	213.15	14.363	626.00	4.1841
310	Quinone	$C_6H_4O_2$	106-51-4	108.095	0.83228	0.25385	683	0.23658	388.85	10.082	683.00	3.2786
311	Silicon tetrafluoride	F_4Si	7783-61-1	104.079	1.1945	0.24128	259	0.16693	186.35	15.635	259.00	4.9507
312	Styrene	C_8H_8	100-42-5	104.149	0.7397	0.2603	636	0.3009	242.54	9.109	636.00	2.8417
313	Succinic acid	$C_4H_6O_4$	110-15-6	118.088	0.70284	0.22268	806	0.28571	460.65	10.261	806.00	3.1563
314	Sulfur dioxide	O_2S	7446-09-5	64.064	2.106	0.25842	430.75	0.2895	197.67	25.298	430.75	8.1495
315	Sulfur hexafluoride	F_6S	2551-62-4	146.055	1.3587	0.2701	318.69	0.2921	223.15	12.631	318.69	5.0304
316	Sulfur trioxide	O_3S	7446-11-9	80.063	1.4969	0.19013	490.85	0.4359	289.95	24.241	490.85	7.8730
317	Terephthalic acid	$C_8H_6O_4$	100-21-0	166.131	0.42685	0.181	1113	0.28571	700.15	8.546	1113.00	2.3583
318	*o*-Terphenyl	$C_{18}H_{14}$	84-15-1	230.304	0.3448	0.25116	857	0.29268	329.35	4.553	857.00	1.3728
319	*o*-Terphenyl [use Eq. (2)]	$C_{18}H_{14}$	84-15-1	230.304	5.7136	–0.003474			288.15	4.713	313.19	4.6256
320	Tetradecane	$C_{14}H_{30}$	629-59-4	198.388	0.27248	0.24007	693	0.28571	279.01	3.889	693.00	1.1350
321	Tetrahydrofuran	C_4H_8O	109-99-9	72.106	1.2543	0.28084	540.15	0.2912	164.65	13.998	540.15	4.4662
322	1,2,3,4-Tetrahydronaphthalene	$C_{10}H_{12}$	119-64-2	132.202	0.67717	0.27772	720	0.2878	237.38	7.638	720.00	2.4383
323	Tetrahydrothiophene	C_4H_8S	110-01-0	88.171	1.1628	0.28954	631.95	0.28674	176.99	12.408	631.95	4.0160
324	2,2,3,3-Tetramethylbutane	C_8H_{18}	594-82-1	114.229	0.58988	0.27201	568	0.27341	373.96	5.724	568.00	2.1686
325	Thiophene	C_4H_4S	110-02-1	84.140	1.2874	0.28194	579.35	0.30781	234.94	13.430	579.35	4.5662
326	Toluene	C_7H_8	108-88-3	92.138	0.8792	0.27136	591.75	0.29241	178.18	10.487	591.75	3.2400
327	1,1,2-Trichloroethane	$C_2H_3Cl_3$	79-00-5	133.404	0.9062	0.25475	602	0.31	236.50	11.478	602.00	3.5572
328	Tridecane	$C_{13}H_{28}$	629-50-5	184.361	0.29934	0.2433	675	0.28571	267.76	4.182	675.00	1.2300
329	Triethyl amine	$C_6H_{15}N$	121-44-8	101.190	0.7035	0.27386	535.15	0.2872	158.45	8.284	535.15	2.5688
330	Trimethyl amine	C_3H_9N	75-50-3	59.110	1.0116	0.25683	433.25	0.2696	156.08	13.144	433.25	3.9388
331	1,2,3-Trimethylbenzene	C_9H_{12}	526-73-8	120.192	0.6531	0.27002	664.5	0.26268	243.15	7.728	664.50	2.4187
332	1,2,4-Trimethylbenzene	C_9H_{12}	95-63-6	120.192	0.60394	0.25956	649.1	0.27713	229.33	7.689	649.10	2.3268
333	2,2,4-Trimethylpentane	C_8H_{18}	540-84-1	114.229	0.59059	0.27424	543.8	0.2847	165.78	6.915	543.80	2.1536
334	2,3,3-Trimethylpentane	C_8H_{18}	560-21-4	114.229	0.6028	0.27446	573.5	0.2741	172.22	7.093	573.50	2.1963
335	1,3,5-Trinitrobenzene	$C_6H_3N_3O_6$	99-35-4	213.105	0.48195	0.23093	846	0.28571	398.40	7.083	846.00	2.0870
336	2,4,6-Trinitrotoluene	$C_7H_5N_3O_6$	118-96-7	227.131	0.37378	0.21379	828	0.29905	354.00	6.452	828.00	1.7484
337	Undecane	$C_{11}H_{24}$	1120-21-4	156.308	0.36703	0.24876	639	0.28571	247.57	4.945	639.00	1.4750
338	1-Undecanol	$C_{11}H_{24}O$	112-42-5	172.308	0.33113	0.23676	703.9	0.2762	288.45	4.859	703.90	1.3986
339	Vinyl acetate	$C_4H_6O_2$	108-05-4	86.089	0.9591	0.2593	519.13	0.27448	180.35	12.287	519.13	3.6988
340	Vinyl acetylene	C_4H_4	689-97-4	52.075	1.2703	0.26041	454	0.297	173.15	15.664	454.00	4.8781
341	Vinyl chloride	C_2H_3Cl	75-01-4	62.498	1.5115	0.2707	432	0.2716	119.36	18.481	432.00	5.5837
342	Vinyl trichlorosilane	$C_2H_3Cl_3Si$	75-94-5	161.490	0.59595	0.24314	543.15	0.24856	178.35	8.824	543.15	2.4511
344	Water [use Eq. (2)]	H_2O	7732-18-5	18.015	–13.851	0.64038	–0.00191	1.8211E-06	273.16	55.497	353.15	54.0012
345	*m*-Xylene	C_8H_{10}	108-38-3	106.165	0.68902	0.26086	617	0.27479	225.30	8.648	617.00	2.6413
346	*o*-Xylene	C_8H_{10}	95-47-6	106.165	0.69962	0.26143	630.3	0.27365	247.98	8.623	630.30	2.6761
347	*p*-Xylene	C_8H_{10}	106-42-3	106.165	0.67752	0.25887	616.2	0.27596	286.41	8.161	616.20	2.6172

Except for *o*-terphenyl and water, liquid density ρ is calculated by

$$\rho = C1/C2^{[1+(1-T/C3)^{C4}]}$$

where ρ is in mol/dm^3 and T is in K. The pressure is equal to the vapor pressure for pressures greater than 1 atm and equal to 1 atm when the vapor pressure is less than 1 atm.

Equation (2), used for the limited temperature ranges as noted for *o*-terphenyl and water, is

$$\rho = C1 + C2T + C3T^2 + C4T^3$$

For water over the entire temperature range of 273.16 to 647.096 K, use

$$\rho = 17.863 + 58.606\tau^{0.35} - 95.396\tau^{2/3} + 213.89\tau - 141.26\tau^{4/3}$$

where $\tau = 1 - T/647.096$.

All substances are listed by chemical family in Table 2-6 and by formula in Table 2-7.

Values in this table were taken from the Design Institute for Physical Properties (DIPPR) of the American Institute of Chemical Engineers (AIChE), copyright 2007 AIChE and reproduced with permission of AICHE and of the DIPPR Evaluated Process Design Data Project Steering Committee. Their source should be cited as R. L. Rowley, W. V. Wilding, J. L. Oscarson, Y. Yang, N. A. Zundel, T. E. Daubert, R. P. Danner, DIPPR® Data Compilation of Pure Chemical Properties, Design Institute for Physical Properties, AIChE, New York (2007).

The number of digits provided for values at T_{min} and T_{max} was chosen for uniformity of appearance and formatting; these do not represent the uncertainties of the physical quantities, but are the result of calculations from the standard thermophysical property formulations within a fixed format.

DENSITIES OF AQUEOUS INORGANIC SOLUTIONS AT 1 ATM

UNITS AND UNITS CONVERSIONS

Most densities are given in grams per cubic centimeter. To convert to pounds per cubic foot, multiply by 62.43. °F = ⅘ °C + 32. Compositions are weight percent unless otherwise stated.

ADDITIONAL REFERENCES

For more detailed data on densities see *International Critical Tables:* tabular index, vol. 3, p. 1; abrasives, vol. 2, p. 87; air, moist, vol. 1, p. 71; building stones, vol. 2, p. 52; clays, vol. 2, p. 56; coals, vol. 2, p. 135; compounds, vol. 1, pp. 106, 176, 313, 341; elements, vol. 1, pp. 102, 340; fibers, vol. 2, p. 237; gases and vapors, vol. 3, pp. 3, 345; glass, vol. 2, p. 93; liquids and vitreous solids, vol. 3, p. 22; vol. 1, pp. 102, 340; vol. 2, pp. 456, 463; vol. 3, pp. 20, 35; liquid coolants and saturated vapors are available from WADC-TR-59-598, 1959; plastics are collected in the *Handbook of Chemistry and Physics,* Chemical Rubber Publishing Co.; solid helium, neon, argon, fluorine, and methane data are given by Johnson (ed.), WADD-TR-60-56, 1960; temperatures of maximum solubility, vol. 3, p. 107; metals, vol. 2, p. 463; oils, fats, and waxes, vol. 2, p. 201; orthobaric, vol. 3, pp. 202, 228, 237, 244; petroleums, vol. 2, pp. 137, 144; plastics, vol. 2, p. 296; porcelains, vol. 2, pp. 68, 75; refrigerating brines, vol. 2, p. 327; rubber, vol. 2, pp. 255, 259; soaps, vol. 5, p. 447; metallic solid solutions, vol. 2, p. 358; solids, vol. 3, pp. 43, 45; vol. 2, p. 456; vol. 3, p. 21; solutions and mixtures, vol. 3, pp. 17, 51, 95, 104, 107, 111, 125, 130; woods, vol. 2, p. 1. Also see the *Handbook of Chemistry and Physics,* Chemical Rubber Publishing Co., 86th ed., etc.

TABLE 2-33 Aluminum Sulfate [$Al_2(SO_4)_3$]*

%	d_4^{15}	%	d_4^{15}
1	1.0093	16	1.1770
2	1.0195	20	1.2272
4	1.0404	24	1.2803
8	1.0837	26	1.3079
12	1.1293		

*International Critical Tables, vol. 3, p. 70.

TABLE 2-34 Ammonia (NH_3)*

%	−15 °C	−10 °C	−5 °C	0 °C	5 °C	10 °C	20 °C	25 °C	%	d_4^{15}
1		0.9943	0.9954	0.9959	0.9958	0.9955	0.9939	0.993	32	0.889
2		.9906	.9915	.9919	.9917	.9913	.9895	.988	36	.877
4		.9834	.9840	.9842	.9837	.9832	.9811	.980	40	.865
8	0.970	.9701	.9701	.9695	.9686	.9677	.9651	.964	45	.849
12	.958	.9576	.9571	.9561	.9548	.9534	.9501	.948	50	.832
16	.947	.9461	.9450	.9435	.9420	.9402	.9362	.934	60	.796
20		.9353	.9335	.9316	.9296	.9275	.9229		70	.755
24		.9249	.9226	.9202	.9179	.9155	.9101		80	.711
28		.9150	.9122	.9094	.9067	.9040	.8980		90	.665
30		.9101	.9070	.9040	.9012	.8983	.8920		100	.618

*International Critical Tables, vol. 3, p. 59.

TABLE 2-35 Ammonium Acetate* (CH_3COONH_4)

%	d_4^{25}
1	0.9992
2	1.0013
4	1.0055
8	1.0136
12	1.0216
16	1.0294
20	1.0368
24	1.0439
28	1.0507
30	1.0540
35	1.0618
40	1.0691
45	1.0760

*International Critical Tables, vol. 3, p. 62.

For data at 16 °C for 3(1)52 percent see Atack, *Handbook of Chemical Data,* p. 33, Reinhold, New York, 1957.

TABLE 2-36 Ammonium Bichromate [$(NH_4)_2Cr_2O_7$]*

%	d_4^{12}
1	1.0051
2	1.0108
4	1.0223
8	1.0463
12	1.0715
16	1.0981
20	1.1263

*International Critical Tables, vol. 3, p. 70.

TABLE 2-37 Ammonium Chloride (NH_4Cl)*

%	0 °C	10 °C	20 °C	30 °C	50 °C	80 °C	100 °C
1	1.0033	1.0029	1.0013	0.9987	0.9910	0.9749	0.9617
2	1.0067	1.0062	1.0045	1.0018	.9940	.9780	.9651
4	1.0135	1.0126	1.0107	1.0077	.9999	.9842	.9718
8	1.0266	1.0251	1.0227	1.0195	1.0116	.9963	.9849
12	1.0391	1.0370	1.0344	1.0310	1.0231	1.0081	.9975
16	1.0510	1.0485	1.0457	1.0422	1.0343	1.0198	1.0096
20	1.0625	1.0596	1.0567	1.0532	1.0454	1.0312	1.0213
24	1.0736	1.0705	1.0674	1.0641	1.0564	1.0426	1.0327

*International Critical Tables, vol. 3, p. 60.

TABLE 2-38 Ammonium Chromate [$(NH_4)_2CrO_4$]*

%	°C	d_4^t
3.80	20	1.0219
10.52	13	1.0627
19.75	13.7	1.1189
28.04	19.6	1.1707

*International Critical Tables, vol. 3, p. 70.

TABLE 2-39 Ammonium Nitrate (NH_4NO_3)*

%	0 °C	10 °C	25 °C	40 °C	60 °C	80 °C
1.0	1.0043	1.0039	1.0011	0.9961	0.9870	0.9755
2.0	1.0088	1.0082	1.0051	1.0000	.9908	.9793
4.0	1.0178	1.0168	1.0132	1.0079	.9985	.9869
8.0	1.0358	1.0340	1.0297	1.0238	1.0142	1.0024
12.0	1.0539	1.0515	1.0464	1.0400	1.0301	1.0181
16.0	1.0721	1.0691	1.0633	1.0565	1.0462	1.0342
20.0	1.0905	1.0870	1.0806	1.0734	1.0627	1.0506
24.0	1.1090	1.1051	1.0982	1.0907	1.0796	1.0673
28.0	1.1277	1.1234	1.1161	1.1082	1.0968	1.0844
30.0	1.1371	1.1327	1.1252	1.1171	1.1055	1.0931
40.0	1.1862	1.1810	1.1727	1.1640	1.1515	1.1385
50.0	1.2380	1.2320	1.2229	1.2136	1.2006	1.1868

*International Critical Tables, vol. 3, p. 59.

TABLE 2-40 Ammonium Sulfate [$(NH_4)_2SO_4$]*

%	0 °C	20 °C	40 °C	80 °C	100 °C
1	1.0061	1.0041	0.9980	0.9777	0.9644
2	1.0124	1.0101	1.0039	.9836	.9705
4	1.0248	1.0220	1.0155	.9953	.9826
8	1.0495	1.0456	1.0387	1.0187	1.0066
12	1.0740	1.0691	1.0619	1.0421	1.0303
16	1.0980	1.0924	1.0849	1.0653	1.0539
20	1.1215	1.1154	1.1077	1.0883	1.0772
24	1.1448	1.1383	1.1304	1.1111	1.1003
28	1.1677	1.1609	1.1529	1.1338	1.1232
35	1.2072	1.2800	1.1919	1.1731	1.1629
40	1.2350	1.2277	1.2196	1.2011	1.1910
50	1.2899	1.2825	1.2745	1.2568	1.2466

*International Critical Tables, vol. 3, p. 60.

TABLE 2-41 Arsenic Acid (H_3AsO_4)*

%	d_4^{15}	%	d_4^{15}
1	1.0057	20	1.1447
2	1.0124	30	1.2331
6	1.0398	40	1.3370
10	1.0681	50	1.4602
16	1.1128	60	1.6070
		70	1.7811

*International Critical Tables, vol. 3, p. 61.

TABLE 2-42 Barium Chloride ($BaCl_2$)*

%	0 °C	20 °C	40 °C	60 °C	80 °C	100 °C
2	1.0181	1.0159	1.0096	1.0004	0.9890	0.9755
4	1.0368	1.0341	1.0275	1.0181	1.0066	.9931
8	1.0760	1.0721	1.0648	1.0551	1.0434	1.0299
12	1.1178	1.1128	1.1047	1.0948	1.0827	1.0692
16	1.1627	1.1564	1.1478	1.1373	1.1249	1.1113
20	1.2105	1.2031	1.1938	1.1828	1.1702	1.1563
24		1.2531	1.2430	1.2316	1.2186	1.2045
26		1.2793	1.2688	1.2571	1.2440	1.2298

International Critical Tables, vol. 3, p. 75.

TABLE 2-43 Cadmium Nitrate [$Cd(NO_3)_2$]*

%	d_4^{18}	%	d_4^{18}
2	1.0154	20	1.1904
4	1.0326	25	1.2488
8	1.0683	30	1.3124
12	1.1061	40	1.4590
16	1.1468	50	1.6356

International Critical Tables, vol. 3, p. 66.

TABLE 2-44 Calcium Chloride ($CaCl_2$)*

%	–5 °C	0 °C	20 °C	30 °C	40 °C	60 °C	80 °C	100 °C	120 °C†	140 °C
2		1.0171	1.0148	1.0120	1.0084	0.9994	0.9881	0.9748	0.9596	0.9428
4		1.0346	1.0316	1.0286	1.0249	1.0158	1.0046	0.9915	0.9765	0.9601
8	1.0708	1.0703	1.0659	1.0626	1.0586	1.0492	1.0382	1.0257	1.0111	0.9954
12	1.1083	1.1072	1.1015	1.0978	1.0937	1.0840	1.0730	1.0610	1.0466	1.0317
16	1.1471	1.1454	1.1386	1.1345	1.1301	1.1202	1.1092	1.0973	1.0835	1.0691
20	1.1874	1.1853	1.1775	1.1730	1.1684	1.1581	1.1471	1.1352	1.1219	1.1080
25		1.2376	1.2284	1.2236	1.2186	1.2079	1.1965	1.1846		
30		1.2922	1.2816	1.2764	1.2709	1.2597	1.2478	1.2359		
35			1.3373	1.3316	1.3255	1.3137	1.3013	1.2893		
40			1.3957	1.3895	1.3826	1.3700	1.3571	1.3450		

International Critical Tables, vol. 3, pp. 72–73.
†Corrected to atmospheric pressure.

TABLE 2-45 Calcium Hydroxide [$Ca(OH)_2$]*

%	d_4^{15}	d_4^{25}
0.05	0.99979	0.99773
.10	1.00044	.99838
.15	1.00110	.99904

International Critical Tables, vol. 3, p. 72.

TABLE 2-46 Calcium Hypochlorite* ($CaOCl_2$)

% total salt	d_4^{15}
2	1.0169
4	1.0345
6	1.0520
8	1.0697
10	1.0876
12	1.1060

International Critical Tables, vol. 3, p. 73.
$CaOCl_2 = 89.15\%$
$CaCl_2 = 7.31\%$
$Ca(ClO_3)_2 = 0.26\%$
$Ca(OH)_2 = 2.92\%$

TABLE 2-47 Calcium Nitrate [$Ca(NO_3)_2$]*

%	6 °C	18 °C	25 °C	30 °C
2°	1.0157	1.0137	1.0120	1.0105
4	1.0316	1.0291	1.0272	1.0256
8	1.0641	1.0608	1.0585	1.0565
12	1.0979	1.0937	1.0911	1.0887
16	1.1330	1.1279	1.1250	1.1224
20	1.1694	1.1636	1.1602	1.1575
25	1.2168	1.2106	1.2065	1.2032
30		1.260		
35		1.311		
40		1.365		
45		1.422		
68†		1.747	1.741	1.736

International Critical Tables, vol. 3, pp. 73–74.
†Supercooled tetrahydrate (m.p. 41.4°C).

TABLE 2-48 Chromic Acid (CrO_3)*

%	d_4^{15}	%	d_4^{15}
1	1.006	20	1.163
2	1.014	26	1.220
6	1.045	30	1.260
10	1.076	40	1.371
16	1.127	50	1.505
		60	1.663

International Critical Tables, vol. 3, p. 69.

TABLE 2-49 Chromium Chloride ($CrCl_3$)*

	d_4^{18}		
%	Violet	Green	Equilibrium mixture of violet and green
1	1.0076	1.0071	1.0075
2	1.0166	1.0157	1.0165
4	1.0349	1.0332	1.0347
8	1.0724	1.0691	1.0722
12	1.1114	1.1065	1.1111
14	1.1316		

International Critical Tables, vol. 3, p. 69.

TABLE 2-50 Copper Nitrate [$Cu(NO_3)_2$]*

%	d_4^{20}	%	d_4^{20}
1	1.007	12	1.107
2	1.015	16	1.147
4	1.032	20	1.189
8	1.069	25	1.248

International Critical Tables, vol. 3, p. 67.

TABLE 2-51 Copper Sulfate ($CuSO_4$)*

%	0 °C	20 °C	40 °C
1	1.0104	1.0086	1.0024
4	1.0429	1.0401	1.0332
8	1.0887	1.084	1.0764
12	1.1379	1.1308	1.1222
16		1.180	
18		1.206	

International Critical Tables, vol. 3, p. 67.

TABLE 2-52 Cuprous Chloride ($CuCl_2$)*

%	0 °C	20 °C	40 °C
1	1.0095	1.0072	1.002
4	1.0387	1.036	1.0305
8	1.0788	1.0754	1.0682
12	1.1208	1.1165	1.107
16	1.1653	1.1595	1.151
20	1.2121	1.2052	1.1953

International Critical Tables, vol. 3, p. 66.

TABLE 2-53 Ferric Chloride ($FeCl_3$)*

%	0 °C	10 °C	20 °C	30 °C
1	1.0086	1.0084	1.0068	1.0040
2	1.0174	1.0168	1.0152	1.0122
4	1.0347	1.0341	1.0324	1.0292
8	1.0703	1.0692	1.0669	1.0636
12	1.1088	1.1071	1.1040	1.1006
16	1.1475	1.1449	1.1418	1.1386
20	1.1870	1.1847	1.1820	1.1786
25	1.2400	1.2380	1.2340	1.2290
30	1.2970	1.2950	1.2910	1.2850
35	1.3605	1.3580	1.3530	1.3475
40	1.4280	1.4235	1.4175	1.4115
45		1.4920	1.4850	
50		1.5610	1.5510	

International Critical Tables, vol. 3, p. 68.

TABLE 2-54 Ferric Sulfate [$Fe_2(SO_4)_3$]*

%	$d_4^{17.5}$
1	1.0072
2	1.0157
4	1.0327
8	1.0670
12	1.1028
16	1.1409
20	1.1811
30	1.3073
40	1.4487
50	1.6127
60	1.7983

*International Critical Tables, vol. 3, p. 68.

TABLE 2-55 Ferric Nitrate [$Fe(NO_3)_3$]*

%	d_4^{18}
1	1.0065
2	1.0144
4	1.0304
8	1.0636
12	1.0989
16	1.1359
20	1.1748
25	1.2281

*International Critical Tables, vol. 3, p. 68.

TABLE 2-56 Ferrous Sulfate ($FeSO_4$)*

%	15 °C	18 °C	20 °C
0.2		1.00068	1.0002
0.4		1.00275	1.0022
0.8		1.00645	1.0062
1.0	1.0090	1.0085	1.0082
4.0	1.0380	1.0375	
8.0	1.0790	1.0785	
12.0	1.1235	1.1220	
16.0	1.1690	1.1675	
20.0	1.2150	1.2135	

*International Critical Tables, vol. 3, p. 68.

TABLE 2-57 Hydrogen Bromide (HBr)*

%	d_4^4	d_4^{10}	d_4^{25}
1.0	1.0073	1.0068	1.0041
2.0	1.0146	1.0139	1.0111
4.0	1.0295	1.0285	1.0255
6.0	1.0448	1.0435	1.0402
8.0	1.0604	1.0589	1.0552
10.0	1.0764	1.0747	1.0707
12.0	1.0928	1.0910	1.0867
14.0	1.1097	1.1078	1.1032
16.0	1.1272	1.1251	1.1202
18.0	1.1453	1.1430	1.1377
20.0	1.1640	1.1615	1.1557
22.0	1.1832	1.1806	1.1743
24.0	1.2030	1.2003	1.1935
26.0	1.2235	1.2206	1.2134
28.0	1.2446	1.2415	1.2340
30.0	1.2663	1.2630	1.2552
40.0	1.3877	1.3838	1.3736
50.0	1.5305	1.5257	1.5127
60.0	1.6950	1.6892	1.6731
65.0	1.7854	1.7792	1.7613

*International Critical Tables, vol. 3, p. 55.

TABLE 2-58 Hydrogen Cyanide (HCN)*

%	d_4^{15}
1	0.998
2	0.996
4	0.993
8	0.984
12	0.971
16	0.956
82	0.752
90	0.724
100	0.691

*International Critical Tables, vol. 3, p. 61.

TABLE 2-59 Hydrogen Chloride (HCl)

%	−5 °C	0 °C	10 °C	20 °C	40 °C	60 °C	80 °C	100 °C
1	1.0048	1.0052	1.0048	1.0032	0.9970	0.9881	0.9768	0.9636
2	1.0104	1.0106	1.0100	1.0082	1.0019	0.9930	0.9819	0.9688
4	1.0213	1.0213	1.0202	1.0181	1.0116	1.0026	0.9919	0.9791
6	1.0321	1.0319	1.0303	1.0279	1.0211	1.0121	1.0016	0.9892
8	1.0428	1.0423	1.0403	1.0376	1.0305	1.0215	1.0111	0.9992
10	1.0536	1.0528	1.0504	1.0474	1.0400	1.0310	1.0206	1.0090
12	1.0645	1.0634	1.0607	1.0574	1.0497	1.0406	1.0302	1.0188
14	1.0754	1.0741	1.0711	1.0675	1.0594	1.0502	1.0398	1.0286
16	1.0864	1.0849	1.0815	1.0776	1.0692	1.0598	1.0494	1.0383
18	1.0975	1.0958	1.0920	1.0878	1.0790	1.0694	1.0590	1.0479
20	1.1087	1.1067	1.1025	1.0980	1.0888	1.0790	1.0685	1.0574
22	1.1200	1.1177	1.1131	1.1083	1.0986	1.0886	1.0780	1.0668
24	1.1314	1.1287	1.1238	1.1187	1.1085	1.0982	1.0874	1.0761
26	1.1426	1.1396	1.1344	1.1290	1.1183	1.1076	1.0967	1.0853
28	1.1537	1.1505	1.1449	1.1392	1.1280	1.1169	1.1058	1.0942
30	1.1648	1.1613	1.1553	1.1493	1.1376	1.1260	1.1149	1.1030
32				1.1593				
34				1.1691				
36				1.1789				
38				1.1885				
40				1.1980				

*International Critical Tables, vol. 3, p. 54.

TABLE 2-60 Hydrogen Fluoride (HF)*

%	d_4^0	d_4^{20}
5	1.020	1.017
10	1.040	1.035
20	1.080	1.070
30	1.119	1.101
40	1.159	1.130
50	1.198	1.155
60	1.235	
70	1.258	
80	1.259	
90	1.178	
95	1.089	
100	1.0005	

*International Critical Tables, vol. 3, p. 54.

TABLE 2-61 Hydrogen Peroxide (H_2O_2)*

%	d_4^{18}	%	d_4^{18}
1	1.0022	26	1.0959
2	1.0058	28	1.1040
4	1.0131	30	1.1122
6	1.0204	35	1.1327
8	1.0277	40	1.1536
10	1.0351	45	1.1749
12	1.0425	50	1.1966
14	1.0499	55	1.2188
16	1.0574	60	1.2416
18	1.0649	70	1.2897
20	1.0725	80	1.3406
22	1.0802	90	1.3931
24	1.0880	100	1.4465

*International Critical Tables, vol. 3, p. 54.

TABLE 2-62 Hydrofluosilic Acid (H_2SiF_6)*

%	$d_4^{17.5}$	%	$d_4^{17.5}$
1	1.0080	16	1.1373
2	1.0161	20	1.1748
4	1.0324	25	1.2235
8	1.0661	30	1.2742
12	1.1011	34	1.3162

*O. Söhnel and P. Novotny, *Densities of Aqueous Solutions of Inorganic Substances*, Elsevier, 1985.

TABLE 2-63 Magnesium Chloride ($MgCl_2$)*

%	0 °C	20 °C	40 °C	60 °C	80 °C	100 °C
2	1.0168	1.0146	1.0084	0.9995	0.9883	0.9753
4	1.0338	1.0311	1.0248	1.0159	1.0050	0.9923
8	1.0683	1.0646	1.0580	1.0493	1.0388	1.0269
12	1.1035	1.0989	1.0921	1.0836	1.0735	1.0622
16	1.1395	1.1342	1.1272	1.1188	1.1092	1.0984
20	1.1764	1.1706	1.1635	1.1552	1.1460	1.1359
25	1.2246	1.2184	1.2111	1.2031	1.1942	1.1847
30	1.2754	1.2688	1.2614	1.2535	1.2451	1.2360

*International Critical Tables, vol. 3, p. 71.

TABLE 2-64 Magnesium Sulfate ($MgSO_4$)*

%	0 °C	20 °C	30 °C	40 °C	50 °C	60 °C	80 °C
2	1.0210	1.0186	1.0158	1.0123	1.0081	1.0032	0.9916
4	1.0423	1.0392	1.0362	1.0326	1.0283	1.0234	1.0118
8	1.0858	1.0816	1.0782	1.0743	1.0700	1.0650	1.0534
12	1.1309	1.1256	1.1220	1.1179	1.1135	1.1083	1.0968
16	1.1777	1.1717	1.1679	1.1637	1.1592		
20	1.2264	1.2198	1.2159	1.2117	1.2072		
26	1.3032	1.2961	1.2922	1.2879	1.2836		

*International Critical Tables, vol. 3, p. 72.

TABLE 2-65 Nickel Chloride ($NiCl_2$)*

%	d_4^{18}
1	1.0082
2	1.0179
4	1.0375
8	1.0785
12	1.1217
16	1.1674
20	1.2163
30	1.353

*International Critical Tables, vol. 3, p. 69.

TABLE 2-66 Nickel Nitrate [$Ni(NO_3)_2$]*

%	d_4^{20}
1	1.0065
2	1.0150
4	1.0325
8	1.0688
12	1.1070
16	1.1480
20	1.191
30	1.311
35	1.377

*International Critical Tables, vol. 3, p. 69.

TABLE 2-67 Nickel Sulfate ($NiSO_4$)*

%	d_4^{18}
1	1.0091
2	1.0198
4	1.0415
8	1.0852
12	1.1325
16	1.1825
18	1.2090

*International Critical Tables, vol. 3, p. 69.

TABLE 2-68 Nitric Acid (HNO_3)*

%	0 °C	5 °C	10 °C	15 °C	20 °C	25 °C	30 °C	40 °C	50 °C	60 °C	80 °C	100 °C
1	1.0058	1.00572	1.00534	1.00464	1.00364	1.00241	1.0009	0.9973	0.9931	0.9882	0.9767	0.9632
2	1.0117	1.01149	1.01099	1.01018	1.00909	1.00778	1.0061	1.0025	0.9982	0.9932	0.9816	0.9681
3	1.0176	1.01730	1.01668	1.01576	1.01457	1.01318	1.0114	1.0077	1.0033	0.9982	0.9865	0.9730
4	1.0236	1.02315	1.02240	1.02137	1.02008	1.01861	1.0168	1.0129	1.0084	1.0033	0.9915	0.9779
5	1.0296	1.02904	1.02816	1.02702	1.02563	1.02408	1.0222	1.0182	1.0136	1.0084	0.9965	0.9829
6	1.0357	1.03497	1.03397	1.03272	1.03122	1.02958	1.0277	1.0235	1.0188	1.0136	1.0015	0.9879
7	1.0418	1.0410	1.0399	1.0385	1.0369	1.0352	1.0333	1.0289	1.0241	1.0188	1.0066	0.9929
8	1.0480	1.0471	1.0458	1.0443	1.0427	1.0409	1.0389	1.0344	1.0295	1.0241	1.0117	0.9980
9	1.0543	1.0532	1.0518	1.0502	1.0485	1.0466	1.0446	1.0399	1.0349	1.0294	1.0169	1.0032
10	1.0606	1.0594	1.0578	1.0561	1.0543	1.0523	1.0503	1.0455	1.0403	1.0347	1.0221	1.0083
11	1.0669	1.0656	1.0639	1.0621	1.0602	1.0581	1.0560	1.0511	1.0458	1.0401	1.0273	1.0134
12	1.0733	1.0718	1.0700	1.0681	1.0661	1.0640	1.0618	1.0567	1.0513	1.0455	1.0326	1.0186
13	1.0797	1.0781	1.0762	1.0742	1.0721	1.0699	1.0676	1.0624	1.0568	1.0509	1.0379	1.0238
14	1.0862	1.0845	1.0824	1.0803	1.0781	1.0758	1.0735	1.0681	1.0624	1.0564	1.0432	1.0289
15	1.0927	1.0909	1.0887	1.0865	1.0842	1.0818	1.0794	1.0739	1.0680	1.0619	1.0485	1.0341
16	1.0992	1.0973	1.0950	1.0927	1.0903	1.0879	1.0854	1.0797	1.0737	1.0675	1.0538	1.0393
17	1.1057	1.1038	1.1014	1.0989	1.0964	1.0940	1.0914	1.0855	1.0794	1.0731	1.0592	1.0444
18	1.1123	1.1103	1.1078	1.1052	1.1026	1.1001	1.0974	1.0913	1.0851	1.0787	1.0646	1.0496
19	1.1189	1.1168	1.1142	1.1115	1.1088	1.1062	1.1034	1.0972	1.0908	1.0843	1.0700	1.0547
20	1.1255	1.1234	1.1206	1.1178	1.1150	1.1123	1.1094	1.1031	1.0966	1.0899	1.0754	1.0598
21	1.1322	1.1300	1.1271	1.1242	1.1213	1.1185	1.1155	1.1090	1.1024	1.0956	1.0808	1.0650
22	1.1389	1.1366	1.1336	1.1306	1.1276	1.1247	1.1217	1.1150	1.1083	1.1013	1.0862	1.0701
23	1.1457	1.1433	1.1402	1.1371	1.1340	1.1310	1.1280	1.1210	1.1142	1.1070	1.0917	1.0753
24	1.1525	1.1501	1.1469	1.1437	1.1404	1.1374	1.1343	1.1271	1.1201	1.1127	1.0972	1.0805
25	1.1594	1.1569	1.1536	1.1503	1.1469	1.1438	1.1406	1.1332	1.1260	1.1185	1.1027	1.0857
26	1.1663	1.1638	1.1603	1.1569	1.1534	1.1502	1.1469	1.1394	1.1320	1.1244	1.1083	1.0910
27	1.1733	1.1707	1.1670	1.1635	1.1600	1.1566	1.1533	1.1456	1.1381	1.1303	1.1139	1.0963
28	1.1803	1.1777	1.1738	1.1702	1.1666	1.1631	1.1597	1.1519	1.1442	1.1362	1.1195	1.1016
29	1.1874	1.1847	1.1807	1.1770	1.1733	1.1697	1.1662	1.1582	1.1503	1.1422	1.1251	1.1069
30	1.1945	1.1917	1.1876	1.1838	1.1800	1.1763	1.1727	1.1645	1.1564	1.1482	1.1307	1.1122
31	1.2016	1.1988	1.1945	1.1906	1.1867	1.1829	1.1792	1.1708	1.1625	1.1542	1.1363	1.1175
32	1.2088	1.2059	1.2014	1.1974	1.1934	1.1896	1.1857	1.1772	1.1687	1.1602	1.1419	1.1228
33	1.2160	1.2131	1.2084	1.2043	1.2002	1.1963	1.1922	1.1836	1.1749	1.1662	1.1476	1.1281
34	1.2233	1.2203	1.2155	1.2113	1.2071	1.2030	1.1988	1.1901	1.1812	1.1723	1.1533	1.1335
35	1.2306	1.2275	1.2227	1.2183	1.2140	1.2098	1.2055	1.1966	1.1876	1.1784	1.1591	1.1390
36	1.2375	1.2344	1.2294	1.2249	1.2205	1.2163	1.2119	1.2028	1.1936	1.1842	1.1645	1.1440
37	1.2444	1.2412	1.2361	1.2315	1.2270	1.2227	1.2182	1.2089	1.1995	1.1899	1.1699	1.1490
38	1.2513	1.2479	1.2428	1.2381	1.2335	1.2291	1.2245	1.2150	1.2054	1.1956	1.1752	1.1540
39	1.2581	1.2546	1.2494	1.2446	1.2399	1.2354	1.2308	1.2210	1.2112	1.2013	1.1805	1.1589
40	1.2649	1.2613	1.2560	1.2511	1.2463	1.2417	1.2370	1.2270	1.2170	1.2069	1.1858	1.1638
41	1.2717	1.2680	1.2626	1.2576	1.2527	1.2480	1.2432	1.2330	1.2229	1.2126	1.1911	1.1687
42	1.2786	1.2747	1.2692	1.2641	1.2591	1.2543	1.2494	1.2390	1.2287	1.2182	1.1963	1.1735
43	1.2854	1.2814	1.2758	1.2706	1.2655	1.2606	1.2556	1.2450	1.2345	1.2238	1.2015	1.1783
44	1.2922	1.2880	1.2824	1.2771	1.2719	1.2669	1.2618	1.2510	1.2403	1.2294	1.2067	1.1831
45	1.2990	1.2947	1.2890	1.2836	1.2783	1.2732	1.2680	1.2570	1.2461	1.2350	1.2119	1.1879
46	1.3058	1.3014	1.2955	1.2901	1.2847	1.2795	1.2742	1.2630	1.2519	1.2406	1.2171	1.1927
47	1.3126	1.3080	1.3021	1.2966	1.2911	1.2858	1.2804	1.2690	1.2577	1.2462	1.2223	1.1976
48	1.3194	1.3147	1.3087	1.3031	1.2975	1.2921	1.2867	1.2750	1.2635	1.2518	1.2275	1.2024
49	1.3263	1.3214	1.3153	1.3096	1.3040	1.2984	1.2929	1.2811	1.2693	1.2575	1.2328	1.2073
50	1.3327	1.3277	1.3215	1.3157	1.3100	1.3043	1.2987	1.2867	1.2748	1.2628	1.2377	1.2118
51	1.3391	1.3339	1.3277	1.3218	1.3160	1.3102	1.3045	1.2923	1.2802	1.2680	1.2425	1.2163
52	1.3454	1.3401	1.3338	1.3278	1.3219	1.3160	1.3102	1.2978	1.2856	1.2731	1.2473	1.2208
53	1.3517	1.3462	1.3399	1.3338	1.3278	1.3218	1.3159	1.3033	1.2909	1.2782	1.2521	1.2252
54	1.3579	1.3523	1.3459	1.3397	1.3336	1.3275	1.3215	1.3087	1.2961	1.2833	1.2568	1.2296
55	1.3640	1.3583	1.3518	1.3455	1.3393	1.3331	1.3270	1.3141	1.3013	1.2883	1.2615	1.2339
56	1.3700	1.3642	1.3576	1.3512	1.3449	1.3386	1.3324	1.3194	1.3064	1.2932	1.2661	1.2382
57	1.3759	1.3700	1.3634	1.3569	1.3505	1.3441	1.3377	1.3246	1.3114	1.2981	1.2706	1.2424
58	1.3818	1.3757	1.3691	1.3625	1.3560	1.3495	1.3430	1.3298	1.3164	1.3029	1.2751	1.2466
59	1.3875	1.3813	1.3747	1.3680	1.3614	1.3548	1.3482	1.3348	1.3213	1.3077	1.2795	1.2507
60	1.3931	1.3868	1.3801	1.3734	1.3667	1.3600	1.3533	1.3398	1.3261	1.3124	1.2839	1.2547
61	1.3986	1.3922	1.3855	1.3787	1.3719	1.3651	1.3583	1.3447	1.3308	1.3169	1.2881	1.2587
62	1.4039	1.3975	1.3907	1.3838	1.3769	1.3700	1.3632	1.3494	1.3354	1.3213	1.2922	1.2625
63	1.4091	1.4027	1.3958	1.3888	1.3818	1.3748	1.3679	1.3540	1.3398	1.3255	1.2962	1.2661
64		1.4078	1.4007	1.3936	1.3866	1.3795	1.3725					

TABLE 2-68 Nitric Acid (HNO_3) (*Concluded*)

%	0 °C	5 °C	10 °C	15 °C	20 °C	25 °C	30 °C	40 °C	50 °C	60 °C	80 °C	100 °C
65		1.4128	1.4055	1.3984	1.3913	1.3841	1.3770					
66		1.4177	1.4103	1.4031	1.3959	1.3887	1.3814					
67		1.4224	1.4150	1.4077	1.4004	1.3932	1.3857					
68		1.4271	1.4196	1.4122	1.4048	1.3976	1.3900					
69		1.4317	1.4241	1.4166	1.4091	1.4019	1.3942					
70		1.4362	1.4285	1.4210	1.4134	1.4061	1.3983					
71		1.4406	1.4328	1.4252	1.4176	1.4102	1.4023					
72		1.4449	1.4371	1.4294	1.4218	1.4142	1.4063					
73		1.4491	1.4413	1.4335	1.4258	1.4182	1.4103					
74		1.4532	1.4454	1.4376	1.4298	1.4221	1.4142					
75		1.4573	1.4494	1.4415	1.4337	1.4259	1.4180					
76		1.4613	1.4533	1.4454	1.4375	1.4296	1.4217					
77		1.4652	1.4572	1.4492	1.4413	1.4333	1.4253					
78		1.4690	1.4610	1.4529	1.4450	1.4369	1.4288					
79		1.4727	1.4647	1.4565	1.4486	1.4404	1.4323					
80		1.4764	1.4683	1.4601	1.4521	1.4439	1.4357					
81		1.4800	1.4718	1.4636	1.4555	1.4473	1.4391					
82		1.4835	1.4753	1.4670	1.4589	1.4507	1.4424					
83		1.4869	1.4787	1.4704	1.4622	1.4540	1.4456					
84		1.4903	1.4820	1.4737	1.4655	1.4572	1.4487					
85		1.4936	1.4852	1.4769	1.4686	1.4603	1.4518					
86		1.4968	1.4883	1.4799	1.4716	1.4633	1.4548					
87		1.4999	1.4913	1.4829	1.4745	1.4662	1.4577					
88		1.5029	1.4942	1.4858	1.4773	1.4690	1.4605					
89		1.5058	1.4970	1.4885	1.4800	1.4716	1.4631					
90		1.5085	1.4997	1.4911	1.4826	1.4741	1.4656					
91		1.5111	1.5023	1.4936	1.4850	1.4766	1.4681					
92		1.5136	1.5048	1.4960	1.4873	1.4789	1.4704					
93		1.5156	1.5068	1.4979	1.4892	1.4807	1.4722					
94		1.5177	1.5088	1.4999	1.4912	1.4826	1.4741					
95		1.5198	1.5109	1.5019	1.4932	1.4846	1.4761					
96		1.5220	1.5130	1.5040	1.4952	1.4867	1.4781					
97		1.5244	1.5152	1.5062	1.4974	1.4889	1.4802					
98		1.5278	1.5187	1.5096	1.5008	1.4922	1.4835					
99		1.5327	1.5235	1.5144	1.5056	1.4969	1.4881					
100		1.5402	1.5310	1.5217	1.5129	1.5040	1.4952					

**International Critical Tables*, vol. 3, pp. 58–59.

TABLE 2-69 Perchloric Acid ($HClO_4$)*

%	d_4^{15}	d_4^{20}	d_4^{25}	d_4^{50}	%	d_4^{15}	d_4^{20}	d_4^{50}
1	1.0050		1.0020	0.9933	28	1.1900	1.1851	1.1645
2	1.0109		1.0070	0.9986	30	1.2067	1.2013	1.1800
4	1.0228		1.0169	0.9906	32	1.2239	1.2183	1.1960
6	1.0348		1.0270	1.0205	34	1.2418	1.2359	1.2130
8	1.0471		1.0372	1.0320	36	1.2603	1.2542	1.2310
10	1.0597		1.0475	1.0440	38	1.2794	1.2732	1.2490
12	1.0726			1.0560	40	1.2991	1.2927	1.2680
14	1.0589			1.0680	45	1.3521	1.3450	1.3180
16	1.0995			1.0810	50	1.4103	1.4018	1.3730
18	1.1135			1.0940	55	1.4733	1.4636	1.4320
20	1.1279			1.1070	60	1.5389	1.5298	1.4950
22	1.1428			1.1205	65	1.6059	1.5986	1.5620
24	1.1581			1.1345	70	1.6736	1.6680	1.6290
26	1.1738	1.1697		1.1490				

**International Critical Tables*, vol. 3, p. 54.

TABLE 2-70 Phosphoric Acid (H_3PO_4)*

°C	2%	6%	14%	20%	26%	35%	50%	75%	100%
0	1.0113	1.0339	1.0811	1.1192					
10	1.0109	1.0330	1.0792	1.1167	1.1567	1.221	1.341		
20	1.0092	1.0309	1.0764	1.1134	1.1529	1.216	1.335	1.579	1.870
30	1.0065	1.0279	1.0728	1.1094	1.1484	1.211	1.329	1.572	1.862
40	1.0029	1.0241	1.0685	1.1048					

**International Critical Tables*, vol. 3, p. 61.

TABLE 2-71 Potassium Bicarbonate ($KHCO_3$)*

°C	1%	2%	4%	6%	8%	10%
0	1.0066	1.0134	1.0270			
10	1.0064	1.0132	1.0268			
15	1.0058	1.0125	1.0260	1.0396	1.0534	1.0674
20	1.0049	1.0117	1.0252			
30	1.0024	1.0092	1.0228			
40	0.9990	1.0058	1.0195			
50	0.9949	1.0017	1.0154			
60	0.9901	0.9969	1.0106			
80	0.9786	0.9855	0.9993			
100	0.9653	0.9722	0.9860			

**International Critical Tables*, vol. 3, p. 90.

TABLE 2-72 Potassium Bromide (KBr)*

%	d_4^{20}
1	1.0054
2	1.0127
6	1.0426
12	1.0903
20	1.1601
30	1.2593
40	1.3746

**International Critical Tables*, vol. 3, p. 87.

TABLE 2-73 Potassium Carbonate (K_2CO_3)*

%	0 °C	10 °C	20 °C	40 °C	60 °C	80 °C	100 °C
1	1.0094	1.0089	1.0072	1.0010	0.9919	0.9803	0.9670
2	1.0189	1.0182	1.0163	1.0098	1.0005	0.9889	0.9756
4	1.0381	1.0369	1.0345	1.0276	1.0180	1.0063	0.9951
8	1.0768	1.0746	1.0715	1.0640	1.0538	1.0418	1.0291
12	1.1160	1.1131	1.1096	1.1013	1.0906	1.0786	1.0663
16	1.1562	1.1530	1.1490	1.1399	1.1290	1.1170	1.1049
20	1.1977	1.1941	1.1898	1.1801	1.1690	1.1570	1.1451
24	1.2405	1.2366	1.2320	1.2219	1.2106	1.1986	1.1869
28	1.2846	1.2804	1.2756	1.2652	1.2538	1.2418	1.2301
30	1.3071	1.3028	1.2979	1.2873	1.2759	1.2640	1.2522
35	1.3646	1.3600	1.3548	1.3440	1.3324	1.3206	1.3089
40	1.4244	1.4195	1.4141	1.4029	1.3913	1.3795	1.3678
45	1.4867	1.4815	1.4759	1.4644	1.4528	1.4408	1.4290
50	1.5517	1.5462	1.5404	1.5285	1.5169	1.5048	1.4928

*International Critical Tables, vol. 3, p. 90.

TABLE 2-74 Potassium Chromate (K_2CrO_4)*

%	d_4^{15}	d_4^{18}
1	1.0073	1.0066
2	1.0155	1.0147
4	1.0321	1.0311
8	1.0659	1.0647
12	1.1009	1.0999
16		1.1366
20		1.1748
24		1.2147
28		1.2566
30		1.2784

*International Critical Tables, vol. 3, p. 92.

TABLE 2-75 Potassium Chlorate ($KClO_3$)*

°C	1%	2%	3%	4%
0	1.0061	1.0124	1.0189	1.0256
10	1.0059	1.0122	1.0187	1.0254
20	1.0045	1.0109	1.0174	1.0241
30	1.0020	1.0085	1.0151	1.0218
40	0.9986	1.0051	1.0116	1.0183
60	0.9895	0.9959	1.0024	1.0091
80	0.9781	0.9845	0.9910	0.9977
100	0.9646	0.9709	0.9774	0.9840

*International Critical Tables, vol. 3, p. 86.

TABLE 2-76 Potassium Chloride (KCl)*

%	0 °C	20 °C	25 °C	40 °C	60 °C	80 °C	100 °C
1.0	1.00661	1.00462	1.00342	0.99847	0.9894	0.9780	0.9646
2.0	1.01335	1.01103	1.00977	1.00471	0.9956	0.9842	0.9708
4.0	1.02690	1.02391	1.02255	1.01727	1.0080	0.9966	0.9634
8.0	1.05431	1.05003	1.04847	1.04278	1.0333	1.0219	1.0888
12.0	1.08222	1.07679	1.07506	1.06897	1.0592	1.0478	1.0350
16.0	1.11068	1.10434	1.10245	1.09600	1.0861	1.0746	1.0619
20.0	1.13973	1.13280	1.13072	1.12399	1.1138	1.1024	1.0897
24.0		1.16226	1.15995	1.15299	1.1425	1.1311	1.1185
28.0				1.18304	1.1723	1.1609	1.1483

%	110 °C	120 °C	130 °C	140 °C
3.79	0.9733	0.9663	0.9583	0.9502
7.45	0.9978	0.9899	0.9827	0.9745
13.62	1.0388	1.0313	1.0238	1.0159

*International Critical Tables, vol. 3, p. 87.

TABLE 2-77 Potassium Chrome Alum [$K_2Cr_2(SO_4)_4$]*

%	d_4^{15}
1	1.007
2	1.016
6	1.052
10	1.089
14	1.129
20	1.193
30	1.315
40	1.456
50	1.615

*International Critical Tables, vol. 3, p. 92.

TABLE 2-78 Potassium Hydroxide (KOH)*

%	d_4^{15}
1.0	1.0083
2.0	1.0175
4.0	1.0359
6.0	1.0544
8.0	1.0730
10.0	1.0918
15.0	1.1396
20.0	1.1884
25.0	1.2387
30.0	1.2905
35.0	1.3440
40.0	1.3991
45.0	1.4558
50.0	1.5143
51.7	1.5355 (sat'd. soln.)

*International Critical Tables, vol. 3, p. 86.

TABLE 2-79 Potassium Nitrate (KNO_3)*

%	0 °C	10 °C	20 °C	40 °C	60 °C	80 °C	100 °C
1	1.00654	1.00615	1.00447	0.99825	0.9890	0.9776	0.9641
2	1.01326	1.01262	1.01075	1.00430	0.9949	0.9834	0.9699
4	1.02677	1.02566	1.02344	1.01652	1.0068	0.9951	0.9816
8	1.05419	1.05226	1.04940	1.04152	1.0313	1.0192	1.0056
12	1.08221	1.07963	1.07620	1.06740	1.0567	1.0442	1.0304
16			1.10392	1.09432	1.0831	1.0703	1.0562
20			1.13261	1.12240	1.1106	1.0974	1.0831
24			1.16233	1.15175	1.1391	1.1256	1.1110

*International Critical Tables, vol. 3, p. 89.

TABLE 2-80 Potassium Dichromate ($K_2Cr_2O_7$)*

%	d_4^{20}
1	1.0052
2	1.0122
4	1.0264
6	1.0408
8	1.0554
10	1.0703

*International Critical Tables, vol. 3, p. 92.

TABLE 2-81 Potassium Sulfate (K_2SO_4)*

%	d_4^{20}
1	1.0063
2	1.0145
4	1.0310
6	1.0477
8	1.0646
10	1.0817

*International Critical Tables, vol. 3, p. 88.

TABLE 2-82 Potassium Sulfite (K_2SO_3)*

%	d_4^{15}
1	1.0073
2	1.0155
4	1.0322
8	1.0667
12	1.1026
16	1.1402
20	1.1793
24	1.2197
26	1.2404

*International Critical Tables, vol. 3, p. 87.

TABLE 2-83 Sodium Acetate ($NaC_2H_3O_2$)*

%	d_4^{20}
1	1.0033
2	1.0084
4	1.0186
8	1.0392
12	1.0598
18	1.0807
20	1.1021
26	1.1351
28	1.1462

*International Critical Tables, vol. 3, p. 83.

TABLE 2-84 Sodium Arsenate (Na_3AsO_4)*

%	d_4^{17}
1	1.0097
2	1.0207
4	1.0431
8	1.0892
10	1.1130
12	1.1373

*International Critical Tables, vol. 3, p. 82.

TABLE 2-85 Sodium Bichromate ($Na_2Cr_2O_7$)*

%	d_4^{15}
1	1.006
2	1.013
4	1.027
8	1.056
12	1.084
16	1.112
20	1.140
24	1.166
28	1.193
30	1.207
35	1.244
40	1.279
45	1.312
50	1.342

*International Critical Tables, vol. 3, p. 86.

TABLE 2-86 Sodium Bromide (NaBr)*

%	d_4^{20}
1	1.0060
2	1.0139
4	1.0298
8	1.0631
10	1.0803
12	1.0981
20	1.1745
30	1.2841
40	1.4138

*International Critical Tables, vol. 3, p. 80.

TABLE 2-87 Sodium Formate (HCOONa)*

%	d_4^{25}
1	1.003
2	1.009
4	1.022
8	1.048
12	1.074
16	1.100
20	1.127
24	1.155
28	1.184
30	1.199
35	1.236
40	1.274

*International Critical Tables, vol. 3, p. 83.

TABLE 2-88 Sodium Carbonate (Na_2CO_3)*

%	0 °C	10 °C	20 °C	30 °C	40 °C	60 °C	80 °C	100 °C
1	1.0109	1.0103	1.0086	1.0058	1.0022	0.9929	0.9814	0.9683
2	1.0219	1.0210	1.0190	1.0159	1.0122	1.0027	0.9910	0.9782
4	1.0439	1.0423	1.0398	1.0363	1.0323	1.0223	1.0105	0.9980
8	1.0878	1.0850	1.0816	1.0775	1.0732	1.0625	1.0503	1.0380
12	1.1319	1.1284	1.1244	1.1200	1.1150	1.1039	1.0914	1.0787
14	1.1543	1.1506	1.1463	1.1417	1.1365	1.1251	1.1125	1.0996
16				1.1636				
18				1.1859				
20				1.2086				
24				1.2552				
28				1.3031				
30				1.3274				

International Critical Tables, vol. 3, pp. 82–83.

TABLE 2-89 Sodium Chlorate ($NaClO_3$)*

%	d_4^{18}	%	d_4^{18}
1	1.0053	18	1.1288
2	1.0121	20	1.1449
4	1.0258	22	1.1614
6	1.0397	24	1.1782
8	1.0538	26	1.1953
10	1.0681	28	1.2128
12	1.0827	30	1.2307
14	1.0977	32	1.2491
16	1.1131	34	1.2680

International Critical Tables, vol. 3, p. 80.

TABLE 2-90 Sodium Chloride (NaCl)*

%	0 °C	10 °C	25 °C	40 °C	60 °C	80 °C	100 °C
1	1.00747	1.00707	1.00409	0.99908	0.9900	0.9785	0.9651
2	1.01509	1.01442	1.01112	1.00593	0.9967	0.9852	0.9719
4	1.03038	1.02920	1.02530	1.01977	1.0103	0.9988	0.9855
8	1.06121	1.05907	1.05412	1.04798	1.0381	1.0264	1.0134
12	1.09244	1.08946	1.08365	1.07699	1.0667	1.0549	1.0420
16	1.12419	1.12056	1.11401	1.10688	1.0962	1.0842	1.0713
20	1.15663	1.15254	1.14533	1.13774	1.1268	1.1146	1.1017
24	1.18999	1.18557	1.17776	1.16971	1.1584	1.1463	1.1331
26	1.20709	1.20254	1.19443	1.18614	1.1747	1.1626	1.1492

International Critical Tables, vol. 3, p. 79.

TABLE 2-91 Sodium Chromate (Na_2CrO_4)*

%	d_4^{18}
1	1.0074
2	1.0164
4	1.0344
8	1.0718
12	1.1110
16	1.1518
20	1.1942
24	1.2383
26	1.2611

International Critical Tables, vol. 3, p. 86.

TABLE 2-92 Sodium Hydroxide (NaOH)*

%	0 °C	15 °C	20 °C	40 °C	60 °C	80 °C	100 °C
1	1.0124	1.01065	1.0095	1.0033	0.9941	0.9824	0.9693
2	1.0244	1.02198	1.0207	1.0139	1.0045	0.9929	0.9797
4	1.0482	1.04441	1.0428	1.0352	1.0254	1.0139	1.0009
8	1.0943	1.08887	1.0869	1.0780	1.0676	1.0560	1.0432
12	1.1399	1.13327	1.1309	1.1210	1.1101	1.0983	1.0855
16	1.1849	1.17761	1.1751	1.1645	1.1531	1.1408	1.1277
20	1.2296	1.22183	1.2191	1.2079	1.1960	1.1833	1.1700
24	1.2741	1.26582	1.2629	1.2512	1.2388	1.2259	1.2124
28	1.3182	1.3094	1.3064	1.2942	1.2814	1.2682	1.2546
32	1.3614	1.3520	1.3490	1.3362	1.3232	1.3097	1.2960
36	1.4030	1.3933	1.3900	1.3768	1.3634	1.3498	1.3360
40	1.4435	1.4334	1.4300	1.4164	1.4027	1.3889	1.3750
44	1.4825	1.4720	1.4685	1.4545	1.4405	1.4266	1.4127
48	1.5210	1.5102	1.5065	1.4922	1.4781	1.4641	1.4503
50	1.5400	1.5290	1.5253	1.5109	1.4967	1.4827	1.4690

International Critical Tables, vol. 3, p. 79.

TABLE 2-93 Sodium Nitrate ($NaNO_3$)*

%	0 °C	20 °C	40 °C	60 °C	80 °C	100 °C
1	1.0071	1.0049	0.9986	0.9894	0.9779	0.9644
2	1.0144	1.0117	1.0050	0.9956	0.9840	0.9704
4	1.0290	1.0254	1.0180	1.0082	0.9964	0.9826
8	1.0587	1.0532	1.0447	1.0340	1.0218	1.0078
12	1.0891	1.0819	1.0724	1.0609	1.0481	1.0340
16	1.1203	1.1118	1.1013	1.0892	1.0757	1.0614
20	1.1526	1.1429	1.1314	1.1187	1.1048	1.0901
24	1.1860	1.1752	1.1629	1.1496	1.1351	1.1200
28	1.2204	1.2085	1.1955	1.1816	1.1667	1.1513
30	1.2380	1.2256	1.2122	1.1980	1.1830	1.1674
35	1.2834	1.2701	1.2560	1.2413	1.2258	1.2100
40	1.3316	1.3175	1.3027	1.2875	1.2715	1.2555
45		1.3683	1.3528	1.3371	1.3206	1.3044

International Critical Tables, vol. 3, p. 82.

TABLE 2-94 Sodium Nitrite ($NaNO_2$)*

%	d_4^{15}
1	1.0058
2	1.0125
4	1.0260
8	1.0535
12	1.0816
16	1.1103
20	1.1394

International Critical Tables, vol. 3, p. 82.

TABLE 2-95 Sodium Silicates*

	Concentration, %												
	1	2	4	8	10	14	20	24	30	36	40	45	50
Formula	d_4^{20}												
$Na_2O/3.9SiO_2$	1.006	1.014	1.030	1.063	1.080	1.116	1.172	1.211	1.275				
$Na_2O/3.36SiO_2$	1.006	1.014	1.030	1.065	1.083	1.120	1.179	1.222	1.290	1.365			
$Na_2O/2.40SiO_2$	1.007	1.016	1.034	1.071	1.090	1.130							
$Na_2O/2.44SiO_2$									1.309	1.387	1.445		
$Na_2O/2.06SiO_2$	1.007	1.016	1.035	1.073	1.093	1.134	1.200	1.247	1.321	1.397	1.450	1.520	1.594
$Na_2O/1.69SiO_2$	1.007	1.017	1.036	1.077	1.098	1.141	1.210	1.259	1.337	1.424			

International Critical Tables, vol. 3, p. 85.

TABLE 2-96 Sodium Sulfate (Na_2SO_4)*

%	0 °C	20 °C	30 °C	40 °C	60 °C	80 °C	100 °C
1	1.0094	1.0073	1.0046	1.0010	0.9919	0.9805	0.9671
2	1.0189	1.0164	1.0135	1.0098	1.0007	0.9892	0.9758
4	1.0381	1.0348	1.0315	1.0276	1.0184	1.0068	0.9934
8	1.0773	1.0724	1.0682	1.0639	1.0544	1.0426	1.0292
12	1.1174	1.1109	1.1062	1.1015	1.0915	1.0795	1.0661
16	1.1585	1.1586	1.1456	1.1406	1.1299	1.1176	1.1042
20	1.2008	1.1915	1.1865	1.1813	1.1696	1.1569	
24	1.2443	1.2336	1.2292	1.2237			

International Critical Tables, vol. 3, p. 81.

TABLE 2-97 Sodium Sulfide (Na_2S)*

%	d_4^{18}
1	1.0098
2	1.0211
4	1.0440
8	1.0907
12	1.1388
16	1.1885
18	1.2140

International Critical Tables, vol. 3, p. 81.

TABLE 2-98 Sodium Sulfite (Na_2SO_3)*

%	d_4^{19}
1	1.0078
2	1.0172
4	1.0363
8	1.0751
12	1.1146
16	1.1549
18	1.1755

International Critical Tables, vol. 3, p. 81.

TABLE 2-99 Sodium Thiosulfate ($Na_2S_2O_3$)*

%	d_4^{20}
1	1.0065
2	1.0148
4	1.0315
8	1.0654
12	1.1003
16	1.1365
20	1.1740
24	1.2128
28	1.2532
30	1.2739
35	1.3273
40	1.3827

International Critical Tables, vol. 3, p. 81.

TABLE 2-100 Sodium Thiosulfate Pentahydrate ($Na_2S_2O_3 \cdot 5H_2O$)

%	d_4^{19}
1	1.0052
2	1.0105
4	1.0211
8	1.0423
12	1.0639
16	1.0863
20	1.1087
24	1.1322
28	1.1558
30	1.1676
40	1.2297
50	1.2954

TABLE 2-101 Stannic Chloride ($SnCl_4$)*

%	d_4^{15}
1	1.007
2	1.015
4	1.031
8	1.064
12	1.099
16	1.135
20	1.173
24	1.212
28	1.255
30	1.278
35	1.337
40	1.403
45	1.475
50	1.555
55	1.644
60	1.742
65	1.851
70	1.971

International Critical Tables, vol. 3, p. 63.

TABLE 2-102 Stannous Chloride ($SnCl_2$)*

%	d_4^{15}
1	1.0068
2	1.0146
4	1.0306
8	1.0638
12	1.0986
16	1.1353
20	1.1743
24	1.2159
28	1.2603
30	1.2837
35	1.3461
40	1.4145
45	1.4897
50	1.5729
55	1.6656
60	1.7695
65	1.8865

International Critical Tables, vol. 3, p. 63.

TABLE 2-103 Sulfuric Acid (H_2SO_4)*

%	0 °C	10 °C	15 °C	20 °C	25 °C	30 °C	40 °C	50 °C	60 °C	80 °C	100 °C
1	1.0074	1.0068	1.0060	1.0051	1.0038	1.0022	0.9986	0.9944	0.9895	0.9779	0.9645
2	1.0147	1.0138	1.0129	1.0118	1.0104	1.0087	1.0050	1.0006	0.9956	0.9839	0.9705
3	1.0219	1.0206	1.0197	1.0184	1.0169	1.0152	1.0113	1.0067	1.0017	0.9900	0.9766
4	1.0291	1.0275	1.0264	1.0250	1.0234	1.0216	1.0176	1.0129	1.0078	0.9961	0.9827
5	1.0364	1.0344	1.0332	1.0317	1.0300	1.0281	1.0240	1.0192	1.0140	1.0022	0.9888
6	1.0437	1.0414	1.0400	1.0385	1.0367	1.0347	1.0305	1.0256	1.0203	1.0084	0.9950
7	1.0511	1.0485	1.0469	1.0453	1.0434	1.0414	1.0371	1.0321	1.0266	1.0146	1.0013
8	1.0585	1.0556	1.0539	1.0522	1.0502	1.0481	1.0437	1.0386	1.0330	1.0209	1.0076
9	1.0660	1.0628	1.0610	1.0591	1.0571	1.0549	1.0503	1.0451	1.0395	1.0273	1.0140
10	1.0735	1.0700	1.0681	1.0661	1.0640	1.0617	1.0570	1.0517	1.0460	1.0338	1.0204
11	1.0810	1.0773	1.0753	1.0731	1.0710	1.0686	1.0637	1.0584	1.0526	1.0403	1.0269
12	1.0886	1.0846	1.0825	1.0802	1.0780	1.0756	1.0705	1.0651	1.0593	1.0469	1.0335
13	1.0962	1.0920	1.0898	1.0874	1.0851	1.0826	1.0774	1.0719	1.0661	1.0536	1.0402
14	1.1039	1.0994	1.0971	1.0947	1.0922	1.0897	1.0844	1.0788	1.0729	1.0603	1.0469
15	1.1116	1.1069	1.1045	1.1020	1.0994	1.0968	1.0914	1.0857	1.0798	1.0671	1.0537
16	1.1194	1.1145	1.1120	1.1094	1.1067	1.1040	1.0985	1.0927	1.0868	1.0740	1.0605
17	1.1272	1.1221	1.1195	1.1168	1.1141	1.1113	1.1057	1.0998	1.0938	1.0809	1.0674
18	1.1351	1.1298	1.1271	1.1243	1.1215	1.1187	1.1129	1.1070	1.1009	1.0879	1.0744
19	1.1430	1.1375	1.1347	1.1318	1.1290	1.1261	1.1202	1.1142	1.1081	1.0950	1.0814
20	1.1510	1.1453	1.1424	1.1394	1.1365	1.1335	1.1275	1.1215	1.1153	1.1021	1.0885
21	1.1590	1.1531	1.1501	1.1471	1.1441	1.1410	1.1349	1.1288	1.1226	1.1093	1.0957
22	1.1670	1.1609	1.1579	1.1548	1.1517	1.1486	1.1424	1.1362	1.1299	1.1166	1.1029
23	1.1751	1.1688	1.1657	1.1626	1.1594	1.1563	1.1500	1.1437	1.1373	1.1239	1.1102
24	1.1832	1.1768	1.1736	1.1704	1.1672	1.1640	1.1576	1.1512	1.1448	1.1313	1.1176
25	1.1914	1.1848	1.1816	1.1783	1.1750	1.1718	1.1653	1.1588	1.1523	1.1388	1.1250
26	1.1996	1.1929	1.1896	1.1862	1.1829	1.1796	1.1730	1.1665	1.1599	1.1463	1.1325
27	1.2078	1.2010	1.1976	1.1942	1.1909	1.1875	1.1808	1.1742	1.1676	1.1539	1.1400
28	1.2160	1.2091	1.2057	1.2023	1.1989	1.1955	1.1887	1.1820	1.1753	1.1616	1.1476
29	1.2243	1.2173	1.2138	1.2104	1.2069	1.2035	1.1966	1.1898	1.1831	1.1693	1.1553
30	1.2326	1.2255	1.2220	1.2185	1.2150	1.2115	1.2046	1.1977	1.1909	1.1771	1.1630
31	1.2409	1.2338	1.2302	1.2267	1.2232	1.2196	1.2126	1.2057	1.1988	1.1849	1.1708
32	1.2493	1.2421	1.2385	1.2349	1.2314	1.2278	1.2207	1.2137	1.2068	1.1928	1.1787
33	1.2577	1.2504	1.2468	1.2432	1.2396	1.2360	1.2289	1.2218	1.2148	1.2008	1.1866
34	1.2661	1.2588	1.2552	1.2515	1.2479	1.2443	1.2371	1.2300	1.2229	1.2088	1.1946
35	1.2746	1.2672	1.2636	1.2599	1.2563	1.2526	1.2454	1.2383	1.2311	1.2169	1.2027
36	1.2831	1.2757	1.2720	1.2684	1.2647	1.2610	1.2538	1.2466	1.2394	1.2251	1.2109
37	1.2917	1.2843	1.2805	1.2769	1.2732	1.2695	1.2622	1.2550	1.2477	1.2334	1.2192
38	1.3004	1.2929	1.2891	1.2855	1.2818	1.2780	1.2707	1.2635	1.2561	1.2418	1.2276
39	1.3091	1.3016	1.2978	1.2941	1.2904	1.2866	1.2793	1.2720	1.2646	1.2503	1.2361
40	1.3179	1.3103	1.3065	1.3028	1.2991	1.2953	1.2880	1.2806	1.2732	1.2589	1.2446
41	1.3268	1.3191	1.3153	1.3116	1.3079	1.3041	1.2967	1.2893	1.2819	1.2675	1.2532
42	1.3357	1.3280	1.3242	1.3205	1.3167	1.3129	1.3055	1.2981	1.2907	1.2762	1.2619
43	1.3447	1.3370	1.3332	1.3294	1.3256	1.3218	1.3144	1.3070	1.2996	1.2850	1.2707
44	1.3538	1.3461	1.3423	1.3384	1.3346	1.3308	1.3234	1.3160	1.3086	1.2939	1.2796
45	1.3630	1.3553	1.3515	1.3476	1.3437	1.3399	1.3325	1.3251	1.3177	1.3029	1.2886
46	1.3724	1.3646	1.3608	1.3569	1.3530	1.3492	1.3417	1.3343	1.3269	1.3120	1.2976
47	1.3819	1.3740	1.3702	1.3663	1.3624	1.3586	1.3510	1.3435	1.3362	1.3212	1.3067
48	1.3915	1.3835	1.3797	1.3758	1.3719	1.3680	1.3604	1.3528	1.3455	1.3305	1.3159
49	1.4012	1.3931	1.3893	1.3854	1.3814	1.3775	1.3699	1.3623	1.3549	1.3399	1.3253
50	1.4110	1.4029	1.3990	1.3951	1.3911	1.3872	1.3795	1.3719	1.3644	1.3494	1.3348
51	1.4209	1.4128	1.4088	1.4049	1.4009	1.3970	1.3893	1.3816	1.3740	1.3590	1.3444
52	1.4310	1.4228	1.4188	1.4148	1.4109	1.4069	1.3991	1.3914	1.3837	1.3687	1.3540
53	1.4412	1.4329	1.4289	1.4248	1.4209	1.4169	1.4091	1.4013	1.3936	1.3785	1.3637
54	1.4515	1.4431	1.4391	1.4350	1.4310	1.4270	1.4191	1.4113	1.4036	1.3884	1.3735
55	1.4619	1.4535	1.4494	1.4453	1.4412	1.4372	1.4293	1.4214	1.4137	1.3984	1.3834
56	1.4724	1.4640	1.4598	1.4557	1.4516	1.4475	1.4396	1.4317	1.4239	1.4085	1.3934
57	1.4830	1.4746	1.4703	1.4662	1.4621	1.4580	1.4500	1.4420	1.4342	1.4187	1.4035
58	1.4937	1.4852	1.4809	1.4768	1.4726	1.4685	1.4604	1.4524	1.4446	1.4290	1.4137
59	1.5045	1.4959	1.4916	1.4875	1.4832	1.4791	1.4709	1.4629	1.4551	1.4393	1.4240
60	1.5154	1.5067	1.5024	1.4983	1.4940	1.4898	1.4816	1.4735	1.4656	1.4497	1.4344
61	1.5264	1.5177	1.5133	1.5091	1.5048	1.5006	1.4923	1.4842	1.4762	1.4602	1.4449
62	1.5375	1.5287	1.5243	1.5200	1.5157	1.5115	1.5031	1.4950	1.4869	1.4708	1.4554
63	1.5487	1.5398	1.5354	1.5310	1.5267	1.5225	1.5140	1.5058	1.4977	1.4815	1.4660
64	1.5600	1.5510	1.5465	1.5421	1.5378	1.5335	1.5250	1.5167	1.5086	1.4923	1.4766

TABLE 2-103 Sulfuric Acid (H_2SO_4) (*Concluded*)

%	0 °C	10 °C	15 °C	20 °C	25 °C	30 °C	40 °C	50 °C	60 °C	80 °C	100 °C
65	1.5714	1.5623	1.5578	1.5533	1.5490	1.5446	1.5361	1.5277	1.5195	1.5031	1.4873
66	1.5828	1.5736	1.5691	1.5646	1.5602	1.5558	1.5472	1.5388	1.5305	1.5140	1.4981
67	1.5943	1.5850	1.5805	1.5760	1.5715	1.5671	1.5584	1.5499	1.5416	1.5249	1.5089
68	1.6059	1.5965	1.5920	1.5874	1.5829	1.5785	1.5697	1.5611	1.5528	1.5359	1.5198
69	1.6176	1.6081	1.6035	1.5989	1.5944	1.5899	1.5811	1.5724	1.5640	1.5470	1.5307
70	1.6293	1.6198	1.6151	1.6105	1.6059	1.6014	1.5925	1.5838	1.5753	1.5582	1.5417
71	1.6411	1.6315	1.6268	1.6221	1.6175	1.6130	1.6040	1.5952	1.5867	1.5694	1.5527
72	1.6529	1.6433	1.6385	1.6338	1.6292	1.6246	1.6155	1.6067	1.5981	1.5806	1.5637
73	1.6648	1.6551	1.6503	1.6456	1.6409	1.6363	1.6271	1.6182	1.6095	1.5919	1.5747
74	1.6768	1.6670	1.6622	1.6574	1.6526	1.6480	1.6387	1.6297	1.6209	1.6031	1.5857
75	1.6888	1.6789	1.6740	1.6692	1.6644	1.6597	1.6503	1.6412	1.6322	1.6142	1.5966
76	1.7008	1.6908	1.6858	1.6810	1.6761	1.6713	1.6619	1.6526	1.6435	1.6252	1.6074
77	1.7128	1.7026	1.6976	1.6927	1.6878	1.6829	1.6734	1.6640	1.6547	1.6361	1.6181
78	1.7247	1.7144	1.7093	1.7043	1.6994	1.6944	1.6847	1.6751	1.6657	1.6469	1.6286
79	1.7365	1.7261	1.7209	1.7158	1.7108	1.7058	1.6959	1.6862	1.6766	1.6575	1.6390
80	1.7482	1.7376	1.7323	1.7272	1.7221	1.7170	1.7069	1.6971	1.6873	1.6680	1.6493
81	1.7597	1.7489	1.7435	1.7383	1.7331	1.7279	1.7177	1.7077	1.6978	1.6782	1.6594
82	1.7709	1.7599	1.7544	1.7491	1.7437	1.7385	1.7281	1.7180	1.7080	1.6882	1.6692
83	1.7815	1.7704	1.7649	1.7594	1.7540	1.7487	1.7382	1.7279	1.7179	1.6979	1.6787
84	1.7916	1.7804	1.7748	1.7693	1.7639	1.7585	1.7479	1.7375	1.7274	1.7072	1.6878
85	1.8009	1.7897	1.7841	1.7786	1.7732	1.7678	1.7571	1.7466	1.7364	1.7161	1.6966
86	1.8095	1.7983	1.7927	1.7872	1.7818	1.7763	1.7657	1.7552	1.7449	1.7245	1.7050
87	1.8173	1.8061	1.8006	1.7951	1.7897	1.7842	1.7736	1.7632	1.7529	1.7324	1.7129
88	1.8243	1.8132	1.8077	1.8022	1.7968	1.7914	1.7809	1.7705	1.7602	1.7397	1.7202
89	1.8306	1.8195	1.8141	1.8087	1.8033	1.7979	1.7874	1.7770	1.7669	1.7464	1.7269
90	1.8361	1.8252	1.8198	1.8144	1.8091	1.8038	1.7933	1.7829	1.7729	1.7525	1.7331
91	1.8410	1.8302	1.8248	1.8195	1.8142	1.8090	1.7986	1.7883	1.7783	1.7581	1.7388
92	1.8453	1.8346	1.8293	1.8240	1.8188	1.8136	1.8033	1.7932	1.7832	1.7633	1.7439
93	1.8490	1.8384	1.8331	1.8279	1.8227	1.8176	1.8074	1.7974	1.7876	1.7681	1.7485
94	1.8520	1.8415	1.8363	1.8312	1.8260	1.8210	1.8109	1.8011	1.7914		
95	1.8544	1.8439	1.8388	1.8337	1.8286	1.8236	1.8137	1.8040	1.7944		
96	1.8560	1.8457	1.8406	1.8355	1.8305	1.8255	1.8157	1.8060	1.7965		
97	1.8569	1.8466	1.8414	1.8364	1.8314	1.8264	1.8166	1.8071	1.7977		
98	1.8567	1.8463	1.8411	1.8361	1.8310	1.8261	1.8163	1.8068	1.7976		
99	1.8551	1.8445	1.8393	1.8342	1.8292	1.8242	1.8145	1.8050	1.7958		
100	1.8517	1.8409	1.8357	1.8305	1.8255	1.8205	1.8107	1.8013	1.7922		

%	$d_4^{5.96}$	%	$d_4^{13.00}$	$d_4^{18.00}$
0.005	1.000 0140	0.05	0.999 810	0.999 028
.01	1.000 0576	0.1	1.000 185	0.999 400
.02	1.000 1434	0.2	1.000 912	1.000 119
.03	1.000 2276	0.3	1.001 623	1.000 820
.04	1.000 3104	0.4	1.002 326	1.001 512
.05	1.000 3920	0.5	1.003 023	1.002 197
.06	1.000 4726	0.6	1.003 716	1.002 877
.07	1.000 5523	0.8	1.005 090	1.004 227
.08	1.000 6313	1.0	1.006 452	1.005 570
.09	1.000 7098	1.2	1.007 807	1.006 909
.10	1.000 7880	1.4	1.009 159	1.008 247
.15	1.001 1732	1.6	1.010 510	1.009 583
.20	1.001 5514	1.8	1.011 860	1.010 918
.25	1.001 9254	2.0	1.013 209	1.012 252
.30	1.002 2961	2.2	1.014 557	1.013 586
.35	1.002 6639	2.4	1.015 904	1.014 919
.40	1.003 0292			
.45	1.003 3923			
.50	1.003 7534			

International Critical Tables, vol. 3, pp. 56–57.

TABLE 2-104 Zinc Bromide ($ZnBr_2$)*

%	0 °C	20 °C	40 °C	60 °C	80 °C	100 °C
2	1.0188	1.0167	1.0102	1.0008	0.9890	0.9751
4	1.0381	1.0354	1.0285	1.0187	1.0065	0.9921
8	1.0777	1.0738	1.0660	1.0554	1.0422	1.0270
12	1.1186	1.1135	1.1046	1.0932	1.0789	1.0629
16	1.1609	1.1544	1.1445	1.1320	1.1169	1.1000
20	1.2043	1.1965	1.1855	1.1720	1.1560	1.1382
30	1.3288	1.3170	1.3030	1.2868	1.2688	1.2489
40	1.477	1.462	1.445	1.427	1.406	1.385
50	1.661	1.643	1.623	1.602	1.579	1.555
60	1.891	1.869	1.845	1.822	1.797	1.771
65	2.026	2.002	1.976	1.951	1.924	1.898

*International Critical Tables, vol. 3, p. 64.

TABLE 2-105 Zinc Chloride ($ZnCl_2$)*

%	0 °C	20 °C	40 °C	60 °C	80 °C	100 °C
2	1.0192	1.0167	1.0099	1.0003	0.9882	0.9739
4	1.0384	1.0350	1.0274	1.0172	1.0044	0.9894
8	1.0769	1.0715	1.0624	1.0508	1.0369	1.0211
12	1.1159	1.1085	1.0980	1.0853	1.0704	1.0541
16	1.1558	1.1468	1.1350	1.1212	1.1055	1.0888
20	1.1970	1.1866	1.1736	1.1590	1.1428	1.1255
30	1.3062	1.2928	1.2778	1.2614	1.2438	1.2252
40	1.4329	1.4173	1.4003	1.3824	1.3637	1.3441
50	1.5860	1.5681	1.5495	1.5300	1.5097	1.4892
60		1.749				
70		1.962				

*International Critical Tables, vol. 3, p. 64.

TABLE 2-106 Zinc Nitrate [$Zn(NO_3)_2$]*

%	18 °C	%	18 °C
2	1.0154	18	1.1652
4	1.0322	20	1.1865
6	1.0496	25	1.2427
8	1.0675	30	1.3029
10	1.0859	35	1.3678
12	1.1048	40	1.4378
14	1.1244	45	1.5134
16	1.1445	50	1.5944

*International Critical Tables, vol. 3, p. 65.

TABLE 2-107 Zinc Sulfate ($ZnSO_4$)*

%	20 °C
2	1.019
4	1.0403
6	1.0620
8	1.0842
10	1.1071
12	1.1308
14	1.1553
16	1.1806

*International Critical Tables, vol. 3, p. 65.

DENSITIES OF AQUEOUS ORGANIC SOLUTIONS*

UNITS AND UNITS CONVERSIONS

Unless otherwise noted, densities are given in grams per cubic centimeter. To convert to pounds per cubic foot, multiply by 62.43.

$$°F = \tfrac{9}{5}\,°C + 32$$

From *International Critical Tables,* vol. 3, pp. 115–129 unless otherwise stated. All compositions are in weight percent in vacuo. All density values are d_4^t = g/mL in vacuo.

*For gasoline and aircraft fuels see Hibbard, NACA Res. Mem. E56I21 (declassified 1958).

TABLE 2-108 Formic Acid (HCOOH)

%	0 °C	15 °C	20 °C	30 °C	%	0 °C	15 °C	20 °C	30 °C	%	0 °C	15 °C	20 °C	30 °C	%	0 °C	15 °C	20 °C	30 °C
0	0.9999	0.9991	0.9982	0.9957	25	1.0706	1.0627	1.0609	1.0540	50	1.1349	1.1225	1.1207	1.1098	75	1.1953	1.1794	1.1769	1.1636
1	1.0028	1.0019	1.0019	0.9980	26	1.0733	1.0652	1.0633	1.0564	51	1.1374	1.1248	1.1223	1.1120	76	1.1976	1.1816	1.1785	1.1656
2	1.0059	1.0045	1.0044	1.0004	27	1.0760	1.0678	1.0656	1.0587	52	1.1399	1.1271	1.1244	1.1142	77	1.1999	1.1837	1.1801	1.1676
3	1.0090	1.0072	1.0070	1.0028	28	1.0787	1.0702	1.0681	1.0609	53	1.1424	1.1294	1.1269	1.1164	78	1.2021	1.1859	1.1818	1.1697
4	1.0120	1.0100	1.0093	1.0053	29	1.0813	1.0726	1.0705	1.0632	54	1.1448	1.1318	1.1295	1.1186	79	1.2043	1.1881	1.1837	1.1717
5	1.0150	1.0124	1.0115	1.0075	30	1.0839	1.0750	1.0729	1.0654	55	1.1472	1.1341	1.1320	1.1208	80	1.2065	1.1902	1.1806	1.1737
6	1.0179	1.0151	1.0141	1.0101	31	1.0866	1.0774	1.0753	1.0676	56	1.1497	1.1365	1.1342	1.1230	81	1.2088	1.1924	1.1876	1.1758
7	1.0207	1.0177	1.0170	1.0125	32	1.0891	1.0798	1.0777	1.0699	57	1.1523	1.1388	1.1361	1.1253	82	1.2110	1.1944	1.1896	1.1778
8	1.0237	1.0204	1.0196	1.0149	33	1.0916	1.0821	1.0800	1.0721	58	1.1548	1.1411	1.1381	1.1274	83	1.2132	1.1965	1.1914	1.1798
9	1.0266	1.0230	1.0221	1.0173	34	1.0941	1.0844	1.0823	1.0743	59	1.1573	1.1434	1.1401	1.1295	84	1.2154	1.1985	1.1929	1.1817
10	1.0295	1.0256	1.0246	1.0197	35	1.0966	1.0867	1.0847	1.0766	60	1.1597	1.1458	1.1424	1.1317	85	1.2176	1.2005	1.1953	1.1837
11	1.0324	1.0281	1.0271	1.0221	36	1.0993	1.0892	1.0871	1.0788	61	1.1621	1.1481	1.1448	1.1338	86	1.2196	1.2025	1.1976	1.1856
12	1.0351	1.0306	1.0296	1.0244	37	1.1018	1.0916	1.0895	1.0810	62	1.1645	1.1504	1.1473	1.1360	87	1.2217	1.2045	1.1994	1.1875
13	1.0379	1.0330	1.0321	1.0267	38	1.1043	1.0940	1.0919	1.0832	63	1.1669	1.1526	1.1493	1.1382	88	1.2237	1.2064	1.2012	1.1893
14	1.0407	1.0355	1.0345	1.0290	39	1.1069	1.0964	1.0940	1.0854	64	1.1694	1.1549	1.1517	1.1403	89	1.2258	1.2084	1.2028	1.1910
15	1.0435	1.0380	1.0370	1.0313	40	1.1095	1.0988	1.0963	1.0876	65	1.1718	1.1572	1.1543	1.1425	90	1.2278	1.2102	1.2044	1.1927
16	1.0463	1.0405	1.0393	1.0336	41	1.1122	1.1012	1.0990	1.0898	66	1.1742	1.1595	1.1565	1.1446	91	1.2297	1.2121	1.2059	1.1945
17	1.0491	1.0430	1.0417	1.0358	42	1.1148	1.1036	1.1015	1.0920	67	1.1766	1.1618	1.1584	1.1467	92	1.2316	1.2139	1.2078	1.1961
18	1.0518	1.0455	1.0441	1.0381	43	1.1174	1.1060	1.1038	1.0943	68	1.1790	1.1640	1.1604	1.1489	93	1.2335	1.2157	1.2099	1.1978
19	1.0545	1.0480	1.0464	1.0404	44	1.1199	1.1084	1.1062	1.0965	69	1.1813	1.1663	1.1628	1.1510	94	1.2354	1.2174	1.2117	1.1994
20	1.0571	1.0505	1.0488	1.0427	45	1.1224	1.1109	1.1085	1.0987	70	1.1835	1.1685	1.1655	1.1531	95	1.2372	1.2191	1.2140	1.2008
21	1.0598	1.0532	1.0512	1.0451	46	1.1249	1.1133	1.1108	1.1009	71	1.1858	1.1707	1.1677	1.1552	96	1.2390	1.2208	1.2158	1.2022
22	1.0625	1.0556	1.0537	1.0473	47	1.1274	1.1156	1.1130	1.1031	72	1.1882	1.1729	1.1702	1.1573	97	1.2408	1.2224	1.2170	1.2036
23	1.0652	1.0580	1.0561	1.0496	48	1.1299	1.1179	1.1157	1.1053	73	1.1906	1.1751	1.1728	1.1595	98	1.2425	1.2240	1.2183	1.2048
24	1.0679	1.0604	1.0585	1.0518	49	1.1324	1.1202	1.1185	1.1076	74	1.1929	1.1773	1.1752	1.1615	99	1.2441	1.2257	1.2202	1.2061
															100	1.2456	1.2273	1.2212	1.2073

TABLE 2-109 Acetic Acid (CH_3COOH)

%	0 °C	10 °C	15 °C	20 °C	25 °C	30 °C	40 °C	%	0 °C	10 °C	15 °C	20 °C	25 °C	30 °C	40 °C
0	0.9999	0.9997	0.9991	0.9982	0.9971	0.9957	0.9922	50	1.0729	1.0654	1.0613	1.0575	1.0534	1.0492	1.0408
1	1.0016	1.0013	1.0006	0.9996	0.9987	0.9971	0.9934	51	1.0738	1.0663	1.0622	1.0582	1.0542	1.0499	1.0414
2	1.0033	1.0029	1.0021	1.0012	1.0000	0.9984	0.9946	52	1.0748	1.0671	1.0629	1.0590	1.0549	1.0506	1.0421
3	1.0051	1.0044	1.0036	1.0025	1.0013	0.9997	0.9958	53	1.0757	1.0679	1.0637	1.0597	1.0555	1.0512	1.0427
4	1.0070	1.0060	1.0051	1.0040	1.0027	1.0011	0.9970	54	1.0765	1.0687	1.0644	1.0604	1.0562	1.0518	1.0432
5	1.0088	1.0076	1.0066	1.0055	1.0041	1.0024	0.9982	55	1.0774	1.0694	1.0651	1.0611	1.0568	1.0525	1.0438
6	1.0106	1.0092	1.0081	1.0069	1.0055	1.0037	0.9994	56	1.0782	1.0701	1.0658	1.0618	1.0574	1.0531	1.0443
7	1.0124	1.0108	1.0096	1.0083	1.0068	1.0050	1.0006	57	1.0790	1.0708	1.0665	1.0624	1.0580	1.0536	1.0448
8	1.0142	1.0124	1.0111	1.0097	1.0081	1.0063	1.0018	58	1.0798	1.0715	1.0672	1.0631	1.0586	1.0542	1.0453
9	1.0159	1.0140	1.0126	1.0111	1.0094	1.0076	1.0030	59	1.0805	1.0722	1.0678	1.0637	1.0592	1.0547	1.0458
10	1.0177	1.0156	1.0141	1.0125	1.0107	1.0089	1.0042	60	1.0813	1.0728	1.0684	1.0642	1.0597	1.0552	1.0462
11	1.0194	1.0171	1.0155	1.0139	1.0120	1.0102	1.0054	61	1.0820	1.0734	1.0690	1.0648	1.0602	1.0557	1.0466
12	1.0211	1.0187	1.0170	1.0154	1.0133	1.0115	1.0065	62	1.0826	1.0740	1.0696	1.0653	1.0607	1.0562	1.0470
13	1.0228	1.0202	1.0184	1.0168	1.0146	1.0127	1.0077	63	1.0833	1.0746	1.0701	1.0658	1.0612	1.0566	1.0473
14	1.0245	1.0217	1.0199	1.0182	1.0159	1.0139	1.0088	64	1.0838	1.0752	1.0706	1.0662	1.0616	1.0571	1.0477
15	1.0262	1.0232	1.0213	1.0195	1.0172	1.0151	1.0099	65	1.0844	1.0757	1.0711	1.0666	1.0621	1.0575	1.0480
16	1.0278	1.0247	1.0227	1.0209	1.0185	1.0163	1.0110	66	1.0850	1.0762	1.0716	1.0671	1.0624	1.0578	1.0483
17	1.0295	1.0262	1.0241	1.0223	1.0198	1.0175	1.0121	67	1.0856	1.0767	1.0720	1.0675	1.0628	1.0582	1.0486
18	1.0311	1.0276	1.0255	1.0236	1.0210	1.0187	1.0132	68	1.0860	1.0771	1.0725	1.0678	1.0631	1.0585	1.0489
19	1.0327	1.0291	1.0269	1.0250	1.0223	1.0198	1.0142	69	1.0865	1.0775	1.0729	1.0682	1.0634	1.0588	1.0491
20	1.0343	1.0305	1.0283	1.0263	1.0235	1.0210	1.0153	70	1.0869	1.0779	1.0732	1.0685	1.0637	1.0590	1.0493
21	1.0358	1.0319	1.0297	1.0276	1.0248	1.0222	1.0164	71	1.0874	1.0783	1.0736	1.0687	1.0640	1.0592	1.0495
22	1.0374	1.0333	1.0310	1.0288	1.0260	1.0233	1.0174	72	1.0877	1.0786	1.0738	1.0690	1.0642	1.0594	1.0496
23	1.0389	1.0347	1.0323	1.0301	1.0272	1.0244	1.0185	73	1.0881	1.0789	1.0741	1.0693	1.0644	1.0595	1.0497
24	1.0404	1.0361	1.0336	1.0313	1.0283	1.0256	1.0195	74	1.0884	1.0792	1.0743	1.0694	1.0645	1.0596	1.0498
25	1.0419	1.0375	1.0349	1.0326	1.0295	1.0267	1.0205	75	1.0887	1.0794	1.0745	1.0696	1.0647	1.0597	1.0499
26	1.0434	1.0388	1.0362	1.0338	1.0307	1.0278	1.0215	76	1.0889	1.0796	1.0746	1.0698	1.0648	1.0598	1.0499
27	1.0449	1.0401	1.0374	1.0349	1.0318	1.0289	1.0225	77	1.0891	1.0797	1.0747	1.0699	1.0648	1.0598	1.0499
28	1.0463	1.0414	1.0386	1.0361	1.0329	1.0299	1.0234	78	1.0893	1.0798	1.0747	1.0700	1.0648	1.0598	1.0498
29	1.0477	1.0427	1.0399	1.0372	1.0340	1.0310	1.0244	79	1.0894	1.0798	1.0747	1.0700	1.0648	1.0597	1.0497
30	1.0491	1.0440	1.0411	1.0384	1.0350	1.0320	1.0253	80	1.0895	1.0798	1.0747	1.0700	1.0647	1.0596	1.0495
31	1.0505	1.0453	1.0423	1.0395	1.0361	1.0330	1.0262	81	1.0895	1.0797	1.0745	1.0699	1.0646	1.0594	1.0493
32	1.0519	1.0465	1.0435	1.0406	1.0372	1.0341	1.0272	82	1.0895	1.0796	1.0743	1.0698	1.0644	1.0592	1.0490
33	1.0532	1.0477	1.0446	1.0417	1.0382	1.0351	1.0281	83	1.0895	1.0795	1.0741	1.0696	1.0642	1.0589	1.0487
34	1.0545	1.0489	1.0458	1.0428	1.0392	1.0361	1.0289	84	1.0893	1.0793	1.0738	1.0693	1.0638	1.0585	1.0483
35	1.0558	1.0501	1.0469	1.0438	1.0402	1.0371	1.0298	85	1.0891	1.0790	1.0735	1.0689	1.0635	1.0582	1.0479
36	1.0571	1.0513	1.0480	1.0449	1.0412	1.0380	1.0306	86	1.0887	1.0787	1.0731	1.0685	1.0630	1.0576	1.0473
37	1.0584	1.0524	1.0491	1.0459	1.0422	1.0390	1.0314	87	1.0883	1.0783	1.0726	1.0680	1.0626	1.0571	1.0467
38	1.0596	1.0535	1.0501	1.0469	1.0432	1.0399	1.0322	88	1.0877	1.0778	1.0721	1.0675	1.0620	1.0564	1.0460
39	1.0608	1.0546	1.0512	1.0479	1.0441	1.0408	1.0330	89	1.0872	1.0773	1.0715	1.0668	1.0613	1.0557	1.0453
40	1.0621	1.0557	1.0522	1.0488	1.0450	1.0416	1.0338	90	1.0865	1.0766	1.0708	1.0661	1.0605	1.0549	1.0445
41	1.0633	1.0568	1.0532	1.0498	1.0460	1.0425	1.0346	91	1.0857	1.0758	1.0700	1.0652	1.0597	1.0541	1.0436
42	1.0644	1.0578	1.0542	1.0507	1.0469	1.0433	1.0353	92	1.0848	1.0749	1.0690	1.0643	1.0587	1.0530	1.0426
43	1.0656	1.0588	1.0551	1.0516	1.0477	1.0441	1.0361	93	1.0838	1.0739	1.0680	1.0632	1.0577	1.0518	1.0414
44	1.0667	1.0598	1.0561	1.0525	1.0486	1.0449	1.0368	94	1.0826	1.0727	1.0667	1.0619	1.0564	1.0506	1.0401
45	1.0679	1.0608	1.0570	1.0534	1.0495	1.0456	1.0375	95	1.0813	1.0714	1.0652	1.0605	1.0551	1.0491	1.0386
46	1.0689	1.0618	1.0579	1.0542	1.0503	1.0464	1.0382	96	1.0798		1.0632	1.0588	1.0535	1.0473	1.0368
47	1.0699	1.0627	1.0588	1.0551	1.0511	1.0471	1.0389	97	1.0780		1.0611	1.0570	1.0516	1.0454	1.0348
48	1.0709	1.0636	1.0597	1.0559	1.0518	1.0479	1.0395	98	1.0759		1.0590	1.0549	1.0495	1.0431	1.0325
49	1.0720	1.0645	1.0605	1.0567	1.0526	1.0486	1.0402	99	1.0730		1.0567	1.0524	1.0468	1.0407	1.0299
								100	1.0697		1.0545	1.0498	1.0440	1.0380	1.0271

TABLE 2-110 Oxalic Acid ($H_2C_2O_4$)

%	$d_4^{17.5}$	%	$d_4^{17.5}$
1	1.0035	8	1.0280
2	1.0070	10	1.0350
4	1.0140	12	1.0420

TABLE 2-111 Methyl Alcohol (CH_3OH)*

%	0 °C	10 °C	15.56 °C	20 °C	15 °C	%	0 °C	10 °C	15.56 °C	20 °C	15 °C	%	0 °C	10 °C	15.56 °C	20 °C	15 °C
0	0.9999	0.9997	0.9990	0.9982	0.99913	35	0.9534	0.9484	0.9456	0.9433	0.94570	70	0.8869	0.8794	0.8748	0.8715	0.87507
1	0.9981	0.9980	0.9973	0.9965	0.99727	36	0.9520	0.9469	0.9440	0.9416	0.94404	71	0.8847	0.8770	0.8726	0.8690	0.87271
2	0.9963	0.9962	0.9955	0.9948	0.99543	37	0.9505	0.9453	0.9422	0.9398	0.94237	72	0.8824	0.8747	0.8702	0.8665	0.87033
3	0.9946	0.9945	0.9938	0.9931	0.99370	38	0.9490	0.9437	0.9405	0.9381	0.94067	73	0.8801	0.8724	0.8678	0.8641	0.86792
4	0.9930	0.9929	0.9921	0.9914	0.99198	39	0.9475	0.9420	0.9387	0.9363	0.93894	74	0.8778	0.8699	0.8653	0.8616	0.86546
5	0.9914	0.9912	0.9904	0.9896	0.99029	40	0.9459	0.9403	0.9369	0.9345	0.93720	75	0.8754	0.8676	0.8629	0.8592	0.86300
6	0.9899	0.9896	0.9889	0.9880	0.98864	41	0.9443	0.9387	0.9351	0.9327	0.93543	76	0.8729	0.8651	0.8604	0.8567	0.86051
7	0.9884	0.9881	0.9872	0.9863	0.98701	42	0.9427	0.9370	0.9333	0.9309	0.93365	77	0.8705	0.8626	0.8579	0.8542	0.85801
8	0.9870	0.9865	0.9857	0.9847	0.98547	43	0.9411	0.9352	0.9315	0.9290	0.93185	78	0.8680	0.8602	0.8554	0.8518	0.85551
9	0.9856	0.9849	0.9841	0.9831	0.98394	44	0.9395	0.9334	0.9297	0.9272	0.93001	79	0.8657	0.8577	0.8529	0.8494	0.85300
10	0.9842	0.9834	0.9826	0.9815	0.98241	45	0.9377	0.9316	0.9279	0.9252	0.92815	80	0.8634	0.8551	0.8503	0.8469	0.85048
11	0.9829	0.9820	0.9811	0.9799	0.98093	46	0.9360	0.9298	0.9261	0.9234	0.92627	81	0.8610	0.8527	0.8478	0.8446	0.84794
12	0.9816	0.9805	0.9796	0.9784	0.97945	47	0.9342	0.9279	0.9242	0.9214	0.92436	82	0.8585	0.8501	0.8452	0.8420	0.84536
13	0.9804	0.9791	0.9781	0.9768	0.97802	48	0.9324	0.9260	0.9223	0.9196	0.92242	83	0.8560	0.8475	0.8426	0.8394	0.84274
14	0.9792	0.9778	0.9766	0.9754	0.97660	49	0.9306	0.9240	0.9204	0.9176	0.92048	84	0.8535	0.8449	0.8400	0.8366	0.84009
15	0.9780	0.9764	0.9752	0.9740	0.97518	50	0.9287	0.9221	0.9185	0.9156	0.91852	85	0.8510	0.8422	0.8374	0.8340	0.83742
16	0.9769	0.9751	0.9738	0.9725	0.97377	51	0.9269	0.9202	0.9166	0.9135	0.91653	86	0.8483	0.8394	0.8347	0.8314	0.83475
17	0.9758	0.9739	0.9723	0.9710	0.97237	52	0.9250	0.9182	0.9146	0.9114	0.91451	87	0.8456	0.8367	0.8320	0.8286	0.83207
18	0.9747	0.9726	0.9709	0.9696	0.97096	53	0.9230	0.9162	0.9126	0.9094	0.91248	88	0.8428	0.8340	0.8294	0.8258	0.82937
19	0.9736	0.9713	0.9695	0.9681	0.96955	54	0.9211	0.9142	0.9106	0.9073	0.91044	89	0.8400	0.8314	0.8267	0.8230	0.82667
20	0.9725	0.9700	0.9680	0.9666	0.96814	55	0.9191	0.9122	0.9086	0.9052	0.90839	90	0.8374	0.8287	0.8239	0.8202	0.82396
21	0.9714	0.9687	0.9666	0.9651	0.96673	56	0.9172	0.9101	0.9065	0.9032	0.90631	91	0.8347	0.8261	0.8212	0.8174	0.82124
22	0.9702	0.9673	0.9652	0.9636	0.96533	57	0.9151	0.9080	0.9045	0.9010	0.90421	92	0.8320	0.8234	0.8185	0.8146	0.81849
23	0.9690	0.9660	0.9638	0.9622	0.96392	58	0.9131	0.9060	0.9024	0.8988	0.90210	93	0.8293	0.8208	0.8157	0.8118	0.81568
24	0.9678	0.9646	0.9624	0.9607	0.96251	59	0.9111	0.9039	0.9002	0.8968	0.89996	94	0.8266	0.8180	0.8129	0.8090	0.81285
25	0.9666	0.9632	0.9609	0.9592	0.96108	60	0.9090	0.9018	0.8980	0.8946	0.89781	95	0.8240	0.8152	0.8101	0.8062	0.80999
26	0.9654	0.9618	0.9595	0.9576	0.95963	61	0.9068	0.8998	0.8958	0.8924	0.89563	96	0.8212	0.8124	0.8073	0.8034	0.80713
27	0.9642	0.9604	0.9580	0.9562	0.95817	62	0.9046	0.8977	0.8936	0.8902	0.89341	97	0.8186	0.8096	0.8045	0.8005	0.80428
28	0.9629	0.9590	0.9565	0.9546	0.95668	63	0.9024	0.8955	0.8913	0.8879	0.89117	98	0.8158	0.8068	0.8016	0.7976	0.80143
29	0.9616	0.9575	0.9550	0.9531	0.95518	64	0.9002	0.8933	0.8890	0.8856	0.88890	99	0.8130	0.8040	0.7987	0.7948	0.79859
30	0.9604	0.9560	0.9535	0.9515	0.95366	65	0.8980	0.8911	0.8867	0.8834	0.88662	100	0.8102	0.8009	0.7959	0.7917	0.79577
31	0.9590	0.9546	0.9521	0.9499	0.95213	66	0.8958	0.8888	0.8844	0.8811	0.88433						
32	0.9576	0.9531	0.9505	0.9483	0.95056	67	0.8935	0.8865	0.8820	0.8787	0.88203						
33	0.9563	0.9516	0.9489	0.9466	0.94896	68	0.8913	0.8842	0.8797	0.8763	0.87971						
34	0.9549	0.9500	0.9473	0.9450	0.94734	69	0.8891	0.8818	0.8771	0.8738	0.87739						

*It should be noted that the values for 100 percent do not agree with some data available elsewhere, e.g., *American Institute of Physics Handbook,* McGraw-Hill, New York, 1957. Also, see Atack, *Handbook of Chemical Data,* Reinhold, New York, 1957. Also, see Tables 2-234 and 2-305 for pure component densities.

TABLE 2-112 Ethyl Alcohol (C_2H_5OH)*

%	10 °C	15 °C	20 °C	25 °C	30 °C	35 °C	40 °C	%	10 °C	15 °C	20 °C	25 °C	30 °C	35 °C	40 °C
0	0.99973	0.99913	0.99823	0.99708	0.99568	0.99406	0.99225	50	0.92126	0.91776	0.91384	0.90985	0.90580	0.90168	0.89750
1	785	725	636	520	379	217	034	51	0.91943	555	160	760	353	0.89940	519
2	602	542	453	336	194	031	0.98846	52	723	333	0.90936	534	125	710	288
3	426	365	275	157	014	0.98849	663	53	502	110	711	307	0.89896	479	056
4	258	195	103	0.98984	0.98839	672	485	54	279	0.90885	485	079	667	248	0.88823
5	098	032	0.98938	817	670	501	311	55	055	659	258	0.89850	437	016	589
6	0.98946	0.98877	780	656	507	335	142	56	0.90831	433	031	621	206	0.88784	356
7	801	729	627	500	347	172	0.97975	57	607	207	0.89803	392	0.88975	552	122
8	660	584	478	346	189	009	808	58	381	0.89980	574	162	744	319	0.87888
9	524	442	331	193	031	0.97846	641	59	154	752	344	0.88931	512	085	653
10	393	304	187	043	0.97875	685	475	60	0.89927	523	113	699	278	0.87851	417
11	267	171	047	0.97897	723	527	312	61	698	293	0.88882	446	044	615	180
12	145	041	0.97910	753	573	371	150	62	468	062	650	233	0.87809	379	0.86943
13	026	0.97914	775	611	424	216	0.96989	63	237	0.88830	417	0.87998	574	142	705
14	0.97911	790	643	472	278	063	829	64	006	597	183	763	337	0.86905	466
15	800	669	514	334	133	0.96911	670	65	0.88774	364	0.87948	527	100	667	227
16	692	552	387	199	0.96990	760	512	66	541	130	713	291	0.86863	429	0.85987
17	583	433	259	062	844	607	352	67	308	0.87895	477	054	625	190	747
18	473	313	129	0.96923	697	452	189	68	074	660	241	0.86817	387	0.85950	407
19	363	191	0.96997	782	547	294	023	69	0.87839	424	004	579	148	710	266
20	252	068	864	639	395	134	0.95856	70	602	187	0.86766	340	0.85908	470	025
21	139	0.96944	729	495	242	0.95973	687	71	365	0.86949	527	100	667	228	0.84783
22	024	818	592	348	087	809	516	72	127	710	287	0.85859	426	0.84986	540
23	0.96907	689	453	199	0.95929	643	343	73	0.86888	470	047	618	184	743	297
24	787	558	312	048	769	476	168	74	648	229	0.85806	376	0.84941	500	053
25	665	424	168	0.95895	607	306	0.94991	75	408	0.85988	564	134	698	257	0.83809
26	539	287	020	738	442	133	810	76	168	747	322	0.84891	455	013	564
27	406	144	0.95867	576	272	0.94955	625	77	0.85927	505	079	647	211	0.83768	319
28	268	0.95996	710	410	098	774	438	78	685	262	0.84835	403	0.83966	523	074
29	125	844	548	241	0.94922	590	248	79	442	018	590	158	720	277	0.82827
30	0.95977	686	382	067	741	403	055	80	197	0.84772	344	0.83911	473	029	578
31	823	524	212	0.94890	557	214	0.93860	81	0.84950	525	096	664	224	0.82780	329
32	665	357	038	709	370	021	662	82	702	277	0.83848	415	0.82974	530	079
33	502	186	0.94860	525	180	0.93825	461	83	453	028	599	164	724	279	0.81828
34	334	011	679	337	0.93986	626	257	84	203	0.83777	348	0.82913	473	027	576
35	162	0.94832	494	146	790	425	051	85	0.83951	525	095	660	220	0.81774	322
36	0.94986	650	306	0.93952	591	221	0.92843	86	697	271	0.82840	405	0.81965	519	067
37	805	464	114	756	390	016	634	87	441	014	583	148	708	262	0.80811
38	620	273	0.93919	556	186	0.92808	422	88	181	0.82754	323	0.81888	448	003	552
39	431	079	720	353	0.92979	597	208	89	0.82919	492	062	626	186	0.80742	291
40	238	0.93882	518	148	770	385	0.91992	90	654	227	0.81797	362	0.80922	478	028
41	042	682	314	0.92940	558	170	774	91	386	0.81959	529	094	655	211	0.79761
42	0.93842	478	107	729	344	0.91952	554	92	114	688	257	0.80823	384	0.79941	491
43	639	271	0.92897	516	128	733	332	93	0.81839	413	0.80983	549	111	669	220
44	433	062	685	301	0.91910	513	108	94	561	134	705	272	0.79835	393	0.78947
45	226	0.92852	472	085	692	291	0.90884	95	278	0.80852	424	0.79991	555	114	670
46	017	640	257	0.91868	472	069	660	96	0.80991	566	138	706	271	0.78831	388
47	0.92806	426	041	649	250	0.90845	434	97	698	274	0.79846	415	0.78981	542	100
48	593	211	0.91823	429	028	621	207	98	399	0.79975	547	117	684	247	0.77806
49	379	0.91995	604	208	0.90805	396	0.89979	99	094	670	243	0.78814	382	0.77946	507
								100	0.79784	360	0.78934	506	075	641	203

*For data from –78° to 78°C, see p. 2-142, Table 2N-5, *American Institute of Physics Handbook*, McGraw-Hill, New York, 1957. See Tables 2-214 and 2-305 for pure component densities.

TABLE 2-113 Densities of Mixtures of C_2H_5OH and H_2O at 20°C

g/mL

% alcohol by weight	Tenths of %										% alcohol by weight	Tenths of %									
	0	1	2	3	4	5	6	7	8	9		0	1	2	3	4	5	6	7	8	9
0	0.99823	804	785	766	748	729	710	692	673	655	50	0.91384	361	339	317	295	272	250	228	206	183
1	636	618	599	581	562	544	525	507	489	471	51	160	138	116	093	071	049	026	004	°981	°959
2	453	435	417	399	381	363	345	327	310	292	52	0.90936	914	891	869	846	824	801	779	756	734
3	275	257	240	222	205	188	171	154	137	120	53	711	689	666	644	621	598	576	553	531	508
4	103	087	070	053	037	020	003	°987	°971	°954	54	485	463	440	417	395	372	349	327	304	281
5	0.98938	922	906	890	874	859	843	827	811	796	55	258	236	213	190	167	145	122	099	076	054
6	780	765	749	734	718	703	688	673	658	642	56	031	008	°985	°962	°939	°917	°894	°871	°848	°825
7	627	612	597	582	567	553	538	523	508	493	57	0.89803	780	757	734	711	688	665	643	620	597
8	478	463	449	434	419	404	389	374	360	345	58	574	551	528	505	482	459	436	413	390	367
9	331	316	301	287	273	258	244	229	215	201	59	344	321	298	275	252	229	206	183	160	137
10	187	172	158	144	130	117	103	089	075	061	60	113	090	067	044	021	°998	°975	°951	°928	°905
11	047	033	019	006	°992	°978	°964	°951	°937	°923	61	0.88882	859	836	812	789	766	743	720	696	673
12	0.97910	896	883	869	855	842	828	815	801	788	62	650	626	603	580	557	533	510	487	463	440
13	775	761	748	735	722	709	696	683	670	657	63	417	393	370	347	323	300	277	253	230	206
14	643	630	617	604	591	578	565	552	539	526	64	183	160	136	113	089	066	042	019	°995	°972
15	514	501	488	475	462	450	438	425	412	400	65	0.87948	925	901	878	854	831	807	784	760	737
16	387	374	361	349	336	323	310	297	284	272	66	713	689	666	642	619	595	572	548	524	501
17	259	246	233	220	207	194	181	168	155	142	67	477	454	430	406	383	359	336	312	288	265
18	129	116	103	089	076	063	050	037	024	010	68	241	218	194	170	147	123	099	075	052	028
19	0.96997	984	971	957	944	931	917	904	891	877	69	004	°981	°957	°933	°909	°885	°862	°838	°814	°790
20	864	850	837	823	810	796	783	769	756	742	70	0.86766	742	718	694	671	647	623	599	575	551
21	729	716	702	688	675	661	647	634	620	606	71	527	503	479	455	431	407	383	339	335	311
22	592	578	564	551	537	523	509	495	481	467	72	287	263	239	215	191	167	143	119	095	071
23	453	439	425	411	396	382	368	354	340	326	73	047	022	°998	°974	°950	°926	°902	°878	°854	°830
24	312	297	283	269	254	240	225	211	196	182	74	0.85806	781	757	733	709	685	661	636	612	588
25	168	153	139	124	109	094	080	065	050	035	75	564	540	515	491	467	443	419	394	370	346
26	020	005	°990	°975	°959	°944	°929	°914	°898	°883	76	322	297	273	249	225	200	176	152	128	103
27	0.95867	851	836	820	805	789	773	757	742	726	77	079	055	031	006	°982	°958	°933	°909	°884	°860
28	710	694	678	662	646	630	613	597	581	565	78	0.84835	811	787	762	738	713	689	664	640	615
29	548	532	516	499	483	466	450	433	416	400	79	590	566	541	517	492	467	443	418	393	369
30	382	365	349	332	315	298	281	264	247	230	80	344	319	294	270	245	220	196	171	146	121
31	212	195	178	161	143	126	108	091	074	056	81	096	072	047	022	°997	°972	°947	°923	°898	°873
32	038	020	003	°985	°967	°950	°932	°914	°896	°878	82	0.83848	823	798	773	748	723	698	674	649	624
33	0.94860	842	824	806	788	770	752	734	715	697	83	599	574	549	523	498	473	448	423	398	373
34	679	660	642	624	605	587	568	550	531	512	84	348	323	297	272	247	222	196	171	146	120
35	494	475	456	438	419	400	382	363	344	325	85	095	070	044	019	°994	°968	°943	°917	°892	°866
36	306	287	268	249	230	211	192	172	153	134	86	0.82840	815	789	763	738	712	686	660	635	609
37	114	095	075	056	036	017	°997	°978	°958	°939	87	583	557	531	505	479	453	427	401	375	349
38	0.93919	899	879	859	840	820	800	780	760	740	88	323	297	271	245	219	193	167	140	114	088
39	720	700	680	660	640	620	599	579	559	539	89	062	035	009	°983	°956	°930	°903	°877	°850	°824
40	518	498	478	458	437	417	396	376	356	335	90	0.81797	770	744	717	690	664	637	610	583	556
41	314	294	273	253	232	212	191	170	149	129	91	529	502	475	448	421	394	366	339	312	285
42	107	086	065	044	023	002	°981	°960	°939	°918	92	257	230	203	175	148	120	093	066	038	010
43	0.92897	876	855	834	812	791	770	749	728	707	93	0.80983	955	928	900	872	844	817	789	761	733
44	685	664	642	621	600	579	557	536	515	493	94	705	677	649	621	593	565	537	509	480	452
45	472	450	429	408	386	365	343	322	300	279	95	424	395	367	338	310	281	253	224	195	166
46	257	236	214	193	171	150	128	106	085	063	96	138	109	080	051	022	°993	°963	°934	°905	°875
47	041	019	°997	°976	°954	°932	°910	°889	°867	°845	97	0.79846	816	787	757	727	698	668	638	608	578
48	0.91823	801	780	758	736	714	692	670	648	626	98	547	517	487	456	426	396	365	335	305	274
49	604	582	560	538	516	494	472	450	428	406	99	243	213	182	151	120	089	059	028	°997	°966
											100	0.78934									

°Indicates change in the first two decimal places.

TABLE 2-114 Specific Gravity {60°/60°F [(15.56°/15.56°C)]} of Mixtures by Volume of C_2H_5OH and H_2O

% alcohol by volume at 60°F	Tenths of %										% alcohol by volume at 60°F	Tenths of %									
	0	1	2	3	4	5	6	7	8	9		0	1	2	3	4	5	6	7	8	9
0	1.00000	°985	°970	°955	°940	°925	°910	°895	°880	865	50	0.93426	407	387	368	348	328	309	289	270	250
1	0.99850	835	820	806	791	776	761	747	732	717	51	230	210	190	171	151	131	111	091	071	051
2	703	688	674	659	645	630	616	602	587	573	52	031	011	°991	°971	°951	°931	°911	°890	°870	°850
3	559	545	531	516	502	488	474	460	446	432	53	0.92830	810	789	769	749	728	708	688	667	647
4	419	405	391	378	364	350	336	323	309	296	54	626	605	585	564	544	523	502	482	461	440
5	282	269	255	242	228	215	202	189	176	163	55	419	398	377	357	336	315	294	273	252	231
6	150	137	124	111	098	085	073	060	047	035	56	210	189	168	147	126	105	084	062	041	020
7	022	009	°997	°984	°972	°960	°947	°935	°923	°911	57	0.91999	978	956	935	914	892	871	849	827	806
8	0.98899	887	875	863	851	838	826	814	803	791	58	784	762	741	719	697	675	653	631	610	588
9	779	767	755	743	731	720	708	696	684	672	59	565	543	521	499	477	455	433	410	388	366
10	661	649	637	625	614	602	590	579	567	556	60	344	322	299	277	255	232	210	188	165	143
11	544	532	521	509	498	487	475	464	452	441	61	120	097	075	052	030	007	°984	°962	°939	°916
12	430	419	408	396	385	374	363	352	341	330	62	0.90893	870	847	825	802	779	756	733	710	687
13	319	308	297	286	275	264	254	243	232	221	63	664	641	618	595	572	549	526	503	480	457
14	210	200	190	179	168	157	147	136	125	115	64	434	411	388	365	341	318	295	272	249	225
15	104	093	083	072	062	051	040	030	019	009	65	202	179	155	132	108	085	061	038	014	°991
16	0.97998	988	977	967	956	946	936	925	915	905	66	0.89967	943	920	896	872	848	825	801	777	753
17	895	885	875	864	854	844	834	824	814	804	67	729	705	681	657	633	609	585	561	537	513
18	794	784	774	764	754	744	734	724	714	704	68	489	465	441	416	392	368	343	319	295	270
19	694	684	674	664	654	645	635	625	615	605	69	245	220	196	171	147	122	098	073	048	024
20	596	586	576	566	556	546	536	526	516	506	70	0.88999	974	950	925	900	875	850	825	801	776
21	496	486	476	466	456	446	436	425	415	405	71	751	725	700	675	650	625	600	574	549	524
22	395	385	375	365	354	344	334	324	313	303	72	499	474	448	423	397	372	346	321	296	270
23	293	283	272	262	252	241	231	221	210	200	73	244	218	193	167	141	116	090	064	039	013
24	189	179	168	158	147	137	126	116	105	095	74	0.87987	961	935	910	884	858	832	806	780	754
25	084	073	063	052	042	031	020	010	°999	°988	75	728	702	676	650	623	597	571	545	518	492
26	0.96978	967	957	946	935	924	914	903	892	881	76	465	439	412	386	359	332	306	279	252	226
27	870	859	848	837	826	815	804	793	782	771	77	199	172	145	118	092	065	038	011	°984	°957
28	760	749	738	727	715	704	693	682	671	659	78	0.86929	902	875	847	820	793	766	738	711	684
29	648	637	625	614	603	591	580	568	557	546	79	656	629	601	574	546	518	491	463	435	408
30	534	522	511	499	488	476	464	453	441	429	80	380	352	324	296	269	241	213	185	157	129
31	418	406	394	382	370	358	346	334	321	309	81	100	072	044	015	°987	°959	°931	°902	°874	°846
32	296	284	271	259	246	234	221	209	196	183	82	0.85817	789	760	732	703	674	646	617	588	560
33	170	157	144	132	119	106	093	080	067	054	83	531	502	473	444	415	386	357	328	299	270
34	041	028	015	002	°988	°975	°962	°948	°935	°921	84	240	211	181	152	122	093	063	033	004	°974
35	0.95908	894	881	867	854	840	826	812	798	784	85	0.84944	914	884	854	824	794	764	734	703	673
36	770	756	742	728	714	700	685	671	657	643	86	642	612	581	551	520	490	459	428	398	367
37	628	614	599	585	570	556	541	526	512	497	87	336	305	274	243	212	181	150	119	088	056
38	482	467	452	437	423	408	393	378	362	347	88	025	°994	°962	°930	°899	°867	°835	°803	°771	°739
39	332	317	302	286	271	256	240	225	209	194	89	0.83707	675	643	610	578	545	513	480	447	415
40	178	162	147	131	115	100	084	068	052	036	90	382	349	315	282	249	216	183	150	116	083
41	020	004	°988	°972	°956	°940	°923	°907	°891	°875	91	049	015	°981	°947	°913	°879	°845	°810	°776	°741
42	0.94858	842	825	809	792	776	759	743	726	710	92	0.82705	670	635	600	565	529	494	458	423	387
43	693	676	660	643	626	609	592	575	558	541	93	351	315	279	243	206	170	133	096	059	022
44	524	507	490	473	455	438	421	403	386	369	94	0.81984	947	909	871	834	796	757	719	681	642
45	351	334	316	298	281	263	245	228	210	192	95	603	564	525	486	446	407	367	327	287	247
46	174	156	138	120	102	084	066	048	030	011	96	206	165	125	084	042	001	°960	°918	°876	°834
47	0.93993	975	956	938	920	901	883	864	845	827	97	0.80792	750	707	664	620	577	533	489	445	401
48	808	789	771	752	733	714	695	676	657	638	98	356	311	265	219	173	127	080	033	°985	°937
49	619	600	581	562	543	523	504	485	465	446	99	0.79889	841	792	743	693	643	593	543	492	441
											100	389									

°Indicates change in first two decimal places.

TABLE 2-115 *n*-Propyl Alcohol (C_3H_7OH)

%	0 °C	15 °C	30 °C	%	0 °C	15 °C	30 °C	%	0 °C	15 °C	30 °C	%	0 °C	15 °C	30 °C	%	0 °C	15 °C	30 °C
0	0.9999	0.9991	0.9957	20	0.9789	0.9723	0.9643	40	0.9430	0.9331	0.9226	60	0.9033	0.8922	0.8807	80	0.8634	0.8516	0.8394
1	0.9982	0.9974	0.9940	21	0.9776	0.9705	0.9622	41	0.9411	0.9310	0.9205	61	0.9013	0.8902	0.8786	81	0.8614	0.8496	0.8373
2	0.9967	0.9960	0.9924	22	0.9763	0.9688	0.9602	42	0.9391	0.9290	0.9184	62	0.8994	0.8882	0.8766	82	0.8594	0.8475	0.8352
3	0.9952	0.9944	0.9908	23	0.9748	0.9670	0.9583	43	0.9371	0.9269	0.9164	63	0.8974	0.8861	0.8745	83	0.8574	0.8454	0.8332
4	0.9939	0.9929	0.9893	24	0.9733	0.9651	0.9563	44	0.9352	0.9248	0.9143	64	0.8954	0.8841	0.8724	84	0.8554	0.8434	0.8311
5	0.9926	0.9915	0.9877	25	0.9717	0.9633	0.9543	45	0.9332	0.9228	0.9122	65	0.8934	0.8820	0.8703	85	0.8534	0.8413	0.8290
6	0.9914	0.9902	0.9862	26	0.9700	0.9614	0.9522	46	0.9311	0.9207	0.9100	66	0.8913	0.8800	0.8682	86	0.8513	0.8393	0.8269
7	0.9904	0.9890	0.9848	27	0.9682	0.9594	0.9501	47	0.9291	0.9186	0.9079	67	0.8894	0.8779	0.8662	87	0.8492	0.8372	0.8248
8	0.9894	0.9877	0.9834	28	0.9664	0.9576	0.9481	48	0.9272	0.9165	0.9057	68	0.8874	0.8759	0.8641	88	0.8471	0.8351	0.8227
9	0.9883	0.9864	0.9819	29	0.9646	0.9556	0.9460	49	0.9252	0.9145	0.9036	69	0.8854	0.8739	0.8620	89	0.8450	0.8330	0.8206
10	0.9874	0.9852	0.9804	30	0.9627	0.9535	0.9439	50	0.9232	0.9124	0.9015	70	0.8835	0.8719	0.8600	90	0.8429	0.8308	0.8185
11	0.9865	0.9840	0.9790	31	0.9608	0.9516	0.9418	51	0.9213	0.9104	0.8994	71	0.8815	0.8700	0.8580	91	0.8408	0.8287	0.8164
12	0.9857	0.9828	0.9775	32	0.9589	0.9495	0.9396	52	0.9192	0.9084	0.8973	72	0.8795	0.8680	0.8559	92	0.8387	0.8266	0.8142
13	0.9849	0.9817	0.9760	33	0.9570	0.9474	0.9375	53	0.9173	0.9064	0.8952	73	0.8776	0.8659	0.8539	93	0.8364	0.8244	0.8120
14	0.9841	0.9806	0.9746	34	0.9550	0.9454	0.9354	54	0.9153	0.9044	0.8931	74	0.8756	0.8639	0.8518	94	0.8342	0.8221	0.8098
15	0.9833	0.9793	0.9730	35	0.9530	0.9434	0.9333	55	0.9132	0.9023	0.8911	75	0.8736	0.8618	0.8497	95	0.8320	0.8199	0.8077
16	0.9825	0.9780	0.9714	36	0.9511	0.9413	0.9312	56	0.9112	0.9003	0.8890	76	0.8716	0.8598	0.8477	96	0.8296	0.8176	0.8054
17	0.9817	0.9768	0.9698	37	0.9491	0.9392	0.9289	57	0.9093	0.8983	0.8869	77	0.8695	0.8577	0.8456	97	0.8272	0.8153	0.8031
18	0.9808	0.9752	0.9680	38	0.9471	0.9372	0.9269	58	0.9073	0.8963	0.8849	78	0.8675	0.8556	0.8435	98	0.8248	0.8128	0.8008
19	0.9800	0.9739	0.9661	39	0.9450	0.9351	0.9247	59	0.9053	0.8942	0.8828	79	0.8655	0.8536	0.8414	99	0.8222	0.8104	0.7984
																100	0.8194	0.8077	0.7958

TABLE 2-116 Isopropyl Alcohol (C_3H_7OH)

%	0 °C	15 °C*	15 °C*	20 °C	30 °C	%	0 °C	15 °C*	15 °C*	20 °C	30 °C	%	0 °C	15 °C*	15 °C*	20 °C	30 °C
0	0.9999	0.9991	0.99913	0.9982	0.9957	35	0.9557		0.9446	0.9419	0.9338	70	0.8761	0.8639	0.86346	0.8584	0.8511
1	0.9980	0.9973	0.9972	0.9962	0.9939	36	0.9536		0.9424	0.9399	0.9315	71	0.8738	0.8615	0.8611	0.8560	0.8487
2	0.9962	0.9956	0.9954	0.9944	0.9921	37	0.9514		0.9401	0.9377	0.9292	72	0.8714	0.8592	0.8588	0.8537	0.8464
3	0.9946	0.9938	0.9936	0.9926	0.9904	38	0.9493		0.9379	0.9355	0.9269	73	0.8691	0.8568	0.8564	0.8513	0.8440
4	0.9930	0.9922	0.9920	0.9909	0.9887	39	0.9472		0.9356	0.9333	0.9246	74	0.8668	0.8545	0.8541	0.8489	0.8416
5	0.9916	0.9906	0.9904	0.9893	0.9871	40	0.9450		0.93333	0.9310	0.9224	75	0.8644	0.8521	0.8517	0.8464	0.8392
6	0.9902	0.9892	0.9890	0.9877	0.9855	41	0.9428		0.9311	0.9287	0.9201	76	0.8621	0.8497	0.8493	0.8439	0.8368
7	0.9890	0.9878	0.9875	0.9862	0.9839	42	0.9406		0.9288	0.9264	0.9177	77	0.8598	0.8474	0.8470	0.8415	0.8344
8	0.9878	0.9864	0.9862	0.9847	0.9824	43	0.9384		0.9266	0.9239	0.9154	78	0.8575	0.8450	0.8446	0.8391	0.8321
9	0.9866	0.9851	0.9849	0.9833	0.9809	44	0.9361		0.9243	0.9215	0.9130	79	0.8551	0.8426	0.8422	0.8366	0.8297
10	0.9856	0.9838	0.98362	0.9820	0.9794	45	0.9338		0.9220	0.9191	0.9106	80	0.8528	0.8403	0.83979	0.8342	0.8273
11	0.9846	0.9826	0.9824	0.9808	0.9778	46	0.9315		0.9197	0.9165	0.9082	81	0.8503	0.8379	0.8374	0.8317	0.8248
12	0.9838	0.9813	0.9812	0.9797	0.9764	47	0.9292		0.9174	0.9141	0.9059	82	0.8479	0.8355	0.8350	0.8292	0.8224
13	0.9829	0.9802	0.9800	0.9876	0.9750	48	0.9270		0.9150	0.9117	0.9036	83	0.8456	0.8331	0.8326	0.8268	0.8200
14	0.9821	0.9790	0.9788	0.9776	0.9735	49	0.9247		0.9127	0.9093	0.9013	84	0.8432	0.8307	0.8302	0.8243	0.8175
15	0.9814	0.9779	0.9777	0.9765	0.9720	50	0.9224		0.91043	0.9069	0.8990	85	0.8408	0.8282	0.8278	0.8219	0.8151
16	0.9806	0.9768	0.9765	0.9754	0.9705	51	0.9201		0.9081	0.9044	0.8966	86	0.8384	0.8259	0.8254	0.8194	0.8127
17	0.9799	0.9756	0.9753	0.9743	0.9690	52	0.9178		0.9058	0.9020	0.8943	87	0.8360	0.8234	0.8229	0.8169	0.8201
18	0.9792	0.9745	0.9741	0.9731	0.9675	53	0.9155		0.9035	0.8996	0.8919	88	0.8336	0.8209	0.8205	0.8145	0.8078
19	0.9784	0.9730	0.9728	0.9717	0.9658	54	0.9132		0.9011	0.8971	0.8895	89	0.8311	0.8184	0.8180	0.8120	0.8053
20	0.9777	0.9719	0.97158	0.9703	0.9642	55	0.9109		0.8988	0.8946	0.8871	90	0.8287	0.8161	0.81553	0.8096	0.8029
21	0.9768	0.9704	0.9703	0.9688	0.9624	56	0.9086		0.8964	0.8921	0.8847	91	0.8262	0.8136	0.8130	0.8072	0.8004
22	0.9759	0.9690	0.9689	0.9669	0.9606	57	0.9063		0.8940	0.8896	0.8823	92	0.8237	0.8110	0.8104	0.8047	0.7979
23	0.9749	0.9675	0.9674	0.9651	0.9587	58	0.9040		0.8917	0.8874	0.8800	93	0.8212	0.8085	0.8079	0.8023	0.7954
24	0.9739	0.9660	0.9659	0.9634	0.9569	59	0.9017		0.8893	0.8850	0.8777	94	0.8186	0.8060	0.8052	0.7998	0.7929
25	0.9727	0.9643	0.9642	0.9615	0.9549	60	0.8994		0.88690	0.8825	0.8752	95	0.8160	0.8034	0.8026	0.7973	0.7904
26	0.9714	0.9626	0.9624	0.9597	0.9529	61	0.8970		0.8845	0.8800	0.8728	96	0.8133	0.8008	0.7999	0.7949	0.7878
27	0.9699	0.9608	0.9605	0.9577	0.9509	62	0.8947	0.8829	0.8821	0.8776	0.8704	97	0.8106	0.7981	0.7972	0.7925	0.7852
28	0.9684	0.9590	0.9586	0.9558	0.9488	63	0.8924	0.8805	0.8798	0.8751	0.8680	98	0.8078	0.7954	0.7945	0.7901	0.7826
29	0.9669	0.9570	0.9568	0.9540	0.9467	64	0.8901	0.8781	0.8775	0.8727	0.8656	99	0.8048	0.7926	0.7918	0.7877	0.7799
30	0.9652	0.9551	0.95493	0.9520	0.9446	65	0.8878	0.8757	0.8752	0.8702	0.8631	100	0.8016	0.7896	0.78913	0.7854	0.7770
31	0.9634		0.9530	0.9500	0.9426	66	0.8854	0.8733	0.8728	0.8679	0.8607						
32	0.9615		0.9510	0.9481	0.9405	67	0.8831	0.8710	0.8705	0.8656	0.8583						
33	0.9596		0.9489	0.9460	0.9383	68	0.8807	0.8686	0.8682	0.8632	0.8559						
34	0.9577		0.9468	0.9440	0.9361	69	0.8784	0.8662	0.8658	0.8609	0.8535						

*Two different observers; see *International Critical Tables*, vol. 3, p. 120.

TABLE 2-117 Glycerol*

Glycerol, %	Density					Glycerol, %	Density					Glycerol, %	Density				
	15 °C	15.5 °C	20 °C	25 °C	30 °C		15 °C	15.5 °C	20 °C	25 °C	30 °C		15 °C	15.5 °C	20 °C	25 °C	30 °C
100	1.26415	1.26381	1.26108	1.15802	1.25495	65	1.17030	1.17000	1.16750	1.16475	1.16195	30	1.07455	1.07435	1.07270	1.07070	1.06855
99	1.26160	1.26125	1.25850	1.25545	1.25235	64	1.16755	1.16725	1.16475	1.16200	1.15925	29	1.07195	1.07175	1.07010	1.06815	1.06605
98	1.25900	1.25865	1.25590	1.25290	1.24975	63	1.16480	1.16445	1.16205	1.15925	1.15650	28	1.06935	1.06915	1.06755	1.06560	1.06355
97	1.25645	1.25610	1.25335	1.25030	1.24710	62	1.16200	1.16170	1.15930	1.15655	1.15375	27	1.06670	1.06655	1.06495	1.06305	1.06105
96	1.25385	1.25350	1.25080	1.24770	1.24450	61	1.15925	1.15895	1.15655	1.15380	1.15100	26	1.06410	1.06390	1.06240	1.06055	1.05855
95	1.25130	1.25095	1.24825	1.24515	1.24190	60	1.15650	1.15615	1.15380	1.15105	1.14830	25	1.06150	1.06130	1.05980	1.05800	1.05605
94	1.24865	1.24830	1.24560	1.24250	1.23930	59	1.15370	1.15340	1.15105	1.14835	1.14555	24	1.05885	1.05870	1.05720	1.05545	1.05350
93	1.24600	1.24565	1.24300	1.23985	1.23670	58	1.15095	1.15065	1.14830	1.14560	1.14285	23	1.05625	1.05610	1.05465	1.05290	1.05100
92	1.24340	1.24305	1.24035	1.23725	1.23410	57	1.14815	1.14785	1.14555	1.14285	1.14010	22	1.05365	1.05350	1.05205	1.05035	1.04850
91	1.24075	1.24040	1.23770	1.23460	1.23150	56	1.14535	1.14510	1.14280	1.14015	1.13740	21	1.05100	1.05090	1.04950	1.04780	1.04600
90	1.23810	1.23775	1.23510	1.23200	1.22890	55	1.14260	1.14230	1.14005	1.13740	1.13470	20	1.04840	1.04825	1.04690	1.04525	1.04350
89	1.23545	1.23510	1.23245	1.22935	1.22625	54	1.13980	1.13955	1.13730	1.13465	1.13195	19	1.04590	1.04575	1.04440	1.04280	1.04105
88	1.23280	1.23245	1.22975	1.22665	1.22360	53	1.13705	1.13680	1.13455	1.13195	1.12925	18	1.04335	1.04325	1.04195	1.04035	1.03860
87	1.23015	1.22980	1.22710	1.22400	1.22095	52	1.13425	1.13400	1.13180	1.12920	1.12650	17	1.04085	1.04075	1.03945	1.03790	1.03615
86	1.22750	1.22710	1.22445	1.22135	1.21830	51	1.13150	1.13125	1.12905	1.12650	1.12380	16	1.03835	1.03825	1.03695	1.03545	1.03370
85	1.22485	1.22445	1.22180	1.21870	1.21565	50	1.12870	1.12845	1.12630	1.12375	1.12110	15	1.03580	1.03570	1.03450	1.03300	1.03130
84	1.22220	1.22180	1.21915	1.21605	1.21300	49	1.12600	1.12575	1.12360	1.12110	1.11845	14	1.03330	1.03320	1.03200	1.03055	1.02885
83	1.21955	1.21915	1.21650	1.21340	1.21035	48	1.12325	1.12305	1.12090	1.11840	1.11580	13	1.03080	1.03070	1.02955	1.02805	1.02640
82	1.21690	1.21650	1.21380	1.21075	1.20770	47	1.12055	1.12030	1.11820	1.11575	1.11320	12	1.02830	1.02820	1.02705	1.02560	1.02395
81	1.21425	1.21385	1.21115	1.20810	1.20505	46	1.11780	1.11760	1.11550	1.11310	1.11055	11	1.02575	1.02565	1.02455	1.02315	1.02150
80	1.21160	1.21120	1.20850	1.20545	1.20240	45	1.11510	1.11490	1.11280	1.11040	1.10795	10	1.02325	1.02315	1.02210	1.02070	1.01905
79	1.20885	1.20845	1.20575	1.20275	1.19970	44	1.11235	1.11215	1.11010	1.10775	1.10530	9	1.02085	1.02075	1.01970	1.01835	1.01670
78	1.20610	1.20570	1.20305	1.20005	1.19705	43	1.10960	1.10945	1.10740	1.10510	1.10265	8	1.01840	1.01835	1.01730	1.01600	1.01440
77	1.20335	1.20300	1.20030	1.19735	1.19435	42	1.10690	1.10670	1.10470	1.10240	1.10005	7	1.01600	1.01590	1.01495	1.01360	1.01205
76	1.20060	1.20025	1.19760	1.19465	1.19170	41	1.10415	1.10400	1.10200	1.09975	1.09740	6	1.01360	1.01350	1.01255	1.01125	1.00970
75	1.19785	1.19750	1.19485	1.19195	1.18900	40	1.10145	1.10130	1.09930	1.09710	1.09475	5	1.01120	1.01110	1.01015	1.00890	1.00735
74	1.19510	1.19480	1.19215	1.18925	1.18635	39	1.09875	1.09860	1.09665	1.09445	1.09215	4	1.00875	1.00870	1.00780	1.00655	1.00505
73	1.19235	1.19205	1.18940	1.18650	1.18365	38	1.09605	1.09590	1.09400	1.09180	1.08955	3	1.00635	1.00630	1.00540	1.00415	1.00270
72	1.18965	1.18930	1.18670	1.18380	1.18100	37	1.09340	1.09320	1.09135	1.08915	1.08690	2	1.00395	1.00385	1.00300	1.00180	1.00035
71	1.18690	1.18655	1.18395	1.18110	1.17830	36	1.09070	1.09050	1.08865	1.08655	1.08430	1	1.00155	1.00145	1.00060	0.99945	0.99800
70	1.18415	1.18385	1.18125	1.17840	1.17565	35	1.08800	1.08780	1.08600	1.08390	1.08165	0	0.99913	0.99905	0.99823	0.99708	0.99568
69	1.18135	1.18105	1.17850	1.17565	1.17290	34	1.08530	1.08515	1.08335	1.08125	1.07905						
68	1.17860	1.17830	1.17575	1.17295	1.17020	33	1.08265	1.08245	1.08070	1.07860	1.07645						
67	1.17585	1.17555	1.17300	1.17020	1.16745	32	1.07995	1.07975	1.07800	1.07600	1.07380						
66	1.17305	1.17275	1.17025	1.16745	1.16470	31	1.07725	1.07705	1.07535	1.07335	1.07120						

*Bosart and Snoddy, *Ind. Eng. Chem.*, **20,** (1928): 1378.

TABLE 2-118 Hydrazine (N_2H_4)*

%	d_4^{15}	%	d_4^{15}
1	1.0002	30	1.0305
2	1.0013	40	1.038
4	1.0034	50	1.044
8	1.0077	60	1.047
12	1.0121	70	1.046
16	1.0164	80	1.040
20	1.0207	90	1.030
24	1.0248	100	1.011
28	1.0286		

**International Critical Tables*, vol. 3, p. 55.

TABLE 2-119 Densities of Aqueous Solutions of Miscellaneous Organic Compounds*

d, d_w, and d_s are the density of the solution, pure water, and pure liquid solute, respectively, all in g/mL. p_s is the wt % solute. 0.0_3255 means 2.55×10^{-4}.

Section A $d = d_w + Ap_s + Bp_s^2 + Cp_s^3$

Name	Formula	t, °C	Range, p_s	A	B	C
Acetaldehyde	C_2H_4O	18	0– 30	$+0.0_3255$	-0.0_516	
Acetamide	C_2H_5NO	15	0– 6	$+0.0_3639$	$+0.0_4171$	
Acetone	C_3H_6O	0	0–100	-0.0_3856	-0.0_5449	-0.0_7588
		4	0–100	-0.0_37648	-0.0_41193	$+0.0_8272$
		15	0–100	-0.0_31009	-0.0_59682	-0.0_8624
		20	0–100	-0.0_31233	-0.0_53529	-0.0_75327
		25	0–100	-0.0_31171	-0.0_5904	-0.0_856
Acetonitrile	C_2H_3N	15	0– 16	-0.0_31175	-0.0_42024	
Allyl alcohol	C_3H_6O	0	0– 89	-0.0_33729	-0.0_41232	$+0.0_72984$
Benzenepentacarboxylic acid	$C_{11}H_6O_{10}$	25	0– 0.6	$+0.0_35615$	-0.0_2117	
Butyl alcohol (*n*-)	$C_4H_{10}O$	20	0– 7.9	-0.0_31651	$+0.0_4285$	
Butyric acid (*n*-)	$C_4H_8O_2$	18	0– 10	$+0.0_3414$	$+0.0_4131$	
		25	0– 62	$+0.0_35135$	-0.0_4166	$+0.0_611$
Chloral hydrate	$C_2H_3Cl_3O_2$	0	0– 70	$+0.0_24489$	$+0.0_42802$	-0.0_71291
		15	0– 78	$+0.0_24455$	$+0.0_42198$	$+0.0_74366$
		30	0– 90	$+0.0_24401$	$+0.0_41887$	$+0.0_76549$
Chloroacetic acid	$C_2H_3ClO_2$	20	0– 32	$+0.0_23648$	$+0.0_5302$	
		25	0– 86	$+0.0_23602$	$+0.0_5552$	$+0.0_722$
Citric acid (hydrate)	$C_6H_3O_7 + H_2O$	18	0– 50	$+0.0_23824$	$+0.0_41141$	$+0.0_717$
Dichloroacetic acid	$C_2H_2Cl_2O_2$	20	0– 30	$+0.0_24427$	$+0.0_5537$	$+0.0_77534$
		25	0– 97	$+0.0_24427$	$+0.0_5537$	$+0.0_77534$
Diethylamine hydrochloride	$C_4H_{12}ClN$	21	0– 36	$+0.0_334$	$+0.0_676$	
Ethylamine hydrochloride	C_2H_8ClN	21	0– 65	$+0.0_21193$	-0.0_5307	-0.0_747
Ethylene glycol	$C_2H_6O_2$	0	0–100	$+0.0_21483$	$+0.0_52992$	-0.0_75248
		15	0– 6	$+0.0_3133$	-0.0_5108	
Ethyl ether	$C_4H_{10}O$	20	0– 5	-0.0_2221	$+0.0_448$	
		25	0– 4.5	-0.0_2221	$+0.0_435$	
tartrate	$C_8H_{14}O_6$	15	0– 95	$+0.0_22367$	$+0.0_5358$	-0.0_76005
Formaldehyde	CH_2O	15	0– 40	$+0.0_22518$	-0.0_5658	$+0.0_6542$
Formamide	CH_3NO	25	22– 96	$+0.0_31217$	$+0.0_53199$	-0.0_72529
Furfural	$C_5H_4O_2$	20	0– 8	$+0.0_21827$	$+0.0_5366$	
		25	0– 8	$+0.0_31664$	$+0.0_421$	
Isoamyl alcohol	$C_5H_{12}O$	20	0– 2.5	$+0.0_2155$	$+0.0_43$	
Isobutyl alcohol	$C_4H_{10}O$	15	0– 8	-0.0_2146	$+0.0_56$	
		20	0– 8	-0.0_2169	$+0.0_438$	
Isobutyric acid	$C_4H_8O_2$	15	0– 9	$+0.0_352$		
		18	0– 9	$+0.0_345$		
		25	0– 12	$+0.0_337$		
Isovaleric acid	$C_5H_{10}O_2$	25	0– 5	$+0.0_3253$	-0.0_4282	
Lactic acid	C_3H_6O	25	0– 9	$+0.0_2231$	$+0.0_5186$	
Maleic acid	$C_4H_4O_4$	25	0– 40	$+0.0_234$	$+0.0_575$	
Malic acid	$C_4H_6O_5$	20	0– 40	$+0.0_33933$	$+0.0_5957$	
		25	0– 40	$+0.0_23736$	$+0.0_4175$	
Malonic acid	$C_3H_4O_4$	20	0– 40	$+0.0_3389$	$+0.0_41066$	
Methyl acetate	$C_3H_6O_2$	20	0– 20	$+0.0_340$	-0.0_574	
glucoside (α-)	$C_7H_{14}O_6$	0	26– 51	$+0.0_33336$	$+0.0_5996$	$+0.01544$
		30	26– 51	$+0.0_33151$	$+0.0_5975$	$+0.0_8978$
Nicotine	$C_{10}H_{14}N_2$	20	0– 60	$+0.0_3642$	$+0.0_5454$	-0.0_7687
Nitrophenol (*p*-)	$C_6H_5NO_3$	15	0– 1.5	$+0.0_33216$	-0.0_455	
Oxalic acid	$C_2H_2O_4$	0	0– 4	$+0.0_25898$	-0.0_33185	$+0.0_441$
		15	0– 4	$+0.0_25494$	-0.0_58	
		17.5	0– 9	$+0.0_25494$	-0.0_58	
		20	0– 4	$+0.0_25264$	-0.0_31996	$+0.0_4254$
		25	0– 4	$+0.0_25108$	-0.0_31607	$+0.0_4208$
Phenol	C_6H_6O	15	0– 5	$+0.0_2111$	-0.0_4283	
		80	0– 65	$+0.0_3462$	-0.0_686	
Phenylglycolic acid	$C_8H_8O_3$	25	0– 11	$+0.0_2207$	$+0.0_423$	
Picoline (α-)	C_6H_7N	25	0– 70	-0.0_4386	-0.0_51405	-0.0_74167
(β-)	C_6H_7N	25	0– 60	-0.0_4683	-0.0_513	
Propionic acid	$C_3H_6O_2$	18	0– 10	$+0.0_395$	-0.0_4172	
		25	0– 40	$+0.0_39245$	-0.0_599	$+0.0_7361$
Pyridine	C_5H_5N	25	0– 60	$+0.0_3229$	-0.0_5204	-0.0_828
Resorcinol	$C_6H_6O_2$	18	0– 52	$+0.0_2201$	$+0.0_5519$	-0.0_819
Succinic acid	$C_4H_6O_4$	25	0– 5.5	$+0.0_2304$		
Tartaric acid (*d, l,* or *dl*)	$C_4H_6O_6$	15	0– 15	$+0.0_24482$	$+0.0_4185$	
		17.5	0– 50	$+0.0_24455$	$+0.0_4185$	
		20	0– 50	$+0.0_24432$	$+0.0_41837$	
		30	0– 50	$+0.0_24335$	$+0.0_4185$	
		40	0– 50	$+0.0_24265$	$+0.0_4185$	
		50	0– 50	$+0.0_24205$	$+0.0_4185$	
		60	0– 50	$+0.0_24155$	$+0.0_4185$	

*From *International Critical Tables*, vol. 3, pp. 111–114.

TABLE 2-119 Densities of Aqueous Solutions of Miscellaneous Organic Compounds (*Concluded*)

Section A $d = d_w + Ap_s + Bp_s^2 + Cp_s^3$ (*Cont.*)

Name	Formula	t, °C	Range, p_s	A	B	C
Tetraethyl ammonium chloride	$C_8H_{20}ClN$	21	0–63	$+0.0_31884$	$+0.0_56$	$+0.0_7122$
Thiourea	CH_4N_2S	15	0–7	$+0.0_32995$	$+0.0_5374$	
Trichloroacetic acid	$C_2HCl_3O_2$	12.5	0–61	$+0.0_3499$	$+0.0_4153$	
		20	10–30	$+0.0_35053$	$+0.0_41387$	
		25	0–94	$+0.0_35051$	$+0.0_56119$	$+0.0_61038$
Triethylamine hydrochloride	$C_6H_{16}ClN$	21	0–54	$+0.0_36$	$+0.0_5558$	-0.0_869
Trimethyl carbinol	$C_4H_{10}O$	20	0–100	-0.0_31117	-0.0_41908	$+0.0_7957$
		25	0–100	-0.0_31286	-0.0_4176	$+0.0_7887$
Urea	CH_4N_2O	14.8	0–12	$+0.0_33213$	-0.0_44802	$+0.0_51216$
		18	0–51	$+0.0_32718$	$+0.0_51552$	$+0.0_72573$
		20	0–35	$+0.0_32702$	$+0.0_53712$	-0.0_72285
		25	0–10	$+0.0_32728$	-0.0_41817	$+0.0_51379$
Urethane	$C_3H_7NO_2$	20	0–56	$+0.0_21278$	-0.0_5245	-0.0_73437
Valeric acid (*n*-)	$C_5H_{10}O_2$	25	0–3	$+0.0_334$	-0.0_427	

Section B $d = d_s + Ap_w + Bp_w^2 + Cp_w^3$

Name	Formula	d_s	t, °C	Range, p_w	A	B	C
Butyl alcohol (*n*-)	$C_4H_{10}O$	0.8097	20	0–20	$+0.0_22103$	-0.0_4113	
Butyric acid (*n*-)	$C_4H_8O_2$	0.9534	25	0–38	$+0.0_21854$	-0.0_42314	
Ethyl ether	$C_4H_{10}O$	0.7077	25	0– 1.1	$+0.0_234$	$+0.0_336$	
Isobutyl alcohol	$C_4H_{10}O$	0.8170	0	0–14	$+0.0_22437$	-0.0_4285	
		0.8055	15	0–16	$+0.0_2224$	-0.0_4129	
Isobutyric acid	$C_4H_8O_2$	0.9425	26	0–80	$+0.0_21808$	-0.0_42358	$+0.0_61253$
Nicotine	$C_{10}H_{14}N_2$	1.0093	20	0–40	$+0.0_2199$	-0.0_4331	$+0.0_7315$
Picoline (α-)	C_6H_7N	0.9404	25	0–30	$+0.0_22715$	-0.0_4393	
(β-)	C_6H_7N	0.9515	25	0–40	$+0.0_21925$	-0.0_4352	$+0.0_625$
Pyridine	C_5H_5N	0.9776	25	0–40	$+0.0_21157$	-0.0_5536	-0.0_62
Trimethyl carbinol	$C_4H_{10}O$	0.7856	20	0–20	$+0.0_22287$	$+0.0_5275$	

Section C $d_t = d_o + At + Bt^2$

Name	Formula	p_s	d_o	Range, °C	A	B
Allyl alcohol	C_3H_6O	76.60	0.9122	0–45	-0.0_38	-0.0_527
Butyl alcohol (*n*-)	$C_4H_{10}O$	80.95	0.8614	0–43	-0.0_37292	-0.0_675
Chloral hydrate	$C_2H_3Cl_3O_2$	2.00	1.0094	7–80	-0.0_42597	-0.0_54313
		10.00	1.0476	7–80	-0.0_47955	-0.0_54253
Ethyl tartrate	$C_7H_{14}O_6$	5.00	1.0150	15–80	-0.0_32103	-0.0_52544
		10.00	1.0270	15–80	-0.0_32116	-0.0_62929
		25.00	1.0665	15–80	-0.0_3401	-0.0_523
Furfural	$C_5H_4O_2$	4.62	1.0125	22–74	-0.0_3232	-0.0_5254
		5.69	1.0140	22–74	-0.0_3221	-0.0_5268
		6.56	1.0155	22–74	-0.0_3211	-0.0_5290
Pyridine	C_5H_5N	9.34	1.0055	11–73	-0.0_3171	-0.0_53615
		21.20	1.0115	14–73	-0.0_3378	-0.0_5248
		29.50	1.0145	12–72	-0.0_3463	-0.0_5235
		40.40	1.0182	9–74	-0.0_3605	-0.0_5167

DENSITIES OF MISCELLANEOUS MATERIALS

TABLE 2-120 Approximate Specific Gravities and Densities of Miscellaneous Solids and Liquids*

Water at 4 °C and normal atmospheric pressure taken as unity. For more detailed data on any material, see the section dealing with the properties of that material.

Substance	Sp. gr.	Aver. density lb/ft^3
Metals, Alloys, Ores		
Aluminum, cast-hammered	2.55–2.80	165
bronze	7.7	481
Brass, cast-rolled	8.4–8.7	534
Bronze, 7.9 to 14% Sn	7.4–8.9	509
phosphor	8.88	554
Copper, cast-rolled	8.8–8.95	556
ore, pyrites	4.1–4.3	262
German silver	8.58	536
Gold, cast-hammered	19.25–19.35	1205
coin (U.S.)	17.18–17.2	1073
Iridium	21.78–22.42	1383
Iron, gray cast	7.03–7.13	442
cast, pig	7.2	450
wrought	7.6–7.9	485
spiegeleisen	7.5	468
ferro-silicon	6.7–7.3	437
ore, hematite	5.2	325
ore, limonite	3.6–4.0	237
ore, magnetite	4.9–5.2	315
slag	2.5–3.0	172
Lead	11.34	710
ore, galena	7.3–7.6	465
Manganese	7.42	475
ore, pyrolusite	3.7–4.6	259
Mercury	13.6	849
Monel metal, rolled	8.97	555
Nickel	8.9	537
Platinum, cast-hammered	21.5	1330
Silver, cast-hammered	10.4–10.6	656
Steel, cold-drawn	7.83	489
machine	7.80	487
tool	7.70–7.73	481
Tin, cast-hammered	7.2–7.5	459
cassiterite	6.4–7.0	418
Tungsten	19.22	1200
Zinc, cast-rolled	6.9–7.2	440
blende	3.9–4.2	253
Various Solids		
Cereals, oats, bulk	0.51	26
barley, bulk	0.62	39
corn, rye, bulk	0.73	45
wheat, bulk	0.77	48
Cork	0.22–0.26	15
Cotton, flax, hemp	1.47–1.50	93
Fats	0.90–0.97	58
Flour, loose	0.40–0.50	28
pressed	0.70–0.80	47
Glass, common	2.40–2.80	162
plate or crown	2.45–2.72	161
crystal	2.90–3.00	184
dint	3.2–4.7	247
Hay and straw, bales	0.32	20
Leather	0.86–1.02	59
Paper	0.70–1.15	58
Potatoes, piled	0.67	44
Rubber, caoutchouc	0.92–0.96	59
goods	1.0–2.0	94
Salt, granulated, piled	0.77	48
Saltpeter	1.07	67
Starch	1.53	96
Sulfur	1.93–2.07	125
Wool	1.32	82

Substance	Sp. gr.	Aver. density lb/ft^3
Timber, Air-dry		
Apple	0.66–0.74	44
Ash, black	0.55	34
white	0.64–0.71	42
Birch, sweet, yellow	0.71–0.72	44
Cedar, white, red	0.35	22
Cherry, wild red	0.43	27
Chestnut	0.48	30
Cypress	0.45–0.48	29
Elm, white	0.56	35
Fir, Douglas	0.48–0.55	32
balsam	0.40	25
Hemlock	0.45–0.50	29
Hickory	0.74–0.80	48
Locust	0.67–0.77	45
Mahogany	0.56–0.85	44
Maple, sugar	0.68	43
white	0.53	33
Oak, chestnut	0.74	46
live	0.87	54
red, black	0.64–0.71	42
white	0.77	48
Pine, Norway	0.55	34
Oregon	0.51	32
red	0.48	30
Southern	0.61–0.67	38–42
white	0.43	27
Poplar	0.43	27
Redwood, California	0.42	26
Spruce, white, red	0.45	28
Teak, African	0.99	62
Indian	0.66–0.88	48
Walnut, black	0.59	37
Willow	0.42–0.50	28
Various Liquids		
Alcohol, ethyl (100%)	0.789	49
methyl (100%)	0.796	50
Acid, muriatic, 40%	1.20	75
nitric, 91%	1.50	94
sulfuric, 87%	1.80	112
Chloroform	1.500	95
Ether	0.736	46
Lye, soda, 66%	1.70	106
Oils, vegetable	0.91–0.94	58
mineral, lubricants	0.88–0.94	57
Turpentine	0.861–0.867	54
Water, 4°C max. density	1.0	62.428
100°C	0.9584	59.830
ice	0.88–0.92	56
snow, fresh fallen	0.125	8
sea water	1.02–1.03	64
Ashlar Masonry		
Bluestone	2.3–2.6	153
Granite, syenite, gneiss	2.4–2.7	159
Limestone	2.1–2.8	153
Marble	2.4–2.8	162
Sandstone	2.0–2.6	143
Rubble Masonry		
Bluestone	2.2–2.5	147
Granite, syenite, gneiss	2.3–2.6	153
Limestone	2.0–2.7	147
Marble	2.3–2.7	156
Sandstone	1.9–2.5	137

Substance	Sp. gr.	Aver. density lb/ft^3
Dry Rubble Masonry		
Granite, syenite, gneiss	1.9–2.3	130
Limestone, marble	1.9–2.1	125
Sandstone, bluestone	1.8–1.9	110
Brick Masonry		
Hard brick	1.8–2.3	128
Medium brick	1.6–2.0	112
Soft brick	1.4–1.9	103
Sand-lime brick	1.4–2.2	112
Concrete Masonry		
Cement, stone, sand	2.2–2.4	144
slag, etc.	1.9–2.3	130
cinder, etc.	1.5–1.7	100
Various Building Materials		
Ashes, cinders	0.64–0.72	40–45
Cement, Portland, loose	1.5	94
Lime, gypsum, loose	0.85–1.00	53–64
Mortar, lime, set	1.4–1.9	103
Portland cement	2.08–2.25	94–135
Portland cement	3.1–3.2	196
Slags, bank slag	1.1–1.2	67–72
bank screenings	1.5–1.9	98–117
machine slag	1.5	96
slag sand	0.8–0.9	49–55
Earth, etc., Excavated		
Clay, dry	1.0	63
damp plastic	1.76	110
and gravel, dry	1.6	100
Earth, dry, loose	1.2	76
dry, packed	1.5	95
moist, loose	1.3	78
moist, packed	1.6	96
mud, flowing	1.7	108
mud, packed	1.8	115
Riprap, limestone	1.3–1.4	80–85
Riprap, sandstone	1.4	90
Riprap, shale	1.7	105
Sand, gravel, dry, loose	1.4–1.7	90–105
gravel, dry, packed	1.6–1.9	100–120
gravel, wet	1.89–2.16	126
Excavations in Water		
Clay	1.28	80
River mud	1.44	90
Sand or gravel	0.96	60
and clay	1.00	65
Soil	1.12	70
Stone riprap	1.00	65
Minerals		
Asbestos	2.1–2.8	153
Barytes	4.50	281
Basalt	2.7–3.2	184
Bauxite	2.55	159
Bluestone	2.5–2.6	159
Borax	1.7–1.8	109
Chalk	1.8–2.8	143
Clay, marl	1.8–2.6	137
Dolomite	2.9	181
Feldspar, orthoclase	2.5–2.7	162
Gneiss	2.7–2.9	175
Granite	2.6–2.7	165
Greenstone, trap	2.8–3.2	187
Gypsum, alabaster	2.3–2.8	159
Hornblende	3.0	187
Limestone	2.1–2.86	155
Marble	2.6–2.86	170
Magnesite	3.0	187
Phosphate rock, apatite	3.2	200
Porphyry	2.6–2.9	172

*From *Marks' Standard Handbook for Mechanical Engineers,* 10th ed., McGraw-Hill, 1996.

TABLE 2-120 Approximate Specific Gravities and Densities of Miscellaneous Solids and Liquids (*Concluded*)

Water at 4°C and normal atmospheric pressure taken as unity. For more detailed data on any material, see the section dealing with the properties of that material.

Substance	Sp. gr.	Aver. density lb/ft^3	Substance	Sp. gr.	Aver. density lb/ft^3	Substance	Sp. gr.	Aver. density lb/ft^3
Minerals (*Cont.*)			Bituminous Substances			Bituminous Substances (*Cont.*)		
Pumice, natural	0.37–0.90	40	Asphaltum	1.1–1.5	81	Petroleum	0.87	54
Quartz, flint	2.5–2.8	165	Coal, anthracite	1.4–1.8	97	refined (kerosene)	0.78–0.82	50
Sandstone	2.0–2.6	143	bituminous	1.2–1.5	84	benzine	0.73–0.75	46
Serpentine	2.7–2.8	171	lignite	1.1–1.4	78	gasoline	0.70–0.75	45
Shale, slate	2.6–2.9	172	peat, turf, dry	0.65–0.85	47	Pitch	1.07–1.15	69
						Tar, bituminous	1.20	75
Soapstone, talc	2.6–2.8	169	charcoal, pine	0.28–0.44	23			
Syenite	2.6–2.7	165	charcoal, oak	0.47–0.57	33	Coal and Coke, Piled		
			coke	1.0–1.4	75	Coal, anthracite	0.75–0.93	47–58
Stone, Quarried, Piled			Graphite	1.64–2.7	135	bituminous, lignite	0.64–0.87	40–54
Basalt, granite, gneiss	1.5	96	Paraffin	0.87–0.91	56	peat, turf	0.32–0.42	20–26
Greenstone, hornblende	1.7	107				charcoal	0.16–0.23	10–14
Limestone, marble, quartz	1.5	95				coke	0.37–0.51	23–32
Sandstone	1.3	82						
Shale	1.5	92						

NOTE: To convert pounds per cubic foot to kilograms per cubic meter, multiply by 16.02. °F = ⅘ °C + 32.

TABLE 2-121 Density (kg/m^3) of Selected Elements as a Function of Temperature

Temperature, K°	Element symbol												
	Al	Be†	Cr	Cu	Au	Ir	Fe	Pb	Mo	Ni	Pt	Ag	Zn†
50	2736	3650	7160	9019	19,490	22,600	7910	11,570	10,260	8960	21,570	10,620	7280
100	2732	3640	7155	9009	19,460	22,580	7900	11,520	10,260	8950	21,550	10,600	7260
150	2726	3630	7150	8992	19,420	22,560	7890	11,470	10,250	8940	21,530	10,575	7230
200	2719	3620	7145	8973	19,380	22,540	7880	11,430	10,250	8930	21,500	10,550	7200
250	2710	3610	7140	8951	19,340	22,520	7870	11,380	10,250	8910	21,470	10,520	7170
300	2701	3600	7135	8930	19,300	22,500	7860	11,330	10,240	8900	21,450	10,490	7135
400	2681	3580	7120	8885	19,210	22,450	7830	11,230	10,220	8860	21,380	10,430	7070
500	2661	3555	7110	8837	19,130	22,410	7800	11,130	10,210	8820	21,330	10,360	7000
600	2639	3530	7080	8787	19,040	22,360	7760	11,010	10,190	8780	21,270	10,300	6935
800	2591		7040	8686	18,860	22,250	7690	10,430	10,160	8690	21,140	10,160	6430
1000	2365	___	7000	8568	18,660	22,140	7650	10,190	10,120	8610	21,010	10,010	6260
1200	2305		6945	8458	18,440	22,030	7620	9,940	10,080	8510	20,870	9,850	
1400	2255		6890	7920	17,230	21,920	7520		10,040	8410	20,720	9,170	
1600			6760	7750	16,950	21,790	7420		10,000	8320	20,570	8,980	
1800			6700	7600		21,660	7320		9,950	7690	20,400		
2000				7460		21,510	7030		9,900	7450	20,220		

NOTE: Above the horizontal line the condensed phase is solid; below the line, it is liquid.
°°R = ⅘ K.
†Polycrystalline form tabulated. Similar tables for an additional 45 elements appear in the *Handbook of Heat Transfer,* 2d ed., McGraw-Hill, New York, 1984.

SOLUBILITIES

UNITS CONVERSIONS

For this subsection, the following units conversions are applicable:

$$°F = \tfrac{9}{5}\,°C + 32.$$

To convert cubic centimeters to cubic feet, multiply by 3.532×10^{-5}.

To convert millimeters of mercury to pounds-force per square inch, multiply by 0.01934.

To convert grams per liter to pounds per cubic foot, multiply by 6.243×10^{-2}.

A database containing solubilities originally published in the International Union for Pure and Applied Chemistry (IUPAC)-National Institute of Standards and Technology (NIST) Solubility Data Series is now available at no cost online at http://srdata.nist.gov/solubility.

TABLE 2-122 Solubilities of Inorganic Compounds in Water at Various Temperatures*

This table shows the grams of anhydrous substance that are soluble in 100 g of water at the temperature in degrees Celsius as indicated; when the name is followed by †, the value is expressed in grams of substance in 100 cm^3 of saturated solution. Solid phase gives the hydrated form in equilibrium with the saturated solution.

	Substance	Formula	Solid phase	0 °C	10 °C	20 °C	30 °C	40 °C	50 °C	60 °C	70 °C	80 °C	90 °C	100 °C	
1	Aluminum chloride	$AlCl_3$	$6H_2O$			69.86[15°]									1
2	sulfate	$Al_2(SO_4)_3$	$18H_2O$	31.2	33.5	36.4	40.4	46.1	52.2	59.2	66.1	73.0	80.8	89.0	2
3	Ammonium aluminum sulfate	$(NH_4)_2Al_2(SO_4)_4$	$24H_2O$	2.1	4.99	7.74	10.94	14.88	20.10	26.70				109.7[96°]	3
4	bicarbonate	NH_4HCO_3		11.9	15.8	21	27								4
5	bromide	NH_4Br		60.6	68	75.5	83.2	91.1	99.2	107.8	116.8	126	135.6	145.6	5
6	chloride	NH_4Cl		29.4	33.3	37.2	41.4	45.8	50.4	55.2	60.2	65.6	71.3	77.3	6
7	chloroplatinate	$(NH_4)_2PtCl_6$			0.7									1.25	7
8	chromate	$(NH_4)_2CrO_4$					40.4								8
9	chromium sulfate	$(NH_4)_2Cr_2(SO_4)_4$	$24H_2O$			10.78[25°]									9
10	dichromate	$(NH_4)_2Cr_2O_7$					47.17								10
11	dihydrogen phosphite	$NH_4H_2PO_3$		171		190[14.5°]	260[31°]								11
12	hydrogen phosphate	$(NH_4)_2HPO_4$				131[15]									12
13	iodide	NH_4I		154.2	163.2	172.3	181.4	190.5	199.6	208.9	218.7	228.8		250.3	13
14	magnesium phosphate	NH_4MgPO_4	$6H_2O$	0.023		0.052		0.036	0.030	0.040	0.016	0.019			14
15	manganese phosphate	NH_4MnPO_4	$7H_2O$			0		0		0	0.005	0.007			15
16	nitrate	NH_4NO_3		118.3		192	241.8	297.0	344.0	421.0	499.0	580.0	740.0	871.0	16
17	oxalate	$(NH_4)_2C_2O_4$	$1H_2O$	2.2	3.1	4.4	5.9	8.0	10.3						17
18	perchlorate†	NH_4ClO_4†		11.56		20.85		30.58		39.05		48.19		57.01	18
19	persulfate	$(NH_4)_2S_2O_8$		58.2											19
20	sulfate	$(NH_4)_2SO_4$		70.6	73.0	75.4	78.0	81.0		88.0		95.3		103.3	20
21	thiocyanate	NH_4CNS		119.8	144	170	207.7								21
22	vanadate (meta)	NH_4VO_3				0.48	0.84	1.32	1.78		3.05				22
23	Antimonious fluoride	SbF_3		384.7		444.7	563.6								23
24	sulfide	Sb_2S_3				0.000175[18°]									24
25	Arsenic oxide	As_2O_5		59.5	62.1	65.8	69.5	71.2		73.0		75.1		76.7	25
26	Arsenious sulfide	As_2S_3		5.17×10^{-5} at 18°											26
27	Barium acetate	$Ba(C_2H_3O_2)_2$	$3H_2O$	59	63	71									27
28	acetate	$Ba(C_2H_3O_2)_2$	$1H_2O$				75	79	77	74	74			75	28
29	carbonate	$BaCO_3$			0.0016[8°]	0.0022[18°]	0.0024 at 24.2°								29
30	chlorate	$Ba(ClO_3)_2$	$1H_2O$	20.34	26.95	33.80	41.70	49.61		66.81		84.84		104.9	30
31	chloride	$BaCl_2$	$2H_2O$	31.6	33.3	35.7	38.2	40.7	43.6	46.4	49.4	52.4		58.8	31
32	chromate	$BaCrO_4$		0.0002	0.00028	0.00037	0.00046								32
33	hydroxide	$Ba(OH)_2$	$8H_2O$	1.67	2.48	3.89	5.59	8.22	13.12	20.94		101.4			33
34	iodide	BaI_2	$6H_2O$	170.2	185.7	203.1	219.6								34
35	iodide	BaI_2	$2H_2O$					231.9		247.3		261.0		271.7	35
36	nitrate	$Ba(NO_3)_2$		5.0	7.0	9.2	11.6	14.2	17.1	20.3		27.0		34.2	36
37	nitrite	$Ba(NO_2)_2$	$1H_2O$			67.5						205.8		300	37
38	oxalate	BaC_2O_4			0.0016[8°]	0.0022[18°]	0.0024 at 24.2°								38
39	perchlorate	$Ba(ClO_4)_2$	$3H_2O$	205.8		289.1		358.7	426.3		495.2		562.3		39
40	sulfate	$BaSO_4$		1.15×10^{-4}	2.0×10^{-4}	2.4×10^{-4}	2.85×10^{-4}								40
41	Beryllium sulfate	$BeSO_4$	$6H_2O$				52		60.67						41
42	sulfate	$BeSO_4$	$4H_2O$				43.78	46.74			62		83	100	42
43	sulfate	$BeSO_4$	$2H_2O$									84.76	98	110	43
44	Boric acid	H_3BO_3		2.66	3.57	5.04	6.60	8.72	11.54	14.81	16.73	23.75	30.38	40.25	44
45	Boron oxide	B_2O_3		1.1	1.5	2.2		4.0		6.2		9.5		15.7	45
46	Bromine	Br_2		4.22	3.4	3.20	3.13								46
47	Cadmium chloride	$CdCl_2$	$4H_2O$	97.59	125.1										47
48	chloride	$CdCl_2$	$2½H_2O$	90.01			132.1								48
49	chloride	$CdCl_2$	$1H_2O$		135.1	134.5		135.3		136.5		140.4		147.0	49
50	cyanide	$Cd(CN)_2$				1.7[15°]									50
51	hydroxide	$Cd(OH)_2$					2.6×10^{-4} at 25°								51
52	sulfate	$CdSO_4$		76.48	76.00	76.60		78.54		83.68			63.13	60.77	52
53	Calcium acetate	$Ca(C_2H_3O_2)_2$	$2H_2O$	37.4	36.0	34.7	33.8	33.2		32.7		33.5			53
54	acetate	$Ca(C_2H_3O_2)_2$	$1H_2O$										31.1	29.7	54

1	Calcium bicarbonate	$Ca(HCO_3)_2$		16.15		16.60		17.05		17.50		17.95		18.40	1
2	chloride	$CaCl_2$	$6H_2O$	59.5	65.0	74.5	102								2
3	chloride	$CaCl_2$	$2H_2O$							136.8	141.7	147.0	152.7	159	3
4	fluoride	CaF_2				$0.0016^{18°}$	$0.0017^{26°}$								4
5	hydroxide	$Ca(OH)_2$		0.185	0.176	0.165	0.153	0.141	0.128	0.116	0.106	0.094	0.085	0.077	5
6	nitrate	$Ca(NO_3)_2$	$4H_2O$	102.0	115.3	129.3	152.6	195.9							6
7	nitrate	$Ca(NO_3)_2$	$3H_2O$					237.5	281.5						7
8	nitrate	$Ca(NO_3)_2$										358.7		363.6	8
9	nitrite	$Ca(NO_2)_2$	$4H_2O$	62.07		76.68									9
10	nitrite	$Ca(NO_2)_2$	$2H_2O$							132.6	151.9		244.8		10
11	oxalate	CaC_2O_4			6.7×10^{-4} at 13°	6.8×10^{-4} at 25°	9.5×10^{-4} at 50°	14×10^{-4} at 95°							11
12	sulfate	$CaSO_4$	$2H_2O$	0.1759	0.1928		0.2090	0.2097		0.2047	0.1966			0.1619	12
13	Carbon dioxide, 760 mm ‡	CO_2		0.3346	0.2318	0.1688	0.1257	0.0973	0.0761	0.0576				0	13
14	monoxide, 760 mm ‡	CO		0.0044	0.0035	0.0028	0.0024	0.0021	0.0018	0.0015	0.0013	0.0010	0.0006	0	14
15	Cesium chloride	CsCl		161.4	174.7	186.5	197.3	208.0	218.5	229.7	239.5	250.0	260.1	270.5	15
16	nitrate	$CsNO_3$		9.33	14.9	23.0	33.9	47.2	64.4	83.8	107.0	134.0	163.0	197.0	16
17	sulfate	Cs_2SO_4		167.1	173.1	178.7	184.1	189.9	194.9	199.9	205.0	210.3	214.9	220.3	17
18	Chlorine, 760 mm ‡	Cl_2		1.46	0.980	0.716	0.562	0.451	0.386	0.324	0.274	0.219	0.125	0	18
19	Chromic anhydride	CrO_3		164.9				174.0	182.1				217.5	206.8	19
20	Cuprio chloride	$CuCl_2$	$2H_2O$	70.7	73.76	77.0	80.34	83.8	87.44	91.2		99.2		107.9	20
21	nitrate	$Cu(NO_3)_2$	$6H_2O$	81.8	95.28	125.1									21
22	nitrate	$Cu(NO_3)_2$	$3H_2O$					159.8		178.8		207.8			22
23	sulfate	$CuSO_4$	$5H_2O$	14.3	17.4	20.7	25	28.5	33.3	40		55		75.4	23
24	sulfide	CuS				3.3×10^{-5} at 18°									24
25	Cuprous chloride	CuCl				$1.52^{25°}$									25
26	Ferric chloride	$FeCl_3$		74.4	81.9	91.8			315.1			525.8		535.7	26
27	Ferrous chloride	$FeCl_2$	$4H_2O$		64.5		73.0	77.3	82.5	88.7		100			27
28	chloride	$FeCl_2$											105.3	105.8	28
29	nitrate	$Fe(NO_3)_2$	$6H_2O$	71.02		83.8				165.6					29
30	sulfate	$FeSO_4$	$7H_2O$	15.65	20.51	26.5	32.9	40.2	48.6						30
31	sulfate	$FeSO_4$	$1H_2O$								50.9	43.6	37.3		31
32	Hydrobromic acid, 760 mm	HBr		221.2	210.3	198			171.5					130	32
33	Hydrochloric acid, 760 mm	HCl		82.3			67.3	63.3	59.6	56.1					33
34	Iodine	I_2				0.029	0.04	0.056	0.078						34
35	Lead acetate	$Pb(C_2H_3O_2)_2$	$3H_2O$				$55.04^{25°}$								35
36	bromide	$PbBr_2$		0.4554		0.85	1.15	1.53	1.94	2.36		3.34		4.75	36
37	carbonate	$PbCO_3$				0.00011									37
38	chloride	$PbCl_2$		0.6728		0.99	1.20	1.45	1.70	1.98		2.62		3.34	38
39	chromate	$PbCrO_4$				7×10^{-6}									39
40	fluoride	PbF_2			0.060	0.064	0.068								40
41	nitrate	$Pb(NO_3)_2$		38.8	48.3	56.5	66	75	85	95		115		38.8	41
42	sulfate	$PbSO_4$		0.0028	0.0035	0.0041	0.0049	0.0056							42
43	Magnesium bromide	$MgBr_2$	$6H_2O$	91.0	94.5	96.5	99.2	101.6	104.1	107.5		113.7		120.2	43
44	chloride	$MgCl_2$	$6H_2O$	52.8	53.5	54.5		57.5		61.0		66.0		73.0	44
45	hydroxide	$Mg(OH)_2$				$0.0009^{18°}$									45
46	nitrate	$Mg(NO_3)_2$	$6H_2O$	66.55				84.74					137.0		46
47	sulfate	$MgSO_4$	$7H_2O$		30.9	35.5	40.8	45.6							47
48	sulfate	$MgSO_4$	$6H_2O$	40.8	42.2	44.5	45.3		50.4	53.5	59.5	64.2	69.0	74.0	48
49	sulfate	$MgSO_4$	$1H_2O$									62.9		68.3	49
50	Manganous sulfate	$MnSO_4$	$7H_2O$	53.23	60.01										50
51	sulfate	$MnSO_4$	$5H_2O$		59.5	62.9	67.76								51
52	sulfate	$MnSO_4$	$4H_2O$			64.5	66.44	68.8	72.6						52
53	sulfate	$MnSO_4$	$1H_2O$						58.17	55.0	52.0	48.0	42.5	34.0	53
54	Mercurous chloride	HgCl		0.00014		0.0002		0.0007							54
55	Molybdic oxide	MoO_3	$2H_2O$			0.138	0.264	0.476	0.687	1.206	2.055	2.106			55
56	Nickel chloride	$NiCl_2$	$6H_2O$	53.9	59.5	64.2	68.9	73.3	78.3	82.2	85.2			87.6	56
57	nitrate	$Ni(NO_3)_2$	$6H_2O$	79.58		96.31		122.2							57
58	nitrate	$Ni(NO_3)_2$	$3H_2O$							163.1	169.1		235.1		58
59	sulfate	$NiSO_4$	$7H_2O$	27.22	32		42.46								59
60	sulfate	$NiSO_4$	$6H_2O$						50.15	54.80	59.44	63.17		76.7	60
61	Nitric oxide, 760 mm	NO		0.00984	0.00757	0.00618	0.00517	0.00440	0.00376	0.00324	0.00267	0.00199	0.00114	0	61
62	Nitrous oxide	N_2O			0.1705	0.1211									62

°By N. A. Lange; abridged from "Table of Solubilities of Inorganic Compounds in Water at Various Temperatures" in *Lange's Handbook of Chemistry,* 10th ed., McGraw-Hill, New York, 1961 (except for NaCl, which is from *CRC Handbook of Chemistry and Physics,* 86th ed., CRC Press, 2005). For tables of the solubility of gases in water at various temperatures, Atack (*Handbook of Chemical Data,* Reinhold, New York, 1957) gives values at closer temperature intervals, usually 1 or 5 °C, than are tabulated here. For materials marked by ‡, additional data are given in tables subsequent to this one. For the solubility of various hydrocarbons in water at high pressures see *J. Chem. Eng. Data,* **4,** 212 (1959).

TABLE 2-122 Solubilities of Inorganic Compounds in Water at Various Temperatures (*Continued*)

	Substance	Formula	Solid phase	0 °C	10 °C	20 °C	30 °C	40 °C	50 °C	60 °C	70 °C	80 °C	90 °C	100 °C	
1	Potassium acetate	$KC_2H_3O_2$	$1\frac{1}{2}H_2O$	216.7	233.9	255.6	283.8	323.3							1
2	acetate	$KC_2H_3O_2$	$\frac{1}{2}H_2O$						337.3	350	364.8	380.1	396.3		2
3	alum	$K_2SO_4{\cdot}Al_2(SO_4)_3$	$24H_2O$	3.0	4.0	5.9	8.39	11.70	17.00	24.75	40.0	71.0	109.0		3
4	bicarbonate	$KHCO_3$		22.4	27.7	33.2	39.1	45.4		60.0					4
5	bisulfate	$KHSO_4$		36.3		51.4		67.3						121.6	5
6	bitartrate	$KHC_4H_4O_6$		0.32	0.40	0.53	0.90	1.32	1.83	2.46		4.6		6.95	6
7	carbonate	K_2CO_3	$2H_2O$	105.5	108	110.5	113.7	116.9	121.2	126.8	133.1	139.8	147.5	155.7	7
8	chlorate	$KClO_3$		3.3	5	7.4	10.5	14	19.3	24.5		38.5		57	8
9	chloride	KCl		27.6	31.0	34.0	37.0	40.0	42.6	45.5	48.3	51.1	54.0	56.7	9
10	chromate	K_2CrO_4		58.2	60.0	61.7	63.4	65.2	66.8	68.6	70.4	72.1	73.9	75.6	10
11	dichromate	$K_2Cr_2O_7$		5	7	12	20	26	34	43	52	61	70	80	11
12	ferricyanide	$K_3Fe(CN)_6$		31	36	43	50	60		66				82.6[104]	12
13	hydroxide	KOH	$2H_2O$	97	103	112	126								13
14	hydroxide	KOH	$1H_2O$						140					178	14
15	nitrate	KNO_3		13.3	20.9	31.6	45.8	63.9	85.5	110.0	138	169	202	246	15
16	nitrite	KNO_2		278.8		298.4		334.9						412.8	16
17	perchlorate	$KClO_4$		0.75	1.05	1.80	2.6	4.4	6.5	9	11.8	14.8	18	21.8	17
18	permanganate	$KMnO_4$		2.83	4.4	6.4	9.0	12.56	16.89	22.2					18
19	persulfate†	$K_2S_2O_8$†	†	1.62	2.60	4.49	7.19	9.89							19
20	sulfate	K_2SO_4		7.35	9.22	11.11	12.97	14.76	16.50	18.17	19.75	21.4	22.8	24.1	20
21	thiocyanate	KCNS		177.0		217.5									21
22	Silver cyanide	AgCN				2.2×10^{-5}									22
23	nitrate	$AgNO_3$		122	170	222	300	376	455	525		669		952	23
24	sulfate	Ag_2SO_4		0.573	0.695	0.796	0.888	0.979	1.08	1.15	1.22	1.30	1.36	1.41	24
25	Sodium acetate	$NaC_2H_3O_2$	$3H_2O$	36.3	40.8	46.5	54.5	65.5	83	139					25
26	acetate	$NaC_2H_3O_2$		119	121	123.5	126	129.5	134	139.5	146	153	161	170	26
27	bicarbonate	$NaHCO_3$		6.9	8.15	9.6	11.1	12.7	14.45	16.4					27
28	carbonate	Na_2CO_3	$10H_2O$	7	12.5	21.5	38.8								28
29	carbonate	Na_2CO_3	$1H_2O$				50.5	48.5		46.4		45.8		45.5	29
30	chlorate	$NaClO_3$		79	89	101	113	126	140	155	172	189		230	30
31	chloride	NaCl		35.65	35.72	35.89	36.09	36.37	36.69	37.04	37.46	37.93	38.47	38.99	31
32	chromate	Na_2CrO_4	$10H_2O$	31.70	50.17	88.7									32
33	chromate	Na_2CrO_4	$4H_2O$				88.7	95.96	104	114.6					33
34	chromate	Na_2CrO_4									123.0	124.8		125.9	34
35	dichromate	$Na_2Cr_2O_7$	$2H_2O$	163.0		177.8			244.8		316.7	376.2			35
36	dichromate	$Na_2Cr_2O_7$												426.3	36
37	dihydrogen phosphate	NaH_2PO_4	$2H_2O$	57.9	69.9	85.2	106.5	138.2							37
38	dihydrogen phosphate	NaH_2PO_4	$1H_2O$						158.6						38
39	dihydrogen phosphate	NaH_2PO_4								179.3	190.3	207.3	225.3	246.6	39
40	hydrogen arsenate	Na_2HAsO_4	$12H_2O$	7.3	15.5	26.5	37	47		65		85			40
41	hydrogen phosphate	Na_2HPO_4	$12H_2O$	1.67	3.6	7.7	20.8								41
42	hydrogen phosphate	Na_2HPO_4	$7H_2O$					51.8							42
43	hydrogen phosphate	Na_2HPO_4	$2H_2O$						80.2	82.9	88.1	92.4	102.9		43
44	hydrogen phosphate	Na_2HPO_4												102.2	44
45	hydroxide	NaOH	$4H_2O$	42											45
46	hydroxide	NaOH	$3\frac{1}{2}H_2O$		51.5										46
47	hydroxide	NaOH	$1H_2O$			109	119	129	145	174					47
48	hydroxide	NaOH											313	347	48
49	nitrate	$NaNO_3$		73	80	88	96	104	114	124		148		180	49
50	nitrite	$NaNO_2$		72.1	78.0	84.5	91.6	98.4	104.1			132.6		163.2	50
51	oxalate	$Na_2C_2O_4$				3.7								6.33	51
52	phosphate, tri-	Na_3PO_4	$12H_2O$	1.5	4.1	11	20	31	43	55		81		108	52
53	pyrophosphate	$Na_4P_2O_7$	$10H_2O$	3.16	3.95	6.23	9.95	13.50	17.45	21.83		30.04		40.26	53
54	sulfate	Na_2SO_4	$10H_2O$	5.0	9.0	19.4	40.8								54
55	sulfate	Na_2SO_4	$7H_2O$	19.5	30	44									55
56	sulfate	Na_2SO_4						48.8	46.7	45.3		43.7		42.5	56
57	sulfide	Na_2S	$9H_2O$		15.42	18.8	22.5	28.5							57
58	sulfide	Na_2S	$5\frac{1}{2}H_2O$						39.82	42.69	45.73	51.40	59.23		58
59	sulfide	Na_2S	$6H_2O$						36.4	39.1	43.31	49.14	57.28		59
60	sulfite	Na_2SO_3	$7H_2O$	13.9	20	26.9	36								60
61	sulfite	Na_2SO_3						28	28.2	28.8		28.3			61
62	tetraborate	$Na_2B_4O_7$	$10H_2O$	1.3	1.6	2.7	3.9		10.5	20.3					62
63	tetraborate	$Na_2B_4O_7$	$5H_2O$								24.4	31.5	41	52.5	63
64	vanadate (meta)	$NaVO_8$	$2H_2O$			15.3[25°]		30.2		68.4					64

TABLE 2-122 Solubilities of Inorganic Compounds in Water at Various Temperatures (*Concluded*)

	Substance	Formula	Solid phase	0 °C	10 °C	20 °C	30 °C	40 °C	50 °C	60 °C	70 °C	80 °C	90 °C	100 °C	
1	Sodium vanadate (meta)	$NaVO_3$				21.10[25°]		26.23		32.97	36.9	38.8[75°]			1
2	Stannous chloride	$SnCl_2$		83.9		269.8[15°]									2
3	sulfate	$SnSO_4$				19								18	3
4	Strontium acetate	$Sr(C_2H_3O_2)_2$	$4H_2O$	36.9	43.61										4
5	acetate	$Sr(C_2H_3O_2)_2$	$½H_2O$		42.95	41.6	39.5		37.35		36.24	36.10		36.4	5
6	chloride	$SrCl_2$	$6H_2O$	43.5	47.7	52.9	58.7	65.3	72.4	81.8					6
7	chloride	$SrCl_2$	$2H_2O$								85.9	90.5		100.8	7
8	nitrate	$Sr(NO_3)_2$	$1H_2O$	52.7		64.0			83.8	97.2			130.4	139	8
9	nitrate	$Sr(NO_3)_2$	$4H_2O$	40.1		70.5									9
10	nitrate	$Sr(NO_3)_2$					88.6	90.1		93.8	96	98	100		10
11	sulfate	$SrSO_4$		0.0113		0.0114	0.0114								11
12	Sulfur dioxide, 760 mm†	SO_2		22.83	16.21	11.29	7.81	5.41	4.5						12
13	Thallium sulfate	Tl_2SO_4		2.70	3.70	4.87	6.16		9.21	10.92	12.74	14.61	16.53	18.45	13
14	Thorium sulfate	$Th(SO_4)_2$	$9H_2O$	0.74	0.98	1.38	1.995	2.998	5.22						14
15	sulfate	$Th(SO_4)_2$	$8H_2O$	1.0	1.25	1.62									15
16	sulfate	$Th(SO_4)_2$	$6H_2O$	1.50		1.90	2.45			6.64					16
17	sulfate	$Th(SO_4)_2$	$4H_2O$					4.04	2.54	1.63	1.09				17
18	Zinc chlorate	$ZnClO_3$	$6H_2O$	145.0	152.5										18
19	chlorate	$ZnClO_3$	$4H_2O$			200.3	209.2	223.2	273.1						19
20	nitrate	$Zn(NO_3)_2$	$6H_2O$	94.78		118.3									20
21	nitrate	$Zn(NO_3)_2$	$3H_2O$					206.9							21
22	sulfate	$ZnSO_4$	$7H_2O$	41.9	47	54.4									22
23	sulfate	$ZnSO_4$	$6H_2O$					70.1	76.8						23
24	sulfate	$ZnSO_4$	$1H_2O$									86.6	83.7	80.8	24

TABLE 2-123 Solubility as a Function of Temperature and Henry's Constant at 25°C for Gases in Water

Name	Formula	*A*	*B*	*C*	*D*	*T* range, K	*H* at 25 °C, atm
Acetylene	C_2H_2	−156.51	8,160.2	21.403	0	274–343	1,330
Carbon dioxide	CO_2	−159.854	8,741.68	21.6694	−1.10261E-03	273–353	1,635
Carbon monoxide	CO	−171.764	8,296.9	23.3376	0	273–353	58,000
Ethane	C_2H_6	−250.812	12,695.6	34.7413	0	275–323	29,400
Ethylene	C_2H_4	−153.027	7,965.2	20.5248	0	287–346	11,726
Helium	He	−105.9768	4,259.62	14.0094	0	273–348	142,900
Hydrogen	H_2	−125.939	5,528.45	16.8893	0	273–345	70,800
Methane	CH_4	−338.217	13,282.1	51.9144	−0.0425831	273–523	39,200
Nitrogen	N_2	−181.587	8,632.13	24.7981	0	273–350	84,600
Oxygen	O_2	−171.2542	8,391.24	23.24323	0	273–333	43,400

The constants can be used to calculate solubility by the equation $\ln x = A + B/T + C \ln T + DT$, where T is in K and x is the mole fraction of the solute dissolved in water when the solute partial pressure is 1 atm. With the assumption that Henry's law is valid up to 1 atm, $H = 1/x$. Values of the constants are from P. G. T. Fogg and W. Gerrard, *Solubility of Gases in Liquids*, Wiley, 1991, New York, and *Solubility Data Series*, vol. 1, *Helium and Neon*, IUPAC, Pergamon Press, Oxford, 1979. For higher-temperature behavior and an up-to-date reference list, see R. Fernandez-Prini, J. L. Alvarez, and A. H. Harvey, *J. Phys. Chem. Ref. Data* **32**(2):903, 2003. To find H at temperatures other than 25 °C, first find the solubility and then take the reciprocal.

TABLE 2-124 Henry's Constant *H* for Various Compounds in Water at 25°C

Compound	CAS no.	Formula	*H*, atm	Rating
Paraffin Hydrocarbons				
Methane	74828	CH_4	36,600	4
Ethane	74840	C_2H_6	26,700	3
Propane	74986	C_3H_8	37,800	3
Butane	106978	C_4H_{10}	51,100	3
Pentane	109660	C_5H_{12}	70,000	3
Octane	111659	C_8H_{18}	274,000	3
Nonane	111842	C_9H_{20}	329,000	3
Olefins				
Ethylene	74851	C_2H_4	11,700	3
Propylene	115071	C_3H_6	11,700	4
Aromatics				
Benzene	71432	C_6H_6	299	10
Toluene	108883	C_7H_8	354	10
o-Xylene	95476	C_8H_{10}	272	10
Cumene	98828	C_9H_{12}	724	9
Phenol	108952	C_6H_6O	0.0394	7
Aldehydes				
Acetaldehyde	75,070	C_2H_4O	5.56	3
Propanal	123,386	C_3H_6O	4.36	4
Ketones				
Methyl ethyl ketone	78,933	C_4H_8O	2.59	5
Esters				
Methyl formate	107313	$C_2H_4O_2$	13.6	3
Ethyl formate	109944	$C_3H_6O_2$	13.6	3
Methyl acetate	79209	$C_3H_6O_2$	5.04	3
Butyl acetate	123864	$C_6H_{12}O_2$	13.6	3
Chlorine Containing				
Methyl chloride	74873	CH_3Cl	556	?
Chloroethane	75003	C_2H_5Cl	681	10
Chlorobenzene	108907	C_6H_5Cl	204	10
Alcohols				
Methanol	67561	CH_4O	0.272	4
Ethanol	64175	C_2H_6O	0.272	4
1-Propanol	71238	C_3H_8O	0.507	3
1-Butanol	71363	$C_4H_{10}O$	0.482	3
Miscellaneous				
Acrylonitrile	107131	C_3H_3N	5.54	3
Dimethyl sulfide	75183	C_2H_6S	121	3
Dimethyl disulfide	624920	$C_2H_6S_2$	68.1	3
Methyl mercaptan	74931	CH_4S	177	3
Ethyl mercaptan	75081	C_2H_6S	161	3
Pyridine	110861	C_5H_5N	0.817	3

Values in this table were taken from the Design Institute for Physical Properties (DIPPR) of the American Institute of Chemical Engineers (AIChE), copyright 2007 AIChE and reproduced with permission of AIChE, the DIPPR Environmental Safety Property Data and Estimations Streering Committee and of the DIPPR Evaluated Process Design Data Project Steering Committee. Their source should be cited as T. N. Rogers, D. A. Zei, R. L. Rowley, W. V. Wilding, J. L. Oscarson, Y. Yang, N. A. Zundel, T. E. Daubert, R. P. Danner, DIPPR® Data Compilation of Pure Chemical Properties, Design Institute for Physical Properties, AIChE, New York (2007). Flammability limits are from B. Lewis and G. Von Elbe, *Combustion, Flames and Explosions of Gases*, New York: Harcourt Brace Jovanovich (1987). Flash point data are from N. I. Sax, *Dangerous Properties of Industrial Materials*, 6th ed, New York: Van Nostrand Reinhold (1984). Autoignition data are from I. Glassman, *Combustion*, 3d ed, New York: Academic Press (1996). The ratings reflect DIPPR® ESP's effort to provide a critical evaluation and quality assessment of each data point with 15 being the highest score possible. The rating is not directly correlated with the estimated experimental uncertainty. The ratings reflect DIPPR Project 911's effort to provide a critical evaluation and quality assessment of each data point, with 10 being the highest score possible. The rating is not directly correlated with the estimated experimental uncertainty. Henry's constant is a strong nonlinear function of temperature. A single value measured at one temperature, if used for calculation at a different temperature, can lead to serious errors. Procedures for extrapolation of single-point values over the ambient temperature range ($4°C < T < 50°C$) are presented in Sec. 22, p. 22–49, under "Estimating Henry's law constants." Estimation procedures for the larger range ($4°C < T < 200°C$) are presented in F. L. Smith and A. H. Harvey, "Avoid Common Pitfalls When Using Henry's Law," *Chem. Eng. Prog.*, **103**(9), 2007. See also Y.-L. Huang, J. D. Olson, and G. E. Keller II, "Steam Stripping for Removal of Organic Pollutants from Water. 2. Vapor-Liquid Equilibrium Data," *Ind. Eng. Chem. Res.*, **31**, pp. 1759–1768, 1992. (Also see the Supplementary Material, which contains the databank of 404 compounds of environmental interest and other useful property data.).

The H in Tables 2-123 to 2-134 is the proportionality constant in Henry's law, $p = Hx$, where x is the mole fraction of the solute in the aqueous liquid phase; p is the partial pressure in atm of the solute in the gas phase; and H is a proportionality constant, generally referred to as Henry's constant. Values of H often have considerable uncertainty and are strong functions of temperature. To convert values of H at 25°C from atm to atm/(mol/m^3), divide by the molar density of water at 25°C, which is 55,342 mol/m^3. Henry's law is valid only for dilute solutions.

Additional values of Henry's constant can be found in "Environmental Simulation Program": OLI Systems, Inc., Morris Plains, N.J; "Estimated Henry's Law Constant," EPA Online Tools for Site Assessment Calculation (http://www.epa.gov/athens/learn2model/part-two/onsite/esthenry.htm); "Compilation of Henry's Law Constants for Inorganic and Organic Species of Potential Importance in Environmental Chemistry," Rolf Sander, Air Chemistry Department, Max-Planck Institute of Chemistry, Mainz, Germany; "Modeling Atmospheric Chemistry: Interactions between Gas-Phase Species and Liquid Cloud/Aerosol Particles," Rolf Sander, *Surv. Geophys.* **20:**1–31, 1999 (http://www.henrys-law.org).

TABLE 2-125 Henry's Constant *H* for Various Compounds in Water at 25 °C from Infinite Dilution Activity Coefficients

Compound	CAS no.	Formula	$H = \gamma^{\infty} P_{vp}$, atm
Pentane	109660	C_5H_{12}	63700
Hexane	1100543	C_6H_{14}	84600
Heptane	142825	C_7H_{16}	120000
Benzene	71432	C_6H_6	309
Toluene	108883	C_7H_8	344
o-Xylene	95476	C_8H_{10}	267
Cumene	98,828	C_9H_{12}	613
Styrene	100425	C_8H_8	145
Formaldehyde	50000	CH_2O	14.3
Acetaldehyde	75070	C_2H_4O	4.54
Propanal	123386	C_3H_6O	5.45
Acetone	67641	C_3H_6O	2.13
Methyl ethyl ketone	78933	C_4H_8O	3.11
Methyl *n*-propyl ketone	107879	$C_5H_{10}O$	4.60
Formic acid	64186	CH_2O_2	0.0404
Methyl acetate	79209	$C_3H_6O_2$	6.38
Ethyl acetate	141786	$C_4H_8O_2$	8.01
Butyl acetate	123864	$C_6H_{12}O_2$	12.3
Chloroethane	75003	C_2H_5Cl	626
1-Chloropropane	74986	C_3H_7Cl	792
Chlorobenzene	108907	C_6H_5Cl	219
Methanol	67561	CH_4O	0.263
Ethanol	64175	C_2H_6O	0.293
Pyridine	110861	C_5H_5N	0.544
Diethyl ether	60297	$C_4H_{10}O$	48.7
Thiophene	110021	C_4H_4S	160

Henry's constant H at 25 °C is the vapor pressure at 25 °C times the infinite dilution activity coefficient, also at 25 °C. Infinite dilution activity coefficients are from Mitchell and Jurs, *J. Chem. Inf. Comput. Sci*. **38:** 200 (1998). Henry's constant is a strong nonlinear function of temperature. A single value measured at one temperature, if used for calculation at a different temperature, can lead to serious errors. Procedures for extrapolation of single-point values over the ambient temperature range (4°C < T < 50°C) are presented in Sec. 22, p. 22–49, under "Estimating Henry's law constants." Estimation procedures for the larger range (4°C < T < 200°C) are presented in F. L. Smith and A. H. Harvey, "Avoid Common Pitfalls When Using Henry's Law," *Chem. Eng. Prog.,* **103**(9), 2007. See also Y.-L. Huang, J. D. Olson, and G. E. Keller II, "Steam Stripping for Removal of Organic Pollutants from Water. 2. Vapor-Liquid Equilibrium Data," *Ind. Eng. Chem. Res.*, **31**, pp. 1759–1768, 1992. (Also see the Supplementary Material, which contains the databank of 404 compounds of environmental interest and other useful property data.)

TABLE 2-126 Air*

t, °C	0	5	10	15	20	25	30	35
$10^{-4} \times H$†	4.32	4.88	5.49	6.07	6.64	7.20	7.71	8.23
t, °C	40	45	50	60	70	80	90	100
$10^{-4} \times H$†	8.70	9.11	9.46	10.1	10.5	10.7	10.8	10.7

**International Critical Tables,* vol. 3, p. 257.

†H is calculated from the absorption coefficients of O_2 and N_2, taking into consideration the correction for constant argon content.

TABLE 2-127 Ammonia-Water at 10 and 20 °C*

	10 °C		20 °C	
Mass fraction NH_3 in liquid	P, kPa	Mass fraction NH_3 in vapor	P, kPa	Mass fraction NH_3 in vapor
0.0	1.23	0.0	2.34	0.0
0.00467	1.37	0.1		
0.00495			2.60	0.1
0.1	7.07	0.84164	11.95	0.82096
0.2	20.07	0.95438	32.34	0.94541
0.3	47.37	0.98565	73.85	0.98199
0.4	99.84	0.99544	150.56	0.99393
0.5	184.44	0.99848	269.50	0.99783
0.6	292.15	0.99943	416.63	0.99913
0.7	399.03	0.99975	560.61	0.99960
0.8	486.44	0.99988	678.61	0.99980
0.9	554.33	0.99995	771.87	0.99991
1.0	615.05	1.0	857.48	1.0

*Selected values from R. Tillner-Roth and D. G. Friend, *J. Phys. Chem. Ref. Data* **27:**63 (1998). This reference lists solubilities for temperatures from –70 to 340°C. Densities, enthalpies, and entropies are listed for both the two-phase and single-phase regions for pressures up to 40 MPa.

TABLE 2-128 Carbon Dioxide (CO_2)*

	Liquid mol fraction $CO_2 \times 10^3$								
Total pressure, atm	0 °C	10 °C	15 °C	20 °C	25 °C	35 °C	50 °C	75 °C	100 °C
1	1.445	0.985	0.802	0.692	0.608	0.473	0.342	0.248	0.187
2	2.89	1.946	1.587	1.374	1.207	0.943	0.683	0.495	0.373
10	12.71	8.81	7.32	6.44	5.74	4.54	3.30	2.41	1.841
20	21.23	15.38	13.13	11.84	10.75	8.64	6.34	4.65	3.62
30	25.79	19.80	17.49	16.22	15.05	12.80	9.10	6.78	5.35
36		21.45	19.42	18.30	17.29	14.80	10.63	7.90	6.35

*Values selected from G. Houghton, A. M. McLean, and P. D. Ritchie, *Chem. Eng. Sci*. **6:**132–137, 1957.

TABLE 2-129 Carbonyl Sulfide (COS)*

t, °C	0	5	10	15	20	25	30
$10^{-3} \times H$	0.92	1.17	1.48	1.82	2.19	2.59	3.04

**International Critical Tables,* vol. 3, p. 261.

TABLE 2-130 Chlorine (Cl_2)

Partial pressure of Cl_2, mmHg	Solubility, g of Cl_2 per liter					
	0 °C	10 °C	20 °C	30 °C	40 °C	50 °C
5	0.488	0.451	0.438	0.424	0.412	0.398
10	0.679	0.603	0.575	0.553	0.532	0.512
30	1.221	1.024	0.937	0.873	0.821	0.781
50	1.717	1.354	1.210	1.106	1.025	0.962
100	2.79	2.08	1.773	1.573	1.424	1.313
150	3.81	2.73	2.27	1.966	1.754	1.599
200	4.78	3.35	2.74	2.34	2.05	1.856
250	5.71	3.95	3.19	2.69	2.34	2.09
300		4.54	3.63	3.03	2.61	2.31
350		5.13	4.06	3.35	2.86	2.53
400		5.71	4.48	3.69	3.11	2.74
450		6.26	4.88	3.98	3.36	2.94
500		6.85	5.29	4.30	3.61	3.14
550		7.39	5.71	4.60	3.84	3.33
600		7.97	6.12	4.91	4.08	3.52
650		8.52	6.52	5.21	4.32	3.71
700		9.09	6.90	5.50	4.54	3.89
750		9.65	7.29	5.80	4.77	4.07
800		10.21	7.69	6.08	4.99	4.27
900			8.46	6.68	5.44	4.62
1000			9.27	7.27	5.89	4.97
1200	$Cl_2.8H_2O_2$ separates		10.84	8.42	6.81	5.67
1500			13.23	10.14	8.05	6.70
2000			17.07	13.02	10.22	8.38
2500			21.0	15.84	12.32	10.03
3000				18.73	14.47	11.70
3500				21.7	16.62	13.38
4000				24.7	18.84	15.04
4500				27.7	20.7	16.75
5000				30.8	23.3	18.46

Partial pressure of Cl_2, mmHg	Solubility, g of Cl_2 per liter					
	60 °C	70 °C	80 °C	90 °C	100 °C	110 °C
5	0.383	0.369	0.351	0.339	0.326	0.316
10	0.492	0.470	0.447	0.431	0.415	0.402
30	0.743	0.704	0.671	0.642	0.627	0.598
50	0.912	0.863	0.815	0.781	0.747	0.722
100	1.228	1.149	1.085	1.034	0.987	0.950
150	1.482	1.382	1.294	1.227	1.174	1.137
200	1.706	1.580	1.479	1.396	1.333	1.276
250	1.914	1.764	1.642	1.553	1.480	1.413
300	2.10	1.932	1.793	1.700	1.610	1.542
350	2.28	2.10	1.940	1.831	1.736	1.661
400	2.47	2.25	2.08	1.965	1.854	1.773
450	2.64	2.41	2.22	2.09	1.972	1.880
500	2.80	2.55	2.35	2.21	2.08	1.986
550	2.97	2.69	2.47	2.32	2.19	2.09
600	3.13	2.83	2.59	2.43	2.29	2.19
650	3.29	2.97	2.72	2.55	2.41	2.28
700	3.44	3.10	2.84	2.66	2.50	2.37
750	3.59	3.23	2.96	2.76	2.60	2.47
800	3.75	3.37	3.08	2.87	2.69	2.56
900	4.04	3.63	3.30	3.08	2.89	2.74
1000	4.36	3.88	3.53	3.28	3.07	2.91
1200	4.92	4.37	3.95	3.67	3.43	3.25
1500	5.76	5.09	4.58	4.23	3.95	3.74
2000	7.14	6.26	5.63	5.17	4.78	4.49
2500	8.48	7.40	6.61	6.05	5.59	5.25
3000	9.83	8.52	7.54	6.92	6.38	5.97
3500	11.22	9.65	8.53	7.79	7.16	6.72
4000	12.54	10.76	9.52	8.65	7.94	7.42
4500	13.88	11.91	10.46	9.49	8.72	8.13
5000	15.26	13.01	11.42	10.35	9.48	8.84

TABLE 2-131 Chlorine Dioxide (ClO_2)

Vol % of ClO_2 in gas phase	Weight of ClO_2, grams per liter of solution						
	0 °C	5 °C	10 °C	15 °C	20 °C	30 °C	40 °C
1	2.00	1.50	1.25	1.00	0.90	0.60	0.46
3	6.00	4.7	3.85	3.20	2.70	1.95	1.30
5	10.0	7.8	6.30	5.25	4.30	3.20	2.25
7	14.0	10.9	8.95	7.35	6.15	4.40	3.20
10	20.0	15.5	12.8	10.5	8.80	6.30	4.50
11		17.0	14.0	11.7	9.70	7.00	5.00
12		18.6	15.3	12.8	10.55	7.50	5.45
13		20.3	16.6	13.8	11.5	8.20	5.85
14			18.0	14.9	12.3	8.80	6.35
15			19.2	16.0	13.2	9.50	6.80
16			20.3	17.0	14.2	10.1	7.20

Ishi, *Chem. Eng. (Japan)*, **22:**153 (1958).

TABLE 2-132 Hydrogen Chloride (HCl)

Weights of HCl per 100 weights of H_2O	Partial pressure of HCl, mmHg			
	0 °C	10 °C	20 °C	30 °C
78.6	510	840		
66.7	130	233	399	627
56.3	29.0	56.4	105.5	188
47.0	5.7	11.8	23.5	44.5
38.9	1.0	2.27	4.90	9.90
31.6	0.175	0.43	1.00	2.17
25.0	0.0316	0.084	0.205	0.48
19.05	0.0056	0.016	0.0428	0.106
13.64	0.00099	0.00305	0.0088	0.0234
8.70	0.000118	0.000583	0.00178	0.00515
4.17	0.000018	0.000069	0.00024	0.00077
2.04		0.0000117	0.000044	0.000151

Weights of HCl per 100 weights of H_2O	Partial pressure of HCl, mm Hg		
	50 °C	80 °C	110 °C
78.6			
66.7			
56.3	535		
47.0	141	623	
38.9	35.7	188	760
31.6	8.9	54.5	253
25.0	2.21	15.6	83
19.05	0.55	4.66	28
13.64	0.136	1.34	9.3
8.70	0.0344	0.39	3.10
4.17	0.0064	0.095	0.93
2.04	0.00140	0.0245	0.280

Enthalpy and phase-equilibrium data for the binary system HCl-H_2O are given by Van Nuys, *Trans. Am. Inst. Chem. Engrs.*, **39,** 663 (1943).

TABLE 2-133 Hydrogen Sulfide (H_2S)

t, °C	0	5	10	15	20	25	30	35
$10^{-2} \times H$	2.68	3.15	3.67	4.23	4.83	5.45	6.09	6.76
t, °C	40	45	50	60	70	80	90	100
$10^{-2} \times H$	7.45	8.14	8.84	10.3	11.9	13.5	14.4	14.8

International Critical Tables, vol. 3, p. 259.

TABLE 2-134 Partial Vapor Pressure of Sulfur Dioxide over Water, mmHg

g SO_2/ 100 g H_2O	Temperature, °C								
	0	10	20	30	40	50	60	90	120
0.01	0.02	0.04	0.07	0.12	0.19	0.29	0.43	1.21	2.82
0.05	0.38	0.66	1.07	1.68	2.53	3.69	5.24	12.9	27.0
0.10	1.15	1.91	3.03	4.62	6.80	9.71	13.5	31.7	63.9
0.15	2.10	3.44	5.37	8.07	11.7	16.5	22.7	52.2	104
0.20	3.17	5.13	7.93	11.8	17.0	23.8	32.6	73.7	145
0.25	4.34	6.93	10.6	15.7	22.5	31.4	42.8	95.8	186
0.30	5.57	8.84	13.5	19.8	28.2	39.2	53.3	118	229
0.40	8.17	12.8	19.4	28.3	40.1	55.3	74.7	164	316
0.50	10.9	17.0	25.6	37.1	52.3	72.0	96.8	211	404
1.00	25.8	39.5	58.4	83.7	117	159	212	454	856
2.00	58.6	88.5	129	183	253	342	453	955	
3.00	93.2	139	202	285	393	530	700		
4.00	129	192	277	389	535	720			
5.00	165	245	353	496	679				
6.00	202	299	430	602	824				
8.00	275	407	585	818					
10.00	351	517	741						
15.00	542	796							
20.00	735								

Condensed from Rabe, A. E. and Harris, J. F., *J. Chem. Eng. Data,* **8** (3), 333–336, 1963.

THERMAL EXPANSION

UNITS CONVERSIONS

For this subsection, the following units conversion is applicable:

$$°F = \tfrac{9}{5}\,°C + 32$$

ADDITIONAL REFERENCES

The tables given under this subject are reprinted by permission from the *Smithsonian Tables.* For more detailed data on thermal expansion, see *International Critical Tables:* tabular index, vol. 3, p. 1; abrasives, vol. 2, p. 87; alloys, vol. 2, p. 463; building stones, vol. 2, p. 54; carbons, vol. 2, p. 303; elements, vol. 1, p. 102; enamels, vol. 2, p. 115; glass, vol. 2, p. 93; metals, vol. 2, p. 459; petroleums, vol. 2, p. 145; porcelains, vol. 2, pp. 70, 78; refractory materials, vol. 2, p. 83; solid insulators, vol. 2, p. 310.

THERMAL EXPANSION OF GASES

No tables of the coefficients of thermal expansion of gases are given in this edition. The coefficient at constant pressure, $1/\upsilon(\partial\upsilon/\partial T)_p$, for an ideal gas is merely the reciprocal of the absolute temperature. For a real gas or liquid, both it and the coefficient at constant volume, $1/p\ (\partial p/\partial T)_v$, should be calculated either from the equation of state or from tabulated *PVT* data.

TABLE 2-135 Linear Expansion of the Solid Elements*

C is the true expansion coefficient at the given temperature; M is the mean coefficient between given temperatures; where one temperature is given, the true coefficient at that temperature is indicated; α and β are coefficients in formula $l_t = l_0(1 + \alpha t + \beta t^2)$; l_0 is length at 0 °C (unless otherwise indicated, when, if x is the reference temperature, $l_t = l_x[1 + \alpha(t - t_x) + \beta(t - t_x)^2]$; l_t is length at t °C).

Element	Temp., °C	$C \times 10^4$	Temp. range, °C	$M \times 10^4$	Temp. range, °C	$\alpha \times 10^4$	$\beta \times 10^6$
Aluminum	20	0.224	100	0.235	0, 500	0.22	0.009
Aluminum	300	0.284	500	0.311			
Antimony	20	0.136‖	20	0.080⊥			
Arsenic	20	0.05					
Bismuth	20	0.014‖	20	0.103⊥			
Cadmium	0	0.54‖	−180, −140	0.59‖	20, 100	0.526‖	
Cadmium	0	0.20⊥	−180, −140	0.117⊥	20, 100	0.214⊥	
Carbon, diamond	50	0.012					
graphite	50	0.06					
Chromium			20, 100	0.068	20, 500	0.086	
Cobalt	20	0.123			6, 121	0.121	0.0064
Copper	20	0.162	100	0.166	0, 625	0.161	0.0040
Copper	200	0.170	300	0.175			
Gold	20	0.140	17, 100	0.143	0, 520	0.142	0.0022
Gold			−191, 17	0.132			
Indium	40	0.417					
Iodine			−190, 17	0.837			
Iridium	20	0.065			0, 80	0.0636	0.0032
Iridium					1070, 1720	0.0679	0.0011
Iron, soft	40	0.1210	0, 100	0.11			
cast	20	0.118			0, 750	0.1158	0.0053
wrought	20	0.119			0, 750	0.1170	0.0053
steel	20	0.114			0, 750	0.1118	0.0053
Lead (99.9)			20, 100	0.291	100, 240	0.269	0.011
	100	0.291	20, 200	0.300			
	280	0.343					
Magnesium	20	0.254	−100, +20	0.240	+20, 500	0.2480	0.0096
			20, 100	0.260			
Manganese	20	0.233	0, 100	0.228			
			−190, 0	0.159	20, 300	0.216	0.0121
Molybdenum†	20	0.053	0, 100	0.052	−142, 19	0.0515	0.0057
			25, 100	0.049	19, +305	0.0501	0.0014
			25, 500	0.055			
Nickel	20	0.126	0, 100	0.130	−190, +20	0.1308	0.0166
					+20, +300	0.1236	0.0066
					500, 1000	0.1346	0.0033
Osmium	40	0.066					
Palladium	20	0.1173			−190, +100	0.1152	0.00517
					0, 1000	0.1167	0.0022
Platinum	20	0.0887			−190, −100	0.0875	0.00314
	20	0.0893			0, +80	0.0890	0.00121
					0, 1000	0.0887	0.00132
Potassium			0, 50	0.83			
Rhodium	40	0.0850	6, 21	0.0876	−75, −112	0.0746	
Ruthenium	40	0.0963					
Selenium	0	0.439	0, 100	0.660			
Silicon	40	0.0763	−3, +18	0.0249	−75, −67	0.0182	
Silver	20	0.1846	0, 100	0.197	0, 875	0.1827	0.00479
	20	0.195			20, 500	0.1939	0.00295
Sodium			−190, −17	0.622	0, 50	0.72	
Steel, 36.4Ni			20, 260	0.031	260, 500	0.144	
			20, 340	0.055	340, 500	0.136	
Tantalum†	20	0.065	−78, 0	0.059	20, 400	0.0646	0.0009
			0, 100	0.0655			
Tellurium	20	0.016‖	20	0.272⊥			
Thallium	40	0.302					
Tin	20	0.214			8, 95	0.2033	0.0263
	20	0.305‖	20	0.154⊥			
Tungsten†	27	0.0444	0, 100	0.045	−105, +502	0.0428	0.00058
Zinc	20‡	0.643‖	−140, −100	0.656‖	+0, 400	0.354	0.010
	20‡	0.125⊥	+20, 100	0.639‖			
	20	0.358	+20, 100	0.141⊥			

**Smithsonian Tables.* For more complete tabulations see Table 142, *Smithsonian Physical Tables,* 9th ed., 1954; *Handbook of Chemistry and Physics,* 40th ed., pp. 2239–2245. Chemical Rubber Publishing Co.; Goldsmith, and Waterman, WADC-TR-58-476, 1959; Johnson (ed.), WADD-TR-60-56, 1960, etc.

†Molybdenum, 300 to 2500 °C; $l_t = l_{300}[1 + 5.00 \times 10^{-6}(t - 300) + 10.5 \times 10^{-10}(t - 300)^2]$

Tantalum, 300 to 2800 °C; $l_t = l_{300}[1 + 6.60 \times 10^{-6}(t - 300) + 5.2 \times 10^{-10}(t - 300)^2]$

Tungsten, 300 to 2700 °C; $l_t = l_{300}[1 + 4.44 \times 10^{-6}(t - 300) + 4.5 \times 10^{-10}(t - 300)^2]$

Beryllium, 20 to 100 °C; 12.3×10^{-6} per °C.

Columbium, 0 to 100 °C; 7.2×10^{-6} per °C.

Tantalum, 20 to 100 °C; 6.6×10^{-6} per °C.

‡These values for zinc were taken from Grüneisen and Goens, *Z. Physik.,* **29:**141 (1924).

TABLE 2-136 Linear Expansion of Miscellaneous Substances*

The coefficient of cubical expansion may be taken as three times the linear coefficient. In the following table, t is the temperature or range of temperature, and C, the coefficient of expansion.

Substance	t, °C	$C \times 10^4$	Substance	t, °C	$C \times 10^4$	Substance	t, °C	$C \times 10^4$
Amber	0–30	0.50	Jena thermometer 59^{III}	0–100	0.058	Topas:		
	0–09	0.61	Jena thermometer 59^{III}	−191–+16	0.424	Parallel to lesser horizontal axis	0–100	0.0832
Bakelite, bleached	20–60	0.22	Gutta percha	20	1.983	Parallel to greater horizontal axis	0–100	0.0836
Brass:			Ice	−20–−1	0.51	Parallel to vertical axis	0–100	0.0472
Cast	0–100	0.1875	Iceland spar:			Tourmaline:		
Wire	0–100	0.1930	Parallel to axis	0–80	0.2631	Parallel to longitudinal axis	0–100	0.0937
Wire	0–100	0.1783–0.193	Perpendicular to axis	0–80	0.0544	Parallel to horizontal axis	0–100	0.0773
71.5 Cu + 27.7 Zn + 0.3 Sn + 0.5 Pb	40	0.1859	Lead tin (solder) 2 Pb + 1 Sn	0–100	0.2508	Type metal	16.6–254	0.1952
71 Cu + 29 Zn	0–100	0.1906	Limestone	25–100	0.09	Vulcanite	0–18	0.6360
Bronze:			Magnalium	12–39	0.238	Wedgwood ware	0–100	0.0890
3 Cu + 1 Sn	16.6–100	0.1844	Manganin		0.181	Wood:		
3 Cu + 1 Sn	16.6–350	0.2116	Marble	15–100	0.117	Parallel to fiber:		
3 Cu + 1 Sn	16.6–957	0.1737	Monel metal	25–100	0.14	Ash	0–100	0.0951
86.3 Cu + 9.7 Sn + 4 Zn	40	0.1782		25–600	0.16	Beech	2.34	0.0257
97.6 Cu + 2.2 Sn + 0.2 P (hard)	0–80	0.1713	Paraffin	0–16	1.0662	Chestnut	2.34	0.0649
97.6 Cu + 2.2 Sn + 0.2 P (soft)	0–80	0.1708	Paraffin	16–38	1.3030	Elm	2.34	0.0565
Caoutchouc		0.657–0.686	Paraffin	38–49	4.7707	Mahogany	2.34	0.0361
Caoutchouc	16.7–25.3	0.770	Platinum-iridium, 10 Pt + 1 Ir	40	0.0884	Maple	2.34	0.0638
Celluloid	20–70	1.00	Platinum-silver, 1 Pt + 2 Ag	0–100	0.1523	Oak	2.34	0.0492
Constantan	4–29	0.1523	Porcelain	20–790	0.0413	Pine	2.34	0.0541
Duralumin, 94Al	20–100	0.23	Porcelain Bayeux	1000–1400	0.0553	Walnut	2.34	0.0658
	20–300	0.25	Quartz:			Across the fiber:		
Ebonite	25.3–35.4	0.842	Parallel to axis	0–80	0.0797	Beech	2.34	0.614
Fluorspar, CaF_2	0–100	0.1950	Parallel to axis	−190 to + 16	0.0521	Chestnut	2.34	0.325
German silver	0–100	0.1836	Perpend. to axis	0–80	0.1337	Elm	2.34	0.443
Gold-platinum, 2 Au + 1 Pt	0–100	0.1523	Quartz glass	−190 to + 16	−0.0026	Mahogany	2.34	0.404
Gold-copper, 2 Au + 1 Cu	0–100	0.1552	Quartz glass	16 to 500	0.0057	Maple	2.34	0.484
Glass:			Quartz glass	16 to 1000	0.0058	Oak	2.34	0.544
Tube	0–100	0.0833	Rock salt	40	0.4040	Pine	2.34	0.341
Tube	0–100	0.0828	Rubber, hard	0	0.691	Walnut	2.34	0.484
Plate	0–100	0.0891	Rubber, hard	−160	0.300	Wax white	10–26	2.300
Crown (mean)	0–100	0.0897	Speculum metal	0–100	0.1933	Wax white	26–31	3.120
Crown (mean)	50–60	0.0954	Steel, 0.14 C, 34.5 Ni	25–100	0.037	Wax white	31–43	4.860
Flint	50–60	0.0788		25–600	0.136	Wax white	43–57	15.227
Jena thermometer 16^{III} normal	0–100	0.081						

Smithsonian Tables.* For a more complete tabulation see Tables 143, 144. *Smithsonian Physical Tables.* 9th ed., 1954, also reprinted in *American Institute of Physics Handbook,* McGraw-Hill, New York, 1957; *Handbook of Chemistry and Physics,* 40th ed., pp. 2239–2245, Chemical Rubber Publishing Co. For data on many solids prior to 1926, see Gruneisen, *Handbuch der Physik,* vol. 10, pp. 1–52, 1926, translation available as *N.A.S.A.* RE 2-18-59W, 1959. For eight plastic solids below 300 K, see Scott, *Cryogenic Engineering,* p. 331, Van Nostrand, Princeton, NJ, 1959. For 11 other materials to 300 K, see Scott, *loc. cit.,* p. 333. For quartz and silica, see Cook, *Brit. J. Appl. Phys.,* **7, 285 (1956).

TABLE 2-137 Volume Expansion of Liquids*

If V_0 is the volume at 0°, then at t° the expansion formula is $V_t = V_0(1 + \alpha t + \beta t^2 + \gamma t^3)$. The table gives values of α, β, and γ, and of C, the true coefficient of volume expansion at 20° for some liquids and solutions. The temperature range of the observation is Δt. Values for the coefficient of volume expansion of liquids can be derived from the tables of specific volumes of the saturated liquid given as a function of temperature later in this section. $C = (dV/dt)/V_0$

Liquid	Range	$\alpha \times 10^3$	$\beta \times 10^6$	$\gamma \times 10^8$	$C \times 10^3$ at 20°
Acetic acid	16–107	1.0630	0.12636	1.0876	1.071
Acetone	0–54	1.3240	3.8090	–0.87983	1.487
Alcohol:					
Amyl	–15–80	0.9001	0.6573	1.18458	0.902
Ethyl, 30% by volume	18–39	0.2928	10.790	–11.87	
Ethyl, 50% by volume	0–39	0.7450	1.85	0.730	
Ethyl, 99.3% by volume	27–46	1.012	2.20		1.12
Ethyl, 500 atm pressure	0–40	0.866			
Ethyl, 3000 atm pressure	0–40	0.524			
Methyl	0–61	1.1342	1.3635	0.8741	1.199
Benzene	11–81	1.17626	1.27776	0.80648	1.237
Bromine	0–59	1.06218	1.87714	–0.30854	1.132
Calcium chloride:					
5.8% solution	18–25	0.07878	4.2742		0.250
40.9% solution	17–24	0.42383	0.8571		0.458
Carbon disulfide	–34–60	1.13980	1.37065	1.91225	1.218
500 atm pressure	0–50	0.940			
3000 atm pressure	0–50	0.581			
Carbon tetrachloride	0–76	1.18384	0.89881	1.35135	1.236
Chloroform	0–63	1.10715	4.66473	–1.74328	1.273
Ether	–15–38	1.51324	2.35918	4.00512	1.656
Glycerin		0.4853	0.4895		0.505
Hydrochloric acid, 33.2% solution	0–33	0.4460	0.215		0.455
Mercury	0–100	0.18182	0.0078		0.18186
Olive oil		0.6821	1.1405	–0.539	0.721
Pentane	0–33	1.4646	3.09319	1.6084	1.608
Potassium chloride, 24.3% solution	16–25	0.2695	2.080		0.353
Phenol	36–157	0.8340	0.10732	0.4446	1.090
Petroleum, 0.8467 density	24–120	0.8994	1.396		0.955
Sodium chloride, 20.6% solution	0–29	0.3640	1.237		0.414
Sodium sulfate, 24% solution	11–40	0.3599	1.258		0.410
Sulfuric acid:					
10.9% solution	0–30	0.2835	2.580		0.387
100.0%	0–30	0.5758	–0.432		0.558
Turpentine	–9–106	0.9003	1.9595	–0.44998	0.973
Water	0–33	–0.06427	8.5053	–6.7900	0.207

Smithsonian Tables,* Table 269. For a detailed discussion of mercury data, see Cook, *Brit. J. Appl. Phys.,* **7, 285 (1956). For data on nitrogen and argon, see Johnson (ed.), WADD-TR-60-56, 1960.

Bromoform[1] 7.7 – 50 °C.

$V_t = 0.34204[1 + 0.00090411(t - 7.7) + 0.0000006766(t - 7.7)^2]$

0.34204 is the specific volume of bromoform at 7.7 °C.

Glycerin[2] –62 to 0 °C.

$V_t = V_0(1 + 4.83 \times 10^{-4}t - 0.49 \times 10^{-6}t^2)$

0 – 80 °C.

$V_t = V_0(1 + 4.83 \times 10^{-4}t + 0.49 \times 10^{-6}t^2)$

Mercury[3] 0 – 300 °C.

$V_t = V_0[1 + 10^{-8}(18{,}153.8t + 0.7548t^2 + 0.001533t^2 + 0.00000536t^4)]$

[1] Sherman and Sherman, *J. Am. Chem. Soc.,* **50,** 1119 (1928). (An obvious error in their equation has been corrected.)
[2] Samsoen, *Ann. phys.,* (10) **9,** 91 (1928).
[3] Harlow, *Phil. Mag.,* (7) **7,** 674 (1929).

TABLE 2-138 Volume Expansion of Solids*

If v_2 and v_1 are the volumes at t_2 and t_1, respectively, then $v_2 = v_1(1 + C\Delta t)$, C being the coefficient of cubical expansion and Δt the temperature interval. Where only a single temperature is stated, C represents the true coefficient of volume expansion at that temperature.

Substance	t or Δt	$C \times 10^4$
Antimony	0–100	0.3167
Beryl	0–100	0.0105
Bismuth	0–100	0.3948
Copper†	0–100	0.4998
Diamond	40	0.0354
Emerald	40	0.0168
Galena	0–100	0.558
Glass, common tube	0–100	0.276
hard	0–100	0.214
Jena, borosilicate 59 III	20–100	0.156
pure silica	0–80	0.0129
Gold	0–100	0.4411
Ice	–20 to –1	1.1250
Iron	0–100	0.3550
Lead†	0–100	0.8399
Paraffin	20	5.88
Platinum	0–100	0.265
Porcelain, Berlin	20	0.0814
chloride	0–100	1.094
nitrate	0–100	1.967
sulfate	20	1.0754
Quartz	0–100	0.3840
Rock salt	50–60	1.2120
Rubber	20	4.87
Silver	0–100	0.5831
Sodium	20	2.13
Stearic acid	33.8–45.4	8.1
Sulfur, native	13.2–50.3	2.23
Tin	0–100	0.6889
Zinc†	0–100	0.8928

**Smithsonian Tables,* Table 268.
†See additional data below.

Aluminum[1] 100 – 530 °C.

$V = V_0(1 + 2.16 \times 10^{-5}t + 0.95 \times 10^{-8}t^2)$

Cadmium[1] 130 – 270 °C.

$V = V_0(1 + 8.04 \times 10^{-5}t + 5.9 \times 10^{-8}t^2)$

Copper[1] 110 – 300 °C.

$V = V_0(1 + 1.62 \times 10^{-5}t + 0.20 \times 10^{-8}t^2)$

Colophony[2] 0 – 34 °C.

$V = V_0(1 + 2.21 \times 10^{-4}t + 0.31 \times 10^{-6}t^2)$

34 – 150 °C.

$V = V_{34}[1 + 7.40 \times 10^{-4}(t - 34) + 5.91 \times 10^{-6}(t - 34)^2]$

Lead[1] 100 – 280 °C.

$V = V_0(1 + 1.60 \times 10^{-5}t + 3.2 \times 10^{-8}t^2)$

Shellac[2] 0 – 46 °C.

$V = V_0(1 + 2.73 \times 10^{-4}t + 0.39 \times 10^{-6}t^2)$

46 – 100 °C.

$V = V_{46}[1 + 13.10 \times 10^{-4}(t - 46) + 0.62 \times 10^{-6}(t - 46)^2]$

Silica (vitreous)[3] 0 – 300 °C.

$V_t = V_0[1 + 10^{-8}(93.6t + 0.7776t^2 - 0.003315t^2 + 0.000005244t^4)$

Sugar (cane, amorphous)[2] 0 – 67 °C.

$V_t = V_0(1 + 2.34 \times 10^{-4}t + 0.14 \times 10^{-6}t^2)$

67 – 160 °C.

$V_t = V_{67}[1 + 5.02 \times 10^{-4}(t - 67) + 0.43 \times 10^{-6}(t - 67)^2]$

Zinc[1] 120 – 360 °C.

$V_t = V_0(1 + 8.50 \times 10^{-5}t + 3.9 \times 10^{-8}t^2)$

[1] Uffelmann, *Phil. Mag.,* (7) **10,** 633 (1930).
[2] Samsoen, *Ann. phys.,* (10) **9,** 83 (1928).
[3] Harlow, *Phil. Mag.,* (7) **7,** 674 (1929).

JOULE-THOMSON EFFECT

UNITS CONVERSIONS

Joule-Thomson coefficients for substances listed in Table 2-184 are given in tables in the Thermodynamic Properties section.

For this subsection, the following units conversions are applicable:

To convert the Joule-Thomson coefficient, μ, in degrees Celsius per atmosphere to degrees Fahrenheit per atmosphere, multiply by 1.8.

$$°F = \tfrac{9}{5}\,°C + 32;\quad °R = \tfrac{9}{5}\,K$$

To convert bars to pounds-force per square inch, multiply by 14.504; to convert bars to kilopascals, multiply by 1×10^2.

TABLE 2-139 Additional References Available for the Joule-Thomson Coefficient

Gas	Pressure range, atm				Temp. range, °C			Other references
	0–10	10–50	50–200	>200	<0	0–300	>300	
Air	12, 15, 16 19, 35	12, 15, 19 35	15, 19, 35		19, 35	12, 15, 16 19, 35		3, 4, 18
Ammonia	28					28		2, 3
Argon	39	39	39		39	39		
Benzene	31	31	31			31	31	
Butane	26	26				26		
Carbon dioxide	7, 8, 28 37	7, 8, 37	7, 8, 37		7, 8, 37	7, 8, 9, 10 37		
Carbon monoxide	17	17			17	17		
Deuterium		22, 24, 25 1*	1,* 22, 24 25		1,* 22, 24, 25			
Dowtherm A	46	46				46	46	
Ethane	45	45				45		
Ethylene						9, 10		
Helium	1, 38	1, 38	38		1, 38	38		48
Hydrogen	24, 30	22, 24, 25 30	24, 30		22, 24, 25 30	24		
Methane		6	6			6		
Mixtures						9, 11		
Natural gas			33	33	33	33		
Nitrogen	13, 28, 40	13, 40	13, 40	13	13, 40	9, 10, 13 28, 40	13	19
Nitrous oxide						9, 10		
Pentane	26, 34, 44	34	34			26, 34, 44		
Propane	41	43				43		
Steam	28, 29, 42	29, 42, 47	42, 47			28, 29, 42 45	29, 42, 47	29, 47

*See also 14 (generalized chart); 18 (review, to 1919); 20–22; 23 (review, to 1948); 27 (review, to 1905); 32, 36, 41, 50.

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TABLE 2-140 Approximate Inversion-Curve Locus in Reduced Coordinates ($T_r = T/T_c$; $P_r = P/P_c$)*

P_r	0	0.5	1	1.5	2	2.5	3	4
T_{rL}	0.782	0.800	0.818	0.838	0.859	0.880	0.903	0.953
T_{rU}	4.984	4.916	4.847	4.777	4.706	4.633	4.550	4.401
P_r	5	6	7	8	9	10	11	11.79
T_{rL}	1.01	1.08	1.16	1.25	1.35	1.50	1.73	2.24
T_{rU}	4.23	4.06	3.88	3.68	3.45	3.18	2.86	2.24

*Calculated from the best three-constant equation recommended by Miller, *Ind. Eng. Chem. Fundam.,* **9,** 585 (1970). T_{rL} refers to the lower curve, and T_{rU}, to the upper curve.

CRITICAL CONSTANTS

ADDITIONAL REFERENCES

Other data and estimation techniques for the elements are contained in Gates and Thodos, *Am. Inst. Chem. Eng. J.*, **6** (1960):50–54; and Ohse and von Tippelskirch, *High Temperatures—High Pressures*, **9** (1977):367–385. For inorganic substances see Mathews, *Chem. Rev.*, **72** (1972):71–100; for organics see Kudchaker, Alani, and Zwolinski, *Chem. Rev.*, **68** (1968):659–735; and for fluorocarbons see *Advances in Fluorine Chemistry*, App. B, Butterworth. Washington, 1963, pp. 173–175. Pages 6–49 and 6–50 of the 84th edition of the *Handbook of Chemistry and Physics* provide an excellent list of references for critical properties.

TABLE 2-141 Critical Constants and Acentric Factors of Inorganic and Organic Compounds

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	T_c, K	P_c, MPa	V_c, m^3/kmol	Z_c	Acentric factor
1	Acetaldehyde	C_2H_4O	75-07-0	44.053	466	5.55	0.154	0.221	0.2907
2	Acetamide	C_2H_5NO	60-35-5	59.067	761	6.6	0.215	0.224	0.4210
3	Acetic acid	$C_2H_4O_2$	64-19-7	60.052	591.95	5.786	0.177	0.208	0.4665
4	Acetic anhydride	$C_4H_6O_3$	108-24-7	102.089	606	4	0.29	0.23	0.4535
5	Acetone	C_3H_6O	67-64-1	58.079	508.2	4.701	0.209	0.233	0.3065
6	Acetonitrile	C_2H_3N	75-05-8	41.052	545.5	4.83	0.173	0.184	0.3379
7	Acetylene	C_2H_2	74-86-2	26.037	308.3	6.138	0.112	0.268	0.1912
8	Acrolein	C_3H_4O	107-02-8	56.063	506	5	0.197	0.234	0.3198
9	Acrylic acid	$C_3H_4O_2$	79-10-7	72.063	615	5.66	0.208	0.23	0.5383
10	Acrylonitrile	C_3H_3N	107-13-1	53.063	535	4.48	0.212	0.214	0.3498
11	Air	Mixture	132259-10-0	28.960	132.45	3.774	0.09147	0.313	
12	Ammonia	H_3N	7664-41-7	17.031	405.65	11.28	0.07247	0.242	0.2526
13	Anisole	C_7H_8O	100-66-3	108.138	645.6	4.25	0.337	0.267	0.3502
14	Argon	Ar	7440-37-1	39.948	150.86	4.898	0.07459	0.291	0.0000
15	Benzamide	C_7H_7NO	55-21-0	121.137	824	5.05	0.346	0.255	0.5585
16	Benzene	C_6H_6	71-43-2	78.112	562.05	4.895	0.256	0.268	0.2103
17	Benzenethiol	C_6H_6S	108-98-5	110.177	689	4.74	0.315	0.261	0.2628
18	Benzoic acid	$C_7H_6O_2$	65-85-0	122.121	751	4.47	0.344	0.246	0.6028
19	Benzonitrile	C_7H_5N	100-47-0	103.121	699.35	4.215	0.3132	0.227	0.3662
20	Benzophenone	$C_{13}H_{10}O$	119-61-9	182.218	830	3.352	0.5677	0.276	0.5019
21	Benzyl alcohol	C_7H_8O	100-51-6	108.138	720.15	4.374	0.382	0.279	0.3631
22	Benzyl ethyl ether	$C_9H_{12}O$	539-30-0	136.191	662	3.11	0.442	0.25	0.4332
23	Benzyl mercaptan	C_7H_8S	100-53-8	124.203	718	4.06	0.367	0.25	0.3126
24	Biphenyl	$C_{12}H_{10}$	92-52-4	154.208	773	3.38	0.497	0.261	0.4029
25	Bromine	Br_2	7726-95-6	159.808	584.15	10.3	0.135	0.286	0.1290
26	Bromobenzene	C_6H_5Br	108-86-1	157.008	670.15	4.519	0.324	0.263	0.2506
27	Bromoethane	C_2H_5Br	74-96-4	108.965	503.8	6.23	0.215	0.32	0.2548
28	Bromomethane	CH_3Br	74-83-9	94.939	467	8	0.156	0.321	0.1922
29	1,2-Butadiene	C_4H_6	590-19-2	54.090	452	4.36	0.22	0.255	0.1659
30	1,3-Butadiene	C_4H_6	106-99-0	54.090	425	4.32	0.221	0.27	0.1950
31	Butane	C_4H_{10}	106-97-8	58.122	425.12	3.796	0.255	0.274	0.2002
32	1,2-Butanediol	$C_4H_{10}O_2$	584-03-2	90.121	680	5.21	0.303	0.279	0.6305
33	1,3-Butanediol	$C_4H_{10}O_2$	107-88-0	90.121	676	4.02	0.305	0.218	0.7043
34	1-Butanol	$C_4H_{10}O$	71-36-3	74.122	563.1	4.414	0.273	0.258	0.5883
35	2-Butanol	$C_4H_{10}O$	78-92-2	74.122	535.9	4.188	0.27	0.254	0.5692
36	1-Butene	C_4H_8	106-98-9	56.106	419.5	4.02	0.241	0.278	0.1845
37	*cis*-2-Butene	C_4H_8	590-18-1	56.106	435.5	4.21	0.234	0.272	0.2019
38	*trans*-2-Butene	C_4H_8	624-64-6	56.106	428.6	4.1	0.238	0.274	0.2176
39	Butyl acetate	$C_6H_{12}O_2$	123-86-4	116.158	575.4	3.09	0.389	0.251	0.4394
40	Butylbenzene	$C_{10}H_{14}$	104-51-8	134.218	660.5	2.89	0.497	0.262	0.3941
41	Butyl mercaptan	$C_4H_{10}S$	109-79-5	90.187	570.1	3.97	0.307	0.257	0.2714
42	*sec*-Butyl mercaptan	$C_4H_{10}S$	513-53-1	90.187	554	4.06	0.307	0.271	0.2506
43	1-Butyne	C_4H_6	107-00-6	54.090	440	4.6	0.208	0.262	0.2470
44	Butyraldehyde	C_4H_8O	123-72-8	72.106	537.2	4.32	0.258	0.25	0.2774
45	Butyric acid	$C_4H_8O_2$	107-92-6	88.105	615.7	4.06	0.293	0.232	0.6805
46	Butyronitrile	C_4H_7N	109-74-0	69.105	582.25	3.79	0.278	0.218	0.3714
47	Carbon dioxide	CO_2	124-38-9	44.010	304.21	7.383	0.094	0.274	0.2236
48	Carbon disulfide	CS_2	75-15-0	76.141	552	7.9	0.16	0.275	0.1107
49	Carbon monoxide	CO	630-08-0	28.010	132.92	3.499	0.0944	0.299	0.0482
50	Carbon tetrachloride	CCl_4	56-23-5	153.823	556.35	4.56	0.276	0.272	0.1926
51	Carbon tetrafluoride	CF_4	75-73-0	88.004	227.51	3.745	0.143	0.283	0.1790
52	Chlorine	Cl_2	7782-50-5	70.906	417.15	7.71	0.124	0.276	0.0688
53	Chlorobenzene	C_6H_5Cl	108-90-7	112.557	632.35	4.519	0.308	0.265	0.2499
54	Chloroethane	C_2H_5Cl	75-00-3	64.514	460.35	5.27	0.2	0.275	0.1902
55	Chloroform	$CHCl_3$	67-66-3	119.378	536.4	5.472	0.239	0.293	0.2219
56	Chloromethane	CH_3Cl	74-87-3	50.488	416.25	6.68	0.143	0.276	0.1531
57	1-Chloropropane	C_3H_7Cl	540-54-5	78.541	503.15	4.58	0.247	0.27	0.2277
58	2-Chloropropane	C_3H_7Cl	75-29-6	78.541	489	4.54	0.247	0.276	0.1986
59	*m*-Cresol	C_7H_8O	108-39-4	108.138	705.85	4.56	0.312	0.242	0.4480
60	*o*-Cresol	C_7H_8O	95-48-7	108.138	697.55	5.01	0.282	0.244	0.4339
61	*p*-Cresol	C_7H_8O	106-44-5	108.138	704.65	5.15	0.277	0.244	0.5072
62	Cumene	C_9H_{12}	98-82-8	120.192	631	3.209	0.434	0.265	0.3274
63	Cyanogen	C_2N_2	460-19-5	52.035	400.15	5.98	0.195	0.351	0.2790
64	Cyclobutane	C_4H_8	287-23-0	56.106	459.93	4.98	0.21	0.273	0.1847

TABLE 2-141 Critical Constants and Acentric Factors of Inorganic and Organic Compounds (*Continued*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	T_c, K	P_c, MPa	V_c, m^3/kmol	Z_c	Acentric factor
65	Cyclohexane	C_6H_{12}	110-82-7	84.159	553.8	4.08	0.308	0.273	0.2081
66	Cyclohexanol	$C_6H_{12}O$	108-93-0	100.159	650.1	4.26	0.322	0.254	0.3690
67	Cyclohexanone	$C_6H_{10}O$	108-94-1	98.143	653	4	0.311	0.229	0.2990
68	Cyclohexene	C_6H_{10}	110-83-8	82.144	560.4	4.35	0.291	0.272	0.2123
69	Cyclopentane	C_5H_{10}	287-92-3	70.133	511.7	4.51	0.26	0.276	0.1949
70	Cyclopentene	C_5H_8	142-29-0	68.117	507	4.8	0.245	0.279	0.1961
71	Cyclopropane	C_3H_6	75-19-4	42.080	398	5.54	0.162	0.271	0.1278
72	Cyclohexyl mercaptan	$C_6H_{12}S$	1569-69-3	116.224	664	3.97	0.355	0.255	0.2641
73	Decanal	$C_{10}H_{20}O$	112-31-2	156.265	674.2	2.6	0.58	0.269	0.5820
74	Decane	$C_{10}H_{22}$	124-18-5	142.282	617.7	2.11	0.617	0.254	0.4923
75	Decanoic acid	$C_{10}H_{20}O_2$	334-48-5	172.265	722.1	2.28	0.639	0.243	0.8126
76	1-Decanol	$C_{10}H_{22}O$	112-30-1	158.281	688	2.308	0.645	0.26	0.6070
77	1-Decene	$C_{10}H_{20}$	872-05-9	140.266	616.6	2.223	0.584	0.253	0.4805
78	Decyl mercaptan	$C_{10}H_{22}S$	143-10-2	174.347	696	2.13	0.624	0.23	0.5874
79	1-Decyne	$C_{10}H_{18}$	764-93-2	138.250	619.85	2.37	0.552	0.254	0.5178
80	Deuterium	D_2	7782-39-0	4.032	38.35	1.6617	0.060263	0.314	–0.1449
81	1,1-Dibromoethane	$C_2H_4Br_2$	557-91-5	187.861	628	6.03	0.276	0.319	0.1250
82	1,2-Dibromoethane	$C_2H_4Br_2$	106-93-4	187.861	650.15	5.477	0.2616	0.265	0.2067
83	Dibromomethane	CH_2Br_2	74-95-3	173.835	611	7.17	0.223	0.315	0.2095
84	Dibutyl ether	$C_8H_{18}O$	142-96-1	130.228	584.1	2.46	0.487	0.247	0.4476
85	*m*-Dichlorobenzene	$C_6H_4Cl_2$	541-73-1	147.002	683.95	4.07	0.351	0.251	0.2790
86	*o*-Dichlorobenzene	$C_6H_4Cl_2$	95-50-1	147.002	705	4.07	0.351	0.244	0.2192
87	*p*-Dichlorobenzene	$C_6H_4Cl_2$	106-46-7	147.002	684.75	4.07	0.351	0.251	0.2846
88	1,1-Dichloroethane	$C_2H_4Cl_2$	75-34-3	98.959	523	5.07	0.24	0.28	0.2339
89	1,2-Dichloroethane	$C_2H_4Cl_2$	107-06-2	98.959	561.6	5.37	0.22	0.253	0.2866
90	Dichloromethane	CH_2Cl_2	75-09-2	84.933	510	6.08	0.185	0.265	0.1986
91	1,1-Dichloropropane	$C_3H_6Cl_2$	78-99-9	112.986	560	4.24	0.291	0.265	0.2529
92	1,2-Dichloropropane	$C_3H_6Cl_2$	78-87-5	112.986	572	4.24	0.291	0.259	0.2564
93	Diethanol amine	$C_4H_{11}NO_2$	111-42-2	105.136	736.6	4.27	0.349	0.243	0.9529
94	Diethyl amine	$C_4H_{11}N$	109-89-7	73.137	496.6	3.71	0.301	0.27	0.3039
95	Diethyl ether	$C_4H_{10}O$	60-29-7	74.122	466.7	3.64	0.28	0.263	0.2811
96	Diethyl sulfide	$C_4H_{10}S$	352-93-2	90.187	557.15	3.96	0.318	0.272	0.2900
97	1,1-Difluoroethane	$C_2H_4F_2$	75-37-6	66.050	386.44	4.52	0.179	0.252	0.2751
98	1,2-Difluoroethane	$C_2H_4F_2$	624-72-6	66.050	445	4.34	0.195	0.229	0.2224
99	Difluoromethane	CH_2F_2	75-10-5	52.023	351.255	5.784	0.123	0.244	0.2771
100	Di-isopropyl amine	$C_6H_{15}N$	108-18-9	101.190	523.1	3.2	0.418	0.308	0.3883
101	Di-isopropyl ether	$C_6H_{14}O$	108-20-3	102.175	500.05	2.88	0.386	0.267	0.3387
102	Di-isopropyl ketone	$C_7H_{14}O$	565-80-0	114.185	576	3.02	0.416	0.262	0.4044
103	1,1-Dimethoxyethane	$C_4H_{10}O_2$	534-15-6	90.121	507.8	3.773	0.297	0.265	0.3277
104	1,2-Dimethoxypropane	$C_5H_{12}O_2$	7778-85-0	104.148	543	3.446	0.35	0.267	0.3522
105	Dimethyl acetylene	C_4H_6	503-17-3	54.090	473.2	4.87	0.221	0.274	0.2385
106	Dimethyl amine	C_2H_7N	124-40-3	45.084	437.2	5.34	0.18	0.264	0.2999
107	2,3-Dimethylbutane	C_6H_{14}	79-29-8	86.175	500	3.15	0.361	0.274	0.2493
108	1,1-Dimethylcyclohexane	C_8H_{16}	590-66-9	112.213	591.15	2.938	0.45	0.269	0.2326
109	*cis*-1,2-Dimethylcyclohexane	C_8H_{16}	2207-01-4	112.213	606.15	2.938	0.46	0.268	0.2324
110	*trans*-1,2-Dimethylcyclohexane	C_8H_{16}	6876-23-9	112.213	596.15	2.938	0.46	0.273	0.2379
111	Dimethyl disulfide	$C_2H_6S_2$	624-92-0	94.199	615	5.36	0.252	0.264	0.2059
112	Dimethyl ether	C_2H_6O	115-10-6	46.068	400.1	5.37	0.17	0.2744	0.2002
113	*N*,*N*-Dimethyl formamide	C_3H_7NO	68-12-2	73.094	649.6	4.42	0.26199	0.214	0.3177
114	2,3-Dimethylpentane	C_7H_{16}	565-59-3	100.202	537.3	2.91	0.393	0.256	0.2964
115	Dimethyl phthalate	$C_{10}H_{10}O_4$	131-11-3	194.184	766	2.78	0.53	0.231	0.6568
116	Dimethylsilane	C_2H_8Si	1111-74-6	60.170	402	3.56	0.258	0.275	0.1300
117	Dimethyl sulfide	C_2H_6S	75-18-3	62.134	503.04	5.53	0.201	0.266	0.1943
118	Dimethyl sulfoxide	C_2H_6OS	67-68-5	78.133	729	5.65	0.227	0.212	0.2806
119	Dimethyl terephthalate	$C_{10}H_{10}O_4$	120-61-6	194.184	772	2.78	0.529	0.229	0.6371
120	1,4-Dioxane	$C_4H_8O_2$	123-91-1	88.105	587	5.208	0.238	0.254	0.2793
121	Diphenyl ether	$C_{12}H_{10}O$	101-84-8	170.207	766.8	3.08	0.503	0.243	0.4389
122	Dipropyl amine	$C_6H_{15}N$	142-84-7	101.190	550	3.14	0.402	0.276	0.4497
123	Dodecane	$C_{12}H_{26}$	112-40-3	170.335	658	1.82	0.755	0.251	0.5764
124	Eicosane	$C_{20}H_{42}$	112-95-8	282.547	768	1.16	1.34	0.243	0.9069
125	Ethane	C_2H_6	74-84-0	30.069	305.32	4.872	0.1455	0.279	0.0995
126	Ethanol	C_2H_6O	64-17-5	46.068	514	6.137	0.168	0.241	0.6436
127	Ethyl acetate	$C_4H_8O_2$	141-78-6	88.105	523.3	3.88	0.286	0.255	0.3664
128	Ethyl amine	C_2H_7N	75-04-7	45.084	456.15	5.62	0.207	0.307	0.2848
129	Ethylbenzene	C_8H_{10}	100-41-4	106.165	617.15	3.609	0.374	0.263	0.3035
130	Ethyl benzoate	$C_9H_{10}O_2$	93-89-0	150.175	698	3.18	0.489	0.268	0.4771
131	2-Ethyl butanoic acid	$C_6H_{12}O_2$	88-09-5	116.158	655	3.41	0.389	0.244	0.6326
132	Ethyl butyrate	$C_6H_{12}O_2$	105-54-4	116.158	571	2.95	0.403	0.25	0.4011
133	Ethylcyclohexane	C_8H_{16}	1678-91-7	112.213	609.15	3.04	0.43	0.258	0.2455
134	Ethylcyclopentane	C_7H_{14}	1640-89-7	98.186	569.5	3.4	0.375	0.269	0.2701
135	Ethylene	C_2H_4	74-85-1	28.053	282.34	5.041	0.131	0.281	0.0862
136	Ethylenediamine	$C_2H_8N_2$	107-15-3	60.098	593	6.29	0.264	0.337	0.4724
137	Ethylene glycol	$C_2H_6O_2$	107-21-1	62.068	720	8.2	0.191	0.262	0.5068
138	Ethyleneimine	C_2H_5N	151-56-4	43.068	537	6.85	0.173	0.265	0.2007
139	Ethylene oxide	C_2H_4O	75-21-8	44.053	469.15	7.19	0.140296	0.25876	0.1974
140	Ethyl formate	$C_3H_6O_2$	109-94-4	74.079	508.4	4.74	0.229	0.257	0.2847

TABLE 2-141 Critical Constants and Acentric Factors of Inorganic and Organic Compounds (*Continued*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	T_c, K	P_c, MPa	V_c, m^3/kmol	Z_c	Acentric factor
141	2-Ethyl hexanoic acid	$C_8H_{16}O_2$	149-57-5	144.211	674.6	2.778	0.528	0.262	0.8067
142	Ethylhexyl ether	$C_8H_{18}O$	5756-43-4	130.228	583	2.46	0.487	0.247	0.4944
143	Ethylisopropyl ether	$C_5H_{12}O$	625-54-7	88.148	489	3.41	0.329	0.276	0.3056
144	Ethylisopropyl ketone	$C_6H_{12}O$	565-69-5	100.159	567	3.32	0.369	0.26	0.3891
145	Ethyl mercaptan	C_2H_6S	75-08-1	62.134	499.15	5.49	0.207	0.274	0.1878
146	Ethyl propionate	$C_5H_{10}O_2$	105-37-3	102.132	546	3.362	0.345	0.256	0.3944
147	Ethylpropyl ether	$C_5H_{12}O$	628-32-0	88.148	500.23	3.37	0.339	0.275	0.3473
148	Ethyltrichlorosilane	$C_2H_5Cl_3Si$	115-21-9	163.506	559.95	3.33	0.414	0.296	0.2691
149	Fluorine	F_2	7782-41-4	37.997	144.12	5.172	0.066547	0.287	0.0530
150	Fluorobenzene	C_6H_5F	462-06-6	96.102	560.09	4.551	0.269	0.263	0.2472
151	Fluoroethane	C_2H_5F	353-36-6	48.060	375.31	5.028	0.164	0.264	0.2200
152	Fluoromethane	CH_3F	593-53-3	34.033	317.42	5.875	0.113	0.252	0.1980
153	Formaldehyde	CH_2O	50-00-0	30.026	408	6.59	0.115	0.223	0.2818
154	Formamide	CH_3NO	75-12-7	45.041	771	7.8	0.163	0.198	0.4124
155	Formic acid	CH_2O_2	64-18-6	46.026	588	5.81	0.125	0.149	0.3173
156	Furan	C4H4O	110-00-9	68.074	490.15	5.5	0.218	0.294	0.2015
157	Helium-4	He	7440-59-7	4.003	5.2	0.2275	0.0573	0.302	–0.3900
158	Heptadecane	$C_{17}H_{36}$	629-78-7	240.468	736	1.34	1.11	0.244	0.7697
159	Heptanal	$C_7H_{14}O$	111-71-7	114.185	616.8	3.16	0.434	0.267	0.4279
160	Heptane	C_7H_{16}	142-82-5	100.202	540.2	2.74	0.428	0.261	0.3495
161	Heptanoic acid	$C_7H_{14}O_2$	111-14-8	130.185	677.3	3.043	0.466	0.252	0.7564
162	1-Heptanol	$C_7H_{16}O$	111-70-6	116.201	632.3	3.085	0.444	0.261	0.5621
163	2-Heptanol	$C_7H_{16}O$	543-49-7	116.201	608.3	3.001	0.447	0.265	0.5628
164	3-Heptanone	$C_7H_{14}O$	106-35-4	114.185	606.6	2.92	0.433	0.251	0.4076
165	2-Heptanone	$C_7H_{14}O$	110-43-0	114.185	611.4	2.94	0.434	0.251	0.4190
166	1-Heptene	C_7H_{14}	592-76-7	98.186	537.4	2.92	0.402	0.263	0.3432
167	Heptyl mercaptan	$C_7H_{16}S$	1639-09-4	132.267	645	2.77	0.465	0.24	0.4226
168	1-Heptyne	C_7H_{12}	628-71-7	96.170	547	3.21	0.387	0.273	0.3778
169	Hexadecane	$C_{16}H_{34}$	544-76-3	226.441	723	1.4	1.04	0.243	0.7174
170	Hexanal	$C_6H_{12}O$	66-25-1	100.159	591	3.46	0.369	0.26	0.3872
171	Hexane	C_6H_{14}	110-54-3	86.175	507.6	3.025	0.371	0.266	0.3013
172	Hexanoic acid	$C_6H_{12}O_2$	142-62-1	116.158	660.2	3.308	0.408	0.246	0.7299
173	1-Hexanol	$C_6H_{14}O$	111-27-3	102.175	611.3	3.446	0.382	0.259	0.5586
174	2-Hexanol	$C_6H_{14}O$	626-93-7	102.175	585.3	3.311	0.385	0.262	0.5574
175	2-Hexanone	$C_6H_{12}O$	591-78-6	100.159	587.61	3.287	0.378	0.254	0.3846
176	3-Hexanone	$C_6H_{12}O$	589-38-8	100.159	582.82	3.32	0.378	0.259	0.3801
177	1-Hexene	C_6H_{12}	592-41-6	84.159	504	3.21	0.348	0.267	0.2888
178	3-Hexyne	C_6H_{10}	928-49-4	82.144	544	3.53	0.331	0.258	0.2183
179	Hexyl mercaptan	$C_6H_{14}S$	111-31-9	118.240	623	3.08	0.412	0.245	0.3681
180	1-Hexyne	C_6H_{10}	693-02-7	82.144	516.2	3.62	0.322	0.272	0.3327
181	2-Hexyne	C_6H_{10}	764-35-2	82.144	549	3.53	0.331	0.256	0.2214
182	Hydrazine	H_4N_2	302-01-2	32.045	653.15	14.7	0.158	0.428	0.3143
183	Hydrogen	H_2	1333-74-0	2.016	33.19	1.313	0.064147	0.305	–0.2160
184	Hydrogen bromide	HBr	10035-10-6	80.912	363.15	8.552	0.1	0.283	0.0734
185	Hydrogen chloride	HCl	7647-01-0	36.461	324.65	8.31	0.081	0.249	0.1315
186	Hydrogen cyanide	CHN	74-90-8	27.025	456.65	5.39	0.139	0.197	0.4099
187	Hydrogen fluoride	HF	7664-39-3	20.006	461.15	6.48	0.069	0.117	0.3823
188	Hydrogen sulfide	H_2S	7783-06-4	34.081	373.53	8.963	0.0985	0.284	0.0942
189	Isobutyric acid	$C_4H_8O_2$	79-31-2	88.105	605	3.7	0.292	0.215	0.6141
190	Isopropyl amine	C_3H_9N	75-31-0	59.110	471.85	4.54	0.221	0.256	0.2759
191	Malonic acid	$C_3H_4O_4$	141-82-2	104.061	805	5.64	0.258	0.217	0.9418
192	Methacrylic acid	$C_4H_6O_2$	79-41-4	86.089	662	4.79	0.28	0.244	0.3318
193	Methane	CH_4	74-82-8	16.042	190.564	4.599	0.0986	0.286	0.0115
194	Methanol	CH_4O	67-56-1	32.042	512.5	8.084	0.117	0.222	0.5658
195	*N*-Methyl acetamide	C_3H_7NO	79-16-3	73.094	718	4.98	0.267	0.223	0.4351
196	Methyl acetate	$C_3H_6O_2$	79-20-9	74.079	506.55	4.75	0.228	0.257	0.3313
197	Methyl acetylene	C_3H_4	74-99-7	40.064	402.4	5.63	0.164	0.276	0.2115
198	Methyl acrylate	$C_4H_6O_2$	96-33-3	86.089	536	4.25	0.27	0.258	0.3423
199	Methyl amine	CH_5N	74-89-5	31.057	430.05	7.46	0.154	0.321	0.2814
200	Methyl benzoate	$C_8H_8O_2$	93-58-3	136.148	693	3.59	0.436	0.272	0.4205
201	3-Methyl-1,2-butadiene	C_5H_8	598-25-4	68.117	490	3.83	0.291	0.274	0.1874
202	2-Methylbutane	C_5H_{12}	78-78-4	72.149	460.4	3.38	0.306	0.27	0.2279
203	2-Methylbutanoic acid	$C_5H_{10}O_2$	116-53-0	102.132	643	3.89	0.347	0.252	0.5894
204	3-Methyl-1-butanol	$C_5H_{12}O$	123-51-3	88.148	577.2	3.93	0.329	0.269	0.5939
205	2-Methyl-1-butene	C_5H_{10}	563-46-2	70.133	465	3.447	0.292	0.26	0.2341
206	2-Methyl-2-butene	C_5H_{10}	513-35-9	70.133	470	3.42	0.292	0.256	0.2870
207	2-Methyl-1-butene-3-yne	C_5H_6	78-80-8	66.101	492	4.38	0.248	0.266	0.1370
208	Methylbutyl ether	$C_5H_{12}O$	628-28-4	88.148	512.74	3.371	0.329	0.26	0.3130
209	Methylbutyl sulfide	$C_5H_{12}S$	628-29-5	104.214	593	3.47	0.36	0.253	0.3229
210	3-Methyl-1-butyne	C_5H_8	598-23-2	68.117	463.2	4.2	0.275	0.3	0.3081
211	Methyl butyrate	$C_5H_{10}O_2$	623-42-7	102.132	554.5	3.473	0.34	0.256	0.3775
212	Methylchlorosilane	CH_5ClSi	993-00-0	80.589	442	4.17	0.246	0.279	0.2252
213	Methylcyclohexane	C_7H_{14}	108-87-2	98.186	572.1	3.48	0.369	0.27	0.2361
214	1-Methylcyclohexanol	$C_7H_{14}O$	590-67-0	114.185	686	4	0.374	0.262	0.2213
215	*cis*-2-Methylcyclohexanol	$C_7H_{14}O$	7443-70-1	114.185	614	3.79	0.374	0.278	0.6805
216	*trans*-2-Methylcyclohexanol	$C_7H_{14}O$	7443-52-9	114.185	617	3.79	0.374	0.276	0.6790

TABLE 2-141 Critical Constants and Acentric Factors of Inorganic and Organic Compounds (*Continued*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	T_c, K	P_c, MPa	V_c, m³/kmol	Z_c	Acentric factor
217	Methylcyclopentane	C_6H_{12}	96-37-7	84.159	532.7	3.79	0.319	0.273	0.2288
218	1-Methylcyclopentene	C_6H_{10}	693-89-0	82.144	542	4.13	0.303	0.278	0.2318
219	3-Methylcyclopentene	C_6H_{10}	1120-62-3	82.144	526	4.13	0.303	0.286	0.2296
220	Methyldichlorosilane	CH_4Cl_2Si	75-54-7	115.034	483	3.95	0.289	0.284	0.2758
221	Methylethyl ether	C_3H_8O	540-67-0	60.095	437.8	4.4	0.221	0.267	0.2314
222	Methylethyl ketone	C_4H_8O	78-93-3	72.106	535.5	4.15	0.267	0.249	0.3234
223	Methylethyl sulfide	C_3H_8S	624-89-5	76.161	533	4.26	0.254	0.244	0.2091
224	Methyl formate	$C_2H_4O_2$	107-31-3	60.052	487.2	6	0.172	0.255	0.2556
225	Methylisobutyl ether	$C_5H_{12}O$	625-44-5	88.148	497	3.41	0.329	0.272	0.3078
226	Methylisobutyl ketone	$C_6H_{12}O$	108-10-1	100.159	574.6	3.27	0.369	0.253	0.3557
227	Methyl Isocyanate	C_2H_3NO	624-83-9	57.051	488	5.48	0.202	0.273	0.3007
228	Methylisopropyl ether	$C_4H_{10}O$	598-53-8	74.122	464.48	3.762	0.276	0.269	0.2656
229	Methylisopropyl ketone	$C_5H_{10}O$	563-80-4	86.132	553.4	3.8	0.31	0.256	0.3208
230	Methylisopropyl sulfide	$C_4H_{10}S$	1551-21-9	90.187	553.1	4.021	0.328	0.28718	0.2461
231	Methyl mercaptan	CH_4S	74-93-1	48.107	469.95	7.23	0.145	0.268	0.1582
232	Methyl methacrylate	$C_5H_8O_2$	80-62-6	100.116	566	3.68	0.323	0.253	0.2802
233	2-Methyloctanoic acid	$C_9H_{18}O_2$	3004-93-1	158.238	694	2.54	0.572	0.252	0.7913
234	2-Methylpentane	C_6H_{14}	107-83-5	86.175	497.7	3.04	0.368	0.27	0.2791
235	Methyl pentyl ether	$C_6H_{14}O$	628-80-8	102.175	546.49	3.042	0.38	0.254	0.3442
236	2-Methylpropane	C_4H_{10}	75-28-5	58.122	407.8	3.64	0.259	0.278	0.1835
237	2-Methyl-2-propanol	$C_4H_{10}O$	75-65-0	74.122	506.2	3.972	0.275	0.26	0.6152
238	2-Methyl propene	C_4H_8	115-11-7	56.106	417.9	4	0.239	0.275	0.1948
239	Methyl propionate	$C_4H_8O_2$	554-12-1	88.105	530.6	4.004	0.282	0.256	0.3466
240	Methylpropyl ether	$C_4H_{10}O$	557-17-5	74.122	476.25	3.801	0.276	0.265	0.2770
241	Methylpropyl sulfide	$C_4H_{10}S$	3877-15-4	90.187	565	3.97	0.307	0.259	0.2737
242	Methylsilane	CH_6Si	992-94-9	46.144	352.5	4.7	0.205	0.329	0.1314
243	alpha-Methyl styrene	C_9H_{10}	98-83-9	118.176	654	3.36	0.399	0.247	0.3230
244	Methyl *tert*-butyl ether	$C_5H_{12}O$	1634-04-4	88.148	497.1	3.287	0.314	0.25	0.2466
245	Methyl vinyl ether	C_3H_6O	107-25-5	58.079	437	4.67	0.21	0.27	0.2416
246	Naphthalene	$C_{10}H_8$	91-20-3	128.171	748.4	4.05	0.407	0.265	0.3020
247	Neon	Ne	7440-01-9	20.180	44.4	2.653	0.0417	0.3	−0.0396
248	Nitroethane	$C_2H_5NO_2$	79-24-3	75.067	593	5.16	0.236	0.247	0.3803
249	Nitrogen	N_2	7727-37-9	28.013	126.2	3.4	0.08921	0.289	0.0377
250	Nitrogen trifluoride	F_3N	7783-54-2	71.002	234	4.461	0.11875	0.272	0.1200
251	Nitromethane	CH_3NO_2	75-52-5	61.040	588.15	6.31	0.173	0.223	0.3480
252	Nitrous oxide	N_2O	10024-97-2	44.013	309.57	7.245	0.0974	0.274	0.1409
253	Nitric oxide	NO	10102-43-9	30.006	180.15	6.48	0.058	0.251	0.5829
254	Nonadecane	$C_{19}H_{40}$	629-92-5	268.521	758	1.21	1.26	0.242	0.8522
255	Nonanal	$C_9H_{18}O$	124-19-6	142.239	658	2.73	0.527	0.263	0.5117
256	Nonane	C_9H_{20}	111-84-2	128.255	594.6	2.29	0.551	0.255	0.4435
257	Nonanoic acid	$C_9H_{18}O_2$	112-05-0	158.238	710.7	2.514	0.584	0.248	0.7724
258	1-Nonanol	$C_9H_{20}O$	143-08-8	144.255	670.9	2.527	0.576	0.261	0.5841
259	2-Nonanol	$C_9H_{20}O$	628-99-9	144.255	649.5	2.541	0.577	0.271	0.5911
260	1-Nonene	C_9H_{18}	124-11-8	126.239	593.1	2.428	0.524	0.258	0.4367
261	Nonyl mercaptan	$C_9H_{20}S$	1455-21-6	160.320	681	2.31	0.571	0.233	0.5260
262	1-Nonyne	C_9H_{16}	3452-09-3	124.223	598.05	2.61	0.497	0.261	0.4710
263	Octadecane	$C_{18}H_{38}$	593-45-3	254.494	747	1.27	1.19	0.243	0.8114
264	Octanal	$C_8H_{16}O$	124-13-0	128.212	638.9	2.96	0.488	0.272	0.4636
265	Octane	C_8H_{18}	111-65-9	114.229	568.7	2.49	0.486	0.256	0.3996
266	Octanoic acid	$C_8H_{16}O_2$	124-07-2	144.211	694.26	2.779	0.523	0.252	0.7706
267	1-Octanol	$C_8H_{18}O$	111-87-5	130.228	652.3	2.783	0.509	0.261	0.5697
268	2-Octanol	$C_8H_{18}O$	123-96-6	130.228	629.8	2.749	0.512	0.269	0.5807
269	2-Octanone	$C_8H_{16}O$	111-13-7	128.212	632.7	2.64	0.497	0.249	0.4549
270	3-Octanone	$C_8H_{16}O$	106-68-3	128.212	627.7	2.704	0.497	0.257	0.4406
271	1-Octene	C_8H_{16}	111-66-0	112.213	566.9	2.663	0.464	0.262	0.3921
272	Octyl mercaptan	$C_8H_{18}S$	111-88-6	146.294	667.3	2.52	0.518	0.235	0.4497
273	1-Octyne	C_8H_{14}	629-05-0	110.197	574	2.88	0.442	0.267	0.4233
274	Oxalic acid	$C_2H_2O_4$	144-62-7	90.035	804	7.02	0.205	0.215	0.9176
275	Oxygen	O_2	7782-44-7	31.999	154.58	5.043	0.0734	0.288	0.0222
276	Ozone	O_3	10028-15-6	47.998	261	5.57	0.089	0.228	0.2119
277	Pentadecane	$C_{15}H_{32}$	629-62-9	212.415	708	1.48	0.969	0.244	0.6863
278	Pentanal	$C_5H_{10}O$	110-62-3	86.132	566.1	3.97	0.313	0.264	0.3472
279	Pentane	C_5H_{12}	109-66-0	72.149	469.7	3.37	0.313	0.27	0.2515
280	Pentanoic acid	$C_5H_{10}O_2$	109-52-4	102.132	639.16	3.63	0.35	0.239	0.7052
281	1-Pentanol	$C_5H_{12}O$	71-41-0	88.148	588.1	3.897	0.326	0.258	0.5748
282	2-Pentanol	$C_5H_{12}O$	6032-29-7	88.148	561	3.7	0.326	0.259	0.5549
283	2-Pentanone	$C_5H_{10}O$	107-87-9	86.132	561.08	3.694	0.301	0.238	0.3433
284	3-Pentanone	$C_5H_{10}O$	96-22-0	86.132	560.95	3.74	0.336	0.269	0.3448
285	1-Pentene	C_5H_{10}	109-67-1	70.133	464.8	3.56	0.293	0.27	0.2372
286	2-Pentyl mercaptan	$C_5H_{12}S$	2084-19-7	104.214	584.3	3.536	0.385	0.28	0.2685
287	Pentyl mercaptan	$C_5H_{12}S$	110-66-7	104.214	598	3.47	0.359	0.251	0.3207
288	1-Pentyne	C_5H_8	627-19-0	68.117	481.2	4.17	0.277	0.289	0.2899
289	2-Pentyne	C_5H_8	627-21-4	68.117	519	4.03	0.276	0.258	0.1752
290	Phenanthrene	$C_{14}H_{10}$	85-01-8	178.229	869	2.9	0.554	0.222	0.4707
291	Phenol	C_6H_6O	108-95-2	94.111	694.25	6.13	0.229	0.243	0.4435
292	Phenyl isocyanate	C_7H_5NO	103-71-9	119.121	653	4.06	0.37	0.277	0.4123

TABLE 2-141 Critical Constants and Acentric Factors of Inorganic and Organic Compounds (*Concluded*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	T_c, K	P_c, MPa	V_c, m³/kmol	Z_c	Acentric factor
293	Phthalic anhydride	$C_8H_4O_3$	85-44-9	148.116	791	4.72	0.421	0.302	0.7025
294	Propadiene	C_3H_4	463-49-0	40.064	394	5.25	0.165	0.264	0.1041
295	Propane	C_3H_8	74-98-6	44.096	369.83	4.248	0.2	0.276	0.1523
296	1-Propanol	C_3H_8O	71-23-8	60.095	536.8	5.169	0.219	0.254	0.6209
297	2-Propanol	C_3H_8O	67-63-0	60.095	508.3	4.765	0.222	0.25	0.6544
298	Propenylcyclohexene	C_3H_{14}	13511-13-2	122.207	636	3.12	0.437	0.258	0.3420
299	Propionaldehyde	C_3H_6O	123-38-6	58.079	504.4	4.92	0.204	0.239	0.2559
300	Propionic acid	$C_3H_6O_2$	79-09-4	74.079	600.81	4.668	0.235	0.22	0.5796
301	Propionitrile	C_3H_5N	107-12-0	55.079	564.4	4.18	0.229	0.204	0.3243
302	Propyl acetate	$C_5H_{10}O_2$	109-60-4	102.132	549.73	3.36	0.345	0.254	0.3889
303	Propyl amine	C_3H_9N	107-10-8	59.110	496.95	4.74	0.26	0.298	0.2798
304	Propylbenzene	C_9H_{12}	103-65-1	120.192	638.35	3.2	0.44	0.265	0.3444
305	Propylene	C_3H_6	115-07-1	42.080	364.85	4.6	0.185	0.281	0.1376
306	Propyl formate	$C_4H_8O_2$	110-74-7	88.105	538	4.02	0.285	0.256	0.3088
307	2-Propyl mercaptan	C_3H_8S	75-33-2	76.161	517	4.75	0.254	0.281	0.2138
308	Propyl mercaptan	C_3H_8S	107-03-9	76.161	536.6	4.63	0.254	0.264	0.2318
309	1,2-Propylene glycol	$C_3H_8O_2$	57-55-6	76.094	626	6.1	0.239	0.28	1.1065
310	Quinone	$C_6H_4O_2$	106-51-4	108.095	683	5.96	0.291	0.305	0.4945
311	Silicon tetrafluoride	F_4Si	7783-61-1	104.079	259	3.72	0.202	0.349	0.3858
312	Styrene	C_8H_8	100-42-5	104.149	636	3.84	0.352	0.256	0.2971
313	Succinic acid	$C_4H_6O_4$	110-15-6	118.088	806	4.71	0.317	0.223	0.9922
314	Sulfur dioxide	O_2S	7446-09-5	64.064	430.75	7.884	0.122	0.269	0.2454
315	Sulfur hexafluoride	F_6S	2551-62-4	146.055	318.69	3.76	0.19852	0.282	0.2151
316	Sulfur trioxide	O_3S	7446-11-9	80.063	490.85	8.21	0.127	0.255	0.4240
317	Terephthalic acid	$C_8H_6O_4$	100-21-0	166.131	1113	3.95	0.424	0.181	1.0591
318	*o*-Terphenyl	$C_{18}H_{14}$	84-15-1	230.304	857	2.99	0.731	0.307	0.5513
319	Tetradecane	$C_{14}H_{30}$	629-59-4	198.388	693	1.57	0.897	0.244	0.6430
320	Tetrahydrofuran	C_4H_8O	109-99-9	72.106	540.15	5.19	0.224	0.259	0.2254
321	1,2,3,4-Tetrahydronaphthalene	$C_{10}H_{12}$	119-64-2	132.202	720	3.65	0.408	0.249	0.3353
322	Tetrahydrothiophene	C_4H_8S	110-01-0	88.171	631.95	5.16	0.249	0.245	0.1996
323	2,2,3,3-Tetramethylbutane	C_8H_{18}	594-82-1	114.229	568	2.87	0.461	0.28	0.2450
324	Thiophene	C_4H_4S	110-02-1	84.140	579.35	5.69	0.219	0.259	0.1970
325	Toluene	C_7H_8	108-88-3	92.138	591.75	4.108	0.316	0.264	0.2640
326	1,1,2-Trichloroethane	$C_2H_3Cl_3$	79-00-5	133.404	602	4.48	0.281	0.252	0.2591
327	Tridecane	$C_{13}H_{28}$	629-50-5	184.361	675	1.68	0.826	0.247	0.6174
328	Triethyl amine	$C_6H_{15}N$	121-44-8	101.190	535.15	3.04	0.39	0.266	0.3162
329	Trimethyl amine	C_3H_9N	75-50-3	59.110	433.25	4.07	0.254	0.287	0.2062
330	1,2,3-Trimethylbenzene	C_9H_{12}	526-73-8	120.192	664.5	3.454	0.414	0.259	0.3666
331	1,2,4-Trimethylbenzene	C_9H_{12}	95-63-6	120.192	649.1	3.232	0.43	0.258	0.3787
332	2,2,4-Trimethylpentane	C_8H_{18}	540-84-1	114.229	543.8	2.57	0.468	0.266	0.3035
333	2,3,3-Trimethylpentane	C_8H_{18}	560-21-4	114.229	573.5	2.82	0.455	0.269	0.2903
334	1,3,5-Trinitrobenzene	$C_6H_3N_3O_6$	99-35-4	213.105	846	3.39	0.479	0.231	0.8623
335	2,4,6-Trinitrotoluene	$C_7H_5N_3O_6$	118-96-7	227.131	828	3.04	0.572	0.253	0.8972
336	Undecane	$C_{11}H_{24}$	1120-21-4	156.308	639	1.95	0.685	0.252	0.5303
337	1-Undecanol	$C_{11}H_{24}O$	112-42-5	172.308	703.9	2.119	0.715	0.259	0.6236
338	Vinyl acetate	$C_4H_6O_2$	108-05-4	86.089	519.13	3.958	0.27	0.248	0.3513
339	Vinyl acetylene	C_4H_4	689-97-4	52.075	454	4.86	0.205	0.264	0.1069
340	Vinyl chloride	C_2H_3Cl	75-01-4	62.498	432	5.67	0.179	0.283	0.1001
341	Vinyl trichlorosilane	$C_2H_3Cl_3Si$	75-94-5	161.490	543.15	3.06	0.408	0.276	0.2815
342	Water	H_2O	7732-18-5	18.015	647.096	22.064	0.0559472	0.229	0.3449
343	*m*-Xylene	C_8H_{10}	108-38-3	106.165	617	3.541	0.375	0.259	0.3265
344	*o*-Xylene	C_8H_{10}	95-47-6	106.165	630.3	3.732	0.37	0.264	0.3101
345	*p*-Xylene	C_8H_{10}	106-42-3	106.165	616.2	3.511	0.378	0.259	0.3218

All substances are listed by chemical family in Table 2-6 and by formula in Table 2-7.

Values in this table were taken from the Design Institute for Physical Properties (DIPPR) of the American Institute of Chemical Engineers (AIChE), copyright 2007 AIChE and reproduced with permission of AICHE and of the DIPPR Evaluated Process Design Data Project Steering Committee. Their source should be cited as R. L. Rowley, W. V. Wilding, J. L. Oscarson, Y. Yang, N. A. Zundel, T. E. Daubert, R. P. Danner, DIPPR® Data Compilation of Pure Chemical Properties, Design Institute for Physical Properties, AIChE, New York (2007).

The number of digits provided for the acentric factor was chosen for uniformity of appearance and formatting; these do not represent the uncertainties of the physical quantities, but are the result of calculations from the standard thermophysical property formulations within a fixed format.

COMPRESSIBILITIES

INTRODUCTION

The compressibility factor Z can be calculated by using the defining equation $Z = PV/(RT)$, where P is pressure, V is molar volume, R is the gas constant, and T is absolute temperature. Values of P, V, and T for substances listed in Table 2-184 are given in tables in the Thermodynamic Properties section. For the units used in these tables, R is 0.008314472 MPa·dm^3/(mol·K). Values at temperatures and pressures other than those in the tables can be generated for many of the substances in Table 2-184 by going to http://webbook.nist.gov and selecting NIST Chemistry WebBook, then Thermophysical Properties of Fluid Systems High Accuracy Data. Results can be pasted into a spreadsheet to facilitate calculation of the compressibility factor.

UNITS CONVERSIONS

For this subsection, the following units conversions are applicable:

$$°R = \tfrac{9}{5}\ K$$

To convert bars to pounds-force per cubic inch, multiply by 14.504. To convert bars to kilopascals, multiply by 1×10^2.

TABLE 2-142 Composition of Selected Refrigerant Mixtures

		Composition (mass percent)			
Mixture	Tables	R-32	R-125	R-134a	R-143a
R-410A	2-290	50	50		
R-404A	2-288		44	4	52
R-507A	2-296		50		50
R-407C (Klea 66)	2-263, 2-264, 2-289	23	25	52	
R-407A (Klea 60)	2-143, 2-261	20	40	40	
R-407B (Klea 61)	2-144, 2-262	10	70	20	

TABLE 2-143 Compressibility Factors for R 407A (Klea 60)

	Pressure, bar								
T, K	1	5	10	15	20	25	30	Z_{dew}	P_{dew}
250	0.9691	0.0163	0.0325	0.0487	0.0648	0.0809	0.0970	0.9340	2.05
260	0.9737	0.0161	0.0321	0.0480	0.0640	0.0798	0.0957	0.9136	3.08
270	0.9773	0.4268	0.0318	0.0476	0.0633	0.0790	0.0947	0.8895	4.46
280	0.9803	0.8932	0.0316	0.0473	0.0630	0.0785	0.0940	0.8614	6.28
290	0.9828	0.9080	0.0360	0.0473	0.0629	0.0784	0.0938	0.8290	8.60
300	0.9848	0.9199	0.8253	0.0476	0.0632	0.0787	0.0942	0.7916	11.53
310	0.9866	0.9298	0.8495	0.7518	0.0641	0.0797	0.0952	0.7485	15.15
320	0.9881	0.9380	0.8689	0.7889	0.5737	0.0816	0.0972	0.6983	19.58
330	0.9893	0.9449	0.8847	0.8173	0.7386	0.6279	0.1011	0.6386	24.96
340	0.9904	0.9509	0.8980	0.8401	0.7752	0.6993	0.6016	0.5641	31.46
350	0.9914	0.9560	0.9092	0.8588	0.8038	0.7425	0.6713	0.4564	39.42
Z_{dew}	0.9593	0.8809	0.8107	0.7502	0.6936	0.6381	0.5813		
T_{dew}, K	234.3	273.3	295.1	309.6	320.9	330.1	337.9		

The values in this table were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties-REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1).

TABLE 2-144 Compressibility Factors for R 407B (Klea 61)

	Pressure, bar								
T, K	1	5	10	15	20	25	30	Z_{dew}	P_{dew}
250	0.9703	0.0180	0.0359	0.0538	0.0716	0.0894	0.1071	0.9251	2.40
260	0.9745	0.0178	0.0355	0.0532	0.0708	0.0883	0.1058	0.9024	3.56
270	0.9779	0.8785	0.0352	0.0527	0.0702	0.0875	0.1048	0.8757	5.10
280	0.9808	0.8961	0.0351	0.0526	0.0699	0.0872	0.1043	0.8446	7.10
290	0.9831	0.9101	0.5520	0.0527	0.0700	0.0872	0.1043	0.8085	9.64
300	0.9851	0.9215	0.8290	0.0533	0.0707	0.0879	0.1050	0.7666	12.81
310	0.9868	0.9310	0.8522	0.7569	0.0721	0.0895	0.1067	0.7178	16.71
320	0.9883	0.9390	0.8709	0.7924	0.6949	0.0925	0.1098	0.6600	21.45
330	0.9895	0.9457	0.8864	0.8200	0.7428	0.6453	0.1164	0.5890	27.18
340	0.9906	0.9515	0.8993	0.8422	0.7784	0.7042	0.6108	0.4916	34.12
350	0.9915	0.9565	0.9103	0.8606	0.8064	0.7462	0.6770		
Z_{dew}	0.9587	0.8774	0.8036	0.7389	0.6776	0.6164	0.5518		
T_{dew}, K	230.6	269.4	291.3	305.9	317.1	326.4	334.3		

The values in this table were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties-REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1).

TABLE 2-145 Compressibilities of Liquids*

At the constant temperature T, the compressibility $\beta = (1/\overline{V}_0)(dV/dP)$. In general as P increases, β decreases rapidly at first and then slowly; the change of β with T is large at low pressures but very small at pressures above 1000 to 2000 megabars. 1 megabar = 0.987 atm = 10^6 dynes/cm^2 based upon the older usage, 1 bar = 1 dyne/cm^2.

Substance	Temp., °C	Pressure, megabars	Compressibility per megabar $\beta \times 10^6$	Substance	Temp., °C	Pressure, megabars	Compressibility per megabar $\beta \times 10^6$	Substance	Temp., °C	Pressure, megabars	Compressibility per megabar $\beta \times 10^6$
Acetone	14	23	111	Ethyl acetate	20	400	75	Methyl alcohol	15	23	103
Acetone	20	500	61	alcohol	14	23	100	alcohol	20	200	95
Acetone	20	1,000	52	alcohol	20	500	63	alcohol	20	400	80
Acetone	40	12,000	9	alcohol	20	1,000	54	alcohol	20	500	65
Amyl alcohol	14	23	88	alcohol	20	12,000	8	alcohol	20	1,000	54
alcohol, iso.	20	200	84	bromide	20	200	100	alcohol	20	12,000	8
alcohol, iso.	20	400	70	bromide	20	400	82	Nitric acid	0	17	32
alcohol, *n*	20	500	61	bromide	20	500	70	Oils:			
alcohol, *n*	20	1,000	46	bromide	20	1,000	54	Almond	15	5	53
alcohol, *n*	20	12,000	8	bromide	20	12,000	8	Castor	15	5	46
alcohol, *n*	40	12,000	8	chloride	15	23	151	Linseed	15	5	51
Benzene	17	5	89	chloride	20	500	102	Olive	15	5	55
Benzene	20	200	77	chloride	20	1,000	66	Rapeseed	20		59
Benzene	20	400	67	chloride	20	12,000	8	Phosphorus trichloride	10	250	71
Bromine	20	200	56	ether	25	23	188	trichloride	20	500	63
Bromine	20	400	51	ether	20	500	84	trichloride	20	1,000	47
Butyl alcohol, iso	18	8	97	ether	20	1,000	61	trichloride	20	12,000	8
alcohol, iso	20	200	81	ether	20	12,000	10	Propyl alcohol (*n*)	20	200	77
alcohol, iso	20	400	64	iodide	20	200	81	alcohol (*n*)	20	400	67
alcohol, iso	20	500	56	iodide	20	400	69	alcohol (*n*?)	20	500	65
alcohol, iso	20	1,000	46	iodide	20	500	64	alcohol (*n*?)	20	1,000	47
alcohol, iso	20	12,000	8	iodide	20	1,000	50	alcohol (*n*?)	20	12,000	7
Carbon bisulfide	16	21	86	iodide	20	12,000	8	Toluene	20	200	74
bisulfide	20	500	57	Gallium	30	300	3.97	Toluene	20	400	64
bisulfide	20	1,000	48	Glycerol	15	5	22	Turpentine	20		74
bisulfide	20	12,000	6	Hexane	20	200	117	Water	20	13	49
tetrachloride	20	200	86	Hexane	20	400	91	Water	20	200	43
tetrachloride	20	400	73	Kerosene	20	500	55	Water	20	400	41
Chloroform	20	200	83	Kerosene	20	1,000	45	Water	20	500	39
Chloroform	20	400	70	Kerosene	20	12,000	8	Water	40	500	38
Dichloroethylsulfide	32	1,000	34	Mercury	20	300	3.95	Water	40	1,000	33
Dichloroethylsulfide	32	2,000	24	Mercury	22	500	3.97	Water	40	12,000	9
Ethyl acetate	13	23	103	Mercury	22	1,000	3.91	Xylene, meta	20	200	69
acetate	20	200	90	Mercury	22	12,000	2.37	meta	20	400	60

* *Smithsonian Tables,* Table 106.

Scott (*Cryogenic Engineering,* Van Nostrand, Princeton, N.J., 1959) gives data for liquid nitrogen (p. 283), oxygen (p. 276), and hydrogen (p. 303). For a convenient index to the high-pressure work of Bridgman, see *American Institute of Physics Handbook,* p. 2-163, McGraw-Hill, New York, 1957.

TABLE 2-146 Compressibilities of Solids

Many data on the compressibility of solids obtained prior to 1926 are contained in Gruneisen, *Handbuch der Physik,* vol. 10, Springer, Berlin, 1926, pp. 1–52; also available as translation, NASA RE 2-18-59W, 1959. See also Tables 271, 273, 276, 278, and other material in *Smithsonian Physical Tables,* 9th ed., 1954. For a review of high-pressure work to 1946, see Bridgman, *Rev. Mod. Phys.,* **18,** 1 (1946).

LATENT HEATS

UNITS CONVERSIONS

For this subsection, the following units conversions are applicable:

$$°F = \tfrac{9}{5}\,°C + 32$$

To convert calories per gram-mole to British thermal units per pound-mole, multiply by 1.799; to convert calories per gram to British thermal units per pound, multiply by 1.799.

To convert millimeters of mercury to pounds-force per square inch, multiply by 1.934×10^{-2}.

TABLE 2-147 Heats of Fusion and Vaporization of the Elements and Inorganic Compounds*

Unless stated otherwise, the values have been taken from the compilations by K. K. Kelley on "Heats of Fusion of Inorganic Compounds," U.S. Bur. Mines Bull. 393 (1936), and "The Free Energies of Vaporization and Vapor Pressures of Inorganic Substances," U.S. Bur. Mines Bull. 383 (1935).

Substance	mp, °C	Heat of fusion,[a,b] cal/mol	bp at 1 atm, °C	Heat of vaporization,[a,b] cal/mol
Aluminum				
Al	660.0	2,550	2057	61,020
Al_2Br_6	97.5	5,420	256.4	10,920
Al_2Cl_6	192.5	16,960	180.2[c]	26,750[c]
$AlF_3·3NaF$	1000	16,380		
Al_2I_6	191.0	7,960	385.5	15,360
Al_2O_3	2045	(26,000)	3000	
Antimony				
Sb	630.5	4,770	1440	46,670
$SbBr_3$	97	3,510		
$SbCl_3$	73.4	3,030	219	10,360
$SbCl_5$	4	2,400	172[d]	11,570
Sb_4O_6	655	(27,000)	1425	17,820
Sb_4S_6	546	11,200		
Argon				
A	−189.3	290	−185.8	1,590
Arsenic				
As	814	(6,620)	610[c]	31,000[c]
$AsBr_3$	31	2,810		
$AsCl_3$	−16	2,420	122	7,570
AsF_5	−80.7	2,800	−52.8	4,980
As_4O_6	313	8,000	457.2	14,300
Barium				
Ba	704	(1,400)[e]	1638	35,670
$BaBr_2$	847	6,000		
$BaCl_2$	960	5,370		
BaF_2	1287	3,000		
$Ba(NO_3)_2$	595	(5,980)		
$Ba_3(PO_4)_2$	1730	18,600		
$BaSO_4$	1350	9,700		
Beryllium				
Be	1280	2,500[e]		
Bismuth				
Bi	271.3	2,505	1420	
$BiBr_3$			461	18,020
$BiCl_3$	224	2,600	441	17,350
Bi_2O_3	817	6,800		
Bi_2S_3	747	8,900		
Boron				
BBr_3			91.3	7,300
BCl_3			12.5	5,680
BF_3	−128	480	−100.9	4,620
B_2H_6	−165.5		−92.4	3,685
B_3H_{10}	−119.8		16	6,470
B_5H_9	−46.9		58	7,700
B_5H_{11}			67	8,500
$B_{10}H_{14}$	99.7	7,800	*f*	11,600
B_2H_5Br	−104		16	6,230
$B_3N_3H_6$	−58		50.4	7,670
Bromine				
Br_2	−7.2	2,580	58.0	7,420
BrF_5	−61.3	1,355	40.4	7,470
Cadmium				
Cd	320.9	1,460	765	23,870
$CdBr_2$	568	(5,000)		
$CdCl_2$	568	5,300	967	29,860
CdF_2	1110	(5,400)		
CdI_2	387	3,660	796	25,400
CdO			1559[c]	53,820[c]
$CdSO_4$	1000	4,790		
Calcium				
Ca	851	2,230	1487	36,580
$CaBr_2$	730	4,180		
$CaCO_3$	1282	(12,700)		
$CaCl_2$	782	6,100		
CaF_2	1392	4,100		
$Ca(NO_3)_2$	561	5,120		
CaO	2707	(12,240)		
$CaO·Al_2O_3·2SiO_2$	1550	29,400		
$CaO·MgO·2SiO_2$	1392	(18,200)		
$CaO·SiO_2$	1512	13,400		
$CaSO_4$	1297	6,700		
Carbon				
C (graphite)	3600	11,000[e]		
CBr_4	90	1,050		
CCl_4	−24.0	644	77	7,280
CF_4			−127.9	3,110
CH_4	−182.5	224	−161.4	2,040
C_2N_2	−27.8	1,938[u]	−21.1	5,576[u]
CNBr	52			11,010[c]
CNCl	−5	2,240	13	6,300
Carbon (*Cont.*)				
CNF			−72.8	5,780[c]
CNI			141	13,980[c]
CO	−205.0	200	−191.5	1,444
CO_2	−57.5	1,900	−78.4[c]	6,030[c, r]
COS	−138.8	1,129[k]	−50.2	4,423[k]
$COCl_2$			8.0	5,990
CS_2	−112.0	1,049[l]		
Cerium				
Ce	775	2,120		
Cesium				
Cs	28.4	500	690	16,320
CsBr			1300	35,990
CsCl	642	3,600	1300	35,690
CsF	715	(2,450)	1251	34,330
CsI			1280	35,930
$CsNO_3$	407	3,250		
Chlorine				
Cl_2	−101.0	1,531[m]	−34.1	4,878[m]
ClF			−101	
ClF_3			11.3	5,890
Cl_2O			2.0	6,280
ClO_2			10.9	7,100
Cl_2O_7			79	8,480
Chromium				
Cr	1550	3,930	2475	
CrO_2Cl_2			117	8,250
Cobalt				
Co	1490	3,660		
$CoCl_2$	727	7,390	1050	27,170
Copper				
Cu	1083.0	3,110	2595	72,810
Cu_2Br_2			1355	16,310
Cu_2Cl_2	430	4,890	1490	11,920
CuI			1336	15,940
$Cu_2(CN)_2$	473	(5,400)		
Cu_2O	1230	(13,400)		
CuO	1447	2,820		
Cu_2S	1127	5,500		
Fluorine				
F_2	−223		−188.2	1,640
F_2O			−144.8	2,650
Gallium				
Ga	29.8	1,336	2071	
Germanium				
Ge	959	(8,300)		
GeH_4	−165		−89.1	3,580
Ge_2H_6	−109		31.4	5,900
Ge_3H_8	−105.6		110.6	7,550
$GeHCl_3$	−71		75[g]	8,000
$GeBr_4$	26.1		189	8,560
$GeCl_4$	−49.5		84	7,030
$Ge(CH_3)_4$	−88		44	6,460
Gold				
Au	1063.0	3,030	2966	81,800
Helium				
He	−271.4		−268.4	22
Hydrogen				
H_2	−259.2	28	−252.7	216
HBr	−86.9	575	−66.7	4,210
HCl	−114.2	476	−85.0	3,860
HCN	−13.2	2,009[j]	25.7	6,027[t]
HF	−83.0	1,094	33.3	7,460
$(HF)_6$			51.2	5,020
HI	−50.8	686		
H_2O	0.0	1,436	100.0	9,729[h, q]
$H_2{}^2O$ (= D_2O)	3.8	1,501[s]	101.4	9,945[eq]
H_2O_2	−2	2,520[c]	158	10,270
HNO_3	−47	600		
H_3PO_2	17.4	2,310		
H_3PO_3	74	3,070		
H_3PO_4	42.4	2,520		
$H_4P_2O_6$	55	8,300		
H_2S	−85.5	568[f]	−60.3	4,463[t]
H_2S_2	−87.6	1,805		
H_2SO_4	10.5	2,360		
H_2Se			−41.3	4,880
H_2SeO_4	58	3,450		
H_2Te	−48.9	1,670	−2.2	5,650
Indium				
In	156.4	781		

*See also subsection "Thermodynamic Properties."

TABLE 2-147 Heats of Fusion and Vaporization of the Elements and Inorganic Compounds (*Continued*)

Substance	mp, °C	Heat of fusion,[a,b] cal/mol	bp at 1 atm, °C	Heat of vaporization,[a,b] cal/mol
Iodine				
I_2	113.0	3,650	183	10,390
ICl(α)	17.2	2,660		
ICl(β)	13.9	2,270		
IF_7			4[c]	7,460[c]
Iron				
Fe	1530	3,560	2735	84,600
$FeCl_2$	677	7,800	1026	30,210
Fe_2Cl_6	304	20,590	319	12,040
$Fe(CO)_5$	−21	3,250	105	9,000
FeO	1380	(7,700)		
FeS	1195	5,000		
Krypton				
Kr	−157	360[e]	152.9	2,310[e]
Lead				
Pb	327.4	1,224	1744	42,060
$PbBr_2$	488	4,290	914	27,700
$PbCl_2$	498	5,650	954	29,600
PbF_2	824	1,860	1293	38,300
PbI_2	412	5,970	872	24,850
$PbMoO_4$	1065	(25,800)		
PbO	890	2,820	1472	51,310
PbS	1114	4,150	1281	(50,000)
$PbSO_4$	1087	9,600		
$PbWO_4$	1123	(15,200)		
Lithium				
Li	179	1,100	1372	32,250
$LiBO_2$	845	(5,570)		
LiBr	552	2,900	1310	35,420
LiCl	614	3,200	1382	35,960
LiF	847	(2,360)	1681	50,970
LiI	440	(1,420)	1171	40,770
LiOH	462	2,480		
Li_2MoO_4	705	4,200		
$LiNO_3$				
Li_2SiO_3	1177	7,210		
Li_4SiO_4	1249	7,430		
Li_2SO_4	857	3,040		
Li_2WO_4	742	(6,700)		
Magnesium				
Mg	650	2,160	1107	32,520
$MgBr_2$	711	8,300		
$MgCl_2$	712	8,100	1418	32,690
MgF_2	1221	5,900		
MgO	2642	18,500		
$Mg_3(PO_4)_2$	1184	(11,300)		
$MgSiO_3$	1524	14,700		
$MgSO_4$	1127	3,500		
$MgZn_2$	589	(8,270)		
Manganese				
Mn	1220	3,450	2152	55,150
$MnCl_2$	650	7,340	1190	29,630
$MnSiO_3$	1274	(8,200)		
$MnTiO_3$	1404	(7,960)		
Mercury				
Hg	−38.9	557	361	13,980
$HgBr_2$	241	3,960	319	14,080
$HgCl_2$	277	4,150	304	14,080
HgI_2	250	4,500	354	14,260
$HgSO_4$	850	(1,440)		
Molybdenum				
Mo	2622	(6,660)	(4800)	(128,000)
MoF_6	17	2,500	36	6,000
MoO_3	745	(2,500)	1151	
Neon				
Ne	−248.5	77	−246.0	440[e]
Nickel				
Ni	1455	4,200	2730	87,300
$NiCl_2$			987[c]	48,360[c]
$Ni(CO)_4$			42.5	7,000
Ni_2S	645	(2,980)		
Ni_3S_2	790	5,800		
Nitrogen				
N_2	−210.0	172	−195.8	1,336
NF_3			−129.0	3,000
NH_3	−77.7	1,352[n]	−33.4	5,581[n]
NH_4CNS	146	(4,700)		
NH_4NO_3	169.6	1,460		
N_2O	−90.8	1,563	−88.5	3,950
NO	−163.6	550	−151.7	3,307
N_2O_4	−13	5,540	30	7,040
N_2O_5			32.4	13,800[c]
NOCl			−6.4	6,140
Osmium				
OsF_8			47.4	6,840
OsO_4 (yellow)	56	4,060	130	9,450
OsO_4 (white)	42	2,340		
Oxygen				
O_2	−218.9	106	−183.0	1,629
O_3			−111	2,880
Palladium				
Pd	1554	4,120		
Phosphorus				
P_4 (yellow)	44.2	615	280	12,520
P_4 (violet)			417[c]	25,600[c]
P_4 (black)			453[c]	33,100
PCl_3			74.2	7,280
PH_3	−133.8	270[o]	−87.7	3,489[o]
P_4O_6	23.8	3,360	174	10,380
P_4O_{10}(α)	569	17,080	591	20,670
P_4O_{10}(β)			358[c]	
$POCl_3$	1.1	3,110	105.1	8,380
P_2S_3			508	
Platinum				
Pt	1773.5	4,700	(4400)	(107,000)
Potassium				
K	63.5	574	776	18,920
KBO_2	947	(5,700)		
KBr	742	5,000	1383	37,060
KCl	770	6,410	1407	38,840
KCN	623	(3,500)		
KCNS	179	2,250		
K_2CO_3	897	7,800		
K_2CrO_4	984	6,920		
$K_2Cr_2O_7$	398	8,770		
KF	857	6,500		
KI	682	4,100	1324	34,690
K_2MoO_4	922	(4,000)		
KNO_3	338	2,840		
KOH	360	(2,000)	1327	30,850
KPO_3	817	2,110		
K_3PO_4	1340	8,900		
$K_4P_2O_7$	1092	14,000		
K_2SO_4	1074	8,100		
K_2TiO_3	810	(10,600)		
K_2WO_4	927	(4,400)		
Praseodymium				
Pr	932	2,700		
Radon				
Rn	−71		−61.8	4,010
Rhenium				
Re	(3000)			
Re_2O_7	296	15,340	362.4	18,060
Re_2O_5	147	3,800		
Rubidium				
Rb	39.1	525	679	18,110
RbBr	677	3,700	1352	37,120
RbCl	717	4,400	1381	36,920
RbF	833	4,130	1408	39,510
RbI	638	2,990	1304	35,960
$RbNO_3$	305	1,340		
Selenium				
Se_2	217	1,220	753	25,490
Se_6			736	20,600
SeF_6			−45.8[c]	6,350[c]
SeO_2			317[c]	20,900
$SeOCl_2$	10	1,010	168	
Silicon				
Si	1427	9,470	2290	
$SiCl_4$	−67.6	1,845	56.8	6,860
Si_2Cl_6	−1		139	
Si_3Cl_8			211.4	12,340
$(SiCl_3)_2O$	−33		135.6	8,820
SiF_4			−94.8[c]	6,130[c]
Si_2F_6	−18.5	3,900	−18.9[c]	10,400[c]
SiF_3Cl	−138		−70.1	4,460
SiF_2Cl_2	−144		−31.5	5,080
SiH_4	−185		−111.6	2,960
Si_2H_6	−132.5		−14.3	5,110
Si_3H_8	−117		53.1	6,780
Si_4H_{10}	−93.5		100	8,890
SiH_3Br	−93.8		2.4	5,650
SiH_2Br_2	−70.0		70.5	6,840
$SiHCl_3$	−126.5		31.8	6,360
$(SiH_3)_3N$	−105.6		48.7	6,850
$(SiH_3)_2O$	−144		−15.4	5,350
SiO_2 (quartz)	1470	3,400	2230	
SiO_2 (cristobalite)	1700	2,100		
Silver				
Ag	960.5	2,700	2212	60,720
AgBr	430	2,180		
AgCl	455	3,155	1564	42,520
AgCN	350	2,750		
AgI	557	2,250	1506	34,450
$AgNO_3$	209	2,755		
Ag_2S	842	3,360		
Ag_2SO_4	657	(4,300)		
Sodium				
Na	97.7	630	914	23,120
$NaBO_2$	966	8,660		

TABLE 2-147 Heats of Fusion and Vaporization of the Elements and Inorganic Compounds (*Concluded*)

Substance	mp, °C	Heat of fusion,[a,b] cal/mol	bp at 1 atm, °C	Heat of vaporization,[a,b] cal/mol
Sodium (*Cont.*)				
NaBr	747	6,140	1392	37,950
NaCl	800	7,220	1465	40,810
$NaClO_3$	255	5,290		
NaCN	562	(4,400)	1500	37,280
NaCNS	323	4,450		
Na_2CO_3	854	7,000		
NaF	992	7,000	1704	53,260
NaI	662	5,240		
Na_2MoO_4	687	3,600		
$NaNO_3$	310	3,760		
NaOH	322	2,000	1378	
$½Na_2O·½Al_2O_3·3SiO_2$	1107	13,150		
$NaPO_3$	988	(5,000)		
$Na_4P_2O_7$	970	(13,700)		
Na_2S	920	(1,200)		
Na_2SiO_3	1087	10,300		
$Na_2Si_2O_5$	884	8,460		
Na_2SO_4	884	5,830		
Na_2WO_4	702	5,800		
Strontium				
Sr	757	2,190	1384	33,610
$SrBr_2$	643	4,780		
$SrCl_2$	872	4,100		
SrF_2	1400	4,260		
$Sr_3(PO_4)_2$	1770	18,500		
Sulfur				
S (rhombic)	112.8		444.6	2,200
S (monoclinic)	119.2			
S_2Cl_2			138	8,720
SF_6			–63.5[c]	5,600[c]
SO_2	–75.5	1,769[g]	–5.0	5,960[g]
$SO_3(\alpha)$	17	2,060	44.8	10,190
$SO_3(\beta)$	32.4	2,890		
$SO_3(\gamma)$	62.2	6,310		
$SOBr_2$			139.5	9,920
$SOCl_2$			75.4	7,600
SO_2Cl_2			69.2	7,760
Tellurium				
Te	453	3,230	1090	
$TeCl_4$			392	16,830
TeF_6			–38.6[c]	6,700[c]
Thallium				
Tl	302.5	1,030	1457	38,810
TlBr	460	5,990	819	23,800
TlCl	427	4,260	807	24,420
Tl_2CO_3	273	4,400		
TlI	440	3,125	823	25,030
$TlNO_3$	207	2,290		
Tl_2S	449	3,000		
Tl_2SO_4	632	5,500		
Tin				
Sn_4	231.8	1,720	2270	68,000
$SnBr_2$	232	(1,700)		
$SnBr_4$	30	3,000		
$SnCl_2$	247	3,050	623	20,740
$SnCl_4$	–33.2	2,190	113	8,330
$Sn(CH_3)_4$			78.3	7,320
SnH_4	–149.8		–52.3	4,420
SnI_4	143.5	(4,300)		
Titanium				
$TiBr_4$	38.2	(2,060)		
$TiCl_4$	–23	2,240	136	8,350
TiO_2	1825	(11,400)		
Tungsten				
W	3390	(8,400)	(5900)	(176,000)
WF_6	–0.4	1,800	17.3	6,350
Uranium				
UF_6			55.1[c]	9,990[c]
Xenon				
Xe	–111.5	740	–108.0	3,110
Zinc				
Zn	419.5	1,595	907	27,430
$ZnCl_2$	283	(5,500)	732	28,710
$Zn(C_2H_5)_2$			118	8,960
ZnO	1975	4,470		
ZnS	1645	(9,000)		
Zirconium				
$ZrBr_4$			357[c]	25,800[c]
$ZrCl_4$			311[c]	25,290[c]
ZrI_4			431[c]	29,030[c]
ZrO_2	2715	20,800		

[a] Values in parentheses are uncertain.
[b] For the freezing point or the normal boiling point unless otherwise stated.
[c] Sublimation.
[d] Decomposes at about 75 °C; value obtained by extrapolation.
[e] Bichowsky and Rossini, *Thermochemistry of the Chemical Substances*, Reinhold, New York (1936).
[f] Decomposes before the normal boiling point is reached.
[g] Decomposes at about 40 °C; value obtained by extrapolation.
[h] See also pp. 2-304 through 2-307 on steam table.
[i] Giauque and Ruehrwein, *J. Am. Chem. Soc.*, **61** (1939): 2626.
[j] Giauque and Egan, *J. Chem. Phys.*, **5** (1937): 45.
[k] Kemp and Giauque, *J. Am. Chem.* Soc., **59** (1937): 79.
[l] Brown and Manov, *J. Am. Chem.* Soc., **59** (1937): 500.
[m] Giauque and Powell, *J. Am. Chem.* Soc. **61** (1939): 1970.
[n] Overstreet and Giauque, *J. Am. Chem.* Soc **59** (1937): 254.
[o] Stephenson and Giauque, *J. Chem. Phys.*, **5** (1937): 149.
[p] Giauque and Stephenson, *J. Am. Chem. Soc.*, **60** (1938): 1389.
[q] Osborne, Stimson, and Ginnings, *Bur. Standards J. Research*, **23,** 197 (1939): 261.
[r] Miles and Menzies, *J. Am. Chem. Soc.*, **58** (1936): 1067.
[s] Long and Kemp, *J. Am. Chem. Soc.*, **58** (1936): 1829.
[t] Giauque and Blue, *J. Am. Chem. Soc.*, **58** (1936): 831.
[u] Ruehrwein and Giauque, *J. Am. Chem. Soc.*, **61** (1939): 2940.

TABLE 2-148 Heats of Fusion of Miscellaneous Materials

Material	mp, °C	Heat of fusion, cal/g
Alloys		
30.5 Pb + 69.5 Sn	183	17
36.9 Pb + 63.1 Sn	179	15.5
63.7 Pb + 36.3 Sn	177.5	11.6
77.8 Pb + 22.2 Sn	176.5	9.54
1 Pb + 9 Sn	236	28
24 Pb + 27.3 Sn + 48.7 Bi	98.8	6.85
25.8 Pb + 14.7 Sn + 52.4 Bi + 7 Cd	75.5	8.4
Silicates		
Anorthite ($CaAl_2Si_2O_8$)		100
Orthoclase ($KAlSi_2O_8$)		100
Microcline ($KAlSi_3O_8$)		83
Wollastonite ($CaSiO_8$)		100
Malacolite ($Ca_8MgSi_4O_{12}$)		94
Diopside ($CaMgSi_2O_4$)		100
Olivine (Mg_2SiO_4)		130
Fayalite (Fe_2SiO_4)		85
Spermaceti	43.9	37.0
Wax (bees')	61.8	42.3

TABLE 2-149 Heats of Fusion of Organic Compounds

The values for the hydrocarbons are from the tables of the American Petroleum Institute Research Project 44 at the National Bureau of Standards, with some from Parks and Huffman, *Ind. Eng. Chem.*, **23,** 1138 (1931).

The values for the nonhydrocarbon compounds were recalculated from data in *International Critical Tables*, vol. 5.

Hydrocarbon compounds	Formula	mp, °C	Heat of fusion, cal/g
Paraffins			
Methane	CH_4	−182.48	14.03
Ethane	C_2H_6	−183.23	22.712
Propane	C_3H_8	−187.65	19.100
n-Butane	C_4H_{10}	−138.33	19.167
2-Methylpropane	C_4H_{10}	−159.60	18.668
n-Pentane	C_5H_{12}	−129.723	27.874
2-Methylbutane	C_5H_{12}	−159.890	17.076
2,2-Dimethylpropane	C_5H_{12}	−16.6	10.786
n-Hexane	C_6H_{14}	−95.320	36.138
2-Methylpentane	C_6H_{14}	−153.680	17.407
2,2-Dimethylbutane	C_6H_{14}	−99.73	1.607
2,3-Dimethylbutane	C_6H_{14}	−128.41	2.251
n-Heptane	C_7H_{16}	−90.595	33.513
2-Methylhexane	C_7H_{16}	−118.270	21.158
3-Ethylpentane	C_7H_{16}	−118.593	22.555
2,2-Dimethylpentane	C_7H_{16}	−123.790	13.982
2,4-Dimethylpentane	C_7H_{16}	−119.230	15.968
3,3-Dimethylpentane	C_7H_{16}	−134.46	16.856
2,2,3-Trimethylbutane	C_7H_{16}	−24.96	5.250
n-Octane	C_8H_{18}	−56.798	43.169
2-Methylheptane	C_8H_{18}	−109.04	21.458
3-Methylpentane	C_8H_{18}	−120.50	23.795
4-Methylheptane	C_8H_{18}	−120.955	22.692
2,2-Dimethylhexane	C_8H_{18}	−121.18	24.226
2,5-Dimethylhexane	C_8H_{18}	−91.200	26.903
3,3-Dimethylhexane	C_8H_{18}	−126.10	14.9
2-Methyl-3-ethylpentane	C_8H_{18}	−114.960	23.690
3-Methyl-3-ethylpentane	C_8H_{18}	−90.870	22.657
2,2,3-Trimethylpentane	C_8H_{18}	−112.27	18.061
2,2,4-Trimethylpentane	C_8H_{18}	−107.365	19.278
2,3,3-Trimethylpentane	C_8H_{18}	−100.70	3.204
2,3,4-Trimethylpentane	C_8H_{18}	−109.210	19.392
2,2,3,3-Tetramethylbutane	C_8H_{18}	+100.69	14.900
n-Nonane	C_9H_{20}	−53.9	41.2
n-Decane	$C_{10}H_{22}$	−30.0	48.3
n-Undecane	$C_{11}H_{24}$	−25.9	34.1
n-Dodecane	$C_{12}H_{26}$	−9.6	51.3
Eicosane	$C_{20}H_{42}$	+36.4	52.0
Pentacosane	$C_{25}H_{52}$	+53.3	53.6
Tritriacontane	$C_{33}H_{68}$	+71.1	54.0
Aromatics			
Benzene	C_6H_6	+5.533	30.100
Methylbenzene (Toluene)	C_7H_8	−94.991	17.171
Ethylbenzene	C_8H_{10}	−94.950	20.629
o-Xylene	C_8H_{10}	−25.187	30.614
m-Xylene	C_8H_{10}	−47.872	26.045
p-Xylene	C_8H_{10}	+13.263	38.526
n-Propylbenzene	C_9H_{12}	−99.500	16.97
Isopropylbenzene	C_9H_{12}	−96.028	19.22
1-Methyl-2-ethylbenzene	C_9H_{12}	−80.833	21.13
1-Methyl-3-ethylbenzene	C_9H_{12}	−95.55	15.14
1-Methyl-4-ethylbenzene	C_9H_{12}	−62.350	25.29
1,2,3-Trimethylbenzene	C_9H_{12}	−25.375	16.64
1,2,4-Trimethylbenzene	C_9H_{12}	−43.80	24.54
1,3,5-Trimethylbenzene	C_9H_{12}	−44.720	18.97
Naphthalene	$C_{10}H_8$	+80.0	36.0
Camphene	$C_{10}H_{12}$	+51	57
Durene	$C_{10}H_{14}$	+79.3	37.4
Isodurene	$C_{10}H_{14}$	−24.0	23.0
Prehnitene	$C_{10}H_{14}$	−7.7	20.0
p-Cymene	$C_{10}H_{14}$	−68.9	17.1
n-Butyl benzene	$C_{10}H_{14}$	−88.5	19.5
tert-Butyl benzene	$C_{10}H_{14}$	−58.1	14.9
β-Methyl naphthalene	$C_{11}H_{10}$	+34.1	20.1
Diphenyl	$C_{12}H_{10}$	+68.6	28.8
Hexamethyl benzene	$C_{12}H_{18}$	+165.5	30.4
Diphenyl methane	$C_{13}H_{12}$	+25.2	26.4
Anthracene	$C_{14}H_{10}$	+216.5	38.7
Phenanthrene	$C_{14}H_{10}$	+96.3	25.0
Tolane	$C_{14}H_{10}$	+60	28.7
Stilbene	$C_{14}H_{12}$	+124	40.0
Dibenzil	$C_{14}H_{14}$	+51.4	30.7
Triphenyl methane	$C_{19}H_{16}$	+92.1	21.1
Alkyl cyclohexanes			
Cyclohexane	C_6H_{12}	+6.67	7.569
Methylcyclohexane	C_7H_{14}	−126.58	16.429
Alkyl cyclopentanes			
Cyclopentane	C_5H_{10}	−93.80	2.068
Methylcyclopentane	C_6H_{12}	−142.445	19.68
Ethylcyclopentane	C_7H_{14}	−138.435	11.10
1,1-Dimethylcyclopentane	C_7H_{14}	−69.73	3.36
cis-1,2-Dimethylcyclopentane	C_7H_{14}	−53.85	3.87
trans-1,2-Dimethylcyclopentane	C_7H_{14}	−117.57	15.68
trans-1,3-Dimethylcyclopentane	C_7H_{14}	−133.680	17.93
Monoolefins			
Ethene (Ethylene)	C_2H_4	−169.15	28.547
Propene (Propylene)	C_3H_6	−185.25	17.054
1-Butene	C_4H_8	−185.35	16.393
cis-2-Butene	C_4H_8	−138.91	31.135
trans-2-Butene	C_4H_8	−105.55	41.564
2-Methylpropene (isobutene)	C_4H_8	−140.35	25.265
1-Pentene	C_5H_{10}	−165.27	16.82
cis-2-pentene	C_5H_{10}	−151.363	24.239
trans-2-pentene	C_5H_{10}	−140.235	26.536
2-Methyl-1-butene	C_5H_{10}	−137.560	26.879
3-Methyl-1-butene	C_5H_{10}	−168.500	18.009
2-Methyl-2-butene	C_5H_{10}	−133.780	25.738
Acetylenes			
Acetylene	C_2H_2	−81.5	23.04
2-Butyne (dimethylacetylene)	C_4H_6	−132.23	40.808

Nonhydrocarbon compounds	Formula	mp, °C	Heat of fusion, cal/g
Acetic acid	$C_2H_4O_2$	16.7	46.68
Acetone	C_3H_6O	−95.5	23.42
Acrylic acid	$C_3H_4O_2$	12.3	37.03
Allo-cinnamic acid	$C_9H_8O_2$	68	27.35
Aminobenzoic acid (*o*-)	$C_7H_7NO_2$	145	35.48
(*m*-)	$C_7H_7NO_2$	179.5	38.03
(*p*-)	$C_7H_7NO_2$	188.5	36.46
Amyl alcohol	$C_5H_{12}O$	−78.9	26.65
Anethole	$C_{10}H_{12}O$	22.5	25.80
Aniline	$C_6H_5NH_2$	−6.3	27.09
Anthraquinone	$C_{14}H_8O_2$	284.8	37.48
Apiol	$C_{12}H_{14}O_4$	29.5	25.80
Azobenzene	$C_{12}H_{10}N_2$	67.1	28.91
Azoxybenzene	$C_{12}H_{10}N_2O$	36	21.62
Benzil	$C_{14}H_{10}O_2$	95.2	22.15
Benzoic acid	$C_7H_8O_2$	122.45	33.90
Benzophenone	$C_{13}H_{10}O$	47.85	23.53
Benzylaniline	$C_{13}H_{13}N$	32.37	21.86
Bromocamphor	$C_{10}H_{15}BrO$	78	41.57
Bromochlorbenzene (*o*-)	C_6H_4BrCl	−12.6	15.41
(*m*-)	C_6H_4BrCl	−21.2	15.29
(*p*-)	C_6H_4BrCl	64.6	23.41
Bromoiodobenzene (*o*-)	C_6H_4BrI	21	12.18
(*m*-)	C_6H_4BrI	9.3	10.27
(*p*-)	C_6H_4BrI	90.1	16.60
Bromol hydrate	$C_2H_3Br_3O_2$	46	16.90
Bromophenol (*p*-)	C_6H_5BrO	63.5	20.50
Bromotoluene (*p*-)	C_7H_7Br	28	20.86
Butyl alcohol (*n*-)	$C_4H_{10}O$	−89.2	29.93
(*t*-)	$C_4H_{10}O$	25.4	21.88
Butyric acid (*n*-)	$C_4H_8O_2$	−5.7	30.04
Capric acid (*n*-)	$C_{10}H_{20}O_2$	31.99	38.87
Caprylic acid (*n*-)	$C_8H_{16}O_2$	16.3	35.40
Carbazole	$C_{12}H_9N$	243	42.05
Carbon tetrachloride	CCl_4	−22.8	41.57
Carvoxime (*d*-)	$C_{10}H_{15}NO$	71.5	23.29
(*l*-)	$C_{10}H_{15}NO$	71	23.41
(*dl*-)	$C_{10}H_{15}NO$	91	24.61
Cetyl alcohol	$C_{16}H_{34}O$	49.27	33.80
Chloracetic acid (α-)	$C_2H_3ClO_2$	61.2	31.06
(β-)	$C_2H_3ClO_2$	56	35.12
Chloral alcoholate	$C_4H_7Cl_3O_2$	9	24.03
hydrate	$C_2H_3Cl_3O_2$	47.4	33.18
Chloroaniline (*p*-)	C_6H_6ClN	71	37.15
Chlorobenzoic acid (*o*-)	$C_7H_5ClO_2$	140.2	39.30
(*m*-)	$C_7H_5ClO_2$	154.25	36.41
(*p*-)	$C_7H_5ClO_2$	239.7	49.21
Chloronitrobenzene (*m*-)	$C_6H_4ClNO_2$	44.4	29.38
(*p*-)	$C_6H_4ClNO_2$	83.5	31.51
Cinnamic acid	$C_9H_8O_2$	133	36.50
anhydride	$C_{18}H_{14}O_3$	48	28.14
Cresol (*p*-)	C_7H_8O	34.6	26.28
Crotonic acid (α-)	$C_4H_6O_2$	72	25.32
(*cis*-)	$C_4H_6O_2$	71.2	34.90
Cyanamide	CH_2N_2	44	49.81
Cyclohexanol	$C_6H_{12}O$	25.46	4.19

TABLE 2-149 Heats of Fusion of Organic Compounds (*Concluded*)

Nonhydrocarbon compounds	Formula	mp, °C	Heat of fusion, cal/g	Nonhydrocarbon compounds	Formula	mp, °C	Heat of fusion, cal/g
Dibromobenzene (*o*-)	$C_6H_4Br_2$	1.8	12.78	Naphthol (α-)	$C_{10}H_8O$	95.0	38.94
(*m*-)	$C_6H_4Br_2$	–6.9	13.38	(β-)	$C_{10}H_8O$	120.6	31.30
(*p*-)	$C_6H_4Br_2$	86	20.55	Naphthylamine (α-)	$C_{10}H_9N$	50	22.34
Dibromophenol (2, 4-)	$C_6H_4Br_2O$	12	13.97	Nitroaniline (*o*-)	$C_6H_6N_2O_2$	71.2	27.88
Dichloroacetic acid	$C_2H_2Cl_2O_2$	–4(?)	14.21	(*m*-)	$C_6H_6N_2O_2$	114.0	40.97
Dichlorobenzene (*o*-)	$C_6H_4Cl_2$	–16.7	21.02	(*p*-)	$C_6H_6N_2O_2$	147.3	36.46
(*m*-)	$C_6H_4Cl_2$	–24.8	20.55	Nitrobenzene	$C_6H_5NO_2$	5.85	22.52
(*p*-)	$C_6H_4Cl_2$	53.13	29.67	Nitrobenzoic acid (*o*-)	$C_7H_5NO_4$	145.8	40.06
Dihydroxybenzene (*o*-)	$C_6H_6O_2$	104.3	49.40	(*m*-)	$C_7H_5NO_4$	141.1	27.59
(*m*-)	$C_6H_6O_2$	109.65	46.20	(*p*-)	$C_7H_5NO_4$	239.2	52.80
(*p*-)	$C_6H_6O_2$	172.3	58.77	Nitronaphthalene	$C_{10}H_7NO_2$	56.7	25.44
Di-iodobenzene (*o*-)	$C_6H_4I_2$	23.4	10.15	Nitrophenol (*o*-)	$C_6H_5NO_3$	45.13	26.76
(*m*-)	$C_6H_4I_2$	34.2	11.54				
(*p*-)	$C_6H_4I_2$	129	16.20	Palmitic acid	$C_{16}H_{32}O_2$	61.82	39.18
Dimethyl tartrate (*dl*-)	$C_6H_{10}O_6$	87	35.12	Paraldehyde	$C_6H_{12}O_3$	10.5	25.02
(*d*-)	$C_6H_{10}O_6$	49	21.50	Pelargic acid (*n*-) (β-)	$C_9H_{18}O_2$		39.04
pyrone	$C_7H_8O_2$	132	56.14	Pelargonic acid (*n*-) (α-)	$C_9H_{18}O_2$	12.35	30.63
Dinitrobenzene (*o*-)	$C_6H_4N_2O_4$	116.93	32.25	Phenol	C_6H_6O	40.92	29.03
(*m*-)	$C_6H_4N_2O_4$	89.7	24.70	Phenylacetic acid	$C_8H_8O_2$	76.7	25.44
(*p*-)	$C_6H_4N_2O_4$	173.5	39.99	Phenylhydrazine	$C_6H_8N_2$	19.6	36.31
Dinitrotoluene (2, 4-)	$C_7H_6N_2O_4$	70.14	26.40	Propyl ether (*n*)	$C_6H_{14}O$	–126.1	20.66
Dioxane	$C_4H_8O_2$	11.0	34.85				
Diphenyl amine	$C_{12}H_{11}N$	52.98	25.23	Quinone	$C_6H_4O_2$	115.7	40.85
Elaidic acid	$C_{18}H_{34}O_2$	44.4	52.08	Stearic acid	$C_{18}H_{30}O_2$	68.82	47.54
Ethyl acetate	$C_4H_8O_2$	83.8	28.43	Succinic anhydride	$C_4H_4O_3$	119	48.74
alcohol	C_2H_6O	–114.4	25.76	Succinonitrile	$C_4H_4N_2$	54.5	11.71
Ethylene dibromide	$C_2H_4Br_2$	10.012	13.52				
Ethyl ether	$C_4H_{10}O$	–116.3	23.54	Tetrachloroxylene (*o*-)	$C_8H_6Cl_4$	86	21.02
				(*p*-)	$C_8H_6Cl_4$	95	22.10
Formic acid	CH_2O_2	8.40	58.89	Thiophene	C_4H_4S	–39.4	14.11
				Thiosinamine	$C_4H_8N_2S$	77	33.45
Glutaric acid	$C_6H_8O_4$	97.5	37.39	Thymol	$C_{10}H_{14}O$	51.5	27.47
Glycerol	$C_3H_8O_3$	18.07	47.49	Toluic acid (*o*-)	$C_8H_8O_2$	103.7	35.40
Glycol, ethylene	$C_2H_6O_2$	–11.5	43.26	(*m*-)	$C_8H_8O_2$	108.75	27.59
				(*p*-)	$C_8H_8O_2$	179.6	39.90
Hydrazo benzene	$C_{12}H_{12}N_2$	134	22.89	Toluidine (*p*-)	C_7H_9N	43.3	39.90
Hydrocinnamic acid	$C_9H_{10}O_2$	48	28.14	Tribromophenol (2, 4, 6-)	$C_6H_3Br_3O$	93	13.38
Hydroxyacetanilide	$C_8H_9NO_2$	91.3	33.59	Trichloroacetic acid	$C_2HCl_3O_2$	57.5	8.60
				Trinitroglycerol	$C_3H_5N_3O_9$	12.3	23.02
Iodotoluene (*p*-)	C_7H_7I	34	18.75	Trinitrotoluene (2, 4, 6-)	$C_7H_5N_3O_6$	80.83	22.34
Isopropyl alcohol	C_3H_8O	–88.5	21.08	Tristearin	$C_{57}H_{110}O_6$	70.8, 54.5	45.63
ether	$C_6H_{14}O$	–86.8	25.79				
				Undecylic acid (α-) (*n*-)	$C_{11}H_{22}O_2$	28.25	32.20
Lauric acid (*n*-)	$C_{12}H_{24}O_2$	43.22	43.72	(β-) (*n*-)	$C_{11}H_{22}O_2$		42.91
Levulinic acid	$C_5H_8O_3$	33	18.97	Urethane	$C_3H_7NO_2$	48.7	40.85
Menthol (*l*-) (α)	$C_{10}H_{20}O$	43.5	18.63	Veratrol	$C_8H_{10}O_2$	22.5	27.45
Methyl alcohol	CH_4O	–97.8	23.7				
Myristic acid	$C_{14}H_{28}O_2$	53.86	47.49	Xylene dibromide (*o*-)	$C_8H_8Br_2$	95	24.25
Methyl cinnamate	$C_{10}H_{10}O_2$	36	26.53	(*m*-)	$C_8H_8Br_2$	77	21.45
fumarate	$C_6H_8O_4$	102	57.93	dichloride (*o*-)	$C_8H_8Cl_2$	55	29.03
oxalate	$C_4H_6O_4$	54.35	42.64	(*m*-)	$C_8H_8Cl_2$	34	26.64
phenylpropiolate	$C_{10}H_8O_2$	18	22.86	(*p*-)	$C_8H_8Cl_2$	100	32.73
succinate	$C_6H_{10}O_4$	19.5	35.72				

TABLE 2-150 Heats of Vaporization of Inorganic and Organic Liquids (J/kmol)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1 × 1E-07	C2	C3	C4	T_{min}, K	ΔH_v at T_{min} × 1E-07	T_{max}, K	ΔH_v at T_{max}
1	Acetaldehyde	C_2H_4O	75-07-0	44.053	3.8366	0.40081			150.15	3.2828	466.00	0
2	Acetamide	C_2H_5NO	60-35-5	59.067	8.107	0.42			353.15	6.2386	761.00	0
3	Acetic acid	$C_2H_4O_2$	64-19-7	60.052	4.0179	2.6037	–5.0031	2.7069	289.81	2.3412	591.95	0
4	Acetic anhydride	$C_4H_6O_3$	108-24-7	102.089	6.352	0.3986			200.15	5.4139	606.00	0
5	Acetone	C_3H_6O	67-64-1	58.079	4.215	0.3397			178.45	3.6390	508.20	0
6	Acetonitrile	C_2H_3N	75-05-8	41.052	4.3511	0.34765			229.32	3.5996	545.50	0
7	Acetylene	C_2H_2	74-86-2	26.037	2.3214	0.35938			192.40	1.6333	308.30	0
8	Acrolein	C_3H_4O	107-02-8	56.063	3.8736	0.29335			185.45	3.3881	506.00	0
9	Acrylic acid	$C_3H_4O_2$	79-10-7	72.063	4.3756	2.2571	–4.5116	2.5738	286.15	2.7965	615.00	0
10	Acrylonitrile	C_3H_3N	107-13-1	53.063	4.155	0.2733			189.63	3.6866	535.00	0
11	Air	Mixture	132259-10-0	28.960	0.8474	0.3822			59.15	0.6759	132.45	0
12	Ammonia	H_3N	7664-41-7	17.031	3.1523	0.3914	–0.2289	0.2309	195.41	2.5298	405.65	0
13	Anisole	C_7H_8O	100-66-3	108.138	5.8662	0.37127			235.65	4.9560	645.60	0
14	Argon	Ar	7440-37-1	39.948	0.87308	0.3526			83.78	0.6561	150.86	0
15	Benzamide	C_7H_7NO	55-21-0	121.137	8.7809	0.1933	0.30877	–0.14162	403.00	7.1286	824.00	0
16	Benzene	C_6H_6	71-43-2	78.112	4.5346	0.39053			278.68	3.4705	562.05	0
17	Benzenethiol	C_6H_6S	108-98-5	110.177	6.225	0.4412			258.27	5.0597	689.00	0
18	Benzoic acid	$C_7H_6O_2$	65-85-0	122.121	10.19	0.478			395.45	7.1277	751.00	0
19	Benzonitrile	C_7H_5N	100-47-0	103.121	6.8077	0.63344	–0.27365		260.40	5.3147	699.35	0
20	Benzophenone	$C_{13}H_{10}O$	119-61-9	182.218	10.523	0.87091	–0.45568		321.35	7.4895	830.00	0
21	Benzyl alcohol	C_7H_8O	100-51-6	108.138	8.4762	0.35251	0.43853	–0.3026	257.85	6.8800	720.15	0
22	Benzyl ethyl ether	$C_9H_{12}O$	539-30-0	136.191	6.228	0.3411			275.65	5.1829	662.00	0
23	Benzyl mercaptan	C_7H_8S	100-53-8	124.203	6.9642	0.44354			243.95	5.7930	718.00	0
24	Biphenyl	$C_{12}H_{10}$	92-52-4	154.208	7.635	0.39182			342.20	6.0719	773.00	0
25	Bromine	Br_2	7726-95-6	159.808	4	0.351			265.85	3.2323	584.15	0
26	Bromobenzene	C_6H_5Br	108-86-1	157.008	5.552	0.37694			242.43	4.6875	670.15	0
27	Bromoethane	C_2H_5Br	74-96-4	108.965	3.9004	0.38012			154.55	3.3933	503.80	0
28	Bromomethane	CH_3Br	74-83-9	94.939	3.169	0.3015			179.47	2.7379	467.00	0
29	1,2-Butadiene	C_4H_6	590-19-2	54.090	3.522	0.395			136.95	3.0540	452.00	0
30	1,3-Butadiene	C_4H_6	106-99-0	54.090	3.2632	0.3701			164.25	2.7235	425.00	0
31	Butane	C_4H_{10}	106-97-8	58.122	3.6238	0.8337	–0.82274	0.39613	134.86	2.8684	425.12	0
32	1,2-Butanediol	$C_4H_{10}O_2$	584-03-2	90.121	8.9754	0.45316			220.00	7.5185	680.00	0
33	1,3-Butanediol	$C_4H_{10}O_2$	107-88-0	90.121	9.2247	0.42442			196.15	7.9759	676.00	0
34	1-Butanol	$C_4H_{10}O$	71-36-3	74.122	7.1274	0.0483	0.8966	–0.5116	183.85	6.3643	563.10	0
35	2-Butanol	$C_4H_{10}O$	78-92-2	74.122	7.9227	0.58361	0.02016	–0.08654	158.45	6.4607	535.90	0
36	1-Butene	C_4H_8	106-98-9	56.106	3.3774	0.5107	–0.17304	0.05181	87.80	3.0197	419.50	0
37	*cis*-2-Butene	C_4H_8	590-18-1	56.106	3.4358	0.38004			134.26	2.9867	435.50	0
38	*trans*-2-Butene	C_4H_8	624-64-6	56.106	3.3191	0.36968			167.62	2.7630	428.60	0
39	Butyl acetate	$C_6H_{12}O_2$	123-86-4	116.158	5.8276	0.38854			199.65	4.9384	575.40	0
40	Butylbenzene	$C_{10}H_{14}$	104-51-8	134.218	6.3487	0.38222			185.30	5.5979	660.50	0
41	Butyl mercaptan	$C_4H_{10}S$	109-79-5	90.187	4.9702	0.41199			157.46	4.3505	570.10	0
42	*sec*-Butyl mercaptan	$C_4H_{10}S$	513-53-1	90.187	4.6432	0.399			133.02	4.1614	554.00	0
43	1-Butyne	C_4H_6	107-00-6	54.090	3.6972	0.39168			147.43	3.1511	440.00	0
44	Butyraldehyde	C_4H_8O	123-72-8	72.106	4.6403	0.3849			176.75	3.9797	537.20	0
45	Butyric acid	$C_4H_8O_2$	107-92-6	88.105	6.1947	1.6524	–2.8505	1.6285	250.00	4.1619	615.70	0
46	Butyronitrile	C_4H_7N	109-74-0	69.105	5.22	0.165	0.6692	–0.539	161.25	4.7223	582.25	0
47	Carbon dioxide	CO_2	124-38-9	44.010	2.173	0.382	–0.4339	0.42213	216.58	1.5202	304.21	0
48	Carbon disulfide	CS_2	75-15-0	76.141	3.496	0.2986			161.11	3.1537	552.00	0
49	Carbon monoxide	CO	630-08-0	28.010	0.8585	0.4921	–0.326	0.2231	68.13	0.6517	132.50	915,280
50	Carbon tetrachloride	CCl_4	56-23-5	153.823	4.3252	0.37688			250.33	3.4528	556.35	0
51	Carbon tetrafluoride	CF_4	75-73-0	88.004	1.9311	0.94983	–1.0615	0.51894	89.56	1.4215	227.51	0
52	Chlorine	Cl_2	7782-50-5	70.906	3.068	0.8458	–0.9001	0.453	172.12	2.2878	417.15	0
53	Chlorobenzene	C_6H_5Cl	108-90-7	112.557	5.148	0.36614			227.95	4.3707	632.35	0
54	Chloroethane	C_2H_5Cl	75-00-3	64.514	3.524	0.3652			134.80	3.1052	460.35	0
55	Chloroform	$CHCl_3$	67-66-3	119.378	4.186	0.3584			209.63	3.5047	536.40	0
56	Chloromethane	CH_3Cl	74-87-3	50.488	2.9745	0.353			175.43	2.4520	416.25	0
57	1-Chloropropane	C_3H_7Cl	540-54-5	78.541	3.989	0.37956			150.35	3.4862	503.15	0
58	2-Chloropropane	C_3H_7Cl	75-29-6	78.541	3.8871	0.38043			155.97	3.3586	489.00	0
59	*m*-Cresol	C_7H_8O	108-39-4	108.138	8.0082	0.45314			285.39	6.3326	705.85	0

60	*o*-Cresol	C_7H_8O	95-48-7	108.138	7.1979	0.40317			304.19	5.7135	697.55	0
61	*p*-Cresol	C_7H_8O	106-44-5	108.138	8.4942	0.50234			307.93	6.3649	704.65	0
62	Cumene	C_9H_{12}	98-82-8	120.192	5.766	0.38939			177.14	5.0717	631.00	0
63	Cyanogen	C_2N_2	460-19-5	52.035	3.384	0.3707			245.25	2.3803	400.15	0
64	Cyclobutane	C_4H_8	287-23-0	56.106	3.334	0.3395			182.48	2.8083	459.93	0
65	Cyclohexane	C_6H_{12}	110-82-7	84.159	4.4902	0.39881			279.69	3.3920	553.80	0
66	Cyclohexanol	$C_6H_{12}O$	108-93-0	100.159	9.1791	0.6382			296.60	6.2221	650.10	0
67	Cyclohexanone	$C_6H_{10}O$	108-94-1	98.143	5.6772	0.37431			242.00	4.7739	653.00	0
68	Cyclohexene	C_6H_{10}	110-83-8	82.144	4.4405	0.37479			169.67	3.8791	560.40	0
69	Cyclopentane	C_5H_{10}	287-92-3	70.133	3.8911	0.36111			179.28	3.3299	511.70	0
70	Cyclopentene	C_5H_8	142-29-0	68.117	3.8107	0.3543			138.13	3.4046	507.00	0
71	Cyclopropane	C_3H_6	75-19-4	42.080	2.7672	0.35588			145.59	2.3532	398.00	0
72	Cyclohexyl mercaptan	$C_6H_{12}S$	1569-69-3	116.224	5.6067	0.38729			189.64	4.9220	664.00	0
73	Decanal	$C_{10}H_{20}O$	112-31-2	156.265	7.9073	0.4129			267.15	6.4201	674.20	0
74	Decane	$C_{10}H_{22}$	124-18-5	142.282	6.6126	0.39797			243.51	5.4168	617.70	0
75	Decanoic acid	$C_{10}H_{20}O_2$	334-48-5	172.265	13.107	1.0674	–0.97372	0.40491	304.55	8.7931	722.10	0
76	1-Decanol	$C_{10}H_{22}O$	112-30-1	158.281	7.9041	–1.36	4.0854	–2.3871	280.05	8.2959	688.00	0
77	1-Decene	$C_{10}H_{20}$	872-05-9	140.266	6.6985	0.76944	–0.79975	0.42379	206.89	5.3524	616.60	0
78	Decyl mercaptan	$C_{10}H_{22}S$	143-10-2	174.347	8.0617	0.41045			247.56	6.7308	696.00	0
79	1-Decyne	$C_{10}H_{18}$	764-93-2	138.250	6.9461	0.42109			229.15	5.7192	619.85	0
80	Deuterium	D_2	7782-39-0	4.032	0.1657	0.352			18.73	0.1309	38.35	0
81	1,1-Dibromoethane	$C_2H_4Br_2$	557-91-5	187.861	5.712	0.5255			210.15	4.6111	628.00	0
82	1,2-Dibromoethane	$C_2H_4Br_2$	106-93-4	187.861	5.37	0.416			282.85	4.2346	650.15	0
83	Dibromomethane	CH_2Br_2	74-95-3	173.835	4.82	0.3771			220.60	4.0709	611.00	0
84	Dibutyl ether	$C_8H_{18}O$	142-96-1	130.228	5.9616	0.38833			175.30	5.1902	584.10	0
85	*m*-Dichlorobenzene	$C_6H_4Cl_2$	541-73-1	147.002	5.6899	0.35765			248.39	4.8419	683.95	0
86	*o*-Dichlorobenzene	$C_6H_4Cl_2$	95-50-1	147.002	6.2117	0.42845			256.15	5.1191	705.00	0
87	*p*-Dichlorobenzene	$C_6H_4Cl_2$	106-46-7	147.002	5.9765	0.38559			326.14	4.6573	684.75	0
88	1,1-Dichloroethane	$C_2H_4Cl_2$	75-34-3	98.959	4.2117	0.36927			176.19	3.6189	523.00	0
89	1,2-Dichloroethane	$C_2H_4Cl_2$	107-06-2	98.959	4.5507	0.34444			237.49	3.7657	561.60	0
90	Dichloromethane	CH_2Cl_2	75-09-2	84.933	4.186	0.4092			178.01	3.5116	510.00	0
91	1,1-Dichloropropane	$C_3H_6Cl_2$	78-99-9	112.986	4.774	0.39204			200.00	4.0147	560.00	0
92	1,2-Dichloropropane	$C_3H_6Cl_2$	78-87-5	112.986	4.675	0.36529			172.71	4.0997	572.00	0
93	Diethanol amine	$C_4H_{11}NO_2$	111-42-2	105.136	10.154	0.3403			301.15	8.4908	736.60	0
94	Diethyl amine	$C_4H_{11}N$	109-89-7	73.137	4.6133	0.42628			223.35	3.5761	496.60	0
95	Diethyl ether	$C_4H_{10}O$	60-29-7	74.122	4.06	0.3868			156.85	3.4651	466.70	0
96	Diethyl sulfide	$C_4H_{10}S$	352-93-2	90.187	4.7659	0.37987			169.20	4.1537	557.15	0
97	1,1-Difluoroethane	$C_2H_4F_2$	75-37-6	66.050	3.2312	0.37653			154.56	2.6659	386.44	0
98	1,2-Difluoroethane	$C_2H_4F_2$	624-72-6	66.050	3.4552	0.3499			215.00	2.7427	445.00	0
99	Difluoromethane	CH_2F_2	75-10-5	52.023	2.8081	0.3364			136.95	2.3781	351.26	0
100	Di-isopropyl amine	$C_6H_{15}N$	108-18-9	101.190	5.007	0.4362			176.85	4.1823	523.10	0
101	Di-isopropyl ether	$C_6H_{14}O$	108-20-3	102.175	4.6117	0.4			187.65	3.8207	500.05	0
102	Di-isopropyl ketone	$C_7H_{14}O$	565-80-0	114.185	5.0256	0.29611			204.81	4.4125	576.00	0
103	1,1-Dimethoxyethane	$C_4H_{10}O_2$	534-15-6	90.121	4.3872	0.56226	–0.60662	0.4202	159.95	3.7528	507.80	0
104	1,2-Dimethoxypropane	$C_5H_{12}O_2$	7778-85-0	104.148	4.7999	0.30724	–0.024545	0.091361	226.10	4.0557	543.00	0
105	Dimethyl acetylene	C_4H_6	503-17-3	54.090	3.856	0.3737			240.91	2.9557	473.20	0
106	Dimethyl amine	C_2H_7N	124-40-3	45.084	4.09	0.42005			180.96	3.2678	437.20	0
107	2,3-Dimethylbutane	C_6H_{14}	79-29-8	86.175	4.1509	0.38383			145.19	3.6388	500.00	0
108	1,1-Dimethylcyclohexane	C_8H_{16}	590-66-9	112.213	5.0402	0.4036			239.66	4.0862	591.15	0
109	*cis*-1,2-Dimethylcyclohexane	C_8H_{16}	2207-01-4	112.213	5.2852	0.41607			223.16	4.3662	606.15	0
110	*trans*-1,2-Dimethylcyclohexane	C_8H_{16}	6876-23-9	112.213	5.1194	0.405			184.99	4.4043	596.15	0
111	Dimethyl disulfide	$C_2H_6S_2$	624-92-0	94.199	4.9825	0.3958			188.44	4.3108	615.00	0
112	Dimethyl ether	C_2H_6O	115-10-6	46.068	2.994	0.3505			131.65	2.6032	400.10	0
113	*N,N*-Dimethyl formamide	C_3H_7NO	68-12-2	73.094	5.9217	0.37996			212.72	5.0931	649.60	0
114	2,3-Dimethylpentane	C_7H_{16}	565-59-3	100.202	4.6533	0.37577			160.00	4.0745	537.30	0
115	Dimethyl phthalate	$C_{10}H_{10}O_4$	131-11-3	194.184	8.1578	0.29346			274.18	7.1632	766.00	0
116	Dimethylsilane	C_2H_8Si	1111-74-6	60.170	2.8365	0.35393			122.93	2.4928	402.00	0
117	Dimethyl sulfide	C_2H_6S	75-18-3	62.134	3.9022	0.37731			174.88	3.3213	503.04	0
118	Dimethyl sulfoxide	C_2H_6OS	67-68-5	78.133	6.629	0.4084			291.67	5.3804	729.00	0
119	Dimethyl terephthalate	$C_{10}H_{10}O_4$	120-61-6	194.184	7.236	0.2424			413.80	6.0070	772.00	0
120	1,4-Dioxane	$C_4H_8O_2$	123-91-1	88.105	5.051	0.3791			284.95	3.9263	587.00	0
121	Diphenyl ether	$C_{12}H_{10}O$	101-84-8	170.207	6.8243	0.30877			300.03	5.8546	766.80	0
122	Dipropyl amine	$C_6H_{15}N$	142-84-7	101.190	5.428	0.3665			210.15	4.5500	550.00	0

TABLE 2-150 Heats of Vaporization of Inorganic and Organic Liquids (J/kmol) (*Continued*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1 × 1E-07	C2	C3	C4	T_{min}, K	ΔH_v at T_{min} × 1E-07	T_{max}, K	ΔH_v at T_{max}
123	Dodecane	$C_{12}H_{26}$	112-40-3	170.335	7.7337	0.40681			263.57	6.2802	658.00	0
124	Eicosane	$C_{20}H_{42}$	112-95-8	282.547	12.86	0.50351	0.32986	–0.42184	309.58	9.5933	768.00	0
125	Ethane	C_2H_6	74-84-0	30.069	2.1091	0.60646	–0.55492	0.32799	90.35	1.7879	305.32	0
126	Ethanol	C_2H_6O	64-17-5	46.068	5.5789	0.31245			159.05	4.9694	514.00	0
127	Ethyl acetate	$C_4H_8O_2$	141-78-6	88.105	4.933	0.3847			189.60	4.1490	523.30	0
128	Ethyl amine	C_2H_7N	75-04-7	45.084	4.275	0.5857	–0.332	0.169	192.15	3.2955	456.15	0
129	Ethylbenzene	C_8H_{10}	100-41-4	106.165	5.4805	0.39524			178.20	4.7900	617.15	0
130	Ethyl benzoate	$C_9H_{10}O_2$	93-89-0	150.175	6.7093	0.33273			238.45	5.8382	698.00	0
131	2-Ethyl butanoic acid	$C_6H_{12}O_2$	88-09-5	116.158	7.898	0.39445			258.15	6.4816	655.00	0
132	Ethyl butyrate	$C_6H_{12}O_2$	105-54-4	116.158	5.6419	0.37985			175.15	4.9090	571.00	0
133	Ethylcyclohexane	C_8H_{16}	1678-91-7	112.213	5.3832	0.41763			161.84	4.7318	609.15	0
134	Ethylcyclopentane	C_7H_{14}	1640-89-7	98.186	4.8287	0.37804			134.71	4.3603	569.50	0
135	Ethylene	C_2H_4	74-85-1	28.053	1.8844	0.36485			104.00	1.5936	282.34	0
136	Ethylenediamine	$C_2H_8N_2$	107-15-3	60.098	5.7521	0.34513			284.29	4.5918	593.00	0
137	Ethylene glycol	$C_2H_6O_2$	107-21-1	62.068	8.3518	0.42625			260.15	6.8989	720.00	0
138	Ethyleneimine	C_2H_5N	151-56-4	43.068	4.94	0.466			195.20	4.0022	537.00	0
139	Ethylene oxide	C_2H_4O	75-21-8	44.053	3.6652	0.37878			160.65	3.1271	469.15	0
140	Ethyl formate	$C_3H_6O_2$	109-94-4	74.079	4.5909	0.4123			193.55	3.7679	508.40	0
141	2-Ethyl hexanoic acid	$C_8H_{16}O_2$	149-57-5	144.211	11.184	0.86189	–0.47845	0.048646	235.00	8.2832	674.60	0
142	Ethylhexyl ether	$C_8H_{18}O$	5756-43-4	130.228	6.2786	0.39513			180.00	5.4262	583.00	0
143	Ethylisopropyl ether	$C_5H_{12}O$	625-54-7	88.148	4.258	0.37221			140.00	3.7556	489.00	0
144	Ethylisopropyl ketone	$C_6H_{12}O$	565-69-5	100.159	5.2207	0.34893			204.15	4.4677	567.00	0
145	Ethyl mercaptan	C_2H_6S	75-08-1	62.134	3.844	0.37534			125.26	3.4489	499.15	0
146	Ethyl propionate	$C_5H_{10}O_2$	105-37-3	102.132	5.3325	0.401			199.25	4.4449	546.00	0
147	Ethylpropyl ether	$C_5H_{12}O$	628-32-0	88.148	5.438	0.60624			145.65	4.4140	500.23	0
148	Ethyltrichlorosilane	$C_2H_5Cl_3Si$	115-21-9	163.506	4.9482	0.39871			167.55	4.2942	559.95	0
149	Fluorine	F_2	7782-41-4	37.997	0.88757	0.34072			53.48	0.7578	144.12	0
150	Fluorobenzene	C_6H_5F	462-06-6	96.102	4.582	0.3717			230.94	3.7605	560.09	0
151	Fluoroethane	C_2H_5F	353-36-6	48.060	2.7617	0.32162			129.95	2.4089	375.31	0
152	Fluoromethane	CH_3F	593-53-3	34.033	2.4708	0.37014			131.35	2.0276	317.42	0
153	Formaldehyde	CH_2O	50-00-0	30.026	3.076	0.2954			181.15	2.5863	408.00	0
154	Formamide	CH_3NO	75-12-7	45.041	7.358	0.3564			275.70	6.2844	771.00	0
155	Formic acid	CH_2O_2	64-18-6	46.026	2.3195	1.9091	–5.0003	3.2641	250.00	1.8865	588.00	0
156	Furan	C_4H_4O	110-00-9	68.074	4.005	0.3995			196.29	3.2647	490.15	0
157	Helium-4	He	7440-59-7	4.003	0.012504	1.3038	–2.6954	1.7098	2.20	0.0097	5.20	0
158	Heptadecane	$C_{17}H_{36}$	629-78-7	240.468	10.473	0.4374			295.13	8.3699	736.00	0
159	Heptanal	$C_7H_{14}O$	111-71-7	114.185	5.956	0.36474			229.80	5.0248	616.80	0
160	Heptane	C_7H_{16}	142-82-5	100.202	5.0014	0.38795			182.57	4.2619	540.20	0
161	Heptanoic acid	$C_7H_{14}O_2$	111-14-8	130.185	11.274	0.86047	–0.40661	–0.012644	265.83	7.9579	677.30	0
162	1-Heptanol	$C_7H_{16}O$	111-70-6	116.201	7.0236	–1.3652	3.987	–2.2545	239.15	7.6498	632.30	0
163	2-Heptanol	$C_7H_{16}O$	543-49-7	116.201	9.6433	0.783	–0.27273	0.038495	230.00	6.9638	608.30	0
164	3-Heptanone	$C_7H_{14}O$	106-35-4	114.185	6.3357	0.42167			234.15	5.1579	606.60	0
165	2-Heptanone	$C_7H_{14}O$	110-43-0	114.185	6.1425	0.39802			238.15	5.0471	611.40	0
166	1-Heptene	C_7H_{14}	592-76-7	98.186	4.9437	0.35428	0.22149	–0.2353	154.12	4.3208	537.40	0
167	Heptyl mercaptan	$C_7H_{16}S$	1639-09-4	132.267	6.5473	0.40968			229.92	5.4656	645.00	0
168	1-Heptyne	C_7H_{12}	628-71-7	96.170	4.8222	0.33858			192.22	4.1647	547.00	0
169	Hexadecane	$C_{16}H_{34}$	544-76-3	226.441	10.156	0.45726			291.31	8.0225	723.00	0
170	Hexanal	$C_6H_{12}O$	66-25-1	100.159	5.6661	0.38533			217.15	4.7495	591.00	0
171	Hexane	C_6H_{14}	110-54-3	86.175	4.4544	0.39002			177.83	3.7647	507.60	0
172	Hexanoic acid	$C_6H_{12}O_2$	142-62-1	116.158	9.0746	0.8926	–0.75172	0.34378	269.25	6.4783	660.20	0
173	1-Hexanol	$C_6H_{14}O$	111-27-3	102.175	7.035	–0.9575	3.1431	–1.8066	228.55	7.1509	611.30	0
174	2-Hexanol	$C_6H_{14}O$	626-93-7	102.175	11.55	2.2877	–3.6724	2.1326	223.00	6.5014	585.30	0
175	2-Hexanone	$C_6H_{12}O$	591-78-6	100.159	5.6231	0.38207			217.35	4.7135	587.61	0
176	3-Hexanone	$C_6H_{12}O$	589-38-8	100.159	5.6232	0.39972			217.50	4.6655	582.82	0
177	1-Hexene	C_6H_{12}	592-41-6	84.159	4.1429	0.49118	–0.44821	0.32105	133.39	3.6691	504.00	0
178	3-Hexyne	C_6H_{10}	928-49-4	82.144	4.808	0.436			170.05	4.0831	544.00	0
179	Hexyl mercaptan	$C_6H_{14}S$	111-31-9	118.240	5.8422	0.38704			192.62	5.0630	623.00	0
180	1-Hexyne	C_6H_{10}	693-02-7	82.144	4.574	0.3698			141.25	4.0640	516.20	0
181	2-Hexyne	C_6H_{10}	764-35-2	82.144	4.911	0.4392			183.65	4.1067	549.00	0

182	Hydrazine	H_4N_2	302-01-2	32.045	5.9794	0.9424	−1.398	0.8862	274.69	4.5238	653.15	0
183	Hydrogen	H_2	1333-74-0	2.016	0.10127	0.698	−1.817	1.447	13.95	0.0913	33.19	0
184	Hydrogen bromide	HBr	10035-10-6	80.912	2.485	0.39			185.15	1.8817	363.15	0
185	Hydrogen chloride	HCl	7647-01-0	36.461	2.2093	0.3466			158.97	1.7498	324.65	0
186	Hydrogen cyanide	CHN	74-90-8	27.025	3.349	0.2053			259.83	2.8176	456.65	0
187	Hydrogen fluoride	HF	7664-39-3	20.006	13.451	13.36	−23.383	10.785	277.56	0.7104	461.15	0
188	Hydrogen sulfide	H_2S	7783-06-4	34.081	2.5676	0.37358			187.68	1.9782	373.53	0
189	Isobutyric acid	$C_4H_8O_2$	79-31-2	88.105	4.0385	0.82698	−2.033	1.4769	227.15	3.5534	605.00	0
190	Isopropyl amine	C_3H_9N	75-31-0	59.110	4.4041	0.43325			177.95	3.5874	471.85	0
191	Malonic acid	$C_3H_4O_4$	141-82-2	104.061	11.767	0.37877			407.95	9.0033	805.00	0
192	Methacrylic acid	$C_4H_6O_2$	79-41-4	86.089	4.6095	0.23331			288.15	4.0342	662.00	0
193	Methane	CH_4	74-82-8	16.042	1.0194	0.26087	−0.14694	0.22154	90.69	0.8724	190.56	0
194	Methanol	CH_4O	67-56-1	32.042	5.0451	0.33594			175.47	4.3825	512.50	0
195	*N*-Methyl acetamide	C_3H_7NO	79-16-3	73.094	7.3402	0.38974			301.15	5.9384	718.00	0
196	Methyl acetate	$C_3H_6O_2$	79-20-9	74.079	4.492	0.3685			175.15	3.8418	506.55	0
197	Methyl acetylene	C_3H_4	74-99-7	40.064	3.1889	0.37881			170.45	2.5882	402.40	0
198	Methyl acrylate	$C_4H_6O_2$	96-33-3	86.089	4.68	0.349			196.32	3.9913	536.00	0
199	Methyl amine	CH_5N	74-89-5	31.057	3.858	0.404			179.69	3.1006	430.05	0
200	Methyl benzoate	$C_8H_8O_2$	93-58-3	136.148	6.8504	0.38852			260.75	5.7026	693.00	0
201	3-Methyl-1,2-butadiene	C_5H_8	598-25-4	68.117	4.1233	0.426			159.53	3.4864	490.00	0
202	2-Methylbutane	C_5H_{12}	78-78-4	72.149	3.7593	0.39173			113.25	3.3657	460.40	0
203	2-Methylbutanoic acid	$C_5H_{10}O_2$	116-53-0	102.132	7.48	0.3933			193.00	6.5004	643.00	0
204	3-Methyl-1-butanol	$C_5H_{12}O$	123-51-3	88.148	10.178	1.3211	−1.2234	0.44836	155.95	7.3738	577.20	0
205	2-Methyl-1-butene	C_5H_{10}	563-46-2	70.133	3.9091	0.39866			135.58	3.4072	465.00	0
206	2-Methyl-2-butene	C_5H_{10}	513-35-9	70.133	3.9248	0.36173			139.39	3.4558	470.00	0
207	2-Methyl -1-butene-3-yne	C_5H_6	78-80-8	66.101	3.648	0.3863			160.15	3.1332	492.00	0
208	Methylbutyl ether	$C_5H_{12}O$	628-28-4	88.148	4.5302	0.37779			157.48	3.9438	512.74	0
209	Methylbutyl sulfide	$C_5H_{12}S$	628-29-5	104.214	5.3416	0.3835			175.30	4.6699	593.00	0
210	3-Methyl-1-butyne	C_5H_8	598-23-2	68.117	3.792	0.3565			183.45	3.1681	463.20	0
211	Methyl butyrate	$C_5H_{10}O_2$	623-42-7	102.132	5.3781	0.39523			187.35	4.5694	554.50	0
212	Methylchlorosilane	CH_5ClSi	993-00-0	80.589	3.2835	0.33116			139.05	2.8974	442.00	0
213	Methylcyclohexane	C_7H_{14}	108-87-2	98.186	4.7528	0.39437			146.58	4.2291	572.10	0
214	1-Methylcyclohexanol	$C_7H_{14}O$	590-67-0	114.185	6.477	0.4853			299.15	4.9050	686.00	0
215	*cis*-2-Methylcyclohexanol	$C_7H_{14}O$	7443-70-1	114.185	7.8011	0.4172			280.15	6.0500	614.00	0
216	*trans*-2-Methylcyclohexanol	$C_7H_{14}O$	7443-52-9	114.185	7.8995	0.42479			269.15	6.1926	617.00	0
217	Methylcyclopentane	C_6H_{12}	96-37-7	84.159	4.3595	0.38507			130.73	3.9115	532.70	0
218	1-Methylcyclopentene	C_6H_{10}	693-89-0	82.144	4.3541	0.36805			146.62	3.8769	542.00	0
219	3-Methylcyclopentene	C_6H_{10}	1120-62-3	82.144	4.209	0.36779			115.00	3.8439	526.00	0
220	Methyldichlorosilane	CH_4Cl_2Si	75-54-7	115.034	3.6756	0.31266			182.55	3.1686	483.00	0
221	Methylethyl ether	C_3H_8O	540-67-0	60.095	3.53	0.376			160.00	2.9751	437.80	0
222	Methylethyl ketone	C_4H_8O	78-93-3	72.106	4.622	0.355			186.48	3.9704	535.50	0
223	Methylethyl sulfide	C_3H_8S	624-89-5	76.161	4.4842	0.41151			167.23	3.8406	533.00	0
224	Methyl formate	$C_2H_4O_2$	107-31-3	60.052	4.103	0.3825			174.15	3.4644	487.20	0
225	Methylisobutyl ether	$C_5H_{12}O$	625-44-5	88.148	4.2678	0.37995			150.00	3.7232	497.00	0
226	Methylisobutyl ketone	$C_6H_{12}O$	108-10-1	100.159	5.4687	0.40583			189.15	4.6507	574.60	0
227	Methyl Isocyanate	C_2H_3NO	624-83-9	57.051	4.2967	0.37922			256.15	3.2402	488.00	0
228	Methylisopropyl ether	$C_4H_{10}O$	598-53-8	74.122	3.8501	0.36453			127.93	3.4235	464.48	0
229	Methylisopropyl ketone	$C_5H_{10}O$	563-80-4	86.132	4.7075	0.33601			180.15	4.1240	553.40	0
230	Methylisopropyl sulfide	$C_4H_{10}S$	1551-21-9	90.187	4.5052	0.36493			171.64	3.9340	553.10	0
231	Methyl mercaptan	CH_4S	74-93-1	48.107	3.4448	0.37427			150.18	2.9825	469.95	0
232	Methyl methacrylate	$C_5H_8O_2$	80-62-6	100.116	5.468	0.4472			224.95	4.3596	566.00	0
233	2-Methyloctanoic acid	$C_9H_{18}O_2$	3004-93-1	158.238	10.53	0.7454	−0.39297	0.047214	240.00	8.1106	694.00	0
234	2-Methylpentane	C_6H_{14}	107-83-5	86.175	4.2522	0.3807			119.55	3.8300	497.70	0
235	Methyl pentyl ether	$C_6H_{14}O$	628-80-8	102.175	5.0002	0.3781			176.00	4.3168	546.49	0
236	2-Methylpropane	C_4H_{10}	75-28-5	58.122	3.188	0.39006			113.54	2.8070	407.80	0
237	2-Methyl-2-propanol	$C_4H_{10}O$	75-65-0	74.122	7.7646	0.56757			298.97	4.6771	506.20	0
238	2-Methyl propene	C_4H_8	115-11-7	56.106	3.2614	0.38073			132.81	2.8195	417.90	0
239	Methyl propionate	$C_4H_8O_2$	554-12-1	88.105	5.008	0.3959			185.65	4.2231	530.60	0
240	Methylpropyl ether	$C_4H_{10}O$	557-17-5	74.122	4.2719	0.43175			133.97	3.7041	476.25	0
241	Methylpropyl sulfide	$C_4H_{10}S$	3877-15-4	90.187	4.8253	0.38087			160.17	4.2499	565.00	0
242	Methylsilane	CH_6Si	992-94-9	46.144	2.2656	0.30269			116.34	2.0069	352.50	0
243	alpha-Methyl styrene	C_9H_{10}	98-83-9	118.176	5.8071	0.37009			249.95	4.8591	654.00	0
244	Methyl *tert*-butyl ether	$C_5H_{12}O$	1634-04-4	88.148	3.872	0.044	0.448	−0.112	164.55	3.6017	497.10	0

TABLE 2-150 Heats of Vaporization of Inorganic and Organic Liquids (J/kmol) (*Concluded*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1 × 1E-07	C2	C3	C4	T_{min}, K	ΔH_v at T_{min} × 1E-07	T_{max}, K	ΔH_v at T_{max}
245	Methyl vinyl ether	C_3H_6O	107-25-5	58.079	3.587	0.3769			151.15	3.0567	437.00	0
246	Naphthalene	$C_{10}H_8$	91-20-3	128.171	7.0911	0.46468			353.43	5.2691	748.40	0
247	Neon	Ne	7440-01-9	20.180	0.2389	0.3494			24.56	0.1803	44.40	0
248	Nitroethane	$C_2H_5NO_2$	79-24-3	75.067	5.1459	0.33017			183.63	4.5533	593.00	0
249	Nitrogen	N_2	7727-37-9	28.013	0.74905	0.40406	−0.317	0.27343	63.15	0.6024	126.20	0
250	Nitrogen trifluoride	F_3N	7783-54-2	71.002	1.6402	0.36494			66.46	1.4519	234.00	0
251	Nitromethane	CH_3NO_2	75-52-5	61.040	4.7417	0.3062			244.60	4.0220	588.15	0
252	Nitrous oxide	N_2O	10024-97-2	44.013	2.3215	0.384			182.30	1.6502	309.57	0
253	Nitric oxide	NO	10102-43-9	30.006	2.131	0.4056			109.50	1.4578	180.15	0
254	Nonadecane	$C_{19}H_{40}$	629-92-5	268.521	11.674	0.45865			305.04	9.2185	758.00	0
255	Nonanal	$C_9H_{18}O$	124-19-6	142.239	7.3363	0.41735			255.15	5.9779	658.00	0
256	Nonane	C_9H_{20}	111-84-2	128.255	6.037	0.38522			219.66	5.0545	594.60	0
257	Nonanoic acid	$C_9H_{18}O_2$	112-05-0	158.238	12.38	0.69869	0.097854	−0.35082	285.55	8.7232	710.70	0
258	1-Nonanol	$C_9H_{20}O$	143-08-8	144.255	7.5429	−1.5966	4.6489	−2.7229	268.15	8.2411	670.90	0
259	2-Nonanol	$C_9H_{20}O$	628-99-9	144.255	7.9797	−1.0341	3.553	−2.1149	238.15	8.0370	649.50	0
260	1-Nonene	C_9H_{18}	124-11-8	126.239	5.9054	0.61039	−0.54533	0.30683	191.91	4.9218	593.10	0
261	Nonyl mercaptan	$C_9H_{20}S$	1455-21-6	160.320	7.5239	0.3991			253.05	6.2506	681.00	0
262	1-Nonyne	C_9H_{16}	3452-09-3	124.223	6.3337	0.3975			223.15	5.2606	598.05	0
263	Octadecane	$C_{18}H_{38}$	593-45-3	254.494	10.969	0.44327			301.31	8.7246	747.00	0
264	Octanal	$C_8H_{16}O$	124-13-0	128.212	6.7735	0.40607			246.00	5.5600	638.90	0
265	Octane	C_8H_{18}	111-65-9	114.229	5.518	0.38467			216.38	4.5898	568.70	0
266	Octanoic acid	$C_8H_{16}O_2$	124-07-2	144.211	12.23	0.69294	0.12287	−0.36132	289.65	8.4658	694.26	0
267	1-Octanol	$C_8H_{18}O$	111-87-5	130.228	7.2468	−1.2464	3.6797	−2.0665	257.65	7.6793	652.30	0
268	2-Octanol	$C_8H_{18}O$	123-96-6	130.228	7.6376	−0.7612	2.7875	−1.6033	241.55	7.3759	629.80	0
269	2-Octanone	$C_8H_{16}O$	111-13-7	128.212	6.5363	0.38718			252.85	5.3646	632.70	0
270	3-Octanone	$C_8H_{16}O$	106-68-3	128.212	6.6142	0.58562	−0.40512	0.22144	255.55	5.2076	627.70	0
271	1-Octene	C_8H_{16}	111-66-0	112.213	5.4859	0.26207	0.50642	−0.43873	171.45	4.7927	566.90	0
272	Octyl mercaptan	$C_8H_{18}S$	111-88-6	146.294	6.8907	0.40017			223.95	5.8506	667.30	0
273	1-Octyne	C_8H_{14}	629-05-0	110.197	5.4046	0.35299			193.55	4.6743	574.00	0
274	Oxalic acid	$C_2H_2O_4$	144-62-7	90.035	11.473	0.37238			462.65	8.3393	804.00	0
275	Oxygen	O_2	7782-44-7	31.999	0.9008	0.4542	−0.4096	0.3183	54.36	0.7742	154.58	0
276	Ozone	O_3	10028-15-6	47.998	1.8587	0.30416			80.15	1.6625	261.00	0
277	Pentadecane	$C_{15}H_{32}$	629-62-9	212.415	9.6741	0.45399			283.07	7.6728	708.00	0
278	Pentanal	$C_5H_{10}O$	110-62-3	86.132	5.1478	0.37541			182.00	4.4502	566.10	0
279	Pentane	C_5H_{12}	109-66-0	72.149	3.9109	0.38681			143.42	3.3968	469.70	0
280	Pentanoic acid	$C_5H_{10}O_2$	109-52-4	102.132	7.3197	1.2093	−1.9114	1.1591	239.15	5.3813	639.16	0
281	1-Pentanol	$C_5H_{12}O$	71-41-0	88.148	7.39	-0.1464	1.4751	−0.9208	195.56	6.7005	588.10	0
282	2-Pentanol	$C_5H_{12}O$	6032-29-7	88.148	11.111	1.8011	−2.1801	1.0641	200.00	6.6655	561.00	0
283	2-Pentanone	$C_5H_{10}O$	107-87-9	86.132	5.174	0.39422			196.29	4.3663	561.08	0
284	3-Pentanone	$C_5H_{10}O$	96-22-0	86.132	5.2359	0.40465			234.18	4.2075	560.95	0
285	1-Pentene	C_5H_{10}	109-67-1	70.133	3.5027	0.3481	−0.19672	0.22394	108.02	3.2232	464.80	0
286	2-Pentyl mercaptan	$C_5H_{12}S$	2084-19-7	104.214	5.0573	0.45827	−0.22568	0.16393	160.75	4.4343	584.30	0
287	Pentyl mercaptan	$C_5H_{12}S$	110-66-7	104.214	5.4315	0.3972			197.45	4.6322	598.00	0
288	1-Pentyne	C_5H_8	627-19-0	68.117	3.954	0.3512			167.45	3.4025	481.20	0
289	2-Pentyne	C_5H_8	627-21-4	68.117	4.4158	0.44347			163.83	3.7321	519.00	0
290	Phenanthrene	$C_{14}H_{10}$	85-01-8	178.229	8.3482	0.33172			372.38	6.9340	869.00	0
291	Phenol	C_6H_6O	108-95-2	94.111	7.306	0.4246			314.06	5.6577	694.25	0
292	Phenyl isocyanate	C_7H_5NO	103-71-9	119.121	5.5769	0.30346			243.15	4.8418	653.00	0
293	Phthalic anhydride	$C_8H_4O_3$	85-44-9	148.116	6.916	0.1755			404.15	6.1001	791.00	0
294	Propadiene	C_3H_4	463-49-0	40.064	2.9535	0.41367			136.87	2.4755	394.00	0
295	Propane	C_3H_8	74-98-6	44.096	2.9209	0.78237	−0.77319	0.39246	85.47	2.4787	369.83	0
296	1-Propanol	C_3H_8O	71-23-8	60.095	6.8988	0.6458	−0.5384	0.3317	146.95	5.8356	536.80	0
297	2-Propanol	C_3H_8O	67-63-0	60.095	7.2542	0.79137	−0.66092	0.34223	185.26	5.5370	508.30	0
298	Propenylcyclohexene	C9H14	13511-13-2	122.207	5.8866	0.38533			199.00	5.0941	636.00	0
299	Propionaldehyde	C3H6O	123-38-6	58.079	4.1492	0.36751			170.00	3.5675	504.40	0
300	Propionic acid	C3H6O2	79-09-4	74.079	4	1.3936	−2.9465	1.794	252.45	3.0922	600.81	0
301	Propionitrile	C_3H_5N	107-12-0	55.079	4.9348	0.41873			180.26	4.2005	564.40	0
302	Propyl acetate	$C_5H_{10}O_2$	109-60-4	102.132	5.4327	0.407			178.15	4.6322	549.73	0

303	Propyl amine	C_3H_9N	107-10-8	59.110	4.4488	0.39494			188.36	3.6857	496.95	0
304	Propylbenzene	C_9H_{12}	103-65-1	120.192	5.8887	0.38534			173.55	5.2110	638.35	0
305	Propylene	C_3H_6	115-07-1	42.080	2.5216	0.33721	–0.18399	0.22377	87.89	2.3177	364.85	0
306	Propyl formate	$C_4H_8O_2$	110-74-7	88.105	4.9687	0.4025			180.25	4.2162	538.00	0
307	2-Propyl mercaptan	C_3H_8S	75-33-2	76.161	4.2191	0.41161			142.61	3.6942	517.00	0
308	Propyl mercaptan	C_3H_8S	107-03-9	76.161	4.4782	0.41073			159.95	3.8723	536.60	0
309	1,2-Propylene glycol	$C_3H_8O_2$	57-55-6	76.094	8.07	0.295			213.15	7.1374	626.00	0
310	Quinone	$C_6H_4O_2$	106-51-4	108.095	6.49	0.3112			388.85	4.9933	683.00	0
311	Silicon tetrafluoride	F_4Si	7783-61-1	104.079	2.4105	0.37988			186.35	1.4873	259.00	0
312	Styrene	C_8H_8	100-42-5	104.149	5.726	0.4055			242.54	4.7128	636.00	0
313	Succinic acid	$C_4H_6O_4$	110-15-6	118.088	12.018	0.37149			460.65	8.7719	806.00	0
314	Sulfur dioxide	O_2S	7446-09-5	64.064	3.676	0.4			197.67	2.8753	430.75	0
315	Sulfur hexafluoride	F_6S	2551-62-4	146.055	2.571	0.383			223.15	1.6208	318.69	0
316	Sulfur trioxide	O_3S	7446-11-9	80.063	7.337	0.5647			289.95	4.4303	490.85	0
317	Terephthalic acid	$C_8H_6O_4$	100-21-0	166.131	8.824				298.15	8.8240	298.15	88,240,000
318	*o*-Terphenyl	$C_{18}H_{14}$	84-15-1	230.304	8.7165	0.3224			329.35	7.4548	857.00	0
319	Tetradecane	$C_{14}H_{30}$	629-59-4	198.388	9.0539	0.44467			279.01	7.2002	693.00	0
320	Tetrahydrofuran	C_4H_8O	109-99-9	72.106	4.3021	0.36972			164.65	3.7610	540.15	0
321	1,2,3,4-Tetrahydronaphthalene	$C_{10}H_{12}$	119-64-2	132.202	6.8086	0.43054			237.38	5.7314	720.00	0
322	Tetrahydrothiophene	C_4H_8S	110-01-0	88.171	5.0642	0.38904			176.99	4.4565	631.95	0
323	2,2,3,3-Tetramethylbutane	C_8H_{18}	594-82-1	114.229	4.9055	0.40678			373.96	3.1691	568.00	0
324	Thiophene	C_4H_4S	110-02-1	84.140	4.5854	0.38756			234.94	3.7484	579.35	0
325	Toluene	C_7H_8	108-88-3	92.138	4.9507	0.37742			178.18	4.3246	591.75	0
326	1,1,2-Trichloroethane	$C_2H_3Cl_3$	79-00-5	133.404	5.0929	0.38013			236.50	4.2130	602.00	0
327	Tridecane	$C_{13}H_{28}$	629-50-5	184.361	8.4339	0.4257			267.76	6.8015	675.00	0
328	Triethyl amine	$C_6H_{15}N$	121-44-8	101.190	4.664	0.3663			158.45	4.1011	535.15	0
329	Trimethyl amine	C_3H_9N	75-50-3	59.110	3.305	0.354			156.08	2.8216	433.25	0
330	1,2,3-Trimethylbenzene	C_9H_{12}	526-73-8	120.192	5.9996	0.35578			247.79	5.0818	664.50	0
331	1,2,4-Trimethylbenzene	C_9H_{12}	95-63-6	120.192	5.9254	0.35709			229.33	5.0713	649.10	0
332	2,2,4-Trimethylpentane	C_8H_{18}	540-84-1	114.229	4.7711	0.37949			165.78	4.1561	543.80	0
333	2,3,3-Trimethylpentane	C_8H_{18}	560-21-4	114.229	4.991	0.383			172.22	4.3530	573.50	0
334	1,3,5-Trinitrobenzene	$C_6H_3N_3O_6$	99-35-4	213.105	10.687	0.38			398.40	8.3906	846.00	0
335	2,4,6-Trinitrotoluene	$C_7H_5N_3O_6$	118-96-7	227.131	10.686	0.40074			354.00	8.5455	828.00	0
336	Undecane	$C_{11}H_{24}$	1120-21-4	156.308	7.2284	0.40607			247.57	5.9240	639.00	0
337	1-Undecanol	$C_{11}H_{24}O$	112-42-5	172.308	8.7274	–1.5834	5.0913	–3.2171	288.45	8.9007	703.90	0
338	Vinyl acetate	$C_4H_6O_2$	108-05-4	86.089	4.77	0.3765			180.35	4.0619	519.13	0
339	Vinyl acetylene	C_4H_4	689-97-4	52.075	3.649	0.4	0.043		173.15	2.9876	454.00	0
340	Vinyl chloride	C_2H_3Cl	75-01-4	62.498	3.4125	0.4513			119.36	2.9491	432.00	0
341	Vinyl trichlorosilane	$C_2H_3Cl_3Si$	75-94-5	161.490	4.5659	0.36278			178.35	3.9520	543.15	0
342	Water	H_2O	7732-18-5	18.015	5.2053	0.3199	–0.212	0.25795	273.16	4.4733	647.10	0
343	*m*-Xylene	C_8H_{10}	108-38-3	106.165	5.4626	0.37289			225.30	4.6112	617.00	0
344	*o*-Xylene	C_8H_{10}	95-47-6	106.165	5.5395	0.37788			247.98	4.5859	630.30	0
345	*p*-Xylene	C_8H_{10}	106-42-3	106.165	5.3819	0.36695			286.41	4.2787	616.20	0

The heat of vaporization ΔH_v is calculated by

$$\Delta H_v = \mathrm{C1}(1 - T_r)^{\mathrm{C2} + \mathrm{C3}T_r + \mathrm{C4}T_r^2 + \mathrm{C5}T_r^3}$$

where $T_r = T/T_c$, T_c is the critical temperature from Table 2-141, ΔH_v is in J/kmol, and T is in K. All substances are listed by chemical family in Table 2-6 and by formula in Table 2-7.

Values in this table were taken from the Design Institute for Physical Properties (DIPPR) of the American Institute of Chemical Engineers (AIChE), copyright 2007 AIChE and reproduced with permission of AICHE and of the DIPPR Evaluated Process Design Data Project Steering Committee. Their source should be cited as R. L. Rowley, W. V. Wilding, J. L. Oscarson, Y. Yang, N. A. Zundel, T. E. Daubert, R. P. Danner, DIPPR® Data Compilation of Pure Chemical Properties, Design Institute for Physical Properties, AIChE, New York (2007).

The number of digits provided for values at T_{min} and T_{max} was chosen for uniformity of appearance and formatting; these do not represent the uncertainties of the physical quantities, but are the result of calculations from the standard thermophysical property formulations within a fixed format.

SPECIFIC HEATS OF PURE COMPOUNDS

UNITS CONVERSIONS

For this subsection, the following units conversions are applicable:

°F = ⁹⁄₅ °C + 32
°R = 1.8 K

To convert calories per gram-kelvin to British thermal units per pound-degree Rankine, multiply by 1.0; to convert calories per mole-kelvin to British thermal units per pound-mole-degree Rankine, multiply by 1.0.

To convert kilojoules per kilogram-kelvin to British thermal units per pound-degree Rankine, multiply by 0.2388.

ADDITIONAL REFERENCES

Additional data are contained in the subsection "Thermodynamic Properties." Data on water are also contained in that subsection. Additional tables for water are found in Eng. Sci. Data Item 68008, 251 Regent Street, London, England, which contains about 5000 values from 1 to 1000 bar, 0 to 1500 °C.

TABLE 2-151 Heat Capacities of the Elements and Inorganic Compounds*

Substance	State†	Heat capacity at constant pressure (T = K; 0 °C = 273.1 K), cal/(mol·K)	Range of temperature, K	Uncertainty, %
Aluminum[1]				
Al	*c*	$4.80 + 0.00322T$	273–931	1
	l	7.00	931–1273	5
$AlBr_3$	*c*	$18.74 + 0.01866T$	273–370	3
	l	29.5	370–407	5
$AlCl_3$	*c*	$13.25 + 0.02800T$	273–465	3
	l	31.2	465–504	3
$AlCl_3·6H_2O$	*c*	76	288–327	?
AlF_3	*c*	19.3	288–326	?
$AlF_3·3½H_2O$	*c*	50.5	288–326	?
$AlF_3·3NaF$	*c*	$38.63 + 0.04760T - 449200/T^2$	273–1273	2
	l	142	1273–1373	?
AlI_3	*c*	$16.88 + 0.02266T$	273–464	3
	l	28.8	464–480	5
Al_2O_3	*c*	$22.08 + 0.008971T - 522500/T^2$	273–1973	3
$Al_2O_3·SiO_2$	*c*, sillimanite	$40.79 + 0.004763T - 992800/T^2$	273–1573	3
	c, disthene	$41.81 + 0.005283T - 1211000/T^2$	273–1673	2
	c, andalusite	$43.96 + 0.001923T - 1086000/T^2$	273–1573	3
$3Al_2O_3·2SiO_2$	*c*, mullite	$59.65 + 0.0670T$	273–576	5
$4Al_2O_3·3SiO_2$	*c*	$113.2 + 0.0652T$	273–575	3
$Al_2(SO_4)_3$	*c*	63.5	273–373	?
$Al_2(SO_4)_3·18H_2O$	*c*	235	288–325	?
Antimony				
Sb	*c*	$5.51 + 0.00178T$	273–903	2
	l	7.15	903–1273	5
$SbBr_3$	*c*	$17.2 + 0.0293T$	273–370	?
$SbCl_3$	*c*	$10.3 + 0.0511T$	273–346	?
Sb_2O_3	*c*	$19.1 + 0.0171T$	273–929	?
Sb_2O_4	*c*	$22.6 + 0.0162T$	273–1198	?
Sb_2S_3	*c*	$24.2 + 0.0132T$	273–821	?
Argon[2]				
A	*g*	4.97	All	0
Arsenic				
As	*c*	$5.17 + 0.00234T$	273–1168	5
$AsCl_3$	*l*	31.9	286–371	?
As_2O_3	*c*	$8.37 + 0.0486T$	273–548	?
As_2S_3	*c*	25.8	293–373	?
Barium				
$BaCl_2$	*c*	$17.0 + 0.00334T$	273–1198	?
$BaCl_2·H_2O$	*c*	28.2	273–307	?
$BaCl_2·2H_2O$	*c*	37.3	273–307	?
$Ba(ClO_3)_2·H_2O$	*c*	51	289–320	?
$BaCO_3$	*c*, α	$17.26 + 0.0131T$	273–1083	5
	c, β	30.0	1083–1255	15
$BaMoO_4$	*c*	34	273–297	?
$Ba(NO_3)_2$	*c*	39.8	285–371	?
$BaSO_4$	*c*	$21.35 + 0.0141T$	273–1323	5
Beryllium[3,4]				
Be	*c*	$4.698 + 0.001555T - 121000/T^2$	273–1173	1
BeO	*c*	$8.69 + 0.00365T - 313000/T^2$	273–1175	5
$BeO·Al_2O_3$	*c*	25.4	273–373	?
$BeSO_4$	*c*	20.8	273–373	?

*From Kelley, U.S. Bur. Mines Bull. 371, 1934. For a revision see Kelley, U.S. Bur. Mines Bull. 477, 1948. Data for many elements and compounds are given by Johnson (ed.), WADD-TR-60-56, 1960, for cryogenic temperatures. Tabulated data for gases can be obtained from many of the references cited in the "Thermodynamic Properties" subsection and other tables in this section. Thinh, Duran, et al., *Hydrocarbon Process.,* **50,** 98 (January 1971), review previous equation fits and give newer fits for 408 hydrocarbons and related compounds. Later publications include Duran, Thinh, et al., *Hydrocarbon Process.*, **55,** 153 (August 1976); Thompson, *J. Chem. Eng. Data,* **22**(4), 431 (1977); and Passut and Danner, *Ind. Eng. Chem. Process Des. Dev.,* **11,** 543 (1972); **13,** 193 (1974).

† The symbols in this column have the following meaning; *c,* crystal; *l,* liquid; *g,* gas; *gls,* glass.

TABLE 2-151 Heat Capacities of the Elements and Inorganic Compounds (*Continued*)

Substance	State†	Heat capacity at constant pressure (T = K; 0 °C = 273.1 K), cal/(mol·K)	Range of temperature, K	Uncertainty, %
Bismuth[4]				
Bi	*c*	$5.38 + 0.00260T$	273–544	3
	l	7.60	544–1273	3
Bi_2O_3	*c*	$23.27 + 0.01105T$	273–777	2
Bi_2S_3	*c*	30.4	284–372	?
Boron				
B	*c*	$1.54 + 0.00440T$	273–1174	5
B_2O_3	*gls*	$5.14 + 0.0320T$	273–513	3
	gls	30.4	513–623	3
BN	*c*	$1.61 + 0.00400T$	273–1173	5
Bromine				
Br_2	*g*	9.00	300–2000	5
Cadmium				
Cd	*c*	$5.46 + 0.002466T$	273–594	1
	l	7.13	594–973	5
CdO	*c*	$9.65 + 0.00208T$	273–2086	?
CdS	*c*	$12.9 + 0.00090T$	273–1273	?
$CdSO_4 \cdot 8/3H_2O$	*c*	51.3	293	?
Calcium				
Ca	*c*	$5.31 + 0.00333T$	273–673	2
	c	$6.29 + 0.00140T$	673–873	2
$CaCl_2$	*c*	$16.9 + 0.00386T$	273–1055	?
$CaCO_3$	*c*	$19.68 + 0.01189T - 307600/T^2$	273–1033	3
CaF_2	*c*	$14.7 + 0.00380T$	273–1651	?
$CaMg(CO_3)_2$	*c*	40.1	299–372	?
$CaMoO_4$	*c*	33	273–297	?
CaO	*c*	$10.00 + 0.00484T - 108000/T^2$	273–1173	2
$Ca(OH)_2$	*c*	21.4	276–373	?
$CaO \cdot Al_2O_3 \cdot 2SiO_2$	*c*, anorthite	$63.13 + 0.01500T - 1537000/T^2$	273–1673	1
	gls	$67.41 + 0.01048T - 1874000/T^2$	273–973	1
$CaO \cdot MgO \cdot 2SiO_2$	*c*, diopside	$54.46 + 0.005746T - 1500000/T^2$	273–1573	1
	gls	$51.68 + 0.009724T - 1308000/T^2$	273–973	1
$CaO \cdot SiO_2$	*c*, wollastonite	$27.95 + 0.002056T - 745600/T^2$	273–1573	1
	c, pseudowollastonite	$25.48 + 0.004132T - 488100/T^2$	273–1673	1
	gls	$23.16 + 0.009672T - 487100/T^2$	273–973	1
CaP_2O_6	*c*	39.5	287–371	?
$CaSO_4$	*c*	$18.52 + 0.02197T - 156800/T^2$	273–1373	5
$CaSO_4 \cdot 2H_2O$	*c*	46.8	282–373	?
$CaWO_4$	*c*	27.9	292–322	?
Carbon[5]				
C	*c*, graphite	$2.673 + 0.002617T - 116900/T^2$	273–1373	2
	c, diamond	$2.162 + 0.003059T - 130300/T^2$	273–1313	3
CH_4	*g*	$5.34 + 0.0115T$	273–1200	2
CO[6]	*g*	$6.60 + 0.00120T$	273–2500	1½
CO_2	*g*	$10.34 + 0.00274T - 195500/T^2$	273–1200	1½
CS_2	*l*	18.4	293	?
Cerium				
Ce	*c*	$5.88 + 0.00123T$	273–908	?
CeO_2	*c*	15.1	273–373	?
$Ce_2(MoO_4)_3$	*c*	96	273–297	?
$Ce_2(SO_4)_3$	*c*	66.4	273–373	?
$Ce_2(SO_4)_3 \cdot 5H_2O$	*c*	131.6	273–319	?
Cesium				
Cs	*c*	$1.96 + 0.0182T$	273–301	3
	l	8.00	302	3
	g	4.97	All	0
CsBr	*c*	$12.6 + 0.00259T$	273–909	?
CsCl	*c*	$11.7 + 0.00309T$	273–752	?
CsF	*c*	$11.3 + 0.00285T$	273–957	?
CsI	*c*	$11.6 + 0.00268T$	273–894	?
Chlorine				
Cl_2	*g*	$8.28 + 0.00056T$	273–2000	1½
Chromium[4]				
Cr	*c*	$4.84 + 0.00295T$	273–1823	5
	l	9.70	1823–1923	10
$CrCl_3$	*c*	23	286–319	?
Cr_2O_3	*c*	$26.0 + 0.00400T$	273–2263	?
CrSb	*c*	$12.3 + 0.00120T$	273–1383	?
$CrSb_2$	*c*	$19.2 + 0.00184T$	273–949	?
$Cr_2(SO_4)_3$	*c*	67.4	273–373	?
Cobalt[4]				
Co	*c*	$5.12 + 0.00333T$	273–1763	5
	l	8.40	1763–1873	5
$CoAs_2 \cdot CoS_2$	*c*	32.9	283–373	?
CoSb	*c*	$11.7 + 0.00156T$	273–1464	?
Co_2Sn	*c*	$15.83 + 0.00950T$	273–903	2
CoS	*c*	$10.6 + 0.00251T$	273–1373	?
$CoSO_4 \cdot 7H_2O$	*c*	96	286–303	?

TABLE 2-151 Heat Capacities of the Elements and Inorganic Compounds (*Continued*)

Substance	State†	Heat capacity at constant pressure (T = K; 0 °C = 273.1 K), cal/(mol·K)	Range of temperature, K	Uncertainty, %
Copper[7]				
Cu	*c*	$5.44 + 0.001462T$	273–1357	1
	l	7.50	1357–1573	3
CuAl	*c*	$9.88 + 0.00500T$	273–733	2
$CuAl_2$	*c*	$16.78 + 0.00366T$	273–773	2
Cu_3Al	*c*	$19.61 + 0.01054T$	273–775	2
CuI	*c*	$12.1 + 0.00286T$	273–675	?
CuI_2	*c*	20.1	274–328	?
CuO	*c*	$10.87 + 0.003576T - 150600/T^2$	273–810	2
$CuO{\cdot}SiO_2{\cdot}H_2O$	*c*	29	293–323	?
CuS	*c*	$10.6 + 0.00264T$	273–1273	?
Cu_2S	*c*, α	$9.38 + 0.0312T$	273–376	3
	c, β	20.9	376–1173	2
CuS·FeS	*c*	24	292–321	?
Cu_2Sb	*c*	$13.73 + 0.01350T$	273–573	2
Cu_2Sb	*c*	$21.79 + 0.00900T$	273–693	2
Cu_2Se	*c*, α	20.85	273–383	5
	c, β	20.35	383–488	5
Cu_3Si	*c*	$20.3 + 0.00587T$	273–1135	?
$CuSO_4$	*c*	24.1	282	?
$CuSO_4{\cdot}H_2O$	*c*	31.3	282	?
$CuSO_4{\cdot}3H_2O$	*c*	49.0	282	?
$CuSO_4{\cdot}5H_2O$	*c*	67.2	282	?
Fluorine[8]				
F_2	*g*	$6.50 + 0.00100T$	300–3000	5
Gallium				
Ga_2O_3	*c*	$18.2 + 0.0252T$	273–923	?
$Ga_2(SO_4)_3$	*c*	62.4	273–373	?
Germanium[4]				
Ge	*c*			
Gold				
Au	*c*	$5.61 + 0.00144T$	273–1336	2
	l	7.00	1336–1573	5
$AuSb_2$	*c*, α	$17.12 + 0.00465T$	273–628	1
	c, βγ	$11.47 + 0.01756T$	628–713	?
Helium[9]				
He	*g*	4.97	All	0
Hydrogen[10]				
H	*g*	4.97	All	0
H_2	*g*	$6.62 + 0.00081T$	273–2500	2
HBr	*g*	$6.80 + 0.00084T$	273–2000	2
HCl	*g*	$6.70 + 0.00084T$	273–2000	1½
HI	*g*	$6.93 + 0.00083T$	273–2000	2
H_2O	*l*	See Tables 2-153 and 2-305		
	g	$8.22 + 0.00015T + 0.00000134T^2$	300–2500	?
H_2S	*g*	$7.20 + 0.00360T$	300–600	8
$H_2S_2O_7$	*c*	27	281	?
	l	58	308	?
Indium				
In	*c*			
Iodine				
I_2	*g*	9.00	300–2000	5
Iridium				
Ir	*c*	$5.50 + 0.00148T$	273–1873	1
Iron[4]				
Fe	*c*, α	$4.13 + 0.00638T$	273–1041	3
	c, β	$6.12 + 0.00336T$	1041–1179	3
	c, γ	8.40	1179–1674	5
	c, δ	10.0	1674–1803	5
	l	8.15	1803–1873	5
$FeAs_2$	*c*	17.8	283–373	?
Fe_3C	*c*	$25.17 + 0.00223T$	273–1173	10
$FeCO_3$	*c*	22.7	293–368	?
FeO	*c*	$12.62 + 0.001492T - 76200/T^2$	273–1173	2
Fe_2O_3	*c*	$24.72 + 0.01604T - 423400/T^2$	273–1097	2
Fe_3O_4	*c*	$41.17 + 0.01882T - 979500/T^2$	273–1065	2
$Fe_2O_3{\cdot}3H_2O$	*c*	47.8	286–373	?
FeS	*c*, α	$2.03 + 0.0390T$	273–411	5
	c, β	$12.05 + 0.00273T$	411–1468	3
FeS_2	*c*	$10.7 + 0.01336T$	273–773	?
FeSi	*c*	$10.54 + 0.00458T$	273–903	2
Fe_2SiO_4	*c*	$33.57 + 0.01907T - 879700/T^2$	273–1161	2
$FeSO_4$	*c*	22	293–373	?
$Fe_2(SO_4)_3$	*c*	66.2	273–373	?
$FeSO_4{\cdot}4H_2O$	*c*	63.6	282	?
$FeSO_4{\cdot}7H_2O$	*c*	96	291–319	?
Krypton				
Kr	*g*	4.97	All	0

TABLE 2-151 Heat Capacities of the Elements and Inorganic Compounds (*Continued*)

Substance	State†	Heat capacity at constant pressure (T = K; 0 °C = 273.1 K), cal/(mol·K)	Range of temperature, K	Uncertainty, %
Lanthanum				
La	*c*	5.91 + 0.00100T	273–1009	?
La_2O_3	*c*	22.6 + 0.00544T	273–2273	?
$La_2(MoO_4)_3$	*c*	86	273–307	?
$La_2(SO_4)_3$	*c*	66.9	273–373	?
$La_2(SO_4)_3·9H_2O$	*c*	152	273–319	?
Lead[4]				
Pb	*c*	5.77 + 0.00202T	273–600	2
	l	6.8	600–1273	5
$Pb_3(AsO_4)_2$	*c*	65.5	286–370	?
PbB_2O_4	*c*	26.5	288–371	?
PbB_4O_7	*c*	41.4	289–371	?
$PbBr_2$	*c*	18.13 + 0.00310T	273–761	2
	l	27.4	761–860	10
$PbCl_2$	*c*	15.88 + 0.00835T	273–771	2
	l	27.2	771–851	10
$2PbCl_2·NH_4Cl$	*c*	53.1	293	?
$PbCO_3$	*c*	21.1	286–320	?
$PbCrO_4$	*c*	29.1	292–323	?
PbF_2	*c*	16.5 + 0.00412T	273–1091	?
PbI_2	*c*	18.66 + 0.00293T	273–648	2
	l	32.3	648–776	20
$PbMoO_4$	*c*	30.4	292–322	?
$Pb(NO_3)_2$	*c*	36.4	286–320	?
PbO	*c*	10.33 + 0.00318T	273–544	2
PbO_2	*c*	12.7 + 0.00780T	273–?	?
$Pb_2P_2O_7$	*c*	48.3	284–371	?
PbS	*c*	10.63 + 0.00401T	273–873	3
$PbSO_4$	*c*	26.4	293–372	?
PbS_2O_3	*c*	29	293–373	?
$PbWO_4$	*c*	35	273–297	?
Lithium				
Li	*c*	0.68 + 0.0180T	273–459	10
	g	4.97	All	0
LiBr	*c*	11.5 + 0.00302T	273–825	?
$LiBr·H_2O$	*c*	22.6	278–318	?
LiCl	*c*	11.0 + 0.00339T	273–887	?
$LiCl·H_2O$	*c*	23.6	279–360	?
LiF	*c*	8.20 + 0.00520T	273–1117	?
LiI	*c*	12.5 + 0.00208T	273–723	?
$LiI·H_2O$	*c*	23.6	277–359	?
$LiI·2H_2O$	*c*	32.9	277–345	?
$LiI·3H_2O$	*c*	43.2	277–347	?
$LiNO_3$	*c*	9.17 + 0.0360T	273–523	5
	l	26.8	523–575	5
Magnesium[4]				
Mg	*c*	6.20 + 0.00133T − 67800/T^2	273–923	1
	l	7.4	923–1048	10
MgAg	*c*	10.58 + 0.00412T	273–905	2
Mg_4Al_3	*c*	34.4 + 0.0198T	273–736	?
MgAu	*c*	11.3 + 0.00189T	273–1433	?
Mg_2Au	*c*	16.2 + 0.00451T	273–1073	?
Mg_3Au	*c*	21.2 + 0.00614T	273–1103	?
$MgCl_2$	*c*	17.3 + 0.00377T	273–991	?
$MgCl_2·6H_2O$	*c*	77.1	292–342	?
$MgCO_3$	*c*	16.9	290	?
$MgCu_2$	*c*	14.96 + 0.00776T	273–903	3
Mg_2Cu	*c*	15.5 + 0.00652T	273–843	?
$MgNi_2$	*c*	15.87 + 0.00692T	273–903	2
MgO	*c*	10.86 + 0.001197T − 208700/T^2	273–2073	2
$MgO·Al_2O_3$	*c*	28	288–319	?
$MgO·SiO_2$	*c*, amphibole	25.60 + 0.004380T − 674200/T^2	273–1373	1
	c, pyroxene	23.35 + 0.008062T − 558800/T^2	273–773	1
	gls	23.30 + 0.007734T − 542000/T^2	273–973	1
$6MgO·MgCl_2·8B_2O_3$	*c*, α	58.7 + 0.408T	273–538	5
	c, β	107.2 + 0.2876T	538–623	5
$Mg(OH)_2$	*c*	18.2	292–323	?
Mg_3Sb_2	*c*	28.2 + 0.00560T	273–1234	?
Mg_2Si	*c*	15.4 + 0.00415T	273–1343	?
$MgSO_4$	*c*	26.7	296–372	?
$MgSO_4·H_2O$	*c*	33	282	?
$MgSO_4·6H_2O$	*c*	80	282	?
$MgSO_4·7H_2O$	*c*	89	291–319	?

TABLE 2-151 Heat Capacities of the Elements and Inorganic Compounds (*Continued*)

Substance	State†	Heat capacity at constant pressure (T = K; 0 °C = 273.1 K), cal/(mol·K)	Range of temperature, K	Uncertainty, %
Manganese				
Mn	*c*, α	$3.76 + 0.00747T$	273–1108	5
	c, β	$5.06 + 0.00395T$	1108–1317	5
	c, γ	$4.80 + 0.00422T$	1317–1493	5
	l	11.0	1493–1673	10
$MnCl_2$	*c*	$16.2 + 0.00520T$	273–923	?
$MnCO_3$	*c*	$7.79 + 0.0421T + 0.0000090T^2$	273–773	?
MnO	*c*	$7.43 + 0.01038T - 0.00000362T^2$	273–1923	?
Mn_2O_3	*c*	$10.33 + 0.0530T - 0.0000257T^2$	273–1173	?
Mn_3O_4	*c*	$19.25 + 0.0538T - 0.0000209T^2$	273–1773	?
MnO_2	*c*	$1.92 + 0.0471T - 0.0000297T^2$	273–773	?
$Mn_2O_3{\cdot}H_2O$	*c*	31	291–322	?
MnS	*c*	$10.21 + 0.00656T - 0.00000242T^2$	273–1883	?
$MnSO_4$	*c*	27.5	293–373	?
$MnSO_4{\cdot}5H_2O$	*c*	78	290–319	?
Mercury[11]				
Hg	*l*	6.61	273–630	1
	g	4.97	All	0
Hg_2	*g*	9.00	300–2000	5
HgCl	*c*	$11.05 + 0.00370T$	273–798	?
$HgCl_2$	*c*	$15.3 + 0.0103T$	273–553	?
$Hg(CN)_2$	*c*	25	285–319	?
HgI	*c*	$11.4 + 0.00461T$	273–563	?
HgI_2	*c*, α	$17.4 + 0.004001T$	273–403	3
	c, β	20.2	403–523	3
HgO	*c*	11.5	278–371	?
HgS	*c*	$10.9 + 0.00365T$	273–853	?
Hg_2SO_4	*c*	31.0	273–307	?
Molybdenum				
Mo	*c*	$5.69 + 0.00188T - 50300/T^2$	273–1773	5
MoO_3	*c*	$15.1 + 0.0121T$	273–1068	?
MoS_2	*c*	$19.7 + 0.00315T$	273–729	?
Neon[12]				
Ne	*g*	4.97	All	0
Nickel[4]				
Ni	*c*, α	$4.26 + 0.00640T$	273–626	2
	c, β	$6.99 + 0.000905T$	626–1725	5
	l	8.55	1725–1903	10
NiO	*c*	$11.3 + 0.00215T$	273–1273	?
NiS	*c*	$9.25 + 0.00640T$	273–597	3
Ni_2Si	*c*	$15.8 + 0.00329T$	273–1582	?
NiSi	*c*	$10.0 + 0.00312T$	273–1273	?
Ni_3Sn	*c*	$20.78 + 0.0102T$	273–904	2
$NiSO_4$	*c*	33.4	293–373	?
$NiSO_4{\cdot}6H_2O$	*c*	82	291–325	?
NiTe	*c*	$11.00 + 0.00433T$	273–700	2
Nitrogen[13]				
N_2	*g*	$6.50 + 0.00100T$	300–3000	3
NH_3	*g*	$6.70 + 0.00630T$	300–800	1½
NH_4Br	*c*	22.8	274–328	?
NH_4Cl	*c*, α	$9.80 + 0.0368T$	273–457	5
	c, β	$5.0 + 0.0340T$	457–523	5
NH_4I	*c*	17.8	273–328	?
NH_4NO_3	*c*	31.8	273–293	?
$(NH_4)_2SO_4$	*c*	51.6	275–328	?
NO	*g*	$8.05 + 0.000233T - 156300/T^2$	300–5000	2
Osmium				
Os	*c*	$5.686 + 0.000875T$	273–1877	1
Oxygen[14]				
O_2	*g*	$8.27 + 0.000258T - 187700/T^2$	300–5000	1
Palladium				
Pd	*c*	$5.41 + 0.00184T$	273–1822	2
Phosphorus				
P	*c*, yellow	5.50	273–317	5
	c, red	$0.21 + 0.0180T$	273–472	10
	l	6.6	317–373	10
PCl_3	*l*	28.7	284–371	?
P_4O_{10}	*c*	$15.72 + 0.1092T$	273–631	2
	g	73.6	631–1371	3
Platinum[4]				
Pt	*c*	$5.92 + 0.00116T$	273–1873	1
Potassium				
K	*c*	$5.24 + 0.00555T$	273–336	5
	l	7.7	336–373	5

TABLE 2-151 Heat Capacities of the Elements and Inorganic Compounds (*Continued*)

Substance	State†	Heat capacity at constant pressure (T = K; 0 °C = 273.1 K), cal/(mol·K)	Range of temperature, K	Uncertainty, %
Potassium—(*Cont.*)				
K	*g*	4.97	All	0
K_2	*g*	9.00	300–2000	5
$KAsO_3$	*c*	25.3	290–372	?
KBO_2	*c*	$12.6 + 0.0126T$	273–1220	?
$K_2B_4O_7$	*c*	51.3	290–372	?
KBr	*c*	$11.49 + 0.00360T$	273–543	2
KCl	*c*	$10.93 + 0.00376T$	273–1043	2
$KClO_3$	*c*	25.7	289–371	?
$KClO_4$	*c*	26.3	287–318	?
$2KCl·CuCl_2·2H_2O$	*c*	63	292–323	?
$2KCl·PtCl_4$	*c*	55	286–319	?
$2KCl·SnCl_4$	*c*	54.5	292–323	?
$2KCl·ZnCl_2$	*c*	43.4	279–319	?
$2KCN·Zn(CN)_2$	*c*	57.4	277–319	?
K_2CO_3	*c*	29.9	296–372	?
K_2CrO_4	*c*	35.9	289–371	?
$K_2Cr_2O_7$	*c*	$42.80 + 0.0410T$	273–671	5
	l	96.9	671–757	5
KF	*c*	$10.8 + 0.00284T$	273–1129	?
$K_4Fe(CN)_6$	*c*	80.1	273–319	?
$K_4Fe(CN)_6·3H_2O$	*c*	114.5	273–310	?
KH_2AsO_4	*c*	32	289–319	?
KH_2PO_4	*c*	28.3	290–320	?
$KHSO_4$	*c*	30	292–324	?
$KMnO_4$	*c*	28	287–318	?
KNO_3	*c*	$6.42 + 0.0530T$	273–401	10
	c	28.8	401–611	5
	l	29.5	611–683	10
$K_2O·Al_2O_3·3SiO_2$	*c*, orthoclase	$69.26 + 0.00821T - 2331000/T^2$	273–1373	1½
	gls, orthoclase	$69.81 + 0.01053 - 2403000/T^2$	273–1373	1½
	c, microcline	$65.65 + 0.01102T - 1748000/T^2$	273–1373	1½
	gls, microcline	$64.83 + 0.01438T - 1641000/T^2$	273–1373	1½
$K_4P_2O_7$	*c*	63.1	290–371	?
K_2SO_4	*c*	33.1	287–371	?
$K_2S_2O_3$	*c*	37	293–373	?
$K_2SO_4·Al_2(SO_4)_3·24H_2O$	*c*	352	292–322	?
$K_2SO_4·Cr_2(SO_4)_3·24H_2O$	*c*	324	292–324	?
$K_2SO_4·MgSO_4·6H_2O$	*c*	106	292–323	?
$K_2SO_4·NiSO_4·6H_2O$	*c*	107	289–319	?
$K_2SO_4·ZnSO_4·6H_2O$	*c*	120	293–317	?
Prometheum				
Pr	*c*			
Radon				
Rn	*g*	4.97	All	0
Rhenium				
Re	*c*	$6.30 + 0.00053T$	273–2273	?
Rhodium				
Rh	*c*	$5.40 + 0.00219T$	273–1877	2
Rubidium				
Rb	*c*	$3.27 + 0.0131T$	273–312	2
	l	7.85	312–373	5
RbBr	*c*	$11.6 + 0.00255T$	273–954	?
RbCl	*c*	$11.5 + 0.00249T$	273–987	?
Rb_2CO_3	*c*	28.4	291–320	?
RbF	*c*	$11.3 + 0.00256T$	273–1048	?
RbI	*c*	$11.6 + 0.00263T$	273–913	?
Scandium				
Sc_2O_3	*c*	21.1	273–373	?
$Sc_2(SO_4)_3$	*c*	62.0	273–373	?
Selenium				
Se	*c*	$4.53 + 0.00550T$	273–490	2
	l	8.35	490–570	3
Silicon				
Si	*c*	$5.74 + 0.000617T - 101000/T^2$	273–1174	2
SiC	*c*	$8.89 + 0.00291T - 284000/T^2$	273–1629	2
$SiCl_4$	*l*	32.4	293–373	?
SiO_2	*c*, quartz, α	$10.87 + 0.008712T - 241200/T^2$	273–848	1
	c, quartz, β	$10.95 + 0.00550T$	848–1873	3½
	c, cristobalite, α	$3.65 + 0.0240T$	273–523	2½
	c, cristobalite, β	$17.09 + 0.000454T - 897200/T^2$	523–1973	2
	gls	$12.80 + 0.00447T - 302000/T^2$	273–1973	3½
Silver[4]				
Ag	*c*	$5.60 + 0.00150T$	273–1234	1
	l	8.2	1234–1573	3

TABLE 2-151 Heat Capacities of the Elements and Inorganic Compounds (*Continued*)

Substance	State†	Heat capacity at constant pressure (T = K; 0 °C = 273.1 K), cal/(mol·K)	Range of temperature, K	Uncertainty, %
Silver—(*Cont.*)				
Ag_3Al	*c*	$22.56 + 0.00570T$	273–902	2
Ag_2Al	*c*	$16.85 + 0.00450T$	273–903	2
$AgAl_{12}$	*c*	$58.62 + 0.0575T$	273–768	5
AgBr	*c*	$8.58 + 0.0141T$	273–703	6
	l	14.9	703–836	5
AgCl	*c*	$9.60 + 0.00929T$	273–728	2
	l	14.05	728–806	5
AgCNO	*c*	18.7	273–353	?
AgI	*c*, α	$8.58 + 0.0141T$	273–423	6
$AgNO_3$	*c*, α	$18.83 + 0.0160T$	273–433	2
	c, β	25.7	433–482	5
	l	30.2	482–541	5
Ag_3PO_4	*c*	37.5	293–325	?
Ag_2S	*c*, α	18.8	273–448	5
	c, β	21.8	448–597	5
Ag_3Sb	*c*	$19.53 + 0.0160T$	273–694	5
Ag_2Se	*c*, α	20.2	273–406	5
	c, β	20.4	406–460	5
Sodium[15]				
Na	*c*	$5.01 + 0.00536T$	273–371	1½
	l	7.50	371–451	2
	g	4.97	All	0
$NaBO_2$	*c*	$10.4 + 0.0199T$	273–1239	?
$Na_2B_4O_7$	*c*	47.9	289–371	?
$Na_2B_4O_7{\cdot}10H_2O$	*c*	147	292–323	?
NaBr	*c*	$11.74 + 0.00233T$	273–543	2
NaCl	*c*	$10.79 + 0.00420T$	273–1074	2
	l	15.9	1073–1205	3
$NaClO_3$	*c*	$9.48 + 0.0468T$	273–528	3
	l	31.8	528–572	5
NaCNO	*c*	13.1	273–353	?
Na_2CO_3	*c*	28.9	288–371	?
NaF	*c*	$10.4 + 0.00289T$	273–1261	?
$Na_2HPO_4{\cdot}7H_2O$	*c*	86.6	275–307	?
$Na_2HPO_4{\cdot}12H_2O$	*c*	133.4	275–307	?
NaI	*c*	$12.5 + 0.00162T$	273–936	?
$NaNO_3$	*c*	$4.56 + 0.0580T$	273–583	5
	l	37.2	583–703	10
$Na_2O{\cdot}Al_2O_3{\cdot}3SiO_2$	*c*, albite	$63.78 + 0.01171T - 1678000/T^2$	273–1373	1
	gls	$61.25 + 0.01768T - 1545000/T^2$	273–1173	1
$NaPO_3$	*c*	22.1	290–319	?
$Na_4P_2O_7$	*c*	60.7	290–371	?
Na_2SO_4	*c*	32.8	289–371	?
$Na_2S_2O_3$	*c*	34.9	273–307	?
$Na_2S_2O_3{\cdot}5H_2O$	*c*	86.2	273–307	?
Sodium-potassium alloys[15]	*l*			
Strontium				
$SrBr_2$	*c*	$18.1 + 0.00311T$	273–923	?
$SrBr_2{\cdot}H_2O$	*c*	28.9	277–370	?
$SrBr_2{\cdot}6H_2O$	*c*	82.1	276–327	?
$SrCl_2$	*c*	$18.2 + 0.00244T$	273–1143	?
$SrCl_2{\cdot}H_2O$	*c*	28.7	276–365	?
$SrCl_2{\cdot}2H_2O$	*c*	38.3	277–366	?
$SrCO_3$	*c*	21.8	281–371	?
SrI_2	*c*	$18.6 + 0.00304T$	273–783	?
$SrI_2{\cdot}H_2O$	*c*	28.5	276–363	?
$SrI_2{\cdot}2H_2O$	*c*	39.1	275–336	?
$SrI_2{\cdot}6H_2O$	*c*	84.9	275–333	?
$SrMoO_4$	*c*	37	273–297	?
$Sr(NO_3)_2$	*c*	38.3	290–320	?
$SrSO_4$	*c*	26.2	293–369	?
Sulfur[16]				
S	*c*, rhombic	$3.63 + 0.00640T$	273–368	3
	c, monoclinic	$4.38 + 0.00440T$	368–392	3
S_2	*g*	$8.58 + 0.00030T$	300–2500	5
S_2Cl_2	*l*	27.5	273–332	?
SO_2	*g*	$7.70 + 0.00530T - 0.00000083T^2$	300–2500	2½
Tantalum				
Ta	*c*	$5.91 + 0.00099T$	273–1173	2
Tellurium				
Te	*c*	$5.19 + 0.00250T$	273–600	3
Thallium				
Tl	*c*, α	$5.32 + 0.00385T$	273–500	1
	c, β	8.12	500–576	1

TABLE 2-151 Heat Capacities of the Elements and Inorganic Compounds (*Concluded*)

Substance	State†	Heat capacity at constant pressure (T = K; 0 °C = 273.1 K), cal/(mol·K)	Range of temperature, K	Uncertainty, %
Thallium—(*Cont.*)				
Tl	*l*	7.12	576–773	3
TlBr	*c*	12.53 + 0.00100T	273–733	10
	l	16.0	733–800	10
TlCl	*c*	12.56 + 0.00088T	273–700	5
	l	14.2	700–803	10
Thorium				
Th	*c*	6.40	273–373	?
ThO_2	*c*	14.6 + 0.00507T	273–1273	?
$Th(SO_4)_2$	*c*	41.2	273–373	?
Tin[4]				
Sn	*c*	5.05 + 0.00480T	273–504	2
	l	6.6	504–1273	10
SnAu	*c*	11.79 + 0.00233T	273–581	1
$SnCl_2$	*c*	16.2 + 0.00926T	273–520	?
$SnCl_4$	*l*	38.4	286–371	?
SnO	*c*	9.40 + 0.00362T	273–1273	?
SnO_2	*c*	13.94 + 0.00565T − 252000/T^2	273–1373	?
SnPt	*c*	11.49 + 0.00190T	273–1318	1
SnS	*c*	12.1 + 0.00165T	273–1153	?
SnS_2	*c*	20.5 + 0.00400T	273–873	?
Titanium				
Ti	*c*	8.91 + 0.00114T − 433000/T^2	273–713	3
$TiCl_4$	*l*	35.7	285–372	?
TiO_2	*c*	11.81 + 0.00754T − 41900/T^2	273–713	3
Tungsten				
W	*c*	5.65 + 0.00866	273–2073	1
WO_3	*c*	16.0 + 0.00774T	273–1550	?
Uranium				
U	*c*	6.64	273–372	?
U_3O_8	*c*	59.8	276–314	?
Vanadium				
V	*c*	5.57 + 0.00097T	273–1993	?
Xenon				
Xe	*g*	4.97	All	0
Zinc[4]				
Zn	*c*	5.25 + 0.00270T	273–692	1
	l	7.59 + 0.00055T	692–1122	3
$ZnCl_2$	*c*	15.9 + 0.00800T	273–638	?
ZnO	*c*	11.40 + 0.00145T − 182400/T^2	273–1573	1
ZnS	*c*	12.81 + 0.00095T − 194600/T^2	273–1173	5
ZnSb	*c*	11.5 + 0.00313T	273–810	?
$ZnSO_4$	*c*	28	293–373	?
$ZnSO_4{\cdot}H_2O$	*c*	34.7	282	?
$ZnSO_4{\cdot}6H_2O$	*c*	80.8	282	?
$ZnSO_4{\cdot}7H_2O$	*c*	100.2	273–307	?
Zirconium				
ZrO_2	*c*	11.62 + 0.01046T − 177700/T^2	273–1673	5
$ZrO_2{\cdot}SiO_2$	*c*	26.7	297–372	?

[1] See also Table 2-152. Data to 298 K are also given by Scott, *Cryogenic Engineering*, Van Nostrand, Princeton, N.J., 1959.
[2] For liquid and gas data, see Johnson (ed.), WADD-TR-60-56, 1960.
[3] Stalder, NACA Tech. Note 4141, 1957 (Fig. 5), gives data from 400 to 2600°R.
[4] See also Table 2-152.
[5] For data from 400 to 5500 °R see Stalder, NACA Tech. Note 4141, 1975 (Fig. 4).
[6] For solid, liquid, and gas data, see Johnson (ed.), WADD-TR-60-56, 1960.
[7] For data from 400 to 2350 °R see Stalder, NACA Tech. Note 4141, 1957.
[8] For solid, liquid, and gas data, see Johnson (ed.), WADD-TR-60-56, 1960.
[9] For liquid and gas data, see Johnson (ed.), WADD-TR-60-56, 1960.
[10] For solid, liquid, and gas data, see Johnson (ed.), WADD-TR-60-56, 1960.
[11] See also Table 2-152; Douglas, Ball, et al., *Bur. Stand. J. Res.,* **46** (1951): 334; Busey and Giaque, *J. Am. Chem. Soc.,* **75** (1953): 806; Sheldon, ASME Pap. 49-A-30, 1949.
[12] For solid, liquid, and gas data, see Johnson (ed.), WADD-TR-56-60, 1960.
[13] For solid, liquid, and gas data, see Johnson (ed.), WADD-TR-56-60, 1960.
[14] For solid, liquid, and gas data, see Johnson (ed.), WADD-TR-56-60, 1960. Ozone: For liquid see Brabets and Waterman, *J. Chem. Phys.*, **28** (1958): 1212.
[15] For data on liquid Na-K alloys to 1500 °F and for liquid Na to 1460 °F, see Lubarsky and Kaufman, NACA Rep. 1270, 1956.
[16] See also Evans and Wagman, *Bur. Stand. J. Res.* **49** (1952): 141; Gratch, OTS PB 124957, 1950; Guthrie, Scott et al., *J. Am. Chem. Soc.,* **76** (1954): 1488.

TABLE 2-152 Specific Heat [kJ/(kg·K)] of Selected Elements

	Temperature, K														
Symbol	4	6	8	10	20	40	60	80	100	200	250	300	400	600	800
Al	0.00026	0.00050	0.00088	0.00140	0.0089	0.0775	0.214	0.357	0.481	0.797	0.859	0.902	0.949	1.042	1.134
Be	0.00008			0.00028	0.0014				0.195	1.109	1.537	1.840	2.191	2.605	2.823
Bi	0.00054	0.00220	0.00541	0.01040	0.0340	0.0729	0.092	0.102	0.109	0.120	0.121	0.122	0.123	0.142	0.136
Cr	0.00016	0.00029	0.00050	0.00081	0.0021	0.0107	0.059	0.127	0.190	0.382	0.424	0.450	0.501	0.565	0.611
Co	0.00036	0.00059	0.00085	0.00121	0.0048	0.0404	0.110	0.184	0.234	0.376	0.406	0.426	0.451	0.509	0.543
Cu	0.00011	0.00024	0.00048	0.00086	0.0076	0.059	0.137	0.203	0.254	0.357	0.377	0.386	0.396	0.431	0.448
Ge			0.00037	0.00081	0.0129	0.0619	0.108	0.153	0.192	0.286	0.305	0.323	0.343	0.364	0.377
Au	0.00018	0.00047	0.00126	0.00255	0.0163	0.0569	0.084	0.100	0.109	0.124	0.127	0.129	0.131	0.136	0.141
Ir				0.00032	0.0021				0.090	0.122	0.128	0.131	0.133	0.140	0.146
Fe	0.00038	0.00061	0.00090	0.00127	0.0039	0.0276	0.086	0.154	0.216	0.384	0.422	0.450	0.491	0.555	0.692
Pb	0.00075	0.00242	0.00747	0.01350	0.0531	0.0944	0.108	0.114	0.118	0.125	0.127	1.129	0.132	0.142	
Mg	0.00034	0.00080	0.00155	0.00172	0.0148	0.138	0.336	0.513	0.648	0.929	0.985	1.005	1.082	1.177	1.263
Hg	0.00417	0.01420	0.01820	0.02250	0.0515	0.0895	0.107	0.116	0.121	0.136	0.141	0.139	0.136	0.135	0.104
Mo	0.00011	0.00019	0.00032	0.00050	0.0029	0.0236	0.061	0.105	0.140	0.223	0.241	0.248	0.261	0.280	0.292
Ni	0.00054	0.00086	0.00121	0.00178	0.0058	0.0380	0.103	0.173	0.232	0.383	0.416	0.444	0.490	0.590	0.530
Pt	0.00019	0.00028	0.00067	0.00112	0.0077	0.0382	0.069	0.088	0.101	0.127	0.132	0.134	0.136	0.140	0.146
Ag	0.00016	0.00035	0.00093	0.00186	0.0159	0.0778	0.133	0.166	0.187	0.225	0.232	0.236	0.240	0.251	0.264
Sn	0.00024	0.00127	0.00423	0.00776	0.0400	0.108	0.149	0.173	0.189	0.214	0.220	0.222	0.245	0.257	0.257
Zn	0.00011	0.00029	0.00096	0.00250	0.0269	0.123	0.205	0.258	0.295	0.366	0.380	0.389	0.404	0.435	0.479

TABLE 2-153 Heat Capacities of Inorganic and Organic Liquids [J/(kmol·K)]

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	C5	T_{min}, K	C_p at T_{min} ×1E-05	T_{max}, K	C_p at T_{max} ×1E-05
1	Acetaldehyde	C_2H_4O	75-07-0	44.053	115,100	−433	1.425			150.15	0.8221	294.00	1.1097
2	Acetamide	C_2H_5NO	60-35-5	59.067	102,300	128.7				354.15	1.4788	571.00	1.7579
3	Acetic acid	$C_2H_4O_2$	64-19-7	60.052	139,640	−320.8	0.8985			289.81	1.2213	391.05	1.5159
4	Acetic anhydride	$C_4H_6O_3$	108-24-7	102.089	36,600	511				250.00	1.6435	350.00	2.1545
5	Acetone	C_3H_6O	67-64-1	58.079	135,600	−177	0.2837	0.000689		178.45	1.1696	329.44	1.3271
6	Acetonitrile	C_2H_3N	75-05-8	41.052	97,582	−122.2	0.34085			229.32	0.8748	354.75	0.9713
7	Acetylene	C_2H_2	74-86-2	26.037	−122,020	3,082.7	−15.895	0.027732		192.40	0.8021	250.00	0.8853
8	Acrolein	C_3H_4O	107-02-8	56.063	103,090	−247.8	1.0343			253.00	1.0660	379.50	1.5801
9	Acrylic acid	$C_3H_4O_2$	79-10-7	72.063	55,300	300				286.15	1.4114	375.00	1.6780
10	Acrylonitrile	C_3H_3N	107-13-1	53.063	109,900	−109.75	0.35441			189.63	1.0183	400.00	1.2271
11	Air	Mixture	132259-10-0	28.960	−214,460	9,185.1	−106.12	0.41616		75.00	0.5307	115.00	0.7132
12	Ammonia [use Eq. (2)]	H_3N	7664-41-7	17.031	61.289	80,925	799.4	−2,651		203.15	0.7575	401.15	4.1847
13	Anisole	C_7H_8O	100-66-3	108.138	150,940	93.455	0.23602			298.15	1.9978	484.20	2.5153
14	Argon	Ar	7440-37-1	39.948	134,390	−1,989.4	11.043			83.78	0.4523	135.00	0.6708
15	Benzamide	C_7H_7NO	55-21-0	121.137	161,440	260.66				403.00	2.6649	563.15	3.0823
16	Benzene	C_6H_6	71-43-2	78.112	129,440	−169.5	0.64781			278.68	1.3251	353.24	1.5040
16	Benzene	C_6H_6	71-43-2	78.112	162,940	−344.94	0.85562			278.68	1.3326	500.00	2.0437
17	Benzenethiol	C_6H_6S	108-98-5	110.177	119,780	180.34				258.27	1.6636	442.29	1.9954
18	Benzoic acid	$C_7H_6O_2$	65-85-0	122.121	−5,480	647.12				395.45	2.5042	450.00	2.8572
19	Benzonitrile	C_7H_5N	100-47-0	103.121	93,383	242.61				260.40	1.5656	464.15	2.0599
20	Benzophenone	$C_{13}H_{10}O$	119-61-9	182.218	156,130	454.49				321.35	3.0218	640.00	4.4700
21	Benzyl alcohol	C_7H_8O	100-51-6	108.138	−334,997	3,644.21	−7.77514	0.00591102		257.85	1.8905	478.60	2.7617
22	Benzyl ethyl ether	$C_9H_{12}O$	539-30-0	136.191	87,500	480				275.65	2.1981	458.15	3.0741
23	Benzyl mercaptan	C_7H_8S	100-53-8	124.203	100,320	346.89				243.95	1.8494	472.03	2.6406
24	Biphenyl	$C_{12}H_{10}$	92-52-4	154.208	121,770	429.3				342.20	2.6868	533.37	3.5075
25	Bromine	Br_2	7726-95-6	159.808	179,400	−667.11	1.0701			265.90	0.7768	331.90	0.7587
26	Bromobenzene	C_6H_5Br	108-86-1	157.008	121,600	−9.45	0.358			293.15	1.4960	495.08	2.0467
27	Bromoethane	C_2H_5Br	74-96-4	108.965	94,364	−109.12	0.44032			160.00	0.8818	320.00	1.0453
28	Bromomethane	CH_3Br	74-83-9	94.939	129,730	−596.54	2.16	−0.0024234		184.45	0.7798	276.71	0.7870
29	1,2-Butadiene	C_4H_6	590-19-2	54.090	135,150	−311.14	0.97007	−0.0001523		136.95	1.1034	290.00	1.2279
30	1,3-Butadiene	C_4H_6	106-99-0	54.090	128,860	−323.1	1.015	0.000032		165.00	1.0333	350.00	1.4148
31	Butane	C_4H_{10}	106-97-8	58.122	191,030	−1,675	12.5	−0.03874	4.6121E-05	134.86	1.1272	400.00	2.2237
32	1,2-Butanediol [use Eq. (2)]	$C_4H_{10}O_2$	584-03-2	90.121	55.136	314,200	280.19	1,413.9		220.00	1.5590	670.00	5.2045
33	1,3-Butanediol [use Eq. (2)]	$C_4H_{10}O_2$	107-88-0	90.121	42.152	324,580	517.35	1,449.5		196.15	0.6251	670.00	5.2437
34	1-Butanol	$C_4H_{10}O$	71-36-3	74.122	191,200	−730.4	2.2998			183.85	1.3465	391.90	2.5817
35	2-Butanol	$C_4H_{10}O$	78-92-2	74.122	426,790	−3,694.6	13.828	−0.0135		158.45	1.3485	372.90	2.7190
36	1-Butene	C_4H_8	106-98-9	56.106	182,050	−1,611	11.963	−0.037454	4.5027E-05	87.80	1.1015	380.00	1.8103
37	*cis*-2-Butene	C_4H_8	590-18-1	56.106	126,680	−65.47	−0.64	0.002912		134.26	1.1340	350.00	1.5022
38	*trans*-2-Butene	C_4H_8	624-64-6	56.106	112,760	−104.7	0.5214			167.62	1.0986	274.03	1.2322
39	Butyl acetate	$C_6H_{12}O_2$	123-86-4	116.158	111,850	384.52				298.15	2.2649	399.26	2.6537
40	Butylbenzene	$C_{10}H_{14}$	104-51-8	134.218	182,470	−13.912	0.72897			185.30	2.0492	400.00	2.9354
41	Butyl mercaptan	$C_4H_{10}S$	109-79-5	90.187	232,190	−804.35	2.7063	−0.0023017		157.46	1.6365	390.00	1.9359
42	*sec*-Butyl mercaptan	$C_4H_{10}S$	513-53-1	90.187	197,890	−491.54	1.7219	−0.0012499		133.02	1.6003	370.00	1.8844
43	1-Butyne	C_4H_6	107-00-6	54.090	136,340	−300.4	1.0216			147.43	1.1426	298.15	1.3759
44	Butyraldehyde	C_4H_8O	123-72-8	72.106	65,682	1,329.1	−7.1579	0.012755		176.75	1.4741	300.00	1.6459
45	Butyric acid	$C_4H_8O_2$	107-92-6	88.105	237,700	−746.4	1.829			267.95	1.6902	436.42	2.6031
46	Butyronitrile	C_4H_7N	109-74-0	69.105	104,000	174				161.25	1.3206	390.75	1.7199
47	Carbon dioxide	CO_2	124-38-9	44.010	−8,304,300	104,370	−433.33	0.60052		220.00	0.7827	290.00	1.6603
48	Carbon disulfide	CS_2	75-15-0	76.141	85,600	−122	0.5605	−0.001452	2.008E-06	161.11	0.7577	552.00	1.3125
49	Carbon monoxide [use Eq. (2)]	CO	630-08-0	28.010	65.429	28,723	−847.39	1,959.6		68.15	0.5912	132.00	6.4799
50	Carbon tetrachloride	CCl_4	56-23-5	153.823	−752,700	8,966.1	−30.394	0.034455		250.33	1.2763	388.71	1.6374
51	Carbon tetrafluoride	CF_4	75-73-0	88.004	104,600	−500.6	2.2851			89.56	0.7810	145.10	0.8007
52	Chlorine	Cl_2	7782-50-5	70.906	63,936	46.35	−0.1623			172.12	0.6711	239.12	0.6574
53	Chlorobenzene	C_6H_5Cl	108-90-7	112.557	−1,307,500	15,338	−53.974	0.063483		227.95	1.3617	360.00	1.8101
54	Chloroethane	C_2H_5Cl	75-00-3	64.514	127,900	−345.15	0.915			134.80	0.9800	340.00	1.1632
55	Chloroform	$CHCl_3$	67-66-3	119.378	124,850	−166.34	0.43209			233.15	1.0956	366.48	1.2192
56	Chloromethane	CH_3Cl	74-87-3	50.488	96,910	−207.9	0.37456	0.000488		175.43	0.7460	373.15	0.9684
57	1-Chloropropane	C_3H_7Cl	540-54-5	78.541	132,280	−153.27	0.50836			150.35	1.2073	319.67	1.3523
58	2-Chloropropane	C_3H_7Cl	75-29-6	78.541	69,362	215.01				200.00	1.1236	308.85	1.3577

TABLE 2-153 Heat Capacities of Inorganic and Organic Liquids [J/(kmol·K)] (*Continued*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	C5	T_{min}, K	C_p at T_{min} × 1E-05	T_{max}, K	C_p at T_{max} × 1E-05
59	*m*-Cresol	C_7H_8O	108-39-4	108.138	–246,700	3,256.8	–7.4202	0.0060467		285.39	2.1895	400.00	2.5578
60	*o*-Cresol	C_7H_8O	95-48-7	108.138	–185,150	3,148	–8.0367	0.007254		304.20	2.3297	400.00	2.5243
61	*p*-Cresol	C_7H_8O	106-44-5	108.138	259,980	–1,112.3	4.9427	–0.0054367		307.93	2.2740	400.00	2.5794
62	Cumene	C_9H_{12}	98-82-8	120.192	61,723	494.81				177.14	1.4937	425.56	2.7229
63	Cyanogen	C_2N_2	460-19-5	52.035	65,516	144.7	0.063229			200.08	0.9700	300.08	1.1463
64	Cyclobutane	C_4H_8	287-23-0	56.106	101,920	–215.81	0.8103			190.00	0.9017	298.15	1.0961
65	Cyclohexane	C_6H_{12}	110-82-7	84.159	–220,600	3,118.3	–9.4216	0.010687		279.69	1.4836	400.00	2.0323
66	Cyclohexanol	$C_6H_{12}O$	108-93-0	100.159	–40,000	853				296.60	2.1300	434.00	3.3020
67	Cyclohexanone	$C_6H_{10}O$	108-94-1	98.143	6,110.4	600.94				290.00	1.8038	489.75	3.0042
68	Cyclohexene	C_6H_{10}	110-83-8	82.144	105,850	–60	0.68			169.67	1.1525	356.12	1.7072
69	Cyclopentane	C_5H_{10}	287-92-3	70.133	122,530	–403.8	1.7344	–0.0010975		179.28	0.9956	322.40	1.3584
70	Cyclopentene	C_5H_8	142-29-0	68.117	125,380	–349.7	1.143			138.13	0.9888	317.38	1.2953
71	Cyclopropane	C_3H_6	75-19-4	42.080	89,952	–196.63	0.65237			150.00	0.7514	298.15	0.8932
72	Cyclohexyl mercaptan	$C_6H_{12}S$	1569-69-3	116.224	177,560	–179.12	0.76723			189.64	1.7118	431.95	2.4334
73	Decanal	$C_{10}H_{20}O$	112-31-2	156.265	150,460	586.63				267.15	3.0718	488.15	4.3682
74	Decane	$C_{10}H_{22}$	124-18-5	142.282	278,620	–197.91	1.0737			243.51	2.9409	460.00	4.1478
75	Decanoic acid	$C_{10}H_{20}O_2$	334-48-5	172.265	219,840	140.41	0.9968			304.75	3.5521	543.15	5.9017
76	1-Decanol	$C_{10}H_{22}O$	112-30-1	158.281	4,988,500	–52,898	216.35	–0.37538	0.00023674	280.05	3.5373	503.00	5.0169
77	1-Decene	$C_{10}H_{20}$	872-05-9	140.266	417,440	–1,616.5	5.3948	–0.004348		206.89	2.7541	443.75	3.8250
78	Decyl mercaptan	$C_{10}H_{22}S$	143-10-2	174.347	314,570	–160.93	0.95561			247.56	3.3330	512.35	4.8297
79	1-Decyne	$C_{10}H_{18}$	764-93-2	138.250	276,900	–371.23	1.5774			229.15	2.7466	447.15	4.2629
80	Deuterium	D_2	7782-39-0	4.032									
81	1,1-Dibromoethane	$C_2H_4Br_2$	557-91-5	187.861	149,400	–231.8	0.5946			210.15	1.2695	381.15	1.4743
82	1,2-Dibromoethane	$C_2H_4Br_2$	106-93-4	187.861	200,560	–491.44	0.9187			282.85	1.3506	410.00	1.5350
83	Dibromomethane	CH_2Br_2	74-95-3	173.835	202,580	–726.3	1.3377			240.00	1.0532	370.10	1.1701
84	Dibutyl ether	$C_8H_{18}O$	142-96-1	130.228	270,720	–259.83	0.95427			175.30	2.5450	450.00	3.4704
85	*m*-Dichlorobenzene	$C_6H_4Cl_2$	541-73-1	147.002	114,880	187.25				248.39	1.6139	400.00	1.8978
86	*o*-Dichlorobenzene	$C_6H_4Cl_2$	95-50-1	147.002	93,093	183.97	0.2314			273.15	1.6061	528.75	2.5506
87	*p*-Dichlorobenzene	$C_6H_4Cl_2$	106-46-7	147.002	133,950	–24.84	0.48191			326.14	1.7711	513.56	2.4829
88	1,1-Dichloroethane	$C_2H_4Cl_2$	75-34-3	98.959	126,340	–94.63	0.32			176.19	1.1960	330.45	1.3001
89	1,2-Dichloroethane	$C_2H_4Cl_2$	107-06-2	98.959	179,170	–444.74	0.93009			237.49	1.2601	356.59	1.3885
90	Dichloromethane	CH_2Cl_2	75-09-2	84.933	98,968	–62.941	0.23265			180.00	0.9518	320.00	1.0265
91	1,1-Dichloropropane	$C_3H_6Cl_2$	78-99-9	112.986	144,560	–53.605	0.30617			180.00	1.4483	361.25	1.6515
92	1,2-Dichloropropane	$C_3H_6Cl_2$	78-87-5	112.986	111,560	149.44				275.00	1.5266	369.52	1.6678
93	Diethanol amine	$C_4H_{11}NO_2$	111-42-2	105.136	184,200	286				301.15	2.7033	541.54	3.3908
94	Diethyl amine	$C_4H_{11}N$	109-89-7	73.137	101,330	243.18				223.35	1.5564	328.60	1.8124
95	Diethyl ether	$C_4H_{10}O$	60-29-7	74.122	44,400	1,301	–5.5	0.008763		156.92	1.4698	460.00	3.3202
96	Diethyl sulfide	$C_4H_{10}S$	352-93-2	90.187	238,520	–1,038.4	4.0587	–0.0044691		181.95	1.5703	322.08	1.7579
97	1,1-Difluoroethane [use Eq. (2)]	$C_2H_4F_2$	75-37-6	66.050	67.155	105,580	310.21	–490.54		154.56	0.9915	359.98	1.6874
98	1,2-Difluoroethane	$C_2H_4F_2$	624-72-6	66.050	82,577	109.85				215.00	1.0619	283.65	1.1374
99	Difluoromethane	CH_2F_2	75-10-5	52.023	263,980	–1,791.1	4.3666			200.00	0.8042	250.00	0.8912
100	Di-isopropyl amine	$C_6H_{15}N$	108-18-9	101.190	98,434	429.04				275.00	2.1642	357.05	2.5162
101	Di-isopropyl ether	$C_6H_{14}O$	108-20-3	102.175	163,000	–4.5	0.62			187.65	1.8399	341.45	2.3375
102	Di-isopropyl ketone	$C_7H_{14}O$	565-80-0	114.185	179,270	28.37	0.5375			204.81	2.0763	410.00	2.8126
103	1,1-Dimethoxyethane	$C_4H_{10}O_2$	534-15-6	90.121	187,790	–313.41	1.1023			159.95	1.6586	337.45	2.0755
104	1,2-Dimethoxypropane	$C_5H_{12}O_2$	7778-85-0	104.148	199,930	–191.5	0.87664			226.10	2.0145	366.15	2.4734
105	Dimethyl acetylene	C_4H_6	503-17-3	54.090	88,153	124.16				240.91	1.1806	300.13	1.2542
106	Dimethyl amine	C_2H_7N	124-40-3	45.084	–214,870	3,787.2	–13.781	0.016924		180.96	1.1947	298.15	1.3779
107	2,3-Dimethylbutane	C_6H_{14}	79-29-8	86.175	129,450	18.5	0.608			145.19	1.4495	331.13	2.0224
108	1,1-Dimethylcyclohexane	C_8H_{16}	590-66-9	112.213	134,500	8.765	0.81151			239.66	1.8321	392.70	2.6309
109	*cis*-1,2-Dimethylcyclohexane	C_8H_{16}	2207-01-4	112.213	150,130	–62.38	0.8851			223.16	1.8029	402.94	2.6870
110	*trans*-1,2-Dimethylcyclohexane	C_8H_{16}	6876-23-9	112.213	155,560	–145.26	1.0932			184.99	1.6610	396.58	2.6989
111	Dimethyl disulfide	$C_2H_6S_2$	624-92-0	94.199	171,580	–256.67	0.5727			188.44	1.4355	360.00	1.5340
112	Dimethyl ether	C_2H_6O	115-10-6	46.068	110,100	–157.47	0.51853			131.65	0.9836	250.00	1.0314
113	*N,N*-Dimethyl formamide	C_3H_7NO	68-12-2	73.094	147,900	–106	0.384			273.82	1.4767	466.44	1.8200
114	2,3-Dimethylpentane	C_7H_{16}	565-59-3	100.202	146,420	59.2	0.604			90.00	1.5664	380.00	2.5613
115	Dimethyl phthalate	$C_{10}H_{10}O_4$	131-11-3	194.184	206,560	325.75				274.16	2.9587	360.00	3.2383
116	Dimethylsilane	C_2H_8Si	1111-74-6	60.170	131,810					298.15	1.3181	298.15	1.3181

117	Dimethyl sulfide	C_2H_6S	75-18-3	62.134	146,950	−380.06	1.2035	−0.00084787		174.88	1.1276	310.48	1.1959
118	Dimethyl sulfoxide	C_2H_6OS	67-68-5	78.133	240,300	−595	1.013			291.67	1.5293	422.15	1.6965
119	Dimethyl terephthalate	$C_{10}H_{10}O_4$	120-61-6	194.184	190,020	431.04				423.40	3.7252	466.35	3.9104
120	1,4-Dioxane	$C_4H_8O_2$	123-91-1	88.105	956,860	−5,559.9	9.6124			284.95	1.5306	374.47	2.2277
121	Diphenyl ether	$C_{12}H_{10}O$	101-84-8	170.207	134,160	447.67				300.03	2.6847	570.00	3.8933
122	Dipropyl amine	$C_6H_{15}N$	142-84-7	101.190	49,120	562.24				277.90	2.0537	407.90	2.7846
123	Dodecane	$C_{12}H_{26}$	112-40-3	170.335	508,210	−1,368.7	3.1015			263.57	3.6292	330.00	3.9429
124	Eicosane	$C_{20}H_{42}$	112-95-8	282.547	352,720	807.32	0.2122			309.58	6.2299	616.93	9.3154
125	Ethane [use Eq. (2)]	C_2H_6	74-84-0	30.069	44.009	89,718	918.77	−1,886		92.00	0.6855	290.00	1.2444
126	Ethanol	C_2H_6O	64-17-5	46.068	102,640	−139.63	−0.030341	0.0020386		159.05	0.8787	390.00	1.6450
127	Ethyl acetate	$C_4H_8O_2$	141-78-6	88.105	226,230	−624.8	1.472			189.60	1.6068	350.21	1.8796
128	Ethyl amine	C_2H_7N	75-04-7	45.084	121,700	38.993				192.15	1.2919	289.73	1.3300
129	Ethylbenzene	C_8H_{10}	100-41-4	106.165	154,040	−142.29	0.80539			178.20	1.5426	409.35	2.3075
130	Ethyl benzoate	$C_9H_{10}O_2$	93-89-0	150.175	124,500	370.6				238.45	2.1287	486.55	3.0482
131	2-Ethyl butanoic acid	$C_6H_{12}O_2$	88-09-5	116.158	56,359	603.02				258.15	2.1203	466.95	3.3794
132	Ethyl butyrate	$C_6H_{12}O_2$	105-54-4	116.158	82,434	422.45	0.20992			285.50	2.2015	428.25	3.0185
133	Ethylcyclohexane	C_8H_{16}	1678-91-7	112.213	132,360	72.74	0.64738			161.84	1.6109	404.95	2.6798
134	Ethylcyclopentane	C_7H_{14}	1640-89-7	98.186	178,520	−518.35	2.3255	−0.0016818		134.71	1.4678	301.82	1.8767
135	Ethylene	C_2H_4	74-85-1	28.053	247,390	−4,428	40.936	−0.1697	0.00026816	104.00	0.7012	252.70	0.9758
136	Ethylenediamine	$C_2H_8N_2$	107-15-3	60.098	184,440	−150.2	0.37044			284.29	1.7168	390.41	1.8226
137	Ethylene glycol	$C_2H_6O_2$	107-21-1	62.068	35,540	436.78	−0.18486			260.15	1.3666	493.15	2.0598
138	Ethyleneimine	C_2H_5N	151-56-4	43.068	46,848	205.35				250.00	0.9819	329.00	1.1441
139	Ethylene oxide	C_2H_4O	75-21-8	44.053	144,710	−758.87	2.8261	−0.003064		160.65	0.8303	283.85	0.8693
140	Ethyl formate	$C_3H_6O_2$	109-94-4	74.079	80,000	223.6				254.20	1.3684	374.20	1.6367
141	2-Ethyl hexanoic acid	$C_8H_{16}O_2$	149-57-5	144.211	207,670	−17.907	1.0493			235.00	2.6141	510.10	4.7157
142	Ethylhexyl ether	$C_8H_{18}O$	5756-43-4	130.228	146,040	458.22				298.15	2.8266	417.15	3.3719
143	Ethylisopropyl ether	$C_5H_{12}O$	625-54-7	88.148	106,250	292.15				298.15	1.9335	326.15	2.0153
144	Ethylisopropyl ketone	$C_6H_{12}O$	565-69-5	100.159	229,250	−404.54	1.1382			204.15	1.9410	386.55	2.4295
145	Ethyl mercaptan	C_2H_6S	75-08-1	62.134	134,670	−234.39	0.59656			125.26	1.1467	315.25	1.2007
146	Ethyl propionate	$C_5H_{10}O_2$	105-37-3	102.132	76,330	400.1				298.15	1.9562	410.00	2.4037
147	Ethylpropyl ether	$C_5H_{12}O$	628-32-0	88.148	103,680	726.3	−2.6047	0.0040957		145.65	1.6686	320.00	2.0358
148	Ethyltrichlorosilane	$C_2H_5Cl_3Si$	115-21-9	163.506	105,150	85.318	0.46693			167.55	1.3255	371.05	2.0109
149	Fluorine	F_2	7782-41-4	37.997	−94,585	7,529.9	−139.6	1.1301	−0.0033241	58.00	0.5541	98.00	0.5966
149	Fluorine	F_2	7782-41-4	37.997	1724,400	−59,924	537.85			53.48	0.5798	56.00	0.5535
150	Fluorobenzene	C_6H_5F	462-06-6	96.102	−991,200	11,734	−40.669	0.047333		239.99	1.3675	319.99	1.5018
151	Fluoroethane	C_2H_5F	353-36-6	48.060	85,663	−118.56	0.55459			140.00	0.7994	240.00	0.8915
152	Fluoromethane	CH_3F	593-53-3	34.033	74,746	−132.32	0.53772			140.00	0.6676	220.00	0.7166
153	Formaldehyde	CH_2O	50-00-0	30.026	61,900	28.3				204.00	0.6767	234.00	0.6852
154	Formamide	CH_3NO	75-12-7	45.041	63,400	150.6				292.00	1.0738	493.00	1.3765
155	Formic acid	CH_2O_2	64-18-6	46.026	78,060	71.54				281.45	0.9820	380.00	1.0525
156	Furan	C_4H_4O	110-00-9	68.074	114,370	−215.69	0.72691			187.55	0.9949	304.50	1.1609
157	Helium-4	He	7440-59-7	4.003	387,220	−465,570	211,800	−42,494	3212.9	2.20	0.1087	4.60	0.2965
157	Helium-4	He	7440-59-7	4.003	410,430	−464,890	135,100			1.80	0.1135	2.10	0.2995
158	Heptadecane	$C_{17}H_{36}$	629-78-7	240.468	376,970	347.82	0.57895			295.13	5.3005	575.30	7.6869
159	Heptanal	$C_7H_{14}O$	111-71-7	114.185	222,360	−105.17	0.65074			229.80	2.3256	381.25	2.7685
160	Heptane [use Eq. (2)]	C_7H_{16}	142-82-5	100.202	61.26	314,410	1,824.6	−2,547.9		182.57	1.9989	520.00	4.0657
161	Heptanoic acid	$C_7H_{14}O_2$	111-14-8	130.185	194,570	−23.206	0.88395			265.83	2.5087	496.15	4.0065
162	1-Heptanol	$C_7H_{16}O$	111-70-6	116.201	2,416,800	−26,105	110.03	−0.19172	0.00011968	239.15	2.3590	448.60	3.8766
163	2-Heptanol	$C_7H_{16}O$	543-49-7	116.201	283,127	−1,037.63	3.44064			230.00	2.2649	432.90	4.7873
164	3-Heptanone	$C_7H_{14}O$	106-35-4	114.185	270,730	−399.89	1.0601			234.15	2.3522	480.00	3.2303
165	2-Heptanone	$C_7H_{14}O$	110-43-0	114.185	265,040	−375.68	1.0024			238.15	2.3242	490.00	3.2163
166	1-Heptene	C_7H_{14}	592-76-7	98.186	267,950	−1,315.9	6.5242	−0.011994	9.3808E-06	154.12	1.8150	366.79	2.4096
167	Heptyl mercaptan	$C_7H_{16}S$	1639-09-4	132.267	236,870	−158.01	0.78982			229.92	2.4229	460.00	3.3131
168	1-Heptyne	C_7H_{12}	628-71-7	96.170	46,798	761.13	−0.62882			200.00	1.7387	372.93	2.4319
169	Hexadecane	$C_{16}H_{34}$	544-76-3	226.441	370,350	231.47	0.68632			291.31	4.9602	560.01	7.1521
170	Hexanal	$C_6H_{12}O$	66-25-1	100.159	117,700	329.52				217.15	1.8926	401.45	2.4999
171	Hexane	C_6H_{14}	110-54-3	86.175	172,120	−183.78	0.88734			177.83	1.6750	460.00	2.7534
172	Hexanoic acid	$C_6H_{12}O_2$	142-62-1	116.158	161,980	44.116	0.709			269.25	2.2526	478.85	3.4568
173	1-Hexanol	$C_6H_{14}O$	111-27-3	102.175	1,638,600	−17,261	71.721	−0.12026	0.000071087	228.55	1.9821	460.00	3.5197
174	2-Hexanol	$C_6H_{14}O$	626-93-7	102.175	267,628	−1,033.06	3.35185			223.00	2.0394	585.30	8.1124
175	2-Hexanone	$C_6H_{12}O$	591-78-6	100.159	208,250	−107.47	0.2062	0.00070293		217.35	2.0185	460.00	2.7087
176	3-Hexanone	$C_6H_{12}O$	589-38-8	100.159	235,960	−345.94	0.94278			217.50	2.0532	460.00	2.7632
177	1-Hexene	C_6H_{12}	592-41-6	84.159	164,640	−200.37	0.8784			133.39	1.5354	336.63	1.9673

TABLE 2-153 Heat Capacities of Inorganic and Organic Liquids [J/(kmol·K)] (*Continued*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	C5	T_{min}, K	C_p at T_{min} × 1E-05	T_{max}, K	C_p at T_{max} × 1E-05
178	3-Hexyne	C_6H_{10}	928-49-4	82.144	82,795	283.4				300.00	1.6781	354.35	1.8322
179	Hexyl mercaptan	$C_6H_{14}S$	111-31-9	118.240	303,320	−1,009	3.3885	−0.002762		192.62	2.1495	430.00	2.7639
180	1-Hexyne	C_6H_{10}	693-02-7	82.144	93,000	326				200.00	1.5820	344.48	2.0530
181	2-Hexyne	C_6H_{10}	764-35-2	82.144	94,860	254.15				300.00	1.7110	357.67	1.8576
182	Hydrazine	H_4N_2	302-01-2	32.045	79,815	50.929	0.043379			274.69	0.9708	653.15	1.3158
183	Hydrogen [use Eq. (2)]	H_2	1333-74-0	2.016	66.653	6,765.9	−123.63	478.27		13.95	0.1262	32.00	1.3122
184	Hydrogen bromide	HBr	10035-10-6	80.912	57,720	9.9				185.15	0.5955	206.45	0.5976
185	Hydrogen chloride	HCl	7647-01-0	36.461	47,300	90				165.00	0.6215	185.00	0.6395
186	Hydrogen cyanide	CHN	74-90-8	27.025	95,398	−197.52	0.3883			259.83	0.7029	298.85	0.7105
187	Hydrogen fluoride	HF	7664-39-3	20.006	62,520	−223.02	0.6297			189.79	0.4288	292.67	0.5119
188	Hydrogen sulfide [use Eq. (2)]	H_2S	7783-06-4	34.081	64.666	49,354	22.493	−1,623		187.68	0.6733	370.00	4.9183
189	Isobutyric acid	$C_4H_8O_2$	79-31-2	88.105	127,540	−65.35	0.82867			270.00	1.7031	427.65	2.5114
190	Isopropyl amine	C_3H_9N	75-31-0	59.110	−32,469	1,977.1	−7.0145	0.0086913		177.95	1.4621	320.00	1.6671
191	Malonic acid	$C_3H_4O_4$	141-82-2	104.061	157,850	−41.619	0.42817			407.95	2.1213	603.75	2.8880
192	Methacrylic acid	$C_4H_6O_2$	79-41-4	86.089	146,290	−58.59	0.3582			288.15	1.5915	434.15	1.8837
193	Methane [use Eq. (2)]	CH_4	74-82-8	16.042	65.708	38,883	−257.95	614.07		90.69	0.5361	190.00	14.9780
194	Methanol	CH_4O	67-56-1	32.042	105,800	−362.23	0.9379			175.47	0.7112	400.00	1.1097
195	*N*-Methyl acetamide	C_3H_7NO	79-16-3	73.094	62,600	243.4				359.00	1.4998	538.50	1.9367
196	Methyl acetate	$C_3H_6O_2$	79-20-9	74.079	61,260	270.9				253.40	1.2991	373.40	1.6241
197	Methyl acetylene	C_3H_4	74-99-7	40.064	79,791	89.49				200.00	0.9769	249.94	1.0216
198	Methyl acrylate	$C_4H_6O_2$	96-33-3	86.089	275,500	−1,147	2.568			196.32	1.4930	353.35	1.9084
199	Methyl amine	CH_5N	74-89-5	31.057	92,520	37.45				179.69	0.9925	266.82	1.0251
200	Methyl benzoate	$C_8H_8O_2$	93-58-3	136.148	125,630	279.75				260.75	1.9857	472.65	2.5785
201	3-Methyl-1,2-butadiene	C_5H_8	598-25-4	68.117	135,370	−133.34	0.63868			159.53	1.3035	314.56	1.5662
202	2-Methylbutane	C_5H_{12}	78-78-4	72.149	108,300	146	−0.292	0.00151		113.25	1.2328	310.00	1.7048
203	2-Methylbutanoic acid	$C_5H_{10}O_2$	116-53-0	102.132	74,200	417.4				321.50	2.0839	481.50	2.7518
204	3-Methyl-1-butanol	$C_5H_{12}O$	123-51-3	88.148	247,870	−1,145	3.4223			155.95	1.5254	404.15	3.4411
205	2-Methyl-1-butene	C_5H_{10}	563-46-2	70.133	149,510	−247.63	0.91849			135.58	1.3282	304.31	1.5921
206	2-Methyl-2-butene	C_5H_{10}	513-35-9	70.133	151,600	−266.72	0.90847			139.39	1.3207	311.71	1.5673
207	2-Methyl-1-butene-3-yne	C_5H_6	78-80-8	66.101	81,919	181.01				298.15	1.3589	305.40	1.3720
208	Methylbutyl ether	$C_5H_{12}O$	628-28-4	88.148	177,850	−171.57	0.74379			157.48	1.6928	343.31	2.0661
209	Methylbutyl sulfide	$C_5H_{12}S$	628-29-5	104.214	198,390	−220.35	0.76096			175.30	1.8315	510.00	2.8394
210	3-Methyl-1-butyne	C_5H_8	598-23-2	68.117	105,200	191.1				200.00	1.4342	299.49	1.6243
211	Methyl butyrate	$C_5H_{10}O_2$	623-42-7	102.132	102,930	129.1	0.62516			277.25	1.8678	415.87	2.6474
212	Methylchlorosilane	CH_5ClSi	993-00-0	80.589	47,726	338.4				250.00	1.3233	325.00	1.5771
213	Methylcyclohexane	C_7H_{14}	108-87-2	98.186	131,340	−63.1	0.8125			146.58	1.3955	320.00	1.9435
214	1-Methylcyclohexanol	$C_7H_{14}O$	590-67-0	114.185	50,578	508.59				300.00	2.0315	441.15	2.7494
215	*cis*-2-Methylcyclohexanol	$C_7H_{14}O$	7443-70-1	114.185	118,600	447.07				300.00	2.5272	438.15	3.1448
216	*trans*-2-Methylcyclohexanol	$C_7H_{14}O$	7443-52-9	114.185	118,170	447.99				300.00	2.5257	440.15	3.1535
217	Methylcyclopentane	C_6H_{12}	96-37-7	84.159	155,920	−490	2.1383	−0.0015585		130.73	1.2492	366.48	1.8682
218	1-Methylcyclopentene	C_6H_{10}	693-89-0	82.144	53,271	327.92				200.00	1.1885	348.64	1.6760
219	3-Methylcyclopentene	C_6H_{10}	1120-62-3	82.144	46,457	346.93				200.00	1.1584	338.05	1.6374
220	Methyldichlorosilane	CH_4Cl_2Si	75-54-7	115.034	27,030	413				250.00	1.3028	350.00	1.7158
221	Methylethyl ether	C_3H_8O	540-67-0	60.095	85,383	199.08	−0.061547			160.00	1.1566	280.50	1.3638
222	Methylethyl ketone	C_4H_8O	78-93-3	72.106	132,300	200.87	−0.9597	0.0019533		186.48	1.4905	373.15	1.7511
223	Methylethyl sulfide	C_3H_8S	624-89-5	76.161	161,240	−288.61	0.78179			167.23	1.3484	339.80	1.5344
224	Methyl formate	$C_2H_4O_2$	107-31-3	60.052	130,200	−396	1.21			174.15	0.9793	304.90	1.2195
225	Methylisobutyl ether	$C_5H_{12}O$	625-44-5	88.148	92,919	324.43				298.15	1.8965	350.00	2.0647
226	Methylisobutyl ketone	$C_6H_{12}O$	108-10-1	100.159	183,650	−79.862	0.60769			189.15	1.9029	389.15	2.4460
227	Methyl Isocyanate	C_2H_3NO	624-83-9	57.051	149,770	−529.82	1.3499			256.15	1.0263	366.00	1.3668
228	Methylisopropyl ether	$C_4H_{10}O$	598-53-8	74.122	143,440	−154.07	0.7255			127.93	1.3560	310.00	1.6540
229	Methylisopropyl ketone	$C_5H_{10}O$	563-80-4	86.132	191,170	−331.04	0.98445			180.15	1.6348	440.00	2.3610
230	Methylisopropyl sulfide	$C_4H_{10}S$	1551-21-9	90.187	211,170	−661.97	2.4216	−0.0021383		171.64	1.5808	357.91	1.8641
231	Methyl mercaptan	CH_4S	74-93-1	48.107	115,300	−263.23	0.60412			150.18	0.8939	298.15	0.9052
232	Methyl methacrylate	$C_5H_8O_2$	80-62-6	100.116	255,100	−938.4	2.413			224.95	1.6611	373.45	2.4118
233	2-Methyloctanoic acid	$C_9H_{18}O_2$	3004-93-1	158.238	226,650	15.421	1.0578			240.00	2.9128	518.15	5.1864
234	2-Methylpentane	C_6H_{14}	107-83-5	86.175	142,220	−47.83	0.739			119.55	1.4706	333.41	2.0842
235	Methyl pentyl ether	$C_6H_{14}O$	628-80-8	102.175	251,890	−468.32	1.2209			176.00	2.0728	372.00	2.4663
236	2-Methylpropane	C_4H_{10}	75-28-5	58.122	172,370	−1,783.9	14.759	−0.047909	0.00005805	113.54	0.9961	380.00	2.0725

237	2-Methyl-2-propanol	$C_4H_{10}O$	75-65-0	74.122	–925,460	7,894.9	–17.661	0.013617		298.96	2.2016	460.00	2.9455
238	2-Methyl propene	C_4H_8	115-11-7	56.106	87,680	217.1	–0.9153	0.002266		132.81	1.0568	343.15	1.4596
239	Methyl propionate	$C_4H_8O_2$	554-12-1	88.105	71,140	335.5				300.00	1.7179	390.00	2.0198
240	Methylpropyl ether	$C_4H_{10}O$	557-17-5	74.122	144,110	–102.09	0.58113			133.97	1.4086	312.20	1.6888
241	Methylpropyl sulfide	$C_4H_{10}S$	3877-15-4	90.187	179,850	–264.1	0.79202			160.17	1.5787	368.69	1.9014
242	Methylsilane	CH_6Si	992-94-9	46.144	113,470					298.15	1.1347	298.15	1.1347
243	alpha-Methyl styrene	C_9H_{10}	98-83-9	118.176	76,822	421.6				249.95	1.8220	438.65	2.6176
244	Methyl *tert*-butyl ether	$C_5H_{12}O$	1634-04-4	88.148	134,300	94.356	–0.0032	0.0009795		164.55	1.5410	328.18	1.9954
245	Methyl vinyl ether	C_3H_6O	107-25-5	58.079	73,600	184.7				151.15	1.0152	278.65	1.2507
246	Naphthalene	$C_{10}H_8$	91-20-3	128.171	29,800	527.5				353.43	2.1623	491.14	2.8888
247	Neon	Ne	7440-01-9	20.180	1,034,100	–138,770	7,154	–162.55	1.3841	24.56	0.3666	40.00	0.6980
248	Nitroethane	$C_2H_5NO_2$	79-24-3	75.067	187,740	–497.6	1.0691			183.63	1.3242	387.22	1.5536
249	Nitrogen	N_2	7727-37-9	28.013	281,970	–12,281	248	–2.2182	0.0074902	63.15	0.5593	112.00	0.7960
250	Nitrogen trifluoride	F_3N	7783-54-2	71.002	101,400	–682.11	3.8912			117.00	0.7486	175.50	1.0154
251	Nitromethane	CH_3NO_2	75-52-5	61.040	116,270	–135.3	0.345			244.60	1.0382	473.15	1.2949
252	Nitrous oxide	N_2O	10024-97-2	44.013	67,556	54.373				182.30	0.7747	200.00	0.7843
253	Nitric oxide	NO	10102-43-9	30.006	–2,979,600	76,602	–652.59	1.8879		109.50	0.6229	150.00	1.9909
254	Nonadecane	$C_{19}H_{40}$	629-92-5	268.521	342,570	762.08	0.20481			305.04	5.9409	603.05	8.7663
255	Nonanal	$C_9H_{18}O$	124-19-6	142.239	136,820	531.29				255.15	2.7238	468.15	3.8554
256	Nonane	C_9H_{20}	111-84-2	128.255	383,080	–1,139.8	2.7101			219.66	2.6348	325.00	2.9890
257	Nonanoic acid	$C_9H_{18}O_2$	112-05-0	158.238	224,336	49.726	0.9813			285.55	3.1855	528.75	5.2498
258	1-Nonanol	$C_9H_{20}O$	143-08-8	144.255	10,483,000	–115,220	476.87	–0.85381	0.00056246	310.00	3.5059	460.00	4.6494
259	2-Nonanol	$C_9H_{20}O$	628-99-9	144.255	329,641	–1,046.78	3.61823			238.15	2.8555	649.50	11.7608
260	1-Nonene	C_9H_{18}	124-11-8	126.239	254,490	–298.06	1.1707			191.91	2.4041	420.02	3.3583
261	Nonyl mercaptan	$C_9H_{20}S$	1455-21-6	160.320	265,350	–46.22	0.79154			253.05	3.0434	492.95	4.3491
262	1-Nonyne	C_9H_{16}	3452-09-3	124.223	253,580	–366.3	1.4881			223.15	2.4594	423.85	3.6566
263	Octadecane	$C_{18}H_{38}$	593-45-3	254.494	399,430	374.64	0.58156			301.31	5.6511	589.86	8.2276
264	Octanal	$C_8H_{16}O$	124-13-0	128.212	130,650	463.61				246.00	2.4470	447.15	3.3795
265	Octane	C_8H_{18}	111-65-9	114.229	224,830	–186.63	0.95891			216.38	2.2934	460.00	3.4189
266	Octanoic acid	$C_8H_{16}O_2$	124-07-2	144.211	205,260	44.392	0.8956			289.65	2.9326	512.85	4.6358
267	1-Octanol	$C_8H_{18}O$	111-87-5	130.228	571,370	–4,849	19.725	–0.021532		250.00	2.5550	467.10	4.1566
268	2-Octanol	$C_8H_{18}O$	123-96-6	130.228	319,198	–1,042.21	3.52943			241.55	2.7338	452.90	5.7113
269	2-Octanone	$C_8H_{16}O$	111-13-7	128.212	300,400	–426.2	1.1172			252.86	2.6406	500.00	3.6660
270	3-Octanone	$C_8H_{16}O$	106-68-3	128.212	289,980	–417.27	1.2218			255.55	2.6314	440.65	3.4335
271	1-Octene	C_8H_{16}	111-66-0	112.213	509,420	–4,279.1	21.477	–0.044462	3.5028E-05	171.45	2.1327	394.41	2.8235
272	Octyl mercaptan	$C_8H_{18}S$	111-88-6	146.294	240,040	–33.198	0.67889			240.00	2.7118	472.19	3.7573
273	1-Octyne	C_8H_{14}	629-05-0	110.197	42,642	886.67	–0.69315			200.00	1.9225	399.35	2.8619
274	Oxalic acid	$C_2H_2O_4$	144-62-7	90.035	175,510	–381.36	0.64623			462.65	1.3740	603.00	1.8052
275	Oxygen	O_2	7782-44-7	31.999	175,430	–6,152.3	113.92	–0.92382	0.0027963	54.36	0.5365	142.00	0.9066
276	Ozone	O_3	10028-15-6	47.998	60,046	281.16				90.00	0.8535	150.00	1.0222
277	Pentadecane	$C_{15}H_{32}$	629-62-9	212.415	346,910	219.54	0.65632			283.07	4.6165	543.84	6.6042
278	Pentanal	$C_5H_{10}O$	110-62-3	86.132	112,050	257.78				200.00	1.6361	376.15	2.0901
279	Pentane	C_5H_{12}	109-66-0	72.149	159,080	–270.5	0.99537			143.42	1.4076	390.00	2.0498
280	Pentanoic acid	$C_5H_{10}O_2$	109-52-4	102.132	145,050	28.344	0.6372			239.15	1.8827	458.95	2.9228
281	1-Pentanol	$C_5H_{12}O$	71-41-0	88.148	201,200	–651.3	2.275			200.14	1.6198	389.15	2.9227
282	2-Pentanol	$C_5H_{12}O$	6032-29-7	88.148	251,596	–1,028.49	3.26306			200.00	1.7642	561.00	7.0158
283	2-Pentanone	$C_5H_{10}O$	107-87-9	86.132	194,590	–263.86	0.76808			196.29	1.7239	375.46	2.0380
284	3-Pentanone	$C_5H_{10}O$	96-22-0	86.132	193,020	–176.43	0.5669			234.18	1.8279	375.14	2.0661
285	1-Pentene	C_5H_{10}	109-67-1	70.133	156,100	–456.94	2.255	–0.003163	0.00000238	108.02	1.2939	350.00	1.7251
286	2-Pentyl mercaptan	$C_5H_{12}S$	2084-19-7	104.214	188,200	–140.84	0.63581			160.75	1.8199	385.15	2.2827
287	Pentyl mercaptan	$C_5H_{12}S$	110-66-7	104.214	213,760	–324.4	0.9472			197.45	1.8664	399.79	2.3546
288	1-Pentyne	C_5H_8	627-19-0	68.117	86,200	256.6				200.00	1.3752	313.33	1.6660
289	2-Pentyne	C_5H_8	627-21-4	68.117	68,671	246.66				200.00	1.1800	329.27	1.4989
290	Phenanthrene	$C_{14}H_{10}$	85-01-8	178.229	103,370	527.03				372.39	2.9963	500.00	3.6688
291	Phenol	C_6H_6O	108-95-2	94.111	101,720	317.61				314.06	2.0147	425.00	2.3670
292	Phenyl isocyanate	C_7H_5NO	103-71-9	119.121	60,834	215.89	0.29552			243.15	1.3080	489.75	2.3745
293	Phthalic anhydride	$C_8H_4O_3$	85-44-9	148.116	145,400	252.4				404.15	2.4741	557.65	2.8615
294	Propadiene	C_3H_4	463-49-0	40.064	66,230	98.275				200.00	0.8589	238.65	0.8968
295	Propane [use Eq. (2)]	C_3H_8	74-98-6	44.096	62.983	113,630	633.21	–873.46		85.47	0.8488	360.00	2.6079
296	1-Propanol	C_3H_8O	71-23-8	60.095	158,760	–635	1.969			146.95	1.0797	400.00	2.1980
297	2-Propanol	C_3H_8O	67-63-0	60.095	471,710	–4,172.1	14.745	–0.0144		185.26	1.1329	355.30	2.0487
298	Propenylcyclohexene	C_9H_{14}	13511-13-2	122.207	201,400	–450.6	1.7053			199.00	1.7926	431.65	3.2463
299	Propionaldehyde	C_3H_6O	123-38-6	58.079	99,306	115.73				200.00	1.2245	328.75	1.3735

TABLE 2-153 Heat Capacities of Inorganic and Organic Liquids [J/(kmol·K)] (*Concluded*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	C5	T_{min}, K	C_p at T_{min} ×1E-05	T_{max}, K	C_p at T_{max} ×1E-05
300	Propionic acid	$C_3H_6O_2$	79-09-4	74.079	213,660	−702.7	1.6605			252.45	1.4209	414.32	2.0756
301	Propionitrile	C_3H_5N	107-12-0	55.079	118,190	−120.98	0.42075			180.26	1.1005	370.50	1.3112
302	Propyl acetate	$C_5H_{10}O_2$	109-60-4	102.132	83,400	384.1				274.70	1.8891	404.70	2.3885
303	Propyl amine	C_3H_9N	107-10-8	59.110	139,530	78				188.36	1.5422	340.00	1.6605
304	Propylbenzene	C_9H_{12}	103-65-1	120.192	174,380	−101.8	0.79			173.55	1.8051	432.39	2.7806
305	Propylene	C_3H_6	115-07-1	42.080	114,140	−343.72	1.0905			87.89	0.9235	225.45	0.9208
306	Propyl formate	$C_4H_8O_2$	110-74-7	88.105	75,700	326.1				298.15	1.7293	398.15	2.0554
307	2-Propyl mercaptan	C_3H_8S	75-33-2	76.161	138,390	−117.11	0.47059			142.61	1.3126	350.00	1.5505
308	Propyl mercaptan	C_3H_8S	107-03-9	76.161	167,330	−319.1	0.8127			159.95	1.3708	340.87	1.5299
309	1,2-Propylene glycol	$C_3H_8O_2$	57-55-6	76.094	58,080	445.2				213.15	1.5297	460.75	2.6321
310	Quinone	$C_6H_4O_2$	106-51-4	108.095	45,810	368.33				388.85	1.8904	683.00	2.9738
311	Silicon tetrafluoride	F_4Si	7783-61-1	104.079	829,380	−7,331.5	19.203			186.35	1.3000	253.15	2.0403
312	Styrene	C_8H_8	100-42-5	104.149	113,340	290.2	−0.6051	0.0013567		242.54	1.6749	418.31	2.2816
313	Succinic acid	$C_4H_6O_4$	110-15-6	118.088	244,770	−236.96	0.63148			460.65	2.6961	604.50	3.3228
314	Sulfur dioxide	O_2S	7446-09-5	64.064	85,743	5.7443				197.67	0.8688	350.00	0.8775
315	Sulfur hexafluoride	F_6S	2551-62-4	146.055	119,500					230.15	1.1950	230.15	1.1950
316	Sulfur trioxide	O_3S	7446-11-9	80.063	258,090					303.15	2.5809	303.15	2.5809
317	Terephthalic acid	$C_8H_6O_4$	100-21-0	166.131									
318	*o*-Terphenyl	$C_{18}H_{14}$	84-15-1	230.304	182,900	635.09				329.35	3.9207	609.15	5.6977
319	Tetradecane	$C_{14}H_{30}$	629-59-4	198.388	353,140	29.13	0.86116			279.01	4.2831	526.73	6.0741
320	Tetrahydrofuran	C_4H_8O	109-99-9	72.106	171,730	−800.47	2.8934	−0.0025015		164.65	1.0721	339.12	1.3546
321	1,2,3,4-Tetrahydronaphthalene	$C_{10}H_{12}$	119-64-2	132.202	81,760	455.38				237.38	1.8986	480.77	3.0069
322	Tetrahydrothiophene	C_4H_8S	110-01-0	88.171	123,300	−130.1	0.6229			176.98	1.1979	394.27	1.6883
323	2,2,3,3-Tetramethylbutane	C_8H_{18}	594-82-1	114.229	43,326	630.73				375.41	2.8011	426.00	3.1202
324	Thiophene	C_4H_4S	110-02-1	84.140	84,864	91.725	0.13243			234.94	1.1372	357.31	1.3455
325	Toluene	C_7H_8	108-88-3	92.138	140,140	−152.3	0.695			178.18	1.3507	500.00	2.3774
326	1,1,2-Trichloroethane	$C_2H_3Cl_3$	79-00-5	133.404	103,350	159.3				236.50	1.4102	300.00	1.5114
327	Tridecane	$C_{13}H_{28}$	629-50-5	184.361	350,180	−104.7	1.0022			267.76	3.9400	508.62	5.5619
328	Triethyl amine	$C_6H_{15}N$	121-44-8	101.190	111,480	368.13				200.00	1.8511	361.92	2.4471
329	Trimethyl amine	C_3H_9N	75-50-3	59.110	136,050	−288	0.9913			156.08	1.1525	276.02	1.3208
330	1,2,3-Trimethylbenzene	C_9H_{12}	526-73-8	120.192	119,450	324.54				247.79	1.9987	449.27	2.6526
331	1,2,4-Trimethylbenzene	C_9H_{12}	95-63-6	120.192	178,800	−128.47	0.83741			229.33	1.9338	350.00	2.3642
332	2,2,4-Trimethylpentane	C_8H_{18}	540-84-1	114.229	95,275	696.7	−1.3765	0.0021734		165.78	1.8285	520.00	3.9095
333	2,3,3-Trimethylpentane	C_8H_{18}	560-21-4	114.229	388,620	−1,439.5	3.2187			280.00	2.3791	320.00	2.5757
334	1,3,5-Trinitrobenzene	$C_6H_3N_3O_6$	99-35-4	213.105	40,364	664.46				398.40	3.0508	475.47	3.5629
335	2,4,6-Trinitrotoluene	$C_7H_5N_3O_6$	118-96-7	227.131	133,530	514.64				354.00	3.1571	475.00	3.7798
336	Undecane	$C_{11}H_{24}$	1120-21-4	156.308	293,980	−114.98	0.96936			247.57	3.2493	433.42	4.2624
337	1-Undecanol	$C_{11}H_{24}O$	112-42-5	172.308	129,450	−3,039.5	27.927	−0.061847	4.3042E-05	289.05	3.9103	520.30	5.5127
338	Vinyl acetate	$C_4H_6O_2$	108-05-4	86.089	136,300	−106.17	0.75175			259.56	1.5939	389.35	2.0892
339	Vinyl acetylene	C_4H_4	689-97-4	52.075	68,720	135				200.00	0.9572	278.25	1.0628
340	Vinyl chloride	C_2H_3Cl	75-01-4	62.498	−10,320	322.8				200.00	0.5424	400.00	1.1880
341	Vinyl trichlorosilane	$C_2H_3Cl_3Si$	75-94-5	161.490	49,516	420.35				178.35	1.2449	363.85	2.0246
342	Water	H_2O	7732-18-5	18.015	276,370	−2,090.1	8.125	−0.014116	9.3701E-06	273.16	0.7615	533.15	0.8939
343	*m*-Xylene	C_8H_{10}	108-38-3	106.165	133,860	7.8754	0.52265			217.00	1.6018	540.15	2.9060
344	*o*-Xylene	C_8H_{10}	95-47-6	106.165	36,500	1,017.5	−2.63	0.00302		247.98	1.7314	417.58	2.2269
345	*p*-Xylene	C_8H_{10}	106-42-3	106.165	−35,500	1,287.2	−2.599	0.002426		286.41	1.7697	600.00	3.2520

For the 11 substances, ammonia, 1,2-butanediol, 1,3-butanediol, carbon monoxide, 1,1-difluoroethane, ethane, heptane, hydrogen, hydrogen sulfide, methane, and propane, the liquid heat capacity C_{pL} is calculated with Eq. (2) below. For all other compounds, Eq. (1) is used. For benzene, fluorine, and helium, two sets of constants are given for Eq. (1) that cover different temperature ranges, as shown in the table.

(1) $$C_{pL} = C1 + C2T + C3T^2 + C4T^3 + C4T^4$$

(2) $$C_{pL} = \frac{C1^2}{t} + C2 - 2C1C3t - C1C4t^2 - \frac{C3^2t^3}{3} - \frac{C3C4t^4}{2} - \frac{C4^2t^5}{5}$$

where $t = 1 - T_r$, $T_r = T/T_c$, T_c is the critical temperature from Table 2-141, C_{pL} is in J/(kmol·K) and T is in K. All substances are listed by chemical family in Table 2-6 and by formula in Table 2-7. For temperatures less than the normal boiling point, the pressure is 1 atm. Above the normal boiling point, the pressure is the vapor pressure.

The number of digits provided for values at T_{min} and T_{max} was chosen for uniformity of appearance and formatting; these do not represent the uncertainties of the physical quantities, but are the result of calculations from the standard thermophysical property formulations within a fixed format.

TABLE 2-154 Specific Heats of Organic Solids
Recalculated from *International Critical Tables*, vol. 5, pp. 101–105

Compound	Formula	Temperature, °C	sp ht, cal/(g·°C)
Acetic acid	$C_2H_4O_2$	–200 to +25	0.330 + 0.00080*t*
Acetone	C_3H_6O	–210 to –80	0.540 + 0.0156*t*
Aminobenzoic acid (*o*-)	$C_7H_7NO_2$	85 to mp	0.254 + 0.00136*t*
(*m*-)	$C_7H_7NO_2$	120 to mp	0.253 + 0.00122*t*
(*p*-)	$C_7H_7NO_2$	128 to mp	0.287 + 0.00088*t*
Aniline	C_6H_7N		0.741
Anthracene	$C_{14}H_{10}$	50	0.308
		100	0.350
		150	0.382
Anthraquinone	$C_{14}H_8O_2$	0 to 270	0.258 + 0.00069*t*
Apiol	$C_{12}H_{14}O_4$	10	0.299
Azobenzene	$C_{12}H_{10}N_2$	28	0.330
Benzene	C_6H_6	–250	0.0399
		–225	0.0908
		–200	0.124
		–150	0.170
		–100	0.227
		–50	0.299
		0	0.375
Benzoic acid	$C_7H_6O_2$	20 to mp	0.287 + 0.00050*t*
Benzophenone	$C_{13}H_{10}O$	–150	0.115
		–100	0.172
		–50	0.220
		0	0.275
		+20	0.303
Betol	$C_{17}H_{12}O_3$	–150	0.129
		–100	0.167
		0	0.248
		+50	0.308
Bromoiodobenzene (*o*-)	C_6H_4BrI	–50 to 0	0.143 + 0.00025*t*
(*m*-)	C_6H_4BrI	–75 to –15	0.143
(*p*-)	C_6H_4BrI	–40 to 50	0.116 + 0.00032*t*
Bromonaphthalene (β-)	$C_{10}H_7Br$	41	0.260
Bromophenol	C_6H_5BrO	32	0.263
Camphene	$C_{10}H_{16}$	35	0.380
Capric acid	$C_{10}H_{20}O_2$	8	0.695
Caprylic acid	$C_8H_{16}O_2$	–2	0.628
Carbon tetrachloride	CCl_4	–240	0.013
		–200	0.081
		–160	0.131
		–120	0.162
		–80	0.182
		–40	0.201
Cerotic acid	$C_{27}H_{54}O_2$	15	0.387
Chloral alcoholate	$C_4H_7Cl_3O_2$	78	0.509
hydrate	$C_2H_3Cl_3O_2$	32	0.213
Chloroacetic acid	$C_2H_3ClO_2$	60	0.363
Chlorobenzoic acid (*o*-)	$C_7H_5ClO_2$	80 to mp	0.228 + 0.00084*t*
(*m*-)	$C_7H_5ClO_2$	94 to mp	0.232 + 0.00073*t*
(*p*-)	$C_7H_5ClO_2$	180 to mp	0.242 + 0.00055*t*
Chlorobromobenzene (*o*-)	C_6H_4BrCl	–34	0.192
(*m*-)	C_6H_4BrCl	–52	0.150
(*p*-)	C_6H_4BrCl	–40	0.150
Crotonic acid	$C_4H_6O_2$	38 to 70	0.520 + 0.00020*t*
Cyamelide	$C_3H_3N_3O_3$	40	0.263
Cyanamide	CH_2N_2	20	0.547
Cyanuric acid	$C_3H_3N_3O_3$	40	0.318
Dextrin	$(C_6H_{10}O_5)x$	0 to 90	0.291 + 0.00096*t*
Dextrose	$C_6H_{12}O_6$	–250	0.016
		–200	0.077
		–100	0.160
		0	0.277
		20	0.300
Dibenzyl	$C_{14}H_{14}$	28	0.363
Dibromobenzene (*o*-)	$C_6H_4Br_2$	–36	0.248
(*m*-)	$C_6H_4Br_2$	–25	0.134
(*p*-)	$C_6H_4Br_2$	–50 to +50	0.139 + 0.00038*t*
Dichloroacetic acid	$C_2H_2Cl_2O_2$		0.406
Dichlorobenzene (*o*-)	$C_6H_4Cl_2$	–48.5	0.185
(*m*-)	$C_6H_4Cl_2$	–52	0.186
(*p*-)	$C_6H_4Cl_2$	–50 to +53	0.219 + 0.0021*t*
Dicyandiamide	$C_2H_4N_4$	0 to 204	0.456

TABLE 2-154 Specific Heats of Organic Solids (*Continued*)
Recalculated from *International Critical Tables,* vol. 5, pp. 101–105

Compound	Formula	Temperature, °C	sp. ht., cal/(g·°C)
Dihydroxybenzene (*o*-)	$C_6H_6O_2$	−163 to mp	0.278 + 0.00098*t*
(*m*-)	$C_6H_6O_2$	−160 to mp	0.269 + 0.00118*t*
(*p*-)	$C_6H_6O_2$	−250	0.025
		−240	0.038
		−220	0.061
		−200	0.081
		−150 to mp	0.268 + 0.00093*t*
Di-iodobenzene (*o*-)	$C_6H_4I_2$	−50 to +15	0.109 + 0.00026*t*
(*m*-)	$C_6H_4I_2$	−52 to −42	0.100 + 0.00026*t*
(*p*-)	$C_6H_4I_2$	−50 to +80	0.101 + 0.00026*t*
Dimethyl oxalate	$C_4H_6O_4$	10 to 50	0.212 + 0.0044*t*
Dimethylpyrene	$C_7H_8O_2$	50	0.368
Dinitrobenzene (*o*-)	$C_6H_4N_2O_4$	−160 to mp	0.252 + 0.00083*t*
(*m*-)	$C_6H_4N_2O_4$	−160 to mp	0.248 + 0.00077*t*
(*p*-)	$C_6H_4N_2O_4$	119 to mp	0.259 + 0.00057*t*
Diphenyl	$C_{12}H_{10}$	40	0.385
Diphenylamine	$C_{12}H_{11}N$	26	0.337
Dulcitol	$C_6H_{14}O_6$	20	0.282
Erythritol	$C_4H_{10}O_4$	60	0.351
Ethyl alcohol	C_2H_6O (crystalline)	−190	0.232
		−180	0.248
		−160	0.282
		−140	0.318
		−130	0.376
	(vitreous)	−190	0.260
		−180	0.296
		−175	0.380
		−170	0.399
Ethylene glycol	$C_2H_6O_2$	−190 to −40	0.366 + 0.00110*t*
Formic acid	CH_2O_2	−22	0.387
		0	0.430
Glutaric acid	$C_5H_8O_4$	20	0.299
Glycerol	$C_3H_8O_3$	−265	0.009
		−260	0.022
		−250	0.047
		−220	0.085
		−200	0.115
		−100	0.217
		0	0.330
Hexachloroethane	C_2Cl_6	25	0.174
Hexadecane	$C_{16}H_{34}$		0.495
Hydroxyacetanilide	$C_8H_9NO_2$	41 to mp	0.249 + 0.00154*t*
Iodobenzene	C_6H_5I	40	0.191
Isopropyl alcohol	C_3H_8O	−200 to −160	0.051 + 0.00165*t*
Lactose	$C_{12}H_{22}O_{11}$	20	0.287
	$C_{12}H_{22}O_{11}·H_2O$	20	0.299
Lauric acid	$C_{12}H_{24}O_2$	−30 to +40	0.430 + 0.000027*t*
Levoglucosane	$C_6H_{10}O_5$	40	0.607
Levulose	$C_6H_{12}O_6$	20	0.275
Malonic acid	$C_3H_4O_4$	20	0.275
Maltose	$C_{12}H_{22}O_{11}$	20	0.320
Mannitol	$C_6H_{14}O_6$	0 to 100	0.313 + 0.00025*t*
Melamine	$C_3H_6N_6$	40	0.351
Myristic acid	$C_{14}H_{28}O_2$	0 to 35	0.381 + 0.00545*t*
Naphthalene	$C_{10}H_8$	−130 to mp	0.281 + 0.00111*t*
Naphthol (α-)	$C_{10}H_8O$	50 to mp	0.240 + 0.00147*t*
(β-)	$C_{10}H_8O$	61 to mp	0.252 + 0.00128*t*
Naphthylamine (α-)	$C_{10}H_9N$	0 to 50	0.270 + 0.0031*t*
Nitroaniline (*o*-)	$C_6H_6N_2O_2$	−160 to mp	0.269 + 0.000920*t*
(*m*-)	$C_6H_6N_2O_2$	−160 to mp	0.275 + 0.000946*t*
(*p*-)	$C_6H_6N_2O_2$	−160 to mp	0.276 + 0.001000*t*
Nitrobenzoic acid (*o*-)	$C_7H_5NO_4$	−163 to mp	0.256 + 0.00085*t*
(*m*-)	$C_7H_5NO_4$	66 to mp	0.258 + 0.00091*t*
(*p*-)	$C_7H_5NO_4$	−160 to mp	0.247 + 0.00077*t*
Nitronaphthalene	$C_{10}H_7NO_2$	0 to 55	0.236 + 0.00215*t*

TABLE 2-154 Specific Heats of Organic Solids (*Concluded*)
Recalculated from *International Critical Tables*, vol. 5, pp. 101–105

Compound	Formula	Temperature, °C	sp ht, cal/(g·°C)
Oxalic acid	$C_2H_2O_4$	−200 to +50	$0.259 + 0.00076t$
	$C_2H_2O_4.2H_2O$	−200	0.117
		−100	0.239
		0	0.338
		+50	0.385
		100	0.416
Palmitic acid	$C_{16}H_{32}O_2$	−180	0.167
		−140	0.208
		−100	0.251
		−50	0.306
		0	0.382
		+20	0.430
Phenol	C_6H_6O	14 to 26	0.561
Phthalic acid	$C_8H_6O_4$	20	0.232
Picric acid	$C_6H_3N_3O_7$	−100	0.165
		0	0.240
		+50	0.263
		100	0.297
		120	0.332
Propionic acid	$C_3H_6O_2$	−33	0.726
Propyl alcohol (*n*-)	C_3H_8O	−200	0.170
		−175	0.363
		−150	0.471
		−130	0.497
Pyrotartaric acid	$C_6H_8O_4$	20	0.301
Quinhydrone	$C_{12}H_{10}O_4$	−250	0.017
		−225	0.061
		−200	0.098
		−100	0.191
		0	0.256
Quinone	$C_6H_4O_2$	−250	0.031
		−225	0.082
		−200	0.113
		−150 to mp	$0.282 + 0.00083t$
Salol	$C_{13}H_{10}O_3$	32	0.289
Stearic acid	$C_{18}H_{36}O_2$	15	0.399
Succinic acid	$C_4H_6O_4$	0 to 160	$0.248 + 0.00153t$
Sucrose	$C_{12}H_{22}O_{11}$	20	0.299
Sugar (cane)	$C_{12}H_{22}O_{11}$	22 to 51	0.301
Tartaric acid	$C_4H_6O_6$	36	0.287
Tartaric acid	$C_4H_6O_6{\cdot}H_2O$	−150	0.112
		−100	0.170
		−50	0.231
		0	0.308
		+50	0.366
Tetrachloroethylene	C_2Cl_4	−40 to 0	$0.198 + 0.00018t$
Tetryl	$C_7H_5N_5O_8$	−100	0.182
		−50	0.199
		0	0.212
		+100	0.236
1 Tetryl + 1 picric acid	$C_{13}H_8N_8O_{15}$	−100 to +100	$0.253 + 0.00072t$
1 Tetryl + 2 TNT	$C_{21}H_{15}N_{11}O_{20}$	−100	0.172
		0	0.280
		+50	0.325
Thymol	$C_{10}H_{14}O$	0 to 49	$0.315 + 0.0031t$
Toluic acid (*o*-)	$C_8H_8O_2$	54 to mp	$0.277 + 0.00120t$
(*m*-)	$C_8H_8O_2$	54 to mp	$0.239 + 0.00195t$
(*p*-)	$C_8H_8O_2$	130 to mp	$0.271 + 0.00106t$
Toluidine (*p*-)	C_7H_9N	0	0.337
		20	0.387
		40	0.440
Trichloroacetic acid	$C_2HCl_3O_2$	solid	0.459
Trimethyl carbinol	$C_4H_{10}O$	−4	0.559
Trinitrotoluene	$C_7H_5N_3O_6$	−100	0.170
		−50	0.253
		0	0.311
		+100	0.385
Trinitroxylene	$C_8H_7N_3O_6$	−185 to +23	0.241
		20 to 50	0.423
Triphenylmethane	$C_{19}H_{16}$	0 to 91	$0.189 + 0.0027t$
Urea	CH_4N_2O	20	0.320

TABLE 2-155 Heat Capacity at Constant Pressure of Inorganic and Organic Compounds in the Ideal Gas State Fit to a Polynomial *Cp* [J/(kmol·K)]

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4 × 1E 05	C5 × 1E 10	T_{min}, K	C_p at T_{min} × 1E-05	T_{max}, K	C_p at T_{max} × 1E-05
1	Acetaldehyde	C_2H_4O	75-07-0	44.053	29,705	127.43	–0.21793			50	0.3553	200	0.4647
7	Acetylene	C_2H_2	74-86-2	26.037	30,800	–53.08	0.384			50	0.2911	200	0.3554
8	Acrolein	C_3H_4O	107-02-8	56.063	30,702	80.95	0.191			50	0.3523	200	0.5453
14	Argon	Ar	7440-37-1	39.948	20,786	0	0			100	0.2079	1,500	0.2079
16	Benzene	C_6H_6	71-43-2	78.112	35,978	–101.69	0.939			50	0.3324	200	0.5320
27	Bromoethane	C_2H_5Br	74-96-4	108.965	27,112	117.99	0			100	0.3891	200	0.5071
29	1,2-Butadiene	C_4H_6	590-19-2	54.090	27,400	177.6	0			50	0.3628	200	0.6292
31	Butane	C_4H_{10}	106-97-8	58.122	17,330	458.16	–0.816			50	0.3820	200	0.7632
34	1-Butanol	$C_4H_{10}O$	71-36-3	74.122	25,300	371.2	–0.461			50	0.4271	200	0.8110
37	*cis*-2-Butene	C_4H_8	590-18-1	56.106	39,760	108.8	0			50	0.4520	200	0.6152
38	*trans*-2-Butene	C_4H_8	624-64-6	56.106	20,908	324.73	–0.411			50	0.3612	200	0.6941
43	1-Butyne	C_4H_6	107-00-6	54.090	25,300	183.2	0			50	0.3446	200	0.6194
59	*m*-Cresol	C_7H_8O	108-39-4	108.138	29,002	158.79	0.635			50	0.3853	200	0.8616
60	*o*-Cresol	C_7H_8O	95-48-7	108.138	16,192	469.81	–0.479			50	0.3849	200	0.9099
61	*p*-Cresol	C_7H_8O	106-44-5	108.138	29,090	166	0.616			50	0.3893	200	0.8693
64	Cyclobutane	C_4H_8	287-23-0	56.106	31,863	37.226	0.23616			50	0.3432	200	0.4876
67	Cyclohexanone	$C_6H_{10}O$	108-94-1	98.143	32,182	116.87	0.547			50	0.3939	200	0.7744
81	1,1-Dibromoethane	$C_2H_4Br_2$	557-91-5	187.861	20,560	285.2	–0.332			100	0.4576	200	0.6432
88	1,1-Dichloroethane	$C_2H_4Cl_2$	75-34-3	98.959	19,560	249.01	–0.22187			100	0.4224	200	0.6049
95	Diethyl ether	$C_4H_{10}O$	60-29-7	74.122	26,040	388	–0.268			50	0.4477	200	0.9292
97	1,1-Difluoroethane	$C_2H_4F_2$	75-37-6	66.050	29,736	72.364	0.228			50	0.3392	200	0.5333
98	1,2-Difluoroethane	$C_2H_4F_2$	624-72-6	66.050	27,581	169.88	–0.1581			50	0.3568	200	0.5523
99	Difluoromethane	CH_2F_2	75-10-5	52.023	33,851	–20.966	0.17584			50	0.3324	200	0.3669
112	Dimethyl ether	C_2H_6O	115-10-6	46.068	25,940	178.46	–0.186			50	0.3440	200	0.5419
120	1,4-Dioxane	$C_4H_8O_2$	123-91-1	88.105	28,345	88.3	0.446			50	0.3388	200	0.6385
125	Ethane	C_2H_6	74-84-0	30.069	31,742	26.567	0.12927			50	0.3339	200	0.4223
126	Ethanol	C_2H_6O	64-17-5	46.068	32,585	87.4	0.05			50	0.3708	200	0.5207
134	Ethylcyclopentane	C_7H_{14}	1640-89-7	98.186	34,710	304.96	–0.084			50	0.4975	200	0.9234
145	Ethyl mercaptan	C_2H_6S	75-08-1	62.134	23,014	271.36	–0.4427			50	0.3548	200	0.5958
151	Fluoroethane	C_2H_5F	353-36-6	48.060	30,358	62.839	0.1067			50	0.3377	200	0.4719
156	Furan	C_4H_4O	110-00-9	68.074	40,860	–160.3	0.87			100	0.3353	200	0.4360
157	Helium-4	He	7440-59-7	4.003	20,786	0	0			100	0.2079	1,500	0.2079
182	Hydrazine	H_4N_2	302-01-2	32.045	32,998	–5.2147	0.21379			50	0.3327	200	0.4051
183	Hydrogen	H_2	1333-74-0	2.016	64,979	–788.17	5.8287	–1845.9	216400	50	0.3797	250	0.2834
190	Isopropyl amine	C_3H_9N	75-31-0	59.110	23,590	310.42	–0.274			50	0.3843	200	0.7471
194	Methanol	CH_4O	67-56-1	32.042	30,270	84.64	–0.188			50	0.3403	200	0.3968
197	Methyl acetylene	C_3H_4	74-99-7	40.064	30,810	35.8	0.27			50	0.3328	200	0.4877
217	Methylcyclopentane	C_6H_{12}	96-37-7	84.159	35,465	147.38	0.242			50	0.4344	200	0.7462
221	Methylethyl ether	C_3H_8O	540-67-0	60.095	23,337	309.03	–0.285			50	0.3808	200	0.7374
231	Methyl mercaptan	CH_4S	74-93-1	48.107	31,520	60.1	0			50	0.3453	200	0.4354
236	2-Methylpropane	C_4H_{10}	75-28-5	58.122	21,380	271.2	–0.092			50	0.3471	200	0.7194

237	2-Methyl-2-propanol	$C_4H_{10}O$	75-65-0	74.122	17,080	381.7	–0.199			50	0.3567	200	0.8546
238	2-Methyl propene	C_4H_8	115-11-7	56.106	24,970	211.8	0			50	0.3556	200	0.6733
243	alpha-Methyl styrene	C_9H_{10}	98-83-9	118.176	37,735	112.94	0.846			50	0.4550	200	0.9416
246	Naphthalene	$C_{10}H_8$	91-20-3	128.171	29,120	82.88	0.964			50	0.3567	200	0.8426
247	Neon	Ne	7440-01-9	20.180	20,786	0	0			100	0.2079	1,500	0.2079
248	Nitroethane	$C_2H_5NO_2$	79-24-3	75.067	33,055	89.54	0.238			50	0.3813	200	0.6048
251	Nitromethane	CH_3NO_2	75-52-5	61.040	38,782	–48.39	0.413			50	0.3740	200	0.4562
253	Nitric oxide	NO	10102-43-9	30.006	34,980	–35.32	0.07729	–5.7357	0.0014526	100	0.3217	1,500	0.3586
289	2-Pentyne	C_5H_8	627-21-4	68.117	24,330	335.7	–0.37			50	0.4019	200	0.7667
290	Phenanthrene	$C_{14}H_{10}$	85-01-8	178.229	27,700	210	1.24			50	0.4130	200	1.1930
294	Propadiene	C_3H_4	463-49-0	40.064	31,690	17.1	0.282			50	0.3325	200	0.4639
295	Propane	C_3H_8	74-98-6	44.096	26,675	147.04	0			50	0.3403	200	0.5608
296	1-Propanol	C_3H_8O	71-23-8	60.095	28,800	257	-0.35			50	0.4078	200	0.6620
304	Propylbenzene	C_9H_{12}	103-65-1	120.192	22,880	538.46	-0.546			50	0.4844	200	1.0873
310	Quinone	$C_6H_4O_2$	106-51-4	108.095	29,668	129.07	0.53105			50	0.3745	200	0.7672
320	Tetrahydrofuran	C_4H_8O	109-99-9	72.106	36,970	–12.28	0.444			50	0.3747	200	0.5227
321	1,2,3,4-Tetrahydronaphthalene	$C_{10}H_{12}$	119-64-2	132.202	28,560	225.1	0.616			50	0.4136	200	0.9822
322	Tetrahydrothiophene	C_4H_8S	110-01-0	88.171	41,195	–88.3	0.942			50	0.3914	200	0.6122
324	Thiophene	C_4H_4S	110-02-1	84.140	36,765	–112.82	0.862			50	0.3328	200	0.4868
331	1,2,4-Trimethylbenzene	C_9H_{12}	95-63-6	120.192	35,652	323.89	0.305			50	0.5261	200	1.1263

Constants in this table can be used in the following equation to calculate the ideal gas heat capacity C_p^0.

$$C_p^0 = C1 + C2T + C3T^2 + C4T^3 + C5T^4$$

where C_p^0 is in J/(kmol·K) and T is in K. All substances are listed by chemical family in Table 2-6 and by formula in Table 2-7.

Values in this table were taken from the Design Institute for Physical Properties (DIPPR) of the American Institute of Chemical Engineers (AIChE), copyright 2007 AIChE and reproduced with permission of AICHE and of the DIPPR Evaluated Process Design Data Project Steering Committee. Their source should be cited as R. L. Rowley, W. V. Wilding, J. L. Oscarson, Y. Yang, N. A. Zundel, T. E. Daubert, R. P. Danner, DIPPR® Data Compilation of Pure Chemical Properties, Design Institute for Physical Properties, AIChE, New York (2007).

The number of digits provided for values at T_{min} and T_{max} was chosen for uniformity of appearance and formatting; these do not represent the uncertainties of the physical quantities, but are the result of calculations from the standard thermophysical property formulations within a fixed format.

TABLE 2-156 Heat Capacity at Constant Pressure of Inorganic and Organic Compounds in the Ideal Gas State Fit to Hyperbolic Functions C_p [J/(kmol·K)]

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1 ×1E-05	C2 ×1E-05	C3 ×1E-03	C4 ×1E-05	C5	T_{min}, K	C_p at T_{min} ×1E-05	T_{max}, K	C_p at T_{max} ×1E-05
1	Acetaldehyde	C_2H_4O	75-07-0	44.053	0.4451	1.0687	1.6141	0.6135	737.8	200	0.4660	1500	1.2994
2	Acetamide	C_2H_5NO	60-35-5	59.067	0.342	1.294	1.075	0.64	502	100	0.3448	1500	1.4997
3	Acetic acid	$C_2H_4O_2$	64-19-7	60.052	0.402	1.3675	1.262	0.7003	569.7	50	0.4020	1500	1.5756
4	Acetic anhydride	$C_4H_6O_3$	108-24-7	102.089	0.713	2.222	1.6203	1.676	746.5	200	0.7665	1500	2.5675
5	Acetone	C_3H_6O	67-64-1	58.079	0.5704	1.632	1.607	0.968	731.5	200	0.6049	1500	1.8820
6	Acetonitrile	C_2H_3N	75-05-8	41.052	0.41914	0.8876	1.5818	0.5032	699.8	100	0.4192	1500	1.1285
7	Acetylene	C_2H_2	74-86-2	26.037	0.3199	0.5424	1.594	0.4325	607.1	200	0.3566	1500	0.7575
8	Acrolein	C_3H_4O	107-02-8	56.063	0.48449	1.2546	1.3979	0.87243	633.26	200	0.5467	1500	1.5620
9	Acrylic acid	$C_3H_4O_2$	79-10-7	72.063	0.6059	1.3703	1.6475	1.0446	751.49	250	0.6984	1500	1.7424
10	Acrylonitrile	C_3H_3N	107-13-1	53.063	0.4678	1.0366	1.3998	0.6536	629.35	200	0.5156	1500	1.3464
11	Air	Mixture	132259-10-0	28.960	0.28958	0.0939	3.012	0.0758	1484	50	0.2896	1500	0.3496
12	Ammonia	H_3N	7664-41-7	17.031	0.33427	0.4898	2.036	0.2256	882	100	0.3343	1500	0.6647
13	Anisole	C_7H_8O	100-66-3	108.138	0.7637	2.9377	1.6051	2.17	751.2	300	1.1302	1200	3.0226
15	Benzamide	C_7H_7NO	55-21-0	121.137	1.9581	1.7019	1.3257	−37.417	41.232	298.15	1.2745	1500	3.2501
16	Benzene	C_6H_6	71-43-2	78.112	0.44767	2.3085	1.4792	1.6836	677.66	200	0.5358	1500	2.4157
17	Benzenethiol	C_6H_6S	108-98-5	110.177	0.6895	2.3275	1.512	1.7516	697.9	200	0.7689	1500	2.6739
18	Benzoic acid	$C_7H_6O_2$	65-85-0	122.121	0.77594	2.6455	1.7925	2.2382	835.9	200	0.8126	1500	2.9712
19	Benzonitrile	C_7H_5N	100-47-0	103.121	0.7186	2.27	1.4669	1.693	680.77	200	0.8053	1500	2.6706
20	Benzophenone	$C_{13}H_{10}O$	119-61-9	182.218	1.0099	4.4898	1.311	2.8395	627.4	300	1.8001	1500	4.9311
21	Benzyl alcohol	C_9H_8O	100-51-6	108.138	0.84115	3.1428	1.9539	2.5743	850.06	298.15	1.1198	1500	3.2880
22	Benzyl ethyl ether	$C_9H_{12}O$	539-30-0	136.191	0.9521	2.8868	0.70207	1.6385	2002.6	300	1.5501	1500	4.3445
23	Benzyl mercaptan	C_7H_8S	100-53-8	124.203	0.99192	2.9633	1.5583	2.2116	719.16	300	1.4156	1200	3.2957
24	Biphenyl	$C_{12}H_{10}$	92-52-4	154.208	1.0759	4.2105	1.9041	4.1785	828.81	200	1.1481	1500	4.5557
25	Bromine	Br_2	7726-95-6	159.808	0.30113	0.08009	0.7514	0.1078	314.6	100	0.3090	1500	0.3794
26	Bromobenzene	C_6H_5Br	108-86-1	157.008	0.721	2.064	1.6504	1.687	765.3	200	0.7679	1500	2.4628
27	Bromoethane	C_2H_5Br	74-96-4	108.965	0.47191	1.2787	1.5957	0.85166	703.87	200	0.5089	1500	1.5121
28	Bromomethane	CH_3Br	74-83-9	94.939	0.3377	0.715	1.578	0.4175	691.4	100	0.3378	1500	0.9107
29	1,2-Butadiene	C_4H_6	590-19-2	54.090	0.575	1.6476	1.527	0.99	677.3	200	0.6269	1500	1.9202
30	1,3-Butadiene	C_4H_6	106-99-0	54.090	0.5095	1.705	1.5324	1.337	685.6	200	0.5756	1500	1.9555
31	Butane	C_4H_{10}	106-97-8	58.122	0.7134	2.43	1.63	1.5033	730.42	200	0.7673	1500	2.6602
32	1,2-Butanediol	$C_4H_{10}O_2$	584-03-2	90.121	1.0478	2.549	1.8776	1.875	833	298.15	1.2667	1500.1	3.0289
33	1,3-Butanediol	$C_4H_{10}O_2$	107-88-0	90.121	1.066	2.575	1.967	1.951	860.5	298.15	1.2679	1500.15	3.0311
34	1-Butanol	$C_4H_{10}O$	71-36-3	74.122	0.7454	2.5907	1.6073	1.732	712.4	200	0.8162	1500	2.8509
35	2-Butanol	$C_4H_{10}O$	78-92-2	74.122	0.90878	2.5508	1.893	1.852	832.13	298.15	1.1257	1500	2.8730
36	1-Butene	C_4H_8	106-98-9	56.106	0.64257	2.0618	1.6768	1.3324	757.06	250	0.7571	1500	2.2898
37	*cis*-2-Butene	C_4H_8	590-18-1	56.106	0.5765	2.115	1.6299	1.2872	739.1	200	0.6199	1500	2.2715
38	*trans*-2-Butene	C_4H_8	624-64-6	56.106	0.6592	2.07	1.6733	1.251	742.2	200	0.7004	1500	2.2904
39	Butyl acetate	$C_6H_{12}O_2$	123-86-4	116.158	1.1684	3.769	1.956	2.818	811.2	300	1.5358	1200	3.6724
40	Butylbenzene	$C_{10}H_{14}$	104-51-8	134.218	1.138	4.454	1.5507	3.0497	708.86	200	1.2659	1500	4.8435
41	Butyl mercaptan	$C_4H_{10}S$	109-79-5	90.187	0.92478	2.7795	1.6837	1.5974	758.68	200	0.9714	1500	3.1008
42	*sec*-Butyl mercaptan	$C_4H_{10}S$	513-53-1	90.187	0.92367	2.5166	1.6109	1.5641	739.2	200	0.9763	1500	2.9615
43	1-Butyne	C_4H_6	107-00-6	54.090	0.5587	1.6694	1.5328	1.07	656	200	0.6238	1500	1.9209
44	Butyraldehyde	C_4H_8O	123-72-8	72.106	0.89657	2.3731	1.9754	1.5866	904.13	200	0.9119	1500	2.6775
45	Butyric acid	$C_4H_8O_2$	107-92-6	88.105	1.488	1.3522	1.146	−678	6.98	298.15	1.1533	1500	2.5905
46	Butyronitrile	C_4H_7N	109-74-0	69.105	0.6906	1.9996	1.5494	1.3146	675	200	0.7607	1500	2.3273
47	Carbon dioxide	CO_2	124-38-9	44.010	0.2937	0.3454	1.428	0.264	588	50	0.2937	5000	0.6335
48	Carbon disulfide	CS_2	75-15-0	76.141	0.301	0.3338	0.896	0.2893	374.7	100	0.3100	1500	0.6148
49	Carbon monoxide	CO	630-08-0	28.010	0.29108	0.08773	3.0851	0.084553	1538.2	60	0.2911	1500	0.3521
50	Carbon tetrachloride	CCl_4	56-23-5	153.823	0.37582	0.7054	0.5121	0.485	236.1	100	0.4730	1500	1.0662
51	Carbon tetrafluoride	CF_4	75-73-0	88.004	0.92004	0.16446	1.0764	−5083.8	2.3486	298	0.6106	1500	1.0465
52	Chlorine	Cl_2	7782-50-5	70.906	0.29142	0.09176	0.949	0.1003	425	50	0.2914	1500	0.3793
53	Chlorobenzene	C_6H_5Cl	108-90-7	112.557	0.8011	2.31	2.157	2.046	897.6	200	0.8219	1500	2.5327
54	Chloroethane	C_2H_5Cl	75-00-3	64.514	0.4568	1.2967	1.5992	0.859	708.8	100	0.4569	1500	1.5112
55	Chloroform	$CHCl_3$	67-66-3	119.378	0.3942	0.6573	0.928	0.493	399.6	100	0.4048	1500	1.0063
56	Chloromethane	CH_3Cl	74-87-3	50.488	0.3409	0.7246	1.723	0.448	780.5	150	0.3424	1500	0.9097
57	1-Chloropropane	C_3H_7Cl	540-54-5	78.541	0.621	1.843	1.629	1.2337	724	200	0.6674	1500	2.1126
58	2-Chloropropane	C_3H_7Cl	75-29-6	78.541	0.61809	1.8023	1.5438	1.1893	685.93	200	0.6768	1500	2.1023
59	*m*-Cresol	C_7H_8O	108-39-4	108.138	0.7515	2.09	0.6666	1.212	2214	200	0.8701	1500	3.2075
60	*o*-Cresol	C_7H_8O	95-48-7	108.138	0.7988	2.853	1.4765	2.042	664.7	200	0.9158	1500	3.2163

61	*p*-Cresol	C_7H_8O	106-44-5	108.138	0.7384	2.908	1.4559	2.091	650.42	200	0.8707	1500	3.2102
62	Cumene	C_9H_{12}	98-82-8	120.192	1.081	3.7932	1.7505	3.0027	794.8	200	1.1480	1500	4.1808
63	Cyanogen	C_2N_2	460-19-5	52.035	0.3545	0.5015	1.057	0.452	396	100	0.3648	1500	0.8100
64	Cyclobutane	C_4H_8	287-23-0	56.106	0.44004	2.3074	1.6283	1.5571	744.9	200	0.4903	1500	2.3234
65	Cyclohexane	C_6H_{12}	110-82-7	84.159	0.432	3.735	1.192	1.635	530.1	100	0.4366	1500	3.6516
66	Cyclohexanol	$C_6H_{12}O$	108-93-0	100.159	0.9043	2.5771	0.7882	1.3068	1952.2	200	0.9648	1500	3.8251
67	Cyclohexanone	$C_6H_{10}O$	108-94-1	98.143	0.67384	3.2598	1.3955	2.0209	677.33	200	0.7802	1500	3.4743
68	Cyclohexene	C_6H_{10}	110-83-8	82.144	0.58171	3.1717	1.5435	2.1273	701.62	150	0.5978	1500	3.2132
69	Cyclopentane	C_5H_{10}	287-92-3	70.133	0.416	3.014	1.4617	1.8095	668.8	100	0.4165	1500	2.9298
70	Cyclopentene	C_5H_8	142-29-0	68.117	0.48074	2.5159	1.5803	1.7454	718.37	150	0.4918	1500	2.5619
71	Cyclopropane	C_3H_6	75-19-4	42.080	0.338	1.6894	1.6135	1.1768	722.8	100	0.3381	1500	1.7213
72	Cyclohexyl mercaptan	$C_6H_{12}S$	1569-69-3	116.224	0.54305	3.9962	1.3575	2.5623	618.54	300	1.2644	1200	3.7236
73	Decanal	$C_{10}H_{20}O$	112-31-2	156.265	1.9641	5.1412	1.8989	4.1278	862.51	200	2.0192	1500	6.0539
74	Decane	$C_{10}H_{22}$	124-18-5	142.282	1.672	5.353	1.6141	3.782	742	200	1.7967	1500	6.0932
75	Decanoic acid	$C_{10}H_{20}O_2$	334-48-5	172.265	0.24457	6.546	1.0899	4.8642	424	298.15	2.5232	1500	6.1099
76	1-Decanol	$C_{10}H_{22}O$	112-30-1	158.281	1.6984	5.392	1.568	3.938	720.5	200	1.8502	1500	6.2186
77	1-Decene	$C_{10}H_{20}$	872-05-9	140.266	1.7101	5.2089	1.7265	3.5935	782.92	298.15	2.2304	1500	5.8745
78	Decyl mercaptan	$C_{10}H_{22}S$	143-10-2	174.347	1.931	5.4815	1.6085	3.74	754.75	200	2.0434	1500	6.4613
79	1-Decyne	$C_{10}H_{18}$	764-93-2	138.250	1.5045	4.3794	1.3291	2.5557	632.01	298	2.1938	1500	5.2794
80	Deuterium	D_2	7782-39-0	4.032	0.3029	0.0975	2.515	–0.0275	368	100	0.3020	1500	0.3425
81	1,1-Dibromoethane	$C_2H_4Br_2$	557-91-5	187.861	0.5927	1.158	1.4931	0.8428	655.5	200	0.6442	1500	1.5673
82	1,2-Dibromoethane	$C_2H_4Br_2$	106-93-4	187.861	0.74906	1.2725	1.981	0.9437	845.2	200	0.7635	1500	1.7041
83	Dibromomethane	CH_2Br_2	74-95-3	173.835	0.391	0.648	1.194	0.42	501	100	0.3929	1500	0.9599
84	Dibutyl ether	$C_8H_{18}O$	142-96-1	130.228	1.6122	4.4777	1.6831	2.918	781.6	200	1.6841	1500	5.2145
85	*m*-Dichlorobenzene	$C_6H_4Cl_2$	541-73-1	147.002	0.7	2.0746	1.3664	1.5983	620.16	200	0.8245	1500	2.5161
86	*o*-Dichlorobenzene	$C_6H_4Cl_2$	95-50-1	147.002	0.6948	2.0804	1.3632	1.594	619.2	200	0.8198	1500	2.5161
87	*p*-Dichlorobenzene	$C_2H_4Cl_2$	106-46-7	147.002	0.6978	2.078	1.3635	1.5965	619.37	200	0.8228	1500	2.5175
88	1,1-Dichloroethane	$C_2H_4Cl_2$	75-34-3	98.959	0.5521	1.205	1.502	0.8719	653.5	200	0.6061	1500	1.5615
89	1,2-Dichloroethane	$C_2H_4Cl_2$	107-06-2	98.959	0.65271	1.1254	1.7376	0.878	795.45	200	0.6722	1500	1.5743
90	Dichloromethane	CH_2Cl_2	75-09-2	84.933	0.3628	0.6804	1.256	0.4275	548	100	0.3637	1500	0.9543
91	1,1-Dichloropropane	$C_3H_6Cl_2$	78-99-9	112.986	0.7145	1.7344	1.524	1.223	674.2	150	0.7268	1500	2.1609
92	1,2-Dichloropropane	$C_3H_6Cl_2$	78-87-5	112.986	0.78658	1.7429	1.7157	1.2627	765.1	200	0.8217	1500	2.1894
93	Diethanol amine	$C_4H_{11}NO_2$	111-42-2	105.136	1.208	3.066	2.089	2.343	891	298.15	1.4197	1500.1	3.4674
94	Diethyl amine	$C_4H_{11}N$	109-89-7	73.137	0.9102	2.674	1.719	1.7926	794.94	200	0.9502	1500	3.0519
95	Diethyl ether	$C_4H_{10}O$	60-29-7	74.122	0.8621	2.551	1.5413	1.437	688.9	200	0.9316	1500	2.9244
96	Diethyl sulfide	$C_4H_{10}S$	352-93-2	90.187	0.91273	2.41	1.6686	1.652	771.08	200	0.9567	1500	2.8724
97	1,1-Difluoroethane	$C_2H_4F_2$	75-37-6	66.050	0.49653	1.2546	1.5394	0.87561	694.17	200	0.5373	1500	1.5424
98	1,2-Difluoroethane	$C_2H_4F_2$	624-72-6	66.050	0.51889	1.2431	1.5048	0.76269	697.51	200	0.5536	1500	1.5510
99	Difluoromethane	CH_2F_2	75-10-5	52.023	0.35489	0.71002	1.5936	0.4622	762	200	0.3681	1500	0.9419
100	Di-isopropyl amine	$C_6H_{15}N$	108-18-9	101.190	1.1384	2.5747	0.7384	1.62	2143	300	1.5995	1500	4.1941
101	Di-isopropyl ether	$C_6H_{14}O$	108-20-3	102.175	1.093	3.683	1.6057	2.342	699	298.15	1.5669	1500	4.0535
102	Di-isopropyl ketone	$C_7H_{14}O$	565-80-0	114.185	1.0869	4.054	1.7802	2.9786	791.6	300	1.5102	1500	4.3093
103	1,1-Dimethoxyethane	$C_4H_{10}O_2$	534-15-6	90.121	1.1556	1.8305	0.95919	0.99605	2826.3	298.15	1.2777	1500	3.0678
104	1,2-Dimethoxypropane	$C_5H_{12}O_2$	7778-85-0	104.148	1.0113	3.2393	1.5611	2.1501	689.3	298.15	1.4638	1500	3.6669
105	Dimethyl acetylene	C_4H_6	503-17-3	54.090	0.6534	1.6179	1.7837	1.0242	821.4	200	0.6721	1500	1.9148
106	Dimethyl amine	C_2H_7N	124-40-3	45.084	0.5565	1.6384	1.7341	1.0899	793.04	200	0.5812	1500	1.8585
107	2,3-Dimethylbutane	C_6H_{14}	79-29-8	86.175	0.7772	4.032	1.544	2.508	649.95	200	0.9363	1500	4.0353
108	1,1-Dimethylcyclohexane	C_8H_{16}	590-66-9	112.213	1.0776	4.6718	1.654	3.3397	792.5	200	1.1535	1500	4.9543
109	*cis*-1,2-Dimethylcyclohexane	C_8H_{16}	2207-01-4	112.213	1.1039	4.6445	1.6943	3.3949	798.35	200	1.1777	1500	4.9243
110	*trans*-1,2-Dimethylcyclohexane	C_8H_{16}	6876-23-9	112.213	1.0991	4.6401	1.6679	3.3736	781.97	200	1.1820	1500	4.9275
111	Dimethyl disulfide	$C_2H_6S_2$	624-92-0	94.199	0.7843	1.4364	1.5836	0.871	730.65	200	0.8155	1500	1.9523
112	Dimethyl ether	C_2H_6O	115-10-6	46.068	0.5148	1.442	1.6034	0.7747	725.4	200	0.5436	1500	1.6581
113	*N,N*-Dimethyl formamide	C_3H_7NO	68-12-2	73.094	0.722	1.783	1.532	1.31	762	200	0.7594	1500	2.2596
114	2,3-Dimethylpentane	C_7H_{16}	565-59-3	100.202	0.85438	4.5772	1.5181	2.974	641.01	200	1.0550	1500	4.5983
115	Dimethyl phthalate	$C_{10}H_{10}O_4$	131-11-3	194.184	1.396	4.78	2.19	3.9705	900.6	300	1.7481	1200	4.4740
116	Dimethylsilane	C_2H_8Si	1111-74-6	60.170	0.61453	1.7438	1.3418	1.0102	592.09	200	0.7095	1500	2.0944
117	Dimethyl sulfide	C_2H_6S	75-18-3	62.134	0.6037	1.3747	1.641	0.7988	743.5	200	0.6298	1500	1.6949
118	Dimethyl sulfoxide	C_2H_6OS	67-68-5	78.133	0.6949	1.524	1.6514	1.0658	722.2	200	0.7355	1500	1.9255
119	Dimethyl terephthalate	$C_{10}H_{10}O_4$	120-61-6	194.184	1.174	5.32	2.105	4.1	818	298.15	1.6816	1000.15	4.1139
120	1,4-Dioxane	$C_4H_8O_2$	123-91-1	88.105	0.56184	2.7034	1.5171	1.7658	700.76	200	0.6403	1500	2.8174
121	Diphenyl ether	$C_{12}H_{10}O$	101-84-8	170.207	1.0985	4.3412	1.6222	3.6455	743.62	300	1.7298	1200	4.5143
122	Dipropyl amine	$C_6H_{15}N$	142-84-7	101.190	1.2114	2.6127	0.78956	1.6903	2394.4	300	1.5900	1500	4.2484
123	Dodecane	$C_{12}H_{26}$	112-40-3	170.335	2.1295	6.633	1.7155	4.5161	777.5	200	2.2442	1500	7.4325

TABLE 2-156 Heat Capacity at Constant Pressure of Inorganic and Organic Compounds in the Ideal Gas State Fit to Hyperbolic Functions C_p [J/(kmol·K)] (*Continued*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1 × 1E-05	C2 × 1E-05	C3 × 1E-03	C4 × 1E-05	C5	T_{min}, K	C_p at T_{min} × 1E-05	T_{max}, K	C_p at T_{max} × 1E-05
124	Eicosane	$C_{20}H_{42}$	112-95-8	282.547	3.2481	11.09	1.636	7.45	726.27	200	3.5235	1500	12.2110
125	Ethane	C_2H_6	74-84-0	30.069	0.40326	1.3422	1.6555	0.73223	752.87	200	0.4256	1500	1.4562
126	Ethanol	C_2H_6O	64-17-5	46.068	0.492	1.4577	1.6628	0.939	744.7	200	0.5224	1500	1.6576
127	Ethyl acetate	$C_4H_8O_2$	141-78-6	88.105	0.9981	2.0931	2.0226	1.803	928.05	200	1.0126	1500	2.6594
128	Ethyl amine	C_2H_7N	75-04-7	45.084	0.594	1.618	1.812	1.078	820	200	0.6139	1500	1.8528
129	Ethylbenzene	C_8H_{10}	100-41-4	106.165	0.7844	3.399	1.559	2.426	702	200	0.8912	1500	3.6147
130	Ethyl benzoate	$C_9H_{10}O_2$	93-89-0	150.175	1.0944	4.1794	0.88375	−1.609	1183.1	300	1.4598	1500	4.2540
131	2-Ethyl butanoic acid	$C_6H_{12}O_2$	88-09-5	116.158	1.0455	2.3148	0.71	1.471	2061.6	300	1.5102	1200.15	3.6330
132	Ethyl butyrate	$C_6H_{12}O_2$	105-54-4	116.158	1.115	3.391	1.6705	2.518	733.6	298	1.5583	1200	3.6213
133	Ethylcyclohexane	C_8H_{16}	1678-91-7	112.213	1.1059	4.6306	1.6628	3.299	781.1	200	1.1875	1500	4.9184
134	Ethylcyclopentane	C_7H_{14}	1640-89-7	98.186	0.82052	4.0342	1.567	2.6697	715.52	200	0.9272	1500	4.1472
135	Ethylene	C_2H_4	74-85-1	28.053	0.3338	0.9479	1.596	0.551	740.8	60	0.3338	1500	1.0987
136	Ethylenediamine	$C_2H_8N_2$	107-15-3	60.098	0.7286	1.8436	1.688	1.199	767.3	300	0.9178	1500	2.2016
137	Ethylene glycol	$C_2H_6O_2$	107-21-1	62.068	0.63012	1.4584	1.673	0.97296	773.65	300	0.7800	1500	1.8095
138	Ethyleneimine	C_2H_5N	151-56-4	43.068	0.343	1.427	1.638	1.037	744.7	150	0.3480	1500	1.5178
139	Ethylene oxide	C_2H_4O	75-21-8	44.053	0.3346	1.2116	1.6084	0.8241	737.3	50	0.3346	1500	1.3297
140	Ethyl formate	$C_3H_6O_2$	109-94-4	74.079	0.537	1.886	1.207	0.864	496	100	0.5412	1500	2.1485
141	2-Ethyl hexanoic acid	$C_8H_{16}O_2$	149-57-5	144.211	1.5777	4.4017	1.7494	3.2378	792.34	298.15	2.0279	1500	5.1201
142	Ethylhexyl ether	$C_8H_{18}O$	5756-43-4	130.228	1.634	4.5119	1.7532	3.1032	809.75	298.15	2.0360	1200	4.8744
143	Ethylisopropyl ether	$C_5H_{12}O$	625-54-7	88.148	1.0953	3.0032	1.7988	2.1311	817.35	298.15	1.3620	1200	3.2289
144	Ethylisopropyl ketone	$C_6H_{12}O$	565-69-5	100.159	1.24	3.2	1.967	2.346	896	298.15	1.4479	1200	3.4234
145	Ethyl mercaptan	C_2H_6S	75-08-1	62.134	0.5576	1.3617	1.5221	0.8073	687.5	200	0.5970	1500	1.6729
146	Ethyl propionate	$C_5H_{10}O_2$	105-37-3	102.132	0.937	2.829	1.648	2.155	724.7	300	1.3377	1200	3.0569
147	Ethylpropyl ether	$C_5H_{12}O$	628-32-0	88.148	1.132	2.94	1.827	2.055	852	298.15	1.3538	1500	3.4535
148	Ethyltrichlorosilane	$C_2H_5Cl_3Si$	115-21-9	163.506	0.85105	1.0378	0.59737	0.94745	2122.7	167	0.8926	1500	2.2349
149	Fluorine	F_2	7782-41-4	37.997	0.29122	0.10132	1.453	0.094101	662.91	50	0.2912	1500	0.3812
150	Fluorobenzene	C_6H_5F	462-06-6	96.102	0.62653	2.1646	1.564	1.7278	724.29	200	0.6914	1500	2.4736
151	Fluoroethane	C_2H_5F	353-36-6	48.060	0.44373	1.3119	1.6422	0.85441	738.77	200	0.4726	1500	1.5008
152	Fluoromethane	CH_3F	593-53-3	34.033	0.33289	0.73989	1.8639	0.46079	891.16	50	0.3329	1500	0.9024
153	Formaldehyde	CH_2O	50-00-0	30.026	0.3327	0.49542	1.8666	0.28075	934.9	50	0.3327	1500	0.7113
154	Formamide	CH_3NO	75-12-7	45.041	0.3822	0.93	1.845	0.69	850	150	0.3833	1500	1.1203
155	Formic acid	CH_2O_2	64-18-6	46.026	0.3381	0.7593	1.1925	0.318	550	50	0.3381	1500	0.9933
156	Furan	C_4H_4O	110-00-9	68.074	0.3727	1.6606	1.5112	1.3145	686	200	0.4376	1500	1.7940
158	Heptadecane	$C_{17}H_{36}$	629-78-7	240.468	2.7878	9.5247	1.6935	6.6651	744.57	200	3.0034	1500	10.4160
159	Heptanal	$C_7H_{14}O$	111-71-7	114.185	1.404	2.5907	0.8315	1.312	2201	200	1.4479	1500	4.2863
160	Heptane	C_7H_{16}	142-82-5	100.202	1.2015	4.001	1.6766	2.74	756.4	200	1.2828	1500	4.4283
161	Heptanoic acid	$C_7H_{14}O_2$	111-14-8	130.185	1.3135	2.3317	0.67567	1.824	1846	300	1.8497	1500	4.2941
162	1-Heptanol	$C_7H_{16}O$	111-70-6	116.201	1.2215	3.991	1.58	2.835	717.7	200	1.3330	1500	4.5346
163	2-Heptanol	$C_7H_{16}O$	543-49-7	116.201	1.4569	2.8252	0.81695	1.766	2537.2	298.15	1.8136	1500	4.6604
164	3-Heptanone	$C_7H_{14}O$	106-35-4	114.185	1.2768	3.381	1.3831	1.888	650.3	200	1.3968	1500	4.1386
165	2-Heptanone	$C_7H_{14}O$	110-43-0	114.185	1.2507	2.148	0.6912	1.619	1759.3	150	1.2688	1200	3.8446
166	1-Heptene	C_7H_{14}	592-76-7	98.186	1.1851	3.6362	1.7359	2.5048	785.73	298.15	1.5434	1500	4.0836
167	Heptyl mercaptan	$C_7H_{16}S$	1639-09-4	132.267	1.442	4.1603	1.6603	2.6572	759.39	200	1.5191	1500	4.7831
168	1-Heptyne	C_7H_{12}	628-71-7	96.170	1.0712	3.0258	1.5273	2.0975	689.62	200	1.1721	1500	3.5985
169	Hexadecane	$C_{16}H_{34}$	544-76-3	226.441	2.6283	8.9733	1.6912	6.264	744.41	200	2.8312	1500	9.8182
170	Hexanal	$C_6H_{12}O$	66-25-1	100.159	1.232	2.2146	0.84	1.219	2205	200	1.2672	1500	3.7314
171	Hexane	C_6H_{14}	110-54-3	86.175	1.044	3.523	1.6946	2.369	761.6	200	1.1117	1500	3.8620
172	Hexanoic acid	$C_6H_{12}O_2$	142-62-1	116.158	1.1622	2.0708	0.68661	1.5355	1932.5	298.15	1.6107	1500	3.7636
173	1-Hexanol	$C_6H_{14}O$	111-27-3	102.175	1.0625	3.521	1.5835	2.462	715.75	200	1.1607	1500	3.9726
174	2-Hexanol	$C_6H_{14}O$	626-93-7	102.175	1.2615	3.5964	1.8445	2.594	819.17	298.15	1.5829	1500	4.0672
175	2-Hexanone	$C_6H_{12}O$	591-78-6	100.159	1.094	1.807	0.689	1.474	1772	200	1.1815	1200	3.3207
176	3-Hexanone	$C_6H_{12}O$	589-38-8	100.159	1.1237	2.936	1.401	1.601	650.5	150	1.1443	1500	3.5874
177	1-Hexene	C_6H_{12}	592-41-6	84.159	1.0434	3.0749	1.7459	2.0728	793.53	298	1.3301	1500	3.4819
178	3-Hexyne	C_6H_{10}	928-49-4	82.144	0.9376	3.015	1.9057	1.986	817	300	1.1909	1500	3.1889
179	Hexyl mercaptan	$C_6H_{14}S$	111-31-9	118.240	1.2662	3.7294	1.6574	2.308	757.8	200	1.3340	1500	4.2483
180	1-Hexyne	C_6H_{10}	693-02-7	82.144	0.9129	2.5577	1.529	1.737	683	200	1.0004	1500	3.0371
181	2-Hexyne	C_6H_{10}	764-35-2	82.144	1.036	3.009	2.116	2.106	902.4	300	1.2215	1500	3.1894
182	Hydrazine	H_4N_2	302-01-2	32.045	0.38711	0.8576	1.7228	0.56635	733.53	200	0.4070	1500	1.0571
183	Hydrogen	H_2	1333-74-0	2.016	0.27617	0.0956	2.466	0.0376	567.6	250	0.2843	1500	0.3225

184	Hydrogen bromide	HBr	10035-10-6	80.912	0.2912	0.0953	2.142	0.0157	1400	50	0.2912	1500	0.3479
185	Hydrogen chloride	HCl	7647-01-0	36.461	0.29157	0.09048	2.0938	–0.00107	120	50	0.2914	1500	0.3406
186	Hydrogen cyanide	CHN	74-90-8	27.025	0.30125	0.3171	1.6102	0.2179	626	100	0.3014	1500	0.5522
187	Hydrogen fluoride	HF	7664-39-3	20.006	0.29134	0.093252	2.905	1.95E–03	1.33E+03	50	0.2913	1500	0.3224
188	Hydrogen sulfide	H_2S	7783-06-4	34.081	0.33288	0.26086	0.9134	–0.17979	949.4	100	0.3329	1500	0.5143
189	Isobutyric acid	$C_4H_8O_2$	79-31-2	88.105	0.74694	2.4356	1.715	1.8484	757.75	298.15	1.0427	1200	2.5383
190	Isopropyl amine	C_3H_9N	75-31-0	59.110	0.68545	2.1876	1.5831	1.3855	691.76	200	0.7510	1500	2.4540
191	Malonic acid	$C_3H_4O_4$	141-82-2	104.061	0.49522	1.8718	1.2958	1.4852	569.96	300	0.9790	1200	2.0517
192	Methacrylic acid	$C_4H_6O_2$	79-41-4	86.089	0.7251	2.089	1.8516	1.6483	798.43	298.15	0.9475	1200.1	2.2057
193	Methane	CH_4	74-82-8	16.042	0.33298	0.79933	2.0869	0.41602	991.96	50	0.3330	1500	0.8890
194	Methanol	CH_4O	67-56-1	32.042	0.39252	0.879	1.9165	0.53654	896.7	200	0.3980	1500	1.0533
195	*N*-Methyl acetamide	C_3H_7NO	79-16-3	73.094	0.6116	2.029	1.7683	1.3302	835.5	300	0.7698	1500	2.2209
196	Methyl acetate	$C_3H_6O_2$	79-20-9	74.079	0.555	1.782	1.26	0.853	562	298	0.8489	1500	2.0754
197	Methyl acetylene	C_3H_4	74-99-7	40.064	0.4478	1.0917	1.5508	0.675	658.2	200	0.4882	1500	1.3293
198	Methyl acrylate	$C_4H_6O_2$	96-33-3	86.089	0.1206	2.3766	1.0543	1.8186	418.8	298.15	0.9908	1200.1	2.1663
199	Methyl amine	CH_5N	74-89-5	31.057	0.41	1.0578	1.708	0.6836	735	150	0.4136	1500	1.2388
200	Methyl benzoate	$C_8H_8O_2$	93-58-3	136.148	0.9396	2.559	0.825	1.36	3000	300	1.2586	1200	3.3569
201	3-Methyl-1,2-butadiene	C_5H_8	598-25-4	68.117	0.671	2.222	1.421	1.194	614.7	150	0.6931	1500	2.5028
202	2-Methylbutane	C_5H_{12}	78-78-4	72.149	0.746	3.265	1.545	1.923	666.7	200	0.8546	1500	3.3792
203	2-Methylbutanoic acid	$C_5H_{10}O_2$	116-53-0	102.132	1.8458	1.743	1.22	–56.11	31.2	300	1.2793	1500	3.2262
204	3-Methyl-1-butanol	$C_5H_{12}O$	123-51-3	88.148	0.92165	3.3371	1.8365	2.4645	757.99	298.15	1.3135	1500	3.4856
205	2-Methyl-1-butene	C_5H_{10}	563-46-2	70.133	0.87026	2.5556	1.7757	1.7636	807.82	200	0.9060	1500	2.8923
206	2-Methyl-2-butene	C_5H_{10}	513-35-9	70.133	0.81924	2.6038	1.7593	1.7195	800.93	200	0.8559	1500	2.8709
207	2-Methyl -1-butene-3-yne	C_5H_6	78-80-8	66.101	0.7906	1.656	1.6926	1.2167	788.4	298.15	0.9632	1500.15	2.1502
208	Methylbutyl ether	$C_5H_{12}O$	628-28-4	88.148	0.82051	3.0869	1.3864	1.7886	613.87	300	1.3300	1200	3.1994
209	Methylbutyl sulfide	$C_5H_{12}S$	628-29-5	104.214	1.0785	2.7388	1.5885	1.9067	749.6	273.15	1.3173	1200	3.1687
210	3-Methyl-1-butyne	C_5H_8	598-23-2	68.117	0.8274	2.1377	1.755	1.5149	782	200	0.8646	1500	2.5255
211	Methyl butyrate	$C_5H_{10}O_2$	623-42-7	102.132	0.894	2.91	1.57	2.073	678.3	298	1.3461	1200	3.0766
212	Methylchlorosilane	CH_5ClSi	993-00-0	80.589	0.59895	1.1636	1.565	0.81581	690.39	200	0.6380	1500	1.5593
213	Methylcyclohexane	C_7H_{14}	108-87-2	98.186	0.9227	4.115	1.6504	2.9006	779.48	200	0.9953	1500	4.3180
214	1-Methylcyclohexanol	$C_7H_{14}O$	590-67-0	114.185	0.7959	2.596	0.6213	2.288	1698.6	300	1.5302	1200	4.1359
215	*cis*-2-Methylcyclohexanol	$C_7H_{14}O$	7443-70-1	114.185	0.92279	2.6709	0.68784	1.9847	1732.4	300	1.5099	1200	4.1467
216	*trans*-2-Methylcyclohexanol	$C_7H_{14}O$	7443-52-9	114.185	0.92279	2.6709	0.68784	1.9847	1732.4	300	1.5099	1200	4.1467
217	Methylcyclopentane	C_6H_{12}	96-37-7	84.159	0.66456	3.507	1.5892	2.3526	727.13	200	0.7510	1500	3.5495
218	1-Methylcyclopentene	C_6H_{10}	693-89-0	82.144	0.69411	3.0209	1.6903	2.1209	781.56	200	0.7464	1500	3.1496
219	3-Methylcyclopentene	C_6H_{10}	1120-62-3	82.144	0.6422	3.0711	1.6387	2.1298	750.25	200	0.7083	1500	3.1549
220	Methyldichlorosilane	CH_4Cl_2Si	75-54-7	115.034	0.7283	1.0307	1.5429	0.7811	668.94	200	0.7717	1500	1.5893
221	Methylethyl ether	C_3H_8O	540-67-0	60.095	0.68681	1.9959	1.5534	1.1168	692.04	200	0.7396	1500	2.2931
222	Methylethyl ketone	C_4H_8O	78-93-3	72.106	0.784	2.1032	1.5488	1.1855	693	200	0.8397	1500	2.4816
223	Methylethyl sulfide	C_3H_8S	624-89-5	76.161	0.75083	1.9577	1.6424	1.1949	749.19	273.16	0.9004	1500	2.3178
224	Methyl formate	$C_2H_4O_2$	107-31-3	60.052	0.506	1.219	1.637	0.894	743	250	0.5888	1500	1.5109
225	Methylisobutyl ether	$C_5H_{12}O$	625-44-5	88.148	0.7284	3.1713	1.352	1.8948	585.14	300	1.3200	1200	3.1987
226	Methylisobutyl ketone	$C_6H_{12}O$	108-10-1	100.159	1.227	2.195	0.842	1.191	2460	298.15	1.4755	1500.15	3.6532
227	Methyl Isocyanate	C_2H_3NO	624-83-9	57.051	0.474	1.226	2.188	0.85983	1008.2	298.15	0.5195	1500	1.3595
228	Methylisopropyl ether	$C_4H_{10}O$	598-53-8	74.122	0.89232	2.4765	1.696	1.5598	791.4	200	0.9280	1500	2.8696
229	Methylisopropyl ketone	$C_5H_{10}O$	563-80-4	86.132	1.5914	1.764	1.2076	–407.4	10.503	300	1.1291	1500	2.9991
230	Methylisopropyl sulfide	$C_4H_{10}S$	1551-21-9	90.187	0.99247	2.7275	2.003	1.8974	849.64	273	1.1377	1500	2.9952
231	Methyl mercaptan	CH_4S	74-93-1	48.107	0.4146	0.8307	1.589	0.4612	716.7	200	0.4329	1500	1.0781
232	Methyl methacrylate	$C_5H_8O_2$	80-62-6	100.116	0.864	1.811	0.7543	0.8	2160	298.15	1.1621	1500	2.8637
233	2-Methyloctanoic acid	$C_9H_{18}O_2$	3004-93-1	158.238	1.7483	4.9288	1.7384	3.5897	788.01	298.15	2.2567	1500	5.7177
234	2-Methylpentane	C_6H_{14}	107-83-5	86.175	0.903	3.801	1.602	2.453	691.6	200	1.0192	1500	3.9617
235	Methyl pentyl ether	$C_6H_{14}O$	628-80-8	102.175	0.94326	3.5965	1.3533	2.0569	599.92	300	1.5600	1200	3.7409
236	2-Methylpropane	C_4H_{10}	75-28-5	58.122	0.6549	2.4776	1.587	1.575	706.99	200	0.7218	1500	2.6656
237	2-Methyl-2-propanol	$C_4H_{10}O$	75-65-0	74.122	0.7704	2.539	1.5502	1.669	679.3	200	0.8567	1500	2.8508
238	2-Methyl propene	C_4H_8	115-11-7	56.106	0.6125	2.066	1.545	1.2057	676	200	0.6763	1500	2.2814
239	Methyl propionate	$C_4H_8O_2$	554-12-1	88.105	0.7765	2.442	1.714	1.818	716	300	1.1242	1200	2.5276
240	Methylpropyl ether	$C_4H_{10}O$	557-17-5	74.122	0.92151	2.3943	1.6936	1.4896	797.79	298	1.1251	1200	2.6391
241	Methylpropyl sulfide	$C_4H_{10}S$	3877-15-4	90.187	0.93775	2.6178	1.7291	1.6236	783.23	298.15	1.1728	1500	2.9904
242	Methylsilane	CH_6Si	992-94-9	46.144	0.46149	1.2781	1.4565	0.79115	643.23	200	0.5141	1500	1.5253
243	alpha-Methyl styrene	C_9H_{10}	98-83-9	118.176	0.78548	3.5969	1.4342	2.5336	651.69	200	0.9445	1500	3.8592
244	Methyl *tert*-butyl ether	$C_5H_{12}O$	1634-04-4	88.148	0.9779	3.091	1.643	2.099	731.191	298	1.3522	1500	3.4779
245	Methyl vinyl ether	C_3H_6O	107-25-5	58.079	0.60865	1.5965	1.619	0.93783	739.55	300	0.7748	1500	1.8871
246	Naphthalene	$C_{10}H_8$	91-20-3	128.171	0.6805	3.5494	1.4262	2.5984	650.1	200	0.8454	1500	3.7359

TABLE 2-156 Heat Capacity at Constant Pressure of Inorganic and Organic Compounds in the Ideal Gas State Fit to Hyperbolic Functions C_p [J/(kmol·K)] (*Concluded*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1 ×1E-05	C2 ×1E-05	C3 ×1E-03	C4 ×1E-05	C5	T_{min}, K	C_p at T_{min} ×1E-05	T_{max}, K	C_p at T_{max} ×1E-05
248	Nitroethane	$C_2H_5NO_2$	79-24-3	75.067	0.54619	1.6492	1.4803	1.0635	666.94	200	0.6062	1500	1.9237
249	Nitrogen	N_2	7727-37-9	28.013	0.29105	0.086149	1.7016	0.0010347	909.79	50	0.2911	1500	0.3484
250	Nitrogen trifluoride	F_3N	7783-54-2	71.002	0.33284	0.49837	0.7093	0.23264	372.91	100	0.3404	1500	0.8092
251	Nitromethane	CH_3NO_2	75-52-5	61.040	0.42267	1.0842	1.4885	0.68603	683.57	200	0.4571	1500	1.3280
252	Nitrous oxide	N_2O	10024-97-2	44.013	0.29338	0.3236	1.1238	0.2177	479.4	100	0.2948	1500	0.5828
254	Nonadecane	$C_{19}H_{40}$	629-92-5	268.521	3.1062	10.575	0.76791	–4.5661	912.03	200	3.3533	1500	11.6130
255	Nonanal	$C_9H_{18}O$	124-19-6	142.239	1.7347	4.5115	1.712	3.3256	810.96	200	1.8005	1500	5.4439
256	Nonane	C_9H_{20}	111-84-2	128.255	1.5175	4.915	1.6448	3.47	749.6	200	1.6257	1500	5.5407
257	Nonanoic acid	$C_9H_{18}O_2$	112-05-0	158.238	0.1266	6.011	1.0815	4.5946	418.2	298.15	2.2953	1500	5.5267
258	1-Nonanol	$C_9H_{20}O$	143-08-8	144.255	1.54	4.936	1.578	3.588	721.11	200	1.6777	1500	5.6606
259	2-Nonanol	$C_9H_{20}O$	628-99-9	144.255	1.8197	3.5542	0.81514	2.1974	2508.8	298.15	2.2720	1500	5.8526
260	1-Nonene	C_9H_{18}	124-11-8	126.239	1.5352	4.6844	1.7288	3.2304	783.67	298.15	2.0014	1500	5.2776
261	Nonyl mercaptan	$C_9H_{20}S$	1455-21-6	160.320	1.7646	5.044	1.6182	3.3857	755.48	200	1.8658	1500	5.9082
262	1-Nonyne	C_9H_{16}	3452-09-3	124.223	1.6289	3.9708	1.8928	3.2136	855.52	298.15	1.9693	1500	4.7924
263	Octadecane	$C_{18}H_{38}$	593-45-3	254.494	2.9502	10.034	0.77107	-4.3012	916.73	200	3.1800	1500	11.0160
264	Octanal	$C_8H_{16}O$	124-13-0	128.212	1.6088	4.218	1.9126	3.278	869	200	1.6504	1500	4.9286
265	Octane	C_8H_{18}	111-65-9	114.229	1.3554	4.431	1.6356	3.054	746.4	200	1.4529	1500	4.9764
266	Octanoic acid	$C_8H_{16}O_2$	124-07-2	144.211	1.4082	4.3436	1.4662	2.7687	659.38	298.15	2.0652	1500	5.0411
267	1-Octanol	$C_8H_{18}O$	111-87-5	130.228	1.3805	4.459	1.5751	3.2016	718.8	200	1.5055	1500	5.0965
268	2-Octanol	$C_8H_{18}O$	123-96-6	130.228	1.6383	3.1897	0.81595	1.9814	2521.3	298.15	2.0428	1500	5.2565
269	2-Octanone	$C_8H_{16}O$	111-13-7	128.212	1.3901	3.806	1.3717	2.2573	660.96	150	1.4162	1500	4.6547
270	3-Octanone	$C_8H_{16}O$	106-68-3	128.212	1.4952	4.4103	0.80211	–2.0958	981.95	200	1.5775	1500	4.9067
271	1-Octene	C_8H_{16}	111-66-0	112.213	1.3599	4.1605	1.7317	2.8675	784.47	298.15	1.7723	1500	4.6807
272	Octyl mercaptan	$C_8H_{18}S$	111-88-6	146.294	1.5981	4.6063	1.6295	3.0301	756.28	200	1.6881	1500	5.3549
273	1-Octyne	C_8H_{14}	629-05-0	110.197	1.2307	3.4942	1.528	2.4617	694.81	200	1.3448	1500	4.1604
274	Oxalic acid	$C_2H_2O_4$	144-62-7	90.035	0.25751	1.1734	2.7969	0.65788	878.91	298.15	0.3201	1000.1	0.6502
275	Oxygen	O_2	7782-44-7	31.999	0.29103	0.1004	2.5265	0.09356	1153.8	50	0.2910	1500	0.3653
276	Ozone	O_3	10028-15-6	47.998	0.33483	0.29577	1.5217	0.27151	680.35	100	0.3349	1500	0.5928
277	Pentadecane	$C_{15}H_{32}$	629-62-9	212.415	2.4679	8.4212	1.6865	5.8537	743.6	200	2.6586	1500	9.2209
278	Pentanal	$C_5H_{10}O$	110-62-3	86.132	1.0743	2.8363	1.9549	2.0146	890.44	200	1.0960	1500	3.2404
279	Pentane	C_5H_{12}	109-66-0	72.149	0.8805	3.011	1.6502	1.892	747.6	200	0.9404	1500	3.2927
280	Pentanoic acid	$C_5H_{10}O_2$	109-52-4	102.132	2.836	1.08	2.107	–3.56	283	298.15	1.3824	1500	3.2952
281	1-Pentanol	$C_5H_{12}O$	71-41-0	88.148	0.906	3.062	1.6054	2.115	717.97	200	0.9890	1500	3.4133
282	2-Pentanol	$C_5H_{12}O$	6032-29-7	88.148	1.0853	3.0747	1.8672	2.2271	825.4	298.15	1.3539	1500	3.4701
283	2-Pentanone	$C_5H_{10}O$	107-87-9	86.132	0.90053	2.7085	1.6592	1.8012	743.96	200	0.9591	1500	3.0797
284	3-Pentanone	$C_5H_{10}O$	96-22-0	86.132	0.96896	2.4907	1.4177	1.301	646.7	200	1.0536	1500	3.0358
285	1-Pentene	C_5H_{10}	109-67-1	70.133	0.82523	2.5943	1.7291	1.768	778.7	298.15	1.0856	1500	2.8897
286	2-Pentyl mercaptan	$C_5H_{12}S$	2084-19-7	104.214	1.1327	2.947	1.7418	2.0987	795.78	298	1.4202	1500	3.4994
287	Pentyl mercaptan	$C_5H_{12}S$	110-66-7	104.214	1.0974	3.2959	1.6761	1.9486	757.67	200	1.1547	1500	3.6956
288	1-Pentyne	C_5H_8	627-19-0	68.117	0.753	2.0905	1.5307	1.378	672.8	200	0.8276	1500	2.4754
289	2-Pentyne	C_5H_8	627-21-4	68.117	0.70737	2.2229	1.557	1.3125	690.78	200	0.7700	1500	2.5052
290	Phenanthrene	$C_{14}H_{10}$	85-01-8	178.229	0.9374	4.758	1.382	3.485	627.4	200	1.1959	1500	5.0645
291	Phenol	C_6H_6O	108-95-2	94.111	0.434	2.445	1.152	1.512	507	100	0.4401	1500	2.6045
292	Phenyl isocyanate	C_7H_5NO	103-71-9	119.121	0.59683	2.5533	1.2397	1.5519	576.78	298.15	1.1054	1500	2.8390
293	Phthalic anhydride	$C_8H_4O_3$	85-44-9	148.116	0.7364	2.544	1.0852	0.808	573	298.15	1.0745	1000.15	2.6737
294	Propadiene	C_3H_4	463-49-0	40.064	0.426	1.1194	1.5772	0.7546	680.8	200	0.4646	1500	1.3376
295	Propane	C_3H_8	74-98-6	44.096	0.5192	1.9245	1.6265	1.168	723.6	200	0.5632	1500	2.0556
296	1-Propanol	C_3H_8O	71-23-8	60.095	0.619	2.0213	1.6293	1.2956	727.4	200	0.6665	1500	2.2458
297	2-Propanol	C_3H_8O	67-63-0	60.095	0.73145	2.0313	1.9375	1.4815	843.37	298.15	0.8966	1500	2.2760
298	Propenylcyclohexene	C_9H_{14}	13511-13-2	122.207	1.0563	4.3397	1.6098	3.181	729.66	300	1.6392	1500	4.6527
299	Propionaldehyde	C_3H_6O	123-38-6	58.079	0.7174	1.914	2.0144	1.1708	930.6	200	0.7266	1500	2.1149
300	Propionic acid	$C_3H_6O_2$	79-09-4	74.079	0.6959	1.7778	1.7098	1.2654	763.78	298.15	0.8938	1500	2.1248
301	Propionitrile	C_3H_5N	107-12-0	55.079	0.5357	1.4617	1.553	0.91197	678.2	200	0.5832	1500	1.7235
302	Propyl acetate	$C_5H_{10}O_2$	109-60-4	102.132	1.7994	1.753	1.196	–4.12	108.2	298.15	1.3594	1500	3.2024
303	Propyl amine	C_3H_9N	107-10-8	59.110	0.76078	2.1049	1.7256	1.3936	789.03	200	0.7933	1500	2.4353

304	Propylbenzene	C_9H_{12}	103-65-1	120.192	0.96885	3.7954	1.5168	2.6618	694.3	200	1.0927	1500	4.1613
305	Propylene	C_3H_6	115-07-1	42.080	0.43852	1.506	1.3988	0.74754	616.46	130	0.4436	1500	1.6817
306	Propyl formate	$C_4H_8O_2$	110-74-7	88.105	0.871	2.447	1.9254	1.888	821.3	298.15	1.1022	1500	2.7484
307	2-Propyl mercaptan	C_3H_8S	75-33-2	76.161	0.73815	1.9529	1.5954	1.2356	730.5	200	0.7825	1500	2.3287
308	Propyl mercaptan	C_3H_8S	107-03-9	76.161	0.7474	1.9523	1.631	1.2112	750.92	200	0.7848	1500	2.3216
309	1,2-Propylene glycol	$C_3H_8O_2$	57-55-6	76.094	2.0114	0.8082	1.8656	–2.4404	279.98	298.15	1.0218	1000.15	2.1175
310	Quinone	$C_6H_4O_2$	106-51-4	108.095	0.6487	2.1227	1.3491	1.514	614.8	200	0.7711	1500	2.4969
311	Silicon tetrafluoride	F_4Si	7783-61-1	104.079	0.3681	0.71245	0.65201	0.46721	286.03	100	0.4182	1500	1.0537
312	Styrene	C_8H_8	100-42-5	104.149	0.893	2.1503	0.772	0.999	2442	100	0.8931	1500	3.2416
313	Succinic acid	$C_4H_6O_4$	110-15-6	118.088	0.71806	2.2669	1.2739	1.7342	537.65	300	1.3370	1200	2.5823
314	Sulfur dioxide	O_2S	7446-09-5	64.064	0.33375	0.25864	0.9328	0.1088	423.7	100	0.3354	1500	0.5695
315	Sulfur hexafluoride	F_6S	2551-62-4	146.055	0.35256	1.227	0.67938	0.78407	351.27	100	0.3872	1500	1.5397
316	Sulfur trioxide	O_3S	7446-11-9	80.063	0.33408	0.49677	0.87322	0.28563	393.74	100	0.3408	1500	0.7967
317	Terephthalic acid	$C_8H_6O_4$	100-21-0	166.131	0.945	2.526	0.829	0.5	2010	298.15	1.2478	1500	3.4444
318	*o*-Terphenyl	$C_{18}H_{14}$	84-15-1	230.304	2.0719	6.2668	2.4044	6.345	967.71	298.15	2.4763	1500	6.6947
319	Tetradecane	$C_{14}H_{30}$	629-59-4	198.388	2.3082	7.8678	1.6823	5.4486	743.1	200	2.4864	1500	8.6225
320	Tetrahydrofuran	C_4H_8O	109-99-9	72.106	0.46905	2.5314	1.5998	1.7051	740.64	200	0.5259	1500	2.5538
321	1,2,3,4-Tetrahydronaphthalene	$C_{10}H_{12}$	119-64-2	132.202	0.8145	4.395	1.471	3.065	666.4	200	0.9881	1500	4.5348
322	Tetrahydrothiophene	C_4H_8S	110-01-0	88.171	0.51848	2.4535	1.5018	1.6871	665.31	200	0.6147	1500	2.5679
323	2,2,3,3-Tetramethylbutane	C_8H_{18}	594-82-1	114.229	1.1352	5.6331	1.6211	3.3829	681.9	200	1.3069	1500	5.5784
324	Thiophene	C_4H_4S	110-02-1	84.140	0.40399	1.627	1.4562	1.322	648.81	200	0.4886	1500	1.8098
325	Toluene	C_7H_8	108-88-3	92.138	0.5814	2.863	1.4406	1.898	650.43	200	0.7016	1500	3.0029
326	1,1,2-Trichloroethane	$C_2H_3Cl_3$	79-00-5	133.404	0.66554	1.1257	1.5454	0.97196	717.04	298.15	0.8496	1500	1.6433
327	Tridecane	$C_{13}H_{28}$	629-50-5	184.361	2.1496	7.3045	1.6695	4.9998	741.02	200	2.3156	1500	8.0251
328	Triethyl amine	$C_6H_{15}N$	121-44-8	101.190	1.2766	2.5559	0.80937	1.4829	2231.7	200	1.3278	1500	4.2046
329	Trimethyl amine	C_3H_9N	75-50-3	59.110	0.7107	1.5051	0.79662	0.84537	2187.6	200	0.7439	1500	2.4322
330	1,2,3-Trimethylbenzene	C_9H_{12}	526-73-8	120.192	1.052	3.79	1.4814	2.331	667.3	200	1.1832	1500	4.1983
331	1,2,4-Trimethylbenzene	C_9H_{12}	95-63-6	120.192	1.0106	3.8314	1.501	2.395	678.3	200	1.1354	1500	4.1854
332	2,2,4-Trimethylpentane	C_8H_{18}	540-84-1	114.229	1.139	5.286	1.594	3.351	677.94	200	1.3139	1500	5.3769
333	2,3,3-Trimethylpentane	C_8H_{18}	560-21-4	114.229	0.982	5.402	1.531	3.493	639.9	200	1.2194	1500	5.3754
334	1,3,5-Trinitrobenzene	$C_6H_3N_3O_6$	99-35-4	213.105	2.0367	1.8181	1.2089	0.79777	1060.8	298.15	2.1054	1500	3.7585
335	2,4,6-Trinitrotoluene	$C_7H_5N_3O_6$	118-96-7	227.131	2.154	2.4432	1.1126	0.58651	950.59	298.15	2.2726	1500	4.3560
336	Undecane	$C_{11}H_{24}$	1120-21-4	156.308	1.9529	6.0998	1.7087	4.1302	775.4	200	2.0594	1500	6.8342
337	1-Undecanol	$C_{11}H_{24}O$	112-42-5	172.308	1.859	5.869	1.5718	4.326	722.7	200	2.0232	1500	6.7834
338	Vinyl acetate	$C_4H_6O_2$	108-05-4	86.089	0.536	2.119	1.198	1.147	510	100	0.5404	1500	2.3750
339	Vinyl acetylene	C_4H_4	689-97-4	52.075	0.55978	1.2141	1.6102	0.89079	710.4	200	0.5967	1500	1.5590
340	Vinyl chloride	C_2H_3Cl	75-01-4	62.498	0.42364	0.8735	1.6492	0.6556	739.07	200	0.4457	1500	1.1423
341	Vinyl trichlorosilane	$C_2H_3Cl_3Si$	75-94-5	161.490	0.84894	1.1471	1.38	0.9	644.61	298.15	1.0788	1500	1.8595
342	Water	H_2O	7732-18-5	18.015	0.33363	0.2679	2.6105	0.08896	1169	100	0.3336	2273.15	0.5276
343	*m*-Xylene	C_8H_{10}	108-38-3	106.165	0.7568	3.3924	1.496	2.247	675.9	200	0.8759	1500	3.5920
344	*o*-Xylene	C_8H_{10}	95-47-6	106.165	0.8521	3.2954	1.4944	2.115	675.8	200	0.9643	1500	3.5965
345	*p*-Xylene	C_8H_{10}	106-42-3	106.165	0.7512	3.397	1.4928	2.247	675.1	200	0.8710	1500	3.5923

Constants in this table can be used in the following equation to calculate the ideal gas heat capacity C_p^0.

$$C_p^0 = \mathrm{C1} + \mathrm{C2}\left[\frac{\mathrm{C3}/T}{\sinh(\mathrm{C3}/T)}\right]^2 + \mathrm{C4}\left[\frac{\mathrm{C5}/T}{\cosh(\mathrm{C5}/T)}\right]^2$$

where C_p^0 is in J/(kmol·K) and T is in K. All substances are listed by chemical family in Table 2-6 and by formula in Table 2-7.

Values in this table were taken from the Design Institute for Physical Properties (DIPPR) of the American Institute of Chemical Engineers (AIChE), copyright 2007 AIChE and reproduced with permission of AICHE and of the DIPPR Evaluated Process Design Data Project Steering Committee. Their source should be cited as R. L. Rowley, W. V. Wilding, J. L. Oscarson, Y. Yang, N. A. Zundel, T. E. Daubert, R. P. Danner, DIPPR® Data Compilation of Pure Chemical Properties, Design Institute for Physical Properties, AIChE, New York (2007).

The number of digits provided for values at T_{min} and T_{max} was chosen for uniformity of appearance and formatting; these do not represent the uncertainties of the physical quantities, but are the result of calculations from the standard thermophysical property formulations within a fixed format.

TABLE 2-157 C_p/C_v: Ratios of Specific Heats of Gases at 1 atm Pressure*

Compound	Formula	Temperature, °C	Ratio of specific heats, $(\gamma) = C_p/C_v$	Compound	Formula	Temperature, °C	Ratio of specific heats, $(\gamma) = C_p/C_v$
Acetaldehyde	C_2H_4O	30	1.14	Hydrogen (*Cont.*)			
Acetic acid	$C_2H_4O_2$	136	1.15	iodide	HI	20–100	1.40
Acetylene	C_2H_2	15	1.26	sulfide	H_2S	15	1.332
		–71	1.31			–45	1.350
Air		925	1.36			–57	1.356
		17	1.403				
		–78	1.408	Iodine	I_2	185	1.30
		–118	1.415	Isobutane	C_4H_{10}	15	1.110
Ammonia	NH_3	15	1.320				
Argon	Ar	15	1.670	Krypton	Kr	19	1.672
		–180	1.715				
		0–100	1.67	Mercury	Hg	360	1.67
				Methane	CH_4	600	1.113
Benzene	C_6H_6	90	1.10			300	1.196
Bromine	Br_2	20–350	1.32			15	1.310
						–80	1.339
Carbon dioxide	CO_2	15	1.299			–115	1.347
		–75	1.37	Methyl acetate	$C_3H_6O_2$	15	1.14
disulfide	CS_2	100	1.21	alcohol	CH_4O	77	1.237
monoxide	CO	15	1.402	ether	C_2H_6O	6–30	1.11
		–180	1.433	Methylal	$C_3H_8O_2$	13	1.06
Chlorine	Cl_2	15	1.355			40	1.09
Chloroform	$CHCl_3$	100	1.15				
Cyanogen	$(CN)_2$	15	1.256	Neon	Ne	19	1.667
Cyclohexane	C_6H_{12}	80	1.315	Nitric oxide	NO	15	1.400
						–45	1.39
Dichlorodifluormethane	CCl_2F_2	25	1.139			–80	1.38
				Nitrogen	N_2	15	1.402
Ethane	C_2H_6	100	1.157			–181	1.433
		15	1.200	Nitrous oxide	N_2O	100	1.28
		–82	1.28			15	1.303
Ethyl alcohol	C_2H_6O	90	1.13			–30	1.31
ether	$C_4H_{10}O$	35	1.08			–70	1.34
		80	1.086				
Ethylene	C_2H_4	100	1.201	Oxygen	O_2	15	1.398
		15	1.253			–76	1.405
		–91	1.345			–181	1.439
Helium	He	–180	1.667	Pentane (*n*-)	C_5H_{12}	86	1.071
Hexane (*n*-)	C_6H_{14}	80	1.066	Phosphorus	P	300	1.17
Hydrogen	H_2	15	1.407	Potassium	K	850	1.77
		–76	1.441				
		–181	1.607	Sodium	Na	750–920	1.68
bromide	HBr	20	1.42	Sulfur dioxide	SO_2	15	1.290
chloride	HCl	15	1.41				
		100	1.40	Xenon	Xe	19	1.678
cyanide	HCN	65	1.31				
		140	1.28				
		210	1.24				

*For compounds that appear in Table 2-184, values are from E. W. Lemmon, M. O. McLinden, and D. G. Friend, "Thermophysical Properties of Fluid Systems" in *NIST Chemistry WebBook*, **NIST Standard Reference Database Number 69**, Eds. P. J. Linstrom and W. G. Mallard, June 2005, National Institute of Standards and Technology, Gaithersburg, Md. (http://webbook.nist.gov). Values for other compounds are from *International Critical Tables*, vol. 5, pp. 80–82.

SPECIFIC HEATS OF AQUEOUS SOLUTIONS

UNITS CONVERSIONS

For this subsection, the following units conversions are applicable:

$$°F = \tfrac{9}{5}\,°C + 32$$

To convert calories per gram-degree Celsius to British thermal units per pound-degree Fahrenheit, multiply by 1.0.

TABLE 2-158 Acetic Acid (at 38 °C)

Mole % acetic acid	0	6.98	30.9	54.5	100
Cal/(g·°C)	1.0	0.911	0.73	0.631	0.535

TABLE 2-159 Ammonia

	Specific heat, cal/(g·°C)			
Mole % NH_3	2.4 °C	20.6 °C	41 °C	61 °C
0	1.01	1.0	0.995	1.0
10.5	0.98	0.995	1.06	1.02
20.9	0.96	0.99	1.03	
31.2	0.956	1.0		
41.4	0.985			

TABLE 2-160 Aniline (at 20 °C)

Mol % aniline	100	95	90.5	82.3	75.2
Cal/(g·°C)	0.497	0.52	0.53	0.56	0.581

TABLE 2-161 Copper Sulfate

Composition	Temperature	Specific heat, cal/(g·°C)
$CuSO_4 + 50H_2O$	12 to 15 °C	0.848
$CuSO_4 + 200H_2O$	12 to 14 °C	0.951
$CuSO_4 + 400H_2O$	13 to 17 °C	0.975

TABLE 2-162 Ethyl Alcohol

	Specific heat, cal/(g·°C)		
Mole % C_2H_5OH	3 °C	23 °C	41 °C
4.16	1.05	1.02	1.02
11.5	1.02	1.03	1.03
37.0	0.805	0.86	0.875
61.0	0.67	0.727	0.748
100.0	0.54	0.577	0.621

TABLE 2-163 Glycerol

	Specific heat, cal/(g·°C)	
Mole % $C_3H_5(OH)_3$	15 °C	32 °C
2.12	0.961	0.960
4.66	0.929	0.924
11.5	0.851	0.841
22.7	0.765	0.758
43.9	0.67	0.672
100.0	0.555	0.576

TABLE 2-164 Hydrochloric Acid

	Specific heat, cal/(g·°C)				
Mole % HCl	0 °C	10 °C	20 °C	40 °C	60 °C
0.0	1.00				
9.09	0.72	0.72	0.74	0.75	0.78
16.7	0.61	0.605	0.631	0.645	0.67
20.0	0.58	0.575	0.591	0.615	0.638
25.9	0.55				0.61

ADDITIONAL REFERENCES

Most of the tables below are from *International Critical Tables,* vol. 5, pp. 115–116, 122–125.

TABLE 2-165 Methyl Alcohol

	Specific heat, cal/(g·°C)		
Mole % CH_3OH	5 °C	20 °C	40 °C
5.88	1.02	1.0	0.995
12.3	0.975	0.982	0.98
27.3	0.877	0.917	0.92
45.8	0.776	0.811	0.83
69.6	0.681	0.708	0.726
100	0.576	0.60	0.617

TABLE 2-166 Nitric Acid

% HNO_3 by Weight	Specific heat at 20 °C, cal/(g·°C)
0	1.000
10	0.900
20	0.810
30	0.730
40	0.675
50	0.650
60	0.640
70	0.615
80	0.575
90	0.515

TABLE 2-167 Phosphoric Acid*

$\%H_2PO_4$	C_p at 21.3 °C cal/(g·°C)	$\%H_3PO_4$	C_p at 21.3 °C cal/(g·°C)
2.50	0.9903	50.00	0.6350
3.80	0.9970	52.19	0.6220
5.33	0.9669	53.72	0.6113
8.81	0.9389	56.04	0.5972
10.27	0.9293	58.06	0.5831
14.39	0.8958	60.23	0.5704
16.23	0.8796	62.10	0.5603
19.99	0.8489	64.14	0.5460
22.10	0.8300	66.13	0.5349
24.56	0.8125	68.14	0.5242
25.98	0.8004	69.97	0.5157
28.15	0.7856	69.50	0.5160
29.96	0.7735	71.88	0.5046
32.09	0.7590	73.71	0.4940
33.95	0.7432	75.79	0.4847
36.26	0.7270	77.69	0.4786
38.10	0.7160	79.54	0.4680
40.10	0.7024	80.00	0.4686
42.08	0.6877	82.00	0.4593
44.11	0.6748	84.00	0.4500
46.22	0.6607	85.98	0.4419
48.16	0.6475	88.01	0.4359
49.79	0.6370	89.72	0.4206

*Z. *Physik. Chem.*, A167, **42** (1933).

TABLE 2-168 Potassium Chloride

	Specific heat, cal/(g·°C)			
Mole % KCl	6 °C	20 °C	33 °C	40 °C
0.99	0.945	0.947	0.947	0.947
3.85	0.828	0.831	0.835	0.837
5.66	0.77	0.775	0.778	0.775
7.41		0.727		

TABLE 2-169 Potassium Hydroxide (at 19 °C)

Mole % KOH	0	0.497	1.64	4.76	9.09
Cal/(g·°C)	1.0	0.975	0.93	0.814	0.75

TABLE 2-170 Normal Propyl Alcohol

	Specific heat, cal/(g·°C)		
Mole % C_3H_7OH	5 °C	20 °C	40 °C
1.55	1.03	1.02	1.01
5.03	1.07	1.06	1.03
11.4	1.035	1.032	0.99
23.1	0.877	0.90	0.91
41.2	0.75	0.78	0.815
73.0	0.612	0.645	0.708
100.0	0.534	0.57	0.621

TABLE 2-171 Sodium Carbonate*

% Na_2CO_3 by weight	Temperature, °C			
	17.6	30.0	76.6	98.0
0.000	0.9992	0.9986	1.0098	1.0084
1.498	0.9807			
2.000		0.9786		
2.901	0.9597			
4.000		0.9594		
5.000	0.9428		0.9761	
6.000		0.9392		
8.000	0.9183			
10.000	0.9086		0.9452	
13.790	0.8924			
13.840		0.8881		
20.000		0.8631	0.8936	
25.000			0.8615	0.8911

J. Chem. Soc. 3062–3079 (1931).

TABLE 2-172 Sodium Chloride

	Specific heat, cal/(g·°C)			
Mole % NaCl	6 °C	20 °C	33 °C	57 °C
0.249		0.99		
0.99	0.96	0.97	0.97	
2.44	0.91	0.915	0.915	0.923
9.09	0.805	0.81	0.81	0.82

TABLE 2-173 Sodium Hydroxide (at 20 °C)

Mole % NaOH	0	0.5	1.0	9.09	16.7	28.6	37.5
Cal/(g·°C)	1.0	0.985	0.97	0.835	0.80	0.784	0.782

TABLE 2-174 Sulfuric Acid*

$\%H_2SO_4$	C_p at 20 °C, cal/(g·°C)	$\%H_2SO_4$	C_p at 20 °C, cal/(g·°C)
0.34	0.9968	35.25	0.7238
0.68	0.9937	37.69	.7023
1.34	0.9877	40.49	.6770
2.65	0.9762	43.75	.6476
3.50	0.9688	47.57	.6153
5.16	0.9549	52.13	.5801
9.82	0.9177	57.65	.5420
15.36	0.8767	64.47	.5012
21.40	0.8339	73.13	.4628
22.27	0.8275	77.91	.4518
23.22	0.8205	81.33	.4481
24.25	0.8127	82.49	.4467
25.39	0.8041	84.48	.4408
26.63	0.7945	85.48	.4346
28.00	0.7837	89.36	.4016
29.52	0.7717	91.81	.3787
30.34	0.7647	94.82	.3554
31.20	0.7579	97.44	.3404
33.11	0.7422	100.00	.3352

*Vinal and Craig, *Bur. Standards J. Research,* **24,** 475 (1940).

TABLE 2-175 Zinc Sulfate

Composition	Temperature	Specific heat, cal/(g·°C)
$ZnSO_4 + 50H_2O$	20 to 52 °C	0.842
$ZnSO_4 + 200H_2O$	20 to 52 °C	0.952

SPECIFIC HEATS OF MISCELLANEOUS MATERIALS

TABLE 2-176 Specific Heats of Miscellaneous Liquids and Solids

Material	Specific heat, cal/(g·°C)
Alumina	0.2 (100 °C); 0.274 (1500 °C)
Alundum	0.186 (100 °C)
Asbestos	0.25
Asphalt	0.22
Bakelite	0.3 to 0.4
Brickwork	About 0.2
Carbon	0.168 (26 to 76 °C)
	0.314 (40 to 892 °C)
	0.387 (56 to 1450 °C)
(gas retort)	0.204
(see under Graphite)	
Cellulose	0.32
Cement, Portland Clinker	0.186
Charcoal (wood)	0.242
Chrome brick	0.17
Clay	0.224
Coal	0.26 to 0.37
tar oils	0.34 (15 to 90 °C)
Coal tars	0.35 (40 °C); 0.45 (200 °C)
Coke	0.265 (21 to 400 °C)
	0.359 (21 to 800 °C)
	0.403 (21 to 1300 °C)
Concrete	0.156 (70 to 312 °F); 0.219 (72 to 1472 °F)
Cryolite	0.253 (16 to 55 °C)
Diamond	0.147
Fireclay brick	0.198 (100 °C); 0.298 (1500 °C)
Fluorspar	0.21 (30 °C)
Gasoline	0.53
Glass (crown)	0.16 to 0.20
(flint)	0.117
(pyrex)	0.20
(silicate)	0.188 to 0.204 (0 to 100 °C)
	0.24 to 0.26 (0 to 700 °C)
wool	0.157
Granite	0.20 (20 to 100 °C)
Graphite	0.165 (26 to 76 °C); 0.390 (56 to 1450 °C)
Gypsum	0.259 (16 to 46 °C)
Kerosene	0.47
Limestone	0.217
Litharge	0.055
Magnesia	0.234 (100 °C); 0.188 (1500 °C)
Magnesite brick	0.222 (100 °C); 0.195 (1500 °C)
Marble	0.21 (18 °C)
Porcelain, fired Berlin	0.189 (60 °C)
Porcelain, green Berlin	0.185 (60 °C)
Porcelain, fired earthenware	0.186 (60 °C)
Porcelain, green earthenware	0.181 (60 °C)

TABLE 2-176 Specific Heats of Miscellaneous Liquids and Solids (*Concluded*)

Material	Specific heat, cal/(g·°C)
Pyrex glass	0.20
Pyrites (copper)	0.131 (30 °C)
Pyrites (iron)	0.136 (30 °C)
Pyroxylin plastics	0.34 to 0.38
Quartz	0.17 (0 °C); 0.28 (350 °C)
Rubber (vulcanized)	0.415
Sand	0.191
Silica	0.316
Silica brick	0.202 (100 °C); 0.195 (1500 °C)
Silicon carbide brick	0.202 (100 °C)
Silk	0.33
Steel	0.12
Stone	about 0.2
Stoneware (common)	0.188 (60 °C)
Turpentine	0.42 (18 °C)
Wood (Oak)	0.570
Woods, miscellaneous	0.45 to 0.65
Wool	0.325
Zirconium oxide	0.11 (100 °C); 0.179 (1500 °C)

TABLE 2-177 Oils (Animal, Vegetable, Mineral Oils)

$$C_p[\text{cal/(g·°C)}] = A/\sqrt{d_4^{15}} + B(t - 15)$$

where d = density, g/cm^3.

°F = 9⁄5 °C + 32; to convert calories per gram-degree Celsius to British thermal units per pound-degree Fahrenheit, multiply by 1.0; to convert grams per cubic centimeter to pounds per cubic foot, multiply by 62.43.

Oils	*A*	*B*
Castor	0.500	0.0007
Citron	(0.438 at 54 °C)	
Fatty drying	0.440	0.0007
nondrying	0.450	0.0007
semidrying	0.445	0.0007
oils (except castor)	0.450	0.0007
Naphthene base	0.405	0.0009
Olive	(0.47 at 7 °C)	
Paraffin base	0.425	0.0009
Petroleum oils	0.415	0.0009

PROPERTIES OF FORMATION AND COMBUSTION REACTIONS

UNITS CONVERSIONS

°F = 9⁄5 °C + 32; to convert kilocalories per gram-mole to British thermal units per pound-mole, multiply by 1.799×10^{-3}.

TABLE 2-178 Heats and Free Energies of Formation of Inorganic Compounds

The values given in the following table for the heats and free energies of formation of inorganic compounds are derived from (*a*) Bichowsky and Rossini, "Thermochemistry of the Chemical Substances," Reinhold, New York, 1936; (*b*) Latimer, "Oxidation States of the Elements and Their Potentials in Aqueous Solution," Prentice-Hall, New York, 1938; (*c*) the tables of the American Petroleum Institute Research Project 44 at the National Bureau of Standards; and (*d*) the tables of Selected Values of Chemical Thermodynamic Properties of the National Bureau of Standards. The reader is referred to the preceding books and tables for additional details as to methods of calculation, standard states, and so on.

Compound	State†	Heat of formation‡§ ΔH (formation) at 25 °C, kcal/mol	Free energy of formation‖¶ ΔF (formation) at 25 °C, kcal/mol
Aluminum			
Al	c	0.00	0.00
$AlBr_3$	c	−123.4	
	aq	−209.5	−189.2
Al_4C_3	c	−30.8	−29.0
$AlCl_3$	c	−163.8	
	aq, 600	−243.9	−209.5
AlF_3	c	−329	
	aq	−360.8	−312.6
AlI_3	c	−72.8	
	aq	−163.4	−152.5
AlN	c	−57.7	−50.4
$Al(NH_4)(SO_4)_2$	c	−561.19	−486.17
$Al(NH_4)(SO_4)_2{\cdot}12H_2O$	c	−1419.36	−1179.26
$Al(NO_3)_3{\cdot}6H_2O$	c	−680.89	−526.32
$Al(NO_3)_3{\cdot}9H_2O$	c	−897.59	
Al_2O_3	c, corundum	−399.09	−376.87
$Al(OH)_3$	c	−304.8	−272.9
$Al_2O_3{\cdot}SiO_2$	c, sillimanite	−648.7	
$Al_2O_3{\cdot}SiO_2$	c, disthene	−642.4	
$Al_2O_3{\cdot}SiO_2$	c, andalusite	−642.0	
$3Al_2O_3{\cdot}2SiO_2$	c, mullite	−1874	
Al_2S_3	c	−121.6	
$Al_2(SO_4)_3$	c	−820.99	−739.53
	aq	−893.9	−759.3
$Al_2(SO_4)_3{\cdot}6H_2O$	c	−1268.15	−1103.39
$Al_2(SO_4)_3{\cdot}18H_2O$	c	−2120	
Antimony			
Sb	c	0.00	0.00
$SbBr_3$	c	−59.9	
$SbCl_3$	c	−91.3	−77.8
$SbCl_5$	l	−104.8	
SbF_3	c	−216.6	
SbI_3	c	−22.8	
Sb_2O_3	c, I, orthorhombic	−165.4	−146.0
	c, II, octahedral	−166.6	
Sb_2O_4	c	−213.0	−186.6
Sb_2O_5	c	−230.0	−196.1
Sb_2S_3	c, black	−38.2	−36.9
Arsenic			
As	c	0.00	0.00
$AsBr_3$	c	−45.9	
$AsCl_3$	l	−80.2	−70.5
AsF_3	l	−223.76	−212.27
AsH_3	g	43.6	37.7
AsI_3	c	−13.6	
As_2O_3	c	−154.1	−134.8
As_2O_5	c	−217.9	−183.9
As_2S_3	c	−20	−20
	amorphous	−34.76	
Barium			
Ba	c	0.00	0.00
$BaBr_2$	c	−180.38	
	aq, 400	−185.67	−183.0
$BaCl_2$	c	−205.25	
	aq, 300	−207.92	−196.5
$Ba(ClO_3)_2$	c	−176.6	
	aq, 1600	−170.0	−134.4
$Ba(ClO_4)_2$	c	−210.2	
	aq, 800		−155.3
$Ba(CN)_2$	c	−48	
$Ba(CNO)_2$	c	−212.1	
	aq		−180.7
$BaCN_2$	c	−63.6	
$BaCO_3$	c, witherite	−284.2	−271.4
$BaCrO_4$	c	−342.2	
Barium (*Cont.*)			
BaF_2	c	−287.9	
	aq, 1600	−284.6	−265.3
BaH_2	c	−40.8	−31.5
$Ba(HCO_3)_2$	aq	−459	−414.4
BaI_2	c	−144.6	
	aq, 400	−155.17	−158.52
$Ba(IO_3)_2$	c	−264.5	
	aq	−237.50	−198.35
$BaMoO_4$	c	−370	
Ba_3N_2	c	−90.7	
$Ba(NO_2)_2$	c	−184.5	
	aq	−179.05	−150.75
$Ba(NO_3)_2$	c	−236.99	−189.94
	aq, 600	−227.74	
BaO	c	−133.0	
$Ba(OH)_2$	c	−225.9	
	aq, 400	−237.76	−209.02
$BaO{\cdot}SiO_2$	c	−363	
$Ba_3(PO_4)_2$	c	−992	
$BaPtCl_6$	c	−284.9	
BaS	c	−111.2	
$BaSO_3$	c	−282.5	
$BaSO_4$	c	−340.2	−313.4
$BaWO_4$	c	−402	
Beryllium			
Be	c	0.00	0.00
$BeBr_2$	c	−79.4	
	aq	−142	−127.9
$BeCl_2$	c	−112.6	
	aq	−163.9	−141.4
BeI_2	c	−39.4	
	aq	−112	−103.4
Be_3N_2	c	−134.5	−122.4
BeO	c	−145.3	−138.3
$Be(OH)_2$	c	−215.6	
BeS	c	−56.1	
$BeSO_4$	c	−281	
	aq		−254.8
Bismuth			
Bi	c	0.00	0.00
$BiCl_3$	c	−90.5	−76.4
	aq	−101.6	
BiI_3	c	−24	
	aq	−27	
BiO	c	−49.5	−43.2
Bi_2O_3	c	−137.1	−117.9
$Bi(OH)_3$	c	−171.1	
Bi_2S_3	c	−43.9	−39.1
$Bi_2(SO_4)_3$	c	−607.1	
Boron			
B	c	0.00	0.00
BBr_3	l	−52.7	
	g	−44.6	−50.9
BCl_3	g	−94.5	−90.8
BF_3	g	−265.2	−261.0
B_2H_6	g	7.5	19.9
BN	c	−32.1	−27.2
B_2O_3	c	−302.0	−282.9
	gls	−297.6	−280.3
$B(OH)_3$	c	−260.0	−229.4
B_2S_3	c	−56.6	
Bromine			
Br_2	l	0.00	0.00
	g	7.47	0.931
BrCl	g	3.06	−0.63

*For footnotes see end of table.

TABLE 2-178 Heats and Free Energies of Formation of Inorganic Compounds (*Continued*)

Compound	State†	Heat of formation‡§ ΔH (formation) at 25 °C, kcal/mol	Free energy of formation‖¶ ΔF (formation) at 25 °C, kcal/mol
Cadmium			
Cd	c	0.00	0.00
$CdBr_2$	c	−75.8	−70.7
	aq, 400	−76.6	−67.6
$CdCl_2$	c	−92.149	−81.889
	aq, 400	−96.44	−81.2
$Cd(CN)_2$	c	36.2	
$CdCO_3$	c	−178.2	−163.2
CdI_2	c	−48.40	
	aq, 400	−47.46	−43.22
Cd_3N_2	c	39.8	
$Cd(NO_3)_2$	aq, 400	−115.67	−71.05
CdO	c	−62.35	−55.28
$Cd(OH)_2$	c	−135.0	−113.7
CdS	c	−34.5	−33.6
$CdSO_4$	c	−222.23	
	aq, 400	−232.635	−194.65
Calcium			
Ca	c	0.00	0.00
$CaBr_2$	c	−162.20	
	aq, 400	−187.19	−181.86
CaC_2	c	−14.8	−16.0
$CaCl_2$	c	−190.6	−179.8
	aq	−209.15	−195.36
$CaCN_2$	c	−85	
$Ca(CN)_2$	c	−43.3	
	aq		−54.0
$CaCO_3$	c, calcite	−289.5	−270.8
	c, aragonite	−289.54	−270.57
$CaCO_3{\cdot}MgCO_3$	c	−558.8	
CaC_2O_4	c	−332.2	
$Ca(C_2H_3O_2)_2$	c	−356.3	
	aq	−364.1	−311.3
CaF_2	c	−290.2	
	aq	−286.5	−264.1
CaH_2	c	−46	−35.7
CaI_2	c	−128.49	
	aq, 400	−156.63	−157.37
Ca_3N_2	c	−103.2	−88.2
$Ca(NO_3)_2$	c	−224.05	−177.38
	aq, 400	−228.29	
$Ca(NO_3)_2{\cdot}2H_2O$	c	−367.95	−293.57
$Ca(NO_3)_2{\cdot}3H_2O$	c	−439.05	−351.58
$Ca(NO_3)_2{\cdot}4H_2O$	c	−509.43	−409.32
CaO	c	−151.7	−144.3
$Ca(OH)_2$	c	−235.58	−213.9
	aq, 800	−239.2	−207.9
$CaO{\cdot}SiO_2$	c, II, wollastonite	−377.9	−357.5
	c, I, pseudo-wollastonite	−376.6	−356.6
CaS	c	−114.3	−113.1
$CaSO_4$	c, insoluble form	−338.73	−311.9
	c, soluble form α	−336.58	−309.8
	c, soluble form β	−335.52	−308.8
$CaSO_4{\cdot}½H_2O$	c	−376.13	
$CaSO_4{\cdot}2H_2O$	c	−479.33	−425.47
$CaWO_4$	c	−387	
Carbon			
C	c, graphite	0.00	0.00
	c, diamond	0.453	0.685
CO	g	−26.416	−32.808
CO_2	g	−94.052	−94.260
Cerium			
Ce	c	0.00	0.00
CeN	c	−78.2	−70.8
Cesium			
Cs	c	0.00	0.00
CsBr	c	−97.64	
	aq, 500	−91.39	−94.86
CsCl	c	−106.31	
	aq, 400	−102.01	−101.61
Cesium (*Cont.*)			
Cs_2CO_3	c	−271.88	
CsF	c	−131.67	
	aq, 400	−140.48	−135.98
CsH	c	−12	−7.30
$CsHCO_3$	c	−230.6	
	aq, 2000	−226.6	−210.56
CsI	c	−83.91	
	aq, 400	−75.74	−82.61
$CsNH_2$	c	−28.2	
$CsNO_3$	c	−121.14	
	aq, 400	−111.54	−96.53
Cs_2O	c	−82.1	
CsOH	c	−100.2	
	aq, 200	−117.0	−107.87
Cs_2S	c	−87	
Cs_2SO_4	c	−344.86	
	aq	−340.12	−316.66
Chlorine			
Cl_2	g	0.00	0.00
ClF	g	−25.7	
ClO	g	33	
ClO_2	g	24.7	29.5
ClO_3	g	37	
Cl_2O	g	18.20	22.40
Cl_2O_7	g	63	
Chromium			
Cr	c	0.00	0.00
$CrBr_3$	aq		−122.7
Cr_3C_2	c	−21.008	−21.20
Cr_4C	c	−16.378	−16.74
$CrCl_2$	c	−103.1	−93.8
	aq		−102.1
CrF_2	c	−152	
CrF_3	c	−231	
CrI_2	c	−63.7	
	aq		−64.1
CrO_3	c	−139.3	
Cr_2O_3	c	−268.8	−249.3
$Cr_2(SO_4)_3$	aq		−626.3
Cobalt			
Co	c	0.00	0.00
$CoBr_2$	c	−55.0	
	aq	−73.61	−61.96
Co_3C	c	9.49	7.08
$CoCl_2$	c	−76.9	−66.6
	aq, 400	−95.58	−75.46
$CoCO_3$	c	−172.39	−155.36
CoF_2	aq	−172.98	−144.2
CoI_2	c	−24.2	
	aq	−43.15	−37.4
$Co(NO_3)_2$	c	−102.8	
	aq	−114.9	−65.3
CoO	c	−57.5	
Co_3O_4	c	−196.5	
$Co(OH)_2$	c	−131.5	−108.9
$Co(OH)_3$	c	−177.0	−142.0
CoS	c	−22.3	−19.8
Co_2S_3	c	−40.0	
$CoSO_4$	c	−216.6	
	aq, 400		−188.9
Columbium			
Cb	c	0.00	0.00
Cb_2O_5	c	−462.96	
Copper			
Cu	c	0.00	0.00
CuBr	c	−26.7	−23.8
$CuBr_2$	c	−34.0	
	aq	−42.4	−33.25
CuCl	c	−31.4	−24.13
$CuCl_2$	c	−48.83	
	aq, 400	−64.7	

TABLE 2-178 Heats and Free Energies of Formation of Inorganic Compounds (*Continued*)

Compound	State†	Heat of formation‡§ ΔH (formation) at 25 °C, kcal/mol	Free energy of formation‖¶ ΔF (formation) at 25 °C, kcal/mol
Copper (*Cont.*)			
$CuClO_4$	aq	−28.3	1.34
$Cu(ClO_3)_2$	aq, 400		15.4
$Cu(ClO_4)_2$	aq		−5.5
CuI	c	−17.8	−16.66
CuI_2	c	−4.8	
	aq	−11.9	−8.76
Cu_3N	c	17.78	
$Cu(NO_3)_2$	c	−73.1	
	aq, 200	−83.6	−36.6
CuO	c	−38.5	−31.9
Cu_2O	c	−43.00	−38.13
$Cu(OH)_2$	c	−108.9	−85.5
CuS	c	−11.6	−11.69
Cu_2S	c	−18.97	−20.56
$CuSO_4$	c	−184.7	−158.3
	aq, 800	−200.78	−160.19
Cu_2SO_4	c	−179.6	
	aq		−152.0
Erbium			
Er	c	0.00	0.00
$Er(OH)_3$	c	−326.8	
Fluorine			
F_2	g	0.00	0.00
F_2O	g	5.5	9.7
Gallium			
Ga	c	0.00	0.00
$GaBr_3$	c	−92.4	
$GaCl_3$	c	−125.4	
GaN	c	−26.2	
Ga_2O	c	−84.3	
Ga_2O_3	c	−259.9	
Germanium			
Ge	c	0.00	0.00
Ge_3N_4	c	−15.7	
GeO_2	c	−128.6	
Gold			
Au	c	0.00	0.00
AuBr	c	−3.4	
$AuBr_3$	c	−14.5	
	aq	−11.0	24.47
AuCl	c	−8.3	
$AuCl_3$	c	−28.3	
	aq	−32.96	4.21
AuI	c	0.2	−0.76
Au_2O_3	c	11.0	18.71
$Au(OH)_3$	c	−100.6	
Hafnium			
Hf	c	0.00	0.00
HfO_2	c	−271.1	−258.2
Hydrogen			
H_3AsO_3	aq	−175.6	−153.04
H_3AsO_4	c	−214.9	
	aq	−214.8	−183.93
HBr	g	−8.66	−12.72
	aq, 400	−28.80	−24.58
HBrO	aq	−25.4	−19.90
$HBrO_3$	aq	−11.51	5.00
HCl	g	−22.063	−22.778
	aq, 400	−39.85	−31.330
HCN	g	31.1	27.94
	aq, 100	24.2	26.55
HClO	aq, 400	−28.18	−19.11
$HClO_3$	aq	−23.4	−0.25
$HClO_4$	aq, 660	−31.4	−10.70
$HC_2H_3O_2$	l	−116.2	−93.56
	aq, 400	−116.74	−96.8
$H_2C_2O_4$	c	−196.7	
	aq, 300	−194.6	−165.64
HCOOH	l	−97.8	−82.7
	aq, 200	−98.0	−85.1
Hydrogen (*Cont.*)			
H_2CO_3	aq	−167.19	−149.0
HF	g	−64.2	−64.7
	aq, 200	−75.75	
HI	g	6.27	0.365
	aq, 400	−13.47	−12.35
HIO	aq	−38	−23.33
HIO_3	c	−56.77	
	aq	−54.8	−32.25
HN_3	g	70.3	78.50
HNO_3	g	−31.99	−17.57
	l	−41.35	−19.05
	aq, 400	−49.210	
$HNO_3 \cdot H_2O$	l	−112.91	−78.36
$HNO_3 \cdot 3H_2O$	l	−252.15	−193.70
H_2O	g	−57.7979	−54.6351
	l	−68.3174	−56.6899
H_2O_2	l	−45.16	−28.23
	aq, 200	−45.80	−31.47
H_3PO_2	c	−145.5	
	aq	−145.6	−120.0
H_3PO_3	c	−232.2	
	aq	−232.2	−204.0
H_3PO_4	c	−306.2	
	aq, 400	−309.32	−270.0
H_2S	g	−4.77	−7.85
	aq, 2000	−9.38	
H_2S_2	l	−3.6	
H_2SO_3	aq, 200	−146.88	−128.54
H_2SO_4	l	−193.69	
	aq, 400	−212.03	
H_2Se	g	20.5	17.0
	aq	18.1	18.4
H_2SeO_3	c	−126.5	
	aq	−122.4	−101.36
H_2SeO_4	c	−130.23	
	aq, 400	−143.4	
H_2SiO_3	c	−267.8	−247.9
H_4SiO_4	c	−340.6	
H_2Te	g	36.9	33.1
H_2TeO_3	c	−145.0	−115.7
	aq	−145.0	
H_2TeO_4	aq	−165.6	
Indium			
In	c	0.00	0.00
$InBr_3$	c	−97.2	
	aq	−112.9	−97.2
$InCl_3$	c	−128.5	
	aq	−145.6	−117.5
InI_3	c	−56.5	
	aq	−67.2	−60.5
InN	c	−4.8	
In_2O_3	c	−222.47	
Iodine			
I_2	c	0.00	0.00
	g	14.88	4.63
IBr	g	10.05	1.24
ICl	g	4.20	−1.32
ICl_3	c	−21.8	−6.05
I_2O_5	c	−42.5	
Iridium			
Ir	c	0.00	0.00
IrCl	c	−20.5	−16.9
$IrCl_2$	c	−40.6	−32.0
$IrCl_3$	c	−60.5	−46.5
IrF_6	l	−130	
IrO_2	c	−40.14	
Iron			
Fe	c, α	0.00	0.00
$FeBr_2$	c	−57.15	
	aq, 540	−78.7	−69.47

TABLE 2-178 Heats and Free Energies of Formation of Inorganic Compounds (*Continued*)

Compound	State†	Heat of formation‡§ ΔH (formation) at 25 °C, kcal/mol	Free energy of formation‖¶ ΔF (formation) at 25 °C, kcal/mol
Iron (*Cont.*)			
$FeBr_3$	aq	−95.5	−76.26
Fe_3C	c	5.69	4.24
$Fe(CO)_5$	l	−187.6	
$FeCO_3$	c, siderite	−172.4	−154.8
$FeCl_2$	c	−81.9	−72.6
	aq	−100.0	−83.0
$FeCl_3$	c	−96.4	
	aq, 2000	−128.5	−96.5
FeF_2	aq, 1200	−177.2	−151.7
FeI_2	c	−24.2	
	aq	−47.7	−45
FeI_3	aq	−49.7	−39.5
Fe_4N	c	−2.55	0.862
$Fe(NO_3)_2$	aq	−118.9	−72.8
$Fe(NO_3)_3$	aq, 800	−156.5	−81.3
FeO	c	−64.62	−59.38
Fe_2O_3	c	−198.5	−179.1
Fe_3O_4	c	−266.9	−242.3
$Fe(OH)_2$	c	−135.9	−115.7
$Fe(OH)_3$	c	−197.3	−166.3
$FeO{\cdot}SiO_2$	c	−273.5	
Fe_2P	c	−13	
FeSi	c	−19.0	
FeS	c	−22.64	−23.23
FeS_2	c, pyrites	−38.62	−35.93
	c, marcasite	−33.0	
$FeSO_4$	c	−221.3	−195.5
	aq, 400	−236.2	−196.4
$Fe_2(SO_4)_3$	aq, 400	−653.3	−533.4
$FeTiO_3$	c, ilmenite	−295.51	−277.06
Lanthanum			
La	c	0.00	0.00
$LaCl_3$	c	−253.1	
	aq	−284.7	
La_3H_8	c	−160	
LaN	c	−72.0	−64.6
La_2O_3	c	−539	
LaS_2	c	−148.3	
La_2S_3	c	−351.4	
$La_2(SO_4)_3$	aq	−972	
Lead			
Pb	c	0.00	0.00
$PbBr_2$	c	−66.24	−62.06
	aq	−56.4	−54.97
$PbCO_3$	c, cerussite	−167.6	−150.0
$Pb(C_2H_3O_2)_2$	c	−232.6	
	aq, 400	−234.2	−184.40
PbC_2O_4	c	−205.3	
$PbCl_2$	c	−85.68	−75.04
	aq	−82.5	−68.47
PbF_2	c	−159.5	−148.1
PbI_2	c	−41.77	−41.47
$Pb(NO_3)_2$	c	−106.88	
	aq, 400	−99.46	−58.3
PbO	c, red	−51.72	−45.53
	c, yellow	−50.86	−43.88
PbO_2	c	−65.0	−52.0
Pb_3O_4	c	−172.4	−142.2
$Pb(OH)_2$	c	−123.0	−102.2
PbS	c	−22.38	−21.98
$PbSO_4$	c	−218.5	−192.9
Lithium			
Li	c	0.00	0.00
LiBr	c	−83.75	
	aq, 400	−95.40	−95.28
$LiBrO_3$	aq	−77.9	−65.70
Li_2C_2	c	−13.0	
LiCN	aq	−31.4	−31.35
LiCNO	aq	−101.2	−94.12
Lithium (*Cont.*)			
$LiC_2H_3O_2$	aq	−183.9	−160.00
Li_2CO_3	c	−289.7	−269.8
	aq, 1900	−293.1	−267.58
LiCl	c	−97.63	
	aq, 278	−106.45	−102.03
$LiClO_3$	aq	−87.5	−70.95
$LiClO_4$	aq	−106.3	−81.4
LiF	c	−145.57	
	aq, 400	−144.85	−136.40
LiH	c	−22.9	
$LiHCO_3$	aq, 2000	−231.1	−210.98
LiI	c	−65.07	
	aq, 400	−80.09	−83.03
$LiIO_3$	aq	−121.3	−102.95
Li_3N	c	−47.45	−37.33
$LiNO_3$	c	−115.350	
	aq, 400	−115.88	−96.95
Li_2O	c	−142.3	
Li_2O_2	c	−151.9	−138.0
	aq	−159	
LiOH	c	−116.58	−106.44
	aq, 400	−121.47	−108.29
$LiOH{\cdot}H_2O$	c	−188.92	
$Li_2O{\cdot}SiO_2$	gls	−374	
Li_2Se	c	−84.9	
	aq	−95.5	−105.64
Li_2SO_4	c	−340.23	−314.66
	aq, 400	−347.02	
$Li_2SO_4{\cdot}H_2O$	c	−411.57	−375.07
Magnesium			
Mg	c	0.00	0.00
$Mg(AsO_4)_2$	c	−731.3	
	aq	−749	−630.14
$MgBr_2$	c	−123.9	
	aq, 400	−167.33	−156.94
$Mg(CN)_2$	aq	−39.7	−29.08
$MgCN_2$	c	−61	
$Mg(C_2H_3O_2)_2$	aq	−344.6	−286.38
$MgCO_3$	c	−261.7	−241.7
$MgCl_2$	c	−153.220	−143.77
	aq, 400	−189.76	
$MgCl_2{\cdot}H_2O$	c	−230.970	−205.93
$MgCl_2{\cdot}2H_2O$	c	−305.810	−267.20
$MgCl_2{\cdot}4H_2O$	c	−453.820	−387.98
$MgCl_2{\cdot}6H_2O$	c	−597.240	−505.45
MgF_2	c	−263.8	
MgI_2	c	−86.8	
	aq, 400	−136.79	−132.45
$MgMoO_4$	c	−329.9	
Mg_3N_2	c	−115.2	−100.8
$Mg(NO_3)_2$	c	−188.770	−140.66
	aq, 400	−209.927	−160.28
$Mg(NO_3)_2{\cdot}2H_2O$	c	−336.625	
$Mg(NO_3)_2{\cdot}6H_2O$	c	−624.48	−496.03
MgO	c	−143.84	−136.17
$MgO{\cdot}SiO_2$	c	−347.5	−326.7
$Mg(OH)_2$	c, ppt.	−221.90	−200.17
	c, brucite	−223.9	−193.3
MgS	c	−84.2	
	aq	−108	
$MgSO_4$	c	−304.94	−277.7
	aq, 400	−325.4	−283.88
MgTe	c	−25	
$MgWO_4$	c	−345.2	
Manganese			
Mn	c, α	0.00	0.00
$MnBr_2$	c	−91	
	aq	−106	−97.8
Mn_3C	c	1.1	1.26

TABLE 2-178 Heats and Free Energies of Formation of Inorganic Compounds (*Continued*)

Compound	State†	Heat of formation‡§ ΔH (formation) at 25 °C, kcal/mol	Free energy of formation‖¶ ΔF (formation) at 25 °C, kcal/mol
Manganese (*Cont.*)			
$Mn(C_2H_3O_2)_2$	c	−270.3	
	aq	−282.7	−227.2
$MnCO_3$	c	−211	−192.5
MnC_2O_4	c	−240.9	
$MnCl_2$	c	−112.0	−102.2
	aq, 400	−128.9	
MnF_2	aq, 1200	−206.1	−180.0
MnI_2	c	−49.8	
	aq	−76.2	−73.3
Mn_5N_2	c	−57.77	−46.49
$Mn(NO_3)_2$	c	−134.9	
	aq, 400	−148.0	−101.1
$Mn(NO_3)_2.6H_2O$	c	−557.07	−441.2
MnO	c	−92.04	−86.77
MnO_2	c	−124.58	−111.49
Mn_2O_3	c	−229.5	−209.9
Mn_3O_4	c	−331.65	−306.22
$MnO.SiO_2$	c	−301.3	−282.1
$Mn(OH)_2$	c	−163.4	−143.1
$Mn(OH)_3$	c	−221	−190
$Mn_3(PO_4)_2$	c	−736	
MnSe	c	−26.3	−27.5
MnS	c, green	−47.0	−48.0
$MnSO_4$	c	−254.18	−228.41
	aq, 400	−265.2	
$Mn_2(SO_4)_3$	c	−635	
	aq	−657	
Mercury			
Hg	l	0.00	0.00
HgBr	g	23	18
$HgBr_2$	c	−40.68	−38.8
	aq	−38.4	−9.74
$Hg(C_2H_3O_2)_2$	c	−196.3	
	aq	−192.5	−139.2
$HgCl_2$	c	−53.4	−42.2
	aq	−50.3	−23.25
HgCl	g	19	14
Hg_2Cl_2	c	−63.13	
$Hg(CN)_2$	c	62.8	
	aq, 1110	66.25	
HgC_2O_4	c	−159.3	
HgH	g	57.1	52.25
HgI_2	c, red	−25.3	−24.0
HgI	g	33	23
Hg_2I_2	c	−28.88	−26.53
$Hg(NO_3)_2$	aq	−56.8	−13.09
$Hg_2(NO_3)_2$	aq	−58.5	−15.65
HgO	c, red	−21.6	−13.94
	c, yellow ppt.	−20.8	
Hg_2O	c	−21.6	−12.80
HgS	c, black	−10.7	−8.80
$HgSO_4$	c	−166.6	
Hg_2SO_4	c	−177.34	−149.12
Molybdenum			
Mo	c	0.00	0.00
Mo_2C	c	4.36	2.91
Mo_2N	c	−8.3	
MoO_2	c	−130	−118.0
MoO_3	c	−180.39	−162.01
MoS_2	c	−56.27	−54.19
MoS_3	c	−61.48	−57.38
Nickel			
Ni	c	0.00	0.00
$NiBr_2$	c	−53.4	
	aq	−72.6	−60.7
Ni_3C	c	9.2	8.88
$Ni(C_2H_3O_2)_2$	aq	−249.6	−190.1
$Ni(CN)_2$	aq	230.9	66.3
$NiCl_2$	c	−75.0	
	aq, 400	−94.34	−74.19
NiF_2	c	−157.5	
	aq	−171.6	−142.9
NiI_2	c	−22.4	
	aq	−42.0	−36.2
$Ni(NO_3)_2$	c	−101.5	
	aq, 200	−113.5	−64.0
NiO	c	−58.4	−51.7
$Ni(OH)_2$	c	−129.8	−105.6
$Ni(OH)_3$	c	−163.2	
NiS	c	−20.4	
$NiSO_4$	c	−216	
	aq, 200	−231.3	−187.6
Nitrogen			
N_2	g	0.00	0.00
NF_3	g	−27	
NH_3	g	−10.96	−3.903
	aq, 200	−19.27	
NH_4Br	c	−64.57	
	aq	−60.27	−43.54
$NH_4C_2H_3O_2$	c	−148.1	
	aq, 400	−148.58	−108.26
NH_4CN	c	−0.7	
	aq	3.6	20.4
NH_4CNS	c	−17.8	
	aq	−12.3	4.4
$(NH_4)_2CO_3$	aq	−223.4	−164.1
$(NH_4)_2C_2O_4$	c	−266.3	
	aq	−260.6	−196.2
NH_4Cl	c	−75.23	−48.59
	aq, 400	−71.20	
NH_4ClO_4	c	−69.4	
	aq	−63.2	−21.1
$(NH_4)_2CrO_4$	c	−276.9	
	aq	−271.3	−209.3
NH_4F	c	−111.6	
	aq	−110.2	−84.7
NH_4I	c	−48.43	
	aq	−44.97	−31.3
NH_4NO_3	c	−87.40	
	aq, 500	−80.89	
NH_4OH	aq	−87.59	
$(NH_4)_2S$	aq, 400	−55.21	−14.50
$(NH_4)_2SO_4$	c	−281.74	−215.06
	aq, 400	−279.33	−214.02
N_2H_4	l	12.06	
$N_2H_4.H_2O$	l	−57.96	
$N_2H_4.H_2SO_4$	c	−232.2	
N_2O	g	19.55	24.82
NO	g	21.600	20.719
NO_2	g	7.96	12.26
N_2O_4	g	2.23	23.41
N_2O_5	c	−10.0	
NOBr	l	11.6	19.26
NOCl	g	12.8	16.1
Osmium			
Os	c	0.00	0.00
OsO_4	c	−93.6	−70.9
	g	−80.1	−68.1
Oxygen			
O_2	g	0.00	0.00
O_3	g	33.88	38.86
Palladium			
Pd	c	0.00	0.00
PdO	c	−20.40	
Phosphorus			
P	c, white (“yellow”)	0.00	0.00
	c, red (“violet”)	−4.22	−1.80
P	g	150.35	141.88

TABLE 2-178 Heats and Free Energies of Formation of Inorganic Compounds (*Continued*)

Compound	State†	Heat of formation‡§ ΔH (formation) at 25 °C, kcal/mol	Free energy of formation‖¶ ΔF (formation) at 25 °C, kcal/mol
Phosphorus (*Cont.*)			
P_2	g	33.82	24.60
P_4	g	13.2	5.89
PBr_3	l	−45	
PBr_5	c	−60.6	
PCl_3	g	−70.0	−65.2
	l	−76.8	−63.3
PCl_5	g	−91.0	−73.2
PH_3	g	2.21	−1.45
PI_3	c	−10.9	
P_2O_5	c	−360.0	
$POCl_3$	g	−138.4	−127.2
Platinum			
Pt	c	0.00	0.00
$PtBr_4$	c	−40.6	
	aq	−50.7	
$PtCl_2$	c	−34	
$PtCl_4$	c	−62.6	
	aq	−82.3	
PtI_4	c	−18	
$Pt(OH)_2$	c	−87.5	−67.9
PtS	c	−20.18	−18.55
PtS_2	c	−26.64	−24.28
Potassium			
K	c	0.00	0.00
K_3AsO_3	aq	−323.0	
K_3AsO_4	aq	−390.3	−355.7
KH_2AsO_4	c	−271.2	−236.7
KBr	c	−94.06	−90.8
	aq, 400	−89.19	−92.0
$KBrO_3$	c	−81.58	−60.30
	aq, 1667	−71.68	
$KC_2H_3O_2$	c	−173.80	
	aq, 400	−177.38	−156.73
KCl	c	−104.348	−97.76
	aq, 400	−100.164	−98.76
$KClO_3$	c	−93.5	−69.30
	aq, 400	−81.34	
$KClO_4$	c	−103.8	−72.86
	aq, 400	−101.14	
KCN	c	−28.1	
	aq, 400	−25.3	−28.08
KCNO	c	−99.6	
	aq	−94.5	−90.85
KCNS	c	−47.0	
	aq, 400	−41.07	−44.08
K_2CO_3	c	−274.01	
	aq, 400	−280.90	−264.04
$K_2C_2O_4$	c	−319.9	
	aq, 400	−315.5	−293.1
K_2CrO_4	c	−333.4	
	aq, 400	−328.2	−306.3
$K_2Cr_2O_7$	c	−488.5	
	aq, 400	−472.1	−440.9
KF	c	−134.50	
	aq, 180	−138.36	−133.13
$K_3Fe(CN)_6$	c	−48.4	
	aq	−34.5	
$K_4Fe(CN)_6$	c	−131.8	
	aq	−119.9	
KH	c	−10	−5.3
$KHCO_3$	c	−229.8	
	aq, 2000	−224.85	−207.71
KI	c	−78.88	−77.37
	aq, 500	−73.95	−79.76
KIO_3	c	−121.69	−101.87
	aq, 400	−115.18	−99.68
KIO_4	aq	−98.1	
$KMnO_4$	c	−192.9	−169.1
	aq, 400	−182.5	−168.0
K_2MoO_4	aq, 880	−364.2	−342.9
Potassium (*Cont.*)			
KNH_2	c	−28.25	
KNO_2	aq	−86.0	−75.9
KNO_3	c	−118.08	−94.29
	aq, 400	−109.79	−93.68
K_2O	c	−86.2	
$K_2O{\cdot}Al_2O_3{\cdot}SiO_2$	c, leucite	−1379.6	
	gls	−1368.2	
$K_2O{\cdot}Al_2O_3{\cdot}SiO_2$	c, adularia	−1784.5	
	c, microcline	−1784.5	
	gls	−1747	
KOH	c	−102.02	
	aq, 400	−114.96	−105.0
K_3PO_3	aq	−397.5	
K_3PO_4	aq	−478.7	−443.3
KH_2PO_4	c	−362.7	−326.1
K_2PtCl_4	c	−254.7	
	aq	−242.6	−226.5
K_2PtCl_6	c	−299.5	−263.6
	aq, 9400	−286.1	
K_2Se	c	−74.4	
	aq	−83.4	−99.10
K_2SeO_4	aq	−267.1	−240.0
K_2S	c	−121.5	
	aq, 400	−110.75	−111.44
K_2SO_3	c	−267.7	
	aq	−269.7	−251.3
K_2SO_4	c	−342.65	−314.62
	aq, 400	−336.48	−310.96
$K_2SO_4{\cdot}Al_2(SO_4)_3$	c	−1178.38	−1068.48
$K_2SO_4{\cdot}Al_2(SO_4)_3{\cdot}$ $24H_2O$	c	−2895.44	−2455.68
$K_2S_2O_6$	c	−418.62	
Rhenium			
Re	c	0.00	0.00
ReF_6	g	−274	
Rhodium			
Rh	c	0.00	0.00
RhO	c	−21.7	
Rh_2O	c	−22.7	
Rh_2O_3	c	−68.3	
Rubidium			
Rb	c	0.00	0.00
RbBr	c	−95.82	
	g	−45.0	−52.50
	aq, 500	−90.54	−93.38
RbCN	aq	−25.9	
Rb_2CO_3	c	−273.22	
	aq, 220	−282.61	−263.78
RbCl	c	−105.06	−98.48
	g	−53.6	−57.9
	aq, ∞	−101.06	−100.13
RbF	c	−133.23	
	aq, 400	−139.31	−134.5
$RbHCO_3$	c	−230.01	
	aq, 2000	−225.59	−209.07
RbI	c	−81.04	
	g	−31.2	−40.5
	aq, 400	−74.57	−81.13
$RbNH_2$	c	−27.74	
$RbNO_3$	c	−119.22	
	aq, 400	−110.52	−95.05
Rb_2O	c	−82.9	
Rb_2O_2	c	−107	
RbOH	c	−101.3	
	aq, 200	−115.8	−106.39
Ruthenium			
Ru	c	0.00	0.00
RuS_2	c	−46.99	−44.11
Selenium			
Se	c, I, hexagonal	0.00	0.00

TABLE 2-178 Heats and Free Energies of Formation of Inorganic Compounds (*Continued*)

Compound	State†	Heat of formation‡§ ΔH (formation) at 25 °C, kcal/mol	Free energy of formation‖¶ ΔF (formation) at 25 °C, kcal/mol
Selenium (*Cont.*)			
	c, II, red, monoclinic	0.2	
Se_2Cl_2	l	−22.06	−13.73
SeF_6	g	−246	−222
SeO_2	c	−56.33	
Silicon			
Si	c	0.00	0.00
$SiBr_4$	l	−93.0	
SiC	c	−28	−27.4
$SiCl_4$	l	−150.0	−133.9
	g	−142.5	−133.0
SiF_4	g	−370	−360
SiH_4	g	−14.8	−9.4
SiI_4	c	−29.8	
Si_3N_4	c	−179.25	−154.74
SiO_2	c, cristobalite, 1600° form	−202.62	
	c, cristobalite, 1100° form	−202.46	
	c, quartz	−203.35	−190.4
	c, tridymite	−203.23	
Silver			
Ag	c	0.00	0.00
AgBr	c	−23.90	−23.02
Ag_2C_2	c	84.5	
$AgC_2H_3O_2$	c	−95.9	
	aq	−91.7	−70.86
AgCN	c	33.8	38.70
Ag_2CO_3	c	−119.5	−103.0
$Ag_2C_2O_4$	c	−158.7	
AgCl	c	−30.11	−25.98
AgF	c	−48.7	
	aq, 400	−53.1	−47.26
AgI	c	−15.14	−16.17
$AgIO_3$	c	−42.02	−24.08
$AgNO_2$	c	−11.6	3.76
	aq	−2.9	9.99
$AgNO_3$	c	−29.4	−7.66
	aq, 6500	−24.02	−7.81
Ag_2O	c	−6.95	−2.23
Ag_2S	c	−5.5	−7.6
Ag_2SO_4	c	−170.1	−146.8
	aq	−165.8	−139.22
Sodium			
Na	c	0.00	0.00
Na_3AsO_3	aq, 500	−314.61	
Na_3AsO_4	c	−366	
	aq, 500	−381.97	−341.17
NaBr	c	−86.72	
	aq, 400	−86.33	−87.17
NaBrO	aq	−78.9	
$NaBrO_3$	aq, 400	−68.89	−57.59
$NaC_2H_3O_2$	c	−170.45	
	aq, 400	−175.450	−152.31
NaCN	c	−22.47	
	aq, 200	−22.29	−23.24
NaCNO	c	−96.3	
	aq	−91.7	−86.00
NaCNS	c	−39.94	
	aq, 400	−38.23	−39.24
Na_2CO_3	c	−269.46	−249.55
	aq, 1000	−275.13	−251.36
$NaCO_2NH_2$	c	−142.17	
$Na_2C_2O_4$	c	−313.8	
	aq, 600	−309.92	−283.42
NaCl	c	−98.321	−91.894
	aq, 400	−97.324	−93.92
$NaClO_3$	c	−83.59	
	aq, 400	−78.42	−62.84
$NaClO_4$	c	−101.12	
Sodium (*Cont.*)			
	aq, 476	−97.66	−73.29
Na_2CrO_4	c	−319.8	
	aq, 800	−323.0	−296.58
$Na_2Cr_2O_7$	aq, 1200	−465.9	−431.18
NaF	c	−135.94	−129.0
	aq, 400	−135.711	−128.29
NaH	c	−14	−9.30
$NaHCO_3$	c	−226.0	−202.66
	aq	−222.1	−202.87
NaI	c	−69.28	
	aq, ∞	−71.10	−74.92
$NaIO_3$	aq, 400	−112.300	−94.84
Na_2MoO_4	c	−364	
	aq	−358.7	−333.18
$NaNO_2$	c	−86.6	
	aq	−83.1	−71.04
$NaNO_3$	c	−111.71	−87.62
	aq, 400	−106.880	−88.84
Na_2O	c	−99.45	−90.06
Na_2O_2	c	−119.2	−105.0
$Na_2O{\cdot}SiO_2$	c	−383.91	−361.49
$Na_2O{\cdot}Al_2O_3{\cdot}3SiO_2$	c, natrolite	−1180	
$Na_2O{\cdot}Al_2O_3{\cdot}4SiO_2$	c	−1366	
NaOH	c	−101.96	−90.60
	aq, 400	−112.193	−100.18
Na_3PO_3	aq, 1000	−389.1	
Na_3PO_4	c	−457	
	aq, 400	−471.9	−428.74
Na_2PtCl_4	aq	−237.2	−216.78
Na_2PtCl_6	c	−272.1	
	aq	−280.9	
Na_2Se	c	−59.1	
	aq, 440	−78.1	−89.42
Na_2SeO_4	c	−254	
	aq, 800	−261.5	−230.30
Na_2S	c	−89.8	
	aq, 400	−105.17	−101.76
Na_2SO_3	c	−261.2	−240.14
	aq, 800	−264.1	−241.58
Na_2SO_4	c	−330.50	−302.38
	aq, 1100	−330.82	−301.28
$Na_2SO_4{\cdot}10H_2O$	c	−1033.85	−870.52
Na_2WO_4	c	−391	
	aq	−381.5	−345.18
Strontium			
Sr	c	0.00	0.00
$SrBr_2$	c	−171.0	
	aq, 400	−187.24	−182.36
$Sr(C_2H_3O_2)_2$	c	−358.0	
	aq	−364.4	−311.80
$Sr(CN)_2$	aq	−59.5	−54.50
$SrCO_3$	c	−290.9	−271.9
$SrCl_2$	c	−197.84	
	aq, 400	−209.20	−195.86
SrF_2	c	−289.0	
$Sr(HCO_3)_2$	aq	−459.1	−413.76
SrI_2	c	−136.1	
	aq, 400	−156.70	−157.87
Sr_3N_2	c	−91.4	−76.5
$Sr(NO_3)_2$	c	−233.2	
	aq, 400	−228.73	−185.70
SrO	c	−140.8	−133.7
$SrO{\cdot}SiO_2$	gls	−364	
SrO_2	c	−153.3	−139.0
Sr_2O	c	−153.6	
$Sr(OH)_2$	c	−228.7	
	aq, 800	−239.4	−208.27
$Sr_3(PO_4)_2$	c	−980	
	aq	−985	−881.54
SrS	c	−113.1	

TABLE 2-178 Heats and Free Energies of Formation of Inorganic Compounds (*Continued*)

Compound	State†	Heat of formation‡§ ΔH (formation) at 25 °C, kcal/mol	Free energy of formation‖¶ ΔF (formation) at 25 °C, kcal/mol
Strontium (*Cont.*)			
	aq	−120.4	−109.78
$SrSO_4$	c	−345.3	
	aq, 400	−345.0	−309.30
$SrWO_4$	c	−393	
Sulfur			
S	c, rhombic	0.00	0.00
	c, monoclinic	−0.071	0.023
	l, λ	0.257	0.072
	l, λμ equilibrium		0.071
	g	53.25	43.57
S_2	g	31.02	19.36
S_6	g	27.78	13.97
S_8	g	27.090	12.770
S_2Br_2	l	−4	
SCl_4	l	−13.7	
S_2Cl_2	l	−14.2	−5.90
S_2Cl_4	l	−24.1	
SF_6	g	−262	−237
SO	g	19.02	12.75
SO_2	g	−70.94	−71.68
SO_3	g	−94.39	−88.59
	l	−103.03	−88.28
	c, α	−105.09	−88.22
	c, β	−105.92	−88.34
	c, γ	−109.34	−88.98
SO_2Cl_2	g	−82.04	−74.06
	l	−89.80	−75.06
Tantalum			
Ta	c	0.00	0.00
TaN	c	−51.2	−45.11
Ta_2O_5	c	−486.0	−453.7
Tellurium			
Te	c	0.00	0.00
$TeBr_4$	c	−49.3	
$TeCl_4$	c	−77.4	−57.4
TeF_6	g	−315	−292
TeO_2	c	−77.56	−64.66
Thallium			
Tl	c	0.00	0.00
TlBr	c	−41.5	−39.43
	aq	−28.0	−32.34
TlCl	c	−49.37	−44.46
	aq	−38.4	−39.09
$TlCl_3$	c	−82.4	
	aq	−91.0	−44.25
TlF	aq	−77.6	−73.46
TlI	c	−31.1	−31.3
	aq	−12.7	−20.09
$TlNO_3$	c	−58.2	−36.32
	aq	−48.4	−34.01
Tl_2O	c	−43.18	
Tl_2O_3	c	−120	
TlOH	c	−57.44	−45.54
	aq	−53.9	−45.35
Tl_2S	c	−22	
Tl_2SO_4	c	−222.8	−197.79
	aq, 800	−214.1	−191.62
Thorium			
Th	c	0.00	0.00
$ThBr_4$	c	−281.5	
	aq	−352.0	−295.31
ThC_2	c	−45.1	
$ThCl_4$	c	−335	
	aq	−392	−322.32
ThI_4	aq	−292.0	−246.33
Th_3N_4	c	−309.0	−282.3
ThO_2	c	−291.6	−280.1
$Th(OH)_4$	c, "soluble"	−336.1	
$Th(SO_4)_2$	c	−632	
	aq	−668.1	−549.2
Tin			
Sn	c, II, tetragonal	0.00	0.00
	c, III, "gray," cubic	0.6	1.1
$SnBr_2$	c	−61.4	
	aq	−60.0	−55.43
$SnBr_4$	c	−94.8	
	aq	−110.6	−97.66
$SnCl_2$	c	−83.6	
	aq	−81.7	−68.94
$SnCl_4$	l	−127.3	−110.4
	aq	−157.6	−124.67
SnI_2	c	−38.9	
	aq	−33.3	−30.95
SnO	c	−67.7	−60.75
SnO_2	c	−138.1	−123.6
$Sn(OH)_2$	c	−136.2	−115.95
$Sn(OH)_4$	c	−268.9	−226.00
SnS	c	−18.61	
Titanium			
Ti	c	0.00	0.00
TiC	c	−110	−109.2
$TiCl_4$	l	−181.4	−165.5
TiN	c	−80.0	−73.17
TiO_2	c, III, rutil	−225.0	−211.9
	amorphous	−214.1	−201.4
Tungsten			
W	c	0.00	0.00
WO_2	c	−130.5	−118.3
WO_3	c	−195.7	−177.3
WS_2	c	−84	
Uranium			
U	c	0.00	0.00
UC_2	c	−29	
UCl_3	c	−213	
UCl_4	c	−251	
U_3N_4	c	−274	−249.6
UO_2	c	−256.6	−242.2
$UO_2(NO_3)_2 \cdot 6H_2O$	c	−756.8	−617.8
UO_3	c	−291.6	
U_3O_8	c	−845.1	
Vanadium			
V	c	0.00	0.00
VCl_2	c	−147	
VCl_3	l	−187	
VCl_4	l	−165	
VN	c	−41.43	−35.08
V_2O_2	c	−195	
V_2O_3	c	−296	−277
V_2O_4	c	−342	−316
V_2O_5	c	−373	−342
Zinc			
Zn	c	0.00	0.00
ZnSb	c	−3.6	−3.88
$ZnBr_2$	c	−77.0	−72.9
	aq, 400	−93.6	
$Zn(C_2H_3O_2)_2$	c	−259.4	
	aq, 400	−269.4	−214.4
$Zn(CN)_2$	c	17.06	
$ZnCO_3$	c	−192.9	−173.5
$ZnCl_2$	c	−99.9	−88.8
	aq, 400	−115.44	
ZnF_2	aq	−192.9	−166.6
ZnI_2	c	−50.50	−49.93
	aq	−61.6	
$Zn(NO_3)_2$	aq, 400	−134.9	−87.7
ZnO	c, hexagonal	−83.36	−76.19
$ZnO \cdot SiO_2$	c	−282.6	
$Zn(OH)_2$	c, rhombic	−153.66	
ZnS	c, wurtzite	−45.3	−44.2
$ZnSO_4$	c	−233.4	
	aq, 400	−252.12	−211.28

TABLE 2-178 Heats and Free Energies of Formation of Inorganic Compounds (*Concluded*)

Compound	State†	Heat of formation‡§ ΔH (formation) at 25 °C, kcal/mol	Free energy of formation‖¶ ΔF (formation) at 25 °C, kcal/mol	Compound	State†	Heat of formation‡§ ΔH (formation) at 25 °C, kcal/mol	Free energy of formation‖¶ ΔF (formation) at 25 °C, kcal/mol
Zirconium				Zirconium (*Cont.*)			
Zr	c	0.00	0.00	ZrO_2	c, monoclinic	–258.5	–244.6
ZrC	c	–29.8	–34.6	$Zr(OH)_4$	c	–411.0	
$ZrCl_4$	c	–268.9		$ZrO(OH)_2$	c	–337	–307.6
ZrN	c	–82.5	–75.9				

† The physical state is indicated as follows: *c,* crystal (solid); *l,* liquid; *g,* gas; *gls,* glass or solid supercooled liquid; *aq,* in aqueous solution. A number following the symbol *aq* applies only to the values of the heats of formation (not to those of free energies of formation); and indicates the number of moles of water per mole of solute; when no number is given, the solution is understood to be dilute. For the free energy of formation of a substance in aqueous solution, the concentration is always that of the hypothetical solution of unit molality.

‡ The increment in heat content, ΔH, is the reaction of forming the given substance from its elements in their standard states. When ΔH is negative, heat is evolved in the process, and, when positive, heat is absorbed.

§ The heat of solution in water of a given solid, liquid, or gaseous compound is given by the difference in the value for the heat of formation of the given compound in the solid, liquid, or gaseous state and its heat of formation in aqueous solution. The following two examples serve as an illustration of the procedure: (1) For NaCl(*c*) and NaCl(*aq,* $400H_2O$), the values of ΔH(formation) are, respectively, –98.321 and –97.324 kcal/mol. Subtraction of the first value from the second gives $\Delta H = 0.998$ kcal/mol for the reaction of dissolving crystalline sodium chloride in 400 mol of water. When this process occurs at a constant pressure of 1 atm, 0.998 kg-cal of energy are absorbed. (2) For HCl(*g*) and HCl(*aq,* $400H_2O$), the values for ΔH(formation) are, respectively, –22.06 and –39.85 kcal/mol. Subtraction of the first from the second gives $\Delta H = -17.79$ kcal/mol for the reaction of dissolving gaseous hydrogen chloride in 400 mol of water. At a constant pressure of 1 atm, 17.79 kcal of energy are evolved in this process.

‖ The increment in the free energy, ΔF, is the reaction of forming the given substance in its standard state from its elements in their standard states. The standard states are: for a gas, fugacity (approximately equal to the pressure) of 1 atm; for a pure liquid or solid, the substance at a pressure of 1 atm; for a substance in aqueous solution, the hypothetical solution of unit molality, which has all the properties of the infinitely dilute solution except the property of concentration.

¶ The free energy of solution of a given substance from its normal standard state as a solid, liquid, or gas to the hypothetical one molal state in aqueous solution may be calculated in a manner similar to that described in footnote § for calculating the heat of solution.

TABLE 2-179 Enthalpies and Gibbs Energies of Formation, Entropies, and Net Enthalpies of Combustion of Inorganic and Organic Compounds at 298.15 K

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	Ideal gas enthalpy of formation, J/kmol × 1E-07	Ideal gas Gibbs energy of formation, J/kmol × 1E-07	Ideal gas entropy, J/(kmol·K) × 1E-05	Standard net enthalpy of combustion, J/kmol × 1E-09
1	Acetaldehyde	C_2H_4O	75-07-0	44.053	–16.64	–13.33	2.642	–1.1045
2	Acetamide	C_2H_5NO	60-35-5	59.067	–23.83	–15.96	2.722	–1.0741
3	Acetic acid	$C_2H_4O_2$	64-19-7	60.052	–46.11	–40.3	2.825	–0.7866
4	Acetic anhydride	$C_4H_6O_3$	108-24-7	102.089	–57.25	–47.34	3.899	–1.675
5	Acetone	C_3H_6O	67-64-1	58.079	–21.57	–15.13	2.954	–1.659
6	Acetonitrile	C_2H_3N	75-05-8	41.052	7.404	9.1868	2.4329	–1.19043
7	Acetylene	C_2H_2	74-86-2	26.037	22.82	21.068	2.0081	–1.257
8	Acrolein	C_3H_4O	107-02-8	56.063	–8.18	–5.68	2.97	–1.5468
9	Acrylic acid	$C_3H_4O_2$	79-10-7	72.063	–35.591	–30.6	3.15	–1.32717
10	Acrylonitrile	C_3H_3N	107-13-1	53.063	18.37	19.37	2.753	–1.69
11	Air	Mixture	132259-10-0	28.960	0	0	1.99	0
12	Ammonia	H_3N	7664-41-7	17.031	–4.5898	–1.64	1.9266	–0.31683
13	Anisole	C_7H_8O	100-66-3	108.138	–6.79	2.27	3.61	–3.6072
14	Argon	Ar	7440-37-1	39.948	0	0	1.54737	0
15	Benzamide	C_7H_7NO	55-21-0	121.137	–10.09	–0.211	3.641	–3.39877
16	Benzene	C_6H_6	71-43-2	78.112	8.288	12.96	2.693	–3.136
17	Benzenethiol	C_6H_6S	108-98-5	110.177	11.15	14.76	3.369	–3.4474
18	Benzoic acid	$C_7H_6O_2$	65-85-0	122.121	–29.41	–21.42	3.69	–3.0951
19	Benzonitrile	C_7H_5N	100-47-0	103.121	21.57	25.78	3.21	–3.5238
20	Benzophenone	$C_{13}H_{10}O$	119-61-9	182.218	5.68	17.3	4.4	–6.2876
21	Benzyl alcohol	C_7H_8O	100-51-6	108.138	–9.025	–0.254	3.713	–3.56
22	Benzyl ethyl ether	$C_9H_{12}O$	539-30-0	136.191	–11.5	3.37	4.39	–4.83
23	Benzyl mercaptan	C_7H_8S	100-53-8	124.203	9.33	16.3	3.607	–4.06
24	Biphenyl	$C_{12}H_{10}$	92-52-4	154.208	17.849	27.63	3.9367	–6.248
25	Bromine	Br_2	7726-95-6	159.808	3.091	0.314	2.4535	
26	Bromobenzene	C_6H_5Br	108-86-1	157.008	10.5018	13.8532	3.24386	–3.01917
27	Bromoethane	C_2H_5Br	74-96-4	108.965	–6.36	–2.582	2.873	–1.285
28	Bromomethane	CH_3Br	74-83-9	94.939	–3.77	–2.819	2.458	–0.70542
29	1,2-Butadiene	C_4H_6	590-19-2	54.090	16.23	19.86	2.93	–2.4617
30	1,3-Butadiene	C_4H_6	106-99-0	54.090	10.924	14.972	2.7889	–2.409
31	Butane	C_4H_{10}	106-97-8	58.122	–12.579	–1.67	3.0991	–2.65732
32	1,2-Butanediol	$C_4H_{10}O_2$	584-03-2	90.121	–44.58	–30.44	4.065	–2.2678
33	1,3-Butanediol	$C_4H_{10}O_2$	107-88-0	90.121	–43.32	–29.18	4.065	–2.2824
34	1-Butanol	$C_4H_{10}O$	71-36-3	74.122	–27.51	–15.07	3.618	–2.454
35	2-Butanol	$C_4H_{10}O$	78-92-2	74.122	–29.29	–16.7	3.566	–2.446
36	1-Butene	C_4H_8	106-98-9	56.106	–0.05	7.041	3.074	–2.5408
37	*cis*-2-Butene	C_4H_8	590-18-1	56.106	–0.74	6.536	3.012	–2.5339
38	*trans*-2-Butene	C_4H_8	624-64-6	56.106	–1.1	6.32	2.965	–2.53
39	Butyl acetate	$C_6H_{12}O_2$	123-86-4	116.158	–48.56	–31.26	4.425	–3.28
40	Butylbenzene	$C_{10}H_{14}$	104-51-8	134.218	–1.314	14.54	4.3949	–5.5644
41	Butyl mercaptan	$C_4H_{10}S$	109-79-5	90.187	–8.78	1.139	3.752	–2.9554
42	*sec*-Butyl mercaptan	$C_4H_{10}S$	513-53-1	90.187	–9.66	0.512	3.667	–2.949
43	1-Butyne	C_4H_6	107-00-6	54.090	16.52	20.225	2.9039	–2.4647
44	Butyraldehyde	C_4H_8O	123-72-8	72.106	–20.7	–11.63	3.4365	–2.3035
45	Butyric acid	$C_4H_8O_2$	107-92-6	88.105	–47.58	–36	3.601	–2.008
46	Butyronitrile	C_4H_7N	109-74-0	69.105	3.40578	10.8658	3.25432	–2.4148
47	Carbon dioxide	CO_2	124-38-9	44.010	–39.351	–39.437	2.13677	
48	Carbon disulfide	CS_2	75-15-0	76.141	11.69	6.68	2.379	–1.0769
49	Carbon monoxide	CO	630-08-0	28.010	–11.053	–13.715	1.97556	–0.283
50	Carbon tetrachloride	CCl_4	56-23-5	153.823	–9.581	–5.354	3.0991	–0.2653
51	Carbon tetrafluoride	CF_4	75-73-0	88.004	–92.21	–87.76	2.62	0.5286
52	Chlorine	Cl_2	7782-50-5	70.906	0	0	2.22972	
53	Chlorobenzene	C_6H_5Cl	108-90-7	112.557	5.109	9.829	3.1403	–2.976
54	Chloroethane	C_2H_5Cl	75-00-3	64.514	–11.226	–6.0499	2.7578	–1.2849
55	Chloroform	$CHCl_3$	67-66-3	119.378	–10.29	–7.01	2.956	–0.38
56	Chloromethane	CH_3Cl	74-87-3	50.488	–8.196	–5.844	2.3418	–0.67538
57	1-Chloropropane	C_3H_7Cl	540-54-5	78.541	–13.318	–5.261	3.1547	–1.867
58	2-Chloropropane	C_3H_7Cl	75-29-6	78.541	–14.477	–6.136	3.0594	–1.863

TABLE 2-179 Enthalpies and Gibbs Energies of Formation, Entropies, and Net Enthalpies of Combustion of Inorganic and Organic Compounds at 298.15 K (*Continued*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	Ideal gas enthalpy of formation, J/kmol × 1E-07	Ideal gas Gibbs energy of formation, J/kmol × 1E-07	Ideal gas entropy, J/(kmol·K) × 1E-05	Standard net enthalpy of combustion, J/kmol × 1E-09
59	*m*-Cresol	C_7H_8O	108-39-4	108.138	–13.23	–4.019	3.5604	–3.52783
60	*o*-Cresol	C_7H_8O	95-48-7	108.138	–12.857	–3.543	3.5259	–3.528
61	*p*-Cresol	C_7H_8O	106-44-5	108.138	–12.535	–3.166	3.5075	–3.52256
62	Cumene	C_9H_{12}	98-82-8	120.192	0.4	13.79	3.86	–4.951
63	Cyanogen	C_2N_2	460-19-5	52.035	30.9072	29.7598	2.41463	–1.0961
64	Cyclobutane	C_4H_8	287-23-0	56.106	2.85	11.22	2.64396	–2.5678
65	Cyclohexane	C_6H_{12}	110-82-7	84.159	–12.33	3.191	2.97276	–3.656
66	Cyclohexanol	$C_6H_{12}O$	108-93-0	100.159	–28.62	–10.95	3.277	–3.4639
67	Cyclohexanone	$C_6H_{10}O$	108-94-1	98.143	–22.61	–9.028	3.3426	–3.299
68	Cyclohexene	C_6H_{10}	110-83-8	82.144	–0.46	10.77	3.10518	–3.532
69	Cyclopentane	C_5H_{10}	287-92-3	70.133	–7.703	3.885	2.929	–3.0709
70	Cyclopentene	C_5H_8	142-29-0	68.117	3.23	11.05	2.91267	–2.9393
71	Cyclopropane	C_3H_6	75-19-4	42.080	5.33	10.44	2.37378	–1.9593
72	Cyclohexyl mercaptan	$C_6H_{12}S$	1569-69-3	116.224	–9.602	4.886	3.646	–3.968
73	Decanal	$C_{10}H_{20}O$	112-31-2	156.265	–33.17	–6.739	5.7912	–5.959
74	Decane	$C_{10}H_{22}$	124-18-5	142.282	–24.946	3.318	5.457	–6.29422
75	Decanoic acid	$C_{10}H_{20}O_2$	334-48-5	172.265	–59.43	–30.5	5.99	–5.72
76	1-Decanol	$C_{10}H_{22}O$	112-30-1	158.281	–39.85	–10.02	5.971	–6.116
77	1-Decene	$C_{10}H_{20}$	872-05-9	140.266	–12.21	12.27	5.433	–6.1809
78	Decyl mercaptan	$C_{10}H_{22}S$	143-10-2	174.347	–21.09	6.165	6.116	–6.6161
79	1-Decyne	$C_{10}H_{18}$	764-93-2	138.250	4.1	25.16	5.263	–6.1037
80	Deuterium	D_2	7782-39-0	4.032	0	0	1.4486	–0.24625
81	1,1-Dibromoethane	$C_2H_4Br_2$	557-91-5	187.861	–4.08	–1.181	3.276	–1.16
82	1,2-Dibromoethane	$C_2H_4Br_2$	106-93-4	187.861	–3.89	–1.054	3.297	–1.1769
83	Dibromomethane	CH_2Br_2	74-95-3	173.835			2.92964	
84	Dibutyl ether	$C_8H_{18}O$	142-96-1	130.228	–33.34	–8.827	5.014	–4.94691
85	*m*-Dichlorobenzene	$C_6H_4Cl_2$	541-73-1	147.002	2.57	7.79	3.4353	–2.825
86	*o*-Dichlorobenzene	$C_6H_4Cl_2$	95-50-1	147.002	3.02	8.29	3.4185	–2.826
87	*p*-Dichlorobenzene	$C_6H_4Cl_2$	106-46-7	147.002	2.25	7.67	3.3674	–2.802
88	1,1-Dichloroethane	$C_2H_4Cl_2$	75-34-3	98.959	–12.941	–7.259	3.0501	–1.1104
89	1,2-Dichloroethane	$C_2H_4Cl_2$	107-06-2	98.959	–12.979	–7.3945	3.0828	–1.105
90	Dichloromethane	CH_2Cl_2	75-09-2	84.933	–9.552	–6.896	2.7018	–0.51388
91	1,1-Dichloropropane	$C_3H_6Cl_2$	78-99-9	112.986	–15.08	–6.52	3.448	–1.72
92	1,2-Dichloropropane	$C_3H_6Cl_2$	78-87-5	112.986	–16.28	–8.018	3.548	–1.707
93	Diethanol amine	$C_4H_{11}NO_2$	111-42-2	105.136	–40.847	–22.574	4.29	–2.4105
94	Diethyl amine	$C_4H_{11}N$	109-89-7	73.137	–7.142	7.308	3.522	–2.8003
95	Diethyl ether	$C_4H_{10}O$	60-29-7	74.122	–25.21	–12.21	3.423	–2.5035
96	Diethyl sulfide	$C_4H_{10}S$	352-93-2	90.187	–8.356	1.774	3.681	–2.9607
97	1,1-Difluoroethane	$C_2H_4F_2$	75-37-6	66.050	–49.7	–43.9485	2.824	–0.773662
98	1,2-Difluoroethane	$C_2H_4F_2$	624-72-6	66.050	–44.77	–39.19	2.88194	–0.823
99	Difluoromethane	CH_2F_2	75-10-5	52.023	–45.23	–42.4747	2.4658	–0.183031
100	Di-isopropyl amine	$C_6H_{15}N$	108-18-9	101.190	–14.38	6.42	4.12	–3.99
101	Di-isopropyl ether	$C_6H_{14}O$	108-20-3	102.175	–31.92	–12.48	3.989	–3.70261
102	Di-isopropyl ketone	$C_7H_{14}O$	565-80-0	114.185	–31.14	–12.37	4.27	–4.095
103	1,1-Dimethoxyethane	$C_4H_{10}O_2$	534-15-6	90.121	–38.97	–23.8	3.726	–2.394
104	1,2-Dimethoxypropane	$C_5H_{12}O_2$	7778-85-0	104.148	–38.42	–20.11	4.038	–2.996
105	Dimethyl acetylene	C_4H_6	503-17-3	54.090	14.57	18.49	2.833	–2.4189
106	Dimethyl amine	C_2H_7N	124-40-3	45.084	–1.845	6.839	2.7296	–1.6146
107	2,3-Dimethylbutane	C_6H_{14}	79-29-8	86.175	–17.68	–0.3125	3.6592	–3.84761
108	1,1-Dimethylcyclohexane	C_8H_{16}	590-66-9	112.213	–18.1	3.52293	3.65012	–4.8639
109	*cis*-1,2-Dimethylcyclohexane	C_8H_{16}	2207-01-4	112.213	–17.2172	4.12124	3.7451	–4.87084
110	*trans*-1,2-Dimethylcyclohexane	C_8H_{16}	6876-23-9	112.213	–17.9996	3.44761	3.70912	–4.86436
111	Dimethyl disulfide	$C_2H_6S_2$	624-92-0	94.199	–2.42	1.516	3.35291	–2.0441
112	Dimethyl ether	C_2H_6O	115-10-6	46.068	–18.41	–11.28	2.667	–1.3284
113	*N*,*N*-Dimethyl formamide	C_3H_7NO	68-12-2	73.094	–19.17	–8.84	3.26	–1.78871
114	2,3-Dimethylpentane	C7H16	565-59-3	100.202	–19.41	0.5717	4.1455	–4.46075
115	Dimethyl phthalate	$C_{10}H_{10}O_4$	131-11-3	194.184	–60.5	–46.7749	6.6	–4.4662
116	Dimethylsilane	C_2H_8Si	1111-74-6	60.170	–9.47	–1.925	2.9953	–2.569

117	Dimethyl sulfide	C_2H_6S	75-18-3	62.134	–3.724	0.7302	2.8585	–1.7443
118	Dimethyl sulfoxide	C_2H_6OS	67-68-5	78.133	–15.046	–8.1441	3.0627	–1.6054
119	Dimethyl terephthalate	$C_{10}H_{10}O_4$	120-61-6	194.184	–64.4	–47.4	5.5	–4.4115
120	1,4-Dioxane	$C_4H_8O_2$	123-91-1	88.105	–31.58	–18.16	3.0012	–2.1863
121	Diphenyl ether	$C_{12}H_{10}O$	101-84-8	170.207	5.2	17.5	4.13	–5.8939
122	Dipropyl amine	$C_6H_{15}N$	142-84-7	101.190	–11.6	8.68	4.29	–4.0189
123	Dodecane	$C_{12}H_{26}$	112-40-3	170.335	–29.072	4.981	6.2415	–7.51368
124	Eicosane	$C_{20}H_{42}$	112-95-8	282.547	–45.646	11.57	9.3787	–12.3908
125	Ethane	C_2H_6	74-84-0	30.069	–8.382	–3.192	2.2912	–1.42864
126	Ethanol	C_2H_6O	64-17-5	46.068	–23.495	–16.785	2.8064	–1.235
127	Ethyl acetate	$C_4H_8O_2$	141-78-6	88.105	–44.45	–32.8	3.597	–2.061
128	Ethyl amine	C_2H_7N	75-04-7	45.084	–4.715	3.616	2.848	–1.5874
129	Ethylbenzene	C_8H_{10}	100-41-4	106.165	2.992	13.073	3.6063	–4.3448
130	Ethyl benzoate	$C_9H_{10}O_2$	93-89-0	150.175	–32.6	–19.05	4.55	–4.41
131	2-Ethyl butanoic acid	$C_6H_{12}O_2$	88-09-5	116.158	–53.78	–35.9	4.23	–3.21203
132	Ethyl butyrate	$C_6H_{12}O_2$	105-54-4	116.158	–48.55	–31.22	4.417	–3.284
133	Ethylcyclohexane	C_8H_{16}	1678-91-7	112.213	–17.15	3.955	3.826	–4.87051
134	Ethylcyclopentane	C_7H_{14}	1640-89-7	98.186	–12.69	4.48	3.783	–4.2839
135	Ethylene	C_2H_4	74-85-1	28.053	5.251	6.844	2.192	–1.323
136	Ethylenediamine	$C_2H_8N_2$	107-15-3	60.098	–1.73	10.3	3.21833	–1.691
137	Ethylene glycol	$C_2H_6O_2$	107-21-1	62.068	–39.22	–30.18	3.04891	–1.0527
138	Ethyleneimine	C_2H_5N	151-56-4	43.068	12.3428	17.7987	2.5062	–1.481
139	Ethylene oxide	C_2H_4O	75-21-8	44.053	–5.263	–1.323	2.4299	–1.218
140	Ethyl formate	$C_3H_6O_2$	109-94-4	74.079	–38.83	–30.31	3.282	–1.50696
141	2-Ethyl hexanoic acid	$C_8H_{16}O_2$	149-57-5	144.211	–55.95	–32.5	5.1	–4.448
142	Ethylhexyl ether	$C_8H_{18}O$	5756-43-4	130.228	–33.37	–9.042	5.076	–4.943
143	Ethylisopropyl ether	$C_5H_{12}O$	625-54-7	88.148	–28.58	–12.64	3.8	–3.103
144	Ethylisopropyl ketone	$C_6H_{12}O$	565-69-5	100.159	–28.61	–13.3	4.069	–3.4863
145	Ethyl mercaptan	C_2H_6S	75-08-1	62.134	–4.63	–0.4814	2.961	–1.7366
146	Ethyl propionate	$C_5H_{10}O_2$	105-37-3	102.132	–46.36	–31.93	4.025	–2.674
147	Ethylpropyl ether	$C_5H_{12}O$	628-32-0	88.148	–27.22	–11.52	3.881	–3.12
148	Ethyltrichlorosilane	$C_2H_5Cl_3Si$	115-21-9	163.506	–59.54	–51.01	4.07	–1.671
149	Fluorine	F_2	7782-41-4	37.997	0	0	2.02682	
150	Fluorobenzene	C_6H_5F	462-06-6	96.102	–11.6566	–6.9036	3.02629	–2.81451
151	Fluoroethane	C_2H_5F	353-36-6	48.060	–26.44	–21.23	2.644	–1.127
152	Fluoromethane	CH_3F	593-53-3	34.033	–23.43	–21.04	2.22734	–0.5219
153	Formaldehyde	CH_2O	50-00-0	30.026	–10.86	–10.26	2.1866	–0.5268
154	Formamide	CH_3NO	75-12-7	45.041	–19.22	–14.71	2.4857	–0.5021
155	Formic acid	CH_2O_2	64-18-6	46.026	–40.55	–37.78	2.487	–0.2115
156	Furan	C_4H_4O	110-00-9	68.074	–3.48	0.08225	2.6714	–1.9959
157	Helium-4	He	7440-59-7	4.003	0	0	1.26044	0
158	Heptadecane	$C_{17}H_{36}$	629-78-7	240.468	–39.445	9.083	8.2023	–10.5618
159	Heptanal	$C_7H_{14}O$	111-71-7	114.185	–26.94	–9.191	4.6138	–4.136
160	Heptane	C_7H_{16}	142-82-5	100.202	–18.765	0.8165	4.2798	–4.46473
161	Heptanoic acid	$C_7H_{14}O_2$	111-14-8	130.185	–53.62	–33.4	4.8	–3.839
162	1-Heptanol	$C_7H_{16}O$	111-70-6	116.201	–33.68	–12.55	4.795	–4.285
163	2-Heptanol	$C_7H_{16}O$	543-49-7	116.201	–35.54	–14.25	4.74	–4.282
164	3-Heptanone	$C_7H_{14}O$	106-35-4	114.185	–30.1	–12.25	4.58	–4.098
165	2-Heptanone	$C_7H_{14}O$	110-43-0	114.185	–30.0453	–11.96	4.486	–4.09952
166	1-Heptene	C_7H_{14}	592-76-7	98.186	–6.289	9.482	4.252	–4.3499
167	Heptyl mercaptan	$C_7H_{16}S$	1639-09-4	132.267	–14.95	3.622	4.939	–4.7865
168	1-Heptyne	C_7H_{12}	628-71-7	96.170	10.3	22.7	4.085	–4.2717
169	Hexadecane	$C_{16}H_{34}$	544-76-3	226.441	–37.417	8.216	7.8102	–9.95145
170	Hexanal	$C_6H_{12}O$	66-25-1	100.159	–24.86	–10.005	4.2214	–3.52
171	Hexane	C_6H_{14}	110-54-3	86.175	–16.694	–0.006634	3.8874	–3.8551
172	Hexanoic acid	$C_6H_{12}O_2$	142-62-1	116.158	–51.19	–33.8	4.41	–3.23
173	1-Hexanol	$C_6H_{14}O$	111-27-3	102.175	–31.62	–13.39	4.402	–3.675
174	2-Hexanol	$C_6H_{14}O$	626-93-7	102.175	–33.46	–15.06	4.349	–3.67
175	2-Hexanone	$C_6H_{12}O$	591-78-6	100.159	–27.9826	–13.0081	4.17856	–3.49
176	3-Hexanone	$C_6H_{12}O$	589-38-8	100.159	–27.76	–12.6	4.092	–3.492
177	1-Hexene	C_6H_{12}	592-41-6	84.159	–4.167	8.7	3.863	–3.7397
178	3-Hexyne	C_6H_{10}	928-49-4	82.144	10.6	19.9	3.76	–3.64
179	Hexyl mercaptan	$C_6H_{14}S$	111-31-9	118.240	–12.92	2.759	4.546	–4.1762

TABLE 2-179 Enthalpies and Gibbs Energies of Formation, Entropies, and Net Enthalpies of Combustion of Inorganic and Organic Compounds at 298.15 K (*Continued*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	Ideal gas enthalpy of formation, J/kmol × 1E-07	Ideal gas Gibbs energy of formation, J/kmol × 1E-07	Ideal gas entropy, J/(kmol·K) × 1E-05	Standard net enthalpy of combustion, J/kmol × 1E-09
180	1-Hexyne	C_6H_{10}	693-02-7	82.144	12.37	21.85	3.694	–3.661
181	2-Hexyne	C_6H_{10}	764-35-2	82.144	10.5	19.9	3.72	–3.64
182	Hydrazine	H_4N_2	302-01-2	32.045	9.5353	15.917	2.3861	–0.5342
183	Hydrogen	H_2	1333-74-0	2.016	0	0	1.30571	–0.24182
184	Hydrogen bromide	HBr	10035-10-6	80.912	–3.629	–5.334	1.98591	–0.06904
185	Hydrogen chloride	HCl	7647-01-0	36.461	–9.231	–9.53	1.86786	–0.0286
186	Hydrogen cyanide	CHN	74-90-8	27.025	13.5143	12.4725	2.01719	–0.62329
187	Hydrogen fluoride	HF	7664-39-3	20.006	–27.33	–27.54	1.7367	0.1524
188	Hydrogen sulfide	H_2S	7783-06-4	34.081	–2.063	–3.344	2.056	–0.518
189	Isobutyric acid	$C_4H_8O_2$	79-31-2	88.105	–48.41	–36.21	3.412	–2.0004
190	Isopropyl amine	C_3H_9N	75-31-0	59.110	–8.38	3.192	3.124	–2.1566
191	Malonic acid	$C_3H_4O_4$	141-82-2	104.061	–76.68	–67	3.7	–0.7732
192	Methacrylic acid	$C_4H_6O_2$	79-41-4	86.089	–36.8	–28.8	3.5	–1.93
193	Methane	CH_4	74-82-8	16.042	–7.452	–5.049	1.8627	–0.80262
194	Methanol	CH_4O	67-56-1	32.042	–20.094	–16.232	2.3988	–0.6382
195	*N*-Methyl acetamide	C_3H_7NO	79-16-3	73.094	–24	–13.5	3.2	–1.71
196	Methyl acetate	$C_3H_6O_2$	79-20-9	74.079	–41.19	–32.42	3.198	–1.461
197	Methyl acetylene	C_3H_4	74-99-7	40.064	18.49	19.384	2.4836	–1.8487
198	Methyl acrylate	$C_4H_6O_2$	96-33-3	86.089	–33.3	–25.7	3.66	–1.9303
199	Methyl amine	CH_5N	74-89-5	31.057	–2.297	3.207	2.433	–0.97508
200	Methyl benzoate	$C_8H_8O_2$	93-58-3	136.148	–28.79	–18.1	4.14	–3.772
201	3-Methyl-1,2-butadiene	C_5H_8	598-25-4	68.117	12.908	19.75	3.2151	–3.032
202	2-Methylbutane	C_5H_{12}	78-78-4	72.149	–15.37	–1.405	3.4374	–3.23954
203	2-Methylbutanoic acid	$C_5H_{10}O_2$	116-53-0	102.132	–49.8	–34.99	3.9	–2.622
204	3-Methyl-1-butanol	$C_5H_{12}O$	123-51-3	88.148	–30.3	–14.1	3.869	–3.062
205	2-Methyl-1-butene	C_5H_{10}	563-46-2	70.133	–3.53	6.668	3.395	–3.1159
206	2-Methyl-2-butene	C_5H_{10}	513-35-9	70.133	–4.18	6.045	3.386	–3.1088
207	2-Methyl -1-butene-3-yne	C_5H_6	78-80-8	66.101	26	30.25	2.78	–2.93
208	Methylbutyl ether	$C_5H_{12}O$	628-28-4	88.148	–25.81	–10.17	3.901	–3.12818
209	Methylbutyl sulfide	$C_5H_{12}S$	628-29-5	104.214	–10.2	2.691	4.118	–3.5723
210	3-Methyl-1-butyne	C_5H_8	598-23-2	68.117	13.8	20.72	3.189	–3.046
211	Methyl butyrate	$C_5H_{10}O_2$	623-42-7	102.132	–45.07	–30.53	3.988	–2.686
212	Methylchlorosilane	CH_5ClSi	993-00-0	80.589	–21.5	–16.61	2.98277	–1.693
213	Methylcyclohexane	C_7H_{14}	108-87-2	98.186	–15.48	2.733	3.433	–4.25714
214	1-Methylcyclohexanol	$C_7H_{14}O$	590-67-0	114.185	–33.2	–12.9	3.75	–4.058
215	cis-2-Methylcyclohexanol	$C_7H_{14}O$	7443-70-1	114.185	–32.7	–12.68	3.853	–4.0574
216	trans-2-Methylcyclohexanol	$C_7H_{14}O$	7443-52-9	114.185	–35.26	–15.24	3.853	–4.0318
217	Methylcyclopentane	C_6H_{12}	96-37-7	84.159	–10.62	3.63	3.399	–3.6741
218	1-Methylcyclopentene	C_6H_{10}	693-89-0	82.144	–0.38	10.38	3.264	–3.534
219	3-Methylcyclopentene	C_6H_{10}	1120-62-3	82.144	0.74	11.38	3.305	–3.5464
220	Methyldichlorosilane	CH_4Cl_2Si	75-54-7	115.034	–40.2	–34.83	3.287	–1.357
221	Methylethyl ether	C_3H_8O	540-67-0	60.095	–21.64	–11.71	3.0881	–1.9314
222	Methylethyl ketone	C_4H_8O	78-93-3	72.106	–23.9	–14.7	3.394	–2.268
223	Methylethyl sulfide	C_3H_8S	624-89-5	76.161	–5.96	1.147	3.332	–2.354
224	Methyl formate	$C_2H_4O_2$	107-31-3	60.052	–35.24	–29.5	2.852	–0.8924
225	Methylisobutyl ether	$C_5H_{12}O$	625-44-5	88.148	–26.6	–10.7	3.81	–3.122
226	Methylisobutyl ketone	$C_6H_{12}O$	108-10-1	100.159	–28.64	–13.51	4.129	–3.4762
227	Methyl Isocyanate	C_2H_3NO	624-83-9	57.051	–6.24	0.0244	1.955	–1.06
228	Methylisopropyl ether	$C_4H_{10}O$	598-53-8	74.122	–25.2	–12.18	3.416	–2.5311
229	Methylisopropyl ketone	$C_5H_{10}O$	563-80-4	86.132	–26.26	–13.93	3.699	–2.877
230	Methylisopropyl sulfide	$C_4H_{10}S$	1551-21-9	90.187	–8.96	1.4509	3.59	–2.957
231	Methyl mercaptan	CH_4S	74-93-1	48.107	–2.29	–0.98	2.55	–1.1517
232	Methyl methacrylate	$C_5H_8O_2$	80-62-6	100.116	–36	–25.4	4.01	–2.54
233	2-Methyloctanoic acid	$C_9H_{18}O_2$	3004-93-1	158.238	–57.95	–31.8	5.533	–5.056
234	2-Methylpentane	C_6H_{14}	107-83-5	86.175	–17.455	–0.5338	3.8089	–3.84915
235	Methyl pentyl ether	$C_6H_{14}O$	628-80-8	102.175	–27.8	–9.35	4.32	–3.739
236	2-Methylpropane	C_4H_{10}	75-28-5	58.122	–13.499	–2.144	2.955	–2.64895
237	2-Methyl-2-propanol	$C_4H_{10}O$	75-65-0	74.122	–31.24	–17.76	3.263	–2.4239

238	2-Methyl propene	C_4H_8	115-11-7	56.106	–1.71	5.808	2.9309	–2.5242
239	Methyl propionate	$C_4H_8O_2$	554-12-1	88.105	–42.75	–31.1	3.596	–2.078
240	Methylpropyl ether	$C_4H_{10}O$	557-17-5	74.122	–23.82	–11.1	3.52	–2.51739
241	Methylpropyl sulfide	$C_4H_{10}S$	3877-15-4	90.187	–8.23	1.793	3.717	–2.962
242	Methylsilane	CH_6Si	992-94-9	46.144	–2.91	1.853	2.565	–1.999
243	alpha-Methyl styrene	C_9H_{10}	98-83-9	118.176	11.83	21.73	3.725	–4.8214
244	Methyl *tert*-butyl ether	$C_5H_{12}O$	1634-04-4	88.148	–28.32	–11.7	3.578	–3.105
245	Methyl vinyl ether	C_3H_6O	107-25-5	58.079	–10.8	–4.73	3.08	–1.77431
246	Naphthalene	$C_{10}H_8$	91-20-3	128.171	15.058	22.408	3.3315	–4.9809
247	Neon	Ne	7440-01-9	20.180	0	0	1.46219	0
248	Nitroethane	$C_2H_5NO_2$	79-24-3	75.067	–10.21	–0.6125	3.168	–1.25
249	Nitrogen	N_2	7727-37-9	28.013	0	0	1.915	
250	Nitrogen trifluoride	F_3N	7783-54-2	71.002	–13.2089	–9.06	2.6062	
251	Nitromethane	CH_3NO_2	75-52-5	61.040	–7.47	–0.6934	2.751	–0.6432
252	Nitrous oxide	N_2O	10024-97-2	44.013	8.205	10.416	2.1985	–0.0820482
253	Nitric oxide	NO	10102-43-9	30.006	9.025	8.657	2.106	–0.0902489
254	Nonadecane	$C_{19}H_{40}$	629-92-5	268.521	–43.579	10.74	8.9866	–11.7812
255	Nonanal	$C_9H_{18}O$	124-19-6	142.239	–31.09	–7.553	5.3988	–5.35
256	Nonane	C_9H_20	111-84-2	128.255	–22.874	2.498	5.064	–5.68455
257	Nonanoic acid	$C_9H_{18}O_2$	112-05-0	158.238	–57.73	–31.7	5.59	–5.061
258	1-Nonanol	$C_9H_{20}O$	143-08-8	144.255	–37.79	–10.86	5.579	–5.506
259	2-Nonanol	$C_9H_{20}O$	628-99-9	144.255	–39.71	–12.61	5.523	–5.506
260	1-Nonene	C_9H_{18}	124-11-8	126.239	–10.35	11.23	5.041	–5.5716
261	Nonyl mercaptan	$C_9H_{20}S$	1455-21-6	160.320	–19.08	5.28	5.724	–6.006
262	1-Nonyne	C_9H_{16}	3452-09-3	124.223	6.17	24.34	4.8699	–5.493
263	Octadecane	$C_{18}H_{38}$	593-45-3	254.494	–41.512	9.91	8.5945	–11.1715
264	Octanal	$C_8H_{16}O$	124-13-0	128.212	–29.02	–8.377	5.0063	–4.74
265	Octane	C_8H_{18}	111-65-9	114.229	–20.875	1.6	4.6723	–5.07415
266	Octanoic acid	$C_8H_{16}O_2$	124-07-2	144.211	–55.6	–32.5	5.2	–4.448
267	1-Octanol	$C_8H_{18}O$	111-87-5	130.228	–35.73	–11.7	5.187	–4.895
268	2-Octanol	$C_8H_{18}O$	123-96-6	130.228	–37.62	–13.43	5.132	–4.894
269	2-Octanone	$C_8H_{16}O$	111-13-7	128.212	–32.16	–11.38	4.962	–4.6984
270	3-Octanone	$C_8H_{16}O$	106-68-3	128.212	–33.9	–12.81	4.879	–4.711
271	1-Octene	C_8H_{16}	111-66-0	112.213	–8.194	10.57	4.637	–4.961
272	Octyl mercaptan	$C_8H_{18}S$	111-88-6	146.294	–17.01	4.457	5.331	–5.3962
273	1-Octyne	C_8H_{14}	629-05-0	110.197	8.23	23.5	4.478	–4.88145
274	Oxalic acid	$C_2H_2O_4$	144-62-7	90.035	–72.37	–66.14	3.433	–0.1989
275	Oxygen	O_2	7782-44-7	31.999	0	0	2.05043	0
276	Ozone	O_3	10028-15-6	47.998	14.2671	16.3164	2.38823	–0.142671
277	Pentadecane	$C_{15}H_{32}$	629-62-9	212.415	–35.311	7.426	7.4181	–9.34237
278	Pentanal	$C_5H_{10}O$	110-62-3	86.132	–22.78	–10.71	3.8289	–2.91
279	Pentane	C_5H_{12}	109-66-0	72.149	–14.676	–0.8813	3.4945	–3.24494
280	Pentanoic acid	$C_5H_{10}O_2$	109-52-4	102.132	–49.13	–34.7	4.02	–2.617
281	1-Pentanol	$C_5H_{12}O$	71-41-0	88.148	–29.57	–14.23	4.01	–3.064
282	2-Pentanol	$C_5H_{12}O$	6032-29-7	88.148	–31.37	–15.88	3.958	–3.058
283	2-Pentanone	$C_5H_{10}O$	107-87-9	86.132	–25.92	–13.83	3.786	–2.87956
284	3-Pentanone	$C_5H_{10}O$	96-22-0	86.132	–25.79	–13.44	3.7	–2.8804
285	1-Pentene	C_5H_{10}	109-67-1	70.133	–2.162	7.837	3.462	–3.13037
286	2-Pentyl mercaptan	$C_5H_{12}S$	2084-19-7	104.214	–11.3	1.814	4.05	–3.564
287	Pentyl mercaptan	$C_5H_{12}S$	110-66-7	104.214	–10.84	1.94408	4.154	–3.5641
288	1-Pentyne	C_5H_8	627-19-0	68.117	14.44	21.03	3.298	–3.051
289	2-Pentyne	C_5H_8	627-21-4	68.117	12.89	19.45	3.3084	–3.0291
290	Phenanthrene	$C_{14}H_{10}$	85-01-8	178.229	20.12	30.219	3.945	–6.8282
291	Phenol	C_6H_6O	108-95-2	94.111	–9.6399	–3.2637	3.1481	–2.921
292	Phenyl isocyanate	C_7H_5NO	103-71-9	119.121	–1.454	4.87212	3.527	–3.298
293	Phthalic anhydride	$C_8H_4O_3$	85-44-9	148.116	–37.14	–30.7001	3.995	–3.1715
294	Propadiene	C_3H_4	463-49-0	40.064	19.05	20.08	2.439	–1.8563
295	Propane	C_3H_8	74-98-6	44.096	–10.468	–2.439	2.702	–2.04311
296	1-Propanol	C_3H_8O	71-23-8	60.095	–25.46	–15.99	3.226	–1.844
297	2-Propanol	C_3H_8O	67-63-0	60.095	–27.21	–17.52	3.175	–1.834
298	Propenylcyclohexene	C_9H_{14}	13511-13-2	122.207	4.677	20.85	4.233	–5.232
299	Propionaldehyde	C_3H_6O	123-38-6	58.079	–18.63	–12.46	3.044	–1.6857
300	Propionic acid	$C_3H_6O_2$	79-09-4	74.079	–47.99	–38.5	2.949	–1.395

TABLE 2-179 Enthalpies and Gibbs Energies of Formation, Entropies, and Net Enthalpies of Combustion of Inorganic and Organic Compounds at 298.15 K (*Concluded*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	Ideal gas enthalpy of formation, J/kmol × 1E-07	Ideal gas Gibbs energy of formation, J/kmol × 1E-07	Ideal gas entropy, J/(kmol·K) × 1E-05	Standard net enthalpy of combustion, J/kmol × 1E-09
301	Propionitrile	C_3H_5N	107-12-0	55.079	5.18	9.74949	2.8614	–1.8007
302	Propyl acetate	$C_5H_{10}O_2$	109-60-4	102.132	–46.48	–32.04	4.023	–2.672
303	Propyl amine	C_3H_9N	107-10-8	59.110	–7.05	4.17	3.242	–2.165
304	Propylbenzene	C_9H_{12}	103-65-1	120.192	0.79	13.76	4.0014	–4.95415
305	Propylene	C_3H_6	115-07-1	42.080	2.023	6.264	2.67	–1.9262
306	Propyl formate	$C_4H_8O_2$	110-74-7	88.105	–40.76	–29.36	3.678	–2.041
307	2-Propyl mercaptan	C_3H_8S	75-33-2	76.161	–7.59	–0.218	3.243	–2.3398
308	Propyl mercaptan	C_3H_8S	107-03-9	76.161	–6.75	0.2583	3.365	–2.3458
309	1,2-Propylene glycol	$C_3H_8O_2$	57-55-6	76.094	–42.15	–30.4	3.52	–1.6476
310	Quinone	$C_6H_4O_2$	106-51-4	108.095	–12.29	–6.92	3.205	–2.658
311	Silicon tetrafluoride	F_4Si	7783-61-1	104.079	–161.494	–157.27	2.82651	0.7055
312	Styrene	C_8H_8	100-42-5	104.149	14.74	21.39	3.451	–4.219
313	Succinic acid	$C_4H_6O_4$	110-15-6	118.088	–82.29	–69.73	4.034	–1.3591
314	Sulfur dioxide	O_2S	7446-09-5	64.064	–29.684	–30.012	2.481	
315	Sulfur hexafluoride	F_6S	2551-62-4	146.055	–122.047	–111.653	2.91625	0.924
316	Sulfur trioxide	O_3S	7446-11-9	80.063	–39.572	–37.095	2.5651	0.1422
317	Terephthalic acid	$C_8H_6O_4$	100-21-0	166.131	–71.79	–59.9	4.48	–3.0576
318	*o*-Terphenyl	$C_{18}H_{14}$	84-15-1	230.304	27.66	42.3	5.263	–9.053
319	Tetradecane	$C_{14}H_{30}$	629-59-4	198.388	–33.244	6.599	7.0259	–8.73282
320	Tetrahydrofuran	C_4H_8O	109-99-9	72.106	–18.418	–7.969	2.9729	–2.325
321	1,2,3,4-Tetrahydronaphthalene	$C_{10}H_{12}$	119-64-2	132.202	2.661	16.71	3.6964	–5.3575
322	Tetrahydrothiophene	C_4H_8S	110-01-0	88.171	–3.376	4.59	3.1	–2.76549
323	2,2,3,3-Tetramethylbutane	C_8H_{18}	594-82-1	114.229	–22.56	2.239	3.893	–5.0639
324	Thiophene	C_4H_4S	110-02-1	84.140	11.544	12.67	2.784	–2.4352
325	Toluene	C_7H_8	108-88-3	92.138	5.017	12.22	3.2099	–3.734
326	1,1,2-Trichloroethane	$C_2H_3Cl_3$	79-00-5	133.404	–14.2	–8.097	3.371	–0.9685
327	Tridecane	$C_{13}H_{28}$	629-50-5	184.361	–31.177	5.771	6.6337	–8.1229
328	Triethyl amine	$C_6H_{15}N$	121-44-8	101.190	–9.58	11.41	4.054	–4.0405
329	Trimethyl amine	C_3H_9N	75-50-3	59.110	–2.431	9.899	2.87	–2.2449
330	1,2,3-Trimethylbenzene	C_9H_{12}	526-73-8	120.192	–0.95	12.61	3.805	–4.934
331	1,2,4-Trimethylbenzene	C_9H_{12}	95-63-6	120.192	–1.38	11.71	3.961	–4.9307
332	2,2,4-Trimethylpentane	C_8H_{18}	540-84-1	114.229	–22.401	1.394	4.2296	–5.06528
333	2,3,3-Trimethylpentane	C_8H_{18}	560-21-4	114.229	–21.845	1.828	4.2702	–5.06876
334	1,3,5-Trinitrobenzene	$C_6H_3N_3O_6$	99-35-4	213.105	6.24	26.79	4.435	–2.6867
335	2,4,6-Trinitrotoluene	$C_7H_5N_3O_6$	118-96-7	227.131	4.34	28.44	4.607	–3.2959
336	Undecane	$C_{11}H_{24}$	1120-21-4	156.308	–27.043	4.116	5.8493	–6.9036
337	1-Undecanol	$C_{11}H_{24}O$	112-42-5	172.308	–41.9	–9.177	6.363	–6.726
338	Vinyl acetate	$C_4H_6O_2$	108-05-4	86.089	–31.49	–22.79	3.28	–1.95
339	Vinyl acetylene	C_4H_4	689-97-4	52.075	30.46	30.6	2.794	–2.362
340	Vinyl chloride	C_2H_3Cl	75-01-4	62.498	2.845	4.195	2.7354	–1.178
341	Vinyl trichlorosilane	$C_2H_3Cl_3Si$	75-94-5	161.490	–48.116	–42.5514	3.73966	–1.544
342	Water	H_2O	7732-18-5	18.015	–24.1814	–22.859	1.88724	
343	*m*-Xylene	C_8H_{10}	108-38-3	106.165	1.732	11.876	3.5854	–4.3318
344	*o*-Xylene	C_8H_{10}	95-47-6	106.165	1.908	12.2	3.5383	–4.333
345	*p*-Xylene	C_8H_{10}	106-42-3	106.165	1.803	12.14	3.52165	–4.333

The compounds are considered to be formed from the elements in their standard states at 298.15 K and 101,325 Pa. These include C (graphite) and S (rhombic). Enthalpy of combustion is the net value for the compound in its standard state at 298.15 K and 101,325 Pa. Products of combustion are taken to be CO_2 (gas), H_2O (gas), Cl_2 (gas), Br_2 (gas), I_2 (gas), SO_2 (gas), N_2 (gas), P_4O_{10} (crystalline), SiO_2 (crystobalite), and Al_2O_3 (crystal, alpha).

TABLE 2-180 Ideal Gas Sensible Enthalpies, $h_T - h_{298}$ (kJ/kmol), of Combustion Products

Temperature, K	CO	CO_2	H	OH	H_2	N	NO	NO_2	N_2	N_2O	O	O_2	SO_2	H_2O
200	−2858	−3414	−2040	−2976	−2774	−2040	−2951	−3495	−2857	−3553	−2186	−2868	−3736	−3282
240	−1692	−2079	−1209	−1756	−1656	−1209	−1743	−2104	−1692	−2164	−1285	−1703	−2258	−1948
260	−1110	−1383	−793	−1150	−1091	−793	−1142	−1392	−1110	−1438	−840	−1118	−1496	−1279
280	−529	−665	−377	−546	−522	−378	−543	−672	−528	−692	−398	−533	−718	−609
298.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
300	54	69	38	55	53	38	55	68	54	72	41	54	74	62
320	638	823	454	654	630	454	652	816	636	854	478	643	881	735
340	1221	1594	870	1251	1209	870	1248	1571	1219	1654	913	1234	1702	1410
360	1805	2382	1285	1847	1791	1286	1845	2347	1802	2470	1346	1828	2538	2088
380	2389	3184	1701	2442	2373	1701	2442	3130	2386	3302	1777	2425	3387	2769
400	2975	4003	2117	3035	2959	2117	3040	3927	2971	4149	2207	3025	4250	3452
420	3563	4835	2532	3627	3544	2533	3638	4735	3557	5010	2635	3629	5126	4139
440	4153	5683	2948	4219	4131	2949	4240	5557	4143	5884	3063	4236	6015	4829
460	4643	6544	3364	4810	4715	3364	4844	6392	4731	6771	3490	4847	6917	5523
480	5335	7416	3779	5401	5298	3780	5450	7239	5320	7670	3918	5463	7831	6222
500	5931	8305	4196	5992	5882	4196	6059	8099	5911	8580	4343	6084	8758	6925
550	7428	10572	5235	7385	6760	5235	7592	10340	7395	10897	5402	7653	11123	8699
600	8942	12907	6274	8943	8811	6274	9144	12555	8894	13295	6462	9244	13544	10501
650	10477	15303	7314	10423	10278	7314	10716	14882	10407	15744	7515	10859	16022	12321
700	12023	17754	8353	11902	11749	8353	12307	17250	11937	18243	8570	12499	18548	14192
750	13592	20260	9392	13391	13223	9329	13919	19671	13481	20791	9620	14158	21117	16082
800	15177	22806	10431	14880	14702	10431	15548	22136	15046	23383	10671	15835	23721	18002
850	16781	25398	11471	16384	16186	11471	17195	24641	16624	26014	11718	17531	26369	19954
900	18401	28030	12510	17888	17676	12510	18858	27179	18223	28681	12767	19241	29023	21938
950	20031	30689	13550	19412	19175	13550	20537	29749	19834	31381	13812	20965	31714	23954
1000	21690	33397	14589	20935	20680	14589	22229	32344	21463	34110	14860	22703	34428	26000
1100	25035	38884	16667	24024	23719	16667	25653	37605	24760	39647	16950	26212	39914	30191
1200	28430	44473	18746	27160	26797	18746	29120	42946	28109	45274	19039	29761	45464	34506
1300	31868	50148	20824	30342	29918	20824	32626	48351	31503	50976	21126	33344	51069	38942
1400	35343	55896	22903	33569	33082	22903	36164	53808	34936	56740	23212	36957	56718	43493
1500	38850	61705	24982	36839	36290	24982	39729	59309	38405	62557	25296	40599	62404	48151
1600	42385	67569	27060	40151	39541	27060	43319	64846	41904	68420	27381	44266	68123	52908
1700	45945	73480	29139	43502	42835	29139	46929	70414	45429	74320	29464	47958	73870	57758
1800	49526	79431	31217	46889	46169	31218	50557	76007	48978	80254	31547	51673	79642	62693
1900	53126	85419	33296	50310	49541	33296	54201	81624	52548	86216	33630	55413	85436	67706
2000	56744	91439	35375	53762	52951	35375	57859	87259	56137	92203	35713	59175	91250	72790
2100	60376	97488	37453	57243	56397	37454	61530	92911	59742	98212	37796	62961	97081	77941
2200	64021	103562	39532	60752	59876	39534	65212	98577	63361	104240	39878	66769	102929	83153
2300	67683	109660	41610	64285	63387	41614	68904	104257	66995	110284	41962	70600	108792	88421
2400	71324	115779	43689	67841	66928	43695	72606	109947	70640	116344	44045	74453	114669	93741
2500	74985	121917	45768	71419	70498	45777	76316	115648	74296	122417	46130	78328	120559	99108
2600	78673	128073	47846	75017	74096	47860	80034	121357	77963	128501	48216	82224	126462	104520
2700	82369	134246	49925	78633	77720	49945	83759	127075	81639	134596	50303	86141	132376	109973
2800	86074	140433	52004	82267	81369	52033	87491	132799	85323	140701	52391	90079	138302	115464
2900	89786	146636	54082	85918	85043	54124	91229	138530	89015	146814	54481	94036	144238	120990
3000	93504	152852	56161	89584	88740	56218	94973	144267	92715	152935	56574	98013	150184	126549
3500	112185	184109	66554	108119	107555	66769	113768	173020	111306	183636	67079	118165	180057	154768
4000	130989	215622	75947	126939	126874	77532	132671	201859	130027	214453	77675	188705	210145	183552
4500	149895	247354	87340	145991	146660	88614	151662	230756	148850	245348	88386	159572	240427	212764
5000	168890	279283	97733	165246	166876	100111	170730	259692	167763	276299	99222	180749	270893	242313

Converted and usually rounded off from JANAF Thermochemical Tables, NSRDS-NBS-37, 1971 (1141 pp.).

TABLE 2-181 Ideal Gas Entropies $s°$, kJ/(kmol·K), of Combustion Products

Temperature, K	CO	CO_2	H	OH	H_2	N	NO	NO_2	N_2	N_2O	O	O_2	SO_2	H_2O
200	186.0	200.0	106.4	171.6	119.4	145.0	198.7	225.9	180.0	205.6	152.2	193.5	233.0	175.5
240	191.3	206.0	110.1	177.1	124.5	148.7	204.1	232.2	185.2	211.9	156.2	198.7	239.9	181.4
260	193.7	208.8	111.8	179.5	126.8	150.4	206.6	235.0	187.6	214.8	158.0	201.1	242.8	184.1
280	195.3	211.5	113.3	181.8	129.2	151.9	208.8	237.7	189.8	217.5	159.7	203.3	245.8	186.6
298.15	197.7	213.8	114.7	183.7	130.7	153.3	210.8	240.0	191.6	220.0	161.1	205.1	248.2	188.8
300	197.8	214.0	114.8	183.9	130.9	153.4	210.9	240.3	191.8	220.2	161.2	205.3	248.5	189.0
320	199.7	216.5	116.2	185.9	132.8	154.8	212.9	242.7	193.7	222.7	162.6	207.2	251.1	191.2
340	201.5	218.8	117.4	187.7	134.5	156.0	214.7	245.0	195.5	225.2	163.9	209.0	253.6	193.3
360	203.2	221.0	118.6	189.4	136.2	157.2	216.4	247.2	197.2	227.5	165.2	210.7	256.0	195.2
380	204.7	223.2	119.7	191.0	137.7	158.3	218.0	249.3	198.7	229.7	166.3	212.5	258.2	197.1
400	206.2	225.3	120.8	192.5	139.2	159.4	219.5	251.3	200.2	231.9	167.4	213.8	260.4	198.8
420	207.7	227.3	121.8	194.0	140.6	160.4	221.0	253.2	201.5	234.0	168.4	215.3	262.5	200.5
440	209.0	229.3	122.8	195.3	141.9	161.4	222.3	255.1	202.9	236.0	169.4	216.7	264.6	202.0
460	210.4	231.2	123.7	196.6	143.2	162.3	223.7	257.0	204.2	238.0	170.4	218.0	266.6	203.6
480	211.6	233.1	124.6	197.9	144.5	163.1	225.0	258.8	205.5	239.9	171.3	219.4	268.5	205.1
500	212.8	234.9	125.5	199.1	145.7	164.0	226.3	260.6	206.7	241.8	172.2	220.7	270.5	206.5
550	215.7	239.2	127.5	201.8	148.6	166.0	229.1	264.7	209.4	246.2	174.2	223.7	274.9	210.5
600	218.3	243.3	129.3	204.4	151.1	167.8	231.9	268.8	212.2	250.4	176.1	226.5	279.2	213.1
650	220.8	247.1	131.0	206.8	153.4	169.4	234.4	272.6	214.6	254.3	177.7	229.1	283.1	215.9
700	223.1	250.8	132.5	209.0	155.6	171.0	236.8	276.0	216.9	258.0	179.3	231.5	286.9	218.7
750	225.2	255.4	133.9	211.1	157.6	172.5	239.0	279.3	219.0	261.5	180.7	233.7	290.4	221.3
800	227.3	257.5	135.2	213.0	159.5	173.8	241.1	282.5	221.0	264.8	182.1	235.9	293.8	223.8
850	229.2	260.6	136.4	214.8	161.4	175.1	243.0	285.5	223.0	268.0	183.4	237.9	297.0	226.2
900	231.1	263.6	137.7	216.5	163.1	176.3	245.0	288.4	224.8	271.1	184.6	239.9	300.1	228.5
950	232.8	266.5	138.8	218.1	164.7	177.4	246.8	291.3	226.5	274.0	185.7	241.8	303.0	230.6
1000	234.5	269.3	139.9	219.7	166.2	178.5	248.4	293.9	228.2	276.8	186.8	243.6	305.8	232.7
1100	237.7	274.5	141.9	222.7	169.1	180.4	251.8	298.9	231.3	282.1	188.8	246.9	311.0	236.7
1200	240.7	279.4	143.7	225.4	171.8	182.2	254.8	303.6	234.2	287.0	190.6	250.0	315.8	240.5
1300	243.4	283.9	145.3	228.0	174.3	183.9	257.6	307.9	236.9	291.5	192.3	252.9	320.3	244.0
1400	246.0	288.2	146.9	230.3	176.6	185.4	260.2	311.9	239.5	295.8	193.8	255.6	324.5	247.4
1500	248.4	292.2	148.3	232.6	178.8	186.9	262.7	315.7	241.9	299.8	195.3	258.1	328.4	250.6
1600	250.7	296.0	149.6	234.7	180.9	188.2	265.0	319.3	244.1	303.6	196.6	260.4	332.1	253.7
1700	252.9	299.6	150.9	236.8	182.9	189.5	267.2	322.7	246.3	307.2	197.9	262.7	335.6	256.6
1800	254.9	303.0	152.1	238.7	184.8	190.7	269.3	325.9	248.3	310.6	199.1	264.8	338.9	259.5
1900	256.8	306.2	153.2	240.6	186.7	191.8	271.3	328.9	250.2	313.8	200.2	266.8	342.0	262.2
2000	258.7	309.3	154.3	242.3	188.4	192.9	273.1	331.8	252.1	316.9	201.3	268.7	345.0	264.8
2100	260.5	312.2	155.3	244.0	190.1	193.9	274.9	334.5	253.8	319.8	202.3	270.6	347.9	267.3
2200	262.2	315.1	156.3	245.7	191.7	194.8	276.6	337.2	255.5	322.6	203.2	272.4	350.6	269.7
2300	263.8	317.8	157.2	247.2	193.3	195.8	278.3	339.7	257.1	325.3	204.2	274.1	353.2	272.0
2400	265.4	320.4	158.1	248.7	194.8	196.7	279.8	342.1	258.7	327.9	205.0	275.7	355.7	274.3
2500	266.9	322.9	158.9	250.2	196.2	197.5	281.4	344.5	260.2	330.4	205.9	277.3	358.1	276.5
2600	268.3	325.3	159.7	251.6	197.7	198.3	282.8	346.7	261.6	332.7	206.7	278.8	360.4	278.6
2700	269.7	327.6	160.5	253.0	199.0	199.1	284.2	348.9	263.0	335.0	207.5	280.3	362.6	380.7
2800	271.0	329.9	161.3	254.3	200.3	199.9	285.6	350.9	264.3	337.3	208.3	281.7	364.8	282.7
2900	272.3	332.1	162.0	255.6	201.6	200.6	286.9	352.9	265.6	339.4	209.0	283.1	366.9	284.6
3000	273.6	334.2	162.7	256.8	202.9	201.3	288.2	354.9	266.9	341.5	209.7	284.4	368.9	286.5
3500	279.4	343.8	165.9	262.5	208.7	204.6	294.0	363.8	272.6	350.9	212.9	290.7	378.1	295.2
4000	284.4	352.2	168.7	267.6	213.8	207.4	299.0	371.5	277.6	359.2	215.8	296.2	386.1	302.9
4500	288.8	359.7	171.1	272.1	218.5	210.1	303.5	378.3	282.1	366.5	218.3	301.1	393.3	309.8
5000	292.8	366.4	173.3	276.1	222.8	212.5	307.5	384.4	286.0	373.0	220.6	305.5	399.7	316.0

Usually rounded off from JANAF Thermochemical Tables, NSRDS-NBS-37, 1971 (1141 pp.). Equilibrium constants can be calculated by combining Δh_f° values from Table 2-179, $h_T - h_{298}$ from Table 2-180, and $s°$ values from the above, using the formula $\ln k_p = -\Delta G/(RT)$, where $\Delta G = \Delta h_f^\circ + (h_T - h_{298}) - T s^\circ$.

HEATS OF SOLUTION

TABLE 2-182 Heats of Solution of Inorganic Compounds in Water

Heat evolved, in kilocalories per gram formula weight, on solution in water at 18 °C. Computed from data in Bichowsky and Rossini, *Thermochemistry of Chemical Substances,* Reinhold, New York, 1936.

Substance	Dilution*	Formula	Heat, kcal/mol
Aluminum bromide	aq	$AlBr_3$	+85.3
chloride	600	$AlCl_3$	+77.9
	600	$AlCl_3 \cdot 6H_2O$	+13.2
fluoride	aq	AlF_3	+31
	aq	$AlF_3 \cdot 1/2H_2O$	+19.0
	aq	$AlF_3 \cdot 3 1/2H_2O$	−1.7
iodide	aq	AlI_3	+89.0
sulfate	aq	$Al_2(SO_4)_3$	+126
	aq	$Al_2(SO_4)_3 \cdot 6H_2O$	+56.2
	aq	$Al_2(SO_4)_3 \cdot 18H_2O$	+6.7
Ammonium bromide	aq	NH_4Br	−4.45
chloride	∞	NH_4Cl	−3.82
chromate	aq	$(NH_4)_2CrO_4$	−5.82
dichromate	600	$(NH_4)_2Cr_2O_7$	−12.9
iodide	aq	NH_4I	−3.56
nitrate	∞	NH_4NO_3	−6.47
perborate	aq	$NH_4BO_3 \cdot H_2O$	−9.0
sulfate	∞	$(NH_4)_2SO_4$	−2.75
sulfate, acid	800	NH_4HSO_4	+0.56
sulfite	aq	$(NH_4)_2SO_3$	−1.2
	aq	$(NH_4)_2SO_3 \cdot H_2O$	−4.13
Antimony fluoride	aq	SbF_3	−1.7
iodide	aq	SbI_3	−0.8
Arsenic acid	aq	H_3AsO_4	−0.4
Barium bromate	∞	$Ba(BrO_3)_2 \cdot H_2O$	−15.9
bromide	∞	$BaBr_2$	+5.3
	∞	$BaBr_2 \cdot H_2O$	−0.8
	∞	$BaBr_2 \cdot 2H_2O$	−3.87
chlorate	∞	$Ba(ClO_3)_2$	−6.7
	∞	$Ba(ClO_3)_2 \cdot H_2O$	−10.6
chloride	∞	$BaCl_2$	+2.4
	∞	$BaCl_2 \cdot H_2O$	−2.17
	∞	$BaCl_2 \cdot 2H_2O$	−4.5
cyanide	aq	$Ba(CN)_2$	+1.5
	aq	$Ba(CN)_2 \cdot H_2O$	−2.4
	aq	$Ba(CN)_2 \cdot 2H_2O$	−4.9
iodate	∞	$Ba(IO_3)_2$	−9.1
	∞	$Ba(IO_3)_2 \cdot H_2O$	−11.3
iodide	∞	BaI_2	+10.5
	∞	$BaI_2 \cdot H_2O$	+2.7
	∞	$BaI_2 \cdot 2H_2O$	+0.14
	∞	$BaI_2 \cdot 2 1/2H_2O$	−0.58
	∞	$BaI_2 \cdot 7H_2O$	−6.61
nitrate	∞	$Ba(NO_3)_2$	−10.2
perchlorate	∞	$Ba(ClO_4)_2$	−2.8
	∞	$Ba(ClO_4)_2 \cdot 3H_2O$	−10.5
sulfide	∞	BaS	+7.2
Beryllium bromide	aq	$BeBr_2$	+62.6
chloride	aq	$BeCl_2$	+51.1
iodide	aq	BeI_2	+72.6
sulfate	aq	$BeSO_4$	+18.1
	aq	$BeSO_4 \cdot H_2O$	+13.5
	aq	$BeSO_4 \cdot 2H_2O$	+7.9
	aq	$BeSO_4 \cdot 4H_2O$	+1.1
Bismuth iodide	aq	BiI_3	+3
Boric acid	aq	H_3BO_3	−5.4
Cadmium bromide	400	$CdBr_2$	+0.4
	400	$CdBr_2 \cdot 4H_2O$	−7.3
chloride	400	$CdCl_2$	+3.1
	400	$CdCl_2 \cdot H_2O$	+0.6
	400	$CdCl_2 \cdot 2 1/2H_2O$	−3.00
nitrate	400	$Cd(NO_3)_2 \cdot H_2O$	+4.17
	400	$Cd(NO_3)_2 \cdot 4H_2O$	−5.08
sulfate	400	$CdSO_4$	+10.69
	400	$CdSO_4 \cdot H_2O$	+6.05
	400	$CdSO_4 \cdot 2 2/3H_2O$	+2.51
Calcium acetate	∞	$Ca(C_2H_3O_2)_2$	+7.6
	∞	$Ca(C_2H_3O_2)_2 \cdot H_2O$	+6.5
Calcium—(*Cont.*)			
bromide	∞	$CaBr_2$	+24.86
	∞	$CaBr_2 \cdot 6H_2O$	−0.9
chloride	∞	$CaCl_2$	+4.9
	∞	$CaCl_2 \cdot H_2O$	+12.3
	∞	$CaCl_2 \cdot 2H_2O$	+12.5
	∞	$CaCl_2 \cdot 4H_2O$	+2.4
	∞	$CaCl_2 \cdot 6H_2O$	−4.11
formate	400	$Ca(CHO_2)_2$	+0.7
iodide	∞	CaI_2	+28.0
	∞	$CaI_2 \cdot 8H_2O$	+1.8
nitrate	∞	$Ca(NO_3)_2$	+4.1
	∞	$Ca(NO_3)_2 \cdot H_2O$	+0.7
	∞	$Ca(NO_3)_2 \cdot 2H_2O$	−3.2
	∞	$Ca(NO_3)_2 \cdot 3H_2O$	−4.2
	∞	$Ca(NO_3)_2 \cdot 4H_2O$	−7.99
phosphate, mono-	aq	$Ca(H_2PO_4)_2 \cdot H_2O$	−0.6
dibasic	aq	$CaHPO_4 \cdot 2H_2O$	−1
sulfate	∞	$CaSO_4$	+5.1
	∞	$CaSO_4 \cdot 1/2H_2O$	+3.6
	∞	$CaSO_4 \cdot 2H_2O$	−0.18
Chromous chloride	aq	$CrCl_2$	+18.6
		$CrCl_2 \cdot 3H_2O$	+5.3
		$CrCl_2 \cdot 4H_2O$	+2.0
iodide	aq	CrI_2	+5.7
Cobaltous bromide	aq	$CoBr_2$	+18.4
	aq	$CoBr_2 \cdot 6H_2O$	−1.25
chloride	400	$CoCl_2$	+18.5
	400	$CoCl_2 \cdot 2H_2O$	+9.8
	400	$CoCl_2 \cdot 6H_2O$	−2.9
iodide	aq	CoI_2	+18.8
sulfate	400	$CoSO_4$	+15.0
	400	$CoSO_4 \cdot 6H_2O$	−1.4
	400	$CoSO_4 \cdot 7H_2O$	−3.6
Cupric acetate	aq	$Cu(C_2H_3O_2)_2$	+2.4
formate	aq	$Cu(CHO_2)_2$	+0.5
nitrate	200	$Cu(NO_3)_2$	+10.3
	200	$Cu(NO_3)_2 \cdot 3H_2O$	−2.6
	200	$Cu(NO_3)_2 \cdot 6H_2O$	−10.7
sulfate	800	$CuSO_4$	+15.9
		$CuSO_4 \cdot H_2O$	+9.3
		$CuSO_4 \cdot 3H_2O$	+3.65
		$CuSO_4 \cdot 5H_2O$	−2.85
Cuprous sulfate	aq	Cu_2SO_4	+11.6
Ferric chloride	1000	$FeCl_3$	+31.7
	1000	$FeCl_3 \cdot 2 1/2H_2O$	+21.0
	1000	$FeCl_3 \cdot 6H_2O$	+5.6
nitrate	800	$Fe(NO_3)_3 \cdot 9H_2O$	−9.1
Ferrous bromide	aq	$FeBr_2$	+18.0
chloride	400	$FeCl_2$	+17.9
	400	$FeCl_2 \cdot 2H_2O$	+8.7
	400	$FeCl_2 \cdot 4H_2O$	+2.7
iodide	aq	FeI_2	+23.3
sulfate	400	$FeSO_4$	+14.7
	400	$FeSO_4 \cdot H_2O$	+7.35
	400	$FeSO_4 \cdot 4H_2O$	+1.4
	400	$FeSO_4 \cdot 7H_2O$	−4.4
Lead acetate	400	$Pb(C_2H_3O_2)_2$	+1.4
	400	$Pb(C_2H_3O_2)_2 \cdot 3H_2O$	−5.9
bromide	aq	$PbBr_2$	−10.1
chloride	aq	$PbCl_2$	−3.4
formate	aq	$Pb(CHO_2)_2$	−6.9
nitrate	400	$Pb(NO_3)_2$	−7.61
Lithium bromide	∞	$LiBr$	+11.54
	∞	$LiBr \cdot H_2O$	+5.30
	∞	$LiBr \cdot 2H_2O$	+2.05
	∞	$LiBr \cdot 3H_2O$	−1.59
chloride	∞	$LiCl$	+8.66

*The numbers represent moles of water used to dissolve 1 g formula weight of substance; ∞ means "infinite dilution"; and *aq* means "aqueous solution of unspecified dilution."

TABLE 2-182 Heats of Solution of Inorganic Compounds in Water (*Continued*)

Substance	Dilution*	Formula	Heat, kcal/mol
Lithium—(*Cont.*)			
	∞	$LiCl·H_2O$	+4.45
	∞	$LiCl·2H_2O$	+1.07
	∞	$LiCl·3H_2O$	−1.98
fluoride	∞	LiF	−0.74
hydroxide	∞	LiOH	+4.74
	∞	$LiOH·⅛H_2O$	+4.39
	∞	$LiOH·H_2O$	+9.6
iodide	∞	LiI	+14.92
	∞	$LiI·½H_2O$	+10.08
	∞	$LiI·H_2O$	+6.93
	∞	$LiI·2H_2O$	+3.43
	∞	$LiI·3H_2O$	−0.17
nitrate	∞	$LiNO_3$	+0.466
	∞	$LiNO_3·3H_2O$	−7.87
sulfate	∞	Li_2SO_4	+6.71
	∞	$Li_2SO_4·H_2O$	+3.77
Magnesium bromide	∞	$MgBr_2$	+43.7
	∞	$MgBr_2·H_2O$	+35.9
	∞	$MgBr_2·6H_2O$	+19.8
chloride	∞	$MgCl_2$	+36.3
	∞	$MgCl_2·2H_2O$	+20.8
	∞	$MgCl_2·4H_2O$	+10.5
	∞	$MgCl_2·6H_2O$	+3.4
iodide	∞	MgI_2	+50.2
nitrate	∞	$Mg(NO_3)_2·6H_2O$	−3.7
phosphate	aq	$Mg_3(PO_4)_2$	+10.2
sulfate	∞	$MgSO_4$	+21.1
	∞	$MgSO_4·H_2O$	+14.0
	∞	$MgSO_4·2H_2O$	+11.7
	∞	$MgSO_4·4H_2O$	+4.9
	∞	$MgSO_4·6H_2O$	+0.55
	∞	$MgSO_4·7H_2O$	−3.18
sulfide	aq	MgS	+25.8
Manganic nitrate	400	$Mn(NO_3)_2$	+12.9
	400	$Mn(NO_3)_2·3H_2O$	−3.9
	400	$Mn(NO_3)_2·6H_2O$	−6.2
sulfate	aq	$Mn_2(SO_4)_3$	+22
Manganous acetate	aq	$Mn(C_2H_3O_2)_2$	+12.2
	aq	$Mn(C_2H_3O_2)_2·4H_2O$	+1.6
bromide	aq	$MnBr_2$	+15
	aq	$MnBr_2·H_2O$	+14.4
	aq	$MnBr_2·4H_2O$	+16.1
chloride	400	$MnCl_2$	+16.0
	400	$MnCl_2·2H_2O$	+8.2
	400	$MnCl_2·4H_2O$	+1.5
formate	aq	$Mn(CHO_2)_2$	+4.3
	aq	$Mn(CHO_2)_2·2H_2O$	−2.9
iodide	aq	MnI_2	+26.2
	aq	$MnI_2·H_2O$	+24.1
	aq	$MnI_2·2H_2O$	+22.7
	aq	$MnI_2·4H_2O$	+19.9
	aq	$MnI_2·6H_2O$	+21.2
sulfate	400	$MnSO_4$	+13.8
	400	$MnSO_4·H_2O$	+11.9
	400	$MnSO_4·7H_2O$	−1.7
Mercuric acetate	aq	$Hg(C_2H_3O_2)_2$	−4.0
bromide	aq	$HgBr_2$	−2.4
chloride	aq	$HgCl_2$	−3.3
nitrate	aq	$Hg(NO_3)_2·½H_2O$	−0.7
Mercurous nitrate	aq	$Hg_2(NO_3)_2·2H_2O$	−11.5
Nickel bromide	aq	$NiBr_2$	+19.0
	aq	$NiBr_2·3H_2O$	+0.2
Nickel chloride	800	$NiCl_2$	+19.23
	800	$NiCl_2·2H_2O$	+10.4
	800	$NiCl_2·4H_2O$	+4.2
	800	$NiCl_2·6H_2O$	−1.15
iodide	aq	NiI_2	+19.4
nitrate	200	$Ni(NO_3)_2$	+11.8
	200	$Ni(NO_3)_2·6H_2O$	−7.5
sulfate	200	$NiSO_4$	+15.1
	200	$NiSO_4·7H_2O$	−4.2
Phosphoric acid, ortho-	400	H_3PO_4	+2.79
	400	$H_3PO_4·½H_2O$	−0.1
pyro-	aq	$H_4P_2O_7$	+25.9
	aq	$H_4P_2O_7·1½H_2O$	+4.65
Potassium acetate	∞	$KC_2H_3O_2$	+3.55
aluminum sulfate	600	$KAl(SO_4)_2$	+48.5
	600	$KAl(SO_4)_2·3H_2O$	+26.6
		$KAl(SO_4)_2·12H_2O$	−10.1
bicarbonate	2000	$KHCO_3$	−5.1
bromate	∞	$KBrO_3$	−10.13
bromide	∞	KBr	−5.13
carbonate	∞	K_2CO_3	+6.58
		$K_2CO_3·½H_2O$	+4.25
		$K_2CO_3·1½H_2O$	−0.43
chlorate	∞	$KClO_3$	−10.31
chloride	∞	KCl	−4.404
chromate	2185	K_2CrO_4	−4.9
chrome sulfate	600	$KCr(SO_4)_2$	+55
		$KCr(SO_4)_2·H_2O$	+42
		$KCr(SO_4)_2·2H_2O$	+33
		$KCr(SO_4)_2·6H_2O$	+7
		$KCr(SO_4)_2·12H_2O$	−9.5
cyanide	200	KCN	−3.0
dichromate	1600	$K_2Cr_2O_7$	−17.8
fluoride	∞	KF	+3.96
	∞	$KF·2H_2O$	−1.85
	∞	$KF·4H_2O$	−6.05
hydrosulfide	∞	KHS	+0.86
	∞	$KHS·¼H_2O$	+1.21
hydroxide	∞	KOH	+12.91
	∞	$KOH·¾H_2O$	+4.27
	∞	$KOH·H_2O$	+3.48
	∞	$KOH·7H_2O$	+0.86
iodate	∞	KIO_3	−6.93
iodide	∞	KI	−5.23
nitrate	∞	KNO_3	−8.633
oxalate	400	$K_2C_2O_4$	−4.6
		$K_2C_2O_4·H_2O$	−7.5
perchlorate	∞	$KClO_4$	−12.94
permanganate	400	$KMnO_4$	−10.4
phosphate, dihydrogen	aq	KH_2PO_4	+4.7
pyrosulfite	aq	$K_2S_2O_5$	−11.0
	aq	$K_2S_2O_5·½H_2O$	−10.22
sulfate	∞	K_2SO_4	−6.32
sulfate, acid	800	$KHSO_4$	−3.10
sulfide	∞	K_2S	−11.0
sulfite	aq	K_2SO_3	+1.8
	aq	$K_2SO_3·H_2O$	+1.37
thiocyanate	∞	KCNS	−6.08
thionate, di-	aq	$K_2S_2O_6$	−13.0
thiosulfate	∞	$K_2S_2O_3$	−4.5
Silver acetate	aq	$AgC_2H_3O_2$	−5.4
nitrate	200	$AgNO_3$	−4.4
Sodium acetate	∞	$NaC_2H_3O_2$	+4.085
	∞	$NaC_2H_3O_2·3H_2O$	−4.665
arsenate	500	Na_3AsO_4	+15.6
	500	$Na_3AsO_4·12H_2O$	−12.61
bicarbonate	1800	$NaHCO_3$	−4.1
borate, tetra-	900	$Na_2B_4O_7$	+10.0
	900	$Na_2B_4O_7·10H_2O$	−16.8
bromide	∞	NaBr	−0.58
	∞	$NaBr·2H_2O$	−4.57
carbonate	∞	Na_2CO_3	+5.57
	∞	$Na_2CO_3·H_2O$	+2.19
	∞	$Na_2CO_3·7H_2O$	−10.81
	∞	$Na_2CO_3·10H_2O$	−16.22
chlorate	∞	$NaClO_3$	−5.37
chloride	∞	NaCl	−1.164
chromate	800	Na_2CrO_4	+2.50
	800	$Na_2CrO_4·4H_2O$	−7.52
	800	$Na_2CrO_4·10H_2O$	−16.0
cyanide	200	NaCN	−0.37
	200	$NaCN·½H_2O$	−0.92

TABLE 2-182 Heats of Solution of Inorganic Compounds in Water (*Concluded*)

Substance	Dilution*	Formula	Heat, kcal/mol	Substance	Dilution*	Formula	Heat, kcal/mol
Sodium—(*Cont.*)				Sodium—(*Cont.*)			
	200	$NaCN·2H_2O$	−4.41	thionate, di-	aq	$Na_2S_2O_6$	−5.80
fluoride	∞	NaF	−0.27		aq	$Na_2S_2O_6·2H_2O$	−11.86
hydrosulfide	∞	NaHS	+4.62	Sodium thiosulfate	aq	$Na_2S_2O_3$	+2.0
	∞	$NaHS·2H_2O$	−1.49		aq	$Na_2S_2O_3·5H_2O$	−11.30
Sodium hydroxide	∞	NaOH	+10.18	Stannic bromide	aq	$SnBr_4$	+15.5
	∞	$NaOH·½H_2O$	+8.17	Stannous bromide	aq	$SnBr_2$	−1.6
	∞	$NaOH·⅔H_2O$	+7.08	iodide	aq	SnI_2	−5.8
	∞	$NaOH·¾H_2O$	+6.48	Strontium acetate	∞	$Sr(C_2H_3O_2)_2$	+6.2
	∞	$NaOH·H_2O$	+5.17		∞	$Sr(C_2H_3O_2)_2·½H_2O$	+5.9
iodide	∞	NaI	+1.57	bromide	∞	$SrBr_2$	+16.4
	∞	$NaI·2H_2O$	−3.89		∞	$SrBr_2·H_2O$	+9.25
metaphosphate	600	$NaPO_3$	+3.97		∞	$SrBr_2·2H_2O$	+6.5
nitrate	∞	$NaNO_3$	−5.05		∞	$SrBr_2·4H_2O$	+0.4
nitrite	aq	$NaNO_2$	−3.6		∞	$SrBr_2·6H_2O$	−6.1
perchlorate	∞	$NaClO_4$	−4.15	chloride	∞	$SrCl_2$	+11.54
phosphate di	1600	Na_2HPO_4	+5.21		∞	$SrCl_2·H_2O$	+6.4
tri-	1600	Na_3PO_4	+13		∞	$SrCl_2·2H_2O$	+2.95
phosphate di	1600	$Na_3PO_4·12H_2O$	−15.3		∞	$SrCl_2·6H_2O$	−7.1
di-	1600	$Na_2HPO_4·2H_2O$	−0.82	iodide	∞	SrI_2	+20.7
	1600	$Na_2HPO_4·7H_2O$	−12.04		∞	$SrI_2·H_2O$	+12.65
	1600	$Na_2HPO_4·12H_2O$	−23.18		∞	$SrI_2·2H_2O$	+10.4
phosphite, mono-	600	NaH_2PO_3	+0.90		∞	$SrI_2·6H_2O$	−4.5
	600	$NaH_2PO_3·2½H_2O$	−5.29	nitrate	∞	$Sr(NO_3)_2$	−4.8
di-	800	Na_2HPO_3	+9.30		∞	$Sr(NO_3)_2·4H_2O$	−12.4
	800	$Na_2HPO_3·5H_2O$	−4.54	sulfate	∞	$SrSO_4$	+0.5
pyrophosphate	1600	$Na_4P_2O_7$	+11.9	Sulfuric acid, pyro-	∞	$H_2S_2O_7$	−18.08
	1600	$Na_4P_2O_7·10H_2O$	−11.7				
di-	1200	$Na_2H_2P_2O_7$	−2.2	Zinc acetate	400	$Zn(C_2H_3O_2)_2$	+9.8
	1200	$Na_2H_2P_2O_7·6H_2O$	−14.0		400	$Zn(C_2H_3O_2)_2·H_2O$	+7.0
sulfate	∞	Na_2SO_4	+0.28		400	$Zn(C_2H_3O_2)_2·2H_2O$	+3.9
	∞	$Na_2SO_4·10H_2O$	−18.74	bromide	400	$ZnBr_2$	+15.0
sulfate, acid	800	$NaHSO_4$	+1.74	chloride	400	$ZnCl_2$	+15.72
	800	$NaHSO_4·H_2O$	+0.15	iodide	aq	ZnI_2	+11.6
sulfide	∞	Na_2S	+15.2	nitrate	400	$Zn(NO_3)_2·3H_2O$	−5
	∞	$Na_2S·4½H_2O$	+0.09		400	$Zn(NO_3)_2·6H_2O$	−6.0
	∞	$Na_2S·5H_2O$	−6.54	sulfate	400	$ZnSO_4$	+18.5
	∞	$Na_2S·9H_2O$	−16.65		400	$ZnSO_4·H_2O$	+10.0
sulfite	∞	Na_2SO_3	+2.8		400	$ZnSO_4·6H_2O$	−0.8
	∞	$Na_2SO_3·7H_2O$	−11.1		400	$ZnSO_4·7H_2O$	−4.3
thiocyanate	∞	NaCNS	−1.83				

NOTE: To convert kilocalories per mole to British thermal units per pound-mole, multiply by 1.799×10^{-3}.

TABLE 2-183 Heats of Solution of Organic Compounds in Water (at Infinite Dilution and Approximately Room Temperature)

Recalculated and rearranged from *International Critical Tables,* vol. 5, pp. 148–150. cal/mol = Btu/(lb·mol) × 1.799.

Solute	Heat of solution, cal/mol solute*	Solute	Heat of solution, cal/mol solute*
Acetic acid (solid), $C_2H_4O_2$	–2,251	Oxalic acid, $C_2H_2O_4$	–2,290
Acetylacetone, $C_5H_8O_2$	–641	($2H_2O$)	–8,485
Acetylurea, $C_3H_6N_2O_2$	–6,812	Phenol (solid), C_6H_6O	–2,605
Aconitic acid, $C_6H_6O_6$	–4,206	Phthalic acid, $C_8H_6O_4$	–4,871
Ammonium benzoate, $C_7H_9NO_2$	–2,700	Picric acid, $C_6H_3N_3O_7$	–7,098
picrate	–8,700	Piperic acid, $C_{12}H_{10}O_4$	–10,492
succinate (*n*-)	–3,489	Piperonylic acid, $C_8H_6O_4$	–9,106
Aniline, hydrochloride, C_6H_8ClN	–2,732	Potassium benzoate	–1,506
Barium picrate	–4,708	citrate	2,820
Benzoic acid, $C_7H_6O_2$	–6,501	tartrate (*n*-) (0.5 H_2O)	–5,562
Camphoric acid, $C_{10}H_{16}O_4$	–502	Pyrogallol, $C_6H_6O_3$	–3,705
Citric acid, $C_6H_8O_7$	–5,401	Pyrotartaric acid	–5,019
Dextrin, $C_{12}H_{30}O_{10}$	268	Quinone	–3,991
Fumaric acid, $C_4H_4O_4$	–5,903	Raffinose, $C_{18}H_{32}O_{16}$ ($5H_2O$)	–9,703
Hexamethylenetetramine, $C_6H_{12}N_4$	4,780	Resorcinol, $C_6H_6O_2$	–3,960
Hydroxybenzamide (*m*-), $C_7H_7NO_2$	–4,161	Silver malonate (*n*-)	–9,799
(*m*-), (HCl)	–7,003	Sodium citrate (tri-)	5,270
(*o*-), $C_7H_7NO_2$	–4,340	picrate	–6,441
(*p*-)	–5,392	potassium tartrate	–1,817
Hydroxybenzoic acid (*o*-), $C_7H_6O_3$	–6,350	($4H_2O$)	–12,342
(*p*-), $C_7H_6O_3$	–5,781	succinate (*n*-)	2,390
Hydroxybenzyl alcohol (*o*-), $C_7H_8O_2$	–3,203	($6H_2O$)	–10,994
Inulin, $C_{36}H_{62}O_{31}$	–96	tartrate (*n*-)	–1,121
Isosuccinic acid, $C_4H_6O_4$	–3,420	($2H_2O$)	–5,882
Itaconic acid, $C_5H_6O_4$	–5,922	Strontium picrate	7,887
Lactose, $C_{12}H_{22}O_{11}·H_2O$	–3,705	($6H_2O$)	–14,412
Lead picrate	–7,098	Succinic acid, $C_4H_6O_4$	–6,405
($2H_2O$)	–13,193	Succinimide, $C_4H_5NO_2$	–4,302
Magnesium picrate	14,699	Sucrose, $C_{12}H_{22}O_{11}$	–1,319
($8H_2O$)	–15,894	Tartaric acid (*d*-)	–3,451
Maleic acid, $C_4H_4O_4$	–4,441	Thiourea, CH_4N_2S	–5,330
Malic acid, $C_4H_6O_5$	–3,150	Urea, CH_4N_2O	–3,609
Malonic acid, $C_3H_4O_4$	–4,493	acetate	–8,795
Mandelic acid, $C_8H_2O_3$	–3,090	formate	–7,194
Mannitol, $C_6H_{14}O_6$	–5,260	nitrate	–10,803
Menthol, $C_{10}H_{20}O$	0	oxalate	–17,806
Nicotine dihydrochloride, $C_{10}H_{16}Cl_2N_2$	6,561	Vanillic acid	–5,160
Nitrobenzoic acid (*m*-), $C_7H_5NO_4$	–5,593	Vanillin	–5,210
(*o*-), $C_7H_5NO_4$	–5,306	Zinc picrate	–11,496
(*p*-), $C_7H_5NO_4$	–8,891	($8H_2O$)	–15,894
Nitrophenol (*m*-), $C_6H_5NO_3$	–5,210		
(*o*-), $C_6H_5NO_3$	–6,310		
(*p*-), $C_6H_5NO_3$	–4,493		

* + denotes heat evolved, and – denotes heat absorbed. The data in the *International Critical Tables* were calculated by E. Anderson.

THERMODYNAMIC PROPERTIES

EXPLANATION OF TABLES

The following subsection presents information on the thermodynamic properties of a number of fluids. In some cases transport properties are also included.

Properties for the compounds listed in Table 2-184 were generated by using the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). Megan Friend's help in generating these tables is acknowledged and gratefully appreciated. The number of digits provided in these tables was chosen for uniformity of appearance and formatting; these do not represent the uncertainties of the physical quantities, but are the result of calculations from the standard thermophysical property formulations within a fixed format.

Properties for many of these compounds can also be generated by going to http://webbook.nist.gov and selecting NIST Chemistry WebBook, then Thermophysical Properties of Fluid Systems High Accuracy Data. This site allows the user to generate tables of thermodynamic properties. The user can select the units as well as the temperatures and/or pressure increments for which properties are to be generated. The resulting table can be copied into a spreadsheet. Because of this capability, properties for the compounds listed in Table 2-184 are not tabulated at as many temperatures and pressures as might otherwise be the case.

Notation

c_p = isobaric specific heat
c_v = isochoric specific heat
e = specific internal energy
h = enthalpy
k = thermal conductivity
p = pressure
s = specific entropy
t = temperature
T = absolute temperature
u = specific internal energy
μ = viscosity
v = specific volume
f = subscript denoting saturated liquid
g = subscript denoting saturated vapor

UNITS CONVERSIONS

For this subsection, the following units conversions are applicable:

c_p, specific heat: To convert kilojoules per kilogram-kelvin to British thermal units per pound–degree Fahrenheit, multiply by 0.23885.

e, internal energy: To convert kilojoules per kilogram to British thermal units per pound, multiply by 0.42992.

g, gravity acceleration: To convert meters per second squared to feet per second squared, multiply by 3.2808.

h, enthalpy: To convert kilojoules per kilogram to British thermal units per pound, multiply by 0.42992.

k, thermal conductivity: To convert watts per meter-kelvin to British thermal unit–feet per hour–square foot–degree Fahrenheit, multiply by 0.57779.

p, pressure: To convert bars to kilopascals, multiply by 1×10^2; to convert bars to pounds-force per square inch, multiply by 14.504; and to convert millimeters of mercury to pounds-force per square inch, multiply by 0.01934.

s, entropy: to convert kilojoules per kilogram-kelvin to British thermal units per pound–degree Rankine, multiply by 0.23885.

t, temperature: $°F = \frac{9}{5}\,°C + 32$.

T, absolute temperature: $°R = \frac{9}{5}\,K$.

u, internal energy: to convert kilojoules per kilogram to British thermal units per pound, multiply by 0.42992.

μ, viscosity: to convert pascal-seconds to pound-force–seconds per square foot, multiply by 0.020885; to convert pascal-seconds to c_p, multiply by 1000.

v, specific volume: to convert cubic meters per kilogram to cubic feet per pound, multiply by 16.018.

ρ, density: to convert kilograms per cubic meter to pounds per cubic foot, multiply by 0.062428.

ADDITIONAL REFERENCES

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TABLE 2-184 List of Substances for Which Thermodynamic Property Tables Were Generated from NIST Standard Reference Database 23

Table no.	Name	Chemical formula	Alternate name
2-185	Acetone	C_3H_6O	
2-187	Air		
2-189	Ammonia	NH_3	
2-190	Argon	Ar	
2-193	Benzene	C_6H_6	
2-195	Butane	C_4H_{10}	
2-196	1-Butene	C_4H_8	
2-197	*cis*-2-Butene	C_4H_8	
2-198	*trans*-2-butene	C_4H_8	
2-199	Carbon dioxide	CO_2	
2-200	Carbon monoxide	CO	
2-203	Carbonyl sulfide	COS	
2-207	Cyclohexane	C_6H_{12}	
2-208	Decane	$C_{10}H_{22}$	
2-209	Deuterium oxide	D_2O	Heavy water
2-210	2,2-Dimethylpropane	C_5H_{14}	Neopentane
2-212	Dodecane	$C_{12}H_{26}$	
2-213	Ethane	C_2H_6	
2-214	Ethanol	C_2H_6O	
2-215	Ethylene	C_2H_4	
2-216	Fluorine	F_2	
2-219	Helium	He	
2-220	Heptane	C_7H_{16}	
2-221	Hexane	C_6H_{14}	
2-223	Normal hydrogen	H_2	
2-224	*para*-Hydrogen	H_2	
2-226	Hydrogen sulfide	H_2S	
2-227	Isobutane	C_4H_{10}	
2-228	Isobutene	C_4H_8	2-methyl propene
2-229	Krypton	Kr	
2-233	Methane	CH_4	
2-234	Methanol	CH_4O	
2-235	2-Methylbutane	C_5H_{12}	Isopentane
2-236	2-Methylpentane	C_6H_{14}	Isohexane
2-238	Neon	Ne	
2-239	Nitrogen	N_2	
2-241	Nitrogen trifluoride	NF_3	
2-242	Nitrous oxide	N_2O	
2-243	Nonane	C_9H_{20}	
2-244	Octane	C_8H_{18}	
2-245	Oxygen	O_2	
2-246	Pentane	C_5H_{12}	
2-248	Propane	C_3H_8	
2-249	Propylene	C_3H_6	
2-250	R-11	CCl_3F	Trichlorofluoromethane
2-251	R-12	CCl_2F_2	Dichlorodifluoromethane
2-252	R-13	$CClF_3$	Chlorotrifluoromethane
2-255	R-22	$CHClF_2$	Chlorodifluoromethane
2-256	R-23	CHF_3	Trifluoromethane
2-257	R-32	CH_2F_2	Difluoromethane
2-258	R-41	CH_3F	Fluoromethane
2-271	R-113	$C_2Cl_3F_3$	1,1,2-Trichlorotrifluoroethane
2-272	R-114	$C_2Cl_2F_4$	1,2-Dichlorotetrafluoroethane
2-274	R-116	C_2F_6	Hexafluoroethane
2-275	R-123	C_2HF_5	2,2-Dichloro-1,1,1-trifluoroethane
2-276	R-124	C_2HClF_4	1-Chloro-1,2,2,2-tetrafluoroethane
2-277	R-125	C_2HF_5	Pentafluoroethane
2-278	R-134a	$C_2H_2F_4$	1,1,1,2-Tetrafluoroethane
2-279	R-141b	$C_2H_3Cl_2F$	1,1-Dichloro-1-fluoroethane
2-280	R-142b	$C_2H_3ClF_2$	1-Chloro-1,1-difluoroethane
2-281	R-143a	$C_2H_3F_3$	1,1,1-Trifluoroethane
2-282	R-152a	$C_2H_4F_2$	1,1-Difluoroethane
2-284	R-218	C_3F_8	Octafluoropropane
2-285	R227ea	C_3HF_7	1,1,1,2,3,3,3-Heptafluoropropane
2-288	R-404A		
2-289	R-407C		
2-290	R-410A		
2-296	R-507A		
2-300	Sulfur dioxide	SO_2	
2-301	Sulfur hexafluoride	SF_6	
2-303	Toluene	C_7H_8	
2-305	Water	H_2O	
2-307	Xenon	Xe	

TABLE 2-185 Thermodynamic Properties of Acetone

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
178.50	2.3265E-06	15.723	0.063601	0.47366	0.47366	0.0080825	0.082500	0.11544	1765.7	–0.43351
180.00	2.8743E-06	15.695	0.063715	0.64687	0.64687	0.0090488	0.082598	0.11550	1757.0	–0.43308
195.00	1.9454E-05	15.416	0.064868	2.3835	2.3835	0.018316	0.083407	0.11604	1672.3	–0.42849
210.00	9.6588E-05	15.141	0.066048	4.1282	4.1282	0.026935	0.084076	0.11660	1591.8	–0.42274
225.00	0.00037556	14.867	0.067264	5.8823	5.8823	0.035003	0.084758	0.11731	1514.4	–0.41520
240.00	0.0012008	14.593	0.068525	7.6487	7.6488	0.042602	0.085541	0.11825	1439.4	–0.40545
255.00	0.0032765	14.319	0.069840	9.4311	9.4314	0.049806	0.086468	0.11946	1366.3	–0.39322
270.00	0.0078514	14.041	0.071218	11.234	11.234	0.056674	0.087553	0.12094	1294.8	–0.37827
285.00	0.016899	13.760	0.072673	13.060	13.062	0.063259	0.088794	0.12270	1224.5	–0.36033
300.00	0.033259	13.474	0.074217	14.915	14.918	0.069601	0.090180	0.12474	1155.2	–0.33907
315.00	0.060720	13.181	0.075867	16.802	16.807	0.075739	0.091697	0.12704	1086.7	–0.31399
330.00	0.10404	12.880	0.077643	18.725	18.733	0.081702	0.093329	0.12962	1018.8	–0.28437
345.00	0.16891	12.568	0.079569	20.687	20.701	0.087517	0.095063	0.13249	951.24	–0.24915
360.00	0.26188	12.243	0.081677	22.693	22.714	0.093209	0.096886	0.13568	883.84	–0.20678
375.00	0.39033	11.904	0.084008	24.746	24.779	0.098798	0.098794	0.13924	816.36	–0.15495
390.00	0.56235	11.545	0.086616	26.852	26.900	0.10431	0.10078	0.14328	748.57	–0.090162
405.00	0.78681	11.163	0.089578	29.015	29.085	0.10975	0.10286	0.14794	680.21	–0.0069455
420.00	1.0733	10.753	0.093001	31.243	31.343	0.11516	0.10504	0.15350	610.99	0.10371
435.00	1.4324	10.304	0.097051	33.546	33.685	0.12056	0.10736	0.16042	540.51	0.25760
450.00	1.8759	9.8043	0.10200	35.938	36.130	0.12599	0.10986	0.16967	468.19	0.48516
465.00	2.4172	9.2319	0.10832	38.445	38.707	0.13150	0.11265	0.18350	392.99	0.85357
480.00	3.0725	8.5423	0.11706	41.117	41.476	0.13720	0.11600	0.20893	312.66	1.5474
495.00	3.8632	7.6072	0.13145	44.096	44.604	0.14341	0.12077	0.28551	221.66	3.3240
508.10	4.6924	4.7000	0.21277	49.249	50.247	0.15437			0	14.310
178.50	2.3265E-06	1.5677E-06	637,900.	36.689	38.173	0.21928	0.050120	0.058440	172.60	3845.4
180.00	2.8743E-06	1.9207E-06	520,660.	36.764	38.260	0.21801	0.050280	0.058600	173.29	3637.4
195.00	1.9454E-05	1.2001E-05	83,324.	37.528	39.149	0.20686	0.051928	0.060265	179.95	2139.7
210.00	9.6588E-05	5.5355E-05	18,065.	38.314	40.059	0.19803	0.053740	0.062119	186.29	1312.0
225.00	0.00037556	0.00020108	4,973.1	39.121	40.989	0.19103	0.055800	0.064267	192.29	834.10
240.00	0.0012008	0.00060385	1,656.0	39.947	41.936	0.18546	0.058169	0.066795	197.94	547.82
255.00	0.0032765	0.0015555	642.89	40.790	42.897	0.18104	0.060883	0.069763	203.19	370.79
270.00	0.0078514	0.0035368	282.74	41.649	43.869	0.17754	0.063945	0.073198	207.99	258.27
285.00	0.016899	0.0072603	137.74	42.522	44.849	0.17479	0.067329	0.077094	212.26	184.97
300.00	0.033259	0.013699	72.996	43.406	45.834	0.17266	0.070988	0.081429	215.93	136.14
315.00	0.060720	0.024107	41.482	44.302	46.821	0.17102	0.074863	0.086172	218.90	102.93
330.00	0.10404	0.040034	24.979	45.207	47.806	0.16980	0.078895	0.091302	221.08	79.878
345.00	0.16891	0.063362	15.782	46.119	48.784	0.16892	0.083030	0.096822	222.35	63.590
360.00	0.26188	0.096367	10.377	47.033	49.751	0.16831	0.087227	0.10277	222.60	51.884
375.00	0.39033	0.14184	7.0503	47.946	50.698	0.16791	0.091459	0.10927	221.70	43.343
390.00	0.56235	0.20329	4.9192	48.849	51.615	0.16768	0.095718	0.11649	219.53	37.032
405.00	0.78681	0.28530	3.5050	49.733	52.490	0.16754	0.10001	0.12481	215.94	32.325
420.00	1.0733	0.39420	2.5368	50.582	53.305	0.16745	0.10438	0.13483	210.76	28.797
435.00	1.4324	0.53918	1.8547	51.376	54.033	0.16734	0.10887	0.14772	203.80	26.154
450.00	1.8759	0.73472	1.3611	52.083	54.636	0.16711	0.11357	0.16583	194.82	24.184
465.00	2.4172	1.0061	0.99393	52.648	55.050	0.16664	0.11865	0.19480	183.50	22.717
480.00	3.0725	1.4051	0.71168	52.968	55.154	0.16569	0.12436	0.25197	169.39	21.551
495.00	3.8632	2.0767	0.48154	52.771	54.631	0.16367	0.13126	0.42947	151.36	20.240
508.10	4.6924	4.7000	0.21277	49.249	50.247	0.15437			0	14.310
Single-Phase Properties										
200.00	0.10000	15.325	0.065254	2.9626	2.9691	0.021248	0.083638	0.11621	1645.6	–0.42678
250.00	0.10000	14.411	0.069389	8.8328	8.8397	0.047436	0.086143	0.11902	1391.1	–0.39768
300.00	0.10000	13.475	0.074210	14.913	14.921	0.069594	0.090180	0.12473	1155.7	–0.33922
328.84	0.10000	12.903	0.077500	18.575	18.583	0.081247	0.093199	0.12941	1024.0	–0.28685
328.84	0.10000	0.038565	25.930	45.137	47.730	0.16988	0.078579	0.090892	220.94	81.384
350.00	0.10000	0.035712	28.002	46.843	49.643	0.17552	0.079533	0.090386	229.44	58.339
400.00	0.10000	0.030709	32.563	50.998	54.255	0.18783	0.085418	0.094849	246.85	30.192
450.00	0.10000	0.027083	36.923	55.474	59.166	0.19939	0.092823	0.10175	262.23	18.173
500.00	0.10000	0.024272	41.200	60.316	64.436	0.21049	0.10033	0.10903	276.40	12.201
550.00	0.10000	0.022008	45.437	65.522	70.066	0.22122	0.10753	0.11612	289.72	8.8355
200.00	1.0000	15.333	0.065220	2.9486	3.0138	0.021178	0.083649	0.11619	1649.7	–0.42708
250.00	1.0000	14.423	0.069336	8.8130	8.8824	0.047357	0.086152	0.11896	1396.0	–0.39848
300.00	1.0000	13.491	0.074123	14.885	14.959	0.069499	0.090182	0.12460	1162.0	–0.34115
350.00	1.0000	12.483	0.080107	21.312	21.392	0.089316	0.095644	0.13326	936.35	–0.24033
400.00	1.0000	11.308	0.088431	28.263	28.351	0.10788	0.10213	0.14605	707.25	–0.042437
416.48	1.0000	10.852	0.092149	30.714	30.806	0.11389	0.10452	0.15210	627.32	0.074613
416.48	1.0000	0.36582	2.7336	50.387	53.120	0.16747	0.10335	0.13228	212.13	29.536
450.00	1.0000	0.31254	3.1996	54.081	57.281	0.17709	0.10087	0.11921	233.76	20.211
500.00	1.0000	0.26538	3.7681	59.388	63.156	0.18947	0.10402	0.11743	256.99	12.984
550.00	1.0000	0.23391	4.2751	64.832	69.107	0.20081	0.10950	0.12100	275.55	9.1542

TABLE 2-185 Thermodynamic Properties of Acetone (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Single-Phase Properties										
200.00	5.0000	15.367	0.065073	2.8871	3.2125	0.020868	0.083704	0.11609	1667.9	–0.42837
250.00	5.0000	14.471	0.069106	8.7271	9.0726	0.047011	0.086197	0.11871	1417.7	–0.40187
300.00	5.0000	13.560	0.073747	14.762	15.130	0.069085	0.090197	0.12408	1189.0	–0.34909
350.00	5.0000	12.588	0.079439	21.128	21.525	0.088784	0.095584	0.13214	972.15	–0.25988
400.00	5.0000	11.490	0.087035	27.958	28.393	0.10711	0.10186	0.14320	759.27	–0.10136
450.00	5.0000	10.123	0.098782	35.450	35.944	0.12488	0.10898	0.16059	538.79	0.26123
500.00	5.0000	7.8139	0.12798	44.435	45.075	0.14406	0.11961	0.23343	262.33	2.3418
550.00	5.0000	1.7344	0.57657	60.563	63.446	0.17943	0.12191	0.17820	205.69	10.650
200.00	10.000	15.410	0.064894	2.8125	3.4614	0.020488	0.083781	0.11598	1689.9	–0.42983
250.00	10.000	14.528	0.068831	8.6237	9.3120	0.046589	0.086264	0.11843	1443.6	–0.40569
300.00	10.000	13.641	0.073307	14.616	15.349	0.068589	0.090234	0.12351	1220.9	–0.35775
350.00	10.000	12.709	0.078687	20.916	21.703	0.088163	0.095554	0.13100	1013.1	–0.27983
400.00	10.000	11.683	0.085592	27.629	28.485	0.10626	0.10166	0.14066	815.03	–0.15336
450.00	10.000	10.491	0.095320	34.864	35.818	0.12352	0.10827	0.15332	622.74	0.080235
500.00	10.000	8.9733	0.11144	42.815	43.930	0.14060	0.11552	0.17314	433.48	0.63674
550.00	10.000	6.6600	0.15015	52.079	53.581	0.15896	0.12442	0.22174	255.34	2.7218
250.00	100.00	15.320	0.065276	7.2620	13.790	0.040421	0.088285	0.11631	1791.8	–0.43634
300.00	100.00	14.657	0.068228	12.852	19.675	0.061873	0.092127	0.11946	1616.6	–0.42000
350.00	100.00	14.023	0.071312	18.631	25.763	0.080632	0.097243	0.12424	1466.4	–0.39555
400.00	100.00	13.409	0.074574	24.654	32.112	0.097579	0.10299	0.12980	1337.4	–0.36734
450.00	100.00	12.813	0.078044	30.941	38.745	0.11320	0.10892	0.13553	1226.9	–0.33807
500.00	100.00	12.234	0.081739	37.489	45.663	0.12777	0.11478	0.14112	1133.0	–0.30922
550.00	100.00	11.674	0.085664	44.286	52.852	0.14147	0.12045	0.14639	1053.8	–0.28171
450.00	500.00	15.616	0.064037	27.237	59.256	0.097266	0.11562	0.13393	2201.1	–0.39010
500.00	500.00	15.306	0.065335	33.413	66.081	0.11164	0.12123	0.13909	2129.8	–0.37710
550.00	500.00	15.012	0.066615	39.856	73.163	0.12514	0.12669	0.14416	2067.5	–0.36510

The values in this table were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data*, **51**(3):785–850, 2006. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in the equation of state are 0.1% in the saturated liquid density between 280 and 310 K, 0.5% in density in the liquid phase below 380 K, and 1% in density elsewhere, including all states at pressures above 100 MPa. The uncertainties in vapor pressure are 0.5% above 270 K (0.25% between 290 and 390 K), and the uncertainties in heat capacities and speeds of sound are 1%. These uncertainties (in caloric properties and sound speeds) may be higher at pressures above the saturation pressure and at temperatures above 320 K in the liquid phase and at supercritical conditions.

TABLE 2-186 Saturated Acetylene*

Temperature, K	Pressure, bar	v_{cond}, m^3/kg	v_g, m^3/kg	h_{cond}, kJ/kg	h_g, kJ/kg	s_{cond}, kJ/(kg·K)	s_g, kJ/(kg·K)
162.0	0.101		5.081	158	983	2.967	8.062
169.3	0.203		2.644	173	994	3.039	7.889
173.9	0.304		1.805	182	999	3.095	7.797
180.0	0.507		1.116	194	1007	3.161	7.672
184.3	0.709		0.810	203	1011	3.216	7.596
189.1	1.013		0.5780	214	1015	3.272	7.511
192.4[t]	1.283		0.4617	221	1018	3.312	7.455
192.4[t]	1.283	0.00164	0.4617	378	1018	4.127	7.455
200.9	2.027	0.00165	0.3011	411	1027	4.296	7.362
209.4	3.040	0.00169	0.2074	445	1035	4.461	7.280
221.5	5.066	0.00174	0.1264	493	1046	4.684	7.180
230.4	7.093	0.00179	0.0907	528	1052	4.837	7.111
240.7	10.13	0.00186	0.0635	565	1058	4.990	7.037
253.2	15.20	0.00195	0.0420	602	1061	5.133	6.947
263.0	20.27	0.00204	0.0309	628	1061	5.231	6.878
271.6	25.33	0.00213	0.0240	654	1060	5.326	6.822
278.9	30.40	0.00223	0.0193	680	1057	5.414	6.767
284.9	35.46	0.00232	0.0159	704	1051	5.494	6.716
290.4	40.53	0.00242	0.0133	727	1041	5.576	6.658
300.0	50.66	0.00270	0.0093	778	1017	5.737	6.534
307.8	60.80	0.00335	0.0061	850	968	5.965	6.351
308.7[c]	62.47	0.00434	0.0043	908	908	6.158	6.158

*Values recalculated into SI units from those of Din. *Thermodynamic Functions of Gases*, vol. 2, Butterworth, London, 1956. Above the solid line the condensed phase is solid; below the line it is liquid. t = triple point; c = critical point.

TABLE 2-187 Thermodynamic Properties of Air

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
59.75	0.005265	33.067	0.030242	−1.0619	−1.0617	−0.01536	0.034011	0.055064	1030.3	−0.40785	171.43	376.64
60	0.005546	33.031	0.030275	−1.0481	−1.0480	−0.01513	0.033955	0.055062	1028.3	−0.40743	171.02	371.92
61	0.006797	32.888	0.030406	−0.99308	−0.99287	−0.01422	0.033731	0.055060	1020.3	−0.40565	169.40	353.83
62	0.008270	32.745	0.030539	−0.93803	−0.93778	−0.01333	0.033512	0.055062	1012.2	−0.40375	167.78	336.91
63	0.009994	32.601	0.030674	−0.88298	−0.88267	−0.01245	0.033298	0.055069	1004.0	−0.40173	166.16	321.09
64	0.012000	32.457	0.030810	−0.82792	−0.82755	−0.01158	0.033089	0.055081	995.77	−0.39958	164.53	306.27
65	0.014320	32.312	0.030949	−0.77286	−0.77241	−0.01073	0.032884	0.055098	987.48	−0.39729	162.91	292.39
66	0.016988	32.166	0.031089	−0.71777	−0.71725	−0.00989	0.032683	0.055120	979.13	−0.39485	161.28	279.38
67	0.020042	32.020	0.031231	−0.66267	−0.66205	−0.00906	0.032486	0.055148	970.72	−0.39227	159.65	267.17
68	0.023520	31.873	0.031375	−0.60755	−0.60681	−0.00824	0.032294	0.055181	962.24	−0.38952	158.01	255.71
69	0.027461	31.725	0.031521	−0.55239	−0.55152	−0.00744	0.032105	0.055220	953.70	−0.38660	156.37	244.94
70	0.031908	31.576	0.031669	−0.49720	−0.49619	−0.00664	0.031920	0.055266	945.10	−0.38352	154.73	234.81
71	0.036905	31.427	0.031820	−0.44196	−0.44079	−0.00586	0.031739	0.055317	936.43	−0.38024	153.09	225.28
72	0.042498	31.277	0.031972	−0.38669	−0.38533	−0.00508	0.031562	0.055376	927.70	−0.37677	151.44	216.31
73	0.048733	31.126	0.032127	−0.33135	−0.32979	−0.00432	0.031388	0.055441	918.90	−0.37310	149.79	207.85
74	0.055659	30.974	0.032285	−0.27597	−0.27417	−0.00357	0.031217	0.055514	910.04	−0.36922	148.14	199.88
75	0.063326	30.821	0.032445	−0.22051	−0.21846	−0.00282	0.031050	0.055594	901.11	−0.36511	146.49	192.35
76	0.071786	30.668	0.032608	−0.16499	−0.16265	−0.00209	0.030886	0.055682	892.11	−0.36076	144.83	185.23
77	0.081091	30.513	0.032773	−0.10939	−0.10673	−0.00136	0.030725	0.055779	883.05	−0.35616	143.16	178.51
78	0.091294	30.357	0.032941	−0.05371	−0.05070	−0.00064	0.030568	0.055884	873.91	−0.35130	141.50	172.14
79	0.10245	30.200	0.033112	0.002063	0.005456	6.86E-05	0.030413	0.055998	864.71	−0.34616	139.83	166.11
80	0.11462	30.042	0.033287	0.057934	0.061749	0.000772	0.030262	0.056122	855.44	−0.34074	138.15	160.39
81	0.12785	29.883	0.033464	0.11391	0.11819	0.001467	0.030113	0.056256	846.09	−0.33500	136.48	154.96
82	0.14221	29.722	0.033645	0.17000	0.17478	0.002156	0.029968	0.056400	836.67	−0.32894	134.80	149.80
83	0.15775	29.560	0.033829	0.22621	0.23155	0.002838	0.029826	0.056556	827.18	−0.32254	133.11	144.90
84	0.17453	29.397	0.034017	0.28255	0.28849	0.003513	0.029686	0.056723	817.61	−0.31577	131.42	140.23
85	0.19262	29.232	0.034209	0.33903	0.34562	0.004181	0.029550	0.056902	807.96	−0.30862	129.78	135.78
86	0.21207	29.066	0.034404	0.39566	0.40296	0.004844	0.029417	0.057094	798.24	−0.30107	128.11	131.54
87	0.23295	28.898	0.034604	0.45245	0.46051	0.005501	0.029286	0.057300	788.44	−0.29308	126.44	127.50
88	0.25531	28.729	0.034808	0.50940	0.51829	0.006153	0.029158	0.057521	778.56	−0.28464	124.76	123.63
89	0.27922	28.558	0.035017	0.56653	0.57631	0.006799	0.029033	0.057757	768.59	−0.27572	123.07	119.93
90	0.30475	28.385	0.035230	0.62386	0.63459	0.007440	0.028911	0.058009	758.55	−0.26628	121.38	116.38
91	0.33196	28.210	0.035449	0.68138	0.69315	0.008077	0.028792	0.058278	748.42	−0.25629	119.69	112.98
92	0.36091	28.033	0.035672	0.73912	0.75199	0.008708	0.028676	0.058566	738.20	−0.24573	118.00	109.72
93	0.39166	27.854	0.035901	0.79709	0.81115	0.009336	0.028563	0.058874	727.90	−0.23455	116.30	106.59
94	0.42429	27.673	0.036137	0.85529	0.87062	0.009960	0.028453	0.059202	717.51	−0.22270	114.61	103.58
95	0.45886	27.489	0.036378	0.91375	0.93044	0.010579	0.028346	0.059553	707.03	−0.21016	112.91	100.68
96	0.49543	27.304	0.036625	0.97248	0.99063	0.011195	0.028241	0.059928	696.46	−0.19686	111.21	97.879
97	0.53408	27.115	0.036880	1.0315	1.0512	0.011808	0.028140	0.060329	685.80	−0.18275	109.51	95.179
98	0.57486	26.924	0.037142	1.0908	1.1122	0.012418	0.028042	0.060757	675.05	−0.16779	107.81	92.571
99	0.61786	26.730	0.037411	1.1505	1.1736	0.013025	0.027948	0.061216	664.20	−0.15189	106.11	90.048
100	0.66313	26.533	0.037688	1.2104	1.2354	0.013630	0.027856	0.061707	653.26	−0.13501	104.41	87.605
101	0.71074	26.333	0.037975	1.2708	1.2978	0.014232	0.027768	0.062232	642.22	−0.11705	102.71	85.236
102	0.76077	26.130	0.038270	1.3315	1.3606	0.014833	0.027684	0.062796	631.08	−0.09794	101.01	82.937
103	0.81329	25.923	0.038575	1.3926	1.4240	0.015431	0.027603	0.063401	619.84	−0.07758	99.316	80.703
104	0.86836	25.713	0.038891	1.4542	1.4880	0.016029	0.027525	0.064052	608.50	−0.05588	97.623	78.529
105	0.92606	25.499	0.039217	1.5162	1.5525	0.016625	0.027452	0.064753	597.06	−0.03271	95.933	76.412
106	0.98645	25.281	0.039556	1.5787	1.6177	0.017221	0.027383	0.065508	585.51	−0.00795	94.247	74.347
107	1.0496	25.058	0.039908	1.6417	1.6836	0.017816	0.027317	0.066323	573.85	0.018543	92.565	72.331
108	1.1156	24.831	0.040273	1.7053	1.7502	0.018411	0.027256	0.067206	562.09	0.046927	90.888	70.361
109	1.1845	24.598	0.040653	1.7695	1.8176	0.019006	0.027200	0.068163	550.21	0.077386	89.216	68.432
110	1.2564	24.361	0.041050	1.8343	1.8858	0.019602	0.027149	0.069205	538.21	0.11012	87.551	66.542
111	1.3314	24.118	0.041464	1.8997	1.9549	0.020200	0.027103	0.070341	526.10	0.14538	85.893	64.688
112	1.4095	23.868	0.041896	1.9659	2.0250	0.020799	0.027062	0.071585	513.86	0.18342	84.242	62.867
113	1.4908	23.613	0.042350	2.0329	2.0960	0.021400	0.027028	0.072951	501.48	0.22456	82.599	61.075
114	1.5753	23.350	0.042826	2.1007	2.1682	0.022004	0.027000	0.074459	488.97	0.26917	80.965	59.311

TABLE 2-187 Thermodynamic Properties of Air (*Continued*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	Cp kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
115	1.6633	23.080	0.043328	2.1695	2.2415	0.022611	0.026979	0.076131	476.31	0.31767	79.340	57.571
116	1.7546	22.801	0.043857	2.2392	2.3161	0.023223	0.026965	0.077996	463.48	0.37057	77.724	55.852
117	1.8495	22.514	0.044417	2.3100	2.3922	0.023840	0.026961	0.080090	450.49	0.42848	76.119	54.152
118	1.9479	22.217	0.045011	2.3821	2.4697	0.024462	0.026966	0.082459	437.29	0.49214	74.523	52.467
119	2.0499	21.908	0.045645	2.4554	2.5490	0.025092	0.026982	0.085163	423.88	0.56243	72.938	50.794
120	2.1557	21.588	0.046323	2.5303	2.6302	0.025731	0.027010	0.088280	410.23	0.64047	71.363	49.130
121	2.2653	21.253	0.047052	2.6069	2.7135	0.026380	0.027053	0.091919	396.30	0.72765	69.798	47.469
122	2.3787	20.903	0.047841	2.6854	2.7992	0.027041	0.027113	0.096227	382.04	0.82574	68.243	45.809
123	2.4960	20.534	0.048700	2.7662	2.8878	0.027717	0.027194	0.10142	367.40	0.93703	66.700	44.141
124	2.6173	20.144	0.049643	2.8496	2.9796	0.028412	0.027300	0.10781	352.31	1.0646	65.170	42.460
125	2.7427	19.727	0.050691	2.9363	3.0753	0.029131	0.027438	0.11589	336.67	1.2125	63.658	40.755
126	2.8721	19.278	0.051871	3.0269	3.1759	0.029880	0.027618	0.12645	320.36	1.3865	62.176	39.013
127	3.0055	18.788	0.053225	3.1227	3.2827	0.030668	0.027855	0.14089	303.21	1.5951	60.751	37.215
128	3.1431	18.242	0.054818	3.2253	3.3976	0.031512	0.028171	0.16186	285.00	1.8510	59.445	35.332
129	3.2845	17.616	0.056765	3.3379	3.5243	0.032436	0.028607	0.19519	265.37	2.1752	58.409	33.316
130	3.4295	16.863	0.059300	3.4661	3.6695	0.033492	0.029242	0.25624	243.75	2.6058	58.054	31.072
131	3.5770	15.869	0.063015	3.6243	3.8497	0.034804	0.030266	0.40151	219.07	3.2246	59.591	28.384
132	3.7228	14.198	0.070432	3.8680	4.1302	0.036863	0.032343	1.0148	189.12	4.2808	67.802	24.467
132.63	3.7858	10.448	0.095715	4.4004	4.7627	0.041603			0	6.3978		
59.75	0.002432	0.004907	203.80	4.8774	5.3730	0.096708	0.020805	0.029217	154.83	58.283	5.2938	4.2197
60	0.002584	0.005192	192.59	4.8825	5.3800	0.096323	0.020809	0.029225	155.14	57.634	5.3199	4.2382
61	0.003274	0.006475	154.45	4.9025	5.4081	0.094825	0.020825	0.029261	156.38	55.151	5.4244	4.3119
62	0.004111	0.008005	124.93	4.9225	5.4361	0.093392	0.020843	0.029302	157.60	52.832	5.5291	4.3855
63	0.005120	0.009817	101.86	4.9424	5.4639	0.092020	0.020864	0.029348	158.81	50.666	5.6340	4.4590
64	0.006325	0.011948	83.693	4.9621	5.4915	0.090705	0.020886	0.029399	159.99	48.640	5.7391	4.5324
65	0.007756	0.014438	69.263	4.9817	5.5189	0.089445	0.020911	0.029455	161.16	46.742	5.8444	4.6057
66	0.009442	0.017326	57.715	5.0012	5.5461	0.088235	0.020938	0.029518	162.30	44.963	5.9500	4.6788
67	0.011416	0.020659	48.406	5.0205	5.5731	0.087074	0.020968	0.029587	163.42	43.293	6.0559	4.7519
68	0.013713	0.024481	40.849	5.0397	5.5998	0.085959	0.021000	0.029663	164.53	41.724	6.1621	4.8248
69	0.016372	0.028841	34.673	5.0587	5.6263	0.084887	0.021035	0.029746	165.60	40.248	6.2688	4.8976
70	0.019431	0.033789	29.595	5.0774	5.6525	0.083855	0.021072	0.029836	166.66	38.858	6.3759	4.9703
71	0.022933	0.039379	25.394	5.0960	5.6784	0.082862	0.021113	0.029934	167.69	37.548	6.4835	5.0429
72	0.026921	0.045664	21.899	5.1144	5.7040	0.081906	0.021156	0.030040	168.70	36.313	6.5917	5.1154
73	0.031443	0.052702	18.975	5.1326	5.7292	0.080983	0.021201	0.030155	169.69	35.146	6.7005	5.1878
74	0.036547	0.060550	16.515	5.1505	5.7541	0.080094	0.021250	0.030278	170.65	34.043	6.8099	5.2602
75	0.042282	0.069268	14.437	5.1682	5.7786	0.079235	0.021302	0.030410	171.58	32.999	6.9202	5.3325
76	0.048702	0.078918	12.671	5.1856	5.8027	0.078406	0.021356	0.030552	172.49	32.010	7.0312	5.4048
77	0.055859	0.089564	11.165	5.2028	5.8264	0.077604	0.021414	0.030703	173.37	31.072	7.1431	5.4771
78	0.063810	0.10127	9.8746	5.2196	5.8497	0.076828	0.021474	0.030865	174.23	30.183	7.2560	5.5494
79	0.072611	0.11410	8.7639	5.2362	5.8726	0.076076	0.021538	0.031037	175.05	29.337	7.3700	5.6217
80	0.082321	0.12813	7.8043	5.2525	5.8949	0.075348	0.021605	0.031220	175.85	28.534	7.4851	5.6940
81	0.093001	0.14343	6.9721	5.2684	5.9169	0.074643	0.021674	0.031415	176.62	27.769	7.6014	5.7664
82	0.10471	0.16006	6.2475	5.2841	5.9383	0.073957	0.021747	0.031621	177.36	27.041	7.7192	5.8389
83	0.11751	0.17811	5.6145	5.2994	5.9591	0.073292	0.021822	0.031840	178.07	26.346	7.8384	5.9116
84	0.13147	0.19765	5.0595	5.3143	5.9795	0.072645	0.021901	0.032072	178.75	25.684	7.9591	5.9844
85	0.14665	0.21875	4.5715	5.3289	5.9993	0.072016	0.021983	0.032317	179.40	25.051	8.0817	6.0574
86	0.16312	0.24150	4.1408	5.3431	6.0185	0.071403	0.022068	0.032577	180.02	24.447	8.2060	6.1307
87	0.18094	0.26598	3.7597	5.3569	6.0372	0.070806	0.022155	0.032851	180.61	23.869	8.3324	6.2043
88	0.20018	0.29228	3.4214	5.3703	6.0552	0.070224	0.022246	0.033141	181.17	23.316	8.4610	6.2781
89	0.22091	0.32048	3.1203	5.3832	6.0726	0.069655	0.022340	0.033447	181.69	22.786	8.5919	6.3524
90	0.24320	0.35068	2.8516	5.3958	6.0893	0.069099	0.022436	0.033770	182.19	22.278	8.7254	6.4272
91	0.26712	0.38298	2.6111	5.4079	6.1054	0.068556	0.022536	0.034111	182.65	21.791	8.8616	6.5024
92	0.29273	0.41747	2.3954	5.4195	6.1207	0.068024	0.022638	0.034472	183.08	21.324	9.0008	6.5782
93	0.32011	0.45426	2.2014	5.4307	6.1354	0.067503	0.022744	0.034853	183.47	20.876	9.1433	6.6547
94	0.34934	0.49345	2.0265	5.4413	6.1492	0.066991	0.022852	0.035256	183.84	20.445	9.2893	6.7318
95	0.38047	0.53517	1.8686	5.4514	6.1624	0.066489	0.022964	0.035681	184.17	20.031	9.4390	6.8098
96	0.41359	0.57953	1.7255	5.4610	6.1747	0.065995	0.023078	0.036132	184.46	19.632	9.5929	6.8887

97	0.44878	0.62667	1.5957	5.4701	6.1862	0.065510	0.023196	0.036610	184.72	19.249	9.7513	6.9686
98	0.48609	0.67671	1.4777	5.4785	6.1968	0.065031	0.023317	0.037116	184.95	18.879	9.9145	7.0495
99	0.52562	0.72980	1.3702	5.4864	6.2066	0.064560	0.023441	0.037654	185.14	18.523	10.083	7.1317
100	0.56742	0.78609	1.2721	5.4936	6.2154	0.064094	0.023568	0.038225	185.30	18.180	10.257	7.2153
101	0.61159	0.84575	1.1824	5.5002	6.2233	0.063633	0.023698	0.038834	185.42	17.848	10.438	7.3003
102	0.65820	0.90895	1.1002	5.5060	6.2302	0.063177	0.023833	0.039483	185.51	17.528	10.626	7.3870
103	0.70732	0.97587	1.0247	5.5112	6.2360	0.062726	0.023970	0.040176	185.55	17.218	10.821	7.4755
104	0.75903	1.0467	0.95535	5.5156	6.2408	0.062277	0.024112	0.040918	185.57	16.918	11.024	7.5659
105	0.81341	1.1217	0.89147	5.5193	6.2444	0.061832	0.024258	0.041714	185.54	16.628	11.237	7.6586
106	0.87055	1.2011	0.83254	5.5221	6.2469	0.061389	0.024408	0.042570	185.48	16.346	11.459	7.7537
107	0.93052	1.2852	0.77810	5.5240	6.2481	0.060947	0.024563	0.043492	185.38	16.072	11.693	7.8514
108	0.9934	1.3742	0.72772	5.5250	6.2480	0.060506	0.024722	0.044490	185.24	15.805	11.939	7.9521
109	1.0593	1.4684	0.68102	5.5251	6.2465	0.060065	0.024887	0.045573	185.07	15.546	12.198	8.0560
110	1.1282	1.5682	0.63767	5.5241	6.2436	0.059623	0.025058	0.046751	184.85	15.292	12.473	8.1634
111	1.2004	1.6740	0.59737	5.5221	6.2391	0.059180	0.025234	0.048038	184.60	15.044	12.764	8.2749
112	1.2757	1.7862	0.55985	5.5188	6.2330	0.058735	0.025418	0.049450	184.30	14.800	13.074	8.3907
113	1.3545	1.9053	0.52486	5.5143	6.2252	0.058286	0.025608	0.051005	183.97	14.561	13.406	8.5114
114	1.4366	2.0318	0.49217	5.5085	6.2156	0.057833	0.025807	0.052727	183.59	14.324	13.762	8.6375
115	1.5223	2.1664	0.46160	5.5012	6.2039	0.057375	0.026015	0.054644	183.17	14.090	14.145	8.7696
116	1.6115	2.3097	0.43296	5.4924	6.1901	0.056910	0.026232	0.056790	182.71	13.856	14.559	8.9086
117	1.7045	2.4625	0.40608	5.4819	6.1740	0.056437	0.026461	0.059209	182.21	13.623	15.008	9.0552
118	1.8013	2.6259	0.38082	5.4695	6.1554	0.055955	0.026701	0.061956	181.66	13.388	15.499	9.2104
119	1.9020	2.8009	0.35702	5.4550	6.1341	0.055461	0.026956	0.065102	181.08	13.151	16.039	9.3755
120	2.0067	2.9889	0.33457	5.4383	6.1097	0.054954	0.027226	0.068738	180.45	12.909	16.635	9.5518
121	2.1156	3.1913	0.31335	5.4190	6.0819	0.054432	0.027514	0.072988	179.78	12.661	17.298	9.7412
122	2.2287	3.4103	0.29323	5.3969	6.0504	0.053890	0.027823	0.078015	179.06	12.405	18.042	9.9456
123	2.3462	3.6481	0.27412	5.3715	6.0147	0.053326	0.028155	0.084052	178.31	12.137	18.884	10.168
124	2.4682	3.9078	0.25590	5.3424	5.9740	0.052735	0.028516	0.091426	177.51	11.854	19.849	10.411
125	2.5949	4.1934	0.23847	5.3089	5.9277	0.052112	0.028910	0.10063	176.68	11.553	20.968	10.681
126	2.7266	4.5101	0.22173	5.2701	5.8746	0.051448	0.029344	0.11241	175.81	11.229	22.288	10.982
127	2.8633	4.8653	0.20554	5.2248	5.8133	0.050732	0.029827	0.12801	174.91	10.874	23.877	11.324
128	3.0055	5.2697	0.18976	5.1713	5.7417	0.049950	0.030371	0.14959	173.96	10.480	25.841	11.720
129	3.1536	5.7405	0.17420	5.1069	5.6563	0.049076	0.030994	0.18134	172.98	10.033	28.367	12.191
130	3.3084	6.3074	0.15854	5.0268	5.5513	0.048067	0.031726	0.23261	171.93	9.5119	31.807	12.775
131	3.4712	7.0343	0.14216	4.9209	5.4143	0.046830	0.032619	0.32992	170.79	8.8740	37.001	13.553
132	3.6462	8.1273	0.12304	4.7566	5.2053	0.045064	0.033814	0.59804	169.40	7.9854	46.996	14.798
132.63	3.7858	10.448	0.095715	4.4004	4.7627	0.041603			0	6.3978		

Single-Phase Properties

100	0.1	0.12283	8.1414	5.6800	6.4941	0.080463	0.021087	0.030116	198.24	17.423	9.4692	7.1068
300	0.1	0.040103	24.936	9.8544	12.348	0.11269	0.020796	0.029149	347.36	2.2510	26.384	18.537
500	0.1	0.024046	41.586	14.072	18.231	0.12770	0.021504	0.029830	446.40	0.50305	39.944	27.090
700	0.1	0.017175	58.223	18.500	24.323	0.13794	0.022817	0.031137	523.89	–0.12430	51.755	34.176
900	0.1	0.013359	74.855	23.201	30.686	0.14593	0.024150	0.032467	589.60	–0.41124	62.543	40.394
1100	0.1	0.010931	91.486	28.145	37.293	0.15255	0.025246	0.033562	648.15	–0.56194	72.680	46.051
1300	0.1	0.009249	108.12	33.282	44.094	0.15823	0.026091	0.034406	701.76	–0.64963	82.381	51.325
1500	0.1	0.008016	124.75	38.568	51.042	0.16320	0.026734	0.035049	751.59	–0.70457	91.781	56.325
1700	0.1	0.007073	141.38	43.966	58.104	0.16762	0.027229	0.035544	798.38	–0.74078	100.97	61.127
1900	0.1	0.006329	158.00	49.453	65.253	0.17160	0.027619	0.035934	842.62	–0.76547	110.01	65.783
100	1	26.593	0.037604	1.2007	1.2383	0.013532	0.027868	0.061355	658.25	–0.14308	104.97	88.326
106.22	1	25.232	0.039632	1.5924	1.6321	0.017351	0.027368	0.065680	582.97	–0.00232	93.879	73.903
108.1	1	1.3836	0.72278	5.5251	6.2479	0.060461	0.024739	0.044597	185.23	15.779	11.965	7.9625
300	1	0.40205	2.4873	9.8022	12.289	0.093372	0.020859	0.029563	348.45	2.1789	26.684	18.672
500	1	0.23974	4.1711	14.046	18.218	0.10851	0.021526	0.029954	448.46	0.47425	40.110	27.179
700	1	0.17119	5.8415	18.485	24.326	0.11877	0.022830	0.031194	525.96	–0.13809	51.868	34.242
900	1	0.13319	7.5079	23.190	30.698	0.12677	0.024159	0.032498	591.54	–0.41899	62.628	40.446
1100	1	0.10902	9.1727	28.138	37.311	0.13340	0.025253	0.033582	649.96	–0.56686	72.748	46.094
1300	1	0.092279	10.837	33.278	44.114	0.13908	0.026096	0.034419	703.44	–0.65304	82.438	51.361
1500	1	0.079999	12.500	38.565	51.065	0.14405	0.026738	0.035057	753.17	–0.70711	91.830	56.357
1700	1	0.070604	14.163	43.964	58.128	0.14847	0.027233	0.035550	799.86	–0.74278	101.01	61.155
1900	1	0.063185	15.827	49.451	65.278	0.15245	0.027622	0.035939	844.02	–0.76711	110.05	65.808
100	5	27.222	0.036735	1.0983	1.2820	0.012483	0.028034	0.058181	710.56	–0.21837	111.13	96.436
300	5	2.0232	0.49426	9.5710	12.042	0.079244	0.021131	0.031423	355.63	1.8817	28.389	19.420

TABLE 2-187 Thermodynamic Properties of Air (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	Cp kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Single Phase Properties												
500	5	1.1814	0.84642	13.935	18.167	0.094907	0.021621	0.030478	458.30	0.36370	40.969	27.606
700	5	0.84321	1.1859	18.417	24.347	0.10529	0.022885	0.031434	535.45	–0.19118	52.433	34.545
900	5	0.65711	1.5218	23.146	30.755	0.11334	0.024197	0.032632	600.34	–0.44905	63.045	40.682
1100	5	0.53874	1.8562	28.107	37.388	0.11999	0.025282	0.033664	658.10	–0.58606	73.076	46.287
1300	5	0.45667	2.1898	33.256	44.205	0.12568	0.026119	0.034473	711.01	–0.66646	82.707	51.523
1500	5	0.39636	2.5229	38.550	51.165	0.13066	0.026757	0.035095	760.23	–0.71716	92.057	56.497
1700	5	0.35015	2.8559	43.954	58.234	0.13509	0.027249	0.035577	806.49	–0.75073	101.21	61.278
1900	5	0.31361	3.1887	49.445	65.389	0.13907	0.027636	0.035958	850.28	–0.77366	110.22	65.917
100	10	27.863	0.035889	0.99444	1.3533	0.011382	0.028284	0.055716	763.47	–0.27969	117.77	105.78
300	10	4.0370	0.24771	9.2885	11.766	0.072612	0.021441	0.033664	369.50	1.5212	31.116	20.637
500	10	2.3157	0.43183	13.802	18.120	0.088894	0.021733	0.031078	471.81	0.25100	42.260	28.194
700	10	1.6542	0.60452	18.336	24.382	0.099422	0.022952	0.031710	547.83	–0.24405	53.257	34.944
900	10	1.2922	0.77388	23.092	30.831	0.10752	0.024243	0.032786	611.64	–0.47890	63.641	40.985
1100	10	1.0618	0.94184	28.070	37.489	0.11420	0.025317	0.033760	668.47	–0.60517	73.538	46.531
1300	10	0.90165	1.1091	33.231	44.321	0.11990	0.026146	0.034537	720.60	–0.67990	83.082	51.728
1500	10	0.78374	1.2759	38.532	51.292	0.12489	0.026780	0.035139	769.17	–0.72730	92.372	56.673
1700	10	0.69321	1.4426	43.943	58.368	0.12932	0.027268	0.035608	814.87	–0.75881	101.48	61.432
1900	10	0.62149	1.6090	49.438	65.528	0.13330	0.027653	0.035981	858.18	–0.78039	110.45	66.054
100	100	33.161	0.030156	0.24746	3.2631	0.001378	0.031980	0.048218	1192.4	–0.47290	179.20	252.46
300	100	21.138	0.047309	7.0356	11.767	0.049067	0.023981	0.038366	818.47	–0.49747	86.312	53.642
500	100	15.089	0.066273	12.371	18.999	0.067619	0.023117	0.034686	772.41	–0.55640	71.549	42.159
700	100	11.803	0.084722	17.367	25.840	0.079134	0.023855	0.034011	790.14	–0.62591	73.572	43.339
900	100	9.7481	0.10258	22.408	32.667	0.087711	0.024903	0.034331	821.78	–0.67702	79.057	46.948
1100	100	8.3307	0.12004	27.580	39.584	0.09465	0.025831	0.034845	857.40	–0.71435	85.797	51.158
1300	100	7.2877	0.13722	32.880	46.602	0.10051	0.026565	0.035323	894.00	–0.74281	93.151	55.511
1500	100	6.4847	0.15421	38.287	53.708	0.10559	0.027131	0.035723	930.40	–0.76506	100.84	59.875
1700	100	5.8456	0.17107	43.779	60.886	0.11009	0.027569	0.036049	966.13	–0.78264	108.75	64.208
1900	100	5.3239	0.18783	49.340	68.123	0.11411	0.027915	0.036317	1001.0	–0.79653	116.78	68.504
300	500	34.106	0.029320	6.2145	20.875	0.033155	0.028875	0.039265	1678.8	–0.57656	208.23	181.12
500	500	29.826	0.033528	11.583	28.348	0.052311	0.026614	0.036111	1573.6	–0.65015	178.50	120.62
700	500	26.714	0.037433	16.768	35.484	0.064323	0.026496	0.035494	1514.8	–0.67879	161.67	97.470
900	500	24.283	0.041180	22.008	42.598	0.073261	0.026991	0.035702	1482.8	–0.68796	151.95	86.531
1100	500	22.305	0.044833	27.358	49.775	0.080460	0.027539	0.036073	1468.3	–0.69130	146.88	81.387
1300	500	20.651	0.048423	32.814	57.025	0.086515	0.028000	0.036415	1465.1	–0.69354	144.95	79.411
1500	500	19.243	0.051966	38.354	64.337	0.091746	0.02836	0.036693	1469.3	–0.69594	145.84	79.312
1700	500	18.027	0.055473	43.961	71.698	0.096353	0.02864	0.036911	1478.5	–0.69875	148.48	80.393
1900	500	16.963	0.058952	49.623	79.098	0.10047	0.02886	0.037085	1491.1	–0.70188	152.39	82.251
300	1000	40.130	0.024919	6.8286	31.747	0.024761	0.032271	0.041510	2208.5	–0.50493	274.96	337.76
500	1000	36.567	0.027347	12.271	39.618	0.044944	0.029334	0.037843	2104.7	–0.57316	247.30	219.41
700	1000	33.895	0.029503	17.554	47.057	0.057468	0.028754	0.036801	2033.9	–0.60504	230.60	174.51
900	1000	31.736	0.031510	22.890	54.399	0.066695	0.028917	0.036702	1984.7	–0.61882	219.72	149.43
1100	1000	29.916	0.033427	28.327	61.754	0.074073	0.029215	0.036858	1951.3	–0.62560	212.46	133.76
1300	1000	28.338	0.035288	33.857	69.145	0.080246	0.029476	0.037051	1929.3	–0.62968	207.70	123.58
1500	1000	26.946	0.037111	39.461	76.573	0.085561	0.029675	0.037224	1915.7	–0.63251	204.81	116.94
1700	1000	25.701	0.038909	45.123	84.032	0.090229	0.029821	0.037369	1908.3	–0.63465	203.41	112.74
1900	1000	24.577	0.040688	50.830	91.519	0.094392	0.029928	0.037491	1905.8	–0.63632	203.25	110.27

This table was generated for a standard three-component dry air containing mole fractions 0.7812 nitrogen, 0.2096 oxygen, and 0.0092 argon. The values in this table were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., Jacobsen, R. T, Penoncello, S. G., and Friend, D. G., "Thermodynamic Properties of Air and Mixtures of Nitrogen, Argon, and Oxygen from 60 to 2000 K at Pressures to 2000 MPa," *J. Phys. Chem. Ref. Data* **29**(3):331–385, 2000. The source for viscosity and thermal conductivity is Lemmon, E. W., and Jacobsen, R. T., "Viscosity and Thermal Conductivity Equations for Nitrogen, Oxygen, Argon, and Air," *Int. J. Thermophys.* **25:**21–69, 2004.

Properties at the freezing point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

In the range from the solidification point to 873 K at pressures to 70 MPa, the estimated uncertainty of density values calculated with the equation of state is 0.1%. The estimated uncertainty of calculated speed of sound values is 0.2% and that for calculated heat capacities is 1%. At temperatures above 873 K and 70 MPa, the estimated uncertainty of calculated density values is 0.5%, increasing to 1.0% at 2000 K and 2000 MPa. For viscosity, the uncertainty is 1% in the dilute gas. The uncertainty is around 2% between 270 and 300 K and increases to 5% outside of this region. There are very few measurements between 130 and 270 K for air to validate this claim, and the uncertainties may be even higher in this supercritical region. For thermal conductivity, the uncertainty for the dilute gas is 2% with increasing uncertainties near the triple points. The uncertainties range from 3% between 140 and 300 K to 5% at the triple point and at high temperatures. The uncertainties above 100 MPa are not known due to a lack of experimental data.

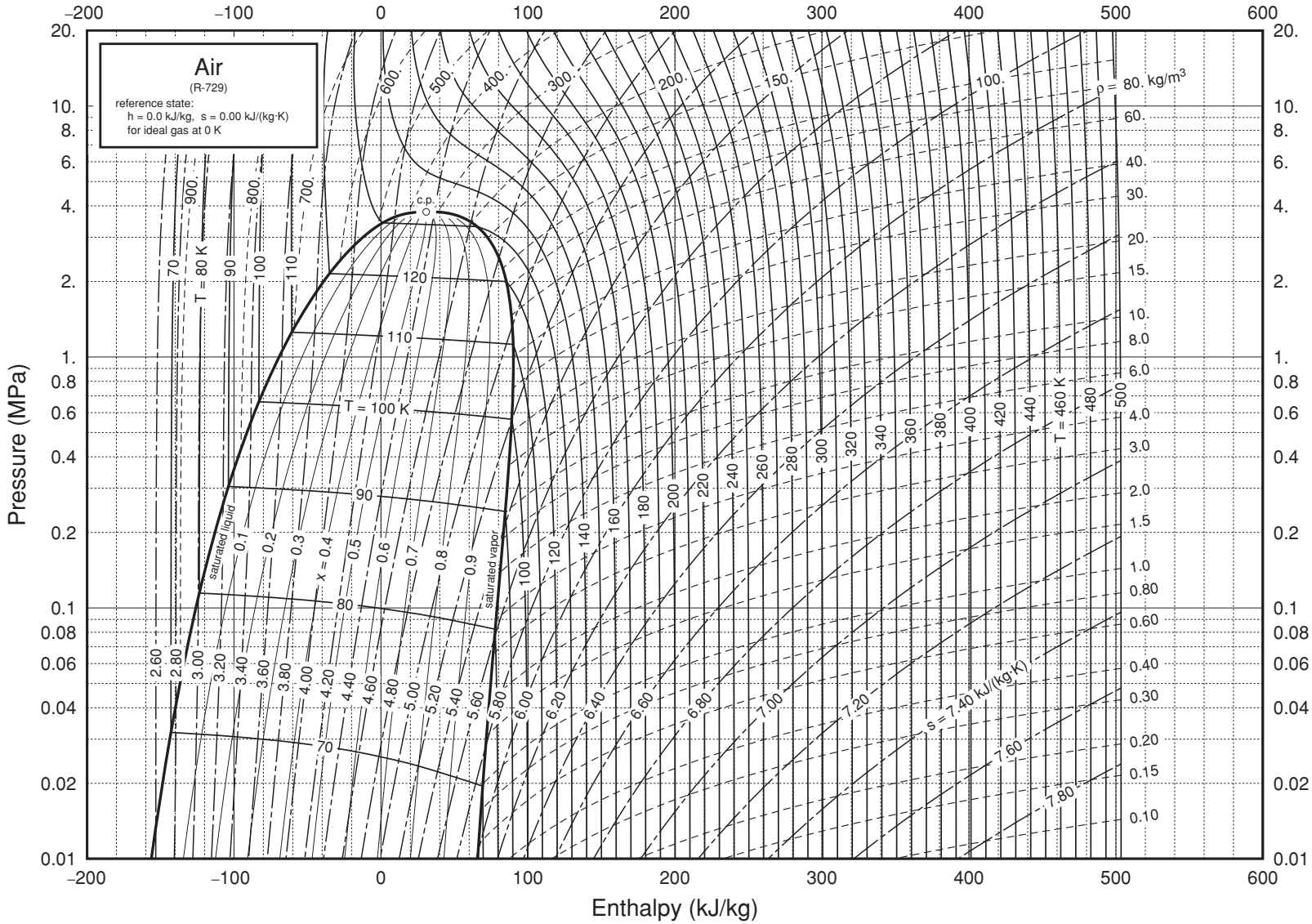

FIG. 2-5 Pressure-enthalpy diagram for dry air. Properties computed with the NIST REFPROP Database, Version 7.0 (Lemmon, E. W., McLinden, M. O., and Huber, M. L., 2002, NIST Standard Reference Database 23, NIST Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, Standard Reference Data Program, National Institute of Standards and Technology), based on the equation of state of Lemmon, E. W., Jacobsen, R. T., Penoncello, S. G., and Friend, D. G., "Thermodynamic Properties of Air and Mixtures of Nitrogen, Argon, and Oxygen from 60 to 2000 K at Pressures to 2000 MPa," *J. Phys. Chem. Ref. Data* **29:**331–385, 2000.

TABLE 2-188 Air

Other tables include Stewart, R. B., S. G. Penoncello, et al., University of Idaho CATS report, 85-5, 1985 (0.1–700 bar, 85–750 K), and Lemmon, E. W., Jacobsen, R. T., Penoncello, S. G., and Friend, D. G., Thermodynamic Properties of Air and Mixtures of Nitrogen, Argon, and Oxygen from 60 to 2000 K at Pressures to 2000 MPa, J. Phys. Chem. Ref. Data, **29**(3): 331–385, 2000. Tables including reactions with hydrocarbons include Gordon, S., NASA Techn. Paper 1907, 4 vols., 1982. See also Gupta, R. N., K-P. Lee, et al., NASA RP 1232, 1990 (89 pp.) and RP 1260, 1991 (75 pp.). Analytic expressions for high temperatures were given by Matsuzaki, R., *Jap. J. Appl. Phys.*, **21,** 7 (1982): 1009–1013 and Japanese National Aerospace Laboratory report NAL TR 671, 1981 (45 pp.). Functions from 1500 to 15,000 K were tabulated by Hilsenrath, J. and M. Klein, AEDC-TR-65-58 = AD 612 301, 1965 (333 pp.). Tables from 10000 to 10,000,000 K were authored by Gilmore, F. R., Lockheed rept. 3-27-67-1, vol 1., 1967 (340 pp.), also published as *Radiative Properties of Air,* IFI/Plenum, New York, 1969 (648 pp.). Saturation and superheat tables and a chart to 7000 psia, 660°R appear in Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants,* ASHRAE, Atlanta, Ga, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity see *Thermophysical Properties of Refrigerants,* ASHRAE, 1993.

AIR, MOIST

An ASHRAE publication, *Thermodynamic Properties of Dry Air and Water and S. I. Psychrometric Charts,* 1983 (360 pp.), extensively reviews moist air properties. Gandiduson, P., *Chem. Eng.,* Oct. 29, 1984 gives on page 118 a nomograph from 50 to 120°F, while equations in SI units were given by Nelson, B., *Chem. Eng. Progr.* **76,** 5 (May 1980): 83–85. Liley, P. E., *2000 Solved Problems in M.E. Thermodynamics,* McGraw-Hill, New York, 1989, gives four simple equations with which most calculations can be made. Devres, Y.O., *Appl. Energy* **48** (1994): 1–18 gives equations with which three known properties can be used to determine four others. Klappert, M. T. and G. F. Schilling, Rand RM-4244-PR = AD 604 856, 1984 (40 pp.) gives tables from 100 to 270 K, while programs from –60 to 2°F are given by Sando, F. A., *ASHRAE Trans.,* **96,** 2 (1990): 299–308.

Viscosity references include Kestin, J. and J. H. Whitelaw, *Int. J. Ht. Mass Transf.* **7,** 11 (1964): 1245–1255; Studnokov, E. L., *Inz.-Fiz. Zhur.* **19,** 2 (1970): 338–340; Hochramer, D. and F. Munczak, *Setzb. Ost. Acad. Wiss II* **175,** 10 (1966): 540–550. For thermal conductivity see, for instance, Mason, E. A. and L. Monchick, *Humidity and Moisture Control in Science and Industry,* Reinhold, New York, 1965 (257–272).

TABLE 2-189 Thermodynamic Properties of Ammonia

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
195.50	0.0060912	43.035	0.023237	0.00000	0.00014154	0.00000	0.049972	0.071565	2124.2	–0.23362	818.99	559.57
200.00	0.0086509	42.754	0.023389	0.32333	0.32353	0.0016351	0.049837	0.071988	2080.2	–0.22917	803.14	507.28
210.00	0.017739	42.111	0.023747	1.0480	1.0484	0.0051707	0.049521	0.072971	1992.7	–0.21883	768.02	414.98
220.00	0.033790	41.442	0.024130	1.7825	1.7833	0.0085874	0.049207	0.073950	1913.7	–0.20813	733.17	346.68
230.00	0.060407	40.748	0.024541	2.5265	2.5279	0.011894	0.048906	0.074883	1839.2	–0.19712	698.80	294.94
240.00	0.10223	40.032	0.024980	3.2793	3.2818	0.015098	0.048613	0.075764	1766.9	–0.18561	665.09	254.85
250.00	0.16494	39.293	0.025450	4.0403	4.0445	0.018205	0.048327	0.076608	1695.6	–0.17327	632.16	223.08
260.00	0.25531	38.533	0.025952	4.8093	4.8160	0.021222	0.048047	0.077448	1624.5	–0.15963	600.07	197.34
270.00	0.38107	37.748	0.026491	5.5862	5.5963	0.024154	0.047774	0.078328	1553.1	–0.14414	568.85	176.06
280.00	0.55092	36.939	0.027072	6.3712	6.3861	0.027010	0.047511	0.079296	1481.0	–0.12612	538.50	158.12
290.00	0.77436	36.101	0.027700	7.1651	7.1866	0.029797	0.047266	0.080412	1407.8	–0.10470	508.99	142.74
300.00	1.0617	35.230	0.028385	7.9691	7.9993	0.032525	0.047044	0.081747	1333.2	–0.078790	480.25	129.33
310.00	1.4240	34.320	0.029138	8.7850	8.8265	0.035203	0.046856	0.083390	1256.7	–0.046923	452.23	117.49
320.00	1.8728	33.363	0.029973	9.6153	9.6714	0.037843	0.046715	0.085465	1177.9	–0.0070718	424.83	106.91
330.00	2.4205	32.350	0.030912	10.463	10.538	0.040458	0.046636	0.088145	1096.5	0.043673	397.96	97.325
340.00	3.0802	31.264	0.031986	11.333	11.432	0.043065	0.046642	0.091701	1011.8	0.10967	371.51	88.555
350.00	3.8660	30.087	0.033237	12.232	12.361	0.045682	0.046767	0.096576	923.38	0.19774	345.32	80.430
360.00	4.7929	28.788	0.034737	13.169	13.335	0.048339	0.047064	0.10357	830.62	0.31928	319.25	72.796
370.00	5.8778	27.321	0.036602	14.158	14.373	0.051075	0.047619	0.11435	732.78	0.49497	293.07	65.493
380.00	7.1402	25.606	0.039054	15.224	15.503	0.053961	0.048589	0.13314	628.75	0.76738	266.57	58.315
390.00	8.6045	23.465	0.042616	16.424	16.790	0.057149	0.050319	0.17550	515.88	1.2455	239.65	50.877
400.00	10.305	20.232	0.049426	17.969	18.478	0.061223	0.054109	0.38707	384.58	2.3557	216.00	41.802
405.40	11.339	13.212	0.075690	20.640	21.499	0.068559			0	5.0513		
195.50	0.0060912	0.0037635	265.71	23.661	25.279	0.12931	0.026510	0.035130	354.12	171.13	19.636	6.8396
200.00	0.0086509	0.0052305	191.19	23.770	25.424	0.12714	0.026650	0.035345	357.91	152.55	19.684	6.9515
210.00	0.017739	0.010249	97.573	24.006	25.737	0.12273	0.027053	0.035961	365.94	120.01	19.860	7.2115
220.00	0.033790	0.018721	53.415	24.233	26.038	0.11884	0.027583	0.036783	373.38	96.215	20.132	7.4846
230.00	0.060407	0.032214	31.043	24.450	26.325	0.11536	0.028245	0.037836	380.19	78.430	20.503	7.7679
240.00	0.10223	0.052667	18.987	24.655	26.596	0.11224	0.029043	0.039142	386.30	64.852	20.978	8.0587
250.00	0.16494	0.082417	12.133	24.846	26.847	0.10942	0.029978	0.040728	391.66	54.280	21.560	8.3552
260.00	0.25531	0.12421	8.0506	25.021	27.077	0.10684	0.031050	0.042623	396.20	45.905	22.258	8.6558
270.00	0.38107	0.18126	5.5168	25.179	27.281	0.10447	0.032253	0.044859	399.86	39.175	23.079	8.9595
280.00	0.55092	0.25729	3.8867	25.317	27.459	0.10227	0.033581	0.047476	402.59	33.701	24.034	9.2664
290.00	0.77436	0.35664	2.8040	25.435	27.606	0.10021	0.035028	0.050530	404.30	29.207	25.138	9.5771
300.00	1.0617	0.48448	2.0641	25.528	27.720	0.098259	0.036584	0.054099	404.95	25.489	26.408	9.8938
310.00	1.4240	0.64702	1.5455	25.595	27.796	0.096395	0.038244	0.058302	404.45	22.391	27.872	10.220
320.00	1.8728	0.85202	1.1737	25.632	27.830	0.094589	0.040004	0.063320	402.70	19.794	29.568	10.561
330.00	2.4205	1.1094	0.90139	25.634	27.816	0.092817	0.041868	0.069443	399.61	17.599	31.559	10.927
340.00	3.0802	1.4325	0.69810	25.595	27.746	0.091046	0.043844	0.077150	395.05	15.728	33.945	11.330
350.00	3.8660	1.8399	0.54350	25.505	27.606	0.089242	0.045954	0.087280	388.86	14.112	36.900	11.792
360.00	4.7929	2.3598	0.42377	25.350	27.381	0.087355	0.048233	0.10141	380.83	12.690	40.752	12.346
370.00	5.8778	3.0375	0.32922	25.107	27.042	0.085316	0.050744	0.12286	370.69	11.400	46.149	13.053
380.00	7.1402	3.9558	0.25279	24.734	26.539	0.083003	0.053589	0.16000	357.96	10.172	54.556	14.025
390.00	8.6045	5.2979	0.18875	24.144	25.768	0.080169	0.056957	0.24170	341.67	8.9038	70.114	15.527
400.00	10.305	7.6973	0.12992	23.047	24.386	0.075992	0.061281	0.59477	318.22	7.3513	113.54	18.529
405.40	11.339	13.212	0.075690	20.640	21.499	0.068559			0	5.0513		

TABLE 2-189 Thermodynamic Properties of Ammonia (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Single-Phase Properties												
200.00	0.10000	42.756	0.023388	0.32270	0.32504	0.0016320	0.049842	0.071983	2080.3	–0.22921	803.24	507.47
239.56	0.10000	40.064	0.024960	3.2461	3.2486	0.014960	0.048626	0.075726	1770.0	–0.18613	666.56	256.42
239.56	0.10000	0.051595	19.382	24.646	26.584	0.11237	0.029005	0.039079	386.05	65.377	20.955	8.0459
300.00	0.10000	0.040502	24.690	26.378	28.847	0.12080	0.028021	0.036849	434.39	27.493	25.100	10.161
400.00	0.10000	0.030171	33.144	29.297	32.612	0.13162	0.030417	0.038883	497.93	10.681	37.215	13.971
500.00	0.10000	0.024091	41.509	32.514	36.665	0.14065	0.033897	0.042280	550.96	5.5276	53.119	17.863
600.00	0.10000	0.020060	49.849	36.096	41.081	0.14869	0.037731	0.046083	597.69	3.2702	68.607	21.682
700.00	0.10000	0.017188	58.179	40.068	45.885	0.15609	0.041678	0.050015	640.16	2.0841	78.312	25.391
200.00	1.0000	42.774	0.023379	0.31651	0.33989	0.0016010	0.049890	0.071938	2081.5	–0.22959	804.23	509.28
298.05	1.0000	35.403	0.028246	7.8111	7.8393	0.031996	0.047085	0.081465	1347.9	–0.084271	485.81	131.82
298.05	1.0000	0.45697	2.1883	25.512	27.700	0.098633	0.036271	0.053356	404.91	26.163	26.145	9.8313
300.00	1.0000	0.45215	2.2117	25.592	27.804	0.098979	0.035866	0.052493	407.16	25.620	26.308	9.9115
400.00	1.0000	0.31157	3.2095	29.019	32.229	0.11177	0.031641	0.041627	488.94	10.494	38.087	13.927
500.00	1.0000	0.24426	4.0940	32.359	36.453	0.12119	0.034312	0.043338	546.79	5.4884	53.750	17.877
600.00	1.0000	0.20197	4.9513	35.994	40.945	0.12937	0.037928	0.046628	595.60	3.2544	69.123	21.717
700.00	1.0000	0.17248	5.7977	39.994	45.792	0.13684	0.041791	0.050341	639.15	2.0746	78.751	25.434
200.00	5.0000	42.852	0.023336	0.28942	0.40611	0.0014649	0.050097	0.071739	2086.8	–0.23126	808.60	517.30
300.00	5.0000	35.450	0.028209	7.8852	8.0263	0.032243	0.047090	0.080899	1361.2	–0.089577	487.57	132.49
362.03	5.0000	28.505	0.035081	13.365	13.540	0.048887	0.047152	0.10538	811.17	0.34968	313.94	71.291
362.03	5.0000	2.4828	0.40277	25.309	27.323	0.086956	0.048722	0.10501	378.95	12.419	41.693	12.475
400.00	5.0000	1.8706	0.53459	27.540	30.213	0.094581	0.038466	0.061581	441.81	9.6373	45.730	14.036
500.00	5.0000	1.3046	0.76650	31.630	35.462	0.10634	0.036193	0.048779	528.14	5.2830	57.294	18.073
600.00	5.0000	1.0412	0.96040	35.527	40.329	0.11521	0.038798	0.049210	586.79	3.1693	71.791	21.941
700.00	5.0000	0.87563	1.1420	39.662	45.373	0.12298	0.042289	0.051836	635.17	2.0254	80.941	25.662
200.00	10.000	42.947	0.023284	0.25644	0.48928	0.0012980	0.050342	0.071495	2093.5	–0.23328	814.02	527.29
300.00	10.000	35.714	0.028000	7.7848	8.0648	0.031903	0.047164	0.079960	1394.2	–0.10159	496.50	136.36
398.32	10.000	20.945	0.047744	17.655	18.132	0.060394	0.053149	0.30653	409.04	2.0704	218.73	43.632
398.32	10.000	7.1390	0.14008	23.303	24.704	0.076892	0.060447	0.46915	323.12	7.6606	101.04	17.793
400.00	10.000	6.5455	0.15278	23.801	25.329	0.078458	0.057611	0.30552	336.28	7.7633	95.455	17.230
500.00	10.000	2.8656	0.34897	30.616	34.106	0.098525	0.038603	0.057806	505.64	4.9335	63.922	18.722
600.00	10.000	2.1650	0.46190	34.920	39.539	0.10844	0.039862	0.052806	577.38	3.0278	76.053	22.393
700.00	10.000	1.7835	0.56069	39.241	44.848	0.11663	0.042896	0.053796	631.50	1.9491	84.235	26.035
300.00	100.00	38.995	0.025644	6.5830	9.1474	0.027511	0.048894	0.072740	1774.7	–0.19551	622.86	193.71
400.00	100.00	33.105	0.030207	13.432	16.453	0.048523	0.046636	0.073557	1378.2	–0.11309	431.98	96.237
500.00	100.00	27.067	0.036945	20.212	23.907	0.065147	0.045999	0.075495	1081.8	0.049919	305.65	60.386
600.00	100.00	21.518	0.046473	26.825	31.472	0.078942	0.046723	0.075193	918.11	0.23722	234.79	46.188
700.00	100.00	17.303	0.057794	33.074	38.854	0.090326	0.048331	0.072317	861.52	0.32753	196.04	41.237
300.00	500.00	45.670	0.021896	4.7114	15.660	0.018023	0.052877	0.067831	2597.1	–0.25055	989.00	376.31
400.00	500.00	42.416	0.023576	10.633	22.421	0.037482	0.051527	0.066802	2353.2	–0.25064	804.05	188.46
500.00	500.00	39.515	0.025307	16.367	29.021	0.052215	0.050431	0.065418	2176.9	–0.25260	674.00	120.77
600.00	500.00	36.909	0.027094	22.007	35.554	0.064127	0.050614	0.065476	2044.6	–0.24722	582.63	91.251
700.00	500.00	34.550	0.028943	27.680	42.152	0.074295	0.051816	0.066615	1943.8	–0.23682	511.57	77.538
300.00	1000.0	49.944	0.020022	4.1818	24.204	0.011750	0.055176	0.065784	3230.2	–0.25989	1324.0	554.62
400.00	1000.0	47.551	0.021030	9.8612	30.891	0.030984	0.054864	0.066677	2997.6	–0.25431	1138.9	274.91
500.00	1000.0	45.362	0.022045	15.432	37.477	0.045686	0.053323	0.065150	2842.8	–0.26084	996.49	174.11
600.00	1000.0	43.378	0.023053	20.911	43.964	0.057514	0.052940	0.064819	2728.6	–0.26235	887.73	129.02
700.00	1000.0	41.556	0.024064	26.418	50.481	0.067559	0.053649	0.065697	2639.0	–0.25820	797.25	107.14

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Tillner-Roth, R., Harms-Watzenberg, F., and Baehr, H. D.,"Eine neue Fundamentalgleichung fuer Ammoniak," *DKV-Tagungsbericht*, **20:**167–181, 1993. The source for viscosity is Fenghour, A., Wakeham, W. A., Vesovic, V., Watson, J. T. R., Millat, J., and Vogel, E., "The Viscosity of Ammonia," *J. Phys. Chem. Ref. Data* **24:**1649–1667, 1995. The source for thermal conductivity is Tufeu, R., Ivanov, D. Y., Garrabos, Y., and Le Neindre, B., "Thermal Conductivity of Ammonia in a Large Temperature and Pressure Range Including the Critical Region," *Ber. Bunsenges. Phys. Chem.* **88:**422–427, 1984.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are 0.2% in density, 2% in heat capacity, and 2% in the speed of sound, except in the critical region. The uncertainty in vapor pressure is 0.2%. The uncertainty varies from 0.5% for the viscosity of the dilute gas phase at moderate temperatures to about 5% for the viscosity at high pressures and temperatures. The uncertainty in thermal conductivity is 2%.

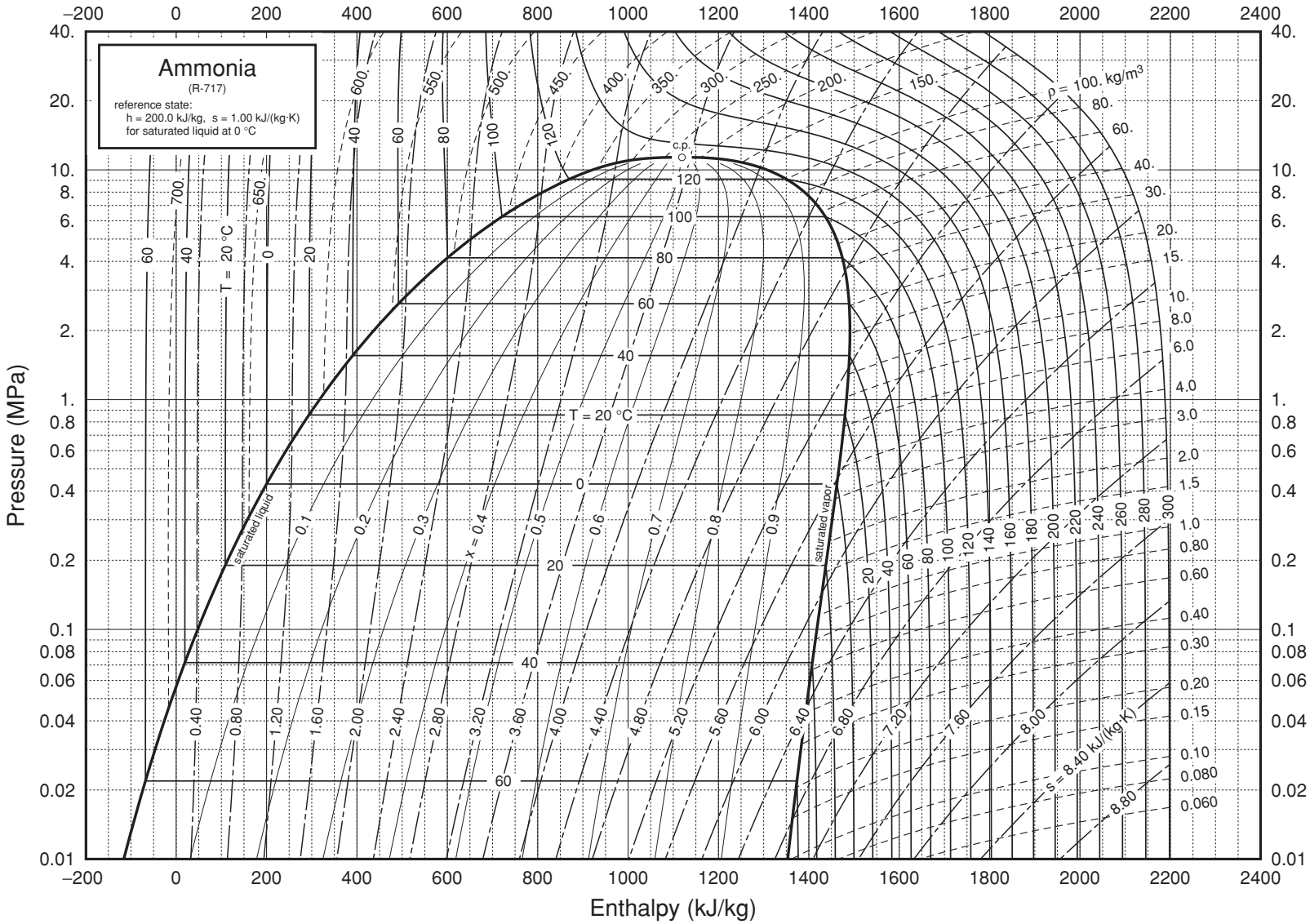

FIG. 2-6 Pressure-enthalpy diagram for ammonia. Properties computed with the NIST REFPROP Database, Version 7.0 (Lemmon, E. W., McLinden, M. O., and Huber, M. L., 2002, NIST Standard Reference Database 23, NIST Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, Standard Reference Data Program, National Institute of Standards and Technology), based on the equation of state of Tillner-Roth, R., Harms-Watzenberg, F., and Baehr, H. D., "Eine neue Fundamentalgleichung für Ammoniak, *DKV-Tagungsbericht* **20**(II):167–181, 1993.

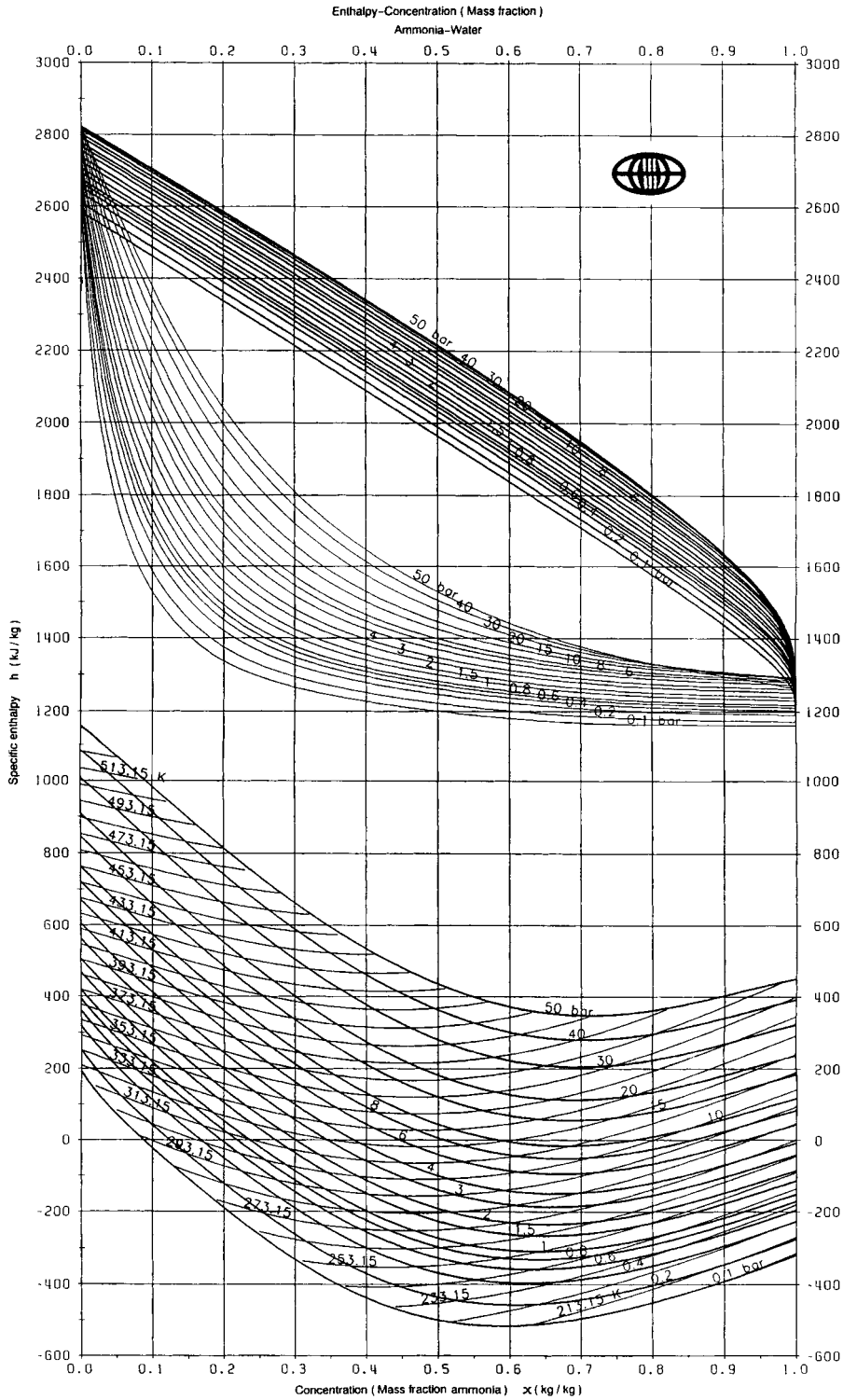

FIG. 2-7 Enthalpy-concentration diagram for aqueous ammonia. From *Thermodynamic and Physical Properties NH_3–H_2O,* Int. Inst. Refrigeration, Paris, France, 1994 (88 pp.). Reproduced by permission. In order to determine equilibrium compositions, draw a vertical from any liquid composition on any boiling line (the lowest plots) to intersect the appropriate auxiliary curve (the intermediate curves). A horizontal then drawn from this point to the appropriate dew line (the upper curves) will establish the vapor composition. The Int. Inst. Refrigeration publication also gives extensive *P-v-x* tables from –50 to 316°C. Other sources include Park, Y. M. and Sonntag, R. E., *ASHRAE Trans.,* **96,** 1 (1990): 150–159 (*x, h, s,* tables, 360 to 640 K); Ibrahim, O. M. and S. A. Klein, *ASHRAE Trans.,* **99,** 1 (1993): 1495–1502 (Eqs., 0.2 to 110 bar, 293 to 413 K); Smolen, T. M., D. B. Manley, et al., *J. Chem. Eng. Data,* **36** (1991): 202–208 (*p-x* correlation, 0.9 to 450 psia, 293–413 K); Ruiter, J. P., *Int. J. Refrig.,* **13** (1990): 223–236 gives ten subroutines for computer calculations.

TABLE 2-190 Thermodynamic Properties of Argon

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
83.806	0.068891	35.465	0.028197	−4.8531	−4.8512	0.053110	0.021956	0.044570	862.43	−0.40500	133.63	290.17
85.000	0.078897	35.284	0.028342	−4.8000	−4.7977	0.053740	0.021764	0.044571	854.24	−0.40120	131.86	279.46
87.000	0.098131	34.977	0.028590	−4.7110	−4.7082	0.054774	0.021461	0.044620	840.43	−0.39386	128.91	262.70
89.000	0.12078	34.667	0.028846	−4.6220	−4.6185	0.055787	0.021178	0.044720	826.48	−0.38530	125.97	247.29
91.000	0.14723	34.353	0.029109	−4.5328	−4.5285	0.056778	0.020912	0.044869	812.39	−0.37551	123.06	233.09
93.000	0.17785	34.035	0.029381	−4.4433	−4.4380	0.057752	0.020662	0.045063	798.14	−0.36447	120.16	219.98
95.000	0.21305	33.713	0.029662	−4.3534	−4.3471	0.058708	0.020424	0.045301	783.72	−0.35214	117.28	207.87
97.000	0.25323	33.386	0.029953	−4.2632	−4.2556	0.059649	0.020198	0.045583	769.14	−0.33847	114.44	196.65
99.000	0.29882	33.054	0.030254	−4.1725	−4.1634	0.060575	0.019982	0.045909	754.37	−0.32336	111.63	186.24
101.00	0.35023	32.715	0.030567	−4.0812	−4.0705	0.061489	0.019777	0.046282	739.40	−0.30671	108.82	176.58
103.00	0.40789	32.371	0.030892	−3.9893	−3.9767	0.062391	0.019580	0.046705	724.21	−0.28840	106.03	167.58
105.00	0.47224	32.020	0.031230	−3.8968	−3.8820	0.063283	0.019393	0.047181	708.81	−0.26827	103.26	159.18
107.00	0.54371	31.662	0.031584	−3.8034	−3.7862	0.064165	0.019214	0.047715	693.16	−0.24614	100.50	151.32
109.00	0.62276	31.296	0.031953	−3.7092	−3.6893	0.065039	0.019044	0.048313	677.26	−0.22181	97.768	143.96
111.00	0.70982	30.921	0.032340	−3.6141	−3.5912	0.065906	0.018883	0.048984	661.08	−0.19503	95.055	137.04
113.00	0.80535	30.538	0.032747	−3.5180	−3.4916	0.066767	0.018731	0.049737	644.60	−0.16549	92.363	130.52
115.00	0.90981	30.144	0.033174	−3.4207	−3.3905	0.067623	0.018589	0.050584	627.79	−0.13284	89.695	124.35
117.00	1.0237	29.739	0.033626	−3.3222	−3.2878	0.068477	0.018458	0.051541	610.64	−0.096667	87.049	118.50
119.00	1.1473	29.322	0.034104	−3.2223	−3.1831	0.069328	0.018337	0.052626	593.11	−0.056465	84.428	112.93
121.00	1.2814	28.891	0.034613	−3.1208	−3.0764	0.070179	0.018229	0.053865	575.16	−0.011619	81.832	107.61
123.00	1.4262	28.446	0.035155	−3.0175	−2.9674	0.071031	0.018134	0.055288	556.75	0.038624	79.260	102.49
125.00	1.5823	27.983	0.035735	−2.9123	−2.8558	0.071886	0.018056	0.056938	537.83	0.095199	76.711	97.565
127.00	1.7503	27.502	0.036361	−2.8049	−2.7413	0.072747	0.017995	0.058870	518.34	0.15928	74.185	92.791
129.00	1.9305	26.999	0.037039	−2.6949	−2.6234	0.073616	0.017955	0.061161	498.21	0.23236	71.679	88.143
131.00	2.1237	26.471	0.037778	−2.5820	−2.5018	0.074496	0.017941	0.063916	477.36	0.31637	69.190	83.595
133.00	2.3303	25.913	0.038591	−2.4655	−2.3756	0.075392	0.017957	0.067291	455.69	0.41386	66.713	79.119
135.00	2.5509	25.320	0.039495	−2.3449	−2.2442	0.076309	0.018011	0.071519	433.10	0.52823	64.243	74.689
137.00	2.7862	24.683	0.040513	−2.2192	−2.1063	0.077253	0.018109	0.076964	409.47	0.66427	61.773	70.276
139.00	3.0369	23.993	0.041678	−2.0871	−1.9605	0.078235	0.018264	0.084237	384.62	0.82889	59.297	65.850
141.00	3.3037	23.233	0.043041	−1.9468	−1.8046	0.079268	0.018501	0.094443	358.17	1.0326	56.816	61.374
143.00	3.5876	22.379	0.044686	−1.7953	−1.6350	0.080375	0.018882	0.10982	329.41	1.2928	54.352	56.802
145.00	3.8896	21.385	0.046762	−1.6277	−1.4458	0.081593	0.019546	0.13580	297.06	1.6405	52.009	52.060
147.00	4.2111	20.163	0.049597	−1.4335	−1.2247	0.083001	0.020842	0.18993	258.79	2.1416	50.224	46.982
149.00	4.5541	18.446	0.054213	−1.1822	−0.93533	0.084835	0.023975	0.37941	209.33	2.9836	51.152	41.002
150.69	4.8630	13.407	0.074586	−0.53575	−0.17304	0.089789			0	5.2503		
83.806	0.068891	0.10150	9.8526	1.0103	1.6891	0.13115	0.012972	0.022172	168.12	35.712	5.3590	6.8558
85.000	0.078897	0.11492	8.7019	1.0212	1.7078	0.13028	0.013015	0.022310	169.08	34.706	5.4485	6.9622
87.000	0.098131	0.14035	7.1253	1.0388	1.7380	0.12887	0.013092	0.022563	170.64	33.127	5.6006	7.1414
89.000	0.12078	0.16979	5.8895	1.0554	1.7668	0.12753	0.013176	0.022845	172.12	31.668	5.7559	7.3219
91.000	0.14723	0.20365	4.9104	1.0710	1.7939	0.12626	0.013267	0.023159	173.52	30.315	5.9147	7.5039
93.000	0.17785	0.24233	4.1266	1.0855	1.8194	0.12504	0.013364	0.023506	174.85	29.056	6.0776	7.6877
95.000	0.21305	0.28625	3.4935	1.0988	1.8431	0.12387	0.013469	0.023892	176.11	27.883	6.2452	7.8736
97.000	0.25323	0.33587	2.9774	1.1108	1.8648	0.12275	0.013580	0.024318	177.29	26.785	6.4180	8.0617
99.000	0.29882	0.39165	2.5533	1.1216	1.8845	0.12167	0.013700	0.024789	178.39	25.755	6.5969	8.2524
101.00	0.35023	0.45412	2.2021	1.1309	1.9021	0.12062	0.013828	0.025310	179.41	24.786	6.7825	8.4461
103.00	0.40789	0.52379	1.9092	1.1387	1.9174	0.11962	0.013964	0.025887	180.36	23.873	6.9760	8.6432
105.00	0.47224	0.60126	1.6632	1.1449	1.9303	0.11864	0.014108	0.026526	181.22	23.009	7.1783	8.8440
107.00	0.54371	0.68714	1.4553	1.1494	1.9406	0.11769	0.014263	0.027235	182.01	22.189	7.3908	9.0492
109.00	0.62276	0.78213	1.2786	1.1521	1.9483	0.11676	0.014427	0.028024	182.71	21.410	7.6149	9.2592
111.00	0.70982	0.88696	1.1274	1.1528	1.9531	0.11585	0.014602	0.028904	183.33	20.667	7.8524	9.4749
113.00	0.80535	1.0025	0.99752	1.1515	1.9549	0.11497	0.014789	0.029890	183.87	19.955	8.1054	9.6969
115.00	0.90981	1.1296	0.88525	1.1480	1.9534	0.11409	0.014989	0.030998	184.33	19.272	8.3764	9.9262
117.00	1.0237	1.2694	0.78776	1.1421	1.9485	0.11323	0.015203	0.032251	184.70	18.615	8.6685	10.164
119.00	1.1473	1.4231	0.70269	1.1336	1.9398	0.11238	0.015432	0.033674	184.98	17.979	8.9853	10.411
121.00	1.2814	1.5920	0.62813	1.1223	1.9271	0.11153	0.015679	0.035305	185.17	17.361	9.3315	10.670
123.00	1.4262	1.7778	0.56248	1.1079	1.9101	0.11069	0.015945	0.037186	185.27	16.758	9.7128	10.942
125.00	1.5823	1.9824	0.50443	1.0901	1.8883	0.10984	0.016234	0.039377	185.28	16.167	10.136	11.228

TABLE 2-190 Thermodynamic Properties of Argon (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
127.00	1.7503	2.2081	0.45288	1.0685	1.8612	0.10899	0.016549	0.041958	185.18	15.585	10.611	11.533
129.00	1.9305	2.4576	0.40690	1.0428	1.8283	0.10813	0.016892	0.045036	184.98	15.007	11.150	11.860
131.00	2.1237	2.7345	0.36570	1.0122	1.7888	0.10725	0.017269	0.048764	184.68	14.430	11.768	12.212
133.00	2.3303	3.0431	0.32861	0.97615	1.7419	0.10635	0.017684	0.053370	184.27	13.851	12.487	12.596
135.00	2.5509	3.3893	0.29505	0.93360	1.6862	0.10542	0.018152	0.059209	183.74	13.262	13.337	13.018
137.00	2.7862	3.7806	0.26451	0.88331	1.6203	0.10445	0.018697	0.066854	183.03	12.655	14.363	13.489
139.00	3.0369	4.2280	0.23652	0.82353	1.5418	0.10343	0.019352	0.077279	182.09	12.019	15.633	14.022
141.00	3.3037	4.7471	0.21066	0.75170	1.4476	0.10233	0.020167	0.092257	180.81	11.341	17.255	14.638
143.00	3.5876	5.3629	0.18647	0.66386	1.3328	0.10113	0.021213	0.11542	179.05	10.606	19.424	15.370
145.00	3.8896	6.1190	0.16342	0.55308	1.1887	0.099762	0.022619	0.15563	176.57	9.7892	22.530	16.274
147.00	4.2111	7.1057	0.14073	0.40516	0.99779	0.098120	0.024694	0.24158	172.74	8.8407	27.572	17.475
149.00	4.5541	8.5869	0.11646	0.17894	0.70930	0.095873	0.028532	0.54500	165.39	7.6233	38.688	19.366
150.69	4.8630	13.407	0.074586	–0.53575	–0.17304	0.089789			133.87	0		
Single-Phase Properties												
100.00	0.10000	0.12304	8.1275	1.2122	2.0249	0.13179	0.012807	0.021852	184.16	25.048	6.4504	8.2341
200.00	0.10000	0.060310	16.581	2.4833	4.1414	0.14649	0.012497	0.020918	263.21	7.4099	12.539	15.998
300.00	0.10000	0.040115	24.928	3.7351	6.2279	0.15495	0.012479	0.020834	322.67	3.6153	17.837	22.741
400.00	0.10000	0.030069	33.257	4.9842	8.3099	0.16094	0.012475	0.020810	372.65	1.9970	22.516	28.704
500.00	0.10000	0.024050	41.580	6.2324	10.390	0.16559	0.012474	0.020801	416.64	1.1105	26.726	34.077
600.00	0.10000	0.020041	49.899	7.4803	12.470	0.16938	0.012473	0.020796	456.40	0.55603	30.573	38.997
700.00	0.10000	0.017177	58.217	8.7279	14.550	0.17258	0.012473	0.020793	492.95	0.17948	34.134	43.556
100.00	1.0000	32.955	0.030345	–4.1375	–4.1072	0.060927	0.019909	0.045870	751.59	–0.32095	110.85	183.08
116.60	1.0000	29.821	0.033533	–3.3421	–3.3086	0.068305	0.018483	0.051339	614.12	–0.10424	87.579	119.65
116.60	1.0000	1.2403	0.80628	1.1435	1.9497	0.11340	0.015159	0.031986	184.63	18.745	8.6079	10.115
200.00	1.0000	0.61937	1.6145	2.3849	3.9995	0.12686	0.012725	0.022195	261.59	7.2269	12.995	16.256
300.00	1.0000	0.40331	2.4795	3.6807	6.1603	0.13563	0.012545	0.021266	323.44	3.5287	18.142	22.901
400.00	1.0000	0.30073	3.3252	4.9476	8.2728	0.14171	0.012507	0.021025	374.06	1.9489	22.749	28.817
500.00	1.0000	0.24013	4.1644	6.2054	10.370	0.14639	0.012493	0.020928	418.25	1.0808	26.915	34.163
600.00	1.0000	0.19997	5.0007	7.4592	12.460	0.15020	0.012487	0.020879	458.06	0.53628	30.733	39.065
700.00	1.0000	0.17137	5.8354	8.7110	14.546	0.15342	0.012483	0.020851	494.61	0.16568	34.272	43.612
100.00	5.0000	33.343	0.029992	–4.1962	–4.0463	0.060330	0.020096	0.044750	777.34	–0.35058	114.41	193.32
200.00	5.0000	3.5342	0.28295	1.8892	3.3039	0.11098	0.013847	0.030481	257.20	6.1700	16.132	18.205
300.00	5.0000	2.0596	0.48554	3.4362	5.8640	0.12145	0.012825	0.023284	328.37	3.1276	19.721	23.850
400.00	5.0000	1.5022	0.66567	4.7860	8.1144	0.12793	0.012643	0.021972	381.06	1.7370	23.882	29.440
500.00	5.0000	1.1914	0.83938	6.0868	10.284	0.13277	0.012578	0.021480	425.81	0.95180	27.811	34.619
600.00	5.0000	0.98986	1.0102	7.3671	12.418	0.13667	0.012547	0.021239	465.68	0.45113	31.477	39.420
700.00	5.0000	0.84774	1.1796	8.6370	14.535	0.13993	0.012530	0.021104	502.09	0.10636	34.910	43.899
100.00	10.000	33.779	0.029604	–4.2615	–3.9654	0.059648	0.020331	0.043670	805.91	–0.37991	118.60	205.82
200.00	10.000	8.4545	0.11828	1.1163	2.2991	0.10142	0.015240	0.048544	267.70	4.1966	23.573	23.429
300.00	10.000	4.1955	0.23835	3.1284	5.5119	0.11472	0.013145	0.025892	338.42	2.6066	22.192	25.583
400.00	10.000	2.9896	0.33449	4.5884	7.9333	0.12170	0.012803	0.023107	391.51	1.4795	25.505	30.479
500.00	10.000	2.3554	0.42455	5.9428	10.188	0.12674	0.012681	0.022129	436.14	0.79870	29.044	35.348
600.00	10.000	1.9532	0.51198	7.2556	12.375	0.13073	0.012621	0.021662	475.69	0.35092	32.479	39.971
700.00	10.000	1.6722	0.59801	8.5473	14.527	0.13404	0.012587	0.021400	511.73	0.036761	35.757	44.338

200.00	100.00	30.368	0.032930	–1.9234	1.3696	0.077319	0.017598	0.034137	854.48	–0.51219	99.994	120.12
300.00	100.00	24.152	0.041404	0.48428	4.6247	0.090561	0.015534	0.031005	733.39	–0.45856	70.273	75.589
400.00	100.00	19.710	0.050736	2.5103	7.5839	0.099092	0.014579	0.028287	690.42	–0.45296	59.077	61.649
500.00	100.00	16.607	0.060216	4.2850	10.307	0.10518	0.014048	0.026288	683.08	–0.49513	54.952	57.655
600.00	100.00	14.372	0.069578	5.9046	12.862	0.10984	0.013716	0.024915	690.94	–0.55858	53.635	57.185
700.00	100.00	12.695	0.078769	7.4268	15.304	0.11361	0.013492	0.023969	705.52	–0.62622	53.660	58.260
200.00	500.00	41.639	0.024016	–2.6867	9.3214	0.063085	0.022923	0.032604	1519.6	–0.60932	218.05	504.85
300.00	500.00	38.382	0.026054	–0.59281	12.434	0.075743	0.019980	0.029872	1443.8	–0.67083	184.82	259.42
400.00	500.00	35.672	0.028033	1.3125	15.329	0.084083	0.018316	0.028142	1393.0	–0.71809	161.66	183.29
500.00	500.00	33.368	0.029969	3.0950	18.079	0.090226	0.017262	0.026929	1358.5	–0.75700	145.02	151.69
600.00	500.00	31.379	0.031868	4.7903	20.724	0.095050	0.016535	0.026007	1334.9	–0.79113	132.94	135.48
700.00	500.00	29.643	0.033734	6.4198	23.287	0.099002	0.016000	0.025273	1318.8	–0.82207	124.11	125.84
300.00	1000.0	44.836	0.022304	–0.13952	22.164	0.068356	0.022820	0.030815	1866.0	–0.61332	267.67	666.74
400.00	1000.0	42.715	0.023411	1.7386	25.150	0.076958	0.020840	0.029020	1823.7	–0.65733	243.17	410.53
500.00	1000.0	40.856	0.024476	3.5106	27.987	0.083293	0.019528	0.027790	1791.9	–0.69220	223.98	297.24
600.00	1000.0	39.201	0.025510	5.2086	30.718	0.088276	0.018596	0.026881	1767.8	–0.72129	208.59	239.91
700.00	1000.0	37.711	0.026518	6.8515	33.369	0.092364	0.017896	0.026165	1749.3	–0.74683	196.06	207.86

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Tegeler, Ch., Span, R., and Wagner, W., "A New Equation of State for Argon Covering the Fluid Region for Temperatures from the Melting Line to 700 K at Pressures up to 1000 MPa," *J. Phys. Chem. Ref. Data* **28**(3):779–850, 1999. The source for viscosity and thermal conductivity is Lemmon, E. W., and Jacobsen, R. T., "Viscosity and Thermal Conductivity Equations for Nitrogen, Oxygen, Argon, and Air," *Int. J. Thermophys.* **25:**21–69, 2004.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The estimated uncertainty in density is less than 0.02% for pressures up to 12 MPa and temperatures up to 340 K with the exception of the critical region and less than 0.03% for pressures up to 30 MPa and temperatures between 235 and 520 K. Elsewhere, the uncertainty in density is generally within 0.2%. In the region with densities up to one-half the critical density and for temperatures between 90 and 450 K, the estimated uncertainty of calculated speeds of sound is in general less than 0.02%. In the liquid and supercritical regions, the uncertainty is less than 1%. The uncertainty in heat capacities is within 0.3% for the vapor and 2% for the liquid. The formulation gives reasonable extrapolation behavior up to very high pressures (50 GPa) and temperatures (17,000 K).

For viscosity, the uncertainty is 0.5% in the dilute gas. Away from the dilute gas (pressures greater than 1 MPa and in the liquid), the uncertainties are as low as 1% between 270 and 300 K at pressures less than 100 MPa, and increase outside that range. The uncertainties are around 2% at temperatures of 180 K and higher. Below this and away from the critical region, the uncertainties steadily increase to around 5% at the triple points of the fluids. The uncertainties in the critical region are higher.

For thermal conductivity, the uncertainty for the dilute gas is 2% with increasing uncertainties near the triple point. For the nondilute gas, the uncertainty is 2% for temperatures greater than 170 K. The uncertainty is 3% at temperatures less than the critical point and 5% in the critical region, except for states very near the critical point.

TABLE 2-191 Liquid-Vapor Equilibrium Data for the Argon-Nitrogen-Oxygen System

Liquid mole fraction				Vapor mole fraction				Relative volatility			p^0 (kPa)			Activity coefficent			Enthalpy kJ/kmol		Isobaric specific heat, kJ/(kmol·K)	
$N_2/(N_2+O_2)$	Ar	N_2	O_2	Ar	N_2	O_2	Temperature K	N_2/Ar	N_2/O_2	Ar/O_2	Ar	N_2	O_2	Ar	N_2	O_2	Liquid	Vapor	Liquid	Vapor
Pressure, 101.325 kPa (1 atm)																				
0.00	0.00	0.00	1.00	0.00000	0.0000	1.0000	90.188	—	—	1.606	136.010	366.29	101.33	1.196	—	1.000	−4268	2550	54.378	31.061
0.00	0.01	0.00	0.99	0.01590	0.0000	0.9841	90.128	—	—	1.600	135.210	364.42	100.69	1.192	—	1.000	−4271	2536	54.269	30.929
0.00	0.02	0.00	0.98	0.03151	0.0000	0.9685	90.070	—	—	1.594	134.430	362.62	100.08	1.188	—	1.001	−4275	2523	54.160	30.801
0.00	0.03	0.00	0.97	0.04684	0.0000	0.9532	90.013	—	—	1.589	133.680	360.86	99.49	1.183	—	1.001	−4278	2510	54.052	30.674
0.00	0.04	0.00	0.96	0.06189	0.0000	0.9381	89.956	—	—	1.583	132.930	359.10	98.89	1.179	—	1.001	−4282	2497	53.944	30.550
0.00	0.05	0.00	0.95	0.07667	0.0000	0.9233	89.901	—	—	1.578	132.200	357.41	98.32	1.175	—	1.002	−4285	2484	53.837	30.429
0.00	0.07	0.00	0.93	0.10548	0.0000	0.8945	89.794	—	—	1.567	130.810	354.14	97.22	1.167	—	1.002	−4292	2460	53.622	30.192
0.00	0.10	0.00	0.90	0.14692	0.0000	0.8531	89.640	—	—	1.550	128.810	349.47	95.65	1.156	—	1.004	−4302	2425	53.302	29.851
0.00	0.20	0.00	0.80	0.27211	0.0000	0.7279	89.183	—	—	1.495	123.040	335.88	91.10	1.120	—	1.012	−4336	2320	52.253	28.822
0.00	0.40	0.00	0.60	0.48104	0.0000	0.5190	88.470	—	—	1.390	114.430	315.46	84.35	1.065	—	1.039	−4409	2147	50.224	27.089
0.00	0.60	0.00	0.40	0.65969	0.0000	0.3403	87.948	—	—	1.292	108.420	301.10	79.66	1.028	—	1.082	−4491	2004	48.281	25.578
0.00	0.80	0.00	0.20	0.82774	0.0000	0.1723	87.566	—	—	1.201	104.180	290.90	76.35	1.006	—	1.143	−4586	1873	46.417	24.123
0.00	0.90	0.00	0.10	0.91247	0.0000	0.0875	87.420	—	—	1.158	102.590	287.07	75.12	1.001	—	1.181	−4638	1808	45.515	23.378
0.10	0.00	0.10	0.90	0.0000	0.3150	0.6850	87.546	2.573	4.138	1.608	103.960	290.37	76.18	1.193	1.099	1.012	−4235	2471	54.388	30.764
0.10	0.01	0.10	0.89	0.0122	0.3108	0.6771	87.529	2.579	4.131	1.602	103.780	289.93	76.04	1.188	1.097	1.013	−4238	2461	54.281	30.669
0.10	0.02	0.10	0.88	0.0242	0.3066	0.6692	87.512	2.584	4.124	1.596	103.590	289.48	75.89	1.184	1.095	1.013	−4241	2452	54.175	30.576
0.10	0.03	0.10	0.87	0.0361	0.3025	0.6614	87.495	2.589	4.117	1.590	103.410	289.03	75.75	1.180	1.093	1.013	−4244	2443	54.068	30.484
0.10	0.04	0.10	0.86	0.0479	0.2985	0.6536	87.479	2.595	4.110	1.584	103.230	288.61	75.61	1.176	1.092	1.014	−4248	2434	53.962	30.392
0.10	0.05	0.10	0.86	0.0596	0.2945	0.6459	87.463	2.600	4.103	1.578	103.060	288.19	75.48	1.172	1.090	1.014	−4251	2425	53.856	30.302
0.10	0.07	0.09	0.84	0.0826	0.2866	0.6308	87.432	2.611	4.089	1.566	102.720	287.38	75.22	1.164	1.086	1.015	−4257	2408	53.645	30.123
0.10	0.10	0.09	0.81	0.1164	0.2751	0.6086	87.389	2.627	4.068	1.549	102.260	286.26	74.86	1.153	1.082	1.017	−4266	2382	53.330	29.861
0.10	0.20	0.08	0.72	0.2230	0.2390	0.5380	87.270	2.680	3.999	1.492	100.980	283.17	73.87	1.119	1.069	1.025	−4300	2302	52.291	29.029
0.10	0.40	0.06	0.54	0.4179	0.1749	0.4072	87.121	2.790	3.866	1.386	99.401	279.34	72.64	1.065	1.057	1.052	−4378	2157	50.269	27.486
0.10	0.60	0.04	0.36	0.6027	0.1167	0.2807	87.077	2.904	3.742	1.288	98.938	278.22	72.28	1.029	1.062	1.093	−4469	2023	48.319	25.986
0.10	0.80	0.02	0.18	0.7916	0.0598	0.1486	87.132	3.023	3.625	1.199	99.517	279.63	72.73	1.008	1.084	1.150	−4575	1889	46.440	24.404
0.10	0.90	0.01	0.09	0.8923	0.0306	0.0771	87.201	3.085	3.569	1.157	100.250	281.40	73.30	1.002	1.101	1.185	−4633	1818	45.527	23.542
0.20	0.00	0.20	0.80	0.0000	0.5104	0.4896	85.511	2.606	4.170	1.600	83.506	240.35	60.37	1.188	1.076	1.027	−4176	2409	54.481	30.819
0.20	0.01	0.20	0.79	0.0098	0.5050	0.4853	85.519	2.611	4.162	1.594	83.580	240.53	60.42	1.184	1.074	1.027	−4179	2403	54.374	30.742
0.20	0.02	0.20	0.78	0.0195	0.4995	0.4810	85.526	2.616	4.154	1.588	83.645	240.69	60.47	1.180	1.073	1.028	−4183	2396	54.267	30.665
0.20	0.03	0.19	0.78	0.0292	0.4941	0.4767	85.534	2.621	4.146	1.582	83.719	240.88	60.53	1.176	1.071	1.028	−4186	2389	54.161	30.588
0.20	0.04	0.19	0.77	0.0388	0.4888	0.4724	85.542	2.626	4.139	1.576	83.793	241.06	60.59	1.172	1.070	1.029	−4190	2383	54.054	30.512
0.20	0.05	0.19	0.76	0.0484	0.4835	0.4682	85.551	2.631	4.131	1.570	83.876	241.27	60.65	1.169	1.069	1.029	−4193	2376	53.948	30.436
0.20	0.07	0.19	0.74	0.0674	0.4729	0.4597	85.568	2.641	4.115	1.558	84.033	241.66	60.77	1.161	1.066	1.030	−4200	2363	53.736	30.285
0.20	0.10	0.18	0.72	0.0957	0.4573	0.4470	85.594	2.656	4.092	1.541	84.274	242.25	60.96	1.150	1.063	1.032	−4211	2344	53.420	30.061
0.20	0.20	0.16	0.64	0.1879	0.4069	0.4052	85.695	2.707	4.017	1.484	85.216	244.59	61.68	1.117	1.054	1.040	−4250	2282	52.376	29.328
0.20	0.40	0.12	0.48	0.3685	0.3108	0.3206	85.947	2.812	3.878	1.379	87.602	250.48	63.52	1.066	1.048	1.066	−4340	2161	50.337	27.881
0.20	0.60	0.08	0.32	0.5541	0.2158	0.2302	86.280	2.921	3.750	1.284	90.832	258.43	66.01	1.030	1.057	1.104	−4444	2038	48.366	26.371
0.20	0.80	0.04	0.16	0.7583	0.1150	0.1267	86.717	3.033	3.630	1.197	95.211	269.15	69.39	1.009	1.082	1.157	−4563	1903	46.464	24.673
0.20	0.90	0.02	0.08	0.8729	0.0599	0.0671	86.987	3.090	3.572	1.156	97.996	275.93	71.55	1.003	1.101	1.188	−4628	1827	45.539	23.701
0.40	0.00	0.40	0.60	0.0000	0.7339	0.2661	82.557	2.639	4.138	1.568	—	179.50	42.12	—	1.036	1.067	−4012	2320	54.860	31.014
0.40	0.01	0.40	0.59	0.0070	0.7285	0.2646	82.590	2.644	4.131	1.562	—	180.11	42.29	—	1.035	1.067	−4017	2316	54.749	30.957
0.40	0.02	0.39	0.59	0.0139	0.7230	0.2630	82.623	2.649	4.123	1.557	—	180.72	42.47	—	1.034	1.067	−4022	2313	54.637	30.899
0.40	0.03	0.39	0.58	0.0209	0.7176	0.2615	82.656	2.654	4.116	1.551	—	181.33	42.65	—	1.033	1.068	−4028	2309	54.526	30.841
0.40	0.04	0.38	0.58	0.0279	0.7121	0.2600	82.689	2.659	4.108	1.545	—	181.95	42.82	—	1.033	1.068	−4033	2305	54.415	30.783
0.40	0.05	0.38	0.57	0.0349	0.7067	0.2585	82.722	2.664	4.101	1.540	—	182.56	43.00	—	1.032	1.068	−4038	2301	54.304	30.724
0.40	0.07	0.37	0.56	0.0490	0.6957	0.2553	82.789	2.673	4.087	1.529	—	183.81	43.37	—	1.031	1.069	−4049	2294	54.083	30.607
0.40	0.10	0.36	0.54	0.0702	0.6792	0.2506	82.890	2.688	4.066	1.513	—	185.71	43.92	—	1.029	1.071	−4066	2282	53.752	30.431
0.40	0.20	0.32	0.48	0.1424	0.6237	0.2340	83.238	2.738	3.998	1.460	—	192.37	45.87	—	1.027	1.077	−4123	2243	52.662	29.830
0.40	0.40	0.24	0.36	0.2971	0.5066	0.1963	83.994	2.842	3.871	1.362	70.40	207.45	50.35	1.069	1.031	1.097	−4250	2158	50.537	28.539
0.40	0.60	0.16	0.24	0.4762	0.3743	0.1496	84.870	2.947	3.753	1.273	77.76	226.01	55.96	1.034	1.049	1.129	−4389	2056	48.489	27.042
0.40	0.80	0.08	0.12	0.6988	0.2133	0.0880	85.936	3.052	3.637	1.192	87.50	250.22	63.43	1.012	1.079	1.171	−4538	1926	46.520	25.171
0.40	0.90	0.04	0.06	0.8364	0.1153	0.0483	86.573	3.101	3.577	1.153	93.75	265.58	68.26	1.004	1.100	1.196	−4616	1844	45.566	24.005
0.60	0.00	0.60	0.40	0.0000	0.8586	0.1414	80.441	2.657	4.047	1.523	—	143.61	31.97	—	1.010	1.121	−3821	2256	55.455	31.192
0.60	0.01	0.59	0.40	0.0054	0.8538	0.1408	80.485	2.661	4.041	1.519	—	144.30	32.16	—	1.009	1.121	−3828	2254	55.334	31.145
0.60	0.02	0.59	0.39	0.0108	0.8489	0.1402	80.530	2.666	4.036	1.514	—	145.00	32.35	—	1.009	1.120	−3836	2252	55.214	31.097
0.60	0.03	0.58	0.39	0.0163	0.8441	0.1396	80.574	2.671	4.030	1.509	—	145.69	32.54	—	1.009	1.121	−3843	2249	55.093	31.050

0.60	0.04	0.58	0.38	0.0218	0.8392	0.1390	80.619	2.676	4.024	1.504	—	146.40	32.74	—	1.008	1.121	–3851	2247	54.973	31.002
0.60	0.05	0.57	0.38	0.0273	0.8343	0.1384	80.664	2.681	4.018	1.499	—	147.12	32.94	—	1.008	1.121	–3859	2245	54.853	30.954
0.60	0.07	0.56	0.37	0.0384	0.8244	0.1372	80.755	2.690	4.007	1.489	—	148.56	33.34	—	1.008	1.121	–3874	2240	54.614	30.857
0.60	0.10	0.54	0.36	0.0554	0.8094	0.1352	80.893	2.705	3.991	1.475	—	150.78	33.95	—	1.007	1.121	–3898	2233	54.257	30.709
0.60	0.20	0.48	0.32	0.1145	0.7573	0.1282	81.368	2.756	3.938	1.429	—	158.60	36.14	—	1.008	1.123	–3978	2207	53.083	30.196
0.60	0.40	0.36	0.24	0.2487	0.6402	0.1112	82.415	2.860	3.839	1.342	—	176.90	41.36	—	1.019	1.135	–4148	2147	50.811	29.035
0.60	0.60	0.24	0.16	0.4170	0.4949	0.0881	83.658	2.967	3.743	1.262	—	200.64	48.32	—	1.041	1.155	–4327	2066	48.644	27.586
0.60	0.80	0.12	0.08	0.6475	0.2979	0.0546	85.216	3.068	3.640	1.186	80.82	233.67	58.30	1.015	1.077	1.186	–4512	1945	46.584	25.615
0.60	0.90	0.06	0.04	0.8025	0.1665	0.0310	86.175	3.111	3.581	1.151	89.80	255.91	65.21	1.006	1.099	1.204	–4604	1858	45.595	24.292
0.80	0.00	0.80	0.20	0.0000	0.9404	0.0596	78.768	2.673	3.942	1.475	—	119.30	25.42	—	0.998	1.189	–3620	2205	56.237	31.347
0.80	0.01	0.79	0.20	0.0044	0.9362	0.0594	78.820	2.677	3.938	1.471	—	120.01	25.60	—	0.998	1.188	–3630	2204	56.103	31.306
0.80	0.02	0.78	0.20	0.0089	0.9319	0.0592	78.871	2.682	3.934	1.467	—	120.70	25.79	—	0.998	1.187	–3640	2202	55.970	31.266
0.80	0.03	0.78	0.19	0.0133	0.9276	0.0590	78.923	2.687	3.930	1.463	—	121.41	25.97	—	0.998	1.187	–3650	2201	55.836	31.225
0.80	0.04	0.77	0.19	0.0179	0.9233	0.0588	78.974	2.691	3.926	1.459	—	122.12	26.16	—	0.998	1.186	–3660	2200	55.704	31.183
0.80	0.05	0.76	0.19	0.0224	0.9190	0.0586	79.027	2.696	3.921	1.455	—	122.85	26.35	—	0.997	1.186	–3670	2198	55.571	31.142
0.80	0.07	0.74	0.19	0.0317	0.9102	0.0581	79.132	2.705	3.913	1.447	—	124.31	26.74	—	0.997	1.185	–3691	2195	55.307	31.058
0.80	0.10	0.72	0.18	0.0458	0.8967	0.0575	79.292	2.720	3.901	1.434	—	126.55	27.34	—	0.997	1.183	–3721	2191	54.914	30.929
0.80	0.20	0.64	0.16	0.0958	0.8492	0.0550	79.848	2.769	3.863	1.395	—	134.60	29.51	—	0.999	1.179	–3825	2175	53.625	30.476
0.80	0.40	0.48	0.12	0.2139	0.7375	0.0486	81.090	2.874	3.793	1.320	—	153.99	34.85	—	1.011	1.178	–4039	2133	51.154	29.417
0.80	0.60	0.32	0.08	0.3708	0.5897	0.0396	82.596	2.982	3.723	1.249	—	180.22	42.32	—	1.036	1.185	–4261	2069	48.829	28.030
0.80	0.80	0.16	0.04	0.6029	0.3716	0.0255	84.549	3.082	3.639	1.181	74.99	219.07	53.85	1.018	1.074	1.201	–4483	1960	46.656	26.011
0.80	0.90	0.08	0.02	0.7712	0.2139	0.0149	85.793	3.121	3.584	1.148	86.14	246.87	62.39	1.008	1.098	1.212	–4591	1872	45.625	24.563
0.90	0.00	0.90	0.10	0.0000	0.9722	0.0278	78.036	2.683	3.891	1.450	—	109.71	22.91	—	0.998	1.228	–3519.2	2182.4	56.7	31.418
0.90	0.01	0.89	0.10	0.0040	0.9683	0.0277	78.090	2.687	3.888	1.447	—	110.4	23.088	—	0.997	1.227	–3530.4	2181.5	56.6	31.380
0.90	0.02	0.88	0.10	0.0081	0.9643	0.0276	78.144	2.692	3.884	1.443	—	111.09	23.267	—	0.997	1.226	–3541.6	2180.5	56.4	31.342
0.90	0.03	0.87	0.10	0.0122	0.9603	0.0275	78.199	2.696	3.881	1.439	—	111.79	23.45	—	0.997	1.225	–3552.8	2179.5	56.3	31.303
0.90	0.04	0.86	0.10	0.0164	0.9562	0.0274	78.254	2.701	3.877	1.436	—	112.5	23.634	—	0.997	1.224	–3564.1	2178.5	56.1	31.264
0.90	0.05	0.86	0.10	0.0206	0.9521	0.0273	78.309	2.705	3.874	1.432	—	113.22	23.82	—	0.997	1.223	–3575.3	2177.5	56.0	31.225
0.90	0.07	0.84	0.09	0.0291	0.9438	0.0271	78.420	2.714	3.867	1.425	—	114.67	24.198	—	0.996	1.221	–3598	2175.3	55.7	31.146
0.90	0.10	0.81	0.09	0.0421	0.9310	0.0268	78.589	2.728	3.857	1.414	—	116.9	24.783	—	0.996	1.219	–3632.1	2172	55.3	31.024
0.90	0.20	0.72	0.08	0.0886	0.8857	0.0257	79.177	2.776	3.825	1.378	—	124.93	26.908	—	0.998	1.211	–3747.3	2159.4	53.9	30.594
0.90	0.40	0.54	0.06	0.1999	0.7772	0.0229	80.497	2.880	3.768	1.308	—	144.49	32.209	—	1.009	1.202	–3983.9	2124.8	51.3	29.578
0.90	0.60	0.36	0.04	0.3513	0.6299	0.0189	82.110	2.988	3.711	1.242	—	171.42	39.784	—	1.034	1.201	–4226.4	2068.5	48.9	28.223
0.90	0.80	0.18	0.02	0.5828	0.4049	0.0124	84.233	3.088	3.638	1.178	72.35	212.4	51.833	1.020	1.073	1.209	–4468.2	1965.6	46.7	26.192
0.90	0.90	0.09	0.01	0.7563	0.2364	0.0073	85.608	3.125	3.585	1.147	84.404	242.58	61.055	1.009	1.097	1.216	–4584.8	1877.8	45.6	24.692
0.97	0.00	0.97	0.03	0.0000	0.9921	0.0080	77.555	2.691	3.857	1.433	—	103.74	21.375	—	0.999	1.257	–3448.5	2167.6	57.0	31.465
0.97	0.01	0.96	0.03	0.0038	0.9883	0.0079	77.610	2.695	3.854	1.430	—	104.41	21.546	—	0.999	1.256	–3460.5	2166.9	56.9	31.429
0.97	0.02	0.95	0.03	0.0077	0.9844	0.0079	77.666	2.700	3.851	1.426	—	105.09	21.722	—	0.998	1.254	–3472.5	2166.1	56.7	31.392
0.97	0.03	0.94	0.03	0.0116	0.9806	0.0079	77.722	2.704	3.848	1.423	—	105.78	21.898	—	0.998	1.253	–3484.6	2165.3	56.6	31.355
0.97	0.04	0.93	0.03	0.0155	0.9767	0.0079	77.779	2.708	3.844	1.420	—	106.49	22.079	—	0.998	1.252	–3496.6	2164.5	56.5	31.318
0.97	0.05	0.92	0.03	0.0195	0.9727	0.0078	77.836	2.712	3.841	1.416	—	107.2	22.261	—	0.998	1.251	–3508.7	2163.7	56.3	31.280
0.97	0.07	0.90	0.03	0.0275	0.9647	0.0078	77.950	2.721	3.835	1.409	—	108.62	22.629	—	0.998	1.249	–3533	2162.1	56.0	31.203
0.97	0.10	0.87	0.03	0.0399	0.9524	0.0077	78.125	2.735	3.826	1.399	—	110.85	23.204	—	0.997	1.245	–3569.5	2159.4	55.6	31.086
0.97	0.20	0.78	0.02	0.0842	0.9084	0.0074	78.734	2.781	3.798	1.366	—	118.85	25.294	—	0.998	1.235	–3692.7	2149.1	54.2	30.670
0.97	0.40	0.58	0.02	0.1912	0.8022	0.0066	80.104	2.884	3.750	1.300	—	138.44	30.551	—	1.009	1.219	–3944.8	2119.2	51.5	29.681
0.97	0.60	0.39	0.01	0.3389	0.6557	0.0055	81.786	2.992	3.702	1.237	—	165.73	38.159	—	1.033	1.212	–4202.1	2068.1	49.0	28.347
0.97	0.80	0.19	0.01	0.5694	0.4270	0.0036	84.018	3.092	3.636	1.176	70.593	207.94	50.496	1.022	1.072	1.215	–4457.7	1969.5	46.7	26.313
0.97	0.90	0.10	0.00	0.7462	0.2516	0.0022	85.481	3.128	3.585	1.146	83.23	239.66	60.153	1.009	1.097	1.219	–4580.2	1881.9	45.7	24.780
1.00	0.00	1.00	0.00	0.0000	1.0000	0.0000	77.355	2.695	—	—	—	101.33	20.762	—	1.000	—	–3418.2	2161.5	57.2	31.485
1.00	0.01	0.99	0.00	0.0037	0.9963	0.0000	77.411	2.699	—	—	—	102	20.932	—	1.000	—	–3430.5	2160.8	57.0	31.449
1.00	0.02	0.98	0.00	0.0075	0.9925	0.0000	77.468	2.703	—	—	—	102.68	21.106	—	0.999	—	–3442.9	2160.1	56.9	31.413
1.00	0.03	0.97	0.00	0.0113	0.9887	0.0000	77.525	2.708	—	—	—	103.37	21.282	—	0.999	—	–3455.3	2159.4	56.7	31.377
1.00	0.04	0.96	0.00	0.0151	0.9849	0.0000	77.582	2.712	—	—	—	104.06	21.459	—	0.999	—	–3467.7	2158.7	56.6	31.340
1.00	0.05	0.95	0.00	0.0190	0.9810	0.0000	77.640	2.716	—	—	—	104.77	21.64	—	0.999	—	–3480.2	2158	56.4	31.303
1.00	0.07	0.93	0.00	0.0269	0.9731	0.0000	77.756	2.725	—	—	—	106.2	22.006	—	0.998	—	–3505.1	2156.5	56.2	31.227
1.00	0.10	0.90	0.00	0.0390	0.9610	0.0000	77.933	2.738	—	—	—	108.41	22.574	—	0.998	—	–3542.7	2154.1	55.7	31.112
1.00	0.20	0.80	0.00	0.0824	0.9176	0.0000	78.550	2.784	—	—	—	116.38	24.647	—	0.999	—	–3669.3	2144.7	54.3	30.701
1.00	0.40	0.60	0.00	0.1877	0.8123	0.0000	79.941	2.885	—	—	—	135.99	29.883	—	1.009	—	–3927.9	2116.8	51.6	29.723
1.00	0.60	0.40	0.00	0.3338	0.6662	0.0000	81.650	2.994	—	—	—	163.38	37.493	—	1.033	—	–4191.7	2067.7	49.0	28.398
1.00	0.80	0.20	0.00	0.5639	0.4361	0.0000	83.928	3.094	—	—	69.867	206.1	49.945	1.022	1.072	—	–4453.2	1971	46.7	26.364
1.00	0.90	0.10	0.00	0.7420	0.2580	0.0000	85.426	3.130	—	—	82.725	238.41	59.766	1.010	1.097	—	–4578.2	1883.6	45.7	24.817
Pressure, 405.3 kPa (4 atm)																				
0.00	0.00	0.00	1.00	0.0000	0.0000	1.0000	105.910	—	—	1.392	503.85	1146.8	405.33	1.120	—	1.000	–3392.4	2857	56.8	33.744
0.00	0.01	0.00	0.99	0.0138	0.0000	0.9862	105.850	—	—	1.388	501.72	1142.6	403.52	1.117	—	1.001	–3397.5	2843.2	56.7	33.638

TABLE 2-191 Liquid-Vapor Equilibrium Data for the Argon-Nitrogen-Oxygen System (*Concluded*)

Liquid mole fraction				Vapor mole fraction				Relative volatility			p^0 (kPa)			Activity coefficent			Enthalpy kJ/kmol		Isobaric specific heat, kJ/(kmol·K)	
$N_2/(N_2+O_2)$	Ar	N_2	O_2	Ar	N_2	O_2	Temperature K	N_2/Ar	N_2/O_2	Ar/O_2	Ar	N_2	O_2	Ar	N_2	O_2	Liquid	Vapor	Liquid	Vapor
Pressure, 405.3 kPa (4 atm)																				
0.00	0.02	0.00	0.98	0.0275	0.0000	0.9725	105.790	—	—	1.385	499.6	1138.3	401.72	1.115	—	1.001	–3402.6	2829.5	56.5	33.534
0.00	0.03	0.00	0.97	0.0410	0.0000	0.9590	105.740	—	—	1.381	497.83	1134.8	400.22	1.112	—	1.001	–3407.8	2816.1	56.4	33.431
0.00	0.04	0.00	0.96	0.0543	0.0000	0.9457	105.680	—	—	1.378	495.72	1130.5	398.43	1.110	—	1.002	–3412.9	2802.8	56.3	33.329
0.00	0.05	0.00	0.95	0.0675	0.0000	0.9326	105.630	—	—	1.374	493.96	1127	396.94	1.107	—	1.002	–3418	2789.7	56.2	33.229
0.00	0.07	0.00	0.93	0.0933	0.0000	0.9067	105.520	—	—	1.367	490.12	1119.3	393.68	1.102	—	1.004	–3428.3	2764	56.0	33.031
0.00	0.10	0.00	0.90	0.1310	0.0000	0.8690	105.370	—	—	1.357	484.91	1108.8	389.27	1.095	—	1.005	–3443.6	2726.7	55.7	32.744
0.00	0.20	0.00	0.80	0.2484	0.0000	0.7516	104.900	—	—	1.322	468.86	1076.5	375.67	1.074	—	1.014	–3495.1	2611.3	54.6	31.846
0.00	0.40	0.00	0.60	0.4556	0.0000	0.5445	104.150	—	—	1.255	444.04	1026.3	354.7	1.040	—	1.037	–3601.7	2411.9	52.5	30.249
0.00	0.60	0.00	0.40	0.6412	0.0000	0.3588	103.590	—	—	1.191	426.16	989.9	339.63	1.016	—	1.071	–3716.7	2238.3	50.5	28.788
0.00	0.80	0.00	0.20	0.8190	0.0000	0.1810	103.190	—	—	1.131	413.71	964.49	329.15	1.003	—	1.115	–3842.6	2076.7	48.6	27.354
0.00	0.90	0.00	0.10	0.9084	0.0000	0.0916	103.030	—	—	1.102	408.8	954.46	325.03	1.001	—	1.142	–3910.1	1997.2	47.6	26.620
0.10	0.00	0.10	0.90	0.0000	0.2399	0.7601	103.430	2.045	2.840	1.389	421.14	979.68	335.41	1.129	0.992	1.021	–3351.1	2779.8	56.8	33.931
0.10	0.01	0.10	0.89	0.0117	0.2369	0.7515	103.400	2.048	2.837	1.385	420.21	977.77	334.62	1.127	0.992	1.022	–3356.1	2769.2	56.7	33.841
0.10	0.02	0.10	0.88	0.0233	0.2339	0.7429	103.380	2.051	2.833	1.381	419.59	976.5	334.1	1.124	0.990	1.022	–3361.1	2758.7	56.5	33.752
0.10	0.03	0.10	0.87	0.0348	0.2309	0.7343	103.360	2.054	2.830	1.378	418.97	975.23	333.57	1.121	0.989	1.022	–3366.1	2748.2	56.4	33.663
0.10	0.04	0.10	0.86	0.0462	0.2280	0.7259	103.340	2.057	2.827	1.374	418.34	973.97	333.05	1.118	0.988	1.022	–3371.1	2737.9	56.3	33.575
0.10	0.05	0.10	0.86	0.0575	0.2251	0.7174	103.320	2.060	2.823	1.370	417.72	972.7	332.53	1.116	0.987	1.023	–3376.2	2727.6	56.2	33.488
0.10	0.07	0.09	0.84	0.0799	0.2193	0.7008	103.280	2.066	2.817	1.363	416.49	970.17	331.49	1.111	0.985	1.024	–3386.3	2707.4	56.0	33.315
0.10	0.10	0.09	0.81	0.1129	0.2109	0.6762	103.220	2.075	2.807	1.352	414.63	966.38	329.93	1.104	0.983	1.026	–3401.7	2677.6	55.7	33.059
0.10	0.20	0.08	0.72	0.2186	0.1841	0.5973	103.060	2.105	2.774	1.317	409.72	956.33	325.8	1.081	0.975	1.032	–3454.5	2583	54.6	32.238
0.10	0.40	0.06	0.54	0.4159	0.1352	0.4489	102.840	2.166	2.709	1.251	403.04	942.64	320.19	1.046	0.968	1.052	–3568	2409.5	52.6	30.684
0.10	0.60	0.04	0.36	0.6047	0.0899	0.3054	102.740	2.229	2.648	1.188	400.02	936.47	317.66	1.021	0.972	1.082	–3693.2	2247.1	50.6	29.163
0.10	0.80	0.02	0.18	0.7958	0.0456	0.1586	102.760	2.294	2.591	1.129	400.62	937.7	318.16	1.006	0.986	1.122	–3830.8	2086.1	48.6	27.585
0.10	0.90	0.01	0.09	0.8955	0.0232	0.0813	102.820	2.328	2.563	1.101	402.43	941.41	319.68	1.002	0.997	1.146	–3904.2	2003.1	47.6	26.748
0.20	0.00	0.20	0.80	0.0000	0.4159	0.5841	101.340	2.061	2.848	1.382	359.58	853.02	283.81	1.138	0.988	1.043	–3293.1	2714.9	56.9	34.186
0.20	0.01	0.20	0.79	0.0101	0.4114	0.5785	101.340	2.064	2.845	1.378	359.58	853.02	283.81	1.135	0.987	1.043	–3298.4	2706.6	56.8	34.106
0.20	0.02	0.20	0.78	0.0201	0.4069	0.5730	101.340	2.067	2.841	1.375	359.58	853.02	283.81	1.132	0.986	1.044	–3303.7	2698.3	56.6	34.026
0.20	0.03	0.19	0.78	0.0301	0.4025	0.5674	101.350	2.070	2.837	1.371	359.85	853.59	284.04	1.129	0.985	1.043	–3309.1	2690.1	56.5	33.946
0.20	0.04	0.19	0.77	0.0400	0.3981	0.5619	101.350	2.072	2.834	1.367	359.85	853.59	284.04	1.127	0.984	1.044	–3314.5	2681.9	56.4	33.867
0.20	0.05	0.19	0.76	0.0499	0.3937	0.5564	101.350	2.075	2.830	1.364	359.85	853.59	284.04	1.124	0.984	1.045	–3319.9	2673.7	56.3	33.787
0.20	0.07	0.19	0.74	0.0696	0.3849	0.5455	101.360	2.081	2.823	1.356	360.13	854.17	284.27	1.119	0.982	1.045	–3330.8	2657.6	56.1	33.630
0.20	0.10	0.18	0.72	0.0989	0.3720	0.5291	101.380	2.089	2.812	1.346	360.69	855.32	284.74	1.111	0.979	1.046	–3347.5	2633.6	55.8	33.395
0.20	0.20	0.16	0.64	0.1948	0.3300	0.4753	101.440	2.118	2.777	1.311	362.36	858.79	286.13	1.089	0.973	1.052	–3405.2	2555.4	54.7	32.622
0.20	0.40	0.12	0.48	0.3822	0.2496	0.3682	101.640	2.176	2.711	1.246	367.98	870.43	290.82	1.052	0.968	1.069	–3530.2	2404.5	52.6	31.093
0.20	0.60	0.08	0.32	0.5719	0.1706	0.2575	101.940	2.237	2.649	1.185	376.52	888.1	297.97	1.026	0.973	1.095	–3668.1	2253.6	50.6	29.517
0.20	0.80	0.04	0.16	0.7738	0.0889	0.1373	102.350	2.299	2.592	1.127	388.44	912.66	307.94	1.009	0.987	1.129	–3818.6	2094.6	48.6	27.809
0.20	0.90	0.02	0.08	0.8829	0.0457	0.0713	102.610	2.330	2.564	1.100	396.13	928.48	314.4	1.004	0.998	1.150	–3898.3	2008.8	47.6	26.873
0.40	0.00	0.40	0.60	0.0000	0.6538	0.3462	97.997	2.082	2.832	1.360	275.25	675.50	213.91	1.156	0.981	1.093	–3143.7	2610.3	57.346	34.697
0.40	0.01	0.40	0.59	0.0079	0.6484	0.3438	98.032	2.084	2.829	1.357	276.05	677.21	214.57	1.153	0.980	1.093	–3150.5	2605.1	57.232	34.629
0.40	0.02	0.39	0.59	0.0157	0.6429	0.3414	98.067	2.087	2.825	1.354	276.85	678.92	215.23	1.150	0.979	1.093	–3157.4	2599.8	57.118	34.560
0.40	0.03	0.39	0.58	0.0236	0.6375	0.3389	98.101	2.090	2.822	1.350	277.63	680.58	215.87	1.148	0.978	1.093	–3164.4	2594.5	57.004	34.492
0.40	0.04	0.38	0.58	0.0315	0.6321	0.3364	98.136	2.092	2.818	1.347	278.43	682.30	216.53	1.145	0.978	1.093	–3171.3	2589.2	56.891	34.423
0.40	0.05	0.38	0.57	0.0394	0.6267	0.3340	98.172	2.095	2.815	1.344	279.26	684.07	217.21	1.142	0.977	1.093	–3178.3	2584.0	56.778	34.354
0.40	0.07	0.37	0.56	0.0552	0.6159	0.3290	98.242	2.100	2.808	1.337	280.88	687.51	218.54	1.137	0.976	1.093	–3192.4	2573.4	56.551	34.217
0.40	0.10	0.36	0.54	0.0790	0.5996	0.3214	98.350	2.108	2.798	1.327	283.38	692.86	220.61	1.130	0.974	1.094	–3213.9	2557.4	56.212	34.009
0.40	0.20	0.32	0.48	0.1595	0.5449	0.2956	98.721	2.136	2.765	1.295	292.12	711.44	227.81	1.106	0.970	1.096	–3287.5	2503.3	55.091	33.304
0.40	0.40	0.24	0.36	0.3285	0.4320	0.2396	99.531	2.192	2.704	1.234	311.88	753.27	244.15	1.067	0.968	1.105	–3444.6	2389.2	52.889	31.817
0.40	0.60	0.16	0.24	0.5155	0.3092	0.1752	100.460	2.249	2.647	1.177	335.75	803.38	263.96	1.037	0.975	1.121	–3613.8	2261.2	50.745	30.162
0.40	0.80	0.08	0.12	0.7330	0.1691	0.0979	101.570	2.307	2.592	1.124	366.00	866.34	289.17	1.015	0.989	1.143	–3793.2	2109.2	48.673	28.233
0.40	0.90	0.04	0.06	0.8588	0.0891	0.0521	102.200	2.335	2.564	1.098	384.05	903.62	304.26	1.007	0.999	1.157	–3886.1	2019.4	47.668	27.117
0.60	0.00	0.60	0.40	0.0000	0.8073	0.1927	95.398	2.095	2.793	1.333	220.63	557.21	169.24	1.180	0.979	1.154	–2969.3	2527.7	58.120	35.181
0.60	0.01	0.59	0.40	0.0064	0.8019	0.1916	95.451	2.097	2.790	1.330	221.66	559.46	170.08	1.177	0.978	1.153	–2978.2	2524.3	57.994	35.120
0.60	0.02	0.59	0.39	0.0129	0.7966	0.1906	95.503	2.100	2.787	1.327	222.67	561.68	170.90	1.174	0.978	1.153	–2987.2	2520.9	57.869	35.057
0.60	0.03	0.58	0.39	0.0194	0.7912	0.1895	95.556	2.102	2.784	1.324	223.70	563.94	171.74	1.172	0.977	1.152	–2996.2	2517.5	57.743	34.995
0.60	0.04	0.58	0.38	0.0259	0.7857	0.1883	95.610	2.105	2.781	1.321	224.76	566.25	172.59	1.169	0.976	1.152	–3005.3	2514.0	57.618	34.932
0.60	0.05	0.57	0.38	0.0325	0.7803	0.1872	95.663	2.108	2.778	1.318	225.80	568.53	173.44	1.166	0.976	1.151	–3014.3	2510.5	57.493	34.869

0.60	0.07	0.56	0.37	0.0457	0.7694	0.1850	95.771	2.113	2.773	1.312	227.93	573.19	175.17	1.160	0.975	1.150	−3032.6	2503.5	57.243	34.742
0.60	0.10	0.54	0.36	0.0657	0.7528	0.1815	95.934	2.121	2.765	1.304	231.17	580.27	177.81	1.152	0.974	1.149	−3060.2	2492.8	56.870	34.550
0.60	0.20	0.48	0.32	0.1350	0.6957	0.1694	96.496	2.148	2.738	1.275	242.61	605.18	187.15	1.127	0.971	1.146	−3154.0	2455.3	55.639	33.887
0.60	0.40	0.36	0.24	0.2878	0.5707	0.1415	97.721	2.203	2.688	1.220	269.02	662.15	208.79	1.084	0.970	1.145	−3349.9	2369.9	53.238	32.433
0.60	0.60	0.24	0.16	0.4690	0.4239	0.1070	99.133	2.260	2.641	1.169	302.05	732.50	236.01	1.049	0.977	1.149	−3554.9	2263.2	50.933	30.730
0.60	0.80	0.12	0.08	0.6962	0.2417	0.0622	100.820	2.314	2.592	1.120	345.35	823.43	271.95	1.021	0.991	1.158	−3766.5	2121.1	48.741	28.628
0.60	0.90	0.06	0.04	0.8358	0.1303	0.0339	101.810	2.339	2.565	1.096	372.80	880.41	294.86	1.010	1.000	1.164	−3873.6	2029.2	47.694	27.351
0.80	0.00	0.80	0.20	0.0000	0.9165	0.0835	93.251	2.106	2.744	1.303	182.01	471.46	138.01	1.212	0.985	1.226	−2783.0	2458.2	59.157	35.652
0.80	0.01	0.79	0.20	0.0055	0.9114	0.0831	93.315	2.108	2.742	1.301	183.08	473.86	138.88	1.209	0.984	1.225	−2794.3	2456.1	59.014	35.593
0.80	0.02	0.78	0.20	0.0110	0.9063	0.0827	93.380	2.111	2.740	1.298	184.17	476.32	139.75	1.205	0.984	1.224	−2805.5	2454.0	58.871	35.533
0.80	0.03	0.78	0.19	0.0165	0.9012	0.0823	93.445	2.113	2.738	1.296	185.27	478.78	140.64	1.202	0.983	1.223	−2816.8	2451.8	58.729	35.474
0.80	0.04	0.77	0.19	0.0221	0.8961	0.0819	93.510	2.116	2.736	1.293	186.37	481.25	141.53	1.199	0.983	1.221	−2828.1	2449.7	58.586	35.414
0.80	0.05	0.76	0.19	0.0277	0.8909	0.0815	93.576	2.118	2.734	1.291	187.50	483.77	142.43	1.196	0.982	1.220	−2839.4	2447.5	58.444	35.354
0.80	0.07	0.74	0.19	0.0390	0.8804	0.0806	93.708	2.123	2.729	1.286	189.76	488.84	144.26	1.190	0.981	1.218	−2862.1	2443.0	58.161	35.232
0.80	0.10	0.72	0.18	0.0563	0.8643	0.0793	93.910	2.131	2.723	1.278	193.27	496.68	147.09	1.181	0.980	1.215	−2896.3	2436.0	57.739	35.047
0.80	0.20	0.64	0.16	0.1171	0.8082	0.0747	94.605	2.157	2.704	1.254	205.71	524.32	157.14	1.153	0.976	1.205	−3011.9	2410.8	56.353	34.405
0.80	0.40	0.48	0.12	0.2562	0.6801	0.0637	96.135	2.212	2.667	1.206	235.21	589.09	181.11	1.104	0.975	1.189	−3249.2	2348.3	53.683	32.970
0.80	0.60	0.32	0.08	0.4302	0.5204	0.0494	97.925	2.268	2.631	1.160	273.62	672.00	212.57	1.062	0.981	1.178	−3492.7	2261.3	51.165	31.234
0.80	0.80	0.16	0.04	0.6627	0.3076	0.0297	100.110	2.321	2.590	1.116	326.60	784.23	256.36	1.028	0.994	1.174	−3738.8	2130.7	48.820	28.996
0.80	0.90	0.08	0.02	0.8139	0.1696	0.0165	101.420	2.343	2.565	1.095	361.80	857.63	285.67	1.013	1.002	1.172	−3860.8	2038.1	47.724	27.577
0.90	0.00	0.90	0.10	0.0000	0.9607	0.0393	92.292	2.111	2.719	1.288	166.50	436.43	125.58	1.231	0.991	1.267	−2687.7	2426.8	59.774	35.885
0.90	0.01	0.89	0.10	0.0051	0.9558	0.0391	92.361	2.114	2.717	1.286	167.59	438.89	126.45	1.227	0.991	1.265	−2700.1	2425.2	59.619	35.827
0.90	0.02	0.88	0.10	0.0102	0.9509	0.0389	92.431	2.116	2.716	1.283	168.69	441.39	127.33	1.224	0.990	1.264	−2712.5	2423.6	59.466	35.768
0.90	0.03	0.87	0.10	0.0153	0.9459	0.0387	92.501	2.119	2.714	1.281	169.79	443.90	128.22	1.221	0.989	1.262	−2724.9	2422.0	59.312	35.709
0.90	0.04	0.86	0.10	0.0205	0.9409	0.0385	92.571	2.121	2.712	1.279	170.91	446.42	129.11	1.218	0.989	1.261	−2737.3	2420.3	59.159	35.650
0.90	0.05	0.86	0.10	0.0258	0.9359	0.0384	92.642	2.123	2.710	1.276	172.04	448.99	130.02	1.214	0.988	1.259	−2749.8	2418.6	59.007	35.590
0.90	0.07	0.84	0.09	0.0364	0.9256	0.0380	92.784	2.128	2.707	1.272	174.33	454.16	131.85	1.208	0.987	1.256	−2774.7	2415.2	58.703	35.469
0.90	0.10	0.81	0.09	0.0526	0.9100	0.0374	93.001	2.136	2.702	1.265	177.86	462.14	134.69	1.199	0.985	1.251	−2812.4	2409.7	58.250	35.286
0.90	0.20	0.72	0.08	0.1099	0.8548	0.0354	93.751	2.161	2.686	1.242	190.51	490.50	144.86	1.169	0.981	1.237	−2939.0	2389.6	56.769	34.648
0.90	0.40	0.54	0.06	0.2429	0.7267	0.0304	95.408	2.216	2.655	1.198	220.83	557.64	169.40	1.115	0.978	1.212	−3197.3	2337.1	53.939	33.216
0.90	0.60	0.36	0.04	0.4131	0.5631	0.0238	97.360	2.272	2.625	1.156	261.03	644.98	202.23	1.069	0.983	1.194	−3460.7	2259.1	51.297	31.467
0.90	0.80	0.18	0.02	0.6471	0.3384	0.0145	99.771	2.324	2.589	1.114	317.92	765.99	249.16	1.031	0.995	1.181	−3724.5	2134.7	48.865	29.170
0.90	0.90	0.09	0.01	0.8034	0.1884	0.0082	101.230	2.346	2.565	1.094	356.53	846.69	281.27	1.015	1.002	1.176	−3854.3	2042.2	47.740	27.687
0.97	0.00	0.97	0.03	0.0000	0.9887	0.0113	91.656	2.116	2.702	1.277	156.79	414.28	117.83	1.245	0.997	1.298	−2620.4	2405.9	60.245	36.049
0.97	0.01	0.96	0.03	0.0048	0.9839	0.0113	91.728	2.118	2.700	1.275	157.87	416.75	118.68	1.242	0.996	1.296	−2633.6	2404.6	60.082	35.990
0.97	0.02	0.95	0.03	0.0097	0.9791	0.0112	91.801	2.120	2.699	1.273	158.97	419.26	119.56	1.238	0.996	1.294	−2646.8	2403.3	59.920	35.932
0.97	0.03	0.94	0.03	0.0146	0.9742	0.0112	91.874	2.123	2.697	1.271	160.07	421.78	120.44	1.235	0.995	1.292	−2660.0	2402.0	59.758	35.873
0.97	0.04	0.93	0.03	0.0196	0.9693	0.0111	91.948	2.125	2.696	1.268	161.20	424.35	121.34	1.231	0.994	1.290	−2673.3	2400.6	59.596	35.813
0.97	0.05	0.92	0.03	0.0246	0.9643	0.0111	92.022	2.128	2.694	1.266	162.33	426.93	122.24	1.228	0.993	1.288	−2686.5	2399.3	59.436	35.754
0.97	0.07	0.90	0.03	0.0347	0.9543	0.0110	92.171	2.132	2.691	1.262	164.62	432.16	124.08	1.221	0.992	1.284	−2713.1	2396.5	59.115	35.634
0.97	0.10	0.87	0.03	0.0503	0.9389	0.0108	92.397	2.140	2.687	1.256	168.15	440.17	126.90	1.212	0.990	1.279	−2753.1	2392.0	58.639	35.450
0.97	0.20	0.78	0.02	0.1053	0.8845	0.0102	93.182	2.165	2.673	1.235	180.86	468.87	137.09	1.180	0.985	1.261	−2887.4	2375.1	57.084	34.814
0.97	0.40	0.58	0.02	0.2344	0.7567	0.0088	94.921	2.219	2.647	1.193	211.56	537.25	161.88	1.123	0.981	1.230	−3160.7	2329.1	54.131	33.381
0.97	0.60	0.39	0.01	0.4019	0.5911	0.0070	96.979	2.274	2.621	1.152	252.78	627.20	195.47	1.074	0.984	1.205	−3437.9	2257.3	51.395	31.622
0.97	0.80	0.19	0.01	0.6366	0.3591	0.0043	99.538	2.326	2.588	1.112	312.06	753.64	244.29	1.034	0.995	1.187	−3714.4	2137.3	48.897	29.289
0.97	0.90	0.10	0.00	0.7962	0.2014	0.0024	101.100	2.347	2.565	1.093	352.96	839.27	278.29	1.016	1.003	1.179	−3849.7	2045.0	47.752	27.763
1.00	0.00	1.00	0.00	0.0000	1.0000	0.0000	91.391	2.118	—	—	152.87	405.30	114.70	1.252	1.000	—	−2591.4	2397.1	60.458	36.119
1.00	0.01	0.99	0.00	0.0047	0.9953	0.0000	91.465	2.120	—	—	153.96	407.79	115.57	1.248	0.999	—	−2605.0	2396.0	60.291	36.060
1.00	0.02	0.98	0.00	0.0095	0.9905	0.0000	91.539	2.122	—	—	155.05	410.30	116.44	1.245	0.998	—	−2618.5	2394.8	60.124	36.002
1.00	0.03	0.97	0.00	0.0143	0.9857	0.0000	91.613	2.125	—	—	156.15	412.81	117.31	1.241	0.998	—	−2632.1	2393.6	59.959	35.943
1.00	0.04	0.96	0.00	0.0192	0.9808	0.0000	91.688	2.127	—	—	157.27	415.38	118.21	1.238	0.997	—	−2645.7	2392.4	59.793	35.883
1.00	0.05	0.95	0.00	0.0241	0.9759	0.0000	91.763	2.129	—	—	158.39	417.95	119.10	1.234	0.996	—	−2659.3	2391.2	59.629	35.824
1.00	0.07	0.93	0.00	0.0341	0.9659	0.0000	91.915	2.134	—	—	160.69	423.20	120.94	1.228	0.995	—	−2686.6	2388.6	59.301	35.704
1.00	0.10	0.90	0.00	0.0493	0.9507	0.0000	92.146	2.141	—	—	164.24	431.27	123.77	1.217	0.993	—	−2727.6	2384.6	58.814	35.520
1.00	0.20	0.80	0.00	0.1035	0.8965	0.0000	92.945	2.166	—	—	176.95	460.07	133.95	1.185	0.987	—	−2865.3	2369.0	57.225	34.883
1.00	0.40	0.60	0.00	0.2310	0.7690	0.0000	94.718	2.220	—	—	207.79	528.92	158.82	1.126	0.982	—	−3144.8	2325.6	54.217	33.450
1.00	0.60	0.40	0.00	0.3973	0.6027	0.0000	96.818	2.275	—	—	249.36	619.80	192.67	1.076	0.985	—	−3428.1	2256.4	51.438	31.687
1.00	0.80	0.20	0.00	0.6322	0.3678	0.0000	99.439	2.327	—	—	309.59	748.43	242.25	1.035	0.996	—	−3710.1	2138.3	48.912	29.339
1.00	0.90	0.10	0.00	0.7931	0.2069	0.0000	101.040	2.347	—	—	351.32	835.85	276.92	1.017	1.003	—	−3847.7	2046.2	47.757	27.795

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source is Lemmon, E. W., Jacobsen, R. T., Penoncello, S. G., and Friend, D. G., "Thermodynamic Properties of Air and Mixtures of Nitrogen, Argon, and Oxygen from 60 to 2000 K at Pressures to 2000 MPa," *J. Phys. Chem. Ref. Data* **29**(3):331–385, 2000. p° is the vapor pressure.

TABLE 2-192 Thermodynamic Properties of the International Standard Atmosphere*

Z, m	*T*, K	*P*, bar	ρ, kg/m^3	*g*, m/s^2	*M*	*a*, m/s	μ, Pa·s	*k*, W/(m·K)	λ, m	*H*, m
0	288.15	1.01325	1.2250	9.80665	28.964	340.29	1.79.–5	2.54.–5	6.63.–8	0
1,000	281.65	0.89876	1.1117	9.8036	28.964	336.43	1.76.–5	2.49.–5	7.31.–8	1,000
2,000	275.15	0.79501	1.0066	9.8005	28.964	332.53	1.73.–5	2.43.–5	8.07.–8	2,999
3,000	268.66	0.70121	0.90925	9.7974	28.964	328.58	1.69.–5	2.38.–5	8.94.–8	2,999
4,000	262.17	0.61660	0.81935	9.7943	28.964	324.59	1.66.–5	2.33.–5	9.92.–8	3,997
5,000	255.68	0.54048	0.73643	9.7912	28.964	320.55	1.63.–5	2.28.–5	1.10.–7	4,996
6,000	249.19	0.47217	0.66011	9.7882	28.964	316.45	1.59.–5	2.22.–5	1.23.–7	5,994
7,000	242.70	0.41105	0.59002	9.7851	28.964	312.31	1.56.–5	2.17.–5	1.38.–7	6,992
8,000	236.22	0.35651	0.52579	9.7820	28.964	308.11	1.53.–5	2.12.–5	1.55.–7	7,990
9,000	229.73	0.30800	0.46706	9.7789	28.964	303.85	1.49.–5	2.06.–5	1.74.–7	8,987
10,000	223.25	0.26499	0.41351	9.7759	28.964	299.53	1.46.–5	2.01.–5	1.97.–7	9,984
15,000	216.65	0.12111	0.19476	9.7605	28.964	295.07	1.42.–5	1.95.–5	4.17.–7	14,965
20,000	216.65	0.05529	0.08891	9.7452	28.964	295.07	1.42.–5	1.95.–5	9.14.–7	19,937
25,000	221.55	0.02549	0.04008	9.7300	28.964	298.39	1.45.–5	1.99.–5	2.03.–6	24,902
30,000	226.51	0.01197	0.01841	9.7147	28.964	301.71	1.48.–5	2.04.–5	4.42.–6	29,859
40,000	250.35	2.87.–3	4.00.–3	9.6844	28.964	317.19	1.60.–5	2.23.–5	2.03.–5	39,750
50,000	270.65	8.00.–4	1.03.–3	9.6542	28.964	329.80	1.70.–5	2.40.–5	7.91.–5	49,610
60,000	247.02	2.20.–4	3.10.–4	9.6241	28.964	315.07	1.58.–5	2.21.–5	2.62.–4	59,439
70,000	219.59	5.22.–5	8.28.–5	9.5942	28.964	297.06	1.44.–5	1.98.–5	9.81.–4	69,238
80,000	198.64	1.05.–5	1.85.–5	9.5644	28.964	282.54	1.32.–5	1.80.–5	4.40.–3	79,006
90,000	186.87	1.84.–6	3.43.–6	9.5348	28.95				2.37.–2	88,744
100,000	195.08	3.20.–7	5.60.–7	9.5052	28.40				0.142	98,451
150,000	634.39	4.54.–9	2.08.–9	9.3597	24.10				33	146,542
200,000	854.56	8.47.–10	2.54.–10	9.2175	21.30				240	193,899
250,000	941.33	2.48.–10	6.07.–11	9.0785	19.19				890	240,540
300,000	976.01	8.77.–11	1.92.–11	8.9427	17.73				2600	286,480
400,000	995.83	1.45.–11	2.80.–12	8.6799	15.98				1.6.+4	376,320
500,000	999.24	3.02.–12	5.22.–13	8.4286	14.33				7.7.+4	463,540
600,000	999.85	8.21.–13	1.14.–13	8.1880	11.51				2.8.+5	548,252
800,000	999.99	1.70.–13	1.14.–14	7.7368	5.54				1.4.+6	710,574
1,000,000	1000.00	7.51.–14	3.56.–15	7.3218	3.94				3.1.+6	864,071

*Extracted from *U.S. Standard Atmosphere, 1976, National Oceanic and Atmospheric Administration,* National Aeronautics and Space Administration and the U.S. Air Force, Washington, 1976. *Z* = geometric altitude, *T* = temperature, *P* = pressure, *g* = acceleration of gravity, *M* = molecular weight, *a* = velocity of sound, μ = viscosity, *k* = thermal conductivity, λ = mean free path, ρ = density, and *H* = geopotential altitude. The notation 1.79.–5 signifies 1.79×10^{-5}.

TABLE 2-193 Thermodynamic Properties of Benzene

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
278.7	0.0047988	11.441	0.087404	–10.278	–10.278	–0.03257	0.095741	0.13301	1369.2	–0.45084
280	0.0051472	11.424	0.087532	–10.105	–10.105	–0.03196	0.095210	0.13274	1366.0	–0.45037
295	0.010954	11.227	0.089073	–8.1218	–8.1208	–0.02506	0.092757	0.13249	1316.2	–0.43580
310	0.021374	11.024	0.090715	–6.1160	–6.1140	–0.01842	0.094410	0.13531	1251.1	–0.41192
325	0.038777	10.816	0.092455	–4.0576	–4.0540	–0.01194	0.097865	0.13934	1180.0	–0.38479
340	0.066128	10.605	0.094297	–1.9360	–1.9297	–0.00556	0.10197	0.14373	1108.1	–0.35639
355	0.10696	10.389	0.096251	0.25114	0.26143	0.000737	0.10619	0.14815	1037.7	–0.32675
370	0.16531	10.170	0.098331	2.5029	2.5192	0.006950	0.11029	0.15251	969.46	–0.29499
385	0.24565	9.9444	0.10056	4.8180	4.8427	0.013084	0.11418	0.15684	903.49	–0.25976
400	0.35284	9.7123	0.10296	7.1959	7.2322	0.019144	0.11788	0.16124	839.45	–0.21937
415	0.49204	9.4716	0.10558	9.6372	9.6892	0.025138	0.12142	0.16581	776.89	–0.17166
430	0.66869	9.2204	0.10845	12.144	12.217	0.031076	0.12487	0.17070	715.33	–0.11372
445	0.88851	8.9560	0.11166	14.721	14.820	0.036970	0.12827	0.17609	654.26	–0.04137
460	1.1575	8.6747	0.11528	17.372	17.506	0.042839	0.13170	0.18223	593.15	0.05173
475	1.4820	8.3719	0.11945	20.108	20.285	0.048703	0.13524	0.18948	531.41	0.17604
490	1.8689	8.0406	0.12437	22.940	23.172	0.054589	0.13896	0.19847	468.41	0.35018
505	2.3256	7.6701	0.13038	25.887	26.190	0.060537	0.14300	0.21044	403.32	0.61096
520	2.8608	7.2419	0.13809	28.980	29.375	0.066611	0.14755	0.22839	335.01	1.0427
535	3.4853	6.7170	0.14888	32.284	32.802	0.072938	0.15298	0.26197	261.60	1.8878
550	4.2145	5.9774	0.16730	35.991	36.696	0.079902	0.16038	0.37221	179.15	4.2186
562.05	4.9012	3.9561	0.25278	41.513	42.752	0.090526			0	15.682
278.7	0.0047988	0.0020778	481.28	22.307	24.617	0.092630	0.067199	0.075641	182.14	69.790
280	0.0051472	0.0022187	450.72	22.394	24.714	0.092396	0.067633	0.076082	182.47	68.760
295	0.010954	0.0044939	222.52	23.427	25.864	0.090149	0.072601	0.081164	186.19	58.188
310	0.021374	0.0083797	119.34	24.522	27.073	0.088632	0.077506	0.086243	189.61	49.702
325	0.038777	0.014587	68.556	25.676	28.334	0.087716	0.082363	0.091352	192.67	42.885
340	0.066128	0.023968	41.723	26.881	29.640	0.087296	0.087187	0.096528	195.28	37.396
355	0.10696	0.037514	26.657	28.135	30.986	0.087285	0.091992	0.10181	197.37	32.960
370	0.16531	0.056356	17.744	29.431	32.365	0.087613	0.096792	0.10724	198.86	29.366
385	0.24565	0.081780	12.228	30.765	33.769	0.088218	0.10160	0.11287	199.67	26.447
400	0.35284	0.11526	8.6760	32.132	35.194	0.089048	0.10643	0.11877	199.73	24.076
415	0.49204	0.15852	6.3082	33.526	36.630	0.090056	0.11129	0.12502	198.94	22.158
430	0.66869	0.21364	4.6807	34.942	38.072	0.091203	0.11620	0.13176	197.20	20.623
445	0.88851	0.28321	3.5310	36.370	39.508	0.092449	0.12117	0.13918	194.42	19.421
460	1.1575	0.37058	2.6984	37.803	40.927	0.093754	0.12624	0.14759	190.45	18.522
475	1.4820	0.48038	2.0817	39.228	42.313	0.095076	0.13144	0.15753	185.11	17.915
490	1.8689	0.61931	1.6147	40.625	43.642	0.096364	0.13684	0.17002	178.19	17.610
505	2.3256	0.79794	1.2532	41.966	44.880	0.097548	0.14252	0.18715	169.36	17.642
520	2.8608	1.0349	0.96626	43.200	45.965	0.098514	0.14867	0.21415	158.20	18.090
535	3.4853	1.3697	0.73008	44.221	46.766	0.099038	0.15562	0.26827	144.00	19.073
550	4.2145	1.9242	0.51970	44.709	46.899	0.098452	0.16433	0.45840	125.56	20.568
562.05	4.9012	3.9561	0.25278	41.513	42.752	0.090526			0	15.682
Single-Phase Properties										
300.00	0.10000	11.161	0.089602	–7.4606	–7.4516	–0.022832	0.092996	0.13320	1296.2	–0.42861
350.00	0.10000	10.462	0.095585	–0.48554	–0.47598	–0.0013533	0.10479	0.14668	1061.0	–0.33684
352.81	0.10000	10.421	0.095958	–0.072586	–0.062991	–0.00017807	0.10558	0.14751	1047.8	–0.33119
352.81	0.10000	0.035232	28.383	27.949	30.787	0.087264	0.091290	0.10103	197.10	33.552
400.00	0.10000	0.030711	32.562	32.595	35.851	0.10072	0.10432	0.11349	210.66	20.922
450.00	0.10000	0.027110	36.887	38.153	41.842	0.11482	0.11715	0.12601	223.76	13.727
500.00	0.10000	0.024299	41.154	44.322	48.437	0.12870	0.12898	0.13766	235.93	9.5972
550.00	0.10000	0.022032	45.388	51.054	55.592	0.14233	0.13981	0.14838	247.41	7.0666
600.00	0.10000	0.020161	49.600	58.300	63.260	0.15567	0.14967	0.15817	258.31	5.4319

TABLE 2-193 Thermodynamic Properties of Benzene (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Single-Phase Properties										
300.00	1.0000	11.170	0.089523	–7.4897	–7.4002	–0.022929	0.092978	0.13308	1301.8	–0.43004
350.00	1.0000	10.476	0.095456	–0.52680	–0.43135	–0.0014714	0.10480	0.14651	1068.0	–0.33971
400.00	1.0000	9.7282	0.10279	7.1526	7.2554	0.019036	0.11785	0.16097	846.37	–0.22423
450.00	1.0000	8.8655	0.11280	15.593	15.706	0.038922	0.12940	0.17801	634.37	–0.013693
451.58	1.0000	8.8350	0.11319	15.873	15.987	0.039545	0.12977	0.17867	627.51	–0.0036091
451.58	1.0000	0.31908	3.1340	36.999	40.133	0.093016	0.12338	0.14272	192.83	18.991
500.00	1.0000	0.27026	3.7002	43.395	47.096	0.10766	0.13222	0.14607	214.43	11.641
550.00	1.0000	0.23728	4.2144	50.362	54.577	0.12192	0.14175	0.15344	231.44	7.9458
600.00	1.0000	0.21298	4.6952	57.755	62.450	0.13561	0.15089	0.16150	245.85	5.8511
300.00	5.0000	11.213	0.089185	–7.6160	–7.1700	–0.023353	0.092913	0.13259	1325.8	–0.43605
350.00	5.0000	10.537	0.094904	–0.70378	–0.22926	–0.0019818	0.10485	0.14581	1097.9	–0.35136
400.00	5.0000	9.8210	0.10182	6.8987	7.4078	0.018394	0.11775	0.15956	886.30	–0.25035
450.00	5.0000	9.0240	0.11082	15.189	15.743	0.038012	0.12877	0.17438	692.84	–0.088322
500.00	5.0000	8.0418	0.12435	24.331	24.953	0.057399	0.13990	0.19602	496.64	0.27193
550.00	5.0000	6.4075	0.15607	35.199	35.979	0.078369	0.15609	0.27120	246.43	2.1959
600.00	5.0000	1.5540	0.64348	53.945	57.162	0.11554	0.16178	0.21373	176.29	9.3898
300.00	10.000	11.263	0.088783	–7.7671	–6.8793	–0.023867	0.092869	0.13203	1354.1	–0.44280
350.00	10.000	10.608	0.094266	–0.91178	0.030879	–0.0025897	0.10497	0.14508	1132.3	–0.36378
400.00	10.000	9.9256	0.10075	6.6097	7.6172	0.017651	0.11774	0.15816	930.56	–0.27601
450.00	10.000	9.1886	0.10883	14.760	15.848	0.037025	0.12832	0.17132	752.83	–0.15003
500.00	10.000	8.3418	0.11988	23.600	24.799	0.055872	0.13831	0.18753	586.00	0.073722
550.00	10.000	7.2764	0.13743	33.351	34.726	0.074776	0.14918	0.21149	420.33	0.56941
600.00	10.000	5.7109	0.17510	44.567	46.318	0.094920	0.16240	0.25868	257.52	2.1761
350.00	50.000	11.061	0.090412	–2.2210	2.2996	–0.0066440	0.10685	0.14195	1337.7	–0.41928
400.00	50.000	10.527	0.094991	4.9365	9.6861	0.013066	0.11931	0.15301	1173.3	–0.37184
450.00	50.000	10.001	0.099985	12.570	17.570	0.031627	0.12871	0.16219	1041.8	–0.32474
500.00	50.000	9.4723	0.10557	20.624	25.902	0.049177	0.13669	0.17116	932.63	–0.26918
550.00	50.000	8.9322	0.11196	29.094	34.691	0.065924	0.14419	0.18047	839.96	–0.20274
600.00	50.000	8.3797	0.11934	37.984	43.951	0.082032	0.15154	0.18989	761.25	–0.12687
350.00	75.000	11.280	0.088652	–2.8344	3.8145	–0.0087087	0.10831	0.14116	1431.4	–0.43585
400.00	75.000	10.798	0.092613	4.2071	11.153	0.010874	0.12070	0.15181	1277.8	–0.39637
450.00	75.000	10.331	0.096793	11.699	18.958	0.029250	0.12977	0.16021	1157.1	–0.36122
500.00	75.000	9.8716	0.10130	19.570	27.167	0.046542	0.13730	0.16819	1058.5	–0.32227
550.00	75.000	9.4118	0.10625	27.813	35.782	0.062956	0.14435	0.17644	975.53	–0.27775
600.00	75.000	8.9496	0.11174	36.435	44.815	0.078670	0.15124	0.18489	905.02	–0.22901

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Polt, A., Platzer, B., and Maurer, G., "Parameter der thermischen Zustandsgleichung von Bender fuer 14 mehratomige reine Stoffe," *Chem. Tech. (Leipzig)*, **44**(6):216–224, 1992. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in density for benzene are 1% in the vapor phase, 0.3% in the liquid phase up to 400 K (with lower uncertainties at lower temperatures), 1% in the liquid phase between 400 and 500 K, and 2% and rising at temperatures above 500 K. Near the saturation line at temperatures below 350 K, the liquid-phase uncertainty decreases to 0.05%. The uncertainties in vapor pressures are 0.15% at temperatures below 380 K, and 0.5% at higher temperatures. The uncertainties in heat capacities and sound speeds are 2% in the vapor phase and 5% in the liquid phase.

TABLE 2-194 Saturated Bromine*

T, K	P, bar	v_f, m^3/kg	v_g, m^3/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)	μ_f, 10^{-4} Pa·s	k_f, W/(m·K)
260	0.042	3.106.–4	3.195	–147.2	51.8	0.903	1.669	0.486	13.4	0.131
280	0.124	3.168.–4	1.169	–138.9	56.2	0.933	1.629	0.479	11.5	0.127
300	0.310	3.232.–4	0.5002	–131.6	60.6	0.956	1.597	0.475	9.3	0.122
320	0.680	3.311.–4	0.2425	–124.2	64.8	0.978	1.570	0.473	7.8	0.118
340	1.330	3.385.–4	0.1309	–112.3	71.1	1.004	1.539	0.471	6.7	0.114
360	2.384	3.464.–4	0.0767	–108.6	73.1	1.026	1.531	0.470	5.7	0.109
380	4.010	3.550.–4	0.0477	–100.6	76.9	1.048	1.515	0.471	5.0	0.104
400	6.390	3.647.–4	0.0311	–93.4	80.6	1.063	1.501	0.475	4.5	0.099
420	9.730	3.752.–4	0.0211	–85.8	84.0	1.084	1.488	0.480	4.0	0.094
440	14.25	3.885.–4	0.0148	–77.7	87.1	1.103	1.477	0.489	3.7	0.089
460	20.17	4.023.–4	0.0107	–69.0	89.9	1.122	1.467	0.503	3.3	0.084
480	27.75	4.179.–4	0.00786	–59.7	92.2	1.142	1.457	0.527	3.1	0.079
500	37.21	4.378.–4	0.00589	–49.3	94.0	1.161	1.448	0.595	2.8	0.073
520	48.81	4.623.–4	0.00445	–37.7	95.0	1.183	1.438	0.710	2.6	0.066
540	62.80	4.938.–4	0.00337	–24.0	94.8	1.207	1.428	0.860	2.5	0.059
560	79.41	5.368.–4	0.00251	–7.1	92.5	1.237	1.414	1.063	2.3	0.050
580	98.90	6.250.–4	0.00167	18.8	82.5	1.280	1.390	2.31	2.2	0.035
584.2[c]	103.4	8.475.–4	0.00085	64.8	64.8	1.356	1.356	∞	2.1	∞

*Reproduced or converted from a tabulation by Seshadri, Viswanath, and Kuloor, *Ind. J. Technol.*, 6 (1970): 191–198. c = critical point.

TABLE 2-195 Thermodynamic Properties of Butane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
134.9	6.6566E-07	12.645	0.079082	–5.2207	–5.2207	–0.02703	0.083783	0.11467	1826.8	–0.57143	176.56	2304.3
140	1.6922E-06	12.563	0.079598	–4.6347	–4.6347	–0.02277	0.083802	0.11492	1793.1	–0.56883	174.84	1887.3
155	0.00001767	12.323	0.081151	–2.9051	–2.9051	–0.01103	0.083864	0.11573	1699.3	–0.55989	169.24	1195.3
170	0.00011616	12.082	0.082767	–1.1617	–1.1617	–0.00030	0.084118	0.11677	1610.1	–0.54850	163.00	844.68
185	0.00054113	11.840	0.084458	0.59963	0.59967	0.009630	0.084688	0.11813	1523.4	–0.53413	156.32	634.79
200	0.0019390	11.596	0.086236	2.3840	2.3842	0.018903	0.085627	0.11986	1438.2	–0.51637	149.36	496.50
215	0.0056671	11.349	0.088115	4.1972	4.1977	0.027645	0.086949	0.12199	1354.1	–0.49482	142.26	399.50
230	0.014106	11.097	0.090113	6.0455	6.0467	0.035954	0.088641	0.12455	1270.8	–0.46909	135.13	328.38
245	0.030885	10.840	0.092253	7.9351	7.9379	0.043912	0.090679	0.12755	1188.2	–0.43868	128.09	274.41
260	0.060978	10.575	0.094562	9.8722	9.8780	0.051585	0.093026	0.13098	1106.4	–0.40288	121.19	232.32
275	0.11065	10.301	0.097075	11.863	11.874	0.059030	0.095645	0.13488	1025.2	–0.36055	114.50	198.71
290	0.18734	10.016	0.099837	13.914	13.933	0.066292	0.098497	0.13925	944.51	–0.30993	108.06	171.28
305	0.29946	9.7171	0.10291	16.031	16.062	0.073412	0.10155	0.14418	864.09	–0.24825	101.92	148.46
320	0.45624	9.4002	0.10638	18.222	18.271	0.080426	0.10478	0.14976	783.62	–0.17103	96.103	129.09
335	0.66761	9.0607	0.11037	20.494	20.568	0.087371	0.10817	0.15620	702.63	–0.07074	90.627	112.34
350	0.94418	8.6916	0.11505	22.858	22.967	0.094284	0.11173	0.16389	620.37	0.066051	85.498	97.559
365	1.2974	8.2822	0.12074	25.328	25.485	0.10121	0.11552	0.17360	535.75	0.26565	80.706	84.220
380	1.7399	7.8141	0.12797	27.928	28.150	0.10822	0.11966	0.18719	447.13	0.58704	76.219	71.859
395	2.2868	7.2504	0.13792	30.703	31.018	0.11543	0.12445	0.21028	352.08	1.1936	71.976	59.958
410	2.9578	6.4885	0.15412	33.782	34.237	0.12318	0.13061	0.27186	246.50	2.7451	67.979	47.596
425.13	3.796	3.9228	0.25492	39.364	40.331	0.13735			0	15.851		
134.9	6.6566E-07	5.935E-07	1684900	22.482	23.604	0.18665	0.055993	0.064308	148.87	361.89	4.8545	3.3208
140	1.6922E-06	1.4538E-06	687860	22.771	23.935	0.18130	0.057048	0.065363	151.48	315.59	5.0913	3.4522
155	0.00001767	1.3712E-05	72930	23.648	24.937	0.16859	0.059941	0.068258	158.89	218.48	5.8353	3.8372
170	0.00011616	8.2203E-05	12165	24.567	25.980	0.15936	0.062670	0.070995	165.94	157.83	6.6513	4.2205
185	0.00054113	0.00035209	2840.2	25.525	27.062	0.15267	0.065393	0.073744	172.61	117.96	7.5389	4.6014
200	0.0019390	0.0011686	855.70	26.519	28.179	0.14788	0.068227	0.076640	178.87	90.683	8.4974	4.9792
215	0.0056671	0.0031862	313.85	27.550	29.328	0.14453	0.071254	0.079787	184.64	71.432	9.5258	5.3531
230	0.014106	0.0074503	134.22	28.614	30.507	0.14230	0.074521	0.083261	189.81	57.513	10.624	5.7226
245	0.030885	0.015434	64.792	29.709	31.711	0.14094	0.078047	0.087120	194.27	47.254	11.792	6.0877
260	0.060978	0.029042	34.433	30.834	32.934	0.14026	0.081835	0.091404	197.86	39.578	13.034	6.4502
275	0.11065	0.050611	19.759	31.984	34.170	0.14011	0.085872	0.096154	200.46	33.766	14.357	6.8133
290	0.18734	0.082943	12.056	33.156	35.414	0.14037	0.090138	0.10142	201.90	29.330	15.775	7.1826
305	0.29946	0.12941	7.7271	34.343	36.657	0.14094	0.094611	0.10730	202.04	25.936	17.311	7.5668
320	0.45624	0.19420	5.1494	35.541	37.890	0.14174	0.099274	0.11394	200.69	23.353	18.999	7.9782
335	0.66761	0.28270	3.5374	36.739	39.100	0.14269	0.10412	0.12161	197.62	21.423	20.889	8.4346
350	0.94418	0.40241	2.4850	37.923	40.270	0.14372	0.10910	0.13080	192.54	20.061	23.058	8.9610
365	1.2974	0.56471	1.7708	39.073	41.370	0.14473	0.11417	0.14259	185.07	19.268	25.626	9.5964
380	1.7399	0.78888	1.2676	40.147	42.353	0.14559	0.11962	0.16009	174.66	19.058	28.813	10.407
395	2.2868	1.1133	0.89820	41.076	43.130	0.14609	0.12600	0.19220	160.51	19.446	33.129	11.532
410	2.9578	1.6409	0.60943	41.673	43.475	0.14572	0.13401	0.28133	141.36	20.469	40.394	13.373
425.13	3.796	3.9228	0.25492	39.364	40.331	0.13735			0	15.851		
Single-Phase Properties												
150.00	0.10000	12.404	0.080622	–3.4846	-3.4765	–0.014834	0.083837	0.11544	1730.2	–0.56316	171.22	1370.9
200.00	0.10000	11.597	0.086227	2.3816	2.3902	0.018891	0.085632	0.11985	1438.8	–0.51649	149.40	496.90
250.00	0.10000	10.753	0.092993	8.5729	8.5822	0.046489	0.091432	0.12863	1161.4	–0.42760	125.81	259.42
272.31	0.10000	10.351	0.096608	11.502	11.512	0.057711	0.095158	0.13415	1039.7	–0.36868	115.68	204.22
272.31	0.10000	0.046045	21.718	31.776	33.948	0.14010	0.085131	0.095267	200.07	34.694	14.113	6.7480
300.00	0.10000	0.041289	24.220	34.241	36.663	0.14959	0.091498	0.10103	211.28	24.802	16.747	7.4522
350.00	0.10000	0.034963	28.601	39.149	42.009	0.16605	0.10399	0.11299	229.21	14.912	22.115	8.6907
400.00	0.10000	0.030400	32.894	44.681	47.970	0.18195	0.11669	0.12545	245.29	9.8194	28.275	9.8987
450.00	0.10000	0.026924	37.142	50.834	54.548	0.19743	0.12893	0.13755	260.14	6.9019	35.230	11.083
500.00	0.10000	0.024176	41.363	57.578	61.714	0.21252	0.14043	0.14897	274.06	5.0916	42.982	12.248
550.00	0.10000	0.021945	45.569	64.875	69.432	0.22723	0.15112	0.15960	287.25	3.8945	51.533	13.395
150.00	1.0000	12.411	0.080576	–3.4986	–3.4180	–0.014927	0.083887	0.11540	1733.9	–0.56354	171.48	1381.3
200.00	1.0000	11.608	0.086150	2.3598	2.4460	0.018782	0.085677	0.11977	1443.9	–0.51758	149.79	500.58

250.00	1.0000	10.770	0.092855	8.5389	8.6318	0.046353	0.091477	0.12845	1168.5	–0.43053	126.34	261.81
300.00	1.0000	9.8412	0.10161	15.271	15.373	0.070896	0.10054	0.14209	899.57	–0.27749	104.51	157.29
350.00	1.0000	8.6953	0.11500	22.851	22.966	0.094264	0.11173	0.16378	621.53	0.063603	85.560	97.696
352.62	1.0000	8.6234	0.11596	23.281	23.397	0.095491	0.11237	0.16540	605.80	0.095319	84.637	95.139
352.62	1.0000	0.42728	2.3404	38.127	40.468	0.14390	0.10997	0.13262	191.42	19.881	23.473	9.0627
400.00	1.0000	0.34181	2.9256	43.808	46.734	0.16057	0.11928	0.13410	221.49	11.545	29.230	10.156
450.00	1.0000	0.28958	3.4533	50.185	53.638	0.17683	0.13036	0.14250	244.24	7.5723	36.235	11.323
500.00	1.0000	0.25369	3.9418	57.063	61.005	0.19234	0.14132	0.15221	262.94	5.3868	44.067	12.475
550.00	1.0000	0.22679	4.4094	64.449	68.858	0.20730	0.15171	0.16189	279.30	4.0325	52.702	13.611
150.00	5.0000	12.442	0.080374	–3.5595	–3.1577	–0.015338	0.084107	0.11525	1749.9	–0.56513	172.63	1428.2
200.00	5.0000	11.653	0.085815	2.2656	2.6947	0.018306	0.085873	0.11943	1466.4	–0.52214	151.52	516.90
250.00	5.0000	10.838	0.092266	8.3942	8.8555	0.045767	0.091674	0.12773	1199.3	–0.44237	128.64	272.30
300.00	5.0000	9.9548	0.10045	15.037	15.539	0.070104	0.10072	0.14034	943.54	–0.31083	107.50	165.96
350.00	5.0000	8.9238	0.11206	22.411	22.971	0.092982	0.11170	0.15798	694.05	–0.067667	89.620	106.76
400.00	5.0000	7.5216	0.13295	30.873	31.537	0.11581	0.12435	0.18921	430.26	0.64313	75.035	65.426
450.00	5.0000	3.1209	0.32042	44.259	45.861	0.14921	0.14234	0.35080	147.05	11.475	55.862	19.322
500.00	5.0000	1.7051	0.58647	54.030	56.962	0.17272	0.14611	0.18483	208.77	6.6929	51.142	14.775
550.00	5.0000	1.3443	0.74389	62.232	65.951	0.18986	0.15448	0.17804	244.93	4.4692	57.838	14.928
150.00	10.000	12.480	0.080129	–3.6330	–2.8317	–0.015840	0.084373	0.11508	1769.4	–0.56694	174.03	1488.3
200.00	10.000	11.707	0.085415	2.1534	3.0075	0.017730	0.086111	0.11906	1493.4	–0.52718	153.61	537.30
250.00	10.000	10.919	0.091586	8.2254	9.1412	0.045071	0.091916	0.12697	1235.4	–0.45489	131.40	285.19
300.00	10.000	10.082	0.099189	14.776	15.768	0.069202	0.10096	0.13868	993.02	–0.34276	110.99	176.33
350.00	10.000	9.1484	0.10931	21.971	23.064	0.091668	0.11182	0.15374	766.31	–0.16435	94.017	116.79
400.00	10.000	8.0346	0.12446	29.964	31.209	0.11339	0.12357	0.17293	554.16	0.17567	81.081	77.782
450.00	10.000	6.5680	0.15225	38.976	40.499	0.13524	0.13606	0.20093	360.83	1.0509	71.907	48.326
500.00	10.000	4.6089	0.21697	49.153	51.323	0.15803	0.14784	0.22343	243.50	2.9827	65.910	27.075
550.00	10.000	3.2339	0.30923	58.940	62.032	0.17846	0.15662	0.20486	242.94	3.2916	65.615	19.386
150.00	30.000	12.622	0.079224	–3.9002	–1.5235	–0.017740	0.085345	0.11453	1842.9	–0.57242	179.28	1748.0
200.00	30.000	11.905	0.083996	1.7557	4.2756	0.015602	0.086999	0.11796	1591.7	–0.54200	161.37	619.22
250.00	30.000	11.197	0.089313	7.6534	10.333	0.042606	0.092823	0.12491	1361.4	–0.48867	141.44	335.06
300.00	30.000	10.483	0.095388	13.956	16.817	0.066223	0.10187	0.13486	1153.4	–0.41613	123.09	214.53
350.00	30.000	9.7548	0.10251	20.772	23.848	0.087875	0.11265	0.14654	971.05	–0.32840	108.07	150.45
400.00	30.000	9.0036	0.11107	28.147	31.479	0.10824	0.12399	0.15873	816.42	–0.22551	97.051	110.91
450.00	30.000	8.2322	0.12147	36.070	39.714	0.12762	0.13519	0.17053	691.11	–0.10687	90.031	83.811
500.00	30.000	7.4563	0.13411	44.490	48.514	0.14616	0.14590	0.18124	595.43	0.023732	86.541	64.099
550.00	30.000	6.7039	0.14917	53.337	57.812	0.16387	0.15594	0.19043	527.27	0.15444	85.903	49.561
150.00	65.000	12.844	0.077859	–4.2847	0.77614	–0.020732	0.086776	0.11392	1957.6	–0.57756	187.43	2300.4
200.00	65.000	12.196	0.081993	1.2046	6.5342	0.012378	0.088354	0.11690	1737.3	–0.55581	173.22	766.46
250.00	65.000	11.576	0.086384	6.9077	12.523	0.039078	0.094214	0.12318	1537.0	–0.51712	156.34	419.12
300.00	65.000	10.979	0.091087	12.978	18.898	0.062302	0.10329	0.13220	1359.9	–0.46758	140.34	275.14
350.00	65.000	10.399	0.096160	19.516	25.767	0.083456	0.11406	0.14267	1208.7	–0.41511	126.97	199.77
400.00	65.000	9.8373	0.10165	26.564	33.172	0.10322	0.12536	0.15351	1082.5	–0.36425	116.89	154.25
450.00	65.000	9.2935	0.10760	34.118	41.112	0.12191	0.13648	0.16402	979.42	–0.31694	110.18	123.77
500.00	65.000	8.7710	0.11401	42.152	49.563	0.13971	0.14709	0.17389	896.76	–0.27399	106.55	101.78
550.00	65.000	8.2737	0.12087	50.632	58.488	0.15671	0.15706	0.18299	831.73	–0.23593	105.59	85.075

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, NIST Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Buecker, D., and Wagner, W., "Reference Equations of State for the Thermodynamic Properties of Fluid Phase *n*-Butane and Isobutane," *J. Phys. Chem. Ref. Data* **35**(2): 929–1019, 2006. The source for viscosity is Vogel, E., Kuechenmeister, C., and Bich, E., "Viscosity for *n*-Butane in the Fluid Region," *High Temp.—High Pressures* **31**(2):173–186, 1999. The source for thermal conductivity is Perkins, R. A, Ramires, M. L. V., Nieto de Castro, C. A., and Cusco, L., "Measurement and Correlation of the Thermal Conductivity of Butane from 135 K to 600 K at Pressures to 70 MPa," *J. Chem. Eng. Data* **47**(5):1263–1271, 2002.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single–phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in density are 0.02% at temperatures below 340 K and pressures below 12 MPa (both liquid and vapor states), 0.1% at temperatures below 270 K and pressures above 12 MPa, 0.2% between 340 and 515 K at pressures less than 0.6 MPa, and 0.4% elsewhere. In the critical region, deviations in pressure are 0.5%. At temperatures above 500 K, the uncertainties in density increase up to 1%. Uncertainties in heat capacities are typically 1%, rising to 5% in the critical region and at pressures above 30 MPa. Uncertainties in the speed of sound are typically 0.5%, rising to 1% at temperatures below 200 K and to 4% in a large area around the critical point.

The uncertainty in viscosity varies from 0.4% in the dilute gas between room temperature and 600 K, to 3.0% over the rest of the fluid surface.

Uncertainty in thermal conductivity is 3%, except in the critical region and dilute gas which have an uncertainty of 5%.

TABLE 2-196 Thermodynamic Properties of 1-Butene

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
87.800	5.95E-13	14.582	0.068578	–19.753	–19.753	–0.12145	0.080229	0.10913	2086.5	–0.55371
150.00	1.2730E-05	13.379	0.074746	–13.108	–13.108	–0.064173	0.071962	0.10631	1744.9	–0.55469
165.00	9.3335E-05	13.097	0.076351	–11.509	–11.509	–0.054011	0.072351	0.10701	1649.6	–0.54558
180.00	0.00046966	12.818	0.078017	–9.8961	–9.8961	–0.044655	0.073193	0.10813	1555.6	–0.53276
195.00	0.0017787	12.538	0.079756	–8.2633	–8.2632	–0.035943	0.074385	0.10964	1463.4	–0.51623
210.00	0.0054125	12.257	0.081585	–6.6054	–6.6050	–0.027753	0.075854	0.11149	1373.4	–0.49587
225.00	0.013876	11.973	0.083519	–4.9174	–4.9162	–0.019990	0.077551	0.11367	1285.6	–0.47138
240.00	0.031052	11.685	0.085582	–3.1944	–3.1918	–0.012577	0.079443	0.11619	1199.6	–0.44220
255.00	0.062301	11.390	0.087798	–1.4319	–1.4264	–0.0054542	0.081507	0.11904	1115.4	–0.40748
270.00	0.11440	11.086	0.090204	0.37503	0.38535	0.0014312	0.083732	0.12227	1032.5	–0.36587
285.00	0.19537	10.771	0.092841	2.2316	2.2497	0.0081238	0.086107	0.12593	950.65	–0.31542
300.00	0.31425	10.442	0.095769	4.1435	4.1736	0.014663	0.088628	0.13010	869.48	–0.25308
315.00	0.48093	10.094	0.099067	6.1173	6.1650	0.021087	0.091289	0.13492	788.58	–0.17406
330.00	0.70602	9.7227	0.10285	8.1613	8.2339	0.027432	0.094094	0.14061	707.49	–0.070421
345.00	1.0009	9.3197	0.10730	10.286	10.393	0.033738	0.097052	0.14758	625.58	0.071832
360.00	1.3777	8.8735	0.11269	12.507	12.662	0.040056	0.10019	0.15666	541.98	0.27973
375.00	1.8505	8.3641	0.11956	14.848	15.069	0.046456	0.10358	0.16976	455.28	0.61278
390.00	2.4356	7.7513	0.12901	17.357	17.672	0.053070	0.10741	0.19258	362.75	1.2326
405.00	3.1556	6.9234	0.14444	20.167	20.622	0.060243	0.11236	0.25490	258.01	2.7886
419.29	4.0057	4.2400	0.23585	25.194	26.139	0.073219			0	14.832
87.800	5.95E-13	8.1441E-13	1.2279E+12	10.763	11.493	0.23442	0.035901	0.044215	126.59	6453.8
150.00	1.2730E-05	1.0208E-05	97966.	13.339	14.586	0.12046	0.046819	0.055138	161.79	519.37
165.00	9.3335E-05	6.8053E-05	14694.	14.060	15.432	0.10927	0.049589	0.057921	168.95	334.05
180.00	0.00046966	0.00031411	3183.5	14.822	16.317	0.10097	0.052497	0.060867	175.70	224.29
195.00	0.0017787	0.0010999	909.21	15.621	17.238	0.094833	0.055552	0.064008	182.01	156.42
210.00	0.0054125	0.0031172	320.80	16.456	18.192	0.090329	0.058761	0.067378	187.84	112.91
225.00	0.013876	0.0074985	133.36	17.323	19.174	0.087076	0.062133	0.071013	193.09	84.169
240.00	0.031052	0.015861	63.049	18.219	20.177	0.084791	0.065668	0.074946	197.63	64.687
255.00	0.062301	0.030305	32.998	19.139	21.195	0.083257	0.069362	0.079208	201.32	51.184
270.00	0.11440	0.053404	18.725	20.081	22.223	0.082311	0.073208	0.083840	204.02	41.642
285.00	0.19537	0.088232	11.334	21.039	23.253	0.081820	0.077198	0.088901	205.56	34.789
300.00	0.31425	0.13847	7.2216	22.009	24.279	0.081681	0.081324	0.094492	205.77	29.808
315.00	0.48093	0.20868	4.7920	22.985	25.290	0.081801	0.085583	0.10078	204.47	26.172
330.00	0.70602	0.30478	3.2811	23.957	26.274	0.082098	0.089980	0.10808	201.43	23.538
345.00	1.0009	0.43505	2.2986	24.912	27.212	0.082489	0.094533	0.11696	196.37	21.690
360.00	1.3777	0.61215	1.6336	25.827	28.078	0.082878	0.099287	0.12863	188.91	20.504
375.00	1.8505	0.85778	1.1658	26.665	28.823	0.083133	0.10434	0.14599	178.55	19.927
390.00	2.4356	1.2160	0.82239	27.351	29.354	0.083025	0.10992	0.17800	164.58	19.957
405.00	3.1556	1.8085	0.55294	27.680	29.425	0.081979	0.11666	0.27163	145.93	20.477
419.29	4.0057	4.2400	0.23585	25.194	26.139	0.073219			0	14.832

Single-Phase Properties										
100.00	0.10000	14.342	0.069727	–18.432	–18.425	–0.10737	0.076348	0.10761	2041.3	–0.55898
200.00	0.10000	12.446	0.080347	–7.7161	–7.7081	–0.033172	0.074849	0.11021	1433.8	–0.51000
266.51	0.10000	11.158	0.089625	–0.050006	–0.041044	–0.00015346	0.083200	0.12149	1051.7	–0.37627
266.51	0.10000	0.047098	21.232	19.860	21.983	0.082486	0.072300	0.082725	203.49	43.586
300.00	0.10000	0.041199	24.273	22.407	24.834	0.092558	0.078346	0.087850	217.19	27.387
400.00	0.10000	0.030377	32.920	31.321	34.613	0.12055	0.099614	0.10831	251.29	10.192
500.00	0.10000	0.024172	41.370	42.371	46.508	0.14700	0.12081	0.12931	280.25	5.2895
100.00	1.0000	14.347	0.069701	–18.441	–18.371	–0.10745	0.076343	0.10760	2045.4	–0.55906
200.00	1.0000	12.457	0.080273	–7.7377	–7.6574	–0.033280	0.074873	0.11013	1439.7	–0.51117
300.00	1.0000	10.465	0.095554	4.1009	4.1965	0.014521	0.088626	0.12974	878.06	–0.26069
344.96	1.0000	9.3208	0.10729	10.280	10.388	0.033722	0.097044	0.14756	625.79	0.071399
344.96	1.0000	0.43467	2.3006	24.909	27.210	0.082488	0.094521	0.11694	196.39	21.694
400.00	1.0000	0.33780	2.9603	30.561	33.521	0.099463	0.10210	0.11588	229.62	11.604
500.00	1.0000	0.25311	3.9508	41.920	45.871	0.12695	0.12152	0.13206	269.53	5.5503
100.00	5.0000	14.371	0.069585	–18.478	–18.131	–0.10783	0.076326	0.10752	2063.2	–0.55939
200.00	5.0000	12.507	0.079955	–7.8313	–7.4315	–0.033753	0.074982	0.10983	1464.8	–0.51602
300.00	5.0000	10.593	0.094404	3.8689	4.3409	0.013736	0.088648	0.12795	924.82	–0.29848
400.00	5.0000	7.7924	0.12833	18.376	19.018	0.055643	0.10867	0.17944	398.89	0.92138
500.00	5.0000	1.6432	0.60858	39.334	42.377	0.10830	0.12539	0.15726	221.46	6.5598
100.00	10.000	14.400	0.069444	–18.524	–17.830	–0.10830	0.076316	0.10743	2084.7	–0.55976
200.00	10.000	12.566	0.079577	–7.9428	–7.1471	–0.034325	0.075127	0.10949	1494.9	–0.52136
300.00	10.000	10.734	0.093162	3.6108	4.5424	0.012845	0.088724	0.12625	976.91	–0.33426
400.00	10.000	8.4254	0.11869	17.389	18.576	0.053002	0.10763	0.15809	531.56	0.27589
500.00	10.000	4.4457	0.22494	35.004	37.254	0.094450	0.12805	0.20133	235.89	3.6822
100.00	30.000	14.511	0.068913	–18.695	–16.628	–0.11011	0.076383	0.10716	2164.7	–0.56070
200.00	30.000	12.781	0.078241	–8.3397	–5.9925	–0.036441	0.075766	0.10853	1602.5	–0.53694
300.00	30.000	11.176	0.089478	2.8019	5.4862	0.0099119	0.089276	0.12244	1142.6	–0.41541
400.00	30.000	9.5263	0.10497	15.547	18.696	0.047777	0.10751	0.14231	802.89	–0.21113
500.00	30.000	7.8006	0.12820	30.094	33.940	0.081710	0.12649	0.16189	578.80	0.077488
200.00	70.000	13.133	0.076142	–8.9642	–3.6342	–0.040078	0.077144	0.10763	1777.6	–0.55246
300.00	70.000	11.778	0.084903	1.7245	7.6677	0.0055841	0.090645	0.11961	1376.9	–0.47674
400.00	70.000	10.537	0.094902	13.811	20.454	0.042252	0.10876	0.13655	1099.3	–0.37969
500.00	70.000	9.3918	0.10648	27.536	34.989	0.074613	0.12760	0.15389	914.99	–0.28997

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Ihmels, E. C., "Thermodynamic Properties of the Butenes. Part II. Short Fundamental Equations of State," *Fluid Phase Equilibria* **228–229C**:173–187, 2005. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of densities calculated by the equation of state (based on a coverage factor of 2) are 0.1% in the liquid phase at temperatures above 270 K (rising to 0.5% in density at temperatures below 200 K), 0.2% at temperatures above the critical temperature and at pressures above 10 MPa, and 0.5% in the vapor phase, including supercritical conditions below 10 MPa. The uncertainty in vapor pressure is 0.25% above 200 K. The uncertainty in heat capacities is 0.5% at saturated liquid conditions, rising to 5% at much higher pressures and at temperatures above 350 K.

TABLE 2-197 Thermodynamic Properties of *cis*-2-Butene

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. Energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
134.30	2.6365E-07	14.084	0.071002	–16.205	–16.205	–0.081920	0.079059	0.11421	1931.8	–0.50947
140.00	8.0149E-07	13.976	0.071549	–15.556	–15.556	–0.077189	0.078138	0.11344	1897.3	–0.51181
155.00	9.6316E-06	13.696	0.073014	–13.866	–13.866	–0.065723	0.076346	0.11195	1805.9	–0.51506
170.00	7.0502E-05	13.419	0.074523	–12.194	–12.194	–0.055424	0.075319	0.11114	1714.3	–0.51402
185.00	0.00035720	13.143	0.076087	–10.529	–10.529	–0.046038	0.074926	0.11096	1623.4	–0.50857
200.00	0.0013683	12.868	0.077715	–8.8626	–8.8625	–0.037376	0.075072	0.11135	1533.6	–0.49860
215.00	0.0042205	12.591	0.079421	–7.1860	–7.1857	–0.029294	0.075681	0.11228	1445.0	–0.48403
230.00	0.010977	12.312	0.081218	–5.4919	–5.4910	–0.021677	0.076690	0.11371	1357.7	–0.46470
245.00	0.024918	12.030	0.083127	–3.7731	–3.7710	–0.014438	0.078045	0.11560	1271.7	–0.44035
260.00	0.050686	11.742	0.085168	–2.0229	–2.0186	–0.0075050	0.079699	0.11795	1186.9	–0.41046
275.00	0.094280	11.446	0.087369	–0.23513	–0.22689	–0.00082003	0.081613	0.12075	1103.2	–0.37418
290.00	0.16294	11.140	0.089765	1.5965	1.6111	0.0056653	0.083753	0.12400	1020.4	–0.33016
305.00	0.26496	10.822	0.092403	3.4781	3.5026	0.011993	0.086090	0.12777	938.24	–0.27626
320.00	0.40952	10.488	0.095344	5.4164	5.4554	0.018199	0.088602	0.13211	856.41	–0.20906
335.00	0.60651	10.134	0.098675	7.4188	7.4786	0.024318	0.091273	0.13720	774.55	–0.12307
350.00	0.86653	9.7540	0.10252	9.4943	9.5831	0.030386	0.094094	0.14328	692.22	–0.0089736
365.00	1.2009	9.3387	0.10708	11.655	11.783	0.036443	0.097073	0.15087	608.84	0.14999
380.00	1.6221	8.8746	0.11268	13.918	14.101	0.042540	0.10024	0.16100	523.58	0.38688
395.00	2.1441	8.3381	0.11993	16.313	16.570	0.048756	0.10367	0.17620	435.01	0.77697
410.00	2.7840	7.6790	0.13023	18.901	19.263	0.055246	0.10763	0.20480	340.18	1.5369
425.00	3.5654	6.7389	0.14839	21.868	22.397	0.062490	0.11310	0.30217	231.16	3.6646
435.75	4.2360	4.2440	0.23563	26.307	27.305	0.073584			0	14.802
134.30	2.6365E-07	2.3611E-07	4235300.	13.340	14.457	0.14638	0.045782	0.054097	153.35	1022.9
140.00	8.0149E-07	6.8856E-07	1452300.	13.603	14.767	0.13940	0.046445	0.054760	156.40	846.64
155.00	9.6316E-06	7.4740E-06	133800.	14.312	15.601	0.12439	0.048209	0.056526	164.10	534.19
170.00	7.0502E-05	4.9890E-05	20044.	15.048	16.461	0.11314	0.050082	0.058410	171.37	352.76
185.00	0.00035720	0.00023239	4303.0	15.811	17.348	0.10465	0.052140	0.060499	178.22	241.97
200.00	0.0013683	0.00082449	1212.9	16.601	18.261	0.098239	0.054433	0.062862	184.64	171.51
215.00	0.0042205	0.0023717	421.65	17.417	19.197	0.093417	0.056990	0.065554	190.57	125.19
230.00	0.010977	0.0057914	172.67	18.259	20.154	0.089825	0.059826	0.068614	195.95	93.915
245.00	0.024918	0.012427	80.467	19.124	21.129	0.087196	0.062937	0.072067	200.67	72.325
260.00	0.050686	0.024061	41.562	20.011	22.117	0.085325	0.066305	0.075928	204.61	57.138
275.00	0.094280	0.042902	23.309	20.917	23.114	0.084057	0.069907	0.080211	207.65	46.280
290.00	0.16294	0.071600	13.966	21.839	24.115	0.083264	0.073716	0.084945	209.64	38.405
305.00	0.26496	0.11331	8.8256	22.775	25.113	0.082846	0.077706	0.090186	210.44	32.629
320.00	0.40952	0.17184	5.8195	23.718	26.101	0.082717	0.081857	0.096045	209.88	28.363
335.00	0.60651	0.25199	3.9684	24.662	27.069	0.082798	0.086156	0.10272	207.78	25.214
350.00	0.86653	0.36018	2.7764	25.597	28.003	0.083015	0.090605	0.11059	203.91	22.923
365.00	1.2009	0.50560	1.9779	26.506	28.882	0.083288	0.095223	0.12039	197.97	21.324
380.00	1.6221	0.70265	1.4232	27.364	29.673	0.083518	0.10007	0.13368	189.62	20.319
395.00	2.1441	0.97689	1.0237	28.124	30.319	0.083563	0.10526	0.15445	178.35	19.863
410.00	2.7840	1.3825	0.72331	28.692	30.706	0.083155	0.11109	0.19596	163.51	19.920
425.00	3.5654	2.0863	0.47931	28.785	30.494	0.081542	0.11843	0.34488	144.08	20.169
435.75	4.2360	4.2440	0.23563	26.307	27.305	0.073584			0	14.802

Single-Phase Properties										
150.00	0.10000	13.790	0.072517	−14.429	−14.421	−0.069410	0.076853	0.11236	1836.9	−0.51448
250.00	0.10000	11.936	0.083783	−3.1958	−3.1874	−0.012105	0.078567	0.11633	1243.8	−0.43122
276.53	0.10000	11.415	0.087603	−0.050523	−0.041763	−0.00015051	0.081821	0.12106	1094.7	−0.37008
276.53	0.10000	0.045328	22.062	21.010	23.216	0.083956	0.070286	0.080672	207.90	45.358
350.00	0.10000	0.034963	28.602	26.707	29.567	0.10426	0.084207	0.093226	235.49	18.349
450.00	0.10000	0.026927	37.137	36.211	39.925	0.13019	0.10536	0.11396	266.57	8.0313
150.00	1.0000	13.797	0.072480	−14.442	−14.369	−0.069498	0.076879	0.11234	1840.9	−0.51475
250.00	1.0000	11.951	0.083676	−3.2258	−3.1421	−0.012226	0.078590	0.11619	1250.7	−0.43363
350.00	1.0000	9.7615	0.10244	9.4809	9.5833	0.030348	0.094087	0.14310	694.58	−0.013023
356.43	1.0000	9.5810	0.10437	10.409	10.513	0.032980	0.095350	0.14630	656.67	0.052242
356.43	1.0000	0.41725	2.3967	25.991	28.388	0.083130	0.092560	0.11449	201.64	22.160
450.00	1.0000	0.28985	3.4501	35.598	39.048	0.10966	0.10690	0.11882	250.49	8.7484
150.00	5.0000	13.827	0.072321	−14.500	−14.138	−0.069886	0.076995	0.11223	1858.7	−0.51590
250.00	5.0000	12.016	0.083219	−3.3549	−2.9388	−0.012747	0.078700	0.11561	1280.3	−0.44345
350.00	5.0000	9.9638	0.10036	9.1178	9.6196	0.029293	0.093949	0.13889	758.54	−0.10935
450.00	5.0000	3.4526	0.28964	29.287	30.736	0.080884	0.12364	0.49664	144.63	13.395
150.00	10.000	13.864	0.072127	−14.569	−13.848	−0.070362	0.077144	0.11212	1880.2	−0.51720
250.00	10.000	12.094	0.082686	−3.5069	−2.6800	−0.013371	0.078849	0.11500	1315.2	−0.45403
350.00	10.000	10.171	0.098318	8.7400	9.7232	0.028171	0.093912	0.13550	825.19	−0.18764
450.00	10.000	7.3847	0.13542	23.767	25.121	0.066644	0.11375	0.17964	387.53	1.0233
150.00	20.000	13.936	0.071757	−14.703	−13.268	−0.071287	0.077453	0.11192	1921.2	−0.51938
250.00	20.000	12.236	0.081725	−3.7846	−2.1501	−0.014539	0.079171	0.11403	1379.1	−0.47093
350.00	20.000	10.498	0.095255	8.1362	10.041	0.026317	0.094047	0.13149	932.72	−0.28055
450.00	20.000	8.4814	0.11791	22.018	24.376	0.062213	0.11264	0.15577	586.98	0.13495
250.00	50.000	12.592	0.079414	−4.4655	−0.49483	−0.017580	0.080215	0.11231	1538.7	−0.50151
350.00	50.000	11.161	0.089596	6.9055	11.385	0.022259	0.094937	0.12655	1160.5	−0.39521
450.00	50.000	9.7684	0.10237	19.807	24.926	0.056195	0.11311	0.14428	893.45	−0.26115

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Ihmels, E. C., "Thermodynamic Properties of the Butenes. Part II. Short Fundamental Equations of State," *Fluid Phase Equilibria* **228–229C**:173–187, 2005. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in densities calculated using the equation of state are 0.1% in the liquid phase at temperatures above 270 K (rising to 0.5% at temperatures below 200 K), 0.2% at temperatures above the critical temperature and at pressures above 10 MPa, and 0.5% in the vapor phase, including supercritical conditions below 10 MPa. The uncertainty in the vapor phase may be higher than 0.5% in some regions. The uncertainty in vapor pressure is 0.2% between 220 and 310 K and 0.5% above 310 K, and the uncertainty in heat capacities is 0.5% at saturated liquid conditions, rising to 5% at much higher pressures and at temperatures above 300 K.

TABLE 2-198 Thermodynamic Properties of *trans*-2-Butene

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
167.60	0.000074817	13.141	0.076099	−12.322	−12.322	−0.056582	0.075471	0.10906	1653.9	−0.53710
170.00	0.000098940	13.097	0.076351	−12.060	−12.060	−0.055030	0.075651	0.10931	1639.3	−0.53489
185.00	0.00047141	12.827	0.077960	−10.409	−10.409	−0.045722	0.076779	0.11086	1549.4	−0.52040
200.00	0.0017229	12.556	0.079642	−8.7337	−8.7336	−0.037018	0.077989	0.11250	1461.5	−0.50389
215.00	0.0051236	12.284	0.081408	−7.0328	−7.0324	−0.028818	0.079349	0.11434	1375.6	−0.48446
230.00	0.012948	12.008	0.083277	−5.3024	−5.3013	−0.021038	0.080901	0.11646	1291.2	−0.46138
245.00	0.028726	11.728	0.085267	−3.5381	−3.5357	−0.013608	0.082660	0.11890	1208.2	−0.43391
260.00	0.057367	11.441	0.087404	−1.7351	−1.7301	−0.0064657	0.084626	0.12171	1126.4	−0.40117
275.00	0.10513	11.146	0.089718	0.11181	0.12124	0.00044042	0.086786	0.12491	1045.4	−0.36199
290.00	0.17951	10.840	0.092251	2.0081	2.0247	0.0071551	0.089124	0.12854	965.18	−0.31463
305.00	0.28905	10.520	0.095056	3.9596	3.9871	0.013718	0.091618	0.13267	885.29	−0.25645
320.00	0.44317	10.183	0.098206	5.9728	6.0163	0.020164	0.094251	0.13740	805.47	−0.18323
335.00	0.65207	9.8227	0.10181	8.0553	8.1216	0.026529	0.097011	0.14294	725.30	−0.088064
350.00	0.92670	9.4330	0.10601	10.217	10.315	0.032849	0.099897	0.14962	644.30	0.041045
365.00	1.2790	9.0030	0.11107	12.471	12.613	0.039171	0.10292	0.15815	561.78	0.22658
380.00	1.7221	8.5154	0.11743	14.840	15.042	0.045556	0.10614	0.17004	476.68	0.51577
395.00	2.2718	7.9376	0.12598	17.363	17.650	0.052111	0.10969	0.18946	387.01	1.0273
410.00	2.9483	7.1898	0.13909	20.137	20.547	0.059086	0.11399	0.23383	288.25	2.1709
425.00	3.7851	5.8610	0.17062	23.657	24.303	0.067765	0.12174	0.63363	165.30	7.0491
428.61	4.0191	4.2130	0.23736	26.217	27.171	0.074373			0	14.836
167.60	0.000074817	0.000053703	18,621.	13.917	15.310	0.10829	0.056121	0.064451	168.85	333.88
170.00	0.000098940	0.000070020	14,282.	14.051	15.465	0.10688	0.056517	0.064850	169.97	313.10
185.00	0.00047141	0.00030677	3259.8	14.913	16.450	0.099458	0.058961	0.067333	176.77	214.55
200.00	0.0017229	0.0010387	962.76	15.805	17.464	0.093969	0.061448	0.069906	183.16	152.47
215.00	0.0051236	0.0028818	347.00	16.724	18.502	0.089946	0.064084	0.072698	189.08	111.85
230.00	0.012948	0.0068419	146.16	17.667	19.560	0.087053	0.066934	0.075804	194.41	84.452
245.00	0.028726	0.014361	69.632	18.632	20.632	0.085037	0.070029	0.079283	199.05	65.512
260.00	0.057367	0.027327	36.594	19.616	21.716	0.083710	0.073369	0.083170	202.86	52.156
275.00	0.10513	0.048069	20.803	20.617	22.804	0.082924	0.076939	0.087492	205.70	42.578
290.00	0.17951	0.079385	12.597	21.632	23.893	0.082564	0.080711	0.092287	207.43	35.618
305.00	0.28905	0.12463	8.0236	22.656	24.976	0.082533	0.084658	0.097621	207.89	30.512
320.00	0.44317	0.18794	5.3209	23.685	26.043	0.082747	0.088756	0.10363	206.90	26.754
335.00	0.65207	0.27462	3.6414	24.709	27.083	0.083130	0.092992	0.11056	204.25	24.009
350.00	0.92670	0.39199	2.5511	25.716	28.080	0.083605	0.097368	0.11889	199.66	22.059
365.00	1.2790	0.55094	1.8151	26.685	29.006	0.084083	0.10191	0.12962	192.81	20.773
380.00	1.7221	0.76954	1.2995	27.583	29.821	0.084447	0.10670	0.14503	183.21	20.089
395.00	2.2718	1.0825	0.92378	28.347	30.445	0.084505	0.11191	0.17158	170.22	19.999
410.00	2.9483	1.5757	0.63463	28.822	30.693	0.083831	0.11800	0.23687	152.90	20.460
425.00	3.7851	2.6760	0.37369	28.287	29.702	0.080468	0.12690	0.83276	129.63	20.057
428.61	4.0191	4.2130	0.23736	26.217	27.171	0.074373			0	14.836

Single-Phase Properties										
200.00	0.10000	12.557	0.079634	–8.7360	–8.7280	–0.037029	0.077991	0.11249	1462.2	–0.50400
273.69	0.10000	11.172	0.089507	–0.051921	–0.042970	–0.00015647	0.086590	0.12461	1052.5	–0.36572
273.69	0.10000	0.045873	21.799	20.529	22.709	0.082975	0.076618	0.087096	205.49	43.299
300.00	0.10000	0.041314	24.205	22.623	25.044	0.091118	0.080917	0.090604	216.41	30.137
400.00	0.10000	0.030400	32.895	31.727	35.016	0.11968	0.10071	0.10946	251.03	11.036
500.00	0.10000	0.024180	41.357	42.796	46.932	0.14618	0.12004	0.12856	280.24	5.7119
200.00	1.0000	12.568	0.079566	–8.7565	–8.6769	–0.037132	0.078010	0.11242	1467.8	–0.50499
300.00	1.0000	10.652	0.093883	3.2597	3.3536	0.011401	0.090766	0.13089	920.75	–0.28393
353.43	1.0000	9.3386	0.10708	10.724	10.831	0.034294	0.10058	0.15138	625.59	0.077370
353.43	1.0000	0.42419	2.3574	25.942	28.299	0.083718	0.098392	0.12109	198.31	21.710
400.00	1.0000	0.34144	2.9288	30.880	33.808	0.098365	0.10374	0.11833	227.44	12.735
500.00	1.0000	0.25402	3.9367	42.308	46.245	0.12606	0.12089	0.13164	268.79	6.0235
200.00	5.0000	12.615	0.079271	–8.8455	–8.4492	–0.037581	0.078096	0.11215	1492.3	–0.50911
300.00	5.0000	10.766	0.092881	3.0452	3.5096	0.010676	0.090769	0.12936	964.95	–0.31451
400.00	5.0000	8.1724	0.12236	17.547	18.158	0.052539	0.10973	0.17328	451.39	0.61704
500.00	5.0000	1.7031	0.58716	39.420	42.355	0.10676	0.12565	0.16251	215.66	7.3063
200.00	10.000	12.671	0.078919	–8.9520	–8.1628	–0.038127	0.078213	0.11184	1521.6	–0.51368
300.00	10.000	10.895	0.091783	2.8039	3.7218	0.0098449	0.090820	0.12787	1014.7	–0.34416
400.00	10.000	8.6867	0.11512	16.708	17.859	0.050312	0.10892	0.15802	568.97	0.18397
500.00	10.000	4.7944	0.20858	34.462	36.547	0.091756	0.12831	0.21038	241.07	3.5123
200.00	25.000	12.827	0.077961	–9.2436	–7.2946	–0.039668	0.078610	0.11112	1602.1	–0.52436
300.00	25.000	11.215	0.089166	2.2040	4.4332	0.0076959	0.091136	0.12501	1139.2	–0.40118
400.00	25.000	9.5005	0.10526	15.305	17.937	0.046401	0.10862	0.14563	778.83	–0.17082
500.00	25.000	7.5935	0.13169	30.258	33.551	0.081157	0.12604	0.16587	531.13	0.22774
200.00	50.000	13.054	0.076608	–9.6567	–5.8263	–0.041984	0.079350	0.11038	1718.0	–0.53554
300.00	50.000	11.620	0.086061	1.4532	5.7562	0.0048127	0.091871	0.12263	1299.8	–0.44882
400.00	50.000	10.240	0.097652	13.991	18.873	0.042428	0.10919	0.13997	994.88	–0.32579
500.00	50.000	8.9015	0.11234	28.100	33.717	0.075482	0.12638	0.15648	788.67	–0.19336

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Ihmels, E. C., "Thermodynamic Properties of the Butenes. Part II. Short Fundamental Equations of State," *Fluid Phase Equilibria* **228–229C:**173–187, 2005. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in densities calculated using the equation of state are 0.1% in the liquid phase at temperatures above 270 K (rising to 0.5% at temperatures below 200 K), 0.2% at temperatures above the critical temperature and at pressures above 10 MPa, and 0.5% in the vapor phase, including supercritical conditions below 10 MPa. The uncertainty in the vapor phase may be higher than 0.5% in some regions. The uncertainty in vapor pressure is 0.3% above 200 K, and the uncertainty in heat capacities is 0.5% at saturated liquid conditions, rising to 5% at much higher pressures and at temperatures above 250 K.

TABLE 2-199 Thermodynamic Properties of Carbon Dioxide

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
216.59	0.51796	26.777	0.037345	3.5030	3.5223	0.022943	0.042895	0.085960	975.85	–0.14430	180.63	256.70
220.00	0.59913	26.497	0.037740	3.7943	3.8169	0.024279	0.042682	0.086338	951.21	–0.13180	176.15	242.01
225.00	0.73509	26.078	0.038347	4.2235	4.2517	0.026209	0.042383	0.087024	915.16	–0.11104	169.67	222.19
230.00	0.89291	25.646	0.038992	4.6554	4.6902	0.028110	0.042103	0.087886	879.09	–0.086994	163.28	204.23
235.00	1.0747	25.201	0.039680	5.0908	5.1334	0.029986	0.041843	0.088954	842.88	–0.059053	156.98	187.88
240.00	1.2825	24.742	0.040418	5.5303	5.5821	0.031840	0.041605	0.090263	806.38	–0.026454	150.75	172.96
245.00	1.5185	24.264	0.041213	5.9749	6.0375	0.033678	0.041393	0.091866	769.44	0.011808	144.58	159.30
250.00	1.7850	23.767	0.042075	6.4256	6.5007	0.035505	0.041212	0.093831	731.78	0.057087	138.47	146.74
255.00	2.0843	23.246	0.043018	6.8836	6.9733	0.037326	0.041079	0.096251	693.01	0.11121	132.40	135.14
260.00	2.4188	22.697	0.044059	7.3505	7.4571	0.039148	0.041029	0.099258	652.58	0.17663	126.35	124.40
265.00	2.7909	22.114	0.045219	7.8282	7.9544	0.040979	0.041109	0.10306	610.07	0.25672	120.31	114.40
270.00	3.2033	21.491	0.046531	8.3190	8.4681	0.042829	0.041351	0.10798	565.46	0.35639	114.25	105.02
275.00	3.6589	20.817	0.048037	8.8266	9.0024	0.044711	0.041750	0.11457	519.14	0.48324	108.17	96.174
280.00	4.1607	20.077	0.049808	9.3560	9.5633	0.046643	0.042270	0.12385	471.54	0.64959	102.03	87.731
285.00	4.7123	19.247	0.051957	9.9154	10.160	0.048657	0.042900	0.13790	422.75	0.87650	95.810	79.548
290.00	5.3177	18.284	0.054693	10.519	10.810	0.050805	0.043734	0.16176	371.95	1.2037	89.546	71.409
295.00	5.9822	17.100	0.058480	11.197	11.547	0.053196	0.045175	0.21098	315.91	1.7218	83.558	62.936
300.00	6.7131	15.434	0.064793	12.036	12.471	0.056151	0.049288	0.38279	245.67	2.7258	80.593	53.107
304.13	7.3773	10.625	0.094118	13.928	14.622	0.063094			0	5.8665		
216.59	0.51796	0.31268	3.1982	17.286	18.943	0.094138	0.027691	0.039992	222.78	26.174	11.014	10.951
220.00	0.59913	0.35941	2.7824	17.329	18.996	0.093276	0.028120	0.040943	223.15	25.084	11.301	11.135
225.00	0.73509	0.43766	2.2849	17.387	19.067	0.092055	0.028782	0.042489	223.49	23.617	11.745	11.409
230.00	0.89291	0.52878	1.8912	17.438	19.127	0.090878	0.029488	0.044244	223.57	22.288	12.221	11.689
235.00	1.0747	0.63442	1.5762	17.481	19.175	0.089736	0.030241	0.046248	223.40	21.077	12.736	11.976
240.00	1.2825	0.75654	1.3218	17.515	19.210	0.088622	0.031042	0.048555	222.96	19.969	13.297	12.272
245.00	1.5185	0.89743	1.1143	17.538	19.230	0.087526	0.031899	0.051242	222.24	18.950	13.917	12.579
250.00	1.7850	1.0599	0.94353	17.550	19.234	0.086439	0.032827	0.054421	221.22	18.005	14.610	12.902
255.00	2.0843	1.2472	0.80180	17.549	19.220	0.085352	0.033844	0.058244	219.87	17.117	15.396	13.245
260.00	2.4188	1.4637	0.68320	17.532	19.185	0.084254	0.034955	0.062912	218.19	16.277	16.306	13.614
265.00	2.7909	1.7149	0.58314	17.498	19.125	0.083133	0.036164	0.068721	216.15	15.476	17.381	14.017
270.00	3.2033	2.0080	0.49800	17.441	19.037	0.081972	0.037482	0.076168	213.75	14.704	18.687	14.469
275.00	3.6589	2.3535	0.42490	17.359	18.913	0.080750	0.038949	0.086123	210.96	13.947	20.325	14.987
280.00	4.1607	2.7663	0.36150	17.241	18.746	0.079437	0.040628	0.10020	207.72	13.185	22.468	15.601
285.00	4.7123	3.2702	0.30579	17.078	18.519	0.077987	0.042629	0.12177	203.94	12.387	25.424	16.361
290.00	5.3177	3.9074	0.25593	16.848	18.209	0.076319	0.045155	0.15906	199.45	11.509	29.821	17.357
295.00	5.9822	4.7654	0.20985	16.509	17.764	0.074270	0.048677	0.23904	193.84	10.459	37.215	18.792
300.00	6.7131	6.1028	0.16386	15.935	17.035	0.071364	0.054908	0.52463	185.33	9.0093	53.689	21.306
304.13	7.3773	10.625	0.094118	13.928	14.622	0.063094			0	5.8665		

Single-Phase Properties												
250.00	0.10000	0.048542	20.601	18.448	20.509	0.11415	0.026766	0.035428	247.79	17.399	12.950	12.565
450.00	0.10000	0.026758	37.372	24.664	28.401	0.13712	0.034775	0.043148	324.41	4.0212	29.346	21.901
650.00	0.10000	0.018506	54.037	32.199	37.602	0.15397	0.040192	0.048529	385.01	1.6551	45.466	29.873
850.00	0.10000	0.014148	70.683	40.636	47.705	0.16750	0.043944	0.052271	437.11	0.78058	60.295	36.707
1050.0	0.10000	0.011452	87.321	49.704	58.436	0.17883	0.046573	0.054895	483.65	0.34646	73.843	42.692
250.00	1.0000	0.53250	1.8779	18.023	19.901	0.093263	0.029361	0.042504	235.08	17.606	13.584	12.691
450.00	1.0000	0.27038	3.6985	24.546	28.244	0.11771	0.034954	0.043866	322.89	3.9880	29.620	21.954
650.00	1.0000	0.18527	5.3976	32.133	37.530	0.13473	0.040239	0.048779	385.36	1.6311	45.651	29.907
850.00	1.0000	0.14131	7.0767	40.591	47.668	0.14830	0.043965	0.052397	438.06	0.76632	60.435	36.732
1050.0	1.0000	0.11430	8.7487	49.671	58.419	0.15965	0.046585	0.054970	484.84	0.33777	73.956	42.712
250.00	5.0000	24.060	0.041563	6.2824	6.4902	0.034925	0.041321	0.090937	762.21	0.015208	142.22	153.15
287.43	5.0000	18.798	0.053196	10.202	10.468	0.049681	0.043268	0.14775	398.39	1.0195	92.760	75.598
287.43	5.0000	3.5600	0.28090	16.977	18.381	0.077209	0.043774	0.13705	201.86	11.974	27.323	16.808
450.00	5.0000	1.4155	0.70647	24.000	27.533	0.10313	0.035769	0.047478	317.50	3.8034	31.164	22.429
650.00	5.0000	0.92982	1.0755	31.842	37.219	0.12091	0.040445	0.049898	387.59	1.5263	46.589	30.157
850.00	5.0000	0.70241	1.4237	40.395	47.513	0.13469	0.044055	0.052945	442.64	0.70611	61.117	36.899
1050.0	5.0000	0.56658	1.7650	49.524	58.349	0.14613	0.046637	0.055297	490.31	0.30129	74.494	42.836
250.00	10.000	24.459	0.040885	6.0862	6.4950	0.034120	0.041488	0.087624	804.05	–0.034849	147.52	162.47
450.00	10.000	2.9910	0.33433	23.276	26.619	0.095787	0.036785	0.052935	314.60	3.4705	33.917	23.679
650.00	10.000	1.8632	0.53671	31.482	36.849	0.11461	0.040693	0.051293	391.91	1.3965	48.005	30.687
850.00	10.000	1.3930	0.71790	40.155	47.334	0.12866	0.044164	0.053603	449.04	0.63635	62.093	37.224
1050.0	10.000	1.1205	0.89248	49.347	58.271	0.14021	0.046701	0.055685	497.48	0.25964	75.242	43.066
250.00	100.00	28.075	0.035619	4.3002	7.8621	0.026023	0.043569	0.073521	1227.6	–0.27302	206.28	287.05
450.00	100.00	19.246	0.051959	16.560	21.756	0.067062	0.040841	0.066107	753.30	–0.11128	106.65	83.996
650.00	100.00	13.677	0.073117	27.132	34.444	0.090445	0.043108	0.061252	646.36	–0.054084	86.093	58.868
850.00	100.00	10.636	0.094022	37.076	46.478	0.10660	0.045620	0.059534	646.61	–0.13292	87.259	54.445
1050.0	100.00	8.7929	0.11373	46.995	58.368	0.11916	0.047676	0.059512	668.90	–0.21482	94.022	55.058
450.00	500.00	28.922	0.034576	13.014	30.302	0.050604	0.047702	0.063434	1576.4	–0.38514	239.59	303.64
650.00	500.00	25.661	0.038969	23.302	42.786	0.073576	0.048419	0.061885	1404.7	–0.40369	197.25	191.14
850.00	500.00	23.144	0.043208	33.551	55.155	0.090166	0.049676	0.061912	1320.1	–0.41098	177.31	145.07
1050.0	500.00	21.126	0.047334	43.903	67.570	0.10328	0.050818	0.062247	1278.7	–0.41674	168.50	123.33

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Span, R., and Wagner, W., "A New Equation of State for Carbon Dioxide Covering the Fluid Region from the Triple-Point Temperature to 1100 K at Pressures up to 800 MPa," *J. Phys. Chem. Ref. Data* **25**(6):1509–1596, 1996. The source for viscosity is Fenghour, A., Wakeham, W. A., and Vesovic, V., "The Viscosity of Carbon Dioxide," *J. Phys. Chem. Ref. Data* **27:**31–44, 1998. The source for thermal conductivity is Vesovic, V., Wakeham, W. A., Olchowy, G. A., Sengers, J. V., Watson, J. T. R., and Millat, J., "The Transport Properties of Carbon Dioxide," *J. Phys. Chem. Ref. Data* **19:**763–808, 1990.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

At pressures up to 30 MPa and temperatures up to 523 K, the estimated uncertainty ranges from 0.03% to 0.05% in density, 0.03% (in the vapor) to 1% in the speed of sound (0.5% in the liquid), and 0.15% (in the vapor) to 1.5% (in the liquid) in heat capacity. Special interest has been focused on the description of the critical region and the extrapolation behavior of the formulation (to the limits of chemical stability). The uncertainty in viscosity ranges from 0.3% in the dilute gas near room temperature to 5% at the highest pressures. The uncertainty in thermal conductivity is less than 5%.

TABLE 2-200 Thermodynamic Properties of Carbon Monoxide

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
68.160	0.015537	30.330	0.032971	–0.81158	–0.81106	–0.010820	0.035351	0.060430	998.20	–0.36906	180.28	274.18
70.000	0.021053	30.064	0.033262	–0.70065	–0.69995	–0.0092140	0.034805	0.060226	980.50	–0.36553	175.49	252.15
72.000	0.028718	29.773	0.033588	–0.58046	–0.57950	–0.0075210	0.034248	0.060064	961.22	–0.36074	170.45	232.14
74.000	0.038447	29.478	0.033924	–0.46058	–0.45927	–0.0058785	0.033724	0.059961	941.89	–0.35489	165.55	215.32
76.000	0.050599	29.180	0.034270	–0.34088	–0.33915	–0.0042823	0.033232	0.059917	922.49	–0.34794	160.76	201.01
78.000	0.065559	28.878	0.034628	–0.22127	–0.21900	–0.0027285	0.032768	0.059930	903.01	–0.33981	156.06	188.69
80.000	0.083738	28.573	0.034999	–0.10165	–0.098716	–0.0012138	0.032329	0.060002	883.44	–0.33041	151.45	177.96
82.000	0.10556	28.262	0.035383	0.018099	0.021834	0.00026503	0.031915	0.060132	863.76	–0.31966	146.89	168.52
84.000	0.13148	27.947	0.035782	0.13806	0.14277	0.0017110	0.031522	0.060324	843.95	–0.30742	142.40	160.13
86.000	0.16196	27.626	0.036197	0.25835	0.26421	0.0031269	0.031150	0.060578	824.00	–0.29356	137.96	152.60
88.000	0.19748	27.300	0.036630	0.37906	0.38629	0.0045153	0.030798	0.060899	803.89	–0.27794	133.57	145.77
90.000	0.23852	26.967	0.037082	0.50030	0.50915	0.0058787	0.030463	0.061291	783.60	–0.26034	129.23	139.52
92.000	0.28559	26.627	0.037556	0.62218	0.63291	0.0072195	0.030146	0.061760	763.12	–0.24056	124.94	133.75
94.000	0.33919	26.280	0.038052	0.74482	0.75773	0.0085399	0.029846	0.062314	742.41	–0.21834	120.69	128.38
96.000	0.39983	25.924	0.038574	0.86835	0.88377	0.0098422	0.029562	0.062962	721.45	–0.19335	116.51	123.34
98.000	0.46805	25.559	0.039125	0.99289	1.0112	0.011129	0.029294	0.063716	700.22	–0.16523	112.38	118.57
100.00	0.54438	25.184	0.039708	1.1186	1.1402	0.012402	0.029043	0.064590	678.68	–0.13353	108.31	114.02
102.00	0.62934	24.798	0.040326	1.2457	1.2710	0.013663	0.028809	0.065604	656.78	–0.097704	104.30	109.66
104.00	0.72348	24.399	0.040985	1.3742	1.4039	0.014916	0.028592	0.066781	634.50	–0.057078	100.36	105.45
106.00	0.82736	23.987	0.041689	1.5045	1.5390	0.016162	0.028395	0.068153	611.77	–0.010824	96.482	101.35
108.00	0.94154	23.560	0.042446	1.6368	1.6768	0.017404	0.028218	0.069759	588.54	0.042104	92.679	97.342
110.00	1.0666	23.114	0.043263	1.7713	1.8175	0.018646	0.028066	0.071656	564.73	0.10304	88.948	93.404
112.00	1.2031	22.649	0.044151	1.9085	1.9616	0.019891	0.027941	0.073916	540.25	0.17371	85.290	89.510
114.00	1.3517	22.161	0.045124	2.0487	2.1097	0.021142	0.027850	0.076648	515.01	0.25641	81.702	85.641
116.00	1.5130	21.646	0.046197	2.1925	2.2624	0.022406	0.027800	0.080005	488.86	0.35427	78.180	81.774
118.00	1.6877	21.099	0.047395	2.3405	2.4205	0.023688	0.027803	0.084225	461.63	0.47167	74.716	77.888
120.00	1.8765	20.513	0.048749	2.4938	2.5853	0.024996	0.027874	0.089692	433.11	0.61495	71.296	73.954
122.00	2.0802	19.878	0.050307	2.6536	2.7583	0.026343	0.028038	0.097070	403.00	0.79382	67.896	69.940
124.00	2.2997	19.179	0.052141	2.8221	2.9420	0.027744	0.028333	0.10762	370.88	1.0239	64.476	65.797
126.00	2.5360	18.390	0.054377	3.0024	3.1403	0.029230	0.028826	0.12411	336.15	1.3325	60.972	61.448
128.00	2.7904	17.464	0.057259	3.2010	3.3608	0.030854	0.029646	0.15392	297.82	1.7728	57.261	56.748
130.00	3.0647	16.288	0.061393	3.4328	3.6210	0.032745	0.031097	0.22603	254.03	2.4703	53.107	51.348
132.86	3.4982	10.850	0.092166	4.2912	4.6137	0.040039			0	6.1475		
68.160	0.015537	0.027707	36.091	5.1252	5.6859	0.084499	0.021089	0.029785	167.25	40.804	6.6865	4.6366
70.000	0.021053	0.036656	27.281	5.1600	5.7343	0.082704	0.021155	0.029947	169.22	38.426	6.8845	4.7768
72.000	0.028718	0.048780	20.500	5.1971	5.7859	0.080887	0.021238	0.030153	171.27	36.126	7.1009	4.9329
74.000	0.038447	0.063796	15.675	5.2334	5.8361	0.079194	0.021333	0.030394	173.22	34.080	7.3188	5.0934
76.000	0.050599	0.082130	12.176	5.2688	5.8849	0.077613	0.021441	0.030672	175.07	32.250	7.5382	5.2589
78.000	0.065559	0.10424	9.5935	5.3031	5.9320	0.076131	0.021563	0.030993	176.80	30.604	7.7592	5.4300
80.000	0.083738	0.13059	7.6573	5.3363	5.9775	0.074739	0.021699	0.031360	178.42	29.116	7.9820	5.6076
82.000	0.10556	0.16171	6.1841	5.3682	6.0210	0.073426	0.021850	0.031777	179.92	27.763	8.2067	5.7922
84.000	0.13148	0.19810	5.0478	5.3988	6.0625	0.072185	0.022017	0.032250	181.29	26.527	8.4335	5.9847
86.000	0.16196	0.24036	4.1605	5.4280	6.1019	0.071007	0.022199	0.032783	182.54	25.392	8.6627	6.1860
88.000	0.19748	0.28906	3.4595	5.4556	6.1388	0.069885	0.022397	0.033383	183.66	24.345	8.8944	6.3968
90.000	0.23852	0.34486	2.8997	5.4816	6.1733	0.068813	0.022611	0.034057	184.65	23.377	9.1291	6.6182
92.000	0.28559	0.40845	2.4483	5.5058	6.2050	0.067785	0.022842	0.034813	185.51	22.477	9.3672	6.8512
94.000	0.33919	0.48058	2.0808	5.5280	6.2338	0.066796	0.023089	0.035661	186.22	21.638	9.6091	7.0969
96.000	0.39983	0.56209	1.7791	5.5482	6.2595	0.065840	0.023352	0.036615	186.80	20.853	9.8555	7.3566
98.000	0.46805	0.65388	1.5293	5.5661	6.2819	0.064912	0.023633	0.037690	187.23	20.118	10.107	7.6317
100.00	0.54438	0.75700	1.3210	5.5816	6.3007	0.064007	0.023931	0.038906	187.52	19.426	10.366	7.9239
102.00	0.62934	0.87260	1.1460	5.5945	6.3157	0.063120	0.024248	0.040288	187.67	18.773	10.632	8.2350
104.00	0.72348	1.0020	0.99799	5.6044	6.3265	0.062248	0.024586	0.041869	187.66	18.154	10.909	8.5675
106.00	0.82736	1.1468	0.87198	5.6112	6.3327	0.061385	0.024945	0.043694	187.51	17.565	11.198	8.9238
108.00	0.94154	1.3088	0.76404	5.6145	6.3339	0.060526	0.025329	0.045820	187.20	17.001	11.502	9.3073
110.00	1.0666	1.4903	0.67102	5.6138	6.3295	0.059665	0.025741	0.048326	186.73	16.458	11.828	9.7221
112.00	1.2031	1.6938	0.59039	5.6088	6.3191	0.058797	0.026186	0.051322	186.11	15.930	12.181	10.173

114.00	1.3517	1.9228	0.52008	5.5986	6.3016	0.057914	0.026671	0.054966	185.33	15.411	12.569	10.667
116.00	1.5130	2.1815	0.45841	5.5827	6.2762	0.057008	0.027203	0.059493	184.38	14.894	13.005	11.213
118.00	1.6877	2.4754	0.40397	5.5598	6.2416	0.056070	0.027794	0.065263	183.27	14.372	13.507	11.821
120.00	1.8765	2.8123	0.35558	5.5286	6.1959	0.055084	0.028462	0.072864	181.99	13.833	14.101	12.509
122.00	2.0802	3.2027	0.31224	5.4872	6.1367	0.054034	0.029229	0.083320	180.52	13.265	14.826	13.301
124.00	2.2997	3.6629	0.27301	5.4324	6.0602	0.052892	0.030133	0.098585	178.84	12.648	15.747	14.234
126.00	2.5360	4.2194	0.23700	5.3595	5.9605	0.051613	0.031233	0.12291	176.93	11.956	16.981	15.373
128.00	2.7904	4.9212	0.20320	5.2594	5.8264	0.050117	0.032636	0.16759	174.68	11.140	18.777	16.840
130.00	3.0647	5.8832	0.16998	5.1113	5.6322	0.048216	0.034579	0.27599	171.86	10.100	21.845	18.936
132.86	3.4982	10.850	0.092166	4.2912	4.6137	0.040039			0	6.1475		
Single-Phase Properties												
100.00	0.10000	0.12298	8.1315	5.7653	6.5785	0.080014	0.021118	0.030153	201.29	17.820	10.075	6.9147
200.00	0.10000	0.060293	16.586	7.8674	9.5259	0.10048	0.020812	0.029239	288.05	5.3111	19.227	12.897
300.00	0.10000	0.040104	24.935	9.9522	12.446	0.11231	0.020833	0.029191	353.12	2.5186	26.605	17.731
400.00	0.10000	0.030062	33.265	12.045	15.371	0.12073	0.021028	0.029364	407.29	1.2653	33.106	21.870
500.00	0.10000	0.024045	41.588	14.169	18.328	0.12733	0.021479	0.029807	454.00	0.56244	39.272	25.540
100.00	1.0000	25.261	0.039586	1.1047	1.1443	0.012262	0.029062	0.064114	685.44	–0.14414	112.87	113.83
108.96	1.0000	23.349	0.042829	1.7009	1.7437	0.017998	0.028142	0.070627	577.22	0.070176	90.884	95.450
108.96	1.0000	1.3931	0.71782	5.6147	6.3325	0.060114	0.025522	0.046966	186.99	16.739	11.655	9.5017
200.00	1.0000	0.61727	1.6200	7.7647	9.3847	0.080819	0.020996	0.030510	286.20	5.1924	19.474	13.192
300.00	1.0000	0.40214	2.4867	9.8936	12.380	0.092976	0.020895	0.029646	354.42	2.4256	26.760	17.918
400.00	1.0000	0.29999	3.3334	12.005	15.338	0.10149	0.021064	0.029598	409.43	1.2088	33.222	22.024
500.00	1.0000	0.23962	4.1732	14.140	18.313	0.10812	0.021505	0.029948	456.39	0.52786	39.364	25.676
100.00	5.0000	25.864	0.038663	0.99666	1.1900	0.011154	0.029263	0.060925	737.92	–0.21740	152.30	112.19
200.00	5.0000	3.4130	0.29299	7.2656	8.7305	0.064994	0.021878	0.038000	285.27	4.3757	22.190	15.094
300.00	5.0000	2.0232	0.49426	9.6364	12.108	0.078767	0.021174	0.031673	362.95	2.0288	27.812	18.716
400.00	5.0000	1.4824	0.67458	11.834	15.207	0.087691	0.021224	0.030585	420.15	0.98413	33.871	22.588
500.00	5.0000	1.1786	0.84845	14.015	18.258	0.094498	0.021618	0.030535	467.56	0.39254	39.837	26.139
100.00	10.000	26.482	0.037761	0.88669	1.2643	0.0099878	0.029539	0.058409	792.04	–0.27800	200.46	110.33
200.00	10.000	7.4298	0.13459	6.5960	7.9419	0.056188	0.022832	0.048831	307.84	2.8854	34.772	19.114
300.00	10.000	4.0263	0.24837	9.3290	11.813	0.072068	0.021511	0.034036	379.01	1.5731	30.972	19.862
400.00	10.000	2.9079	0.34389	11.634	15.073	0.081462	0.021420	0.031689	435.68	0.74980	35.414	23.298
500.00	10.000	2.3052	0.43381	13.870	18.208	0.088461	0.021755	0.031188	482.48	0.25486	40.797	26.682
100.00	50.000	29.422	0.033988	0.39153	2.0910	0.0040257	0.031398	0.052094	1066.8	–0.43831	567.46	99.463
200.00	50.000	20.591	0.048566	4.5424	6.9707	0.038097	0.025036	0.045541	706.01	–0.28689	256.88	50.929
300.00	50.000	14.766	0.067725	7.7949	11.181	0.055259	0.023212	0.039083	609.73	–0.21242	139.18	34.086
400.00	50.000	11.439	0.087418	10.518	14.889	0.065951	0.022620	0.035519	604.51	–0.27153	94.476	31.319
500.00	50.000	9.3865	0.10654	13.024	18.350	0.073681	0.022659	0.033937	622.30	–0.36911	76.899	32.167
100.00	100.00	31.474	0.031772	0.095937	3.2732	–0.00053857	0.033037	0.050530	1282.4	–0.47725	1005.7	90.560
200.00	100.00	24.888	0.040181	3.9022	7.9203	0.031951	0.026437	0.043352	987.69	–0.50923	536.84	73.380
300.00	100.00	20.200	0.049505	7.0625	12.013	0.048608	0.024358	0.038799	866.60	–0.54516	331.69	54.648
400.00	100.00	16.970	0.058928	9.8487	15.741	0.059353	0.023555	0.036051	822.33	–0.59581	229.18	45.748
500.00	100.00	14.662	0.068206	12.449	19.269	0.067230	0.023434	0.034683	808.91	–0.64123	173.58	42.504

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data*, **51**(3):785–850,2006. The source for viscosity and thermal conductivity is Version 9.08 of the NIST14 database.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The equation of state is valid from the triple point to 500 K with pressures to 100 MPa. At higher pressures, the deviations from the equation increase rapidly, and it is not recommended to use the equation above 100 MPa. The uncertainties in the equation are 0.3% in density (approaching 1% near the critical point), 0.2% in vapor pressure, and 2% in heat capacities. For viscosity, estimated uncertainty is 2%. For thermal conductivity, estimated uncertainty, except near the critical region, is 4–6%.

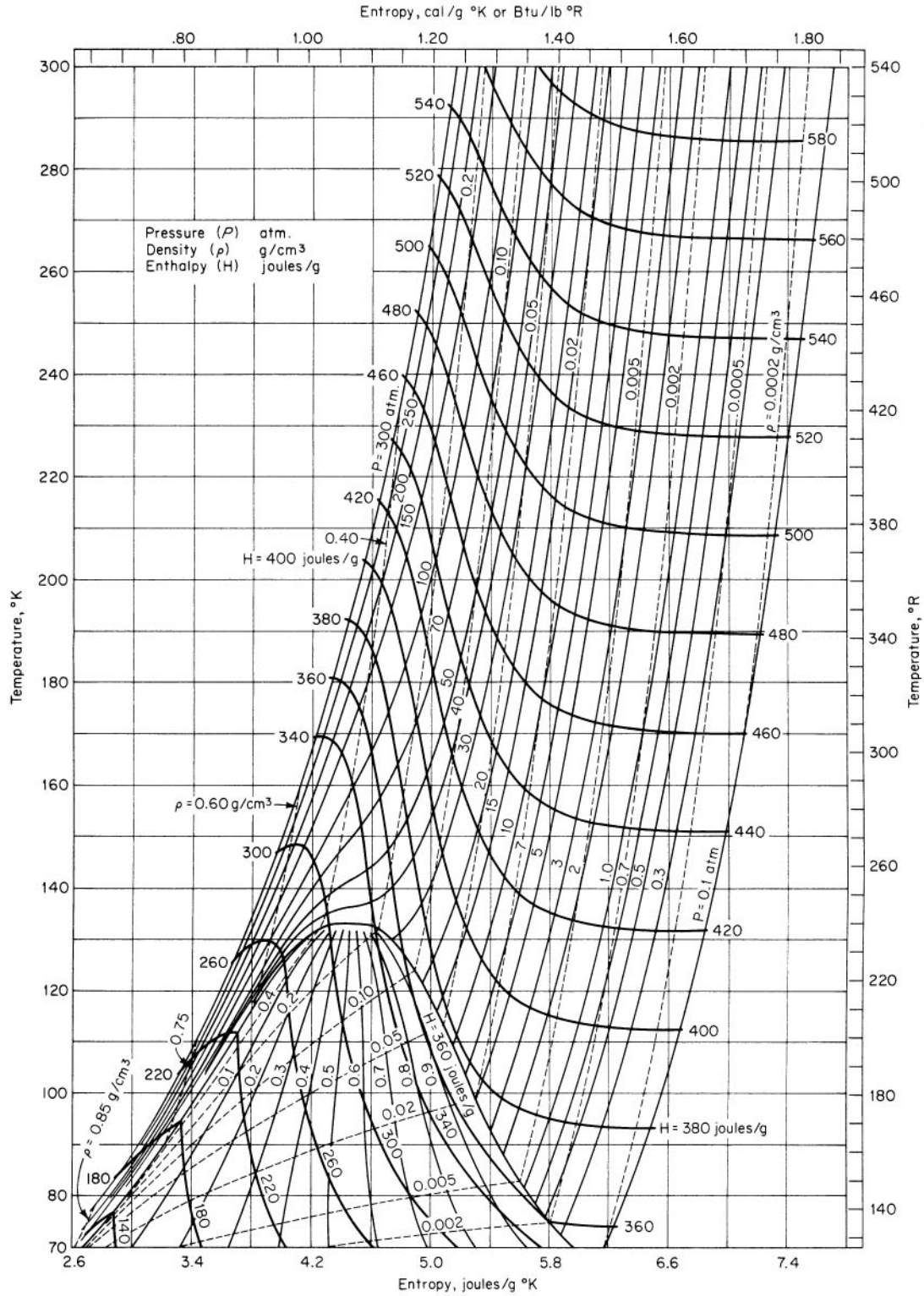

FIG. 2-8 Temperature-entropy diagram for carbon monoxide. Pressure *P*, in atmospheres; density ρ, in grams per cubic centimeter; enthalpy *H*, in joules per gram. (*From Hust and Stewart, NBS Tech. Note 202, 1963.*)

TABLE 2-201 Thermophysical Properties of Saturated Carbon Tetrachloride

T, K	P, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)	μ_f, 10^{-6} Pa·s	k_f, W/(m·K)	Pr
280	0.064	0.000 619	2.414	205.5	420.7	1.018	1.787	0.835	1042	0.1043	8.34
290	0.105	0.000 625	1.495	212.9	425.7	1.042	1.775	0.844	892	0.1020	7.38
300	0.165	0.000 633	0.971	220.9	430.9	1.068	1.768	0.853	774	0.0998	6.62
310	0.251	0.000 641	0.669	228.8	436.1	1.095	1.764	0.863	679	0.0975	6.01
320	0.370	0.000 649	0.463	236.9	441.3	1.121	1.760	0.874	603	0.0952	5.54
330	0.531	0.000 657	0.3306	246.0	446.4	1.149	1.756	0.885	539	0.0930	5.13
340	0.743	0.000 666	0.2407	254.5	451.5	1.174	1.754	0.897	486	0.0907	4.81
350	1.017	0.000 674	0.1802	263.1	456.6	1.199	1.752	0.910	441	0.0884	4.54
360	1.361	0.000 684	0.1370	271.8	461.7	1.224	1.751	0.924	402	0.0861	4.31
370	1.795	0.000 694	0.1053	280.8	466.6	1.248	1.751	0.939	368	0.0839	4.12
380	2.327	0.000 704	0.0820	289.7	471.5	1.272	1.750	0.954	338	0.0816	3.95
390	2.970	0.000 715	0.0651	298.1	475.8	1.295	1.751	0.970	311	0.0794	3.80
400	3.735	0.000 727	0.0525	307.9	481.2	1.319	1.752	0.987	287	0.0771	3.67
410	4.642	0.000 739	0.0426	317.1	485.8	1.341	1.753	1.010	265	0.0749	3.57
420	5.700	0.000 753	0.0350	326.0	490.4	1.363	1.754	1.034	246	0.0726	3.50
430	6.927	0.000 766	0.02899	335.2	494.9	1.384	1.756	1.060	227	0.0704	3.42
440	8.342	0.000 780	0.02413	344.3	499.2	1.405	1.757	1.094	211	0.0682	3.38
450	9.958	0.000 796	0.02020	353.6	503.4	1.426	1.759	1.141	195	0.0660	3.37
460	11.792	0.000 801	0.01692	363.1	507.3	1.446	1.760	1.207	180	0.0638	3.36
470	13.869	0.000 834	0.01425	372.8	511.1	1.467	1.761	1.240	167	0.0666	3.36
480	16.21	0.000 856	0.01205	382.6	514.6	1.487	1.762	1.278	156	0.0594	3.36
490	18.83	0.000 880	0.01011	392.0	517.5	1.507	1.763	1.320	145	0.0511	3.35
500	21.77	0.000 858	0.00858	402.5	520.2	1.526	1.762	1.375	133	0.0549	3.35
510	25.02	0.000 945	0.00722	412.9	522.6	1.546	1.761	1.44			
520	28.68	0.000 987	0.00607	424.3	524.2	1.568	1.760	1.52			
530	32.71	0.001 041	0.00500	436.4	524.5	1.590	1.756				
540	37.18	0.001 121	0.00400	448.3	522.7	1.614	1.749				
550	44.12	0.001 248	0.00309	463.4	518.2	1.638	1.738				
556.4[c]	45.60	0.001 792	0.00179	494.4	494.4	1.692	1.692				

c = critical point. Base points: $h_f = 200$ at 273.15 K = 0°C = $h_A - 300$ kJ/kg; $s_f = 1.000$ at 273.15 K = 0°C = $s_A - 4.000$ kJ/(kg·K). Values mostly rounded and converted from Altunin, V. V., V. Z. Geller, et al., *Thermophysical Properties of Freons*, vol. 9, Hemisphere, Washington, DC, 1987 (243 pp.). Some irregularities exist in these data.

TABLE 2-202 Saturated Carbon Tetrafluoride (R14)*

T, K	P, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)	μ_f, 10^{-4} Pa·s	k_f, W/(m·K)
100	0.0089	5.370.–4	10.77	495.8	648.4	5.487	7.003	0.887		0.136
110	0.0286	5.515.–4	3.648	502.7	652.9	5.556	6.919	0.887		0.128
120	0.0924	5.668.–4	1.228	510.4	657.1	5.624	6.847	0.890		0.119
130	0.2986	5.834.–4	0.4051	518.8	661.1	5.691	6.786	0.896		0.111
140	0.6901	6.018.–4	0.1855	527.7	664.8	5.757	6.736	0.904	3.56	0.104
150	1.4074	6.225.–4	0.0951	537.2	668.3	5.822	6.696	0.922	3.28	0.097
160	2.598	6.460.–4	0.0532	549.4	671.4	5.885	6.662	0.975	3.03	0.089
170	4.426	6.733.–4	0.0318	557.6	674.0	5.947	6.629	1.031	2.80	0.081
180	7.067	7.055.–4	0.0200	568.2	676.1	6.007	6.607	1.104	2.59	0.072
190	10.702	7.449.–4	0.0131	579.3	677.4	6.066	6.583	1.203	2.39	0.064
200	15.531	7.957.–4	0.0087	591.0	677.8	6.124	6.558	1.334	2.19	0.057
210	21.794	8.674.–4	0.0058	603.5	676.4	6.182	6.536	1.506	2.01	0.049
220	29.269	9.931.–4	0.0036	618.5	671.4	6.233	6.490	1.73	1.85	0.042
227.5[c]	37.45	1.598.–3	0.0016	646.9	646.9	6.371	6.371	∞		∞

*P, v, h, and s values interpolated, extrapolated, and converted from Oguchi, *Reito*, **52** (1977): 869–889. c = critical point. The notation 5.370.–4 signifies 5.370×10^{-4}.

Equations and constants approximated to ASHRAE tables are given by Mecaryk, K. and M. Masaryk, *Heat Recovery Systems and CHP,* **11,** 2–3 (1991). The 1993 ASHRAE *Handbook—Fundamentals* (S.I. ed.) contains a saturation table from –140 to –45.65 °C and an enthalpy–log-pressure diagram from 0.1 to 300 bar, –140 to 300 °C. For properties to 1000 bar from 90 to 420 K, see Rublo, R. G., J. A. Zollweg, et al., *J. Chem. Eng. Data*, **36** (1991): 171–184. Saturation and superheat tables and a diagram to 80 bar, 600 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.). Chari, Ph.D. thesis, University of Michigan, 1960, presents saturation-temperature tables in fps units for 1°F increments from –270 to –51°F. Thermodynamic and transport properties, equations, and computer code and tables at constant entropy from 89 to 845 K are given by Hunt, J. L. and Boney, L. R., NASA TN D-7181, 1973 (105 pp.), largely based upon the Chari data.

TABLE 2-203 Thermodynamic Properties of Carbonyl Sulfide

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
134.30	0.000064435	22.518	0.044409	–6.2965	–6.2965	–0.036049	0.050295	0.074835	1449.7	–0.47647
140.00	0.00014316	22.330	0.044783	–5.8733	–5.8733	–0.032962	0.049071	0.073691	1423.0	–0.48236
150.00	0.00049244	22.002	0.045451	–5.1446	–5.1446	–0.027934	0.047317	0.072140	1376.1	–0.48929
160.00	0.0014232	21.674	0.046138	–4.4289	–4.4289	–0.023315	0.045963	0.071067	1329.2	–0.49217
170.00	0.0035714	21.346	0.046847	–3.7220	–3.7219	–0.019029	0.044919	0.070377	1282.3	–0.49125
180.00	0.0079826	21.016	0.047583	–3.0204	–3.0201	–0.015019	0.044118	0.070000	1235.4	–0.48674
190.00	0.016210	20.683	0.048349	–2.3213	–2.3206	–0.011239	0.043507	0.069885	1188.5	–0.47875
200.00	0.030380	20.345	0.049151	–1.6224	–1.6209	–0.0076537	0.043047	0.069996	1141.6	–0.46727
210.00	0.053219	20.002	0.049994	–0.92144	–0.91878	–0.0042337	0.042708	0.070307	1094.7	–0.45221
220.00	0.088035	19.653	0.050884	–0.21676	–0.21228	–0.00095536	0.042464	0.070804	1047.8	–0.43335
230.00	0.13868	19.295	0.051827	0.49332	0.50050	0.0022014	0.042299	0.071479	1000.8	–0.41029
240.00	0.20947	18.927	0.052834	1.2104	1.2214	0.0052538	0.042198	0.072335	953.72	–0.38249
250.00	0.30513	18.548	0.053914	1.9359	1.9524	0.0082168	0.042150	0.073381	906.38	–0.34913
260.00	0.43069	18.155	0.055080	2.6716	2.6954	0.011104	0.042147	0.074640	858.76	–0.30911
270.00	0.59148	17.747	0.056348	3.4192	3.4525	0.013927	0.042186	0.076145	810.74	–0.26092
280.00	0.79300	17.320	0.057737	4.1805	4.2263	0.016699	0.042262	0.077949	762.21	–0.20244
290.00	1.0409	16.870	0.059276	4.9579	5.0196	0.019432	0.042376	0.080132	713.03	–0.13069
300.00	1.3412	16.394	0.060998	5.7542	5.8360	0.022138	0.042533	0.082812	663.05	–0.041371
310.00	1.6998	15.885	0.062953	6.5728	6.6798	0.024832	0.042738	0.086180	612.06	0.071920
320.00	2.1232	15.335	0.065210	7.4185	7.5570	0.027531	0.043007	0.090546	559.82	0.21913
330.00	2.6180	14.733	0.067877	8.2981	8.4758	0.030256	0.043365	0.096471	505.95	0.41667
340.00	3.1915	14.060	0.071123	9.2217	9.4487	0.033041	0.043857	0.10507	449.91	0.69379
350.00	3.8523	13.287	0.075261	10.207	10.497	0.035938	0.044569	0.11899	390.71	1.1092
360.00	4.6109	12.352	0.080962	11.289	11.662	0.039054	0.045699	0.14652	326.44	1.8033
370.00	5.4827	11.072	0.090320	12.572	13.067	0.042698	0.047851	0.23509	252.51	3.2373
378.77	6.3688	7.4100	0.13495	15.239	16.099	0.050522			0	8.9233
134.30	0.000064435	0.000057710	17,328.	14.600	15.716	0.12786	0.022770	0.031089	159.29	230.42
140.00	0.00014316	0.00012301	8,129.4	14.730	15.894	0.12252	0.023105	0.031429	162.31	199.85
150.00	0.00049244	0.00039506	2,531.3	14.963	16.209	0.11442	0.023740	0.032079	167.40	158.07
160.00	0.0014232	0.0010711	933.62	15.201	16.529	0.10767	0.024427	0.032795	172.22	127.26
170.00	0.0035714	0.0025330	394.79	15.443	16.853	0.10200	0.025159	0.033580	176.77	104.13
180.00	0.0079826	0.0053579	186.64	15.689	17.179	0.097198	0.025933	0.034438	181.06	86.482
190.00	0.016210	0.010340	96.715	15.938	17.505	0.093108	0.026745	0.035375	185.07	72.846
200.00	0.030380	0.018492	54.078	16.187	17.830	0.089601	0.027592	0.036399	188.78	62.184
210.00	0.053219	0.031038	32.218	16.436	18.151	0.086575	0.028471	0.037521	192.15	53.756
220.00	0.088035	0.049400	20.243	16.684	18.466	0.083945	0.029382	0.038751	195.15	47.024
230.00	0.13868	0.075184	13.301	16.927	18.772	0.081643	0.030323	0.040105	197.76	41.595
240.00	0.20947	0.11018	9.0759	17.166	19.067	0.079610	0.031293	0.041602	199.92	37.175
250.00	0.30513	0.15639	6.3942	17.397	19.348	0.077800	0.032292	0.043268	201.62	33.545
260.00	0.43069	0.21605	4.6285	17.619	19.613	0.076171	0.033320	0.045137	202.81	30.541
270.00	0.59148	0.29173	3.4278	17.830	19.858	0.074687	0.034376	0.047258	203.46	28.040
280.00	0.79300	0.38642	2.5879	18.027	20.079	0.073316	0.035463	0.049700	203.53	25.945
290.00	1.0409	0.50374	1.9852	18.207	20.273	0.072030	0.036585	0.052570	202.98	24.185
300.00	1.3412	0.64823	1.5427	18.365	20.434	0.070799	0.037748	0.056029	201.77	22.698
310.00	1.6998	0.82581	1.2109	18.497	20.556	0.069593	0.038964	0.060340	199.84	21.437
320.00	2.1232	1.0446	0.95730	18.596	20.629	0.068379	0.040251	0.065951	197.14	20.357
330.00	2.6180	1.3165	0.75961	18.651	20.640	0.067117	0.041639	0.073691	193.61	19.412
340.00	3.1915	1.6600	0.60241	18.647	20.570	0.065750	0.043181	0.085260	189.17	18.546
350.00	3.8523	2.1078	0.47442	18.555	20.383	0.064185	0.044969	0.10478	183.76	17.674
360.00	4.6109	2.7278	0.36660	18.321	20.011	0.062245	0.047203	0.14532	177.26	16.625
370.00	5.4827	3.7183	0.26894	17.782	19.256	0.059425	0.050441	0.28170	169.47	14.934
378.77	6.3688	7.4100	0.13495	15.239	16.099	0.050522			0	8.9233

Single-Phase Properties										
150.00	0.10000	22.003	0.045448	–5.1456	–5.1411	–0.027941	0.047320	0.072138	1376.4	–0.48934
200.00	0.10000	20.347	0.049148	–1.6235	–1.6186	–0.0076594	0.043049	0.069990	1141.9	–0.46739
222.70	0.10000	19.557	0.051133	–0.025288	–0.020175	–0.000090227	0.042413	0.070969	1035.1	–0.42755
222.70	0.10000	0.055571	17.995	16.750	18.550	0.083293	0.029634	0.039104	195.90	45.441
250.00	0.10000	0.049051	20.387	17.590	19.628	0.087860	0.030973	0.040014	207.32	32.301
300.00	0.10000	0.040528	24.674	19.215	21.683	0.095346	0.033493	0.042188	226.21	19.802
350.00	0.10000	0.034596	28.905	20.954	23.845	0.10201	0.035716	0.044263	243.37	13.574
150.00	1.0000	22.015	0.045423	–5.1547	–5.1093	–0.028002	0.047344	0.072112	1379.4	–0.48974
200.00	1.0000	20.365	0.049103	–1.6382	–1.5891	–0.0077331	0.043071	0.069917	1145.9	–0.46887
250.00	1.0000	18.572	0.053843	1.9164	1.9703	0.0081385	0.042163	0.073223	910.91	–0.35287
288.48	1.0000	16.940	0.059031	4.8385	4.8975	0.019018	0.042357	0.079771	720.56	–0.14261
288.48	1.0000	0.48426	2.0650	18.180	20.245	0.072221	0.036412	0.052100	203.11	24.434
300.00	1.0000	0.45571	2.1944	18.640	20.834	0.074222	0.036112	0.050249	209.62	21.627
350.00	1.0000	0.36985	2.7038	20.566	23.270	0.081735	0.036823	0.048032	233.01	14.214
150.00	5.0000	22.068	0.045315	–5.1945	–4.9679	–0.028269	0.047452	0.072006	1392.3	–0.49145
200.00	5.0000	20.446	0.048909	–1.7019	–1.4574	–0.0080546	0.043169	0.069609	1163.4	–0.47508
250.00	5.0000	18.707	0.053456	1.8087	2.0760	0.0077029	0.042245	0.072395	935.94	–0.37256
300.00	5.0000	16.644	0.060080	5.5592	5.8596	0.021479	0.042516	0.080087	701.33	–0.11429
350.00	5.0000	13.583	0.073622	10.000	10.369	0.035328	0.044139	0.10909	422.84	0.86866
150.00	10.000	22.132	0.045183	–5.2426	–4.7907	–0.028596	0.047587	0.071886	1408.1	–0.49341
200.00	10.000	20.543	0.048678	–1.7780	–1.2912	–0.0084436	0.043292	0.069265	1184.3	–0.48206
250.00	10.000	18.864	0.053012	1.6837	2.2138	0.0071898	0.042351	0.071522	965.13	–0.39347
300.00	10.000	16.938	0.059038	5.3293	5.9197	0.020687	0.042551	0.077434	746.52	–0.18740
350.00	10.000	14.430	0.069300	9.3887	10.082	0.033492	0.043442	0.091456	517.30	0.36632
150.00	20.000	22.256	0.044932	–5.3340	–4.4353	–0.029231	0.047854	0.071679	1438.4	–0.49677
200.00	20.000	20.726	0.048249	–1.9196	–0.95458	–0.0091833	0.043536	0.068683	1223.7	–0.49387
250.00	20.000	19.146	0.052230	1.4600	2.5046	0.0062486	0.042574	0.070163	1018.0	–0.42634
300.00	20.000	17.418	0.057411	4.9523	6.1005	0.019350	0.042705	0.074036	821.57	–0.28388
350.00	20.000	15.414	0.064877	8.6515	9.9491	0.031203	0.043268	0.080401	634.40	–0.00046299
200.00	50.000	21.201	0.047167	–2.2782	0.080117	–0.011163	0.044246	0.067514	1327.4	–0.51767
250.00	50.000	19.828	0.050433	0.93091	3.4526	0.0038870	0.043245	0.067745	1148.2	–0.48534
300.00	50.000	18.430	0.054259	4.1637	6.8767	0.016368	0.043321	0.069343	986.75	–0.42082
350.00	50.000	16.985	0.058876	7.4493	10.393	0.027205	0.043748	0.071325	844.44	–0.32515

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data*, **51**(3):785–850, 2006. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The resulting equation has uncertainties of 0.1% in density in the liquid below 450 K, 1% in density at temperatures between 450 and 500 K, 3% in density at temperatures above 500 K, 0.5% in density in the vapor phase and at supercritical conditions below 10 MPa and 450 K, 0.5% in vapor pressure, and 2% in isobaric heat capacity.

TABLE 2-204 Saturated Cesium*

T, K	P, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)
301.6^m	2.66.–9	5.444.–4	7.01.+7	74.6	637.6	0.696	2.563	0.245
400	3.83.–6	5.615.–4	6.54.+4	98.5	651.9	0.765	2.148	0.240
500	3.11.–4	5.800.–4	1001	122.0	666.1	0.817	1.905	0.232
600	5.65.–3	5.999.–4	65.63	144.9	678.4	0.859	1.748	0.224
700	0.0440	6.215.–4	9.671	167.0	688.9	0.893	1.638	0.219
800	0.2029	6.443.–4	2.353	188.7	698.3	0.922	1.559	0.217
900	0.6620	6.689.–4	0.796	210.6	707.3	0.975	1.500	0.222
1000	1.693	6.954.–4	0.335	233.2	716.4	0.972	1.455	0.231
1200	6.790	7.628.–4	0.097	281.1	736.1	1.015	1.394	0.248
1500	27.6	8.84.–4	0.029	358.8	772.2	1.072	1.345	0.275

*Converted from tables in Vargaftik, *Tables of the Thermophysical Properties of Liquids and Gases,* Nauka, Moscow, 1972, and Hemisphere, Washington, 1975. m = melting point. The notation 2.66.–9 signifies 2.66×10^{-9}.

Many of the Vargaftik values also appear in Ohse, R. W., *Handbook of Thermodynamic and Transport Properties of Alkali Metals,* Blackwell Sci. Pubs., Oxford, 1985 (1020 pp.). This source contains superheat data.

Saturation and superheat tables and a diagram to 30 bar, 1550 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.,* Stanford Univ. publ., 1979 (173 pp.).

For a Mollier diagram from 0.1 to 327 psia, 1300–2700 °R, see Weatherford, W. D., J. C. Tyler, et al., WADD-TR-61-96, 1961.

An extensive review of properties of the solid and the saturated liquid was given by Alcock, C. B., M. W. Chase, et al., *J. Phys. Chem. Ref. Data,* **23,** 3 (1994): 385–497.

TABLE 2-205 Thermophysical Properties of Saturated Chlorine

T, °C	P, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)	c_{pg}, kJ/(kg·K)	μ_f, 10^{-6} Pa·s	μ_g, 10^{-6} Pa·s	k_f,W/(m·K)	k_g,W/(m·K)	Pr_f	Pr_g
–50	0.475	0.000 623	0.5448	221.5	518.2	1.7650	3.0946	0.9454	0.476	565	10.3	0.1684	0.0061	3.17	0.809
–40	0.773	0.000 634	0.3481	231.0	522.2	1.8074	3.0562	0.9474	0.484	520	10.8	0.1650	0.0065	2.99	0.815
–30	1.203	0.000 645	0.2314	240.6	526.1	1.8480	3.0223	0.9496	0.497	483	11.4	0.1613	0.0069	2.85	0.820
–20	1.802	0.000 656	0.1593	250.3	529.9	1.8869	2.9921	0.9520	0.513	452	11.9	0.1573	0.0074	2.74	0.826
–10	2.608	0.000 668	0.1134	260.0	533.9	1.9243	2.9649	0.9547	0.532	422	12.4	0.1527	0.0078	2.64	0.841
0	3.664	0.000 681	0.0829	269.7	537.4	1.9604	2.9402	0.9579	0.554	393	13.0	0.1478	0.0083	2.55	0.864
10	5.014	0.000 695	0.0619	279.4	540.5	1.9953	2.9177	0.9618	0.579	368	13.5	0.1427	0.0088	2.48	0.888
20	6.702	0.000 710	0.0471	289.2	543.3	2.0291	2.8924	0.9667	0.607	348	14.1	0.1378	0.0093	2.45	0.918
30	8.774	0.000 726	0.0364	299.0	545.7	2.0622	2.8777	0.9728	0.638	333	14.7	0.1327	0.0099	2.44	0.950
40	11.27	0.000 744	0.0286	308.8	548.0	2.0946	2.8593	0.9816	0.674	318	15.2	0.1282	0.0104	2.43	0.985
50	14.25	0.000 763	0.02276	318.6	549.8	2.1264	2.8417	0.9968	0.720	304	15.8	0.1230	0.0110	2.46	1.034
60	17.76	0.000 784	0.01827	329.1	551.2	2.1578	2.8245	1.022	0.786	290	16.4	0.1171	0.0117	2.53	1.107
70	21.85	0.000 808	0.01481	340.0	552.1	2.1892	2.8074	1.054	0.885	278	17.1	0.1122	0.0126	2.61	1.201
80	26.65	0.000 834	0.01202	351.4	552.5	2.2207	2.7900	1.124	1.017	267	17.9	0.1050	0.0137	2.85	1.331
90	32.17	0.000 865	0.00972	364.1	552.4	2.2528	2.7714	1.253	1.205	256	18.7	0.0986	0.0149	3.26	1.510
100	38.44	0.000 901	0.00789	377.8	551.0	2.2860	2.7502	1.418	1.434	247	19.5	0.0916	0.0163	3.82	1.700
110	45.54	0.000 956	0.00639	391.3	548.8	2.3207	2.7317	1.632	1.696	238	20.6	0.0850	0.0178	4.57	1.96
120	53.57	0.001 016	0.00508	407.1	543.7	2.3590	2.7064	1.891	1.960	230	22.2	0.0775	0.0195	5.61	2.23
130	62.68	0.001 121	0.00392	426.1	535.0	2.4032	2.6733								
140	72.84	0.001 335	0.00282	451.1	517.3	2.4595	2.6198								
144[c]	77.10	0.001 77	0.00177	483.1	483.1	2.5365	2.5365								

c = critical point.

Values interpolated and converted from Martin, J. J., 1977 (private communication), and from *Heat Exchanger Design Handbook,* vol. 5, Hemisphere, Washington, DC, 1983. Values of Ziegler, *Chem.-Ing.-Tech.,* **22** (1950): 229, apparently were also used in Landolt-Bornstein, **IVa,** (1967): 238–239, and in Ullmans *Enzyklopädie der technische Chemie,* 9, Verlag Chemie, Weinheim, 1975 (317–372).

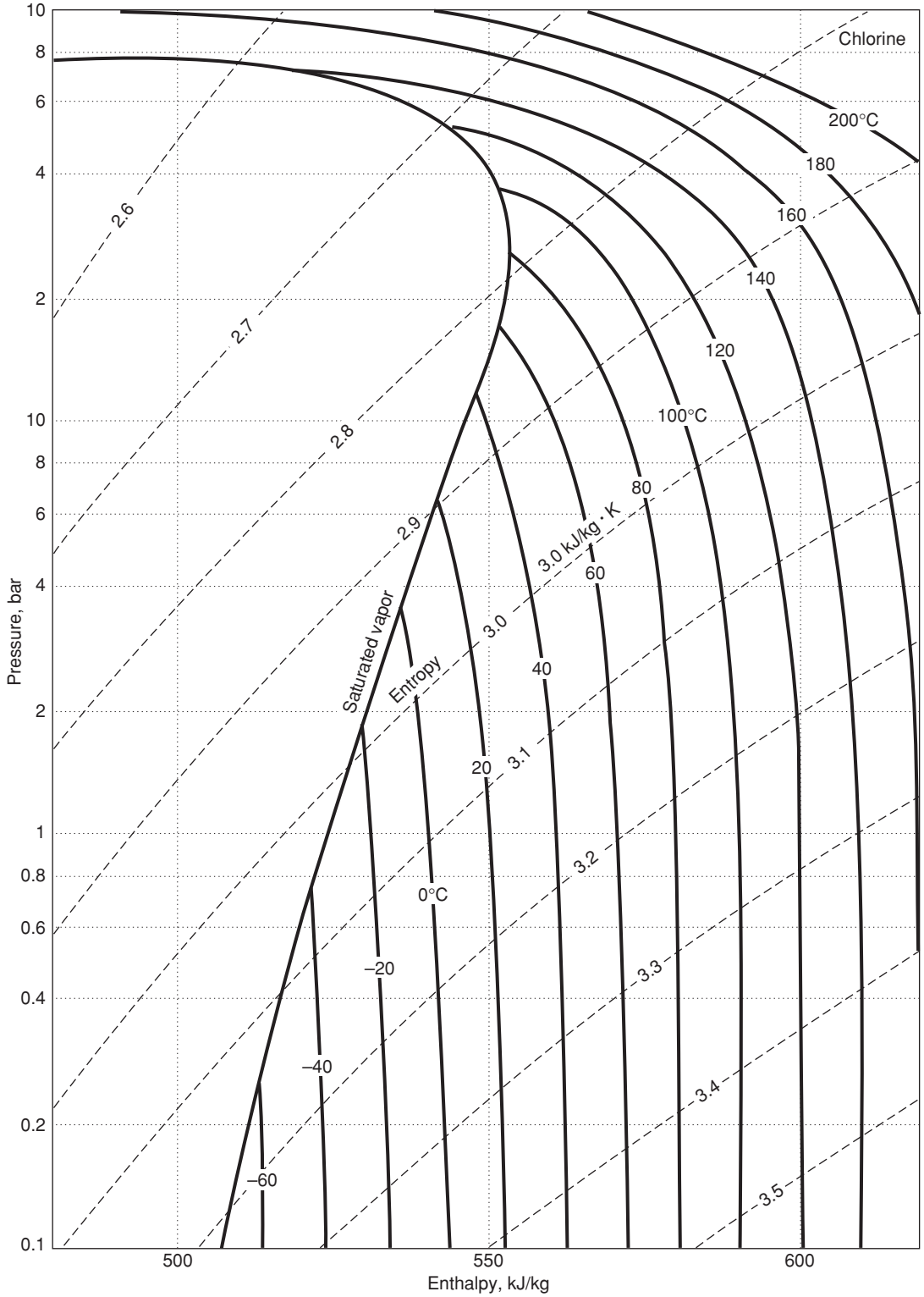

FIG. 2-9 Enthalpy–log-pressure diagram for chlorine.

TABLE 2-206 Saturated Chloroform (R20)

T, K	P, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)	μ_f, 10^{-6} Pa·s	k_f, W/(m·K)	Pr_f
280	0.115	0.000 660	1.689	–46.0	219.5	–0.165	0.798		748	0.120	
300	0.293	0.000 678	0.714	–32.6	230.6	–0.105	0.773		587	0.114	
320	0.620	0.000 695	0.358	–13.4	241.1	–0.041	0.754		468	0.109	
340	1.224	0.000 715	0.190	5.2	252.1	0.015	0.741		381	0.103	
360	2.255	0.000 739	0.107	23.3	263.0	0.065	0.731	1.03	319	0.095	3.35
380	3.830	0.000 765	0.0653	41.7	273.7	0.114	0.725	1.07	273	0.0921	3.17
400	6.039	0.000 795	0.0425	61.4	284.2	0.165	0.722	1.11	237	0.0863	3.04
420	9.058	0.000 822	0.0288	82.8	294.2	0.217	0.721	1.15	206	0.0808	2.93
440	13.39	0.000 871	0.0195	106.1	303.6	0.270	0.719	1.21	177	0.0750	2.86
460	18.80	0.000 921	0.0137	131.6	311.2	0.325	0.716	1.32	155	0.0694	2.95
480	26.00	0.000 980	0.00962	157.4	316.5	0.380	0.711	1.43	129.6	0.0641	2.89
500	34.66	0.001 059	0.00673	186.2	320.8	0.436	0.706	1.59	105.5	0.0584	2.87
520	44.68	0.001 193	0.00467	219.6	321.3	0.499	0.694		81.2	0.0518	
530	50.44	0.001 328	0.00359	242.7	315.7	0.540	0.678		67.7	0.0461	
536.6[c]	54.72	0.002 00	0.00200	284.1	284.1	0.602	0.602				

c = critical point. $h_f = s_f = 0$ at n.b.p., 334.5 K.
P, v, h, and *s* interpolated from Altunin, V. V., V. Z. Geller, et al., *Thermophysical Properties of Freons,* U.S.S.R. N.S.R.D.S. series, vol. 9., Hemisphere, 1987.

TABLE 2-207 Thermodynamic Properties of Cyclohexane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
					Saturated Properties					
279.47	0.0052538	9.4045	0.10633	−12.076	−12.075	−0.038084	0.094354	0.13918	1403.6	−0.50892
290.00	0.0089097	9.2862	0.10769	−10.567	−10.566	−0.032787	0.10358	0.14714	1314.7	−0.47482
300.00	0.014139	9.1736	0.10901	−9.0626	−9.0611	−0.027686	0.11089	0.15372	1245.3	−0.44719
310.00	0.021670	9.0604	0.11037	−7.4959	−7.4935	−0.022550	0.11715	0.15959	1185.7	−0.42239
320.00	0.032188	8.9462	0.11178	−5.8733	−5.8697	−0.017398	0.12261	0.16495	1132.8	−0.39928
330.00	0.046481	8.8309	0.11324	−4.1995	−4.1942	−0.012248	0.12749	0.16991	1084.4	−0.37708
340.00	0.065433	8.7142	0.11476	−2.4777	−2.4702	−0.0071081	0.13193	0.17461	1039.4	−0.35516
350.00	0.090023	8.5958	0.11634	−0.71047	−0.70000	−0.0019852	0.13604	0.17911	996.64	−0.33304
360.00	0.12131	8.4756	0.11799	1.1006	1.1149	0.0031169	0.13992	0.18349	955.45	−0.31028
370.00	0.16044	8.3533	0.11971	2.9544	2.9736	0.0081966	0.14362	0.18781	915.28	−0.28642
380.00	0.20862	8.2285	0.12153	4.8503	4.8756	0.013253	0.14720	0.19210	875.71	−0.26103
390.00	0.26711	8.1009	0.12344	6.7880	6.8210	0.018287	0.15069	0.19642	836.40	−0.23356
400.00	0.33727	7.9701	0.12547	8.7677	8.8100	0.023301	0.15412	0.20079	797.11	−0.20340
410.00	0.42046	7.8357	0.12762	10.790	10.843	0.028296	0.15751	0.20528	757.60	−0.16978
420.00	0.51814	7.6970	0.12992	12.855	12.922	0.033275	0.16088	0.20990	717.72	−0.13174
430.00	0.63180	7.5533	0.13239	14.964	15.048	0.038241	0.16425	0.21472	677.33	−0.087993
440.00	0.76300	7.4037	0.13507	17.119	17.222	0.043199	0.16762	0.21980	636.33	−0.036876
450.00	0.91333	7.2473	0.13798	19.321	19.447	0.048153	0.17101	0.22522	594.66	0.023882
460.00	1.0845	7.0828	0.14119	21.572	21.726	0.053108	0.17442	0.23106	552.32	0.097405
470.00	1.2781	6.9085	0.14475	23.876	24.061	0.058071	0.17788	0.23747	509.35	0.18807
480.00	1.4961	6.7225	0.14875	26.236	26.458	0.063050	0.18140	0.24464	465.88	0.30221
490.00	1.7402	6.5223	0.15332	28.655	28.922	0.068054	0.18499	0.25284	422.08	0.44929
500.00	2.0124	6.3048	0.15861	31.140	31.459	0.073094	0.18868	0.26259	378.12	0.64479
510.00	2.3150	6.0655	0.16487	33.699	34.081	0.078189	0.19249	0.27496	333.83	0.91793
520.00	2.6505	5.7961	0.17253	36.350	36.807	0.083372	0.19650	0.29284	287.99	1.3377
530.00	3.0222	5.4765	0.18260	39.135	39.687	0.088731	0.20083	0.32631	236.86	2.1175
540.00	3.4352	5.0307	0.19878	42.215	42.898	0.094586	0.20611	0.43566	171.37	4.2415
550.00	3.8928	4.1555	0.24065	46.176	47.113	0.10213	0.21549	0.97375	108.39	10.542
553.64	4.0750	3.2438	0.30828	48.978	50.235	0.10770			0	19.224
279.47	0.0052538	0.0022692	440.68	19.476	21.791	0.083095	0.088889	0.097282	173.20	37.820
290.00	0.0089097	0.0037161	269.10	20.430	22.828	0.082366	0.093915	0.10238	175.72	39.495
300.00	0.014139	0.0057156	174.96	21.380	23.854	0.082030	0.098579	0.10715	177.99	39.306
310.00	0.021670	0.0085063	117.56	22.370	24.917	0.082001	0.10318	0.11190	180.09	38.189
320.00	0.032188	0.012293	81.348	23.397	26.015	0.082241	0.10775	0.11667	182.00	36.613
330.00	0.046481	0.017306	57.785	24.459	27.145	0.082719	0.11233	0.12149	183.70	34.853
340.00	0.065433	0.023800	42.017	25.555	28.305	0.083406	0.11692	0.12641	185.14	33.070
350.00	0.090023	0.032056	31.195	26.684	29.492	0.084277	0.12155	0.13145	186.30	31.353
360.00	0.12131	0.042386	23.593	27.842	30.704	0.085309	0.12623	0.13663	187.14	29.750
370.00	0.16044	0.055130	18.139	29.029	31.939	0.086481	0.13097	0.14199	187.65	28.282
380.00	0.20862	0.070668	14.151	30.242	33.194	0.087775	0.13577	0.14756	187.78	26.956
390.00	0.26711	0.089425	11.183	31.480	34.467	0.089174	0.14063	0.15338	187.51	25.772
400.00	0.33727	0.11188	8.9379	32.739	35.754	0.090660	0.14557	0.15949	186.80	24.723
410.00	0.42046	0.13860	7.2152	34.019	37.053	0.092220	0.15059	0.16596	185.62	23.803
420.00	0.51814	0.17021	5.8751	35.315	38.359	0.093839	0.15569	0.17286	183.94	23.004
430.00	0.63180	0.20749	4.8195	36.625	39.670	0.095502	0.16088	0.18030	181.73	22.319
440.00	0.76300	0.25135	3.9785	37.945	40.980	0.097195	0.16615	0.18840	178.96	21.739
450.00	0.91333	0.30293	3.3011	39.270	42.285	0.098905	0.17153	0.19737	175.58	21.259
460.00	1.0845	0.36362	2.7501	40.597	43.579	0.10062	0.17701	0.20746	171.56	20.872
470.00	1.2781	0.43522	2.2977	41.918	44.855	0.10231	0.18259	0.21903	166.87	20.572
480.00	1.4961	0.52006	1.9228	43.228	46.105	0.10398	0.18828	0.23261	161.44	20.351
490.00	1.7402	0.62133	1.6095	44.519	47.319	0.10560	0.19406	0.24895	155.22	20.204
500.00	2.0124	0.74350	1.3450	45.779	48.486	0.10715	0.19990	0.26922	148.10	20.128
510.00	2.3150	0.89342	1.1193	46.995	49.586	0.10859	0.20573	0.29534	139.91	20.128
520.00	2.6505	1.0826	0.92368	48.145	50.593	0.10988	0.21142	0.33088	130.29	20.237
530.00	3.0222	1.3338	0.74972	49.186	51.452	0.11093	0.21669	0.38411	118.65	20.538
540.00	3.4352	1.7017	0.58765	50.020	52.039	0.11151	0.22086	0.48310	104.10	21.201
550.00	3.8928	2.3597	0.42378	50.334	51.984	0.11099	0.22221	0.96007	87.229	22.656
553.64	4.0750	3.2438	0.30828	48.978	50.235	0.10770			0	19.224

Single-Phase Properties										
300.00	0.10000	9.1745	0.10900	–9.0661	–9.0552	–0.027698	0.11091	0.15371	1245.8	–0.44737
353.45	0.10000	8.5546	0.11690	–0.090837	–0.079147	–0.00022335	0.13740	0.18063	982.29	–0.32529
353.45	0.10000	0.035368	28.274	27.080	29.907	0.084616	0.12316	0.13322	186.62	30.786
400.00	0.10000	0.030817	32.450	33.301	36.546	0.10224	0.14262	0.15196	200.08	18.560
500.00	0.10000	0.024334	41.095	49.598	53.708	0.14037	0.18205	0.19081	224.91	8.2156
600.00	0.10000	0.020172	49.575	69.610	74.568	0.17831	0.21697	0.22554	246.67	4.7321
700.00	0.10000	0.017244	57.992	92.840	98.639	0.21535	0.24653	0.25502	266.50	3.1661
300.00	1.0000	9.1840	0.10888	–9.1021	–8.9932	–0.027818	0.11106	0.15360	1250.6	–0.44930
400.00	1.0000	7.9861	0.12522	8.7122	8.8374	0.023162	0.15416	0.20043	803.90	–0.20919
455.22	1.0000	7.1625	0.13962	20.490	20.630	0.050740	0.17279	0.22821	572.63	0.060445
455.22	1.0000	0.33339	2.9995	39.963	42.963	0.099799	0.17438	0.20248	173.56	21.046
500.00	1.0000	0.27733	3.6058	48.369	51.975	0.11868	0.18654	0.20332	198.76	11.678
600.00	1.0000	0.21435	4.6653	68.879	73.544	0.15793	0.21804	0.22955	233.28	5.2822
700.00	1.0000	0.17821	5.6112	92.287	97.898	0.19542	0.24682	0.25703	258.70	3.2649
300.00	5.0000	9.2252	0.10840	–9.2570	–8.7150	–0.028339	0.11167	0.15315	1272.4	–0.45730
400.00	5.0000	8.0768	0.12381	8.3977	9.0168	0.022365	0.15438	0.19856	843.04	–0.23916
500.00	5.0000	6.5774	0.15204	30.362	31.122	0.071493	0.18830	0.24756	459.37	0.29542
600.00	5.0000	1.8230	0.54855	63.154	65.897	0.13428	0.23018	0.32421	141.27	9.9456
700.00	5.0000	1.0620	0.94165	89.416	94.125	0.17787	0.24921	0.27380	220.29	3.9618
300.00	10.000	9.2742	0.10783	–9.4403	–8.3620	–0.028964	0.11229	0.15264	1300.3	–0.46622
400.00	10.000	8.1782	0.12228	8.0451	9.2679	0.021455	0.15456	0.19678	888.19	–0.26775
500.00	10.000	6.8741	0.14547	29.472	30.927	0.069619	0.18805	0.23749	554.89	0.059727
600.00	10.000	4.9059	0.20384	55.388	57.426	0.11776	0.22275	0.30052	265.77	1.5290
700.00	10.000	2.6733	0.37407	84.812	88.552	0.16576	0.25026	0.30095	217.61	2.8239
300.00	25.000	9.4073	0.10630	–9.9312	–7.2736	–0.030689	0.11356	0.15139	1386.2	–0.48739
400.00	25.000	8.4285	0.11864	7.1716	10.138	0.019116	0.15480	0.19342	1006.6	–0.32157
500.00	25.000	7.3968	0.13519	27.819	31.199	0.065971	0.18805	0.22750	739.78	–0.16655
600.00	25.000	6.2973	0.15880	51.613	55.583	0.11034	0.21982	0.25993	540.01	0.046982
700.00	25.000	5.1531	0.19406	78.272	83.123	0.15273	0.24808	0.28977	414.69	0.35809
400.00	75.000	8.9762	0.11141	5.2440	13.599	0.013443	0.15529	0.18906	1308.3	–0.39015
500.00	75.000	8.2410	0.12134	25.023	34.124	0.059111	0.18956	0.22091	1084.3	–0.31328
600.00	75.000	7.5637	0.13221	47.767	57.683	0.10198	0.22144	0.24976	931.19	–0.25806
700.00	75.000	6.9477	0.14393	73.174	83.969	0.14245	0.24950	0.27541	824.46	–0.21348

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Penoncello, S. G., Goodwin, A. R. H., and Jacobsen, R. T., "A Thermodynamic Property Formulation for Cyclohexane," *Int. J. Thermophys.* **16**(2):519–531, 1995. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are 0.1% in density, 2% in heat capacity, and 1% in the speed of sound, except in the critical region.

TABLE 2-208 Thermodynamic Properties of Decane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
243.50	1.4042E-06	5.4064	0.18497	–69.252	–69.252	–0.20307	0.22393	0.28635	1468.5	–0.48339	144.08	2433.6
250.00	2.8673E-06	5.3702	0.18621	–67.383	–67.383	–0.19549	0.22704	0.28898	1438.4	–0.47764	142.30	2066.6
270.00	1.9993E-05	5.2597	0.19012	–61.516	–61.516	–0.17292	0.23712	0.29787	1349.4	–0.45826	136.88	1350.0
290.00	0.00010141	5.1502	0.19417	–55.461	–55.461	–0.15129	0.24780	0.30773	1265.6	–0.43680	131.57	957.69
310.00	0.00039985	5.0409	0.19838	–49.202	–49.202	–0.13043	0.25893	0.31832	1186.0	–0.41360	126.38	718.75
330.00	0.0012883	4.9312	0.20279	–42.725	–42.725	–0.11018	0.27034	0.32946	1109.9	–0.38881	121.32	561.90
350.00	0.0035240	4.8206	0.20744	–36.021	–36.020	–0.090462	0.28191	0.34100	1036.6	–0.36228	116.40	452.88
370.00	0.0084305	4.7082	0.21239	–29.084	–29.082	–0.071189	0.29354	0.35282	965.68	–0.33365	111.63	373.57
390.00	0.018060	4.5936	0.21770	–21.908	–21.905	–0.052306	0.30512	0.36483	896.48	–0.30225	107.04	313.65
410.00	0.035300	4.4757	0.22343	–14.493	–14.485	–0.033764	0.31659	0.37700	828.54	–0.26699	102.62	266.90
430.00	0.063919	4.3538	0.22968	-6.8339	–6.8192	–0.015527	0.32790	0.38931	761.40	–0.22626	98.409	229.40
450.00	0.10855	4.2266	0.23659	1.0694	1.0950	0.0024370	0.33901	0.40181	694.57	–0.17752	94.401	198.56
470.00	0.17465	4.0927	0.24434	9.2198	9.2624	0.020158	0.34991	0.41460	627.57	–0.11677	90.612	172.63
490.00	0.26846	3.9499	0.25317	17.622	17.690	0.037667	0.36059	0.42793	559.85	–0.037250	87.051	150.36
510.00	0.39696	3.7952	0.26349	26.283	26.388	0.054997	0.37108	0.44218	490.80	0.073195	83.726	130.83
530.00	0.56801	3.6240	0.27594	35.219	35.375	0.072193	0.38143	0.45818	419.70	0.23865	80.640	113.31
550.00	0.79054	3.4286	0.29166	44.457	44.687	0.089321	0.39176	0.47770	345.68	0.51353	77.794	97.183
570.00	1.0751	3.1943	0.31306	54.055	54.391	0.10649	0.40231	0.50540	267.65	1.0476	75.192	81.781
590.00	1.4353	2.8870	0.34638	64.149	64.646	0.12397	0.41372	0.55950	184.05	2.4223	72.934	66.154
610.00	1.8918	2.3754	0.42098	75.300	76.096	0.14276	0.42875	0.87382	91.074	9.9501	73.097	47.430
617.70	2.1014	1.6400	0.60976	82.386	83.668	0.15491			0	34.686		
243.50	1.4042E-06	6.9358E-07	1,441,800.	–15.410	–13.386	0.026360	0.19210	0.20042	121.84	320.14	6.4788	4.3408
250.00	2.8673E-06	1.3795E-06	724,920.	–14.150	–12.071	0.025751	0.19573	0.20405	123.41	287.01	6.7500	4.4520
270.00	1.9993E-05	8.9067E-06	112,280.	–10.121	–7.8760	0.025744	0.20739	0.21571	128.09	208.26	7.6856	4.7935
290.00	0.00010141	4.2071E-05	23,769.	–5.8536	–3.4432	0.028079	0.21963	0.22797	132.58	154.49	8.7681	5.1337
310.00	0.00039985	0.00015529	6,439.4	–1.3417	1.2331	0.032268	0.23228	0.24065	136.85	116.99	9.9889	5.4722
330.00	0.0012883	0.00047076	2,124.2	3.4167	6.1533	0.037934	0.24518	0.25363	140.87	90.369	11.339	5.8086
350.00	0.0035240	0.0012178	821.18	8.4178	11.312	0.044772	0.25823	0.26684	144.56	71.168	12.808	6.1419
370.00	0.0084305	0.0027701	361.00	13.654	16.697	0.052538	0.27134	0.28022	147.82	57.142	14.385	6.4713
390.00	0.018060	0.0056755	176.20	19.113	22.295	0.061027	0.28446	0.29376	150.52	46.790	16.056	6.7963
410.00	0.035300	0.010678	93.649	24.781	28.087	0.070070	0.29754	0.30748	152.52	39.094	17.808	7.1172
430.00	0.063919	0.018742	53.355	30.642	34.053	0.079524	0.31053	0.32142	153.66	33.355	19.629	7.4356
450.00	0.10855	0.031091	32.164	36.677	40.168	0.089267	0.32343	0.33567	153.78	29.089	21.506	7.7555
470.00	0.17465	0.049284	20.290	42.864	46.408	0.099191	0.33621	0.35042	152.66	25.969	23.438	8.0842
490.00	0.26846	0.075371	13.268	49.176	52.738	0.10919	0.34890	0.36600	150.07	23.781	25.431	8.4344
510.00	0.39696	0.11219	8.9134	55.580	59.118	0.11917	0.36154	0.38308	145.68	22.413	27.522	8.8280
530.00	0.56801	0.16399	6.0979	62.026	65.490	0.12901	0.37421	0.40300	139.04	21.855	29.799	9.3033
550.00	0.79054	0.23784	4.2045	68.438	71.762	0.13855	0.38707	0.42896	129.53	22.255	32.477	9.9327
570.00	1.0751	0.34741	2.8784	74.676	77.770	0.14751	0.40046	0.47018	116.14	24.065	36.104	10.874
590.00	1.4353	0.52650	1.8993	80.422	83.148	0.15533	0.41513	0.56612	97.344	28.492	42.347	12.566
610.00	1.8918	0.92143	1.0853	84.493	86.546	0.15989	0.43359	1.2127	71.032	37.614	59.648	17.240
617.70	2.1014	1.6400	0.60976	82.386	83.668	0.15491			0	34.686		

Single-Phase Properties

250.00	0.10000	5.3706	0.18620	–67.388	–67.369	–0.19551	0.22705	0.28898	1438.9	–0.47770	142.33	2069.3
350.00	0.10000	4.8213	0.20741	–36.029	–36.008	–0.090485	0.28192	0.34098	1037.4	–0.36251	116.44	453.43
446.75	0.10000	4.2477	0.23542	–0.23039	–0.20685	–0.00046204	0.33722	0.39976	705.42	–0.18612	95.037	203.20
446.75	0.10000	0.028735	34.801	35.686	39.166	0.087670	0.32134	0.33333	153.83	29.697	21.198	7.7032
450.00	0.10000	0.028470	35.125	36.739	40.251	0.090090	0.32313	0.33498	154.68	28.767	21.529	7.7604
550.00	0.10000	0.022477	44.491	71.828	76.277	0.16222	0.37514	0.38484	176.60	12.764	32.572	9.4815
650.00	0.10000	0.018766	53.287	111.67	117.00	0.23014	0.41928	0.42830	194.21	7.0015	44.613	11.158
250.00	1.0000	5.3745	0.18606	–67.431	–67.245	–0.19569	0.22712	0.28892	1443.8	–0.47822	142.62	2093.8
350.00	1.0000	4.8284	0.20711	–36.104	–35.897	–0.090699	0.28198	0.34075	1044.7	–0.36461	116.88	458.58
450.00	1.0000	4.2417	0.23575	0.92464	1.1604	0.0021144	0.33902	0.40097	706.99	–0.18764	95.062	201.71
550.00	1.0000	3.4433	0.29042	44.348	44.638	0.089120	0.39165	0.47560	353.85	0.47267	78.107	98.236
565.17	1.0000	3.2558	0.30715	51.697	52.004	0.10233	0.39972	0.49744	286.94	0.87812	75.797	85.478
565.17	1.0000	0.31644	3.1602	73.196	76.356	0.14542	0.39714	0.45776	119.81	23.453	35.085	10.603
650.00	1.0000	0.21839	4.5790	109.33	113.91	0.20734	0.42517	0.44558	167.63	8.8875	44.104	11.626
250.00	5.0000	5.3914	0.18548	–67.618	–66.691	–0.19644	0.22744	0.28869	1465.1	–0.48040	143.89	2204.8
350.00	5.0000	4.8586	0.20582	–36.424	–35.395	–0.091624	0.28223	0.33985	1075.7	–0.37303	118.77	481.47
450.00	5.0000	4.3034	0.23237	0.32894	1.4908	0.00076852	0.33912	0.39795	757.95	–0.22390	97.851	215.38
550.00	5.0000	3.6402	0.27471	42.808	44.181	0.086242	0.39052	0.45616	467.92	0.098466	82.872	114.20
650.00	5.0000	2.6391	0.37891	91.156	93.050	0.16772	0.43712	0.52513	213.89	1.6230	75.400	55.304
350.00	10.000	4.8938	0.20434	–36.797	–34.754	–0.092723	0.28255	0.33892	1112.2	–0.38180	121.04	510.17
450.00	10.000	4.3700	0.22883	–0.32038	1.9680	–0.00073280	0.33929	0.39532	813.41	–0.25552	101.03	231.67
550.00	10.000	3.7932	0.26363	41.527	44.163	0.083766	0.39008	0.44754	562.29	–0.060225	87.304	129.37
650.00	10.000	3.1242	0.32009	88.002	91.203	0.16225	0.43362	0.49145	369.51	0.31317	81.597	76.394
350.00	100.00	5.3085	0.18838	–41.033	–22.195	–0.10704	0.28785	0.33463	1562.8	–0.43121	152.54	1088.0
450.00	100.00	4.9747	0.20102	–6.2415	13.860	–0.016697	0.34377	0.38610	1360.6	–0.37226	139.48	498.37
550.00	100.00	4.6758	0.21387	33.447	54.834	0.065371	0.39337	0.43213	1216.3	–0.32986	130.26	308.65
650.00	100.00	4.4066	0.22693	77.332	100.03	0.14078	0.43497	0.47043	1111.9	–0.30079	124.76	219.90
550.00	300.00	5.3265	0.18774	28.160	84.482	0.047128	0.40016	0.43412	1858.1	–0.34462	192.00	698.31
650.00	300.00	5.1406	0.19453	71.521	129.88	0.12288	0.44112	0.47265	1766.6	–0.32003	188.95	480.95

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W,. and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data*, **51**(3):785–850, 2006. The source for viscosity is Huber, M. L., Laesecke, A., and Xiang, H. W, "Viscosity Correlations for Minor Constituent Fluids in Natural Gas: *n*-Octane, *n*-Nonane and *n*-decane," *Fluid Phase Equilibria* **224:**263–270, 2004. The source for thermal conductivity is Huber, M. L., and Perkins, R. A., "Thermal Conductivity Correlations for Minor Constituent Fluids in Natural Gas: *n*-Octane, *n*-Nonane and *n*-Decane," *Fluid Phase Equilibria* **227:**47–55, 2004.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in density are 0.05% in the saturated liquid density between 290 and 320 K, 0.2% in the liquid phase at temperatures to 400 K (with somewhat higher uncertainties above 100 MPa, up to 0.5%), 1% in the liquid phase up to 500 MPa, and 2% at higher temperatures as well as in the vapor phase. Vapor pressures have an uncertainty of 0.2%, and the uncertainties in liquid heat capacities and liquid sound speeds are 1%. The uncertainty in heat capacities may be higher at pressures above 10 MPa. The estimated uncertainty in viscosity is 1% along the saturated liquid line, 2% in compressed liquid to 200 MPa, 5% in vapor and supercritical regions. Uncertainty in thermal conductivity is 3%, except in the supercritical region and dilute gas which have an uncertainty of 5%.

TABLE 2-209 Thermodynamic Properties of Deuterium Oxide (Heavy Water)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
276.97	0.00066103	55.198	0.018117	–8.2294	–8.2294	–0.025460	0.084185	0.084334	1324.3	–0.22218	564.56	2085.6
280.00	0.00082243	55.214	0.018111	–7.9735	–7.9735	–0.024541	0.084523	0.084574	1332.9	–0.21843	569.58	1868.6
300.00	0.0030641	55.126	0.018140	–6.2759	–6.2758	–0.018685	0.084432	0.084957	1394.9	–0.19991	596.96	1046.6
320.00	0.0094511	54.780	0.018255	–4.5798	–4.5796	–0.013212	0.082466	0.084598	1436.7	–0.18770	615.88	688.90
340.00	0.025012	54.254	0.018432	–2.8930	–2.8926	–0.0080990	0.079894	0.084075	1455.5	–0.17806	628.04	497.65
360.00	0.058391	53.593	0.018659	–1.2168	–1.2157	–0.0033082	0.077173	0.083580	1455.6	–0.16908	634.49	381.94
380.00	0.12292	52.817	0.018933	0.45077	0.45310	0.0011999	0.074503	0.083248	1440.4	–0.15944	635.99	306.06
400.00	0.23743	51.937	0.019254	2.1139	2.1185	0.0054654	0.071990	0.083196	1413.3	–0.14815	633.11	253.36
420.00	0.42676	50.957	0.019624	3.7786	3.7870	0.0095268	0.069689	0.083502	1376.7	–0.13444	626.31	215.11
440.00	0.72190	49.875	0.020050	5.4521	5.4666	0.013420	0.067622	0.084212	1331.9	–0.11766	616.01	186.33
460.00	1.1598	48.687	0.020539	7.1417	7.1655	0.017176	0.065790	0.085360	1279.7	–0.097022	602.53	164.01
480.00	1.7833	47.386	0.021103	8.8551	8.8927	0.020824	0.064181	0.087004	1219.9	–0.071339	586.08	146.23
500.00	2.6406	45.961	0.021758	10.601	10.658	0.024390	0.062780	0.089266	1152.3	–0.038642	566.82	131.71
520.00	3.7850	44.390	0.022528	12.390	12.475	0.027902	0.061580	0.092393	1076.5	0.0043364	544.81	119.53
540.00	5.2758	42.641	0.023452	14.236	14.360	0.031394	0.060585	0.096848	991.90	0.063056	520.11	109.01
560.00	7.1787	40.660	0.024594	16.162	16.339	0.034909	0.059829	0.10351	897.91	0.14707	492.75	99.548
580.00	9.5679	38.357	0.026071	18.203	18.453	0.038511	0.059403	0.11428	793.19	0.27477	462.70	90.597
600.00	12.530	35.563	0.028119	20.425	20.777	0.042313	0.059524	0.13431	674.99	0.48803	430.22	81.477
620.00	16.171	31.867	0.031381	22.980	23.487	0.046577	0.060792	0.18616	537.16	0.91327	396.40	70.992
640.00	20.654	24.976	0.040039	26.745	27.572	0.052801	0.066781	0.82671	359.72	2.2860	420.92	53.746
643.89	21.660	17.875	0.055943	29.926	31.137	0.058280			0	3.7063		
276.97	0.00066103	0.00028721	3481.8	36.006	38.307	0.14256	0.025895	0.034265	389.85	394.78	16.529	9.6017
280.00	0.00082242	0.00035350	2828.9	36.083	38.409	0.14111	0.025952	0.034329	391.88	363.66	16.753	9.6779
300.00	0.0030641	0.0012303	812.82	36.589	39.079	0.13250	0.026375	0.034822	404.89	220.57	18.277	10.228
320.00	0.0094511	0.0035636	280.61	37.091	39.743	0.12530	0.026887	0.035451	417.19	143.76	19.890	10.840
340.00	0.025012	0.0089021	112.33	37.585	40.394	0.11922	0.027487	0.036239	428.74	100.20	21.616	11.492
360.00	0.058391	0.019720	50.709	38.064	41.025	0.11403	0.028182	0.037225	439.47	74.063	23.487	12.169
380.00	0.12292	0.039608	25.247	38.521	41.624	0.10955	0.029002	0.038484	449.26	57.443	25.539	12.856
400.00	0.23743	0.073418	13.621	38.946	42.180	0.10562	0.030006	0.040139	457.95	46.206	27.812	13.544
420.00	0.42676	0.12741	7.8485	39.329	42.679	0.10213	0.031275	0.042357	465.33	38.108	30.356	14.226
440.00	0.72190	0.20947	4.7740	39.660	43.106	0.098964	0.032903	0.045350	471.15	31.903	33.231	14.897
460.00	1.1598	0.32939	3.0359	39.925	43.447	0.096048	0.034981	0.049371	475.13	26.904	36.529	15.558
480.00	1.7833	0.49953	2.0019	40.116	43.686	0.093309	0.037576	0.054720	476.97	22.747	40.398	16.213
500.00	2.6406	0.73576	1.3591	40.219	43.808	0.090688	0.040723	0.061780	476.36	19.244	45.081	16.871
520.00	3.7850	1.0594	0.94392	40.219	43.792	0.088127	0.044416	0.071116	472.96	16.294	50.974	17.547
540.00	5.2758	1.5008	0.66632	40.096	43.612	0.085564	0.048619	0.083703	466.44	13.819	58.649	18.267
560.00	7.1787	2.1062	0.47479	39.815	43.224	0.082917	0.053289	0.10149	456.44	11.743	68.218	19.071
580.00	9.5679	2.9537	0.33856	39.318	42.557	0.080069	0.058406	0.12892	442.43	9.9759	79.570	20.029
600.00	12.530	4.1942	0.23842	38.492	41.479	0.076817	0.064014	0.17822	423.35	8.4154	98.667	21.290
620.00	16.171	6.2033	0.16120	37.081	39.688	0.072707	0.070293	0.29956	395.96	6.9363	133.97	23.259
640.00	20.654	11.096	0.090120	33.747	35.608	0.065358	0.077762	1.5264	343.38	5.1241	285.74	28.595
643.89	21.660	17.875	0.055943	29.926	31.137	0.058280			0	3.7063		

Single-Phase Properties

300.00	0.10000	55.129	0.018139	–6.2760	–6.2742	–0.018686	0.084425	0.084951	1395.1	–0.19991	597.01	1046.5
374.20	0.10000	53.053	0.018849	–0.032221	–0.030336	–0.000080962	0.075265	0.083320	1446.2	–0.16237	636.03	325.15
374.20	0.10000	0.032646	30.631	38.391	41.454	0.11078	0.028748	0.038084	446.53	61.573	24.923	12.656
400.00	0.10000	0.030411	32.883	39.139	42.427	0.11330	0.028403	0.037410	462.35	46.430	27.024	13.658
500.00	0.10000	0.024157	41.395	42.023	46.162	0.12163	0.029147	0.037685	515.85	19.445	36.485	17.747
600.00	0.10000	0.020087	49.784	45.017	49.996	0.12861	0.030636	0.039048	562.30	10.077	47.629	21.980
700.00	0.10000	0.017202	58.134	48.166	53.980	0.13475	0.032285	0.040652	604.21	6.0901	60.182	26.224
800.00	0.10000	0.015045	66.469	51.481	58.128	0.14029	0.033959	0.042306	642.79	4.1486	73.869	30.405
300.00	1.0000	55.152	0.018132	–6.2770	–6.2589	–0.018689	0.084361	0.084894	1397.1	–0.19988	597.49	1046.3
400.00	1.0000	51.959	0.019246	2.1086	2.1279	0.0054522	0.071968	0.083157	1415.4	–0.14835	633.54	253.63
453.53	1.0000	49.083	0.020374	6.5927	6.6131	0.015974	0.066357	0.084938	1297.4	–0.10418	607.22	170.66
453.53	1.0000	0.28575	3.4996	39.847	43.347	0.096969	0.034254	0.047940	474.06	28.417	35.408	15.345
500.00	1.0000	0.25193	3.9693	41.482	45.451	0.10139	0.032240	0.043385	503.79	19.634	38.239	17.445
600.00	1.0000	0.20474	4.8843	44.748	49.632	0.10902	0.031708	0.041087	556.10	10.106	48.345	21.886
700.00	1.0000	0.17382	5.7529	48.001	53.754	0.11537	0.032710	0.041565	600.64	6.1060	60.651	26.233
800.00	1.0000	0.15139	6.6052	51.363	57.969	0.12100	0.034141	0.042787	640.67	4.1567	74.254	30.468
300.00	5.0000	55.254	0.018098	–6.2816	–6.1911	–0.018705	0.084079	0.084647	1405.7	–0.19974	599.61	1045.2
400.00	5.0000	52.073	0.019204	2.0813	2.1773	0.0053836	0.071858	0.082958	1426.2	–0.14937	635.76	255.02
500.00	5.0000	46.085	0.021699	10.558	10.667	0.024304	0.062722	0.088880	1163.3	–0.042258	568.91	132.48
536.66	5.0000	42.947	0.023284	13.923	14.039	0.030810	0.060736	0.095981	1006.7	0.051819	524.42	110.68
536.66	5.0000	1.4172	0.70563	40.127	43.655	0.085995	0.047884	0.081310	467.76	14.202	57.219	18.142
600.00	5.0000	1.1342	0.88170	43.329	47.738	0.093213	0.038071	0.054713	524.33	9.9010	53.862	21.508
700.00	5.0000	0.91389	1.0942	47.210	52.681	0.10085	0.034830	0.046443	584.32	6.1037	63.474	26.310
800.00	5.0000	0.77903	1.2836	50.818	57.237	0.10693	0.034981	0.045153	631.66	4.1656	76.389	30.769
300.00	10.000	55.380	0.018057	–6.2874	–6.1068	–0.018725	0.083735	0.084346	1415.9	–0.19956	602.23	1043.9
400.00	10.000	52.214	0.019152	2.0479	2.2394	0.0052992	0.071726	0.082718	1439.3	–0.15059	638.50	256.74
500.00	10.000	46.341	0.021579	10.471	10.687	0.024128	0.062611	0.088119	1185.7	–0.049352	573.22	134.06
583.19	10.000	37.950	0.026351	18.544	18.807	0.039101	0.059377	0.11663	775.32	0.30140	457.66	89.173
583.19	10.000	3.1198	0.32053	39.212	42.417	0.079584	0.059266	0.13479	439.77	9.7157	81.935	20.204
600.00	10.000	2.7732	0.36059	40.719	44.325	0.082812	0.051641	0.097980	468.72	9.0626	72.595	21.210
700.00	10.000	1.9660	0.50864	46.072	51.158	0.093421	0.038049	0.054970	562.64	5.9486	69.164	26.519
800.00	10.000	1.6183	0.61793	50.085	56.265	0.10025	0.036102	0.048671	621.09	4.1215	80.100	31.206
300.00	50.000	56.338	0.017750	–6.3323	–5.4448	–0.018905	0.081303	0.082295	1484.2	–0.19786	622.24	1038.3
400.00	50.000	53.254	0.018778	1.8073	2.7462	0.0046700	0.070872	0.081058	1527.2	–0.15849	659.16	269.56
500.00	50.000	48.076	0.020801	9.8899	10.930	0.022920	0.062103	0.083801	1327.9	–0.088396	603.54	145.01
600.00	50.000	40.498	0.024693	18.559	19.794	0.039048	0.057208	0.096053	997.60	0.10313	493.46	98.391
700.00	50.000	26.703	0.037449	29.678	31.551	0.057059	0.055751	0.15684	588.37	1.0407	331.10	62.248
800.00	50.000	12.014	0.083233	42.333	46.495	0.077124	0.045204	0.10482	569.23	2.4839	169.04	40.739
300.00	100.00	57.439	0.017410	–6.3859	–4.6449	–0.019168	0.078994	0.080433	1546.7	–0.19571	645.56	1041.5
700.00	100.00	35.855	0.027890	25.888	28.677	0.050728	0.052858	0.095839	944.96	0.21724	435.02	84.790
800.00	100.00	26.322	0.037991	34.906	38.706	0.064110	0.045160	0.10162	785.38	0.69848	323.29	66.016

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Hill, P. G., MacMillan, R. D. C., and Lee, V., "A Fundamental Equation of State for Heavy Water," *J. Phys. Chem. Ref. Data*, **11**(1):1–14, 1982. The source for viscosity is International Association for the Properties of Water and Steam, "Viscosity and Thermal Conductivity of Heavy Water Substance," Physical Chemistry of Aqueous Systems: Proceedings of the 12th International Conference on the Properties of Water and Steam, Orlando, Fla., Sept. 11–16, 1994, A107-A138. The source for thermal conductivity is International Association for the Properties of Water and Steam, "Viscosity and Thermal Conductivity of Heavy Water Substance," Physical Chemistry of Aqueous Systems: Proceedings of the 12th International Conference on the Properties of Water and Steam, Orlando, Fla., Sept. 11–16, 1994, A107-A138.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

For a discussion of the uncertainties associated with the equation of state and thermal conductivity entries of this table, please see the source references given above. The uncertainty in viscosity is 1% in the liquid below 474 K, 2% in the liquid at higher temperatures and in the vapor, and 5% between 623 and 723 K at pressures between 16 and 50 MPa. The uncertainty in viscosity is 2% in the liquid below 623 K and in the vapor below 573 K, 5% elsewhere in the liquid and vapor, and 10% in the critical region (623 to 723 K and 21.66 to 50 MPa).

TABLE 2-210 Thermodynamic Properties of 2,2-Dimethylpropane (Neopentane)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
256.60	0.035401	8.7017	0.11492	–4.0448	–4.0407	–0.014961	0.11106	0.14987	1061.0	–0.45488
260.00	0.041178	8.6547	0.11554	–3.5333	–3.5286	–0.012981	0.11212	0.15116	1043.4	–0.44532
270.00	0.062611	8.5146	0.11745	–2.0036	–1.9963	–0.0072081	0.11525	0.15504	992.29	–0.41587
280.00	0.091973	8.3711	0.11946	–0.43520	–0.42422	–0.0015039	0.11839	0.15903	941.76	–0.38403
290.00	0.13106	8.2236	0.12160	1.1729	1.1889	0.0041396	0.12153	0.16315	891.68	–0.34919
300.00	0.18184	8.0715	0.12389	2.8218	2.8444	0.0097305	0.12467	0.16742	841.93	–0.31054
310.00	0.24636	7.9140	0.12636	4.5127	4.5439	0.015276	0.12781	0.17188	792.35	–0.26700
320.00	0.32680	7.7503	0.12903	6.2470	6.2892	0.020784	0.13096	0.17655	742.82	–0.21713
330.00	0.42545	7.5792	0.13194	8.0264	8.0826	0.026263	0.13411	0.18151	693.20	–0.15892
340.00	0.54466	7.3993	0.13515	9.8530	9.9266	0.031720	0.13728	0.18683	643.34	–0.089543
350.00	0.68688	7.2090	0.13872	11.729	11.825	0.037165	0.14047	0.19263	593.09	–0.0048767
360.00	0.85466	7.0060	0.14273	13.659	13.781	0.042610	0.14369	0.19910	542.29	0.10132
370.00	1.0507	6.7873	0.14733	15.647	15.802	0.048067	0.14696	0.20651	490.74	0.23893
380.00	1.2778	6.5488	0.15270	17.699	17.894	0.053555	0.15032	0.21536	438.21	0.42456
390.00	1.5390	6.2842	0.15913	19.824	20.069	0.059099	0.15380	0.22655	384.34	0.68847
400.00	1.8380	5.9837	0.16712	22.038	22.345	0.064738	0.15752	0.24199	328.55	1.0924
410.00	2.1788	5.6295	0.17764	24.368	24.755	0.070543	0.16164	0.26680	269.76	1.7855
420.00	2.5668	5.1798	0.19306	26.878	27.373	0.076679	0.16662	0.32099	205.53	3.2489
430.00	3.0111	4.4559	0.22442	29.850	30.525	0.083875	0.17440	0.65083	129.02	8.3551
433.74	3.1963	3.2700	0.30581	32.506	33.484	0.090610			0	19.128
256.60	0.035401	0.016951	58.993	18.019	20.107	0.079147	0.097392	0.10663	176.08	42.543
260.00	0.041178	0.019508	51.262	18.336	20.447	0.079232	0.098838	0.10818	176.77	40.673
270.00	0.062611	0.028804	34.717	19.288	21.461	0.079672	0.10307	0.11278	178.55	35.912
280.00	0.091973	0.041222	24.259	20.267	22.498	0.080361	0.10727	0.11744	179.94	32.069
290.00	0.13106	0.057423	17.415	21.271	23.554	0.081260	0.11146	0.12220	180.88	28.950
300.00	0.18184	0.078145	12.797	22.298	24.625	0.082334	0.11562	0.12709	181.34	26.412
310.00	0.24636	0.10423	9.5944	23.346	25.710	0.083553	0.11978	0.13214	181.26	24.346
320.00	0.32680	0.13664	7.3187	24.411	26.803	0.084890	0.12394	0.13741	180.58	22.672
330.00	0.42545	0.17651	5.6655	25.490	27.901	0.086318	0.12810	0.14299	179.24	21.330
340.00	0.54466	0.22521	4.4402	26.580	28.999	0.087815	0.13228	0.14898	177.18	20.277
350.00	0.68688	0.28448	3.5152	27.676	30.091	0.089355	0.13648	0.15554	174.30	19.485
360.00	0.85466	0.35651	2.8049	28.773	31.170	0.090912	0.14073	0.16293	170.51	18.940
370.00	1.0507	0.44433	2.2506	29.862	32.226	0.092458	0.14505	0.17158	165.68	18.642
380.00	1.2778	0.55219	1.8110	30.932	33.246	0.093957	0.14948	0.18223	159.65	18.607
390.00	1.5390	0.68654	1.4566	31.969	34.211	0.095360	0.15407	0.19633	152.23	18.876
400.00	1.8380	0.85798	1.1655	32.946	35.088	0.096596	0.15892	0.21707	143.15	19.520
410.00	2.1788	1.0863	0.92056	33.817	35.822	0.097537	0.16422	0.25302	132.06	20.655
420.00	2.5668	1.4175	0.70547	34.476	36.287	0.097901	0.17039	0.33783	118.40	22.431
430.00	3.0111	2.0429	0.48949	34.498	35.972	0.096542	0.17895	0.86890	100.88	24.389
433.74	3.1963	3.2700	0.30581	32.506	33.484	0.090610			0	19.128

Single-Phase Properties										
300.00	0.10000	0.041573	24.054	22.482	24.888	0.087934	0.11446	0.12428	186.71	24.744
350.00	0.10000	0.035109	28.482	28.668	31.516	0.10834	0.13169	0.14083	203.23	14.420
400.00	0.10000	0.030488	32.800	35.683	38.963	0.12820	0.14811	0.15694	217.95	9.4234
450.00	0.10000	0.026981	37.063	43.493	47.199	0.14758	0.16371	0.17238	231.47	6.6348
500.00	0.10000	0.024215	41.296	52.060	56.190	0.16652	0.17858	0.18715	244.10	4.9220
550.00	0.10000	0.021973	45.510	61.352	65.903	0.18502	0.19273	0.20124	256.02	3.7932
300.00	1.0000	8.0927	0.12357	2.7638	2.8874	0.0095365	0.12470	0.16698	852.01	–0.31857
350.00	1.0000	7.2257	0.13839	11.687	11.825	0.037043	0.14045	0.19204	599.54	–0.017539
367.56	1.0000	6.8424	0.14615	15.155	15.301	0.046731	0.14616	0.20459	503.42	0.20165
367.56	1.0000	0.42120	2.3741	29.597	31.971	0.092083	0.14399	0.16932	166.96	18.691
400.00	1.0000	0.35635	2.8062	34.611	37.418	0.10628	0.15145	0.16863	188.60	12.099
450.00	1.0000	0.29713	3.3655	42.712	46.077	0.12667	0.16541	0.17859	211.98	7.6415
500.00	1.0000	0.25832	3.8712	51.444	55.315	0.14613	0.17958	0.19109	230.27	5.3700
550.00	1.0000	0.22988	4.3501	60.842	65.192	0.16494	0.19337	0.20397	245.89	4.0038
300.00	5.0000	8.1890	0.12211	2.4999	3.1104	0.0086423	0.12485	0.16516	897.98	–0.35167
350.00	5.0000	7.4104	0.13495	11.213	11.887	0.035660	0.14039	0.18654	671.51	–0.13585
400.00	5.0000	6.4044	0.15614	21.099	21.879	0.062302	0.15611	0.21533	444.29	0.37314
450.00	5.0000	4.6105	0.21690	33.057	34.142	0.091100	0.17461	0.30156	198.33	3.5214
500.00	5.0000	1.9914	0.50215	47.248	49.759	0.12411	0.18590	0.24909	166.16	7.2775
550.00	5.0000	1.4527	0.68839	57.986	61.428	0.14637	0.19664	0.22704	205.52	4.5988
300.00	10.000	8.2958	0.12054	2.2072	3.4126	0.0076277	0.12506	0.16345	949.31	–0.38267
350.00	10.000	7.5920	0.13172	10.739	12.056	0.034237	0.14048	0.18250	743.85	–0.22237
400.00	10.000	6.7750	0.14760	20.216	21.692	0.059940	0.15568	0.20328	555.11	0.041740
450.00	10.000	5.7764	0.17312	30.691	32.422	0.085190	0.17074	0.22624	391.52	0.55851
500.00	10.000	4.5715	0.21875	42.114	44.301	0.11020	0.18530	0.24770	276.41	1.5460
550.00	10.000	3.4249	0.29198	53.968	56.887	0.13419	0.19832	0.25208	234.55	2.4058
400.00	100.00	8.5990	0.11629	15.633	27.262	0.045388	0.15862	0.18487	1257.1	–0.42302
450.00	100.00	8.2554	0.12113	24.735	36.848	0.067954	0.17287	0.19848	1172.6	–0.38739
500.00	100.00	7.9290	0.12612	34.489	47.101	0.089546	0.18665	0.21152	1103.1	–0.35738
550.00	100.00	7.6203	0.13123	44.867	57.990	0.11029	0.19993	0.22395	1046.3	–0.33233
550.00	200.00	8.6161	0.11606	42.742	65.955	0.10250	0.20230	0.22337	1444.9	–0.36818

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data*, **51**(3):785–850, 2006. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in density in the equation of state range from 0.2% in the liquid phase at pressures less than 10 MPa to 1% in the liquid phase at higher pressures (up to 200 MPa) and at temperatures above the critical point (up to 550 K). The uncertainty in density in the vapor phase is 0.5%. Uncertainties in other properties are 0.1% for the vapor pressure, 2% in liquid-phase heat capacities, 0.5% in vapor-phase heat capacities, 1% for liquid-phase sound speeds, and 0.02% for vapor-phase sound speeds.

TABLE 2-211 Saturated Diphenyl*

T, K	P, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)	μ_f, 10^{-4} Pa·s	k_f, W/(m·K)
343	0.0010	1.010.–3	252.5	0.0	444.2	0.000	1.298	1.760	15.0	0.139
350	0.0016	1.014.–3	156.1	13.0	444.2	0.036	1.266	1.782	13.5	0.138
360	0.0029	1.021.–3	85.0	30.0	446.7	0.084	1.236	1.813	11.7	0.136
370	0.0049	1.030.–3	49.9	47.2	449.7	0.130	1.213	1.844	10.3	0.135
380	0.0064	1.037.–3	29.9	65.0	454.5	0.178	1.200	1.875	9.1	0.133
390	0.0129	1.046.–3	18.3	82.7	462.7	0.224	1.194	1.906	8.1	0.132
400	0.0200	1.054.–3	11.7	99.3	461.2	0.273	1.202	1.936	7.3	0.130
420	0.0432	1.072.–3	5.84	139.9	499.0	0.358	1.228	1.998	6.0	0.127
440	0.0879	1.092.–3	3.021	180.3	532.4	0.451	1.267	2.060	5.0	0.125
460	0.1694	1.112.–3	1.652	222.7	569.7	0.545	1.378	2.122	4.3	0.122
480	0.3112	1.132.–3	0.9594	267.6	611.6	0.652	1.367	2.184	3.7	0.119
500	0.5218	1.154.–3	0.4452	314.9	651.8	0.746	1.424	2.246	3.3	0.116
520	0.8375	1.177.–3	0.3652	361.5	687.8	0.824	1.477	2.308	2.7	0.113
540	1.290	1.204.–3	0.2261	404.5	723.8	0.915	1.529	2.370	2.4	0.110
560	1.941	1.230.–3	0.1447	457.2	762.7	1.032	1.582	2.432	2.2	0.107
580	2.818	1.258.–3	0.0977	522.3	801.7	1.125	1.635	2.494	1.90	0.105
600	3.926	1.291.–3	0.0685	563.7	842.4	1.223	1.688	2.556	1.71	0.102
620	5.408	1.326.–3	0.0504	630.4	886.4	1.316	1.740	2.618	1.54	0.099
640	7.328	1.366.–3	0.0381	689.1	930.9	1.375	1.748	2.680	1.39	0.096
660	9.572	1.412.–3	0.0301	745.9	977.1	1.457	1.791	2.741	1.24	0.093
680	12.05	1.465.–3	0.0236	802.8	1024.9	1.585	1.856	2.803	1.10	0.090
700	15.21	1.529.–3	0.0186	860.1	1073.1	1.663	1.951	2.865	0.97	0.087
720	19.14	1.56.–3	0.0147	917.5	1116.7	1.746	2.003	2.93		
740	23.93	1.70.–3	0.0113	975.2	1152.8	1.822	2.058	3.00		
760	28.71	1.95.–3	0.0085	1033.1	1182.5	1.901	2.099			
780	34.83	2.16.–3	0.0058	1091.2	1163.0	1.977	2.107			
800	42.46	3.18.–3	0.0032	1148.4	1148.4	2.047	2.047			

*Interpolated by P. E. Liley from the Landolt-Börnstein band IVa, p. 557, 1967 tables based on *Technical Data on Fuel,* British National Committee, World Energy Conference, London.

TABLE 2-212 Thermodynamic Properties of Dodecane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
263.60	6.2621E-07	4.5291	0.22079	–96.621	–96.621	–0.26003	0.28923	0.35985	1427.2	–0.45503	143.93	2892.5
270.00	1.2617E-06	4.5008	0.22218	–94.309	–94.309	–0.25136	0.29275	0.36265	1398.7	–0.45038	142.27	2447.1
290.00	8.8545E-06	4.4131	0.22660	–86.960	–86.960	–0.22511	0.30440	0.37246	1313.5	–0.43398	137.24	1578.5
310.00	4.5799E-05	4.3261	0.23115	–79.402	–79.402	–0.19991	0.31679	0.38355	1233.4	–0.41526	132.45	1112.9
330.00	0.00018556	4.2393	0.23589	–71.612	–71.612	–0.17556	0.32968	0.39559	1157.5	–0.39464	127.86	832.98
350.00	0.00061679	4.1522	0.24084	–63.574	–63.574	–0.15192	0.34285	0.40831	1085.1	–0.37230	123.43	650.53
370.00	0.0017432	4.0641	0.24605	–55.276	–55.276	–0.12887	0.35616	0.42150	1015.6	–0.34817	119.12	524.02
390.00	0.0043088	3.9747	0.25159	–46.712	–46.711	–0.10633	0.36947	0.43503	948.42	–0.32197	114.92	431.83
410.00	0.0095271	3.8833	0.25751	–37.875	–37.872	–0.084231	0.38269	0.44878	883.07	–0.29316	110.81	361.82
430.00	0.019190	3.7893	0.26390	–28.762	–28.757	–0.062532	0.39574	0.46268	819.18	–0.26089	106.77	306.78
450.00	0.035739	3.6920	0.27085	–19.371	–19.361	–0.041187	0.40859	0.47672	756.37	–0.22391	102.79	262.21
470.00	0.062299	3.5907	0.27850	–9.6999	–9.6825	–0.020162	0.42118	0.49091	694.32	–0.18039	98.863	225.20
490.00	0.10268	3.4842	0.28701	0.25270	0.28217	0.00057539	0.43351	0.50530	632.70	–0.12755	94.976	193.79
510.00	0.16136	3.3713	0.29662	10.490	10.538	0.021053	0.44557	0.52003	571.20	–0.061022	91.129	166.63
530.00	0.24347	3.2503	0.30766	21.016	21.091	0.041300	0.45738	0.53534	509.51	0.026306	87.324	142.76
550.00	0.35486	3.1189	0.32063	31.839	31.953	0.061352	0.46897	0.55164	447.33	0.14688	83.568	121.46
570.00	0.50211	2.9736	0.33629	42.975	43.144	0.081249	0.48040	0.56974	384.30	0.32430	79.876	102.19
590.00	0.69279	2.8091	0.35598	54.448	54.695	0.10105	0.49179	0.59128	320.04	0.60884	76.283	84.516
610.00	0.93585	2.6161	0.38225	66.310	66.667	0.12086	0.50334	0.62041	253.82	1.1288	72.856	68.050
630.00	1.2426	2.3747	0.42111	78.676	79.199	0.14087	0.51558	0.67253	183.58	2.3418	69.764	52.302
650.00	1.6298	2.0078	0.49805	92.046	92.858	0.16193	0.53081	0.91317	100.02	8.0937	68.073	35.652
658.10	1.8176	1.3300	0.75188	101.36	102.72	0.17683			0	40.219		
263.60	6.2621E-07	2.8572E-07	3,499,900.	–33.699	–31.507	–0.013011	0.24443	0.25274	115.35	330.02	6.7106	3.8271
270.00	1.2617E-06	5.6205E-07	1,779,200.	–32.120	–29.875	–0.012718	0.24903	0.25734	116.70	296.37	7.0413	3.9297
290.00	8.8545E-06	3.6724E-06	272,300.	–26.993	–24.582	–0.010011	0.26382	0.27214	120.83	215.32	8.1425	4.2511
310.00	4.5799E-05	1.7772E-05	56,267.	–21.566	–18.989	–0.0050291	0.27906	0.28739	124.81	160.20	9.3434	4.5733
330.00	0.00018556	6.7670E-05	14,778.	–15.834	–13.092	0.0017708	0.29454	0.30288	128.63	121.85	10.640	4.8958
350.00	0.00061679	0.00021228	4,710.8	–9.7983	–6.8927	0.010028	0.31008	0.31848	132.26	94.623	12.030	5.2183
370.00	0.0017432	0.00056862	1,758.6	–3.4632	–0.39757	0.019454	0.32559	0.33408	135.66	74.946	13.512	5.5399
390.00	0.0043088	0.0013382	747.29	3.1615	6.3814	0.029808	0.34098	0.34965	138.74	60.510	15.090	5.8599
410.00	0.0095271	0.0028309	353.24	10.063	13.428	0.040891	0.35619	0.36515	141.40	49.785	16.769	6.1775
430.00	0.019190	0.0054855	182.30	17.224	20.723	0.052536	0.37119	0.38060	143.51	41.738	18.561	6.4920
450.00	0.035739	0.0098881	101.13	24.628	28.242	0.064598	0.38596	0.39603	144.95	35.662	20.479	6.8034
470.00	0.062299	0.016797	59.534	32.254	35.962	0.076955	0.40048	0.41151	145.55	31.061	22.543	7.1122
490.00	0.10268	0.027184	36.786	40.078	43.855	0.089500	0.41475	0.42715	145.16	27.591	24.775	7.4202
510.00	0.16136	0.042311	23.635	48.075	51.889	0.10213	0.42878	0.44316	143.58	25.017	27.206	7.7302
530.00	0.24347	0.063865	15.658	56.215	60.027	0.11477	0.44259	0.45987	140.61	23.184	29.871	8.0477
550.00	0.35486	0.094219	10.614	64.460	68.226	0.12730	0.45625	0.47792	135.98	22.013	32.819	8.3808
570.00	0.50211	0.13692	7.3034	72.758	76.425	0.13964	0.46984	0.49854	129.36	21.503	36.118	8.7440
590.00	0.69279	0.19777	5.0563	81.036	84.539	0.15163	0.48353	0.52443	120.31	21.771	39.870	9.1635
610.00	0.93585	0.28746	3.4787	89.170	92.425	0.16308	0.49764	0.56276	108.12	23.181	44.272	9.6956
630.00	1.2426	0.43012	2.3249	96.902	99.791	0.17355	0.51290	0.64061	91.557	26.817	49.828	10.493
650.00	1.6298	0.71569	1.3973	103.34	105.62	0.18156	0.53205	1.0334	67.007	37.545	60.081	12.293
658.10	1.8176	1.3300	0.75188	101.36	102.72	0.17683			49.653	0		

TABLE 2-212 Thermodynamic Properties of Dodecane (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Single-Phase Properties												
300.00	0.10000	4.3700	0.22883	–83.216	–83.193	–0.21241	0.31053	0.37786	1273.5	–0.42497	134.86	1315.3
400.00	0.10000	3.9300	0.25445	–42.339	–42.313	–0.095254	0.37610	0.44184	916.43	–0.30827	112.91	395.13
488.89	0.10000	3.4902	0.28651	–0.30755	–0.27889	–0.00056937	0.43283	0.50449	636.11	–0.13079	95.191	195.41
488.89	0.10000	0.026496	37.741	39.638	43.413	0.088800	0.41397	0.42628	145.21	27.759	24.647	7.4030
500.00	0.10000	0.025735	38.857	44.299	48.185	0.098451	0.42081	0.43268	147.79	25.222	25.670	7.5935
600.00	0.10000	0.020711	48.284	89.425	94.254	0.18229	0.47769	0.48757	167.29	12.534	35.525	9.2766
700.00	0.10000	0.017494	57.163	139.71	145.42	0.26108	0.52517	0.53435	183.12	7.4958	46.039	10.929
300.00	1.0000	4.3739	0.22863	–83.277	–83.048	–0.21262	0.31061	0.37775	1279.2	–0.42580	135.18	1330.4
400.00	1.0000	3.9374	0.25398	–42.444	–42.190	–0.095518	0.37615	0.44147	924.90	–0.31138	113.40	400.40
500.00	1.0000	3.4447	0.29030	5.1293	5.4196	0.010431	0.43951	0.51125	616.23	–0.11178	93.839	183.76
600.00	1.0000	2.7332	0.36588	60.165	60.531	0.11067	0.49726	0.60093	296.10	0.75711	74.943	77.601
614.58	1.0000	2.5662	0.38968	69.090	69.480	0.12541	0.50605	0.62919	238.23	1.3130	72.109	64.404
614.58	1.0000	0.31406	3.1841	90.990	94.175	0.16559	0.50099	0.57515	104.78	23.748	45.410	9.8451
700.00	1.0000	0.21164	4.7249	136.66	141.39	0.23754	0.53113	0.55438	152.31	9.1496	51.144	11.188
300.00	5.0000	4.3910	0.22774	–83.541	–82.402	–0.21351	0.31099	0.37733	1303.7	–0.42924	136.59	1398.2
400.00	5.0000	3.9683	0.25200	–42.890	–41.630	–0.096648	0.37639	0.44002	960.72	–0.32355	115.50	423.55
500.00	5.0000	3.5099	0.28491	4.2808	5.7054	0.0087025	0.43938	0.50646	674.60	–0.16525	97.177	201.12
600.00	5.0000	2.9472	0.33930	57.896	59.593	0.10677	0.49475	0.57114	420.49	0.19333	81.179	99.888
700.00	5.0000	2.1498	0.46517	117.69	120.02	0.19979	0.54281	0.63863	215.10	1.5765	70.846	42.370
300.00	10.000	4.4115	0.22668	–83.856	–81.590	–0.21459	0.31147	0.37689	1333.1	–0.43298	138.29	1484.7
400.00	10.000	4.0039	0.24976	–43.403	–40.906	–0.097972	0.37674	0.43856	1001.9	–0.33581	117.98	452.04
500.00	10.000	3.5776	0.27952	3.3852	6.1804	0.0068314	0.43944	0.50252	735.90	–0.20845	100.85	221.12
600.00	10.000	3.0995	0.32263	56.144	59.370	0.10365	0.49390	0.55974	517.52	–0.0053841	86.682	119.96
700.00	10.000	2.5593	0.39074	113.82	117.72	0.19351	0.53945	0.60482	359.64	0.33979	77.506	65.788
400.00	100.00	4.3951	0.22753	–48.840	–26.088	–0.11422	0.38400	0.43214	1472.8	–0.39899	149.79	967.99
500.00	100.00	4.1426	0.24140	–4.0985	20.041	–0.011523	0.44564	0.48959	1297.7	–0.35002	140.67	510.30
600.00	100.00	3.9126	0.25559	46.019	71.578	0.082301	0.49884	0.53969	1169.1	–0.31375	134.18	334.45
700.00	100.00	3.7019	0.27013	100.67	127.69	0.16871	0.54304	0.58105	1073.9	–0.28792	129.56	242.80
600.00	300.00	4.4838	0.22302	40.123	107.03	0.062648	0.50752	0.54106	1807.8	–0.33126	190.55	737.48
700.00	300.00	4.3441	0.23020	94.208	163.27	0.14926	0.55080	0.58241	1725.5	–0.31036	190.65	531.88

The values in these tables were generated from the NIST REFPROP software (Lemmon, E.W., McLinden, M.O., and Huber, M.L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E.W., and Huber, M.L., "Thermodynamic Properties of *n*-Dodecane," *Energy & Fuels,* **18:**960–967, 2004. The source for viscosity and thermal conductivity is Huber, M.L., Laesecke, A., and Perkins, R.A., "Transport Properties of *n*-Dodecane," *Energy & Fuels* **18:** 968–975, 2004.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties (where the uncertainties can be considered as estimates of a combined expanded uncertainty with a coverage factor of 2) of density values calculated using the equation of state in the liquid phase (including at saturation) are 0.2% for pressures less than 200 MPa and 0.5% for higher pressures. The uncertainty for heat capacities is 1%, and that for sound speeds is 0.5%. The estimated uncertainties of vapor pressures calculated using the Maxwell criterion are 0.2% for temperatures above 350 K and approach 5% as the temperature decreases to the triple point temperature. These estimated uncertainties for calculated properties are consistent with the experimental accuracies of the various available experimental data. The estimated uncertainty in viscosity is 0.5% along the saturated-liquid line, 2% in compressed liquid to 200 MPa, 5% in vapor and supercritical regions. Uncertainty in thermal conductivity is 3%, except in the supercritical region and dilute gas which have an uncertainty of 5%.

TABLE 2-213 Thermodynamic Properties of Ethane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
90.368	1.1421E-06	21.668	0.046151	–6.5907	–6.5907	–0.04975	0.048264	0.069935	2008.7	–0.55899	255.62	1280.8
100	1.1081E-05	21.316	0.046913	–5.9245	–5.9245	–0.04275	0.046324	0.068639	1938.4	–0.56656	247.83	873.22
110	7.4287E-05	20.951	0.04773	–5.2401	–5.2401	–0.03623	0.045172	0.068351	1866.4	–0.56429	239.12	633.38
120	0.0003523	20.584	0.048581	–4.5559	–4.5559	–0.03027	0.044453	0.068544	1794.4	–0.55668	229.91	485.78
130	0.0012839	20.214	0.049469	–3.8686	–3.8685	–0.02477	0.043962	0.068959	1722.0	–0.54585	220.35	388.17
140	0.0038136	19.840	0.050402	–3.1764	–3.1762	–0.01964	0.043607	0.069499	1649.1	–0.53246	210.57	319.79
150	0.009638	19.461	0.051385	–2.4784	–2.4779	–0.01483	0.043351	0.070139	1575.5	–0.51640	200.71	269.55
160	0.021405	19.074	0.052426	–1.7736	–1.7724	–0.01028	0.043183	0.070888	1501.3	–0.49723	190.84	231.16
170	0.042819	18.680	0.053534	–1.0608	–1.0585	–0.00596	0.043100	0.071768	1426.3	–0.47424	181.03	200.83
180	0.078638	18.275	0.054720	–0.3389	–0.33459	–0.00183	0.043108	0.072812	1350.5	–0.44655	171.34	176.18
190	0.13459	17.858	0.055998	0.3938	0.40133	0.002133	0.043210	0.074056	1273.7	–0.41304	161.84	155.68
200	0.21723	17.426	0.057386	1.1391	1.1515	0.005957	0.043411	0.075548	1196.0	–0.37225	152.56	138.27
210	0.33380	16.976	0.058907	1.8991	1.9188	0.009667	0.043717	0.077345	1117.3	–0.32220	143.47	123.23
220	0.49205	16.504	0.060590	2.6766	2.7064	0.013287	0.044131	0.079529	1037.3	–0.26011	134.60	110.05
230	0.70018	16.006	0.062476	3.4747	3.5184	0.016839	0.044661	0.082221	956.09	–0.18185	125.95	98.339
240	0.96679	15.475	0.064622	4.2973	4.3598	0.020347	0.045314	0.085612	873.25	–0.08101	117.51	87.799
250	1.3008	14.901	0.067112	5.1501	5.2374	0.023839	0.046109	0.090024	788.33	0.05295	109.29	78.190
260	1.7118	14.270	0.070079	6.0406	6.1606	0.027349	0.047076	0.096059	700.52	0.23862	101.24	69.305
270	2.2100	13.559	0.073750	6.9809	7.1438	0.030924	0.048269	0.10496	608.92	0.51141	93.309	60.936
280	2.8067	12.728	0.078565	7.9919	8.2124	0.034644	0.049743	0.11989	512.38	0.94945	85.434	52.839
290	3.5159	11.684	0.085590	9.1194	9.4204	0.038677	0.051927	0.15219	405.70	1.7713	77.574	44.603
300	4.3573	10.094	0.099071	10.525	10.957	0.043620	0.057488	0.30137	274.91	3.9421	71.489	34.970
305.32	4.8722	6.8569	0.14584	12.490	13.200	0.050820			0	9.6957		
90.368	1.1421E-06	1.5201E-06	657,870	10.542	11.293	0.14815	0.026809	0.035124	180.93	249.88	2.9082	3.0427
100	1.1081E-05	1.3327E-05	75,033	10.803	11.634	0.13284	0.027384	0.035699	189.86	199.02	3.4563	3.3157
110	7.4287E-05	8.1234E-05	12,310	11.080	11.994	0.12045	0.027997	0.036318	198.61	177.19	4.0447	3.6034
120	0.0003523	0.00035326	2,830.8	11.362	12.359	0.11069	0.028651	0.036992	206.89	158.49	4.6568	3.8961
130	0.0012839	0.0011893	840.82	11.648	12.728	0.10289	0.029380	0.037770	214.69	129.38	5.2959	4.1937
140	0.0038136	0.0032857	304.35	11.938	13.099	0.096610	0.030154	0.038623	222.01	96.433	5.9661	4.4956
150	0.0096380	0.0077732	128.65	12.231	13.471	0.091501	0.030876	0.039449	228.84	70.230	6.6725	4.8011
160	0.021405	0.016263	61.489	12.525	13.841	0.087308	0.031513	0.040235	235.12	54.075	7.4216	5.1100
170	0.042819	0.030843	32.422	12.817	14.205	0.083831	0.032173	0.041138	240.73	45.339	8.2209	5.4223
180	0.078638	0.054053	18.500	13.104	14.559	0.080912	0.033015	0.042375	245.54	40.255	9.0790	5.7388
190	0.13459	0.088865	11.253	13.384	14.898	0.078433	0.034120	0.044070	249.41	36.410	10.005	6.0609
200	0.21723	0.13870	7.2100	13.654	15.221	0.076302	0.035457	0.046220	252.26	32.914	11.011	6.3908
210	0.33380	0.20749	4.8195	13.914	15.523	0.074447	0.036937	0.048771	254.02	29.687	12.109	6.7319
220	0.49205	0.29989	3.3346	14.160	15.801	0.072806	0.038486	0.051718	254.65	26.853	13.318	7.0889
230	0.70018	0.42157	2.3721	14.389	16.050	0.071324	0.040077	0.055176	254.05	24.485	14.662	7.4687
240	0.96679	0.57983	1.7246	14.597	16.264	0.069948	0.041742	0.059419	252.14	22.563	16.179	7.8814
250	1.3008	0.78456	1.2746	14.776	16.434	0.068624	0.043548	0.064956	248.79	21.017	17.930	8.3424
260	1.7118	1.0502	0.9522	14.915	16.545	0.067290	0.045586	0.072712	243.81	19.757	20.023	8.8764
270	2.2100	1.3998	0.71441	14.999	16.578	0.065865	0.047971	0.084634	237.02	18.700	22.667	9.5257
280	2.8067	1.8748	0.53338	14.998	16.495	0.064224	0.050986	0.10591	228.10	17.721	26.327	10.373
290	3.5159	2.5679	0.38943	14.846	16.215	0.062107	0.055181	0.15523	216.50	16.582	32.319	11.617
300	4.3573	3.8079	0.26261	14.314	15.458	0.058625	0.062820	0.39989	200.51	14.497	47.465	14.023
305.32	4.8722	6.8569	0.14584	12.490	13.200	0.050820			0	9.6957		

TABLE 2-213 Thermodynamic Properties of Ethane (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Single-Phase Properties												
100.00	0.10000	21.317	0.046910	–5.9253	–5.9206	–0.042756	0.046328	0.068636	1938.8	–0.56660	247.88	873.92
200.00	0.10000	0.061716	16.203	13.768	15.388	0.083336	0.034553	0.043810	257.90	30.845	10.723	6.3683
300.00	0.10000	0.040388	24.760	17.702	20.178	0.10263	0.044475	0.053048	312.23	10.722	21.218	9.4081
400.00	0.10000	0.030155	33.162	22.785	26.102	0.11958	0.057153	0.065586	355.24	5.0759	35.965	12.213
500.00	0.10000	0.024084	41.521	29.137	33.289	0.13557	0.069620	0.078001	393.08	2.7932	53.769	14.778
600.00	0.10000	0.020056	49.861	36.675	41.661	0.15080	0.080870	0.089227	427.63	1.6883	73.338	17.135
100.00	1.0000	21.329	0.046885	–5.9325	–5.8856	–0.042828	0.046362	0.068612	1942.4	–0.56691	248.30	880.24
200.00	1.0000	17.457	0.057283	1.1164	1.1737	0.0058431	0.043441	0.075331	1204.0	–0.37737	153.30	139.33
241.10	1.0000	15.414	0.064876	4.3894	4.4543	0.020731	0.045394	0.086038	864.04	–0.068172	116.60	86.702
241.10	1.0000	0.59982	1.6672	14.618	16.285	0.069802	0.041932	0.059951	251.85	22.377	16.358	7.9293
300.00	1.0000	0.43455	2.3012	17.331	19.632	0.082230	0.045482	0.057061	296.92	11.381	22.177	9.6518
400.00	1.0000	0.30970	3.2290	22.568	25.797	0.099896	0.057476	0.067069	348.76	5.1250	36.459	12.417
500.00	1.0000	0.24355	4.1060	28.986	33.092	0.11613	0.069783	0.078784	390.24	2.7821	54.084	14.954
600.00	1.0000	0.20145	4.9639	36.562	41.526	0.13147	0.080969	0.089708	426.64	1.6715	73.562	17.289
100.00	5.0000	21.381	0.046771	–5.9638	–5.7300	–0.043144	0.046517	0.068510	1957.7	–0.56823	250.17	909.15
200.00	5.0000	17.610	0.056786	1.0063	1.2902	0.0052852	0.043595	0.074345	1242.5	–0.40076	156.99	144.70
300.00	5.0000	10.907	0.091680	10.087	10.546	0.042046	0.053743	0.17141	359.63	2.3430	73.067	39.648
400.00	5.0000	1.7653	0.56647	21.484	24.316	0.083790	0.059017	0.076481	322.27	5.2035	39.974	13.905
500.00	5.0000	1.2769	0.78316	28.293	32.209	0.10138	0.070476	0.082676	380.40	2.6757	55.976	15.995
600.00	5.0000	1.0245	0.97605	36.055	40.936	0.11726	0.081384	0.091919	424.37	1.5738	74.801	18.124
100.00	10.000	21.444	0.046634	–6.0016	–5.5352	–0.043532	0.046712	0.068393	1976.2	–0.56975	252.48	947.29
200.00	10.000	17.786	0.056225	0.88047	1.4427	0.0046352	0.043786	0.073343	1286.7	–0.42471	161.36	151.27
300.00	10.000	12.680	0.078863	9.0258	9.8145	0.038217	0.050799	0.10280	579.32	0.58968	86.388	52.867
400.00	10.000	4.1977	0.23822	19.826	22.208	0.073976	0.060880	0.096368	310.38	4.4129	48.699	17.942
500.00	10.000	2.6794	0.37322	27.390	31.122	0.093896	0.071226	0.088180	377.77	2.3866	59.523	17.954
600.00	10.000	2.0757	0.48177	35.421	40.239	0.11050	0.081836	0.094716	427.41	1.4041	76.885	19.504
100.00	30.000	21.682	0.046121	–6.1384	–4.7548	–0.045002	0.047466	0.068003	2044.8	–0.57447	261.51	1127.3
200.00	30.000	18.371	0.054434	0.46960	2.1026	0.0024068	0.044528	0.070795	1433.6	–0.48623	177.27	177.04
300.00	30.000	14.784	0.067640	7.6392	9.6684	0.032933	0.050618	0.081850	909.38	–0.18133	112.64	77.610
400.00	30.000	10.812	0.092490	15.788	18.563	0.058427	0.061395	0.094994	585.71	0.40872	81.974	42.216
500.00	30.000	7.6781	0.13024	24.381	28.288	0.080115	0.072527	0.098504	497.87	0.71195	78.720	30.510
600.00	30.000	5.8933	0.16968	33.201	38.291	0.098343	0.082911	0.10204	505.75	0.59060	88.635	27.539
200.00	70.000	19.230	0.052001	0.098974	3.5411	0.0010269	0.045892	0.068554	1648.3	–0.54018	204.45	230.70
300.00	70.000	16.537	0.060469	6.4673	10.700	0.027905	0.051766	0.075512	1238.5	–0.42067	145.70	113.52
400.00	70.000	14.033	0.071259	13.756	18.744	0.050977	0.062135	0.085472	970.70	–0.27243	115.84	71.766
500.00	70.000	11.869	0.084254	21.871	27.769	0.071077	0.073299	0.094785	827.80	–0.15903	107.39	53.331
600.00	70.000	10.144	0.098582	30.754	37.654	0.089078	0.083730	0.10274	764.56	–0.10326	111.32	44.741

The values in these tables were generated from the NIST REFPROP software (Lemmon, E.W., McLinden, M.O., and Huber, M.L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Buecker, D., and Wagner, W., "A Reference Equation of State for the Thermodynamic Properties of Ethane for Temperatures from the Melting Line to 675 K and Pressures up to 900 MPa," *J. Phys. Chem. Ref. Data*, **35**(1):205–206, 2006. The source for viscosity and thermal conductivity is Friend, D.G., Ingham, H., and Ely, J.F., "Thermophysical Properties of Ethane," *J. Phys. Chem. Ref. Data*, **35**(1):205–266, 2006.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in the equation of state are 0.02% to 0.04% in density from the melting line up to temperatures of 520 K and pressures of 30 MPa. The uncertainties increase to 0.3% at higher temperatures and to 1% at higher pressures. The uncertainty in speed of sound ranges from 0.02% in the gaseous phase to 0.15% in the liquid phase. Above 450 K, the uncertainties increase to 0.3% at lower pressures and to 1% at higher pressures. At pressures above 40 MPa at all temperatures, the uncertainties are 1% up to 100 MPa, and 5% at higher pressures. The uncertainties in heat capacities range from 2% in the vapor and liquid regions below 450 K and 30 MPa to 5% at high pressures. The uncertainties in vapor pressure are 0.01% above 170 K and 10 MPa below 170 K. The uncertainty in viscosity is 2%. The uncertainty in thermal conductivity is 2%.

TABLE 2-214 Thermodynamic Properties of Ethanol

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
250.00	0.00027007	17.911	0.055831	6.9274	6.9275	0.037330	0.076657	0.093612	1325.0	–0.44553	178.12	3140.9
265.00	0.00089527	17.642	0.056681	8.3792	8.3793	0.042968	0.083798	0.10028	1260.8	–0.41423	173.58	2182.0
280.00	0.0025823	17.376	0.057551	9.9424	9.9426	0.048704	0.091653	0.10829	1202.8	–0.37872	169.56	1564.4
295.00	0.0066146	17.106	0.058460	11.630	11.631	0.054574	0.099433	0.11678	1149.2	–0.34323	165.87	1152.5
310.00	0.015298	16.828	0.059426	13.445	13.446	0.060574	0.10670	0.12524	1098.1	–0.30910	162.38	869.40
325.00	0.032394	16.537	0.060469	15.385	15.387	0.066684	0.11322	0.13340	1048.0	–0.27615	159.01	669.49
340.00	0.063544	16.231	0.061610	17.444	17.448	0.072875	0.11893	0.14115	997.94	–0.24356	155.69	524.87
355.00	0.11663	15.905	0.062872	19.615	19.622	0.079123	0.12381	0.14847	947.31	–0.21011	152.39	417.88
370.00	0.20205	15.557	0.064281	21.892	21.905	0.085403	0.12792	0.15543	895.56	–0.17428	149.09	337.04
385.00	0.33279	15.181	0.065871	24.268	24.290	0.091699	0.13130	0.16215	842.31	–0.13410	145.78	274.76
400.00	0.52446	14.774	0.067684	26.740	26.775	0.098000	0.13405	0.16883	787.16	–0.086812	142.47	225.91
415.00	0.79509	14.331	0.069779	29.307	29.362	0.10430	0.13625	0.17576	729.67	–0.028333	139.18	186.93
430.00	1.1649	13.843	0.072241	31.970	32.054	0.11061	0.13798	0.18341	669.25	0.047976	135.93	155.35
445.00	1.6559	13.298	0.075202	34.737	34.862	0.11695	0.13934	0.19262	605.07	0.15384	132.78	129.37
460.00	2.2916	12.676	0.078889	37.629	37.810	0.12335	0.14041	0.20504	535.80	0.31228	129.85	107.62
475.00	3.0963	11.941	0.083745	40.684	40.943	0.12991	0.14134	0.22469	459.19	0.57597	127.41	88.972
490.00	4.0954	11.007	0.090848	44.002	44.374	0.13684	0.14234	0.26508	371.03	1.0976	126.33	72.213
505.00	5.3159	9.5842	0.10434	47.926	48.480	0.14485	0.14382	0.41790	264.74	2.5369	129.43	55.104
513.90	6.1480	5.9910	0.16692	53.880	54.906	0.15723			0	8.6373		
250.00	0.00027007	0.00012998	7693.7	49.039	51.116	0.21409	0.058885	0.067215	226.86	149.30	14.936	7.2715
265.00	0.00089527	0.00040670	2458.8	49.932	52.134	0.20808	0.060795	0.069146	233.03	111.11	15.737	7.7433
280.00	0.0025823	0.0011115	899.69	50.851	53.174	0.20310	0.062753	0.071149	238.89	87.283	16.612	8.2114
295.00	0.0066146	0.0027080	369.28	51.792	54.234	0.19899	0.064753	0.073238	244.41	71.858	17.566	8.6756
310.00	0.015298	0.0059814	167.18	52.749	55.307	0.19561	0.066816	0.075464	249.49	61.180	18.602	9.1353
325.00	0.032394	0.012150	82.305	53.717	56.383	0.19282	0.068988	0.077921	254.02	53.164	19.731	9.5902
340.00	0.063544	0.022975	43.525	54.684	57.450	0.19053	0.071336	0.080736	257.88	46.697	20.969	10.040
355.00	0.11663	0.040873	24.466	55.640	58.494	0.18862	0.073932	0.084059	260.92	41.226	22.341	10.486
370.00	0.20205	0.069039	14.485	56.573	59.500	0.18701	0.076838	0.088058	263.02	36.486	23.886	10.929
385.00	0.33279	0.11160	8.9606	57.469	60.451	0.18562	0.080106	0.092930	264.03	32.353	25.659	11.372
400.00	0.52446	0.17385	5.7521	58.312	61.329	0.18438	0.083774	0.098936	263.82	28.756	27.741	11.820
415.00	0.79509	0.26261	3.8080	59.087	62.115	0.18322	0.087876	0.10646	262.27	25.644	30.251	12.283
430.00	1.1649	0.38683	2.5851	59.774	62.785	0.18208	0.092450	0.11610	259.21	22.967	33.369	12.774
445.00	1.6559	0.55876	1.7897	60.348	63.312	0.18088	0.097544	0.12898	254.44	20.681	37.377	13.318
460.00	2.2916	0.79629	1.2558	60.777	63.654	0.17954	0.10323	0.14727	247.61	18.747	42.735	13.961
475.00	3.0963	1.1286	0.88602	61.004	63.747	0.17792	0.10966	0.17612	238.10	17.136	50.248	14.786
490.00	4.0954	1.6143	0.61945	60.916	63.453	0.17578	0.11709	0.23200	224.59	15.831	61.578	15.982
505.00	5.3159	2.4339	0.41086	60.144	62.328	0.17228	0.12644	0.42053	203.70	14.728	82.512	18.148
513.90	6.1480	5.9910	0.16692	53.880	54.906	0.15723			0	8.6373		

TABLE 2-214 Thermodynamic Properties of Ethanol (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Single-Phase Properties												
300.00	0.10000	17.016	0.058768	12.219	12.225	0.056554	0.10193	0.11962	1132.5	–0.33179	164.74	1047.2
351.05	0.10000	15.993	0.062527	19.033	19.040	0.077475	0.12261	0.14658	960.72	–0.21908	153.26	443.11
351.05	0.10000	0.035314	28.317	55.390	58.222	0.18909	0.073221	0.083127	260.21	42.587	21.965	10.369
400.00	0.10000	0.030577	32.704	59.207	62.477	0.20043	0.080640	0.089997	279.09	28.685	26.374	11.853
500.00	0.10000	0.024191	41.338	67.925	72.058	0.22176	0.092910	0.10162	312.39	11.830	37.865	14.768
600.00	0.10000	0.020086	49.786	77.796	82.775	0.24127	0.10403	0.11252	341.55	5.6356	52.622	17.543
300.00	1.0000	17.034	0.058707	12.202	12.261	0.056497	0.10191	0.11954	1137.9	–0.33273	165.24	1053.2
400.00	1.0000	14.795	0.067589	26.715	26.783	0.097937	0.13400	0.16857	791.85	–0.089821	142.87	227.32
423.85	1.0000	14.049	0.071181	30.866	30.938	0.10802	0.13732	0.18015	694.41	0.013963	137.25	167.52
423.85	1.0000	0.33095	3.0216	59.504	62.526	0.18255	0.090516	0.11184	260.65	24.014	32.003	12.568
500.00	1.0000	0.25567	3.9114	67.014	70.925	0.20078	0.096953	0.11008	300.64	12.007	39.539	14.859
600.00	1.0000	0.20473	4.8846	77.311	82.195	0.22131	0.10581	0.11605	337.33	5.6301	53.583	17.678
300.00	5.0000	17.111	0.058443	12.129	12.421	0.056249	0.10185	0.11922	1161.4	–0.33665	167.43	1079.6
400.00	5.0000	14.961	0.066842	26.516	26.851	0.097435	0.13359	0.16658	829.44	–0.11211	146.07	238.82
500.00	5.0000	10.220	0.097846	46.419	46.908	0.14179	0.14311	0.32410	308.88	1.7596	127.42	61.882
501.39	5.0000	10.013	0.099875	46.876	47.375	0.14272	0.14340	0.35152	292.31	2.0063	128.00	59.510
501.39	5.0000	2.1809	0.45852	60.445	62.737	0.17336	0.12389	0.34099	209.80	15.000	75.676	17.454
600.00	5.0000	1.1372	0.87939	74.966	79.363	0.20395	0.11419	0.13659	314.06	5.6703	61.725	18.972
300.00	10.000	17.203	0.058131	12.041	12.623	0.055950	0.10179	0.11885	1189.5	–0.34096	170.07	1111.8
400.00	10.000	15.147	0.066020	26.293	26.953	0.096860	0.13313	0.16456	872.36	–0.13414	149.80	252.40
500.00	10.000	11.521	0.086800	44.752	45.620	0.13830	0.14031	0.22204	464.50	0.60618	130.15	80.680
600.00	10.000	2.8001	0.35713	71.266	74.837	0.19172	0.12599	0.18744	273.66	5.6926	84.190	23.411
300.00	100.00	18.389	0.054380	10.984	16.422	0.051802	0.10149	0.11571	1558.1	–0.37198	207.54	1611.3
400.00	100.00	17.030	0.058722	24.075	29.947	0.090466	0.12901	0.15081	1348.2	–0.25352	195.29	435.09
500.00	100.00	15.408	0.064899	39.356	45.846	0.12589	0.13221	0.16433	1166.1	–0.17199	188.35	192.15
600.00	100.00	13.601	0.073523	55.055	62.407	0.15608	0.12575	0.16553	1015.1	–0.082822	187.31	109.49
300.00	200.00	19.244	0.051963	10.349	20.742	0.048505	0.10196	0.11495	1830.4	–0.37578	238.67	2085.4
400.00	200.00	18.138	0.055134	22.905	33.931	0.086238	0.12678	0.14539	1660.3	–0.28090	228.57	591.02
500.00	200.00	16.878	0.059250	37.295	49.145	0.12014	0.12868	0.15623	1525.6	–0.22946	224.49	269.30
600.00	200.00	15.505	0.064494	51.902	64.801	0.14869	0.12066	0.15566	1422.7	–0.19099	226.40	148.43

The values in these tables were generated from the NIST REFPROP software (Lemmon, E.W., McLinden, M.O., and Huber, M.L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Dillon, H.E., and Penoncello, S.G., "A Fundamental Equation for Calculation of the Thermodynamic Properties of Ethanol," *Int. J. Thermophys.*, **25**(2):321–335, 2004. The source for viscosity is Kiselev, S. B., Ely, J. F., Abdulagatov, I. M., and Huber, M. L.,"Generalized SAFT-DFT/DMT Model for the Thermodynamic, Interfacial, and Transport Properties of Associating Fluids: Application for *n*-Alkanols," *Ind. Eng. Chem. Res.*, **44:**6916–6927, 2005. The source for thermal conductivity is unpublished, 2004; however, the fit uses functional form found in Marsh, K., Perkins, R., and Ramires, M.L.V., "Measurement and Correlation of the Thermal Conductivity of Propane from 86 to 600 K at Pressures to 70 MPa," *J. Chem. Eng. Data,* **47**(4):932–940, 2002.

Properties at the critical point temperature are given in the last entry of the saturation tables. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in the equation of state are 0.2% in density, 3% in heat capacities, 1% in speed of sound, and 0.5% in vapor pressure and saturation densities. The estimated uncertainty in the liquid phase along the saturation boundary is approximately 3%, increasing to 10% at pressures to 100 MPa, and is estimated at 10% in the vapor phase. The estimated uncertainty in the liquid phase is approximately 5% and is estimated as 10% in the vapor phase.

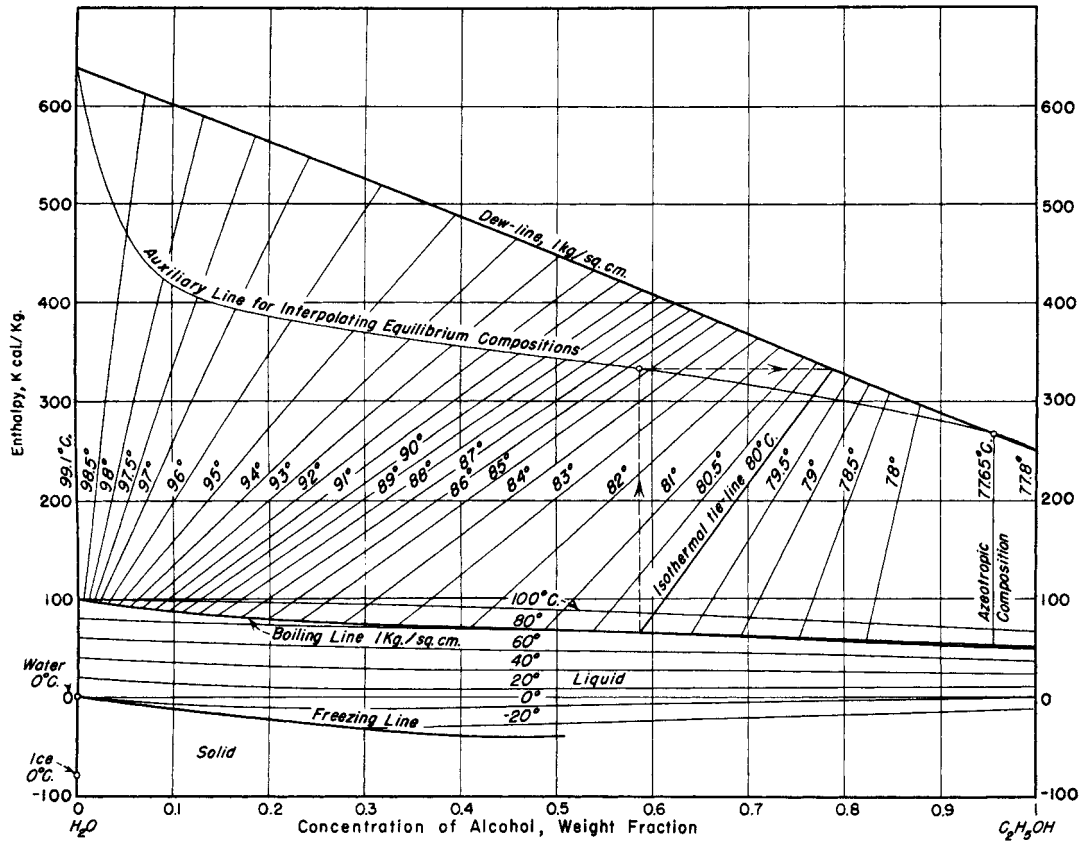

FIG. 2-10 Enthalpy-concentration diagram for aqueous ethyl alcohol. Reference states: Enthalpies of liquid water and ethyl alcohol at 0 °C are zero. NOTE: In order to interpolate equilibrium compositions, a vertical may be erected from any liquid composition on the boiling line and its intersection with the auxiliary line determined. A horizontal from this intersection will establish the equilibrium vapor composition on the dew line. (*Bosnjakovic,* Technische Thermodynamik, *T. Steinkopff, Leipzig, 1935.*)

TABLE 2-215 Thermodynamic Properties of Ethylene

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
103.99	0.00012196	23.334	0.042856	–4.4352	–4.4352	–0.033074	0.045503	0.068155	1766.6	–0.50257	270.65	685.73
105.00	0.00014568	23.288	0.042940	–4.3661	–4.3661	–0.032412	0.045394	0.068183	1760.2	–0.50171	269.25	662.48
115.00	0.00069745	22.834	0.043793	–3.6839	–3.6838	–0.026206	0.044202	0.068194	1694.4	–0.49455	255.56	488.07
125.00	0.0025267	22.375	0.044692	–3.0030	–3.0029	–0.020529	0.042929	0.067951	1626.0	–0.48779	242.07	378.67
135.00	0.0073921	21.909	0.045643	–2.3250	–2.3247	–0.015311	0.041693	0.067669	1556.2	–0.47928	228.83	305.49
145.00	0.018309	21.435	0.046652	–1.6496	–1.6488	–0.010484	0.040562	0.067475	1485.3	–0.46747	215.95	253.84
155.00	0.039755	20.952	0.047729	–0.97554	–0.97364	–0.0059884	0.039568	0.067448	1413.2	–0.45105	203.50	215.68
165.00	0.077693	20.456	0.048885	–0.30104	–0.29724	–0.0017710	0.038729	0.067649	1339.9	–0.42866	191.54	186.36
175.00	0.13944	19.945	0.050137	0.37612	0.38311	0.0022141	0.038051	0.068127	1265.0	–0.39877	180.09	163.03
185.00	0.23344	19.417	0.051502	1.0585	1.0706	0.0060075	0.037536	0.068937	1188.5	–0.35944	169.21	143.88
195.00	0.36901	18.865	0.053008	1.7492	1.7688	0.0096456	0.037184	0.070151	1110.0	–0.30804	158.78	127.73
205.00	0.55614	18.286	0.054687	2.4516	2.4820	0.013162	0.036995	0.071867	1029.3	–0.24081	148.78	113.76
215.00	0.80534	17.671	0.056589	3.1699	3.2155	0.016589	0.036970	0.074242	946.13	–0.15205	139.15	101.40
225.00	1.1276	17.011	0.058784	3.9095	3.9758	0.019960	0.037115	0.077537	860.08	–0.032706	129.81	90.217
235.00	1.5342	16.291	0.061382	4.6774	4.7715	0.023314	0.037446	0.082229	770.62	0.13270	120.64	79.891
245.00	2.0376	15.488	0.064566	5.4842	5.6157	0.026699	0.037996	0.089292	676.97	0.37286	111.48	70.142
255.00	2.6509	14.560	0.068682	6.3476	6.5297	0.030191	0.038851	0.10110	577.38	0.74844	102.11	60.685
265.00	3.3898	13.419	0.074519	7.3042	7.5568	0.033937	0.040322	0.12549	467.22	1.4173	92.171	51.112
275.00	4.2752	11.793	0.084795	8.4637	8.8262	0.038375	0.043922	0.21287	334.73	2.9732	81.576	40.397
282.35	5.0417	7.6368	0.13095	10.545	11.206	0.046609			0	8.7988		
103.99	0.00012196	0.00014109	7087.6	10.621	11.486	0.12003	0.024972	0.033295	202.67	154.90	6.8012	0.77270
105.00	0.00014568	0.00016690	5991.6	10.647	11.520	0.11888	0.024975	0.033300	203.65	150.43	6.7393	1.0011
115.00	0.00069745	0.00073000	1369.9	10.895	11.850	0.10888	0.025028	0.033376	213.03	114.92	6.6223	2.7342
125.00	0.0025267	0.0024363	410.46	11.142	12.179	0.10093	0.025131	0.033533	221.86	90.667	7.0116	3.8262
135.00	0.0073921	0.0066178	151.11	11.385	12.502	0.094519	0.025307	0.033814	230.09	73.502	7.5850	4.5578
145.00	0.018309	0.015333	65.217	11.624	12.818	0.089286	0.025577	0.034263	237.62	60.977	8.2013	5.0886
155.00	0.039755	0.031379	31.869	11.855	13.122	0.084954	0.025956	0.034922	244.36	51.588	8.8125	5.5112
165.00	0.077693	0.058231	17.173	12.078	13.412	0.081316	0.026454	0.035833	250.18	44.379	9.4170	5.8799
175.00	0.13944	0.099997	10.000	12.289	13.683	0.078216	0.027081	0.037045	254.99	38.733	10.036	6.2279
185.00	0.23344	0.16142	6.1950	12.486	13.933	0.075532	0.027844	0.038617	258.69	34.236	10.700	6.5765
195.00	0.36901	0.24802	4.0319	12.667	14.155	0.073165	0.028751	0.040637	261.18	30.602	11.446	6.9410
205.00	0.55614	0.36638	2.7294	12.829	14.346	0.071037	0.029816	0.043243	262.38	27.626	12.313	7.3341
215.00	0.80534	0.52471	1.9058	12.966	14.501	0.069079	0.031060	0.046651	262.18	25.155	13.346	7.7689
225.00	1.1276	0.73386	1.3627	13.074	14.610	0.067225	0.032511	0.051237	260.50	23.074	14.607	8.2612
235.00	1.5342	1.0092	0.99086	13.144	14.664	0.065409	0.034212	0.057696	257.19	21.287	16.186	8.8342
245.00	2.0376	1.3747	0.72745	13.162	14.645	0.063551	0.036243	0.067503	252.09	19.706	18.250	9.5251
255.00	2.6509	1.8719	0.53422	13.105	14.522	0.061532	0.038789	0.084393	244.94	18.213	21.166	10.404
265.00	3.3898	2.5886	0.38631	12.923	14.232	0.059128	0.042250	0.12086	235.28	16.604	26.045	11.632
275.00	4.2752	3.7947	0.26352	12.460	13.587	0.055687	0.048136	0.26071	221.57	14.315	39.168	13.765
282.35	5.0417	7.6368	0.13095	10.545	11.206	0.046609			0	8.7988		

Single-Phase Properties

150.00	0.10000	21.197	0.047176	–1.3137	–1.3090	–0.0082061	0.040048	0.067428	1449.9	–0.46008	209.74	233.39
169.16	0.10000	20.246	0.049393	–0.020110	–0.015171	–0.000089238	0.038427	0.067811	1309.0	–0.41725	186.72	176.06
169.16	0.10000	0.073519	13.602	12.167	13.527	0.079970	0.026699	0.036297	252.31	41.871	9.6709	6.0256
225.00	0.10000	0.054182	18.456	13.722	15.568	0.090386	0.028730	0.037508	291.07	20.438	12.903	7.8384
300.00	0.10000	0.040315	24.805	16.100	18.580	0.10190	0.034782	0.043294	330.82	10.015	20.558	10.381
375.00	0.10000	0.032159	31.096	18.990	22.099	0.11234	0.042202	0.050626	364.16	5.6845	31.002	12.827
450.00	0.10000	0.026764	37.364	22.436	26.173	0.12222	0.049547	0.057930	394.34	3.5485	42.200	15.092
150.00	1.0000	21.223	0.047119	–1.3281	–1.2810	–0.0083026	0.040075	0.067329	1456.3	–0.46205	210.67	232.98
221.33	1.0000	17.260	0.057938	3.6350	3.6929	0.018726	0.037041	0.076196	892.05	–0.080890	133.22	94.208
221.33	1.0000	0.65028	1.5378	13.038	14.576	0.067898	0.031952	0.049381	261.30	23.800	14.112	8.0724
225.00	1.0000	0.63206	1.5821	13.173	14.755	0.068701	0.031799	0.048297	265.10	22.637	14.323	8.1765
300.00	1.0000	0.42535	2.3510	15.822	18.173	0.081821	0.035459	0.046096	320.09	10.271	21.362	10.589
375.00	1.0000	0.32964	3.0336	18.803	21.836	0.092696	0.042478	0.051961	358.72	5.7053	31.533	13.017
450.00	1.0000	0.27097	3.6904	22.297	25.987	0.10277	0.049700	0.058724	391.57	3.5291	42.581	15.284
150.00	5.0000	21.333	0.046876	–1.3902	–1.1558	–0.0087214	0.040199	0.066921	1483.4	–0.47016	214.70	231.18
225.00	5.0000	17.364	0.057591	3.7130	4.0009	0.019071	0.037097	0.073970	926.49	–0.13327	135.08	93.288
281.98	5.0000	9.0494	0.11050	9.9242	10.477	0.044044	0.061633	3.8740	189.76	7.3487	145.71	27.667
281.98	5.0000	6.2408	0.16024	11.247	12.048	0.049617	0.066988	5.9539	191.76	10.151	182.63	19.004
300.00	5.0000	3.1277	0.31972	13.977	15.576	0.061893	0.040822	0.089599	263.71	10.910	30.862	13.344
375.00	5.0000	1.8590	0.53792	17.877	20.567	0.076837	0.043817	0.060244	337.12	5.6244	35.453	14.287
450.00	5.0000	1.4297	0.69947	21.650	25.147	0.087965	0.050366	0.062753	381.96	3.3730	45.106	16.277
150.00	10.000	21.464	0.046589	–1.4634	–0.99754	–0.0092238	0.040364	0.066475	1515.1	–0.47905	219.60	229.03
225.00	10.000	17.739	0.056372	3.5022	4.0659	0.018094	0.037190	0.070996	996.58	–0.22081	140.93	96.609
300.00	10.000	11.510	0.086881	9.6517	10.521	0.042563	0.041889	0.11956	420.01	1.9372	79.635	37.621
375.00	10.000	4.3583	0.22945	16.483	18.778	0.067434	0.045508	0.077265	328.58	4.7029	45.198	17.402
450.00	10.000	3.0293	0.33011	20.798	24.099	0.080391	0.051131	0.068674	379.55	2.9790	50.075	18.014
150.00	100.00	23.148	0.043200	–2.3062	2.0139	–0.015964	0.043582	0.063328	1891.7	–0.54092	294.42	199.89
225.00	100.00	20.862	0.047935	1.8396	6.6331	0.0090426	0.040468	0.060888	1581.0	–0.54008	200.24	126.05
300.00	100.00	18.775	0.053261	5.9492	11.275	0.026831	0.043293	0.063490	1328.5	–0.48350	154.23	98.312
375.00	100.00	16.889	0.059210	10.287	16.208	0.041488	0.048765	0.068211	1143.7	–0.41039	131.89	81.449
450.00	100.00	15.219	0.065708	14.942	21.513	0.054370	0.054851	0.073224	1020.9	–0.34600	121.24	70.072
150.00	300.00	25.298	0.039530	–2.9624	8.8964	–0.024942	0.048504	0.062644	2343.7	–0.54689	432.13	161.49
225.00	300.00	23.718	0.042162	0.79998	13.448	–0.00029268	0.044752	0.059805	2151.3	–0.57336	275.32	155.50
300.00	300.00	22.336	0.044772	4.5667	17.998	0.017143	0.047124	0.062135	1984.6	–0.55352	209.21	157.18
375.00	300.00	21.120	0.047350	8.6213	22.826	0.031488	0.052222	0.066814	1847.1	–0.51701	178.33	156.74
450.00	300.00	20.042	0.049894	13.065	28.033	0.044131	0.057988	0.072043	1740.6	–0.48199	163.32	153.81

The values in these tables were generated from the NIST REFPROP software (Lemmon, E.W., McLinden, M.O., and Huber, M.L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Smukala, J., Span, R., and Wagner, W., "A New Equation of State for Ethylene Covering the Fluid Region for Temperatures from the Melting Line to 450 K at Pressures up to 300 MPa," *J. Phys. Chem. Ref. Data*, **29**(5):1053–1122, 2000. The source for viscosity is Holland, P.M., Eaton, B.E., and Hanley, H.J.M., "A Correlation of the Viscosity and Thermal Conductivity Data of Gaseous and Liquid Ethylene," *J. Phys. Chem. Ref. Data*, **12**(4):917–932, 1983. The source for thermal conductivity is Holland, P.M., Eaton, B.E., and Hanley, H.J.M., "A Correlation of the Viscosity and Thermal Conductivity Data of Gaseous and Liquid Ethylene," *J. Phys. Chem. Ref. Data*, **12**(4):917–932, 1983.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in density of the equation of state range from 0.02% in the liquid and most of the vapor phase to 0.1% for supercritical states. At $p > 100$ MPa, the uncertainty in density is 0.5%. The uncertainty in heat capacity is 3% in the liquid phase, 0.2% in the vapor phase, and as high as 5% in the supercritical region at higher pressures. For the speed of sound, the uncertainty is 0.05 to 0.1% in the vapor phase, rising to 3% in the liquid phase. The uncertainty in vapor pressure is less than 0.05% above 140 K. The uncertainty in viscosity is 5%, increasing to 10% in the dense liquid. The uncertainty in thermal conductivity is 5%, increasing to 10% in the dense liquid.

TABLE 2-216 Thermodynamic Properties of Fluorine

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
53.481	0.00023881	44.917	0.022263	–1.7783	–1.7783	–0.026073	0.036802	0.057963	1041.6	–0.30422
55.000	0.00038159	44.657	0.022393	–1.6923	–1.6923	–0.024487	0.035214	0.055732	1040.8	–0.31810
60.000	0.0014872	43.829	0.022816	–1.4151	–1.4151	–0.019663	0.034254	0.055680	1043.5	–0.31768
65.000	0.0046126	43.005	0.023253	–1.1355	–1.1354	–0.015187	0.033385	0.056098	1019.2	–0.31059
70.000	0.011981	42.169	0.023714	–0.85459	–0.85430	–0.011024	0.032745	0.056274	973.15	–0.30322
75.000	0.027062	41.315	0.024204	–0.57283	–0.57217	–0.0071357	0.032241	0.056496	921.41	–0.29375
80.000	0.054668	40.437	0.024730	–0.28975	–0.28840	–0.0034817	0.031737	0.056860	871.16	–0.28123
85.000	0.10090	39.531	0.025296	–0.0046707	–0.0021183	–0.000024789	0.031196	0.057394	823.90	–0.26509
90.000	0.17296	38.590	0.025913	0.28316	0.28764	0.0032663	0.030634	0.058117	779.02	–0.24474
95.000	0.27894	37.609	0.026589	0.57448	0.58190	0.0064180	0.030073	0.059051	735.47	–0.21935
100.00	0.42751	36.582	0.027336	0.87013	0.88182	0.0094534	0.029532	0.060243	692.27	–0.18762
105.00	0.62778	35.499	0.028170	1.1711	1.1887	0.012394	0.029024	0.061773	648.60	–0.14746
110.00	0.88912	34.351	0.029112	1.4785	1.5044	0.015261	0.028561	0.063791	603.67	–0.095557
115.00	1.2212	33.119	0.030194	1.7943	1.8312	0.018078	0.028159	0.066559	556.65	–0.026510
120.00	1.6342	31.777	0.031470	2.1213	2.1728	0.020877	0.027847	0.070566	506.54	0.068825
125.00	2.1389	30.280	0.033025	2.4642	2.5349	0.023700	0.027681	0.076800	452.05	0.20691
130.00	2.7475	28.549	0.035027	2.8314	2.9276	0.026617	0.027791	0.087576	391.41	0.42042
135.00	3.4739	26.416	0.037855	3.2397	3.3712	0.029765	0.028512	0.10995	321.84	0.78572
140.00	4.3357	23.427	0.042685	3.7349	3.9200	0.033502	0.030963	0.18235	238.35	1.5459
144.41	5.2394	15.603	0.064090	4.7226	5.0584	0.041160			0	4.3227
53.481	0.00023881	0.00053725	1861.3	5.3412	5.7857	0.11536	0.020800	0.029129	127.97	76.144
55.000	0.00038159	0.00083488	1197.8	5.3726	5.8296	0.11228	0.020805	0.029139	129.76	71.404
60.000	0.0014872	0.0029857	334.92	5.4753	5.9734	0.10348	0.020831	0.029204	135.46	58.461
65.000	0.0046126	0.0085667	116.73	5.5765	6.1149	0.096356	0.020886	0.029341	140.83	48.604
70.000	0.011981	0.020743	48.208	5.6750	6.2526	0.090504	0.020984	0.029589	145.85	40.910
75.000	0.027062	0.044003	22.726	5.7697	6.3847	0.085622	0.021139	0.029984	150.47	34.772
80.000	0.054668	0.084093	11.892	5.8592	6.5093	0.081489	0.021361	0.030562	154.65	29.788
85.000	0.10090	0.14789	6.7617	5.9423	6.6246	0.077936	0.021653	0.031349	158.34	25.696
90.000	0.17296	0.24329	4.1103	6.0181	6.7290	0.074837	0.022013	0.032368	161.52	22.322
95.000	0.27894	0.37919	2.6372	6.0855	6.8212	0.072094	0.022432	0.033644	164.12	19.545
100.00	0.42751	0.56568	1.7678	6.1438	6.8995	0.069630	0.022900	0.035219	166.12	17.279
105.00	0.62778	0.81460	1.2276	6.1916	6.9623	0.067380	0.023406	0.037174	167.46	15.449
110.00	0.88912	1.1406	0.87675	6.2274	7.0070	0.065284	0.023951	0.039668	168.12	13.988
115.00	1.2212	1.5630	0.63979	6.2487	7.0300	0.063285	0.024547	0.043016	168.05	12.827
120.00	1.6342	2.1098	0.47398	6.2511	7.0256	0.061318	0.025234	0.047844	167.26	11.886
125.00	2.1389	2.8245	0.35404	6.2277	6.9850	0.059301	0.026096	0.055492	165.81	11.069
130.00	2.7475	3.7825	0.26438	6.1664	6.8928	0.057119	0.027303	0.069276	163.76	10.250
135.00	3.4739	5.1364	0.19469	6.0431	6.7195	0.054567	0.029246	0.099896	161.03	9.2577
140.00	4.3357	7.3237	0.13654	5.7921	6.3841	0.051103	0.033084	0.21077	156.46	7.8082
144.41	5.2394	15.603	0.064090	4.7226	5.0584	0.041160			0	4.3227
Single-Phase Properties										
84.922	0.10000	39.546	0.025287	–0.0091317	–0.0066030	–0.000077307	0.031205	0.057385	824.62	–0.26537
84.922	0.10000	0.14668	6.8177	5.9411	6.6228	0.077988	0.021648	0.031335	158.29	25.754
100.00	0.10000	0.12275	8.1468	6.2721	7.0868	0.083019	0.021268	0.030345	173.11	17.864
150.00	0.10000	0.080628	12.403	7.3358	8.5761	0.095107	0.021022	0.029539	213.56	7.4423
200.00	0.10000	0.060267	16.593	8.3977	10.057	0.10363	0.021401	0.029803	246.33	4.1219
250.00	0.10000	0.048155	20.766	9.4869	11.564	0.11035	0.022142	0.030505	274.27	2.6600
300.00	0.10000	0.040106	24.934	10.617	13.110	0.11598	0.023021	0.031368	298.96	1.8799
100.00	1.0000	36.645	0.027289	0.86105	0.88834	0.0093623	0.029558	0.060025	696.10	–0.19109
111.80	1.0000	33.918	0.029483	1.5911	1.6206	0.016279	0.028409	0.064682	587.03	–0.073051
111.80	1.0000	1.2803	0.78106	6.2369	7.0180	0.064557	0.024158	0.040751	168.18	13.540
150.00	1.0000	0.85139	1.1746	7.1946	8.3692	0.075007	0.021931	0.032606	207.71	7.3873

200.00	1.0000	0.61498	1.6261	8.3181	9.9441	0.084080	0.021681	0.030928	244.27	4.1390
250.00	1.0000	0.48577	2.0586	9.4313	11.490	0.090978	0.022225	0.031046	273.76	2.6581
300.00	1.0000	0.40251	2.4844	10.573	13.057	0.096691	0.023032	0.031678	299.28	1.8692
100.00	5.0000	37.065	0.026980	0.80142	0.93632	0.0087568	0.029727	0.058693	721.70	–0.21256
143.33	5.0000	19.879	0.050304	4.2229	4.4744	0.037196	0.036294	0.63033	169.23	2.8620
143.33	5.0000	10.490	0.095333	5.3751	5.8518	0.046806	0.039553	1.0196	148.40	6.0573
150.00	5.0000	6.5097	0.15362	6.2260	6.9941	0.054653	0.027354	0.084441	177.58	6.7256
200.00	5.0000	3.3899	0.29499	7.9204	9.3953	0.068706	0.022993	0.037593	237.67	3.8562
250.00	5.0000	2.5221	0.39650	9.1743	11.157	0.076582	0.022698	0.033813	273.06	2.4478
300.00	5.0000	2.0427	0.48954	10.377	12.824	0.082665	0.023148	0.033134	301.36	1.6957
100.00	10.000	37.536	0.026641	0.73479	1.0012	0.0080653	0.029857	0.057385	752.43	–0.23402
150.00	10.000	24.141	0.041423	3.9349	4.3491	0.034822	0.027090	0.094016	324.06	0.86131
200.00	10.000	7.6450	0.13080	7.3273	8.6354	0.060060	0.024489	0.050206	240.08	3.1116
250.00	10.000	5.2188	0.19162	8.8378	10.754	0.069563	0.023418	0.037864	278.39	2.0656
300.00	10.000	4.1242	0.24247	10.136	12.561	0.076160	0.023411	0.035025	307.87	1.4058
100.00	15.000	37.961	0.026343	0.67509	1.0702	0.0074311	0.029870	0.056345	783.34	-0.25114
150.00	15.000	27.008	0.037026	3.5725	4.1279	0.032052	0.026615	0.070563	415.88	0.33099
200.00	15.000	12.412	0.080569	6.7026	7.9111	0.053898	0.025220	0.060759	263.46	2.0529
250.00	15.000	7.9757	0.12538	8.4961	10.377	0.064977	0.024073	0.042125	289.64	1.7085
300.00	15.000	6.1790	0.16184	9.9020	12.330	0.072112	0.023725	0.036972	318.16	1.1770
100.00	20.000	38.348	0.026077	0.62089	1.1424	0.0068429	0.029763	0.055495	815.20	–0.26507
150.00	20.000	28.645	0.034910	3.3586	4.0568	0.030382	0.026518	0.062828	480.50	0.11826
200.00	20.000	16.458	0.060762	6.1944	7.4096	0.049659	0.025474	0.062710	304.19	1.2436
250.00	20.000	10.648	0.093913	8.1664	10.045	0.061490	0.024527	0.045421	307.96	1.3200
300.00	20.000	8.1626	0.12251	9.6749	12.125	0.069094	0.024015	0.038840	331.68	0.98352

The values in these tables were generated from the NIST REFPROP software (Lemmon, E.W., McLinden, M.O., and Huber, M.L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is de Reuck, K.M., "International Thermodynamic Tables of the Fluid State—11 Fluorine," *International Union of Pure and Applied Chemistry*, Pergamon Press, Oxford, 1990. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are 0.2% in density, 2% in heat capacity, and 1.5% in the speed of sound, except in the critical region.

TABLE 2-217 Flutec

Proprietary name for a series of fluorocarbons produced by the Imperial Smelting Corp., Avonmouth, Bristol, UK. Bulletins of thermodynamic properties include PP1 (C_6F_{14}), PP2 (C_7F_{14}), PP3 (C_8F_{16}), PP5 ($C_{10}F_{18}$), PP9 ($C_{11}F_{20}$), and PP50, usually for 0.1–100 kg/m^2, 0–500°C. See also Green, S. W., *Chem. & Ind.* (1969): 63–67.

TABLE 2-218 Halon

A series of fire-extinguishing fluids. Halon 1211 is produced by ICI, and Halon 1301, by duPont, the latter issuing a bulletin with thermodynamic properties and a diagram for the range 0.6–600 psia, –160–460°F.

TABLE 2-219 Thermodynamic Properties of Helium

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
2.1768	0.0048565	36.537	0.027370	–0.030158	–0.030025	–0.0087120	0.025164	0.025289	216.83	–1.0411	13.522	3.5963
2.2000	0.0051477	36.523	0.027380	–0.029596	–0.029455	–0.0084552	0.023062	0.023216	216.59	–1.1290	13.631	3.6153
2.3500	0.0073079	36.396	0.027475	–0.026858	–0.026658	–0.0072478	0.014101	0.014502	215.68	–1.7580	14.294	3.7039
2.5000	0.010001	36.217	0.027611	–0.025011	–0.024734	–0.0064839	0.010092	0.010808	216.03	–2.2958	14.894	3.7456
2.6500	0.013298	35.992	0.027784	–0.023514	–0.023145	–0.0059016	0.0085050	0.0095913	216.74	–2.5162	15.442	3.7541
2.8000	0.017270	35.727	0.027990	–0.022106	–0.021623	–0.0053835	0.0080743	0.0095802	216.57	–2.4447	15.946	3.7391
2.9500	0.021983	35.423	0.028230	–0.020660	–0.020040	–0.0048790	0.0081637	0.010142	215.08	–2.2326	16.408	3.7074
3.1000	0.027502	35.082	0.028504	–0.019120	–0.018336	–0.0043676	0.0084575	0.010969	212.50	–1.9844	16.829	3.6637
3.2500	0.033890	34.705	0.028814	–0.017461	–0.016485	–0.0038422	0.0088040	0.011921	209.15	–1.7406	17.209	3.6113
3.4000	0.041209	34.291	0.029162	–0.015675	–0.014473	–0.0033010	0.0091348	0.012944	205.24	–1.5095	17.548	3.5525
3.5500	0.049518	33.838	0.029553	–0.013757	–0.012294	–0.0027443	0.0094238	0.014037	200.91	–1.2873	17.844	3.4890
3.7000	0.058879	33.342	0.029993	–0.011706	–0.0099402	–0.0021719	0.0096652	0.015223	196.21	–1.0669	18.098	3.4218
3.8500	0.069351	32.799	0.030489	–0.0095155	–0.0074010	–0.0015832	0.0098629	0.016553	191.15	–0.84045	18.307	3.3516
4.0000	0.080998	32.203	0.031053	–0.0071756	–0.0046603	–0.00097628	0.010024	0.018104	185.70	–0.59987	18.474	3.2785
4.1500	0.093886	31.545	0.031700	–0.0046702	–0.0016940	–0.00034763	0.010158	0.019993	179.82	–0.33639	18.599	3.2025
4.3000	0.10809	30.813	0.032454	–0.0019735	0.0015343	0.00030858	0.010273	0.022416	173.44	–0.03948	18.688	3.1231
4.4500	0.12368	29.986	0.033349	0.00095551	0.0050800	0.0010017	0.010378	0.025720	166.48	0.30472	18.753	3.0392
4.6000	0.14075	29.032	0.034445	0.0041842	0.0090322	0.0017471	0.010481	0.030604	158.80	0.71637	18.811	2.9490
4.7500	0.15942	27.895	0.035849	0.0078334	0.013548	0.0025725	0.010592	0.038735	150.22	1.2278	18.892	2.8488
4.9000	0.17983	26.456	0.037798	0.012155	0.018953	0.0035365	0.010726	0.055286	140.44	1.8978	19.051	2.7312
5.0500	0.20225	24.384	0.041010	0.017863	0.026157	0.0048066	0.010920	0.10769	128.80	2.8635	19.490	2.5752
5.1953	0.22637	17.399	0.057475	0.034500	0.047510	0.0087388			0	5.6142		
2.1768	0.0048565	0.28619	3.4942	0.045977	0.062946	0.033998	0.013890	0.024259	83.225	27.717	3.9767	0.53761
2.2000	0.0051477	0.30076	3.3249	0.046200	0.063316	0.033714	0.013900	0.024319	83.564	27.045	4.0381	0.54487
2.3500	0.0073079	0.40515	2.4682	0.047628	0.065665	0.032039	0.013945	0.024692	85.668	23.375	4.4135	0.59162
2.5000	0.010001	0.52873	1.8913	0.049016	0.067931	0.030582	0.013954	0.025049	87.618	20.607	4.7651	0.63825
2.6500	0.013298	0.67363	1.4845	0.050355	0.070096	0.029283	0.013937	0.025413	89.415	18.480	5.1055	0.68502
2.8000	0.017270	0.84193	1.1878	0.051635	0.072147	0.028106	0.013897	0.025800	91.063	16.819	5.4423	0.73220
2.9500	0.021983	1.0357	0.96551	0.052848	0.074072	0.027023	0.013840	0.026230	92.568	15.504	5.7797	0.77999
3.1000	0.027502	1.2573	0.79536	0.053985	0.075859	0.026018	0.013767	0.026720	93.934	14.450	6.1203	0.82863
3.2500	0.033890	1.5091	0.66264	0.055037	0.077494	0.025074	0.013682	0.027292	95.167	13.597	6.4659	0.87831
3.4000	0.041209	1.7941	0.55738	0.055993	0.078962	0.024180	0.013588	0.027973	96.271	12.902	6.8180	0.92926
3.5500	0.049518	2.1157	0.47265	0.056842	0.080247	0.023324	0.013485	0.028799	97.250	12.329	7.1823	0.98171
3.7000	0.058879	2.4783	0.40351	0.057570	0.081328	0.022495	0.013376	0.029817	98.108	11.856	7.5561	1.0359
3.8500	0.069351	2.8871	0.34637	0.058158	0.082179	0.021684	0.013262	0.031095	98.847	11.460	7.9453	1.0922
4.0000	0.080998	3.3494	0.29856	0.058586	0.082769	0.020881	0.013144	0.032736	99.469	11.127	8.3558	1.1509
4.1500	0.093886	3.8747	0.25808	0.058825	0.083055	0.020074	0.013022	0.034897	99.978	10.841	8.7965	1.2125
4.3000	0.10809	4.4768	0.22337	0.058834	0.082977	0.019249	0.012898	0.037844	100.38	10.587	9.2815	1.2776
4.4500	0.12368	5.1759	0.19320	0.058554	0.082449	0.018388	0.012770	0.042056	100.67	10.349	9.8336	1.3473
4.6000	0.14075	6.0046	0.16654	0.057896	0.081335	0.017465	0.012637	0.048501	100.88	10.104	10.490	1.4230
4.7500	0.15942	7.0212	0.14243	0.056698	0.079403	0.016437	0.012496	0.059461	101.05	9.8116	11.319	1.5075
4.9000	0.17983	8.3467	0.11981	0.054637	0.076183	0.015216	0.012341	0.081908	101.28	9.3953	12.465	1.6065
5.0500	0.20225	10.326	0.096844	0.050816	0.070403	0.013568	0.012146	0.15172	101.95	8.6477	14.402	1.7364
5.1953	0.22637	17.399	0.057475	0.034500	0.047510	0.0087388			0	5.6142		

Single-Phase Properties

100.00	0.10000	0.12010	8.3265	1.2679	2.1006	0.089342	0.012475	0.020791	589.24	–0.54790	73.713	9.7778
350.00	0.10000	0.034351	29.111	4.3860	7.2972	0.11538	0.012472	0.020785	1101.2	–0.61403	173.53	22.154
600.00	0.10000	0.020042	49.896	7.5039	12.494	0.12659	0.012472	0.020785	1441.5	–0.57336	252.40	32.215
850.00	0.10000	0.014148	70.681	10.622	17.690	0.13383	0.012472	0.020786	1715.7	–0.54223	321.87	41.153
1100.0	0.10000	0.010933	91.467	13.740	22.886	0.13919	0.012472	0.020786	1951.7	–0.51882	385.47	49.382
1350.0	0.10000	0.0089085	112.25	16.857	28.083	0.14344	0.012472	0.020786	2162.0	–0.50057	444.91	57.105
100.00	1.0000	1.1854	0.84359	1.2672	2.1108	0.070191	0.012506	0.020837	596.88	–0.54470	74.600	9.8922
350.00	1.0000	0.34233	2.9212	4.3875	7.3086	0.096243	0.012477	0.020782	1104.7	–0.61441	174.19	22.180
600.00	1.0000	0.20005	4.9988	7.5054	12.504	0.10744	0.012474	0.020783	1444.0	–0.57410	253.00	32.231
850.00	1.0000	0.14131	7.0768	10.623	17.700	0.11468	0.012473	0.020784	1717.6	–0.54296	322.43	41.164
1100.0	1.0000	0.10923	9.1550	13.741	22.896	0.12004	0.012473	0.020784	1953.3	–0.51949	386.00	49.391
1350.0	1.0000	0.089021	11.233	16.859	28.092	0.12430	0.012472	0.020784	2163.5	–0.50117	445.41	57.112
100.00	5.0000	5.6058	0.17839	1.2641	2.1560	0.056777	0.012635	0.021029	630.65	–0.53640	79.465	10.374
350.00	5.0000	1.6858	0.59320	4.3938	7.3598	0.082880	0.012500	0.020769	1120.3	–0.61554	176.72	22.297
600.00	5.0000	0.99204	1.0080	7.5120	12.552	0.094074	0.012484	0.020771	1454.9	–0.57711	255.23	32.299
850.00	5.0000	0.70266	1.4232	10.630	17.745	0.10131	0.012479	0.020775	1726.3	–0.54605	324.52	41.212
1100.0	5.0000	0.54393	1.8385	13.747	22.939	0.10667	0.012477	0.020777	1960.6	–0.52237	387.99	49.428
1350.0	5.0000	0.44368	2.2539	16.864	28.134	0.11092	0.012475	0.020779	2169.9	–0.50380	447.32	57.143
100.00	10.000	10.505	0.095194	1.2606	2.2125	0.050975	0.012775	0.021226	672.30	–0.53355	85.417	10.926
350.00	10.000	3.3086	0.30224	4.4013	7.4237	0.077139	0.012527	0.020755	1140.1	–0.61584	179.43	22.435
600.00	10.000	1.9638	0.50921	7.5200	12.612	0.088326	0.012497	0.020756	1468.8	–0.58023	257.42	32.383
850.00	10.000	1.3957	0.71649	10.637	17.802	0.095556	0.012487	0.020763	1737.3	–0.54953	326.55	41.272
1100.0	10.000	1.0823	0.92394	13.754	22.994	0.10091	0.012482	0.020769	1969.9	–0.52572	389.94	49.475
1350.0	10.000	0.88379	1.1315	16.871	28.186	0.10516	0.012479	0.020772	2178.0	–0.50691	449.21	57.181
100.00	50.000	35.384	0.028261	1.2602	2.6732	0.037457	0.013484	0.021607	962.59	–0.53310	127.36	14.393
350.00	50.000	14.387	0.069507	4.4519	7.9272	0.063904	0.012710	0.020725	1299.0	–0.59388	197.39	23.353
600.00	50.000	9.0593	0.11038	7.5781	13.097	0.075052	0.012587	0.020666	1584.0	–0.58658	268.59	32.979
850.00	50.000	6.6048	0.15140	10.695	18.265	0.082253	0.012543	0.020682	1829.4	–0.56519	334.90	41.713
1100.0	50.000	5.1933	0.19256	13.811	23.438	0.087587	0.012521	0.020701	2047.7	–0.54419	397.07	49.825
1350.0	50.000	4.2772	0.23380	16.926	28.615	0.091828	0.012508	0.020716	2245.9	–0.52586	455.79	57.471
100.00	100.00	51.724	0.019333	1.3032	3.2366	0.031667	0.013965	0.021327	1228.1	–0.51530	197.79	18.001
350.00	100.00	24.886	0.040183	4.5034	8.5217	0.058239	0.012884	0.020817	1482.2	–0.55155	217.91	24.221
600.00	100.00	16.512	0.060563	7.6393	13.696	0.069398	0.012683	0.020630	1727.9	–0.57040	281.89	33.590
850.00	100.00	12.359	0.080910	10.759	18.850	0.076579	0.012605	0.020615	1948.4	–0.56473	342.93	42.188
1350.0	100.00	8.2113	0.12178	16.988	29.166	0.086124	0.012542	0.020653	2335.4	-0.53766	458.27	57.800

The values in these tables were generated from the NIST REFPROP software (Lemmon, E.W., McLinden, M.O., and Huber, M.L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is McCarty, R.D., and Arp, V. D., "A New Wide Range Equation of State for Helium," *Adv. Cryo. Eng.* **35:**1465–1475, 1990. The source for viscosity is Arp, V. D., McCarty, R. D., and Friend, D. G., "Thermophysical Properties of Helium-4 from 0.8 to 1500 K with Pressures to 2000 MPa," *NIST Technical Note* 1334, Boulder, Colo., 1998. The source for thermal conductivity is Hands, B. A., and Arp, V. D., "A Correlation of Thermal Conductivity Data for Helium," *Cryogenics,* **21**(12):697–703, 1981.

Properties at the triple point and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state range from 1% at low temperatures (<20 K) to 0.1% at temperatures between 200 and 400 K, and from 3% in the speed of sound in the liquid phase to 0.1% in the speed of sound between 100 and 500 K. The uncertainty in heat capacities is about 5%. The uncertainty in viscosity is 10%. The uncertainty in thermal conductivity is 5%, except at low temperatures where it increases to 10%.

TABLE 2-220 Thermodynamic Properties of Heptane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
182.55	1.7549E-07	7.7457	0.12910	–41.621	–41.621	–0.15398	0.14886	0.19662	1669.5	–0.52328	155.74	3857.1
185.00	2.5788E-07	7.7246	0.12946	–41.139	–41.139	–0.15136	0.14924	0.19687	1656.1	–0.52236	155.56	3523.8
205.00	4.0249E-06	7.5549	0.13236	–37.178	–37.178	–0.13103	0.15264	0.19936	1550.9	–0.51267	153.03	1889.1
225.00	3.5822E-05	7.3882	0.13535	–33.158	–33.158	–0.11232	0.15666	0.20287	1452.3	–0.49878	149.21	1175.0
245.00	0.00021055	7.2229	0.13845	–29.056	–29.056	–0.094861	0.16146	0.20746	1358.8	–0.48063	144.65	805.42
265.00	0.00090411	7.0579	0.14169	–24.852	–24.852	–0.078369	0.16706	0.21311	1269.3	–0.45837	139.70	589.93
285.00	0.0030469	6.8917	0.14510	–20.526	–20.525	–0.062631	0.17337	0.21972	1183.0	–0.43224	134.59	452.87
305.00	0.0084921	6.7233	0.14874	–16.058	–16.057	–0.047486	0.18029	0.22715	1099.5	–0.40232	129.47	359.75
325.00	0.020357	6.5515	0.15264	–11.436	–11.433	–0.032809	0.18765	0.23527	1018.0	–0.36834	124.41	293.16
345.00	0.043242	6.3747	0.15687	–6.6463	–6.6396	–0.018509	0.19534	0.24397	938.09	–0.32951	119.45	243.54
365.00	0.083287	6.1914	0.16151	–1.6791	–1.6656	–0.0045150	0.20321	0.25320	859.20	–0.28429	114.61	205.28
385.00	0.14809	5.9995	0.16668	3.4744	3.4991	0.0092301	0.21119	0.26293	780.76	–0.22999	109.90	174.90
405.00	0.24655	5.7965	0.17252	8.8226	8.8651	0.022774	0.21920	0.27327	702.10	–0.16200	105.28	150.12
425.00	0.38874	5.5785	0.17926	14.375	14.445	0.036160	0.22720	0.28444	622.51	–0.072112	100.73	129.39
445.00	0.58581	5.3401	0.18726	20.147	20.256	0.049436	0.23517	0.29693	541.08	0.055234	96.175	111.58
465.00	0.85019	5.0723	0.19715	26.159	26.327	0.062666	0.24315	0.31186	456.64	0.25318	91.522	95.804
485.00	1.1961	4.7587	0.21014	32.455	32.706	0.075947	0.25123	0.33203	367.46	0.60537	86.595	81.246
505.00	1.6406	4.3628	0.22921	39.129	39.506	0.089485	0.25971	0.36700	270.69	1.3922	81.058	66.925
525.00	2.2070	3.7651	0.26559	46.501	47.087	0.10393	0.26971	0.48246	161.32	4.2679	74.208	50.757
540.13	2.7311	2.3153	0.43191	55.157	56.336	0.12095			0	26.539		
182.55	1.7549E-07	1.1562E-07	8,649,000.	1.0688	2.5867	0.088185	0.11339	0.12171	127.51	478.91	4.8076	0.93944
185.00	2.5788E-07	1.6766E-07	5,964,600.	1.3477	2.8859	0.086612	0.11424	0.12255	128.33	454.07	4.9177	1.6197
205.00	4.0249E-06	2.3614E-06	423,480.	3.7004	5.4048	0.076690	0.12103	0.12935	134.83	301.84	5.8582	3.8170
225.00	3.5822E-05	1.9151E-05	52,218.	6.1891	8.0596	0.070867	0.12796	0.13628	140.99	208.67	6.8855	4.4411
245.00	0.00021055	0.00010342	9,669.6	8.8178	10.854	0.068037	0.13529	0.14363	146.83	148.90	8.0159	4.8725
265.00	0.00090411	0.00041102	2,433.0	11.592	13.792	0.067457	0.14313	0.15153	152.32	109.17	9.2615	5.2813
285.00	0.0030469	0.0012912	774.44	14.516	16.875	0.068598	0.15149	0.16002	157.38	82.064	10.631	5.6934
305.00	0.0084921	0.0033793	295.92	17.589	20.102	0.071069	0.16033	0.16910	161.89	63.190	12.128	6.1135
325.00	0.020357	0.0076646	130.47	20.809	23.465	0.074569	0.16957	0.17874	165.69	49.846	13.757	6.5434
345.00	0.043242	0.015529	64.395	24.169	26.954	0.078862	0.17912	0.18891	168.60	40.301	15.521	6.9849
365.00	0.083287	0.028777	34.750	27.660	30.555	0.083760	0.18889	0.19961	170.42	33.422	17.424	7.4417
385.00	0.14809	0.049694	20.123	31.271	34.251	0.089105	0.19880	0.21088	170.92	28.458	19.473	7.9194
405.00	0.24655	0.081188	12.317	34.984	38.021	0.094763	0.20878	0.22285	169.84	24.914	21.682	8.4272
425.00	0.38874	0.12711	7.8674	38.780	41.838	0.10061	0.21881	0.23587	166.88	22.470	24.071	8.9798
445.00	0.58581	0.19291	5.1838	42.627	45.663	0.10653	0.22889	0.25064	161.58	20.951	26.681	9.6020
465.00	0.85019	0.28714	3.4827	46.478	49.439	0.11237	0.23906	0.26877	153.35	20.312	29.592	10.339
485.00	1.1961	0.42516	2.3521	50.254	53.067	0.11793	0.24945	0.29447	141.27	20.689	32.980	11.280
505.00	1.6406	0.64076	1.5607	53.786	56.346	0.12283	0.26036	0.34231	123.97	22.542	37.355	12.649
525.00	2.2070	1.0396	0.96195	56.608	58.731	0.12611	0.27248	0.50359	99.655	26.764	45.104	15.245
540.13	2.7311	2.3153	0.43191	55.157	56.336	0.12095			0	26.539		

Single-Phase Properties												
200.00	0.10000	7.5975	0.13162	–38.176	–38.163	–0.13596	0.15175	0.19864	1576.9	–0.51551	153.84	2174.6
300.00	0.10000	6.7666	0.14778	–17.194	–17.180	–0.051241	0.17852	0.22520	1120.8	–0.41037	130.79	380.51
371.09	0.10000	6.1340	0.16303	–0.13101	–0.11470	–0.00030834	0.20564	0.25610	835.31	–0.26890	113.16	195.32
371.09	0.10000	0.034210	29.231	28.747	31.670	0.085345	0.19189	0.20297	170.72	31.736	18.032	7.5845
400.00	0.10000	0.031296	31.953	34.506	37.702	0.10099	0.20404	0.21430	179.24	23.441	20.824	8.1460
500.00	0.10000	0.024471	40.864	57.027	61.114	0.15307	0.24438	0.25347	203.88	10.262	31.544	10.052
600.00	0.10000	0.020221	49.453	83.290	88.236	0.20242	0.27936	0.28808	224.61	5.6176	43.213	11.883
200.00	1.0000	7.6022	0.13154	–38.202	–38.071	–0.13609	0.15181	0.19861	1581.3	–0.51586	154.03	2203.0
300.00	1.0000	6.7756	0.14759	–17.244	–17.096	–0.051406	0.17857	0.22503	1127.5	–0.41229	131.16	385.02
400.00	1.0000	5.8668	0.17045	7.3729	7.5433	0.019169	0.21722	0.26994	732.61	–0.19065	107.01	158.14
474.30	1.0000	4.9336	0.20269	29.049	29.251	0.068829	0.24689	0.32029	415.88	0.38883	89.279	88.930
474.30	1.0000	0.34452	2.9026	48.251	51.154	0.11501	0.24385	0.27933	148.28	20.343	31.091	10.743
500.00	1.0000	0.30146	3.3172	54.943	58.260	0.12960	0.25108	0.27563	166.14	14.530	33.576	11.093
600.00	1.0000	0.22064	4.5322	82.131	86.663	0.18133	0.28189	0.29560	207.02	6.3945	44.625	12.599
200.00	5.0000	7.6229	0.13118	–38.316	–37.661	–0.13667	0.15208	0.19848	1600.2	–0.51732	154.89	2331.7
300.00	5.0000	6.8141	0.14675	–17.456	–16.722	–0.052121	0.17879	0.22435	1156.4	–0.42010	132.76	405.07
400.00	5.0000	5.9526	0.16799	6.9316	7.7715	0.018047	0.21734	0.26714	783.30	–0.23205	109.78	169.17
500.00	5.0000	4.8210	0.20743	35.998	37.035	0.083125	0.25622	0.32159	423.74	0.32892	89.492	84.960
600.00	5.0000	2.2376	0.44691	72.724	74.958	0.15188	0.29509	0.43674	134.50	7.5010	63.671	27.947
200.00	10.000	7.6479	0.13075	–38.454	–37.147	–0.13737	0.15241	0.19835	1623.3	–0.51893	155.94	2498.6
300.00	10.000	6.8595	0.14578	–17.705	–16.247	–0.052975	0.17908	0.22363	1190.5	–0.42839	134.68	430.15
400.00	10.000	6.0454	0.16542	6.4514	8.1056	0.016799	0.21753	0.26465	838.61	–0.26850	112.88	182.05
500.00	10.000	5.0885	0.19652	34.818	36.783	0.080607	0.25576	0.30908	532.87	0.040826	95.612	98.261
600.00	10.000	3.8337	0.26084	67.259	69.867	0.14081	0.29039	0.35093	303.32	0.87871	82.499	55.622
300.00	50.000	7.1493	0.13987	–19.254	–12.260	–0.058701	0.18121	0.22068	1412.7	–0.46360	147.62	635.00
400.00	50.000	6.5292	0.15316	3.9425	11.600	0.0096885	0.21935	0.25730	1139.8	–0.37509	130.89	269.35
500.00	50.000	5.9397	0.16836	30.741	39.159	0.071034	0.25677	0.29309	940.60	–0.29668	119.90	158.19
600.00	50.000	5.3846	0.18572	60.741	70.026	0.12723	0.28945	0.32327	800.70	–0.23327	114.54	109.31
300.00	100.00	7.4106	0.13494	–20.560	–7.0660	–0.064263	0.18354	0.21976	1622.2	–0.47764	160.40	909.65
400.00	100.00	6.8927	0.14508	2.1360	16.644	0.0037009	0.22143	0.25527	1385.0	–0.40643	146.71	364.81
500.00	100.00	6.4248	0.15565	28.397	43.961	0.064512	0.25865	0.29041	1216.1	–0.35005	137.75	209.24
600.00	100.00	6.0005	0.16665	57.894	74.559	0.12021	0.29113	0.32068	1095.6	–0.31028	133.53	143.14

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Span, R., and Wagner, W., "Equations of State for Technical Applications. II. Results for Nonpolar Fluids," *Int. J. Thermophys.,* **24**(1):41–109, 2003. The source for viscosity is NIST14, Version 9.08. The source for thermal conductivity is NIST14, Version 9.08.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are approximately 0.2% (to 0.5% at high pressures) in density, 1% (in the vapor phase) to 2% in heat capacity, 1% (in the vapor phase) to 2% in the speed of sound, and 0.2% in vapor pressure, except in the critical region. For viscosity, estimated uncertainty is 2%. For thermal conductivity, estimated uncertainty, except near the critical region, is 4–6%.

TABLE 2-221 Thermodynamic Properties of Hexane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
177.83	1.2771E-06	8.8394	0.11313	–30.053	–30.053	–0.11799	0.11891	0.16166	1638.9	–0.55189	155.43	2392.6
180.00	1.7416E-06	8.8166	0.11342	–29.702	–29.702	–0.11602	0.11944	0.16212	1626.3	–0.54996	155.64	2235.0
195.00	1.2006E-05	8.6607	0.11546	–27.247	–27.247	–0.10292	0.12299	0.16527	1542.5	–0.53626	155.51	1474.2
210.00	6.0531E-05	8.5066	0.11756	–24.744	–24.744	–0.090556	0.12642	0.16850	1463.6	–0.52146	153.36	1048.0
225.00	0.00023840	8.3535	0.11971	–22.190	–22.190	–0.078815	0.12992	0.17196	1388.4	–0.50504	149.89	786.13
240.00	0.00077035	8.2006	0.12194	–19.583	–19.583	–0.067597	0.13361	0.17575	1316.2	–0.48667	145.59	613.59
255.00	0.0021200	8.0472	0.12427	–16.916	–16.916	–0.056819	0.13753	0.17992	1246.3	–0.46617	140.79	493.58
270.00	0.0051148	7.8927	0.12670	–14.184	–14.183	–0.046408	0.14172	0.18448	1178.5	–0.44339	135.74	406.45
285.00	0.011066	7.7363	0.12926	–11.380	–11.379	–0.036304	0.14616	0.18943	1112.3	–0.41819	130.60	340.96
300.00	0.021865	7.5774	0.13197	–8.4998	–8.4969	–0.026456	0.15084	0.19474	1047.6	–0.39031	125.50	290.31
315.00	0.040031	7.4151	0.13486	–5.5378	–5.5324	–0.016823	0.15571	0.20040	984.03	–0.35939	120.53	250.18
330.00	0.068721	7.2487	0.13796	–2.4895	–2.4800	–0.0073691	0.16074	0.20638	921.37	–0.32478	115.73	217.72
345.00	0.11169	7.0772	0.14130	0.64962	0.66541	0.0019333	0.16590	0.21269	859.40	–0.28553	111.15	190.99
360.00	0.17326	6.8995	0.14494	3.8834	3.9085	0.011109	0.17114	0.21932	797.86	–0.24020	106.82	168.61
375.00	0.25821	6.7141	0.14894	7.2160	7.2544	0.020180	0.17645	0.22633	736.47	–0.18658	102.74	149.58
390.00	0.37176	6.5194	0.15339	10.652	10.709	0.029166	0.18178	0.23378	674.93	–0.12130	98.910	133.16
405.00	0.51954	6.3129	0.15840	14.195	14.278	0.038087	0.18713	0.24184	612.85	–0.038945	95.319	118.78
420.00	0.70759	6.0916	0.16416	17.854	17.970	0.046965	0.19251	0.25078	549.78	0.069646	91.941	105.97
435.00	0.94243	5.8506	0.17092	21.638	21.799	0.055828	0.19791	0.26113	485.05	0.22117	88.736	94.348
450.00	1.2313	5.5825	0.17913	25.562	25.782	0.064717	0.20338	0.27400	417.67	0.44954	85.638	83.551
465.00	1.5827	5.2736	0.18963	29.656	29.956	0.073697	0.20902	0.29208	346.06	0.83549	82.537	73.177
480.00	2.0071	4.8943	0.20432	33.983	34.393	0.082910	0.21509	0.32426	267.23	1.6275	79.234	62.632
495.00	2.5196	4.3496	0.22990	38.752	39.331	0.092809	0.22251	0.42766	174.59	4.0963	75.402	50.415
507.82	3.0429	2.7059	0.36957	45.698	46.822	0.10743			0	21.950		
177.83	1.2771E-06	8.6377E-07	1,157,700.	6.5712	8.0497	0.096281	0.095572	0.10389	136.57	381.55	5.2567	3.0564
180.00	1.7416E-06	1.1637E-06	859,330.	6.7793	8.2759	0.094966	0.096248	0.10456	137.36	363.60	5.3651	3.2844
195.00	1.2006E-05	7.4054E-06	135,040.	8.2570	9.8783	0.087463	0.10079	0.10910	142.71	265.13	6.1371	4.1334
210.00	6.0531E-05	3.4674E-05	28,840.	9.8013	11.547	0.082256	0.10523	0.11356	147.84	198.42	6.9555	4.5617
225.00	0.00023840	0.00012750	7,842.9	11.411	13.281	0.078835	0.10975	0.11809	152.75	151.75	7.8286	4.9114
240.00	0.00077035	0.00038658	2,586.8	13.086	15.079	0.076827	0.11444	0.12282	157.43	118.24	8.7644	5.2472
255.00	0.0021200	0.0010029	997.06	14.827	16.941	0.075951	0.11936	0.12783	161.83	93.691	9.7697	5.5832
270.00	0.0051148	0.0022917	436.35	16.633	18.865	0.075993	0.12457	0.13317	165.91	75.403	10.851	5.9228
285.00	0.011066	0.0047185	211.93	18.505	20.850	0.076780	0.13005	0.13886	169.59	61.606	12.012	6.2669
300.00	0.021865	0.0089152	112.17	20.440	22.893	0.078177	0.13579	0.14492	172.79	51.090	13.258	6.6161
315.00	0.040031	0.015688	63.742	22.438	24.989	0.080072	0.14178	0.15136	175.43	43.011	14.592	6.9712
330.00	0.068721	0.026023	38.427	24.494	27.135	0.082372	0.14798	0.15817	177.42	36.767	16.018	7.3333
345.00	0.11169	0.041099	24.332	26.606	29.324	0.085000	0.15435	0.16537	178.64	31.926	17.540	7.7043
360.00	0.17326	0.062314	16.048	28.769	31.549	0.087889	0.16085	0.17297	179.01	28.172	19.162	8.0869
375.00	0.25821	0.091349	10.947	30.977	33.804	0.090978	0.16746	0.18106	178.39	25.277	20.892	8.4853
390.00	0.37176	0.13027	7.6763	33.223	36.077	0.094213	0.17415	0.18976	176.64	23.080	22.739	8.9054
405.00	0.51954	0.18173	5.5026	35.497	38.356	0.097538	0.18092	0.19931	173.59	21.471	24.719	9.3563
420.00	0.70759	0.24933	4.0108	37.783	40.621	0.10090	0.18775	0.21014	169.01	20.386	26.858	9.8524
435.00	0.94243	0.33826	2.9563	40.061	42.848	0.10422	0.19467	0.22312	162.60	19.809	29.203	10.417
450.00	1.2313	0.45679	2.1892	42.299	44.994	0.10741	0.20173	0.24003	153.94	19.784	31.843	11.090
465.00	1.5827	0.61964	1.6138	44.438	46.992	0.11033	0.20903	0.26537	142.42	20.448	34.979	11.951
480.00	2.0071	0.85826	1.1651	46.363	48.702	0.11272	0.21678	0.31367	127.17	22.098	39.160	13.186
495.00	2.5196	1.2664	0.78962	47.752	49.742	0.11384	0.22558	0.46871	106.85	25.172	46.755	15.416
507.82	3.0429	2.7059	0.36957	45.698	46.822	0.10743			0	21.950		

Single-Phase Properties

200.00	0.10000	8.6098	0.11615	–26.420	–26.409	–0.098737	0.12414	0.16632	1516.3	–0.53154	155.01	1308.5
300.00	0.10000	7.5784	0.13195	–8.5042	–8.4910	–0.026471	0.15084	0.19472	1048.3	–0.39056	125.55	290.66
341.45	0.10000	7.1184	0.14048	–0.10255	–0.088504	–0.00025850	0.16467	0.21117	874.04	–0.29532	112.22	196.89
341.45	0.10000	0.037028	27.006	26.101	28.801	0.084352	0.15282	0.16363	178.43	32.965	17.170	7.6155
400.00	0.10000	0.030895	32.368	35.725	38.962	0.11177	0.17421	0.18376	196.30	17.891	23.256	8.9061
500.00	0.10000	0.024344	41.078	54.980	59.088	0.15654	0.20940	0.21824	221.55	8.1885	35.216	11.054
600.00	0.10000	0.020168	49.583	77.506	82.464	0.19908	0.23990	0.24850	243.38	4.6052	48.247	13.104
200.00	1.0000	8.6159	0.11606	–26.445	–26.329	–0.098862	0.12419	0.16628	1521.0	–0.53204	155.38	1327.2
300.00	1.0000	7.5906	0.13174	–8.5541	–8.4223	–0.026637	0.15088	0.19451	1055.7	–0.39338	126.12	294.62
400.00	1.0000	6.4028	0.15618	12.928	13.084	0.034934	0.18534	0.23836	642.57	–0.081596	96.993	124.96
438.24	1.0000	5.7953	0.17255	22.473	22.645	0.057745	0.19908	0.26364	470.76	0.26228	88.060	91.958
438.24	1.0000	0.36099	2.7701	40.550	43.320	0.10492	0.19618	0.22634	160.93	19.754	29.744	10.551
500.00	1.0000	0.27702	3.6098	53.661	57.271	0.13470	0.21315	0.22970	196.29	10.036	36.713	11.711
600.00	1.0000	0.21383	4.6765	76.704	81.381	0.17859	0.24143	0.25320	230.76	5.0002	49.365	13.575
200.00	5.0000	8.6424	0.11571	–26.553	–25.975	–0.099407	0.12440	0.16610	1541.5	–0.53416	157.01	1411.9
300.00	5.0000	7.6426	0.13085	–8.7667	–8.1124	–0.027355	0.15106	0.19368	1087.5	–0.40464	128.58	312.23
400.00	5.0000	6.5335	0.15306	12.434	13.199	0.033675	0.18536	0.23424	702.66	–0.15548	100.50	136.08
500.00	5.0000	4.8882	0.20457	38.358	39.381	0.091842	0.22066	0.30042	311.48	1.0544	81.341	64.368
600.00	5.0000	1.5349	0.65149	71.648	74.906	0.15663	0.24956	0.30605	173.73	6.3809	59.195	20.153
200.00	10.000	8.6744	0.11528	–26.683	–25.530	–0.10007	0.12466	0.16591	1566.5	–0.53649	159.01	1521.9
300.00	10.000	7.7032	0.12982	–9.0138	–7.7156	–0.028204	0.15128	0.19280	1124.9	–0.41638	131.56	334.21
400.00	10.000	6.6684	0.14996	11.917	13.416	0.032326	0.18546	0.23093	765.76	–0.21470	104.41	148.74
500.00	10.000	5.3956	0.18533	36.755	38.608	0.088363	0.21933	0.27365	455.87	0.25439	88.518	80.764
600.00	10.000	3.6515	0.27386	65.462	68.201	0.14220	0.24998	0.31536	248.16	1.7834	79.582	43.840
300.00	50.000	8.0787	0.12378	–10.511	–4.3222	–0.033766	0.15301	0.18931	1362.7	–0.46412	152.57	513.27
400.00	50.000	7.3187	0.13664	9.3999	16.232	0.025137	0.18689	0.22225	1090.0	–0.36559	128.45	231.13
500.00	50.000	6.5956	0.15162	32.487	40.068	0.078194	0.21979	0.25371	895.54	–0.27952	115.10	140.55
600.00	50.000	5.9215	0.16888	58.351	66.794	0.12685	0.24844	0.27993	763.82	–0.21072	111.13	100.20
300.00	100.00	8.4063	0.11896	–11.737	0.15835	–0.039032	0.15494	0.18811	1582.2	–0.48273	175.12	753.68
400.00	100.00	7.7789	0.12855	7.6799	20.535	0.019368	0.18864	0.21997	1345.0	–0.40550	152.26	319.21
500.00	100.00	7.2120	0.13866	30.244	44.110	0.071845	0.22138	0.25089	1178.8	–0.34615	138.03	188.34
600.00	100.00	6.7006	0.14924	55.635	70.559	0.11999	0.24989	0.27732	1062.8	–0.30501	132.17	132.10

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Span, R., and Wagner, W., "Equations of State for Technical Applications. II. Results for Nonpolar Fluids," *Int. J. Thermophys.* **24**(1):41–109, 2003. The source for viscosity and thermal conductivity is NIST14, Version 9.08.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are approximately 0.2% (to 0.5% at high pressures) in density, 1% (in the vapor phase) to 2% in heat capacity, 1% (in the vapor phase) to 2% in the speed of sound, and 0.2% in vapor pressure, except in the critical region. For viscosity, estimated uncertainty is 2%. For thermal conductivity, estimated uncertainty, except near the critical region, is 4–6 %.

TABLE 2-222 Saturated Hydrazine

Temperature, K	Pressure, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)
386.6	1.013	0.001 053	0.9833	−105.9	65.4	0.5994	1.0426
390	1.135	0.001 060	0.8850	−104.8	66.0	0.6029	1.0409
400	1.560	0.001 081	0.6579	−101.4	68.2	0.6120	1.0360
410	2.102	0.001 104	0.4994	−97.6	70.6	0.6211	1.0314
420	2.786	0.001 127	0.3850	−93.9	73.0	0.6300	1.0275
440	4.732	0.001 178	0.2355	−86.1	77.6	0.6492	1.0212
460	7.610	0.001 235	0.1500	−76.9	82.1	0.6707	1.0163
480	11.76	0.001 299	0.1005	−67.1	86.6	0.6916	1.0118
500	17.42	0.001 374	0.0690	−57.3	90.8	0.7124	1.0086
520	29.59	0.001 460	0.0407	−47.8	94.6	0.7320	1.0058
540	34.75	0.001 563	0.0353	−36.0	97.7	0.7566	1.0042
560	47.09	0.001 681	0.0263	−25.2	101.2	0.7762	1.0020
580	62.44	0.001 835	0.0196	−12.4	103.6	0.8002	1.0002
600	81.17	0.002 045	0.0142	5.2	104.2	0.8335	0.9988
620	102.7	0.002 320	0.0106	23.2	103.6	0.8671	0.9967
640	128.1	0.002 86	0.0074	45.9	98.1	0.9035	0.9906
653[c]	146.9	0.004 33	0.0043	83.7	83.7	0.9715	0.9715

Converted from E. F. Fricke, Republic Aviation Co. rept. F-5028-101. *c* = critical point.

TABLE 2-223 Thermodynamic Properties of Normal Hydrogen

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
13.957	0.0077031	38.148	0.026214	–0.10434	–0.10414	–0.0059480	0.011064	0.015654	1361.1	–1.4137	76.293	25.463
14.000	0.0078936	38.129	0.026226	–0.10367	–0.10346	–0.0059000	0.010957	0.015547	1359.6	–1.4230	76.650	25.310
15.000	0.013436	37.701	0.026524	–0.088896	–0.088539	–0.0048799	0.0096961	0.014420	1318.5	–1.5204	84.106	22.215
16.000	0.021534	37.261	0.026838	–0.074446	–0.073868	–0.0039471	0.0096482	0.014709	1271.6	–1.4695	90.079	19.784
17.000	0.032848	36.802	0.027172	–0.059414	–0.058521	–0.0030355	0.010003	0.015557	1226.6	–1.3623	94.784	17.815
18.000	0.048078	36.321	0.027533	–0.043440	–0.042116	–0.0021219	0.010462	0.016642	1185.5	–1.2409	98.405	16.182
19.000	0.067960	35.812	0.027923	–0.026375	–0.024477	–0.0011983	0.010915	0.017842	1147.3	–1.1194	101.10	14.799
20.000	0.093249	35.274	0.028350	–0.0081516	–0.0055080	–0.00026211	0.011323	0.019120	1110.7	–1.0003	103.01	13.607
21.000	0.12472	34.702	0.028817	0.011274	0.014868	0.00068790	0.011677	0.020476	1074.7	–0.88232	104.24	12.565
22.000	0.16314	34.092	0.029333	0.031947	0.036732	0.0016528	0.011978	0.021935	1038.2	–0.76268	104.87	11.641
23.000	0.20932	33.439	0.029905	0.053929	0.060188	0.0026344	0.012235	0.023539	1000.5	–0.63795	104.98	10.811
24.000	0.26406	32.738	0.030546	0.077308	0.085375	0.0036357	0.012457	0.025351	960.99	–0.50414	104.60	10.057
25.000	0.32818	31.979	0.031271	0.10222	0.11248	0.0046610	0.012655	0.027465	919.10	–0.35648	103.79	9.3625
26.000	0.40250	31.152	0.032101	0.12884	0.14176	0.0057167	0.012840	0.030024	874.29	–0.18882	102.53	8.7151
27.000	0.48788	30.242	0.033067	0.15744	0.17357	0.0068122	0.013025	0.033265	826.00	0.0073109	100.83	8.1034
28.000	0.58524	29.225	0.034217	0.18843	0.20846	0.0079614	0.013224	0.037610	773.58	0.24446	98.654	7.5160
29.000	0.69554	28.067	0.035629	0.22245	0.24723	0.0091865	0.013460	0.043909	716.22	0.54283	95.935	6.9409
30.000	0.81989	26.706	0.037444	0.26061	0.29132	0.010527	0.013764	0.054194	652.73	0.93827	92.547	6.3620
31.000	0.95964	25.017	0.039973	0.30524	0.34360	0.012063	0.014198	0.074872	581.16	1.5038	88.221	5.7518
32.000	1.1168	22.637	0.044175	0.36302	0.41236	0.014035	0.014926	0.14185	497.24	2.4292	82.176	5.0391
33.190	1.3301	14.940	0.066934	0.53004	0.61907	0.020012			0	5.3208		
13.957	0.0077031	0.067540	14.806	0.68715	0.80120	0.058918	0.013157	0.021964	304.61	31.943	10.375	0.66345
14.000	0.0078936	0.069018	14.489	0.68764	0.80201	0.058777	0.013129	0.021944	305.17	31.808	10.431	0.66695
15.000	0.013436	0.11050	9.0494	0.69864	0.82024	0.055705	0.012872	0.021898	316.15	28.572	11.624	0.74268
16.000	0.021534	0.16764	5.9651	0.70899	0.83745	0.053010	0.012907	0.022199	325.05	25.724	12.681	0.81064
17.000	0.032848	0.24349	4.1069	0.71875	0.85365	0.050622	0.012992	0.022618	333.00	23.407	13.681	0.87421
18.000	0.048078	0.34126	2.9303	0.72783	0.86871	0.048480	0.013083	0.023121	340.22	21.522	14.669	0.93555
19.000	0.067960	0.46437	2.1535	0.73614	0.88249	0.046537	0.013178	0.023724	346.75	19.961	15.675	0.99611
20.000	0.093249	0.61652	1.6220	0.74359	0.89484	0.044755	0.013280	0.024449	352.59	18.642	16.716	1.0569
21.000	0.12472	0.80187	1.2471	0.75005	0.90558	0.043103	0.013392	0.025329	357.75	17.507	17.806	1.1186
22.000	0.16314	1.0251	0.97549	0.75541	0.91455	0.041554	0.013514	0.026401	362.25	16.513	18.956	1.1819
23.000	0.20932	1.2919	0.77406	0.75951	0.92154	0.040085	0.013650	0.027724	366.11	15.629	20.180	1.2472
24.000	0.26406	1.6089	0.62153	0.76218	0.92630	0.038674	0.013802	0.029376	369.34	14.829	21.493	1.3151
25.000	0.32818	1.9848	0.50383	0.76318	0.92853	0.037303	0.013973	0.031482	371.95	14.091	22.916	1.3863
26.000	0.40250	2.4307	0.41141	0.76224	0.92783	0.035950	0.014167	0.034234	373.96	13.396	24.477	1.4619
27.000	0.48788	2.9618	0.33763	0.75895	0.92368	0.034594	0.014392	0.037960	375.38	12.726	26.218	1.5433
28.000	0.58524	3.6003	0.27775	0.75276	0.91531	0.033206	0.014655	0.043253	376.19	12.061	28.202	1.6331
29.000	0.69554	4.3810	0.22826	0.74277	0.90154	0.031749	0.014971	0.051322	376.39	11.374	30.535	1.7362
30.000	0.81989	5.3643	0.18642	0.72747	0.88031	0.030160	0.015358	0.065054	375.97	10.624	33.407	1.8628
31.000	0.95964	6.6763	0.14978	0.70374	0.84748	0.028317	0.015854	0.093486	374.91	9.7362	37.226	2.0375
32.000	1.1168	8.6823	0.11518	0.66274	0.79136	0.025879	0.016535	0.18606	373.31	8.5059	43.200	2.3378
33.190	1.3301	14.940	0.066934	0.53004	0.61907	0.020012			0	5.3208		

TABLE 2-223 Thermodynamic Properties of Normal Hydrogen (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Single-Phase Properties												
25.000	0.10000	0.50823	1.9676	0.81207	1.0088	0.049309	0.012734	0.022519	403.66	12.894	20.761	1.3142
100.00	0.10000	0.12030	8.3127	1.7949	2.6261	0.079163	0.014263	0.022637	808.92	1.4058	68.334	4.1896
175.00	0.10000	0.068680	14.560	3.0224	4.4785	0.092882	0.018150	0.026480	1026.9	0.13575	117.11	6.1845
250.00	0.10000	0.048077	20.800	4.4642	6.5442	0.10269	0.020003	0.028323	1209.1	–0.22980	160.59	7.9025
325.00	0.10000	0.036986	27.037	5.9947	8.6984	0.11022	0.020681	0.028998	1371.7	–0.38965	197.72	9.4561
400.00	0.10000	0.030054	33.273	7.5545	10.882	0.11626	0.020865	0.029180	1519.7	–0.47650	234.06	10.892
25.000	1.0000	32.746	0.030538	0.089693	0.12023	0.0041410	0.012580	0.025394	985.14	–0.51115	106.80	9.9923
31.268	1.0000	24.474	0.040861	0.31894	0.35980	0.012531	0.014353	0.084709	560.14	1.7031	86.829	5.5759
31.268	1.0000	7.1182	0.14049	0.69511	0.83559	0.027747	0.016014	0.10713	374.52	9.4548	38.524	2.0997
100.00	1.0000	1.2044	0.83027	1.7679	2.5982	0.059751	0.014331	0.023244	817.03	1.3036	70.413	4.2550
175.00	1.0000	0.68243	1.4653	3.0101	4.4754	0.073667	0.018190	0.026659	1035.8	0.11718	118.31	6.2213
250.00	1.0000	0.47788	2.0926	4.4576	6.5501	0.083515	0.020028	0.028401	1217.3	–0.23428	161.46	7.9283
325.00	1.0000	0.36797	2.7176	5.9910	8.7086	0.091062	0.020699	0.029039	1379.1	–0.39039	198.43	9.4759
400.00	1.0000	0.29924	3.3418	7.5525	10.894	0.097113	0.020878	0.029204	1526.4	–0.47605	234.65	10.908
25.000	5.0000	35.661	0.028042	0.046611	0.18682	0.0021443	0.012376	0.020610	1223.4	–0.90198	119.36	13.101
100.00	5.0000	5.9683	0.16755	1.6549	2.4927	0.045314	0.014583	0.025613	865.94	0.86369	80.395	4.5875
175.00	5.0000	3.3132	0.30183	2.9582	4.4673	0.059998	0.018352	0.027370	1077.3	0.032971	123.58	6.3871
250.00	5.0000	2.3268	0.42978	4.4292	6.5781	0.070022	0.020136	0.028723	1254.0	–0.25678	165.19	8.0420
325.00	5.0000	1.7990	0.55587	5.9750	8.7543	0.077631	0.020776	0.029211	1412.0	–0.39563	201.36	9.5631
400.00	5.0000	1.4680	0.68120	7.5440	10.950	0.083710	0.020937	0.029304	1556.2	–0.47537	237.09	10.979
25.000	10.000	37.930	0.026364	0.020221	0.28386	0.00059913	0.012222	0.018499	1402.1	–1.0762	131.12	16.625
100.00	10.000	11.417	0.087588	1.5346	2.4105	0.038585	0.014838	0.027423	955.43	0.39679	94.196	5.1692
175.00	10.000	6.3697	0.15699	2.9000	4.4699	0.053931	0.018532	0.028063	1133.3	–0.068718	130.39	6.6199
250.00	10.000	4.5028	0.22209	4.3966	6.6175	0.064133	0.020260	0.029065	1300.6	–0.28786	169.92	8.1898
325.00	10.000	3.5006	0.28567	5.9563	8.8130	0.071811	0.020867	0.029402	1453.0	–0.40519	205.05	9.6733
400.00	10.000	2.8687	0.34859	7.5339	11.020	0.077921	0.021006	0.029419	1593.1	–0.47687	240.15	11.067
100.00	50.000	31.993	0.031257	1.1768	2.7397	0.023964	0.016349	0.026254	1710.1	–0.57213	192.47	10.534
175.00	50.000	22.700	0.044053	2.6415	4.8442	0.039587	0.019545	0.029321	1632.6	–0.46415	189.52	9.1377
250.00	50.000	17.524	0.057066	4.2297	7.0830	0.050225	0.020999	0.030163	1690.7	–0.46214	211.67	9.7772
325.00	50.000	14.304	0.069911	5.8539	9.3494	0.058153	0.021434	0.030202	1784.8	–0.48443	237.63	10.827
400.00	50.000	12.107	0.082595	7.4773	11.607	0.064404	0.021458	0.029985	1887.2	–0.51016	267.11	11.965
175.00	100.00	33.019	0.030286	2.5589	5.5875	0.033643	0.020316	0.029140	2128.4	–0.52750	282.17	13.079
250.00	100.00	27.257	0.036688	4.1604	7.8292	0.044291	0.021603	0.030346	2125.4	–0.50698	303.19	12.218
325.00	100.00	23.228	0.043051	5.8083	10.113	0.052281	0.021923	0.030469	2170.6	–0.51215	327.83	12.546
400.00	100.00	20.261	0.049356	7.4555	12.391	0.058588	0.021864	0.030246	2235.8	–0.52481	356.83	13.289

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Younglove, B. A., "Thermophysical Properties of Fluids. I. Argon, Ethylene, Parahydrogen, Nitrogen, Nitrogen Trifluoride, and Oxygen," *J. Phys. Chem. Ref. Data*, Suppl. 1, **11:** 1–11, 1982. The source for viscosity is McCarty, R. D., and Weber, L. A., "Thermophysical Properties of Parahydrogen from the Freezing Liquid Line to 5000 R for Pressures to 10,000 psia," *N.B.S. Tech. Note 617*, 1972. The source for thermal conductivity is McCarty, R. D., and Weber, L. A., "Thermophysical Properties of Parahydrogen from the Freezing Liquid Line to 5000 R for Pressures to 10,000 psia," *N.B.S. Tech. Note* 617, 1972.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in density are 0.1% in the liquid phase, 0.25% in the vapor phase, and 0.2% in the supercritical region. The uncertainty in heat capacity is 3%, and the uncertainty in speed of sound is 2% in the liquid phase and 1% elsewhere. The uncertainty in viscosity ranges from 4% to 15%. The uncertainty in thermal conductivity below 100 K is estimated to be 3% below 150 atm and up to 10% below 700 atm. For temperatures around 100 K at low densities, the uncertainty is about 1%. Above 100 K, the uncertainty is estimated to be on the order of 10%.

TABLE 2-224 Thermodynamic Properties of *para*-Hydrogen

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
13.800	0.0070373	38.214	0.026168	–0.10640	–0.10621	–0.0060986	0.010937	0.015530	1376.3	–1.4263	75.249	26.035
14.000	0.0078936	38.129	0.026226	–0.10334	–0.10313	–0.0058783	0.010548	0.015138	1367.4	–1.4615	76.869	25.310
15.000	0.013436	37.701	0.026524	–0.088758	–0.088401	–0.0048719	0.0096208	0.014345	1320.2	–1.5284	84.107	22.215
16.000	0.021534	37.261	0.026838	–0.074351	–0.073773	–0.0039418	0.0096210	0.014682	1272.2	–1.4722	90.003	19.784
17.000	0.032848	36.802	0.027172	–0.059344	–0.058452	–0.0030317	0.0099778	0.015532	1227.2	–1.3645	94.698	17.815
18.000	0.048078	36.321	0.027533	–0.043395	–0.042071	–0.0021196	0.010438	0.016618	1186.0	–1.2427	98.339	16.182
19.000	0.067960	35.812	0.027923	–0.026352	–0.024454	–0.0011972	0.010895	0.017822	1147.7	–1.1207	101.06	14.799
20.000	0.093249	35.274	0.028350	–0.0081471	–0.0055035	–0.00026188	0.011306	0.019103	1111.1	–1.0012	103.00	13.607
21.000	0.12472	34.702	0.028817	0.011263	0.014857	0.00068738	0.011663	0.020462	1075.0	–0.88292	104.25	12.565
22.000	0.16314	34.092	0.029333	0.031923	0.036709	0.0016517	0.011966	0.021923	1038.4	–0.76309	104.89	11.641
23.000	0.20932	33.439	0.029905	0.053894	0.060154	0.0026329	0.012226	0.023529	1000.7	–0.63820	105.01	10.811
24.000	0.26406	32.738	0.030546	0.077266	0.085332	0.0036338	0.012450	0.025344	961.13	–0.50428	104.64	10.057
25.000	0.32818	31.979	0.031271	0.10217	0.11243	0.0046588	0.012652	0.027461	919.17	–0.35652	103.82	9.3625
26.000	0.40250	31.152	0.032101	0.12879	0.14171	0.0057145	0.012841	0.030025	874.28	–0.18881	102.56	8.7151
27.000	0.48788	30.242	0.033067	0.15739	0.17353	0.0068101	0.013030	0.033270	825.90	0.0073097	100.85	8.1034
28.000	0.58524	29.225	0.034217	0.18839	0.20842	0.0079596	0.013235	0.037620	773.39	0.24439	98.669	7.5160
29.000	0.69554	28.067	0.035629	0.22242	0.24721	0.0091852	0.013476	0.043924	715.93	0.54264	95.941	6.9409
30.000	0.81989	26.706	0.037444	0.26061	0.29131	0.010526	0.013785	0.054215	652.36	0.93791	92.543	6.3620
31.000	0.95964	25.017	0.039973	0.30526	0.34362	0.012063	0.014225	0.074899	580.72	1.5033	88.209	5.7518
32.000	1.1168	22.637	0.044175	0.36307	0.41240	0.014036	0.014957	0.14188	496.76	2.4286	82.155	5.0391
32.938	1.2838	15.556	0.064284	0.51279	0.59532	0.019385			0	5.2019		
13.800	0.0070373	0.062340	16.041	0.68576	0.79865	0.059471	0.012705	0.021484	305.17	33.288	10.454	0.65046
14.000	0.0078936	0.069018	14.489	0.68798	0.80235	0.058799	0.012720	0.021535	307.13	32.412	10.649	0.66695
15.000	0.013436	0.11050	9.0494	0.69878	0.82037	0.055713	0.012797	0.021823	316.53	28.670	11.625	0.74268
16.000	0.021534	0.16764	5.9651	0.70909	0.83754	0.053015	0.012879	0.022172	325.20	25.755	12.604	0.81064
17.000	0.032848	0.24349	4.1069	0.71881	0.85372	0.050625	0.012967	0.022593	333.13	23.433	13.595	0.87421
18.000	0.048078	0.34126	2.9303	0.72787	0.86876	0.048482	0.013059	0.023097	340.35	21.544	14.603	0.93555
19.000	0.067960	0.46437	2.1535	0.73616	0.88251	0.046538	0.013158	0.023703	346.87	19.978	15.637	0.99611
20.000	0.093249	0.61652	1.6220	0.74359	0.89484	0.044755	0.013263	0.024433	352.69	18.654	16.705	1.0569
21.000	0.12472	0.80187	1.2471	0.75004	0.90557	0.043102	0.013378	0.025315	357.84	17.516	17.816	1.1186
22.000	0.16314	1.0251	0.97549	0.75539	0.91453	0.041553	0.013503	0.026390	362.33	16.521	18.981	1.1819
23.000	0.20932	1.2919	0.77406	0.75948	0.92151	0.040083	0.013641	0.027714	366.17	15.634	20.214	1.2472
24.000	0.26406	1.6089	0.62153	0.76213	0.92626	0.038672	0.013795	0.029369	369.39	14.832	21.529	1.3151
25.000	0.32818	1.9848	0.50383	0.76314	0.92848	0.037301	0.013969	0.031478	371.98	14.092	22.951	1.3863
26.000	0.40250	2.4307	0.41141	0.76219	0.92778	0.035948	0.014168	0.034235	373.96	13.396	24.507	1.4619
27.000	0.48788	2.9618	0.33763	0.75891	0.92363	0.034592	0.014397	0.037965	375.33	12.725	26.241	1.5433
28.000	0.58524	3.6003	0.27775	0.75272	0.91527	0.033204	0.014666	0.043264	376.10	12.058	28.217	1.6331
29.000	0.69554	4.3810	0.22826	0.74275	0.90151	0.031747	0.014986	0.051337	376.25	11.370	30.541	1.7362
30.000	0.81989	5.3643	0.18642	0.72747	0.88031	0.030159	0.015380	0.065075	375.77	10.621	33.404	1.8628
31.000	0.95964	6.6763	0.14978	0.70375	0.84749	0.028317	0.015881	0.093513	374.65	9.7335	37.214	2.0375
32.000	1.1168	8.6823	0.11518	0.66278	0.79141	0.025880	0.016566	0.18609	372.98	8.5044	43.179	2.3378
32.938	1.2838	15.556	0.064284	0.51279	0.59532	0.019385			0	5.2019		
Single-Phase Properties												
50.000	0.10000	0.24255	4.1229	1.1351	1.5474	0.064284	0.012710	0.021301	583.04	4.8322	38.576	2.4717
125.00	0.10000	0.096180	10.397	2.4062	3.4459	0.086764	0.022470	0.030820	841.25	0.59482	106.18	4.9004
200.00	0.10000	0.060094	16.641	4.2197	5.8837	0.10202	0.024087	0.032413	1054.3	–0.023305	155.64	6.7798
275.00	0.10000	0.043708	22.879	5.9434	8.2313	0.11200	0.022011	0.030330	1250.9	–0.27924	183.10	8.4358
350.00	0.10000	0.034345	29.116	7.5556	10.467	0.11919	0.021169	0.029486	1418.7	–0.41834	212.22	9.9461
50.000	1.0000	2.6201	0.38166	1.0703	1.4520	0.043845	0.012853	0.024464	575.43	4.4711	42.291	2.6080
125.00	1.0000	0.95806	1.0438	2.3861	3.4298	0.067460	0.022526	0.031195	848.73	0.55405	107.83	4.9523
200.00	1.0000	0.59708	1.6748	4.2097	5.8845	0.082821	0.024121	0.032545	1062.6	–0.032981	156.70	6.8120
275.00	1.0000	0.43458	2.3010	5.9379	8.2390	0.092837	0.022033	0.030392	1258.8	–0.28185	183.91	8.4592
350.00	1.0000	0.34179	2.9257	7.5525	10.478	0.10004	0.021186	0.029519	1425.9	–0.41854	212.88	9.9645

TABLE 2-224 Thermodynamic Properties of *para*-Hydrogen (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Single-Phase Properties												
50.000	5.0000	16.715	0.059826	0.73484	1.0340	0.024551	0.013420	0.041376	692.39	1.6074	79.882	4.3382
125.00	5.0000	4.6789	0.21372	2.3021	3.3707	0.053441	0.022747	0.032653	888.35	0.37288	115.33	5.1978
200.00	5.0000	2.9000	0.34482	4.1677	5.8918	0.069234	0.024261	0.033076	1100.2	–0.078236	161.31	6.9555
275.00	5.0000	2.1189	0.47194	5.9145	8.2742	0.079371	0.022129	0.030649	1293.6	–0.29566	187.32	8.5624
350.00	5.0000	1.6731	0.59770	7.5394	10.528	0.086623	0.021255	0.029661	1457.5	–0.42110	215.63	10.045
50.000	10.000	26.141	0.038254	0.53828	0.92082	0.017729	0.013420	0.031369	1020.9	–0.00090690	109.43	6.6673
125.00	10.000	8.9624	0.11158	2.2107	3.3264	0.047053	0.022979	0.033916	952.54	0.16557	125.40	5.5904
200.00	10.000	5.5879	0.17896	4.1201	5.9097	0.063249	0.024419	0.033613	1149.8	–0.13543	167.23	7.1499
275.00	10.000	4.1087	0.24339	5.8874	8.3212	0.073512	0.022240	0.030928	1337.5	–0.31595	191.64	8.6948
350.00	10.000	3.2606	0.30669	7.5240	10.591	0.080815	0.021338	0.029822	1497.0	–0.42707	219.08	10.147
50.000	50.000	41.635	0.024018	0.33890	1.5398	0.0075571	0.014831	0.021072	1903.0	–0.85893	205.72	18.078
125.00	50.000	28.231	0.035422	1.8792	3.6503	0.032377	0.024288	0.034391	1571.6	–0.41268	207.03	9.5718
200.00	50.000	20.660	0.048403	3.8955	6.3157	0.049075	0.025325	0.034876	1590.0	–0.39075	219.10	9.2598
275.00	50.000	16.295	0.061368	5.7445	8.8129	0.059704	0.022913	0.031923	1701.1	–0.44355	229.75	10.106
350.00	50.000	13.485	0.074155	7.4386	11.146	0.067214	0.021862	0.030536	1813.9	–0.48674	249.51	11.203
125.00	100.00	38.364	0.026066	1.8103	4.4169	0.026596	0.025170	0.033554	2093.0	–0.46785	308.69	15.278
200.00	100.00	30.845	0.032420	3.8148	7.0568	0.043119	0.026034	0.034871	2056.2	–0.43974	320.11	12.564
275.00	100.00	25.763	0.038815	5.6828	9.5643	0.053790	0.023474	0.032151	2114.9	–0.48043	324.21	12.252
350.00	100.00	22.144	0.045159	7.4012	11.917	0.061362	0.022320	0.030806	2185.5	–0.50940	340.22	12.765

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Younglove, B. A., "Thermophysical Properties of Fluids. I. Argon, Ethylene, Parahydrogen, Nitrogen, Nitrogen Trifluoride, and Oxygen," *J. Phys. Chem. Ref. Data*, Suppl. 1, **11:** 1–11, 1982. The source for viscosity is McCarty, R. D., and Weber, L. A., "Thermophysical Properties of Parahydrogen from the Freezing Liquid Line to 5000 R for Pressures to 10,000 psia," *N.B.S. Tech. Note* 617, 1972. The source for thermal conductivity is McCarty, R. D., and Weber, L. A., "Thermophysical Properties of Parahydrogen from the Freezing Liquid Line to 5000 R for Pressures to 10,000 psia," *N.B.S. Tech. Note* 617, 1972.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in density are 0.1% in the liquid phase, 0.25% in the vapor phase, and 0.2% in the supercritical region. The uncertainty in heat capacity is 3%, and the uncertainty in speed of sound is 2% in the liquid phase and 1% elsewhere. The uncertainty in viscosity ranges from 4% to 15%. The uncertainty in thermal conductivity below 100 K is estimated to be 3% below 150 atm and up to 10% below 700 atm. For temperatures around 100 K at low densities, the uncertainty is about 1%. Above 100 K, the uncertainty is estimated to be on the order of 10%.

TABLE 2-225 Saturated Hydrogen Peroxide*

T, K	P, bar	v_f, m^3/kg	v_g, m^3/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)	μ_f, 10^{-4} Pa·s	k_f, W/(m·K)
273	0.0004	0.00068	1672	–5577	–4027	2.990	8.662	1.45	18.0	0.483
300	0.0031	0.00069	235	–5510	–3995	3.224	8.269	1.48	11.3	0.481
350	0.0564	0.00072	15.1	–5376	–3933	3.631	7.758	1.54	4.3	0.474
400	0.4521	0.00076	2.12	–5238	–3878	4.032	7.440	1.61	2.2	0.464
450	2.143	0.00081	0.487	–5091	–3820	4.346	7.172	1.68	1.3	0.453
500	7.126	0.00088	0.155	–4945	–3777	4.656	6.992	1.75	0.89	0.443
550	18.56	0.00095	0.0605	–4794	–3745	4.941	6.846	1.82	0.65	0.431
600	40.75	0.00107	0.0268	–4635	–3731	5.209	6.720	1.90	0.50	0.416
650	79.27	0.00125	0.0125	–4463	–3746	5.485	6.582			
700	141.7	0.00171	0.0048	–4195	–3860	5.682	6.339			
708.5[c]	155.3	0.00284	0.0028	–4012	–4012	5.732	5.732			

*Values reproduced or converted from a tabulation by Tsykalo and Tabachnikov in V. A. Rabinovich (ed.), *Thermophysical Properties of Gases and Liquids,* Standartov, Moscow, 1968; NBS-NSF transl. TT 69-55091, 1970. The reader may be reminded that very pure hydrogen peroxide is very difficult to obtain owing to its decomposition or instability. c = critical point. The FMC Corp., Philadelphia, PA tech. bull. 67, 1969 (100 pp.) contains an enthalpy-pressure diagram to 3000 psia, 1100 K.

TABLE 2-226 Thermodynamic Properties of Hydrogen Sulfide

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
187.70	0.023259	29.116	0.034345	–1.7210	–1.7202	–0.0085877	0.044390	0.068835	1437.8	–0.34039	254.24	439.13
190.00	0.027106	29.003	0.034479	–1.5628	–1.5619	–0.0077504	0.044124	0.068707	1425.8	–0.33923	251.74	428.67
200.00	0.050340	28.505	0.035082	–0.87841	–0.87664	–0.0042394	0.043042	0.068273	1373.4	–0.33253	240.93	385.68
210.00	0.087474	27.998	0.035717	–0.19759	–0.19446	–0.00091743	0.042067	0.068029	1321.0	–0.32287	230.26	346.75
220.00	0.14366	27.480	0.036390	0.48138	0.48661	0.0022415	0.041188	0.067975	1268.4	–0.30988	219.81	311.74
230.00	0.22485	26.949	0.037107	1.1602	1.1686	0.0052596	0.040393	0.068115	1215.6	–0.29305	209.52	280.37
240.00	0.33767	26.403	0.037875	1.8406	1.8534	0.0081564	0.039677	0.068461	1162.3	–0.27174	199.43	252.29
250.00	0.48934	25.838	0.038702	2.5245	2.5434	0.010949	0.039030	0.069032	1108.5	–0.24509	189.56	227.14
260.00	0.68751	25.253	0.039599	3.2135	3.2408	0.013654	0.038449	0.069859	1053.9	–0.21197	179.91	204.60
270.00	0.94022	24.642	0.040580	3.9100	3.9481	0.016285	0.037930	0.070989	998.54	–0.17084	170.48	184.32
280.00	1.2558	24.002	0.041662	4.6161	4.6685	0.018857	0.037470	0.072490	942.08	–0.11959	161.26	166.02
290.00	1.6429	23.327	0.042868	5.3348	5.4053	0.021385	0.037070	0.074466	884.34	–0.055218	152.24	149.44
300.00	2.1103	22.609	0.044230	6.0696	6.1629	0.023885	0.036732	0.077082	825.04	0.026636	143.40	134.32
310.00	2.6672	21.838	0.045791	6.8248	6.9469	0.026373	0.036462	0.080603	763.84	0.13260	134.71	120.43
320.00	3.3233	21.000	0.047618	7.6068	7.7650	0.028873	0.036273	0.085498	700.23	0.27324	126.16	107.58
330.00	4.0889	20.073	0.049818	8.4246	8.6283	0.031414	0.036191	0.092666	633.51	0.46655	117.71	95.533
340.00	4.9755	19.021	0.052573	9.2932	9.5548	0.034044	0.036265	0.10410	562.59	0.74618	109.36	84.050
350.00	5.9969	17.776	0.056256	10.241	10.578	0.036848	0.036600	0.12534	485.59	1.1841	101.19	72.784
360.00	7.1713	16.172	0.061837	11.335	11.779	0.040035	0.037471	0.17963	398.86	1.9714	93.864	61.060
370.00	8.5294	13.436	0.074429	12.903	13.538	0.044599	0.040079	0.63367	292.76	3.9324	92.754	46.102
373.10	8.9987	10.190	0.098135	14.470	15.353	0.049374			0	6.3885		
187.70	0.023259	0.015024	66.559	16.328	17.876	0.095815	0.025347	0.034000	245.84	55.730	10.628	8.0025
190.00	0.027106	0.017314	57.758	16.382	17.947	0.094930	0.025386	0.034078	247.20	53.868	10.775	8.1053
200.00	0.050340	0.030704	32.569	16.611	18.250	0.091395	0.025586	0.034487	252.82	46.796	11.429	8.5566
210.00	0.087474	0.051165	19.545	16.832	18.541	0.088301	0.025837	0.035021	257.96	41.090	12.107	9.0159
220.00	0.14366	0.080932	12.356	17.043	18.818	0.085567	0.026142	0.035698	262.58	36.435	12.816	9.4844
230.00	0.22485	0.12253	8.1613	17.244	19.079	0.083129	0.026502	0.036537	266.64	32.601	13.566	9.9634
240.00	0.33767	0.17879	5.5933	17.431	19.320	0.080933	0.026917	0.037563	270.10	29.412	14.365	10.455
250.00	0.48934	0.25286	3.9547	17.604	19.539	0.078934	0.027388	0.038807	272.91	26.737	15.227	10.961
260.00	0.68751	0.34834	2.8707	17.761	19.735	0.077092	0.027914	0.040312	275.05	24.476	16.166	11.485
270.00	0.94022	0.46937	2.1305	17.899	19.902	0.075375	0.028496	0.042139	276.47	22.550	17.202	12.031
280.00	1.2558	0.62086	1.6107	18.016	20.039	0.073752	0.029136	0.044378	277.15	20.897	18.360	12.604
290.00	1.6429	0.80887	1.2363	18.108	20.139	0.072193	0.029838	0.047166	277.05	19.466	19.675	13.213
300.00	2.1103	1.0411	0.96050	18.171	20.198	0.070669	0.030608	0.050723	276.12	18.212	21.197	13.867
310.00	2.6672	1.3280	0.75300	18.199	20.207	0.069149	0.031458	0.055410	274.34	17.097	22.997	14.582
320.00	3.3233	1.6843	0.59373	18.183	20.156	0.067594	0.032407	0.061879	271.64	16.081	25.187	15.380
330.00	4.0889	2.1323	0.46898	18.109	20.027	0.065956	0.033485	0.071400	268.00	15.116	27.946	16.300
340.00	4.9755	2.7096	0.36906	17.957	19.793	0.064157	0.034746	0.086837	263.35	14.142	31.600	17.405
350.00	5.9969	3.4881	0.28669	17.684	19.403	0.062064	0.036293	0.11617	257.65	13.053	36.820	18.833
360.00	7.1713	4.6442	0.21532	17.192	18.736	0.059360	0.038364	0.19265	250.84	11.629	45.513	20.940
370.00	8.5294	6.9933	0.14299	16.046	17.266	0.054674	0.041755	0.80649	242.80	9.0701	70.939	25.604
373.10	8.9987	10.190	0.098135	14.470	15.353	0.049374			0	6.3885		

TABLE 2-226 Thermodynamic Properties of Hydrogen Sulfide (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Single-Phase Properties												
200.00	0.10000	28.506	0.035080	–0.87902	–0.87551	–0.0042425	0.043042	0.068269	1373.6	–0.33258	240.95	385.79
212.60	0.10000	27.865	0.035888	–0.021243	–0.017654	–0.000082766	0.041830	0.067997	1307.4	–0.31984	227.54	337.30
212.60	0.10000	0.057900	17.271	16.888	18.615	0.087559	0.025911	0.035183	259.21	39.791	12.288	9.1366
300.00	0.10000	0.040389	24.759	19.164	21.640	0.099486	0.025979	0.034563	309.73	16.968	17.999	12.954
400.00	0.10000	0.030157	33.160	21.830	25.146	0.10956	0.027268	0.035693	356.35	8.9467	24.990	17.172
500.00	0.10000	0.024088	41.515	24.642	28.794	0.11770	0.028923	0.037297	396.06	5.5432	32.218	21.094
600.00	0.10000	0.020059	49.853	27.626	32.611	0.12465	0.030708	0.039059	431.20	3.7250	39.592	24.714
700.00	0.10000	0.017187	58.182	30.789	36.607	0.13081	0.032534	0.040873	463.05	2.6185	47.091	28.082
200.00	1.0000	28.528	0.035053	–0.89011	–0.85506	–0.0042980	0.043058	0.068210	1377.6	–0.33351	241.31	387.91
272.07	1.0000	24.513	0.040795	4.0550	4.0958	0.016821	0.037830	0.071266	986.97	–0.16116	168.56	180.39
272.07	1.0000	0.49800	2.0080	17.925	19.933	0.075033	0.028623	0.042564	276.67	22.188	17.430	12.147
300.00	1.0000	0.43539	2.2968	18.775	21.072	0.079019	0.027626	0.039427	296.60	17.369	19.015	13.337
400.00	1.0000	0.31003	3.2255	21.626	24.852	0.089907	0.027708	0.037234	351.09	9.0111	25.609	17.465
500.00	1.0000	0.24394	4.0993	24.507	28.606	0.098281	0.029100	0.038036	393.73	5.5366	32.691	21.319
600.00	1.0000	0.20183	4.9547	27.525	32.480	0.10534	0.030799	0.039492	430.30	3.7023	39.980	24.893
700.00	1.0000	0.17237	5.8015	30.710	36.511	0.11155	0.032589	0.041157	462.94	2.5947	47.423	28.227
200.00	5.0000	28.625	0.034935	–0.93837	–0.76369	–0.0045411	0.043127	0.067957	1394.7	–0.33745	242.90	397.26
300.00	5.0000	22.858	0.043749	5.9433	6.1620	0.023458	0.036740	0.075047	855.61	–0.017492	146.15	139.57
340.26	5.0000	18.992	0.052654	9.3164	9.5797	0.034113	0.036269	0.10449	560.70	0.75500	109.14	83.760
340.26	5.0000	2.7266	0.36675	17.952	19.786	0.064108	0.034782	0.087361	263.22	14.116	31.710	17.437
400.00	5.0000	1.8047	0.55412	20.549	23.319	0.073747	0.030043	0.048271	325.86	9.1749	29.786	19.070
500.00	5.0000	1.2939	0.77288	23.863	27.728	0.083609	0.029940	0.041996	384.33	5.4471	35.063	22.459
600.00	5.0000	1.0365	0.96476	27.065	31.889	0.091196	0.031216	0.041590	427.30	3.5816	41.773	25.773
700.00	5.0000	0.87211	1.1466	30.353	36.086	0.097665	0.032838	0.042472	463.26	2.4840	48.924	28.935
200.00	10.000	28.741	0.034793	–0.99643	-0.64850	–0.0048367	0.043212	0.067668	1415.5	–0.34197	244.82	408.90
300.00	10.000	23.238	0.043033	5.7496	6.1800	0.022795	0.036779	0.072377	902.78	–0.077399	150.49	148.08
400.00	10.000	5.0473	0.19812	18.370	20.351	0.062081	0.034651	0.10189	291.29	8.2243	44.719	23.639
500.00	10.000	2.8037	0.35667	22.959	26.526	0.076030	0.031080	0.048875	375.68	5.1487	38.963	24.438
600.00	10.000	2.1399	0.46730	26.466	31.139	0.084452	0.031755	0.044597	426.01	3.3812	44.210	27.165
700.00	10.000	1.7663	0.56617	29.903	35.564	0.091275	0.033155	0.044212	465.45	2.3347	50.878	30.013
300.00	75.000	26.050	0.038388	4.3332	7.2123	0.017506	0.037754	0.061705	1276.9	–0.33612	187.18	232.59
400.00	75.000	21.973	0.045510	9.9713	13.384	0.035260	0.035381	0.061962	983.51	–0.18247	134.39	124.22
500.00	75.000	17.947	0.055720	15.404	19.583	0.049092	0.034762	0.061649	786.35	0.057516	103.90	81.074
600.00	75.000	14.519	0.068874	20.474	25.640	0.060142	0.034994	0.059227	688.11	0.27314	87.712	62.531
700.00	75.000	11.974	0.083511	25.148	31.412	0.069045	0.035721	0.056291	654.55	0.36585	82.684	54.563
300.00	150.00	27.794	0.035979	3.5100	8.9069	0.013888	0.038777	0.058983	1538.4	–0.40376	214.24	311.25
400.00	150.00	24.751	0.040403	8.6429	14.703	0.030575	0.036402	0.057226	1302.6	–0.37006	165.64	174.85
500.00	150.00	21.937	0.045585	13.539	20.377	0.043238	0.035779	0.056273	1132.1	–0.31802	135.75	119.57
600.00	150.00	19.449	0.051416	18.248	25.960	0.053420	0.036044	0.055409	1019.1	–0.26874	118.38	93.323
700.00	150.00	17.335	0.057687	22.811	31.464	0.061906	0.036804	0.054711	949.06	–0.23292	110.03	79.581

The values in these tables were generated from the NIST REFPROP software (Lemmon, E.W., McLinden, M.O., and Huber, M.L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data* **51**(3): 785–850, 2006. The source for viscosity and thermal conductivity is NIST14, Version 9.08.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in density are 0.1% in the liquid phase below the critical temperature, 0.4% in the vapor phase, 1% at supercritical temperatures up to 500 K, and 2.5% at higher temperatures. Uncertainties will be higher near the critical point, and may be lower than 0.5% between 400 and 500 K. The uncertainty in vapor pressure is 0.25%, and the uncertainty in heat capacities is estimated to be 1%. For viscosity, estimated uncertainty is 2%. For thermal conductivity, estimated uncertainty, except near the critical region, is 4–6%.

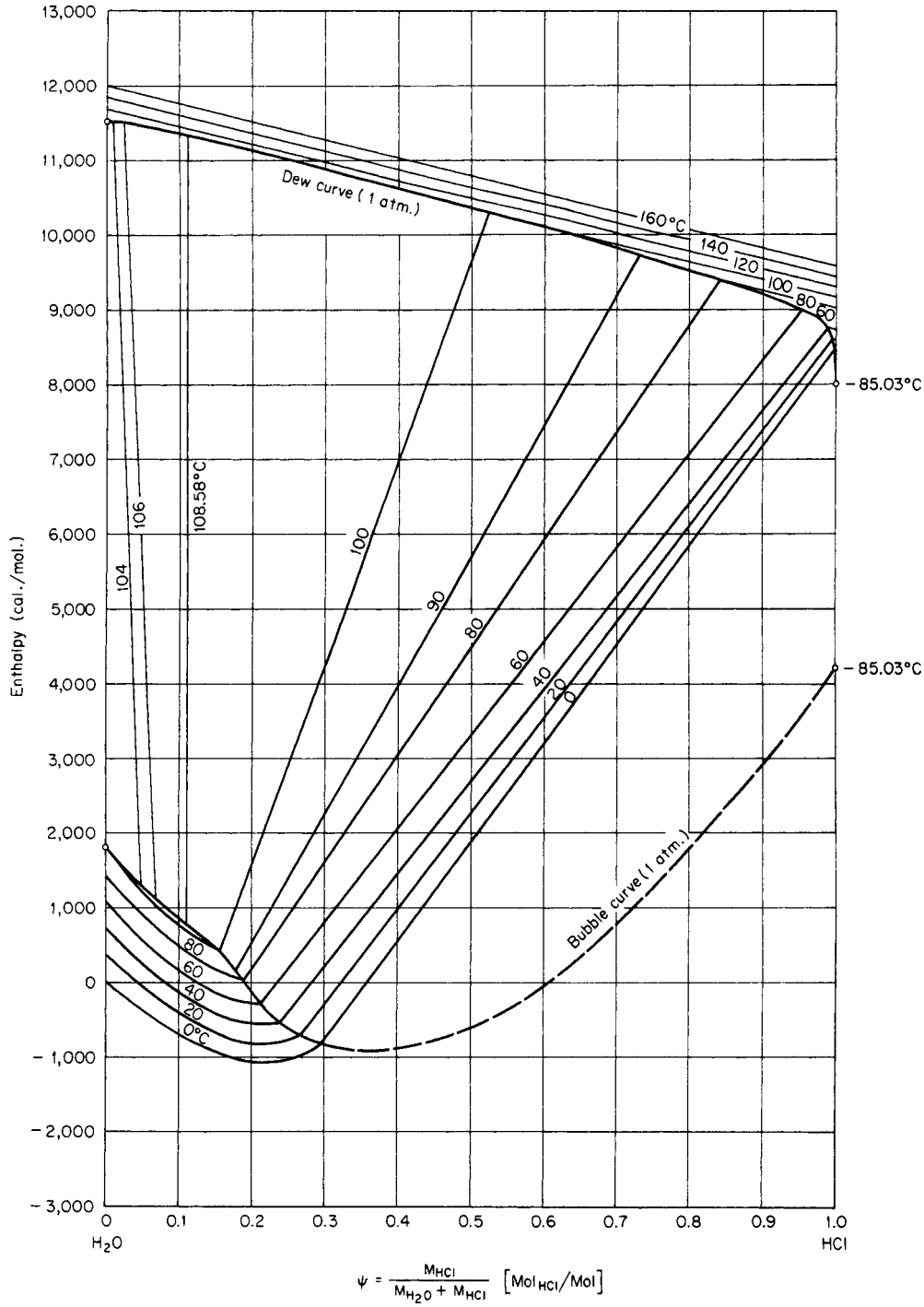

FIG. 2-11 Enthalpy-concentration diagram for aqueous hydrogen chloride at 1 atm. Reference states: enthalpy of liquid water at 0°C is zero; enthalpy of pure saturated HCl vapor at 1 atm (−85.03°C) is 8000 kcal/mol. NOTE: It should be observed that the weight basis includes the vapor, which is particularly important in the two-phase region. Saturation values may be read at the ends of the tie lines. [*Van Nuys,* Trans. Am. Inst. Chem. Eng., **39,** *663 (1943).*]

TABLE 2-227 Thermodynamic Properties of Isobutane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
113.73	2.2891E-08	12.738	0.078508	–6.5316	–6.5316	–0.03951	0.068243	0.098159	1999.8	–0.68375	157.92	8767.2
115	3.1711E-08	12.717	0.078635	–6.4068	–6.4068	–0.03842	0.068392	0.098388	1988.6	–0.68180	157.70	8096.1
130	8.8064E-07	12.473	0.080171	–4.9101	–4.9101	–0.02619	0.070255	0.10118	1863.4	–0.65814	154.39	3698.4
145	1.1510E-05	12.229	0.081772	–3.3714	–3.3714	–0.01499	0.072110	0.10397	1750.1	–0.63434	150.06	2060.1
160	8.8176E-05	11.984	0.083447	–1.7912	–1.7911	–0.00463	0.073940	0.10673	1645.3	–0.61032	144.95	1302.4
175	0.00045673	11.736	0.085209	–0.16946	–0.16942	0.005061	0.075811	0.10951	1546.1	–0.58545	139.28	897.76
190	0.0017628	11.485	0.087069	1.4945	1.4946	0.014182	0.077792	0.11237	1450.9	–0.55901	133.23	657.25
205	0.0054294	11.231	0.089043	3.2024	3.2029	0.022832	0.079933	0.11540	1358.6	–0.53024	126.94	502.16
220	0.014023	10.971	0.091150	4.9572	4.9585	0.031092	0.082269	0.11865	1268.6	–0.49839	120.56	395.73
235	0.031511	10.705	0.093415	6.7622	6.7652	0.039028	0.084817	0.12216	1180.3	–0.46255	114.21	319.15
250	0.06335	10.431	0.095866	8.6216	8.6277	0.046697	0.087581	0.12600	1093.4	–0.42158	107.94	262.04
265	0.11640	10.148	0.098544	10.540	10.551	0.054149	0.090556	0.13021	1007.7	–0.37389	101.85	218.23
280	0.19876	9.8523	0.10150	12.522	12.543	0.061427	0.093728	0.13486	922.77	–0.31712	95.986	183.83
295	0.31952	9.5416	0.10480	14.575	14.608	0.068569	0.097085	0.14006	838.36	–0.24757	90.398	156.24
310	0.48858	9.2114	0.10856	16.705	16.758	0.075615	0.10062	0.14598	753.97	–0.15928	85.118	133.64
325	0.71658	8.8560	0.11292	18.920	19.001	0.082601	0.10432	0.15290	669.03	–0.04193	80.169	114.69
340	1.0148	8.4662	0.11812	21.234	21.354	0.089574	0.10821	0.16139	582.74	0.12359	75.561	98.394
355	1.3957	8.0276	0.12457	23.665	23.839	0.096591	0.11234	0.17260	494.00	0.37690	71.293	83.919
370	1.8727	7.5139	0.13309	26.245	26.494	0.10375	0.11686	0.18958	401.01	0.81512	67.356	70.526
385	2.4620	6.8650	0.14567	29.045	29.404	0.11123	0.12220	0.22324	300.29	1.7502	63.794	57.352
400	3.1856	5.8674	0.17043	32.319	32.862	0.11975	0.13078	0.36901	184.38	4.9259	61.898	42.498
407.81	3.629	3.8798	0.25775	35.910	36.846	0.12937			0	16.282		
113.73	2.2891E-08	2.4207E-08	41,310,000	20.462	21.408	0.20615	0.042812	0.051127	139.39	577.37	2.2717	2.8476
115	3.1711E-08	3.3165E-08	30,152,000	20.517	21.473	0.20401	0.043157	0.051472	140.07	553.27	2.3426	2.8811
130	8.8064E-07	8.1474E-07	1,227,400	21.194	22.275	0.18292	0.047087	0.055402	147.92	348.08	3.2114	3.2763
145	1.1510E-05	9.5478E-06	104,740	21.928	23.133	0.16780	0.050787	0.059103	155.36	233.14	4.1386	3.6690
160	8.8176E-05	6.6294E-05	15,084	22.716	24.046	0.15686	0.054332	0.062655	162.43	164.07	5.1239	4.0588
175	0.00045673	0.0003141	3,183.6	23.555	25.009	0.14894	0.057806	0.066151	169.14	120.18	6.1666	4.4452
190	0.0017628	0.0011181	894.34	24.442	26.018	0.14325	0.061291	0.06969	175.44	91.024	7.2652	4.8275
205	0.0054294	0.0032007	312.43	25.374	27.070	0.13926	0.064859	0.07337	181.26	70.957	8.4173	5.2047
220	0.014023	0.0077418	129.17	26.348	28.159	0.13655	0.068567	0.077281	186.48	56.748	9.6201	5.5763
235	0.031511	0.016419	60.904	27.360	29.279	0.13483	0.072455	0.081501	190.96	46.450	10.872	5.9424
250	0.06335	0.031405	31.842	28.406	30.423	0.13388	0.076548	0.086099	194.52	38.843	12.174	6.3045
265	0.11640	0.055358	18.064	29.481	31.584	0.13352	0.080855	0.091145	197.02	33.140	13.532	6.6660
280	0.19876	0.091469	10.933	30.581	32.754	0.13361	0.085375	0.096722	198.29	28.823	14.961	7.0328
295	0.31952	0.14360	6.9638	31.700	33.925	0.13405	0.090101	0.10295	198.13	25.545	16.487	7.4136
310	0.48858	0.21659	4.6171	32.830	35.086	0.13474	0.09503	0.11003	196.37	23.074	18.151	7.8217
325	0.71658	0.31684	3.1561	33.960	36.222	0.13559	0.10017	0.11832	192.73	21.254	20.022	8.2772
340	1.0148	0.45354	2.2049	35.075	37.313	0.13651	0.10541	0.12842	186.90	20.032	22.207	8.8129
355	1.3957	0.64121	1.5596	36.146	38.323	0.13739	0.11078	0.14204	178.45	19.459	24.900	9.4859
370	1.8727	0.90588	1.1039	37.123	39.190	0.13806	0.11703	0.16455	166.77	19.526	28.498	10.409
385	2.4620	1.3046	0.76649	37.906	39.793	0.13822	0.12502	0.21348	150.88	20.215	34.050	11.844
400	3.1856	2.0369	0.49095	38.148	39.712	0.13688	0.13683	0.43911	128.90	21.293	46.452	14.761
407.81	3.629	3.8798	0.25775	35.910	36.846	0.12937			0	16.282		

Single-Phase Properties												
200.00	0.10000	11.317	0.088361	2.6255	2.6343	0.019983	0.079206	0.11436	1389.7	–0.54030	129.10	547.68
261.07	0.10000	10.223	0.097817	10.031	10.040	0.052213	0.089756	0.12906	1030.1	–0.38717	103.43	228.69
261.07	0.10000	0.048038	20.817	29.197	31.278	0.13356	0.079705	0.089774	196.48	34.485	13.170	6.5710
300.00	0.10000	0.041143	24.305	32.513	34.944	0.14664	0.089474	0.098798	212.04	21.436	17.082	7.5436
400.00	0.10000	0.030372	32.925	42.834	46.127	0.17863	0.11631	0.12501	245.50	8.6878	28.880	9.9294
500.00	0.10000	0.024169	41.375	55.743	59.881	0.20922	0.14101	0.14952	274.09	4.5740	43.232	12.195
200.00	1.0000	11.329	0.088272	2.6017	2.6900	0.019864	0.079268	0.11426	1395.0	–0.54183	129.47	552.65
300.00	1.0000	9.4575	0.10574	15.229	15.335	0.070771	0.098270	0.14150	819.00	–0.23012	89.092	149.88
339.34	1.0000	8.4843	0.11786	21.129	21.247	0.089265	0.10803	0.16097	586.60	0.11482	75.758	99.071
339.34	1.0000	0.44655	2.2394	35.027	37.266	0.13647	0.10518	0.12792	187.21	20.073	22.102	8.7869
400.00	1.0000	0.33698	2.9675	42.086	45.054	0.15757	0.11833	0.13200	224.30	9.9934	29.559	10.129
500.00	1.0000	0.25270	3.9573	55.288	59.246	0.18916	0.14174	0.15229	263.78	4.7852	44.232	12.391
200.00	5.0000	11.379	0.087884	2.4992	2.9387	0.019346	0.079538	0.11385	1417.9	–0.54814	131.11	574.91
300.00	5.0000	9.5950	0.10422	14.958	15.479	0.069851	0.098458	0.13915	870.18	–0.28002	92.042	160.04
400.00	5.0000	6.7797	0.14750	31.029	31.767	0.11631	0.12520	0.20584	328.20	1.3689	64.364	56.352
500.00	5.0000	1.6118	0.62041	52.732	55.834	0.17060	0.14556	0.17644	219.06	5.5914	50.270	15.871
200.00	10.000	11.438	0.087424	2.3778	3.2521	0.018721	0.079860	0.11339	1445.4	–0.55506	133.10	603.11
300.00	10.000	9.7443	0.10262	14.662	15.689	0.068827	0.098710	0.13705	926.11	–0.32494	95.422	172.11
400.00	10.000	7.5550	0.13236	29.780	31.103	0.11292	0.12349	0.17456	486.23	0.34096	70.562	72.797
500.00	10.000	4.0999	0.24391	48.735	51.174	0.15751	0.14786	0.21137	239.25	3.1085	61.481	28.154
200.00	15.000	11.496	0.086989	2.2631	3.5679	0.018121	0.080166	0.11300	1471.7	–0.56110	135.03	631.76
300.00	15.000	9.8755	0.10126	14.403	15.922	0.067905	0.098964	0.13552	975.70	–0.35793	98.548	183.72
400.00	15.000	7.9692	0.12548	29.065	30.948	0.11092	0.12324	0.16619	583.15	0.062447	75.048	84.081
500.00	15.000	5.5655	0.17968	46.521	49.217	0.15156	0.14693	0.19670	343.01	1.1026	67.712	41.020
200.00	30.000	11.654	0.085807	1.9531	4.5274	0.016439	0.081000	0.11206	1544.8	–0.57512	140.47	720.69
300.00	30.000	10.198	0.098056	13.768	16.709	0.065552	0.099691	0.13266	1100.2	–0.41943	106.90	216.98
400.00	30.000	8.6989	0.11496	27.757	31.205	0.10708	0.12354	0.15745	775.70	–0.21676	85.299	109.96
500.00	30.000	7.1701	0.13947	43.945	48.129	0.14475	0.14649	0.18019	572.71	0.033041	78.479	66.356

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Buecker, D., and Wagner, W., "Reference Equations of State for the Thermodynamic Properties of Fluid Phase *n*-Butane and Isobutane," *J. Phys. Chem. Ref. Data* **35**(2):929–1019, 2006. The source for viscosity is Vogel, E., Kuechenmeister, C., and Bich, E., "Viscosity Correlation for Isobutane over Wide Ranges of the Fluid Region," *Int. J. Thermophys*, **21**(2):343–356, 2000. The source for thermal conductivity is Perkins, R. A., "Measurement and Correlation of the Thermal Conductivity of Isobutane from 114 K to 600 K at Pressures to 70 MPa," *J. Chem. Eng. Data* **47**(5):1272–1279, 2002.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in density are 0.02% at temperatures below 340 K and pressures below 12 MPa (both liquid and vapor states), 0.3% at temperatures below 300 K and pressures above 12 MPa, 0.1% in the vapor phase between 340 and 450 K, and 0.5% elsewhere. In the critical region, deviations in pressure are 0.5%. Uncertainties in heat capacities are typically 1–2%, rising to 5% in the critical region and at temperatures below 200 K. Uncertainties in the speed of sound are typically 1–2%, rising to 5% at temperatures below 200 K and in the critical region. The uncertainty in viscosity varies from 0.4% in the dilute gas between room temperature and 600 K to 3.0% over the rest of the fluid surface. Uncertainty in thermal conductivity is 3%, except in the critical region and dilute gas which have an uncertainty of 5%.

TABLE 2-228 Thermodynamic Properties of Isobutene (2-Methyl 1-Propene)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
132.40	6.7619E-07	13.667	0.073170	–15.196	–15.196	–0.078577	0.074156	0.10623	1842.9	–0.56574
135.00	1.1116E-06	13.619	0.073428	–14.919	–14.919	–0.076509	0.074179	0.10642	1827.0	–0.56403
150.00	1.3438E-05	13.343	0.074943	–13.315	–13.315	–0.065239	0.074543	0.10755	1734.4	–0.55349
165.00	9.7764E-05	13.070	0.076514	–11.692	–11.692	–0.054931	0.075233	0.10881	1641.6	–0.54130
180.00	0.00048920	12.796	0.078149	–10.049	–10.049	–0.045402	0.076215	0.11028	1549.8	–0.52677
195.00	0.0018451	12.522	0.079860	–8.3822	–8.3821	–0.036508	0.077475	0.11203	1459.4	–0.50932
210.00	0.0055971	12.246	0.081662	–6.6870	–6.6865	–0.028133	0.079001	0.11407	1370.6	–0.48847
225.00	0.014316	11.966	0.083571	–4.9587	–4.9575	–0.020185	0.080776	0.11645	1283.4	–0.46371
240.00	0.031980	11.681	0.085610	–3.1926	–3.1899	–0.012587	0.082776	0.11917	1197.6	–0.43442
255.00	0.064075	11.389	0.087805	–1.3838	–1.3782	–0.0052767	0.084977	0.12224	1113.1	–0.39974
270.00	0.11754	11.088	0.090191	0.47283	0.48343	0.0017979	0.087351	0.12570	1029.6	–0.35836
285.00	0.20057	10.774	0.092812	2.3824	2.4010	0.0086815	0.089877	0.12958	946.77	–0.30827
300.00	0.32243	10.446	0.095729	4.3506	4.3814	0.015413	0.092533	0.13397	864.37	–0.24634
315.00	0.49324	10.098	0.099027	6.3837	6.4326	0.022030	0.095306	0.13900	781.98	–0.16750
330.00	0.72386	9.7251	0.10283	8.4899	8.5643	0.028568	0.098189	0.14491	699.15	–0.063276
345.00	1.0259	9.3181	0.10732	10.680	10.790	0.035068	0.10119	0.15215	615.32	0.081482
360.00	1.4121	8.8642	0.11281	12.969	13.128	0.041581	0.10433	0.16163	529.74	0.29633
375.00	1.8963	8.3412	0.11989	15.383	15.611	0.048183	0.10770	0.17548	441.23	0.64712
390.00	2.4955	7.7041	0.12980	17.975	18.299	0.055015	0.11149	0.20028	347.41	1.3162
405.00	3.2319	6.8249	0.14652	20.892	21.365	0.062470	0.11647	0.27285	242.00	3.0714
418.09	4.0157	4.1700	0.23981	25.759	26.722	0.075104			0	15.166
132.40	6.7619E-07	6.1426E-07	1,628,000.	12.185	13.286	0.13654	0.045424	0.053739	152.35	932.58
135.00	1.1116E-06	9.9037E-07	1,009,700.	12.304	13.427	0.13346	0.046004	0.054319	153.69	849.42
150.00	1.3438E-05	1.0775E-05	92,803.	13.018	14.265	0.11863	0.049224	0.057543	161.19	514.47
165.00	9.7764E-05	7.1284E-05	14,028.	13.778	15.150	0.10775	0.052312	0.060645	168.31	329.24
180.00	0.00048920	0.00032720	3,056.2	14.581	16.076	0.099740	0.055381	0.063755	175.06	220.54
195.00	0.0018451	0.0011411	876.38	15.424	17.041	0.093867	0.058529	0.066994	181.39	153.60
210.00	0.0055971	0.0032245	310.13	16.303	18.039	0.089606	0.061825	0.070461	187.22	110.74
225.00	0.014316	0.0077400	129.20	17.214	19.064	0.086578	0.065309	0.074224	192.45	82.434
240.00	0.031980	0.016347	61.174	18.155	20.112	0.084503	0.068992	0.078326	196.96	63.248
255.00	0.064075	0.031202	32.049	19.122	21.176	0.083170	0.072865	0.082797	200.59	49.962
270.00	0.11754	0.054953	18.197	20.111	22.250	0.082415	0.076909	0.087668	203.21	40.590
285.00	0.20057	0.090771	11.017	21.118	23.328	0.082110	0.081099	0.092989	204.65	33.877
300.00	0.32243	0.14247	7.0191	22.138	24.401	0.082147	0.085414	0.098854	204.73	29.016
315.00	0.49324	0.21479	4.6557	23.164	25.460	0.082436	0.089840	0.10544	203.27	25.486
330.00	0.72386	0.31394	3.1853	24.185	26.491	0.082890	0.094375	0.11307	200.03	22.947
345.00	1.0259	0.44866	2.2289	25.186	27.473	0.083425	0.099036	0.12238	194.71	21.185
360.00	1.4121	0.63242	1.5812	26.144	28.377	0.083938	0.10387	0.13473	186.95	20.076
375.00	1.8963	0.88850	1.1255	27.018	29.152	0.084292	0.10900	0.15340	176.23	19.567
390.00	2.4955	1.2646	0.79073	27.725	29.699	0.084244	0.11468	0.18881	161.89	19.640
405.00	3.2319	1.8955	0.52758	28.046	29.751	0.083176	0.12162	0.29879	142.88	20.140
418.09	4.0157	4.1700	0.23981	25.759	26.722	0.075104			0	15.166

Single-Phase Properties

150.00	0.10000	13.344	0.074938	–13.316	–13.309	–0.065249	0.074545	0.10754	1734.9	–0.55354
250.00	0.10000	11.488	0.087047	–1.9936	–1.9849	–0.0076921	0.084223	0.12117	1141.5	–0.41214
265.81	0.10000	11.173	0.089503	–0.050895	–0.041944	–0.00015725	0.086672	0.12469	1052.8	–0.37070
265.81	0.10000	0.047251	21.164	19.833	21.949	0.082576	0.075763	0.086265	202.59	42.897
350.00	0.10000	0.034911	28.645	26.949	29.814	0.10818	0.092639	0.10158	234.72	15.195
450.00	0.10000	0.026911	37.160	37.274	40.990	0.13616	0.11313	0.12171	266.02	6.9323
550.00	0.10000	0.021943	45.572	49.523	54.081	0.16237	0.13123	0.13969	293.54	4.0208
150.00	1.0000	13.352	0.074895	–13.330	–13.255	–0.065342	0.074562	0.10751	1739.5	–0.55391
250.00	1.0000	11.506	0.086914	–2.0267	–1.9398	–0.0078249	0.084239	0.12099	1149.4	–0.41526
343.85	1.0000	9.3507	0.10694	10.509	10.616	0.034571	0.10096	0.15153	621.79	0.068431
343.85	1.0000	0.43682	2.2893	25.111	27.400	0.083383	0.098674	0.12159	195.20	21.295
350.00	1.0000	0.42121	2.3741	25.767	28.142	0.085521	0.098979	0.11981	199.99	19.480
450.00	1.0000	0.28769	3.4759	36.712	40.188	0.11575	0.11442	0.12599	251.31	7.4906
550.00	1.0000	0.22650	4.4150	49.150	53.565	0.14255	0.13168	0.14162	285.82	4.1331
150.00	5.0000	13.386	0.074707	–13.390	–13.017	–0.065747	0.074643	0.10737	1759.5	–0.55549
250.00	5.0000	11.581	0.086351	–2.1681	–1.7364	–0.0083971	0.084319	0.12027	1182.8	–0.42781
350.00	5.0000	9.4333	0.10601	10.992	11.522	0.035956	0.10188	0.14839	663.68	–0.014643
450.00	5.0000	2.4761	0.40387	32.462	34.481	0.092351	0.12422	0.22025	169.25	10.828
550.00	5.0000	1.3207	0.75720	47.230	51.016	0.12568	0.13385	0.15463	255.06	4.4151
150.00	10.000	13.426	0.074480	–13.463	–12.718	–0.066244	0.074751	0.10722	1783.6	–0.55725
250.00	10.000	11.668	0.085703	–2.3329	–1.4758	–0.0090755	0.084439	0.11952	1221.8	–0.44099
350.00	10.000	9.6916	0.10318	10.547	11.579	0.034624	0.10172	0.14363	741.89	–0.13006
450.00	10.000	6.6358	0.15070	26.495	28.002	0.075649	0.12143	0.19240	325.60	1.5013
550.00	10.000	3.1171	0.32081	44.413	47.621	0.11510	0.13595	0.17757	248.73	3.4960
150.00	20.000	13.504	0.074050	–13.601	–12.120	–0.067205	0.074987	0.10695	1829.3	–0.56021
250.00	20.000	11.827	0.084554	–2.6298	–0.93871	–0.010332	0.084720	0.11836	1292.1	–0.46137
350.00	20.000	10.075	0.099256	9.8719	11.857	0.032532	0.10175	0.13862	862.17	–0.25114
450.00	20.000	8.0205	0.12468	24.414	26.907	0.070229	0.11990	0.16238	539.83	0.19834
550.00	20.000	5.7872	0.17279	40.594	44.050	0.10458	0.13615	0.17749	377.20	0.90256
250.00	50.000	12.214	0.081874	–3.3402	0.75353	–0.013539	0.085706	0.11640	1463.7	–0.49631
350.00	50.000	10.805	0.092548	8.5711	13.199	0.028177	0.10258	0.13309	1105.6	–0.38284
450.00	50.000	9.4377	0.10596	22.086	27.384	0.063736	0.12031	0.15031	858.20	–0.25457
550.00	50.000	8.1524	0.12266	37.030	43.163	0.095351	0.13651	0.16471	704.72	–0.13437

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W, and Ihmels, E. C., "Thermodynamic Properties of the Butenes. Part II. Short Fundamental Equations of State," *Fluid Phase Equilibria,* **228–229C:**173–187, 2005. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in densities calculated using the equation of state are 0.1% in the liquid phase at temperatures above 270 K (rising to 0.5% at temperatures below 200 K), 0.2% at temperatures above the critical temperature and at pressures above 10 MPa, and 0.5% in the vapor phase, including supercritical conditions below 10 MPa. The uncertainty in the vapor phase may be higher than 0.5% in some regions. The uncertainty in vapor pressure is 0.5% above 250 K, and the uncertainty in heat capacities is 0.5% at saturated liquid conditions, rising to 5% at much higher pressures and at temperatures above 250 K.

TABLE 2-229 Thermodynamic Properties of Krypton

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
115.77	0.073503	29.197	0.034250	–0.17537	–0.17285	–0.00146	0.021225	0.043334	698.97	–0.50800
120	0.10344	28.814	0.034705	0.008003	0.011593	9.61E-05	0.020889	0.043577	681.44	–0.49215
125	0.15007	28.353	0.035270	0.22606	0.23136	0.001877	0.020519	0.043953	660.52	–0.47002
130	0.21125	27.880	0.035867	0.44593	0.45351	0.003602	0.020175	0.044431	639.35	–0.44379
135	0.28957	27.396	0.036502	0.66802	0.67859	0.005280	0.019855	0.045022	617.89	–0.41290
140	0.38778	26.896	0.037180	0.89279	0.90720	0.006916	0.019558	0.045743	596.06	–0.37662
145	0.50867	26.381	0.037906	1.1207	1.1400	0.008518	0.019283	0.046614	573.82	–0.33403
150	0.65513	25.847	0.038689	1.3524	1.3778	0.010092	0.019030	0.047664	551.09	–0.28396
155	0.83007	25.291	0.039539	1.5885	1.6213	0.011644	0.018799	0.048934	527.76	–0.22485
160	1.0365	24.710	0.040469	1.8297	1.8716	0.013181	0.018594	0.050480	503.74	–0.15466
165	1.2774	24.100	0.041494	2.0770	2.1300	0.014711	0.018417	0.052386	478.86	–0.07060
170	1.5560	23.455	0.042636	2.3317	2.398	0.016241	0.018276	0.054776	452.95	0.03121
175	1.8754	22.766	0.043925	2.5952	2.6775	0.017781	0.018179	0.057846	425.75	0.15636
180	2.2390	22.024	0.045404	2.8697	2.9713	0.019345	0.018142	0.061924	396.95	0.31329
185	2.6505	21.213	0.047140	3.1584	3.2833	0.020950	0.018193	0.067602	366.08	0.51538
190	3.1140	20.309	0.049240	3.4661	3.6194	0.022623	0.018377	0.076087	332.48	0.78550
195	3.6340	19.267	0.051903	3.8015	3.9901	0.024412	0.018781	0.090283	295.17	1.1669
200	4.2163	17.995	0.055571	4.1824	4.4167	0.026413	0.019602	0.11946	252.47	1.7554
205	4.8690	16.222	0.061645	4.6620	4.9622	0.028917	0.021432	0.21813	200.85	2.8313
209.48	5.5255	10.850	0.092166	5.8827	6.3920	0.035568			0	6.4431
115.77	0.073503	0.078418	12.752	7.9735	8.9108	0.077003	0.013270	0.022596	136.12	49.758
120	0.10344	0.10724	9.3246	8.0103	8.9748	0.074790	0.013453	0.023062	138.00	45.644
125	0.15007	0.15089	6.6272	8.0498	9.0444	0.072381	0.013699	0.023713	140.03	41.448
130	0.21125	0.20670	4.8380	8.0846	9.1066	0.070164	0.013976	0.024485	141.85	37.834
135	0.28957	0.27668	3.6142	8.1140	9.1606	0.068109	0.014283	0.025395	143.45	34.693
140	0.38778	0.36308	2.7542	8.1375	9.2055	0.066190	0.014618	0.026463	144.82	31.940
145	0.50867	0.46836	2.1351	8.1544	9.2405	0.064384	0.014982	0.027716	145.98	29.510
150	0.65513	0.59537	1.6796	8.1640	9.2644	0.062670	0.015372	0.029193	146.92	27.351
155	0.83007	0.74740	1.3380	8.1655	9.2761	0.061030	0.015789	0.030948	147.64	25.418
160	1.0365	0.92843	1.0771	8.1578	9.2742	0.059447	0.016235	0.033060	148.13	23.675
165	1.2774	1.1433	0.87464	8.1395	9.2567	0.057903	0.016713	0.035646	148.39	22.088
170	1.5560	1.3983	0.71513	8.1089	9.2216	0.056379	0.017230	0.038887	148.42	20.627
175	1.8754	1.7017	0.58764	8.0637	9.1657	0.054856	0.017796	0.043072	148.21	19.260
180	2.2390	2.0649	0.48428	8.0007	9.0850	0.053310	0.018426	0.048693	147.75	17.955
185	2.6505	2.5046	0.39926	7.9154	8.9736	0.051708	0.019147	0.056647	147.01	16.679
190	3.1140	3.0471	0.32818	7.8004	8.8224	0.050007	0.019998	0.068771	145.97	15.388
195	3.6340	3.7380	0.26752	7.6434	8.6156	0.048132	0.021054	0.089467	144.56	14.023
200	4.2163	4.6709	0.21409	7.4192	8.3219	0.045939	0.022465	0.13256	142.62	12.486
205	4.8690	6.1126	0.16360	7.0576	7.8541	0.043024	0.024624	0.27498	139.66	10.545
209.48	5.5255	10.850	0.092166	5.8827	6.3920	0.035568			0	6.4431

Single-Phase Properties										
200.00	0.10000	0.060557	16.513	9.0557	10.707	0.086165	0.012553	0.021091	181.32	15.987
300.00	0.10000	0.040171	24.893	10.313	12.803	0.094664	0.012488	0.020880	222.65	7.9817
400.00	0.10000	0.030088	33.236	11.564	14.888	0.10066	0.012478	0.020832	257.24	4.8486
500.00	0.10000	0.024059	41.565	12.813	16.970	0.10531	0.012475	0.020813	287.64	3.1571
600.00	0.10000	0.020044	49.889	14.062	19.051	0.10910	0.012474	0.020804	315.11	2.0967
700.00	0.10000	0.017179	58.210	15.310	21.131	0.11231	0.012474	0.020799	340.36	1.3720
200.00	1.0000	0.64884	1.5412	8.8431	10.384	0.065940	0.013359	0.024440	176.18	15.667
300.00	1.0000	0.40911	2.4443	10.207	12.651	0.075164	0.012634	0.021770	221.94	7.8257
400.00	1.0000	0.30268	3.3039	11.493	14.797	0.081341	0.012536	0.021250	257.69	4.7410
500.00	1.0000	0.24094	4.1505	12.761	16.911	0.086060	0.012509	0.021058	288.54	3.0825
600.00	1.0000	0.20035	4.9913	14.020	19.012	0.089890	0.012498	0.020965	316.19	2.0440
700.00	1.0000	0.17155	5.8291	15.276	21.105	0.093117	0.012492	0.020912	341.52	1.3340
200.00	5.0000	18.695	0.053490	4.0257	4.2932	0.025582	0.018694	0.092820	286.26	1.3105
205.94	5.0000	15.764	0.063436	4.7766	5.0938	0.029518	0.022035	0.27057	189.55	3.1528
205.94	5.0000	6.5051	0.15373	6.9575	7.7261	0.042300	0.025196	0.34754	138.88	10.086
300.00	5.0000	2.2268	0.44908	9.6909	11.936	0.060067	0.013335	0.026859	220.60	6.9488
400.00	5.0000	1.5501	0.64511	11.172	14.397	0.067171	0.012800	0.023237	260.80	4.2506
500.00	5.0000	1.2103	0.82624	12.528	16.659	0.072221	0.012660	0.022154	293.14	2.7636
600.00	5.0000	0.99847	1.0015	13.839	18.847	0.076212	0.012603	0.021667	321.36	1.8241
700.00	5.0000	0.85191	1.1738	15.130	20.999	0.079530	0.012572	0.021402	346.89	1.1768
200.00	10.000	20.764	0.048160	3.5349	4.0165	0.022941	0.017485	0.059683	386.03	0.41868
300.00	10.000	4.9580	0.20169	8.9533	10.970	0.051900	0.014221	0.035983	225.22	5.4452
400.00	10.000	3.1738	0.31508	10.764	13.915	0.060436	0.013132	0.025901	267.23	3.6190
500.00	10.000	2.4249	0.41238	12.241	16.365	0.065913	0.012848	0.023506	300.18	2.3913
600.00	10.000	1.9842	0.50399	13.620	18.660	0.070099	0.012733	0.022506	328.56	1.5769
700.00	10.000	1.6870	0.59277	14.954	20.881	0.073525	0.012672	0.021979	354.04	1.0028
200.00	100.00	27.903	0.035839	1.8128	5.3966	0.012020	0.019196	0.036607	779.27	–0.62535
300.00	100.00	23.193	0.043116	4.6453	8.9569	0.026484	0.016847	0.034479	643.59	–0.55209
400.00	100.00	19.351	0.051678	7.1023	12.270	0.036035	0.015591	0.031754	570.49	–0.49661
500.00	100.00	16.428	0.060871	9.2300	15.317	0.042844	0.014841	0.029280	537.49	–0.48427
600.00	100.00	14.234	0.070256	11.121	18.146	0.048008	0.014355	0.027397	525.89	–0.50576
700.00	100.00	12.558	0.079631	12.850	20.814	0.052122	0.014021	0.026021	525.42	–0.54812
200.00	200.00	30.673	0.032602	1.2743	7.7946	0.0070011	0.020666	0.035096	976.34	–0.69885
300.00	200.00	27.185	0.036785	3.8223	11.179	0.020757	0.018195	0.032708	867.80	–0.72858
400.00	200.00	24.274	0.041196	6.1068	14.346	0.029882	0.016813	0.030662	798.01	–0.75899
500.00	200.00	21.877	0.045709	8.1787	17.321	0.036526	0.015938	0.028881	754.77	–0.79823
600.00	200.00	19.905	0.050239	10.086	20.134	0.041659	0.015341	0.027435	728.59	–0.84213
700.00	200.00	18.266	0.054748	11.868	22.818	0.045799	0.014910	0.026300	713.29	–0.88605

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W, and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data* **51**(3):785–850, 2006. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The equation of state is valid from the triple point to 750 K with pressures to 200 MPa, although the uncertainties increase substantially above 100 MPa. The uncertainties in density are typically 0.2% below 100 MPa, increasing to 1% at pressures up to 200 MPa. The uncertainty in vapor pressure is 0.2%, and the uncertainties in speed of sound are 0.01% in the vapor phase (including supercritical conditions) at low pressures, 1% below 20 MPa in the liquid phase, and 3% below 100 MPa at other state points. The limited amount of heat capacity data shows that the uncertainty is 1% near the triple point, and uncertainties in heat capacities at other states are probably within 2%, at least at pressures up to 20 MPa.

TABLE 2-230 Saturated Lithium*

T, K	P, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)
453.7^m	1.78.–13	1.912.–3		1703	24259	6.776	56.492	4.30
500	8.21.–12	1.946.–3		1905	24390	7.199	52.169	4.34
600	4.18.–9	1.988.–3		2334	24674	7.983	45.216	4.23
700	3.51.–7	2.028.–3	2.40.+7	2697	24869	8.633	40.307	4.19
800	9.57.–6	2.070.–3	9.94.+5	3174	25162	9.192	36.678	4.17
900	1.24.–4	2.114.–3	8.55.+4	3590	25341	9.682	33.850	4.16
1000	9.60.–4	2.160.–3	1.22.+4	4006	25477	10.120	31.591	4.16
1200	0.0204	2.262.–3	669.3	4835	25654	10.876	28.225	4.14
1400	0.1794	2.370.–3	86.06	5668	25778	11.518	25.882	4.19
1500	0.4269	2.433.–3	38.17	6088	25845	11.808	24.979	4.20

*Converted from tables in Vargaftik, *Tables of the Thermophysical Properties of Liquids and Gases,* Nauka, Moscow, 1972, and Hemisphere, Washington, 1975. m = melting point. The notation 1.78.–13 signifies 1.78×10^{-13}.

Many of the Vargaftik values also appear in Ohse, R. W., *Handbook of Thermodynamic and Transport Properties of Alkali Metals,* Blackwell Sci. Pubs., Oxford, 1985 (1020 pp.). This source contains superheat data.

Saturation and superheat tables and a diagram to 14 bar, 2200 K are given by Reynolds, W. C., *Thermodynamic properties in S.I.,* Stanford Univ. publ., 1979 (173 pp.). For a Mollier diagram from 0.1 to 140 psia, 2100–3600 °R, see Weatherford, P. M., J. C. Tyler, et al., WADD-TR-61-96, 1961.

An extensive review of properties of the solid and the saturated liquid was given by Alcock, C. B., M. W. Chase, et al., *J. Phys. Chem. Ref. Data,* **23,** 3 (1994): 385–497.

TABLE 2-231 Lithium Bromide—Water Solutions

Ruiter, J. P., *Rev. Int. Froid = Int. J. Refrig.,* **13** (1990): 223–236 gives subroutines for computer calculations. See also ASHRAE *Handbook—Fundamentals.*

TABLE 2-232 Saturated Mercury*

T, K	P, bar	$v_f \times 10^5$, m^3/kg	v_g, m^3/kg	h_f, kJ/kg	h_g, kJ/kg	h_{fg}, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)
203.15	$2.298 \cdot 10^{-11}$	7.26239	$3.665 \cdot 10^{9}$	33.131	342.637	309.506	0.32434	1.84787
213.15	$1.288 \cdot 10^{-10}$	7.27570	$6.862 \cdot 10^{8}$	34.567	343.674	309.107	0.33124	1.78142
223.15	$6.169 \cdot 10^{-10}$	7.28900	$1.499 \cdot 10^{8}$	35.997	344.710	308.713	0.33780	1.72123
233.15	$2.580 \cdot 10^{-9}$	7.30231	$3.746 \cdot 10^{7}$	37.422	345.746	308.324	0.34404	1.66647
243.15	$9.573 \cdot 10^{-9}$	7.31563	$1.053 \cdot 10^{7}$	38.842	346.782	307.940	0.35001	1.61647
253.15	$3.198 \cdot 10^{-8}$	7.32896	$3.281 \cdot 10^{6}$	40.258	347.819	307.561	0.35571	1.57065
263.15	$9.736 \cdot 10^{-8}$	7.34229	$1.120 \cdot 10^{6}$	41.668	348.855	307.187	0.36118	1.52852
273.15	$2.728 \cdot 10^{-7}$	7.35563	$4.150 \cdot 10^{5}$	43.074	349.891	306.817	0.36642	1.48967
283.15	$7.101 \cdot 10^{-7}$	7.36898	$1.653 \cdot 10^{5}$	44.476	350.927	306.451	0.37146	1.45375
293.15	$1.729 \cdot 10^{-6}$	7.38234	$7.026 \cdot 10^{4}$	45.874	351.964	306.090	0.37631	1.42045
303.15	$3.968 \cdot 10^{-6}$	7.39572	$3.167 \cdot 10^{4}$	47.268	353.000	305.732	0.38099	1.38951
313.15	$8.626 \cdot 10^{-6}$	7.40911	$1.505 \cdot 10^{4}$	48.659	354.036	305.377	0.38550	1.36068
323.15	$1.786 \cdot 10^{-5}$	7.42252	$7.501 \cdot 10^{3}$	50.046	355.072	305.026	0.38986	1.33378
333.15	$3.356 \cdot 10^{-5}$	7.43594	$3.905 \cdot 10^{3}$	51.430	356.108	304.678	0.39408	1.30862
343.15	$6.724 \cdot 10^{-5}$	7.44938	$2.115 \cdot 10^{3}$	52.810	357.145	304.335	0.39816	1.28505
353.15	$1.232 \cdot 10^{-4}$	7.46285	$1.188 \cdot 10^{3}$	54.188	358.181	303.993	0.40212	1.26292
363.15	$2.182 \cdot 10^{-4}$	7.47633	$6.899 \cdot 10^{2}$	55.563	359.217	303.654	0.40596	1.24213
373.15	$3.745 \cdot 10^{-4}$	7.48984	413.0	56.936	360.253	303.317	0.40969	1.22255
383.15	$6.247 \cdot 10^{-4}$	7.50337	254.2	58.306	361.289	302.983	0.41331	1.20408
393.15	$1.015 \cdot 10^{-3}$	7.51693	153.6	59.674	362.326	302.652	0.41684	1.18665
403.15	$1.608 \cdot 10^{-3}$	7.53052	103.9	61.039	363.362	302.323	0.42027	1.17017
413.15	$2.491 \cdot 10^{-3}$	7.55415	68.75	62.403	364.397	301.994	0.42361	1.15456
423.15	$3.778 \cdot 10^{-3}$	7.55780	46.43	63.765	365.433	301.668	0.42687	1.13978
433.15	$5.618 \cdot 10^{-3}$	7.57148	31.96	65.125	366.469	301.344	0.43004	1.12575
443.15	$8.204 \cdot 10^{-3}$	7.58520	22.39	66.484	367.504	301.020	0.43314	1.11242
453.15	$1.178 \cdot 10^{-2}$	7.59897	15.95	67.842	368.539	300.697	0.43617	1.09975
463.15	$1.664 \cdot 10^{-2}$	7.61277	11.54	69.198	369.574	300.376	0.43913	1.08768
473.15	$2.315 \cdot 10^{-2}$	7.62662	8.469	70.553	370.609	300.056	0.44203	1.07619
483.15	$3.177 \cdot 10^{-2}$	7.64051	6.301	71.908	371.642	299.734	0.44486	1.06524
493.15	$4.304 \cdot 10^{-2}$	7.65444	4.748	73.261	372.676	299.415	0.44763	1.05478
503.15	$5.758 \cdot 10^{-2}$	7.66843	3.621	74.614	373.708	299.094	0.45035	1.04479
513.15	$7.614 \cdot 10^{-2}$	7.68247	2.793	75.967	374.740	298.773	0.45301	1.03525
523.15	$9.959 \cdot 10^{-2}$	7.69656	2.176	77.319	375.771	298.452	0.45562	1.02611
533.15	0.12892	7.71071	1.7132	78.671	376.800	298.129	0.45818	1.01737
543.15	0.16527	7.72491	1.3613	80.023	377.829	297.806	0.46069	1.00899
553.15	0.20993	7.73918	1.0912	81.375	378.855	297.480	0.46316	1.00095
563.15	0.26435	7.75351	0.88213	82.728	379.880	297.152	0.46558	0.99324
573.15	0.33015	7.7679	0.71874	84.080	380.904	296.824	0.46796	0.98584
583.15	0.40910	7.7823	0.59002	85.434	381.925	296.491	0.47030	0.97893
593.15	0.50320	7.7969	0.48779	86.788	382.944	296.156	0.47260	0.97190
603.15	0.61460	7.8115	0.40600	88.143	383.960	295.817	0.47487	0.96532
613.15	0.74567	7.8262	0.34008	89.499	384.973	295.474	0.47709	0.95899
623.15	0.89896	7.8409	0.28660	90.856	385.984	295.128	0.47929	0.95289
633.15	1.0772	7.8558	0.24291	92.215	386.991	294.776	0.48145	0.94702
643.15	1.2834	7.8707	0.20702	93.575	387.994	294.419	0.48358	0.94135
653.15	1.5207	7.8858	0.17735	94.937	388.994	294.057	0.48568	0.93589
663.15	1.9725	7.9008	0.15269	96.300	389.989	293.689	0.48774	0.93061
673.15	2.1024	7.9160	0.13207	97.666	390.980	293.314	0.48978	0.92552
683.15	2.454	7.9313	0.11476	99.033	391.966	292.933	0.49180	0.92059
693.15	2.852	7.9467	0.10014	100.403	392.947	292.544	0.49378	0.91583
703.15	3.299	7.9622	0.08775	101.775	393.923	292.148	0.49574	0.91123
713.15	3.801	7.9778	0.07719	103.150	394.893	291.743	0.49768	0.90677
723.15	4.362	7.9935	0.06815	104.528	395.858	291.330	0.49959	0.90245
733.15	4.986	8.0094	0.06039	105.908	396.816	290.908	0.50148	0.89827
743.15	5.679	8.0252	0.05369	107.292	397.767	290.475	0.50335	0.89422
753.15	6.446	8.0413	0.04789	108.679	398.711	290.032	0.50519	0.89029
763.15	7.292	8.0574	0.04285	110.069	399.649	289.580	0.50702	0.88647
773.15	8.222	8.074	0.03846	111.463	400.579	289.116	0.50882	0.88277
783.15	9.242	8.090	0.03462	112.861	401.501	288.640	0.51061	0.87917
793.15	10.358	8.106	0.03124	114.262	402.415	288.153	0.51238	0.87568
803.15	11.576	8.123	0.02827	115.668	403.321	287.653	0.51412	0.87228
813.15	12.901	8.140	0.02565	117.078	404.218	287.140	0.51586	0.86898
823.15	14.340	8.157	0.02333	118.492	405.106	286.614	0.51757	0.86576
833.15	15.899	8.174	0.02126	119.911	405.985	286.074	0.51927	0.86263

*From Vukalovich, Ivanov, Fokin, and Yakovlev, *Thermophysical Properties of Mercury,* Standartov, Moscow, 1971. For the saturated liquid the specific volume at 203.15 K is 7.26239×10^{-5} m^3/kg, etc. All the tabular values for 203.15 K, 213.15 K, 223.15 K, and 233.15 K represent a metastable equilibrium between the subcooled liquid and the saturated vapor.

Saturation and superheat tables and a diagram to 100 bar, 1600 K are given by Reynolds, W. C., *Thermodynamic properties in S.I.,* Stanford Univ. publ., 1979 (173 pp.). For a Mollier diagram from 1 to 8200 psia and 2700°R, see Weatherford, W. D., J. C. Tyler, et al., WADD-TR-61-96, 1961.

TABLE 2-232 Saturated Mercury* (*Concluded*)

T, K	P, bar	$v_f \times 10^5$, m^3/kg	v_g, m^3/kg	h_f, kJ/kg	h_g, kJ/kg	h_{fg}, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)
843.15	17.584	8.191	0.019426	121.335	406.855	285.520	0.52095	0.85959
853.15	19.403	8.209	0.017785	122.763	407.715	284.952	0.52262	0.85662
863.15	21.36	8.226	0.016317	124.197	408.565	284.368	0.52427	0.85372
873.15	23.46	8.244	0.015000	125.636	409.405	283.769	0.52591	0.85090
883.15	25.72	8.262	0.013815	127.080	410.235	283.155	0.52753	0.84815
893.15	28.14	8.280	0.012748	128.530	411.054	282.524	0.52914	0.84546
903.15	30.72	8.298	0.011784	129.986	411.861	281.875	0.53074	0.84284
913.15	33.47	8.316	0.010911	131.448	412.658	281.210	0.53232	0.84028
923.15	36.41	8.335	0.010120	132.915	413.444	280.529	0.53389	0.83777
933.15	39.53	8.353	0.009401	134.389	414.218	279.829	0.53545	0.83533
943.15	42.85	8.372	0.008746	135.869	414.980	279.111	0.53700	0.83294
953.15	46.36	8.391	0.008150	137.356	415.731	278.375	0.53854	0.83060
963.15	50.09	8.410	0.007604	138.850	416.469	277.619	0.54006	0.82831
973.15	54.03	8.430	0.007105	140.350	417.195	276.845	0.54158	0.82606
983.15	58.20	8.450	0.006648	141.858	417.909	276.051	0.54308	0.82387
993.15	62.59	8.468	0.006228	143.372	418.610	275.238	0.54458	0.82172
1003.15	67.22	8.488	0.005842	144.894	419.298	274.404	0.54607	0.81961
1013.15	72.10	8.508	0.005487	146.424	419.974	273.550	0.54754	0.81754
1023.15	77.22	8.529	0.005159	147.961	420.636	272.675	0.54901	0.81552
1033.15	82.60	8.550	0.004856	149.506	421.286	271.780	0.55047	0.81353
1043.15	88.25	8.570	0.004576	151.059	421.923	270.864	0.55192	0.81158
1053.15	94.17	8.590	0.004317	152.619	422.546	269.927	0.55336	0.80966
1063.15	100.37	8.612	0.004077	154.188	423.156	268.968	0.55479	0.80778
1073.15	106.85	8.632	0.003854	155.766	423.752	267.986	0.55621	0.80593

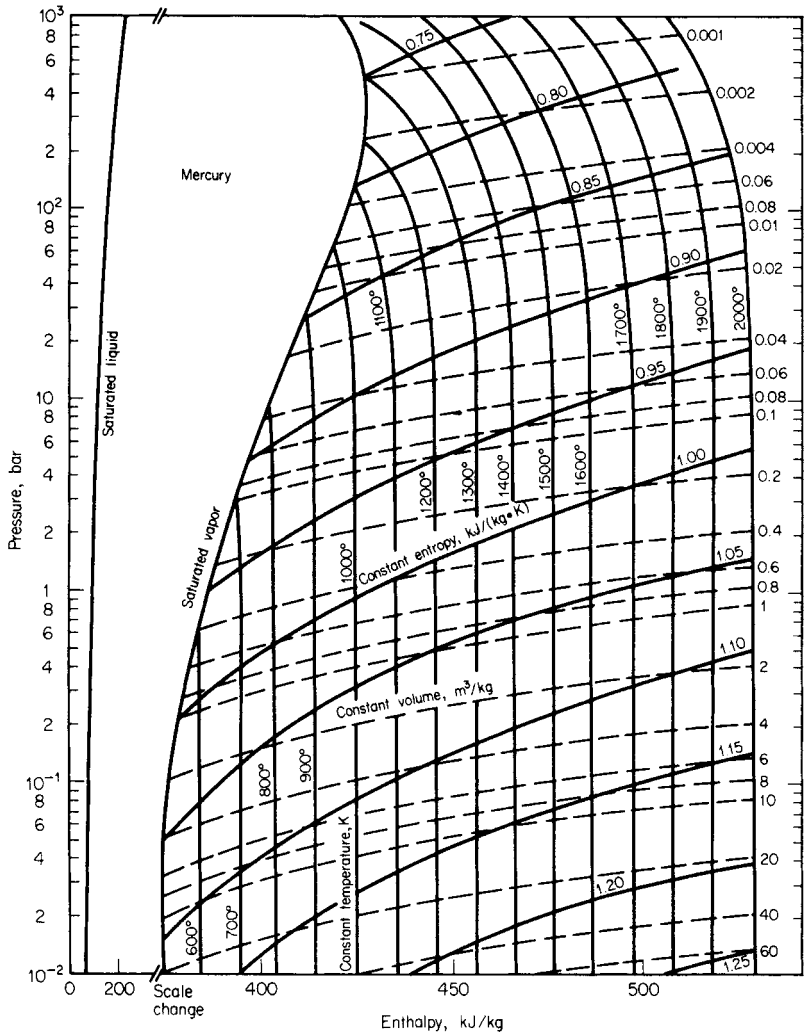

FIG. 2-12 Enthalpy-log-pressure diagram for mercury. (*Drawn from tabular data in footnote reference to Table 2-232.*)

TABLE 2-233 Thermodynamic Properties of Methane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
90.694	0.011696	28.142	0.035534	–1.1526	–1.1522	–0.011389	0.034776	0.054029	1538.6	–0.48191	211.24	204.52
100.00	0.034376	27.357	0.036554	–0.64728	–0.64602	–0.0060856	0.033908	0.054681	1452.0	–0.45812	199.67	155.78
105.00	0.056377	26.923	0.037143	–0.37306	–0.37097	–0.0034096	0.033500	0.055135	1403.9	–0.44202	193.03	136.86
110.00	0.088130	26.478	0.037768	–0.096585	–0.093257	–0.00083691	0.033115	0.055656	1354.7	–0.42328	186.18	121.34
115.00	0.13221	26.021	0.038431	0.18242	0.18750	0.0016441	0.032749	0.056253	1304.6	–0.40145	179.21	108.39
120.00	0.19143	25.551	0.039138	0.46425	0.47174	0.0040439	0.032400	0.056941	1253.5	–0.37589	172.15	97.432
125.00	0.26876	25.065	0.039896	0.74927	0.75999	0.0063722	0.032069	0.057741	1201.3	–0.34578	165.04	88.031
130.00	0.36732	24.562	0.040714	1.0379	1.0529	0.0086383	0.031757	0.058684	1148.1	–0.31006	157.91	79.868
135.00	0.49035	24.038	0.041600	1.3307	1.3511	0.010851	0.031469	0.059809	1093.6	–0.26735	150.78	72.699
140.00	0.64118	23.491	0.042569	1.6284	1.6557	0.013020	0.031206	0.061169	1037.7	–0.21579	143.65	66.333
145.00	0.82322	22.917	0.043636	1.9317	1.9676	0.015154	0.030974	0.062840	980.17	–0.15286	136.54	60.620
150.00	1.0400	22.309	0.044825	2.2418	2.2884	0.017264	0.030780	0.064932	920.85	–0.075032	129.43	55.437
155.00	1.2950	21.661	0.046165	2.5602	2.6199	0.019362	0.030631	0.067613	859.39	0.022798	122.32	50.682
160.00	1.5921	20.964	0.047702	2.8887	2.9647	0.021462	0.030541	0.071156	795.43	0.14836	115.19	46.266
165.00	1.9351	20.202	0.049500	3.2304	3.3262	0.023584	0.030531	0.076044	728.42	0.31398	108.01	42.105
170.00	2.3283	19.355	0.051667	3.5895	3.7098	0.025755	0.030634	0.083218	657.52	0.54087	100.73	38.115
175.00	2.7765	18.384	0.054394	3.9734	4.1244	0.028021	0.030920	0.094816	581.27	0.86918	93.324	34.196
180.00	3.2852	17.218	0.058078	4.3965	4.5873	0.030467	0.031554	0.11699	497.01	1.3866	85.799	30.193
185.00	3.8617	15.668	0.063825	4.8955	5.1420	0.033313	0.033085	0.17822	398.59	2.3397	78.733	25.773
190.00	4.5186	12.515	0.079902	5.7074	6.0685	0.038000	0.041746	1.5082	250.31	5.2488	96.970	18.982
190.56	4.5992	10.139	0.098628	6.2136	6.6672	0.041109			0	6.8877		
90.694	0.011696	0.015630	63.981	6.8310	7.5793	0.084885	0.025243	0.033851	249.13	47.921	8.8517	3.6388
100.00	0.034376	0.042048	23.782	7.0469	7.8644	0.079019	0.025487	0.034425	260.09	37.826	10.015	3.9976
105.00	0.056377	0.066154	15.116	7.1582	8.0104	0.076413	0.025652	0.034853	265.31	33.883	10.669	4.1951
110.00	0.088130	0.099622	10.038	7.2654	8.1501	0.074103	0.025842	0.035378	270.01	30.662	11.350	4.3964
115.00	0.13221	0.14457	6.9171	7.3680	8.2825	0.072036	0.026056	0.036016	274.17	28.004	12.062	4.6019
120.00	0.19143	0.20332	4.9183	7.4652	8.4067	0.070168	0.026295	0.036786	277.76	25.790	12.811	4.8123
125.00	0.26876	0.27844	3.5915	7.5562	8.5215	0.068464	0.026560	0.037714	280.76	23.928	13.604	5.0285
130.00	0.36732	0.37278	2.6825	7.6403	8.6257	0.066891	0.026854	0.038836	283.13	22.347	14.449	5.2517
135.00	0.49035	0.48962	2.0424	7.7165	8.7180	0.065421	0.027182	0.040203	284.86	20.993	15.355	5.4833
140.00	0.64118	0.63279	1.5803	7.7837	8.7970	0.064029	0.027549	0.041885	285.93	19.819	16.334	5.7254
145.00	0.82322	0.80691	1.2393	7.8406	8.8608	0.062694	0.027965	0.043985	286.31	18.789	17.402	5.9806
150.00	1.0400	1.0177	0.98256	7.8856	8.9074	0.061391	0.028439	0.046657	285.97	17.870	18.581	6.2526
155.00	1.2950	1.2728	0.78568	7.9166	8.9340	0.060098	0.028989	0.050144	284.88	17.035	19.904	6.5462
160.00	1.5921	1.5821	0.63206	7.9306	8.9369	0.058789	0.029636	0.054849	283.01	16.255	21.423	6.8688
165.00	1.9351	1.9603	0.51014	7.9238	8.9109	0.057431	0.030412	0.061496	280.30	15.500	23.225	7.2313
170.00	2.3283	2.4294	0.41163	7.8898	8.8482	0.055982	0.031374	0.071527	276.66	14.732	25.477	7.6515
175.00	2.7765	3.0268	0.33038	7.8184	8.7357	0.054371	0.032615	0.088273	271.99	13.896	28.545	8.1609
180.00	3.2852	3.8257	0.26139	7.6893	8.5480	0.052471	0.034338	0.12151	266.04	12.892	33.392	8.8251
185.00	3.8617	5.0137	0.19945	7.4515	8.2217	0.049961	0.037087	0.21701	258.03	11.492	43.706	9.8238
190.00	4.5186	7.8027	0.12816	6.7850	7.3641	0.044819	0.045796	2.2590	238.55	8.4951	119.40	12.455
190.56	4.5992	10.139	0.098628	6.2136	6.6672	0.041109			0	6.8877		

Single-Phase Properties												
100.00	0.10000	27.360	0.036549	–0.64803	–0.64438	–0.0060931	0.033911	0.054672	1452.6	–0.45829	199.74	155.91
111.51	0.10000	26.341	0.037963	–0.012738	–0.0089413	–0.000079677	0.033003	0.055828	1339.7	–0.41705	184.09	117.20
111.51	0.10000	0.11186	8.9395	7.2969	8.1908	0.073456	0.025904	0.035558	271.33	29.808	11.561	4.4579
200.00	0.10000	0.060518	16.524	9.5570	11.209	0.093427	0.025259	0.033784	369.98	9.2893	21.941	7.8096
300.00	0.10000	0.040158	24.901	12.175	14.665	0.10741	0.027479	0.035869	449.74	4.3216	34.552	11.245
400.00	0.10000	0.030082	33.243	15.151	18.475	0.11834	0.032300	0.040652	510.56	2.2395	50.127	14.272
500.00	0.10000	0.024055	41.572	18.673	22.831	0.12803	0.038196	0.046533	561.86	1.2245	68.564	16.976
600.00	0.10000	0.020042	49.895	22.795	27.784	0.13705	0.044179	0.052509	608.04	0.68722	88.921	19.431
100.00	1.0000	27.403	0.036493	–0.65829	–0.62179	–0.0061960	0.033950	0.054562	1459.6	–0.46060	200.62	157.63
149.14	1.0000	22.416	0.044610	2.1878	2.2325	0.016902	0.030810	0.064535	931.21	–0.089695	130.66	56.297
149.14	1.0000	0.97852	1.0220	7.8788	8.9007	0.061614	0.028353	0.046147	286.08	18.022	18.368	6.2043
200.00	1.0000	0.64363	1.5537	9.3582	10.912	0.073276	0.025879	0.036730	357.81	9.5001	23.028	8.0145
300.00	1.0000	0.40776	2.4524	12.072	14.524	0.087922	0.027621	0.036721	447.04	4.2699	35.152	11.367
400.00	1.0000	0.30205	3.3108	15.083	18.393	0.099023	0.032360	0.041056	510.57	2.2001	50.558	14.357
500.00	1.0000	0.24058	4.1567	18.623	22.780	0.10879	0.038227	0.046766	562.99	1.1998	68.902	17.040
600.00	1.0000	0.20012	4.9971	22.755	27.752	0.11784	0.044198	0.052659	609.73	0.67124	89.200	19.483
100.00	5.0000	27.586	0.036250	–0.70190	–0.52065	–0.0066393	0.034116	0.054117	1490.0	–0.46993	204.45	165.28
200.00	5.0000	5.4706	0.18279	7.8197	8.7337	0.051495	0.032029	0.11667	291.29	8.9784	40.612	10.828
300.00	5.0000	2.1799	0.45874	11.590	13.884	0.072954	0.028262	0.041234	439.25	3.9428	38.480	12.194
400.00	5.0000	1.5333	0.65221	14.779	18.040	0.084897	0.032614	0.042903	513.11	2.0089	52.693	14.872
500.00	5.0000	1.2013	0.83240	18.401	22.563	0.094971	0.038361	0.047789	569.49	1.0870	70.509	17.410
600.00	5.0000	0.99281	1.0072	22.581	27.617	0.10417	0.044277	0.053309	618.13	0.60013	90.498	19.768
100.00	10.000	27.802	0.035969	–0.75239	–0.39270	–0.0071652	0.034314	0.053642	1525.7	–0.47979	209.07	174.83
200.00	10.000	16.593	0.060268	5.1551	5.7578	0.034542	0.030129	0.085085	567.92	1.0266	84.234	29.399
300.00	10.000	4.6859	0.21340	10.942	13.077	0.065137	0.028995	0.048165	444.53	3.2606	44.730	13.896
400.00	10.000	3.1002	0.32256	14.401	17.627	0.078246	0.032902	0.045220	522.58	1.7355	55.941	15.766
500.00	10.000	2.3887	0.41863	18.132	22.318	0.088698	0.038516	0.049007	580.99	0.94125	72.781	18.011
600.00	10.000	1.9619	0.50971	22.371	27.468	0.098073	0.044371	0.054070	630.63	0.51200	92.268	20.217
200.00	100.00	25.496	0.039222	3.0510	6.9732	0.020596	0.032058	0.048512	1541.0	–0.51619	188.05	80.392
300.00	100.00	21.266	0.047024	7.0865	11.789	0.040126	0.031823	0.048281	1267.5	–0.44889	137.68	47.835
400.00	100.00	17.881	0.055926	11.121	16.713	0.054276	0.035273	0.050523	1115.8	–0.37484	120.38	37.584
500.00	100.00	15.305	0.065340	15.405	21.939	0.065922	0.040312	0.054139	1044.8	–0.32811	120.87	33.590
600.00	100.00	13.357	0.074869	20.074	27.561	0.076160	0.045724	0.058364	1018.4	–0.30439	130.36	32.111
200.00	500.00	33.003	0.030301	2.3322	17.482	0.0061671	0.037832	0.047821	2664.2	–0.53926	429.60	205.24
300.00	500.00	30.786	0.032482	5.9505	22.192	0.025271	0.037006	0.047114	2500.0	–0.55416	358.93	106.90
400.00	500.00	28.929	0.034567	9.7401	27.024	0.039152	0.039890	0.049933	2360.3	–0.52806	312.36	78.768
500.00	500.00	27.331	0.036588	13.934	32.228	0.050747	0.044407	0.054280	2250.3	–0.49035	285.41	66.669
600.00	500.00	25.934	0.038559	18.612	37.892	0.061061	0.049344	0.059017	2168.1	–0.45514	272.14	60.413

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Setzmann, U., and Wagner, W., "A New Equation of State and Tables of Thermodynamic Properties for Methane Covering the Range from the Melting Line to 625 K at Pressures up to 1000 MPa," *J. Phys. Chem. Ref. Data* **20**(6):1061–1151, 1991. The source for viscosity is Younglove, B. A., and Ely, J. F., "Thermophysical Properties of Fluids. II. Methane, Ethane, Propane, Isobutane and Normal Butane," *J. Phys. Chem. Ref. Data* **16**:577–798, 1987. The source for thermal conductivity is Friend, D. G., Ely, J. F., and Ingham, H., "Tables for the Thermophysical Properties of Methane," *NIST Tech. Note* 1325, 1989.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in density are 0.03% for pressures below 12 MPa and temperatures below 350 K and up to 0.07% for pressures less than 50 MPa. For the speed of sound, the uncertainty ranges from 0.03% (in the vapor phase) to 0.3% depending on temperature and pressure. Heat capacities may be generally calculated within an uncertainty of 1%. The uncertainty in viscosity is 2%, except in the critical region which is 5%. The uncertainty in thermal conductivity of the dilute gas between 130 and 625 K is 2.5%. For temperatures below 130 K, the uncertainty is less than 10%. Excluding the dilute gas, the uncertainty is 2% between 110 and 725 K at pressures up to 70 MPa, except near the critical point which has an uncertainty of 5% or greater. For the vapor at lower temperatures and the dense liquid near the triple point, an uncertainty of 10% is possible.

TABLE 2-234 Thermodynamic Properties of Methanol

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
175.61	1.8635E-07	28.230	0.035423	−12.440	−12.440	−0.049524	0.056728	0.070390	1625.1	−0.40884
180.00	3.7619E-07	28.096	0.035592	−12.130	−12.130	−0.047781	0.056689	0.070750	1590.2	−0.40373
195.00	3.2175E-06	27.629	0.036194	−11.067	−11.067	−0.042108	0.056604	0.070897	1496.4	−0.39791
210.00	1.9841E-05	27.163	0.036815	−10.001	−10.001	−0.036846	0.057072	0.071215	1425.3	−0.39361
225.00	9.4330E-05	26.703	0.037449	−8.9277	−8.9277	−0.031908	0.057992	0.072004	1363.2	−0.38674
240.00	0.00036348	26.250	0.038096	−7.8395	−7.8395	−0.027226	0.059275	0.073141	1304.6	−0.37793
255.00	0.0011791	25.802	0.038756	−6.7318	−6.7318	−0.022750	0.060916	0.074617	1248.2	−0.36733
270.00	0.0033166	25.360	0.039432	−5.5991	−5.5990	−0.018434	0.062917	0.076487	1194.1	−0.35457
285.00	0.0082787	24.922	0.040125	−4.4351	−4.4347	−0.014239	0.065250	0.078803	1142.6	−0.33915
300.00	0.018682	24.484	0.040844	−3.2329	−3.2322	−0.010129	0.067864	0.081584	1093.5	−0.32073
315.00	0.038692	24.041	0.041595	−1.9858	−1.9842	−0.0060725	0.070693	0.084823	1046.3	−0.29904
330.00	0.074453	23.590	0.042390	−0.68700	−0.68385	−0.0020451	0.073674	0.088505	1000.2	−0.27385
345.00	0.13447	23.124	0.043244	0.66961	0.67543	0.0019747	0.076752	0.092616	954.32	−0.24479
360.00	0.22992	22.638	0.044174	2.0901	2.1003	0.0060049	0.079881	0.097164	907.64	−0.21121
375.00	0.37483	22.123	0.045203	3.5806	3.5975	0.010061	0.083033	0.10219	859.31	−0.17199
390.00	0.58617	21.571	0.046358	5.1475	5.1746	0.014159	0.086189	0.10776	808.48	−0.12529
405.00	0.88399	20.973	0.047681	6.7983	6.8404	0.018314	0.089346	0.11405	754.41	−0.068163
420.00	1.2914	20.315	0.049226	8.5423	8.6058	0.022546	0.092514	0.12133	696.47	0.0042669
435.00	1.8349	19.579	0.051075	10.392	10.485	0.026879	0.095722	0.13007	634.17	0.10021
450.00	2.5433	18.741	0.053360	12.364	12.500	0.031347	0.099032	0.14120	567.09	0.23444
465.00	3.4456	17.759	0.056310	14.488	14.682	0.036009	0.10257	0.15679	494.36	0.43762
480.00	4.5713	16.553	0.060411	16.820	17.096	0.040977	0.10666	0.18345	412.12	0.79465
495.00	5.9794	14.880	0.067203	19.521	19.923	0.046590	0.11250	0.25717	308.94	1.6506
510.00	7.7496	11.689	0.085547	23.297	23.960	0.054351	0.12653	1.1088	192.83	4.6061
513.38	8.2159	8.7852	0.11383	25.917	26.852	0.059911			0	6.7425
175.61	1.8635E-07	1.2764E-07	7,834,400.	28.219	29.679	0.19032	0.031874	0.040287	239.95	1187400.
180.00	3.7619E-07	2.5140E-07	3,977,700.	28.353	29.850	0.18544	0.032397	0.040854	242.62	857090.
195.00	3.2175E-06	1.9855E-06	503,660.	28.810	30.430	0.17069	0.035224	0.043954	251.06	293110.
210.00	1.9841E-05	1.1378E-05	87,892.	29.259	31.003	0.15841	0.040104	0.049389	258.49	105090.
225.00	9.4330E-05	5.0556E-05	19,780.	29.698	31.564	0.14806	0.047248	0.057480	265.30	39363.
240.00	0.00036348	0.00018304	5,463.4	30.123	32.109	0.13923	0.056324	0.067973	271.89	15552.
255.00	0.0011791	0.00056065	1,783.7	30.534	32.637	0.13164	0.066572	0.080135	278.43	6557.5
270.00	0.0033166	0.0014959	668.48	30.932	33.149	0.12508	0.077055	0.093000	284.90	2971.8
285.00	0.0082787	0.0035581	281.05	31.321	33.648	0.11938	0.086920	0.10564	291.19	1449.9
300.00	0.018682	0.0076845	130.13	31.703	34.134	0.11442	0.095581	0.11740	297.15	759.96
315.00	0.038692	0.015300	65.359	32.077	34.606	0.11009	0.10279	0.12798	302.63	426.34
330.00	0.074453	0.028438	35.164	32.442	35.060	0.10627	0.10860	0.13749	307.47	254.84
345.00	0.13447	0.049870	20.052	32.789	35.485	0.10287	0.11331	0.14644	311.48	161.53
360.00	0.22992	0.083267	12.009	33.108	35.869	0.099808	0.11736	0.15559	314.48	108.02
375.00	0.37483	0.13344	7.4940	33.385	36.194	0.096984	0.12125	0.16605	316.20	75.802
390.00	0.58617	0.20674	4.8370	33.601	36.436	0.094317	0.12546	0.17917	316.34	55.467
405.00	0.88399	0.31179	3.2073	33.736	36.571	0.091723	0.13033	0.19663	314.53	42.002
420.00	1.2914	0.46071	2.1706	33.767	36.570	0.089128	0.13587	0.21986	310.36	32.587
435.00	1.8349	0.67055	1.4913	33.687	36.423	0.086505	0.14101	0.24709	303.71	25.532
450.00	2.5433	0.96219	1.0393	33.541	36.184	0.083978	0.14238	0.26502	295.26	19.860
465.00	3.4456	1.3555	0.73775	33.439	35.981	0.081813	0.13589	0.25879	285.25	15.568
480.00	4.5713	1.9102	0.52352	33.258	35.652	0.079634	0.12618	0.27959	267.83	13.904
495.00	5.9794	2.9050	0.34423	32.267	34.325	0.075685	0.12608	0.42448	247.46	12.099
510.00	7.7496	5.1706	0.19340	29.688	31.187	0.068520	0.13259	1.9096	212.65	9.5115
513.38	8.2159	8.7852	0.11383	25.917	26.852	0.059911			0	6.7425

Single-Phase Properties

200.00	0.10000	27.474	0.036398	–10.713	–10.709	–0.040317	0.056702	0.070943	1471.5	–0.39677
300.00	0.10000	24.486	0.040839	–3.2341	–3.2300	–0.010133	0.067862	0.081580	1094.1	–0.32081
337.30	0.10000	23.366	0.042798	–0.034546	–0.030266	–0.000089518	0.075163	0.090451	977.93	–0.26023
337.30	0.10000	0.037626	26.577	32.613	35.271	0.10457	0.11100	0.14187	309.54	202.71
400.00	0.10000	0.030452	32.839	36.075	39.359	0.11581	0.044972	0.054208	349.19	40.941
500.00	0.10000	0.024157	41.396	40.921	45.060	0.12851	0.051823	0.060380	387.15	12.933
600.00	0.10000	0.020089	49.779	46.476	51.454	0.14014	0.059065	0.067441	420.71	4.3382
200.00	1.0000	27.491	0.036376	–10.720	–10.684	–0.040354	0.056724	0.070932	1475.1	–0.39705
300.00	1.0000	24.514	0.040793	–3.2472	–3.2064	–0.010176	0.067848	0.081541	1100.0	–0.32177
400.00	1.0000	21.193	0.047185	6.2298	6.2770	0.016901	0.088257	0.11177	775.46	–0.090229
409.75	1.0000	20.772	0.048143	7.3401	7.3883	0.019645	0.090347	0.11623	736.51	–0.047179
409.75	1.0000	0.35352	2.8287	33.758	36.586	0.090904	0.13203	0.20333	313.48	38.678
500.00	1.0000	0.25202	3.9680	40.335	44.303	0.10818	0.056676	0.068069	376.08	13.330
600.00	1.0000	0.20501	4.8778	46.300	51.178	0.12070	0.061344	0.070369	413.09	4.5635
200.00	5.0000	27.561	0.036283	–10.752	–10.571	–0.040517	0.056820	0.070883	1490.9	–0.39825
300.00	5.0000	24.635	0.040592	–3.3039	–3.1010	–0.010367	0.067795	0.081377	1125.5	–0.32568
400.00	5.0000	21.441	0.046640	6.0896	6.3228	0.016546	0.087676	0.11029	818.58	–0.11504
484.95	5.0000	16.076	0.062203	17.655	17.966	0.042725	0.10826	0.19836	381.15	0.98684
484.95	5.0000	2.1711	0.46060	33.047	35.350	0.078574	0.12499	0.32263	260.06	13.826
500.00	5.0000	1.7679	0.56566	35.907	38.735	0.085457	0.098975	0.17315	301.43	12.155
600.00	5.0000	1.1389	0.87808	45.247	49.638	0.10553	0.072927	0.087489	379.21	5.1009
200.00	10.000	27.648	0.036169	–10.791	–10.430	–0.040716	0.056935	0.070820	1509.9	–0.39966
300.00	10.000	24.779	0.040357	–3.3713	–2.9677	–0.010598	0.067746	0.081196	1155.3	–0.32990
400.00	10.000	21.717	0.046048	5.9321	6.3925	0.016141	0.087087	0.10880	865.91	–0.13884
500.00	10.000	15.932	0.062765	19.374	20.002	0.046226	0.10760	0.18959	424.68	0.83939
600.00	10.000	2.6640	0.37537	43.262	47.015	0.096406	0.088868	0.12122	343.60	5.0965
200.00	100.00	28.911	0.034588	–11.305	–7.8460	–0.043691	0.057827	0.068992	1772.1	–0.41976
300.00	100.00	26.630	0.037552	–4.2043	–0.44914	–0.013840	0.067889	0.079818	1515.8	–0.35799
400.00	100.00	24.493	0.040827	4.3449	8.4277	0.011565	0.082823	0.098951	1334.7	–0.26099
500.00	100.00	22.020	0.045413	14.917	19.458	0.036085	0.095694	0.12152	1164.1	–0.14407
600.00	100.00	19.139	0.052250	27.300	32.525	0.059862	0.10406	0.13787	977.50	–0.023905
300.00	500.00	30.547	0.032736	–5.4195	10.949	–0.022106	0.070293	0.080627	2316.0	–0.34762
400.00	500.00	29.154	0.034300	2.2795	19.430	0.0022308	0.077541	0.089761	2194.8	–0.30897
500.00	500.00	27.670	0.036140	11.020	29.089	0.023726	0.084883	0.10419	2123.2	–0.24751
600.00	500.00	26.003	0.038457	21.094	40.322	0.044161	0.092281	0.12017	2074.1	–0.19279

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is de Reuck, K. M., and Craven, R. J. B., "Methanol, International Thermodynamic Tables of the Fluid State—12," *IUPAC*, Blackwell Scientific Publications, London, 1993. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are generally 0.1% in density and 2% in the speed of sound, except in the critical region and high pressures.

TABLE 2-235 Thermodynamic Properties of 2-Methyl Butane (Isopentane)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. Cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
112.65	8.9347E-11	10.936	0.091442	–26.072	–26.072	–0.13287	0.088268	0.12675	2024.6	–0.61677	177.46	18091
115	1.9071E-10	10.903	0.091719	–25.774	–25.774	–0.13026	0.087968	0.12625	2007.2	–0.61938	177.30	15987
130	1.1761E-08	10.698	0.093478	–23.896	–23.896	–0.11491	0.087279	0.12456	1899.0	–0.62810	174.59	7701.7
145	2.8119E-07	10.500	0.095242	–22.028	–22.028	–0.10131	0.088069	0.12473	1796.0	–0.62623	169.97	4126.6
160	3.4585E-06	10.306	0.097028	–20.148	–20.148	–0.08897	0.089805	0.12613	1698.3	–0.61691	164.30	2438.0
175	2.6222E-05	10.116	0.09885	–18.240	–18.240	–0.07757	0.092192	0.12840	1605.5	–0.60215	158.07	1564.5
190	0.00013839	9.9281	0.10072	–16.293	–16.293	–0.06690	0.095056	0.13133	1517.0	–0.58328	151.59	1074.5
205	0.00055325	9.7405	0.10266	–14.298	–14.298	–0.05679	0.098282	0.13478	1432.2	–0.56116	145.02	779.51
220	0.0017804	9.5525	0.10468	–12.247	–12.247	–0.04714	0.10179	0.13865	1350.7	–0.53631	138.51	591.10
235	0.0048228	9.3629	0.10680	–10.136	–10.136	–0.03786	0.10553	0.14289	1271.9	–0.50892	132.11	464.45
250	0.011375	9.1708	0.10904	–7.9595	–7.9583	–0.02888	0.10944	0.14744	1195.4	–0.47898	125.89	375.48
265	0.023974	8.9750	0.11142	–5.7124	–5.7097	–0.02016	0.11351	0.15230	1120.7	–0.44620	119.87	310.55
280	0.046069	8.7745	0.11397	–3.3908	–3.3856	–0.01163	0.11771	0.15744	1047.6	–0.41003	114.07	261.53
295	0.082015	8.5679	0.11671	–0.99085	–0.98128	–0.00329	0.12200	0.16288	975.50	–0.36957	108.49	223.37
310	0.13700	8.3537	0.11971	1.4914	1.5078	0.004922	0.12638	0.16864	904.21	–0.32346	103.13	192.84
325	0.21693	8.1302	0.12300	4.0602	4.0869	0.013015	0.13084	0.17476	833.33	–0.26964	98.008	167.77
340	0.32835	7.8950	0.12666	6.7200	6.7616	0.021017	0.13535	0.18133	762.50	–0.20494	93.105	146.69
355	0.47831	7.6451	0.13080	9.4764	9.5389	0.028954	0.13992	0.18849	691.33	–0.12436	88.417	128.56
370	0.67436	7.3765	0.13557	12.336	12.428	0.036852	0.14455	0.19649	619.38	–0.01964	83.934	112.60
385	0.92461	7.0835	0.14117	15.310	15.440	0.044740	0.14926	0.20576	546.13	0.12385	79.645	98.258
400	1.2378	6.7572	0.14799	18.410	18.593	0.052658	0.15409	0.21716	470.92	0.33435	75.537	85.057
415	1.6238	6.3830	0.15667	21.662	21.916	0.060668	0.15915	0.23260	392.75	0.67407	71.596	72.595
430	2.0941	5.9327	0.16856	25.110	25.463	0.068880	0.16468	0.25764	309.77	1.3120	67.829	60.422
445	2.6640	5.3333	0.18750	28.871	29.370	0.077578	0.17145	0.31907	217.58	2.9280	64.403	47.740
460.35	3.3782	3.2710	0.30572	35.298	36.331	0.092549			0	18.924		
112.65	8.9527E-11	9.5585E-11	1.05E+10	7.8069	8.7435	0.17618	0.044856	0.053170	124.05		2.3120	2.775
115	1.9071E-10	1.9975E-10	5.01E+09	7.9134	8.8695	0.17099	0.045769	0.054083	125.14	1474.9	2.3996	2.827
130	1.1761E-08	1.0881E-08	91,905,000	8.6432	9.7241	0.14371	0.051515	0.059829	131.91	867.62	3.0011	3.1624
145	2.8119E-07	2.3324E-07	4,287,500	9.4580	10.664	0.12415	0.057098	0.065412	138.36	543.86	3.6746	3.5046
160	3.4585E-06	2.5998E-06	384,650	10.355	11.686	0.10999	0.062541	0.070856	144.53	358.94	4.4196	3.853
175	2.6222E-05	1.8023E-05	55,485	11.333	12.788	0.099732	0.067888	0.076206	150.45	247.17	5.2372	4.2074
190	0.00013839	8.7629E-05	11,412	12.390	13.969	0.092376	0.073180	0.081510	156.12	176.38	6.1289	4.5669
205	0.00055325	0.00032489	3,077.9	13.524	15.227	0.087227	0.078451	0.086811	161.53	129.80	7.0964	4.931
220	0.0017804	0.00097556	1,025.1	14.732	16.557	0.083784	0.083733	0.092156	166.66	98.138	8.1416	5.2989
235	0.0048228	0.0024804	403.15	16.011	17.955	0.081674	0.089051	0.09759	171.43	76.055	9.2673	5.6698
250	0.011375	0.0055234	181.05	17.357	19.416	0.080615	0.094425	0.10316	175.77	60.317	10.477	6.0432
265	0.023974	0.011056	90.449	18.766	20.935	0.080389	0.099871	0.10890	179.56	48.903	11.776	6.4187
280	0.046069	0.020302	49.256	20.234	22.503	0.080825	0.10539	0.11485	182.71	40.504	13.169	6.7963
295	0.082015	0.034759	28.769	21.756	24.115	0.081787	0.11100	0.12105	185.07	34.252	14.664	7.1769
310	0.13700	0.056212	17.790	23.326	25.763	0.083164	0.11669	0.12757	186.54	29.560	16.270	7.5619
325	0.21693	0.086783	11.523	24.939	27.438	0.084865	0.12246	0.13447	186.97	26.024	17.997	7.9543
340	0.32835	0.12904	7.7495	26.587	29.132	0.086812	0.12831	0.14187	186.20	23.372	19.860	8.3586
355	0.47831	0.18620	5.3705	28.263	30.831	0.088933	0.13425	0.14999	184.05	21.417	21.877	8.7821
370	0.67436	0.26252	3.8092	29.953	32.522	0.091161	0.14029	0.15916	180.31	20.043	24.077	9.2355
385	0.92461	0.36398	2.7474	31.643	34.183	0.093423	0.14648	0.17005	174.70	19.189	26.507	9.7357
400	1.2378	0.49975	2.0010	33.305	35.782	0.095630	0.15286	0.18403	166.85	18.851	29.248	10.311
415	1.6238	0.68534	1.4591	34.899	37.268	0.097660	0.15958	0.20431	156.26	19.092	32.469	11.011
430	2.0941	0.95152	1.0510	36.342	38.543	0.099299	0.16690	0.24064	142.23	20.076	36.596	11.947
445	2.6640	1.3789	0.72521	37.430	39.362	0.10003	0.17558	0.34061	123.63	22.072	43.254	13.438
460.35	3.3782	3.2710	0.30572	35.298	36.331	0.092549			0	18.924		

Single-Phase Properties

150.00	0.10000	10.435	0.095828	–21.406	–21.396	–0.097086	0.088566	0.12508	1763.3	–0.62386	168.19	3428.5
225.00	0.10000	9.4905	0.10537	–11.554	–11.543	–0.044025	0.10302	0.14001	1324.8	–0.52760	136.40	543.85
300.00	0.10000	8.4975	0.11768	–0.17289	–0.16112	–0.00053568	0.12345	0.16476	951.69	–0.35493	106.68	212.48
300.60	0.10000	8.4890	0.11780	–0.074609	–0.062829	–0.00020836	0.12363	0.16499	948.83	–0.35312	106.46	211.22
300.60	0.10000	0.041839	23.901	22.336	24.726	0.082257	0.11311	0.12344	185.73	32.344	15.250	7.3199
375.00	0.10000	0.032734	30.549	31.687	34.742	0.11194	0.13702	0.14615	210.31	14.520	23.271	9.1730
450.00	0.10000	0.027025	37.003	42.874	46.575	0.14064	0.16045	0.16919	231.26	8.0746	32.656	10.981
150.00	1.0000	10.441	0.095776	–21.422	–21.326	–0.097192	0.088617	0.12507	1767.4	–0.62411	168.39	3436.2
225.00	1.0000	9.5002	0.10526	–11.582	–11.477	–0.044150	0.10306	0.13992	1330.6	–0.52893	136.76	547.08
300.00	1.0000	8.5157	0.11743	–0.22558	–0.10815	–0.00071178	0.12349	0.16444	960.79	–0.36015	107.23	214.82
375.00	1.0000	7.2951	0.13708	13.279	13.417	0.039387	0.14609	0.19894	600.15	0.013112	82.749	108.44
388.92	1.0000	7.0019	0.14282	16.107	16.250	0.046804	0.15050	0.20848	526.70	0.17073	78.555	94.715
388.92	1.0000	0.39567	2.5273	32.081	34.609	0.094009	0.14812	0.17332	172.88	19.050	27.189	9.8772
450.00	1.0000	0.30367	3.2931	41.914	45.207	0.11931	0.16299	0.17764	207.91	9.5995	34.291	11.376
150.00	5.0000	10.466	0.095550	–21.491	–21.013	–0.097661	0.088840	0.12500	1785.1	–0.62511	169.25	3470.1
225.00	5.0000	9.5418	0.10480	–11.704	–11.180	–0.044697	0.10325	0.13954	1355.9	–0.53441	138.31	561.26
300.00	5.0000	8.5922	0.11638	–0.44721	0.13471	–0.0014609	0.12363	0.16321	999.20	–0.38047	109.58	224.97
375.00	5.0000	7.4791	0.13371	12.787	13.456	0.038048	0.14600	0.19336	670.90	–0.10299	86.612	119.86
450.00	5.0000	5.7922	0.17265	28.764	29.627	0.077218	0.16985	0.24769	327.62	1.0932	68.533	59.364
150.00	10.000	10.496	0.095275	–21.575	–20.622	–0.098235	0.089117	0.12494	1806.7	–0.62619	170.30	3511.8
225.00	10.000	9.5915	0.10426	–11.848	–10.805	–0.045356	0.10348	0.13913	1386.1	–0.54037	140.18	578.68
300.00	10.000	8.6795	0.11521	–0.69963	0.45251	–0.0023313	0.12382	0.16197	1043.2	–0.40072	112.31	237.18
375.00	10.000	7.6607	0.13054	12.293	13.598	0.036668	0.14603	0.18923	742.26	–0.18850	90.691	132.45
450.00	10.000	6.3848	0.15662	27.389	28.955	0.073910	0.16843	0.22130	471.81	0.27965	75.593	78.440
225.00	100.00	10.235	0.097700	–13.576	–3.8061	–0.054491	0.10727	0.13669	1787.0	–0.57796	165.84	860.73
300.00	100.00	9.6137	0.10402	–3.2651	7.1368	–0.012648	0.12720	0.15576	1539.5	–0.50239	145.78	420.70
375.00	100.00	9.0393	0.11063	8.5444	19.607	0.024366	0.14895	0.17686	1352.4	–0.43356	130.89	290.41
450.00	100.00	8.5029	0.11761	21.892	33.653	0.058454	0.17040	0.19748	1210.1	–0.37778	121.48	234.19
375.00	500.00	10.851	0.092161	5.2760	51.356	0.0033611	0.15705	0.17792	2411.2	–0.44269	211.59	864.12
450.00	500.00	10.550	0.094785	18.067	65.459	0.037589	0.17779	0.19805	2302.8	–0.40062	205.82	747.58

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data* **51**(3):785–850, 2006. The source for viscosity and thermal conductivity is NIST14, Version 9.08.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties are approximately 0.2% in density at temperatures up to 320 K, 0.5% in density at higher temperatures, 2% in heat capacity above 250 K, 4% in heat capacity at lower temperatures, 0.1% in the vapor phase speed of sound, 3% in the liquid-phase speed of sound, and 0.4% in vapor pressure at temperatures above 200 K. For viscosity, estimated uncertainty is 2%. For thermal conductivity, estimated uncertainty, except near the critical region, is 4–6%

TABLE 2-236 Thermodynamic Properties of 2-Methyl Pentane (Isohexane)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. Energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
119.60	7.3432E-12	9.3708	0.10671	–36.470	–36.470	–0.17002	0.10838	0.15299	2019.9	–0.59545
120.00	8.6393E-12	9.3662	0.10677	–36.409	–36.409	–0.16951	0.10835	0.15291	2016.9	–0.59577
140.00	2.6628E-09	9.1438	0.10936	–33.376	–33.376	–0.14612	0.10816	0.15094	1877.8	–0.60440
160.00	1.6516E-07	8.9315	0.11196	–30.354	–30.354	–0.12595	0.10991	0.15162	1750.1	–0.60052
180.00	3.6662E-06	8.7257	0.11460	–27.297	–27.297	–0.10795	0.11321	0.15435	1631.2	–0.58671
200.00	4.0345E–05	8.5239	0.11732	–24.169	–24.169	–0.091478	0.11773	0.15866	1519.7	–0.56534
220.00	0.00026966	8.3237	0.12014	–20.943	–20.943	–0.076105	0.12318	0.16418	1414.3	–0.53846
240.00	0.0012504	8.1236	0.12310	–17.596	–17.596	–0.061550	0.12928	0.17061	1314.2	–0.50751
260.00	0.0044049	7.9216	0.12624	–14.114	–14.113	–0.047617	0.13582	0.17772	1218.4	–0.47322
280.00	0.012572	7.7163	0.12960	–10.484	–10.483	–0.034172	0.14266	0.18535	1126.1	–0.43565
300.00	0.030459	7.5058	0.13323	–6.6984	–6.6944	–0.021115	0.14969	0.19342	1036.6	–0.39411
320.00	0.064855	7.2881	0.13721	–2.7483	–2.7394	–0.0083705	0.15683	0.20190	948.94	–0.34721
340.00	0.12457	7.0608	0.14163	1.3732	1.3908	0.0041212	0.16404	0.21081	862.49	–0.29249
360.00	0.22023	6.8210	0.14661	5.6736	5.7059	0.016411	0.17128	0.22027	776.48	–0.22585
380.00	0.36396	6.5643	0.15234	10.162	10.218	0.028548	0.17854	0.23047	690.10	–0.14022
400.00	0.56922	6.2850	0.15911	14.852	14.942	0.040580	0.18581	0.24183	602.46	–0.022615
420.00	0.85081	5.9735	0.16740	19.761	19.903	0.052569	0.19312	0.25521	512.43	0.15352
440.00	1.2253	5.6136	0.17814	24.925	25.143	0.064603	0.20057	0.27266	418.45	0.45116
460.00	1.7125	5.1716	0.19337	30.414	30.745	0.076849	0.20838	0.30051	317.90	1.0612
480.00	2.3384	4.5506	0.21975	36.430	36.944	0.089761	0.21745	0.37420	204.95	2.9251
497.70	3.0426	2.7150	0.36832	44.813	45.934	0.10771			0	22.418
119.60	7.3432E-12	7.7171E-12	1.2958E+11	3.2114	4.2058	0.17008	0.062593	0.070908	114.33	1878.9
120.00	8.6393E-12	8.8145E-12	1.1345E+11	3.2365	4.2342	0.16919	0.062751	0.071065	114.51	1852.6
140.00	2.6628E-09	2.2870E-09	43,7250,000.	4.5677	5.7317	0.13321	0.070285	0.078600	122.90	971.14
160.00	1.6516E-07	1.2415E-07	8,054,900.	6.0465	7.3769	0.10987	0.077610	0.085925	130.73	557.20
180.00	3.6662E-06	2.4497E-06	4,08,210.	7.6734	9.1700	0.094644	0.085136	0.093451	138.07	341.59
200.00	4.0345E-05	2.4265E-05	41,212.	9.4535	11.116	0.084949	0.092992	0.10131	144.98	220.67
220.00	0.00026966	0.00014751	6,779.4	11.391	13.220	0.079177	0.10116	0.10950	151.49	148.98
240.00	0.0012504	0.00062783	1,592.8	13.489	15.480	0.076268	0.10956	0.11797	157.59	104.56
260.00	0.0044049	0.0020480	488.27	15.742	17.893	0.075483	0.11814	0.12670	163.19	76.030
280.00	0.012572	0.0054602	183.14	18.144	20.447	0.076291	0.12686	0.13570	168.11	57.168
300.00	0.030459	0.012471	80.187	20.686	23.128	0.078294	0.13569	0.14499	172.17	44.401
320.00	0.064855	0.025273	39.568	23.355	25.921	0.081194	0.14461	0.15463	175.13	35.601
340.00	0.12457	0.046680	21.422	26.139	28.807	0.084758	0.15360	0.16471	176.74	29.461
360.00	0.22023	0.080240	12.463	29.022	31.767	0.088803	0.16265	0.17537	176.73	25.167
380.00	0.36396	0.13054	7.6606	31.987	34.775	0.093173	0.17176	0.18690	174.77	22.214
400.00	0.56922	0.20388	4.9048	35.009	37.801	0.097727	0.18095	0.19986	170.42	20.301
420.00	0.85081	0.30983	3.2276	38.050	40.796	0.10231	0.19027	0.21550	163.11	19.294
440.00	1.2253	0.46493	2.1509	41.048	43.683	0.10674	0.19983	0.23692	151.97	19.227
460.00	1.7125	0.70383	1.4208	43.875	46.308	0.11068	0.20995	0.27434	135.67	20.404
480.00	2.3384	1.1281	0.88647	46.190	48.263	0.11334	0.22144	0.38625	112.14	23.602
497.70	3.0426	2.7150	0.36832	44.813	45.934	0.10771			0	22.418

Single-Phase Properties										
150.00	0.10000	9.0371	0.11065	–31.868	–31.857	–0.13572	0.10883	0.15099	1813.1	–0.60387
250.00	0.10000	8.0239	0.12463	–15.876	–15.864	–0.054530	0.13251	0.17408	1266.4	–0.49091
332.95	0.10000	7.1422	0.14001	–0.099839	–0.085838	–0.00025709	0.16149	0.20761	892.88	–0.31289
332.95	0.10000	0.037947	26.353	25.145	27.780	0.083438	0.15042	0.16110	176.34	31.381
350.00	0.10000	0.035789	27.941	27.784	30.578	0.091632	0.15693	0.16712	181.93	25.747
450.00	0.10000	0.027168	36.808	45.429	49.110	0.13801	0.19438	0.20338	209.65	10.406
550.00	0.10000	0.022045	45.361	66.610	71.146	0.18212	0.22795	0.23660	232.80	5.5017
150.00	1.0000	9.0415	0.11060	–31.886	–31.775	–0.13584	0.10889	0.15098	1816.8	–0.60402
250.00	1.0000	8.0324	0.12450	–15.912	–15.787	–0.054671	0.13256	0.17397	1272.3	–0.49228
350.00	1.0000	6.9610	0.14366	3.4284	3.5720	0.010082	0.16769	0.21498	829.36	–0.26842
428.63	1.0000	5.8255	0.17166	21.956	22.127	0.057750	0.19631	0.26204	472.47	0.26084
428.63	1.0000	0.36934	2.7075	39.354	42.062	0.10426	0.19435	0.22372	158.83	19.140
450.00	1.0000	0.33044	3.0263	43.784	46.810	0.11507	0.19990	0.22188	173.64	14.396
550.00	1.0000	0.23887	4.1863	65.703	69.889	0.16131	0.22981	0.24260	216.16	6.1837
150.00	5.0000	9.0608	0.11037	–31.962	–31.410	–0.13635	0.10915	0.15096	1833.1	–0.60459
250.00	5.0000	8.0692	0.12393	–16.063	–15.443	–0.055282	0.13278	0.17352	1297.7	–0.49791
350.00	5.0000	7.0426	0.14199	3.1052	3.8152	0.0091444	0.16784	0.21301	873.72	–0.29846
450.00	5.0000	5.7124	0.17506	26.615	27.490	0.068380	0.20366	0.26396	476.76	0.22550
550.00	5.0000	2.3237	0.43035	58.312	60.464	0.13398	0.24134	0.37655	137.16	8.5257
150.00	10.000	9.0844	0.11008	–32.055	–30.954	–0.13698	0.10949	0.15093	1853.0	–0.60519
250.00	10.000	8.1131	0.12326	–16.241	–15.009	–0.056017	0.13305	0.17304	1328.1	–0.50401
350.00	10.000	7.1333	0.14019	2.7454	4.1473	0.0080780	0.16805	0.21116	923.39	–0.32667
450.00	10.000	5.9777	0.16729	25.695	27.368	0.066210	0.20340	0.25395	576.50	–0.0027791
550.00	10.000	4.3857	0.22801	52.778	55.059	0.12162	0.23673	0.29917	305.87	1.0063
250.00	100.00	8.6765	0.11525	–18.375	–6.8492	–0.066142	0.13735	0.17026	1729.6	–0.54229
350.00	100.00	8.0271	0.12458	–0.67131	11.787	–0.0037487	0.17182	0.20310	1445.5	–0.44895
450.00	100.00	7.4403	0.13440	20.331	33.771	0.051327	0.20635	0.23620	1247.4	–0.37634
550.00	100.00	6.9067	0.14479	44.426	58.905	0.10166	0.23764	0.26573	1108.2	–0.32474
450.00	500.00	9.0895	0.11002	16.069	71.078	0.028505	0.21492	0.23767	2315.0	–0.39042
550.00	500.00	8.7910	0.11375	39.474	96.350	0.079120	0.24537	0.26717	2204.0	–0.35059

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M.O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data* **51**(3):785–850, 2006. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in the equation of state are 0.2% in density in the liquid phase, 0.5% in density in the vapor phase, 1% in density above the critical temperature, 0.2% in vapor pressure between 280 and 350 K, 0.5% in vapor pressure at higher temperatures, 2% in heat capacities, and 1% in the speed of sound.

TABLE 2-237 Saturated Methyl Chloride*

T, K	P, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)	μ_f, 10^{-4} Pa·s	k_f, W/(m·K)
175	0.0117	8.84.–4	27.90	274.5	764.3	3.529	6.328	1.469		
180	0.0165	8.91.–4	19.85	280.9	767.7	3.570	6.274	1.472		
185	0.0233	8.97.–4	14.12	287.5	771.0	3.603	6.222	1.475		
190	0.0327	9.04.–4	10.12	294.5	774.3	3.647	6.172	1.477		
195	0.0462	9.10.–4	7.208	301.7	777.5	3.684	6.124	1.480		
200	0.0653	9.17.–4	5.137	309.0	780.7	3.722	6.080	1.483	4.44	0.241
205	0.0919	9.25.–4	3.835	316.3	783.9	3.756	6.038	1.486	4.27	0.236
210	0.1315	9.33.–4	2.656	323.7	787.0	3.791	5.998	1.489	4.11	0.232
215	0.181	9.40.–4	1.975	331.0	790.1	3.825	5.961	1.492	3.96	0.228
220	0.243	9.48.–4	1.505	338.4	793.2	3.859	5.928	1.496	3.82	0.224
225	0.319	9.56.–4	1.168	345.7	796.3	3.892	5.896	1.500	3.69	0.219
230	0.417	9.65.–4	0.911	353.1	799.3	3.925	5.866	1.504	3.57	0.215
235	0.539	9.73.–4	0.718	360.5	802.3	3.957	5.845	1.508	3.46	0.211
240	0.688	9.81.–4	0.572	368.0	805.3	3.988	5.822	1.513	3.35	0.207
245	0.866	9.89.–4	0.462	375.6	808.2	4.019	5.786	1.518	3.25	0.202
250	1.076	9.98.–4	0.377	383.2	811.1	4.050	5.762	1.523	3.16	0.198
255	1.328	10.08.–4	0.311	390.7	814.0	4.080	5.740	1.528	3.08	0.194
260	1.627	10.18.–4	0.257	398.3	816.8	4.110	5.720	1.533	3.00	0.190
265	1.970	10.27.–4	0.215	406.0	819.4	4.139	5.699	1.539	2.92	0.186
270	2.364	10.36.–4	0.1807	413.7	822.0	4.168	5.680	1.546	2.85	0.182
275	2.830	10.46.–4	0.1524	421.5	824.4	4.197	5.662	1.554	2.78	0.177
280	3.347	10.57.–4	0.1301	429.4	826.8	4.225	5.644	1.565	2.72	0.173
285	3.936	10.68.–4	0.1115	437.3	829.0	4.253	5.628	1.574	2.66	0.169
290	4.612	10.79.–4	0.0960	445.2	831.2	4.280	5.612	1.583	2.61	0.165
295	5.361	10.91.–4	0.0830	453.2	833.2	4.308	5.597	1.594	2.56	0.160
300	6.189	11.03.–4	0.0723	461.2	835.2	4.334	5.581	1.605	2.51	0.156
305	7.110	11.15.–4	0.0632	469.3	837.0	4.361	5.567	1.617	2.46	0.152
310	8.111	11.27.–4	0.0556	477.4	838.8	4.388	5.553	1.631	2.42	0.148
315	9.243	11.40.–4	0.0489	485.6	840.5	4.414	5.540	1.644	2.37	0.143
320	10.47	11.55.–4	0.0433	493.8	841.9	4.440	5.527	1.658	2.33	0.139
325	11.78	11.70.–4	0.0386	502.1	843.3	4.465	5.516		2.30	0.135
330	13.27	11.86.–4	0.0343	510.4	844.5	4.491	5.504		2.27	0.131
340	16.52	12.17.–4	0.0282	518.8	846.4	4.542	5.481		2.12	0.124
350	20.53	12.54.–4	0.0228	538.3	847.5	4.592	5.457		1.99	0.117
360	25.29	12.97.–4	0.0186	562.9	847.6	4.643	5.434		1.87	0.110
370	30.74	13.47.–4	0.0151	581.6	845.9	4.694	5.398		1.77	0.103
380	36.99	14.11.–4	0.0117	602.8	842.6	4.747	5.382		1.67	0.095
390	44.05	14.67.–4	0.0096	622.9	837.4	4.805	5.358		1.59	0.086
400	52.29	15.66.–4	0.0075	643.6	826.4	4.870	5.323		1.51	0.075
405	56.6	16.48.–4	0.0063	663.2	819.1	4.904	5.289			
410	61.5	17.97.–4	0.0052	677.3	807.1	4.954	5.256			
415	67.4	21.10.–4	0.0038	714.1	778.6	5.025	5.200			
416[c]	69.0	27.40.–4	0.0027	749.3	749.3	5.116	5.116			

*Interpolated by P. E. Liley from the Landolt-Börnstein band IVa, p. 677, 1967 tables by Steinle/Dienemann. c = critical point. The notation 8.84.–4 signifies 8.84×10^{-4}.

TABLE 2-238 Thermodynamic Properties of Neon

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
24.562	0.043464	62.059	0.016114	–0.099873	–0.099172	–0.0038092	0.018679	0.043081	674.66	–0.22893
25.000	0.050920	61.645	0.016222	–0.081689	–0.080863	–0.0030751	0.018439	0.040416	652.08	–0.25101
26.000	0.071611	60.761	0.016458	–0.042983	–0.041805	–0.0015561	0.018193	0.037847	617.51	–0.27322
27.000	0.098173	59.903	0.016694	–0.0055930	–0.0039541	–0.00014422	0.018006	0.037540	596.00	–0.27053
28.000	0.13159	59.032	0.016940	0.031967	0.034196	0.0012227	0.017803	0.038200	579.65	–0.25492
29.000	0.17287	58.129	0.017203	0.070340	0.073314	0.0025706	0.017589	0.039303	564.56	–0.23297
30.000	0.22307	57.186	0.017487	0.10979	0.11370	0.0039099	0.017371	0.040595	548.99	–0.20788
31.000	0.28324	56.198	0.017794	0.15041	0.15545	0.0052441	0.017156	0.041956	532.26	–0.18090
32.000	0.35446	55.162	0.018128	0.19218	0.19860	0.0065735	0.016952	0.043347	514.19	–0.15212
33.000	0.43782	54.078	0.018492	0.23507	0.24317	0.0078977	0.016768	0.044788	494.83	–0.12096
34.000	0.53443	52.941	0.018889	0.27908	0.28917	0.0092172	0.016614	0.046343	474.28	–0.086349
35.000	0.64543	51.749	0.019324	0.32426	0.33673	0.010534	0.016498	0.048115	452.65	–0.046782
36.000	0.77202	50.493	0.019805	0.37073	0.38602	0.011853	0.016426	0.050251	429.96	–0.00027396
37.000	0.91543	49.162	0.020341	0.41874	0.43736	0.013181	0.016404	0.052967	406.17	0.055871
38.000	1.0770	47.736	0.020948	0.46869	0.49125	0.014529	0.016438	0.056597	381.08	0.12549
39.000	1.2581	46.187	0.021651	0.52120	0.54844	0.015914	0.016536	0.061719	354.35	0.21441
40.000	1.4603	44.462	0.022491	0.57729	0.61014	0.017363	0.016715	0.069475	325.39	0.33222
41.000	1.6855	42.471	0.023545	0.63879	0.67848	0.018922	0.017014	0.082509	293.27	0.49632
42.000	1.9355	40.021	0.024987	0.70940	0.75776	0.020686	0.017522	0.10852	256.54	0.74180
43.000	2.2121	36.640	0.027292	0.79805	0.85843	0.022883	0.018471	0.17680	213.78	1.1433
44.000	2.5168	31.327	0.031921	0.92402	1.0044	0.026030	0.020210	0.44810	170.57	1.8283
44.492	2.6786	23.882	0.041873	1.0877	1.1999	0.030313			0	2.9448
24.562	0.043464	0.22026	4.5402	1.4817	1.6790	0.068586	0.035186	0.047919	113.01	27.054
25.000	0.050920	0.25406	3.9361	1.4898	1.6902	0.067767	0.029819	0.041791	115.48	23.404
26.000	0.071611	0.34598	2.8903	1.5046	1.7116	0.065882	0.022043	0.033098	121.12	18.114
27.000	0.098173	0.46111	2.1687	1.5159	1.7288	0.064031	0.018031	0.028839	126.17	15.446
28.000	0.13159	0.60299	1.6584	1.5247	1.7430	0.062250	0.016001	0.026943	130.23	14.023
29.000	0.17287	0.77543	1.2896	1.5318	1.7547	0.060549	0.015021	0.026349	133.28	13.110
30.000	0.22307	0.98260	1.0177	1.5372	1.7642	0.058928	0.014604	0.026517	135.55	12.393
31.000	0.28324	1.2292	0.81356	1.5411	1.7716	0.057377	0.014497	0.027183	137.25	11.758
32.000	0.35446	1.5204	0.65772	1.5435	1.7767	0.055888	0.014566	0.028231	138.54	11.166
33.000	0.43782	1.8625	0.53690	1.5443	1.7794	0.054449	0.014745	0.029633	139.52	10.606
34.000	0.53443	2.2630	0.44190	1.5432	1.7794	0.053047	0.015000	0.031418	140.26	10.073
35.000	0.64543	2.7308	0.36619	1.5401	1.7765	0.051670	0.015316	0.033669	140.78	9.5602
36.000	0.77202	3.2778	0.30508	1.5347	1.7702	0.050303	0.015688	0.036531	141.11	9.0641
37.000	0.91543	3.9193	0.25515	1.5265	1.7601	0.048930	0.016118	0.040243	141.24	8.5780
38.000	1.0770	4.6762	0.21385	1.5150	1.7453	0.047531	0.016614	0.045207	141.18	8.0944
39.000	1.2581	5.5788	0.17925	1.4994	1.7249	0.046079	0.017189	0.052136	140.93	7.6033
40.000	1.4603	6.6734	0.14985	1.4784	1.6972	0.044539	0.017863	0.062405	140.49	7.0917
41.000	1.6855	8.0363	0.12443	1.4500	1.6597	0.042855	0.018664	0.079029	139.83	6.5404
42.000	1.9355	9.8091	0.10195	1.4107	1.6080	0.040930	0.019634	0.10997	138.95	5.9193
43.000	2.2121	12.303	0.081282	1.3530	1.5328	0.038566	0.020823	0.18428	137.87	5.1760
44.000	2.5168	16.541	0.060455	1.2537	1.4058	0.035154	0.022208	0.55080	136.83	4.1789
44.492	2.6786	23.882	0.041873	1.0877	1.1999	0.030313			0	2.9448

TABLE 2-238 Thermodynamic Properties of Neon (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Single-Phase Properties										
100.00	0.10000	0.12034	8.3098	2.4474	3.2784	0.091975	0.012479	0.020851	262.24	1.6033
200.00	0.10000	0.060106	16.637	3.6964	5.3601	0.10641	0.012475	0.020800	370.87	0.12447
300.00	0.10000	0.040072	24.955	4.9441	7.4396	0.11484	0.012473	0.020791	454.13	–0.30667
400.00	0.10000	0.030057	33.270	6.1915	9.5185	0.12082	0.012473	0.020789	524.31	–0.49467
500.00	0.10000	0.024047	41.585	7.4388	11.597	0.12546	0.012473	0.020787	586.15	–0.59137
600.00	0.10000	0.020040	49.899	8.6861	13.676	0.12925	0.012472	0.020787	642.06	–0.64538
700.00	0.10000	0.017178	58.214	9.9333	15.755	0.13245	0.012472	0.020786	693.47	–0.67670
100.00	1.0000	1.2090	0.82716	2.4215	3.2486	0.072572	0.012547	0.021444	264.06	1.5285
200.00	1.0000	0.59828	1.6715	3.6864	5.3579	0.087212	0.012502	0.020926	373.32	0.11185
300.00	1.0000	0.39903	2.5061	4.9392	7.4453	0.095677	0.012491	0.020841	456.29	–0.30952
400.00	1.0000	0.29952	3.3387	6.1891	9.5278	0.10167	0.012485	0.020813	526.19	–0.49518
500.00	1.0000	0.23978	4.1705	7.4379	11.608	0.10631	0.012482	0.020800	587.81	–0.59127
600.00	1.0000	0.19992	5.0020	8.6861	13.688	0.11010	0.012480	0.020794	643.54	–0.64516
700.00	1.0000	0.17143	5.8334	9.9339	15.767	0.11331	0.012478	0.020791	694.81	–0.67651
100.00	5.0000	6.1145	0.16355	2.3075	3.1252	0.058098	0.012814	0.024056	275.27	1.1885
200.00	5.0000	2.9287	0.34145	3.6436	5.3508	0.073620	0.012619	0.021453	384.50	0.054603
300.00	5.0000	1.9580	0.51074	4.9181	7.4718	0.082226	0.012565	0.021051	465.95	–0.32325
400.00	5.0000	1.4747	0.67810	6.1787	9.5693	0.088261	0.012539	0.020917	534.57	–0.49810
500.00	5.0000	1.1837	0.84478	7.4338	11.658	0.092921	0.012523	0.020858	595.18	–0.59116
600.00	5.0000	0.98897	1.0112	8.6860	13.742	0.096721	0.012513	0.020828	650.12	–0.64435
700.00	5.0000	0.84934	1.1774	9.9366	15.824	0.099930	0.012506	0.020810	700.76	–0.67575
100.00	10.000	12.113	0.082559	2.1736	2.9992	0.051158	0.013095	0.026878	296.54	0.80676
200.00	10.000	5.6967	0.17554	3.5933	5.3487	0.067620	0.012752	0.022026	399.17	–0.014628
300.00	10.000	3.8255	0.26141	4.8930	7.5070	0.076381	0.012653	0.021291	478.16	–0.34148
400.00	10.000	2.8938	0.34556	6.1661	9.6217	0.082467	0.012603	0.021040	545.08	–0.50266
500.00	10.000	2.3306	0.42908	7.4286	11.719	0.087148	0.012573	0.020927	604.43	–0.59158
600.00	10.000	1.9519	0.51231	8.6858	13.809	0.090958	0.012553	0.020868	658.38	–0.64363
700.00	10.000	1.6795	0.59540	9.9399	15.894	0.094172	0.012539	0.020835	708.23	–0.67492
100.00	100.00	50.564	0.019777	1.4006	3.3783	0.028294	0.016249	0.028809	728.18	–0.37331
200.00	100.00	34.632	0.028875	3.1327	6.0202	0.046773	0.014308	0.024694	673.52	–0.43751
300.00	100.00	26.457	0.037796	4.6205	8.4001	0.056445	0.013708	0.023102	694.50	–0.49312
400.00	100.00	21.512	0.046486	6.0160	10.665	0.062965	0.013422	0.022262	729.70	–0.54535
500.00	100.00	18.185	0.054990	7.3645	12.863	0.067874	0.013245	0.021756	767.75	–0.58985
600.00	100.00	15.781	0.063366	8.6852	15.022	0.071810	0.013121	0.021432	805.72	–0.62513
700.00	100.00	13.955	0.071657	9.9877	17.153	0.075096	0.013028	0.021216	842.83	–0.65210
300.00	500.00	59.131	0.016912	4.6368	13.093	0.042072	0.015948	0.024091	1306.5	–0.47221
400.00	500.00	53.366	0.018738	6.0941	15.463	0.048897	0.015200	0.023386	1293.9	–0.49185
500.00	500.00	48.708	0.020530	7.5120	17.777	0.054063	0.014770	0.022915	1294.1	–0.50859
600.00	500.00	44.864	0.022290	8.9046	20.049	0.058207	0.014481	0.022544	1301.3	–0.52455
700.00	500.00	41.633	0.024020	10.278	22.288	0.061658	0.014265	0.022235	1312.5	–0.53993

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Katti, R. S., Jacobsen, R. T., Stewart, R. B., and Jahangiri, M., "Thermodynamic Properties for Neon for Temperatures from the Triple Point to 700 K at Pressures to 700 MPa," *Adv. Cryo. Eng.* **31**:1189–1197, 1986. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are 0.1% in density, 2% in heat capacity, and 1% in the speed of sound, except in the critical region. The uncertainty in vapor pressure is 0.2%.

TABLE 2-239 Thermodynamic Properties of Nitrogen

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
63.151	0.012520	30.957	0.032303	–4.2230	–4.2226	0.067951	0.032951	0.056033	995.28	–0.40419	173.24	311.59
65.000	0.017404	30.685	0.032589	–4.1194	–4.1188	0.069569	0.032591	0.056121	976.36	–0.39833	169.51	282.07
67.000	0.024300	30.387	0.032909	–4.0071	–4.0063	0.071270	0.032207	0.056231	956.04	–0.39135	165.49	254.55
69.000	0.033213	30.085	0.033239	–3.8946	–3.8935	0.072924	0.031831	0.056360	935.83	–0.38364	161.47	230.85
71.000	0.044527	29.779	0.033581	–3.7819	–3.7804	0.074535	0.031463	0.056512	915.66	–0.37508	157.47	210.32
73.000	0.058656	29.468	0.033935	–3.6689	–3.6669	0.076105	0.031106	0.056690	895.49	–0.36560	153.46	192.43
75.000	0.076043	29.153	0.034302	–3.5556	–3.5530	0.077637	0.030760	0.056899	875.28	–0.35506	149.47	176.75
77.000	0.097152	28.832	0.034683	–3.4419	–3.4385	0.079133	0.030427	0.057142	855.00	–0.34334	145.48	162.94
79.000	0.12247	28.506	0.035080	–3.3278	–3.3235	0.080597	0.030105	0.057425	834.61	–0.33029	141.50	150.71
81.000	0.15251	28.175	0.035493	–3.2132	–3.2078	0.082030	0.029795	0.057752	814.07	–0.31574	137.55	139.82
83.000	0.18780	27.837	0.035924	–3.0980	–3.0913	0.083436	0.029499	0.058130	793.36	–0.29951	133.61	130.07
85.000	0.22886	27.492	0.036375	–2.9822	–2.9739	0.084815	0.029215	0.058566	772.44	–0.28135	129.66	121.31
87.000	0.27626	27.139	0.036847	–2.8657	–2.8555	0.086172	0.028944	0.059068	751.28	–0.26099	125.72	113.38
89.000	0.33055	26.779	0.037343	–2.7483	–2.7360	0.087507	0.028687	0.059647	729.84	–0.23813	121.77	106.18
91.000	0.39230	26.409	0.037865	–2.6301	–2.6152	0.088823	0.028444	0.060315	708.09	–0.21237	117.83	99.602
93.000	0.46210	26.030	0.038417	–2.5107	–2.4930	0.090123	0.028215	0.061088	685.99	–0.18326	113.89	93.568
95.000	0.54052	25.640	0.039002	–2.3902	–2.3691	0.091408	0.028001	0.061983	663.50	–0.15025	109.95	88.004
97.000	0.62817	25.238	0.039623	–2.2683	–2.2434	0.092682	0.027804	0.063026	640.57	–0.11264	106.02	82.847
99.000	0.72566	24.822	0.040288	–2.1449	–2.1156	0.093946	0.027624	0.064246	617.14	–0.069613	102.08	78.042
101.00	0.83358	24.390	0.041000	–2.0196	–1.9854	0.095204	0.027464	0.065684	593.17	–0.020100	98.144	73.543
103.00	0.95259	23.941	0.041769	–1.8923	–1.8525	0.096459	0.027327	0.067392	568.58	0.037239	94.208	69.306
105.00	1.0833	23.471	0.042605	–1.7625	–1.7163	0.097715	0.027214	0.069443	543.30	0.10414	90.272	65.292
107.00	1.2264	22.978	0.043520	–1.6298	–1.5765	0.098977	0.027133	0.071937	517.24	0.18288	86.337	61.464
109.00	1.3826	22.457	0.044530	–1.4938	–1.4323	0.10025	0.027088	0.075021	490.29	0.27654	82.404	57.786
111.00	1.5526	21.902	0.045658	–1.3537	–1.2828	0.10154	0.027089	0.078914	462.32	0.38936	78.472	54.224
113.00	1.7371	21.306	0.046935	–1.2086	–1.1271	0.10285	0.027149	0.083966	433.19	0.52741	74.544	50.740
115.00	1.9370	20.658	0.048407	–1.0571	–0.96336	0.10420	0.027290	0.090771	402.67	0.69974	70.626	47.290
117.00	2.1533	19.943	0.050144	–0.89741	–0.78944	0.10561	0.027545	0.10044	370.43	0.92076	66.728	43.824
119.00	2.3869	19.134	0.052262	–0.72635	–0.60161	0.10710	0.027981	0.11531	335.85	1.2154	62.883	40.270
121.00	2.6391	18.187	0.054985	–0.53833	–0.39322	0.10873	0.028755	0.14140	297.68	1.6317	59.196	36.509
123.00	2.9116	16.997	0.058834	–0.32093	–0.14962	0.11059	0.030317	0.20028	253.32	2.2811	56.121	32.310
125.00	3.2069	15.210	0.065747	–0.031475	0.17937	0.11310	0.034680	0.46831	195.48	3.5308	56.435	26.935
126.19	3.3958	11.184	0.089414	0.51527	0.81891	0.11807			0	6.0831		
63.151	0.012520	0.024070	41.546	1.2945	1.8147	0.16355	0.021007	0.029647	161.11	40.718	5.6209	4.3763
65.000	0.017404	0.032594	30.680	1.3299	1.8639	0.16161	0.021059	0.029788	163.20	38.268	5.8164	4.5123
67.000	0.024300	0.044300	22.573	1.3675	1.9160	0.15966	0.021123	0.029969	165.37	35.907	6.0298	4.6601
69.000	0.033213	0.059031	16.940	1.4042	1.9668	0.15786	0.021196	0.030180	167.43	33.803	6.2457	4.8088
71.000	0.044527	0.077273	12.941	1.4400	2.0162	0.15618	0.021278	0.030427	169.39	31.922	6.4645	4.9585
73.000	0.058656	0.099542	10.046	1.4747	2.0639	0.15461	0.021370	0.030712	171.23	30.231	6.6870	5.1096
75.000	0.076043	0.12638	7.9124	1.5082	2.1099	0.15314	0.021472	0.031039	172.95	28.707	6.9138	5.2621
77.000	0.097152	0.15838	6.3140	1.5404	2.1539	0.15176	0.021585	0.031413	174.55	27.328	7.1458	5.4164
79.000	0.12247	0.19613	5.0986	1.5713	2.1957	0.15046	0.021709	0.031839	176.03	26.074	7.3839	5.5727
81.000	0.15251	0.24030	4.1614	1.6007	2.2353	0.14923	0.021845	0.032323	177.38	24.931	7.6295	5.7313
83.000	0.18780	0.29157	3.4297	1.6284	2.2725	0.14806	0.021994	0.032873	178.60	23.884	7.8837	5.8924
85.000	0.22886	0.35069	2.8515	1.6544	2.3070	0.14694	0.022157	0.033496	179.68	22.923	8.1483	6.0565
87.000	0.27626	0.41846	2.3897	1.6784	2.3386	0.14587	0.022334	0.034204	180.63	22.035	8.4251	6.2238
89.000	0.33055	0.49576	2.0171	1.7005	2.3672	0.14485	0.022528	0.035008	181.43	21.212	8.7163	6.3948
91.000	0.39230	0.58355	1.7137	1.7203	2.3925	0.14385	0.022738	0.035925	182.10	20.446	9.0247	6.5700
93.000	0.46210	0.68291	1.4643	1.7377	2.4143	0.14289	0.022967	0.036973	182.62	19.730	9.3533	6.7499
95.000	0.54052	0.79504	1.2578	1.7525	2.4324	0.14195	0.023217	0.038177	182.99	19.057	9.7060	6.9353
97.000	0.62817	0.92134	1.0854	1.7645	2.4463	0.14103	0.023489	0.039568	183.21	18.421	10.087	7.1270
99.000	0.72566	1.0634	0.94038	1.7733	2.4557	0.14012	0.023787	0.041185	183.28	17.815	10.503	7.3260
101.00	0.83358	1.2231	0.81759	1.7788	2.4603	0.13922	0.024113	0.043081	183.18	17.236	10.960	7.5334
103.00	0.95259	1.4027	0.71291	1.7804	2.4595	0.13832	0.024471	0.045326	182.93	16.676	11.467	7.7509
105.00	1.0833	1.6049	0.62309	1.7778	2.4528	0.13742	0.024860	0.048012	182.51	16.132	12.035	7.9804
107.00	1.2264	1.8331	0.54553	1.7703	2.4394	0.13651	0.025284	0.051276	181.93	15.600	12.679	8.2245

TABLE 2-239 Thermodynamic Properties of Nitrogen (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
109.00	1.3826	2.0916	0.47811	1.7573	2.4183	0.13557	0.025750	0.055332	181.19	15.075	13.419	8.4867
111.00	1.5526	2.3860	0.41911	1.7377	2.3884	0.13461	0.026284	0.060528	180.28	14.546	14.284	8.7716
113.00	1.7371	2.7240	0.36711	1.7102	2.3479	0.13360	0.026924	0.067435	179.15	13.996	15.315	9.0860
115.00	1.9370	3.1162	0.32091	1.6730	2.2946	0.13253	0.027721	0.077010	177.75	13.409	16.580	9.4395
117.00	2.1533	3.5786	0.27944	1.6234	2.2251	0.13138	0.028723	0.091003	176.01	12.767	18.186	9.8474
119.00	2.3869	4.1370	0.24172	1.5572	2.1341	0.13009	0.029997	0.11312	173.87	12.045	20.329	10.336
121.00	2.6391	4.8380	0.20670	1.4665	2.0119	0.12860	0.031683	0.15295	171.17	11.203	23.424	10.953
123.00	2.9116	5.7846	0.17287	1.3343	1.8376	0.12675	0.034185	0.24490	167.43	10.148	28.604	11.813
125.00	3.2069	7.3244	0.13653	1.1039	1.5417	0.12400	0.039278	0.66512	160.26	8.6030	41.535	13.326
126.19	3.3958	11.184	0.089414	0.51527	0.81891	0.11807			0	6.0831		
Single-Phase Properties												
100.00	0.10000	0.12268	8.1514	2.0396	2.8547	0.15950	0.021049	0.030012	201.64	16.082	9.3806	6.9581
600.00	0.10000	0.020037	49.908	12.573	17.564	0.21217	0.021796	0.030118	496.27	0.021483	44.840	29.577
1100.0	0.10000	0.010930	91.489	24.284	33.433	0.23131	0.024932	0.033248	660.05	–0.65654	70.075	44.199
1600.0	0.10000	0.0075152	133.06	37.272	50.579	0.24414	0.026815	0.035130	788.94	–0.81543	92.344	56.398
100.00	1.0000	24.658	0.040554	–2.0907	–2.0501	0.094493	0.027546	0.064564	609.42	–0.054514	100.58	76.255
103.75	1.0000	23.768	0.042073	–1.8441	–1.8020	0.096928	0.027281	0.068113	559.22	0.060996	92.738	67.783
103.75	1.0000	1.4754	0.67778	1.7800	2.4577	0.13799	0.024612	0.046272	182.79	16.471	11.671	7.8351
600.00	1.0000	0.19960	5.0099	12.554	17.564	0.19300	0.021812	0.030198	498.66	0.0061465	44.992	29.626
1100.0	1.0000	0.10899	9.1755	24.277	33.452	0.21216	0.024938	0.033267	662.07	–0.65940	70.155	44.221
1600.0	1.0000	0.074993	13.335	37.270	50.605	0.22499	0.026820	0.035138	790.64	–0.81612	92.399	56.411
100.00	5.0000	25.436	0.039314	–2.2176	–2.0210	0.093188	0.027713	0.059868	673.24	–0.17096	108.13	84.510
600.00	5.0000	0.98084	1.0195	12.469	17.567	0.17948	0.021881	0.030539	509.60	–0.057679	45.797	29.882
1100.0	5.0000	0.53797	1.8588	24.247	33.541	0.19875	0.024969	0.033350	671.08	–0.67112	70.555	44.330
1600.0	5.0000	0.37146	2.6921	37.259	50.720	0.21161	0.026839	0.035170	798.18	–0.81886	92.663	56.476
100.00	10.000	26.188	0.038186	–2.3398	–1.9580	0.091882	0.028004	0.056646	734.22	–0.25658	115.90	93.648
600.00	10.000	1.9183	0.52130	12.368	17.581	0.17355	0.021965	0.030926	523.87	–0.12928	46.995	30.284
1100.0	10.000	1.0590	0.94433	24.211	33.654	0.19296	0.025006	0.033447	682.37	–0.68394	71.130	44.493
1600.0	10.000	0.73435	1.3618	37.246	50.864	0.20583	0.026863	0.035209	807.57	–0.82170	93.033	56.570
600.00	500.00	27.434	0.036451	10.778	29.003	0.13791	0.026493	0.035336	1574.4	–0.70223	177.40	103.10
1100.0	500.00	21.868	0.045729	23.840	46.705	0.15935	0.027586	0.035848	1501.4	–0.72394	149.37	79.801
1600.0	500.00	18.335	0.054541	37.584	64.855	0.17295	0.028647	0.036665	1506.6	–0.73166	147.47	79.226
600.00	1000.0	34.270	0.029180	11.714	40.894	0.13093	0.029169	0.036905	2107.2	–0.61888	278.97	208.00
1100.0	1000.0	29.362	0.034057	25.065	59.122	0.15303	0.029373	0.036577	1985.1	–0.65271	232.49	129.86
1600.0	1000.0	25.920	0.038580	38.999	77.579	0.16685	0.029977	0.037212	1942.0	–0.65439	214.36	110.35

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Span, R., Lemmon, E. W., Jacobsen, R. T., Wagner, W., and Yokozeki, A., "A Reference Quality Thermodynamic Property Formulation for Nitrogen," *J. Phys. Chem. Ref. Data* **29**(6):1361–1433, 2000. See also *Int. J. Thermophys.* **14**(4):1121–1132, 1998. The source for viscosity is Lemmon, E. W., and Jacobsen, R. T., "Viscosity and Thermal Conductivity Equations for Nitrogen, Oxygen, Argon, and Air," *Int. J. Thermophys.* **25:**21–69, 2004. The source for thermal conductivity is Lemmon, E. W., and Jacobsen, R. T., "Viscosity and Thermal Conductivity Equations for Nitrogen, Oxygen, Argon, and Air," *Int. J. Thermophys.* **25:**21–69, 2004.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainty in density of the equation of state is 0.02% from the triple point up to temperatures of 523 K and pressures up to 12 MPa and from temperatures of 240 to 523 K at pressures less than 30 MPa. In the range from 270 to 350 K at pressures less than 12 MPa, the uncertainty in density is 0.01%. The uncertainty at very high pressures (>1 GPa) is 0.6% in density. The uncertainty in pressure in the critical region is estimated to be 0.02%. In the gaseous and supercritical region, the speed of sound can be calculated with a typical uncertainty of 0.005% to 0.1%. At liquid states and at high pressures, the uncertainty increases to 0.5% to 1.5%. For pressures up to 30 MPa, the estimated uncertainty for heat capacities ranges from 0.3% at gaseous and gaslike supercritical states up to 0.8% at liquid states and at certain gaseous and supercritical states at low temperatures. The uncertainty is 2% for pressures up to 200 MPa and larger at higher pressures. The estimated uncertainties of vapor pressure, saturated-liquid density, and saturated-vapor density are in general 0.02% for each property. The formulation yields a reasonable extrapolation behavior up to the limits of chemical stability of nitrogen.

For viscosity, the uncertainty is 0.5% in dilute gas. Away from the dilute gas (pressures greater than 1 MPa and in the liquid), the uncertainties are as low as 1% between 270 and 300 K at pressures less than 100 MPa, and increase outside that range. The uncertainties are around 2% at temperatures of 180 K and higher. Below this and away from the critical region, the uncertainties steadily increase to around 5% at the triple points of the fluids. The uncertainties in the critical region are higher.

For thermal conductivity, the uncertainty for the dilute gas is 2% with increasing uncertainties near the triple point. For the nondilute gas, the uncertainty is 2% for temperatures greater than 150 K. The uncertainty is 3% at temperatures less than the critical point and 5% in the critical region, except for states very near the critical point.

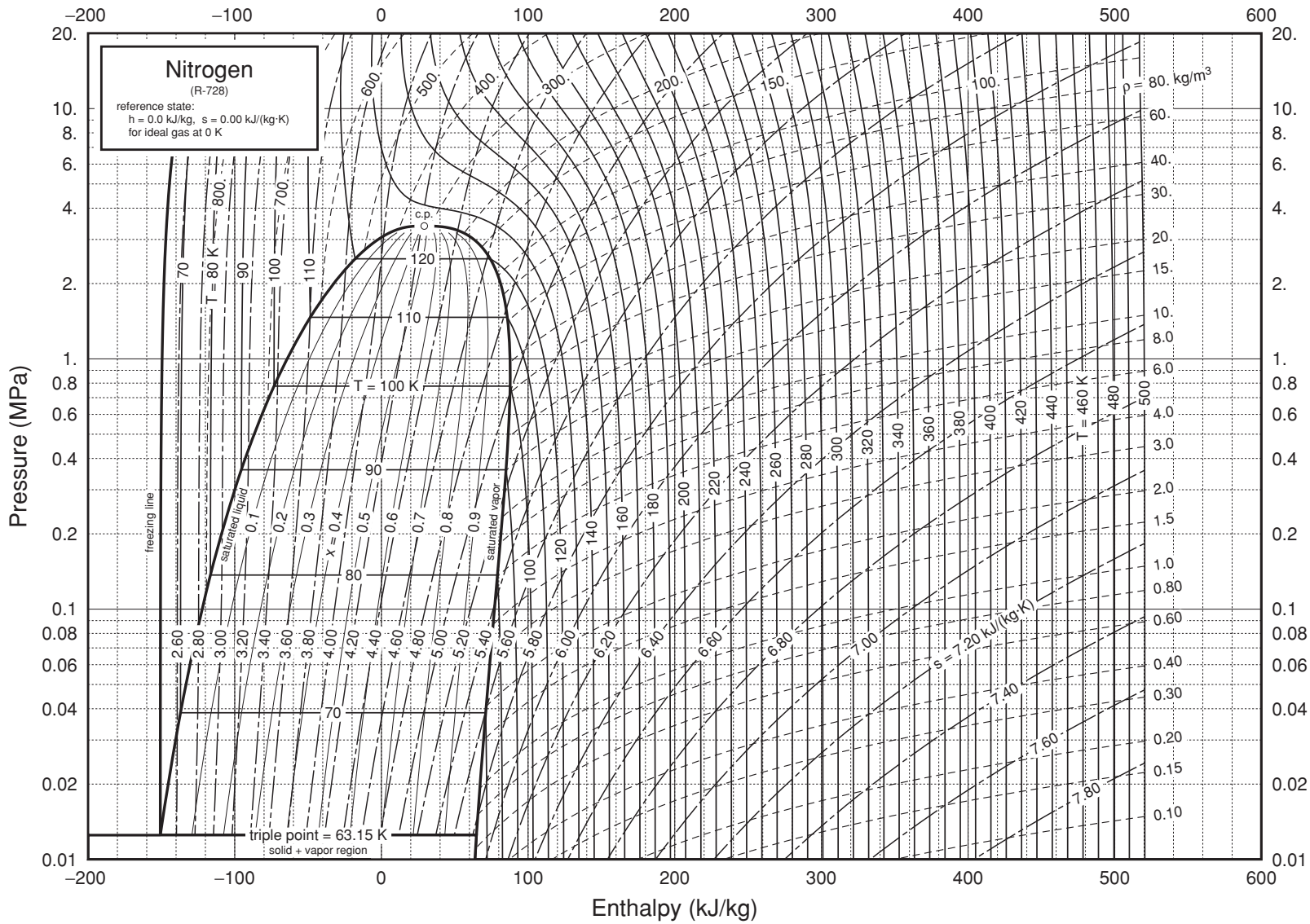

FIG. 2-13 Pressure-enthalpy diagram for nitrogen. Properties computed with the NIST REFPROP Database, Version 7.0 (Lemmon, E. W., McLinden, M. O., and Huber, M. L., 2002, NIST Standard Reference Database 23, NIST Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, Standard Reference Data Program, National Institute of Standards and Technology), based on the equation of state of Span, R., Lemmon, E. W., Jacobsen, R. T., Wagner, W., and Yokozeki, A,. "A Reference Equation of State for the Thermodynamic Properties of Nitrogen for Temperatures from 63.151 to 1000 K and Pressures to 2200 MPa.," *J. Phys. Chem. Ref. Data* **29**:1361–1433, 2000.

TABLE 2-240 Saturated Nitrogen Tetroxide

Pressure, bar	Temperature, K	v_f, m^3/kg	v_g, m^3/kg	M_f	M_g
1.0133	299.32	0.000 694	0.2996	91.857	79.157
2	309.57	0.000 711	0.1630	91.886	76.503
4	326.66	0.000 733	0.0876	91.766	73.538
6	337.43	0.000 749	0.0608	91.625	71.748
8	345.45	0.000 762	0.0469	91.488	70.480
10	351.88	0.000 774	0.0382	91.346	69.483
15	364.09	0.000 800	0.0262	90.979	67.742
20	373.17	0.000 822	0.0199	90.601	66.547
30	386.57	0.000 863	0.0133	89.823	64.997
40	396.52	0.000 903	0.0098	89.018	64.099
50	404.50	0.000 945	0.00761	88.191	63.532
60	411.20	0.000 993	0.00607	87.344	63.181
80	422.07	0.001 129	0.00394	85.602	62.959
100	430.76	0.001 577	0.00209	83.817	63.366

Condensed from McCarty, R. D., H-U. Steurer, et al., NBS IR 86 - 3054, 1986 (106 pp.). M = mol wt for the reaction $N_2O_4 \rightarrow 2NO_2 \rightarrow 2NO + O_2$. No derived thermodynamic functions were tabulated due to unduly large differences in literature values, but 92 references are given.

TABLE 2-241 Thermodynamic Properties of Nitrogen Trifluoride

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
90.000	0.00015612	25.006	0.039990	–3.8551	–3.8551	–0.033490	0.045791	0.070957	1081.4	–0.44772
95.000	0.00040547	24.719	0.040455	–3.4999	–3.4999	–0.029648	0.045221	0.071116	1049.3	–0.44233
100.00	0.00094625	24.427	0.040938	–3.1442	–3.1442	–0.026000	0.044514	0.071131	1018.1	–0.43718
105.00	0.0020164	24.132	0.041439	–2.7887	–2.7886	–0.022531	0.043768	0.071067	986.86	–0.43184
110.00	0.0039755	23.831	0.041962	–2.4336	–2.4335	–0.019227	0.043048	0.070980	955.57	–0.42594
115.00	0.0073310	23.526	0.042506	–2.0790	–2.0786	–0.016074	0.042394	0.070913	924.52	–0.41921
120.00	0.012759	23.217	0.043073	–1.7245	–1.7240	–0.013057	0.041825	0.070898	894.02	–0.41143
125.00	0.021119	22.902	0.043664	–1.3701	–1.3691	–0.010163	0.041346	0.070958	864.29	–0.40241
130.00	0.033457	22.583	0.044281	–1.0151	–1.0137	–0.0073784	0.040957	0.071113	835.40	–0.39193
135.00	0.051008	22.259	0.044925	–0.65928	–0.65699	–0.0046923	0.040653	0.071379	807.28	–0.37972
140.00	0.075184	21.931	0.045599	–0.30195	–0.29853	–0.0020929	0.040428	0.071771	779.79	–0.36549
145.00	0.10757	21.596	0.046304	0.057452	0.062433	0.00042986	0.040274	0.072303	752.68	–0.34889
150.00	0.14989	21.256	0.047046	0.41959	0.42664	0.0028858	0.040186	0.072988	725.72	–0.32951
155.00	0.20401	20.908	0.047829	0.78514	0.79490	0.0052840	0.040159	0.073841	698.67	–0.30688
160.00	0.27193	20.552	0.048658	1.1549	1.1681	0.0076328	0.040187	0.074876	671.28	–0.28044
165.00	0.35573	20.186	0.049539	1.5295	1.5472	0.0099402	0.040269	0.076114	643.36	–0.24950
170.00	0.45760	19.809	0.050483	1.9100	1.9331	0.012214	0.040404	0.077577	614.73	–0.21319
175.00	0.57979	19.418	0.051499	2.2972	2.3270	0.014461	0.040591	0.079300	585.25	–0.17042
180.00	0.72462	19.011	0.052602	2.6920	2.7301	0.016690	0.040834	0.081326	554.78	–0.11971
185.00	0.89450	18.584	0.053808	3.0957	3.1438	0.018907	0.041136	0.083719	523.23	–0.059078
190.00	1.0918	18.135	0.055141	3.5095	3.5697	0.021121	0.041505	0.086571	490.50	0.014249
195.00	1.3192	17.659	0.056630	3.9350	4.0097	0.023341	0.041953	0.090023	456.52	0.10427
200.00	1.5791	17.148	0.058316	4.3742	4.4663	0.025577	0.042494	0.094298	421.22	0.21696
205.00	1.8742	16.595	0.060260	4.8297	4.9426	0.027843	0.043150	0.099779	384.52	0.36170
210.00	2.2073	15.987	0.062552	5.3052	5.4433	0.030157	0.043953	0.10717	346.33	0.55413
215.00	2.5815	15.305	0.065340	5.8067	5.9754	0.032548	0.044950	0.11795	306.49	0.82239
220.00	3.0003	14.514	0.068899	6.3449	6.5516	0.035068	0.046220	0.13575	264.69	1.2231
225.00	3.4682	13.541	0.073850	6.9434	7.1995	0.037830	0.047920	0.17267	220.19	1.8903
230.00	3.9918	12.148	0.082320	7.6794	8.0080	0.041203	0.050506	0.30655	171.03	3.2539
234.00	4.4607	7.9200	0.12626	9.3687	9.9320	0.049280			0	8.0982
90.000	0.00015612	0.00020869	4791.8	9.0527	9.8008	0.11824	0.025384	0.033709	118.26	125.93
95.000	0.00040547	0.00051363	1946.9	9.1794	9.9688	0.11213	0.025553	0.033889	121.38	109.58
100.00	0.00094625	0.0011394	877.68	9.3064	10.137	0.10681	0.025759	0.034117	124.38	96.037
105.00	0.0020164	0.0023144	432.07	9.4337	10.305	0.10217	0.026007	0.034400	127.25	84.718
110.00	0.0039755	0.0043618	229.26	9.5609	10.472	0.098099	0.026301	0.034747	129.99	75.177
115.00	0.0073310	0.0077094	129.71	9.6879	10.639	0.094513	0.026641	0.035166	132.58	67.076
120.00	0.012759	0.012896	77.545	9.8143	10.804	0.091341	0.027032	0.035666	135.01	60.154
125.00	0.021119	0.020570	48.615	9.9397	10.966	0.088521	0.027474	0.036255	137.27	54.206
130.00	0.033457	0.031490	31.756	10.064	11.126	0.086004	0.027968	0.036942	139.35	49.068
135.00	0.051008	0.046520	21.496	10.186	11.282	0.083746	0.028515	0.037735	141.23	44.607
140.00	0.075184	0.066627	15.009	10.305	11.434	0.081709	0.029116	0.038644	142.91	40.717
145.00	0.10757	0.092885	10.766	10.422	11.580	0.079863	0.029770	0.039680	144.37	37.310
150.00	0.14989	0.12648	7.9063	10.536	11.721	0.078179	0.030477	0.040854	145.59	34.315
155.00	0.20401	0.16872	5.9269	10.645	11.854	0.076634	0.031236	0.042183	146.58	31.671
160.00	0.27193	0.22107	4.5236	10.750	11.980	0.075207	0.032049	0.043684	147.30	29.330
165.00	0.35573	0.28514	3.5071	10.850	12.097	0.073880	0.032913	0.045384	147.77	27.250
170.00	0.45760	0.36279	2.7564	10.943	12.205	0.072636	0.033831	0.047313	147.95	25.397
175.00	0.57979	0.45613	2.1923	11.031	12.302	0.071459	0.034801	0.049515	147.85	23.743
180.00	0.72462	0.56766	1.7616	11.110	12.386	0.070337	0.035825	0.052050	147.44	22.263
185.00	0.89450	0.70033	1.4279	11.181	12.458	0.069254	0.036905	0.055001	146.73	20.936
190.00	1.0918	0.85776	1.1658	11.241	12.514	0.068196	0.038044	0.058491	145.68	19.746
195.00	1.3192	1.0445	0.95740	11.289	12.552	0.067150	0.039245	0.062704	144.29	18.678
200.00	1.5791	1.2665	0.78960	11.323	12.570	0.066097	0.040516	0.067933	142.53	17.718
205.00	1.8742	1.5317	0.65287	11.340	12.563	0.065016	0.041867	0.074677	140.38	16.854
210.00	2.2073	1.8518	0.54001	11.333	12.525	0.063879	0.043315	0.083847	137.79	16.072
215.00	2.5815	2.2450	0.44543	11.296	12.446	0.062642	0.044890	0.097325	134.71	15.354

TABLE 2-241 Thermodynamic Properties of Nitrogen Trifluoride (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
220.00	3.0003	2.7432	0.36453	11.213	12.307	0.061229	0.046643	0.11971	131.07	14.662
225.00	3.4682	3.4146	0.29286	11.055	12.071	0.059479	0.048690	0.16599	126.78	13.900
230.00	3.9918	4.4712	0.22365	10.725	11.618	0.056898	0.051363	0.32814	121.80	12.709
234.00	4.4607	7.9200	0.12626	9.3687	9.9320	0.049280			0	8.0982
Single-Phase Properties										
100.00	0.10000	24.430	0.040934	–3.1452	–3.1411	–0.026009	0.044502	0.071124	1018.9	–0.43728
143.95	0.10000	21.667	0.046153	–0.018242	–0.013626	–0.000094174	0.040301	0.072179	758.35	–0.35259
143.95	0.10000	0.086803	11.520	10.398	11.550	0.080236	0.029628	0.039451	144.08	37.990
200.00	0.10000	0.060926	16.413	12.215	13.856	0.093729	0.034723	0.043508	169.06	15.650
300.00	0.10000	0.040232	24.856	16.237	18.723	0.11332	0.045284	0.053741	203.45	5.5743
400.00	0.10000	0.030102	33.220	21.208	24.530	0.12997	0.053558	0.061943	232.46	2.8668
500.00	0.10000	0.024060	41.562	26.869	31.025	0.14444	0.059251	0.067609	258.38	1.7661
100.00	1.0000	24.449	0.040901	–3.1540	–3.1131	–0.026098	0.044398	0.071055	1026.3	–0.43816
187.76	1.0000	18.339	0.054527	3.3230	3.3775	0.020131	0.041331	0.085231	505.29	–0.020346
187.76	1.0000	0.78400	1.2755	11.215	12.491	0.068667	0.037527	0.056853	146.19	20.263
200.00	1.0000	0.70199	1.4245	11.738	13.162	0.072132	0.037614	0.053386	154.62	16.645
300.00	1.0000	0.41548	2.4068	16.042	18.449	0.093526	0.045687	0.055540	199.37	5.5586
400.00	1.0000	0.30407	3.2887	21.082	24.371	0.11051	0.053632	0.062664	231.33	2.8289
500.00	1.0000	0.24110	4.1476	26.771	30.918	0.12510	0.059244	0.067998	258.62	1.7349
100.00	5.0000	24.532	0.040763	–3.1921	–2.9883	–0.026483	0.043955	0.070771	1057.9	–0.44174
200.00	5.0000	17.659	0.056627	4.1435	4.4266	0.024397	0.041665	0.087072	477.43	0.053822
300.00	5.0000	2.4334	0.41095	15.064	17.119	0.076882	0.047559	0.067409	183.97	5.3277
400.00	5.0000	1.5833	0.63161	20.512	23.670	0.095734	0.053907	0.066129	228.50	2.5958
500.00	5.0000	1.2132	0.82425	26.341	30.462	0.11087	0.059206	0.069735	260.85	1.5696
100.00	10.000	24.630	0.040600	–3.2377	–2.8317	–0.026951	0.043446	0.070455	1094.6	–0.44552
200.00	10.000	18.214	0.054902	3.8853	4.4343	0.023042	0.041251	0.081506	536.12	–0.078962
300.00	10.000	5.9501	0.16806	13.534	15.214	0.066202	0.049590	0.093780	185.51	3.9475
400.00	10.000	3.2770	0.30515	19.798	22.849	0.088300	0.054171	0.070777	231.76	2.1918
500.00	10.000	2.4256	0.41227	25.826	29.949	0.10414	0.059167	0.071809	266.86	1.3296
100.00	25.000	24.895	0.040168	–3.3631	–2.3589	–0.028280	0.042128	0.069766	1191.1	–0.45304
200.00	25.000	19.339	0.051709	3.3539	4.6466	0.020118	0.041959	0.074322	642.55	–0.26070
300.00	25.000	12.709	0.078686	10.815	12.782	0.052928	0.049110	0.086464	338.34	0.50765
400.00	25.000	7.8701	0.12706	17.964	21.141	0.077032	0.054897	0.079284	285.01	0.90188
500.00	25.000	5.7388	0.17425	24.506	28.863	0.094275	0.059344	0.076236	303.16	0.66132
100.00	50.000	25.271	0.039572	–3.5465	–1.5679	–0.030335	0.040341	0.069490	1322.6	–0.45498
200.00	50.000	20.560	0.048639	2.8054	5.2373	0.016816	0.044958	0.070043	734.96	–0.38097
300.00	50.000	15.995	0.062520	9.4909	12.617	0.046643	0.052084	0.076746	484.09	–0.15530
400.00	50.000	12.237	0.081722	16.326	20.412	0.069057	0.057087	0.078504	397.17	0.026532
500.00	50.000	9.6861	0.10324	23.086	28.248	0.086544	0.060630	0.078201	380.22	0.066751

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Younglove, B. A., "Thermophysical Properties of Fluids. I. Argon, Ethylene, Parahydrogen, Nitrogen, Nitrogen Trifluoride, and Oxygen," *J. Phys. Chem. Ref. Data* Suppl. 1, **11:** 1–11, 1982. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the critical point temperature are given in the last entry of the saturation tables. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in density are 0.25% in the liquid phase and 0.3% in the vapor and supercritical regions. The uncertainty in speed of sound and heat capacity is 5%.

TABLE 2-242 Thermodynamic Properties of Nitrous Oxide

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
182.33	0.087837	28.113	0.035570	–0.18142	–0.17830	–0.00096900	0.042295	0.075603	1149.6	–0.26723
185.00	0.10325	27.935	0.035797	0.020258	0.023954	0.00012922	0.042134	0.075669	1132.4	–0.26287
190.00	0.13782	27.599	0.036234	0.39840	0.40340	0.0021464	0.041852	0.075851	1100.2	–0.25377
195.00	0.18085	27.257	0.036688	0.77745	0.78408	0.0041159	0.041596	0.076111	1068.2	–0.24334
200.00	0.23367	26.910	0.037161	1.1577	1.1664	0.0060420	0.041365	0.076452	1036.3	–0.23146
205.00	0.29767	26.557	0.037656	1.5396	1.5508	0.0079284	0.041155	0.076875	1004.5	–0.21798
210.00	0.37431	26.197	0.038173	1.9234	1.9377	0.0097789	0.040967	0.077388	972.70	–0.20272
215.00	0.46509	25.829	0.038716	2.3094	2.3274	0.011597	0.040797	0.077995	940.94	–0.18545
220.00	0.57160	25.453	0.039288	2.6982	2.7206	0.013385	0.040645	0.078706	909.16	–0.16592
225.00	0.69544	25.069	0.039891	3.0899	3.1177	0.015148	0.040510	0.079533	877.35	–0.14379
230.00	0.83828	24.674	0.040529	3.4852	3.5192	0.016888	0.040392	0.080489	845.46	–0.11869
235.00	1.0018	24.268	0.041207	3.8844	3.9257	0.018607	0.040290	0.081595	813.47	–0.090113
240.00	1.1878	23.849	0.041930	4.2881	4.3379	0.020311	0.040203	0.082875	781.31	–0.057462
245.00	1.3979	23.417	0.042705	4.6969	4.7566	0.022000	0.040132	0.084362	748.95	–0.019968
250.00	1.6341	22.968	0.043538	5.1115	5.1826	0.023681	0.040078	0.086100	716.31	0.023355
255.00	1.8982	22.502	0.044440	5.5326	5.6170	0.025355	0.040041	0.088150	683.32	0.073794
260.00	2.1920	22.015	0.045423	5.9614	6.0609	0.027028	0.040025	0.090597	649.86	0.13307
265.00	2.5177	21.505	0.046501	6.3990	6.5161	0.028704	0.040030	0.093564	615.81	0.20351
270.00	2.8772	20.966	0.047697	6.8471	6.9843	0.030391	0.040064	0.097233	580.97	0.28843
275.00	3.2728	20.393	0.049037	7.3078	7.4682	0.032097	0.040134	0.10189	545.11	0.39261
280.00	3.7068	19.777	0.050564	7.7841	7.9715	0.033833	0.040251	0.10803	507.90	0.52333
285.00	4.1820	19.106	0.052339	8.2804	8.4993	0.035615	0.040437	0.11651	468.86	0.69225
290.00	4.7012	18.361	0.054464	8.8039	9.0600	0.037468	0.040727	0.12910	427.31	0.91943
295.00	5.2681	17.505	0.057125	9.3670	9.6680	0.039439	0.041190	0.14997	382.17	1.2430
300.00	5.8874	16.466	0.060732	9.9960	10.354	0.041620	0.041979	0.19222	331.57	1.7475
305.00	6.5663	15.022	0.066569	10.768	11.205	0.044293	0.043564	0.32907	271.24	2.6810
309.52	7.2447	10.270	0.097371	12.745	13.450	0.051414			0	6.2530
182.33	0.087837	0.059336	16.853	14.931	16.411	0.090017	0.025545	0.034993	211.93	44.590
185.00	0.10325	0.068951	14.503	14.984	16.481	0.089089	0.025844	0.035439	212.91	42.793
190.00	0.13782	0.090180	11.089	15.082	16.610	0.087443	0.026427	0.036334	214.62	39.645
195.00	0.18085	0.11615	8.6098	15.176	16.733	0.085908	0.027038	0.037309	216.14	36.768
200.00	0.23367	0.14754	6.7780	15.268	16.852	0.084469	0.027674	0.038365	217.48	34.146
205.00	0.29767	0.18508	5.4030	15.356	16.965	0.083117	0.028331	0.039506	218.62	31.765
210.00	0.37431	0.22958	4.3558	15.440	17.071	0.081842	0.029006	0.040736	219.56	29.606
215.00	0.46509	0.28190	3.5474	15.521	17.170	0.080634	0.029694	0.042062	220.30	27.653
220.00	0.57160	0.34298	2.9156	15.596	17.262	0.079485	0.030395	0.043494	220.82	25.888
225.00	0.69544	0.41387	2.4162	15.666	17.346	0.078387	0.031105	0.045048	221.13	24.295
230.00	0.83828	0.49575	2.0171	15.730	17.421	0.077332	0.031824	0.046741	221.20	22.858
235.00	1.0018	0.58993	1.6951	15.789	17.487	0.076314	0.032552	0.048600	221.04	21.560
240.00	1.1878	0.69791	1.4329	15.840	17.541	0.075325	0.033289	0.050660	220.64	20.387
245.00	1.3979	0.82145	1.2174	15.883	17.584	0.074359	0.034037	0.052967	219.98	19.325
250.00	1.6341	0.96261	1.0388	15.917	17.614	0.073408	0.034798	0.055585	219.07	18.361
255.00	1.8982	1.1239	0.88979	15.941	17.630	0.072464	0.035577	0.058600	217.88	17.483
260.00	2.1920	1.3082	0.76438	15.953	17.629	0.071519	0.036377	0.062136	216.41	16.679
265.00	2.5177	1.5196	0.65808	15.952	17.609	0.070564	0.037205	0.066370	214.64	15.939
270.00	2.8772	1.7627	0.56730	15.935	17.567	0.069588	0.038072	0.071572	212.56	15.251
275.00	3.2728	2.0443	0.48917	15.899	17.500	0.068575	0.038988	0.078164	210.15	14.603
280.00	3.7068	2.3734	0.42135	15.839	17.401	0.067508	0.039971	0.086856	207.39	13.981
285.00	4.1820	2.7632	0.36189	15.749	17.262	0.066361	0.041046	0.098934	204.24	13.366
290.00	4.7012	3.2349	0.30912	15.618	17.071	0.065093	0.042252	0.11700	200.67	12.734
295.00	5.2681	3.8252	0.26142	15.429	16.806	0.063636	0.043653	0.14723	196.63	12.043
300.00	5.8874	4.6102	0.21691	15.145	16.422	0.061848	0.045376	0.20883	192.02	11.210
305.00	6.5663	5.8106	0.17210	14.661	15.791	0.059328	0.047733	0.40691	186.66	10.014
309.52	7.2447	10.270	0.097371	12.745	13.450	0.051414			0	6.2530

TABLE 2-242 Thermodynamic Properties of Nitrous Oxide (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Single-Phase Properties										
200.00	0.10000	0.061319	16.308	15.382	17.013	0.092110	0.025918	0.035025	221.52	31.472
300.00	0.10000	0.040304	24.811	18.214	20.695	0.10698	0.030437	0.038943	267.85	10.733
400.00	0.10000	0.030129	33.190	21.467	24.786	0.11873	0.034363	0.042764	306.03	5.6159
500.00	0.10000	0.024075	41.537	25.072	29.226	0.12862	0.037563	0.045926	339.54	3.4059
200.00	1.0000	26.940	0.037120	1.1429	1.1800	0.0059677	0.041381	0.076317	1040.5	–0.23345
234.95	1.0000	24.272	0.041200	3.8803	3.9215	0.018590	0.040291	0.081583	813.80	–0.090429
234.95	1.0000	0.58888	1.6981	15.788	17.486	0.076324	0.032545	0.048580	221.04	21.573
300.00	1.0000	0.42412	2.3578	17.944	20.302	0.086931	0.031268	0.041833	260.01	10.924
400.00	1.0000	0.30696	3.2578	21.310	24.568	0.099190	0.034610	0.043833	303.02	5.5924
500.00	1.0000	0.24260	4.1220	24.963	29.085	0.10926	0.037680	0.046488	338.49	3.3701
200.00	5.0000	27.091	0.036913	1.0679	1.2525	0.0055897	0.041467	0.075665	1061.6	–0.24314
292.69	5.0000	17.918	0.055811	9.1008	9.3799	0.038510	0.040948	0.13883	403.56	1.0778
292.69	5.0000	3.5344	0.28294	15.525	16.940	0.064339	0.042976	0.13106	198.56	12.373
300.00	5.0000	3.1047	0.32209	16.114	17.725	0.066990	0.039518	0.091593	212.60	11.486
400.00	5.0000	1.6773	0.59621	20.558	23.539	0.083920	0.035787	0.049876	290.66	5.4199
500.00	5.0000	1.2538	0.79755	24.469	28.457	0.094897	0.038199	0.049186	334.89	3.1966
200.00	10.000	27.269	0.036672	0.97935	1.3461	0.0051379	0.041579	0.074951	1086.5	–0.25384
300.00	10.000	18.407	0.054327	9.1891	9.7324	0.038771	0.040304	0.11033	462.21	0.72534
400.00	10.000	3.7981	0.26329	19.470	22.102	0.075432	0.037387	0.061591	279.96	4.9171
500.00	10.000	2.6054	0.38381	23.835	27.673	0.087896	0.038831	0.052973	333.21	2.9341
200.00	25.000	27.751	0.036035	0.74199	1.6429	0.0038961	0.041933	0.073298	1154.2	–0.27902
300.00	25.000	20.902	0.047843	8.0747	9.2708	0.034710	0.039937	0.082004	654.64	0.10041
400.00	25.000	11.546	0.086610	16.070	18.235	0.060433	0.040060	0.087395	352.41	1.7332
500.00	25.000	6.9433	0.14402	21.962	25.563	0.076883	0.040346	0.063761	357.12	1.8422
300.00	50.000	22.869	0.043727	7.1665	9.3528	0.031190	0.040453	0.072893	828.55	–0.14288
400.00	50.000	17.051	0.058649	13.791	16.723	0.052389	0.040588	0.073379	568.05	0.23352
500.00	50.000	12.463	0.080236	19.764	23.776	0.068153	0.041531	0.067192	477.36	0.52378

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data* **51**(3):785–850, 2006. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in the equation of state are 0.1% in density in the liquid and vapor phases between 220 and 300 K, 0.25% at temperatures above 300 K and at temperatures below 220 K, and 0.5% in the critical region, except very close to the critical point. The uncertainty in vapor pressure is 0.2%, that for heat capacities is 3%, and that for the speed of sound in the vapor phase is 0.05% above 220 K. The uncertainty in the liquid phase is not known but is estimated to be within 5%.

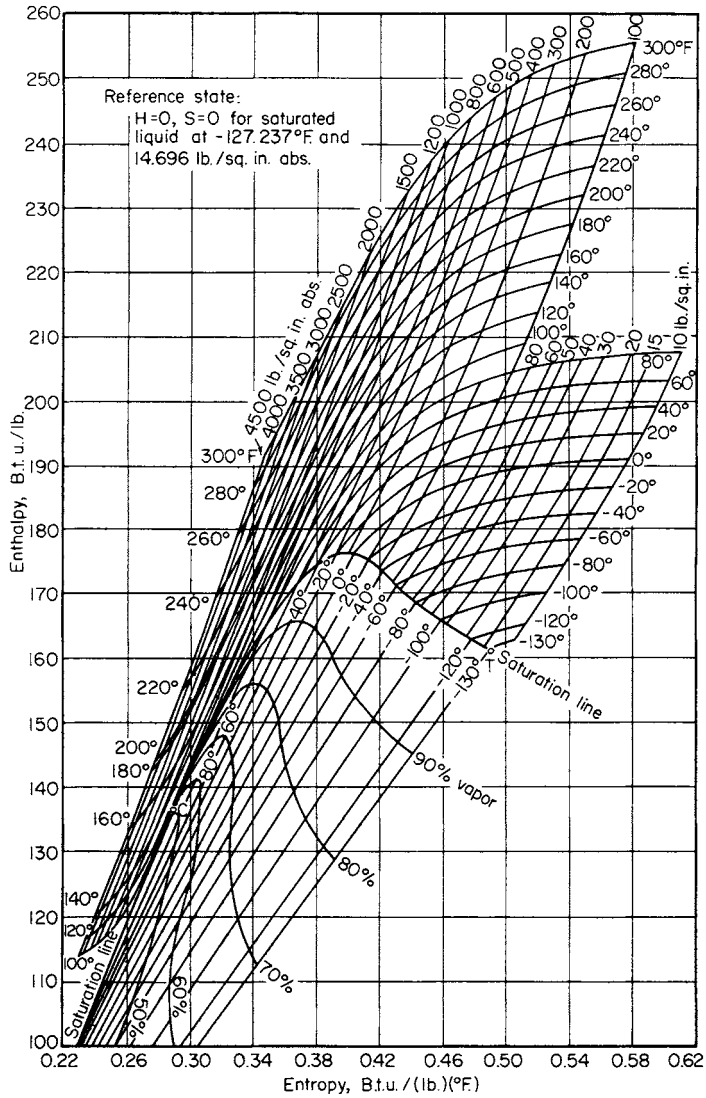

FIG. 2-14 Mollier diagram for nitrous oxide. (*Fig. 9, Univ. Texas Rep., Cont. DAI-23-072-ORD-685, June 1, 1956, by Couch and Kobe. Reproduced by permission.*) Some irregularity in the compressibility factors from 80 to 160 atm, 50 to 100 °C exists (*Couch, private communication, 1967*). See Couch et al., *J. Chem. Eng. Data*, **6,** (1961) for PVT data.

TABLE 2-243 Thermodynamic Properties of Nonane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
219.70	4.4449E-07	6.0520	0.16524	–60.675	–60.675	–0.19174	0.19748	0.25433	1544.5	–0.50071	153.02	4037.3
220.00	4.6229E-07	6.0501	0.16529	–60.599	–60.599	–0.19139	0.19757	0.25440	1543.0	–0.50053	152.90	3978.4
240.00	4.8933E-06	5.9249	0.16878	–55.459	–55.459	–0.16904	0.20402	0.25984	1449.8	–0.48613	145.29	1914.0
260.00	3.3858E-05	5.8013	0.17237	–50.195	–50.195	–0.14797	0.21164	0.26681	1361.7	–0.46790	138.35	1194.3
280.00	0.00016888	5.6785	0.17610	–44.779	–44.779	–0.12791	0.22016	0.27497	1277.9	–0.44671	131.98	842.44
300.00	0.00065182	5.5557	0.18000	–39.190	–39.190	–0.10863	0.22932	0.28402	1197.9	–0.42315	126.11	638.13
320.00	0.0020515	5.4321	0.18409	–33.413	–33.413	–0.089996	0.23894	0.29376	1121.1	–0.39747	120.68	505.83
340.00	0.0054791	5.3071	0.18843	–27.437	–27.436	–0.071883	0.24886	0.30400	1046.8	–0.36960	115.63	413.37
360.00	0.012806	5.1799	0.19305	–21.252	–21.249	–0.054209	0.25894	0.31464	974.60	–0.33918	110.92	344.96
380.00	0.026830	5.0496	0.19803	–14.851	–14.846	–0.036909	0.26908	0.32557	903.98	–0.30546	106.50	292.08
400.00	0.051367	4.9154	0.20344	–8.2313	–8.2208	–0.019932	0.27921	0.33677	834.45	–0.26723	102.33	249.76
420.00	0.091247	4.7760	0.20938	–1.3870	–1.3679	–0.0032367	0.28927	0.34824	765.54	–0.22257	98.374	214.92
440.00	0.15227	4.6299	0.21599	5.6854	5.7183	0.013213	0.29920	0.36002	696.76	–0.16849	94.594	185.56
460.00	0.24110	4.4754	0.22345	12.991	13.045	0.029452	0.30899	0.37228	627.57	–0.10004	90.947	160.30
480.00	0.36527	4.3096	0.23204	20.537	20.622	0.045513	0.31863	0.38530	557.35	–0.0087139	87.384	138.18
500.00	0.53313	4.1286	0.24221	28.335	28.464	0.061438	0.32814	0.39965	485.36	0.12153	83.848	118.43
520.00	0.75413	3.9259	0.25472	36.408	36.600	0.077283	0.33756	0.41650	410.60	0.32444	80.262	100.46
540.00	1.0392	3.6898	0.27102	44.798	45.080	0.093141	0.34703	0.43881	331.60	0.68436	76.518	83.674
560.00	1.4023	3.3948	0.29457	53.602	54.015	0.10920	0.35685	0.47629	245.76	1.4810	72.450	67.309
594.55	2.2820	1.8100	0.55249	73.819	75.080	0.144498	—	—	—	31.599	—	—
219.70	4.4449E-07	2.4333E-07	4,109,700.	–9.8808	–8.0542	0.047770	0.16161	0.16993	122.37	363.94	6.2016	4.0513
220.00	4.6229E-07	2.5273E-07	3,956,800.	–9.8323	–8.0032	0.047676	0.16174	0.17006	122.45	361.95	6.2133	4.0567
240.00	4.8933E-06	2.4522E-06	407,790.	–6.5064	–4.5110	0.043246	0.17103	0.17935	127.73	254.36	7.0659	4.4125
260.00	3.3858E-05	1.5664E-05	63,840.	–2.9862	–0.82471	0.041911	0.18119	0.18951	132.76	183.36	8.0682	4.7673
280.00	0.00016888	7.2578E-05	13,778.	0.74180	3.0688	0.042975	0.19199	0.20033	137.56	135.32	9.2127	5.1206
300.00	0.00065182	0.00026168	3,821.5	4.6851	7.1760	0.045920	0.20323	0.21161	142.11	102.10	10.493	5.4722
320.00	0.0020515	0.00077364	1,292.6	8.8457	11.497	0.050349	0.21478	0.22326	146.36	78.695	11.902	5.8211
340.00	0.0054791	0.0019519	512.31	13.220	16.027	0.055950	0.22652	0.23519	150.21	61.932	13.436	6.1663
360.00	0.012806	0.0043356	230.65	17.802	20.756	0.062471	0.23839	0.24737	153.55	49.767	15.091	6.5069
380.00	0.026830	0.0086887	115.09	22.580	25.668	0.069707	0.25032	0.25979	156.23	40.846	16.864	6.8425
400.00	0.051367	0.016023	62.412	27.541	30.747	0.077488	0.26226	0.27245	158.10	34.258	18.757	7.1737
420.00	0.091247	0.027625	36.200	32.671	35.974	0.085673	0.27416	0.28541	158.99	29.384	20.773	7.5025
440.00	0.15227	0.045117	22.165	37.952	41.327	0.094142	0.28601	0.29878	158.70	25.803	22.918	7.8332
460.00	0.24110	0.070581	14.168	43.363	46.779	0.10279	0.29779	0.31276	157.00	23.233	25.205	8.1731
480.00	0.36527	0.10681	9.3627	48.876	52.296	0.11150	0.30950	0.32778	153.58	21.504	27.655	8.5341
500.00	0.53313	0.15781	6.3369	54.456	57.834	0.12018	0.32118	0.34467	148.05	20.545	30.306	8.9361
520.00	0.75413	0.22994	4.3490	60.045	63.325	0.12868	0.33293	0.36530	139.82	20.405	33.233	9.4142
540.00	1.0392	0.33476	2.9872	65.548	68.652	0.13679	0.34492	0.39454	127.99	21.346	36.613	10.039
560.00	1.4023	0.49815	2.0074	70.762	73.577	0.14413	0.35757	0.44973	111.07	24.126	40.989	10.990
594.55	2.2820	1.8100	0.55249	73.819	75.080	0.144498	—	—	—	31.599	—	—

Single-Phase Properties

250.00	0.10000	5.8635	0.17055	–52.849	–52.832	–0.15838	0.20771	0.26315	1405.7	–0.47750	141.78	1483.4
300.00	0.10000	5.5564	0.17997	–39.196	–39.178	–0.10865	0.22933	0.28401	1198.6	–0.42329	126.15	638.82
350.00	0.10000	5.2447	0.19067	–24.378	–24.359	–0.063016	0.25389	0.30925	1011.2	–0.35500	113.28	377.18
400.00	0.10000	4.9160	0.20342	–8.2368	–8.2164	–0.019946	0.27921	0.33675	834.97	–0.26752	102.36	249.91
423.42	0.10000	4.7515	0.21046	–0.19510	–0.17406	–0.00041018	0.29097	0.35022	753.80	–0.21411	97.717	209.56
423.42	0.10000	0.030145	33.173	33.563	36.880	0.087103	0.27619	0.28766	159.03	28.690	21.130	7.5587
450.00	0.10000	0.027993	35.724	41.125	44.697	0.10500	0.28978	0.30044	165.87	22.301	23.838	8.0448
500.00	0.10000	0.024798	40.326	56.284	60.317	0.13790	0.31440	0.32419	177.26	14.792	29.272	8.9428
250.00	1.0000	5.8679	0.17042	–52.889	–52.719	–0.15854	0.20778	0.26309	1410.5	–0.47809	142.11	1501.9
300.00	1.0000	5.5624	0.17978	–39.250	–39.070	–0.10883	0.22940	0.28387	1204.4	–0.42451	126.55	645.13
350.00	1.0000	5.2530	0.19037	–24.450	–24.260	–0.063223	0.25395	0.30900	1018.5	–0.35745	113.76	380.90
400.00	1.0000	4.9280	0.20292	–8.3375	–8.1346	–0.020199	0.27927	0.33627	844.45	–0.27280	102.96	252.79
450.00	1.0000	4.5708	0.21878	9.1743	9.3930	0.021057	0.30414	0.36516	674.11	–0.14850	93.482	174.91
500.00	1.0000	4.1469	0.24114	28.203	28.444	0.061172	0.32810	0.39811	496.26	0.096651	84.482	120.06
250.00	5.0000	5.8875	0.16985	–53.064	–52.214	–0.15925	0.20809	0.26282	1431.5	–0.48055	143.55	1587.0
300.00	5.0000	5.5884	0.17894	–39.480	–38.585	–0.10961	0.22969	0.28333	1229.8	–0.42952	128.25	673.50
350.00	5.0000	5.2884	0.18909	–24.758	–23.813	–0.064113	0.25422	0.30802	1049.7	–0.36725	115.82	397.43
400.00	5.0000	4.9781	0.20088	–8.7590	–7.7546	–0.021267	0.27950	0.33447	884.19	–0.29292	105.52	265.35
450.00	5.0000	4.6466	0.21521	8.5689	9.6450	0.019689	0.30429	0.36159	727.45	–0.19528	96.800	186.34
500.00	5.0000	4.2772	0.23380	27.246	28.415	0.059215	0.32797	0.38941	574.69	–0.043276	89.174	132.45
250.00	10.000	5.9111	0.16917	–53.273	–51.582	–0.16011	0.20848	0.26253	1456.9	–0.48327	145.29	1699.9
300.00	10.000	5.6194	0.17796	–39.753	–37.973	–0.11054	0.23005	0.28275	1260.0	–0.43494	130.31	709.84
350.00	10.000	5.3297	0.18763	–25.116	–23.240	–0.065168	0.25456	0.30700	1086.3	–0.37743	118.27	418.13
400.00	10.000	5.0347	0.19862	–9.2354	–7.2492	–0.022500	0.27981	0.33273	929.33	–0.31235	108.48	280.67
450.00	10.000	4.7272	0.21154	7.9189	10.034	0.018184	0.30452	0.35854	784.82	–0.23486	100.47	199.70
500.00	10.000	4.3995	0.22730	26.321	28.594	0.057270	0.32803	0.38371	650.34	–0.13338	93.894	145.66
300.00	100.00	6.0143	0.16627	–43.037	–26.410	–0.12342	0.23562	0.27987	1662.5	–0.46881	158.86	1638.6
350.00	100.00	5.8100	0.17212	–29.086	–11.875	–0.078654	0.25980	0.30194	1534.1	–0.43419	149.98	851.44
400.00	100.00	5.6178	0.17800	–13.998	3.8029	–0.036820	0.28476	0.32520	1426.4	–0.40174	143.57	557.39
450.00	100.00	5.4358	0.18396	2.2421	20.639	0.0028129	0.30915	0.34808	1335.5	–0.37331	139.19	406.92
500.00	100.00	5.2628	0.19001	19.589	38.590	0.040621	0.33224	0.36974	1258.2	–0.34915	136.49	316.22
500.00	300.00	5.9601	0.16778	15.017	65.352	0.023367	0.33895	0.37096	1885.2	–0.36365	184.31	733.45

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data* **51**(3):785–850, 2006. The source for viscosity is Huber, M. L., Laesecke, A., and Xiang, H. W., "Viscosity Correlations for Minor Constituent Fluids in Natural Gas: *n*-Octane, *n*-Nonane and *n*-Decane," *Fluid Phase Equilibria* **224**:263–270, 2004. The source for thermal conductivity is Huber, M. L., and Perkins, R. A., "Thermal Conductivity Correlations for Minor Constituent Fluids in Natural Gas: *n*-Octane, *n*-Nonane and *n*-Decane," *Fluid Phase Equilibria* **227**:47–55, 2004.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in the equation are 0.05% in the saturated-liquid density between 280 and 335 K and 0.2% in density in the liquid phase below 430 K and 10 MPa. The uncertainty increases to 0.3% up to 100 MPa and 0.5% up to 800 MPa. In the vapor phase and at supercritical state points, the uncertainty in density is 1%, whereas in the liquid phase between 430 K and the critical point it is 0.5% in density. Other uncertainties are 0.2% in vapor pressure between 300 and 430 K, 0.5% in vapor pressure at higher temperatures, 2% in heat capacities below 550 K, 5% at higher temperatures, and 1% in the liquid-phase speed of sound below 430 K. The estimated uncertainty in viscosity is 1.0% along the saturated-liquid line, 5% elsewhere. Uncertainty in thermal conductivity is 3%, except in the supercritical region and dilute gas which have an uncertainty of 5%.

TABLE 2-244 Thermodynamic Properties of Octane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
216.37	1.9889E-06	6.6864	0.14956	–47.586	–47.586	–0.15718	0.18017	0.22965	1496.9	–0.50088	153.28	2275.3
220.00	3.0719E-06	6.6606	0.15014	–46.751	–46.751	–0.15335	0.18100	0.23031	1479.7	–0.49876	151.81	2055.6
240.00	2.5565E-05	6.5193	0.15339	–42.103	–42.103	–0.13313	0.18613	0.23473	1388.4	–0.48455	144.08	1275.2
260.00	0.00014507	6.3793	0.15676	–37.353	–37.353	–0.11412	0.19222	0.24044	1301.6	–0.46633	136.89	875.51
280.00	0.00061336	6.2396	0.16027	–32.477	–32.477	–0.096062	0.19917	0.24730	1218.5	–0.44452	130.16	644.21
300.00	0.0020600	6.0991	0.16396	–27.455	–27.454	–0.078739	0.20684	0.25511	1138.6	–0.41949	123.83	498.03
320.00	0.0057644	5.9569	0.16787	–22.268	–22.267	–0.062005	0.21505	0.26370	1061.2	–0.39136	117.86	399.06
340.00	0.013932	5.8120	0.17206	–16.904	–16.901	–0.045746	0.22363	0.27290	985.87	–0.35994	112.19	328.21
360.00	0.029907	5.6633	0.17657	–11.351	–11.345	–0.029879	0.23245	0.28260	912.09	–0.32455	106.78	275.06
380.00	0.058269	5.5097	0.18150	–5.6010	–5.5904	–0.014338	0.24139	0.29271	839.36	–0.28395	101.59	233.59
400.00	0.10483	5.3495	0.18693	0.35204	0.37164	0.00092888	0.25035	0.30321	767.20	–0.23602	96.614	200.14
420.00	0.17652	5.1809	0.19302	6.5150	6.5490	0.015963	0.25926	0.31416	695.05	–0.17723	91.804	172.37
440.00	0.28132	5.0012	0.19995	12.895	12.951	0.030805	0.26810	0.32572	622.34	–0.10167	87.139	148.75
460.00	0.42812	4.8068	0.20804	19.502	19.591	0.045494	0.27685	0.33823	548.39	0.0013050	82.591	128.19
480.00	0.62676	4.5922	0.21776	26.352	26.489	0.060080	0.28552	0.35240	472.36	0.15251	78.136	109.92
500.00	0.88820	4.3477	0.23000	33.473	33.677	0.074631	0.29419	0.36979	393.17	0.39829	73.755	93.322
520.00	1.2251	4.0556	0.24657	40.921	41.223	0.089269	0.30300	0.39457	309.23	0.86399	69.457	77.803
540.00	1.6533	3.6731	0.27225	48.832	49.282	0.10426	0.31238	0.44291	217.99	2.0228	65.431	62.572
560.00	2.1958	3.0341	0.32959	57.752	58.476	0.12068	0.32413	0.68855	115.40	7.6023	64.209	45.346
569.32	2.4978	2.0564	0.48629	64.527	65.741	0.13332			0	28.218		
216.37	1.9889E-06	1.1056E-06	904,510.	–1.8491	–0.050104	0.062519	0.14278	0.15110	129.10	314.66	6.1594	4.2034
220.00	3.0719E-06	1.6794E-06	595,460.	–1.3282	0.50093	0.061430	0.14422	0.15253	130.14	294.38	6.3194	4.2717
240.00	2.5565E-05	1.2813E-05	78,047.	1.6370	3.6323	0.057431	0.15246	0.16078	135.72	207.62	7.2936	4.6468
260.00	0.00014507	6.7137E-05	14,895.	4.7709	6.9318	0.056201	0.16128	0.16962	141.02	150.42	8.4195	5.0206
280.00	0.00061336	0.00026380	3,790.7	8.0822	10.407	0.057097	0.17068	0.17906	146.04	111.63	9.6907	5.3924
300.00	0.0020600	0.00082859	1,206.9	11.576	14.062	0.059649	0.18058	0.18906	150.71	84.719	11.102	5.7614
320.00	0.0057644	0.0021820	458.30	15.253	17.894	0.063500	0.19087	0.19955	154.94	65.728	12.651	6.1263
340.00	0.013932	0.0049961	200.15	19.108	21.897	0.068366	0.20147	0.21047	158.59	52.133	14.338	6.4865
360.00	0.029907	0.010232	97.731	23.136	26.058	0.074020	0.21227	0.22178	161.53	42.292	16.164	6.8419
380.00	0.058269	0.019165	52.177	27.323	30.363	0.080278	0.22318	0.23348	163.56	35.112	18.138	7.1948
400.00	0.10483	0.033420	29.922	31.658	34.794	0.086985	0.23415	0.24557	164.51	29.858	20.268	7.5505
420.00	0.17652	0.055042	18.168	36.123	39.330	0.094013	0.24512	0.25818	164.17	26.034	22.571	7.9191
440.00	0.28132	0.086662	11.539	40.698	43.945	0.10124	0.25607	0.27154	162.27	23.316	25.072	8.3171
460.00	0.42812	0.13183	7.5854	45.358	48.605	0.10857	0.26700	0.28610	158.49	21.503	27.811	8.7715
480.00	0.62676	0.19572	5.1093	50.064	53.266	0.11587	0.27795	0.30284	152.37	20.514	30.863	9.3258
500.00	0.88820	0.28672	3.4877	54.757	57.855	0.12299	0.28899	0.32404	143.24	20.401	34.377	10.056
520.00	1.2251	0.42068	2.3771	59.333	62.245	0.12970	0.30032	0.35598	130.05	21.459	38.702	11.113
540.00	1.6533	0.63573	1.5730	63.555	66.156	0.13551	0.31238	0.42387	111.06	24.546	44.855	12.885
560.00	2.1958	1.0851	0.92161	66.584	68.608	0.13877	0.32642	0.78365	83.717	31.412	57.602	17.102
569.32	2.4978	2.0564	0.48629	64.527	65.741	0.13332			0	28.218		

Single-Phase Properties

300.00	0.10000	6.0999	0.16394	–27.460	–27.444	–0.078758	0.20684	0.25509	1139.3	–0.41966	123.88	498.56
398.30	0.10000	5.3634	0.18645	–0.16168	–0.14303	–0.00035827	0.24959	0.30230	773.32	–0.24045	97.030	202.73
398.30	0.10000	0.031955	31.294	31.284	34.413	0.086401	0.23322	0.24453	164.48	30.243	20.080	7.5200
400.00	0.10000	0.031787	31.459	31.684	34.830	0.087444	0.23402	0.24527	164.97	29.707	20.249	7.5528
500.00	0.10000	0.024611	40.633	57.485	61.548	0.14688	0.27938	0.28878	189.53	12.431	31.224	9.4433
600.00	0.10000	0.020274	49.325	87.490	92.422	0.20307	0.31885	0.32771	209.46	6.6034	43.584	11.290
300.00	1.0000	6.1073	0.16374	–27.511	–27.347	–0.078927	0.20690	0.25495	1145.7	–0.42119	124.30	503.48
400.00	1.0000	5.3654	0.18638	0.25030	0.43668	0.00067378	0.25038	0.30262	778.09	–0.24368	97.295	202.65
500.00	1.0000	4.3556	0.22959	33.432	33.661	0.074548	0.29416	0.36900	396.85	0.38286	73.948	93.722
507.20	1.0000	4.2495	0.23532	36.111	36.346	0.079880	0.29733	0.37746	363.62	0.52889	72.196	87.646
507.20	1.0000	0.32874	3.0419	56.425	59.467	0.12547	0.29302	0.33370	139.04	20.620	35.810	10.386
600.00	1.0000	0.22849	4.3766	85.870	90.247	0.18117	0.32280	0.33940	186.79	8.0078	45.491	11.637
300.00	5.0000	6.1393	0.16288	–27.730	–26.915	–0.079664	0.20714	0.25435	1173.4	–0.42743	126.15	525.55
400.00	5.0000	5.4311	0.18413	–0.17211	0.74852	–0.00039889	0.25054	0.30044	823.37	–0.27213	100.17	213.73
500.00	5.0000	4.5686	0.21888	32.275	33.369	0.072174	0.29359	0.35339	499.49	0.076618	79.631	105.97
600.00	5.0000	3.0593	0.32688	70.832	72.466	0.14322	0.33497	0.44331	188.23	2.6621	64.841	42.657
300.00	10.000	6.1772	0.16188	–27.987	–26.368	–0.080546	0.20745	0.25373	1206.2	–0.43408	128.36	553.60
400.00	10.000	5.5037	0.18170	–0.64047	1.1765	–0.0016150	0.25077	0.29842	873.81	–0.29834	103.45	227.34
500.00	10.000	4.7443	0.21078	31.275	33.383	0.070056	0.29343	0.34556	588.81	–0.072942	84.985	118.55
600.00	10.000	3.7971	0.26336	67.577	70.211	0.13708	0.33156	0.38999	358.22	0.45738	73.121	61.952
300.00	50.000	6.4220	0.15572	–29.605	–21.819	–0.086527	0.20976	0.25121	1422.7	–0.46254	143.51	798.49
400.00	50.000	5.8987	0.16953	–3.1776	5.2989	–0.0087968	0.25276	0.29206	1159.5	–0.38084	123.35	335.22
500.00	50.000	5.4043	0.18504	27.307	36.559	0.060791	0.29481	0.33234	965.74	–0.30867	110.66	198.43
600.00	50.000	4.9374	0.20254	61.436	71.563	0.12452	0.33146	0.36666	826.07	–0.24994	103.74	134.83
300.00	100.00	6.6452	0.15048	–30.984	–15.936	–0.092407	0.21232	0.25061	1629.4	–0.47349	158.61	1163.7
400.00	100.00	6.2050	0.16116	–5.0534	11.063	–0.015013	0.25503	0.29032	1399.1	–0.40628	141.31	478.53
500.00	100.00	5.8089	0.17215	24.893	42.108	0.054099	0.29686	0.32988	1233.7	–0.35233	131.06	291.34
600.00	100.00	5.4489	0.18352	58.505	76.857	0.11736	0.33331	0.36412	1113.8	–0.31375	125.82	208.31

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Span, R., and Wagner, W., "Equations of State for Technical Applications. II. Results for Nonpolar Fluids," *Int. J. Thermophys.* **24**(1):41–109, 2003. The source for viscosity is Huber, M. L., Laesecke, A., and Xiang, H. W., "Viscosity Correlations for Minor Constituent Fluids in Natural Gas: *n*-Octane, *n*-Nonane and *n*-Decane," *Fluid Phase Equilibria* **224**:263–270, 2004. The source for thermal conductivity is Huber, M. L., and Perkins, R. A., "Thermal Conductivity Correlations for Minor Constituent Fluids in Natural Gas: *n*-Octane, *n*-Nonane and *n*-Decane," *Fluid Phase Equilibria* **227**:47–55, 2004.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are approximately 0.2% (to 0.5% at high pressures) in density, 1% (in the vapor phase) to 2% in heat capacity, 1% (in the vapor phase) to 2% in the speed of sound, and 0.2% in vapor pressure, except in the critical region. The estimated uncertainty in viscosity is 0.5% along the saturated-liquid line, 2% in compressed liquid to 200 MPa, 5% in vapor and supercritical regions. Uncertainty in thermal conductivity is 3%, except in the supercritical region and dilute gas which have an uncertainty of 5%.

TABLE 2-245 Thermodynamic Properties of Oxygen

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
54.361	0.00014628	40.816	0.024500	–6.1954	–6.1954	0.066946	0.038252	0.053541	1123.4	–0.37992	201.92	773.62
55.000	0.00017857	40.734	0.024549	–6.1613	–6.1612	0.067571	0.037651	0.053489	1126.9	–0.37886	201.02	747.53
60.000	0.00072582	40.064	0.024960	–5.8938	–5.8938	0.072225	0.034835	0.053548	1127.4	–0.37011	193.94	578.07
65.000	0.0023349	39.367	0.025402	–5.6258	–5.6257	0.076516	0.033469	0.053668	1101.7	–0.36312	186.82	457.94
70.000	0.0062623	38.656	0.025869	–5.3573	–5.3572	0.080495	0.032532	0.053697	1066.3	–0.35686	179.70	371.79
75.000	0.014547	37.936	0.026360	–5.0889	–5.0885	0.084199	0.031745	0.053719	1027.5	–0.34972	172.58	308.66
80.000	0.030123	37.203	0.026879	–4.8202	–4.8194	0.087667	0.031030	0.053808	987.43	–0.34056	165.44	261.22
85.000	0.056831	36.457	0.027430	–4.5510	–4.5495	0.090931	0.030365	0.054012	946.87	–0.32856	158.27	224.62
90.000	0.099350	35.692	0.028017	–4.2806	–4.2778	0.094023	0.029745	0.054361	905.90	–0.31302	151.05	195.64
95.000	0.16308	34.905	0.028649	–4.0084	–4.0038	0.096967	0.029169	0.054880	864.40	–0.29316	143.81	172.12
100.00	0.25400	34.092	0.029333	–3.7337	–3.7263	0.099787	0.028636	0.055599	822.19	–0.26804	136.55	152.56
105.00	0.37853	33.245	0.030079	–3.4556	–3.4442	0.10250	0.028146	0.056557	779.06	–0.23637	129.25	135.93
110.00	0.54340	32.360	0.030903	–3.1732	–3.1564	0.10513	0.027703	0.057816	734.77	–0.19639	121.92	121.52
115.00	0.75559	31.426	0.031820	–2.8853	–2.8612	0.10770	0.027311	0.059469	689.03	–0.14551	114.57	108.81
120.00	1.0223	30.434	0.032858	–2.5904	–2.5568	0.11022	0.026976	0.061666	641.52	–0.079899	107.23	97.426
125.00	1.3509	29.367	0.034051	–2.2867	–2.2407	0.11271	0.026712	0.064659	591.86	0.0063780	99.912	87.086
130.00	1.7491	28.203	0.035457	–1.9711	–1.9091	0.11520	0.026536	0.068905	539.50	0.12309	92.634	77.571
135.00	2.2250	26.907	0.037165	–1.6394	–1.5567	0.11773	0.026485	0.075327	483.69	0.28750	85.404	68.687
140.00	2.7878	25.415	0.039347	–1.2839	–1.1742	0.12035	0.026634	0.086099	423.10	0.53357	78.217	60.223
145.00	3.4477	23.599	0.042375	–0.88908	–0.74298	0.12319	0.027189	0.10778	355.20	0.93865	71.056	51.869
150.00	4.2186	21.110	0.047372	–0.41330	–0.21346	0.12654	0.028982	0.17484	273.80	1.7389	64.190	42.900
154.58	5.0428	13.630	0.073368	0.66752	1.0375	0.13442			0	5.0628		
54.361	0.00014628	0.00032370	3089.2	1.1195	1.5714	0.20982	0.021241	0.029631	140.32	507.90	4.4204	4.0962
55.000	0.00017857	0.00039060	2560.2	1.1327	1.5898	0.20850	0.021297	0.029698	141.11	480.26	4.4842	4.1481
60.000	0.00072582	0.0014561	686.75	1.2355	1.7339	0.19935	0.021815	0.030320	147.03	284.62	4.9840	4.5528
65.000	0.0023349	0.0043291	230.99	1.3377	1.8770	0.19194	0.022310	0.030934	152.65	156.71	5.4863	4.9555
70.000	0.0062623	0.010804	92.556	1.4393	2.0189	0.18587	0.022565	0.031294	158.07	87.254	5.9925	5.3557
75.000	0.014547	0.023509	42.536	1.5397	2.1584	0.18083	0.022513	0.031336	163.33	52.570	6.5051	5.7533
80.000	0.030123	0.045891	21.791	1.6377	2.2941	0.17659	0.022239	0.031177	168.36	35.817	7.0277	6.1486
85.000	0.056831	0.082138	12.175	1.7320	2.4239	0.17297	0.021896	0.031019	173.06	27.728	7.5654	6.5423
90.000	0.099350	0.13710	7.2938	1.8209	2.5455	0.16984	0.021624	0.031053	177.30	23.649	8.1241	6.9355
95.000	0.16308	0.21627	4.6239	1.9031	2.6571	0.16708	0.021515	0.031420	180.99	21.338	8.7113	7.3301
100.00	0.25400	0.32579	3.0695	1.9772	2.7569	0.16462	0.021605	0.032204	184.06	19.753	9.3362	7.7281
105.00	0.37853	0.47267	2.1156	2.0421	2.8430	0.16238	0.021894	0.033461	186.44	18.446	10.010	8.1324
110.00	0.54340	0.66506	1.5036	2.0966	2.9136	0.16032	0.022361	0.035245	188.14	17.250	10.748	8.5467
115.00	0.75559	0.91283	1.0955	2.1391	2.9668	0.15838	0.022978	0.037647	189.13	16.118	11.571	8.9760
120.00	1.0223	1.2284	0.81405	2.1678	3.0000	0.15652	0.023726	0.040839	189.41	15.045	12.509	9.4273
125.00	1.3509	1.6285	0.61407	2.1801	3.0097	0.15471	0.024597	0.045146	188.96	14.029	13.607	9.9112
130.00	1.7491	2.1366	0.46803	2.1722	2.9908	0.15289	0.025604	0.051204	187.75	13.062	14.940	10.445
135.00	2.2250	2.7893	0.35852	2.1380	2.9357	0.15100	0.026794	0.060349	185.74	12.120	16.641	11.061
140.00	2.7878	3.6487	0.27407	2.0670	2.8311	0.14896	0.028269	0.075824	182.82	11.155	18.977	11.823
145.00	3.4477	4.8412	0.20656	1.9383	2.6505	0.14659	0.030276	0.10781	178.78	10.071	22.582	12.881
150.00	4.2186	6.7170	0.14888	1.6938	2.3219	0.14345	0.033574	0.21201	172.82	8.6358	29.666	14.721
154.58	5.0428	13.630	0.073368	0.66752	1.0375	0.13442			0	5.0628		

Single-Phase Properties

100.00	0.10000	0.12316	8.1192	2.0355	2.8474	0.17297	0.020885	0.029925	188.37	18.479	9.0852	7.7121
300.00	0.10000	0.040116	24.928	6.2338	8.7265	0.20531	0.021078	0.029435	329.72	2.6530	26.485	20.652
500.00	0.10000	0.024050	41.579	10.604	14.762	0.22069	0.022781	0.031108	421.27	0.75388	41.046	30.486
700.00	0.10000	0.017177	58.216	15.357	21.179	0.23147	0.024672	0.032992	493.31	0.10517	53.966	38.653
900.00	0.10000	0.013360	74.849	20.438	27.923	0.23994	0.026045	0.034363	555.60	–0.18735	65.867	45.806
100.00	1.0000	34.158	0.029276	–3.7444	–3.7151	0.099680	0.028683	0.055399	826.85	–0.27181	137.23	153.89
119.62	1.0000	30.512	0.032774	–2.6131	–2.5803	0.11003	0.027000	0.061476	645.19	–0.085501	107.79	98.249
119.62	1.0000	1.2018	0.83209	2.1662	2.9983	0.15666	0.023665	0.040564	189.41	15.124	12.433	9.3921
300.00	1.0000	0.40337	2.4791	6.1772	8.6563	0.18598	0.021148	0.029887	329.90	2.6066	26.894	20.846
500.00	1.0000	0.24010	4.1649	10.576	14.741	0.20149	0.022802	0.031240	422.68	0.73726	41.288	30.630
700.00	1.0000	0.17135	5.8360	15.340	21.176	0.21230	0.024682	0.033052	494.87	0.098376	54.139	38.766
900.00	1.0000	0.13328	7.5029	20.426	27.929	0.22078	0.026051	0.034395	557.14	–0.19062	66.001	45.899
100.00	5.0000	34.497	0.028988	–3.7983	–3.6533	0.099132	0.028935	0.054458	850.39	–0.28978	140.71	160.92
154.36	5.0000	16.011	0.062457	0.35374	0.66602	0.13204	0.038878	3.5718	163.89	4.2044	75.954	29.668
154.36	5.0000	11.160	0.089610	1.0294	1.4774	0.13729	0.041906	4.2513	158.85	6.0016	72.313	20.574
300.00	5.0000	2.0616	0.48505	5.9227	8.3480	0.17177	0.021448	0.032003	332.25	2.3730	28.797	21.766
500.00	5.0000	1.1908	0.83975	10.454	14.653	0.18787	0.022894	0.031815	429.36	0.66261	42.362	31.267
700.00	5.0000	0.84728	1.1802	15.264	21.165	0.19881	0.024726	0.033309	501.98	0.068114	54.901	39.261
900.00	5.0000	0.65931	1.5167	20.373	27.956	0.20734	0.026076	0.034537	564.07	–0.20519	66.593	46.305
100.00	10.000	34.885	0.028665	–3.8593	–3.5726	0.098498	0.029235	0.053516	877.07	–0.30803	144.82	169.49
300.00	10.000	4.2056	0.23778	5.6024	7.9802	0.16499	0.021790	0.034749	339.35	2.0332	31.466	23.153
500.00	10.000	2.3538	0.42484	10.306	14.554	0.18182	0.022999	0.032491	438.67	0.56900	43.708	32.074
700.00	10.000	1.6705	0.59861	15.171	21.157	0.19292	0.024776	0.033613	511.24	0.030534	55.839	39.873
900.00	10.000	1.3010	0.76866	20.307	27.993	0.20150	0.026104	0.034706	572.92	–0.22339	67.321	46.804
100.00	25.000	35.884	0.027867	–4.0109	–3.3142	0.096845	0.030037	0.051627	945.24	–0.34532	155.97	194.38
300.00	25.000	10.393	0.096215	4.7194	7.1247	0.15490	0.022521	0.040917	390.80	1.0167	41.851	29.605
500.00	25.000	5.6243	0.17780	9.8920	14.337	0.17346	0.023256	0.034167	472.62	0.30658	47.943	34.705
700.00	25.000	3.9923	0.25048	14.907	21.169	0.18495	0.024901	0.034397	541.32	–0.076019	58.651	41.714
900.00	25.000	3.1222	0.32028	20.117	28.124	0.19369	0.026174	0.035155	600.66	–0.27597	69.464	48.271
100.00	75.000	38.263	0.026135	–4.3340	–2.3739	0.092788	0.031906	0.049123	1115.1	–0.39472	184.96	274.96
300.00	75.000	21.603	0.046289	3.1884	6.6601	0.14315	0.023601	0.041272	645.54	–0.18640	75.261	53.378
500.00	75.000	13.760	0.072675	8.8798	14.330	0.16284	0.023725	0.036534	619.75	–0.20732	64.149	45.084
700.00	75.000	10.201	0.098029	14.192	21.544	0.17498	0.025126	0.035903	657.04	–0.31840	68.835	48.269
900.00	75.000	8.1749	0.12233	19.571	28.745	0.18403	0.026293	0.036153	701.72	–0.40609	76.863	53.163

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Schmidt, R., and Wagner, W., "A New Form of the Equation of State for Pure Substances and Its Application to Oxygen," *Fluid Phase Equilibria*, **19:**175–200, 1985. The source for viscosity and thermal conductivity is Lemmon, E. W., and Jacobsen, R. T., "Viscosity and Thermal Conductivity Equations for Nitrogen, Oxygen, Argon, and Air," *Int. J. Thermophys*. **25:**21–69, 2004.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are 0.1% in density, 2% in heat capacity, and 1% in the speed of sound, except in the critical region. For viscosity, the uncertainty is 1% in the dilute gas at temperatures above 200 K, and 5% in the dilute gas at lower temperatures. The uncertainty is around 2% between 270 and 300 K, and increases to 5% outside of this region. The uncertainty may be higher in the liquid near the triple point. The uncertainty for the dilute gas is 2% with increasing uncertainties near the triple point. For thermal conductivity, the uncertainties range from 3% between 270 and 300 K to 5% elsewhere. The uncertainties above 100 MPa are not known due to a lack of experimental data.

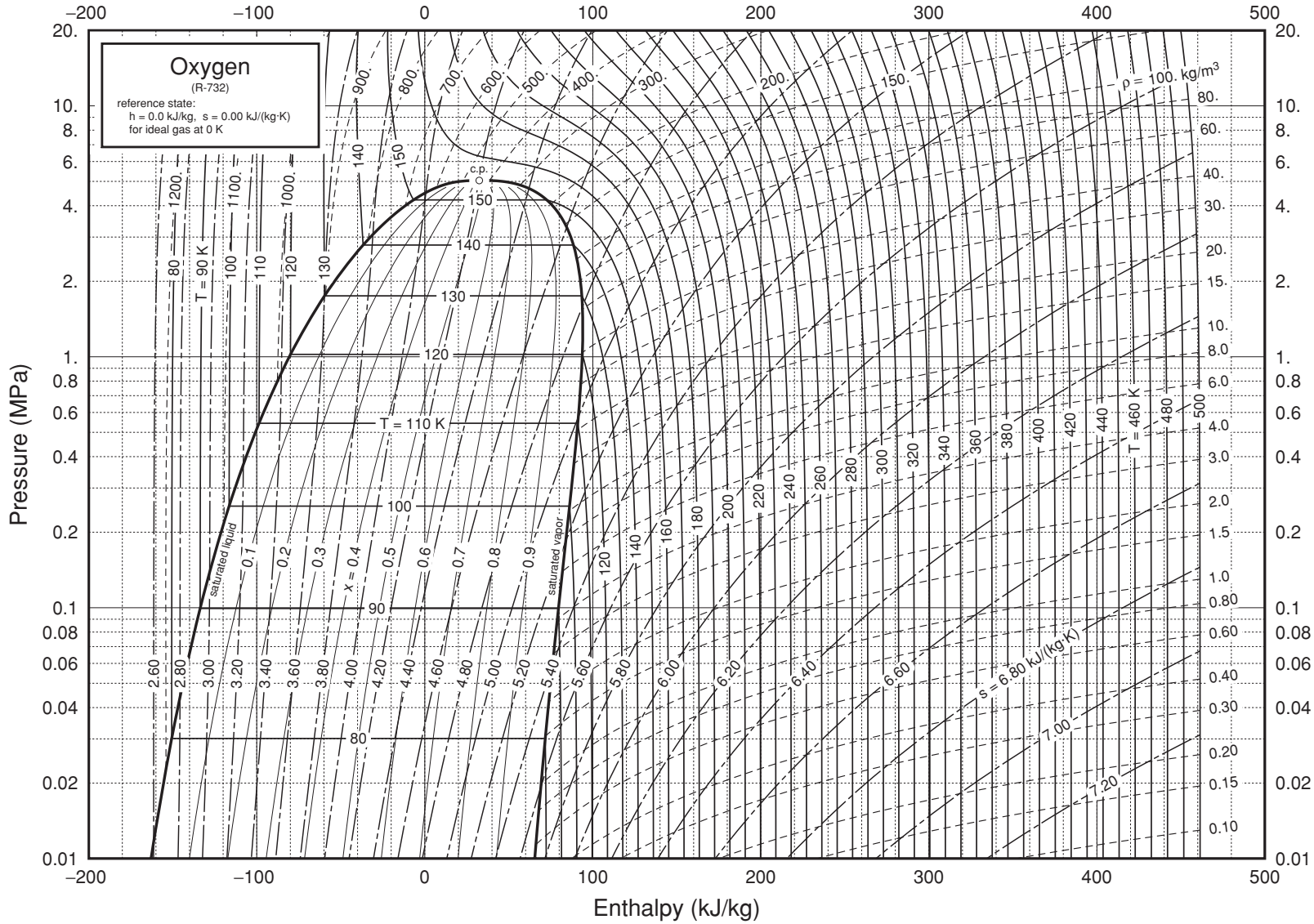

FIG. 2-15 Pressure-enthalpy diagram for oxygen. Properties computed with the NIST REFPROP Database, Version 7.0 (Lemmon, E. W., McLinden, M. O. and Huber, M. L., 2002, NIST Standard Reference Database 23, NIST Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, Standard Reference Data Program, National Institute of Standards and Technology), based on the equation of state of Schmidt, R., and Wagner, W., "A New Form of the Equation of State for Pure Substances and Its Application to Oxygen," *Fluid Phase Equilibria* **19:**175–200, 1985.

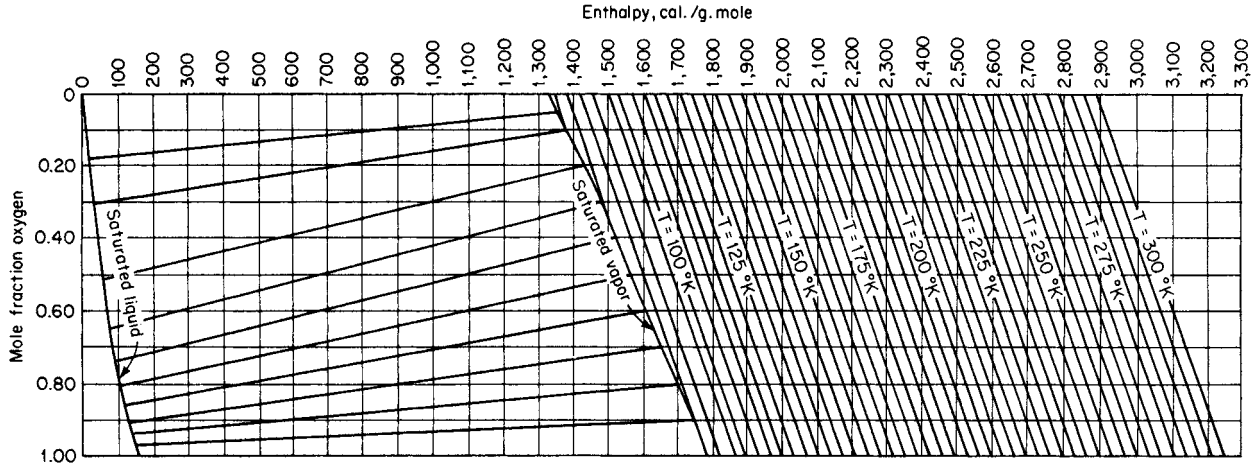

FIG. 2-16 Enthalpy-concentration diagram for oxygen-nitrogen mixture at 1 atm. Reference states: Enthalpies of liquid oxygen and liquid nitrogen at the normal boiling point of nitrogen are zero. (*Dodge,* Chemical Engineering Thermodynamics, *McGraw-Hill, New York, 1944.*) Wilson, Silverberg, and Zellner, AFAPL TDR 64-64 (AD 603151), 1964, p. 314, present extensive vapor-liquid equilibrium data for the three-component system argon-nitrogen-oxygen as well as for binary systems including oxygen-nitrogen. Calculations for this mixture are also available with the NIST REFPROP software.

TABLE 2-246 Thermodynamic Properties of Pentane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
143.47	7.6322E-08	10.566	0.094640	–25.092	–25.092	–0.11487	0.10392	0.14205	1829.9	–0.54905	175.03	3709.1
150.00	2.6809E-07	10.482	0.095399	–24.164	–24.164	–0.10855	0.10408	0.14201	1788.3	–0.54859	172.92	2750.8
165.00	3.1471E-06	10.292	0.097163	–22.032	–22.032	–0.095008	0.10469	0.14231	1696.9	–0.54514	167.37	1587.7
180.00	2.3256E-05	10.105	0.098964	–19.892	–19.892	–0.082594	0.10558	0.14312	1610.3	–0.53850	161.20	1048.4
195.00	0.00012116	9.9190	0.10082	–17.737	–17.737	–0.071091	0.10680	0.14441	1527.4	–0.52866	154.70	757.19
210.00	0.00048191	9.7339	0.10273	–15.558	–15.557	–0.060326	0.10837	0.14621	1447.4	–0.51549	148.08	581.46
225.00	0.0015504	9.5483	0.10473	–13.348	–13.347	–0.050163	0.11032	0.14853	1369.7	–0.49891	141.47	466.22
240.00	0.0042112	9.3613	0.10682	–11.099	–11.099	–0.040489	0.11267	0.15137	1293.8	–0.47884	134.95	385.57
255.00	0.0099767	9.1719	0.10903	–8.8042	–8.8031	–0.031215	0.11539	0.15473	1219.4	–0.45516	128.57	326.15
270.00	0.021139	8.9791	0.11137	–6.4555	–6.4532	–0.022266	0.11847	0.15857	1146.3	–0.42770	122.40	280.49
285.00	0.040858	8.7818	0.11387	–4.0461	–4.0414	–0.013582	0.12186	0.16289	1074.0	–0.39609	116.43	244.17
300.00	0.073168	8.5788	0.11657	–1.5694	–1.5608	–0.0051134	0.12552	0.16766	1002.5	–0.35971	110.69	214.42
315.00	0.12293	8.3688	0.11949	0.98088	0.99557	0.0031816	0.12940	0.17288	931.46	–0.31748	105.17	189.45
330.00	0.19575	8.1499	0.12270	3.6106	3.6346	0.011338	0.13348	0.17857	860.59	–0.26769	99.882	168.04
345.00	0.29786	7.9200	0.12626	6.3259	6.3635	0.019386	0.13770	0.18478	789.61	–0.20766	94.813	149.32
360.00	0.43606	7.6765	0.13027	9.1332	9.1900	0.027354	0.14204	0.19161	718.18	–0.13303	89.958	132.67
375.00	0.61766	7.4155	0.13485	12.040	12.123	0.035271	0.14649	0.19928	645.89	–0.036610	85.304	117.61
390.00	0.85052	7.1319	0.14022	15.057	15.176	0.043168	0.15103	0.20814	572.27	0.094152	80.839	103.78
405.00	1.1432	6.8175	0.14668	18.197	18.364	0.051083	0.15570	0.21894	496.72	0.28299	76.544	90.837
420.00	1.5050	6.4595	0.15481	21.482	21.715	0.059073	0.16056	0.23325	418.39	0.58010	72.402	78.483
435.00	1.9472	6.0340	0.16573	24.952	25.275	0.067234	0.16578	0.25525	335.90	1.1123	68.402	66.354
450.00	2.4836	5.4866	0.18226	28.698	29.150	0.075780	0.17187	0.30145	246.17	2.3196	64.610	53.842
465.00	3.1355	4.5754	0.21856	33.125	33.811	0.085678	0.18139	0.60959	138.75	7.5108	63.369	38.530
469.70	3.3710	3.2156	0.31099	36.504	37.552	0.093548			0	19.135		
143.47	7.6322E-08	6.3981E-08	15,630,000.	8.3431	9.5360	0.12648	0.070619	0.078934	135.94	542.15	4.0211	3.2806
150.00	2.6809E-07	2.1496E-07	4,652,000.	8.8107	10.058	0.11959	0.072591	0.080906	138.80	453.68	4.3338	3.4236
165.00	3.1471E-06	2.2940E-06	435,920.	9.9311	11.303	0.10702	0.076717	0.085033	145.17	311.80	5.0759	3.7558
180.00	2.3256E-05	1.5540E-05	64,349.	11.110	12.607	0.097955	0.080473	0.088791	151.28	222.93	5.8544	4.0934
195.00	0.00012116	7.4749E-05	13,378.	12.343	13.964	0.091475	0.084066	0.092395	157.11	164.55	6.6764	4.4362
210.00	0.00048191	0.00027623	3,620.1	13.627	15.372	0.086957	0.087665	0.096021	162.67	124.69	7.5505	4.7837
225.00	0.0015504	0.00083048	1,204.1	14.962	16.829	0.083956	0.091392	0.099805	167.92	96.614	8.4862	5.1356
240.00	0.0042112	0.0021198	471.75	16.347	18.333	0.082144	0.095331	0.10385	172.81	76.365	9.4926	5.4918
255.00	0.0099767	0.0047454	210.73	17.780	19.882	0.081276	0.099526	0.10823	177.25	61.487	10.578	5.8525
270.00	0.021139	0.0095553	104.65	19.260	21.472	0.081162	0.10400	0.11297	181.16	50.401	11.752	6.2179
285.00	0.040858	0.017654	56.645	20.787	23.101	0.081654	0.10874	0.11811	184.42	42.052	13.022	6.5890
300.00	0.073168	0.030405	32.889	22.357	24.763	0.082633	0.11373	0.12367	186.93	35.715	14.394	6.9672
315.00	0.12293	0.049446	20.224	23.968	26.454	0.084003	0.11894	0.12966	188.56	30.879	15.879	7.3547
330.00	0.19575	0.076727	13.033	25.617	28.168	0.085681	0.12435	0.13613	189.17	27.184	17.484	7.7547
345.00	0.29786	0.11460	8.7259	27.297	29.896	0.087596	0.12993	0.14317	188.63	24.375	19.221	8.1719
360.00	0.43606	0.16601	6.0239	29.002	31.629	0.089684	0.13567	0.15092	186.76	22.275	21.106	8.6130
375.00	0.61766	0.23477	4.2594	30.721	33.352	0.091880	0.14155	0.15968	183.35	20.767	23.164	9.0883
390.00	0.85052	0.32623	3.0654	32.439	35.046	0.094117	0.14759	0.17000	178.13	19.785	25.433	9.6135
405.00	1.1432	0.44834	2.2305	34.133	36.682	0.096313	0.15383	0.18300	170.76	19.316	27.980	10.215
420.00	1.5050	0.61427	1.6279	35.764	38.214	0.098358	0.16037	0.20125	160.78	19.406	30.941	10.939
435.00	1.9472	0.84898	1.1779	37.264	39.557	0.10007	0.16742	0.23193	147.55	20.186	34.634	11.885
450.00	2.4836	1.2118	0.82522	38.471	40.520	0.10105	0.17552	0.30440	130.14	21.884	40.108	13.312
465.00	3.1355	1.9618	0.50974	38.730	40.328	0.099694	0.18671	0.82173	106.55	24.088	55.658	16.549
469.70	3.3710	3.2156	0.31099	36.504	37.552	0.093548			0	19.135		

Single-Phase Properties

200.00	0.10000	9.8581	0.10144	–17.016	–17.006	–0.067441	0.10728	0.14495	1501.0	–0.52472	152.53	690.14
300.00	0.10000	8.5793	0.11656	–1.5709	–1.5592	–0.0051184	0.12552	0.16765	1002.8	–0.35984	110.71	214.50
308.83	0.10000	8.4562	0.11826	–0.077672	–0.065846	–0.00021257	0.12778	0.17068	960.65	–0.33565	107.41	199.24
308.83	0.10000	0.040733	24.550	23.300	25.755	0.083398	0.11677	0.12714	188.00	32.712	15.254	7.1940
400.00	0.10000	0.030611	32.668	35.260	38.527	0.11949	0.14472	0.15376	217.34	12.986	24.749	9.3018
500.00	0.10000	0.024257	41.224	51.273	55.396	0.15700	0.17449	0.18314	243.86	6.4310	37.084	11.487
600.00	0.10000	0.020135	49.665	70.070	75.037	0.19274	0.20055	0.20906	267.28	3.8205	50.416	13.525
200.00	1.0000	9.8656	0.10136	–17.038	–16.937	–0.067555	0.10733	0.14489	1505.8	–0.52539	152.82	696.76
300.00	1.0000	8.5958	0.11634	–1.6210	–1.5046	–0.0052858	0.12555	0.16737	1011.2	–0.36413	111.23	217.09
398.07	1.0000	6.9671	0.14353	16.730	16.874	0.047422	0.15353	0.21364	531.90	0.18628	78.507	96.722
398.07	1.0000	0.38746	2.5809	33.355	35.936	0.095310	0.15092	0.17655	174.46	19.468	26.763	9.9253
400.00	1.0000	0.38317	2.6098	33.666	36.276	0.096162	0.15126	0.17612	175.97	18.915	26.951	9.9649
500.00	1.0000	0.26375	3.7914	50.465	54.257	0.13622	0.17624	0.18896	226.09	7.2197	38.498	12.017
600.00	1.0000	0.20980	4.7663	69.531	74.297	0.17270	0.20129	0.21181	257.70	3.9909	51.523	13.960
200.00	5.0000	9.8980	0.10103	–17.137	–16.632	–0.068053	0.10753	0.14467	1527.0	–0.52817	154.08	726.41
300.00	5.0000	8.6652	0.11540	–1.8329	–1.2559	–0.0060014	0.12571	0.16627	1047.2	–0.38106	113.46	228.42
400.00	5.0000	7.1612	0.13964	16.501	17.199	0.046820	0.15388	0.20601	606.55	0.017312	82.387	107.19
500.00	5.0000	3.2553	0.30719	42.207	43.743	0.10528	0.19073	0.42935	135.39	9.4810	59.214	26.017
600.00	5.0000	1.2834	0.77916	66.610	70.506	0.15448	0.20500	0.23291	220.81	4.4347	57.890	17.494
200.00	10.000	9.9373	0.10063	–17.255	–16.249	–0.068660	0.10778	0.14442	1552.6	–0.53127	155.61	763.99
300.00	10.000	8.7452	0.11435	–2.0763	–0.93280	–0.0068390	0.12592	0.16515	1088.8	–0.39826	116.08	242.27
400.00	10.000	7.3792	0.13552	15.896	17.251	0.045232	0.15383	0.20020	687.58	–0.10747	86.892	120.04
500.00	10.000	5.4581	0.18321	37.622	39.455	0.094589	0.18299	0.24567	349.25	0.88491	69.546	57.792
600.00	10.000	3.0774	0.32495	62.405	65.655	0.14230	0.20754	0.26294	229.05	2.8865	67.434	28.573
200.00	50.000	10.209	0.097953	–18.043	–13.146	–0.072988	0.10968	0.14331	1731.1	–0.54573	166.40	1086.9
300.00	50.000	9.2247	0.10840	–3.5039	1.9164	–0.012155	0.12755	0.16079	1343.9	–0.46478	132.95	346.81
400.00	50.000	8.2838	0.12072	13.310	19.346	0.037795	0.15501	0.18829	1056.0	–0.35370	109.81	195.02
500.00	50.000	7.3733	0.13562	32.748	39.529	0.082724	0.18248	0.21473	853.23	–0.25198	97.812	130.14
600.00	50.000	6.5265	0.15322	54.478	62.139	0.12389	0.20695	0.23672	723.60	–0.17131	94.951	95.489
200.00	100.00	10.479	0.095431	–18.760	–9.2168	–0.077502	0.11180	0.14305	1911.9	–0.55097	177.42	1550.8
300.00	100.00	9.6305	0.10384	–4.6330	5.7508	–0.017033	0.12937	0.15917	1570.5	–0.49017	148.83	473.34
400.00	100.00	8.8688	0.11275	11.680	22.955	0.032278	0.15665	0.18547	1325.1	–0.40837	128.55	270.23
500.00	100.00	8.1734	0.12235	30.587	42.822	0.076502	0.18394	0.21138	1153.2	–0.34418	117.64	187.06
600.00	100.00	7.5451	0.13254	51.860	65.113	0.11708	0.20826	0.23383	1035.8	–0.29936	114.07	142.50

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Span, R., and Wagner, W., "Equations of State for Technical Applications. II. Results for Nonpolar Fluids," *Int. J. Thermophys.* **24**(1):41–109, 2003. The source for viscosity and thermal conductivity is NIST14, Version 9.08.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are approximately 0.2% (to 0.5% at high pressures) in density, 1% (in the vapor phase) to 2% in heat capacity, 1% (in the vapor phase) to 2% in the speed of sound, and 0.2% in vapor pressure, except in the critical region. For viscosity, estimated uncertainty is 2%. For thermal conductivity, estimated uncertainty, except near the critical region, is 4–6%.

TABLE 2-247 Saturated Potassium*

T, K	P, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)
336.4[m]	1.37.–9	0.001208		93.8	2327	1.928	8.567	0.822
400	1.84.–7	0.001229	4.64.+6	145.5	2342	2.068	7.559	0.805
500	3.13.–5	0.001266	3.39.+4	225.1	2390	2.246	6.576	0.785
600	9.26.–4	0.001304	3164	302.7	2433	2.388	5.937	0.771
700	0.01022	0.001346	142.3	379.4	2468	2.506	5.490	0.762
800	0.06116	0.001389	26.75	455.5	2498	2.608	5.161	0.761
1000	0.7322	0.001488	2.691	609.7	2552	2.780	4.722	0.792
1200	3.913	0.001605	0.584	773.5	2610	2.929	4.459	0.846
1400	12.44	0.001742	0.207	948.0	2679	3.063	4.299	0.899
1500	20.0	0.001816	0.132	1040.0	2718	3.123	4.209	0.924

*Converted from tables in Vargaftik, *Tables of the Thermophysical Properties of Liquids and Gases,* Nauka, Moscow, 1972; and Hemisphere, Washington, 1975. m = melting point. The notation $1.37.–9$ signifies 1.37×10^{-9}.

Many of the Vargaftik values also appear in Ohse, R. W., *Handbook of Thermodynamic and Transport Properties of Alkali Metals,* Blackwell Sci. Pubs., Oxford, 1985 (1020 pp.). This source contains superheat data. Saturation and superheat tables and a diagram to 30 bar, 1650 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.,* Stanford Univ. publ., 1979 (173 pp.). For a Mollier diagram from 0.1 to 250 psia, 1300 to 2700°R, see Weatherford, W. D., J. C. Tyler, et al., WADD-TR-61-96, 1961. An extensive review of properties of the solid and the saturated liquid is given by Alcock, C. B., M. W. Chase, et al., *J. Phys. Chem. Ref. Data,* **23,** 3 (1994):385–497.

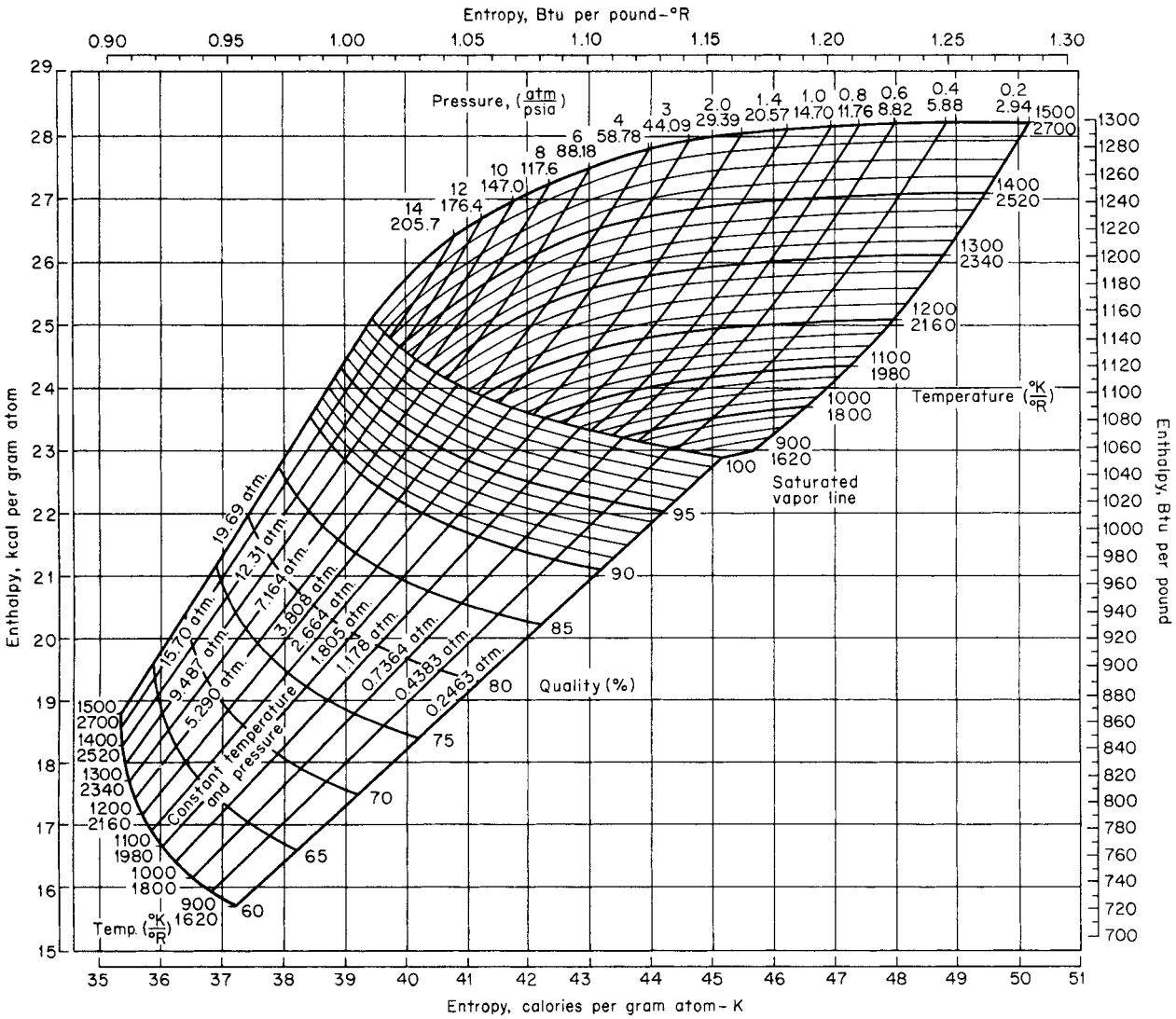

FIG. 2-17 Mollier diagram for potassium. Basis: enthalpy = 0.0 cal/g atom at 298 K; entropy = 15.8 cal/(g atom·K) at 298 K. (*Aerojet-General Rep. AGN8194, vol. 2, 1967. Reproduced by permission.*)

TABLE 2-248 Thermodynamic Properties of Propane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
100.00	2.5330E-08	16.287	0.061397	–7.4323	–7.4323	–0.048110	0.058376	0.083833	2030.4	–0.62852	203.23	3780.3
115.00	1.0677E-06	15.941	0.062730	–6.1638	–6.1638	–0.036293	0.058304	0.085262	1930.7	–0.61354	196.90	1822.7
130.00	1.7600E-05	15.596	0.064117	–4.8753	–4.8753	–0.025763	0.058442	0.086525	1827.2	–0.59904	189.40	1080.5
145.00	0.00015328	15.251	0.065568	–3.5682	–3.5682	–0.016249	0.058710	0.087764	1724.5	–0.58338	181.11	729.42
160.00	0.00084980	14.904	0.067094	–2.2418	–2.2418	–0.0075455	0.059141	0.089109	1623.4	–0.56521	172.30	534.62
175.00	0.0033874	14.554	0.068710	–0.89395	–0.89372	0.00050603	0.059774	0.090658	1523.6	–0.54342	163.19	412.89
190.00	0.010547	14.198	0.070434	0.47907	0.47981	0.0080327	0.060636	0.092484	1424.7	–0.51702	153.97	329.94
205.00	0.027195	13.834	0.072288	1.8816	1.8836	0.015137	0.061740	0.094646	1326.6	–0.48497	144.76	269.81
220.00	0.060583	13.459	0.074301	3.3189	3.3234	0.021903	0.063087	0.097193	1229.1	–0.44601	135.72	224.28
235.00	0.12030	13.070	0.076511	4.7964	4.8056	0.028399	0.064672	0.10018	1131.9	–0.39841	126.91	188.66
250.00	0.21798	12.663	0.078968	6.3203	6.3375	0.034686	0.066484	0.10368	1034.8	–0.33958	118.40	160.10
265.00	0.36693	12.234	0.081740	7.8975	7.9275	0.040815	0.068514	0.10780	937.63	–0.26538	110.26	136.69
280.00	0.58173	11.775	0.084925	9.5360	9.5854	0.046833	0.070755	0.11272	839.90	–0.16892	102.52	117.11
295.00	0.87805	11.277	0.088673	11.246	11.324	0.052790	0.073209	0.11880	741.08	–0.037850	95.209	100.38
310.00	1.2726	10.726	0.093229	13.041	13.159	0.058740	0.075898	0.12672	640.30	0.15178	88.324	85.735
325.00	1.7837	10.097	0.099036	14.943	15.120	0.064759	0.078882	0.13817	536.11	0.45297	81.819	72.510
340.00	2.4320	9.3403	0.10706	16.996	17.257	0.070985	0.082328	0.15818	425.33	1.0100	75.581	60.014
355.00	3.2432	8.3162	0.12025	19.317	19.707	0.077769	0.087215	0.21184	300.04	2.3857	69.491	47.137
369.83	4.2477	5.0000	0.20000	23.653	24.503	0.090537			0	12.890		
100.00	2.5330E-08	3.0465E-08	32,825,000.	15.887	16.718	0.19339	0.032981	0.041296	153.65	420.53	2.4171	2.9792
115.00	1.0677E-06	1.1166E-06	895,550.	16.399	17.356	0.16822	0.035381	0.043696	163.64	267.23	3.2182	3.3431
130.00	1.7600E-05	1.6284E-05	61,410.	16.947	18.028	0.15042	0.037630	0.045946	172.99	181.79	4.0849	3.7167
145.00	0.00015328	0.00012717	7,863.4	17.527	18.732	0.13755	0.039780	0.048104	181.78	130.32	5.0168	4.0976
160.00	0.00084980	0.00063940	1,564.0	18.137	19.466	0.12813	0.041911	0.050262	190.03	97.395	6.0131	4.4832
175.00	0.0033874	0.0023346	428.34	18.775	20.226	0.12119	0.044098	0.052519	197.68	75.331	7.0721	4.8708
190.00	0.010547	0.0067219	148.77	19.437	21.007	0.11607	0.046406	0.054975	204.61	59.995	8.1917	5.2578
205.00	0.027195	0.016180	61.804	20.120	21.801	0.11230	0.048888	0.057727	210.64	49.008	9.3706	5.6429
220.00	0.060583	0.033974	29.435	20.819	22.602	0.10953	0.051579	0.060867	215.59	40.931	10.611	6.0262
235.00	0.12030	0.064224	15.570	21.528	23.401	0.10753	0.054504	0.064488	219.25	34.865	11.922	6.4107
250.00	0.21798	0.11195	8.9325	22.242	24.189	0.10609	0.057677	0.068703	221.39	30.235	13.323	6.8027
265.00	0.36693	0.18328	5.4561	22.954	24.956	0.10507	0.061104	0.073667	221.82	26.669	14.845	7.2123
280.00	0.58173	0.28598	3.4968	23.656	25.690	0.10435	0.064794	0.079635	220.30	23.923	16.544	7.6551
295.00	0.87805	0.43050	2.3229	24.336	26.376	0.10381	0.068763	0.087064	216.53	21.832	18.503	8.1548
310.00	1.2726	0.63231	1.5815	24.977	26.989	0.10335	0.072895	0.096756	210.16	20.354	20.863	8.7494
325.00	1.7837	0.91726	1.0902	25.543	27.488	0.10282	0.077315	0.11131	200.74	19.511	23.881	9.5073
340.00	2.4320	1.3363	0.74835	25.971	27.791	0.10197	0.083072	0.13963	187.44	19.120	28.187	10.574
355.00	3.2432	2.0253	0.49375	26.098	27.699	0.10028	0.091334	0.22264	168.95	18.854	36.060	12.373
369.83	4.2477	5.0000	0.20000	23.653	24.503	0.090537			0	12.890		
Single-Phase Properties												
100.00	0.10000	16.288	0.061394	–7.4332	–7.4270	–0.048119	0.058377	0.083831	2030.8	–0.62854	203.26	3784.5
200.00	0.10000	13.958	0.071646	1.4085	1.4157	0.012800	0.061348	0.093874	1359.8	–0.49655	147.87	288.12
230.74	0.10000	13.182	0.075860	4.3719	4.3795	0.026576	0.064197	0.099283	1159.5	–0.41295	129.38	197.97
230.74	0.10000	0.054083	18.490	21.326	23.175	0.10803	0.053648	0.063403	218.35	36.423	11.542	6.3010
300.00	0.10000	0.040726	24.554	25.482	27.937	0.12602	0.065918	0.074796	249.37	16.357	18.513	8.1962
400.00	0.10000	0.030257	33.050	33.084	36.389	0.15020	0.085775	0.094327	286.19	7.1977	30.995	10.819
500.00	0.10000	0.024125	41.452	42.616	46.761	0.17327	0.10431	0.11276	318.30	3.9113	46.363	13.290
100.00	1.0000	16.295	0.061368	–7.4410	–7.3796	–0.048197	0.058391	0.083810	2034.6	–0.62871	203.49	3822.7
200.00	1.0000	13.974	0.071560	1.3862	1.4577	0.012688	0.061383	0.093756	1366.3	–0.49871	148.40	290.36
300.00	1.0000	11.101	0.090085	11.833	11.924	0.054770	0.074077	0.12118	707.81	0.017030	92.871	95.307
300.09	1.0000	11.097	0.090112	11.844	11.934	0.054806	0.074092	0.12123	707.18	0.018141	92.828	95.215

TABLE 2-248 Thermodynamic Properties of Propane (*Continued*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Single-Phase Properties												
300.09	1.0000	0.49153	2.0344	24.559	26.593	0.10366	0.070157	0.090035	214.68	21.259	19.249	8.3433
400.00	1.0000	0.32145	3.1109	32.638	35.749	0.12993	0.086666	0.097825	272.57	7.6356	31.915	10.996
500.00	1.0000	0.24776	4.0362	42.322	46.359	0.15353	0.10468	0.11438	311.60	3.9684	47.555	13.477
100.00	5.0000	16.326	0.061251	–7.4751	–7.1688	–0.048542	0.058457	0.083721	2051.3	–0.62944	204.51	3995.6
200.00	5.0000	14.047	0.071191	1.2900	1.6459	0.012202	0.061542	0.093272	1394.2	–0.50758	150.70	300.33
300.00	5.0000	11.363	0.088002	11.506	11.946	0.053658	0.074005	0.11643	779.30	–0.10225	97.139	103.08
400.00	5.0000	2.5448	0.39296	29.499	31.463	0.10822	0.093912	0.16341	197.49	10.349	42.438	14.948
500.00	5.0000	1.4059	0.71129	40.868	44.425	0.13725	0.10638	0.12446	284.88	4.1092	52.411	15.207
100.00	10.000	16.365	0.061108	–7.5164	–6.9053	–0.048966	0.058554	0.083620	2071.2	–0.63025	205.77	4219.8
200.00	10.000	14.133	0.070758	1.1767	1.8843	0.011619	0.061744	0.092746	1427.0	–0.51720	153.49	312.82
300.00	10.000	11.627	0.086007	11.173	12.033	0.052499	0.074065	0.11280	851.72	–0.19531	101.80	111.73
400.00	10.000	7.5861	0.13182	24.108	25.426	0.090675	0.093138	0.16714	338.94	1.7653	68.250	41.091
500.00	10.000	3.2486	0.30783	38.754	41.832	0.12746	0.10818	0.14277	275.78	3.4683	58.851	19.828
100.00	50.000	16.644	0.060081	–7.8016	–4.7976	–0.052119	0.059685	0.083087	2203.4	–0.63391	214.99	6389.5
200.00	50.000	14.696	0.068047	0.46479	3.8672	0.0076714	0.063347	0.090345	1638.0	–0.56103	173.15	416.61
300.00	50.000	12.850	0.077822	9.6226	13.514	0.046601	0.075522	0.10376	1203.5	–0.42987	129.30	167.38
400.00	50.000	11.043	0.090552	20.208	24.735	0.078767	0.092492	0.12069	901.34	–0.26933	103.15	95.902
500.00	50.000	9.3527	0.10692	32.246	37.592	0.10739	0.10930	0.13596	721.97	–0.11844	94.269	63.347
100.00	100.00	16.946	0.059010	–8.0684	–2.1674	–0.055583	0.061388	0.082816	2328.3	–0.63418	225.01	10396.
200.00	100.00	15.221	0.065700	–0.13496	6.4350	0.0038087	0.065107	0.089250	1833.0	–0.58053	193.78	561.59
300.00	100.00	13.700	0.072994	8.6070	15.906	0.042047	0.077244	0.10131	1467.7	–0.49303	155.37	229.66
400.00	100.00	12.331	0.081095	18.712	26.822	0.073340	0.094108	0.11714	1214.6	–0.40159	129.74	138.80
500.00	100.00	11.114	0.089974	30.308	39.306	0.10113	0.11078	0.13224	1052.7	–0.33205	118.57	98.032

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Buecker, D., and Wagner, W., "Reference Equations of State for the Thermodynamic Properties of Fluid Phase *n*-Butane and Isobutane," *J. Phys. Chem. Ref. Data* **35**(2):929–1019, 2006. The source for viscosity is Vogel, E., Kuechenmeister, C., Bich, E., and Laesecke, A., "Reference Correlation of the Viscosity of Propane," *J. Phys. Chem. Ref. Data* **27**(5):947–970, 1998. The source for thermal conductivity is Marsh, K., Perkins, R., and Ramires, M. L. V., "Measurement and Correlation of the Thermal Conductivity of Propane from 86 to 600 K at Pressures to 70 MPa," *J. Chem. Eng. Data* **47**(4):932–940, 2002.

Properties at the critical point temperature are given in the last entry of the saturation tables. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

Typical uncertainties in density are 0.02% in the liquid phase, 0.05% in the vapor phase and at supercritical temperatures, and 0.1% in the critical region, except very near the critical point, where the uncertainty in pressure is 0.1%. For vapor pressures, the uncertainty is 0.02% above 180 K, 0.05% above 1 Pa (115 K), and dropping to 0.001 mPa at the triple point. The uncertainty in heat capacity (isobaric, isochoric, and saturated) is 0.5% at temperatures above 125 K and 2% at temperatures below 125 K for the liquid, and is 0.5% for all vapor states. The uncertainty in the liquid-phase speed of sound is 0.5%, and that for the vapor phase is 0.05%. The uncertainties are higher for all properties very near the critical point except pressure (saturated vapor/liquid and single phase). The uncertainty in viscosity varies from 0.4% in the dilute gas between room temperature and 600 K, to about 2.5% from 100 to 475 K up to about 30 MPa, and to about 4% outside this range. Uncertainty in thermal conductivity is 3%, except in the critical region and dilute gas which have an uncertainty of 5%.

TABLE 2-249 Thermodynamic Properties of Propylene

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
105.00	1.8242E-07	17.799	0.056183	–6.2877	–6.2877	–0.039412	0.047146	0.074152	1984.2	–0.63335
120.00	4.8828E-06	17.383	0.057526	–5.1660	–5.1660	–0.029431	0.048479	0.076350	1860.6	–0.61019
135.00	5.9371E-05	16.973	0.058917	–3.9917	–3.9917	–0.020215	0.051603	0.080066	1740.6	–0.57672
150.00	0.00041697	16.567	0.060361	–2.7699	–2.7699	–0.011635	0.053564	0.082659	1637.2	–0.55180
165.00	0.0019723	16.162	0.061873	–1.5160	–1.5159	–0.0036693	0.054606	0.084443	1542.5	–0.53067
180.00	0.0069671	15.755	0.063470	–0.23811	–0.23766	0.0037429	0.055253	0.085952	1450.8	–0.50839
195.00	0.019747	15.343	0.065175	1.0625	1.0638	0.010683	0.055851	0.087538	1359.1	–0.48173
210.00	0.047272	14.922	0.067016	2.3884	2.3916	0.017233	0.056582	0.089404	1266.3	–0.44843
225.00	0.099223	14.487	0.069027	3.7442	3.7510	0.023468	0.057524	0.091663	1171.8	–0.40645
240.00	0.18775	14.035	0.071251	5.1356	5.1490	0.029455	0.058697	0.094401	1075.9	–0.35329
255.00	0.32701	13.559	0.073750	6.5692	6.5933	0.035251	0.060098	0.097711	978.69	–0.28530
270.00	0.53269	13.054	0.076607	8.0523	8.0931	0.040906	0.061715	0.10174	880.57	–0.19657
285.00	0.82165	12.509	0.079945	9.5938	9.6595	0.046469	0.063540	0.10676	781.63	–0.077005
300.00	1.2118	11.911	0.083956	11.205	11.307	0.051993	0.065577	0.11327	681.71	0.092061
315.00	1.7225	11.240	0.088971	12.904	13.057	0.057541	0.067855	0.12246	580.13	0.34911
330.00	2.3751	10.455	0.095644	14.722	14.949	0.063218	0.070450	0.13754	475.08	0.78805
345.00	3.1956	9.4631	0.10567	16.734	17.071	0.069261	0.073575	0.17154	362.18	1.7115
360.00	4.2202	7.8236	0.12782	19.290	19.829	0.076741	0.078178	0.39594	229.03	4.9073
365.57	4.6646	5.3086	0.18837	21.862	22.741	0.084569			0	12.042
105.00	1.8242E-07	2.0896E-07	4,785,700.	16.041	16.914	0.18156	0.031371	0.039685	162.00	260.32
120.00	4.8828E-06	4.8940E-06	204,330.	16.525	17.522	0.15964	0.033039	0.041354	172.27	186.64
135.00	5.9371E-05	5.2900E-05	18,904.	17.032	18.154	0.14383	0.034573	0.042891	181.89	139.37
150.00	0.00041697	0.00033450	2,989.5	17.560	18.807	0.13221	0.036090	0.044423	190.90	107.24
165.00	0.0019723	0.0014403	694.32	18.109	19.479	0.12357	0.037686	0.046064	199.27	84.470
180.00	0.0069671	0.0046776	213.78	18.676	20.166	0.11710	0.039423	0.047910	206.90	67.837
195.00	0.019747	0.012310	81.237	19.258	20.862	0.11221	0.041343	0.050046	213.67	55.441
210.00	0.047272	0.027633	36.188	19.850	21.560	0.10851	0.043468	0.052548	219.38	46.072
225.00	0.099223	0.054946	18.200	20.446	22.252	0.10570	0.045811	0.055492	223.85	38.921
240.00	0.18775	0.099531	10.047	21.042	22.928	0.10354	0.048376	0.058970	226.88	33.424
255.00	0.32701	0.16779	5.9598	21.630	23.579	0.10186	0.051168	0.063112	228.25	29.182
270.00	0.53269	0.26768	3.7358	22.202	24.192	0.10053	0.054191	0.068131	227.73	25.909
285.00	0.82165	0.40967	2.4410	22.749	24.754	0.099433	0.057457	0.074408	225.06	23.398
300.00	1.2118	0.60872	1.6428	23.254	25.245	0.098452	0.060989	0.082685	219.92	21.502
315.00	1.7225	0.88863	1.1253	23.693	25.632	0.097460	0.064833	0.094593	211.93	20.107
330.00	2.3751	1.2929	0.77343	24.022	25.859	0.096280	0.069077	0.11448	200.59	19.116
345.00	3.1956	1.9214	0.52045	24.137	25.801	0.094563	0.073899	0.15900	185.21	18.381
360.00	4.2202	3.1801	0.31446	23.631	24.958	0.090988	0.079791	0.42332	164.25	17.115
365.57	4.6646	5.3086	0.18837	21.862	22.741	0.084569			0	12.042
Single-Phase Properties										
100.00	0.10000	17.939	0.055745	–6.6629	–6.6573	–0.043075	0.049534	0.076050	2009.3	–0.61954
200.00	0.10000	15.206	0.065766	1.4997	1.5063	0.012896	0.056075	0.088113	1328.9	–0.47165
225.17	0.10000	14.482	0.069051	3.7598	3.7667	0.023538	0.057536	0.091692	1170.7	–0.40591
225.17	0.10000	0.055346	18.068	20.453	22.260	0.10567	0.045839	0.055529	223.89	38.850
300.00	0.10000	0.040648	24.601	24.309	26.769	0.12289	0.056666	0.065495	258.13	16.866
400.00	0.10000	0.030232	33.078	30.772	34.080	0.14382	0.072240	0.080757	295.63	7.2207
500.00	0.10000	0.024118	41.463	38.745	42.891	0.16342	0.086809	0.095223	328.33	3.7462
600.00	0.10000	0.020074	49.815	48.088	53.070	0.18194	0.099688	0.10806	357.96	2.2036
100.00	1.0000	17.947	0.055720	–6.6707	–6.6149	–0.043152	0.049534	0.076021	2014.7	–0.61988
200.00	1.0000	15.224	0.065684	1.4781	1.5437	0.012788	0.056080	0.087997	1335.9	–0.47384
292.39	1.0000	12.222	0.081820	10.378	10.460	0.049191	0.064516	0.10973	732.56	–0.0016360
292.39	1.0000	0.49938	2.0025	23.004	25.006	0.098942	0.059161	0.078164	222.86	22.395
300.00	1.0000	0.47670	2.0978	23.500	25.598	0.10094	0.059932	0.077330	228.89	20.287

TABLE 2-249 Thermodynamic Properties of Propylene (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Single-Phase Properties										
400.00	1.0000	0.31858	3.1389	30.390	33.529	0.12371	0.073331	0.084055	283.73	7.6465
500.00	1.0000	0.24704	4.0480	38.516	42.564	0.14381	0.087329	0.096722	322.07	3.8350
600.00	1.0000	0.20332	4.9183	47.935	52.854	0.16254	0.099980	0.10888	354.28	2.2229
200.00	5.0000	15.306	0.065334	1.3850	1.7117	0.012317	0.056114	0.087522	1365.9	–0.48279
300.00	5.0000	12.206	0.081924	10.889	11.299	0.050918	0.065369	0.10822	752.67	–0.041773
400.00	5.0000	2.2829	0.43803	27.896	30.087	0.10377	0.080080	0.12610	221.38	9.5490
500.00	5.0000	1.3832	0.72298	37.351	40.966	0.12811	0.089729	0.10566	297.48	4.0173
600.00	5.0000	1.0713	0.93348	47.197	51.865	0.14796	0.10124	0.11304	342.05	2.2088
200.00	10.000	15.402	0.064925	1.2752	1.9245	0.011753	0.056174	0.087009	1401.2	–0.49245
300.00	10.000	12.515	0.079905	10.553	11.352	0.049747	0.065258	0.10422	828.84	–0.15061
400.00	10.000	7.5283	0.13283	22.740	24.068	0.085918	0.081711	0.16868	302.55	2.6128
500.00	10.000	3.1462	0.31784	35.603	38.781	0.11902	0.092261	0.12166	287.51	3.5544
600.00	10.000	2.2419	0.44605	46.180	50.641	0.14065	0.10253	0.11891	340.40	1.9833
200.00	100.00	16.616	0.060184	–0.021002	5.9974	0.0040990	0.058338	0.083715	1815.4	–0.55416
300.00	100.00	14.839	0.067390	8.0040	14.743	0.039443	0.067573	0.092245	1457.4	–0.48492
400.00	100.00	13.274	0.075333	17.017	24.550	0.067574	0.081108	0.10402	1192.7	–0.40335
500.00	100.00	11.892	0.084087	27.127	35.536	0.092040	0.094320	0.11555	1020.4	–0.33132
600.00	100.00	10.680	0.093635	38.256	47.620	0.11404	0.10601	0.12591	913.65	–0.27115
200.00	200.00	17.488	0.057182	–0.77627	10.660	–0.0018754	0.060831	0.083362	2084.9	–0.55991
300.00	200.00	16.028	0.062389	6.8870	19.365	0.033304	0.070484	0.091727	1796.1	–0.51205
400.00	200.00	14.825	0.067452	15.619	29.110	0.061259	0.084735	0.10329	1568.7	–0.45996
500.00	200.00	13.819	0.072363	25.539	40.011	0.085539	0.098618	0.11458	1403.8	–0.42037
600.00	200.00	12.963	0.077142	36.558	51.987	0.10734	0.11085	0.12471	1282.8	–0.39117

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Angus, S., Armstrong, B., and de Reuck, K. M., "International Thermodynamic Tables of the Fluid State—7 Propylene," *International Union of Pure and Applied Chemistry*, Pergamon Press, Oxford, 1980. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are generally 0.1% in density (except in the critical region), 1% in the heat capacity in the vapor phase, and 2–5% in the heat capacity in the liquid phase.

TABLE 2-250 Thermodynamic Properties of R-11, Trichlorofluoromethane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
162.68	6.5101E-06	12.874	0.077673	15.035	15.035	0.079300	0.074722	0.10506	1224.2	–0.60355
165.00	9.0030E-06	12.841	0.077878	15.280	15.280	0.080791	0.074630	0.10557	1221.1	–0.59915
180.00	5.8433E-05	12.618	0.079249	16.886	16.886	0.090108	0.075084	0.10851	1178.8	–0.57445
195.00	0.00027433	12.392	0.080694	18.531	18.531	0.098885	0.076137	0.11069	1119.8	–0.55514
210.00	0.0010018	12.164	0.082210	20.204	20.204	0.10715	0.077185	0.11231	1057.5	–0.53850
225.00	0.0030014	11.933	0.083801	21.899	21.899	0.11494	0.078127	0.11364	996.42	–0.52214
240.00	0.0076770	11.699	0.085475	23.613	23.614	0.12232	0.078986	0.11489	937.75	–0.50429
255.00	0.017281	11.462	0.087246	25.346	25.347	0.12932	0.079799	0.11621	881.67	–0.48363
270.00	0.035048	11.219	0.089131	27.099	27.102	0.13600	0.080594	0.11767	827.91	–0.45904
285.00	0.065240	10.971	0.091150	28.875	28.881	0.14240	0.081391	0.11933	776.09	–0.42946
300.00	0.11311	10.715	0.093329	30.677	30.687	0.14856	0.082199	0.12124	725.77	–0.39364
315.00	0.18478	10.449	0.095702	32.508	32.525	0.15452	0.083025	0.12343	676.56	–0.34999
330.00	0.28718	10.172	0.098308	34.371	34.399	0.16030	0.083873	0.12595	628.04	–0.29629
345.00	0.42787	9.8812	0.10120	36.271	36.315	0.16594	0.084749	0.12888	579.81	–0.22926
360.00	0.61496	9.5733	0.10446	38.213	38.277	0.17145	0.085663	0.13232	531.47	–0.14389
375.00	0.85703	9.2442	0.10818	40.203	40.295	0.17687	0.086633	0.13648	482.57	–0.032121
390.00	1.1631	8.8882	0.11251	42.247	42.378	0.18223	0.087686	0.14171	432.58	0.11986
405.00	1.5427	8.4966	0.11769	44.359	44.541	0.18756	0.088870	0.14871	380.86	0.33760
420.00	2.0061	8.0545	0.12415	46.558	46.808	0.19292	0.090270	0.15899	326.51	0.67402
435.00	2.5648	7.5340	0.13273	48.882	49.223	0.19840	0.092058	0.17674	268.20	1.2582
450.00	3.2329	6.8663	0.14564	51.423	51.894	0.20422	0.094658	0.21832	203.77	2.4973
465.00	4.0318	5.7930	0.17262	54.535	55.231	0.21124	0.099494	0.43941	132.04	6.3140
471.11	4.4076	4.0330	0.24796	57.789	58.881	0.21886			0	15.427
162.68	6.5101E-06	4.8133E-06	207,760.	44.924	46.276	0.27134	0.049536	0.057858	107.23	1885.7
165.00	9.0030E-06	6.5631E-06	152,370.	45.039	46.411	0.26946	0.050011	0.058335	107.92	1701.5
180.00	5.8433E-05	3.9056E-05	25,605.	45.809	47.305	0.25910	0.052998	0.061344	112.26	905.28
195.00	0.00027433	0.00016934	5,905.3	46.618	48.238	0.25123	0.055869	0.064262	116.42	508.88
210.00	0.0010018	0.00057483	1,739.7	47.463	49.206	0.24525	0.058662	0.067140	120.39	301.60
225.00	0.0030014	0.0016103	621.01	48.339	50.203	0.24074	0.061395	0.070004	124.15	188.62
240.00	0.0076770	0.0038729	258.21	49.242	51.224	0.23736	0.064063	0.072855	127.67	124.75
255.00	0.017281	0.0082428	121.32	50.168	52.265	0.23488	0.066646	0.075684	130.89	87.418
270.00	0.035048	0.015895	62.911	51.115	53.320	0.23310	0.069122	0.078487	133.75	64.864
285.00	0.065240	0.028297	35.340	52.075	54.381	0.23188	0.071480	0.081281	136.17	50.774
300.00	0.11311	0.047202	21.186	53.045	55.441	0.23108	0.073723	0.084113	138.07	41.663
315.00	0.18478	0.074674	13.391	54.015	56.490	0.23060	0.075868	0.087058	139.37	35.564
330.00	0.28718	0.11315	8.8379	54.979	57.517	0.23036	0.077940	0.090222	140.01	31.344
345.00	0.42787	0.16555	6.0405	55.928	58.512	0.23028	0.079972	0.093753	139.89	28.342
360.00	0.61496	0.23549	4.2464	56.851	59.462	0.23030	0.081998	0.097861	138.95	26.165
375.00	0.85703	0.32766	3.0519	57.736	60.352	0.23035	0.084057	0.10286	137.09	24.577
390.00	1.1631	0.44843	2.2300	58.569	61.163	0.23039	0.086191	0.10929	134.19	23.443
405.00	1.5427	0.60714	1.6471	59.331	61.872	0.23035	0.088457	0.11813	130.10	22.687
420.00	2.0061	0.81886	1.2212	59.992	62.442	0.23014	0.090937	0.13148	124.58	22.277
435.00	2.5648	1.1115	0.89966	60.498	62.805	0.22962	0.093775	0.15496	117.29	22.202
450.00	3.2329	1.5503	0.64504	60.727	62.813	0.22849	0.097282	0.20995	107.74	22.379
465.00	4.0318	2.3952	0.41751	60.210	61.894	0.22557	0.10241	0.51972	95.245	21.779
471.11	4.4076	4.0330	0.24796	57.789	58.881	0.21886			0	15.427
Single-Phase Properties										
200.00	0.10000	12.317	0.081186	19.084	19.092	0.10168	0.076484	0.11128	1099.8	–0.54951
296.49	0.10000	10.776	0.092803	30.252	30.262	0.14714	0.082009	0.12077	737.44	–0.40266
296.49	0.10000	0.042088	23.760	52.817	55.193	0.23123	0.073207	0.083443	137.67	43.472
300.00	0.10000	0.041523	24.083	53.078	55.486	0.23221	0.073294	0.083384	138.61	41.094
400.00	0.10000	0.030462	32.827	60.756	64.039	0.25678	0.079843	0.088628	161.80	15.373
500.00	0.10000	0.024206	41.312	69.066	73.197	0.27719	0.085650	0.094219	181.31	9.4764
600.00	0.10000	0.020110	49.728	77.853	82.825	0.29474	0.089636	0.098111	198.74	6.5190

TABLE 2-250 Thermodynamic Properties of R-11, Trichlorofluoromethane (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Single-Phase Properties										
200.00	1.0000	12.325	0.081134	19.066	19.147	0.10159	0.076374	0.11122	1106.2	–0.55026
300.00	1.0000	10.733	0.093174	30.637	30.730	0.14843	0.082161	0.12101	731.85	–0.39806
382.43	1.0000	9.0718	0.11023	41.208	41.318	0.17953	0.087142	0.13891	457.99	0.036901
382.43	1.0000	0.38339	2.6083	58.156	60.765	0.23038	0.085101	0.10582	135.79	23.965
400.00	1.0000	0.35322	2.8311	59.743	62.574	0.23501	0.083835	0.10080	143.19	19.717
500.00	1.0000	0.25738	3.8853	68.469	72.354	0.25684	0.086291	0.097662	172.67	10.081
600.00	1.0000	0.20723	4.8256	77.413	82.239	0.27486	0.090004	0.10006	194.29	6.6365
200.00	5.0000	12.359	0.080912	18.988	19.393	0.10120	0.075954	0.11098	1133.5	–0.55346
300.00	5.0000	10.810	0.092509	30.464	30.926	0.14785	0.082048	0.12006	757.72	–0.41608
400.00	5.0000	8.8674	0.11277	43.167	43.731	0.18456	0.087727	0.13909	448.07	0.070413
500.00	5.0000	2.1555	0.46393	64.141	66.460	0.23416	0.094709	0.18205	120.07	14.043
600.00	5.0000	1.2189	0.82040	75.225	79.327	0.25776	0.091726	0.11326	173.08	7.0186
200.00	10.000	12.399	0.080649	18.894	19.700	0.10072	0.075562	0.11072	1164.8	–0.55716
300.00	10.000	10.899	0.091755	30.263	31.181	0.14716	0.082018	0.11907	787.03	–0.43502
400.00	10.000	9.1187	0.10966	42.641	43.737	0.18319	0.087335	0.13358	500.70	–0.076836
500.00	10.000	6.3465	0.15757	56.993	58.568	0.21613	0.093373	0.17100	231.94	1.9364
600.00	10.000	3.0124	0.33196	71.945	75.265	0.24670	0.093817	0.13897	167.77	5.3068
200.00	20.000	12.475	0.080163	18.716	20.320	0.099796	0.075119	0.11027	1220.3	–0.56373
300.00	20.000	11.057	0.090438	29.905	31.714	0.14590	0.082196	0.11753	838.26	–0.46461
400.00	20.000	9.4912	0.10536	41.844	43.951	0.18104	0.087334	0.12773	578.74	–0.23372
500.00	20.000	7.6205	0.13123	54.651	57.275	0.21072	0.091707	0.13823	378.80	0.31683
600.00	20.000	5.5967	0.17868	67.668	71.241	0.23619	0.094708	0.13794	265.18	1.2664
200.00	30.000	12.543	0.079723	18.552	20.943	0.098918	0.075012	0.10990	1268.1	–0.56938
300.00	30.000	11.197	0.089311	29.591	32.270	0.14476	0.082559	0.11638	882.50	–0.48678
400.00	30.000	9.7739	0.10231	41.235	44.304	0.17932	0.087676	0.12450	638.80	–0.31979
500.00	30.000	8.2190	0.12167	53.466	57.116	0.20788	0.091885	0.13097	464.35	–0.028029
600.00	30.000	6.6706	0.14991	65.781	70.278	0.23188	0.095040	0.13106	357.26	0.34752

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Jacobsen, R. T., Penoncello, S. G., and Lemmon, E. W., "A Fundamental Equation for Trichlorofluoromethane (R-11)," *Fluid Phase Equilibria* **80**:45–56, 1992. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are 0.1% in density for the liquid, and 0.25% for the vapor, 2% in heat capacity, and 1% in the speed of sound, except in the critical region. The uncertainty in vapor pressure is 0.2%.

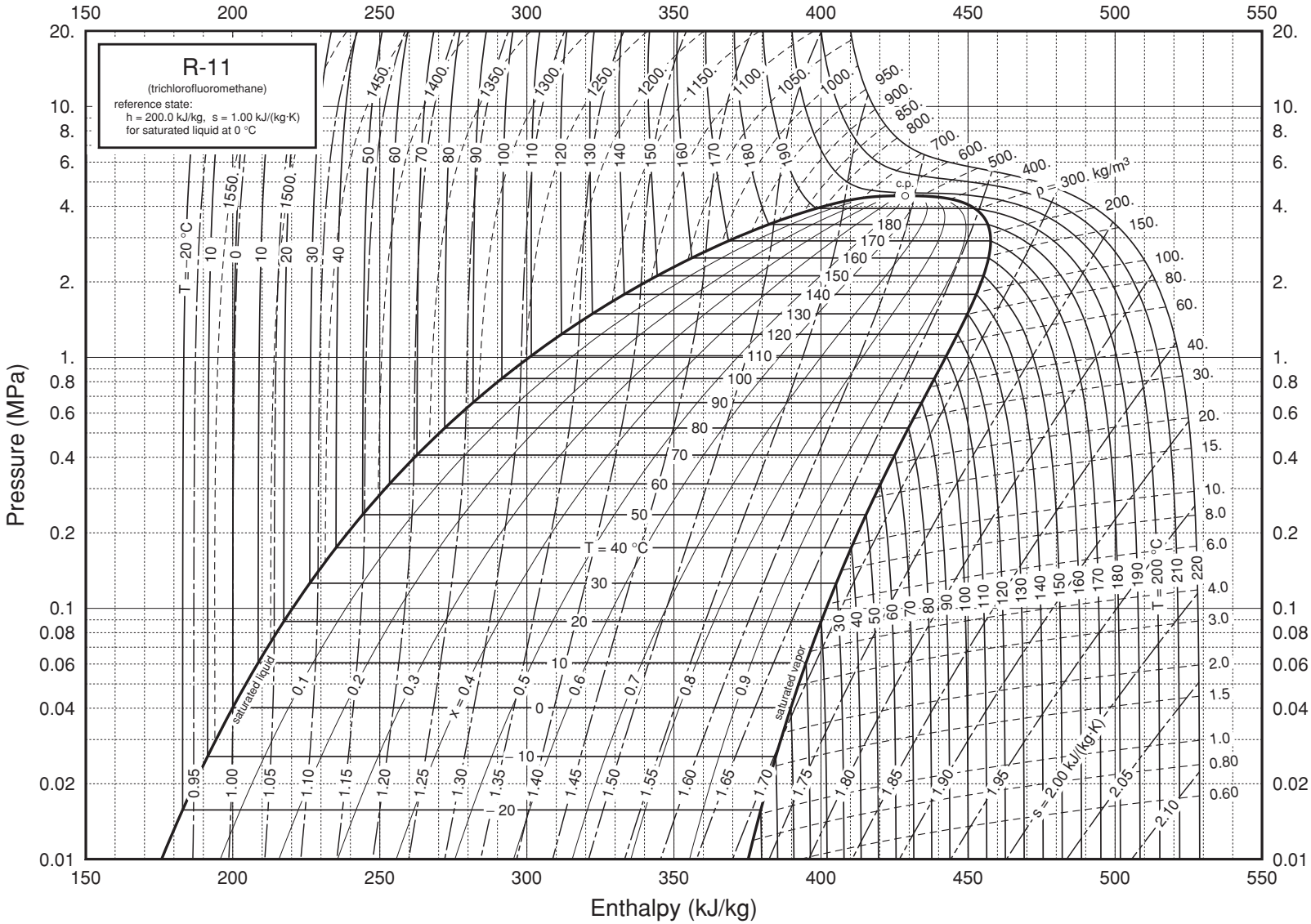

FIG. 2-18 Pressure-enthalpy diagram for Refrigerant 11. Properties computed with the NIST REFPROP Database, Version 7.0 (Lemmon, E. W., McLinden, M. O., and Huber, M. L., 2002, NIST Standard Reference Database 23, NIST Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, Standard Reference Data Program, National Institute of Standards and Technology), based on the equation of state of Jacobsen, R. T., Penoncello, S. G., and Lemmon, E. W., "A Fundamental Equation for Trichlorofluoromethane (R-11)," *Fluid Phase Equilibria* **80:**45–56, 1992.

TABLE 2-251 Thermodynamic Properties of R-12, Dichlorodifluoromethane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
116.10	2.4255E-07	15.125	0.066114	8.0204	8.0204	0.033619	0.069219	0.10352	1310.0	–0.53048
120.00	5.8432E-07	15.039	0.066492	8.4220	8.4220	0.037021	0.068095	0.10239	1290.2	–0.53554
135.00	1.0092E-05	14.712	0.067972	9.9342	9.9342	0.048899	0.065219	0.099608	1215.7	–0.54646
150.00	9.1829E-05	14.387	0.069505	11.419	11.419	0.059328	0.063937	0.098564	1143.1	–0.54643
165.00	0.00053030	14.064	0.071106	12.897	12.897	0.068717	0.063633	0.098622	1072.5	–0.53813
180.00	0.0021945	13.738	0.072790	14.381	14.381	0.077328	0.063942	0.099406	1003.9	–0.52327
195.00	0.0070692	13.409	0.074574	15.881	15.882	0.085332	0.064638	0.10070	937.07	–0.50270
210.00	0.018793	13.075	0.076482	17.403	17.405	0.092852	0.065582	0.10237	872.00	–0.47654
225.00	0.043015	12.733	0.078538	18.953	18.956	0.099978	0.066683	0.10436	808.46	–0.44424
240.00	0.087479	12.380	0.080776	20.533	20.540	0.10678	0.067882	0.10664	746.23	–0.40455
255.00	0.16186	12.013	0.083241	22.149	22.162	0.11331	0.069143	0.10925	685.03	–0.35528
270.00	0.27747	11.629	0.085990	23.803	23.827	0.11961	0.070443	0.11226	624.56	–0.29292
285.00	0.44693	11.223	0.089104	25.502	25.541	0.12574	0.071775	0.11579	564.41	–0.21173
300.00	0.68394	10.787	0.092703	27.250	27.314	0.13172	0.073152	0.12012	504.07	–0.10203
315.00	1.0032	10.312	0.096973	29.059	29.157	0.13762	0.074611	0.12572	442.82	0.053692
330.00	1.4203	9.7818	0.10223	30.943	31.088	0.14348	0.076246	0.13360	379.59	0.29048
345.00	1.9528	9.1671	0.10909	32.930	33.143	0.14940	0.078279	0.14625	312.77	0.68965
360.00	2.6209	8.4050	0.11898	35.078	35.390	0.15556	0.081286	0.17199	239.96	1.4874
375.00	3.4527	7.3032	0.13693	37.570	38.042	0.16248	0.087150	0.26475	158.26	3.7100
385.12	4.1362	4.6728	0.21401	41.164	42.049	0.17270			0	13.369
116.10	2.4255E-07	2.5127E-07	3,979,800.	33.279	34.244	0.25949	0.034581	0.042896	99.513	532.61
120.00	5.8432E-07	5.8564E-07	1,707,500.	33.415	34.413	0.25361	0.035365	0.043680	100.95	464.92
135.00	1.0092E-05	8.9910E-06	111,220.	33.968	35.091	0.23524	0.038409	0.046725	106.27	288.39
150.00	9.1829E-05	7.3643E-05	13,579.	34.567	35.814	0.22196	0.041427	0.049750	111.28	190.47
165.00	0.00053030	0.00038683	2,585.1	35.208	36.579	0.21224	0.044365	0.052712	116.02	132.65
180.00	0.0021945	0.0014695	680.49	35.888	37.381	0.20511	0.047211	0.055621	120.49	96.659
195.00	0.0070692	0.0043835	228.13	36.602	38.214	0.19986	0.049977	0.058515	124.63	73.304
210.00	0.018793	0.010883	91.884	37.342	39.069	0.19601	0.052681	0.061451	128.34	57.635
225.00	0.043015	0.023468	42.611	38.102	39.935	0.19322	0.055348	0.064497	131.52	46.836
240.00	0.087479	0.045368	22.042	38.873	40.801	0.19120	0.058002	0.067735	134.05	39.210
255.00	0.16186	0.080547	12.415	39.647	41.657	0.18976	0.060669	0.071271	135.80	33.704
270.00	0.27747	0.13381	7.4735	40.415	42.488	0.18873	0.063373	0.075247	136.64	29.653
285.00	0.44693	0.21108	4.7376	41.165	43.283	0.18799	0.066138	0.079875	136.46	26.640
300.00	0.68394	0.32006	3.1244	41.887	44.024	0.18742	0.068991	0.085504	135.10	24.405
315.00	1.0032	0.47149	2.1209	42.562	44.689	0.18693	0.071972	0.092789	132.40	22.790
330.00	1.4203	0.68182	1.4667	43.166	45.249	0.18639	0.075158	0.10314	128.14	21.703
345.00	1.9528	0.97985	1.0206	43.655	45.648	0.18565	0.078715	0.12016	122.00	21.085
360.00	2.6209	1.4275	0.70055	43.941	45.777	0.18441	0.083065	0.15653	113.54	20.831
375.00	3.4527	2.2257	0.44930	43.738	45.289	0.18181	0.089754	0.30373	102.14	20.225
385.12	4.1362	4.6728	0.21401	41.164	42.049	0.17270			0	13.369

Single-Phase Properties

125.00	0.10000	14.931	0.066977	8.9296	8.9363	0.041166	0.066915	0.10121	1265.3	–0.54064
225.00	0.10000	12.734	0.078531	18.951	18.959	0.099970	0.066686	0.10435	808.74	–0.44443
243.09	0.10000	12.306	0.081264	20.863	20.871	0.10814	0.068138	0.10715	733.55	–0.39528
243.09	0.10000	0.051383	19.462	39.033	40.979	0.19086	0.058549	0.068435	134.48	37.929
325.00	0.10000	0.037543	26.636	44.257	46.920	0.21187	0.067874	0.076721	156.65	16.166
425.00	0.10000	0.028469	35.126	51.527	55.039	0.23360	0.076661	0.085212	179.16	8.3282
525.00	0.10000	0.022973	43.529	59.527	63.880	0.25225	0.082795	0.091242	198.90	5.1283
125.00	1.0000	14.938	0.066945	8.9186	8.9856	0.041078	0.066988	0.10119	1267.0	–0.54091
225.00	1.0000	12.752	0.078422	18.922	19.001	0.099842	0.066739	0.10418	813.10	–0.44741
314.87	1.0000	10.316	0.096933	29.043	29.140	0.13757	0.074598	0.12566	443.35	0.052069
314.87	1.0000	0.46996	2.1279	42.556	44.684	0.18693	0.071945	0.092716	132.43	22.802
325.00	1.0000	0.44273	2.2587	43.348	45.606	0.18982	0.071678	0.089701	137.48	19.919
425.00	1.0000	0.30150	3.3167	51.055	54.372	0.21333	0.077527	0.088660	171.39	8.7630
525.00	1.0000	0.23568	4.2430	59.210	63.453	0.23250	0.083185	0.092926	195.20	5.1839
125.00	5.0000	14.968	0.066807	8.8706	9.2046	0.040691	0.067308	0.10110	1274.3	–0.54205
225.00	5.0000	12.827	0.077958	18.799	19.189	0.099289	0.066963	0.10352	831.96	–0.45954
325.00	5.0000	10.252	0.097546	29.898	30.385	0.14025	0.075544	0.12368	450.15	0.017671
425.00	5.0000	2.2637	0.44176	47.937	50.146	0.19225	0.083408	0.14054	131.42	10.771
525.00	5.0000	1.3295	0.75217	57.642	61.402	0.21615	0.085038	0.10337	180.93	5.2339
125.00	10.000	15.006	0.066639	8.8124	9.4788	0.040215	0.067691	0.10099	1283.4	–0.54334
225.00	10.000	12.917	0.077418	18.655	19.429	0.098631	0.067222	0.10281	854.41	–0.47253
325.00	10.000	10.544	0.094842	29.472	30.420	0.13887	0.075613	0.11858	501.05	–0.12043
425.00	10.000	6.6383	0.15064	42.586	44.093	0.17528	0.084440	0.16445	204.25	2.4031
525.00	10.000	3.0541	0.32743	55.399	58.673	0.20629	0.087008	0.12146	177.27	4.2532
225.00	100.00	13.992	0.071470	17.017	24.164	0.090059	0.069779	0.098455	1155.1	–0.55347
325.00	100.00	12.599	0.079369	26.406	34.343	0.12742	0.077370	0.10504	937.26	–0.49945
425.00	100.00	11.358	0.088042	36.302	45.106	0.15626	0.084005	0.10984	788.21	–0.45110
525.00	100.00	10.262	0.097444	46.498	56.243	0.17978	0.088827	0.11260	690.80	–0.41225
225.00	200.00	14.702	0.068017	16.054	29.657	0.083541	0.070631	0.097995	1397.8	–0.56210
325.00	200.00	13.559	0.073751	25.016	39.766	0.12065	0.077764	0.10414	1220.9	–0.52944
425.00	200.00	12.582	0.079477	34.535	50.431	0.14923	0.084238	0.10881	1091.3	–0.50685
525.00	200.00	11.738	0.085195	44.429	61.468	0.17254	0.088994	0.11168	999.41	–0.49445

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Marx, V., Pruss, A., and Wagner, W., "Neue Zustandsgleichungen fuer R 12, R 22, R 11 und R 113. Beschreibung des thermodynamishchen Zustandsverhaltens bei Temperaturen bis 525 K und Druecken bis 200 MPa," Duesseldorf: *VDI Verlag*, Series 19 (Waermetechnik/Kaeltetechnik), No. 57, 1992. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in density are 0.2% below the critical point temperature and increase to 1% in and above the critical region. The uncertainties for vapor pressures are 0.2% above 200 K and greater than 1% below 200 K. The uncertainties in heat capacities and sound speeds are 1% each.

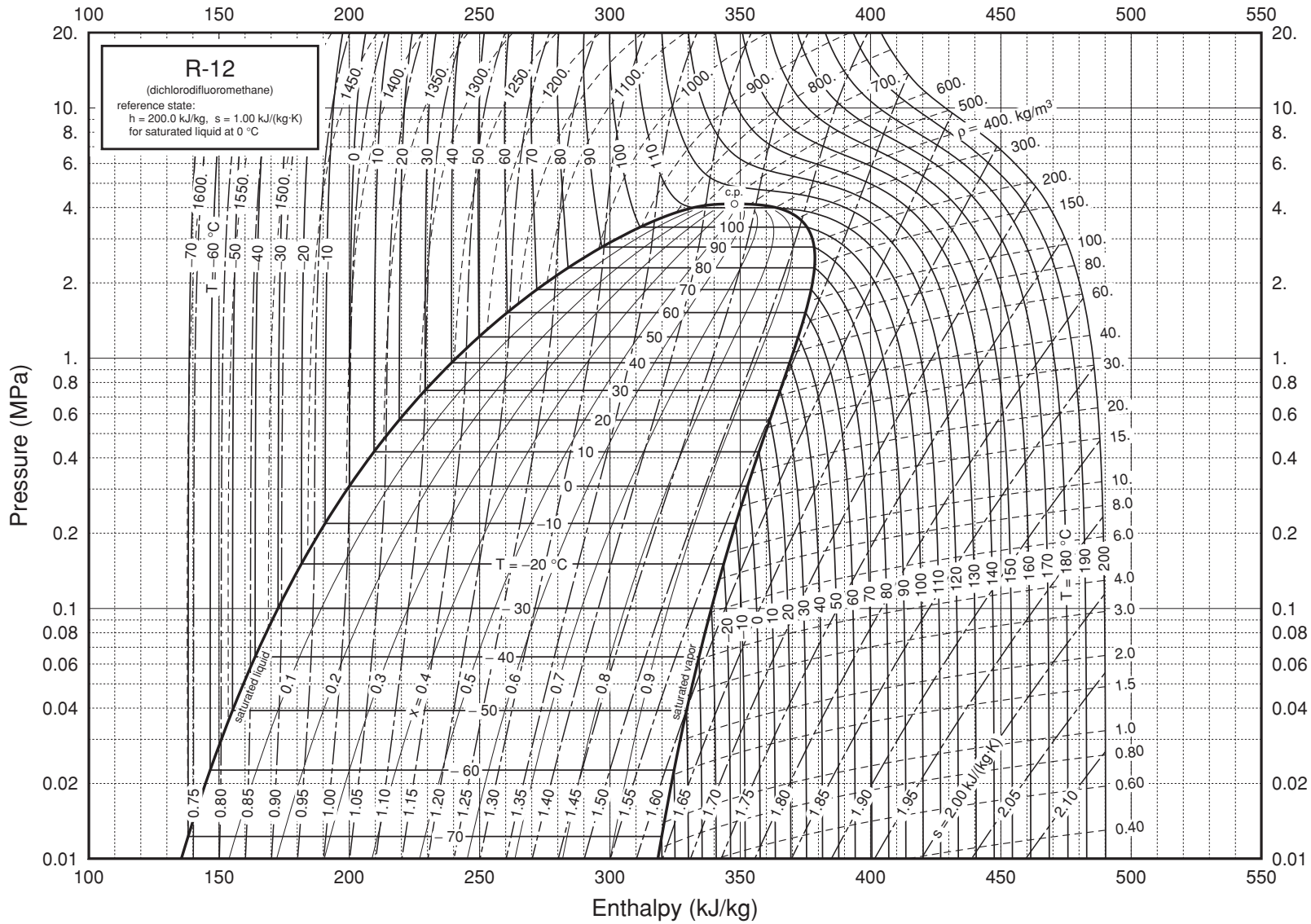

FIG. 2-19 Pressure-enthalpy diagram for Refrigerant 12. Properties computed with the NIST REFPROP Database, Version 7.0 (Lemmon, E. W., McLinden, M. O., and Huber, M. L., 2002, NIST Standard Reference Database 23, NIST Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, Standard Reference Data Program, National Institute of Standards and Technology), based on the equation of state of Marx, V., Pruβ, A., and Wagner, W., "Neue Zustandsgleichungen für R 12, R 22, R 11 und R 113. Beschreibung des thermodynamischen Zustandsverhaltens bei Temperaturen bis 525 K und Drücken bis 200 MPa," VDI-Fortschritt-Ber. Series 19, No. 57, Düsseldorf: VDI Verlag, 1992.

TABLE 2-252 Thermodynamic Properties of R-13, Chlorotrifluoromethane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
92.000	3.2889E-07	17.840	0.056054	3.4760	3.4760	0.0038039	0.059797	0.077526	918.05	–0.61098
100.00	2.6891E-06	17.596	0.056830	4.1217	4.1217	0.010530	0.059177	0.083231	1032.1	–0.56374
110.00	2.3101E-05	17.288	0.057844	4.9721	4.9721	0.018633	0.057632	0.086329	1078.3	–0.53784
120.00	0.00013272	16.976	0.058907	5.8413	5.8413	0.026196	0.055848	0.087308	1072.1	–0.52512
130.00	0.00056195	16.660	0.060023	6.7158	6.7159	0.033195	0.054335	0.087538	1039.3	–0.51544
140.00	0.0018797	16.339	0.061202	7.5918	7.5919	0.039687	0.053311	0.087670	992.15	–0.50447
150.00	0.0052264	16.012	0.062451	8.4698	8.4701	0.045744	0.052818	0.087987	937.71	–0.49023
160.00	0.012543	15.679	0.063780	9.3523	9.3531	0.051439	0.052815	0.088595	879.99	–0.47186
170.00	0.026741	15.337	0.065200	10.242	10.244	0.056835	0.053227	0.089527	821.49	–0.44883
180.00	0.051763	14.987	0.066725	11.143	11.146	0.061982	0.053972	0.090788	763.71	–0.42058
190.00	0.092557	14.626	0.068370	12.057	12.063	0.066925	0.054972	0.092386	707.45	–0.38628
200.00	0.15496	14.254	0.070158	12.988	12.999	0.071701	0.056159	0.094338	653.03	–0.34462
210.00	0.24553	13.866	0.072118	13.939	13.956	0.076341	0.057477	0.096688	600.48	–0.29355
220.00	0.37145	13.461	0.074289	14.913	14.940	0.080874	0.058882	0.099513	549.57	–0.22995
230.00	0.54033	13.033	0.076727	15.914	15.955	0.085328	0.060340	0.10294	499.97	–0.14899
240.00	0.76025	12.577	0.079511	16.947	17.007	0.089732	0.061829	0.10719	451.26	–0.043013
250.00	1.0397	12.083	0.082762	18.018	18.104	0.094118	0.063338	0.11266	402.91	0.10085
260.00	1.3878	11.537	0.086674	19.137	19.258	0.098526	0.064870	0.12009	354.31	0.30583
270.00	1.8145	10.919	0.091587	20.319	20.485	0.10301	0.066451	0.13115	304.57	0.61895
280.00	2.3316	10.183	0.098198	21.591	21.820	0.10769	0.068161	0.15049	252.29	1.1529
290.00	2.9538	9.2260	0.10839	23.021	23.341	0.11280	0.070241	0.19837	194.59	2.2680
300.00	3.7065	7.4440	0.13434	25.005	25.503	0.11981	0.074099	0.74301	122.38	6.3031
302.00	3.8790	5.5800	0.17921	26.462	27.158	0.12522			0	11.123
92.000	3.2889E-07	4.2996E-07	2,325,800.	22.976	23.741	0.22408	0.026152	0.034466	98.239	846.97
100.00	2.6891E-06	3.2343E-06	309,190.	23.192	24.023	0.20954	0.027668	0.035983	101.74	607.63
110.00	2.3101E-05	2.5261E-05	39,587.	23.477	24.392	0.19518	0.029536	0.037856	105.92	414.42
120.00	0.00013272	0.00013307	7,514.8	23.781	24.778	0.18400	0.031384	0.039718	109.91	291.57
130.00	0.00056195	0.00052045	1,921.4	24.101	25.181	0.17523	0.033228	0.041601	113.70	210.73
140.00	0.0018797	0.0016191	617.64	24.435	25.596	0.16829	0.035092	0.043546	117.29	155.99
150.00	0.0052264	0.0042135	237.33	24.782	26.022	0.16276	0.037002	0.045603	120.64	118.01
160.00	0.012543	0.0095248	104.99	25.137	26.454	0.15832	0.038978	0.047816	123.73	91.120
170.00	0.026741	0.019245	51.961	25.499	26.888	0.15474	0.041033	0.050218	126.48	71.760
180.00	0.051763	0.035532	28.144	25.864	27.321	0.15184	0.043168	0.052835	128.85	57.628
190.00	0.092557	0.060985	16.398	26.231	27.749	0.14948	0.045375	0.055688	130.77	47.196
200.00	0.15496	0.098644	10.137	26.597	28.168	0.14755	0.047639	0.058800	132.18	39.425
210.00	0.24553	0.15204	6.5771	26.959	28.574	0.14595	0.049946	0.062214	133.00	33.599
220.00	0.37145	0.22536	4.4373	27.315	28.963	0.14462	0.052282	0.066006	133.16	29.214
230.00	0.54033	0.32372	3.0891	27.659	29.329	0.14347	0.054636	0.070318	132.58	25.919
240.00	0.76025	0.45374	2.2039	27.987	29.663	0.14246	0.057009	0.075407	131.16	23.463
250.00	1.0397	0.62459	1.6010	28.289	29.954	0.14152	0.059411	0.081759	128.80	21.667
260.00	1.3878	0.84999	1.1765	28.552	30.185	0.14055	0.061872	0.090357	125.37	20.399
270.00	1.8145	1.1527	0.86755	28.753	30.327	0.13947	0.064450	0.10345	120.73	19.555
280.00	2.3316	1.5762	0.63445	28.850	30.329	0.13808	0.067265	0.12745	114.75	19.007
290.00	2.9538	2.2289	0.44866	28.740	30.066	0.13599	0.070591	0.19031	107.22	18.455
300.00	3.7065	3.7166	0.26906	27.886	28.884	0.13108	0.075537	0.91719	98.019	15.921
302.00	3.8790	5.5800	0.17921	26.462	27.158	0.12522			0	11.123
Single-Phase Properties										
100.00	0.10000	17.598	0.056826	4.1207	4.1264	0.010520	0.059127	0.083227	1033.2	–0.56370
175.00	0.10000	15.165	0.065942	10.689	10.696	0.059427	0.053557	0.090103	792.98	–0.43564
191.43	0.10000	14.574	0.068616	12.189	12.196	0.067617	0.055131	0.092642	699.56	–0.38082
191.43	0.10000	0.065539	15.258	26.284	27.809	0.14918	0.045695	0.056115	131.00	45.943
250.00	0.10000	0.048881	20.458	29.189	31.235	0.16476	0.052574	0.061514	150.16	17.864
325.00	0.10000	0.037259	26.839	33.487	36.171	0.18198	0.061422	0.069986	170.52	8.3711
400.00	0.10000	0.030170	33.145	38.384	41.699	0.19726	0.068694	0.077154	188.46	5.2121

TABLE 2-252 Thermodynamic Properties of R-13, Chlorotrifluoromethane (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Single-Phase Properties										
100.00	1.0000	17.609	0.056790	4.1118	4.1686	0.010431	0.058689	0.083187	1042.6	–0.56328
175.00	1.0000	15.188	0.065843	10.666	10.731	0.059291	0.053474	0.089928	800.56	–0.43907
248.71	1.0000	12.149	0.082311	17.878	17.960	0.093552	0.063142	0.11187	409.14	0.079502
248.71	1.0000	0.59985	1.6671	28.252	29.919	0.14164	0.059099	0.080842	129.16	21.866
250.00	1.0000	0.59355	1.6848	28.338	30.023	0.14205	0.059028	0.080216	129.97	21.418
325.00	1.0000	0.39827	2.5108	33.099	35.610	0.16162	0.062521	0.073958	162.24	8.9819
400.00	1.0000	0.31126	3.2128	38.116	41.329	0.17744	0.068870	0.078791	184.36	5.3350
100.00	5.0000	17.658	0.056633	4.0724	4.3555	0.010032	0.056929	0.083080	1081.6	–0.56120
175.00	5.0000	15.284	0.065427	10.564	10.891	0.058704	0.053220	0.089221	831.21	–0.45278
250.00	5.0000	12.436	0.080411	17.696	18.098	0.092801	0.062047	0.10644	461.89	–0.057256
325.00	5.0000	3.5611	0.28081	29.869	31.273	0.13759	0.071896	0.18862	120.24	10.597
400.00	5.0000	1.8042	0.55425	36.726	39.497	0.16061	0.070112	0.090875	170.26	5.4004
100.00	10.000	17.716	0.056446	4.0235	4.5880	0.0095294	0.055111	0.083086	1124.6	–0.55799
175.00	10.000	15.396	0.064954	10.446	11.096	0.058009	0.053119	0.088480	863.64	–0.46709
250.00	10.000	12.772	0.078295	17.377	18.160	0.091462	0.061300	0.10203	518.33	–0.17104
325.00	10.000	8.8242	0.11332	25.758	26.891	0.12181	0.069005	0.13617	240.23	1.3924
400.00	10.000	4.2213	0.23689	34.655	37.023	0.14997	0.071938	0.11434	173.36	3.9992
100.00	15.000	17.772	0.056268	3.9751	4.8192	0.0090235	0.053642	0.083232	1162.0	–0.55407
175.00	15.000	15.499	0.064521	10.336	11.304	0.057352	0.053200	0.087860	890.77	–0.47907
250.00	15.000	13.041	0.076680	17.115	18.265	0.090334	0.061058	0.099258	562.82	–0.24338
325.00	15.000	9.9265	0.10074	24.846	26.357	0.11854	0.068084	0.11665	322.91	0.49723
400.00	15.000	6.3827	0.15667	32.962	35.312	0.14333	0.072431	0.11694	213.68	1.9494
175.00	35.000	15.857	0.063065	9.9615	12.169	0.055005	0.054657	0.086150	962.40	–0.51269
250.00	35.000	13.811	0.072404	16.358	18.892	0.086896	0.062146	0.093881	679.17	–0.38660
325.00	35.000	11.718	0.085341	23.258	26.245	0.11257	0.069359	0.10153	492.75	–0.18758
400.00	35.000	9.7082	0.10301	30.364	33.969	0.13395	0.074599	0.10349	383.00	0.022671

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Magee, J. W., Outcalt, S. L., and Ely, J. F., "Molar Heat Capacity $C(v)$, Vapor Pressure, and (p, Rho, T) Measurements from 92 to 350 K at Pressures to 35 MPa and a New Equation of State for Chlorotrifluoromethane (R13)," *Int. J. Thermophys.* **21**(5):1097–1121, 2000. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are 0.15% in density and 2% in heat capacity, except in the critical region. The uncertainty in vapor pressure is 0.1%.

TABLE 2-253 Saturated Refrigerant 13B1, Bromotrifluoromethane*

T, K	P, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)	μ_f, 10^{-4} Pa·s	k_f, W/(m·K)
170	0.059	4.594.–4	1.6015	–40.90	90.95	–0.2033	0.5723	0.597	9.54	0.101
180	0.127	4.677.–4	0.7840	–34.75	94.37	–0.1682	0.5491	0.618	7.60	0.096
190	0.250	4.765.–4	0.4190	–28.51	97.83	–0.1345	0.5305	0.634	6.20	0.091
200	0.455	4.860.–4	0.2407	–22.17	101.32	–0.1020	0.5154	0.648	5.13	0.086
210	0.777	4.961.–4	0.1467	–15.68	104.82	–0.0704	0.5033	0.663	4.33	0.082
215.4	1.013	5.020.–4	0.1147	–12.09	106.70	–0.0536	0.4978	0.670	3.97	0.079
220	1.254	5.071.–4	0.0940	–9.02	108.28	–0.0396	0.4936	0.676	3.71	0.077
230	1.933	5.190.–4	0.0628	–2.19	111.68	–0.0094	0.4857	0.690	3.22	0.073
240	2.863	5.321.–4	0.0433	4.83	114.99	0.0202	0.4793	0.703	2.83	0.068
250	4.096	5.466.–4	0.0308	12.03	118.16	0.0494	0.4739	0.721	2.51	0.063
260	5.690	5.627.–4	0.0224	19.44	121.16	0.0781	0.4693	0.742	2.25	0.059
270	7.703	5.809.–4	0.0166	27.06	123.93	0.1064	0.4652	0.767	2.04	0.054
280	10.20	6.018.–4	0.0124	34.94	126.41	0.1345	0.4612	0.800	1.84	0.049
290	13.25	6.264.–4	0.0094	43.11	128.51	0.1625	0.4570	0.842	1.69	0.045
300	16.91	6.562.–4	0.0072	51.68	130.09	0.1908	0.4522	0.891	1.57	0.040
310	21.28	6.940.–4	0.0055	60.81	130.97	0.2197	0.4460	0.951	1.45	0.035
320	26.44	7.458.–4	0.0041	70.80	130.76	0.2503	0.4376	1.09	1.26	0.030
330	32.48	8.295.–4	0.0030	82.42	128.59	0.2845	0.4245	1.29	0.99	0.026
340.2[c]	39.64	1.344.–3	0.0013	108.70	108.70	0.3605	0.3605	∞	0.35	∞

*Values reproduced or converted from Table 4, p. 17.83, *ASHRAE Handbook, 1981: Fundamentals,* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, 1981. Copyright material. Reproduced by permission of the copyright owner. c = critical point. The notation 4.594.–4 signifies 4.594×10^{-4}.

The 1993 ASHRAE *Handbook—Fundamentals* (SI ed.) contains a table at closer temperature increments and also an enthalpy–log-pressure diagram from 0.1 to 35 bar, –80 to 220 °C. For tables and a chart to 500 psia, 480 °F, see Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants,* ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity, see *Thermophysical Properties of Refrigerants,* ASHRAE, 1993.

Refrigerant 14 (tetrafluoromethane) See Carbon Tetrafluoride (Table 2-202).

Refrigerant 20 See Chloroform (Table 2-206).

TABLE 2-254 Saturated Refrigerant 21, Dichlorofluoromethane

Temperature, K	Pressure, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ·(kg·K)
250	0.2415	0.000 677	0.8292	16.6	274.8	0.0687	1.1015
260	0.3953	0.000 687	0.5247	26.5	279.9	0.1076	1.0820
270	0.6200	0.000 698	0.3455	36.6	284.9	0.1454	1.0653
280	0.9364	0.000 709	0.2355	46.7	290.0	0.1824	1.0511
290	1.3682	0.000 722	0.1654	57.1	295.0	0.2186	1.0389
300	1.9417	0.000 735	0.1192	67.7	300.0	0.2543	1.0286
310	2.6849	0.000 748	0.0879	78.4	304.8	0.2894	1.0196
320	3.6279	0.000 763	0.0661	89.5	309.5	0.3242	1.0119
330	4.8022	0.000 778	0.0505	100.7	314.1	0.3586	1.0051
340	6.2409	0.000 794	0.0391	112.3	318.4	0.3927	0.9989
350	7.978	0.000 812	0.0307	124.1	322.4	0.4266	0.9932
360	10.049	0.000 830	0.0243	136.2	326.1	0.4602	0.9877
370	12.489	0.000 850	0.0194	148.6	329.3	0.4935	0.9820
380	15.337	0.000 870	0.0155	161.2	331.9	0.5264	0.9758
390	18.630	0.000 893	0.0125	173.9	333.8	0.5587	0.9688
400	22.41	0.000 918	0.01011	186.4	334.8	0.5896	0.9605
410	26.72	0.000 944	0.00820	198.3	334.7	0.6180	0.9506
420	31.60	0.000 972	0.00672	208.7	333.7	0.6418	0.9394
430	37.10	0.001 002	0.00564	216.4	332.4	0.6587	0.9286
440	43.26	0.001 034	0.00491	221.1	332.3	0.6682	0.9208

Reproduced and rounded from unpublished Center for Applied Thermodynamic Studies, Moscow ID report, 1981. For a thermodynamic diagram to 350 bar, 370 °C, see Rombusch, U. K., *Allgem. Warme.,* **11,** 3 (1962).

TABLE 2-255 Thermodynamic Properties of R-22, Chlorodifluoromethane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
115.73	3.7947E-07	19.907	0.050235	2.5595	2.5595	0.0065813	0.061918	0.092976	1410.9	–0.44463
120.00	9.9588E-07	19.777	0.050564	2.9559	2.9559	0.0099451	0.061567	0.092700	1388.4	–0.44526
135.00	1.7187E-05	19.325	0.051747	4.3400	4.3400	0.020814	0.060123	0.091960	1312.3	–0.44448
150.00	0.00015627	18.873	0.052985	5.7179	5.7179	0.030493	0.059099	0.091824	1239.0	–0.43872
165.00	0.00089946	18.420	0.054289	7.0951	7.0951	0.039243	0.058356	0.091789	1166.5	–0.43084
180.00	0.0037009	17.963	0.055670	8.4715	8.4717	0.047227	0.057679	0.091751	1095.0	–0.42063
195.00	0.011835	17.500	0.057141	9.8483	9.8490	0.054574	0.057097	0.091898	1024.5	–0.40608
210.00	0.031218	17.028	0.058726	11.230	11.232	0.061399	0.056707	0.092431	954.55	–0.38505
225.00	0.070909	16.542	0.060453	12.622	12.627	0.067804	0.056579	0.093482	884.79	–0.35555
240.00	0.14319	16.036	0.062359	14.034	14.043	0.073877	0.056737	0.095120	814.96	–0.31561
255.00	0.26329	15.506	0.064493	15.472	15.489	0.079692	0.057171	0.097391	744.97	–0.26263
270.00	0.44888	14.944	0.066919	16.945	16.975	0.085308	0.057856	0.10037	674.69	–0.19248
285.00	0.71966	14.341	0.069730	18.462	18.513	0.090782	0.058767	0.10424	603.91	–0.097827
300.00	1.0970	13.686	0.073070	20.034	20.114	0.096166	0.059887	0.10941	532.11	0.035333
315.00	1.6039	12.956	0.077181	21.676	21.800	0.10152	0.061218	0.11688	458.37	0.23608
330.00	2.2661	12.114	0.082547	23.418	23.605	0.10696	0.062814	0.12929	381.15	0.57205
345.00	3.1130	11.069	0.090340	25.325	25.606	0.11267	0.064858	0.15550	298.16	1.2334
360.00	4.1837	9.5229	0.10501	27.613	28.053	0.11931	0.068488	0.25950	201.90	3.0745
369.30	4.9900	6.0582	0.16506	30.901	31.725	0.12907			0	10.366
115.73	3.7947E-07	3.9436E-07	2,535,700.	27.807	28.769	0.23305	0.028465	0.036779	119.91	398.80
120.00	9.9588E-07	9.9813E-07	1,001,900.	27.929	28.927	0.22637	0.028872	0.037186	121.91	367.18
135.00	1.7187E-05	1.5313E-05	65,305.	28.373	29.495	0.20715	0.030386	0.038703	128.58	269.83
150.00	0.00015627	0.00012533	7,979.0	28.840	30.087	0.19295	0.031990	0.040316	134.79	197.57
165.00	0.00089946	0.00065634	1,523.6	29.329	30.699	0.18230	0.033655	0.042018	140.59	146.30
180.00	0.0037009	0.0024808	403.09	29.836	31.328	0.17421	0.035388	0.043849	145.98	110.28
195.00	0.011835	0.0073561	135.94	30.357	31.966	0.16800	0.037218	0.045881	150.87	84.902
210.00	0.031218	0.018161	55.062	30.885	32.603	0.16317	0.039177	0.048204	155.15	66.865
225.00	0.070909	0.038991	25.647	31.411	33.229	0.15937	0.041300	0.050920	158.70	53.872
240.00	0.14319	0.075182	13.301	31.928	33.833	0.15634	0.043615	0.054144	161.35	44.348
255.00	0.26329	0.13342	7.4950	32.428	34.401	0.15386	0.046138	0.058023	162.96	37.240
270.00	0.44888	0.22208	4.5029	32.900	34.922	0.15178	0.048881	0.062763	163.38	31.852
285.00	0.71966	0.35201	2.8409	33.335	35.380	0.14996	0.051851	0.068713	162.45	27.725
300.00	1.0970	0.53822	1.8580	33.717	35.755	0.14830	0.055064	0.076534	159.98	24.549
315.00	1.6039	0.80363	1.2443	34.021	36.017	0.14666	0.058574	0.087659	155.73	22.102
330.00	2.2661	1.1882	0.84159	34.207	36.114	0.14486	0.062516	0.10579	149.36	20.201
345.00	3.1130	1.7777	0.56253	34.184	35.935	0.14261	0.067254	0.14389	140.39	18.613
360.00	4.1837	2.8529	0.35052	33.661	35.127	0.13896	0.074178	0.29995	127.92	16.641
369.30	4.9900	6.0582	0.16506	30.901	31.725	0.12907			0	10.366

Single-Phase Properties										
150.00	0.10000	18.874	0.052982	5.7167	5.7220	0.030484	0.059102	0.091820	1239.3	–0.43876
232.06	0.10000	16.306	0.061325	13.284	13.290	0.070699	0.056618	0.094177	851.94	–0.33819
232.06	0.10000	0.053734	18.610	31.656	33.517	0.15786	0.042364	0.052366	160.06	49.032
250.00	0.10000	0.049441	20.226	32.442	34.465	0.16180	0.043860	0.053391	166.39	38.154
350.00	0.10000	0.034652	28.859	37.325	40.211	0.18105	0.053191	0.061845	196.16	13.439
450.00	0.10000	0.026819	37.287	43.093	46.822	0.19762	0.061672	0.070141	221.08	6.7638
550.00	0.10000	0.021901	45.660	49.620	54.186	0.21238	0.068475	0.076877	243.30	4.0604
150.00	1.0000	18.885	0.052952	5.7053	5.7582	0.030408	0.059134	0.091780	1241.8	–0.43921
250.00	1.0000	15.711	0.063648	14.961	15.024	0.077665	0.057020	0.096318	773.25	–0.28642
296.57	1.0000	13.841	0.072248	19.669	19.741	0.094938	0.059612	0.10807	548.68	0.00029448
296.57	1.0000	0.48960	2.0425	33.635	35.677	0.14867	0.054305	0.074523	160.70	25.205
350.00	1.0000	0.37703	2.6523	36.754	39.407	0.16025	0.055369	0.068138	184.85	14.183
450.00	1.0000	0.27693	3.6110	42.774	46.385	0.17776	0.062289	0.072300	216.22	6.8582
550.00	1.0000	0.22209	4.5027	49.400	53.903	0.19283	0.068737	0.077971	241.16	4.0624
150.00	5.0000	18.931	0.052823	5.6555	5.9197	0.030074	0.059277	0.091614	1253.0	–0.44109
250.00	5.0000	15.837	0.063142	14.822	15.138	0.077105	0.057135	0.095206	797.37	–0.30700
350.00	5.0000	11.141	0.089759	25.585	26.034	0.11341	0.064765	0.14356	317.33	1.0314
450.00	5.0000	1.6422	0.60893	41.131	44.175	0.16067	0.065284	0.087278	194.56	7.0507
550.00	5.0000	1.1832	0.84520	48.377	52.603	0.17760	0.069855	0.083655	232.93	3.9600
150.00	10.000	18.987	0.052667	5.5953	6.1220	0.029665	0.059460	0.091420	1266.7	–0.44331
250.00	10.000	15.982	0.062569	14.663	15.289	0.076450	0.057274	0.094054	825.41	–0.32844
350.00	10.000	12.008	0.083275	24.782	25.615	0.11098	0.063647	0.11843	412.24	0.39255
450.00	10.000	4.2433	0.23566	38.423	40.780	0.14893	0.068870	0.12461	184.82	5.5220
550.00	10.000	2.5432	0.39321	47.019	50.951	0.16944	0.071068	0.092204	229.21	3.5059
150.00	30.000	19.198	0.052089	5.3741	6.9367	0.028113	0.060251	0.090769	1318.0	–0.45090
250.00	30.000	16.469	0.060719	14.132	15.953	0.074181	0.057799	0.091018	921.00	–0.38542
350.00	30.000	13.518	0.073976	23.279	25.499	0.10621	0.063170	0.10053	603.47	–0.13764
450.00	30.000	10.241	0.097648	33.086	36.016	0.13259	0.069234	0.10864	392.35	0.40072
550.00	30.000	7.3810	0.13548	42.738	46.802	0.15425	0.073417	0.10533	317.51	0.89994
150.00	60.000	19.480	0.051336	5.0916	8.1717	0.026007	0.061560	0.089983	1384.9	–0.45992
250.00	60.000	17.029	0.058724	13.533	17.056	0.071434	0.058519	0.088686	1034.6	–0.42947
350.00	60.000	14.650	0.068258	22.111	26.206	0.10216	0.063912	0.094730	764.59	–0.31532
450.00	60.000	12.381	0.080770	31.083	35.929	0.12657	0.070220	0.099099	589.21	–0.17799
550.00	60.000	10.405	0.096108	40.152	45.919	0.14662	0.075020	0.10030	492.11	–0.055349

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Kamei, A., Beyerlein, S. W., and Jacobsen, R. T., "Application of Nonlinear Regression in the Development of a Wide Range Formulation for HCFC-22," *Int. J. Thermophys.* **16:**1155–1164, 1995. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are 0.1% in density, 1% in heat capacity, and 0.3% in the speed of sound, except in the critical region. The uncertainty in vapor pressure is 0.2%.

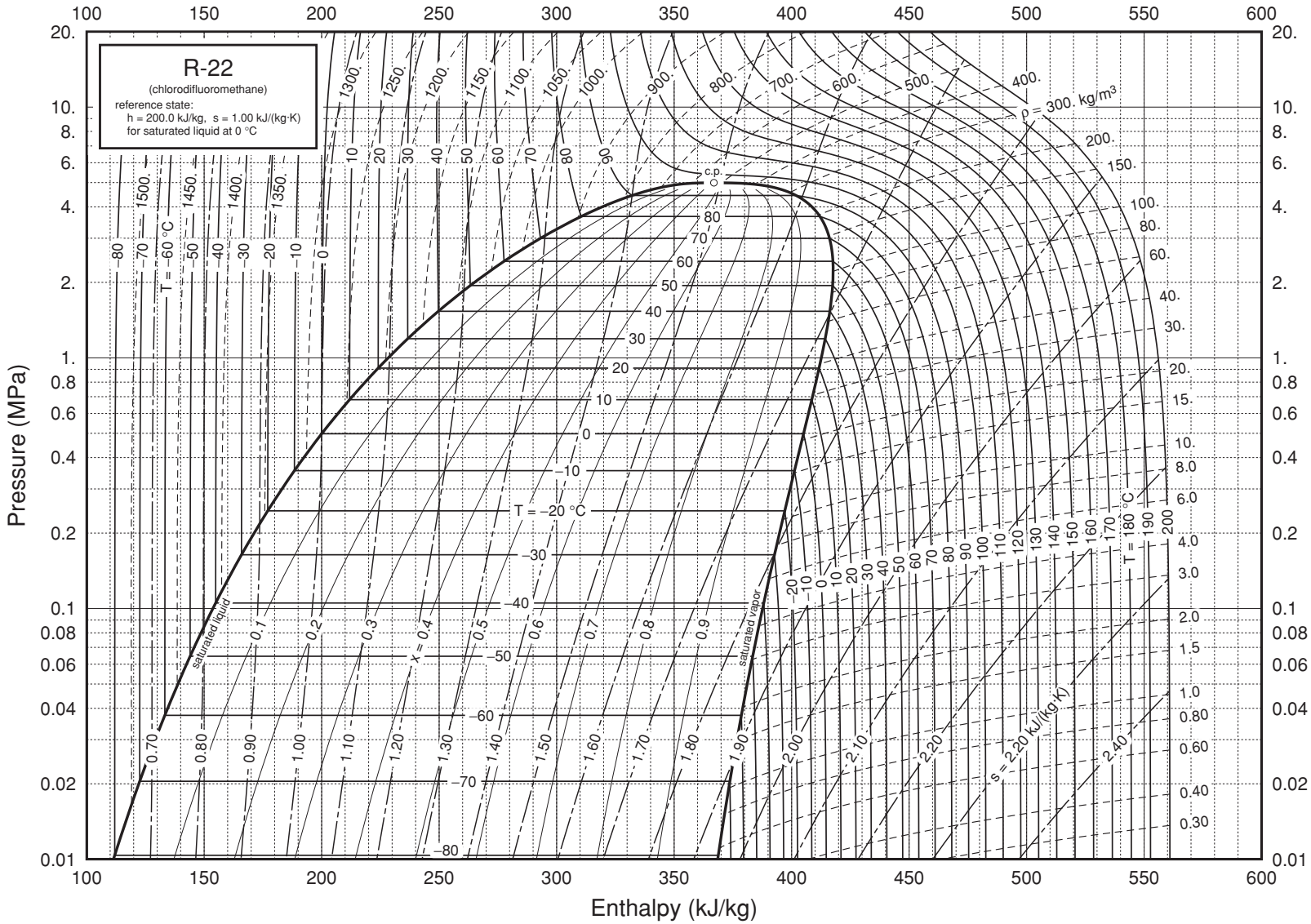

FIG. 2-20 Pressure-enthalpy diagram for Refrigerant 22. Properties computed with the NIST REFPROP Database, Version 7.0 (Lemmon, E. W., McLinden, M. O., and Huber, M. L., 2002, NIST Standard Reference Database 23, NIST Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, Standard Reference Data Program, National Institute of Standards and Technology), based on the equation of state of Kamei, A., Beyerlein, S. W., and Jacobsen, R. T., "Application of Nonlinear Regression in the Development of a Wide Range Formulation for HCFC-22," *Int. J. Thermophysics* **16:**1155–1164, 1995.

TABLE 2-256 Thermodynamic Properties of R-23, Trifluoromethane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
118.02	5.8041E-05	24.308	0.041139	–0.25719	–0.25719	–0.0049376	0.057095	0.085477	1211.2	–0.37494	268.59	2055.0
120.00	8.1883E-05	24.217	0.041293	–0.088512	–0.088509	–0.0035202	0.055755	0.084936	1208.8	–0.37515	261.17	1889.2
130.00	0.00038808	23.746	0.042112	0.75355	0.75356	0.0032204	0.052298	0.083783	1168.8	–0.37102	229.32	1285.4
140.00	0.0014276	23.263	0.042987	1.5903	1.5904	0.0094218	0.051128	0.083657	1111.2	–0.36298	204.76	927.74
150.00	0.0043019	22.771	0.043915	2.4276	2.4278	0.015198	0.050605	0.083836	1051.8	–0.35278	185.36	702.09
160.00	0.011055	22.272	0.044900	3.2675	3.2680	0.020619	0.050302	0.084188	994.03	–0.34018	169.64	551.48
170.00	0.024979	21.763	0.045950	4.1116	4.1127	0.025736	0.050114	0.084721	938.04	–0.32445	156.60	446.01
180.00	0.050823	21.243	0.047074	4.9618	4.9642	0.030596	0.050024	0.085477	883.23	–0.30465	145.55	369.03
190.00	0.094862	20.709	0.048288	5.8204	5.8250	0.035238	0.050032	0.086504	829.00	–0.27966	135.98	310.79
200.00	0.16485	20.158	0.049608	6.6899	6.6981	0.039699	0.050140	0.087863	774.87	–0.24798	127.54	265.32
210.00	0.26991	19.584	0.051061	7.5735	7.5873	0.044011	0.050350	0.089628	720.45	–0.20758	119.92	228.80
220.00	0.42035	18.982	0.052680	8.4748	8.4969	0.048206	0.050666	0.091906	665.40	–0.15554	112.91	198.71
230.00	0.62755	18.345	0.054512	9.3983	9.4325	0.052315	0.051093	0.094862	609.38	–0.087415	106.33	173.29
240.00	0.90390	17.660	0.056625	10.350	10.401	0.056370	0.051645	0.098763	552.02	0.0038879	100.01	151.31
250.00	1.2628	16.913	0.059125	11.336	11.411	0.060409	0.052347	0.10409	492.89	0.13049	93.771	131.85
260.00	1.7190	16.081	0.062186	12.370	12.477	0.064481	0.053248	0.11180	431.39	0.31494	87.445	114.17
270.00	2.2887	15.123	0.066126	13.469	13.621	0.068658	0.054447	0.12412	366.67	0.60438	80.778	97.624
280.00	2.9913	13.958	0.071643	14.670	14.885	0.073078	0.056175	0.14787	297.30	1.1166	73.344	81.444
290.00	3.8516	12.367	0.080863	16.074	16.386	0.078112	0.059136	0.21909	220.12	2.2579	64.064	64.222
299.29	4.8317	7.5200	0.13298	19.029	19.672	0.088893			0	8.4094		
118.02	5.8041E-05	5.9176E-05	16,899.	19.268	20.249	0.16881	0.026617	0.034991	135.67	1947.8	3.7962	5.3460
120.00	8.1883E-05	8.2116E-05	12,178.	19.320	20.317	0.16652	0.026770	0.035155	136.72	1684.9	3.9025	5.4612
130.00	0.00038808	0.00035955	2,781.2	19.581	20.661	0.15635	0.027678	0.036154	141.80	854.63	4.4400	6.0411
140.00	0.0014276	0.0012302	812.86	19.845	21.005	0.14810	0.028813	0.037439	146.52	472.27	4.9794	6.6166
150.00	0.0043019	0.0034701	288.17	20.109	21.348	0.14134	0.030153	0.039008	150.89	282.89	5.5230	7.1868
160.00	0.011055	0.0083994	119.06	20.372	21.688	0.13574	0.031671	0.040857	154.87	182.40	6.0746	7.7511
170.00	0.024979	0.017990	55.587	20.632	22.020	0.13107	0.033344	0.042992	158.43	125.40	6.6400	8.3091
180.00	0.050823	0.034921	28.636	20.886	22.342	0.12714	0.035155	0.045436	161.51	90.972	7.2268	8.8611
190.00	0.094862	0.062608	15.972	21.133	22.648	0.12378	0.037094	0.048225	164.02	68.962	7.8452	9.4081
200.00	0.16485	0.10526	9.5007	21.369	22.935	0.12088	0.039149	0.051416	165.89	54.182	8.5073	9.9521
210.00	0.26991	0.16798	5.9532	21.589	23.196	0.11834	0.041312	0.055095	167.03	43.846	9.2284	10.497
220.00	0.42035	0.25707	3.8900	21.791	23.426	0.11607	0.043578	0.059399	167.35	36.378	10.028	11.048
230.00	0.62755	0.38050	2.6281	21.968	23.617	0.11399	0.045950	0.064561	166.76	30.839	10.931	11.616
240.00	0.90390	0.54888	1.8219	22.112	23.759	0.11203	0.048442	0.070995	165.16	26.639	11.970	12.216
250.00	1.2628	0.77721	1.2866	22.214	23.839	0.11012	0.051088	0.079472	162.43	23.387	13.197	12.873
260.00	1.7190	1.0885	0.91866	22.256	23.835	0.10816	0.053955	0.091578	158.44	20.801	14.687	13.633
270.00	2.2887	1.5223	0.65691	22.209	23.712	0.10603	0.057163	0.11107	153.01	18.652	16.578	14.579
280.00	2.9913	2.1579	0.46341	22.017	23.403	0.10350	0.060947	0.14938	145.86	16.699	19.150	15.906
290.00	3.8516	3.2161	0.31093	21.529	22.727	0.099978	0.065857	0.26628	136.34	14.524	23.215	18.223
299.29	4.8317	7.5200	0.13298	19.029	19.672	0.088893			0	8.4094		
Single-Phase Properties												
150.00	0.10000	22.773	0.043911	2.4262	2.4306	0.015189	0.050608	0.083827	1052.1	–0.35289	185.41	702.64
190.90	0.10000	20.660	0.048402	5.8986	5.9034	0.035649	0.050037	0.086612	824.11	–0.27709	135.18	306.22
190.90	0.10000	0.065782	15.202	21.155	22.675	0.12350	0.037275	0.048496	164.22	67.381	7.9031	9.4574
250.00	0.10000	0.048799	20.492	23.373	25.422	0.13604	0.038440	0.047375	188.56	22.325	11.046	12.547
350.00	0.10000	0.034513	28.974	27.705	30.603	0.15338	0.048023	0.056526	220.23	8.0459	16.386	17.318
450.00	0.10000	0.026771	37.355	32.978	36.713	0.16869	0.057058	0.065464	247.21	4.0690	21.735	21.621
150.00	1.0000	22.792	0.043874	2.4134	2.4573	0.015103	0.050638	0.083752	1055.5	–0.35386	185.86	707.90
242.93	1.0000	17.448	0.057313	10.635	10.692	0.057555	0.051834	0.10015	534.88	0.036629	98.175	145.37
242.93	1.0000	0.60881	1.6425	22.147	23.790	0.11147	0.049200	0.073220	164.48	25.601	12.308	12.401
250.00	1.0000	0.57474	1.7399	22.544	24.284	0.11347	0.046933	0.067137	169.72	23.136	12.612	12.737
350.00	1.0000	0.35949	2.7818	27.401	30.182	0.13337	0.048882	0.059316	214.59	8.0837	17.536	17.376
450.00	1.0000	0.27164	3.6813	32.791	36.472	0.14914	0.057361	0.066629	245.15	4.0345	22.720	21.629

TABLE 2-256 Thermodynamic Properties of R-23, Trifluoromethane (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Single-Phase Properties												
150.00	5.0000	22.876	0.043714	2.3577	2.5763	0.014729	0.050778	0.083431	1070.0	–0.35795	187.83	731.40
250.00	5.0000	17.302	0.057797	11.094	11.383	0.059422	0.051903	0.098833	539.89	0.027079	97.307	141.75
350.00	5.0000	2.2512	0.44420	25.765	27.986	0.11523	0.053415	0.081317	190.19	7.7729	23.888	19.400
450.00	5.0000	1.4480	0.69062	31.931	35.384	0.13386	0.058685	0.072566	237.91	3.7699	27.113	22.593
150.00	10.000	22.976	0.043523	2.2910	2.7262	0.014275	0.050969	0.083065	1086.9	–0.36259	190.23	761.17
250.00	10.000	17.719	0.056437	10.828	11.392	0.058319	0.051625	0.094482	590.19	–0.061719	101.24	153.45
350.00	10.000	6.4822	0.15427	22.835	24.378	0.10116	0.058836	0.14411	186.97	4.7798	39.852	30.808
450.00	10.000	3.1053	0.32203	30.818	34.039	0.12572	0.060182	0.081111	235.46	3.2093	33.390	25.446
150.00	50.000	23.670	0.042247	1.8477	3.9600	0.011072	0.052531	0.080990	1193.2	–0.38760	207.85	1020.9
250.00	50.000	19.633	0.050935	9.5803	12.127	0.052740	0.052051	0.083522	826.45	–0.29649	121.46	226.71
350.00	50.000	15.604	0.064086	17.587	20.792	0.081836	0.057678	0.089445	563.57	–0.085583	92.030	113.25
450.00	50.000	12.055	0.082953	25.724	29.871	0.10464	0.064073	0.091553	437.72	0.13382	77.100	73.803
250.00	100.00	20.957	0.047717	8.7360	13.508	0.048428	0.053244	0.080401	1002.1	–0.36685	137.85	307.24
350.00	100.00	17.954	0.055698	16.172	21.741	0.076094	0.059172	0.084434	778.97	–0.30018	111.99	167.69
450.00	100.00	15.405	0.064915	23.879	30.370	0.097761	0.065748	0.087934	652.70	–0.24430	100.34	119.14

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Penoncello, S. G., Lemmon, E. W., Jacobsen, R. T., and Shan, Z., "A Fundamental Equation for Triflurormethane (R-23)," *J. Phys. Chem. Ref. Data*, **32**(4):1473–1499, 2003. The source for viscosity and thermal conductivity is Shan, Z., Penoncello, S. G., and Jacobsen, R. T., "A Generalized Model for Viscosity and Thermal Conductivity of Trifluoromethane (R-23)," *ASHRAE Trans.* **106**:1–11, 2000.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are 0.1% in density, 0.5% in heat capacities and speed of sound, and 0.2% in vapor pressures.Uncertainties in the critical region will be higher. The uncertainty in viscosity is 1%. The uncertainty in thermal conductivity is 2%.

TABLE 2-257 Thermodynamic Properties of R-32, Difluoromethane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)
Saturated Properties											
136.34	4.8000E-05	27.473	0.036399	–0.99220	–0.99220	–0.0054608	0.055447	0.082847	1414.4	–0.33760	242.91
140.00	8.3535E-05	27.302	0.036627	–0.68946	–0.68946	–0.0032696	0.054980	0.082588	1395.1	–0.33728	241.74
150.00	0.00032474	26.835	0.037265	0.13324	0.13325	0.0024067	0.053793	0.081975	1342.3	–0.33542	237.64
160.00	0.0010410	26.364	0.037930	0.95053	0.95057	0.0076815	0.052740	0.081513	1289.9	–0.33191	232.45
170.00	0.0028536	25.889	0.038626	1.7640	1.7641	0.012613	0.051818	0.081215	1237.6	–0.32650	226.39
180.00	0.0068782	25.409	0.039357	2.5753	2.5756	0.017251	0.051021	0.081087	1185.7	–0.31891	219.64
190.00	0.014904	24.921	0.040127	3.3862	3.3868	0.021635	0.050345	0.081137	1133.8	–0.30886	212.37
200.00	0.029545	24.424	0.040944	4.1983	4.1995	0.025800	0.049783	0.081373	1082.1	–0.29600	204.70
210.00	0.054344	23.916	0.041814	5.0135	5.0158	0.029778	0.049333	0.081803	1030.4	–0.27988	196.75
220.00	0.093819	23.394	0.042745	5.8337	5.8377	0.033594	0.048988	0.082443	978.59	–0.25996	188.62
230.00	0.15345	22.858	0.043749	6.6608	6.6675	0.037271	0.048747	0.083313	926.62	–0.23550	180.39
240.00	0.23965	22.303	0.044838	7.4969	7.5077	0.040830	0.048604	0.084442	874.35	–0.20551	172.14
250.00	0.35967	21.726	0.046028	8.3443	8.3609	0.044291	0.048559	0.085874	821.65	–0.16864	163.92
260.00	0.52157	21.124	0.047340	9.2056	9.2303	0.047671	0.048610	0.087676	768.33	–0.12292	155.78
270.00	0.73415	20.491	0.048802	10.084	10.120	0.050989	0.048761	0.089947	714.18	–0.065518	147.75
280.00	1.0069	19.820	0.050454	10.983	11.034	0.054264	0.049019	0.092852	658.88	0.0079177	139.86
290.00	1.3501	19.102	0.052350	11.908	11.979	0.057517	0.049399	0.096659	602.05	0.10428	132.11
300.00	1.7749	18.323	0.054577	12.866	12.963	0.060775	0.049934	0.10185	543.11	0.23517	124.48
310.00	2.2934	17.460	0.057273	13.867	13.998	0.064076	0.050685	0.10938	481.27	0.42163	116.94
320.00	2.9194	16.477	0.060691	14.930	15.107	0.067477	0.051776	0.12140	415.41	0.70602	109.42
330.00	3.6686	15.299	0.065364	16.088	16.328	0.071088	0.053487	0.14404	343.84	1.1876	101.80
340.00	4.5614	13.740	0.072779	17.428	17.760	0.075179	0.056594	0.20457	263.77	2.1660	94.166
350.00	5.6311	10.732	0.093180	19.453	19.977	0.081343	0.066340	1.2085	163.70	5.4955	97.067
351.26	5.7826	8.1501	0.12270	20.836	21.546	0.085769			0	8.0731	
136.34	4.8000E-05	4.2353E-05	23,611.	21.981	23.115	0.17135	0.025987	0.034319	169.60	881.12	6.9492
140.00	8.3535E-05	7.1788E-05	13,930.	22.076	23.239	0.16765	0.026110	0.034451	171.76	769.01	6.9554
150.00	0.00032474	0.00026061	3,837.2	22.335	23.581	0.15872	0.026507	0.034889	177.47	541.12	7.0006
160.00	0.0010410	0.00078411	1,275.3	22.593	23.921	0.15125	0.027014	0.035477	182.88	391.73	7.0875
170.00	0.0028536	0.0020270	493.35	22.850	24.258	0.14493	0.027667	0.036272	187.97	291.02	7.2166
180.00	0.0068782	0.0046295	216.01	23.103	24.589	0.13955	0.028505	0.037336	192.69	221.02	7.3887
190.00	0.014904	0.0095503	104.71	23.350	24.910	0.13492	0.029560	0.038728	197.00	170.81	7.6049
200.00	0.029545	0.018112	55.213	23.588	25.219	0.13090	0.030843	0.040483	200.85	133.79	7.8668
210.00	0.054344	0.032028	31.223	23.816	25.513	0.12738	0.032341	0.042613	204.20	106.00	8.1765
220.00	0.093819	0.053428	18.717	24.032	25.788	0.12428	0.034016	0.045105	206.99	84.924	8.5374
230.00	0.15345	0.084890	11.780	24.234	26.042	0.12151	0.035821	0.047943	209.19	68.870	8.9546
240.00	0.23965	0.12949	7.7224	24.421	26.272	0.11901	0.037709	0.051127	210.73	56.605	9.4365
250.00	0.35967	0.19093	5.2375	24.590	26.474	0.11674	0.039648	0.054696	211.57	47.194	9.9965
260.00	0.52157	0.27370	3.6537	24.738	26.643	0.11464	0.041621	0.058741	211.65	39.922	10.656
270.00	0.73415	0.38340	2.6083	24.860	26.775	0.11268	0.043631	0.063434	210.90	34.246	11.449
280.00	1.0069	0.52726	1.8966	24.952	26.862	0.11079	0.045693	0.069063	209.26	29.758	12.431
290.00	1.3501	0.71503	1.3985	25.006	26.894	0.10895	0.047840	0.076110	206.64	26.148	13.691
300.00	1.7749	0.96054	1.0411	25.011	26.858	0.10709	0.050119	0.085424	202.95	23.187	15.376
310.00	2.2934	1.2848	0.77830	24.950	26.735	0.10516	0.052598	0.098649	198.02	20.693	17.748
320.00	2.9194	1.7233	0.58029	24.797	26.491	0.10305	0.055390	0.11948	191.66	18.510	21.309
330.00	3.6686	2.3442	0.42658	24.503	26.068	0.10060	0.058707	0.15836	183.49	16.477	27.173
340.00	4.5614	3.3211	0.30111	23.943	25.316	0.097403	0.063103	0.26199	172.68	14.312	38.601
350.00	5.6311	5.7166	0.17493	22.380	23.365	0.091024	0.071998	1.9028	154.59	10.637	87.141
351.26	5.7826	8.1501	0.12270	20.836	21.546	0.085769			0	8.0731	
Single-Phase Properties											
150.00	0.10000	26.836	0.037263	0.13226	0.13599	0.0024002	0.053795	0.081971	1342.7	–0.33547	237.67
221.24	0.10000	23.329	0.042866	5.9359	5.9402	0.034057	0.048953	0.082538	972.15	–0.25719	187.60
221.24	0.10000	0.056727	17.628	24.058	25.821	0.12392	0.034234	0.045439	207.30	82.688	8.5859
225.00	0.10000	0.055592	17.988	24.191	25.989	0.12467	0.033681	0.044513	209.39	76.114	8.7199
300.00	0.10000	0.040576	24.645	26.760	29.224	0.13708	0.035327	0.044188	241.95	25.024	12.643
375.00	0.10000	0.032244	31.013	29.631	32.733	0.14749	0.041082	0.049630	267.64	12.117	18.907

TABLE 2-257 Thermodynamic Properties of R-32, Difluoromethane (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)
Single-Phase Properties											
150.00	1.0000	26.851	0.037243	0.12350	0.16075	0.0023417	0.053807	0.081935	1345.7	–0.33584	237.89
225.00	1.0000	23.159	0.043179	6.2265	6.2697	0.035360	0.048867	0.082690	957.47	–0.25084	185.10
279.77	1.0000	19.836	0.050414	10.962	11.013	0.054190	0.049012	0.092777	660.15	0.0060372	140.04
279.77	1.0000	0.52357	1.9100	24.951	26.861	0.11084	0.045646	0.068922	209.31	29.848	12.406
300.00	1.0000	0.46100	2.1692	25.950	28.120	0.11518	0.041298	0.057916	223.83	23.889	13.334
375.00	1.0000	0.33917	2.9484	29.227	32.175	0.12727	0.042549	0.053538	259.50	11.929	19.059
150.00	5.0000	26.915	0.037154	0.085198	0.27097	0.0020846	0.053863	0.081784	1358.9	–0.33741	238.83
225.00	5.0000	23.298	0.042923	6.1394	6.3541	0.034970	0.048922	0.082027	978.81	–0.26135	187.71
300.00	5.0000	18.710	0.053448	12.637	12.905	0.060001	0.049679	0.096911	586.17	0.13431	128.72
344.33	5.0000	12.808	0.078078	18.130	18.520	0.077304	0.059015	0.28240	224.84	2.9944	91.412
344.33	5.0000	3.9887	0.25071	23.524	24.777	0.095475	0.065786	0.39574	166.61	13.148	48.235
375.00	5.0000	2.3228	0.43051	26.928	29.080	0.10755	0.050835	0.090625	218.44	10.800	26.239
150.00	10.000	26.993	0.037047	0.038702	0.40917	0.0017692	0.053932	0.081608	1375.0	–0.33924	239.97
225.00	10.000	23.461	0.042625	6.0369	6.4632	0.034504	0.048996	0.081303	1004.1	–0.27287	190.81
300.00	10.000	19.196	0.052094	12.346	12.867	0.058997	0.049538	0.092105	639.69	0.031716	134.49
375.00	10.000	10.448	0.095714	21.112	22.069	0.085980	0.057265	0.21222	231.14	3.5190	77.284
150.00	30.000	27.285	0.036650	–0.13357	0.96593	0.00056834	0.054209	0.081027	1436.1	–0.34524	244.02
225.00	30.000	24.030	0.041614	5.6813	6.9297	0.032836	0.049307	0.079197	1094.1	–0.30661	201.89
300.00	30.000	20.517	0.048739	11.542	13.004	0.056105	0.049670	0.083697	789.57	–0.15824	152.78
375.00	30.000	16.472	0.060708	17.786	19.607	0.075712	0.052941	0.093069	536.98	0.21392	112.94
225.00	70.000	24.916	0.040135	5.1400	7.9495	0.030109	0.049916	0.076915	1240.7	–0.34341	219.54
300.00	70.000	22.090	0.045270	10.583	13.752	0.052355	0.050281	0.078370	986.17	–0.28333	179.29
375.00	70.000	19.309	0.051788	16.127	19.752	0.070195	0.053544	0.081767	788.81	–0.18583	147.00

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Tillner-Roth, R., and Yokozeki, A., "An International Standard Equation of State for Difluoromethane (R-32) for Temperatures from the Triple Point at 136.34 K to 435 K and Pressures up to 70 MPa," *J. Phys. Chem. Ref. Data* **26**(6):1273–1328, 1997. Validated equations for the viscosity are not currently available for this fluid. The source for thermal conductivity is unpublished; however, the fit uses the functional form found in Marsh, K., Perkins, R., and Ramires, M. L. V., "Measurement and Correlation of the Thermal Conductivity of Propane from 86 to 600 K at Pressures to 70 MPa," *J. Chem. Eng. Data* **47**(4):932–940, 2002.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

For the equation of state, typical uncertainties are 0.05% for density, 0.02% for the vapor pressure, and 0.5% to 1% for the heat capacity and speed of sound in the liquid phase. In the vapor phase, the uncertainty in the speed of sound is 0.02%. For thermal conductivity, the estimated uncertainty of the correlation is 5%, except for the dilute gas and points approaching critical where the uncertainty rises to 10%.

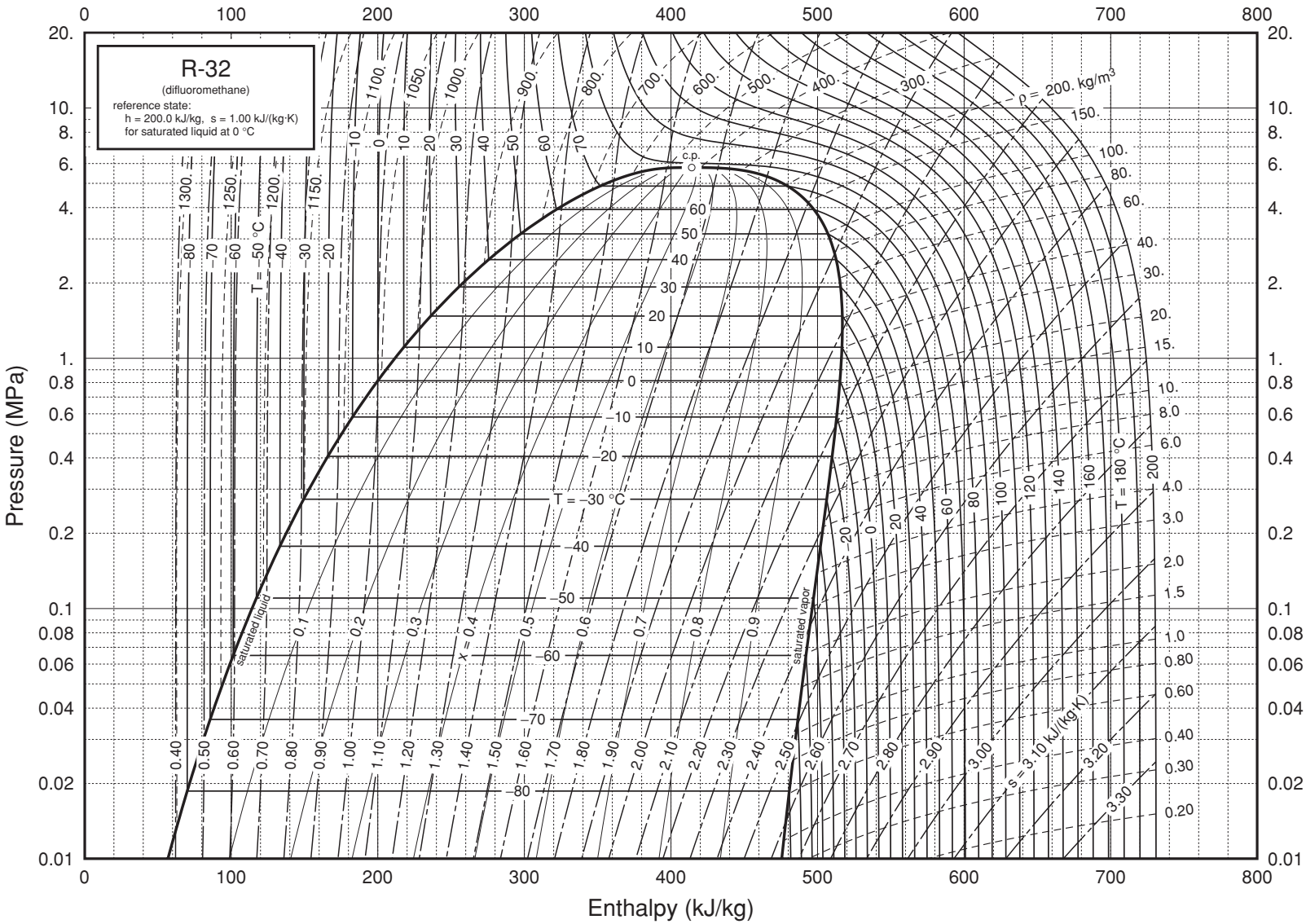

FIG. 2-21 Pressure-enthalpy diagram for Refrigerant 32. Properties computed with the NIST REFPROP Database, Version 7.0 (Lemmon, E. W., McLinden, M. O., and Huber, M. L., 2002, NIST Standard Reference Database 23, NIST Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, Standard Reference Data Program, National Institute of Standards and Technology), based on the equation of state of Tillner-Roth, R., and Yokozeki, A., "An International Standard Equation of State for Difluoromethane (R-32) for Temperatures from the Triple Point at 136.34 K to 435 K and Pressures up to 70 MPa," *J. Phys. Chem. Ref. Data* **26**(6):1273–1328, 1997.

TABLE 2-258 Thermodynamic Properties of R-41, Fluoromethane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
129.82	0.00034504	29.650	0.033727	–3.7550	–3.7549	–0.019920	0.050428	0.072206	1413.8	–0.35314
130.00	0.00035370	29.640	0.033738	–3.7420	–3.7420	–0.019820	0.050396	0.072196	1413.1	–0.35309
140.00	0.0012519	29.080	0.034388	–3.0231	–3.0230	–0.014492	0.048727	0.071584	1371.7	–0.35022
150.00	0.0036677	28.514	0.035070	–2.3102	–2.3100	–0.0095735	0.047265	0.071018	1325.5	–0.34606
160.00	0.0092373	27.942	0.035788	–1.6024	–1.6021	–0.0050057	0.045989	0.070568	1276.1	–0.33979
170.00	0.020585	27.362	0.036548	–0.89848	–0.89772	–0.00073794	0.044881	0.070278	1224.2	–0.33071
180.00	0.041505	26.770	0.037355	–0.19668	–0.19513	0.0032736	0.043923	0.070180	1170.6	–0.31808
190.00	0.077054	26.165	0.038218	0.50493	0.50787	0.0070672	0.043101	0.070303	1115.6	–0.30109
200.00	0.13355	25.544	0.039148	1.2085	1.2137	0.010676	0.042407	0.070678	1059.3	–0.27874
210.00	0.21852	24.901	0.040159	1.9164	1.9251	0.014131	0.041832	0.071342	1001.8	–0.24979
220.00	0.34056	24.233	0.041266	2.6312	2.6453	0.017458	0.041372	0.072345	943.19	–0.21256
230.00	0.50928	23.534	0.042492	3.3561	3.3778	0.020682	0.041022	0.073761	883.36	–0.16475
240.00	0.73518	22.796	0.043868	4.0946	4.1268	0.023828	0.040783	0.075695	822.19	–0.10306
250.00	1.0296	22.010	0.045434	4.8508	4.8976	0.026921	0.040657	0.078315	759.47	–0.022535
260.00	1.4048	21.164	0.047251	5.6304	5.6968	0.029987	0.040652	0.081902	694.85	0.084654
270.00	1.8740	20.239	0.049410	6.4408	6.5334	0.033058	0.040786	0.086969	627.81	0.23174
280.00	2.4519	19.207	0.052065	7.2930	7.4207	0.036178	0.041098	0.094564	557.39	0.44318
290.00	3.1548	18.018	0.055501	8.2059	8.3810	0.039414	0.041677	0.10725	481.85	0.77036
300.00	4.0027	16.564	0.060372	9.2189	9.4606	0.042906	0.042763	0.13357	397.63	1.3453
310.00	5.0232	14.501	0.068961	10.456	10.802	0.047088	0.045267	0.23071	295.99	2.6641
317.28	5.9062	9.3000	0.10753	12.765	13.400	0.055113			0	7.4905
129.82	0.00034504	0.00031992	3125.8	14.466	15.544	0.12874	0.025226	0.033592	205.35	365.81
130.00	0.00035370	0.00032749	3053.5	14.470	15.550	0.12858	0.025228	0.033595	205.49	363.97
140.00	0.0012519	0.0010777	927.93	14.716	15.878	0.12051	0.025399	0.033848	213.06	278.51
150.00	0.0036677	0.0029538	338.55	14.957	16.199	0.11382	0.025715	0.034322	220.17	217.09
160.00	0.0092373	0.0070026	142.80	15.190	16.509	0.10819	0.026225	0.035097	226.74	170.82
170.00	0.020585	0.014779	67.662	15.411	16.804	0.10339	0.026955	0.036230	232.71	135.12
180.00	0.041505	0.028398	35.214	15.620	17.081	0.099254	0.027900	0.037744	238.00	107.41
190.00	0.077054	0.050558	19.779	15.813	17.337	0.095640	0.029030	0.039636	242.53	85.993
200.00	0.13355	0.084573	11.824	15.988	17.567	0.092444	0.030304	0.041897	246.25	69.518
210.00	0.21852	0.13444	7.4384	16.144	17.769	0.089580	0.031684	0.044538	249.08	56.880
220.00	0.34056	0.20496	4.8791	16.278	17.940	0.086979	0.033143	0.047606	250.96	47.167
230.00	0.50928	0.30200	3.3112	16.388	18.075	0.084582	0.034668	0.051200	251.81	39.654
240.00	0.73518	0.43294	2.3098	16.470	18.168	0.082334	0.036262	0.055502	251.54	33.780
250.00	1.0296	0.60737	1.6464	16.519	18.214	0.080186	0.037939	0.060820	250.07	29.121
260.00	1.4048	0.83844	1.1927	16.527	18.203	0.078086	0.039727	0.067681	247.30	25.360
270.00	1.8740	1.1452	0.87319	16.484	18.121	0.075974	0.041668	0.077052	243.07	22.257
280.00	2.4519	1.5578	0.64192	16.374	17.948	0.073776	0.043822	0.090909	237.22	19.624
290.00	3.1548	2.1293	0.46963	16.167	17.649	0.071373	0.046290	0.11407	229.42	17.292
300.00	4.0027	2.9728	0.33638	15.803	17.149	0.068535	0.049264	0.16236	219.09	15.070
310.00	5.0232	4.4455	0.22495	15.090	16.220	0.064565	0.053237	0.33830	204.65	12.533
317.28	5.9062	9.3000	0.10753	12.765	13.400	0.055113			0	7.4905

Single-Phase Properties										
150.00	0.10000	28.517	0.035067	–2.3112	–2.3077	–0.0095803	0.047264	0.071013	1326.0	–0.34613
194.60	0.10000	25.882	0.038637	0.82800	0.83187	0.0087476	0.042767	0.070442	1089.8	–0.29155
194.60	0.10000	0.064499	15.504	15.896	17.446	0.094125	0.029600	0.040629	244.34	77.876
225.00	0.10000	0.054701	18.281	16.776	18.604	0.099660	0.027396	0.036814	265.51	44.413
300.00	0.10000	0.040421	24.739	18.906	21.380	0.11030	0.029496	0.038140	305.33	18.192
375.00	0.10000	0.032197	31.059	21.292	24.398	0.11926	0.034142	0.042610	336.84	9.5450
150.00	1.0000	28.539	0.035039	–2.3206	–2.2855	–0.0096430	0.047252	0.070965	1330.7	–0.34675
225.00	1.0000	23.924	0.041800	2.9761	3.0179	0.019009	0.041178	0.072808	918.60	–0.19408
249.10	1.0000	22.083	0.045284	4.7819	4.8272	0.026644	0.040664	0.078045	765.18	–0.030727
249.10	1.0000	0.58959	1.6961	16.516	18.212	0.080377	0.037784	0.060289	250.26	29.499
300.00	1.0000	0.43831	2.2815	18.437	20.718	0.089572	0.032042	0.044524	291.25	17.553
375.00	1.0000	0.33366	2.9971	21.029	24.026	0.099411	0.034956	0.044943	329.85	9.3564
150.00	5.0000	28.637	0.034919	–2.3615	–2.1869	–0.0099181	0.047205	0.070762	1351.1	–0.34938
225.00	5.0000	24.159	0.041392	2.8706	3.0775	0.018535	0.041150	0.071655	952.55	–0.21829
300.00	5.0000	17.057	0.058628	9.0202	9.3133	0.042218	0.042199	0.11693	436.81	1.0494
309.79	5.0000	14.557	0.068696	10.426	10.769	0.046985	0.045181	0.22600	298.41	2.6188
309.79	5.0000	4.4014	0.22720	15.113	16.249	0.064673	0.053137	0.32991	205.02	12.597
375.00	5.0000	2.0056	0.49861	19.699	22.192	0.082450	0.038898	0.060151	299.64	8.3579
150.00	10.000	28.756	0.034776	–2.4107	–2.0629	–0.010253	0.047153	0.070531	1375.8	–0.35235
225.00	10.000	24.428	0.040937	2.7503	3.1596	0.017985	0.041136	0.070486	991.68	–0.24309
300.00	10.000	18.494	0.054071	8.4188	8.9595	0.040105	0.041153	0.090910	556.97	0.45639
375.00	10.000	5.4445	0.18367	17.496	19.333	0.070759	0.043934	0.10163	274.07	6.1896
150.00	30.000	29.189	0.034259	–2.5895	–1.5617	–0.011513	0.047004	0.069806	1467.3	–0.36156
225.00	30.000	25.306	0.039516	2.3574	3.5429	0.016117	0.041195	0.067503	1123.5	–0.30724
300.00	30.000	20.991	0.047639	7.3266	8.7557	0.036076	0.040629	0.072733	794.05	–0.067863
375.00	30.000	15.862	0.063045	12.699	14.590	0.053392	0.043123	0.082994	538.73	0.53694
225.00	70.000	26.558	0.037653	1.8062	4.4419	0.013266	0.041529	0.064822	1323.8	–0.36575
300.00	70.000	23.298	0.042923	6.3044	9.3090	0.031929	0.041001	0.065644	1056.2	–0.28880
375.00	70.000	20.079	0.049804	10.864	14.350	0.046913	0.043364	0.068927	851.76	–0.15494

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data*, **51**(3):785–850, 2006. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in the equation of state are 0.1% in density (except near the critical point), 0.25% in vapor-pressure, 1% in heat capacities, 0.2% in the vapor-phase speed of sound, and 3% in the liquid speed of sound. The liquid speed of sound uncertainty is an estimate and cannot be verified without experimental information. The uncertainties above 290 K in vapor pressure may be as high as 0.5%.

TABLE 2-259 Saturated R-401A (SUVA MP 39)

Temp., °C	P_f, bar	P_g, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)	μ_f, 10^{-6} Pa·s	k_f, W/(m·K)	Pr_f
−40	0.733	0.533	0.000 712	0.3778	154.0	385.0	0.8188	1.8244	1.078	351	0.1209	3.13
−30	1.155	0.871	0.000 728	0.2391	164.9	390.6	0.8647	1.8059	1.109	323	0.1154	3.06
−20	1.748	1.361	0.000 744	0.1576	176.2	396.3	0.9099	1.7907	1.137	291	0.1107	2.99
−10	2.553	2.043	0.000 762	0.1075	188.6	401.8	0.9577	1.7781	1.165	266	0.1057	2.93
0	3.615	2.965	0.000 781	0.0755	200.0	407.3	1.0000	1.7675	1.197	241	0.1012	2.85
10	4.984	4.177	0.000 803	0.0544	212.7	412.6	1.0454	1.7587	1.233	221	0.0967	2.82
20	6.712	5.733	0.000 826	0.0399	225.3	417.6	1.0884	1.7510	1.277	202	0.0922	2.80
30	8.857	7.697	0.000 851	0.0298	238.3	422.2	1.1316	1.7439	1.329	186	0.0877	2.83
40	11.475	10.133	0.000 878	0.0225	252.0	426.5	1.1752	1.7372	1.392	170	0.0830	2.85
50	14.628	13.112	0.000 909	0.0172	266.4	430.1	1.2194	1.7304	1.468	157	0.0781	2.95
60	18.378	16.711	0.000 944	0.01313	281.6	433.0	1.2647	1.7228	1.564	143	0.0737	3.04
70	22.79	21.01	0.000 988	0.01005	297.9	434.9	1.3118	1.7138	1.652	131	0.0684	3.16
80	27.92	26.12	0.001 028	0.00764	315.9	435.4	1.3616	1.7022	1.802	122	0.0631	3.48
90	33.83	32.13	0.001 084	0.00570	336.2	433.5	1.4163	1.6858	1.958	115	0.0577	3.90
100	40.53	39.22	0.001 140	0.00403	361.4	426.9	1.4820	1.6584	2.16	110	0.0533	4.46
108.0[c]	46.04	46.04	0.001 96	0.00196	397	397						

c = critical point. SUVA MP 39 = R401A = $CHClF_2$ (R22) 53% wt + CH_3CHF_2 (R 152a) 13% wt + $CHClFCF_3$ (R124) 34% wt, near-azeotropic blend. Some values read from charts are approximate. Material used by permission of DuPont Fluoroproducts.

TABLE 2-260 R-401A (SUVA MP 39) at Atmospheric Pressure

Temp., °C	−27.01	−20	0	20	40	60	80	100	120	140
v (m³/kg)	0.2102	0.2167	0.2351	0.2534	0.2715	0.2896	0.3076	0.3256	0.3435	0.3613
h (kJ/kg)	351.7	396.9	410.4	424.5	439.2	454.4	470.3	486.6	503.5	521.2
s (kJ/kg·K)	1.8009	1.8193	1.8706	1.9204	1.9689	2.0161	2.0623	2.1073	2.1513	2.1943
c_p (kJ/kg·K)	0.648	0.669	0.698	0.727	0.757	0.787	0.811	0.836	0.859	0.883
μ (10^{-6} Pa·s)	10.17	10.43	11.18	11.93	12.68	13.42	14.17	14.89	15.61	16.32
k (W/m·K)	0.00878	0.00921	0.01041	0.01161	0.01282	0.01404	0.01536	0.01668	0.01796	0.01929
Pr	0.750	0.758	0.750	0.749	0.749	0.748	0.748	0.748	0.747	0.747
Z	0.9829	0.9852	0.9906	0.9949	0.9979	1.0005	1.0025	1.0043	1.0056	1.0060

For composition see footnote to Table 2-259. Some values read from charts are approximate. Material used by permission of DuPont Fluoroproducts.

TABLE 2-261 Thermodynamic Properties of Saturated R-407A (Klea 60)

Pressure, bar	T_f, K	T_g, K	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)
1	227.3	234.0	0.000 7118	0.2097	−7.80	229.64		0.9965
1.5	236.1	242.5	0.000 7263	0.1433	3.92	235.02		0.9833
2	242.8	249.1	0.000 7381	0.1093	12.89	239.07		0.9744
2.5	248.3	254.5	0.000 7483	0.0885	20.27	242.35		0.9679
3	253.0	259.1	0.000 7573	0.0744	26.57	245.08		0.9629
4	260.7	266.8	0.000 7735	0.0564	37.23	249.54		0.9552
5	267.3	273.1	0.000 7880	0.0442	46.12	253.07		0.9496
6	272.9	278.5	0.000 8012	0.0384	53.84	255.24		0.9450
8	282.1	287.5	0.000 8254	0.0286	67.02	260.70		0.9378
10	289.8	295.0	0.000 8480	0.0228	78.23	263.86		0.9318
12.5	297.9	302.8	0.000 8750	0.01802	90.50	266.95		0.9257
15	304.8	309.5	0.000 9017	0.01481	101.51	269.12		0.9190
17.5	311.0	315.4	0.000 9290	0.01247	111.64	270.58		0.9128
20	316.5	320.7	0.000 9613	0.01069	121.18	271.46		0.9065
22.5	321.4	325.5	0.000 9884	0.00928	130.31	271.79		0.8999
25	326.1	329.8	0.001 023	0.00828	139.17	271.63		0.8927
27.5	330.4	333.9	0.001 063	0.00717	147.89	270.97		0.8850
30	334.5	337.6	0.001 115	0.00635	156.58	269.81		0.8765

$h_f = s_f = 0$ at 233.15 K = –40 °C. Converted and interpolated from *Thermodynamic Properties of Klea 60* (British units, 20 pp.), copyright ICI Chemicals and Polymers Limited, 1993. Reproduced by permission. T_f = bubble point temperature; T_g = dew point temperature.

TABLE 2-262 Thermodynamic Properties of Saturated R-407B (Klea 61)

Pressure, bar	T_f, K	T_g, K	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)
1	225.6	230.0	0.000 6852	0.1800	−9.45	191.64		0.8433
1.5	234.3	238.5	0.000 6994	0.1230	2.52	196.90		0.8341
2	241.8	245.0	0.000 7110	0.0937	9.72	200.88		0.8282
2.5	246.4	250.4	0.000 7211	0.0758	16.59	204.10		0.8245
3	251.1	254.9	0.000 7301	0.0637	22.47	206.80		0.8215
4	258.9	262.6	0.000 7463	0.04831	32.43	211.22		0.8172
5	265.4	269.0	0.000 7607	0.03888	40.76	214.74		0.8141
6	270.9	274.4	0.000 7740	0.03249	48.00	217.65		0.8123
8	280.2	283.4	0.000 7985	0.02435	59.82	222.21		0.8080
10	287.8	290.9	0.000 8214	0.01936	70.98	225.63		0.8048
12.5	295.8	298.7	0.000 8491	0.01528	82.59	228.80		0.8010
15	302.8	305.5	0.000 8768	0.01251	93.02	231.08		0.7971
17.5	308.8	311.4	0.000 9053	0.01049	102.67	232.64		0.7929
20	314.3	316.7	0.000 9353	0.00896	111.79	233.60		0.7882
22.5	319.3	321.5	0.000 9680	0.00774	120.55	233.99		0.7829
25	323.9	325.9	0.001 005	0.00674	129.11	233.85		0.7769
27.5	328.1	330.0	0.001 048	0.00590	137.62	233.16		0.7700
30	332.1	333.7	0.001 102	0.00518	146.21	231.84		0.7619

Converted and interpolated from *Thermodynamic Properties of Klea 61* (British units, 20 pp.), copyright ICI Chemicals and Polymers Limited, 1993. Reproduced by permission. T_f = bubble-point temperature; T_g = dew-point temperature. $h_f = s_f = 0$ at 233.15 K = –40°C.

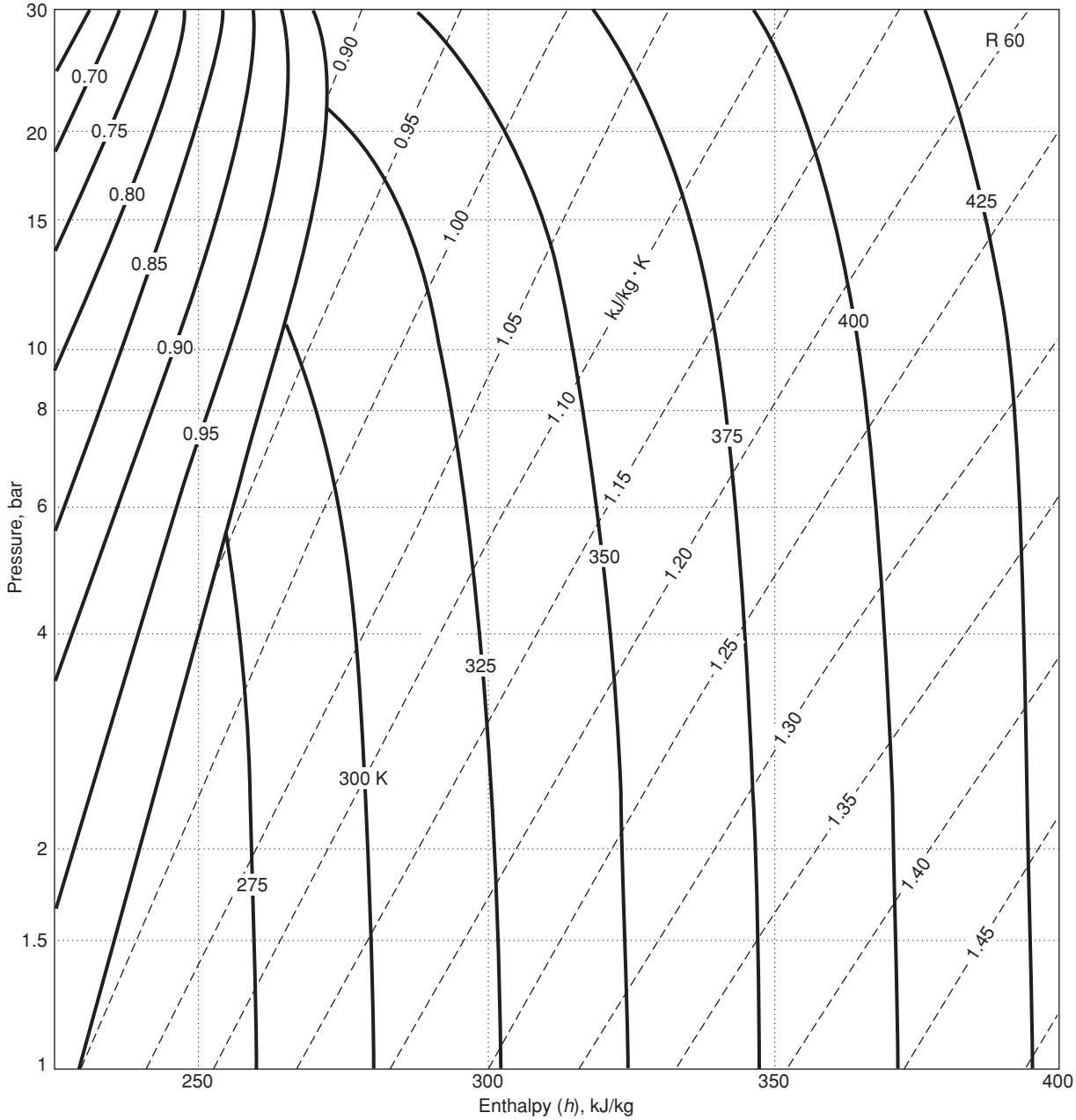

FIG. 2-22 Enthalpy–log-pressure diagram for R-407A (Klea 60).

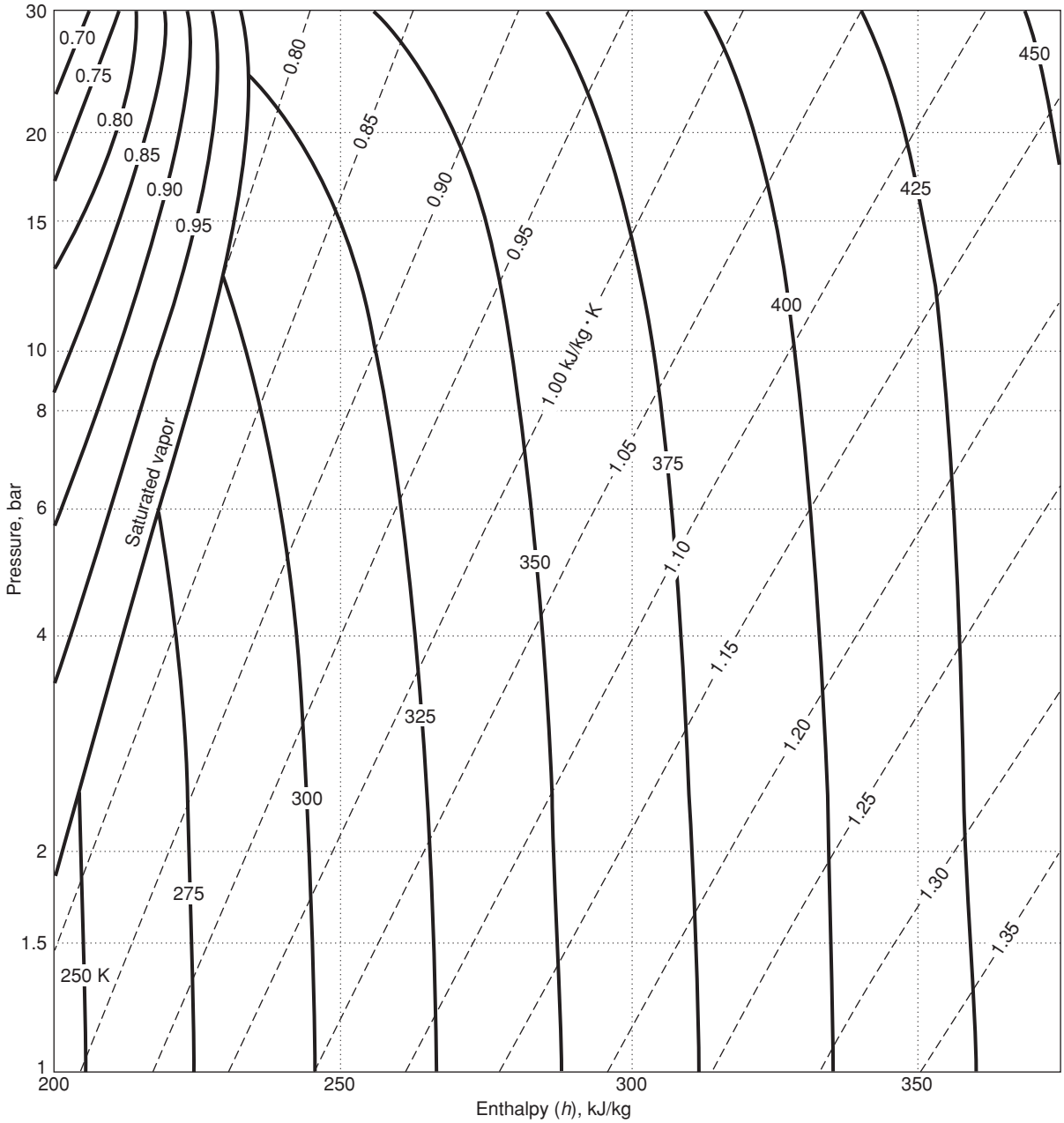

FIG. 2-23 Enthalpy–log-pressure diagram for R-407B (Klea 61).

TABLE 2-263 Saturated R-404A (SUVA HP 62)

Temp., °C	P_f, bar	P_g, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)	μ_f, 10^{-6} Pa·s	k_f, W/(m·K)	Pr_f
–50	0.852	0.821	0.000 761	0.2244	133.1	337.3	0.7318	1.6487		370	0.0970	
–40	1.367	1.325	0.000 779	0.1434	145.6	343.8	0.7862	1.6380		318		
–30	2.095	2.041	0.000 799	0.0953	159.9	350.3	0.8460	1.6301	1.220	276	0.0868	3.88
–20	3.087	3.018	0.000 820	0.0656	172.8	356.5	0.8975	1.6245	1.260	238	0.0834	3.60
–10	4.404	4.321	0.000 843	0.0463	186.1	362.6	0.9487	1.6202	1.302	207	0.0801	3.37
0	6.111	6.013	0.000 868	0.03338	200.0	368.3	1.0000	1.6188	1.351	181	0.0767	3.19
10	8.278	8.165	0.000 898	0.02444	214.5	373.6	1.0515	1.6138	1.412	158	0.0733	3.04
20	10.977	10.851	0.000 933	0.01809	229.9	378.3	1.1038	1.6106	1.489	138	0.0698	2.94
30	14.287	14.150	0.000 977	0.01348	246.2	382.2	1.1574	1.6065	1.592	122	0.0663	2.93
40	18.292	18.148	0.001 037	0.01003	263.8	385.0	1.2130	1.6005	1.753	106	0.0624	2.98
50	23.08	22.94	0.001 122	0.00739	283.2	386.1	1.2723	1.5910	2.09	91	0.0583	3.26
60	28.75	28.63	0.001 261	0.00527	305.8	384.2	1.3389	1.5742		76	0.0535	
70	35.58			0.00285	339.8	375.9				61		
72.1[c]	37.32	37.32	0.002 06	0.00206	361	361						

c = critical point. SUVA HP 62 = CHF_2CF_3 (R125) 44% wt + CH_3CF_3 (R143a) 52% wt + CH_2FCF_3 (R134a) 4% wt, near-azeotropic blend. Material used by permission of DuPont Fluoroproducts. Some values read from charts may be approximate.

TABLE 2-264 R-404A (SUVA HP 62) at Atmospheric Pressure

Temp., °C	–45.63	–40	–20	0	20	40	60	80	100	120
v (m³/kg)	0.1866	0.1921	0.2100	0.2278	0.2455	0.2630	0.2805	0.2980	0.3153	0.3325
h (kJ/kg)	336.0	344.4	359.9	376.2	393.1	410.9	429.3	448.4	468.2	488.7
s (kJ/kg·K)	1.6599	1.6636	1.7274	1.7891	1.8491	1.9076	1.9646	2.0203	2.0747	2.1278
c_p (kJ/kg·K)	0.732	0.738	0.781	0.821	0.860	0.897	0.933	0.967	1.000	1.032
μ (10^{-6} Pa·s)	9.47	9.68	10.45	11.22	11.99	12.76	13.53	14.30	15.07	15.84
k (W/m·K)	0.00860	0.00932	0.01059	0.01186	0.01313	0.01440	0.01568	0.01695	0.01827	0.01949
Pr	0.806	0.767	0.771	0.777	0.785	0.795	0.805	0.816	0.827	0.839
Z	0.9755	0.9800	0.9867	0.9919	0.9961	0.9989	1.0014	1.0037	1.0050	1.0060

v,h, and s from DuPont bull. T—HP62—SI, June 1993 (17 pp.). c_p and k from DuPont bull. ART 18, June 1993 (37 pp.). Some values read from charts may be approximate. Material used by permission of DuPont Fluoroproducts.

TABLE 2-265 Saturated R-401B (SUVA MP 66)

Temp., °C	P_f, bar	P_g, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)	μ_f, 10^{-6} Pa·s	k_f, W/(m·K)	Pr_f
–40	0.788	0.585	0.000 710	0.3498	153.8	386.0	0.8184	1.8291	1.078	349	0.1209	3.11
–30	1.239	0.952	0.000 725	0.2224	164.8	391.6	0.8643	1.8100	1.109	313	0.1154	3.01
–20	1.872	1.479	0.000 740	0.1471	176.0	397.1	0.9095	1.7940	1.137	282	0.1106	2.90
–10	2.726	2.212	0.000 758	0.1008	188.6	402.6	0.9577	1.7807	1.165	257	0.1057	2.83
0	3.850	3.198	0.000 778	0.0710	200.0	407.8	1.0000	1.7694	1.197	236	0.1012	2.79
10	5.297	4.491	0.000 801	0.05124	212.6	412.9	1.0450	1.7598	1.233	217	0.0967	2.77
20	7.120	6.146	0.000 827	0.03771	225.1	417.7	1.0879	1.7512	1.277	198	0.0922	2.74
30	9.379	8.229	0.000 858	0.02818	238.2	422.1	1.1311	1.7433	1.329	181	0.0877	2.74
40	12.133	10.808	0.000 895	0.02131	251.9	426.1	1.1747	1.7357	1.392	168	0.0830	2.82
50	15.444	13.955	0.000 939	0.01625	266.3	429.4	1.2190	1.7278	1.468	151	0.0781	2.84
60	19.378	17.750	0.000 994	0.01244	281.6	431.9	1.2645	1.7191	1.564	139	0.0737	2.95
70	24.00	22.28	0.001 066	0.00951	298.1	433.4	1.3120	1.7088	1.652	127	0.0684	3.07
80	29.37	27.64	0.001 164	0.00721	316.3	433.2	1.3625	1.6956	1.802	116	0.0631	3.31
90	35.55	33.96	0.001 313	0.00534	337.2	430.4	1.4187	1.6768			0.0577	
100	42.30										0.0533	
106.1[c]	46.82	46.82	0.001 95	0.00195	389	389						

c = critical point. SUVA MP 66 = R-401B = $CHClF_2$ (R22) 61% wt + CH_3CHF_2 (R152a) 11% wt + $CHClFCF_3$ (R124) 28% wt, near-azeotropic blend. Material used by permission of DuPont Fluoroproducts. Some values read from charts are approximate.

TABLE 2-266 R-401B (SUVA MP 66) at Atmospheric Pressure

Temp., °C	–28.63[b]	–20	0	20	40	60	80	100	120	140
v (m³/kg)	0.2086	0.2177	0.2362	0.2545	0.2727	0.2908	0.3089	0.3269	0.3449	0.3629
h (kJ/kg)	392.2	397.9	411.2	425.1	439.6	454.6	470.1	486.2	502.7	519.4
s (kJ/kg·K)	1.8081	1.8299	1.8804	1.9295	1.9772	2.0237	2.0690	2.1132	2.1564	2.1986
c_p (kJ/kg·K)	0.641	0.652	0.688	0.716	0.744	0.771	0.796	0.822	0.844	0.866
μ (10^{-6} Pa·s)	9.78	10.43	11.18	11.93	12.68	13.42	14.17	14.89	15.61	16.32
k (W/m·K)	0.00817	0.00921	0.01041	0.01161	0.01282	0.01404	0.01536	0.01668	0.01796	0.01929
Pr	0.767	0.738	0.737	0.736	0.735	0.735	0.734	0.734	0.733	0.733
Z	0.9652	0.9730	0.9783	0.9822	0.9852	0.9876	0.9896	0.9912	0.9925	0.9937

v, h, and s from DuPont bull. T—MP 66—SI, Jan. 1993 (17 pp.). c_p, μ, and k from DuPont bull. ART 10, Jan. 1993 (27 pp.). Some values read from charts may be approximate. Material used by permission of DuPont Fluoroproducts. *b* = normal boiling point.

TABLE 2-267 Saturated R-402A (SUVA HP 80)

Temp., °C	P_f, bar	P_g, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)	μ_f, 10^{-6} Pa·s	k_f, W/(m·K)	Pr_f
–50	0.962	0.872	0.000 679	0.2033	139.6	334.1	0.7578	1.6327		377	0.0970	
–40	1.520	1.403	0.000 695	0.1303	150.8	339.9	0.8070	1.6206		317		
–30	2.305	2.156	0.000 713	0.0869	163.1	345.6	0.8584	1.6110	1.193	283	0.0880	3.84
–20	3.370	3.188	0.000 733	0.0598	174.9	351.1	0.9053	1.6034	1.217	247	0.0849	3.54
–10	4.776	4.560	0.000 757	0.0423	187.6	356.4	0.9541	1.5972	1.236	215	0.0813	3.27
0	6.588	6.336	0.000 785	0.03060	200.0	361.3	1.0000	1.5919	1.253	188	0.0778	3.03
10	8.877	8.592	0.000 819	0.02248	213.0	365.9	1.0461	1.5870	1.286	165	0.0743	2.86
20	11.720	11.404	0.000 860	0.01671	226.7	369.8	1.0927	1.5820	1.340	146	0.0708	2.76
30	15.195	14.855	0.000 911	0.01250	241.2	373.1	1.1403	1.5762	1.412	128	0.0672	2.69
40	19.388	19.034	0.000 977	0.00936	256.8	375.4	1.1897	1.5690	1.512	113	0.0634	2.70
50	24.39	24.04	0.001 070	0.00696	273.9	376.2	1.2420	1.5589	1.64	98	0.0593	2.71
60	30.30	29.97	0.001 212	0.00505	293.6	374.6	1.2998	1.5433	1.81	83	0.0551	2.79
70										68		
75.5[c]	41.35	41.35	0.001 850	0.00185	340	340						

c = critical point. SUVA HP 80 = R-402A = CHF_2CF_3 (R125) 60% wt + $CH_3CH_2CH_3$ (R290) 2% wt + $CHClF_2$ (R22) 38% wt, near-azeotropic blend. Material used by permission of DuPont Fluoroproducts. Some values, read from charts, may be approximate.

TABLE 2-268 R-402A (SUVA HP 80) at Atmospheric Pressure

Temp., °C	−46.95[b]	−40	−20	0	20	40	60	80	100	120
v (m^3/kg)	0.1768	0.1827	0.1996	0.2164	0.2331	0.2497	0.2663	0.2828	0.2992	0.3155
h (kJ/kg)	335.9	340.5	354.3	368.6	383.5	398.7	414.9	431.4	448.5	466.1
s (kJ/kg·K)	1.6286	1.6490	1.7055	1.7599	1.8124	1.8633	1.9128	1.9610	2.0081	2.0541
c_p (kJ/kg·K)	0.648	0.654	0.687	0.721	0.749	0.779	0.807	0.836	0.863	0.890
μ (10^{-6} Pa·s)	9.42	9.69	10.45	11.22	11.99	12.75	13.52	14.29	15.06	15.82
k (W/m·K)	0.00888	0.00932	0.01059	0.01186	0.01313	0.01440	0.01568	0.01695	0.01822	0.01949
Pr	0.687	0.680	0.678	0.681	0.685	0.690	0.696	0.703	0.713	0.722
Z	0.9673	0.9697	0.9758	0.9804	0.9840	0.9868	0.9892	0.9910	0.9923	0.9932

b = normal boiling pt. v, h, and s from DuPont bull. T—HP 80—SI, Jan. 1993 (17 pp.). c_p, μ, and k from DuPont bull. ART 18, June 1993 (37 pp.). Some values read from charts may be approximate. Material used by permission of DuPont Fluoroproducts.

TABLE 2-269 Saturated R-402B (SUVA HP 81)

Temp., °C	P_f, bar	P_g, bar	v_f, m^3/kg	v_g, m^3/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)	μ_f, 10^{-6} Pa·s	k_f, W/(m·K)	Pr_f
−50	0.883	0.787	0.000 687	0.2425	140.3	351.7	0.7606	1.7122		383	0.1031	
−40	1.403	1.273	0.000 702	0.1548	151.4	357.2	0.8092	1.6957		333	0.0983	
−30	2.135	1.967	0.000 719	0.1028	163.3	362.7	0.8589	1.6820	1.178	290	0.0941	3.63
−20	3.132	2.923	0.000 739	0.0707	174.9	368.0	0.9054	1.6706	1.191	253	0.0900	3.35
−10	4.451	4.198	0.000 761	0.0499	187.8	373.0	0.9550	1.6611	1.204	223	0.0863	3.11
0	6.153	5.852	0.000 787	0.03610	200.0	377.8	1.0000	1.6528	1.221	195	0.0818	2.91
10	8.307	7.959	0.000 817	0.02656	212.7	382.2	1.0450	1.6451	1.288	173	0.0790	2.82
20	10.984	10.591	0.000 854	0.01980	226.0	386.0	1.0905	1.6376	1.313	151	0.0753	2.63
30	14.261	13.827	0.000 899	0.01490	240.1	389.3	1.1367	1.6299	1.37	137	0.0715	2.49
40	18.216	17.750	0.000 955	0.01125	255.1	391.5	1.1842	1.6211	1.75	122	0.0676	3.16
50	22.93	22.45	0.001 030	0.00848	271.4	392.8	1.2339	1.6104	2.07	106	0.0633	3.47
60	28.50	28.03	0.001 136	0.00632	289.5	392.2	1.2873	1.5961		91	0.0586	
70	35.01	34.60	0.001 307	0.00456	299.6	390.9	1.3164	1.5866		75	0.0544	
80												
82.6[c]	44.45	44.45	0.001 88	0.00188	351	351						

c = critical point. SUVA HP 81 = R402B (38/2/60) = CHF_2CF_3 (R125) 38% wt + $CH_3CH_2CH_3$ (R290) 2% wt + $CHClF_2$ (R22) 60% wt, near-azeotropic blend. Material used by permission of DuPont Fluoroproducts. Some values read from charts may be approximate.

TABLE 2-270 R-402B (SUVA HP 81) at Atmospheric Pressure

Temp., °C	−44.87[b]	−40	−20	0	20	40	60	80	100	120
v (m^3/kg)	0.1903	0.1960	0.2142	0.2322	0.2500	0.2678	0.2856	0.3032	0.3209	0.3386
h (kJ/kg)	354.7	357.7	370.8	384.6	398.8	413.6	428.9	444.7	461.0	477.7
s (kJ/kg·K)	1.7032	1.7169	1.7711	1.8232	1.8735	1.9222	1.9696	2.0158	2.0607	2.1047
c_p (kJ/kg·K)	1.187	1.177	1.169	1.159	1.149	1.143	1.134	1.128	1.124	1.120
μ (10^{-6} Pa·s)	10.16	10.33	11.10	11.86	12.62	13.39	14.15	14.78	15.54	16.30
k (W/m·K)	0.00739	0.00768	0.00902	0.01036	0.01170	0.01304	0.01438	0.01572	0.01706	0.01840
Pr	1.632	1.583	1.439	1.327	1.239	1.174	1.124	1.061	1.024	0.992
Z	0.9622	0.9703	0.9766	0.9811	0.9843	0.9870	0.9894	0.9909	0.9926	0.9940

b = normal boiling point. v, h, and s from DuPont bull. T—HP 81—SI, Jan. 1993 (17 pp.). c_p, μ, and k from DuPont bull. ART 18, June 1993 (37 pp.). Some values, read from charts, may be approximate. Material used by permission of DuPont Fluoroproducts.

TABLE 2-271 Thermodynamic Properties of R-113, 1,1,2-Trichlorotrifluoroethane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
					Saturated Properties					
236.93	0.0018714	9.0987	0.10991	31.483	31.484	0.16386	0.11672	0.16341	907.79	–0.45956
240.00	0.0022999	9.0614	0.11036	31.985	31.986	0.16596	0.11694	0.16366	897.63	–0.45692
250.00	0.0043168	8.9395	0.11186	33.627	33.627	0.17266	0.11797	0.16467	863.61	–0.44732
260.00	0.0076484	8.8172	0.11342	35.279	35.280	0.17914	0.11931	0.16593	828.94	–0.43622
270.00	0.012885	8.6941	0.11502	36.945	36.947	0.18543	0.12084	0.16735	794.26	–0.42364
280.00	0.020766	8.5702	0.11668	38.626	38.629	0.19154	0.12245	0.16891	759.92	–0.40951
290.00	0.032185	8.4450	0.11841	40.323	40.327	0.19750	0.12410	0.17056	726.09	–0.39367
300.00	0.048190	8.3183	0.12022	42.036	42.042	0.20331	0.12576	0.17231	692.84	–0.37590
310.00	0.069977	8.1897	0.12211	43.767	43.776	0.20898	0.12740	0.17414	660.17	–0.35588
320.00	0.098880	8.0588	0.12409	45.516	45.528	0.21453	0.12901	0.17606	628.04	–0.33321
330.00	0.13636	7.9252	0.12618	47.284	47.301	0.21998	0.13060	0.17807	596.38	–0.30739
340.00	0.18400	7.7884	0.12840	49.071	49.095	0.22531	0.13215	0.18020	565.13	–0.27774
350.00	0.24349	7.6479	0.13076	50.879	50.911	0.23055	0.13367	0.18247	534.20	–0.24340
360.00	0.31660	7.5029	0.13328	52.708	52.751	0.23571	0.13517	0.18491	503.50	–0.20323
370.00	0.40521	7.3529	0.13600	54.560	54.616	0.24079	0.13665	0.18755	472.94	–0.15569
380.00	0.51127	7.1968	0.13895	56.437	56.508	0.24579	0.13813	0.19047	442.41	–0.098686
390.00	0.63682	7.0336	0.14217	58.340	58.430	0.25074	0.13961	0.19374	411.80	–0.029233
400.00	0.78398	6.8619	0.14573	60.271	60.386	0.25564	0.14112	0.19749	380.97	0.057005
410.00	0.95499	6.6797	0.14971	62.235	62.378	0.26050	0.14266	0.20191	349.77	0.16660
420.00	1.1522	6.4845	0.15421	64.236	64.414	0.26533	0.14428	0.20730	317.99	0.31000
430.00	1.3781	6.2728	0.15942	66.280	66.500	0.27015	0.14601	0.21416	285.39	0.50481
440.00	1.6354	6.0390	0.16559	68.379	68.650	0.27500	0.14794	0.22344	251.65	0.78295
450.00	1.9271	5.7742	0.17318	70.548	70.881	0.27990	0.15016	0.23712	216.41	1.2078
460.00	2.2568	5.4624	0.18307	72.817	73.230	0.28494	0.15288	0.25998	179.46	1.9196
470.00	2.6288	5.0712	0.19719	75.247	75.765	0.29024	0.15638	0.30706	141.14	3.2778
480.00	3.0498	4.5104	0.22171	78.016	78.692	0.29621	0.16109	0.47179	101.80	6.5781
487.21	3.3923	2.9887	0.33460	82.401	83.536	0.30602			0	19.849
236.93	0.0018714	0.00095199	1050.4	61.277	63.243	0.29790	0.098915	0.10733	106.58	82.183
240.00	0.0022999	0.0011554	865.51	61.580	63.570	0.29756	0.099759	0.10819	107.21	77.881
250.00	0.0043168	0.0020850	479.61	62.580	64.650	0.29675	0.10244	0.11094	109.17	66.150
260.00	0.0076484	0.0035597	280.92	63.602	65.750	0.29634	0.10502	0.11361	111.03	57.141
270.00	0.012885	0.0057917	172.66	64.643	66.868	0.29625	0.10751	0.11623	112.77	50.111
280.00	0.020766	0.0090358	110.67	65.701	67.999	0.29644	0.10994	0.11883	114.38	44.541
290.00	0.032185	0.013590	73.586	66.774	69.143	0.29686	0.11231	0.12142	115.82	40.065
300.00	0.048190	0.019793	50.523	67.860	70.295	0.29748	0.11463	0.12402	117.08	36.421
310.00	0.069977	0.028029	35.677	68.957	71.453	0.29826	0.11691	0.12666	118.14	33.419
320.00	0.098880	0.038727	25.822	70.061	72.615	0.29918	0.11917	0.12935	118.97	30.923
330.00	0.13636	0.052364	19.097	71.172	73.776	0.30020	0.12140	0.13214	119.57	28.833
340.00	0.18400	0.069475	14.394	72.286	74.934	0.30131	0.12362	0.13503	119.89	27.074
350.00	0.24349	0.090662	11.030	73.400	76.086	0.30248	0.12583	0.13807	119.93	25.594
360.00	0.31660	0.11662	8.5752	74.513	77.228	0.30370	0.12804	0.14130	119.66	24.353
370.00	0.40521	0.14813	6.7508	75.621	78.356	0.30495	0.13024	0.14477	119.05	23.322
380.00	0.51127	0.18615	5.3719	76.720	79.467	0.30621	0.13246	0.14857	118.07	22.480
390.00	0.63682	0.23182	4.3136	77.808	80.555	0.30747	0.13469	0.15281	116.69	21.816
400.00	0.78398	0.28656	3.4897	78.878	81.614	0.30871	0.13695	0.15765	114.87	21.322
410.00	0.95499	0.35216	2.8396	79.926	82.638	0.30991	0.13926	0.16333	112.57	21.000
420.00	1.1522	0.43104	2.3200	80.944	83.617	0.31105	0.14165	0.17026	109.72	20.858
430.00	1.3781	0.52654	1.8992	81.922	84.539	0.31210	0.14414	0.17911	106.25	20.915
440.00	1.6354	0.64356	1.5539	82.844	85.386	0.31304	0.14679	0.19114	102.05	21.204
450.00	1.9271	0.78990	1.2660	83.689	86.129	0.31379	0.14969	0.20894	97.003	21.779
460.00	2.2568	0.97939	1.0210	84.417	86.721	0.31426	0.15299	0.23897	90.902	22.716
470.00	2.6288	1.2415	0.80548	84.942	87.059	0.31427	0.15703	0.30270	83.480	24.091
480.00	3.0498	1.6684	0.59937	85.005	86.833	0.31317	0.16277	0.54016	74.333	25.627
487.21	3.3923	2.9887	0.33460	82.401	83.536	0.30602			0	19.849

TABLE 2-271 Thermodynamic Properties of R-113, 1,1,2-Trichlorotrifluoroethane (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Single-Phase Properties										
250.00	0.10000	8.9405	0.11185	33.623	33.634	0.17265	0.11797	0.16466	864.02	–0.44747
320.34	0.10000	8.0543	0.12416	45.576	45.588	0.21472	0.12907	0.17612	626.96	–0.33239
320.34	0.10000	0.039138	25.551	70.099	72.654	0.29921	0.11925	0.12945	119.00	30.846
325.00	0.10000	0.038492	25.979	70.661	73.259	0.30109	0.11993	0.12998	120.05	29.068
400.00	0.10000	0.030653	32.623	80.120	83.382	0.32908	0.13100	0.14005	135.10	14.858
475.00	0.10000	0.025598	39.065	90.324	94.230	0.35391	0.14017	0.14891	148.01	9.5374
250.00	1.0000	8.9494	0.11174	33.589	33.701	0.17251	0.11802	0.16456	867.87	–0.44882
325.00	1.0000	8.0093	0.12485	46.338	46.463	0.21708	0.12985	0.17671	618.26	–0.32646
400.00	1.0000	6.8729	0.14550	60.238	60.383	0.25555	0.14107	0.19705	384.09	0.047064
412.41	1.0000	6.6340	0.15074	62.713	62.864	0.26166	0.14304	0.20311	342.18	0.19754
412.41	1.0000	0.36984	2.7039	80.174	82.878	0.31019	0.13983	0.16487	111.93	20.948
475.00	1.0000	0.28704	3.4839	89.325	92.809	0.33262	0.14241	0.15696	133.62	11.300
250.00	5.0000	8.9881	0.11126	33.441	33.998	0.17191	0.11826	0.16413	884.22	–0.45442
325.00	5.0000	8.0819	0.12373	46.082	46.701	0.21629	0.13008	0.17538	644.07	–0.34900
400.00	5.0000	7.0485	0.14187	59.694	60.403	0.25417	0.14058	0.19113	433.49	–0.086367
475.00	5.0000	5.5199	0.18116	74.959	75.865	0.28950	0.15167	0.23166	217.18	1.2219
250.00	10.000	9.0343	0.11069	33.266	34.373	0.17119	0.11861	0.16368	903.13	–0.46053
325.00	10.000	8.1644	0.12248	45.791	47.016	0.21536	0.13042	0.17407	672.87	–0.37126
400.00	10.000	7.2197	0.13851	59.149	60.534	0.25274	0.14040	0.18683	481.58	–0.18229
475.00	10.000	6.0609	0.16499	73.507	75.157	0.28621	0.14885	0.20446	313.71	0.32498
325.00	100.00	9.0570	0.11041	42.816	53.857	0.20444	0.13658	0.16811	970.17	–0.48114
400.00	100.00	8.5204	0.11737	54.955	66.691	0.23995	0.14351	0.17396	867.10	–0.45624
475.00	100.00	8.0191	0.12470	67.454	79.924	0.27026	0.14864	0.17872	788.68	–0.42986
475.00	200.00	8.7846	0.11384	65.196	87.963	0.26222	0.14928	0.17693	1035.9	–0.46436

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Marx, V., Pruss, A., and Wagner, W., "Neue Zustandsgleichungen fuer R 12, R 22, R 11 und R 113. Beschreibung des thermodynamishchen Zustandsverhaltens bei Temperaturen bis 525 K und Druecken bis 200 MPa," Duesseldorf: *VDI Verlag*, Series 19 (Waermetechnik/Kaeltetechnik), No. 57, 1992. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainty in density is 0.2%, that for vapor pressure is 0.3%, and that for the isobaric heat capacity is 2%. The uncertainties are higher in and above the critical region.

TABLE 2-272 Thermodynamic Properties of R-114, 1,2-Dichlorotetrafluoroethane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
275.00	0.094764	8.9110	0.11222	34.479	34.490	0.17204	0.11622	0.16411	636.17	–0.32927
280.00	0.11455	8.8268	0.11329	35.301	35.314	0.17500	0.11691	0.16513	617.82	–0.31514
285.00	0.13740	8.7415	0.11440	36.128	36.143	0.17792	0.11763	0.16623	599.54	–0.29975
290.00	0.16362	8.6548	0.11554	36.960	36.979	0.18082	0.11838	0.16741	581.32	–0.28301
295.00	0.19353	8.5667	0.11673	37.798	37.820	0.18368	0.11917	0.16866	563.14	–0.26478
300.00	0.22746	8.4771	0.11796	38.641	38.668	0.18652	0.11997	0.16998	545.01	–0.24491
305.00	0.26574	8.3858	0.11925	39.491	39.523	0.18933	0.12079	0.17138	526.89	–0.22318
310.00	0.30872	8.2927	0.12059	40.348	40.385	0.19212	0.12162	0.17286	508.80	–0.19936
315.00	0.35677	8.1976	0.12199	41.211	41.255	0.19488	0.12247	0.17441	490.70	–0.17315
320.00	0.41024	8.1004	0.12345	42.082	42.133	0.19763	0.12333	0.17606	472.58	–0.14418
325.00	0.46953	8.0007	0.12499	42.960	43.019	0.20035	0.12419	0.17781	454.45	–0.11201
330.00	0.53501	7.8984	0.12661	43.846	43.913	0.20306	0.12507	0.17967	436.26	–0.076088
335.00	0.60708	7.7932	0.12832	44.739	44.817	0.20575	0.12595	0.18167	418.03	–0.035744
340.00	0.68615	7.6847	0.13013	45.642	45.731	0.20843	0.12684	0.18383	399.72	0.0098734
345.00	0.77265	7.5726	0.13205	46.553	46.655	0.21109	0.12775	0.18617	381.32	0.061838
350.00	0.86701	7.4565	0.13411	47.475	47.591	0.21375	0.12866	0.18875	362.81	0.12152
355.00	0.96967	7.3358	0.13632	48.407	48.539	0.21640	0.12959	0.19162	344.17	0.19072
360.00	1.0811	7.2098	0.13870	49.350	49.500	0.21904	0.13054	0.19485	325.38	0.27180
365.00	1.2018	7.0779	0.14129	50.306	50.476	0.22169	0.13152	0.19854	306.40	0.36794
370.00	1.3323	6.9389	0.14412	51.276	51.468	0.22434	0.13252	0.20284	287.21	0.48354
375.00	1.4730	6.7916	0.14724	52.261	52.478	0.22700	0.13356	0.20795	267.77	0.62482
380.00	1.6246	6.6345	0.15073	53.265	53.510	0.22967	0.13465	0.21417	248.03	0.80081
385.00	1.7878	6.4651	0.15468	54.291	54.567	0.23237	0.13581	0.22201	227.95	1.0252
390.00	1.9630	6.2804	0.15922	55.343	55.655	0.23511	0.13705	0.23227	207.45	1.3196
395.00	2.1511	6.0759	0.16459	56.428	56.782	0.23790	0.13842	0.24644	186.45	1.7200
400.00	2.3530	5.8442	0.17111	57.557	57.960	0.24078	0.13997	0.26750	164.86	2.2906
405.00	2.5694	5.5731	0.17943	58.749	59.211	0.24379	0.14180	0.30245	142.55	3.1570
410.00	2.8015	5.2381	0.19091	60.042	60.577	0.24704	0.14408	0.37230	119.37	4.5962
415.00	3.0507	4.7774	0.20932	61.532	62.171	0.25078	0.14726	0.57876	95.263	7.3420
418.83	3.2516	3.3932	0.29471	64.391	65.349	0.25828			0	18.568
275.00	0.094764	0.043032	23.239	55.626	57.828	0.25690	0.10567	0.11538	116.26	24.935
280.00	0.11455	0.051392	19.458	56.123	58.352	0.25728	0.10683	0.11680	116.64	24.301
285.00	0.13740	0.060964	16.403	56.622	58.875	0.25769	0.10799	0.11826	116.94	23.725
290.00	0.16362	0.071869	13.914	57.121	59.397	0.25812	0.10916	0.11977	117.15	23.203
295.00	0.19353	0.084238	11.871	57.620	59.917	0.25859	0.11032	0.12133	117.27	22.730
300.00	0.22746	0.098213	10.182	58.119	60.435	0.25908	0.11150	0.12295	117.29	22.303
305.00	0.26574	0.11395	8.7760	58.617	60.949	0.25958	0.11268	0.12465	117.20	21.919
310.00	0.30872	0.13161	7.5984	59.113	61.459	0.26010	0.11387	0.12643	117.00	21.576
315.00	0.35677	0.15138	6.6059	59.608	61.965	0.26063	0.11508	0.12831	116.68	21.272
320.00	0.41024	0.17347	5.7648	60.100	62.465	0.26117	0.11630	0.13031	116.25	21.005
325.00	0.46953	0.19810	5.0480	60.589	62.959	0.26171	0.11754	0.13245	115.69	20.776
330.00	0.53501	0.22553	4.4340	61.074	63.446	0.26225	0.11880	0.13475	115.00	20.582
335.00	0.60708	0.25605	3.9055	61.554	63.925	0.26279	0.12008	0.13725	114.17	20.423
340.00	0.68615	0.28999	3.4484	62.029	64.395	0.26332	0.12139	0.13998	113.19	20.301
345.00	0.77265	0.32774	3.0512	62.497	64.855	0.26384	0.12274	0.14299	112.05	20.216
350.00	0.86701	0.36975	2.7045	62.957	65.302	0.26435	0.12412	0.14634	110.75	20.169
355.00	0.96967	0.41655	2.4007	63.408	65.736	0.26484	0.12555	0.15013	109.28	20.160
360.00	1.0811	0.46878	2.1332	63.849	66.155	0.26531	0.12703	0.15444	107.63	20.193
365.00	1.2018	0.52722	1.8967	64.277	66.557	0.26575	0.12856	0.15945	105.77	20.269
370.00	1.3323	0.59285	1.6868	64.690	66.938	0.26615	0.13016	0.16534	103.71	20.392
375.00	1.4730	0.66690	1.4995	65.086	67.295	0.26651	0.13185	0.17244	101.42	20.565
380.00	1.6246	0.75097	1.3316	65.461	67.624	0.26681	0.13363	0.18118	98.885	20.790
385.00	1.7878	0.84722	1.1803	65.810	67.920	0.26705	0.13552	0.19228	96.087	21.072
390.00	1.9630	0.95861	1.0432	66.126	68.174	0.26720	0.13755	0.20692	92.999	21.411
395.00	2.1511	1.0895	0.91784	66.401	68.376	0.26725	0.13975	0.22720	89.593	21.805
400.00	2.3530	1.2467	0.80213	66.621	68.509	0.26715	0.14217	0.25728	85.834	22.243

TABLE 2-272 Thermodynamic Properties of R-114, 1,2-Dichlorotetrafluoroethane (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
405.00	2.5694	1.4416	0.69369	66.763	68.545	0.26684	0.14487	0.30666	81.678	22.687
410.00	2.8015	1.6966	0.58941	66.782	68.433	0.26620	0.14792	0.40278	77.066	23.035
415.00	3.0507	2.0686	0.48342	66.570	68.045	0.26493	0.15144	0.67085	71.914	22.963
418.83	3.2516	3.3932	0.29471	64.391	65.349	0.25828			0	18.568
Single-Phase Properties										
300.00	0.10000	0.041312	24.206	58.335	60.756	0.26666	0.11051	0.11990	122.03	19.386
350.00	0.10000	0.035003	28.569	64.107	66.964	0.28578	0.11931	0.12828	132.80	12.959
400.00	0.10000	0.030432	32.860	70.284	73.570	0.30341	0.12703	0.13580	142.49	9.4836
450.00	0.10000	0.026945	37.113	76.817	80.529	0.31980	0.13376	0.14241	151.42	7.3132
500.00	0.10000	0.024188	41.342	83.661	87.796	0.33510	0.13956	0.14813	159.78	5.8366
300.00	1.0000	8.4984	0.11767	38.583	38.701	0.18633	0.11994	0.16950	551.87	–0.25320
350.00	1.0000	7.4651	0.13396	47.454	47.588	0.21369	0.12863	0.18840	364.95	0.11384
356.40	1.0000	7.3010	0.13697	48.670	48.807	0.21714	0.12986	0.19249	338.92	0.21213
356.40	1.0000	0.43061	2.3223	63.533	65.855	0.26498	0.12596	0.15128	108.84	20.165
400.00	1.0000	0.34682	2.8833	69.357	72.240	0.28188	0.12912	0.14474	126.86	11.867
450.00	1.0000	0.29218	3.4226	76.104	79.526	0.29904	0.13466	0.14726	141.14	8.1166
500.00	1.0000	0.25510	3.9201	83.069	86.989	0.31477	0.14003	0.15132	152.73	6.1412
300.00	5.0000	8.6001	0.11628	38.303	38.884	0.18538	0.11983	0.16738	584.86	–0.28910
350.00	5.0000	7.6832	0.13015	46.919	47.570	0.21213	0.12793	0.18096	420.00	–0.048046
400.00	5.0000	6.4329	0.15545	56.400	57.177	0.23775	0.13659	0.20814	251.68	0.75207
450.00	5.0000	3.3217	0.30105	69.251	70.756	0.26953	0.14905	0.34888	94.479	9.2719
500.00	5.0000	1.7533	0.57034	79.658	82.509	0.29444	0.14423	0.18709	121.74	7.0501
300.00	10.000	8.7118	0.11479	37.991	39.139	0.18430	0.11975	0.16542	621.41	–0.32232
350.00	10.000	7.8877	0.12678	46.398	47.666	0.21057	0.12746	0.17597	473.47	–0.15701
400.00	10.000	6.9197	0.14452	55.329	56.774	0.23488	0.13488	0.18894	338.62	0.18601
450.00	10.000	5.6865	0.17586	64.892	66.650	0.25812	0.14158	0.20710	225.09	1.0459
500.00	10.000	4.2030	0.23793	74.962	77.341	0.28064	0.14594	0.21449	163.22	2.5802
300.00	15.000	8.8106	0.11350	37.713	39.415	0.18332	0.11973	0.16394	654.14	–0.34729
350.00	15.000	8.0508	0.12421	45.970	47.834	0.20926	0.12720	0.17290	517.56	–0.22334
400.00	15.000	7.2160	0.13858	54.628	56.707	0.23294	0.13421	0.18200	398.49	–0.017272
450.00	15.000	6.2819	0.15919	63.643	66.030	0.25489	0.14025	0.19084	301.49	0.34360
500.00	15.000	5.2683	0.18981	72.897	75.744	0.27536	0.14487	0.19667	235.39	0.89448
300.00	20.000	8.8998	0.11236	37.460	39.707	0.18241	0.11973	0.16278	683.99	–0.36679
350.00	20.000	8.1881	0.12213	45.603	48.046	0.20811	0.12704	0.17079	555.75	–0.26854
400.00	20.000	7.4361	0.13448	54.086	56.775	0.23141	0.13385	0.17821	446.47	–0.12632
450.00	20.000	6.6421	0.15056	62.835	65.846	0.25277	0.13972	0.18438	358.35	0.081032
500.00	20.000	5.8257	0.17165	71.746	75.179	0.27243	0.14442	0.18846	294.31	0.35805

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Platzer, B., Polt, A., and Maurer, G., *Thermophysical Properties of Refrigerants,* Springer-Verlag, Berlin, 1990. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the critical point temperature are given in the last entry of the saturation tables. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainty in density is 0.2% up to 400 K and 1% at higher temperatures. The vapor pressure uncertainty is 1.5%. In the liquid phase, the uncertainty in isobaric heat capacity is 3%.

TABLE 2-273 Saturated Refrigerant 115, Chloropentafluoroethane*

Temp., °F	Pressure, lb/in² abs.	Volume, ft³/lb		Enthalpy, Btu/lb		Entropy, Btu/(lb)(°F)	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
–100	2.327	0.00966	10.57	–13.07	45.83	–0.0335	0.1302
–80	4.573	0.00986	5.624	–8.78	48.39	–0.0219	0.1286
–60	8.306	0.01009	3.218	–4.43	50.96	–0.0108	0.1278
–40	14.13	0.01033	1.953	0.00	53.53	0.0000	0.1275
–20	22.74	0.01060	1.245	4.50	56.07	0.0104	0.1277
0	34.94	0.01090	0.8257	9.09	58.56	0.0206	0.1282
20	51.59	0.01123	0.5657	13.76	61.00	0.0305	0.1290
40	73.65	0.01161	0.3979	18.54	63.35	0.0401	0.1298
60	102.1	0.01204	0.2857	23.45	65.60	0.0496	0.1308
80	138.1	0.01255	0.2081	28.54	67.71	0.0591	0.1317
100	182.7	0.01316	0.1530	33.85	69.63	0.0686	0.1325
120	237.3	0.01393	0.1125	39.50	71.24	0.0782	0.1330
140	303.2	0.01496	0.0817	45.67	72.36	0.0884	0.1329
160	382.0	0.01664	0.0567	52.76	72.42	0.0996	0.1314
170	427.0	0.01838	0.0444	56.56	71.33	0.1055	0.1290
175.89[c]	457.6	0.0261	0.0261	64.30	64.30	0.1175	0.1175

*Unpublished data of General Chemicals Division, Allied Chemical Company. Used by permission. *c* = critical temperature.

No material in SI units appears in the 1993 ASHRAE *Handbook—Fundamentals* (SI ed.). Tables and a chart to 50 ata, 200 °C are given by Mathias, H. and H. J. Loffler, Techn. Univ. Berlin rept., 1966 (42 pp.). A chart to 1500 psia, 500 °F was given by Mears, W. H., E. Rosenthal, et al., *J. Chem. Eng. Data,* **11,** 3 (1966): 338–343.

TABLE 2-274 Thermodynamic Properties of R-116, Hexafluoroethane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
173.10	0.026084	12.304	0.081274	13.031	13.033	0.073325	0.083104	0.12322	653.29	–0.38383
175.00	0.029802	12.247	0.081649	13.266	13.268	0.074672	0.083413	0.12375	645.09	–0.37807
180.00	0.041661	12.097	0.082664	13.887	13.891	0.078175	0.084236	0.12518	623.59	–0.36202
185.00	0.057021	11.945	0.083720	14.516	14.521	0.081622	0.085077	0.12670	602.22	–0.34452
190.00	0.076558	11.789	0.084824	15.153	15.159	0.085018	0.085933	0.12829	580.95	–0.32540
195.00	0.10101	11.631	0.085979	15.797	15.806	0.088366	0.086803	0.12996	559.75	–0.30443
200.00	0.13116	11.469	0.087192	16.450	16.461	0.091671	0.087686	0.13173	538.61	–0.28132
205.00	0.16784	11.303	0.088469	17.111	17.126	0.094937	0.088580	0.13361	517.48	–0.25573
210.00	0.21194	11.134	0.089818	17.781	17.800	0.098169	0.089485	0.13560	496.36	–0.22722
215.00	0.26438	10.959	0.091248	18.461	18.485	0.10137	0.090402	0.13773	475.20	–0.19525
220.00	0.32611	10.779	0.092769	19.151	19.181	0.10454	0.091330	0.14002	453.97	–0.15913
225.00	0.39814	10.594	0.094395	19.851	19.889	0.10769	0.092270	0.14249	432.64	–0.11798
230.00	0.48150	10.401	0.096140	20.563	20.609	0.11082	0.093224	0.14520	411.18	–0.070666
235.00	0.57725	10.201	0.098026	21.286	21.343	0.11394	0.094193	0.14818	389.53	–0.015673
240.00	0.68650	9.9926	0.10007	22.023	22.092	0.11705	0.095179	0.15152	367.64	0.049034
245.00	0.81042	9.7735	0.10232	22.774	22.857	0.12015	0.096188	0.15531	345.46	0.12626
250.00	0.95020	9.5423	0.10480	23.541	23.640	0.12326	0.097226	0.15970	322.91	0.21998
255.00	1.1071	9.2968	0.10756	24.325	24.444	0.12638	0.098301	0.16491	299.89	0.33604
260.00	1.2826	9.0336	0.11070	25.130	25.272	0.12952	0.099429	0.17129	276.28	0.48338
265.00	1.4781	8.7482	0.11431	25.959	26.128	0.13269	0.10063	0.17942	251.91	0.67638
270.00	1.6952	8.4341	0.11857	26.818	27.019	0.13593	0.10195	0.19040	226.54	0.93994
275.00	1.9360	8.0803	0.12376	27.715	27.955	0.13926	0.10345	0.20651	199.81	1.3211
280.00	2.2027	7.6671	0.13043	28.667	28.954	0.14274	0.10525	0.23354	171.13	1.9215
285.00	2.4983	7.1502	0.13986	29.710	30.059	0.14651	0.10768	0.29195	139.42	3.0109
290.00	2.8276	6.3727	0.15692	30.973	31.417	0.15106	0.11183	0.54643	102.12	5.6531
293.03	3.0477	4.4440	0.22502	33.029	33.715	0.15879			0	13.224
173.10	0.026084	0.018437	54.238	28.993	30.408	0.17370	0.067328	0.076383	106.90	43.932
175.00	0.029802	0.020874	47.907	29.113	30.541	0.17338	0.067932	0.077064	107.29	42.424
180.00	0.041661	0.028519	35.064	29.433	30.893	0.17263	0.069527	0.078887	108.24	38.839
185.00	0.057021	0.038215	26.168	29.755	31.247	0.17203	0.071130	0.080765	109.07	35.743
190.00	0.076558	0.050323	19.872	30.079	31.601	0.17155	0.072742	0.082706	109.78	33.062
195.00	0.10101	0.065236	15.329	30.406	31.954	0.17118	0.074365	0.084719	110.35	30.736
200.00	0.13116	0.083387	11.992	30.733	32.306	0.17090	0.076000	0.086816	110.78	28.716
205.00	0.16784	0.10525	9.5011	31.061	32.656	0.17069	0.077648	0.089011	111.05	26.960
210.00	0.21194	0.13135	7.6132	31.389	33.003	0.17056	0.079312	0.091322	111.15	25.435
215.00	0.26438	0.16228	6.1624	31.716	33.345	0.17049	0.080992	0.093772	111.07	24.112
220.00	0.32611	0.19868	5.0331	32.041	33.683	0.17046	0.082691	0.096389	110.80	22.967
225.00	0.39814	0.24133	4.1437	32.364	34.014	0.17047	0.084412	0.099211	110.33	21.983
230.00	0.48150	0.29110	3.4353	32.682	34.336	0.17051	0.086158	0.10229	109.63	21.143
235.00	0.57725	0.34902	2.8652	32.995	34.649	0.17056	0.087932	0.10569	108.69	20.435
240.00	0.68650	0.41636	2.4018	33.302	34.950	0.17063	0.089742	0.10951	107.50	19.850
245.00	0.81042	0.49465	2.0216	33.599	35.237	0.17068	0.091594	0.11388	106.02	19.381
250.00	0.95020	0.58587	1.7069	33.885	35.507	0.17072	0.093497	0.11901	104.24	19.024
255.00	1.1071	0.69256	1.4439	34.157	35.755	0.17073	0.095465	0.12520	102.13	18.777
260.00	1.2826	0.81820	1.2222	34.409	35.977	0.17069	0.097518	0.13296	99.661	18.637
265.00	1.4781	0.96766	1.0334	34.636	36.164	0.17056	0.099682	0.14316	96.789	18.605
270.00	1.6952	1.1482	0.87090	34.830	36.306	0.17033	0.10200	0.15741	93.477	18.677
275.00	1.9360	1.3717	0.72904	34.975	36.387	0.16992	0.10454	0.17918	89.681	18.837
280.00	2.2027	1.6592	0.60271	35.047	36.375	0.16924	0.10743	0.21720	85.354	19.040
285.00	2.4983	2.0572	0.48610	34.992	36.207	0.16807	0.11094	0.30201	80.445	19.127
290.00	2.8276	2.7232	0.36721	34.631	35.669	0.16572	0.11584	0.66697	74.869	18.438
293.03	3.0477	4.4440	0.22502	33.029	33.715	0.15879			0	13.224

Single-Phase Properties										
175.00	0.10000	12.249	0.081637	13.263	13.271	0.074658	0.083417	0.12373	645.46	–0.37835
194.81	0.10000	11.637	0.085935	15.773	15.782	0.088242	0.086771	0.12990	560.54	–0.30525
194.81	0.10000	0.064625	15.474	30.394	31.941	0.17119	0.074304	0.084642	110.33	30.817
250.00	0.10000	0.049033	20.394	34.892	36.932	0.19368	0.087457	0.096533	126.48	13.742
325.00	0.10000	0.037293	26.815	42.103	44.784	0.22106	0.10389	0.11253	144.51	6.5149
400.00	0.10000	0.030174	33.141	50.430	53.744	0.24582	0.11740	0.12590	160.19	3.7890
175.00	1.0000	12.272	0.081484	13.232	13.314	0.074480	0.083472	0.12349	650.25	–0.38185
250.00	1.0000	9.5480	0.10473	23.534	23.638	0.12323	0.097224	0.15951	323.69	0.21614
251.65	1.0000	9.4631	0.10567	23.797	23.903	0.12428	0.097576	0.16132	315.37	0.25543
251.65	1.0000	0.61920	1.6150	33.976	35.591	0.17073	0.094138	0.12091	103.59	18.931
325.00	1.0000	0.40237	2.4853	41.594	44.080	0.20033	0.10529	0.11782	135.84	7.1157
400.00	1.0000	0.31155	3.2097	50.096	53.305	0.22584	0.11796	0.12829	156.26	3.8772
250.00	5.0000	9.9221	0.10078	23.073	23.577	0.12134	0.097206	0.14935	376.03	0.0088070
325.00	5.0000	3.7219	0.26868	37.500	38.843	0.17386	0.11497	0.24037	101.35	7.5484
400.00	5.0000	1.7961	0.55676	48.386	51.170	0.20825	0.12060	0.14444	144.06	3.8425
250.00	10.000	10.261	0.097459	22.648	23.622	0.11954	0.097376	0.14319	425.10	–0.12130
325.00	10.000	7.1151	0.14055	34.117	35.522	0.16098	0.11174	0.17544	207.64	1.0712
400.00	10.000	3.9471	0.25335	46.132	48.666	0.19742	0.12255	0.16440	156.43	2.4329
250.00	20.000	10.747	0.093053	22.031	23.892	0.11682	0.097852	0.13725	498.98	–0.24812
325.00	20.000	8.5892	0.11643	32.498	34.826	0.15497	0.11132	0.15339	328.94	0.093523
400.00	20.000	6.4948	0.15397	43.572	46.651	0.18769	0.12291	0.16013	246.48	0.50074
250.00	50.000	11.642	0.085893	20.902	25.197	0.11135	0.099289	0.13120	647.29	–0.37511
325.00	50.000	10.197	0.098067	30.607	35.511	0.14736	0.11250	0.14332	516.00	–0.28102
400.00	50.000	8.8968	0.11240	40.984	46.604	0.17805	0.12396	0.15192	437.11	–0.20643

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data* **51**(3):785–850, 2006. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in the equation are 0.5% in density for liquid and vapor states and 1% in density or pressure for supercritical states. For vapor pressure, the uncertainty is 0.3%, that for vapor-phase speed of sounds is 0.2%, and the uncertainty for heat capacities is 5%.

TABLE 2-275 Thermodynamic Properties of R-123, 2,2-Dichloro-1,1,1-Trifluoroethane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
166.00	4.2021E-06	11.580	0.086355	15.111	15.111	0.081219	0.096271	0.14206	1243.8	–0.47555	115.89	4953.8
170.00	7.5115E-06	11.520	0.086807	15.678	15.678	0.084599	0.096537	0.14181	1227.9	–0.47661	114.18	4180.7
185.00	5.1172E-05	11.298	0.088511	17.800	17.800	0.096559	0.096881	0.14120	1167.0	–0.47672	109.51	2571.4
200.00	0.00024954	11.079	0.090257	19.919	19.919	0.10757	0.097283	0.14151	1104.3	–0.47027	105.59	1795.0
215.00	0.00093965	10.861	0.092076	22.050	22.050	0.11785	0.098162	0.14272	1040.9	–0.45811	101.48	1337.4
230.00	0.0028868	10.640	0.093989	24.204	24.204	0.12753	0.099479	0.14455	977.54	–0.44149	97.035	1036.8
245.00	0.0075380	10.415	0.096017	26.388	26.389	0.13673	0.10110	0.14676	914.89	–0.42124	92.395	825.41
260.00	0.017260	10.185	0.098182	28.607	28.609	0.14552	0.10291	0.14919	853.42	–0.39765	87.716	669.88
275.00	0.035500	9.9497	0.10051	30.863	30.867	0.15395	0.10483	0.15176	793.34	–0.37048	83.129	551.59
290.00	0.066848	9.7073	0.10302	33.158	33.165	0.16208	0.10680	0.15443	734.70	–0.33894	78.719	459.38
305.00	0.11700	9.4567	0.10575	35.492	35.504	0.16993	0.10879	0.15722	677.42	–0.30164	74.533	386.07
320.00	0.19264	9.1962	0.10874	37.867	37.888	0.17753	0.11080	0.16020	621.30	–0.25640	70.585	326.86
335.00	0.30136	8.9238	0.11206	40.286	40.319	0.18492	0.11283	0.16350	566.09	–0.19988	66.863	278.37
350.00	0.45147	8.6365	0.11579	42.751	42.804	0.19212	0.11491	0.16729	511.47	–0.12681	63.340	238.12
365.00	0.65201	8.3301	0.12005	45.270	45.349	0.19917	0.11704	0.17186	457.07	–0.028618	59.972	204.30
380.00	0.91268	7.9984	0.12502	47.853	47.967	0.20612	0.11927	0.17772	402.48	0.10963	56.709	175.46
395.00	1.2440	7.6316	0.13103	50.514	50.677	0.21300	0.12167	0.18579	347.23	0.31613	53.486	150.45
410.00	1.6577	7.2132	0.13863	53.281	53.510	0.21990	0.12433	0.19804	290.69	0.65103	50.222	128.23
425.00	2.1672	6.7113	0.14900	56.204	56.527	0.22695	0.12747	0.21999	231.85	1.2687	46.810	107.74
440.00	2.7898	6.0457	0.16541	59.412	59.873	0.23446	0.13159	0.27613	168.40	2.7240	43.102	87.306
455.00	3.5547	4.6936	0.21305	63.738	64.496	0.24446	0.13975	1.2865	90.823	10.053	39.324	58.622
456.83	3.6619	3.5964	0.27805	65.873	66.891	0.24965			0	16.566		
166.00	4.2021E-06	3.0446E-06	328,450.	47.940	49.320	0.28730	0.064141	0.072457	100.97	335.67	1.6736	5.5300
170.00	7.5115E-06	5.3144E-06	188,170.	48.198	49.612	0.28421	0.065216	0.073532	102.08	305.67	1.9014	5.7017
185.00	5.1172E-05	3.3272E-05	30,055.	49.206	50.744	0.27463	0.069152	0.077473	106.14	219.47	2.7552	6.3386
200.00	0.00024954	0.00015013	6,660.7	50.269	51.931	0.26763	0.072951	0.081290	110.02	162.12	3.6080	6.9646
215.00	0.00093965	0.00052637	1,899.8	51.386	53.171	0.26259	0.076634	0.085017	113.72	122.83	4.4590	7.5791
230.00	0.0028868	0.0015145	660.29	52.550	54.456	0.25906	0.080226	0.088699	117.20	95.252	5.3073	8.1817
245.00	0.0075380	0.0037253	268.44	53.755	55.779	0.25669	0.083755	0.092390	120.41	75.497	6.1533	8.7712
260.00	0.017260	0.0080830	123.72	54.996	57.131	0.25522	0.087245	0.096144	123.27	61.102	6.9987	9.3465
275.00	0.035500	0.015852	63.083	56.264	58.504	0.25445	0.090715	0.10001	125.72	50.463	7.8477	9.9065
290.00	0.066848	0.028647	34.907	57.553	59.887	0.25422	0.094177	0.10405	127.66	42.504	8.7073	10.450
305.00	0.11700	0.048445	20.642	58.855	61.270	0.25440	0.097639	0.10832	129.01	36.493	9.5872	10.979
320.00	0.19264	0.077628	12.882	60.163	62.645	0.25489	0.10111	0.11290	129.68	31.923	10.500	11.494
335.00	0.30136	0.11908	8.3975	61.468	63.999	0.25560	0.10459	0.11790	129.58	28.442	11.463	12.002
350.00	0.45147	0.17640	5.6690	62.760	65.319	0.25645	0.10810	0.12353	128.62	25.804	12.497	12.515
365.00	0.65201	0.25423	3.9334	64.026	66.591	0.25737	0.11165	0.13011	126.67	23.846	13.627	13.054
380.00	0.91268	0.35900	2.7855	65.252	67.794	0.25829	0.11529	0.13821	123.57	22.466	14.889	13.656
395.00	1.2440	0.50026	1.9990	66.412	68.899	0.25913	0.11908	0.14902	119.13	21.617	16.332	14.390
410.00	1.6577	0.69385	1.4412	67.468	69.857	0.25977	0.12313	0.16522	113.03	21.309	18.039	15.384
425.00	2.1672	0.97042	1.0305	68.348	70.581	0.26002	0.12767	0.19466	104.85	21.605	20.168	16.913
440.00	2.7898	1.4081	0.71016	68.866	70.847	0.25940	0.13325	0.27310	93.850	22.561	23.176	19.744
455.00	3.5547	2.5178	0.39718	67.881	69.293	0.25500	0.14227	1.6671	78.287	21.950	30.870	29.346
456.83	3.6619	3.5964	0.27805	65.873	66.891	0.24965			0	16.566		

Single-Phase Properties

200.00	0.10000	11.080	0.090251	19.917	19.926	0.10756	0.097300	0.14151	1104.5	–0.47033	105.61	1797.1
300.00	0.10000	9.5412	0.10481	34.709	34.720	0.16734	0.10812	0.15627	696.38	–0.31484	75.903	408.75
300.61	0.10000	9.5309	0.10492	34.805	34.815	0.16766	0.10820	0.15639	694.05	–0.31326	75.734	405.88
300.61	0.10000	0.041795	23.926	58.473	60.866	0.25432	0.096626	0.10704	128.68	38.084	9.3269	10.826
400.00	0.10000	0.030530	32.754	68.902	72.178	0.28673	0.11170	0.12066	150.93	14.728	15.085	14.262
500.00	0.10000	0.024219	41.290	80.750	84.879	0.31502	0.12437	0.13300	169.33	7.9263	20.780	17.224
600.00	0.10000	0.020111	49.724	93.743	98.716	0.34022	0.13502	0.14352	185.60	5.0504	26.460	19.696
200.00	1.0000	11.087	0.090194	19.896	19.986	0.10745	0.097447	0.14145	1105.5	–0.47094	105.80	1815.8
300.00	1.0000	9.5586	0.10462	34.660	34.764	0.16717	0.10822	0.15597	701.57	–0.31949	76.273	413.78
384.30	1.0000	7.8974	0.12662	48.607	48.733	0.20809	0.11994	0.17975	386.73	0.16009	55.784	167.94
384.30	1.0000	0.39525	2.5301	65.592	68.122	0.25855	0.11636	0.14096	122.45	22.169	15.282	13.849
400.00	1.0000	0.36390	2.7480	67.553	70.301	0.26410	0.11698	0.13715	129.70	18.389	16.135	14.368
500.00	1.0000	0.25890	3.8625	80.024	83.887	0.29441	0.12571	0.13778	160.11	8.3865	21.585	17.431
600.00	1.0000	0.20738	4.8220	93.232	98.054	0.32022	0.13546	0.14581	181.06	5.1181	27.069	19.994
200.00	5.0000	11.118	0.089944	19.803	20.253	0.10699	0.098069	0.14121	1110.5	–0.47345	106.62	1902.1
300.00	5.0000	9.6324	0.10382	34.450	34.969	0.16646	0.10865	0.15478	723.64	–0.33792	77.874	436.12
400.00	5.0000	7.7754	0.12861	50.791	51.434	0.21368	0.12180	0.17810	388.06	0.14142	55.285	160.58
500.00	5.0000	2.1822	0.45826	74.934	77.225	0.27035	0.13698	0.23468	111.01	11.061	30.182	28.291
600.00	5.0000	1.2117	0.82529	90.757	94.883	0.30270	0.13749	0.16051	161.94	5.1664	30.009	24.445
200.00	10.000	11.156	0.089639	19.691	20.588	0.10642	0.098779	0.14095	1117.0	–0.47622	107.63	2017.3
300.00	10.000	9.7177	0.10290	34.208	35.237	0.16564	0.10912	0.15357	749.33	–0.35684	79.793	464.14
400.00	10.000	8.0432	0.12433	50.152	51.395	0.21200	0.12141	0.17093	447.83	–0.033773	58.469	181.18
500.00	10.000	5.5005	0.18180	68.419	70.237	0.25388	0.13402	0.21202	205.61	1.7914	41.785	78.103
600.00	10.000	2.8283	0.35357	87.359	90.895	0.29164	0.13939	0.18482	163.33	3.7808	35.942	39.777
200.00	20.000	11.229	0.089054	19.480	21.261	0.10532	0.099998	0.14055	1130.7	–0.48062	109.63	2276.1
300.00	20.000	9.8704	0.10131	33.778	35.804	0.16412	0.10993	0.15175	795.84	–0.38528	83.416	521.04
400.00	20.000	8.4163	0.11882	49.229	51.605	0.20949	0.12134	0.16430	534.29	–0.19523	63.653	217.09
500.00	20.000	6.7515	0.14812	65.791	68.753	0.24770	0.13081	0.17889	348.69	0.27303	49.919	115.74
600.00	20.000	4.9944	0.20022	83.034	87.039	0.28102	0.13822	0.18342	257.14	0.96765	41.677	74.025
200.00	40.000	11.368	0.087968	19.099	22.618	0.10325	0.10179	0.14011	1160.1	–0.48571	113.48	2947.0
300.00	40.000	10.125	0.098764	33.072	37.023	0.16152	0.11120	0.14952	875.49	–0.42067	90.039	640.89
400.00	40.000	8.9071	0.11227	47.981	52.472	0.20590	0.12199	0.15901	653.37	–0.32210	72.037	282.73
500.00	40.000	7.7025	0.12983	63.586	68.779	0.24225	0.13053	0.16697	503.02	–0.17413	60.777	165.05
600.00	40.000	6.5412	0.15288	79.686	85.801	0.27327	0.13791	0.17293	409.64	0.011715	52.389	115.87

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Younglove, B. A., and McLinden, M. O., "An International Standard Equation of State for the Thermodynamic Properties of Refrigerant 123 (2,2-Dichloro-1,1,1-Trifluoroethane)," *J. Phys. Chem. Ref. Data* **23**:731–779, 1994. The source for viscosity is Tanaka, Y, and Sotani, T., "Transport Properties (Thermal Conductivity and Viscosity)," in McLinden, M. O., Ed., *R123—Thermodynamic and Physical Properties,* Paris: International Institute of Refrigeration, 1995. See also *Int. J. Thermophys.* **17**(2):293–328, 1996. The source for thermal conductivity is Laesecke, A., Perkins, R. A., and Howley, J. B., "An Improved Correlation for the Thermal Conductivity of HCFC123 (2,2-Dichloro-1,1,1-Trifluoroethane)," *Int. J. Refrigeration* **19:**231–238, 1996.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are 0.1% in density, 1.5% in heat capacity, and 2% in the speed of sound, except in the critical region. The uncertainty in vapor pressure is 0.1%. Uncertainties are greater below 180 K. The uncertainty in viscosity is 5%. The uncertainty in thermal conductivity is 2%.

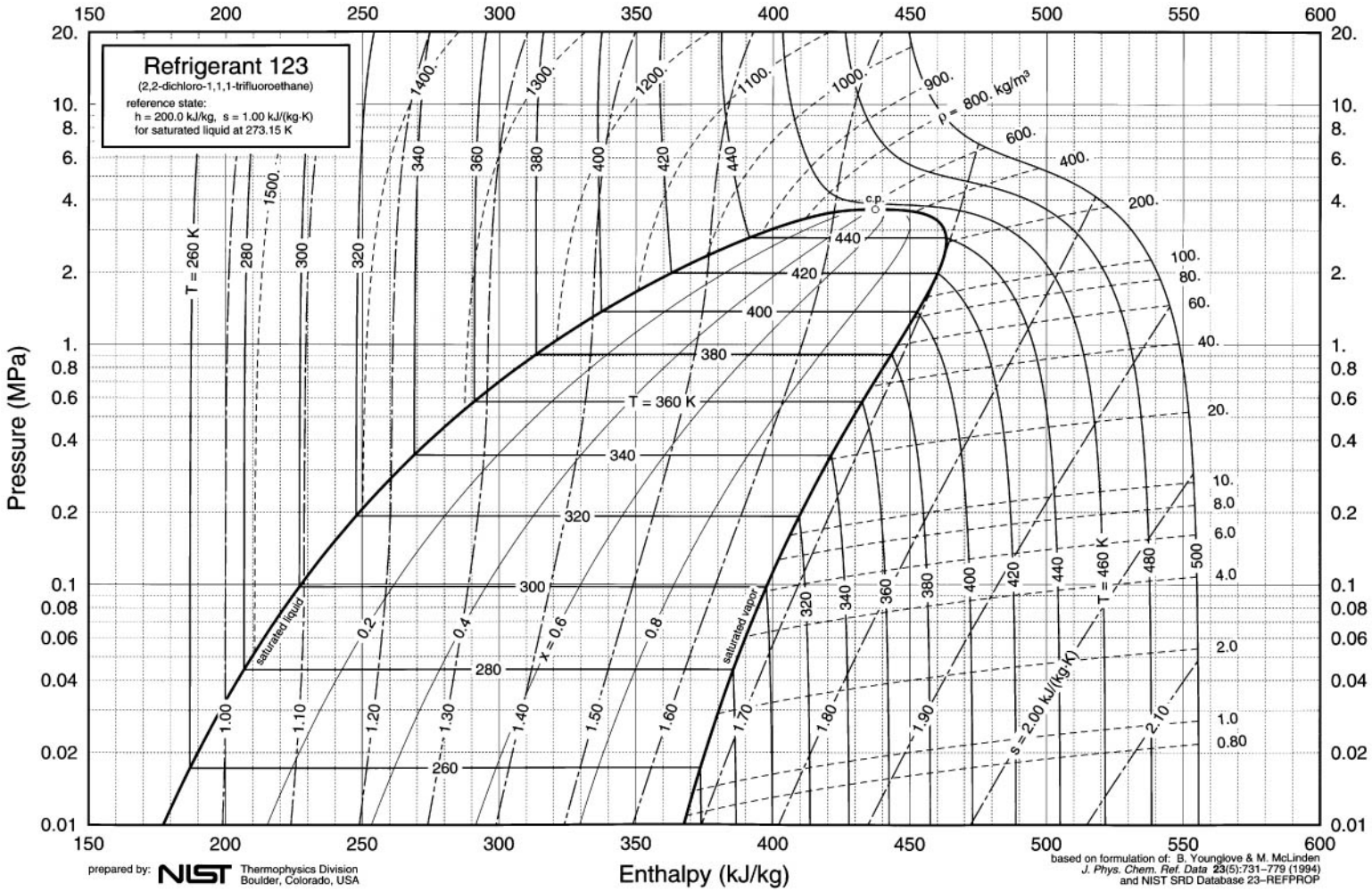

FIG. 2-24 Enthalpy–log-pressure diagram for Refrigerant 123.

TABLE 2-276 Thermodynamic Properties of R-124, 2-Chloro-1,1,1,2-Tetrafluoroethane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
120.00	2.6739E-08	13.576	0.073661	6.7015	6.7015	0.027106	0.088123	0.12662	1293.6	–0.48257
135.00	8.0309E-07	13.288	0.075255	8.6014	8.6014	0.042024	0.087495	0.12684	1225.8	–0.47832
150.00	1.1223E-05	13.003	0.076906	10.510	10.510	0.055431	0.087696	0.12778	1157.4	–0.47012
165.00	9.0881E-05	12.718	0.078626	12.437	12.437	0.067673	0.088451	0.12919	1089.0	–0.45872
180.00	0.00049265	12.433	0.080432	14.388	14.388	0.078987	0.089589	0.13095	1021.3	–0.44440
195.00	0.0019732	12.145	0.082339	16.367	16.367	0.089547	0.091000	0.13299	954.41	–0.42707
210.00	0.0062626	11.853	0.084369	18.378	18.379	0.099484	0.092610	0.13527	888.65	–0.40640
225.00	0.016573	11.554	0.086547	20.426	20.427	0.10890	0.094368	0.13778	824.09	–0.38173
240.00	0.037986	11.248	0.088904	22.512	22.515	0.11787	0.096239	0.14055	760.75	–0.35205
255.00	0.077612	10.931	0.091481	24.641	24.648	0.12648	0.098199	0.14361	698.57	–0.31583
270.00	0.14453	10.601	0.094332	26.816	26.830	0.13477	0.10024	0.14702	637.46	–0.27079
285.00	0.24955	10.253	0.097528	29.043	29.067	0.14280	0.10235	0.15090	577.23	–0.21337
300.00	0.40500	9.8843	0.10117	31.327	31.368	0.15061	0.10454	0.15545	517.54	–0.13780
315.00	0.62447	9.4868	0.10541	33.677	33.743	0.15826	0.10685	0.16102	457.87	–0.034029
330.00	0.92279	9.0506	0.11049	36.106	36.208	0.16580	0.10933	0.16825	397.44	0.11699
345.00	1.3163	8.5590	0.11684	38.634	38.788	0.17332	0.11213	0.17860	335.05	0.35590
360.00	1.8234	7.9793	0.12532	41.302	41.531	0.18092	0.11553	0.19587	269.18	0.78492
375.00	2.4663	7.2348	0.13822	44.202	44.543	0.18889	0.12005	0.23450	198.17	1.7419
390.00	3.2770	6.0066	0.16648	47.714	48.259	0.19827	0.12812	0.46802	115.48	5.4469
395.43	3.6243	4.1033	0.24371	50.813	51.696	0.20684			0	14.607
120.00	2.6739E-08	2.6799E-08	37,314,000.	36.727	37.725	0.28563	0.051678	0.059992	92.125	997.50
135.00	8.0309E-07	7.1548E-07	1,397,700.	37.530	38.653	0.26462	0.055405	0.063720	97.256	558.90
150.00	1.1223E-05	8.9989E-06	111,120.	38.388	39.636	0.24960	0.059044	0.067361	102.10	338.42
165.00	9.0881E-05	6.6260E-05	15,092.	39.300	40.671	0.23879	0.062605	0.070933	106.70	218.53
180.00	0.00049265	0.00032946	3,035.3	40.262	41.757	0.23104	0.066113	0.074474	111.05	149.08
195.00	0.0019732	0.0012200	819.64	41.269	42.887	0.22555	0.069600	0.078043	115.13	106.83
210.00	0.0062626	0.0036077	277.19	42.318	44.054	0.22175	0.073111	0.081721	118.89	80.088
225.00	0.016573	0.0089652	111.54	43.400	45.248	0.21922	0.076698	0.085612	122.21	62.512
240.00	0.037986	0.019455	51.400	44.507	46.459	0.21764	0.080420	0.089837	124.99	50.458
255.00	0.077612	0.037965	26.340	45.631	47.675	0.21678	0.084321	0.094522	127.10	41.824
270.00	0.14453	0.068150	14.674	46.762	48.883	0.21645	0.088420	0.099789	128.40	35.421
285.00	0.24955	0.11457	8.7285	47.892	50.070	0.21649	0.092708	0.10578	128.75	30.583
300.00	0.40500	0.18300	5.4645	49.009	51.222	0.21679	0.097166	0.11271	128.00	26.921
315.00	0.62447	0.28114	3.5569	50.100	52.321	0.21724	0.10179	0.12102	125.97	24.195
330.00	0.92279	0.42003	2.3808	51.145	53.342	0.21772	0.10663	0.13162	122.47	22.252
345.00	1.3163	0.61719	1.6202	52.111	54.244	0.21811	0.11180	0.14664	117.17	21.001
360.00	1.8234	0.90480	1.1052	52.940	54.955	0.21821	0.11757	0.17189	109.67	20.405
375.00	2.4663	1.3577	0.73653	53.497	55.314	0.21761	0.12466	0.23071	99.240	20.431
390.00	3.2770	2.2903	0.43662	53.233	54.664	0.21470	0.13608	0.61311	84.410	20.196
395.43	3.6243	4.1033	0.24371	50.813	51.696	0.20684			0	14.607

TABLE 2-276 Thermodynamic Properties of R-124, 2-Chloro-1,1,1,2-Tetrafluoroethane (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Single-Phase Properties										
150.00	0.10000	13.004	0.076901	10.509	10.516	0.055420	0.087698	0.12777	1157.7	–0.47016
225.00	0.10000	11.556	0.086537	20.423	20.431	0.10889	0.094369	0.13777	824.54	–0.38192
260.87	0.10000	10.804	0.092562	25.487	25.496	0.12976	0.098988	0.14489	674.53	–0.29941
260.87	0.10000	0.048164	20.763	46.073	48.150	0.21660	0.085902	0.096509	127.71	39.096
300.00	0.10000	0.041129	24.314	49.579	52.011	0.23038	0.092039	0.10148	138.33	22.359
375.00	0.10000	0.032447	30.820	57.006	60.088	0.25436	0.10524	0.11403	155.52	10.936
450.00	0.10000	0.026891	37.187	65.395	69.114	0.27627	0.11804	0.12661	170.43	6.3680
150.00	1.0000	13.011	0.076859	10.494	10.570	0.055319	0.087712	0.12773	1160.8	–0.47053
225.00	1.0000	11.570	0.086432	20.392	20.479	0.10875	0.094382	0.13761	829.31	–0.38397
300.00	1.0000	9.9082	0.10093	31.280	31.381	0.15045	0.10452	0.15494	523.28	–0.14686
333.28	1.0000	8.9488	0.11175	36.649	36.760	0.16744	0.10991	0.17017	384.03	0.15954
333.28	1.0000	0.45731	2.1867	51.364	53.551	0.21782	0.10772	0.13441	121.47	21.922
375.00	1.0000	0.36697	2.7250	56.110	58.835	0.23277	0.10870	0.12428	140.23	12.660
450.00	1.0000	0.28511	3.5074	64.848	68.356	0.25590	0.11949	0.13091	162.32	6.7329
150.00	5.0000	13.042	0.076674	10.428	10.811	0.054877	0.087777	0.12756	1174.3	–0.47207
225.00	5.0000	11.630	0.085982	20.262	20.692	0.10817	0.094440	0.13696	849.95	–0.39231
300.00	5.0000	10.055	0.099451	30.991	31.488	0.14947	0.10448	0.15210	558.86	–0.19712
375.00	5.0000	7.8072	0.12809	43.322	43.963	0.18645	0.11692	0.19006	276.48	0.71939
450.00	5.0000	2.0764	0.48161	61.347	63.755	0.23451	0.12778	0.18398	124.73	8.2236
150.00	10.000	13.080	0.076452	10.348	11.113	0.054334	0.087856	0.12736	1190.9	–0.47382
225.00	10.000	11.702	0.085459	20.109	20.963	0.10747	0.094513	0.13626	874.54	–0.40129
300.00	10.000	10.213	0.097912	30.675	31.654	0.14838	0.10449	0.14957	597.87	–0.24225
375.00	10.000	8.3628	0.11958	42.388	43.584	0.18379	0.11566	0.17088	359.58	0.22172
450.00	10.000	5.4895	0.18217	56.064	57.886	0.21844	0.12834	0.21040	179.08	2.3542
150.00	20.000	13.153	0.076029	10.197	11.717	0.053282	0.088011	0.12702	1222.7	–0.47677
225.00	20.000	11.832	0.084516	19.827	21.518	0.10615	0.094657	0.13514	920.41	–0.41563
300.00	20.000	10.473	0.095482	30.150	32.059	0.14651	0.10459	0.14630	664.60	–0.30098
375.00	20.000	8.9796	0.11136	41.285	43.513	0.18054	0.11536	0.15949	462.43	–0.080024
450.00	20.000	7.2897	0.13718	53.276	56.020	0.21090	0.12652	0.17382	319.21	0.35516
150.00	40.000	13.287	0.075260	9.9211	12.932	0.051293	0.088302	0.12653	1282.4	–0.48099
225.00	40.000	12.057	0.082941	19.345	22.662	0.10380	0.094922	0.13366	1002.2	–0.43482
300.00	40.000	10.865	0.092042	29.347	33.028	0.14350	0.10483	0.14289	772.84	–0.36270
375.00	40.000	9.6799	0.10331	39.971	44.103	0.17641	0.11550	0.15243	600.05	–0.26440
450.00	40.000	8.5132	0.11746	51.192	55.890	0.20504	0.12642	0.16186	479.46	–0.14030

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is de Vries, B., Tillner-Roth, R., and Baehr, H. D., "Thermodynamic Properties of HCFC 124," *19th Int. Congress of Refrigeration*, The Hague, The Netherlands, International Institute of Refrigeration, **IVa**:582–589, 1995. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are 0.05% in density, 1% in heat capacity, and 1% in the speed of sound, except in the critical region. The uncertainty in vapor pressure is 0.1%.

TABLE 2-277 Thermodynamic Properties of R-125, Pentafluoroethane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
172.52	0.0029140	14.086	0.070990	10.457	10.457	0.058837	0.081329	0.12417	932.57	–0.38374	116.02	1152.4
180.00	0.0056285	13.885	0.072020	11.389	11.389	0.064124	0.082012	0.12500	893.63	–0.37406	112.52	957.54
190.00	0.012328	13.613	0.073461	12.646	12.647	0.070919	0.083102	0.12647	843.11	–0.35818	107.79	768.40
200.00	0.024602	13.336	0.074988	13.919	13.921	0.077448	0.084327	0.12825	793.91	–0.33901	103.06	631.00
210.00	0.045417	13.052	0.076615	15.210	15.214	0.083750	0.085644	0.13028	745.67	–0.31627	98.331	527.00
220.00	0.078505	12.762	0.078360	16.523	16.529	0.089856	0.087029	0.13254	698.07	–0.28935	93.653	445.76
230.00	0.12833	12.461	0.080247	17.858	17.869	0.095792	0.088472	0.13505	650.89	–0.25723	89.019	380.67
240.00	0.20004	12.150	0.082305	19.219	19.235	0.10158	0.089971	0.13785	603.92	–0.21839	84.443	327.41
250.00	0.29934	11.824	0.084572	20.607	20.632	0.10725	0.091529	0.14102	556.99	–0.17062	79.940	283.01
260.00	0.43250	11.481	0.087098	22.025	22.063	0.11282	0.093153	0.14468	510.02	–0.11056	75.520	245.39
270.00	0.60624	11.117	0.089954	23.478	23.532	0.11830	0.094843	0.14903	462.91	–0.032921	71.187	213.02
280.00	0.82782	10.724	0.093245	24.971	25.048	0.12374	0.096594	0.15440	415.46	0.070972	66.940	184.73
290.00	1.1050	10.295	0.097130	26.511	26.619	0.12916	0.098430	0.16135	367.36	0.21606	62.772	159.60
300.00	1.4463	9.8162	0.10187	28.112	28.259	0.13461	0.10043	0.17099	318.17	0.43036	58.667	136.86
310.00	1.8610	9.2637	0.10795	29.793	29.994	0.14015	0.10274	0.18593	267.31	0.77370	54.597	115.81
320.00	2.3600	8.5923	0.11638	31.595	31.869	0.14593	0.10571	0.21395	213.55	1.4029	50.534	95.602
330.00	2.9579	7.6744	0.13030	33.632	34.017	0.15231	0.11043	0.29625	153.34	2.9184	46.661	74.602
339.17	3.6179	4.7790	0.20925	37.417	38.174	0.16438			0	12.361		
172.52	0.0029140	0.0020381	490.65	31.863	33.293	0.19120	0.059815	0.068285	116.43	90.257	5.2349	7.4339
180.00	0.0056285	0.0037809	264.49	32.307	33.795	0.18860	0.061648	0.070217	118.54	77.516	5.7185	7.7624
190.00	0.012328	0.0078784	126.93	32.913	34.477	0.18582	0.064126	0.072893	121.15	64.018	6.3724	8.1999
200.00	0.024602	0.015031	66.529	33.530	35.167	0.18368	0.066646	0.075712	123.47	53.589	7.0353	8.6344
210.00	0.045417	0.026661	37.508	34.157	35.860	0.18207	0.069223	0.078713	125.44	45.456	7.7081	9.0657
220.00	0.078505	0.044514	22.465	34.788	36.552	0.18087	0.071864	0.081939	127.01	39.066	8.3929	9.4944
230.00	0.12833	0.070679	14.148	35.421	37.237	0.18000	0.074575	0.085437	128.11	34.014	9.0929	9.9221
240.00	0.20004	0.10763	9.2907	36.052	37.911	0.17940	0.077362	0.089271	128.68	29.998	9.8136	10.353
250.00	0.29934	0.15835	6.3153	36.678	38.568	0.17900	0.080230	0.093526	128.64	26.787	10.563	10.791
260.00	0.43250	0.22645	4.4159	37.292	39.202	0.17874	0.083141	0.098283	127.93	24.232	11.356	11.246
270.00	0.60624	0.31661	3.1585	37.890	39.805	0.17857	0.086003	0.10368	126.44	22.293	12.213	11.732
280.00	0.82782	0.43510	2.2983	38.460	40.363	0.17844	0.088869	0.11025	124.10	20.938	13.169	12.266
290.00	1.1050	0.59084	1.6925	38.988	40.858	0.17826	0.092050	0.11918	120.81	20.043	14.286	12.884
300.00	1.4463	0.79742	1.2540	39.453	41.267	0.17797	0.095933	0.13255	116.42	19.438	15.680	13.638
310.00	1.8610	1.0777	0.92787	39.828	41.554	0.17744	0.10077	0.15449	110.71	19.016	17.586	14.635
320.00	2.3600	1.4778	0.67670	40.054	41.651	0.17649	0.10679	0.19725	103.29	18.738	20.574	16.104
330.00	2.9579	2.1269	0.47016	39.964	41.355	0.17454	0.11481	0.32843	93.550	18.404	26.607	18.766
339.17	3.6179	4.7790	0.20925	37.417	38.174	0.16438			0	12.361		

TABLE 2-277 Thermodynamic Properties of R-125, Pentafluoroethane (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Single-Phase Properties												
200.00	0.10000	13.337	0.074979	13.916	13.924	0.077436	0.084327	0.12823	794.34	–0.33920	103.09	631.60
224.79	0.10000	12.619	0.079245	17.160	17.168	0.092721	0.087714	0.13371	675.42	–0.27468	91.425	412.85
224.79	0.10000	0.055877	17.897	35.092	36.881	0.18042	0.073155	0.083578	127.60	36.498	8.7263	9.6994
300.00	0.10000	0.040689	24.576	41.155	43.613	0.20616	0.086960	0.095910	149.16	13.603	14.156	13.041
400.00	0.10000	0.030228	33.082	50.746	54.054	0.23608	0.10398	0.11252	172.25	5.6807	22.115	17.070
500.00	0.10000	0.024108	41.479	61.864	66.012	0.26271	0.11764	0.12607	192.24	3.1093	30.917	20.691
200.00	1.0000	13.355	0.074878	13.888	13.963	0.077295	0.084329	0.12805	799.42	–0.34145	103.50	638.78
286.46	1.0000	10.452	0.095673	25.960	26.055	0.12724	0.097767	0.15865	384.49	0.15862	64.240	168.19
286.46	1.0000	0.53072	1.8842	38.807	40.691	0.17833	0.090862	0.11564	122.09	20.318	13.866	12.653
300.00	1.0000	0.48261	2.0720	40.159	42.231	0.18359	0.092286	0.11224	129.90	16.539	14.732	13.270
400.00	1.0000	0.31780	3.1466	50.310	53.456	0.21585	0.10520	0.11626	165.47	5.9354	22.513	17.404
500.00	1.0000	0.24593	4.0661	61.591	65.657	0.24302	0.11806	0.12764	189.33	3.1109	31.336	21.014
200.00	5.0000	13.432	0.074450	13.768	14.140	0.076686	0.084364	0.12732	820.94	–0.35061	105.29	671.00
300.00	5.0000	10.214	0.097901	27.606	28.095	0.13288	0.099404	0.15790	379.39	0.16755	62.727	155.81
400.00	5.0000	2.1222	0.47120	47.739	50.095	0.19593	0.11164	0.15240	136.55	6.6581	27.340	22.244
500.00	5.0000	1.3333	0.75004	60.288	64.038	0.22710	0.12001	0.13643	180.53	2.9952	33.551	23.530
200.00	10.000	13.522	0.073953	13.626	14.366	0.075959	0.084459	0.12655	845.71	–0.36040	107.42	712.07
300.00	10.000	10.597	0.094369	27.096	28.039	0.13109	0.098728	0.14971	441.85	–0.0032571	67.164	177.37
400.00	10.000	5.5436	0.18039	43.724	45.528	0.18103	0.11417	0.19389	165.42	2.8474	40.583	46.568
500.00	10.000	2.8438	0.35165	58.555	62.072	0.21813	0.12198	0.14925	183.47	2.4316	37.529	29.745
200.00	30.000	13.835	0.072281	13.138	15.306	0.073355	0.085197	0.12439	927.73	–0.38765	115.19	889.29
300.00	30.000	11.489	0.087039	25.838	28.449	0.12645	0.098551	0.13883	597.35	–0.23171	79.855	245.90
400.00	30.000	9.0272	0.11078	39.705	43.028	0.16830	0.11217	0.15193	391.05	0.060756	59.824	112.78
500.00	30.000	6.8239	0.14654	54.141	58.538	0.20288	0.12339	0.15662	307.14	0.34144	53.649	67.694
300.00	60.000	12.259	0.081575	24.732	29.626	0.12196	0.10001	0.13426	735.32	–0.32748	93.938	338.04
400.00	60.000	10.465	0.095559	37.854	43.587	0.16206	0.11339	0.14453	563.68	–0.23451	75.022	173.26
500.00	60.000	8.9121	0.11221	51.703	58.436	0.19516	0.12470	0.15193	471.23	–0.15582	67.810	113.08

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Jacobsen, R. T., "A New Functional Form and New Fitting Techniques for Equations of State with Application to Pentafluoroethane (HFC-125)," *J. Phys. Chem. Ref. Data* **34**(1):69–108, 2005. The source for viscosity is Huber, M. L., and Laesecke, A.,"Correlation for the Viscosity of Pentafluoroethane (R125) from the Triple Point to 500 K at Pressures up to 60 MPa," *Ind. Eng. Chem. Res.*, **45**(12):4447–4453, 2006. The source for thermal conductivity is Perkins, R., and Huber, M. L., "Measurement and Correlation of the Thermal Conductivity of Pentafluoroethane (R125) from 190 K to 512 K at Pressures to 70 MPa," *J. Chem. Eng. Data* **51**(3):898–904, 2006.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainty in density is 0.1% at temperatures from the triple point to 400 K at pressures up to 60 MPa, except in the critical region, where an uncertainty of 0.2% in pressure is generally attained. In the limited region between 340 and 400 K and at pressures from 4 to 10 MPa, as well as for all states above 400 K, the uncertainty in density increases to 0.5%. At temperatures below 330 K and pressures below 30 MPa, the uncertainty in density in the liquid phase may be as low as 0.04%. In the vapor and supercritical region, speed of sound data are represented within 0.05% at pressures below 1 MPa. The estimated uncertainty for heat capacities is 0.5%, and the estimated uncertainty for the speed of sound in the liquid phase is 0.5% for $T > 250$ K. The estimated uncertainties of vapor pressures and saturated liquid densities calculated using the Maxwell criterion are 0.1% for each property, and the estimated uncertainty for saturated vapor densities is 0.2%. The uncertainty in density increases as the critical point is approached, while the accompanying uncertainty in calculated pressures is 0.2%. The viscosity correlation has an estimated uncertainty of 3.0% along the saturation boundary in the liquid phase, and 0.8% in the vapor. For thermal conductivity, the estimated uncertainty of the correlation is 3%, except for the dilute gas and points approaching critical, where the uncertainty rises to 5%.

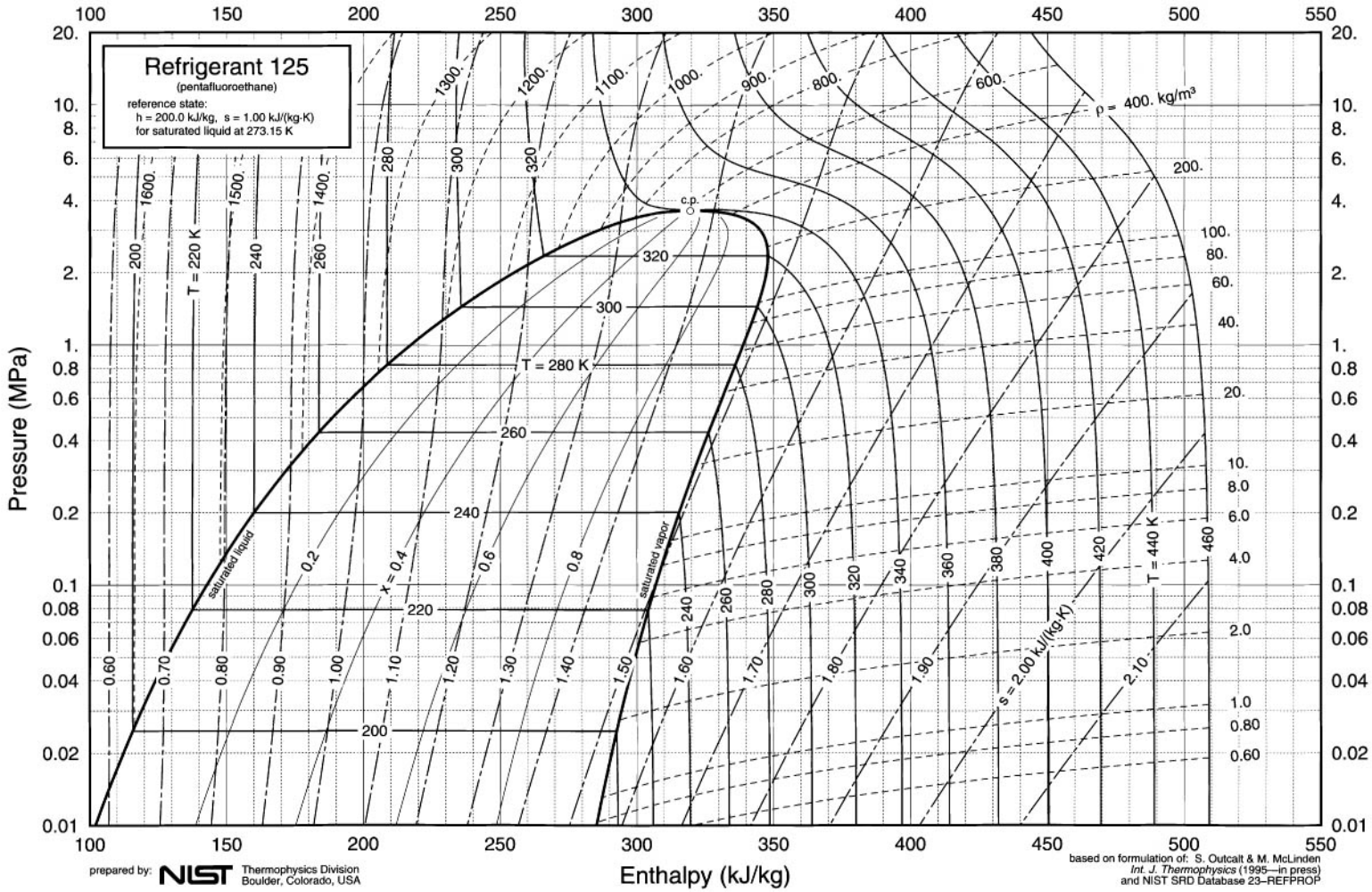

FIG. 2-25 Enthalpy–log-pressure diagram for Refrigerant 125.

TABLE 2-278 Thermodynamic Properties of R-134a, 1,1,1,2-Tetrafluoroethane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
169.85	0.00038956	15.594	0.064126	7.2907	7.2907	0.042100	0.080831	0.12079	1120.0	–0.38145	145.24	2153.6
170.00	0.00039617	15.590	0.064142	7.3088	7.3088	0.042207	0.080824	0.12079	1119.2	–0.38136	145.15	2139.7
180.00	0.0011275	15.331	0.065228	8.5179	8.5179	0.049117	0.080732	0.12112	1068.3	–0.37370	139.12	1479.1
190.00	0.0028170	15.069	0.066362	9.7328	9.7330	0.055686	0.081114	0.12193	1017.7	–0.36352	133.32	1106.2
200.00	0.0063130	14.804	0.067550	10.957	10.958	0.061966	0.081784	0.12303	967.61	–0.35119	127.74	867.31
210.00	0.012910	14.535	0.068798	12.194	12.195	0.067999	0.082633	0.12434	918.33	–0.33678	122.36	702.27
220.00	0.024433	14.262	0.070116	13.444	13.446	0.073815	0.083595	0.12582	869.85	–0.32011	117.17	582.15
230.00	0.043287	13.984	0.071512	14.710	14.713	0.079441	0.084636	0.12746	822.11	–0.30082	112.14	491.22
240.00	0.072481	13.699	0.072999	15.992	15.997	0.084899	0.085734	0.12927	775.00	–0.27839	107.27	420.20
250.00	0.11561	13.406	0.074593	17.293	17.301	0.090209	0.086879	0.13126	728.39	–0.25204	102.53	363.25
260.00	0.17684	13.104	0.076311	18.613	18.627	0.095389	0.088067	0.13348	682.14	–0.22073	97.922	316.57
270.00	0.26082	12.791	0.078179	19.956	19.976	0.10046	0.089298	0.13597	636.12	–0.18299	93.414	277.54
280.00	0.37271	12.465	0.080227	21.322	21.352	0.10543	0.090576	0.13883	590.17	–0.13675	88.995	244.34
290.00	0.51805	12.121	0.082499	22.716	22.759	0.11032	0.091908	0.14216	544.15	–0.079015	84.644	215.64
300.00	0.70282	11.758	0.085050	24.141	24.201	0.11516	0.093303	0.14615	497.89	–0.0052732	80.341	190.46
310.00	0.93340	11.368	0.087965	25.603	25.685	0.11996	0.094777	0.15108	451.23	0.091533	76.063	168.04
320.00	1.2166	10.945	0.091364	27.108	27.219	0.12475	0.096352	0.15740	404.00	0.22306	71.781	147.78
330.00	1.5599	10.478	0.095439	28.667	28.816	0.12956	0.098067	0.16598	355.90	0.41006	67.464	129.20
340.00	1.9715	9.9483	0.10052	30.297	30.495	0.13446	0.10001	0.17863	306.37	0.69376	63.075	111.81
350.00	2.4611	9.3237	0.10725	32.029	32.293	0.13952	0.10241	0.20012	254.06	1.1714	58.581	95.095
360.00	3.0405	8.5279	0.11726	33.932	34.289	0.14496	0.10601	0.24863	196.05	2.1419	54.062	78.146
370.00	3.7278	7.2558	0.13782	36.283	36.797	0.15159	0.11372	0.52085	127.23	5.1434	51.767	57.956
374.21	4.0591	5.0171	0.19932	38.947	39.756	0.15938			0	11.931		
169.85	0.00038956	0.00027611	3621.7	32.764	34.175	0.20038	0.051318	0.059719	126.79	373.57	3.0801	6.8294
170.00	0.00039617	0.00028055	3564.4	32.772	34.184	0.20029	0.051354	0.059756	126.84	370.78	3.0921	6.8353
180.00	0.0011275	0.00075481	1324.8	33.287	34.781	0.19502	0.053742	0.062208	130.05	234.43	3.8934	7.2319
190.00	0.0028170	0.0017896	558.79	33.821	35.395	0.19075	0.056118	0.064682	133.11	160.10	4.6952	7.6253
200.00	0.0063130	0.0038201	261.77	34.371	36.023	0.18729	0.058489	0.067201	135.98	116.94	5.4978	8.0147
210.00	0.012910	0.0074704	133.86	34.934	36.662	0.18451	0.060874	0.069802	138.63	90.215	6.3018	8.3993
220.00	0.024433	0.013574	73.669	35.508	37.308	0.18228	0.063296	0.072534	141.01	72.584	7.1080	8.7786
230.00	0.043287	0.023188	43.125	36.090	37.956	0.18050	0.065783	0.075455	143.06	60.236	7.9176	9.1524
240.00	0.072481	0.037603	26.593	36.675	38.602	0.17909	0.068357	0.078618	144.73	51.130	8.7324	9.5209
250.00	0.11561	0.058360	17.135	37.261	39.242	0.17797	0.071031	0.082078	145.98	44.137	9.5551	9.8853
260.00	0.17684	0.087278	11.458	37.844	39.870	0.17709	0.073812	0.085888	146.75	38.613	10.389	10.247
270.00	0.26082	0.12651	7.9043	38.420	40.482	0.17640	0.076698	0.090115	146.99	34.169	11.241	10.611
280.00	0.37271	0.17865	5.5976	38.986	41.073	0.17586	0.079686	0.094850	146.63	30.561	12.118	10.980
290.00	0.51805	0.24685	4.0511	39.538	41.636	0.17542	0.082776	0.10023	145.61	27.621	13.035	11.363
300.00	0.70282	0.33512	2.9840	40.069	42.166	0.17504	0.085974	0.10650	143.88	25.230	14.011	11.771
310.00	0.93340	0.44874	2.2285	40.573	42.653	0.17469	0.089297	0.11404	141.33	23.301	15.081	12.219
320.00	1.2166	0.59505	1.6805	41.038	43.083	0.17432	0.092780	0.12355	137.86	21.768	16.303	12.735
330.00	1.5599	0.78498	1.2739	41.451	43.438	0.17387	0.096484	0.13638	133.33	20.578	17.780	13.358
340.00	1.9715	1.0363	0.96498	41.785	43.687	0.17326	0.10052	0.15548	127.57	19.687	19.711	14.164
350.00	2.4611	1.3818	0.72368	41.994	43.775	0.17232	0.10510	0.18870	120.33	19.033	22.525	15.300
360.00	3.0405	1.8973	0.52707	41.973	43.576	0.17075	0.11074	0.26594	111.25	18.448	27.365	17.140
370.00	3.7278	2.8805	0.34717	41.323	42.617	0.16731	0.11928	0.70016	99.370	17.050	40.137	21.336
374.21	4.0591	5.0171	0.19932	38.947	39.756	0.15938			0	11.931		

Single-Phase Properties

200.00	0.10000	14.805	0.067543	10.955	10.962	0.061955	0.081787	0.12301	968.03	–0.35132	127.78	868.18
246.79	0.10000	13.501	0.074068	16.873	16.880	0.088519	0.086506	0.13060	743.31	–0.26099	104.04	380.27
246.79	0.10000	0.050898	19.647	37.073	39.037	0.17830	0.070161	0.080931	145.63	46.198	9.2899	9.7687
275.00	0.10000	0.044972	22.236	39.124	41.348	0.18716	0.073781	0.083445	154.76	29.047	11.540	10.906
350.00	0.10000	0.034753	28.775	45.154	48.032	0.20860	0.086248	0.095065	175.31	12.552	17.537	13.823
425.00	0.10000	0.028455	35.143	52.096	55.610	0.22818	0.098386	0.10695	192.97	6.7852	23.539	16.650
200.00	1.0000	14.819	0.067479	10.933	11.001	0.061846	0.081812	0.12291	972.08	–0.35256	128.11	876.60
275.00	1.0000	12.657	0.079009	20.597	20.676	0.10281	0.089915	0.13695	619.10	–0.16746	91.627	262.84
312.54	1.0000	11.264	0.088775	25.980	26.069	0.12117	0.095165	0.15252	439.31	0.12101	74.978	162.71
312.54	1.0000	0.48242	2.0729	40.695	42.768	0.17460	0.090164	0.11623	140.54	22.877	15.374	12.343
350.00	1.0000	0.39132	2.5555	44.290	46.846	0.18694	0.090315	0.10603	159.63	13.885	17.989	13.936
425.00	1.0000	0.29983	3.3352	51.597	54.933	0.20785	0.099891	0.11116	185.14	7.0297	23.806	16.917
200.00	5.0000	14.880	0.067202	10.839	11.175	0.061371	0.081929	0.12246	989.55	–0.35768	129.56	915.11
275.00	5.0000	12.804	0.078103	20.385	20.776	0.10203	0.089864	0.13495	651.41	–0.19924	94.015	277.35
350.00	5.0000	9.8674	0.10134	31.397	31.904	0.13765	0.10066	0.17178	320.01	0.59952	63.012	109.32
425.00	5.0000	2.0736	0.48225	48.647	51.058	0.18734	0.10791	0.15381	148.25	7.9048	28.574	20.974
200.00	10.000	14.954	0.066874	10.727	11.395	0.060796	0.082085	0.12196	1010.3	–0.36339	131.31	966.05
275.00	10.000	12.967	0.077121	20.149	20.920	0.10115	0.089868	0.13304	687.36	–0.22964	96.744	295.02
350.00	10.000	10.478	0.095440	30.642	31.597	0.13537	0.099573	0.15486	400.60	0.21924	68.919	128.79
425.00	10.000	6.1370	0.16295	43.563	45.193	0.17038	0.11141	0.20870	177.89	3.0434	44.888	46.711
200.00	30.000	15.216	0.065720	10.326	12.298	0.058683	0.082769	0.12047	1084.1	–0.38053	137.79	1211.0
275.00	30.000	13.479	0.074190	19.398	21.624	0.098210	0.090220	0.12865	801.47	–0.30014	105.87	364.87
350.00	30.000	11.662	0.085750	29.071	31.644	0.13038	0.098885	0.13885	582.52	–0.15240	82.955	183.26
425.00	30.000	9.7202	0.10288	39.385	42.471	0.15838	0.10808	0.14967	425.63	0.10364	67.154	107.03
275.00	70.000	14.181	0.070517	18.373	23.310	0.093839	0.091314	0.12519	962.41	–0.35619	119.84	521.91
350.00	70.000	12.797	0.078141	27.492	32.961	0.12484	0.099542	0.13226	787.10	–0.30093	99.868	277.09
425.00	70.000	11.494	0.087004	37.066	43.157	0.15121	0.10829	0.13963	661.39	–0.23655	86.640	181.77

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Tillner-Roth, R., and Baehr, H. D., "An International Standard Formulation of the Thermodynamic Properties of 1,1,1,2-Tetrafluoroethane (HFC-134a) for temperatures from 170 K to 455 K at Pressures up to 70 MPa," *J. Phys. Chem. Ref. Data* **23**:657–729, 1994. The source for viscosity is Huber, M. L., Laesecke, A., and Perkins, R. A., "Model for the Viscosity and Thermal Conductivity of Refrigerants, Including a New Correlation for the Viscosity of R134a," *Ind. Eng. Chem. Res.* **42**:3163–3178, 2003. The source for thermal conductivity is Perkins, R. A., Laesecke, A., Howley, J., Ramires, M. L. V., Gurova, A. N., and Cusco, L.,"Experimental Thermal Conductivity Values for the IUPAC Round-Robin Sample of 1,1,1,2-Tetrafluoroethane (R134a)," NISTIR, 2000.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

Typical uncertainties are 0.05% for density, 0.02% for vapor pressure, 0.5% to 1% for heat capacity, 0.05% for vapor speed of sound, and 1% for liquid speed of sound, except in the critical region. The uncertainty in viscosity is 1.5% along the saturated-liquid line, 3% in the liquid phase, 0.5% in the dilute gas, 3% to 5% in the vapor phase, and 5% in the supercritical region, rising to 8% at pressures above 40 MPa. Below 200 K, the uncertainty is 8%. The uncertainty in thermal conductivity is 5%.

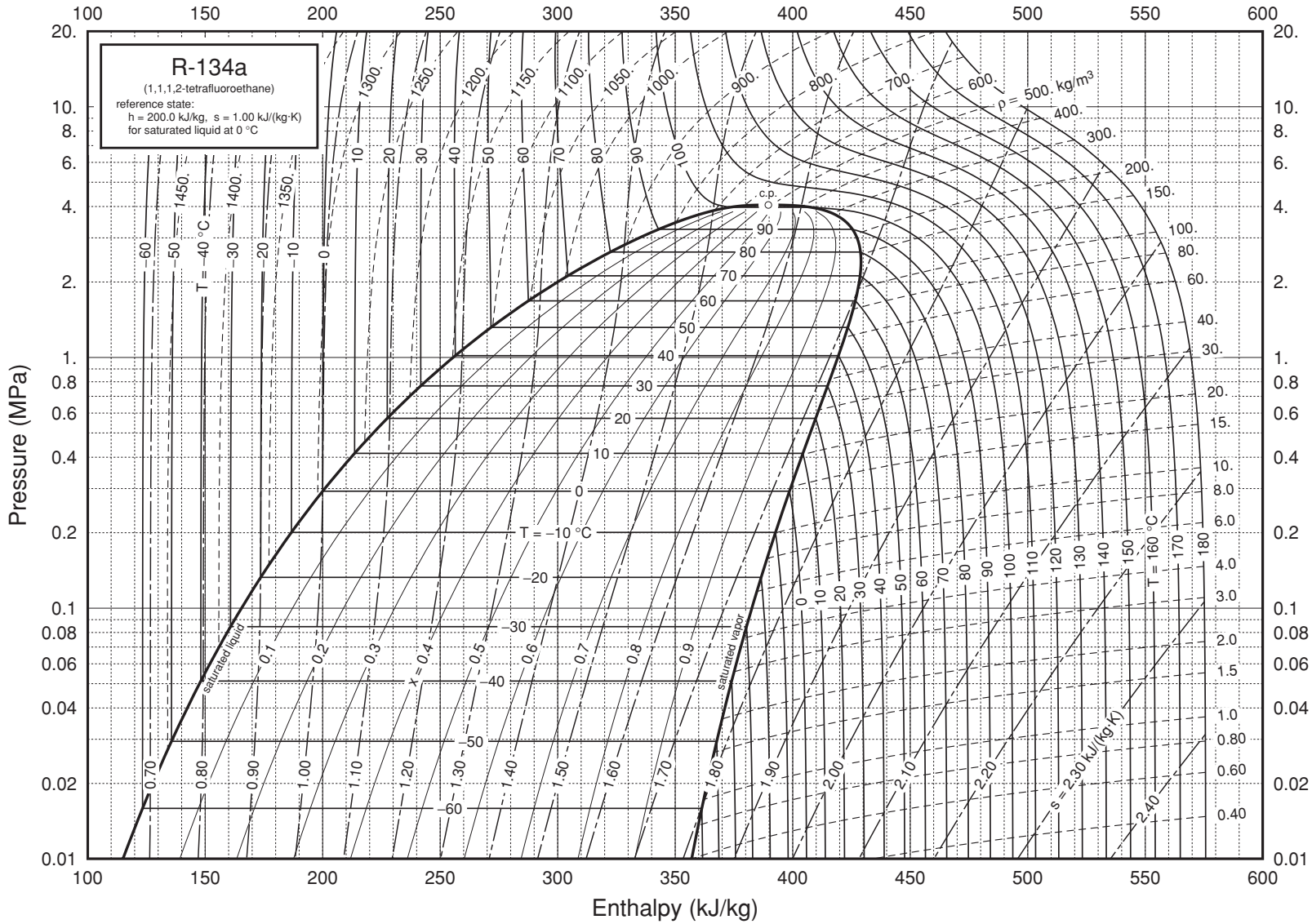

FIG. 2-26 Pressure-enthalpy diagram for Refrigerant 134a. Properties computed with the NIST REFPROP Database, Version 7.0 (Lemmon, E. W., McLinden, M. O., and Huber, M. L., 2002, NIST Standard Reference Database 23, NIST Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, Standard Reference Data Program, National Institute of Standards and Technology), based on the equation of state of Tillner-Roth, R., and Baehr, H. D., "An International Standard Formulation of the Thermodynamic Properties of 1,1,1,2-Tetrafluoroethane (HFC-134a) Covering Temperatures from 170 K to 455 K at Pressures up to 70 MPa," *J. Phys. Chem. Ref. Data* **23**(5):657–729, 1994.

TABLE 2-279 Thermodynamic Properties of R-141b, 1,1-Dichloro-1-Fluoroethane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
169.68	6.4927E-06	12.560	0.079620	9.9164	9.9164	0.054895	0.094555	0.13580	1362.2	–0.46011
175.00	1.3392E-05	12.475	0.080158	10.635	10.635	0.059062	0.093422	0.13422	1336.2	–0.46486
190.00	7.9884E-05	12.241	0.081696	12.622	12.622	0.069959	0.091221	0.13103	1264.8	–0.47325
205.00	0.00035111	12.009	0.083271	14.573	14.573	0.079842	0.090109	0.12928	1196.3	–0.47511
220.00	0.0012182	11.779	0.084897	16.505	16.506	0.088942	0.089760	0.12859	1130.5	–0.47131
235.00	0.0035074	11.549	0.086588	18.434	18.434	0.097423	0.089963	0.12869	1067.1	–0.46244
250.00	0.0086986	11.318	0.088358	20.369	20.370	0.10540	0.090575	0.12943	1005.9	–0.44884
265.00	0.019117	11.083	0.090224	22.319	22.321	0.11298	0.091495	0.13069	946.56	–0.43061
280.00	0.038053	10.845	0.092205	24.291	24.294	0.12022	0.092648	0.13238	888.79	–0.40759
295.00	0.069799	10.602	0.094324	26.290	26.297	0.12717	0.093975	0.13446	832.34	–0.37931
310.00	0.11960	10.351	0.096609	28.323	28.334	0.13389	0.095432	0.13691	776.95	–0.34494
325.00	0.19353	10.092	0.099093	30.393	30.412	0.14041	0.096986	0.13972	722.38	–0.30314
340.00	0.29839	9.8211	0.10182	32.505	32.535	0.14677	0.098610	0.14292	668.39	–0.25184
355.00	0.44157	9.5371	0.10485	34.664	34.710	0.15299	0.10029	0.14659	614.74	–0.18789
370.00	0.63091	9.2365	0.10827	36.876	36.945	0.15909	0.10201	0.15085	561.17	–0.10633
385.00	0.87470	8.9148	0.11217	39.148	39.246	0.16512	0.10377	0.15592	507.38	0.00079658
400.00	1.1817	8.5660	0.11674	41.489	41.627	0.17110	0.10557	0.16222	452.97	0.14720
415.00	1.5611	8.1809	0.12224	43.912	44.103	0.17706	0.10745	0.17053	397.38	0.35834
430.00	2.0234	7.7444	0.12913	46.442	46.703	0.18308	0.10945	0.18264	339.70	0.68768
445.00	2.5805	7.2267	0.13838	49.122	49.480	0.18925	0.11171	0.20353	278.17	1.2701
460.00	3.2487	6.5517	0.15263	52.069	52.565	0.19586	0.11464	0.25500	208.92	2.5762
475.00	4.0574	5.2532	0.19036	55.987	56.760	0.20453	0.12111	0.92342	118.23	8.4848
477.50	4.2117	3.9210	0.25504	58.424	59.498	0.21020			0	15.683
169.68	6.4927E-06	4.6024E-06	217,280.	42.292	43.703	0.25401	0.054464	0.062782	117.92	881.00
175.00	1.3392E-05	9.2047E-06	108,640.	42.585	44.040	0.24995	0.055738	0.064059	119.57	725.60
190.00	7.9884E-05	5.0581E-05	19,770.	43.445	45.025	0.24050	0.059180	0.067515	124.11	439.35
205.00	0.00035111	0.00020615	4,850.8	44.353	46.056	0.23342	0.062459	0.070830	128.46	282.90
220.00	0.0012182	0.00066719	1,498.8	45.303	47.129	0.22814	0.065653	0.074095	132.61	192.43
235.00	0.0035074	0.0018021	554.92	46.291	48.237	0.22424	0.068824	0.077393	136.53	137.32
250.00	0.0086986	0.0042156	237.22	47.312	49.376	0.22143	0.072021	0.080793	140.16	102.08
265.00	0.019117	0.0087866	113.81	48.362	50.538	0.21946	0.075271	0.084345	143.44	78.530
280.00	0.038053	0.016681	59.949	49.437	51.718	0.21816	0.078582	0.088081	146.30	62.188
295.00	0.069799	0.029348	34.074	50.531	52.910	0.21739	0.081944	0.092019	148.66	50.500
310.00	0.11960	0.048516	20.612	51.641	54.106	0.21703	0.085336	0.096171	150.46	41.951
325.00	0.19353	0.076209	13.122	52.763	55.302	0.21700	0.088731	0.10056	151.61	35.598
340.00	0.29839	0.11480	8.7112	53.890	56.489	0.21722	0.092106	0.10521	152.02	30.835
355.00	0.44157	0.16710	5.9846	55.016	57.659	0.21763	0.095442	0.11023	151.61	27.254
370.00	0.63091	0.23659	4.2267	56.134	58.801	0.21817	0.098733	0.11578	150.27	24.582
385.00	0.87470	0.32780	3.0507	57.234	59.902	0.21877	0.10198	0.12213	147.85	22.633
400.00	1.1817	0.44696	2.2373	58.300	60.944	0.21939	0.10522	0.12983	144.19	21.289
415.00	1.5611	0.60344	1.6572	59.311	61.898	0.21994	0.10848	0.13996	139.04	20.490
430.00	2.0234	0.81289	1.2302	60.231	62.720	0.22033	0.11185	0.15495	132.06	20.229
445.00	2.5805	1.1059	0.90427	60.993	63.326	0.22037	0.11548	0.18176	122.74	20.562
460.00	3.2487	1.5609	0.64064	61.427	63.508	0.21965	0.11977	0.25134	110.25	21.544
475.00	4.0574	2.6472	0.37776	60.578	62.110	0.21579	0.12640	1.1603	93.316	21.336
477.50	4.2117	3.9210	0.25504	58.424	59.498	0.21020			0	15.683

TABLE 2-279 Thermodynamic Properties of R-141b, 1,1-Dichloro-1-Fluoroethane (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Single-Phase Properties										
200.00	0.10000	12.087	0.082735	13.923	13.931	0.076634	0.090387	0.12973	1219.1	–0.47521
300.00	0.10000	10.519	0.095063	26.963	26.973	0.12943	0.094448	0.13523	813.87	–0.36865
304.82	0.10000	10.438	0.095799	27.617	27.627	0.13160	0.094917	0.13602	795.96	–0.35757
304.82	0.10000	0.041044	24.364	51.257	53.693	0.21711	0.084163	0.094713	149.91	44.615
400.00	0.10000	0.030497	32.790	59.875	63.154	0.24405	0.096356	0.10524	173.74	15.111
500.00	0.10000	0.024216	41.296	70.152	74.282	0.26884	0.10833	0.11691	194.56	8.0045
200.00	1.0000	12.094	0.082685	13.904	13.987	0.076539	0.090431	0.12969	1222.5	–0.47573
300.00	1.0000	10.536	0.094914	26.923	27.018	0.12930	0.094476	0.13502	819.45	–0.37223
391.53	1.0000	8.7668	0.11407	40.158	40.272	0.16773	0.10455	0.15848	483.80	0.058567
391.53	1.0000	0.37577	2.6612	57.703	60.364	0.21904	0.10339	0.12527	146.42	21.978
400.00	1.0000	0.36041	2.7746	58.638	61.413	0.22169	0.10298	0.12252	150.55	19.770
500.00	1.0000	0.25865	3.8663	69.520	73.387	0.24841	0.10961	0.12123	184.02	8.7395
200.00	5.0000	12.127	0.082464	13.822	14.234	0.076124	0.090629	0.12954	1237.0	–0.47789
300.00	5.0000	10.606	0.094284	26.751	27.222	0.12872	0.094606	0.13416	843.29	–0.38665
400.00	5.0000	8.7814	0.11388	41.014	41.584	0.16989	0.10538	0.15604	502.40	0.0060632
500.00	5.0000	2.5394	0.39380	63.911	65.880	0.22278	0.12220	0.29767	113.94	14.372
200.00	10.000	12.166	0.082198	13.722	14.544	0.075616	0.090880	0.12937	1254.5	–0.48033
300.00	10.000	10.688	0.093559	26.550	27.486	0.12803	0.094784	0.13326	871.09	–0.40188
400.00	10.000	9.0042	0.11106	40.515	41.625	0.16859	0.10531	0.15122	554.81	–0.10586
500.00	10.000	6.4723	0.15451	56.831	58.376	0.20581	0.11637	0.19130	265.53	1.3996
300.00	100.00	11.645	0.085873	24.317	32.904	0.11935	0.098509	0.12788	1200.2	–0.49651
400.00	100.00	10.676	0.093670	36.738	46.105	0.15726	0.10834	0.13645	995.82	–0.44654
500.00	100.00	9.7763	0.10229	49.945	60.174	0.18863	0.11752	0.14460	852.98	–0.39437
400.00	400.00	12.505	0.079970	33.644	65.632	0.14209	0.11569	0.13564	1606.9	–0.48581
500.00	400.00	11.986	0.083429	46.201	79.572	0.17316	0.12401	0.14302	1498.0	–0.46416

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data* **51**(3):785–850, 2006. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The equation has uncertainties of 0.2% in density between 180 and 400 K at pressures to 100 MPa, and 0.5% in density at higher pressures. The uncertainty in density may be higher as temperatures approach 400 K. Vapor pressures are represented with an uncertainty of 0.2% from 270 to 400 K. The uncertainty in speed of sound is 0.01% in the vapor phase and 0.5% in the liquid phase. There are no heat capacity data to verify the equation of state; however, the uncertainties are estimated to be within 2%.

TABLE 2-280 Thermodynamic Properties of R-142b, 1-Chloro-1,1-Difluoroethane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
142.72	3.6327E-06	14.439	0.069257	5.0138	5.0138	0.026013	0.067327	0.11000	1457.9	–0.49370
150.00	1.1727E-05	14.281	0.070022	5.8147	5.8147	0.031486	0.068270	0.11005	1403.7	–0.49255
165.00	9.0545E-05	13.963	0.071619	7.4687	7.4687	0.041995	0.070168	0.11057	1301.7	–0.48684
180.00	0.00047371	13.650	0.073262	9.1343	9.1343	0.051656	0.072051	0.11158	1209.7	–0.47689
195.00	0.0018484	13.339	0.074968	10.818	10.818	0.060640	0.073955	0.11299	1125.1	–0.46285
210.00	0.0057557	13.028	0.076756	12.526	12.526	0.069077	0.075895	0.11477	1046.0	–0.44466
225.00	0.015025	12.715	0.078649	14.263	14.264	0.077064	0.077877	0.11689	971.28	–0.42204
240.00	0.034108	12.396	0.080672	16.033	16.036	0.084681	0.079897	0.11931	899.90	–0.39443
255.00	0.069220	12.069	0.082856	17.841	17.847	0.091990	0.081949	0.12205	831.11	–0.36085
270.00	0.12829	11.732	0.085239	19.692	19.703	0.099042	0.084027	0.12513	764.28	–0.31977
285.00	0.22078	11.380	0.087873	21.590	21.609	0.10588	0.086128	0.12859	698.87	–0.26876
300.00	0.35741	11.010	0.090824	23.538	23.571	0.11255	0.088252	0.13253	634.41	–0.20400
315.00	0.54995	10.617	0.094190	25.545	25.597	0.11908	0.090406	0.13714	570.43	–0.11928
330.00	0.81110	10.193	0.098109	27.617	27.696	0.12551	0.092605	0.14271	506.46	–0.0039877
345.00	1.1545	9.7272	0.10280	29.765	29.884	0.13189	0.094876	0.14984	441.95	0.16142
360.00	1.5950	9.2033	0.10866	32.009	32.182	0.13828	0.097271	0.15984	376.09	0.41716
375.00	2.1496	8.5896	0.11642	34.381	34.632	0.14477	0.099910	0.17613	307.44	0.86137
390.00	2.8397	7.8118	0.12801	36.963	37.327	0.15160	0.10313	0.21217	232.74	1.8155
405.00	3.6991	6.5381	0.15295	40.117	40.683	0.15973	0.10871	0.44141	141.73	5.3582
410.26	4.0548	4.4380	0.22533	43.151	44.065	0.16786			0	14.009
142.72	3.6327E-06	3.0614E-06	326,650.	32.685	33.872	0.22821	0.043630	0.051946	118.57	826.84
150.00	1.1727E-05	9.4031E-06	106,350.	33.008	34.256	0.22109	0.045288	0.053606	121.19	618.59
165.00	9.0545E-05	6.6018E-05	15,147.	33.711	35.083	0.20935	0.048631	0.056964	126.42	363.33
180.00	0.00047371	0.00031681	3,156.4	34.461	35.956	0.20067	0.051923	0.060296	131.39	230.77
195.00	0.0018484	0.0011428	875.03	35.253	36.870	0.19424	0.055225	0.063688	136.07	156.62
210.00	0.0057557	0.0033148	301.68	36.082	37.819	0.18952	0.058589	0.067227	140.40	112.18
225.00	0.015025	0.0081206	123.14	36.944	38.794	0.18609	0.062056	0.070991	144.30	83.865
240.00	0.034108	0.017432	57.365	37.831	39.787	0.18365	0.065643	0.075042	147.66	64.873
255.00	0.069220	0.033721	29.655	38.737	40.790	0.18196	0.069344	0.079422	150.35	51.637
270.00	0.12829	0.060064	16.649	39.657	41.793	0.18086	0.073133	0.084167	152.25	42.170
285.00	0.22078	0.10020	9.9797	40.582	42.786	0.18019	0.076978	0.089331	153.23	35.289
300.00	0.35741	0.15871	6.3006	41.506	43.758	0.17984	0.080851	0.095026	153.15	30.249
315.00	0.54995	0.24138	4.1428	42.419	44.697	0.17972	0.084737	0.10147	151.86	26.559
330.00	0.81110	0.35595	2.8094	43.306	45.585	0.17972	0.088646	0.10911	149.19	23.894
345.00	1.1545	0.51364	1.9469	44.149	46.397	0.17975	0.092615	0.11883	144.89	22.043
360.00	1.5950	0.73250	1.3652	44.916	47.094	0.17970	0.096730	0.13261	138.64	20.877
375.00	2.1496	1.0462	0.95585	45.551	47.605	0.17937	0.10116	0.15586	129.97	20.328
390.00	2.8397	1.5347	0.65159	45.920	47.771	0.17838	0.10632	0.21004	118.18	20.306
405.00	3.6991	2.5436	0.39314	45.483	46.938	0.17518	0.11368	0.55965	102.00	19.783
410.26	4.0548	4.4380	0.22533	43.151	44.065	0.16786			0	14.009

TABLE 2-280 Thermodynamic Properties of R-142b, 1-Chloro-1,1-Difluoroethane (Concluded)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/mol·K	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Single-Phase Properties										
150.00	0.10000	14.282	0.070018	5.8131	5.8201	0.031476	0.068275	0.11005	1404.1	–0.49259
225.00	0.10000	12.716	0.078641	14.260	14.268	0.077053	0.077880	0.11688	971.75	–0.42221
263.70	0.10000	11.875	0.084211	18.910	18.918	0.096110	0.083152	0.12379	792.14	–0.33806
263.70	0.10000	0.047556	21.028	39.269	41.372	0.18126	0.071534	0.082128	151.56	45.775
300.00	0.10000	0.041113	24.323	41.979	44.411	0.19205	0.076432	0.085864	162.77	26.250
375.00	0.10000	0.032446	30.820	48.175	51.257	0.21237	0.087964	0.096734	182.58	12.432
450.00	0.10000	0.026895	37.182	55.179	58.897	0.23092	0.098211	0.10678	199.94	7.4502
150.00	1.0000	14.289	0.069982	5.7989	5.8689	0.031381	0.068317	0.11003	1407.4	–0.49289
225.00	1.0000	12.730	0.078553	14.234	14.312	0.076937	0.077905	0.11676	976.69	–0.42404
300.00	1.0000	11.034	0.090630	23.498	23.589	0.11241	0.088238	0.13215	640.59	–0.21142
338.73	1.0000	9.9277	0.10073	28.857	28.957	0.12923	0.093915	0.14661	469.03	0.084297
338.73	1.0000	0.44153	2.2648	43.804	46.069	0.17974	0.090944	0.11443	146.90	22.728
375.00	1.0000	0.36746	2.7214	47.311	50.033	0.19087	0.091549	0.10695	164.80	14.567
450.00	1.0000	0.28570	3.5002	54.646	58.146	0.21058	0.099383	0.11074	190.29	7.9246
150.00	5.0000	14.321	0.069826	5.7370	6.0861	0.030965	0.068506	0.10997	1421.7	–0.49417
225.00	5.0000	12.791	0.078178	14.121	14.512	0.076430	0.078025	0.11629	997.91	–0.43157
300.00	5.0000	11.170	0.089523	23.263	23.710	0.11162	0.088194	0.13015	676.41	–0.25069
375.00	5.0000	8.9978	0.11114	33.787	34.343	0.14314	0.098897	0.15862	373.38	0.42121
450.00	5.0000	2.2231	0.44982	50.992	53.241	0.18867	0.10800	0.17517	139.23	10.314
150.00	10.000	14.360	0.069636	5.6618	6.3581	0.030454	0.068749	0.10991	1439.0	–0.49558
225.00	10.000	12.864	0.077739	13.987	14.765	0.075821	0.078190	0.11578	1023.0	–0.43976
300.00	10.000	11.321	0.088335	23.001	23.885	0.11072	0.088215	0.12826	716.03	–0.28769
375.00	10.000	9.4491	0.10583	33.097	34.155	0.14120	0.098194	0.14723	451.41	0.11527
450.00	10.000	6.5247	0.15326	45.004	46.536	0.17118	0.10853	0.18939	220.16	2.1126
225.00	30.000	13.119	0.076223	13.519	15.805	0.073606	0.078954	0.11435	1110.6	–0.46323
300.00	30.000	11.787	0.084836	22.183	24.728	0.10777	0.088691	0.12401	840.46	–0.37159
375.00	30.000	10.406	0.096097	31.547	34.430	0.13659	0.097974	0.13464	635.15	–0.22643
450.00	30.000	8.9530	0.11169	41.538	44.889	0.16199	0.10623	0.14384	484.32	–0.010974
225.00	60.000	13.434	0.074437	12.957	17.423	0.070756	0.080223	0.11326	1217.3	–0.48274
300.00	60.000	12.284	0.081409	21.322	26.207	0.10439	0.089774	0.12130	975.81	–0.42589
375.00	60.000	11.180	0.089443	30.259	35.626	0.13238	0.098881	0.12975	801.25	–0.35484
450.00	60.000	10.119	0.098828	39.706	45.636	0.15670	0.10699	0.13689	675.38	–0.27949

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data* **51**(3):785–850, 2006. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in density are 0.3% in the liquid phase below 370 K, 1% at higher temperatures in the liquid and supercritical regions, and 0.5% in the vapor phase. Uncertainties for other properties are 0.5% for vapor pressure, 2% for heat capacities and liquid sound speeds, and 0.2% for vapor sound speeds.

TABLE 2-281 Thermodynamic Properties of R-143a, 1,1,1-Trifluoroethane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
161.34	0.0010749	15.832	0.063163	4.4138	4.4138	0.026403	0.068393	0.10179	1058.1	–0.43936
170.00	0.0025084	15.583	0.064174	5.2969	5.2971	0.031735	0.068179	0.10225	1016.7	–0.42914
180.00	0.0059324	15.291	0.065399	6.3240	6.3244	0.037606	0.068405	0.10325	969.14	–0.41402
190.00	0.012629	14.994	0.066693	7.3629	7.3637	0.043223	0.068990	0.10460	921.61	–0.39585
200.00	0.024624	14.692	0.068062	8.4164	8.4181	0.048626	0.069825	0.10621	874.04	–0.37472
210.00	0.044602	14.384	0.069519	9.4869	9.4900	0.053849	0.070836	0.10803	826.46	–0.35034
220.00	0.075908	14.069	0.071077	10.576	10.581	0.058915	0.071969	0.11005	778.88	–0.32211
230.00	0.12252	13.745	0.072753	11.685	11.694	0.063848	0.073190	0.11227	731.28	–0.28906
240.00	0.18902	13.410	0.074570	12.817	12.831	0.068665	0.074475	0.11474	683.65	–0.24979
250.00	0.28049	13.062	0.076556	13.973	13.995	0.073385	0.075809	0.11750	635.90	–0.20231
260.00	0.40251	12.698	0.078751	15.156	15.188	0.078027	0.077186	0.12066	587.94	–0.14368
270.00	0.56112	12.314	0.081208	16.368	16.414	0.082607	0.078605	0.12435	539.61	–0.069548
280.00	0.76276	11.904	0.084004	17.615	17.680	0.087149	0.080078	0.12879	490.70	0.026895
290.00	1.0144	11.461	0.087249	18.903	18.991	0.091675	0.081625	0.13438	440.95	0.15683
300.00	1.3234	10.975	0.091119	20.239	20.360	0.096221	0.083293	0.14180	389.93	0.34002
310.00	1.6983	10.426	0.095914	21.638	21.801	0.10083	0.085172	0.15244	337.04	0.61491
320.00	2.1483	9.7846	0.10220	23.125	23.344	0.10559	0.087455	0.16980	281.21	1.0681
330.00	2.6850	8.9829	0.11132	24.750	25.048	0.11065	0.090641	0.20591	220.39	1.9469
340.00	3.3250	7.7913	0.12835	26.688	27.114	0.11659	0.096654	0.35704	149.32	4.3897
345.86	3.7618	5.1285	0.19499	29.429	30.163	0.12527			0	12.397
161.34	0.0010749	0.00080362	1244.4	25.521	26.859	0.16552	0.044397	0.052938	137.57	385.09
170.00	0.0025084	0.0017832	560.78	25.895	27.302	0.16118	0.046371	0.055037	140.62	262.77
180.00	0.0059324	0.0039967	250.20	26.340	27.824	0.15705	0.048691	0.057550	143.91	176.43
190.00	0.012629	0.0081006	123.45	26.796	28.355	0.15370	0.051040	0.060156	146.92	124.70
200.00	0.024624	0.015110	66.180	27.262	28.892	0.15100	0.053424	0.062886	149.60	92.835
210.00	0.044602	0.026311	38.007	27.736	29.431	0.14881	0.055867	0.065796	151.89	72.442
220.00	0.075908	0.043269	23.111	28.213	29.968	0.14704	0.058395	0.068954	153.71	58.764
230.00	0.12252	0.067850	14.738	28.693	30.498	0.14560	0.061026	0.072428	155.02	49.133
240.00	0.18902	0.10227	9.7783	29.170	31.018	0.14444	0.063766	0.076287	155.74	42.049
250.00	0.28049	0.14916	6.7041	29.641	31.521	0.14349	0.066612	0.080611	155.81	36.657
260.00	0.40251	0.21175	4.7225	30.102	32.003	0.14270	0.069560	0.085515	155.15	32.456
270.00	0.56112	0.29409	3.4004	30.548	32.456	0.14202	0.072606	0.091184	153.70	29.136
280.00	0.76276	0.40144	2.4910	30.972	32.872	0.14141	0.075756	0.097932	151.36	26.498
290.00	1.0144	0.54109	1.8481	31.366	33.240	0.14081	0.079035	0.10632	148.04	24.406
300.00	1.3234	0.72367	1.3818	31.715	33.544	0.14017	0.082489	0.11743	143.59	22.765
310.00	1.6983	0.96617	1.0350	32.000	33.758	0.13940	0.086214	0.13359	137.85	21.499
320.00	2.1483	1.2991	0.76974	32.183	33.837	0.13838	0.090400	0.16076	130.56	20.526
330.00	2.6850	1.7898	0.55871	32.184	33.684	0.13682	0.095488	0.22018	121.34	19.682
340.00	3.3250	2.6696	0.37458	31.732	32.977	0.13384	0.10298	0.47999	109.29	18.259
345.86	3.7618	5.1285	0.19499	29.429	30.163	0.12527			0	12.397

TABLE 2-281 Thermodynamic Properties of R-143a, 1,1,1-Trifluoroethane (Concluded)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Single-Phase Properties										
200.00	0.10000	14.694	0.068054	8.4143	8.4211	0.048616	0.069829	0.10620	874.45	–0.37493
225.63	0.10000	13.888	0.072006	11.198	11.205	0.061709	0.072648	0.11128	752.07	–0.30416
225.63	0.10000	0.056043	17.843	28.483	30.268	0.14619	0.059863	0.070868	154.52	52.958
300.00	0.10000	0.040759	24.534	33.380	35.833	0.16745	0.070758	0.079793	179.93	18.414
400.00	0.10000	0.030247	33.061	41.260	44.566	0.19247	0.086121	0.094695	207.36	7.5341
500.00	0.10000	0.024114	41.469	50.551	54.698	0.21503	0.099065	0.10751	231.13	4.1010
600.00	0.10000	0.020066	49.836	61.004	65.987	0.23558	0.10950	0.11790	252.55	2.5191
200.00	1.0000	14.715	0.067956	8.3891	8.4570	0.048489	0.069866	0.10604	879.27	–0.37736
289.48	1.0000	11.485	0.087067	18.835	18.922	0.091441	0.081543	0.13406	443.55	0.14902
289.48	1.0000	0.53292	1.8765	31.346	33.223	0.14084	0.078861	0.10583	148.24	24.503
300.00	1.0000	0.49298	2.0285	32.269	34.298	0.14449	0.077834	0.099455	155.53	20.787
400.00	1.0000	0.32001	3.1249	40.778	43.903	0.17212	0.087343	0.098681	198.53	7.7199
500.00	1.0000	0.24665	4.0544	50.244	54.298	0.19527	0.099519	0.10927	227.30	4.0976
600.00	1.0000	0.20246	4.9391	60.781	65.720	0.21607	0.10975	0.11891	251.11	2.4913
200.00	5.0000	14.806	0.067539	8.2811	8.6188	0.047943	0.070021	0.10541	900.01	–0.38724
300.00	5.0000	11.380	0.087876	19.812	20.251	0.094764	0.082741	0.13222	452.11	0.11636
400.00	5.0000	2.2504	0.44436	38.004	40.225	0.15165	0.093496	0.13815	159.25	8.1026
500.00	5.0000	1.3639	0.73318	48.802	52.468	0.17903	0.10135	0.11872	213.49	3.8903
600.00	5.0000	1.0491	0.95318	59.789	64.554	0.20106	0.11075	0.12364	246.86	2.2996
200.00	10.000	14.913	0.067054	8.1545	8.8250	0.047292	0.070195	0.10473	924.61	–0.39776
300.00	10.000	11.776	0.084916	19.382	20.231	0.093258	0.082583	0.12585	514.06	–0.037998
400.00	10.000	6.3531	0.15740	33.679	35.253	0.13608	0.095653	0.17697	196.98	2.9315
500.00	10.000	3.0122	0.33199	46.933	50.252	0.16976	0.10303	0.13206	211.16	3.0876
600.00	10.000	2.1596	0.46305	58.580	63.211	0.19339	0.11178	0.12945	248.28	1.9304
200.00	50.000	15.598	0.064113	7.3673	10.573	0.042937	0.070934	0.10170	1089.7	–0.44295
300.00	50.000	13.358	0.074862	17.612	21.355	0.086486	0.083360	0.11389	794.12	–0.33796
400.00	50.000	11.268	0.088747	28.859	33.296	0.12077	0.096003	0.12454	590.09	–0.20571
500.00	50.000	9.4018	0.10636	40.839	46.157	0.14943	0.10668	0.13213	478.93	–0.077157
600.00	50.000	7.8978	0.12662	53.306	59.637	0.17399	0.11548	0.13720	431.69	–0.0052131
300.00	100.00	14.343	0.069721	16.500	23.472	0.081539	0.084059	0.11166	1008.9	–0.40055
400.00	100.00	12.767	0.078330	27.298	35.131	0.11502	0.097186	0.12126	833.69	–0.35302
500.00	100.00	11.435	0.087453	38.923	47.668	0.14296	0.10821	0.12921	723.22	–0.31534
600.00	100.00	10.314	0.096952	51.227	60.923	0.16711	0.11716	0.13566	656.57	–0.28902

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Jacobsen, R. T., "An International Standard Formulation for the Thermodynamic Properties of 1,1,1-Trifluoroethane (HFC-143a) for Temperatures from 161 to 450 K and Pressures to 50 MPa," *J. Phys. Chem. Ref. Data* **29**(4):521–552, 2000. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The estimated uncertainties of properties calculated using the equation of state are 0.1% in density, 0.5% in heat capacities, 0.02% in the speed of sound for the vapor at pressures less than 1 MPa, 0.5% in speed of sound elsewhere, and 0.1% in vapor pressure, except in the critical region.

TABLE 2-282 Thermodynamic Properties of R-152a, 1,1-Difluoroethane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
154.56	6.4139E-05	18.061	0.055369	0.91117	0.91117	0.0073929	0.065711	0.097583	1400.9	–0.43262
160.00	0.00012983	17.910	0.055836	1.4460	1.4460	0.010794	0.066998	0.098932	1359.2	–0.42405
170.00	0.00041463	17.630	0.056720	2.4420	2.4421	0.016832	0.067926	0.10007	1293.7	–0.41381
180.00	0.0011411	17.350	0.057638	3.4453	3.4454	0.022566	0.068069	0.10053	1236.1	–0.40568
190.00	0.0027751	17.067	0.058594	4.4524	4.4525	0.028011	0.068043	0.10090	1182.6	–0.39686
200.00	0.0060859	16.781	0.059592	5.4638	5.4641	0.033199	0.068097	0.10143	1131.3	–0.38620
210.00	0.012233	16.491	0.060638	6.4814	6.4822	0.038164	0.068309	0.10218	1081.2	–0.37317
220.00	0.022836	16.198	0.061737	7.5077	7.5091	0.042938	0.068689	0.10317	1031.8	–0.35753
230.00	0.040024	15.899	0.062897	8.5448	8.5474	0.047548	0.069217	0.10439	982.80	–0.33902
240.00	0.066451	15.594	0.064128	9.5949	9.5992	0.052017	0.069868	0.10583	933.98	–0.31735
250.00	0.10530	15.281	0.065440	10.660	10.667	0.056365	0.070618	0.10747	885.23	–0.29203
260.00	0.16024	14.960	0.066846	11.741	11.752	0.060607	0.071447	0.10932	836.44	–0.26235
270.00	0.23541	14.628	0.068363	12.841	12.857	0.064759	0.072342	0.11140	787.50	–0.22731
280.00	0.33537	14.283	0.070011	13.962	13.985	0.068835	0.073294	0.11374	738.29	–0.18547
290.00	0.46506	13.924	0.071819	15.105	15.138	0.072848	0.074300	0.11641	688.71	–0.13478
300.00	0.62978	13.546	0.073821	16.273	16.319	0.076812	0.075363	0.11951	638.61	–0.072262
310.00	0.83519	13.147	0.076065	17.470	17.533	0.080741	0.076490	0.12318	587.86	0.0064939
320.00	1.0873	12.719	0.078621	18.699	18.785	0.084652	0.077694	0.12765	536.30	0.10833
330.00	1.3925	12.257	0.081587	19.968	20.081	0.088567	0.078997	0.13333	483.73	0.24433
340.00	1.7577	11.748	0.085118	21.284	21.434	0.092513	0.080433	0.14093	429.89	0.43380
350.00	2.1907	11.176	0.089475	22.662	22.858	0.096532	0.082059	0.15192	374.37	0.71349
360.00	2.7000	10.510	0.095147	24.126	24.383	0.10070	0.083973	0.16999	316.40	1.1636
370.00	3.2967	9.6829	0.10328	25.730	26.070	0.10515	0.086395	0.20774	254.38	2.0014
380.00	3.9966	8.4686	0.11808	27.655	28.127	0.11043	0.090038	0.35969	183.93	4.1151
386.41	4.5168	5.5715	0.17949	30.732	31.543	0.11914			0	11.292
154.56	6.4139E-05	4.9919E-05	20,032.	26.412	27.697	0.18069	0.037824	0.046148	154.04	336.54
160.00	1.2983E-04	9.7623E-05	10,244.	26.619	27.949	0.17644	0.038592	0.046923	156.44	294.63
170.00	0.00041463	0.00029357	3,406.3	27.009	28.422	0.16965	0.040032	0.048389	160.70	233.22
180.00	0.0011411	0.00076374	1,309.3	27.412	28.906	0.16401	0.041518	0.049922	164.78	186.99
190.00	0.0027751	0.0017625	567.37	27.825	29.399	0.15931	0.043061	0.051550	168.64	151.71
200.00	0.0060859	0.0036817	271.61	28.247	29.900	0.15538	0.044675	0.053297	172.27	124.45
210.00	0.012233	0.0070756	141.33	28.676	30.405	0.15208	0.046371	0.055192	175.63	103.17
220.00	0.022836	0.012679	78.873	29.110	30.911	0.14931	0.048158	0.057260	178.66	86.396
230.00	0.040024	0.021415	46.696	29.546	31.415	0.14697	0.050042	0.059528	181.32	73.068
240.00	0.066451	0.034408	29.063	29.984	31.915	0.14500	0.052027	0.062017	183.57	62.400
250.00	0.10530	0.052990	18.871	30.419	32.406	0.14332	0.054111	0.064754	185.35	53.805
260.00	0.16024	0.078721	12.703	30.851	32.887	0.14189	0.056291	0.067769	186.60	46.838
270.00	0.23541	0.11343	8.8162	31.277	33.352	0.14067	0.058564	0.071103	187.28	41.163
280.00	0.33537	0.15926	6.2791	31.694	33.800	0.13960	0.060926	0.074811	187.33	36.517
290.00	0.46506	0.21879	4.5705	32.099	34.224	0.13866	0.063373	0.078977	186.70	32.701
300.00	0.62978	0.29518	3.3877	32.488	34.622	0.13782	0.065904	0.083731	185.34	29.557
310.00	0.83519	0.39242	2.5483	32.857	34.985	0.13704	0.068522	0.089270	183.16	26.966
320.00	1.0873	0.51573	1.9390	33.199	35.308	0.13629	0.071233	0.095924	180.10	24.832
330.00	1.3925	0.67231	1.4874	33.506	35.577	0.13552	0.074054	0.10426	176.06	23.083
340.00	1.7577	0.87269	1.1459	33.764	35.779	0.13470	0.077013	0.11534	170.91	21.662
350.00	2.1907	1.1336	0.88218	33.953	35.886	0.13375	0.080160	0.13140	164.49	20.515
360.00	2.7000	1.4847	0.67352	34.036	35.855	0.13256	0.083590	0.15806	156.55	19.584
370.00	3.2967	1.9912	0.50220	33.933	35.589	0.13088	0.087501	0.21461	146.71	18.738
380.00	3.9966	2.8726	0.34812	33.381	34.772	0.12792	0.092461	0.44168	134.10	17.420
386.41	4.5168	5.5715	0.17949	30.732	31.543	0.11914			0	11.292

TABLE 2-282 Thermodynamic Properties of R-152a, 1,1-Difluoroethane (Concluded)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Single-Phase Properties										
200.00	0.10000	16.782	0.059586	5.4618	5.4678	0.033189	0.068102	0.10142	1131.7	–0.38632
248.83	0.10000	15.318	0.065282	10.535	10.541	0.055862	0.070526	0.10726	890.93	–0.29520
248.83	0.10000	0.050481	19.809	30.369	32.350	0.14351	0.053862	0.064421	185.16	54.718
300.00	0.10000	0.040939	24.427	33.323	35.766	0.15598	0.060341	0.069611	204.37	27.531
400.00	0.10000	0.030290	33.014	40.103	43.405	0.17786	0.074770	0.083404	235.25	10.509
500.00	0.10000	0.024131	41.441	48.286	52.430	0.19794	0.088343	0.096818	261.80	5.4858
200.00	1.0000	16.798	0.059530	5.4436	5.5031	0.033097	0.068150	0.10133	1135.5	–0.38750
300.00	1.0000	13.568	0.073703	16.249	16.323	0.076732	0.075359	0.11920	642.81	–0.078450
316.76	1.0000	12.861	0.077752	18.296	18.374	0.083384	0.077294	0.12609	553.13	0.072197
316.76	1.0000	0.47247	2.1165	33.092	35.208	0.13653	0.070342	0.093615	181.20	25.479
400.00	1.0000	0.32539	3.0733	39.505	42.579	0.15720	0.076729	0.088940	222.89	10.836
500.00	1.0000	0.24847	4.0246	47.922	51.947	0.17807	0.088892	0.098930	256.19	5.4940
200.00	5.0000	16.867	0.059288	5.3645	5.6609	0.032698	0.068345	0.10098	1152.1	–0.39242
300.00	5.0000	13.783	0.072554	16.011	16.373	0.075926	0.075345	0.11645	684.64	–0.13417
400.00	5.0000	3.1526	0.31720	34.823	36.409	0.13126	0.092011	0.26333	148.13	12.808
500.00	5.0000	1.4336	0.69753	46.169	49.657	0.16117	0.091345	0.11166	232.93	5.3800
200.00	10.000	16.949	0.059000	5.2700	5.8600	0.032215	0.068554	0.10058	1172.7	–0.39792
300.00	10.000	14.014	0.071358	15.752	16.466	0.075036	0.075376	0.11401	729.99	–0.18420
400.00	10.000	9.5224	0.10502	28.480	29.530	0.11233	0.087211	0.16027	310.79	1.2458
500.00	10.000	3.4436	0.29039	43.674	46.578	0.15056	0.094041	0.13591	219.92	4.4385
200.00	30.000	17.248	0.057977	4.9338	6.6732	0.030434	0.069111	0.099355	1253.5	–0.41462
300.00	30.000	14.709	0.067986	14.971	17.010	0.072215	0.075740	0.10883	869.51	–0.29079
400.00	30.000	11.934	0.083794	26.048	28.561	0.10535	0.085262	0.12249	576.62	–0.0089214
500.00	30.000	8.9569	0.11165	38.069	41.418	0.13400	0.094199	0.13295	407.30	0.48690
200.00	60.000	17.625	0.056738	4.5216	7.9258	0.028097	0.069524	0.098187	1367.5	–0.42991
300.00	60.000	15.424	0.064836	14.174	18.064	0.069098	0.076558	0.10570	1020.4	–0.35644
400.00	60.000	13.309	0.075135	24.599	29.107	0.10080	0.086520	0.11507	770.60	–0.24663
500.00	60.000	11.312	0.088399	35.736	41.039	0.12739	0.095954	0.12324	613.84	–0.11541

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Outcalt, S. L., and McLinden, M. O., "A Modified Benedict-Webb-Rubin Equation of State for the Thermodynamic Properties of R152a (1,1-Difluoroethane)," *J. Phys. Chem. Ref. Data* **25**(2):605–636, 1996. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are 0.1% in density, 2% in heat capacity, and 0.05% in the vapor speed of sound, except in the critical region. The uncertainty in vapor pressure is 0.1%.

TABLE 2-283 Saturated Refrigerant 216a, 1,3-Dichloro-1,1,2,2,3,3-Hexafluoropropane

Temp., °F	Pressure, lb/in² abs.	Volume, ft³/lb		Enthalpy, Btu/lb		Entropy, Btu/(lb)(°F)	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
–40	0.339	0.00927	59.957	0.000	62.415	0.0000	0.1487
–20	0.713	0.00942	29.749	4.778	65.276	0.0111	0.1487
0	1.382	0.00958	15.986	9.541	68.208	0.0217	0.1493
20	2.497	0.00974	9.184	14.298	71.199	0.0318	0.1504
40	4.247	0.00992	5.582	19.056	74.239	0.0415	0.1520
60	6.862	0.01010	3.558	23.821	77.319	0.0509	0.1538
80	10.612	0.01030	2.361	28.598	80.429	0.0599	0.1559
100	15.797	0.01050	1.6215	33.391	83.559	0.0686	0.1582
120	22.753	0.01073	1.1462	38.205	86.701	0.0770	0.1607
140	31.845	0.01097	0.8304	43.049	89.845	0.0852	0.1632
160	43.468	0.01124	0.6142	47.930	92.981	0.0931	0.1658
180	58.046	0.01153	0.4623	52.861	96.099	0.1009	0.1685
200	76.033	0.01186	0.3529	57.857	99.186	0.1085	0.1712
220	97.913	0.01223	0.2725	62.939	102.225	0.1161	0.1739
240	124.21	0.01266	0.2121	68.132	105.196	0.1235	0.1765
260	155.50	0.01317	0.1660	73.474	108.066	0.1309	0.1790
280	192.40	0.01378	0.1300	79.015	110.789	0.1384	0.1813
300	235.63	0.01458	0.1013	84.835	113.282	0.1460	0.1834
320	286.03	0.01570	0.0776	91.089	115.373	0.1539	0.1851
340	344.81	0.01764	0.0565	98.234	116.538	0.1628	0.1856
355.98[c]	399.45	0.02771	0.0277	110.248	110.248	0.1773	0.1773

*From published data, Chemicals Division, Union Carbide Corporation. Used by permission. The paper describing these data is by Shank, *ASHRAE J.*, **1**(1965): 94–101. *c* = critical temperature.

The 1993 ASHRAE *Handbook—Fundamentals* (SI ed.) gives material for integral degrees Celsius with temperatures on the ITS 90 scale from –118.59 to 113.26 °C. The thermodynamic diagram from 0.1 to 30 bar extends to 180 °C. For tables and a diagram to 400 psia, 360 °F, see Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993. Thermal conductivity data as a function of pressure and temperature are reported by Krauss, R. and K. Stephan, *Proc. 12th Symp. Thermophys. Props.*, Boulder, CO, 1994.

TABLE 2-284 Thermodynamic Properties of R-218, Octafluoropropane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
125.45	2.0186E-06	10.687	0.093572	12.346	12.346	0.057736	0.086723	0.14866	1157.7	–0.48474
130.00	4.8985E-06	10.598	0.094353	13.024	13.024	0.063044	0.088773	0.14939	1119.0	–0.48168
140.00	2.7215E-05	10.407	0.096088	14.528	14.528	0.074187	0.093214	0.15145	1041.4	–0.47276
150.00	0.00011605	10.219	0.097856	16.054	16.054	0.084719	0.097514	0.15392	972.09	–0.46146
160.00	0.00040065	10.033	0.099670	17.607	17.607	0.094739	0.10165	0.15668	909.32	–0.44819
170.00	0.0011659	9.8482	0.10154	19.189	19.189	0.10433	0.10561	0.15964	851.65	–0.43313
180.00	0.0029499	9.6632	0.10349	20.800	20.801	0.11354	0.10942	0.16276	797.99	–0.41623
190.00	0.0066482	9.4771	0.10552	22.444	22.445	0.12242	0.11310	0.16603	747.52	–0.39731
200.00	0.013606	9.2890	0.10765	24.121	24.122	0.13102	0.11667	0.16944	699.61	–0.37604
210.00	0.025681	9.0979	0.10992	25.832	25.835	0.13937	0.12014	0.17301	653.72	–0.35194
220.00	0.045264	8.9027	0.11233	27.580	27.585	0.14750	0.12355	0.17675	609.45	–0.32433
230.00	0.075274	8.7022	0.11491	29.365	29.374	0.15544	0.12690	0.18069	566.44	–0.29229
240.00	0.11911	8.4950	0.11772	31.190	31.204	0.16320	0.13022	0.18489	524.41	–0.25451
250.00	0.18060	8.2795	0.12078	33.056	33.077	0.17082	0.13351	0.18940	483.09	–0.20911
260.00	0.26395	8.0537	0.12417	34.966	34.998	0.17832	0.13680	0.19432	442.24	–0.15332
270.00	0.37369	7.8151	0.12796	36.923	36.971	0.18571	0.14010	0.19980	401.64	–0.082915
280.00	0.51466	7.5602	0.13227	38.933	39.001	0.19302	0.14343	0.20607	361.06	0.0089029
290.00	0.69206	7.2843	0.13728	41.000	41.095	0.20029	0.14683	0.21355	320.24	0.13369
300.00	0.91150	6.9802	0.14326	43.134	43.265	0.20754	0.15035	0.22299	278.86	0.31279
310.00	1.1793	6.6366	0.15068	45.351	45.528	0.21483	0.15405	0.23603	236.46	0.59020
320.00	1.5030	6.2324	0.16045	47.677	47.918	0.22226	0.15812	0.25690	192.26	1.0733
330.00	1.8924	5.7189	0.17486	50.177	50.508	0.23002	0.16294	0.30134	144.68	2.1079
340.00	2.3634	4.9092	0.20370	53.102	53.583	0.23893	0.17021	0.52335	89.750	5.6878
345.02	2.6402	3.3400	0.29940	56.252	57.042	0.24883			0	17.096
125.45	2.0186E-06	1.9353E-06	516,720.	37.874	38.917	0.26954	0.072287	0.080604	78.648	854.14
130.00	4.8985E-06	4.5321E-06	220,650.	38.208	39.289	0.26508	0.074826	0.083144	79.920	682.22
140.00	2.7215E-05	2.3384E-05	42,765.	38.983	40.147	0.25718	0.080190	0.088516	82.654	432.76
150.00	1.1605E-04	9.3093E-05	10,742.	39.808	41.055	0.25139	0.085274	0.093623	85.299	288.12
160.00	0.00040065	0.00030151	3,316.6	40.680	42.009	0.24725	0.090119	0.098514	87.846	200.28
170.00	0.0011659	0.00082688	1,209.4	41.595	43.005	0.24442	0.094776	0.10326	90.278	144.70
180.00	0.0029499	0.0019804	504.96	42.548	44.038	0.24263	0.099300	0.10792	92.569	108.17
190.00	0.0066482	0.0042437	235.65	43.536	45.102	0.24167	0.10374	0.11258	94.686	83.339
200.00	0.013606	0.0082953	120.55	44.553	46.193	0.24138	0.10814	0.11730	96.589	65.928
210.00	0.025681	0.015024	66.559	45.596	47.305	0.24161	0.11253	0.12213	98.233	53.394
220.00	0.045264	0.025536	39.161	46.661	48.433	0.24227	0.11693	0.12712	99.570	44.174
230.00	0.075274	0.041158	24.297	47.744	49.573	0.24326	0.12135	0.13232	100.55	37.278
240.00	0.11911	0.063461	15.758	48.843	50.720	0.24452	0.12577	0.13776	101.12	32.063
250.00	0.18060	0.094301	10.604	49.952	51.867	0.24598	0.13020	0.14351	101.22	28.095
260.00	0.26395	0.13591	7.3580	51.067	53.009	0.24759	0.13463	0.14970	100.79	25.083
270.00	0.37369	0.19105	5.2343	52.183	54.139	0.24929	0.13906	0.15649	99.737	22.826
280.00	0.51466	0.26332	3.7977	53.291	55.246	0.25104	0.14352	0.16420	97.968	21.188
290.00	0.69206	0.35768	2.7958	54.381	56.316	0.25277	0.14802	0.17340	95.356	20.088
300.00	0.91150	0.48153	2.0767	55.437	57.330	0.25442	0.15262	0.18521	91.730	19.493
310.00	1.1793	0.64702	1.5456	56.433	58.256	0.25589	0.15742	0.20207	86.859	19.423
320.00	1.5030	0.87704	1.1402	57.322	59.035	0.25700	0.16259	0.23055	80.422	19.958
330.00	1.8924	1.2252	0.81620	57.996	59.540	0.25739	0.16855	0.29532	72.007	21.201
340.00	2.3634	1.8924	0.52844	58.081	59.330	0.25584	0.17647	0.62247	61.241	22.532
345.02	2.6402	3.3400	0.29940	56.252	57.042	0.24883			0	17.096

Single-Phase Properties										
150.00	0.10000	10.220	0.097848	16.052	16.061	0.084701	0.097521	0.15391	972.51	–0.46154
225.00	0.10000	8.8041	0.11358	28.465	28.477	0.15148	0.12523	0.17867	588.11	–0.30918
236.07	0.10000	8.5773	0.11659	30.468	30.479	0.16017	0.12892	0.18321	540.83	–0.27015
236.07	0.10000	0.053789	18.591	48.410	50.269	0.24400	0.12403	0.13558	100.95	33.943
300.00	0.10000	0.040933	24.430	56.919	59.362	0.27801	0.14104	0.15028	116.42	12.416
375.00	0.10000	0.032372	30.891	68.272	71.361	0.31363	0.16055	0.16927	131.00	6.1732
150.00	1.0000	10.228	0.097772	16.028	16.125	0.084540	0.097582	0.15385	976.23	–0.46230
225.00	1.0000	8.8236	0.11333	28.413	28.527	0.15125	0.12522	0.17828	594.72	–0.31433
300.00	1.0000	6.9891	0.14308	43.116	43.259	0.20748	0.15030	0.22248	280.68	0.30296
303.52	1.0000	6.8645	0.14568	43.905	44.051	0.21010	0.15163	0.22705	264.07	0.39586
303.52	1.0000	0.53424	1.8718	55.797	57.669	0.25497	0.15428	0.19038	90.170	19.406
375.00	1.0000	0.35613	2.8080	67.521	70.329	0.29246	0.16284	0.17689	120.35	7.1384
150.00	5.0000	10.262	0.097443	15.923	16.411	0.083839	0.097864	0.15361	992.31	–0.46544
225.00	5.0000	8.9050	0.11230	28.196	28.757	0.15027	0.12525	0.17677	622.21	–0.33410
300.00	5.0000	7.2996	0.13699	42.444	43.129	0.20518	0.14888	0.20895	346.02	0.039275
375.00	5.0000	4.0113	0.24930	60.519	61.765	0.26018	0.17483	0.31884	101.99	4.7668
150.00	10.000	10.304	0.097050	15.799	16.769	0.082988	0.098234	0.15336	1011.4	–0.46885
225.00	10.000	8.9969	0.11115	27.949	29.060	0.14913	0.12538	0.17531	653.07	–0.35341
300.00	10.000	7.5606	0.13227	41.847	43.170	0.20307	0.14819	0.20166	403.66	–0.10223
375.00	10.000	5.6952	0.17559	57.659	59.415	0.25128	0.16841	0.23156	219.93	0.67650
150.00	20.000	10.382	0.096321	15.565	17.492	0.081360	0.099023	0.15301	1046.6	–0.47434
225.00	20.000	9.1565	0.10921	27.517	29.701	0.14709	0.12580	0.17326	706.41	–0.38080
300.00	20.000	7.9189	0.12628	40.989	43.515	0.19992	0.14793	0.19500	486.73	–0.22897
375.00	20.000	6.5981	0.15156	55.836	58.867	0.24552	0.16668	0.21331	339.02	0.012472
150.00	30.000	10.454	0.095654	15.351	18.220	0.079818	0.099855	0.15280	1078.7	–0.47844
225.00	30.000	9.2933	0.10760	27.147	30.375	0.14527	0.12636	0.17191	751.98	–0.39925
300.00	30.000	8.1774	0.12229	40.353	44.022	0.19747	0.14819	0.19173	549.34	–0.28972
375.00	30.000	7.0690	0.14146	54.800	59.044	0.24210	0.16662	0.20796	416.45	–0.15627

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data* **51**(3):785–850, 2006. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainty in density is 0.2% for the liquid phase and 0.5% for the vapor phase. Above the critical temperature, the uncertainties are estimated to be 1% in density and 0.5% in pressure. Calculated vapor pressures have an uncertainty of 0.5%. The uncertainties for heat capacities and sound speeds are 1%.

TABLE 2-285 Thermodynamic Properties of R-227ea, 1,1,1,2,3,3,3-Heptafluoropropane

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
146.35	7.0312E-06	11.086	0.090205	12.227	12.227	0.063811	0.11121	0.16308	1068.8	–0.42071
150.00	1.2811E-05	11.020	0.090746	12.821	12.821	0.067824	0.11136	0.16271	1048.3	–0.42085
160.00	5.6086E-05	10.841	0.092245	14.446	14.446	0.078309	0.11222	0.16238	994.14	–0.41876
170.00	0.00019958	10.663	0.093780	16.072	16.072	0.088164	0.11357	0.16286	942.81	–0.41349
180.00	0.00059967	10.487	0.095359	17.705	17.705	0.097501	0.11528	0.16396	893.95	–0.40546
190.00	0.0015672	10.310	0.096992	19.352	19.352	0.10641	0.11723	0.16554	847.26	–0.39497
200.00	0.0036466	10.133	0.098689	21.017	21.017	0.11495	0.11934	0.16750	802.44	–0.38217
210.00	0.0076967	9.9539	0.10046	22.703	22.704	0.12317	0.12157	0.16976	759.23	–0.36707
220.00	0.014961	9.7727	0.10233	24.413	24.414	0.13112	0.12386	0.17228	717.37	–0.34954
230.00	0.027114	9.5883	0.10429	26.148	26.151	0.13884	0.12618	0.17502	676.63	–0.32930
240.00	0.046286	9.3999	0.10638	27.912	27.917	0.14635	0.12851	0.17797	636.81	–0.30590
250.00	0.075058	9.2065	0.10862	29.706	29.714	0.15367	0.13085	0.18114	597.69	–0.27867
260.00	0.11644	9.0068	0.11103	31.531	31.544	0.16083	0.13318	0.18454	559.10	–0.24663
270.00	0.17384	8.7997	0.11364	33.390	33.410	0.16784	0.13549	0.18822	520.85	–0.20842
280.00	0.25102	8.5834	0.11650	35.286	35.315	0.17474	0.13781	0.19225	482.77	–0.16205
290.00	0.35208	8.3560	0.11967	37.220	37.262	0.18153	0.14011	0.19673	444.69	–0.10460
300.00	0.48145	8.1148	0.12323	39.197	39.256	0.18824	0.14243	0.20183	406.42	–0.031613
310.00	0.64388	7.8563	0.12729	41.221	41.303	0.19488	0.14477	0.20782	367.76	0.064014
320.00	0.84450	7.5756	0.13200	43.299	43.411	0.20149	0.14716	0.21515	328.49	0.19426
330.00	1.0889	7.2652	0.13764	45.442	45.592	0.20810	0.14964	0.22467	288.32	0.38093
340.00	1.3836	6.9135	0.14465	47.666	47.866	0.21476	0.15227	0.23817	246.84	0.66802
350.00	1.7358	6.4988	0.15387	50.002	50.269	0.22158	0.15517	0.26018	203.37	1.1593
360.00	2.1552	5.9733	0.16741	52.517	52.877	0.22873	0.15867	0.30696	156.53	2.1701
370.00	2.6553	5.1649	0.19361	55.458	55.972	0.23696	0.16399	0.51614	102.78	5.2930
375.95	2.9991	3.4100	0.29326	59.193	60.073	0.24773			0	16.489
146.35	7.0312E-06	5.7786E-06	173,050.	41.158	42.374	0.26981	0.072002	0.080321	89.345	630.83
150.00	1.2811E-05	1.0273E-05	97,345.	41.423	42.670	0.26682	0.073562	0.081883	90.352	540.51
160.00	5.6086E-05	4.2170E-05	23,714.	42.179	43.509	0.25995	0.077861	0.086194	93.045	363.36
170.00	0.00019958	0.00014128	7,078.0	42.976	44.389	0.25474	0.082177	0.090535	95.643	253.26
180.00	0.00059967	0.00040123	2,492.3	43.814	45.308	0.25085	0.086488	0.094896	98.141	182.56
190.00	0.0015672	0.00099473	1,005.3	44.689	46.265	0.24805	0.090782	0.099275	100.53	135.75
200.00	0.0036466	0.0022037	453.78	45.600	47.255	0.24613	0.095053	0.10368	102.77	103.86
210.00	0.0076967	0.0044452	224.96	46.543	48.275	0.24494	0.099298	0.10813	104.85	81.549
220.00	0.014961	0.0082891	120.64	47.515	49.320	0.24433	0.10352	0.11263	106.73	65.553
230.00	0.027114	0.014469	69.111	48.513	50.387	0.24421	0.10771	0.11721	108.37	53.830
240.00	0.046286	0.023890	41.858	49.533	51.470	0.24448	0.11188	0.12189	109.71	45.075
250.00	0.075058	0.037635	26.571	50.570	52.565	0.24507	0.11601	0.12670	110.73	38.434
260.00	0.11644	0.056982	17.550	51.622	53.666	0.24591	0.12010	0.13166	111.36	33.337
270.00	0.17384	0.083437	11.985	52.684	54.768	0.24695	0.12416	0.13684	111.55	29.395
280.00	0.25102	0.11880	8.4176	53.752	55.864	0.24813	0.12818	0.14232	111.26	26.339
290.00	0.35208	0.16526	6.0510	54.818	56.949	0.24942	0.13216	0.14822	110.42	23.978
300.00	0.48145	0.22559	4.4328	55.878	58.012	0.25076	0.13612	0.15475	108.94	22.183
310.00	0.64388	0.30344	3.2956	56.922	59.044	0.25211	0.14009	0.16227	106.75	20.864
320.00	0.84450	0.40387	2.4761	57.938	60.029	0.25342	0.14409	0.17136	103.73	19.969
330.00	1.0889	0.53442	1.8712	58.909	60.946	0.25463	0.14817	0.18320	99.740	19.477
340.00	1.3836	0.70732	1.4138	59.808	61.764	0.25564	0.15244	0.20027	94.584	19.399
350.00	1.7358	0.94497	1.0582	60.587	62.424	0.25630	0.15704	0.22897	88.022	19.775
360.00	2.1552	1.2970	0.77102	61.146	62.807	0.25632	0.16228	0.29185	79.757	20.625
370.00	2.6553	1.9293	0.51831	61.164	62.540	0.25471	0.16893	0.56287	69.452	21.487
375.95	2.9991	3.4100	0.29326	59.193	60.073	0.24773			0	16.489

Single-Phase Properties										
150.00	0.10000	11.021	0.090739	12.819	12.828	0.067809	0.11137	0.16271	1048.6	–0.42089
225.00	0.10000	9.6823	0.10328	25.274	25.284	0.13499	0.12502	0.17360	697.31	–0.34002
256.43	0.10000	9.0790	0.11014	30.875	30.886	0.15829	0.13235	0.18330	572.84	–0.25870
256.43	0.10000	0.049336	20.269	51.245	53.272	0.24559	0.11864	0.12987	111.18	35.009
300.00	0.10000	0.041177	24.286	56.684	59.112	0.26660	0.12925	0.13881	122.16	17.772
375.00	0.10000	0.032454	30.813	67.081	70.162	0.29941	0.14667	0.15550	137.79	8.4581
450.00	0.10000	0.026888	37.191	78.645	82.364	0.32903	0.16079	0.16939	151.34	5.1086
150.00	1.0000	11.028	0.090682	12.799	12.890	0.067676	0.11146	0.16267	1051.5	–0.42131
225.00	1.0000	9.6973	0.10312	25.234	25.337	0.13482	0.12507	0.17337	702.21	–0.34268
300.00	1.0000	8.1405	0.12284	39.137	39.260	0.18804	0.14240	0.20096	412.50	–0.045381
326.58	1.0000	7.3754	0.13559	44.701	44.837	0.20584	0.14878	0.22108	302.19	0.30867
326.58	1.0000	0.48574	2.0587	58.583	60.642	0.25423	0.14676	0.17873	101.23	19.600
375.00	1.0000	0.36801	2.7173	66.118	68.835	0.27764	0.15025	0.16647	123.32	10.030
450.00	1.0000	0.28468	3.5127	78.039	81.552	0.30854	0.16198	0.17375	144.14	5.4173
150.00	5.0000	11.058	0.090430	12.712	13.164	0.067092	0.11182	0.16253	1064.0	–0.42305
225.00	5.0000	9.7613	0.10245	25.066	25.578	0.13406	0.12533	0.17247	723.03	–0.35330
300.00	5.0000	8.3150	0.12026	38.729	39.330	0.18665	0.14230	0.19592	454.01	–0.12586
375.00	5.0000	6.0063	0.16649	54.845	55.677	0.23506	0.15968	0.25736	188.73	1.3729
450.00	5.0000	1.9568	0.51103	74.454	77.009	0.28716	0.16853	0.21820	117.53	5.8791
225.00	10.000	9.8358	0.10167	24.870	25.887	0.13316	0.12567	0.17153	747.22	–0.36439
300.00	10.000	8.4921	0.11776	38.308	39.485	0.18518	0.14237	0.19196	496.71	–0.18923
375.00	10.000	6.7736	0.14763	53.368	54.845	0.23077	0.15755	0.21921	286.63	0.34861
450.00	10.000	4.4095	0.22679	70.066	72.334	0.27322	0.17015	0.23938	162.15	2.0189
225.00	30.000	10.091	0.099103	24.209	27.182	0.13000	0.12709	0.16914	829.42	–0.39369
300.00	30.000	8.9874	0.11127	37.111	40.449	0.18079	0.14335	0.18477	619.36	–0.30379
375.00	30.000	7.8569	0.12728	51.038	54.856	0.22359	0.15736	0.19887	467.67	–0.17451
450.00	30.000	6.7284	0.14862	65.707	70.165	0.26078	0.16895	0.20846	368.25	–0.017558
225.00	60.000	10.391	0.096240	23.457	29.231	0.12610	0.12922	0.16752	926.46	–0.41551
300.00	60.000	9.4675	0.10562	35.965	42.302	0.17614	0.14519	0.18109	743.76	–0.36285
375.00	60.000	8.5978	0.11631	49.374	56.353	0.21789	0.15896	0.19315	617.08	–0.30676
450.00	60.000	7.7868	0.12842	63.495	71.201	0.25396	0.17036	0.20230	530.91	–0.25596

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is an interim equation from Lemmon, E. W., personal communication (NIST, Boulder, CO, 2006). Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in the equation of state are 0.2% in density, except in a small region close to the critical point, 0.2% in vapor pressure between 250 and 360 K, 0.4% in vapor pressure outside this region, 1% in heat capacities (with increasing uncertainties in the critical region and at higher temperatures), 0.1% in the vapor-phase speed of sound, and 3% in the liquid-phase speed of sound.

TABLE 2-286 Saturated Refrigerant 245cb 1,1,1,2,2-Pentafluoropropane*

T, K	P, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)
172	0.0034	6.46.–4	31.49	–63.4	133.8	–0.3131	0.8327
180	0.0076	6.57.–4	14.63	–55.9	138.7	–0.2707	0.8099
190	0.0190	6.70.–4	6.20	–46.2	145.1	–0.2182	0.7885
200	0.0425	6.83.–4	2.91	–36.0	151.7	–0.1666	0.7725
210	0.0870	6.97.–4	1.48	–25.7	158.5	–0.1157	0.7612
220	0.1654	7.11.–4	0.822	–14.8	165.4	–0.0654	0.7539
230	0.2946	7.25.–4	0.475	–3.6	172.5	–0.0156	0.7500
240	0.4958	7.40.–4	0.292	8.0	179.6	0.0337	0.7487
250	0.7946	7.55.–4	0.192	19.9	186.8	0.0824	0.7497
260	1.2204	7.72.–4	0.125	32.3	194.0	0.1305	0.7525
270	1.806	7.89.–4	0.0862	44.9	201.1	0.1781	0.7567
280	2.584	8.08.–4	0.0611	57.9	208.3	0.2249	0.7621
290	3.600	8.30.–4	0.0443	71.1	215.3	0.2711	0.7683
300	4.888	8.53.–4	0.0327	84.6	222.2	0.3161	0.7751
310	6.491	8.80.–4	0.0246	98.4	228.9	0.3614	0.7822
320	8.456	9.11.–4	0.0186	112.6	235.3	0.4057	0.7893
330	10.83	9.48.–4	0.0143	127.1	241.4	0.4497	0.7960
340	13.67	9.93.–4	0.0111	142.1	246.9	0.4937	0.8018
350	17.04	0.00105	0.0084	157.2	251.5	0.5382	0.8060
360	21.02	0.00113	0.0063	174.7	254.8	0.5844	0.8071
370	25.71	0.00125	0.0045	193.6	255.2	0.6349	0.8013
375	28.46	0.00137	0.0036	205.2	252.5	0.6649	0.7953
380.1[c]	31.37	0.00204	0.0020	231.8	231.8	0.7341	0.7341

*Values converted from tables of Shank, *Thermodynamic Properties of UCON 245 Refrigerant,* Union Carbide Corporation, New York, 1966. See also Shank, *J. Chem. Eng. Data,* **12,** 474–480 (1967). c = critical point. The notation 6.46.–4 signifies 6.46×10^{-4}.

TABLE 2-287 Refrigerant RC 318, Octafluorocyclobutane*

T, K	P, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)	μ_f, 10^{-4} Pa·s	k_f, W/(m·K)
200	0.0216	5.507.–4	3.810	353.5	498.0	3.909	4.560			
210	0.0449	5.593.–4	1.931	361.0	500.1	3.947	4.564			
220	0.0875	5.683.–4	1.038	369.2	502.2	3.984	4.569			
230	0.1608	5.778.–4	0.588	377.6	504.4	4.022	4.574	0.98	11.7	0.088
240	0.2810	5.879.–4	0.349	386.4	510.9	4.060	4.578	1.00	9.55	0.085
250	0.466	5.988.–4	0.2166	395.6	517.4	4.097	4.584	1.02	7.90	0.082
260	0.741	6.106.–4	0.1401	405.2	524.0	4.133	4.592	1.03	6.63	0.078
270	1.133	6.234.–4	0.0938	415.1	530.7	4.172	4.599	1.05	5.64	0.075
280	1.672	6.375.–4	0.0647	425.8	537.3	4.210	4.609	1.07	4.85	0.071
290	2.392	6.529.–4	0.0458	436.2	543.9	4.247	4.618	1.09	4.22	0.068
300	3.325	6.694.–4	0.0332	447.3	550.4	4.284	4.626	1.12	3.70	0.065
310	4.522	6.893.–4	0.0245	458.7	556.9	4.322	4.638	1.15	3.20	0.061
320	6.007	7.115.–4	0.0184	470.5	563.3	4.359	4.648	1.18	2.94	0.058
330	7.826	7.365.–4	0.0139	482.7	569.4	4.396	4.659	1.23	2.66	0.054
340	10.018	7.666.–4	0.0106	495.2	575.4	4.433	4.669	1.27	2.33	0.051
350	12.632	8.034.–4	0.0082	508.1	581.0	4.469	4.678	1.32	2.00	0.048
360	15.71	8.508.–4	0.0062	521.5	585.8	4.507	4.685	1.39		
370	19.33	9.172.–4	0.0047	535.6	589.9	4.544	4.691			
380	23.59	1.031.–3	0.0033	551.4	591.5	4.585	4.691			
388.5[c]	27.83	1.613.–3	0.0016	577.2	577.2	4.651	4.651			

*Values of P, v, h, and s interpolated, extrapolated, and converted from tables of Oguchi, *Reito,* **52** (1977): 869–889. Values of c_p, μ, and k interpolated and converted from tables in *Thermophysical Properties of Refrigerants,* American Society of Heating, Refrigerating and Air-Conditioning Engineers, New York, 1976. c = critical point.

Saturation and superheat tables and a diagram to 80 bar, 580 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.,* Stanford Univ. publ., 1979 (173 pp.). For equations, see Cipollone, R., *ASHRAE Trans.,* **97,** 2 (1991): 262–267.

TABLE 2-288 Thermodynamic Properties of R-404A

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
200.00	0.022649	14.209	0.070377	10.353	10.355	0.058867	0.076939	0.11881	859.89	–0.34161
205.00	0.030989	14.059	0.071131	10.948	10.950	0.061803	0.077522	0.11915	831.56	–0.33384
210.00	0.041658	13.907	0.071905	11.544	11.547	0.064678	0.078116	0.11965	804.42	–0.32460
215.00	0.055101	13.755	0.072703	12.144	12.148	0.067498	0.078719	0.12028	778.20	–0.31394
220.00	0.071804	13.600	0.073527	12.746	12.751	0.070269	0.079326	0.12103	752.69	–0.30185
225.00	0.092293	13.444	0.074380	13.353	13.359	0.072995	0.079940	0.12188	727.72	–0.28830
230.00	0.11713	13.286	0.075265	13.963	13.972	0.075679	0.080558	0.12282	703.16	–0.27318
235.00	0.14693	13.126	0.076185	14.578	14.590	0.078326	0.081183	0.12386	678.91	–0.25636
240.00	0.18232	12.963	0.077145	15.199	15.213	0.080939	0.081815	0.12499	654.88	–0.23766
245.00	0.22397	12.796	0.078147	15.824	15.842	0.083520	0.082456	0.12621	631.01	–0.21683
250.00	0.27258	12.627	0.079197	16.456	16.478	0.086073	0.083107	0.12754	607.23	–0.19356
255.00	0.32888	12.453	0.080301	17.094	17.120	0.088600	0.083770	0.12899	583.50	–0.16749
260.00	0.39363	12.275	0.081465	17.738	17.770	0.091104	0.084446	0.13057	559.77	–0.13814
265.00	0.46763	12.092	0.082697	18.390	18.429	0.093589	0.085137	0.13229	535.99	–0.10493
270.00	0.55168	11.904	0.084006	19.049	19.096	0.096056	0.085846	0.13419	512.13	–0.067104
275.00	0.64664	11.709	0.085402	19.717	19.772	0.098510	0.086574	0.13630	488.15	–0.023728
280.00	0.75338	11.508	0.086899	20.394	20.460	0.10095	0.087326	0.13866	464.02	0.026418
285.00	0.87280	11.298	0.088513	21.081	21.159	0.10339	0.088104	0.14133	439.69	0.084928
290.00	1.0059	11.078	0.090266	21.780	21.870	0.10583	0.088914	0.14438	415.13	0.15392
295.00	1.1536	10.848	0.092182	22.490	22.597	0.10826	0.089761	0.14793	390.28	0.23626
300.00	1.3169	10.605	0.094295	23.215	23.339	0.11071	0.090653	0.15211	365.11	0.33594
305.00	1.4970	10.346	0.096652	23.956	24.101	0.11317	0.091603	0.15715	339.56	0.45865
310.00	1.6950	10.069	0.099314	24.717	24.885	0.11566	0.092625	0.16339	313.56	0.61280
315.00	1.9122	9.7686	0.10237	25.500	25.695	0.11818	0.093744	0.17139	287.00	0.81141
320.00	2.1499	9.4384	0.10595	26.310	26.538	0.12075	0.094998	0.18212	259.73	1.0757
325.00	2.4096	9.0688	0.11027	27.157	27.423	0.12341	0.096455	0.19751	231.53	1.4433
330.00	2.6932	8.6431	0.11570	28.054	28.365	0.12619	0.098241	0.22197	201.95	1.9881
335.00	3.0027	8.1285	0.12302	29.026	29.396	0.12918	0.10064	0.26871	170.20	2.8807
340.00	3.3414	7.4362	0.13448	30.147	30.597	0.13261	0.10445	0.40392	134.59	4.6353
345.00	3.7150	5.7429	0.17413	32.108	32.755	0.13874	0.11650	8.2559	89.976	10.564
345.27	3.7348	4.9400	0.20243	32.875	33.631	0.14126			0	12.409
200.00	0.021264	0.013010	76.866	29.920	31.555	0.16521	0.058696	0.068032	138.13	88.073
205.00	0.029285	0.017550	56.979	30.185	31.853	0.16408	0.059968	0.069509	139.28	77.215
210.00	0.039592	0.023271	42.971	30.451	32.152	0.16307	0.061245	0.071021	140.34	68.305
215.00	0.052629	0.030378	32.919	30.718	32.451	0.16217	0.062526	0.072573	141.29	60.948
220.00	0.068883	0.039095	25.579	30.987	32.749	0.16138	0.063815	0.074172	142.12	54.835
225.00	0.088879	0.049667	20.134	31.256	33.046	0.16068	0.065113	0.075826	142.84	49.721
230.00	0.11318	0.062359	16.036	31.525	33.340	0.16006	0.066424	0.077546	143.43	45.413
235.00	0.14240	0.077463	12.909	31.795	33.633	0.15952	0.067750	0.079344	143.88	41.761
240.00	0.17718	0.095292	10.494	32.063	33.922	0.15903	0.069095	0.081232	144.18	38.642
245.00	0.21817	0.11619	8.6063	32.330	34.208	0.15861	0.070463	0.083226	144.33	35.962
250.00	0.26610	0.14055	7.1149	32.596	34.489	0.15823	0.071855	0.085343	144.32	33.645
255.00	0.32169	0.16879	5.9247	32.859	34.765	0.15789	0.073276	0.087604	144.14	31.630
260.00	0.38571	0.20137	4.9659	33.119	35.034	0.15759	0.074728	0.090033	143.77	29.871
265.00	0.45896	0.23885	4.1867	33.375	35.296	0.15732	0.076214	0.092660	143.22	28.327
270.00	0.54225	0.28183	3.5483	33.626	35.550	0.15707	0.077737	0.095524	142.46	26.970
275.00	0.63645	0.33102	3.0210	33.872	35.794	0.15684	0.079300	0.098671	141.49	25.773
280.00	0.74245	0.38725	2.5823	34.111	36.028	0.15661	0.080909	0.10217	140.29	24.718
285.00	0.86115	0.45152	2.2148	34.342	36.249	0.15639	0.082567	0.10609	138.85	23.789
290.00	0.99353	0.52501	1.9047	34.563	36.455	0.15616	0.084282	0.11056	137.16	22.972
295.00	1.1406	0.60922	1.6414	34.773	36.645	0.15592	0.086062	0.11574	135.19	22.256
300.00	1.3034	0.70599	1.4165	34.968	36.814	0.15566	0.087917	0.12186	132.92	21.633
305.00	1.4830	0.81772	1.2229	35.147	36.960	0.15536	0.089863	0.12929	130.34	21.094

TABLE 2-288 Thermodynamic Properties of R-404A (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties (Concluded)										
310.00	1.6806	0.94761	1.0553	35.304	37.078	0.15501	0.091922	0.13856	127.41	20.630
315.00	1.8975	1.1001	0.90903	35.435	37.159	0.15459	0.094123	0.15062	124.10	20.234
320.00	2.1351	1.2815	0.78032	35.530	37.196	0.15408	0.096513	0.16713	120.38	19.889
325.00	2.3950	1.5019	0.66583	35.578	37.173	0.15343	0.099162	0.19141	116.21	19.571
330.00	2.6789	1.7781	0.56239	35.558	37.065	0.15257	0.10220	0.23111	111.51	19.233
335.00	2.9893	2.1438	0.46645	35.429	36.824	0.15136	0.10585	0.30867	106.19	18.763
340.00	3.3299	2.6882	0.37199	35.084	36.323	0.14946	0.11074	0.53035	100.03	17.851
345.00	3.7109	4.2113	0.23746	33.615	34.496	0.14379	0.12022	8.6291	90.307	14.130
345.27	3.7348	4.9400	0.20243	32.875	33.631	0.14126			0	12.409
Single-Phase Properties										
226.65	0.10000	13.392	0.074669	13.554	13.561	0.073887	0.080143	0.12218	719.55	–0.28348
227.41	0.10000	0.055492	18.021	31.386	33.188	0.16038	0.065742	0.076645	143.14	47.558
300.00	0.10000	0.040750	24.540	36.596	39.050	0.18269	0.076875	0.085907	166.24	16.998
400.00	0.10000	0.030243	33.066	45.121	48.428	0.20956	0.092844	0.10141	191.81	6.9229
500.00	0.10000	0.024113	41.471	55.103	59.250	0.23365	0.10612	0.11456	213.92	3.7455
289.79	1.0000	11.088	0.090189	21.750	21.840	0.10572	0.088879	0.14425	416.16	0.15078
290.23	1.0000	0.52866	1.8916	34.573	36.464	0.15615	0.084363	0.11078	137.07	22.936
300.00	1.0000	0.49205	2.0323	35.486	37.518	0.15972	0.083854	0.10554	143.42	19.634
400.00	1.0000	0.31957	3.1292	44.644	47.773	0.18922	0.094142	0.10545	183.69	7.1401
500.00	1.0000	0.24648	4.0571	54.804	58.861	0.21391	0.10659	0.11631	210.41	3.7496
300.00	5.0000	10.994	0.090955	22.770	23.225	0.10919	0.089725	0.14193	427.56	0.11428
400.00	5.0000	2.2256	0.44932	41.867	44.113	0.16875	0.10069	0.14547	148.00	7.6582
500.00	5.0000	1.3561	0.73741	53.389	57.076	0.19774	0.10859	0.12579	198.35	3.5826
300.00	10.000	11.371	0.087944	22.323	23.203	0.10763	0.089307	0.13525	489.01	–0.035312
400.00	10.000	6.1241	0.16329	37.557	39.190	0.15323	0.10301	0.18569	184.17	2.8522
500.00	10.000	2.9622	0.33758	51.539	54.915	0.18852	0.11046	0.13925	198.11	2.8527
300.00	25.000	12.107	0.082594	21.419	23.484	0.10432	0.089393	0.12713	614.12	–0.22002
400.00	25.000	9.2730	0.10784	34.286	36.982	0.14304	0.10166	0.14227	381.56	0.20064
500.00	25.000	6.6326	0.15077	47.758	51.527	0.17548	0.11215	0.14633	292.53	0.65319
300.00	50.000	12.867	0.077719	20.472	24.358	0.10057	0.090168	0.12262	753.19	–0.32391
400.00	50.000	10.834	0.092300	32.538	37.153	0.13731	0.10251	0.13302	559.24	–0.19415
500.00	50.000	9.0225	0.11083	45.317	50.859	0.16786	0.11339	0.14051	455.37	–0.070101

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., "Pseudo Pure-Fluid Equations of State for the Refrigerant Blends R-410A, R-404A, R-507A, and R-407C," *Int. J. Thermophys.* **24**(4):991–1006, 2003. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the critical point temperature are given in the last entry of the saturation tables. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The estimated uncertainty of density values calculated with the equation of state is 0.1%. The estimated uncertainty of calculated heat capacities and speed of sound values is 0.5%. Uncertainties of bubble and dew point pressures are 0.5%.

TABLE 2-289 Thermodynamic Properties of R-407C

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
200.00	0.019158	17.036	0.058698	8.8272	8.8283	0.050593	0.070988	0.11073	956.60	–0.31996
210.00	0.035795	16.697	0.059892	9.9359	9.9380	0.056002	0.071320	0.11118	903.06	–0.30662
220.00	0.062640	16.352	0.061156	11.051	11.055	0.061189	0.071817	0.11203	851.40	–0.28934
230.00	0.10366	15.999	0.062503	12.175	12.182	0.066188	0.072410	0.11319	801.12	–0.26790
240.00	0.16353	15.637	0.063949	13.312	13.323	0.071026	0.073074	0.11465	751.77	–0.24161
250.00	0.24755	15.264	0.065512	14.464	14.480	0.075728	0.073803	0.11641	703.01	–0.20937
260.00	0.36157	14.877	0.067218	15.632	15.657	0.080314	0.074597	0.11853	654.53	–0.16951
270.00	0.51193	14.472	0.069099	16.822	16.857	0.084805	0.075463	0.12111	606.09	–0.11964
280.00	0.70540	14.045	0.071198	18.035	18.085	0.089223	0.076412	0.12427	557.44	–0.056172
290.00	0.94916	13.591	0.073576	19.278	19.348	0.093590	0.077458	0.12822	508.32	0.026372
300.00	1.2507	13.102	0.076322	20.555	20.651	0.097931	0.078624	0.13331	458.46	0.13683
310.00	1.6182	12.567	0.079573	21.877	22.006	0.10228	0.079950	0.14013	407.51	0.29038
320.00	2.0599	11.969	0.083552	23.255	23.427	0.10668	0.081509	0.14989	354.98	0.51547
330.00	2.5851	11.278	0.088671	24.711	24.940	0.11119	0.083453	0.16541	300.07	0.87274
340.00	3.2038	10.435	0.095832	26.287	26.594	0.11596	0.086157	0.19551	241.20	1.5203
350.00	3.9255	9.2661	0.10792	28.110	28.534	0.12137	0.090943	0.28993	174.57	3.0499
359.35	4.6317	5.2600	0.19011	32.145	33.025	0.13372			0	10.947
200.00	0.011312	0.0068643	145.68	30.051	31.699	0.16726	0.048920	0.057805	149.59	109.12
210.00	0.022624	0.013151	76.041	30.504	32.224	0.16412	0.050967	0.060200	152.36	88.122
220.00	0.041929	0.023450	42.644	30.957	32.745	0.16151	0.053143	0.062854	154.78	72.006
230.00	0.072846	0.039384	25.391	31.409	33.259	0.15933	0.055439	0.065784	156.79	59.560
240.00	0.11979	0.062913	15.895	31.857	33.761	0.15749	0.057839	0.069010	158.33	49.904
250.00	0.18793	0.096374	10.376	32.298	34.248	0.15593	0.060328	0.072563	159.36	42.378
260.00	0.28317	0.14256	7.0147	32.728	34.715	0.15460	0.062897	0.076500	159.80	36.483
270.00	0.41203	0.20484	4.8820	33.145	35.157	0.15343	0.065542	0.080917	159.60	31.840
280.00	0.58173	0.28739	3.4796	33.544	35.568	0.15240	0.068266	0.085971	158.69	28.163
290.00	0.80008	0.39560	2.5278	33.918	35.940	0.15144	0.071085	0.091920	156.99	25.236
300.00	1.0757	0.53670	1.8632	34.259	36.263	0.15051	0.074027	0.099203	154.41	22.898
310.00	1.4179	0.72101	1.3869	34.556	36.523	0.14956	0.077140	0.10861	150.83	21.024
320.00	1.8375	0.96439	1.0369	34.790	36.696	0.14852	0.080507	0.12170	146.11	19.516
330.00	2.3470	1.2939	0.77283	34.931	36.745	0.14727	0.084283	0.14208	140.03	18.284
340.00	2.9627	1.7642	0.56682	34.916	36.595	0.14560	0.088801	0.18030	132.24	17.206
350.00	3.7100	2.5260	0.39588	34.578	36.047	0.14299	0.095065	0.28700	122.09	15.951
359.35	4.6317	5.2600	0.19011	32.145	33.025	0.13372			0	10.947

TABLE 2-289 Thermodynamic Properties of R-407C (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Single-Phase Properties										
200.00	0.10000	17.038	0.058692	8.8253	8.8312	0.050583	0.070990	0.11072	956.99	–0.32010
229.25	0.10000	16.026	0.062399	12.091	12.097	0.065819	0.072363	0.11310	804.85	–0.26966
236.25	0.10000	0.053062	18.846	31.690	33.574	0.15814	0.056928	0.067764	157.81	53.242
300.00	0.10000	0.040722	24.557	35.535	37.991	0.17467	0.063341	0.072378	179.00	20.041
400.00	0.10000	0.030231	33.079	42.554	45.862	0.19722	0.076588	0.085147	205.99	7.7925
500.00	0.10000	0.024109	41.479	50.849	54.997	0.21756	0.088895	0.097330	229.27	4.0471
291.84	1.0000	13.504	0.074050	19.510	19.584	0.094388	0.077662	0.12906	499.23	0.044233
297.47	1.0000	0.49738	2.0105	34.177	36.187	0.15075	0.073268	0.097199	155.15	23.442
300.00	1.0000	0.48865	2.0465	34.384	36.431	0.15156	0.072744	0.095419	156.77	22.566
400.00	1.0000	0.31821	3.1425	42.101	45.244	0.17694	0.078067	0.089213	198.26	7.9701
500.00	1.0000	0.24608	4.0637	50.576	54.639	0.19786	0.089416	0.099001	225.88	4.0390
300.00	5.0000	13.412	0.074559	20.240	20.613	0.096862	0.078093	0.12762	507.10	0.027202
400.00	5.0000	2.1880	0.45703	39.458	41.743	0.15675	0.086188	0.12964	161.10	8.5257
500.00	5.0000	1.3504	0.74050	49.289	52.992	0.18193	0.091753	0.10811	213.00	3.9036
300.00	10.000	13.740	0.072780	19.898	20.626	0.095679	0.077756	0.12301	558.94	–0.063246
400.00	10.000	7.1029	0.14079	34.426	35.834	0.13888	0.090433	0.20031	184.71	3.3408
500.00	10.000	2.9957	0.33381	47.547	50.885	0.17282	0.094263	0.12254	207.67	3.3327
300.00	25.000	14.443	0.069238	19.146	20.877	0.092972	0.077634	0.11624	672.43	–0.19834
400.00	25.000	10.899	0.091752	30.990	33.284	0.12855	0.087056	0.13223	399.92	0.28513
500.00	25.000	7.3363	0.13631	43.479	46.886	0.15889	0.096319	0.13592	289.22	0.97116
300.00	50.000	15.220	0.065703	18.302	21.587	0.089730	0.078160	0.11176	802.78	–0.28843
400.00	50.000	12.648	0.079064	29.255	33.209	0.12310	0.087179	0.12077	579.57	–0.12975
500.00	50.000	10.260	0.097468	40.787	45.660	0.15086	0.096753	0.12761	457.54	0.047330

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., "Pseudo Pure-Fluid Equations of State for the Refrigerant Blends R-410A, R-404A, R-507A, and R-407C," *Int. J. Thermophys.* **24**(4):991–1006, 2003. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the critical point temperature are given in the last entry of the saturation tables. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The estimated uncertainty of density values calculated with the equation of state is 0.1%. The estimated uncertainty of calculated heat capacities and speed of sound values is 0.5%. Uncertainties of bubble and dew point pressures are 0.5%.

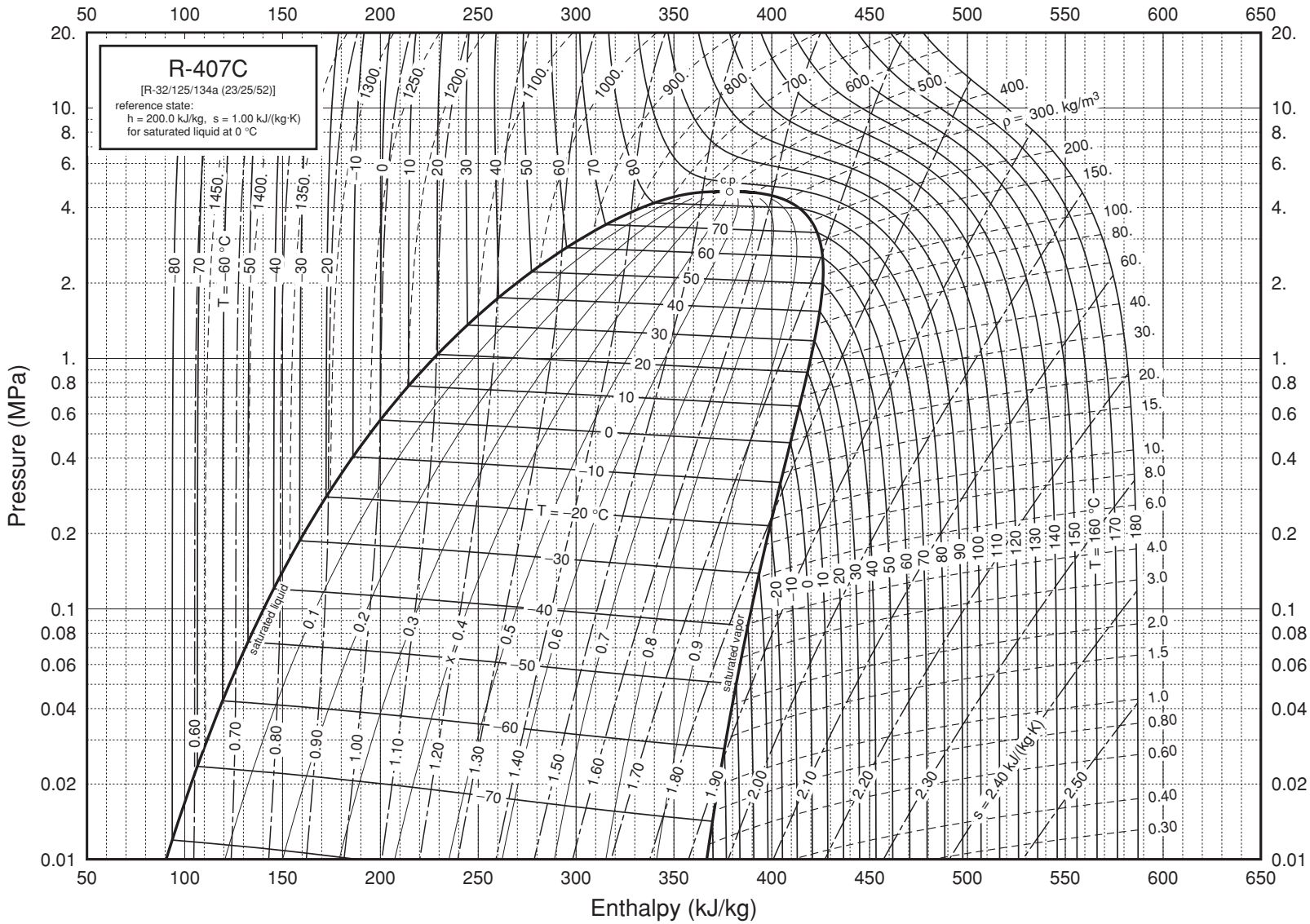

FIG. 2-27 Pressure-enthalpy diagram for Refrigerant 407C. Properties computed with the NIST REFPROP Database, Version 7.0 (Lemmon, E. W., McLinden, M. O., and Huber, M. L., 2002, NIST Standard Reference Database 23, NIST Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, Standard Reference Data Program, National Institute of Standards and Technology), based on the mixture model of Lemmon, E. W., and Jacobsen, R. T., "Equations of State for Mixtures of R-32, R-125, R-134a, R-143a, and R-152a," *J. Phys. Chem. Ref. Data* **33**:593–620, 2004.

TABLE 2-290 Thermodynamic Properties of R-410A

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
200.00	0.029160	19.510	0.051256	7.0380	7.0395	0.040995	0.062260	0.097942	929.01	–0.30179
210.00	0.053727	19.093	0.052375	8.0188	8.0217	0.045781	0.062050	0.098396	879.84	–0.28524
215.00	0.071143	18.881	0.052962	8.5112	8.5149	0.048098	0.062014	0.098729	855.20	–0.27544
220.00	0.092819	18.667	0.053571	9.0052	9.0101	0.050370	0.062020	0.099138	830.52	–0.26446
225.00	0.11946	18.449	0.054202	9.5012	9.5077	0.052600	0.062066	0.099628	805.81	–0.25217
230.00	0.15182	18.229	0.054858	9.9997	10.008	0.054791	0.062151	0.10020	781.06	–0.23841
235.00	0.19070	18.005	0.055542	10.501	10.512	0.056948	0.062271	0.10088	756.26	–0.22300
240.00	0.23697	17.776	0.056255	11.006	11.019	0.059073	0.062426	0.10165	731.41	–0.20574
245.00	0.29152	17.543	0.057002	11.514	11.530	0.061169	0.062615	0.10253	706.48	–0.18637
250.00	0.35531	17.305	0.057786	12.026	12.047	0.063240	0.062837	0.10353	681.45	–0.16459
255.00	0.42933	17.062	0.058611	12.543	12.568	0.065289	0.063092	0.10466	656.31	–0.14006
260.00	0.51461	16.812	0.059482	13.065	13.096	0.067318	0.063380	0.10594	631.02	–0.11232
265.00	0.61223	16.555	0.060406	13.593	13.630	0.069331	0.063701	0.10738	605.55	–0.080861
270.00	0.72330	16.290	0.061388	14.127	14.172	0.071331	0.064057	0.10902	579.88	–0.045000
275.00	0.84899	16.016	0.062439	14.669	14.722	0.073321	0.064451	0.11088	553.95	–0.0039006
280.00	0.99048	15.732	0.063567	15.218	15.281	0.075304	0.064884	0.11300	527.72	0.043515
285.00	1.1490	15.436	0.064785	15.776	15.851	0.077284	0.065363	0.11543	501.14	0.098651
290.00	1.3260	15.127	0.066109	16.344	16.432	0.079266	0.065893	0.11825	474.14	0.16337
295.00	1.5226	14.802	0.067559	16.924	17.026	0.081254	0.066483	0.12156	446.66	0.24022
300.00	1.7404	14.459	0.069160	17.516	17.636	0.083253	0.067147	0.12550	418.60	0.33275
305.00	1.9809	14.095	0.070948	18.123	18.263	0.085270	0.067901	0.13029	389.87	0.44607
310.00	2.2456	13.704	0.072969	18.747	18.911	0.087314	0.068773	0.13630	360.33	0.58788
315.00	2.5364	13.282	0.075293	19.392	19.583	0.089398	0.069800	0.14413	329.82	0.77028
320.00	2.8550	12.816	0.078025	20.064	20.287	0.091537	0.071046	0.15493	298.10	1.0135
325.00	3.2037	12.294	0.081343	20.772	21.032	0.093762	0.072616	0.17109	264.83	1.3544
330.00	3.5848	11.685	0.085578	21.531	21.837	0.096123	0.074717	0.19853	229.46	1.8665
335.00	4.0009	10.930	0.091491	22.376	22.742	0.098732	0.077843	0.25685	190.98	2.7232
340.00	4.4556	9.8413	0.10161	23.414	23.867	0.10194	0.083650	0.46832	147.49	4.4554
344.49	4.9012	6.3240	0.15813	25.988	26.763	0.11022			0	9.7623
200.00	0.029010	0.017797	56.190	26.495	28.125	0.14644	0.042482	0.052236	164.41	113.67
210.00	0.053489	0.031567	31.678	26.835	28.530	0.14345	0.044604	0.055055	167.03	90.100
215.00	0.070844	0.041089	24.338	27.002	28.726	0.14212	0.045719	0.056590	168.16	80.508
220.00	0.092447	0.052763	18.953	27.167	28.919	0.14087	0.046862	0.058205	169.16	72.155
225.00	0.11900	0.066925	14.942	27.329	29.107	0.13972	0.048026	0.059899	170.03	64.889
230.00	0.15125	0.083936	11.914	27.488	29.290	0.13864	0.049206	0.061674	170.75	58.571
235.00	0.19000	0.10420	9.5972	27.645	29.468	0.13762	0.050400	0.063533	171.32	53.077
240.00	0.23611	0.12814	7.8039	27.798	29.640	0.13667	0.051603	0.065483	171.73	48.299
245.00	0.29049	0.15625	6.4000	27.947	29.806	0.13577	0.052814	0.067535	171.97	44.137
250.00	0.35407	0.18905	5.2895	28.092	29.965	0.13492	0.054033	0.069705	172.04	40.508
255.00	0.42786	0.22714	4.4026	28.232	30.116	0.13411	0.055260	0.072011	171.93	37.336
260.00	0.51287	0.27117	3.6877	28.367	30.258	0.13333	0.056497	0.074481	171.62	34.560
265.00	0.61019	0.32190	3.1066	28.496	30.392	0.13259	0.057747	0.077148	171.11	32.123
270.00	0.72092	0.38018	2.6303	28.619	30.515	0.13187	0.059014	0.080057	170.39	29.979
275.00	0.84622	0.44702	2.2371	28.733	30.626	0.13116	0.060302	0.083265	169.45	28.087
280.00	0.98729	0.52357	1.9100	28.839	30.725	0.13047	0.061618	0.086846	168.27	26.412
285.00	1.1454	0.61123	1.6360	28.935	30.809	0.12978	0.062969	0.090901	166.84	24.924
290.00	1.3218	0.71170	1.4051	29.019	30.876	0.12908	0.064364	0.095568	165.16	23.598
295.00	1.5179	0.82707	1.2091	29.090	30.925	0.12837	0.065814	0.10104	163.20	22.410
300.00	1.7351	0.95997	1.0417	29.144	30.951	0.12764	0.067335	0.10760	160.94	21.338

305.00	1.9749	1.1138	0.89779	29.178	30.951	0.12688	0.068945	0.11566	158.36	20.365
310.00	2.2390	1.2933	0.77322	29.189	30.920	0.12606	0.070671	0.12589	155.44	19.470
315.00	2.5291	1.5048	0.66456	29.170	30.850	0.12517	0.072551	0.13943	152.13	18.632
320.00	2.8472	1.7576	0.56894	29.112	30.732	0.12418	0.074643	0.15831	148.40	17.826
325.00	3.1955	2.0668	0.48384	29.002	30.548	0.12305	0.077041	0.18670	144.16	17.018
330.00	3.5766	2.4582	0.40681	28.817	30.272	0.12169	0.079915	0.23464	139.30	16.153
335.00	3.9935	2.9848	0.33503	28.510	29.848	0.11995	0.083629	0.33370	133.59	15.123
340.00	4.4504	3.7974	0.26334	27.951	29.123	0.11740	0.089197	0.65947	126.39	13.641
344.49	4.9012	6.3240	0.15813	25.988	26.763	0.11022			0	9.7623
Single-Phase Properties										
221.45	0.10000	18.604	0.053751	9.1488	9.1541	0.051020	0.062030	0.099271	823.36	–0.26104
221.53	0.10000	0.056810	17.603	27.217	28.977	0.14051	0.047215	0.058714	169.44	69.827
300.00	0.10000	0.040605	24.628	31.028	33.491	0.15794	0.050980	0.059877	198.35	19.643
400.00	0.10000	0.030202	33.111	36.670	39.981	0.17654	0.061554	0.070067	227.37	7.7467
500.00	0.10000	0.024099	41.495	43.331	47.480	0.19323	0.071249	0.079663	252.59	4.0758
280.32	1.0000	15.713	0.063641	15.253	15.317	0.075429	0.064913	0.11314	526.05	0.046760
280.42	1.0000	0.53054	1.8849	28.848	30.733	0.13041	0.061731	0.087169	168.16	26.279
300.00	1.0000	0.46599	2.1460	30.151	32.297	0.13580	0.057548	0.075210	180.65	20.254
400.00	1.0000	0.31478	3.1769	36.304	39.481	0.15648	0.062713	0.073258	220.92	7.7768
500.00	1.0000	0.24505	4.0808	43.106	47.187	0.17364	0.071665	0.081012	249.79	4.0343
300.00	5.0000	14.870	0.067248	17.202	17.539	0.082188	0.066139	0.11773	472.56	0.17344
400.00	5.0000	1.9755	0.50621	34.349	36.880	0.13813	0.068570	0.097588	192.34	7.6786
500.00	5.0000	1.3185	0.75845	42.072	45.864	0.15821	0.073521	0.087959	239.51	3.7957
300.00	10.000	15.342	0.065180	16.830	17.482	0.080897	0.065435	0.11125	533.86	0.036775
400.00	10.000	5.7949	0.17257	30.845	32.570	0.12363	0.074099	0.16518	182.45	5.0121
500.00	10.000	2.8642	0.34914	40.710	44.202	0.14982	0.075667	0.098492	233.93	3.3106
300.00	25.000	16.289	0.061392	16.058	17.592	0.078110	0.065000	0.10273	658.09	–0.14678
400.00	25.000	11.685	0.085582	26.530	28.670	0.10987	0.072157	0.11830	379.59	0.50709
500.00	25.000	7.4115	0.13493	37.197	40.570	0.13644	0.078574	0.11515	291.31	1.2724
300.00	50.000	17.287	0.057845	15.231	18.123	0.074923	0.065499	0.097459	792.80	–0.26163
400.00	50.000	14.049	0.071182	24.722	28.281	0.10409	0.072480	0.10533	566.13	–0.063564
500.00	50.000	11.128	0.089864	34.526	39.019	0.12804	0.079657	0.10880	449.76	0.13566

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., "Pseudo Pure-Fluid Equations of State for the Refrigerant Blends R-410A, R-404A, R-507A, and R-407C," *Int. J. Thermophys.* **24**(4):991–1006, 2003. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the critical point temperature are given in the last entry of the saturation tables. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The estimated uncertainty of density values calculated with the equation of state is 0.1%. The estimated uncertainty of calculated heat capacities and speed of sound values is 0.5%. Uncertainties of bubble and dew point pressures are 0.5%.

TABLE 2-291 Saturated Refrigerant 500*

T, K	P, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)	μ_f, 10^{-4} Pa·s	k_f, W/(m·K)
200	0.1219	6.966.–4	1.360	–29.56	185.87	–0.1363	0.9408	1.044	6.11	0.113
210	0.2258	7.090.–4	0.766	–21.03	191.25	–0.0948	0.9161	1.018	5.15	0.109
220	0.3936	7.222.–4	0.457	–12.17	196.63	–0.0536	0.8955	0.997	4.42	0.106
230	0.6511	7.361.–4	0.286	–2.97	201.96	–0.0130	0.8782	0.987	3.85	0.102
240	1.0291	7.509.–4	0.187	6.58	207.23	0.0277	0.8638	0.987	3.42	0.098
250	1.5632	7.668.–4	0.1261	16.50	212.40	0.0680	0.8517	0.997	3.04	0.094
260	2.2932	7.839.–4	0.0879	26.78	217.45	0.1082	0.8415	1.017	2.74	0.090
270	3.2624	8.024.–4	0.0628	37.44	222.35	0.1481	0.8329	1.048	2.48	0.086
280	4.5172	8.226.–4	0.0459	48.48	227.06	0.1878	0.8257	1.089	2.26	0.082
290	6.1064	8.450.–4	0.0342	59.91	231.56	0.2275	0.8194	1.140	2.08	0.078
300	8.0809	8.699.–4	0.0259	71.76	235.79	0.2671	0.8139	1.201	1.92	0.074
310	10.49	8.981.–4	0.0198	84.05	239.69	0.3067	0.8088	1.273	1.77	0.070
320	13.40	9.306.–4	0.0154	96.83	243.19	0.3464	0.8038	1.355	1.63	0.066
330	16.86	9.690.–4	0.0119	110.17	246.14	0.3864	0.7985	1.447	1.48	0.062
340	20.93	1.016.–3	0.0093	124.20	248.36	0.4271	0.7922	1.550	1.34	0.058
350	25.70	1.077.–3	0.0072	139.18	249.47	0.4689	0.7841	1.663		
360	31.25	1.162.–3	0.0055	155.66	248.71	0.5135	0.7721	1.919		
370	37.72	1.307.–3	0.0040	175.59	244.26	0.5650	0.7509	2.07		
378.6[c]	44.26	2.012.–3	0.0020	219.50	219.50	0.6729	0.6729	∞		

*Values reproduced and converted from Table 12, p. 17.99, *ASHRAE Handbook, 1981: Fundamentals,* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, 1981. Copyright material. Reproduced by permission of the copyright owner. c = critical point. The notation 6.966.–4 signifies 6.966×10^{-4}.

The 1993 ASHRAE *Handbook—Fundamentals* (SI ed.) gives material for integral degrees Celsius with temperatures on the IPTS 68 scale from –70 to 105.60 °C. The thermodynamic diagram from 0.1 to 70 bar extends to 240 °C. Equations and constants approximated to the 1985 ASHRAE tables were given by Mecaryk, K. and M. Masaryk, *Heat Recovery Systems and CHP,* **11,** 2/3 (1991): 193–197. Saturation and superheat tables and a diagram to 80 bar, 560 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.,* Stanford Univ. publ., 1979 (173 pp.). Tables and a chart to 1000 psia, 480 °F are given by Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants,* ASHRAE, Atlanta, GA, 1986 (521 pp.). Specific heat and viscosity appear in *Thermophysical Properties of Refrigerants,* ASHRAE, 1993.

TABLE 2-292 Saturated Refrigerant 502*

T, K	P, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)	μ_f, 10^{-4} Pa·s	k_f, W/(m·K)
200	0.2274	6.381.–4	0.646	–29.04	153.34	–0.1337	0.7782	1.018	5.72	0.103
210	0.4098	6.507.–4	0.374	–20.83	158.42	–0.0937	0.7599	1.036	4.88	0.099
220	0.6965	6.640.–4	0.228	–12.15	163.49	–0.0534	0.7449	1.055	4.23	0.095
230	1.1251	6.783.–4	0.146	–2.99	168.50	–0.0128	0.7328	1.075	3.71	0.091
240	1.7392	6.938.–4	0.0969	6.66	173.42	0.0280	0.7228	1.097	3.28	0.087
250	2.5867	7.105.–4	0.0665	16.78	178.20	0.0691	0.7148	1.120	2.94	0.083
260	3.7188	7.289.–4	0.0470	27.36	182.81	0.1102	0.7082	1.144	2.65	0.079
270	5.1893	7.492.–4	0.0340	38.36	187.21	0.1514	0.7027	1.170	2.41	0.075
280	7.0530	7.720.–4	0.0251	49.77	191.35	0.1923	0.6980	1.197	2.18	0.072
290	9.3660	7.979.–4	0.0188	61.55	195.16	0.2330	0.6937	1.225	1.99	0.068
300	12.19	8.280.–4	0.0143	73.68	198.56	0.2734	0.6896	1.254	1.79	0.064
310	15.57	8.637.–4	0.0109	86.17	201.43	0.3134	0.6852	1.285	1.59	0.060
320	19.60	9.081.–4	0.0084	99.06	203.57	0.3532	0.6798	1.317	1.40	0.056
330	24.35	9.666.–4	0.0064	112.53	204.62	0.3933	0.6723	1.351	1.23	0.052
340	29.95	1.053.–3	0.0048	127.13	203.71	0.4351	0.6604	1.386	1.07	0.048
350	36.62	1.220.–3	0.0033	145.44	197.82	0.4859	0.6355	1.422	0.93	0.044
355.3[c]	40.75	1.786.–3	0.0018	174.00	174.00	0.5634	0.5634			

*Values reproduced and converted from Table 13, p. 17.101, *ASHRAE Handbook, 1981: Fundamentals,* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, 1981. Copyright material. Reproduced by permission of the copyright owner. c = critical point. The notation 6.381.–4 signifies 6.381×10^{-4}.

The 1993 ASHRAE *Handbook—Fundamentals* (SI ed.) gives material for integral degrees Celsius with temperatures on the IPTS 68 scale from –70 to 82.2 °C. The thermodynamic diagram from 0.1 to 80 bar extends to 180 °C. Equations and constants approximated to 1985 ASHRAE tables are given by Mecaryk, K., and M. Masaryk, *Heat Recovery Systems and CHP,* **11,** 2/3 (1991): 193–197. Saturation and superheat tables and a diagram to 20 bar, 515 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.,* Stanford Univ. publ., 1979 (173 pp.). Tables and a chart to 1000 psia, 400 °F appear in Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants,* ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat and viscosity, see *Thermophysical Properties of Refrigerants,* ASHRAE, 1993.

TABLE 2-293 Saturated Refrigerant 503*

T, K	P, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)	μ_f, 10^{-4} Pa·s	k_f, W/(m·K)
150	0.0750	6.384.–4	1.894	–89.60	111.02	–0.4694	0.8681	0.482	6.12	0.128
160	0.1798	6.478.–4	0.837	–79.73	115.40	–0.4057	0.8139	0.554	5.05	0.123
170	0.3828	6.585.–4	0.414	–69.55	119.70	–0.3441	0.7691	0.620	4.16	0.116
180	0.7395	6.700.–4	0.224	–59.08	123.84	–0.2844	0.7318	0.682	3.43	0.111
190	1.3187	6.850.–4	0.130	–48.36	127.77	–0.2267	0.7003	0.747	2.94	0.105
200	2.1999	7.014.–4	0.0803	–37.45	131.45	–0.1710	0.6735	0.817	2.56	0.099
210	3.4713	7.204.–4	0.0520	–26.36	134.84	–0.1173	0.6503	0.896	2.25	0.094
220	5.2281	7.426.–4	0.0350	–15.10	137.87	–0.0656	0.6298	0.988	1.98	0.088
230	7.5713	7.687.–4	0.0242	– 3.65	140.49	–0.0155	0.6112	1.017	1.73	0.082
240	10.61	8.001.–4	0.0172	8.07	142.58	0.0334	0.5939	1.227	1.52	0.076
250	14.46	8.386.–4	0.0124	20.22	143.98	0.0817	0.5767	1.382	1.33	0.070
260	19.25	8.874.–4	0.0090	33.10	144.38	0.1305	0.5585	1.57	1.17	0.065
270	25.13	9.526.–4	0.0064	47.22	143.23	0.1816	0.5373	1.79	1.03	0.059
280	32.27	1.050.–3	0.0045	63.64	139.25	0.2384	0.5085	2.03	0.91	0.054
290	40.87	1.264.–3	0.0028	86.41	127.51	0.3131	0.4548	2.35		
292.6[c]	43.57	1.773.–3	0.0018	110.20	110.20	0.3864	0.3864	∞		∞

*P, v, h, and s values reproduced and converted from Table 14, p. 17.103, *ASHRAE Handbook, 1981: Fundamentals*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, 1981. Copyright material. Reproduced by permission of the copyright owner. c_p, μ, and k values interpolated and converted from *Thermophysical Properties of Refrigerants*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, New York, 1976. c = critical point. The notation 6.384.–4 signifies 6.384×10^{-4}.

Saturation and superheat tables and a diagram to 80 bar, 600 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.). Tables and a chart to 1000 psia, 460 °F are given by Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat and viscosity see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993. The 1993 ASHRAE *Handbook—Fundamentals* (SI ed.) gives material for integral degrees Celsius with temperatures on the IPTS 68 scale for saturation conditions from –125 to 19.50 °C. The thermodynamic diagram from 0.1 to 80 bar extends to 220 °C.

TABLE 2-294 Saturated Refrigerant 504*

Temp., °F	Pressure, lb/in² abs.	Volume, ft³/lb		Enthalpy, Btu/lb		Entropy, Btu/(lb)(°F)	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
–120	2.964	0.01095	15.31	–21.48	86.69	–0.0565	0.2609
–100	6.042	0.01119	7.874	–16.39	89.31	–0.0420	0.2519
–80	11.34	0.01146	4.372	–11.12	91.84	–0.0277	0.2435
–60	19.85	0.01175	2.585	–5.65	94.25	–0.0137	0.2362
–40	32.76	0.01206	1.609	0.00	96.50	0.0000	0.2299
–20	51.44	0.01242	1.045	5.85	98.58	0.0135	0.2244
0	77.41	0.01282	0.7029	11.91	100.45	0.0269	0.2195
20	112.3	0.01328	0.4859	18.22	102.09	0.0401	0.2150
40	158.0	0.01379	0.3431	24.81	103.44	0.0533	0.2107
60	216.2	0.01443	0.2458	31.78	104.41	0.0667	0.2065
80	289.2	0.01522	0.1773	39.25	104.85	0.0804	0.2020
100	379.1	0.01629	0.1274	47.43	104.49	0.0948	0.1968
120	488.3	0.01783	0.0893	56.78	102.72	0.1107	0.1899
140	618.1	0.02083	0.0578	69.97	97.70	0.1322	0.1784
150	692.2	0.02597	0.0394	76.96	89.76	0.1432	0.1642

*Unpublished data of Allied Chemical Company, 1970. Used by permission.

TABLE 2-295 Thermodynamic Properties of Refrigerant 507*

Temp., K	Pressure, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)
230.5	1.013	0.000 574	0.1280	–3.1	143.3	–0.015	0.620
240	1.59	0.000 602	0.0826	10.3	150.2	0.042	0.623
250	2.42	0.000 627	0.0546	22.6	154.5	0.092	0.619
260	3.54	0.000 658	0.0377	37.6	159.0	0.149	0.617
270	4.95	0.000 695	0.0270	51.6	163.8	0.202	0.618
280	6.70	0.000 738	0.0198	64.7	169.0	0.250	0.620
290	8.85	0.000 787	0.0148	77.2	174.6	0.295	0.634
300	11.52	0.000 839	0.0112	89.4	180.3	0.336	0.640
310	14.74	0.000 903	0.0084	101.6	185.4	0.378	0.648
320	18.76	0.001 006	0.0062	115.7	188.6	0.422	0.649
330	23.65	0.001 221	0.0042	135.5	189.3	0.481	0.641
340	29.57	0.001 618	0.0025	161.7	179.9	0.557	0.611
341.5[c]	32.67	0.001 97	0.0020	172.7	172.7	0.590	0.590

*Azeotropic mixture of R152a and R218. $h_f = s_f = 0$ at 233.15 K = –40 °C. Interpolated, extrapolated and converted from Lavrenchenko, G. K., M. G. Khmelnuk, et al., *Int. J. Refrig.*, **17,** 7 (1994): 461. Some values are tentative. This source also gives a ln P–h diagram from 0.6 to 30 bar, –50 to 70 °C. Differences exist between the published diagram and tables. c = critical point.

TABLE 2-296 Thermodynamic Properties of R-507A

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
200.00	0.023233	14.130	0.070772	10.553	10.555	0.059915	0.077250	0.11931	851.53	–0.34068
210.00	0.042731	13.828	0.072318	11.749	11.752	0.065751	0.078412	0.12015	796.42	–0.32336
215.00	0.056515	13.675	0.073126	12.351	12.355	0.068583	0.079028	0.12081	770.28	–0.31246
220.00	0.073637	13.521	0.073961	12.956	12.962	0.071366	0.079658	0.12158	744.80	–0.30008
225.00	0.094634	13.365	0.074825	13.566	13.573	0.074104	0.080295	0.12247	719.84	–0.28620
230.00	0.12008	13.206	0.075722	14.179	14.188	0.076802	0.080939	0.12345	695.27	–0.27072
235.00	0.15060	13.045	0.076655	14.798	14.809	0.079463	0.081589	0.12453	671.01	–0.25349
240.00	0.18683	12.882	0.077628	15.421	15.436	0.082089	0.082245	0.12569	646.97	–0.23433
245.00	0.22945	12.715	0.078646	16.051	16.069	0.084685	0.082907	0.12696	623.07	–0.21297
250.00	0.27919	12.545	0.079714	16.686	16.708	0.087253	0.083579	0.12833	599.27	–0.18910
255.00	0.33679	12.371	0.080837	17.328	17.355	0.089796	0.084260	0.12982	575.51	–0.16232
260.00	0.40302	12.192	0.082022	17.976	18.009	0.092316	0.084954	0.13144	551.75	–0.13214
265.00	0.47868	12.008	0.083277	18.632	18.672	0.094817	0.085661	0.13321	527.94	–0.097937
270.00	0.56461	11.819	0.084612	19.296	19.344	0.097301	0.086385	0.13517	504.05	–0.058916
275.00	0.66165	11.623	0.086039	19.968	20.025	0.099772	0.087128	0.13735	480.04	–0.014071
280.00	0.77071	11.419	0.087571	20.650	20.718	0.10223	0.087895	0.13978	455.86	0.037902
285.00	0.89272	11.208	0.089225	21.343	21.422	0.10469	0.088688	0.14254	431.49	0.098716
290.00	1.0286	10.986	0.091024	22.046	22.140	0.10714	0.089513	0.14571	406.87	0.17067
295.00	1.1794	10.753	0.092996	22.763	22.873	0.10960	0.090377	0.14941	381.97	0.25689
300.00	1.3462	10.507	0.095177	23.495	23.623	0.11207	0.091290	0.15379	356.72	0.36179
305.00	1.5300	10.244	0.097618	24.243	24.392	0.11455	0.092263	0.15912	331.07	0.49171
310.00	1.7322	9.9616	0.10039	25.011	25.185	0.11707	0.093316	0.16577	304.91	0.65619
315.00	1.9539	9.6544	0.10358	25.803	26.006	0.11962	0.094477	0.17441	278.14	0.87027
320.00	2.1967	9.3151	0.10735	26.626	26.862	0.12224	0.095794	0.18622	250.55	1.1591
325.00	2.4622	8.9322	0.11195	27.487	27.763	0.12494	0.097351	0.20363	221.86	1.5687
330.00	2.7523	8.4856	0.11785	28.405	28.729	0.12779	0.099317	0.23262	191.54	2.1936
335.00	3.0697	7.9323	0.12607	29.412	29.799	0.13089	0.10208	0.29323	158.62	3.2672
340.00	3.4178	7.1361	0.14013	30.620	31.099	0.13460	0.10695	0.52176	121.00	5.5872
343.77	3.7049	4.9640	0.20145	32.908	33.654	0.14193			0	12.382
200.00	0.023222	0.014226	70.296	29.992	31.624	0.16527	0.059362	0.068766	137.04	85.105
210.00	0.042726	0.025154	39.755	30.526	32.225	0.16325	0.061910	0.071764	139.19	65.962
215.00	0.056512	0.032678	30.602	30.796	32.525	0.16240	0.063188	0.073318	140.11	58.876
220.00	0.073634	0.041875	23.881	31.067	32.825	0.16166	0.064473	0.074919	140.92	53.008
225.00	0.094628	0.052996	18.869	31.338	33.124	0.16100	0.065766	0.076576	141.60	48.113
230.00	0.12007	0.066313	15.080	31.610	33.420	0.16043	0.067072	0.078300	142.16	44.001
235.00	0.15057	0.082125	12.177	31.881	33.715	0.15992	0.068393	0.080105	142.57	40.521
240.00	0.18678	0.10075	9.9251	32.152	34.005	0.15947	0.069735	0.082005	142.84	37.557
245.00	0.22938	0.12256	8.1593	32.421	34.292	0.15907	0.071100	0.084017	142.95	35.013
250.00	0.27908	0.14794	6.7597	32.688	34.575	0.15872	0.072492	0.086159	142.90	32.816
255.00	0.33664	0.17732	5.6396	32.953	34.851	0.15841	0.073915	0.088453	142.67	30.909
260.00	0.40281	0.21120	4.7348	33.214	35.121	0.15814	0.075372	0.090927	142.26	29.244
265.00	0.47840	0.25014	3.9977	33.471	35.384	0.15788	0.076865	0.093613	141.66	27.785
270.00	0.56424	0.29478	3.3924	33.724	35.638	0.15765	0.078399	0.096551	140.85	26.502
275.00	0.66119	0.34585	2.8914	33.970	35.882	0.15744	0.079978	0.099795	139.83	25.372
280.00	0.77015	0.40424	2.4738	34.209	36.115	0.15723	0.081605	0.10341	138.57	24.376
285.00	0.89202	0.47097	2.1233	34.440	36.334	0.15702	0.083287	0.10750	137.08	23.500
290.00	1.0278	0.54731	1.8271	34.661	36.539	0.15680	0.085030	0.11218	135.32	22.730
295.00	1.1784	0.63483	1.5752	34.869	36.726	0.15656	0.086845	0.11764	133.29	22.057
300.00	1.3450	0.73552	1.3596	35.063	36.892	0.15630	0.088742	0.12415	130.95	21.472
305.00	1.5287	0.85197	1.1737	35.239	37.033	0.15600	0.090740	0.13211	128.30	20.967

310.00	1.7307	0.98768	1.0125	35.391	37.144	0.15565	0.092861	0.14217	125.29	20.534
315.00	1.9522	1.1475	0.87142	35.515	37.217	0.15521	0.095142	0.15545	121.90	20.163
320.00	2.1948	1.3389	0.74689	35.601	37.241	0.15467	0.097636	0.17401	118.07	19.838
325.00	2.4602	1.5733	0.63559	35.634	37.198	0.15397	0.10043	0.20216	113.77	19.531
330.00	2.7503	1.8717	0.53427	35.589	37.058	0.15303	0.10368	0.25052	108.90	19.179
335.00	3.0678	2.2784	0.43891	35.411	36.758	0.15166	0.10772	0.35438	103.35	18.634
340.00	3.4166	2.9318	0.34109	34.936	36.101	0.14932	0.11346	0.74186	96.734	17.407
343.77	3.7049	4.9640	0.20145	32.908	33.654	0.14193			0	12.382
Single-Phase Properties										
226.14	0.10000	13.329	0.075025	13.705	13.712	0.074720	0.080441	0.12268	714.23	–0.28283
226.14	0.10000	0.055821	17.915	31.400	33.191	0.16087	0.066061	0.076961	141.74	47.115
300.00	0.10000	0.040743	24.544	36.736	39.190	0.18376	0.077477	0.086497	165.13	16.625
400.00	0.10000	0.030241	33.067	45.323	48.629	0.21080	0.093474	0.10204	190.54	6.8071
500.00	0.10000	0.024113	41.472	55.366	59.514	0.23504	0.10672	0.11516	212.51	3.6966
288.99	1.0000	11.032	0.090648	21.903	21.994	0.10665	0.089344	0.14503	411.87	0.15510
289.02	1.0000	0.53150	1.8815	34.618	36.500	0.15684	0.084683	0.11121	135.69	22.873
300.00	1.0000	0.49044	2.0390	35.647	37.686	0.16087	0.084205	0.10551	142.77	19.202
400.00	1.0000	0.31937	3.1312	44.851	47.983	0.19047	0.094741	0.10601	182.55	7.0158
500.00	1.0000	0.24643	4.0580	55.070	59.128	0.21530	0.10718	0.11688	209.06	3.6962
300.00	5.0000	10.905	0.091702	23.040	23.498	0.11052	0.090271	0.14306	420.12	0.12774
400.00	5.0000	2.2078	0.45293	42.120	44.385	0.17014	0.10115	0.14483	147.77	7.5193
500.00	5.0000	1.3533	0.73892	53.669	57.364	0.19916	0.10913	0.12621	197.37	3.5221
300.00	10.000	11.289	0.088585	22.583	23.469	0.10892	0.089813	0.13611	482.39	–0.028276
400.00	10.000	6.0317	0.16579	37.890	39.548	0.15478	0.10349	0.18529	182.13	2.8871
500.00	10.000	2.9478	0.33924	51.842	55.234	0.18999	0.11096	0.13942	197.45	2.8080
300.00	25.000	12.033	0.083106	21.667	23.744	0.10556	0.089890	0.12779	608.04	–0.21781
400.00	25.000	9.2040	0.10865	34.588	37.304	0.14446	0.10218	0.14278	377.87	0.20389
500.00	25.000	6.5873	0.15181	48.091	51.887	0.17699	0.11266	0.14661	290.93	0.64689
300.00	50.000	12.796	0.078149	20.711	24.618	0.10177	0.090684	0.12322	746.86	–0.32316
400.00	50.000	10.770	0.092847	32.830	37.472	0.13868	0.10306	0.13357	554.88	–0.19407
500.00	50.000	8.9711	0.11147	45.655	51.229	0.16935	0.11396	0.14097	452.46	–0.072291

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., "Pseudo Pure-Fluid Equations of State for the Refrigerant Blends R-410A, R-404A, R-507A, and R-407C," *Int. J. Thermophys.* **24**(4):991–1006, 2003. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the critical point temperature are given in the last entry of the saturation tables. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The estimated uncertainty of density values calculated with the equation of state is 0.1%. The estimated uncertainty of calculated heat capacities and speed of sound values is 0.5%. Uncertainties of bubble and dew point pressures are 0.5%.

TABLE 2-297 Saturated Rubidium*

T, K	P, bar	v_f, m^3/kg	v_g, m^3/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)
312.7^m	2.46.–9	6.75.–4		118.7	1036	0.998	3.932	0.379
400	1.69.–6	6.98.–4	2.3.+5	151.6	1057	1.091	3.355	0.375
500	1.73.–4	7.22.–4	2790	188.8	1078	1.174	2.953	0.369
600	0.0037	7.46.–4	156.6	225.4	1096	1.241	2.692	0.362
700	0.0317	7.73.–4	20.75	261.3	1111	1.296	2.511	0.357
800	0.1584	8.10.–4	4.662	296.8	1124	1.343	2.378	0.353
1000	1.467	8.65.–4	0.605	367.6	1150	1.422	2.205	0.360
1200	6.466	9.40.–4	0.159	440.1	1179	1.490	2.104	0.385
1400	18.6	1.03.–3						
1500	28.5	1.08.–3						

*Converted from tables in Vargaftik, *Tables of the Thermophysical Properties of Liquids and Gases,* Nauka, Moscow, 1972, and Hemisphere, Washington, 1975. m = melting point. The notation 2.46.–9 signifies 2.46×10^{-9}.

Many of the Vargaftik values also appear in Ohse, R. W., *Handbook of Thermodynamic and Transport Properties of Alkali Metals,* Blackwell Sci. Pubs., Oxford, 1985 (1020 pp.). This source contains superheat data.

Saturation and superheat tables and a diagram to 40 bar, 1600 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.,* Stanford Univ. publ., 1979 (173 pp.).

For a Mollier diagram from 0.1 to 320 psia, 1200 to 2700 °R, see Weatherford, W. D., J. C. Tyler, et al., WADD-TR-61-96, 1961. An extensive review of properties of the solid and the saturated liquid was given by Alcock, C. B., M. W. Chase, et al., *J. Phys. Chem. Ref. Data,* **23,** 3 (1994): 385–497.

TABLE 2-298 Thermophysical Properties of Saturated Seawater

Temp., °C	Pressure, bar	v, $(m^3/kg)10^3$	c_p, kJ/(kg·K)	μ, Ns/m^2	k, W/(m·K)	N_{Pr}	$10^5\kappa$, 1/bar
0	0.005993	1.000158	4.000	0.001884	0.560	13.46	5.06
1	0.006438	1.000099	4.000	0.001827	0.563	12.98	5.02
2	0.006916	1.000057	4.000	0.001772	0.565	12.55	4.98
3	0.007427	1.000033	4.000	0.001720	0.567	12.13	4.95
4	0.007970	1.000025	4.001	0.001669	0.569	11.74	4.92
5	0.008548	1.000033	4.001	0.001620	0.571	11.35	4.89
6	0.009163	1.000057	4.001	0.001574	0.574	10.97	4.86
7	0.009816	1.000096	4.002	0.001529	0.576	10.62	4.83
8	0.010511	1.000149	4.002	0.001486	0.578	10.29	4.80
9	0.011248	1.000261	4.002	0.001445	0.580	9.97	4.78
10	0.01203	1.000298	4.003	0.001405	0.582	9.70	4.76
11	0.01286	1.000392	4.003	0.001367	0.584	9.37	4.74
12	0.01374	1.000500	4.003	0.001330	0.586	9.09	4.72
13	0.01467	1.000620	4.004	0.001294	0.588	8.81	4.70
14	0.01566	1.000727	4.004	0.001259	0.590	8.54	4.68
15	0.01671	1.000899	4.005	0.001226	0.592	8.29	4.66
16	0.01781	1.001055	4.005	0.001195	0.594	8.06	4.65
17	0.01898	1.001224	4.006	0.001165	0.595	7.82	4.63
18	0.02022	1.001404	4.006	0.001136	0.597	7.62	4.62
19	0.02153	1.001595	4.007	0.001107	0.599	7.41	4.60
20	0.02291	1.001796	4.007	0.001080	0.600	7.21	4.59
21	0.02437	1.002009	4.007	0.001054	0.602	7.02	4.57
22	0.02591	1.002232	4.008	0.001029	0.604	6.82	4.56
23	0.02753	1.002465	4.008	0.001005	0.605	6.66	4.55
24	0.02924	1.002708	4.009	0.000981	0.607	6.48	4.54
25	0.03104	1.002961	4.009	0.000958	0.608	6.31	4.53
26	0.03294	1.003224	4.009	0.000936	0.609	6.16	4.52
27	0.03494	1.003496	4.010	0.000915	0.611	6.01	4.51
28	0.03705	1.003778	4.010	0.000895	0.612	5.86	4.50
29	0.03926	1.004069	4.011	0.000875	0.614	5.72	4.49
30	0.04159	1.004369	4.011	0.000855	0.615	5.58	4.48

$\kappa = (-1/V)(\partial v/\partial p)_T \cdot 10^5$. Thus, at 0 °C, the compressibility is 5.06×10^{-5}/bar.

For further information see, for instance, Bromley, LeR. A., *J. Chem. Eng. Data,* **12,** 2 (1967): 202–206; **13,** 1 (1968): 60–62 and **13,** 3: 399–402; **15,** 2 (1970): 246–253; and *A.I.Ch.E.J.,* **20,** 2 (1974): 326–335.

Thermal conductivity data sources include Castelli, V. J., E. M. Stanley, et al., *Deep Sea Res.,* **211** (1974): 311–318; Levy, F. L., *Int. J. Refrig.,* **5,** 3 (1982): 155–159.

For velocity of sound, see, for instance, U.S. Naval Oceanographic Office SP 58, 1962 (50 pp.). More recent information is contained in UNESCO technical papers. See *Marine Science* No. 38, 1981 (6 pp.) and No. 44, 1983 (53 pp.).

For sea ice properties, see Fukusako, S., *Int. J. Thermophys.,* **11,** 2 (1990): 353–372.

TABLE 2-299 Saturated Sodium

Temp., K	Pressure, bar	v_f, m³/kg	v_g, m³/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/(kg·K)	s_g, kJ/(kg·K)	c_{pf}, kJ/(kg·K)	c_{pg}, kJ/(kg·K)	μ_f, 10^{-6} Pa·s	μ_g, 10^{-6} Pa·s	k_f, W/(m·K)	k_g, W/(m·K)	Pr_f	Pr_g
371	1.59.–10	0.001 078	8.54.+9	207	4739	2.259	14.475	1.383		688		89.4		0.0106	
400	1.80.–9	0.001 088	8.08.+8	247	4757	2.920	14.195	1.372	0.86	599		87.2		0.0094	
500	8.99.–7	0.001 115	1.99.+6	382	4817	3.222	12.092	1.334	1.25	415		80.1		0.0069	
600	5.57.–5	0.001 144	38022	514	4872	3.462	10.745	1.301	1.80	321		73.7		0.0057	
700	0.00105	0.001 174	2320	642	4921	3.661	10.631	1.277	2.28	264		68.0		0.0050	
800	0.00941	0.001 208	291.5	769	4966	3.830	9.076	1.260	2.59	227	19.6	62.9	0.0343	0.0045	1.48
900	0.05147	0.001 242	58.8	895	5007	3.978	8.547	1.252	2.72	201	20.6	58.3	0.0406	0.0043	1.38
1000	0.1995	0.001 280	16.6	1020	5044	4.110	8.134	1.252	2.70	181	23.0	54.2	0.0455	0.0042	1.36
1100	0.6016	0.001 323	5.95	1146	5079	4.230	7.805	1.261	2.62	166	25.3	50.5	0.0492	0.0042	1.35
1154.7	1.013	0.001 347	3.89	1215	5097	4.290	7.652	1.271	2.56	159	26.5	48.7	0.0522	0.0041	1.30
1200	1.50	0.001 366	2.54	1273	5111	4.340	7.538	1.279	2.51	153	27.5	47.2	0.0547	0.0041	1.26
1300	3.26	0.001 416	1.24	1402	5140	4.444	7.319	1.305	2.43	143	29.9	44.0	0.0570	0.0042	1.27
1400	6.30	0.001 471	0.676	1534	5168	4.542	7.138	1.340	2.39	135	32.2	41.1	0.0592	0.0044	1.30
1500	11.13	0.001 531	0.400	1671	5193	4.636	6.984	1.384	2.36	128	34.6	38.2		0.0046	
1600	18.28	0.001 597	0.253	1812	5217	4.727	6.855	1.437	2.34	122	37.1	35.4		0.0050	
1700	28.28	0.001 675	0.168	1959	5238	4.816	6.745	1.500	2.41	117		32.6		0.0054	
1800	41.61	0.001 761	0.117	2113	5256	4.904	6.650	1.574	2.46	112		29.7		0.0059	
1900	58.70	0.001 862	0.084	2274	5268	4.992	6.568	1.661	2.53	108		26.6		0.0067	
2000	79.91	0.001 984	0.063	2444	5273	5.079	6.494	1.764	2.66	104		23.2		0.0079	
2100	105.5	0.002 174	0.0472	2625	5265			1.926	2.91						
2200	135.7	0.002 320	0.0361	2822	5241			2.190	3.40						
2300	170.6	0.002 584	0.0275	3047	5188			2.690	4.47						
2400	210.3	0.002 985	0.0203	3331	5078			4.012	8.03						
2500	254.7	0.004 19	0.0098	3965	4617			39.3	417.						
2503.7[c]	256.4	0.004 57	0.0046	4294	4294										

c = critical point.

s_f values converted from Cordfunke, E. H. P. and R. J. M. Konings, *Thermochemical Data for Reactor Materials and Fission Products,* North Holland Elsevier, NY, 1990. s_g determined as $s_f + (h_g - h_f)/T$. μ_g and k_g values estimated by P. E. Liley. All other values are from Fink, J. K. and L. Leibowitz, Argonne Nat. Lab Rept. ANL/RE-95-2, 1995. The Fink and Leibowitz work also appeared in *High Temp. Materials Sci.,* **35,** 65–103, 1996. Saturation and superheat tables and a diagram to 14 bar, 1700 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.,* Stanford Univ. publ., 1979 (173 pp.). For a Mollier diagram for 0.1–150 psia, 1500–2700 °R, see Weatherford, P. M., J. C. Tyler, et al., WADD-TR-61-96, 1961.

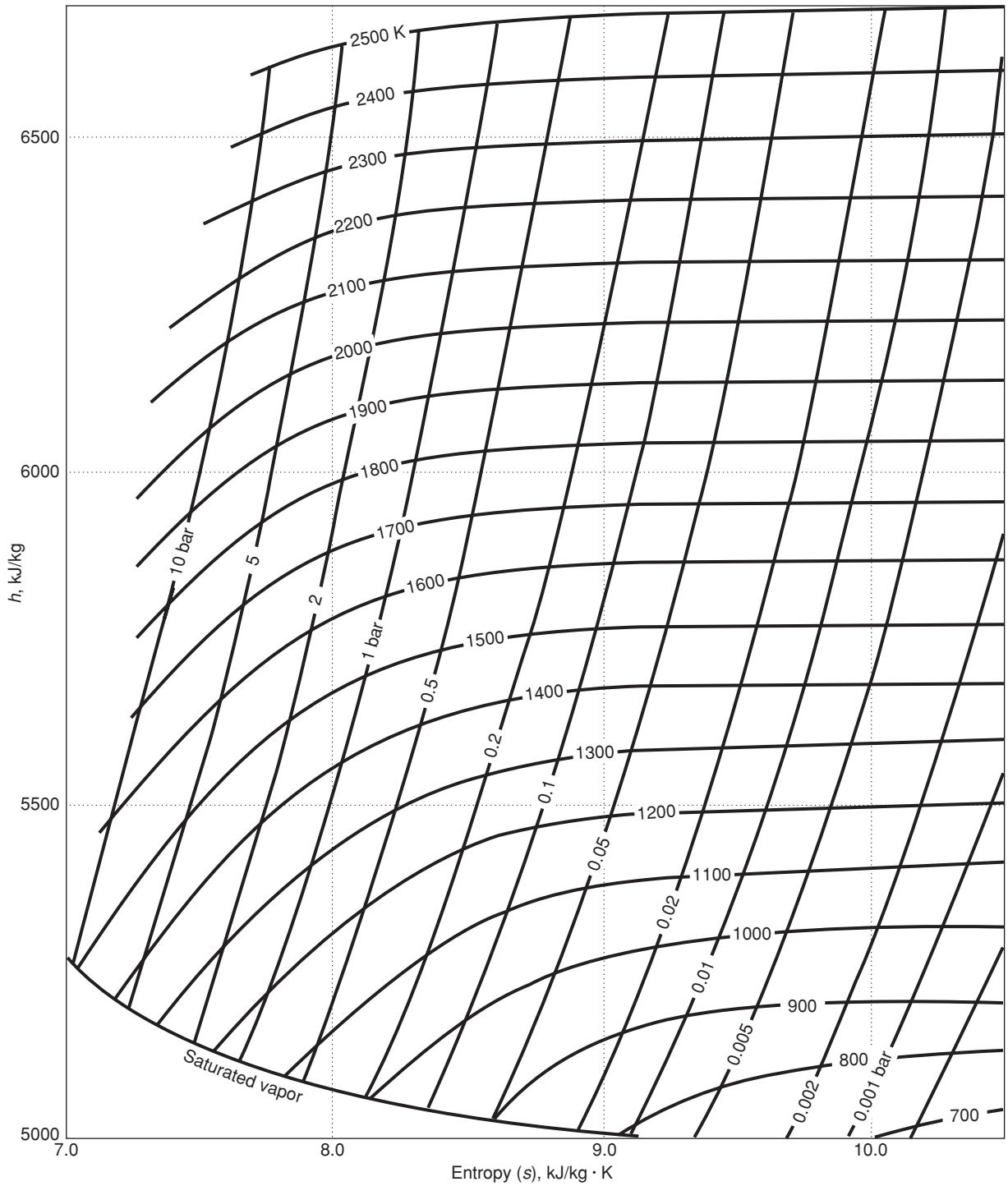

FIG. 2-28 Mollier Diagram for Sodium. Drawn from the Vargaftik et al. values in Ohse, R. W., *Handbook of Thermodynamic and Transport Properties of Alkali Metals,* Blackwell Sci. Pubs., Oxford, UK, 1985. These values are identical with those of Vargaftik, N. B., *Handbook of Thermophysical Properties of Gases and Liquids,* Moscow, 1972, and the Hemisphere translation, p. 19. An apparent discontinuity exists between the superheat values and the saturation values, not reproduced here. For a Mollier diagram in f.p.s. units from 0.1 to 150 psia, 1500 to 2700°R, see Fig. 3-36, p. 3-232 of the 6th edition of this handbook. An extensive review of properties of the solid and the saturated liquid was given by Alcock, C. B., Chase, M. W. et al., *J. Phys. Chem. Ref. Data,* **23**(3), 385–497, 1994.

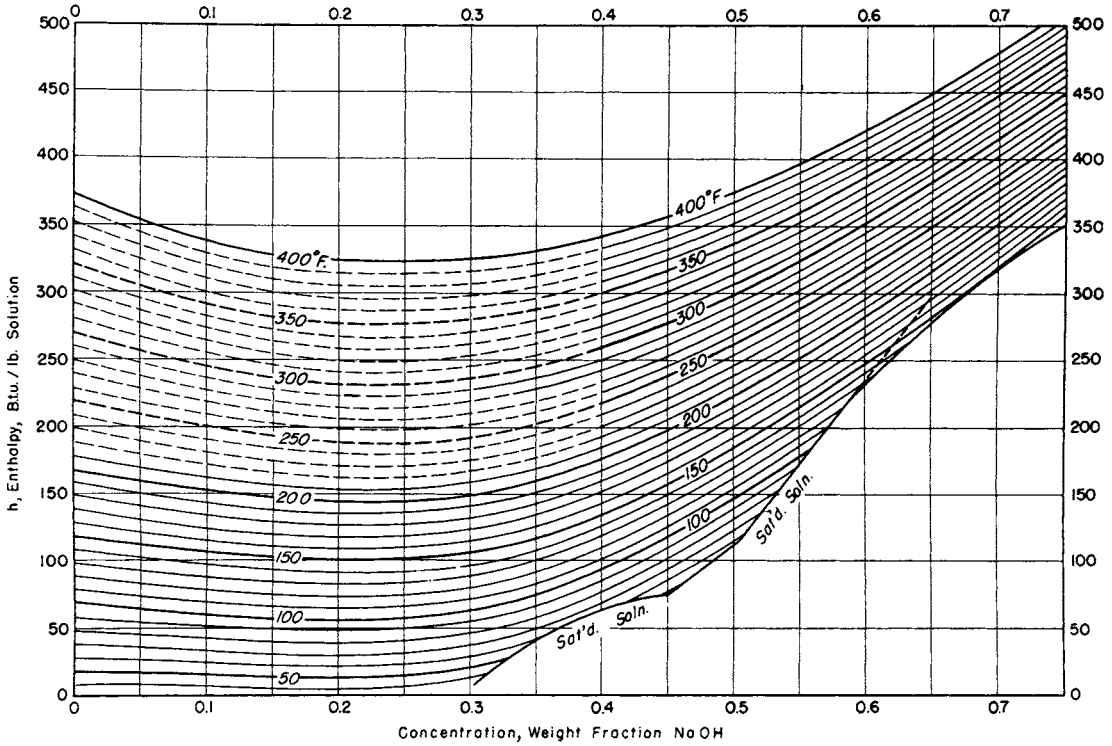

FIG. 2-29 Enthalpy-concentration diagram for aqueous sodium hydroxide at 1 atm. Reference states: enthalpy of liquid water at 32 °F and vapor pressure is zero; partial molal enthalpy of infinitely dilute NaOH solution at 64 °F and 1 atm is zero. [*McCabe,* Trans. Am. Inst. Chem. Eng., ***31,*** *129 (1935).*]

TABLE 2-300 Thermodynamic Properties of Sulfur Dioxide

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
					Saturated Properties					
197.70	0.0016602	25.290	0.039541	–5.7212	–5.7211	–0.024986	0.056222	0.088123	1361.6	–0.31925
200.00	0.0020260	25.205	0.039674	–5.5186	–5.5185	–0.023967	0.056094	0.088031	1350.1	–0.31864
210.00	0.0045390	24.835	0.040265	–4.6402	–4.6400	–0.019681	0.055527	0.087673	1301.1	–0.31528
220.00	0.0093340	24.463	0.040878	–3.7650	–3.7646	–0.015610	0.054955	0.087396	1253.3	–0.31064
230.00	0.017835	24.088	0.041514	–2.8921	–2.8914	–0.011730	0.054393	0.087214	1206.4	–0.30450
240.00	0.031988	23.709	0.042179	–2.0207	–2.0194	–0.0080208	0.053849	0.087137	1160.3	–0.29665
250.00	0.054309	23.324	0.042875	–1.1497	–1.1473	–0.0044649	0.053331	0.087177	1114.8	–0.28683
260.00	0.087910	22.932	0.043608	–0.27785	–0.27402	–0.0010454	0.052843	0.087344	1069.7	–0.27473
270.00	0.13649	22.532	0.044382	0.59591	0.60197	0.0022525	0.052388	0.087651	1024.9	–0.26000
280.00	0.20431	22.122	0.045204	1.4729	1.4821	0.0054424	0.051969	0.088112	980.26	–0.24217
290.00	0.29614	21.701	0.046081	2.3545	2.3682	0.0085368	0.051587	0.088748	935.65	–0.22070
300.00	0.41725	21.267	0.047021	3.2423	3.2619	0.011547	0.051243	0.089582	890.99	–0.19485
310.00	0.57327	20.818	0.048035	4.1378	4.1653	0.014485	0.050938	0.090647	846.15	–0.16370
320.00	0.77025	20.352	0.049136	5.0430	5.0809	0.017362	0.050675	0.091988	801.04	–0.12603
330.00	1.0145	19.865	0.050340	5.9601	6.0112	0.020187	0.050455	0.093668	755.54	–0.080167
340.00	1.3128	19.354	0.051670	6.8916	6.9594	0.022972	0.050281	0.095777	709.53	–0.023832
350.00	1.6720	18.814	0.053153	7.8408	7.9296	0.025730	0.050157	0.098448	662.87	0.046220
360.00	2.0994	18.239	0.054828	8.8116	8.9267	0.028473	0.050089	0.10189	615.37	0.13476
370.00	2.6028	17.621	0.056750	9.8095	9.9572	0.031220	0.050089	0.10644	566.77	0.24913
380.00	3.1904	16.949	0.059001	10.842	11.030	0.033991	0.050173	0.11271	516.72	0.40128
390.00	3.8713	16.204	0.061713	11.921	12.160	0.036818	0.050373	0.12189	464.59	0.61221
400.00	4.6557	15.355	0.065124	13.066	13.369	0.039753	0.050753	0.13673	409.36	0.92296
410.00	5.5562	14.340	0.069734	14.317	14.704	0.042899	0.051457	0.16539	349.05	1.4276
420.00	6.5903	12.987	0.077001	15.782	16.290	0.046536	0.052928	0.24772	279.41	2.4089
430.00	7.7908	9.8261	0.10177	18.415	19.207	0.053143	0.058931	3.7896	182.70	5.8716
430.64	7.8753	8.1950	0.12203	19.585	20.546	0.056233			0	7.4962
197.70	0.0016602	0.0010120	988.16	21.102	22.743	0.11899	0.028340	0.036808	182.19	299.66
200.00	0.0020260	0.0012211	818.93	21.164	22.824	0.11774	0.028464	0.036952	183.16	280.77
210.00	0.0045390	0.0026096	383.20	21.435	23.174	0.11277	0.029049	0.037650	187.23	214.32
220.00	0.0093340	0.0051346	194.76	21.702	23.520	0.10841	0.029713	0.038475	191.08	166.88
230.00	0.017835	0.0094158	106.20	21.967	23.861	0.10458	0.030462	0.039438	194.70	132.33
240.00	0.031988	0.016257	61.512	22.226	24.194	0.10120	0.031293	0.040551	198.07	106.70
250.00	0.054309	0.026653	37.519	22.480	24.518	0.098195	0.032204	0.041819	201.15	87.372
260.00	0.087910	0.041793	23.928	22.726	24.830	0.095507	0.033186	0.043246	203.92	72.572
270.00	0.13649	0.063061	15.858	22.964	25.128	0.093090	0.034230	0.044838	206.35	61.089
280.00	0.20431	0.092046	10.864	23.191	25.411	0.090902	0.035327	0.046602	208.42	52.073
290.00	0.29614	0.13055	7.6600	23.407	25.676	0.088908	0.036465	0.048552	210.09	44.917
300.00	0.41725	0.18062	5.5366	23.611	25.921	0.087077	0.037638	0.050709	211.33	39.185
310.00	0.57327	0.24460	4.0883	23.799	26.142	0.085379	0.038838	0.053111	212.12	34.550
320.00	0.77025	0.32522	3.0748	23.969	26.338	0.083789	0.040062	0.055813	212.43	30.772
330.00	1.0145	0.42570	2.3491	24.120	26.503	0.082284	0.041310	0.058901	212.22	27.666
340.00	1.3128	0.54995	1.8184	24.247	26.634	0.080838	0.042587	0.062502	211.47	25.092
350.00	1.6720	0.70287	1.4227	24.345	26.724	0.079427	0.043900	0.066814	210.13	22.939
360.00	2.0994	0.89084	1.1225	24.409	26.765	0.078025	0.045264	0.072150	208.17	21.118
370.00	2.6028	1.1225	0.89086	24.430	26.748	0.076601	0.046699	0.079031	205.54	19.558
380.00	3.1904	1.4103	0.70908	24.396	26.658	0.075116	0.048236	0.088395	202.18	18.192
390.00	3.8713	1.7733	0.56391	24.289	26.472	0.073516	0.049922	0.10210	198.02	16.958
400.00	4.6557	2.2444	0.44556	24.079	26.153	0.071714	0.051835	0.12442	192.95	15.777
410.00	5.5562	2.8887	0.34618	23.705	25.628	0.069543	0.054121	0.16795	186.81	14.529
420.00	6.5903	3.8804	0.25770	23.009	24.707	0.066577	0.057117	0.29279	179.31	12.934
430.00	7.7908	6.6270	0.15090	20.801	21.976	0.059582	0.062123	4.6423	168.96	9.1885
430.64	7.8753	8.1950	0.12203	19.585	20.546	0.056233			0	7.4962

Single-Phase Properties										
200.00	0.10000	25.206	0.039672	–5.5197	–5.5158	–0.023973	0.056096	0.088028	1350.4	–0.31868
262.84	0.10000	22.819	0.043823	–0.030118	–0.025736	–0.000097639	0.052710	0.087416	1057.0	–0.27084
262.84	0.10000	0.047141	21.213	22.794	24.916	0.094795	0.033476	0.043681	204.65	69.019
300.00	0.10000	0.040764	24.532	24.043	26.497	0.10042	0.032826	0.041994	219.46	39.646
400.00	0.10000	0.030240	33.068	27.458	30.765	0.11269	0.035338	0.043891	252.48	15.140
500.00	0.10000	0.024117	41.465	31.151	35.297	0.12279	0.038292	0.046720	280.65	8.3690
200.00	1.0000	25.219	0.039653	–5.5302	–5.4905	–0.024025	0.056110	0.087995	1353.1	–0.31905
300.00	1.0000	21.287	0.046976	3.2251	3.2721	0.011490	0.051245	0.089444	894.23	–0.19703
329.46	1.0000	19.892	0.050272	5.9101	5.9604	0.020035	0.050466	0.093567	758.01	–0.082891
329.46	1.0000	0.41969	2.3827	24.112	26.495	0.082363	0.041242	0.058722	212.25	27.819
400.00	1.0000	0.31968	3.1281	27.007	30.135	0.092405	0.037220	0.048421	244.07	15.238
500.00	1.0000	0.24701	4.0483	30.891	34.939	0.10312	0.038821	0.048357	276.82	8.3664
200.00	5.0000	25.271	0.039570	–5.5759	–5.3780	–0.024255	0.056174	0.087853	1365.0	–0.32064
300.00	5.0000	21.420	0.046686	3.1113	3.3448	0.011108	0.051267	0.088566	915.79	–0.21095
400.00	5.0000	15.439	0.064770	13.003	13.327	0.039592	0.050649	0.13367	417.04	0.87444
403.99	5.0000	14.976	0.066773	13.548	13.882	0.040973	0.050981	0.14563	386.08	1.0922
403.99	5.0000	2.4748	0.40407	23.955	25.975	0.070906	0.052690	0.13790	190.64	15.297
500.00	5.0000	1.3950	0.71686	29.591	33.176	0.087109	0.041506	0.058653	259.84	8.2323
300.00	10.000	21.575	0.046350	2.9776	3.4411	0.010654	0.051308	0.087615	941.12	–0.22613
400.00	10.000	16.326	0.061251	12.327	12.940	0.037839	0.049804	0.11122	501.11	0.46626
500.00	10.000	3.4161	0.29273	27.477	30.404	0.076991	0.045669	0.085639	241.12	7.4245
300.00	20.000	21.859	0.045748	2.7336	3.6486	0.0098108	0.051422	0.086075	987.39	–0.25095
400.00	20.000	17.379	0.057542	11.494	12.644	0.035620	0.049297	0.096839	608.17	0.15187
500.00	20.000	9.7192	0.10289	22.208	24.266	0.061366	0.049635	0.13354	292.48	2.7261
300.00	35.000	22.232	0.044980	2.4136	3.9878	0.0086740	0.051645	0.084373	1048.5	–0.27869
400.00	35.000	18.377	0.054417	10.681	12.586	0.033379	0.049231	0.088711	717.32	–0.043488
500.00	35.000	13.607	0.073492	19.322	21.894	0.054113	0.048429	0.097089	462.83	0.67011

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Span, R., *J. Chem. Eng. Data*, **51**(3):785–850, 2006. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainty in density of the equation of state ranges from 0.1% at low temperatures in the liquid and vapor to 0.5% at the highest temperatures. The uncertainty in heat capacities is 2%, and the uncertainty in vapor pressure is 0.4% at temperatures above 270 K. The uncertainty in vapor pressure increases at lower temperatures due to the lack of experimental data. In the critical region, the uncertainties are higher for all properties except vapor pressure.

TABLE 2-301 Thermodynamic Properties of Sulfur Hexafluoride

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
222.38	0.22436	12.677	0.078884	22.560	22.578	0.11968	0.063933	0.10620	578.22	–0.32279
225.00	0.25012	12.592	0.079415	22.842	22.862	0.12094	0.066189	0.11001	565.05	–0.29395
230.00	0.30561	12.424	0.080489	23.405	23.430	0.12342	0.069989	0.11631	539.86	–0.24573
235.00	0.37011	12.249	0.081642	23.996	24.026	0.12596	0.073230	0.12154	514.71	–0.20297
240.00	0.44448	12.066	0.082875	24.610	24.647	0.12855	0.076028	0.12596	489.70	–0.16256
245.00	0.52962	11.878	0.084192	25.244	25.288	0.13117	0.078482	0.12981	464.88	–0.12208
250.00	0.62644	11.682	0.085600	25.894	25.948	0.13380	0.080672	0.13330	440.25	–0.079442
255.00	0.73591	11.480	0.087108	26.559	26.623	0.13643	0.082667	0.13661	415.80	–0.032633
260.00	0.85899	11.270	0.088731	27.238	27.315	0.13908	0.084519	0.13994	391.49	0.020496
265.00	0.99671	11.051	0.090487	27.932	28.022	0.14172	0.086274	0.14344	367.25	0.082465
270.00	1.1502	10.822	0.092400	28.640	28.746	0.14438	0.087968	0.14730	343.00	0.15646
275.00	1.3204	10.581	0.094507	29.363	29.488	0.14704	0.089631	0.15173	318.65	0.24678
280.00	1.5088	10.325	0.096852	30.105	30.251	0.14973	0.091292	0.15702	294.10	0.35955
285.00	1.7164	10.050	0.099503	30.867	31.037	0.15244	0.092978	0.16356	269.23	0.50392
290.00	1.9447	9.7505	0.10256	31.653	31.852	0.15519	0.094719	0.17202	243.92	0.69427
295.00	2.1952	9.4189	0.10617	32.470	32.703	0.15801	0.096558	0.18353	218.04	0.95460
300.00	2.4696	9.0428	0.11059	33.327	33.600	0.16093	0.098567	0.20035	191.41	1.3279
305.00	2.7698	8.6013	0.11626	34.240	34.562	0.16399	0.10090	0.22773	163.77	1.8996
310.00	3.0984	8.0537	0.12417	35.238	35.623	0.16732	0.10399	0.28254	134.40	2.8784
318.73	3.7539	5.0926	0.19636	38.575	39.312	0.17871			0	11.978
222.38	0.22436	0.13009	7.6872	36.790	38.515	0.19135	0.069340	0.080626	112.78	24.151
225.00	0.25012	0.14419	6.9355	36.943	38.678	0.19124	0.070316	0.081915	112.82	23.609
230.00	0.30561	0.17448	5.7314	37.235	38.987	0.19106	0.072196	0.084476	112.77	22.653
235.00	0.37011	0.20966	4.7696	37.528	39.293	0.19093	0.074101	0.087187	112.56	21.791
240.00	0.44448	0.25032	3.9949	37.820	39.595	0.19083	0.076031	0.090076	112.19	21.015
245.00	0.52962	0.29713	3.3655	38.110	39.892	0.19077	0.077991	0.093176	111.65	20.317
250.00	0.62644	0.35086	2.8502	38.397	40.183	0.19074	0.079983	0.096531	110.92	19.693
255.00	0.73591	0.41240	2.4248	38.681	40.465	0.19072	0.082010	0.10020	109.99	19.139
260.00	0.85899	0.48285	2.0711	38.960	40.739	0.19071	0.084077	0.10426	108.86	18.652
265.00	0.99671	0.56348	1.7747	39.232	41.001	0.19070	0.086191	0.10882	107.50	18.230
270.00	1.1502	0.65592	1.5246	39.496	41.249	0.19069	0.088360	0.11403	105.91	17.872
275.00	1.3204	0.76219	1.3120	39.749	41.481	0.19066	0.090597	0.12013	104.06	17.578
280.00	1.5088	0.88492	1.1301	39.988	41.693	0.19059	0.092917	0.12746	101.93	17.349
285.00	1.7164	1.0276	0.97310	40.209	41.879	0.19048	0.095345	0.13657	99.489	17.185
290.00	1.9447	1.1953	0.83661	40.407	42.034	0.19030	0.097913	0.14840	96.707	17.086
295.00	2.1952	1.3951	0.71677	40.573	42.147	0.19003	0.10068	0.16473	93.543	17.049
300.00	2.4696	1.6387	0.61023	40.695	42.202	0.18960	0.10372	0.18917	89.944	17.065
305.00	2.7698	1.9464	0.51377	40.751	42.174	0.18895	0.10722	0.23074	85.845	17.098
310.00	3.0984	2.3611	0.42353	40.693	42.006	0.18791	0.11155	0.31922	81.148	17.036
318.73	3.7539	5.0926	0.19636	38.575	39.312	0.17871			0	11.978

Single-Phase Properties										
225.00	0.10000	0.054962	18.194	37.124	38.943	0.19969	0.069072	0.078403	117.21	20.832
300.00	0.10000	0.040537	24.669	43.122	45.589	0.22504	0.089337	0.098060	135.40	8.9939
375.00	0.10000	0.032243	31.015	50.424	53.525	0.24859	0.10425	0.11277	151.16	4.9674
450.00	0.10000	0.026801	37.312	58.668	62.399	0.27014	0.11482	0.12326	165.37	3.1241
525.00	0.10000	0.022943	43.585	67.581	71.940	0.28973	0.12235	0.13075	178.44	2.1242
225.00	1.0000	12.618	0.079249	22.807	22.886	0.12079	0.066092	0.10946	570.46	–0.30187
265.11	1.0000	11.046	0.090528	27.948	28.038	0.14178	0.086313	0.14352	366.71	0.083989
265.11	1.0000	0.56543	1.7686	39.238	41.007	0.19070	0.086239	0.10893	107.47	18.222
300.00	1.0000	0.45567	2.1946	42.504	44.699	0.20379	0.091458	0.10595	122.90	10.582
375.00	1.0000	0.33888	2.9509	50.051	53.002	0.22845	0.10508	0.11588	145.14	5.2070
450.00	1.0000	0.27473	3.6399	58.408	62.048	0.25042	0.11528	0.12496	162.15	3.1619
525.00	1.0000	0.23243	4.3024	67.387	71.689	0.27022	0.12264	0.13181	176.71	2.1142
300.00	5.0000	9.6705	0.10341	32.693	33.210	0.15873	0.096509	0.16433	257.24	0.56212
375.00	5.0000	2.2583	0.44281	47.826	50.040	0.20902	0.10970	0.14796	119.18	6.1481
450.00	5.0000	1.5252	0.65566	57.112	60.390	0.23421	0.11717	0.13497	151.89	3.1819
525.00	5.0000	1.2155	0.82269	66.464	70.578	0.25515	0.12378	0.13716	173.02	2.0030
300.00	10.000	10.303	0.097057	31.996	32.966	0.15625	0.095358	0.14728	332.30	0.14584
375.00	10.000	5.9487	0.16810	44.159	45.840	0.19435	0.11121	0.18759	145.44	2.6476
450.00	10.000	3.3384	0.29955	55.295	58.291	0.22473	0.11863	0.15056	154.01	2.5753
525.00	10.000	2.4910	0.40144	65.252	69.266	0.24729	0.12474	0.14433	177.25	1.6978
300.00	25.000	11.266	0.088766	30.853	33.072	0.15199	0.095576	0.13478	455.74	–0.17165
375.00	25.000	9.1060	0.10982	41.023	43.768	0.18375	0.10890	0.14958	314.62	0.14966
450.00	25.000	7.0706	0.14143	51.697	55.233	0.21161	0.11870	0.15437	248.92	0.47538
525.00	25.000	5.5874	0.17897	62.312	66.786	0.23536	0.12549	0.15348	234.29	0.57992
300.00	50.000	12.151	0.082298	29.792	33.906	0.14767	0.098484	0.12950	565.06	–0.30996
375.00	50.000	10.625	0.094118	39.323	44.029	0.17775	0.10946	0.14045	454.58	–0.19915
450.00	50.000	9.2093	0.10859	49.451	54.881	0.20410	0.11846	0.14799	394.01	–0.10589
525.00	50.000	8.0206	0.12468	59.888	66.122	0.22720	0.12538	0.15134	361.13	–0.058213

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is de Reuck, K. M., Craven, R. J. B., and Cole, W. A., "Report on the Development of an Equation of State for Sulphur Hexafluoride," *IUPAC* Thermodynamic Tables Project Centre, London, 1991. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties of the equation of state are 0.1% in density, 2% in heat capacity, and 5% in the speed of sound, except in the critical region.

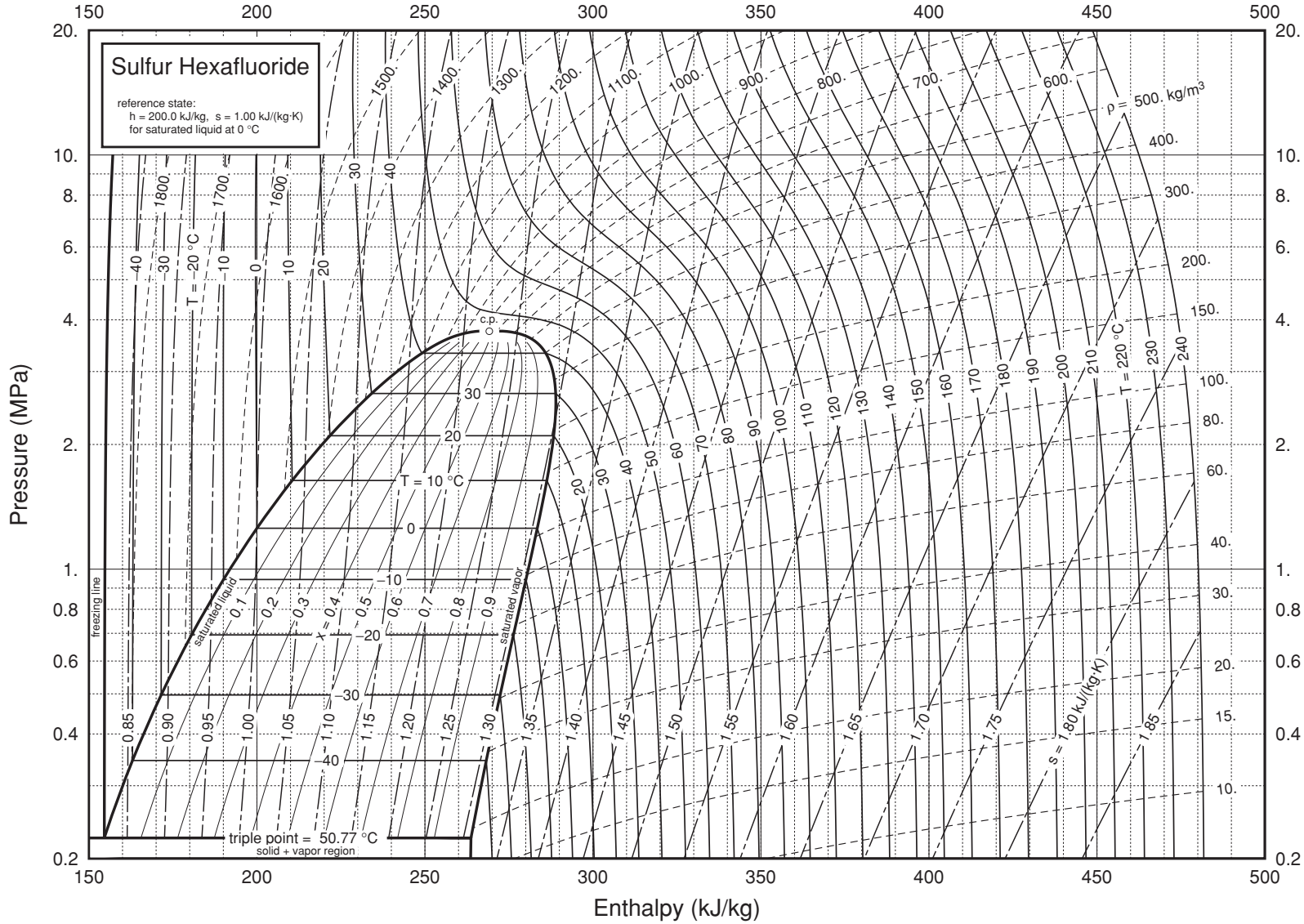

FIG. 2-30 Pressure-enthalpy diagram for sulfur hexafluoride (SF_6). Properties computed with the NIST REFPROP Database, Version 7.0 (Lemmon, E. W., McLinden, M. O., and Huber, M. L., 2002, NIST Standard Reference Database 23, NIST Reference Fluid Thermodynamic and Transport Properties—REFPROP, Version 7.0, Standard Reference Data Program, National Institute of Standards and Technology), based on the equation of state of de Reuck, K. M., Craven, R. J. B., and Cole, W. A., "Report on the Development of an Equation of State for Sulphur Hexafluoride," IUPAC Thermodynamic Tables Project Centre, London, 1991.

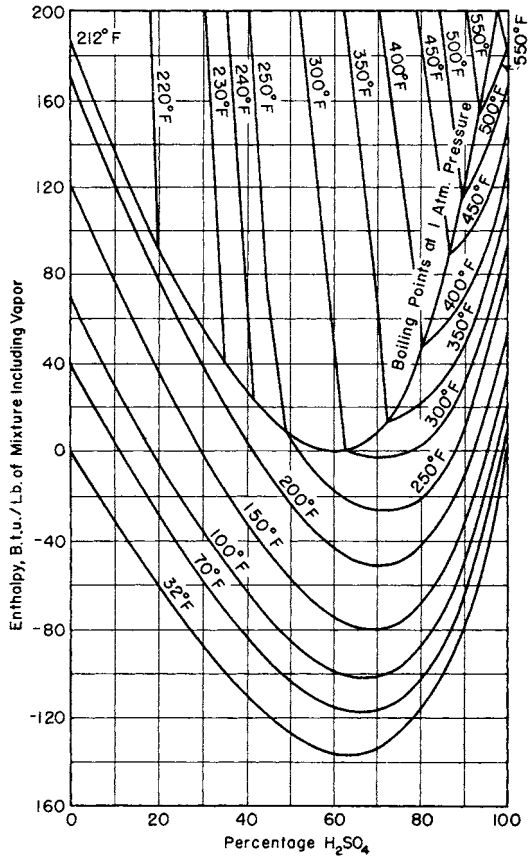

FIG. 2-31 Enthalpy-concentration diagram for aqueous sulfuric acid at 1 atm. Reference states: enthalpies of pure-liquid components at 32° F and vapor pressures are zero. NOTE: It should be observed that the weight basis includes the vapor, which is particularly important in the two-phase region. The upper ends of the tie lines in this region are assumed to be pure water. (*Hougen and Watson,* Chemical Process Principles, *part I, Wiley, New York, 1943.*)

TABLE 2-302 Saturated SUVA AC 9000

DuPont bulletin T–AC–9000–SI, 1994 (16 pp.) gives tables and a chart to 100 bar, 235°C. With a stated composition of 23% wt CH_2F_2 (R23), 25% wt CHF_2CF_3 (R125), and 52% wt CH_2FCH_3 (R134a) this is apparently identical to KLEA 66, to which the reader is referred.

TABLE 2-303 Thermodynamic Properties of Toluene

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa
Saturated Properties										
178.00	3.9393E-08	10.580	0.094517	–31.779	–31.779	–0.11617	0.094332	0.13565	1887.6	–0.57170
180.00	5.5336E-08	10.559	0.094708	–31.508	–31.508	–0.11466	0.094377	0.13561	1876.5	–0.57178
200.00	1.0833E-06	10.349	0.096627	–28.792	–28.792	–0.10035	0.095732	0.13627	1768.3	–0.56718
220.00	1.1479E-05	10.144	0.098582	–26.046	–26.046	–0.087266	0.098418	0.13855	1664.8	–0.55455
240.00	7.7542E-05	9.9416	0.10059	–23.242	–23.242	–0.075068	0.10209	0.14205	1565.9	–0.53604
260.00	0.00037312	9.7408	0.10266	–20.358	–20.358	–0.063529	0.10651	0.14648	1471.5	–0.51329
280.00	0.0013829	9.5402	0.10482	–17.378	–17.378	–0.052490	0.11147	0.15162	1381.2	–0.48747
300.00	0.0041774	9.3385	0.10708	–14.290	–14.289	–0.041839	0.11682	0.15729	1294.5	–0.45928
320.00	0.010727	9.1347	0.10947	–11.084	–11.083	–0.031496	0.12243	0.16337	1210.9	–0.42904
340.00	0.024170	8.9275	0.11201	–7.7538	–7.7511	–0.021403	0.12819	0.16976	1130.0	–0.39664
360.00	0.048980	8.7157	0.11474	–4.2939	–4.2882	–0.011516	0.13403	0.17640	1051.3	–0.36162
380.00	0.090988	8.4979	0.11768	–0.70017	–0.68946	–0.0018023	0.13988	0.18325	974.11	–0.32305
400.00	0.15731	8.2722	0.12089	3.0306	3.0496	0.0077653	0.14571	0.19032	898.08	–0.27947
420.00	0.25622	8.0367	0.12443	6.9017	6.9336	0.017209	0.15148	0.19764	822.67	–0.22860
440.00	0.39698	7.7887	0.12839	10.917	10.968	0.026551	0.15718	0.20531	747.37	–0.16688
460.00	0.58974	7.5246	0.13290	15.082	15.160	0.035811	0.16280	0.21350	671.66	–0.088509
480.00	0.84559	7.2394	0.13813	19.404	19.521	0.045015	0.16836	0.22253	594.94	0.016497
500.00	1.1766	6.9258	0.14439	23.896	24.066	0.054196	0.17388	0.23298	516.53	0.16681
520.00	1.5964	6.5719	0.15216	28.580	28.823	0.063400	0.17943	0.24610	435.57	0.40139
540.00	2.1207	6.1562	0.16244	33.494	33.839	0.072709	0.18518	0.26495	350.82	0.81616
560.00	2.7691	5.6334	0.17751	38.729	39.220	0.082291	0.19153	0.30025	260.06	1.7226
580.00	3.5688	4.8513	0.20613	44.585	45.321	0.092723	0.20008	0.44025	157.29	4.9610
591.75	4.1264	3.1690	0.31556	50.827	52.129	0.10409			0	19.734
178.00	3.9393E-08	2.6618E-08	37,569,000.	12.076	13.556	0.13852	0.054735	0.063049	136.02	821.69
180.00	5.5336E-08	3.6974E-08	27,046,000.	12.186	13.683	0.13640	0.055322	0.063636	136.69	783.08
200.00	1.0833E-06	6.5146E-07	1,535,000.	13.353	15.016	0.11869	0.061435	0.069750	143.14	496.50
220.00	1.1479E-05	6.2760E-06	159,340.	14.646	16.475	0.10601	0.067930	0.076246	149.27	328.33
240.00	7.7542E-05	3.8866E-05	25,729.	16.071	18.066	0.097048	0.074733	0.083057	155.12	225.22
260.00	0.00037312	0.00017271	5,790.1	17.632	19.793	0.090897	0.081779	0.090124	160.70	159.61
280.00	0.0013829	0.00059503	1,680.6	19.331	21.655	0.086914	0.089005	0.097403	166.00	116.50
300.00	0.0041774	0.0016815	594.71	21.165	23.649	0.084624	0.096358	0.10486	170.96	87.391
320.00	0.010727	0.0040644	246.04	23.130	25.769	0.083666	0.10379	0.11248	175.47	67.283
340.00	0.024170	0.0086767	115.25	25.218	28.003	0.083758	0.11127	0.12026	179.42	53.119
360.00	0.048980	0.016770	59.631	27.421	30.342	0.084678	0.11875	0.12819	182.67	42.979
380.00	0.090988	0.029922	33.420	29.730	32.770	0.086250	0.12622	0.13630	185.07	35.624
400.00	0.15731	0.050060	19.976	32.133	35.275	0.088329	0.13364	0.14463	186.44	30.237
420.00	0.25622	0.079525	12.575	34.618	37.840	0.090796	0.14100	0.15326	186.62	26.277
440.00	0.39698	0.12122	8.2496	37.172	40.447	0.093548	0.14832	0.16234	185.42	23.381
460.00	0.58974	0.17889	5.5901	39.776	43.073	0.096491	0.15558	0.17214	182.60	21.313
480.00	0.84559	0.25767	3.8810	42.408	45.690	0.099533	0.16283	0.18316	177.87	19.928
500.00	1.1766	0.36515	2.7386	45.035	48.257	0.10258	0.17013	0.19639	170.89	19.156
520.00	1.5964	0.51366	1.9468	47.606	50.713	0.10550	0.17758	0.21403	161.17	19.007
540.00	2.1207	0.72590	1.3776	50.033	52.955	0.10811	0.18540	0.24190	148.11	19.581
560.00	2.7691	1.0524	0.95020	52.136	54.768	0.11005	0.19407	0.30118	130.92	21.067
580.00	3.5688	1.6605	0.60222	53.371	55.520	0.11031	0.20499	0.55687	108.57	23.353
591.75	4.1264	3.1690	0.31556	50.827	52.129	0.10409			0	19.734

Single-Phase Properties

200.00	0.10000	10.350	0.096623	–28.794	–28.784	–0.10036	0.095737	0.13627	1768.7	–0.56720
325.00	0.10000	9.0842	0.11008	–10.267	–10.256	–0.028962	0.12386	0.16493	1191.0	–0.42130
383.28	0.10000	8.4614	0.11818	–0.097277	–0.085459	–0.00022242	0.14084	0.18440	961.57	–0.31629
383.28	0.10000	0.032692	30.589	30.118	33.177	0.086560	0.12744	0.13765	185.37	34.622
450.00	0.10000	0.027344	36.572	39.369	43.026	0.11021	0.14828	0.15755	202.98	18.656
575.00	0.10000	0.021125	47.338	60.145	64.879	0.15289	0.18229	0.19099	230.86	8.1724
700.00	0.10000	0.017270	57.904	84.697	90.487	0.19311	0.20915	0.21767	255.08	4.5991
200.00	1.0000	10.354	0.096581	–28.811	–28.715	–0.10045	0.095778	0.13625	1771.8	–0.56742
325.00	1.0000	9.0933	0.10997	–10.303	–10.193	–0.029074	0.12389	0.16482	1196.3	–0.42281
450.00	1.0000	7.6732	0.13032	12.928	13.058	0.031073	0.16000	0.20893	715.87	–0.13702
489.95	1.0000	7.0876	0.14109	21.616	21.757	0.049581	0.17110	0.22749	556.21	0.083851
489.95	1.0000	0.30691	3.2583	43.717	46.976	0.10105	0.16645	0.18937	174.71	19.469
575.00	1.0000	0.23372	4.2786	59.065	63.344	0.13184	0.18481	0.19848	210.35	9.4517
700.00	1.0000	0.18116	5.5199	84.035	89.555	0.17301	0.21011	0.22077	244.28	4.8519
200.00	5.0000	10.373	0.096400	–28.887	–28.405	–0.10083	0.095961	0.13619	1785.8	–0.56831
325.00	5.0000	9.1328	0.10950	–10.460	–9.9129	–0.029562	0.12404	0.16434	1219.1	–0.42907
450.00	5.0000	7.7765	0.12859	12.548	13.191	0.030217	0.16002	0.20635	761.15	–0.18092
575.00	5.0000	5.6051	0.17841	41.699	42.591	0.087531	0.19430	0.28257	285.95	1.3449
700.00	5.0000	1.1698	0.85487	80.250	84.524	0.15419	0.21547	0.24819	197.87	5.8706
200.00	10.000	10.397	0.096178	–28.980	–28.018	–0.10130	0.096187	0.13612	1802.9	–0.56932
325.00	10.000	9.1800	0.10893	–10.647	–9.5580	–0.030150	0.12422	0.16382	1246.4	–0.43597
450.00	10.000	7.8890	0.12676	12.131	13.398	0.029259	0.16009	0.20400	810.93	–0.22080
575.00	10.000	6.1856	0.16166	40.014	41.630	0.084396	0.19242	0.24975	425.25	0.38997
700.00	10.000	3.2697	0.30584	73.814	76.873	0.13965	0.21978	0.30359	189.44	3.9797
325.00	100.00	9.7930	0.10211	–12.967	–2.7551	–0.038333	0.12727	0.16019	1609.1	–0.48598
450.00	100.00	8.9423	0.11183	8.2140	19.397	0.019038	0.16256	0.19397	1308.6	–0.38806
575.00	100.00	8.1649	0.12248	33.274	45.521	0.070122	0.19323	0.22291	1104.9	–0.31962
700.00	100.00	7.4598	0.13405	61.439	74.845	0.11620	0.21782	0.24523	967.84	–0.27316
450.00	500.00	10.545	0.094835	3.6375	51.055	–0.00069710	0.17022	0.19432	2238.9	–0.40813
575.00	500.00	10.097	0.099035	27.662	77.179	0.050390	0.20000	0.22274	2087.2	–0.35992
700.00	500.00	9.7036	0.10305	54.974	106.50	0.096461	0.22392	0.24550	1977.5	–0.32978

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data* **51**(3):785–850, 2006. Validated equations for the viscosity and thermal conductivity are not currently available for this fluid.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in density in the equation of state are 0.05% in the liquid phase up to 540 K, 0.5% up to the critical temperature, 1% at higher temperatures, 0.5% at pressures from 100 to 500 MPa, and 0.2% in the vapor phase. The uncertainty for the saturated-liquid density (and densities near atmospheric pressure) approaches 0.01% around 300 K. The uncertainties in vapor pressure are 0.3% from 270 to 305 K, 0.05% from 305 to 425 K, 0.1% up to 555 K, and 0.15% up to the critical temperature. The uncertainty in heat capacities is 0.5% and rises to 3% in the critical region. The uncertainty in the speed of sound is 1% up to 500 K and 100 MPa and rises to 2% at higher pressures and higher temperatures.

TABLE 2-304 Saturated Solid/Vapor Water*

Temp., °F	Pressure, lb/in² abs.	Volume, ft³/lb		Enthalpy, Btu/lb		Entropy, Btu/(lb)(°F)	
		Solid	Vapor	Solid	Vapor	Solid	Vapor
−160	4.949.−8	0.01722	3.607.+9	−222.05	990.38	−0.4907	3.5549
−150	1.620.−7	0.01723	1.139.+9	−218.82	994.80	−0.4801	3.4387
−140	4.928.−7	0.01724	3.864.+8	−215.49	999.21	−0.4695	3.3301
−130	1.403.−6	0.01725	1.400.+8	−212.08	1003.63	−0.4590	3.2284
−120	3.757.−6	0.01726	5.386.+7	−208.58	1008.05	−0.4485	3.1330
−110	9.517.−6	0.01728	2.189.+7	−204.98	1012.47	−0.4381	3.0434
−100	2.291.−5	0.01729	9.352.+6	−201.28	1016.89	−0.4277	2.9591
−90	5.260.−5	0.01730	4.186.+6	−197.49	1021.31	−0.4173	2.8796
−80	1.157.−4	0.01731	1.955.+6	−193.60	1025.73	−0.4069	2.8045
−70	2.443.−4	0.01732	9.501.+5	−189.61	1030.15	−0.3965	2.7336
−60	4.972.−4	0.01734	4.788.+5	−185.52	1034.58	−0.3862	2.6664
−50	9.776.−4	0.01735	2.496.+5	−181.34	1039.00	−0.3758	2.6028
−45	1.354.−3	0.01736	1.824.+5	−179.21	1041.21	−0.3707	2.5723
−40	1.861.−3	0.01737	1.343.+5	−177.06	1043.42	−0.3655	2.5425
−35	2.540.−3	0.01737	9.961.+4	−174.88	1045.63	−0.3604	2.5135
−30	3.440.−3	0.01738	7.441.+4	−172.68	1047.84	−0.3552	2.4853
−25	4.627.−3	0.01739	5.596.+4	−170.46	1050.05	−0.3501	2.4577
−20	6.181.−3	0.01739	4.237.+4	−168.21	1052.26	−0.3449	2.4308
−15	8.204.−3	0.01740	3.228.+4	−165.94	1054.47	−0.3398	2.4046
−10	1.082.−2	0.01741	2.475.+4	−163.65	1056.67	−0.3347	2.3791
−5	1.419.−2	0.01741	1.909.+4	−161.33	1058.88	−0.3295	2.3541
0	1.849.−2	0.01742	1.481.+4	−158.98	1061.09	−0.3244	2.3297
5	2.396.−2	0.01743	1.155.+4	−156.61	1063.29	−0.3193	2.3039
10	3.087.−2	0.01744	9.060.+3	−154.22	1065.50	−0.3142	2.2827
15	3.957.−2	0.01744	7.144.+3	−151.80	1067.70	−0.3090	2.2600
16	4.156.−2	0.01745	6.817.+3	−151.32	1068.14	−0.3080	2.2555
18	4.581.−2	0.01745	6.210.+3	−150.34	1069.02	−0.3060	2.2466
20	5.045.−2	0.01745	5.662.+3	−149.36	1069.90	−0.3039	2.2378
22	5.552.−2	0.01746	5.166.+3	−148.38	1070.38	−0.3019	2.2291
24	6.105.−2	0.01746	4.717.+3	−147.39	1071.66	−0.2998	2.2205
26	6.708.−2	0.01746	4.311.+3	−146.40	1072.53	−0.2978	2.2119
28	7.365.−2	0.01746	3.943.+3	−145.40	1073.41	−0.2957	2.2034
30	8.080.−2	0.01747	3.608.+3	−144.40	1074.29	−0.2937	2.1950
31	8.461.−2	0.01747	3.453.+3	−143.90	1074.73	−0.2927	2.1908
32	8.858.−2	0.01747	3.305.+3	−143.40	1075.16	−0.2916	2.1867

*Condensed from *Fundamentals,* American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1967 and 1972. Reproduced by permission. The validity of many standard reference tables has been critically reviewed by Jancso, Pupezin, and van Hook, *J. Phys. Chem.,* **74** (1970):2984. Current information on the properties of solid, vapor, and liquid water properties can be found at http://www.iapws.org. The notation 4.949.−8, 3.607.+9, etc., means 4.949×10^{-8}, 3.607×10^{9}, etc.

TABLE 2-305 Thermodynamic Properties of Water

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
273.16	0.000612	55.497	0.018019	0	1.1E-05	0	0.075978	0.076023	1402.3	–0.24142	561.04	1791.2
280	0.000992	55.501	0.018018	0.51875	0.51877	0.001876	0.075669	0.075688	1434.1	–0.23515	574.04	1433.7
290	0.001920	55.440	0.018038	1.2742	1.2742	0.004527	0.075095	0.075429	1472.1	–0.22720	592.73	1084.0
300	0.003537	55.315	0.018078	2.0278	2.0279	0.007082	0.074412	0.075320	1501.4	–0.22024	610.28	853.84
310	0.006231	55.139	0.018136	2.7808	2.7810	0.009551	0.073645	0.075294	1523.2	–0.21393	626.05	693.54
320	0.010546	54.919	0.018209	3.5339	3.5340	0.011941	0.072811	0.075317	1538.7	–0.20804	639.71	577.02
330	0.017213	54.662	0.018294	4.2873	4.2876	0.014260	0.071927	0.075373	1548.7	–0.20241	651.18	489.49
340	0.027188	54.371	0.018392	5.0414	5.0419	0.016511	0.071008	0.075456	1553.9	–0.19690	660.55	421.97
350	0.041682	54.049	0.018502	5.7964	5.7972	0.018700	0.070070	0.075567	1554.8	–0.19140	668.00	368.77
360	0.062194	53.698	0.018623	6.5526	6.5538	0.020830	0.069124	0.075708	1552.0	–0.18581	673.76	326.10
370	0.090535	53.321	0.018754	7.3104	7.3121	0.022906	0.068180	0.075883	1545.8	–0.18005	678.02	291.36
380	0.12885	52.918	0.018897	8.0701	8.0725	0.024932	0.067247	0.076098	1536.5	–0.17404	681.00	262.69
390	0.17964	52.490	0.019051	8.8320	8.8354	0.026911	0.066331	0.076357	1524.3	–0.16769	682.83	238.77
400	0.24577	52.038	0.019217	9.5966	9.6013	0.028847	0.065438	0.076664	1509.5	–0.16092	683.64	218.60
410	0.33045	51.563	0.019394	10.364	10.371	0.030743	0.064570	0.077026	1492.2	–0.15366	683.52	201.43
420	0.43730	51.064	0.019583	11.136	11.144	0.032602	0.063731	0.077447	1472.5	–0.14581	682.53	186.68
430	0.57026	50.541	0.019786	11.911	11.923	0.034427	0.062920	0.077934	1450.6	–0.13728	680.70	173.91
440	0.73367	49.994	0.020003	12.692	12.706	0.036222	0.062140	0.078495	1426.5	–0.12794	678.05	162.77
450	0.9322	49.421	0.020234	13.477	13.496	0.037988	0.061390	0.079136	1400.4	–0.11767	674.59	152.98
460	1.1709	48.824	0.020482	14.269	14.293	0.039729	0.060671	0.079869	1372.2	–0.10631	670.28	144.31
470	1.4551	48.199	0.020748	15.068	15.098	0.041448	0.059984	0.080706	1342.0	–0.09369	665.12	136.58
480	1.7905	47.545	0.021033	15.875	15.913	0.043147	0.059327	0.081662	1309.8	–0.07959	659.07	129.64
490	2.1831	46.861	0.021340	16.690	16.737	0.044830	0.058702	0.082757	1275.7	–0.06372	652.06	123.37
500	2.6392	46.145	0.021671	17.515	17.573	0.046498	0.058109	0.084013	1239.6	–0.04578	644.05	117.66
510	3.1655	45.393	0.022030	18.352	18.421	0.048156	0.057548	0.085464	1201.5	–0.02534	634.95	112.42
520	3.7690	44.603	0.022420	19.200	19.285	0.049807	0.057023	0.087149	1161.3	–0.00189	624.68	107.57
530	4.4569	43.770	0.022847	20.064	20.165	0.051454	0.056536	0.089124	1119.1	0.025264	613.15	103.05
540	5.2369	42.889	0.023316	20.943	21.065	0.053102	0.056089	0.091464	1074.6	0.057002	600.26	98.792
550	6.1172	41.954	0.023836	21.841	21.987	0.054756	0.055690	0.094275	1027.9	0.094527	585.95	94.746
560	7.1062	40.956	0.024417	22.762	22.935	0.056422	0.055347	0.097713	978.54	0.13949	570.21	90.857
570	8.2132	39.885	0.025072	23.709	23.915	0.058106	0.055071	0.10201	926.44	0.19425	553.08	87.074
580	9.448	38.725	0.025823	24.688	24.932	0.059821	0.054881	0.10754	871.23	0.26220	534.74	83.342
590	10.821	37.456	0.026698	25.707	25.996	0.061577	0.054808	0.11491	812.49	0.34857	515.43	79.600
600	12.345	36.048	0.027741	26.777	27.119	0.063396	0.054902	0.12526	749.57	0.46172	495.46	75.773
610	14.033	34.451	0.029026	27.917	28.324	0.065309	0.055258	0.14100	681.27	0.61660	475.03	71.759
620	15.901	32.577	0.030697	29.160	29.648	0.067371	0.056100	0.16852	604.73	0.84473	454.10	67.382
630	17.969	30.210	0.033101	30.585	31.180	0.069715	0.058152	0.23108	513.19	1.2251	432.51	62.244
640	20.265	26.729	0.037413	32.422	33.180	0.072737	0.064521	0.46736	400.66	1.9542	414.93	55.247
647.1	22.064	17.874	0.055948	36.314	37.548	0.079393			0	3.7410		
273.16	0.000612	0.000269	3711.0	42.785	45.055	0.16494	0.025553	0.033947	409.00	592.65	17.071	9.2163
280	0.000992	0.000426	2345.4	42.954	45.280	0.16174	0.025657	0.034073	413.92	477.26	17.442	9.3815
290	0.001920	0.000797	1254.3	43.201	45.609	0.15741	0.025816	0.034270	420.99	351.65	18.031	9.6414
300	0.003537	0.001420	704.01	43.446	45.936	0.15344	0.025982	0.034483	427.89	264.35	18.673	9.9195
310	0.006231	0.002424	412.60	43.690	46.261	0.14981	0.026158	0.034716	434.63	203.74	19.369	10.213
320	0.010546	0.003978	251.39	43.931	46.582	0.14647	0.026350	0.034980	441.18	161.25	20.117	10.518
330	0.017213	0.006304	158.62	44.169	46.900	0.14339	0.026568	0.035287	447.54	130.92	20.922	10.833
340	0.027188	0.009681	103.30	44.404	47.212	0.14054	0.026821	0.035653	453.68	108.77	21.784	11.157
350	0.041682	0.014448	69.213	44.634	47.519	0.13791	0.027118	0.036091	459.58	92.178	22.707	11.487
360	0.062194	0.021014	47.586	44.860	47.819	0.13546	0.027469	0.036617	465.22	79.440	23.695	11.823
370	0.090535	0.029859	33.491	45.079	48.111	0.13317	0.027883	0.037249	470.57	69.427	24.750	12.162
380	0.12885	0.041537	24.075	45.291	48.393	0.13104	0.028372	0.038004	475.61	61.373	25.875	12.504
390	0.17964	0.056683	17.642	45.496	48.665	0.12904	0.028944	0.038903	480.32	54.749	27.074	12.848
400	0.24577	0.076014	13.156	45.691	48.924	0.12715	0.029608	0.039963	484.67	49.181	28.347	13.192
410	0.33045	0.10034	9.9666	45.876	49.170	0.12537	0.030369	0.041203	488.65	44.405	29.699	13.538
420	0.43730	0.13055	7.6601	46.050	49.400	0.12369	0.031230	0.042634	492.22	40.237	31.128	13.883
430	0.57026	0.16765	5.9649	46.211	49.613	0.12208	0.032187	0.044269	495.39	36.550	32.638	14.228
440	0.73367	0.21276	4.7002	46.359	49.807	0.12054	0.033234	0.046114	498.12	33.259	34.230	14.573

TABLE 2-305 Thermodynamic Properties of Water (*Continued*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
450	0.93220	0.26711	3.7438	46.492	49.982	0.11907	0.034362	0.048177	500.41	30.307	35.904	14.917
460	1.1709	0.33209	3.0113	46.609	50.134	0.11764	0.035561	0.050469	502.24	27.653	37.663	15.261
470	1.4551	0.40925	2.4435	46.708	50.263	0.11627	0.036821	0.053005	503.60	25.265	39.512	15.606
480	1.7905	0.50035	1.9986	46.788	50.367	0.11493	0.038137	0.055809	504.45	23.118	41.455	15.952
490	2.1831	0.60738	1.6464	46.848	50.442	0.11362	0.039503	0.058919	504.78	21.187	43.502	16.300
500	2.6392	0.73265	1.3649	46.885	50.487	0.11233	0.040920	0.062388	504.55	19.450	45.666	16.653
510	3.1655	0.87884	1.1379	46.898	50.500	0.11105	0.042391	0.066289	503.71	17.886	47.969	17.011
520	3.7690	1.0491	0.95318	46.883	50.475	0.10979	0.043920	0.070723	502.23	16.475	50.442	17.377
530	4.4569	1.2473	0.80174	46.838	50.411	0.10852	0.045519	0.075827	500.05	15.197	53.130	17.755
540	5.2369	1.4780	0.67659	46.758	50.302	0.10724	0.047197	0.081789	497.10	14.035	56.102	18.149
550	6.1172	1.7471	0.57238	46.641	50.142	0.10595	0.048968	0.088873	493.31	12.973	59.456	18.563
560	7.1062	2.0620	0.48497	46.478	49.925	0.10462	0.050848	0.097461	488.58	11.997	63.341	19.007
570	8.2132	2.4325	0.41110	46.264	49.641	0.10324	0.052856	0.10813	482.79	11.093	67.981	19.489
580	9.4480	2.8720	0.34819	45.988	49.278	0.10180	0.055017	0.12178	475.80	10.248	73.721	20.024
590	10.821	3.3994	0.29417	45.636	48.819	0.10026	0.057361	0.13994	467.41	9.4499	81.108	20.634
600	12.345	4.0434	0.24732	45.188	48.242	0.098600	0.059939	0.16540	457.33	8.6837	91.052	21.350
610	14.033	4.8497	0.20620	44.613	47.506	0.096755	0.062831	0.20384	445.11	7.9329	105.17	22.229
620	15.901	5.9009	0.16946	43.855	46.550	0.094631	0.066197	0.26923	429.99	7.1743	126.66	23.374
630	17.969	7.3737	0.13562	42.801	45.238	0.092029	0.070465	0.40819	410.21	6.3669	163.44	25.018
640	20.265	9.8331	0.10170	41.095	43.156	0.088324	0.077576	0.94736	379.64	5.3854	250.01	27.938
647.1	22.064	17.874	0.055948	36.314	37.548	0.079393			0	3.7410		
Single-Phase Properties												
300	0.1	55.317	0.018078	2.0277	2.0295	0.007081	0.074406	0.075315	1501.5	–0.22024	610.32	853.83
372.76	0.1	53.212	0.018793	7.5196	7.5214	0.02347	0.067921	0.075938	1543.5	–0.17843	678.97	282.91
372.76	0.1	0.032769	30.517	45.138	48.190	0.13257	0.02801	0.037444	471.99	67.038	25.053	12.256
400	0.1	0.030397	32.898	45.900	49.189	0.13516	0.02717	0.036170	490.31	47.254	27.008	13.285
500	0.1	0.024154	41.401	48.619	52.759	0.14313	0.02717	0.035693	548.31	19.298	35.861	17.270
600	0.1	0.020086	49.786	51.387	56.365	0.14970	0.028103	0.036513	598.61	10.567	46.367	21.407
700	0.1	0.017201	58.136	54.256	60.069	0.15541	0.029225	0.037592	643.92	6.6444	57.964	25.564
800	0.1	0.015044	66.471	57.240	63.887	0.16050	0.030431	0.038778	685.47	4.5167	70.385	29.669
900	0.1	0.013369	74.799	60.347	67.827	0.16514	0.031687	0.040024	724.03	3.2280	83.466	33.685
1000	0.1	0.012030	83.123	63.581	71.893	0.16943	0.032963	0.041293	760.17	2.3885	97.085	37.592
1100	0.1	0.010936	91.444	66.941	76.085	0.17342	0.034228	0.042554	794.33	1.8122	111.15	41.382
1200	0.1	0.010024	99.763	70.426	80.402	0.17718	0.035458	0.043781	826.85	1.4006	125.58	45.054
300	1	55.340	0.018070	2.0263	2.0444	0.007077	0.074353	0.075270	1503.0	–0.22022	610.73	853.67
400	1	52.060	0.019209	9.5914	9.6106	0.028834	0.065422	0.076628	1511.3	–0.16113	684.10	218.80
453.03	1	49.243	0.020307	13.717	13.737	0.038518	0.061169	0.079348	1392.0	–0.11435	673.37	150.24
453.03	1	0.28559	3.5015	46.529	50.030	0.11863	0.034718	0.048846	501.02	29.473	36.427	15.021
500	1	0.25158	3.9749	48.111	52.086	0.12295	0.030084	0.041065	535.74	19.741	38.799	17.051
600	1	0.20466	4.8861	51.123	56.009	0.13011	0.029002	0.038358	592.58	10.615	47.636	21.329
700	1	0.17377	5.7547	54.087	59.842	0.13602	0.029629	0.038495	640.55	6.6387	58.735	25.550
800	1	0.15134	6.6074	57.121	63.729	0.14121	0.030651	0.039301	683.48	4.5077	70.983	29.687
900	1	0.13418	7.4524	60.258	67.710	0.14590	0.031821	0.040358	722.85	3.2212	84.000	33.718
1000	1	0.12058	8.2932	63.511	71.804	0.15021	0.033051	0.041522	759.50	2.3837	97.573	37.630
1100	1	0.10951	9.1313	66.885	76.016	0.15422	0.034290	0.042719	794.01	1.8089	111.57	41.420
1200	1	0.10032	9.9677	70.380	80.347	0.15799	0.035504	0.043905	826.77	1.3982	125.89	45.088
300	5	55.439	0.018038	2.0204	2.1106	0.007057	0.074119	0.075070	1509.8	–0.22012	612.54	853.00
400	5	52.173	0.019167	9.5643	9.6601	0.028766	0.065337	0.076438	1520.9	–0.16222	686.54	219.84
500	5	46.267	0.021614	17.474	17.582	0.046415	0.058082	0.083643	1250.0	–0.04945	646.52	118.27
537.09	5	43.151	0.023175	20.685	20.801	0.052622	0.056215	0.090740	1087.8	0.047232	604.15	100.01
537.09	5	1.4072	0.71063	46.785	50.338	0.10762	0.046699	0.079952	498.04	14.362	55.203	18.032
600	5	1.1320	0.88340	49.734	54.151	0.11436	0.034611	0.051045	561.07	10.407	54.653	21.062
700	5	0.91269	1.0957	53.286	58.765	0.12148	0.031678	0.043318	624.59	6.5536	62.680	25.547

800	5	0.77805	1.2853	56.576	63.002	0.12714	0.031683	0.041848	674.39	4.4532	73.950	29.806
900	5	0.68224	1.4658	59.855	67.183	0.13207	0.032430	0.041922	717.57	3.1856	86.626	33.891
1000	5	0.60918	1.6416	63.197	71.405	0.13652	0.033447	0.042571	756.57	2.3599	99.971	37.821
1100	5	0.55109	1.8146	66.632	75.705	0.14061	0.034565	0.043465	792.63	1.7924	113.64	41.606
1200	5	0.50355	1.9859	70.172	80.101	0.14444	0.035704	0.044458	826.45	1.3865	127.51	45.257
300	10	55.561	0.017998	2.0131	2.1931	0.007031	0.073834	0.074829	1518.2	–0.21999	614.81	852.28
400	10	52.312	0.019116	9.5311	9.7222	0.028682	0.065233	0.076208	1532.7	–0.16351	689.57	221.13
500	10	46.517	0.021497	17.389	17.604	0.046244	0.058028	0.082910	1271.3	–0.05669	651.64	119.55
584.15	10	38.213	0.026169	25.105	25.367	0.060543	0.054835	0.11032	847.33	0.29540	526.83	81.795
584.15	10	3.0787	0.32482	45.852	49.100	0.10117	0.055964	0.128640	472.51	9.9124	76.543	20.267
600	10	2.7628	0.36195	47.183	50.802	0.10405	0.047271	0.092535	503.34	9.4382	71.110	21.036
700	10	1.9625	0.50956	52.145	57.241	0.11405	0.034838	0.051779	602.20	6.3228	69.301	25.704
800	10	1.6157	0.61893	55.851	62.040	0.12046	0.033089	0.045603	662.61	4.3529	78.476	30.054
900	10	1.3945	0.71709	59.334	66.505	0.12572	0.033219	0.044062	710.98	3.1289	90.516	34.176
1000	10	1.2345	0.81002	62.798	70.898	0.13035	0.033947	0.043952	753.03	2.3241	103.50	38.111
1100	10	1.1111	0.90002	66.314	75.314	0.13456	0.034908	0.044427	791.02	1.7683	116.73	41.882
1200	10	1.0119	0.98820	69.910	79.792	0.13846	0.035954	0.045164	826.16	1.3695	130.00	45.506
300	100	57.573	0.017369	1.8921	3.6290	0.006516	0.069812	0.071696	1667.9	–0.21618	654.50	856.88
400	100	54.500	0.018349	9.0423	10.877	0.027360	0.063582	0.073086	1717.3	–0.17905	741.80	243.50
500	100	49.914	0.020034	16.289	18.292	0.043895	0.057324	0.075607	1555.7	–0.12564	730.42	138.92
600	100	43.935	0.022761	23.820	26.097	0.058109	0.052776	0.081104	1300.4	–0.02079	645.83	101.51
700	100	36.179	0.027640	31.916	34.680	0.071320	0.049610	0.091576	1020.0	0.21155	510.14	79.363
800	100	26.768	0.037359	40.700	44.435	0.084331	0.047143	0.10108	813.97	0.65939	351.46	62.042
900	100	19.073	0.052429	48.805	54.048	0.095669	0.043932	0.088057	765.30	1.0399	257.03	53.250
1000	100	14.734	0.067868	55.188	61.975	0.10404	0.041345	0.071678	792.50	1.0944	232.07	51.518
1100	100	12.246	0.081656	60.470	68.635	0.11039	0.040131	0.062539	832.67	0.98401	223.70	52.497
1200	100	10.631	0.094062	65.222	74.628	0.11561	0.039810	0.057826	872.28	0.83544	219.07	54.415
300	500	63.750	0.015686	1.5247	9.3678	0.003746	0.063403	0.068296	2228.6	–0.19915	763.82	1089.4
400	500	60.862	0.016431	7.9635	16.179	0.023347	0.059634	0.067603	2258.7	–0.19486	929.09	320.18
500	500	57.695	0.017332	14.264	22.930	0.038412	0.055769	0.067522	2200.7	–0.18339	1096.6	189.08
600	500	54.316	0.018411	20.481	29.687	0.050731	0.052734	0.067584	2093.8	–0.16883	1097.9	141.83
700	500	50.847	0.019667	26.606	36.439	0.061141	0.050315	0.067436	1970.5	–0.15188	935.15	118.47
800	500	47.385	0.021104	32.615	43.167	0.070124	0.048442	0.067080	1850.1	–0.13256	738.72	104.70
900	500	44.018	0.022718	38.492	49.851	0.077998	0.047068	0.066596	1743.4	–0.11124	572.49	95.388
1000	500	40.814	0.024501	44.233	56.484	0.084987	0.046126	0.066041	1655.7	–0.08910	445.17	88.418
1100	500	37.834	0.026432	49.839	63.055	0.091251	0.045537	0.065356	1589.3	–0.06907	350.97	83.021
1200	500	35.124	0.028470	55.312	69.547	0.096900	0.045218	0.064451	1543.9	–0.05511	282.78	78.952
400	1000	65.942	0.015165	7.4792	22.644	0.019833	0.057934	0.065743	2718.6	–0.19303	1172.7	329.93
500	1000	63.253	0.015810	13.357	29.167	0.034391	0.055063	0.064967	2677.2	–0.19158	2199.5	190.55
600	1000	60.572	0.016509	19.141	35.650	0.046212	0.053055	0.064676	2602.3	–0.18789	3250.5	137.73
700	1000	57.937	0.017260	24.836	42.096	0.056150	0.051393	0.064219	2513.7	–0.18439	3202.2	108.98
800	1000	55.384	0.018056	30.435	48.491	0.064689	0.050059	0.063663	2423.7	–0.18105	2408.7	91.430
900	1000	52.937	0.018890	35.938	54.828	0.072155	0.049062	0.063101	2338.7	–0.17779	1610.7	80.198
1000	1000	50.611	0.019759	41.354	61.113	0.078776	0.048373	0.062594	2261.5	–0.17459	1052.9	72.716
1100	1000	48.415	0.020655	46.695	67.350	0.084722	0.047942	0.062176	2193.2	–0.17139	703.41	67.520
1200	1000	46.349	0.021575	51.976	73.551	0.090117	0.047713	0.061861	2133.6	–0.16808	487.61	63.774

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Wagner, W., and Pruss, A., "The IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use," *J. Phys. Chem. Ref. Data* **31**(2):387–535, 2002. The source for viscosity is International Association for the Properties of Water and Steam, *Revised Release on the IAPS Formulation 1985 for the Viscosity of Ordinary Water Substance*, IAPWS, 1997. The source for thermal conductivity is the International Association for the Properties of Water and Steam, *Revised Release on the IAPS Formulation 1985 for the Thermal Conductivity of Ordinary Water Substance*, IAPWS, 1998.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainty in density of the equation of state is 0.0001% at 1 atm in the liquid phase, and 0.001% at other liquid states at pressures up to 10 MPa and temperatures to 423 K. In the vapor phase, the uncertainty is 0.05% or less. The uncertainties rise at higher temperatures and/or pressures, but are generally less than 0.1% in density except at extreme conditions. The uncertainty in pressure in the critical region is 0.1%. The uncertainty of the speed of sound is 0.15% in the vapor and 0.1% or less in the liquid, and increases near the critical region and at high temperatures and pressures. The uncertainty in isobaric heat capacity is 0.2% in the vapor and 0.1% in the liquid, with increasing values in the critical region and at high pressures. The uncertainties of saturation conditions are 0.025% in vapor pressure, 0.0025% in saturated-liquid density, and 0.1% in saturated-vapor density. The uncertainties in the saturated densities increase substantially as the critical region is approached. For the uncertainties in the viscosity and thermal conductivity, see the IAPWS Release.

TABLE 2-306 Thermodynamic Properties of Water Substance along the Melting Line

P, bar	T, °C	$10^3\, v_f$, m³/kg	h_f, kJ/kg	s_f, kJ/kg·K	c_{pf}, kJ/kg·K	c_{melt}, kJ/kg·K	$10^6\alpha_f$, K^{-1}	$10^6 K_{f,T}$ bar^{-1}
6.117×10^{-3t}	0.0100	1.00021	0	0	4.219	3.969	–67.42	50.90
1.01325	0.0026	1.00016	0.0719	–0.0001	4.218	3.970	–67.17	50.88
50	–0.3618	0.99770	3.5140	–0.0054	4.196	3.997	–54.92	50.30
100	–0.7410	0.99523	6.9794	–0.0110	4.174	4.023	–42.52	49.73
150	–1.1249	0.99278	10.3964	–0.0167	4.152	4.047	–30.24	49.17
200	–1.5166	0.99037	13.7648	–0.0225	4.132	4.070	–18.05	48.63
250	–1.9151	0.98798	17.0843	–0.0285	4.112	4.092	–5.93	48.11
300	–2.3206	0.98562	20.3547	–0.0347	4.092	4.113	6.12	47.59
400	–3.1532	0.98098	26.7472	–0.0474	4.056	4.150	30.09	46.61
500	–4.0156	0.97643	32.9403	–0.0607	4.022	4.184	53.97	45.68
600	–4.909	0.97196	38.932	–0.0747	3.992	4.215	77.87	44.80
800	–6.790	0.96326	50.300	–0.1046	3.937	4.270	126.18	43.19
1000	–8.803	0.95493	60.836	–0.1371	3.893	4.320	175.98	41.74

Condensed from U. Grigull, Private communication, January 18, 1995.

Materials prepared at Technical University München, Germany by U. Grigull and S. Marek. For a table as a function of temperature, see Grigull, U. and S. Marek, *Warme u. Stoff.,* **30** (1994): 1–8.

t = the triple point (at 6.117×10^{-3} bar, 0.01 °C); $v_f = 0.0010021$ m³/kg: $\alpha_f = -67.42 \times 10^{-6}$/K.

Other equations for properties are given by Jones, F. E. and G. L. Harris, *J. Res. N.I.S.T.,* **97,** 3 (1992): 335–340, and by Wagner, W. and A. Pruss, *J. Phys. Chem. Ref. Data,* **22,** 3 (1993): 783–787. Steam tables include Walker, W. A., U.S. Naval Ordn. Lab. rept. NOLTR NOLTR-66-217 = AD 651105 (0–1000 bar, 0–150°C), 1967 (72 pp.); Grigull, U., J. Straub, et al., *Steam Tables in S.I. Units* (0.01–1000 bar, 0–1000 °C), Springer-Verlag, Berlin, 1990 (133 pp.); Tseng, C. M., T. A. Hamp, et al., Atomic Energy of Canada rept. (30 props, sat liq & vap., 1–220 bar), AECL-5910 1977 (90 pp.). For dissociation, see e.g., Knonicek, V., *Rozpr. Cesko Acad Ved., Rada techn ved* (0.01–100 bar, 1000–5000 K). **77,** 1 (1967). The proceedings of the 10th international conference on the properties of steam were edited by Sytchev, V. V. and A. A. Aleksandrov, Plenum, NY, 1984; and for the 11th conference by Pichal, M. and O. Sifner, Hemisphere, 1989 (550 pp.). Current information on the properties of solid, vapor, and liquid water properties can be found at http://www.iapws.org.

For electrical conductivity, see e.g., Marshall, W. L., *J. Chem. Eng. Data,* **32** (1987): 221–226.

TABLE 2-307 Thermodynamic Properties of Xenon

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Saturated Properties												
161.40	0.081748	22.592	0.044263	–0.16663	–0.16301	–0.00099337	0.022064	0.044446	653.38	–0.63704	72.081	516.89
170.00	0.13343	22.155	0.045137	0.21574	0.22176	0.0013152	0.021486	0.044730	629.12	–0.60760	68.920	457.99
175.00	0.17325	21.895	0.045673	0.43915	0.44706	0.0026109	0.021176	0.044972	614.85	–0.58689	67.037	427.78
180.00	0.22153	21.630	0.046232	0.66366	0.67390	0.0038765	0.020884	0.045274	600.43	–0.56326	65.137	400.07
185.00	0.27933	21.361	0.046815	0.88953	0.90261	0.0051149	0.020609	0.045640	585.85	–0.53642	63.229	374.57
190.00	0.34774	21.085	0.047426	1.1170	1.1335	0.0063292	0.020349	0.046075	571.10	–0.50604	61.320	351.01
195.00	0.42789	20.804	0.048068	1.3464	1.3669	0.0075220	0.020104	0.046585	556.14	–0.47173	59.415	329.16
200.00	0.52091	20.516	0.048743	1.5779	1.6033	0.0086959	0.019873	0.047179	540.97	–0.43300	57.519	308.84
205.00	0.62797	20.220	0.049455	1.8119	1.8429	0.0098535	0.019656	0.047868	525.55	–0.38927	55.633	289.88
210.00	0.75025	19.916	0.050210	2.0487	2.0864	0.010997	0.019453	0.048666	509.85	–0.33987	53.759	272.13
215.00	0.88893	19.603	0.051013	2.2887	2.3341	0.012130	0.019264	0.049590	493.84	–0.28392	51.897	255.47
220.00	1.0452	19.279	0.051869	2.5324	2.5866	0.013254	0.019091	0.050663	477.47	–0.22039	50.048	239.78
225.00	1.2203	18.944	0.052787	2.7802	2.8446	0.014373	0.018933	0.051914	460.71	–0.14796	48.209	224.96
230.00	1.4155	18.596	0.053776	3.0328	3.1089	0.015488	0.018794	0.053385	443.49	–0.064982	46.379	210.92
235.00	1.6321	18.232	0.054847	3.2907	3.3802	0.016605	0.018675	0.055128	425.74	0.030670	44.554	197.57
240.00	1.8712	17.852	0.056017	3.5550	3.6598	0.017726	0.018580	0.057218	407.38	0.14178	42.730	184.83
245.00	2.1344	17.451	0.057304	3.8265	3.9488	0.018857	0.018515	0.059766	388.30	0.27205	40.903	172.63
250.00	2.4229	17.026	0.058735	4.1068	4.2491	0.020002	0.018487	0.062932	368.36	0.42662	39.071	160.90
255.00	2.7382	16.572	0.060344	4.3976	4.5628	0.021170	0.018507	0.066972	347.41	0.61272	37.238	149.54
260.00	3.0820	16.082	0.062183	4.7014	4.8930	0.022371	0.018591	0.072312	325.20	0.84107	35.418	138.48
265.00	3.4561	15.545	0.064330	5.0218	5.2441	0.023618	0.018767	0.079722	301.44	1.1284	33.653	127.61
270.00	3.8623	14.945	0.066910	5.3646	5.6230	0.024935	0.019077	0.090763	275.68	1.5023	32.016	116.78
275.00	4.3032	14.254	0.070156	5.7397	6.0416	0.026360	0.019604	0.10917	247.28	2.0135	30.622	105.75
280.00	4.7818	13.411	0.074566	6.1681	6.5247	0.027976	0.020521	0.14668	215.12	2.7688	29.654	94.067
285.00	5.3025	12.242	0.081686	6.7103	7.1435	0.030022	0.022329	0.26914	176.78	4.0593	29.742	80.469
289.73	5.8420	8.4000	0.11905	8.2423	8.9377	0.036074			0	8.3700		
161.40	0.081748	0.062613	15.971	11.189	12.495	0.077430	0.013321	0.022698	128.33	64.799	3.1160	13.386
170.00	0.13343	0.098131	10.190	11.261	12.621	0.074250	0.013615	0.023442	130.83	57.103	3.3040	14.014
175.00	0.17325	0.12476	8.0157	11.298	12.687	0.072554	0.013809	0.023957	132.15	53.274	3.4175	14.392
180.00	0.22153	0.15646	6.3913	11.332	12.748	0.070955	0.014020	0.024539	133.36	49.835	3.5348	14.781
185.00	0.27933	0.19385	5.1587	11.362	12.803	0.069442	0.014247	0.025194	134.47	46.729	3.6563	15.180
190.00	0.34774	0.23755	4.2096	11.388	12.852	0.068004	0.014491	0.025929	135.46	43.913	3.7826	15.592
195.00	0.42789	0.28826	3.4691	11.409	12.893	0.066633	0.014750	0.026755	136.35	41.350	3.9143	16.018
200.00	0.52091	0.34671	2.8842	11.426	12.928	0.065319	0.015025	0.027681	137.13	39.009	4.0523	16.460
205.00	0.62797	0.41374	2.4170	11.437	12.954	0.064056	0.015314	0.028722	137.79	36.862	4.1975	16.920
210.00	0.75025	0.49026	2.0397	11.442	12.973	0.062836	0.015618	0.029898	138.35	34.888	4.3511	17.399
215.00	0.88893	0.57731	1.7322	11.442	12.981	0.061653	0.015938	0.031232	138.80	33.066	4.5144	17.901
220.00	1.0452	0.67606	1.4791	11.434	12.980	0.060498	0.016273	0.032757	139.13	31.378	4.6894	18.429
225.00	1.2203	0.78791	1.2692	11.420	12.968	0.059367	0.016625	0.034515	139.35	29.805	4.8787	18.987
230.00	1.4155	0.91450	1.0935	11.397	12.945	0.058252	0.016996	0.036563	139.45	28.333	5.0855	19.579
235.00	1.6321	1.0578	0.94537	11.365	12.908	0.057147	0.017389	0.038982	139.43	26.946	5.3151	20.212
240.00	1.8712	1.2202	0.81952	11.322	12.856	0.056042	0.017808	0.041885	139.29	25.629	5.5745	20.892
245.00	2.1344	1.4049	0.71181	11.268	12.787	0.054930	0.018258	0.045436	139.02	24.367	5.8750	21.630
250.00	2.4229	1.6157	0.61892	11.199	12.699	0.053801	0.018748	0.049883	138.62	23.142	6.2336	22.437
255.00	2.7382	1.8581	0.53818	11.114	12.588	0.052641	0.019288	0.055621	138.07	21.938	6.6778	23.333
260.00	3.0820	2.1394	0.46742	11.009	12.450	0.051434	0.019894	0.063311	137.36	20.732	7.2524	24.341
265.00	3.4561	2.4705	0.40477	10.878	12.277	0.050157	0.020590	0.074154	136.47	19.500	8.0324	25.501
270.00	3.8623	2.8685	0.34861	10.713	12.059	0.048773	0.021413	0.090577	135.36	18.207	9.1495	26.874
275.00	4.3032	3.3629	0.29736	10.500	11.779	0.047224	0.022428	0.11833	133.95	16.800	10.852	28.575
280.00	4.7818	4.0140	0.24913	10.209	11.400	0.045388	0.023764	0.17512	132.11	15.185	13.688	30.845
285.00	5.3025	4.9911	0.20036	9.7610	10.823	0.042934	0.025741	0.35495	129.38	13.131	19.481	34.410
289.73	5.8420	8.4000	0.11905	8.2423	8.9377	0.036074			0	8.3700		
Single-Phase Properties												
200.00	0.10000	0.061174	16.347	11.693	13.328	0.080422	0.012825	0.021719	143.95	39.340	3.8225	16.051
300.00	0.10000	0.040297	24.816	12.971	15.453	0.089046	0.012529	0.021011	177.58	18.027	5.5664	23.114
400.00	0.10000	0.030132	33.188	14.227	17.546	0.095069	0.012489	0.020884	205.37	10.987	7.2216	30.061

TABLE 2-307 Thermodynamic Properties of Xenon (*Concluded*)

Temperature K	Pressure MPa	Density mol/dm^3	Volume dm^3/mol	Int. energy kJ/mol	Enthalpy kJ/mol	Entropy kJ/(mol·K)	C_v kJ/(mol·K)	C_p kJ/(mol·K)	Sound speed m/s	Joule-Thomson K/MPa	Therm. cond. mW/(m·K)	Viscosity μPa·s
Single-Phase Properties (*Concluded*)												
500.00	0.10000	0.024077	41.533	15.479	19.632	0.099724	0.012480	0.020841	229.73	7.4876	8.7865	36.679
600.00	0.10000	0.020054	49.866	16.728	21.715	0.10352	0.012477	0.020822	251.71	5.3775	10.259	42.919
700.00	0.10000	0.017184	58.193	17.977	23.796	0.10673	0.012475	0.020811	271.90	3.9611	11.644	48.797
200.00	1.0000	20.545	0.048673	1.5644	1.6131	0.0086285	0.019883	0.047017	543.44	–0.43967	57.759	310.61
218.61	1.0000	19.370	0.051625	2.4644	2.5160	0.012943	0.019137	0.050348	482.05	–0.23885	50.560	244.05
218.61	1.0000	0.64740	1.5446	11.437	12.982	0.060816	0.016178	0.032313	139.05	31.834	4.6396	18.280
300.00	1.0000	0.42338	2.3619	12.735	15.097	0.069105	0.013071	0.023342	174.22	17.710	5.9066	23.825
400.00	1.0000	0.30719	3.2553	14.081	17.337	0.075560	0.012653	0.021812	204.53	10.799	7.4612	30.617
500.00	1.0000	0.24284	4.1179	15.373	19.491	0.080369	0.012555	0.021347	229.84	7.3466	8.9749	37.129
600.00	1.0000	0.20128	4.9682	16.646	21.614	0.084241	0.012521	0.021143	252.27	5.2698	10.414	43.291
700.00	1.0000	0.17205	5.8123	17.910	23.723	0.087491	0.012506	0.021033	272.69	3.8786	11.777	49.110
200.00	5.0000	20.777	0.048130	1.4588	1.6995	0.0080923	0.019975	0.045835	562.91	–0.48921	59.693	324.93
282.15	5.0000	12.969	0.077107	6.3800	6.7656	0.028774	0.021130	0.17857	199.64	3.2255	29.468	88.606
282.15	5.0000	4.3744	0.22860	10.045	11.188	0.044447	0.024500	0.22292	131.10	14.382	15.582	32.133
300.00	5.0000	3.0178	0.33137	11.189	12.846	0.050182	0.017212	0.057127	155.40	14.736	9.7191	29.671
400.00	5.0000	1.6846	0.59361	13.369	16.337	0.060390	0.013445	0.027264	202.15	9.6973	8.7332	33.661
500.00	5.0000	1.2596	0.79390	14.889	18.859	0.066031	0.012902	0.023853	231.38	6.6609	9.8856	39.357
600.00	5.0000	1.0212	0.97922	16.278	21.175	0.070256	0.012724	0.022627	255.44	4.7873	11.137	45.049
700.00	5.0000	0.86365	1.1579	17.615	23.404	0.073694	0.012645	0.022028	276.67	3.5219	12.377	50.547
200.00	10.000	21.038	0.047533	1.3406	1.8159	0.0074790	0.020097	0.044678	584.79	–0.53901	61.959	341.91
300.00	10.000	13.284	0.075281	6.6026	7.3554	0.029493	0.018200	0.088497	258.88	2.0533	29.649	94.113
400.00	10.000	3.8169	0.26199	12.321	14.941	0.052029	0.014472	0.037766	204.59	7.6552	11.158	39.566
500.00	10.000	2.6239	0.38111	14.257	18.068	0.059048	0.013339	0.027456	235.98	5.6862	11.280	42.848
600.00	10.000	2.0706	0.48294	15.817	20.646	0.063756	0.012977	0.024556	260.98	4.1777	12.172	47.602
700.00	10.000	1.7304	0.57792	17.251	23.030	0.067433	0.012819	0.023262	282.62	3.0965	13.210	52.559
200.00	100.00	23.707	0.042181	0.22766	4.4458	0.00066778	0.022077	0.038788	819.84	–0.80697	91.685	582.16
300.00	100.00	20.755	0.048181	3.3951	8.2132	0.015969	0.018781	0.036811	690.23	–0.77003	62.741	293.11
400.00	100.00	18.043	0.055422	6.2728	11.815	0.026343	0.017019	0.035156	597.21	–0.68464	46.987	188.96
500.00	100.00	15.689	0.063739	8.8555	15.229	0.033970	0.015937	0.033084	538.16	–0.60849	38.256	141.62
600.00	100.00	13.750	0.072728	11.158	18.431	0.039814	0.015222	0.030987	504.61	–0.56578	33.282	118.14
700.00	100.00	12.188	0.082045	13.232	21.437	0.044451	0.014724	0.029184	487.44	–0.55679	30.399	106.02
400.00	500.00	25.007	0.039989	4.1551	24.150	0.012220	0.020738	0.032768	1164.9	–0.96827	96.278	544.58
500.00	500.00	23.787	0.042040	6.3322	27.352	0.019372	0.019369	0.031337	1121.3	–1.0167	80.779	424.61
600.00	500.00	22.695	0.044062	8.3949	30.426	0.024980	0.018396	0.030178	1086.3	–1.0606	71.145	352.34
700.00	500.00	21.712	0.046058	10.364	33.393	0.029555	0.017664	0.029185	1058.1	–1.1030	64.734	304.58

The values in these tables were generated from the NIST REFPROP software (Lemmon, E. W., McLinden, M. O., and Huber, M. L., NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties—REFPROP, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, Md., 2002, Version 7.1). The primary source for the thermodynamic properties is Lemmon, E. W., and Span, R., "Short Fundamental Equations of State for 20 Industrial Fluids," *J. Chem. Eng. Data* **51**(3):785–850, 2006. The source for viscosity and thermal conductivity is McCarty, R. D., *Correlations for the Thermophysical Properties of Xenon*, National Institute of Standards and Technology, Boulder, Colo., 1989.

Properties at the triple point temperature and the critical point temperature are given in the first and last entries of the saturation tables, respectively. In the single-phase table, when the temperature range for a given isobar includes a vapor-liquid phase boundary, the temperature of phase equilibrium is noted, and properties for both the saturated liquid and saturated vapor are given (with liquid properties given in the upper line). Lines are omitted from the temperature-pressure grid of the single-phase table, when the system would be in the solid phase or if there are potential problems with the source property surface.

The uncertainties in the equation of state are 0.2% in density up to 100 MPa, rising to 1% at higher pressures, 0.2% in vapor pressure, 1% in the speed of sound, and 2% in heat capacities. For viscosity, estimated uncertainty is less than 5%. For thermal conductivity, estimated uncertainty is less than 6%.

TABLE 2-308 Surface Tension (N/m) of Saturated Liquid Refrigerants*

	Temperature, °C								
R no.	–50	–25	0	25	50	75	100	125	150
11	0.0279	0.0244	0.0210	0.0178	0.0146	0.0116	0.0087	0.0060	0.0036
12	0.0188	0.0152	0.0118	0.0085	0.0055	0.0029	0.0007	—	—
13	0.0092	0.0056	0.0025	0.0002	—	—	—	—	—
22	0.0197	0.0156	0.0117	0.0081	0.0047	0.0018	—	—	—
23	0.0115	0.0065	0.0025		—	—	—	—	—
32				0.0069	0.0032	0.0002	—	—	—
113	—	0.0231	0.0201	0.0172	0.0144	0.0118	0.0092	0.0067	0.0045
114			0.0138	0.0109	0.0082	0.0056	0.0033	0.0012	—
115			0.0075	0.0047	0.0022		—	—	—
134a	0.0192	0.0154	0.0117	0.0082	0.0050	0.0021	0.0000	—	—
142b	0.0213	0.0178	0.0145	0.0113	0.0083	0.0055	0.0029		—
152a	0.0201	0.0166	0.0132	0.0100	0.0068	0.0038	0.0011	—	—
170	0.0100	0.0051	0.0032	0.0005	—	—	—	—	—
290			0.0101	0.0082	0.0041	0.0016	—	—	—
C318	—	0.0143	0.0113	0.0085	0.0048	0.0033	0.0011	—	—
502	0.0159	0.0121	0.0086	0.0054	0.0026		—	—	—
503	0.0094	0.0053	0.0018	—	—	—	—	—	—
600		0.0180	0.0150	0.0122	0.0094	0.0068	0.0043	0.0020	0.0001
600a			0.0132	0.0101	0.0073	0.0047	0.0024	0.0005	—
718	—	—	0.0755	0.0720	0.0680	0.0636	0.0590	0.0540	0.0488
744		0.0096	0.0044	0.0005	—	—	—	—	—
1150	0.0100	0.0055	0.0013						
1270	0.0171	0.0136	0.0102	0.0070	0.0041	0.0014			

*Dashes indicate inaccessible states; blanks indicate no available data.

Values and equations were given by Srinivasan, K., *Can. J. Chem. Eng.* (27 liquids), **68** (1990): 493; Lielmezs, J. and T. A. Herrick, *Chem. Eng. J.* (34 liquids), **32** (1986): 165–169. Somayajulu, G. R., *Int. J. Thermophys.* (64 liquids); **9,** 4 (1988): 559–566; Ibrahim, N. and S. Murad, *Chem. Eng. Commun.* (29 polar liquids), **79** (1979): 165–174; Yaws, C. L.; Morachevsky, A. G. and I. B. Sladkov, *Physico-Chemical Properties of Molecular Inorganic Compounds* (200 compounds), Khimiya, Leningrad, 1987, Jasper, J., *J. Phys. Chem. Ref. Data* (2200 compounds), **1,** (1972): 841–1009; and Vargaftik, N. B., B. N. Volkov, et al., *J. Phys. Chem. Ref. Data* (water), **12,** 3 (1983): 817–820. See also Escobedo, J. and Mansoori, G. R., *AIChE J.,* **42**(5), May 1996: 1425–1433.

TABLE 2-309 Surface Tension σ (dyn/cm) of Various Liquids

Compound	*T*, K	σ	Compound	*T*, K	σ	Compound	*T*, K	σ
Acetic acid	293	27.59	*p*-Cresol	313	34.88	Isobutyric acid	293	25.04
	333	23.62		373	29.32		313	23.2
Acetone	298	24.02	Cyclohexane	293	25.24		333	21.36
	308	22.34		313	22.87		363	18.6
	318	21.22		333	20.49	Methyl formate	293	24.62
Aniline	293	42.67	Cyclopentane	293	22.61		323	20.05
	313	40.5		313	19.68		373	12.9
	333	38.33	Diethyl ether	288	17.56		423	6.3
	353	36.15		303	16.2		473	0.87
Benzene	293	28.88	2,3-Dimethylbutane	293	17.38	Methyl alcohol	293	22.56
	313	26.25		313	15.38		313	20.96
	333	23.67	Ethyl acetate	293	23.97		333	19.41
	353	21.2		313	21.65	Phenol	313	39.27
Benzonitrile	293	39.37		333	19.32		333	37.13
	323	35.89		353	17		373	32.96
	363	31.26		373	14.68	*n*-Propyl alcohol	293	23.71
Bromobenzene	293	35.82	Ethyl benzoate	293	35.04		313	22.15
	323	32.34		313	32.92		333	20.6
	373	26.54		333	30.81		363	18.27
n-Butane	203	23.31	Ethyl bromide	283	25.36	*n*-Propyl benzene	293	29.98
	233	19.69		303	23.04		313	26.83
	293	12.46	Ethyl mercaptan	288	23.87		333	24.68
Carbon disulfide	293	32.32		303	22.68		353	22.53
	313	29.35	Formamide	298	57.02		373	20.38
Carbon tetrachloride	288	27.65		338	53.66	Pyridine	293	37.21
	308	25.21		373	50.71		313	34.6
	328	22.76	*n*-Heptane	293	20.14		333	31.98
	348	20.31		313	18.18			
	368	17.86		333	16.22			
Chlorobenzene	293	33.59		353	14.26			
	323	30.01						
	373	24.06						

Methyl formate values from D. B. Macleod, *Trans. Faradaay Soc.* **19**:38, 1923. All others from J. J. Jasper, *J. Phys. Chem. Ref. Data* **1**:841, 1972.

TABLE 2-310 Velocity of Sound (m/s) in Gaseous Refrigerants at Atmospheric Pressure*

	Temperature, °C								
R. no.	–50	–25	0	25	50	75	100	125	150
14	158	166	173	180	187	194	200	206	212
170	272	286	299	311	323	334	344	355	364
290	—	227	238	249	258	268	277	286	294
600	—	—	200	210	220	228	237	245	252
600a	—	—	201	211	221	229	237	246	253
718	—	—	—	—	—	—	473	490	505
744		248	258	269	279	288	297	307	316
1150	290	305	318	330	341	352	363	373	384
1270	—	235	246	257	267	277	286	295	303

*Dashes indicate inaccessible states; blanks indicate no available data. Values for the velocity of sound for all compounds listed in Table 2-184 are given in their respective tables earlier in this section.

TABLE 2-311 Velocity of Sound (m/s) in Saturated Liquid Refrigerants*

	Temperature, °C								
R. no.	–50	–25	0	25	50	75	100	125	150
14	182	—	—	—	—	—	—	—	—
290	1210	982	884	719	551	367	—	—	—
600	1290	1163	1031	896	759	609	477	325	142
600a	1205	1078	947	812	661	528	378	208	—
718	—	—	1402	1495	1542	1554	1543	1514	1468
744		751	525	272	—	—	—	—	—
1150	874	644	372						
1270	1184	1022	859	694	524	335			

*Dashes indicate inaccessible states; blanks indicate no available data. Values for the velocity of sound for all compounds listed in Table 2-184 are given in their respective tables earlier in this section.

TRANSPORT PROPERTIES

INTRODUCTION

Extensive tables of the viscosity and thermal conductivity of air and of water or steam for various pressures and temperatures are given with the thermodynamic-property tables. The thermal conductivity and the viscosity for the saturated-liquid state are also tabulated for many fluids along with the thermodynamic-property tables earlier in this section.

UNITS CONVERSIONS

For this subsection the following units conversions are applicable:

Diffusivity: to convert square centimeters per second to square feet per hour, multiply by 3.8750; to convert square meters per second to square feet per hour, multiply by 38,750.

Pressure: to convert bars to pounds-force per square inch, multiply by 14.504.

Temperature: °F = ⅘ °C + 32; °R = ⅘ K.

Thermal conductivity: to convert watts per meter-kelvin to British thermal unit–feet per hour–square foot–degree Fahrenheit, multiply by 0.57779; and to convert British thermal unit–feet per hour–square foot–degree Fahrenheit to watts per meter-kelvin, multiply by 1.7307.

Viscosity: to convert pascal-seconds to centipoises, multiply by 1000.

ADDITIONAL REFERENCES

An extensive coverage of the general pressure and temperature variation of thermal conductivity is given in the monograph by Vargaftik, Filippov, Tarzimanov, and Totskiy, *Thermal Conductivity of Liquids and Gases* (in Russian), Standartov, Moscow, 1978, now published in English translation by CRC Press, Miami, FL.

For a similar work on viscosity, see Stephan and Lucas, *Viscosity of Dense Fluids*, Plenum, New York and London, 1979. Tables and polynomial fits for refrigerants in both the gaseous and the liquid state are contained in *ASHRAE Handbook—Fundamentals*, SI ed., ASHRAE, Atlanta, 2005. Other sources for viscosity include Fischer & Porter Co. catalog 10-A-94, "Fluid densities and viscosities," 1953 (200 industrial fluids in 48 pp.) and van Velzen, D., R. L. Cardozo et al., EURATOM Ispra, Italy rept. 4735 e, 1972 (160 pp.). Liquid viscosity, 314 cpds, is summarized in *I&EC Fundtls.*, 11 (1972): 20–26. Five hundred forty-nine binary and ternary systems are discussed in Skubla, P., *Coll. Czech. Chem. Commun.*, **46** (1981): 303–339.

See also Duhne, C. R., *Chem. Eng.* (NY), **86,** 15 (July 16, 1979): 83–91 (equations and 326 liquids); and Rao, K. V. K., *Chem. Eng.* (NY), **90,** 11 (May 30, 1983): 90–91 (nomograph, 87 liquids). For rheology, non-Newtonian behavior, and the like, see, for instance, Barnes, H., *The Chem. Engr.* (UK), (June 24, 1993): 17–23; Hyman, W. A., *I&EC Fundtls.*, **16** (1976): 215–218; and Ferguson, J. and Z. Kemblowski, *Applied Fluid Rheology*, Elsevier, 1991 (325 pp.). Other sources for thermal conductivity include Ho, C. Y., R. W. Powell et al., *J. Phys. Chem. Ref. Data*, **1** (1972) and **3,** suppl. 1 (1974); Childs, Ericks et al., N.B.S. Monogr. 131, 1973; Jamieson, D. T., J. B. Irving et al., *Liquid Thermal Conductivity*, H.M.S.O., Edinburgh, Scotland, 1975 (220 pp.).

Other references include Poling, Prausnitz, and O'Connell, *The Properties of Gases and Liquids*, 5th ed., McGraw-Hill, New York, 2000; Vargaftik, Vinogradov, and Yargin, *Handbook of Physical Properties of Liquids and Gases*, Begell House, New York, 1996; Yaws, *Chemical Properties Handbook: Physical, Thermodynamics, Environmental Transport, Safety & Health Related Properties for Organic & Inorganic Chemicals*, McGraw-Hill, New York, 1998; and Riazi, *Characterization and Properties of Petroleum Fractions*, ASTM, West Conshohocken, Pa., 2005. Free web resources include the NIST Webbook at http://webbook.nist.gov and the KDB (Korea thermophysical properties) database at http://www.cheric.org/research/kdb/.

TABLE 2-312 Vapor Viscosity of Inorganic and Organic Substances (Pa·s)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	T_{min}, K	Viscosity at T_{min}	T_{max}, K	Viscosity at T_{max}
1	Acetaldehyde	C_2H_4O	75-07-0	44.053	1.222E-07	0.787	77		150.15	4.171E-06	1000	2.605E-05
2	Acetamide	C_2H_5NO	60-35-5	59.067	1.423E-07	0.7574	272.14		353.33	6.842E-06	1000	2.094E-05
3	Acetic acid	$C_2H_4O_2$	64-19-7	60.052	2.7449E-08	1.0123	7.4948		289.81	8.315E-06	1000	2.966E-05
4	Acetic anhydride	$C_4H_6O_3$	108-24-7	102.089	1.20E-07	0.7915	105.3		200.15	5.213E-06	1000	2.572E-05
5	Acetone	C_3H_6O	67-64-1	58.079	3.1005E-08	0.9762	23.139		178.45	4.329E-06	1000	2.571E-05
6	Acetonitrile	C_2H_3N	75-05-8	41.052	5.1964E-08	0.8857	38.805		229.32	5.476E-06	1000	2.271E-05
7	Acetylene	C_2H_2	74-86-2	26.037	1.2025E-06	0.4952	291.4		192.40	6.468E-06	600	1.923E-05
8	Acrolein	C_3H_4O	107-02-8	56.063	6.523E-07	0.579	410.8		185.45	4.174E-06	1000	2.523E-05
9	Acrylic acid	$C_3H_4O_2$	79-10-7	72.063	1.7154E-07	0.7418	138.4		286.15	7.680E-06	1000	2.532E-05
10	Acrylonitrile	C_3H_3N	107-13-1	53.063	4.302E-08	0.9114	54.3		189.63	3.985E-06	1000	2.213E-05
11	Air	Mixture	132259-10-0	28.960	1.425E-06	0.5039	108.3		80.00	5.508E-06	2000	6.227E-05
12	Ammonia	H_3N	7664-41-7	17.031	4.1855E-08	0.9806	30.8		195.41	6.378E-06	1000	3.551E-05
13	Anisole	C_7H_8O	100-66-3	108.138	1.7531E-07	0.72	176.17		235.65	5.122E-06	1000	2.155E-05
14	Argon	Ar	7440-37-1	39.948	9.2121E-07	0.60529	83.24		83.78	6.742E-06	3273.1	1.001E-11
15	Benzamide	C_7H_7NO	55-21-0	121.137	2.5082E-08	0.96663			403.00	8.274E-06	1000	1.992E-05
16	Benzene	C_6H_6	71-43-2	78.112	3.134E-08	0.9676	7.9		278.68	7.077E-06	1000	2.486E-05
17	Benzenethiol	C_6H_6S	108-98-5	110.177	1.1184E-07	0.8002	152.43		442.29	1.089E-05	1000	2.441E-05
18	Benzoic acid	$C_7H_6O_2$	65-85-0	122.121	7.4266E-08	0.8289	91.197		395.45	8.578E-06	1000	2.087E-05
19	Benzonitrile	C_7H_5N	100-47-0	103.121	4.2137E-08	0.92271	45.387		260.40	6.079E-06	1000	2.363E-05
20	Benzophenone	$C_{13}H_{10}O$	119-61-9	182.218	3.779E-07	0.6005	409		321.35	5.324E-06	1000	1.698E-05
21	Benzyl alcohol	C_7H_8O	100-51-6	108.138	6.9022E-08	0.84014	74.746		257.85	5.680E-06	1000	2.129E-05
22	Benzyl ethyl ether	$C_9H_{12}O$	539-30-0	136.191	1.56E-07	0.7181	180		458.15	9.122E-06	1000	1.886E-05
23	Benzyl mercaptan	C_7H_8S	100-53-8	124.203	4.0138E-08	0.90735	34.714		243.95	5.151E-06	1000	2.045E-05
24	Biphenyl	$C_{12}H_{10}$	92-52-4	154.208	1.3874E-06	0.4434	678.22		342.20	6.186E-06	1000	1.768E-05
25	Bromine	Br_2	7726-95-6	159.808	7.3534E-08	0.93798			265.85	1.383E-05	600	2.967E-05
26	Bromobenzene	C_6H_5Br	108-86-1	157.008	2.232E-07	0.7146	184.9		429.24	1.187E-05	1000	2.623E-05
27	Bromoethane	C_2H_5Br	74-96-4	108.965	5.29E-07	0.632	226		154.55	5.195E-06	1000	3.396E-05
28	Bromomethane	CH_3Br	74-83-9	94.939	7.8796E-08	0.90476			179.47	8.626E-06	1000	4.081E-05
29	1,2-Butadiene	C_4H_6	590-19-2	54.090	6.0259E-07	0.5309	199.64		136.95	3.340E-06	1000	1.966E-05
30	1,3-Butadiene	C_4H_6	106-99-0	54.090	2.696E-07	0.6715	134.7		164.25	4.553E-06	1000	2.457E-05
31	Butane	C_4H_{10}	106-97-8	58.122	3.4387E-08	0.94604			134.86	3.559E-06	1000	2.369E-05
32	1,2-Butanediol	$C_4H_{10}O_2$	584-03-2	90.121	7.5626E-08	0.83521	71.798		220.00	5.157E-06	1000	2.260E-05
33	1,3-Butanediol	$C_4H_{10}O_2$	107-88-0	90.121	7.0728E-08	0.84383	64.391		196.15	4.580E-06	1000	2.259E-05
34	1-Butanol	$C_4H_{10}O$	71-36-3	74.122	1.4031E-06	0.4611	537		183.85	3.961E-06	1000	2.207E-05
35	2-Butanol	$C_4H_{10}O$	78-92-2	74.122	1.2114E-07	0.76972	92.661		158.45	3.772E-06	1000	2.259E-05
36	1-Butene	C_4H_8	106-98-9	56.106	6.9744E-07	0.5462	305.25		87.80	1.795E-06	1000	2.325E-05
37	*cis*-2-Butene	C_4H_8	590-18-1	56.106	4.2898E-08	0.91349			134.26	3.770E-06	1000	2.360E-05
38	*trans*-2-Butene	C_4H_8	624-64-6	56.106	1.05E-06	0.4867	358.7		167.62	4.044E-06	1000	2.229E-05
39	Butyl acetate	$C_6H_{12}O_2$	123-86-4	116.158	1.006E-07	0.77881	95.108		199.65	4.216E-06	1000	1.993E-05
40	Butylbenzene	$C_{10}H_{14}$	104-51-8	134.218	3.4205E-07	0.59764	234.21		185.30	3.425E-06	1000	1.720E-05
41	Butyl mercaptan	$C_4H_{10}S$	109-79-5	90.187	5.4539E-08	0.88896	43.687		157.46	3.833E-06	1000	2.427E-05
42	*sec*-Butyl mercaptan	$C_4H_{10}S$	513-53-1	90.187	3.1378E-08	0.96513			133.02	3.520E-06	1000	2.466E-05
43	1-Butyne	C_4H_6	107-00-6	54.090	2.7856E-06	0.377	663.14		147.43	3.329E-06	800	1.893E-05
44	Butyraldehyde	C_4H_8O	123-72-8	72.106	8.0079E-08	0.8178	65.855		176.75	4.017E-06	1000	2.134E-05
45	Butyric acid	$C_4H_8O_2$	107-92-6	88.105	2.128E-06	0.4273	886	–41,400	267.95	6.220E-06	1000	2.208E-05
46	Butyronitrile	C_4H_7N	109-74-0	69.105	8.0223E-08	0.80561	75.207		161.25	3.284E-06	1000	1.948E-05
47	Carbon dioxide	CO_2	124-38-9	44.010	2.148E-06	0.46	290		194.67	9.749E-06	1500	5.203E-05
48	Carbon disulfide	CS_2	75-15-0	76.141	5.8204E-08	0.9262	44.581		161.11	5.048E-06	800	2.693E-05
49	Carbon monoxide	CO	630-08-0	28.010	1.1127E-06	0.5338	94.7		68.15	4.434E-06	1250	4.654E-05
50	Carbon tetrachloride	CCl_4	56-23-5	153.823	3.137E-06	0.3742	491.5		250.33	8.361E-06	1000	2.789E-05
51	Carbon tetrafluoride	CF_4	75-73-0	88.004	2.1709E-06	0.45853	208		89.56	5.132E-06	1000	4.267E-05
52	Chlorine	Cl_2	7782-50-5	70.906	2.60E-07	0.7423	98.3		200.00	8.900E-06	1000	3.992E-05
53	Chlorobenzene	C_6H_5Cl	108-90-7	112.557	1.065E-07	0.7942	94.7		227.95	5.611E-06	1000	2.348E-05
54	Chloroethane	C_2H_5Cl	75-00-3	64.514	3.12E-07	0.6711	139		134.80	4.127E-06	1000	2.824E-05
55	Chloroform	$CHCl_3$	67-66-3	119.378	1.696E-07	0.7693	96.6		209.63	7.091E-06	1000	3.143E-05
56	Chloromethane	CH_3Cl	74-87-3	50.488	8.60E-08	0.8706	35.8		230.00	8.468E-06	700	2.454E-05
57	1-Chloropropane	C_3H_7Cl	540-54-5	78.541	3.638E-07	0.6417	208.3		150.35	3.805E-06	1000	2.534E-05
58	2-Chloropropane	C_3H_7Cl	75-29-6	78.541	3.8802E-07	0.6367	205.08		155.97	4.175E-06	1000	2.618E-05
59	*m*-Cresol	C_7H_8O	108-39-4	108.138	1.4427E-07	0.7438	166.15		285.39	6.113E-06	1000	2.108E-05

TABLE 2-312 Vapor Viscosity of Inorganic and Organic Substances (Pa·s) (*Continued*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	T_{min}, K	Viscosity at T_{min}	T_{max}, K	Viscosity at T_{max}
60	*o*-Cresol	C_7H_8O	95-48-7	108.138	8.7371E-08	0.80775	98.538		304.19	6.688E-06	1000	2.108E-05
61	*p*-Cresol	C_7H_8O	106-44-5	108.138	1.4305E-07	0.7451	159.8		307.93	6.731E-06	1000	2.120E-05
62	Cumene	C_9H_{12}	98-82-8	120.192	3.3699E-07	0.60751	221.17		177.14	3.480E-06	1000	1.834E-05
63	Cyanogen	C_2N_2	460-19-5	52.035	4.0854E-08	0.97182	6.6762		245.25	8.353E-06	600	2.024E-05
64	Cyclobutane	C_4H_8	287-23-0	56.106	1.0881E-06	0.48359	330.86		182.48	4.797E-06	1000	2.308E-05
65	Cyclohexane	C_6H_{12}	110-82-7	84.159	6.77E-08	0.8367	36.7		279.69	6.671E-06	900	1.928E-05
66	Cyclohexanol	$C_6H_{12}O$	108-93-0	100.159	7.9581E-08	0.8376	104.97		296.60	6.917E-06	1000	2.346E-05
67	Cyclohexanone	$C_6H_{10}O$	108-94-1	98.143	5.2312E-08	0.89422	58.008		242.00	5.714E-06	1000	2.381E-05
68	Cyclohexene	C_6H_{10}	110-83-8	82.144	1.3326E-06	0.4537	445		169.67	3.778E-06	1000	2.118E-05
69	Cyclopentane	C_5H_{10}	287-92-3	70.133	2.3619E-07	0.67465	139		179.28	4.409E-06	1000	2.191E-05
70	Cyclopentene	C_5H_8	142-29-0	68.117	3.026E-07	0.64991	167.14		138.13	3.369E-06	1000	2.309E-05
71	Cyclopropane	C_3H_6	75-19-4	42.080	1.7578E-06	0.4265	370.34		145.59	4.150E-06	1000	2.441E-05
72	Cyclohexyl mercaptan	$C_6H_{12}S$	1569-69-3	116.224	3.915E-08	0.91427	22.264		189.64	4.238E-06	1000	2.118E-05
73	Decanal	$C_{10}H_{20}O$	112-31-2	156.265	1.2638E-07	0.7248	176.88		267.15	4.365E-06	1000	1.605E-05
74	Decane	$C_{10}H_{22}$	124-18-5	142.282	2.64E-08	0.9487	71		243.51	3.755E-06	1000	1.730E-05
75	Decanoic acid	$C_{10}H_{20}O_2$	334-48-5	172.265	7.1748E-08	0.7982	109.38		304.55	5.070E-06	1000	1.605E-05
76	1-Decanol	$C_{10}H_{22}O$	112-30-1	158.281	5.5065E-08	0.8341	79.56		280.05	4.715E-06	1000	1.622E-05
77	1-Decene	$C_{10}H_{20}$	872-05-9	140.266	6.1192E-08	0.82546	77.434		206.89	3.632E-06	1000	1.701E-05
78	Decyl mercaptan	$C_{10}H_{22}S$	143-10-2	174.347	3.272E-08	0.9302	39.13		247.56	4.761E-06	1000	1.944E-05
79	1-Decyne	$C_{10}H_{18}$	764-93-2	138.250	5.6914E-07	0.50744	273.3		229.15	4.091E-06	1000	1.488E-05
80	Deuterium	D_2	7782-39-0	4.032	2.4999E-07	0.6878	0.5962		60.00	4.137E-06	480	1.744E-05
81	1,1-Dibromoethane	$C_2H_4Br_2$	557-91-5	187.861	1.4125E-07	0.8097	83.243		210.15	7.685E-06	1000	3.502E-05
82	1,2-Dibromoethane	$C_2H_4Br_2$	106-93-4	187.861	1.1379E-07	0.8502	93.816		282.85	1.038E-05	1000	3.696E-05
83	Dibromomethane	CH_2Br_2	74-95-3	173.835	2.9444E-07	0.728	154.74		370.10	1.538E-05	1000	3.895E-05
84	Dibutyl ether	$C_8H_{18}O$	142-96-1	130.228	7.7147E-08	0.79906	80.765		175.30	3.278E-06	1000	1.781E-05
85	*m*-Dichlorobenzene	$C_6H_4Cl_2$	541-73-1	147.002	2.334E-07	0.714	260		248.39	5.850E-06	1000	2.569E-05
86	*o*-Dichlorobenzene	$C_6H_4Cl_2$	95-50-1	147.002	1.603E-07	0.763	205		256.15	6.127E-06	1000	2.588E-05
87	*p*-Dichlorobenzene	$C_6H_4Cl_2$	106-46-7	147.002	1.5913E-07	0.7639	193.14		326.14	8.313E-06	1000	2.611E-05
88	1,1-Dichloroethane	$C_2H_4Cl_2$	75-34-3	98.959	2.0135E-07	0.73421	111.98		176.19	5.487E-06	1000	2.887E-05
89	1,2-Dichloroethane	$C_2H_4Cl_2$	107-06-2	98.959	1.4321E-07	0.7785	98.159		237.49	7.164E-06	1000	2.824E-05
90	Dichloromethane	CH_2Cl_2	75-09-2	84.933	7.6787E-07	0.5741	276.16		178.01	5.895E-06	1000	3.175E-05
91	1,1-Dichloropropane	$C_3H_6Cl_2$	78-99-9	112.986	1.4906E-07	0.7617	105.9		200.00	5.515E-06	1000	2.599E-05
92	1,2-Dichloropropane	$C_3H_6Cl_2$	78-87-5	112.986	1.1989E-07	0.79108	84.37		172.71	4.742E-06	1000	2.611E-05
93	Diethanol amine	$C_4H_{11}NO_2$	111-42-2	105.136	3.3628E-08	0.9426	39.587		301.15	6.450E-06	1000	2.176E-05
94	Diethyl amine	$C_4H_{11}N$	109-89-7	73.137	4.3184E-07	0.6035	247		223.35	5.364E-06	1000	2.239E-05
95	Diethyl ether	$C_4H_{10}O$	60-29-7	74.122	1.948E-06	0.41	495.8		156.85	3.720E-06	1000	2.212E-05
96	Diethyl sulfide	$C_4H_{10}S$	352-93-2	90.187	6.5492E-08	0.86232	59.455		169.20	4.046E-06	1000	2.388E-05
97	1,1-Difluoroethane	$C_2H_4F_2$	75-37-6	66.050	2.7228E-06	0.39531	445.07		154.56	5.148E-06	1000	2.891E-05
98	1,2-Difluoroethane	$C_2H_4F_2$	624-72-6	66.050	4.3934E-07	0.64867	169.64		215.00	8.001E-06	1000	3.317E-05
99	Difluoromethane	CH_2F_2	75-10-5	52.023	7.7484E-07	0.57978	198.7		136.95	5.478E-06	1000	1.172E-12
100	Di-isopropyl amine	$C_6H_{15}N$	108-18-9	101.190	4.138E-07	0.5999	269.5		357.05	8.016E-06	1000	2.055E-05
101	Di-isopropyl ether	$C_6H_{14}O$	108-20-3	102.175	1.691E-07	0.7114	124		187.65	4.218E-06	1000	2.049E-05
102	Di-isopropyl ketone	$C_7H_{14}O$	565-80-0	114.185	9.2797E-08	0.7819	93.399		204.81	4.089E-06	1000	1.881E-05
103	1,1-Dimethoxyethane	$C_4H_{10}O_2$	534-15-6	90.121	4.4172E-08	0.91098			159.95	4.497E-06	1000	2.388E-05
104	1,2-Dimethoxypropane	$C_5H_{12}O_2$	7778-85-0	104.148	3.9833E-08	0.91566			226.10	5.701E-06	1000	2.225E-05
105	Dimethyl acetylene	C_4H_6	503-17-3	54.090	1.9377E-06	0.4093	492.69		240.91	6.006E-06	1000	2.194E-05
106	Dimethyl amine	C_2H_7N	124-40-3	45.084	2.757E-07	0.6841	133.2		180.96	5.563E-06	1000	2.744E-05
107	2,3-Dimethylbutane	C_6H_{14}	79-29-8	86.175	6.8567E-07	0.52542	278.82		145.19	3.211E-06	1000	2.021E-05
108	1,1-Dimethylcyclohexane	C_8H_{16}	590-66-9	112.213	7.822E-07	0.4994	371.6		392.70	7.936E-06	1000	1.796E-05
109	*cis*-1,2-Dimethylcyclohexane	C_8H_{16}	2207-01-4	112.213	8.4576E-07	0.487	398		402.94	7.900E-06	1000	1.749E-05
110	*trans*-1,2-Dimethylcyclohexane	C_8H_{16}	6876-23-9	112.213	9.9104E-07	0.4723	436.89		396.58	7.957E-06	1000	1.801E-05
111	Dimethyl disulfide	$C_2H_6S_2$	624-92-0	94.199	3.2282E-08	0.97742			188.44	5.405E-06	1000	2.762E-05
112	Dimethyl ether	C_2H_6O	115-10-6	46.068	0.00000268	0.3975	534		131.65	3.688E-06	1000	2.722E-05
113	*N,N*-Dimethyl formamide	C_3H_7NO	68-12-2	73.094	3.5538E-06	0.3766	1176.1		212.72	4.097E-06	1000	2.202E-05
114	2,3-Dimethylpentane	C_7H_{16}	565-59-3	100.202	5.0372E-07	0.54462	227.44		160.00	3.300E-06	1000	1.766E-05
115	Dimethyl phthalate	$C_{10}H_{10}O_4$	131-11-3	194.184	5.2195E-08	0.85584	69.036		274.18	5.089E-06	1000	1.804E-05
116	Dimethylsilane	C_2H_8Si	1111-74-6	60.170	4.7238E-08	0.90849			122.93	3.739E-06	1000	2.511E-05
117	Dimethyl sulfide	C_2H_6S	75-18-3	62.134	5.2854E-07	0.6112	302.85		174.88	4.544E-06	1000	2.766E-05
118	Dimethyl sulfoxide	C_2H_6OS	67-68-5	78.133	8.6101E-08	0.8345	167.86		291.67	6.231E-06	1000	2.350E-05

119	Dimethyl terephthalate	$C_{10}H_{10}O_4$	120-61-6	194.184	4.8739E-08	0.8749	51.885		413.80	8.433E-06	1000	1.953E-05
120	1,4-Dioxane	$C_4H_8O_2$	123-91-1	88.105	2.7334E-07	0.7393	129.93		284.95	1.226E-05	1000	3.995E-05
121	Diphenyl ether	$C_{12}H_{10}O$	101-84-8	170.207	2.8451E-08	0.93622			300.03	5.933E-06	1000	1.831E-05
122	Dipropyl amine	$C_6H_{15}N$	142-84-7	101.190	1.29E-07	0.744	117.03		210.15	4.429E-06	1000	1.970E-05
123	Dodecane	$C_{12}H_{26}$	112-40-3	170.335	6.344E-08	0.8287	219.5		263.57	3.511E-06	1000	1.593E-05
124	Eicosane	$C_{20}H_{42}$	112-95-8	282.547	2.9236E-07	0.62458	702.84		309.58	3.214E-06	1000	1.284E-05
125	Ethane	C_2H_6	74-84-0	30.069	2.5906E-07	0.67988	98.902		90.35	2.643E-06	1000	2.583E-05
126	Ethanol	C_2H_6O	64-17-5	46.068	1.0613E-07	0.8066	52.7		200.00	6.029E-06	1000	2.651E-05
127	Ethyl acetate	$C_4H_8O_2$	141-78-6	88.105	3.214E-06	0.3572	667		189.60	4.632E-06	1000	2.274E-05
128	Ethyl amine	C_2H_7N	75-04-7	45.084	4.934E-07	0.5924	239.17		192.15	4.953E-06	1000	2.384E-05
129	Ethylbenzene	C_8H_{10}	100-41-4	106.165	4.2231E-07	0.58154	239.21		178.20	3.673E-06	1000	1.893E-05
130	Ethyl benzoate	$C_9H_{10}O_2$	93-89-0	150.175	6.3441E-08	0.8369	73.63		238.45	4.733E-06	1000	1.915E-05
131	2-Ethyl butanoic acid	$C_6H_{12}O_2$	88-09-5	116.158	9.2371E-08	0.7908	102.32		258.15	5.344E-06	1000	1.975E-05
132	Ethyl butyrate	$C_6H_{12}O_2$	105-54-4	116.158	1.6175E-07	0.7163	142.27	3,590	175.15	3.392E-06	1000	1.989E-05
133	Ethylcyclohexane	C_8H_{16}	1678-91-7	112.213	4.107E-07	0.57143	230.06		161.84	3.103E-06	1000	1.729E-05
134	Ethylcyclopentane	C_7H_{14}	1640-89-7	98.186	2.1696E-06	0.3812	577.77		134.71	2.659E-06	1000	1.914E-05
135	Ethylene	C_2H_4	74-85-1	28.053	2.0789E-06	0.4163	352.7		169.41	5.714E-06	1000	2.726E-05
136	Ethylenediamine	$C_2H_8N_2$	107-15-3	60.098	1.3744E-07	0.7557	122.8		284.29	6.863E-06	1000	2.264E-05
137	Ethylene glycol	$C_2H_6O_2$	107-21-1	62.068	8.6706E-08	0.83923	75.512		260.15	7.150E-06	1000	2.655E-05
138	Ethyleneimine	C_2H_5N	151-56-4	43.068	2.8132E-07	0.6792	238.46		329.00	8.359E-06	1000	2.477E-05
139	Ethylene oxide	C_2H_4O	75-21-8	44.053	4.3403E-08	0.94806			160.65	5.356E-06	1000	3.032E-05
140	Ethyl formate	$C_3H_6O_2$	109-94-4	74.079	6.761E-07	0.5804	354.9		193.55	5.069E-06	1000	2.750E-05
141	2-Ethyl hexanoic acid	$C_8H_{16}O_2$	149-57-5	144.211	2.5704E-08	0.94738			235.00	4.532E-06	1000	1.787E-05
142	Ethylhexyl ether	$C_8H_{18}O$	5756-43-4	130.228	7.9129E-08	0.79565	83.193		180.00	3.371E-06	1000	1.781E-05
143	Ethylisopropyl ether	$C_5H_{12}O$	625-54-7	88.148	1.3974E-07	0.74266	98.58		140.00	3.219E-06	1000	2.150E-05
144	Ethylisopropyl ketone	$C_6H_{12}O$	565-69-5	100.159	1.0498E-07	0.76988	100.41		204.15	4.224E-06	1000	1.946E-05
145	Ethyl mercaptan	C_2H_6S	75-08-1	62.134	8.5992E-08	0.8427	58.148		125.26	3.441E-06	1000	2.742E-05
146	Ethyl propionate	$C_5H_{10}O_2$	105-37-3	102.132	5.53E-07	0.6061	273.66		199.25	5.768E-06	1000	2.857E-05
147	Ethylpropyl ether	$C_5H_{12}O$	628-32-0	88.148	5.1539E-07	0.5726	288.76		145.65	2.994E-06	1000	2.088E-05
148	Ethyltrichlorosilane	$C_2H_5Cl_3Si$	115-21-9	163.506	3.2769E-08	0.9729			167.55	4.779E-06	1000	2.718E-05
149	Fluorine	F_2	7782-41-4	37.997	6.36E-07	0.6638	61.6		53.48	4.148E-06	1000	5.874E-05
150	Fluorobenzene	C_6H_5F	462-06-6	96.102	2.1174E-07	0.7087	157.42		357.88	9.491E-06	1000	2.446E-05
151	Fluoroethane	C_2H_5F	353-36-6	48.060	8.8742E-07	0.5404	251.82		129.95	4.192E-06	1000	2.963E-05
152	Fluoromethane	CH_3F	593-53-3	34.033	1.2269E-07	0.82167			131.35	6.752E-06	1000	3.579E-05
153	Formaldehyde	CH_2O	50-00-0	30.026	4.758E-07	0.6405	161.7		181.15	7.025E-06	1000	3.419E-05
154	Formamide	CH_3NO	75-12-7	45.041	6.829E-08	0.8774	54.864		275.60	7.882E-06	1000	2.776E-05
155	Formic acid	CH_2O_2	64-18-6	46.026	2.8608E-07	0.6958	184.25		281.45	8.751E-06	1000	2.954E-05
156	Furan	C_4H_4O	110-00-9	68.074	6.432E-07	0.5854	325.3		187.55	5.037E-06	1000	2.768E-05
157	Helium-4	He	7440-59-7	4.003	3.253E-07	0.7162	–9.6	107	20.00	3.531E-06	2000	7.561E-05
158	Heptadecane	$C_{17}H_{36}$	629-78-7	240.468	3.1338E-07	0.6238	692.2		295.13	3.254E-06	1000	1.377E-05
159	Heptanal	$C_7H_{14}O$	111-71-7	114.185	8.4633E-08	0.79185	94.487		229.80	4.444E-06	1000	1.836E-05
160	Heptane	C_7H_{16}	142-82-5	100.202	6.672E-08	0.82837	85.752		182.57	3.391E-06	1000	1.878E-05
161	Heptanoic acid	$C_7H_{14}O_2$	111-14-8	130.185	7.2834E-08	0.81279	89.874		265.83	5.088E-06	1000	1.834E-05
162	1-Heptanol	$C_7H_{16}O$	111-70-6	116.201	2.572E-07	0.6502	248.6		239.15	4.440E-06	1000	1.838E-05
163	2-Heptanol	$C_7H_{16}O$	543-49-7	116.201	9.1526E-08	0.78346	100.28		230.00	4.516E-06	1000	1.864E-05
164	3-Heptanone	$C_7H_{14}O$	106-35-4	114.185	8.9656E-08	0.78236	100.14		234.15	4.485E-06	1000	1.812E-05
165	2-Heptanone	$C_7H_{14}O$	110-43-0	114.185	8.8629E-08	0.78376	100.18		238.15	4.550E-06	1000	1.809E-05
166	1-Heptene	C_7H_{14}	592-76-7	98.186	7.7509E-08	0.81089	69.927		154.12	3.169E-06	1000	1.962E-05
167	Heptyl mercaptan	$C_7H_{16}S$	1639-09-4	132.267	4.697E-08	0.8932	57.6		229.92	4.832E-06	1000	2.124E-05
168	1-Heptyne	C_7H_{12}	628-71-7	96.170	5.9501E-07	0.52758	274.02		192.22	3.932E-06	1000	1.787E-05
169	Hexadecane	$C_{16}H_{34}$	544-76-3	226.441	1.2463E-07	0.7322	395	6,000	291.31	3.274E-06	1000	1.399E-05
170	Hexanal	$C_6H_{12}O$	66-25-1	100.159	9.6724E-08	0.78044	97.798		217.15	4.444E-06	1000	1.933E-05
171	Hexane	C_6H_{14}	110-54-3	86.175	1.7514E-07	0.70737	157.14		177.83	3.631E-06	1000	2.005E-05
172	Hexanoic acid	$C_6H_{12}O_2$	142-62-1	116.158	8.4032E-08	0.80073	96.779		269.25	5.457E-06	1000	1.934E-05
173	1-Hexanol	$C_6H_{14}O$	111-27-3	102.175	1.5773E-07	0.7189	163.3		228.55	4.567E-06	1000	1.945E-05
174	2-Hexanol	$C_6H_{14}O$	626-93-7	102.175	1.0652E-07	0.77022	105.85		223.00	4.650E-06	1000	1.970E-05
175	2-Hexanone	$C_6H_{12}O$	591-78-6	100.159	9.782E-08	0.7772	99.53		217.35	4.397E-06	1000	1.909E-05
176	3-Hexanone	$C_6H_{12}O$	589-38-8	100.159	9.8882E-08	0.7755	99.825		217.50	4.403E-06	1000	1.907E-05
177	1-Hexene	C_6H_{12}	592-41-6	84.159	8.006E-08	0.81293	65.274		133.39	2.871E-06	1000	2.064E-05
178	3-Hexyne	C_6H_{10}	928-49-4	82.144	5.2127E-07	0.5444	237.01		170.05	3.567E-06	1000	1.811E-05
179	Hexyl mercaptan	$C_6H_{14}S$	111-31-9	118.240	4.3636E-08	0.90747	42.32		192.62	4.235E-06	1000	2.209E-05
180	1-Hexyne	C_6H_{10}	693-02-7	82.144	2.9986E-07	0.62647	178.17		141.25	2.947E-06	1000	3.758E-13
181	2-Hexyne	C_6H_{10}	764-35-2	82.144	5.5562E-07	0.5337	244.38		183.65	3.851E-06	1000	1.782E-05

TABLE 2-312 Vapor Viscosity of Inorganic and Organic Substances (Pa·s) (*Continued*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	T_{min}, K	Viscosity at T_{min}	T_{max}, K	Viscosity at T_{max}
182	Hydrazine	H_4N_2	302-01-2	32.045	2.3489E-07	0.7151	205.05		274.69	7.460E-06	1673.15	4.225E-05
183	Hydrogen	H_2	1333-74-0	2.016	1.797E-07	0.685	–0.59	140	13.95	6.517E-07	3000	4.330E-05
184	Hydrogen bromide	HBr	10035-10-6	80.912	9.17E-08	0.9273			206.45	1.285E-05	800	4.512E-05
185	Hydrogen chloride	HCl	7647-01-0	36.461	4.924E-07	0.6702	157.7		200.00	9.594E-06	1000	4.358E-05
186	Hydrogen cyanide	CHN	74-90-8	27.025	1.278E-08	1.0631	340		300.00	2.576E-06	425	4.421E-06
187	Hydrogen fluoride	HF	7664-39-3	20.006	4.5101E-14	3.0005	–521.83	76,111	285.50	9.931E-06	472.68	2.019E-05
188	Hydrogen sulfide	H_2S	7783-06-4	34.081	3.9314E-08	1.0134			250.00	1.058E-05	480	2.050E-05
189	Isobutyric acid	$C_4H_8O_2$	79-31-2	88.105	1.1202E-07	0.7822	100.3		227.15	5.415E-06	1000	2.261E-05
190	Isopropyl amine	C_3H_9N	75-31-0	59.110	5.2542E-08	0.88063			177.95	5.037E-06	1000	2.304E-05
191	Malonic acid	$C_3H_4O_4$	141-82-2	104.061	8.4213E-08	0.82573	102.08		407.95	9.639E-06	1000	2.293E-05
192	Methacrylic acid	$C_4H_6O_2$	79-41-4	86.089	9.113E-08	0.8222	93.57		288.15	7.242E-06	1000	2.440E-05
193	Methane	CH_4	74-82-8	16.042	5.2546E-07	0.59006	105.67		90.69	3.468E-06	1000	2.800E-05
194	Methanol	CH_4O	67-56-1	32.042	3.0663E-07	0.69655	205		240.00	7.523E-06	1000	3.128E-05
195	*N*-Methyl acetamide	C_3H_7NO	79-16-3	73.094	8.0599E-08	0.8392	77.332		301.15	7.714E-06	1000	2.464E-05
196	Methyl acetate	$C_3H_6O_2$	79-20-9	74.079	1.3226E-06	0.4885	504.3		250.00	6.505E-06	800	2.125E-05
197	Methyl acetylene	C_3H_4	74-99-7	40.064	1.163E-06	0.4787	316		170.45	4.769E-06	800	2.045E-05
198	Methyl acrylate	$C_4H_6O_2$	96-33-3	86.089	1.648E-06	0.4444	510.66		196.32	4.781E-06	1000	2.350E-05
199	Methyl amine	CH_5N	74-89-5	31.057	5.6409E-07	0.5863	231.9		179.69	5.167E-06	1000	2.628E-05
200	Methyl benzoate	$C_8H_8O_2$	93-58-3	136.148	7.4106E-08	0.82436	83.086		260.75	5.515E-06	1000	2.034E-05
201	3-Methyl-1,2-butadiene	C_5H_8	598-25-4	68.117	4.0824E-07	0.5923	208.22		159.53	3.572E-06	1000	2.022E-05
202	2-Methylbutane	C_5H_{12}	78-78-4	72.149	2.4344E-08	0.97376	–91.597	18,720	150.00	2.621E-06	1000	2.191E-05
203	2-Methylbutanoic acid	$C_5H_{10}O_2$	116-53-0	102.132	1.869E-07	0.7096	192		450.15	1.000E-05	1000	2.109E-05
204	3-Methyl-1-butanol	$C_5H_{12}O$	123-51-3	88.148	8.8783E-08	0.80279	77.075		155.95	3.423E-06	1000	2.111E-05
205	2-Methyl-1-butene	C_5H_{10}	563-46-2	70.133	5.0602E-07	0.55258	199.82		135.58	3.083E-06	1000	1.918E-05
206	2-Methyl-2-butene	C_5H_{10}	513-35-9	70.133	8.5423E-07	0.47389	239.34		139.39	3.263E-06	1000	1.820E-05
207	2-Methyl-1-butene-3-yne	C_5H_6	78-80-8	66.101	5.6844E-07	0.553	227.18		160.15	3.893E-06	1000	2.112E-05
208	Methylbutyl ether	$C_5H_{12}O$	628-28-4	88.148	3.9342E-08	0.91086			157.48	3.947E-06	1000	2.125E-05
209	Methylbutyl sulfide	$C_5H_{12}S$	628-29-5	104.214	4.995E-08	0.89479	44.662		175.30	4.052E-06	1000	2.312E-05
210	3-Methyl-1-butyne	C_5H_8	598-23-2	68.117	4.0748E-08	0.92709			183.45	5.112E-06	1000	2.463E-05
211	Methyl butyrate	$C_5H_{10}O_2$	623-42-7	102.132	3.733E-07	0.6177	256.5		187.35	3.993E-06	1000	2.118E-05
212	Methylchlorosilane	CH_5ClSi	993-00-0	80.589	4.8806E-08	0.92549			139.05	4.698E-06	1000	2.917E-05
213	Methylcyclohexane	C_7H_{14}	108-87-2	98.186	6.5281E-07	0.5294	310.59		146.58	2.934E-06	1000	1.930E-05
214	1-Methylcyclohexanol	$C_7H_{14}O$	590-67-0	114.185	8.5736E-08	0.80277	100.77		299.15	6.232E-06	1000	1.994E-05
215	*cis*-2-Methylcyclohexanol	$C_7H_{14}O$	7443-70-1	114.185	2.40E-07	0.68	210		280.15	6.331E-06	1000	2.175E-05
216	*trans*-2-Methylcyclohexanol	$C_7H_{14}O$	7443-52-9	114.185	2.00E-07	0.704	187		269.15	6.062E-06	1000	2.181E-05
217	Methylcyclopentane	C_6H_{12}	96-37-7	84.159	9.0798E-07	0.495	355.89		130.73	2.722E-06	1000	2.046E-05
218	1-Methylcyclopentene	C_6H_{10}	693-89-0	82.144	3.7026E-08	0.92849			146.62	3.800E-06	1000	2.259E-05
219	3-Methylcyclopentene	C_6H_{10}	1120-62-3	82.144	3.9771E-08	0.92242			115.00	3.165E-06	1000	2.327E-05
220	Methyldichlorosilane	CH_4Cl_2Si	75-54-7	115.034	1.977E-07	0.7453	131.22		182.55	5.574E-06	1000	3.009E-05
221	Methylethyl ether	C_3H_8O	540-67-0	60.095	2.6098E-07	0.68276	133.4		160.00	4.552E-06	1000	2.573E-05
222	Methylethyl ketone	C_4H_8O	78-93-3	72.106	2.6552E-08	0.98316			186.48	4.534E-06	1000	2.364E-05
223	Methylethyl sulfide	C_3H_8S	624-89-5	76.161	8.6219E-08	0.83591	72.564		167.23	4.341E-06	1000	2.588E-05
224	Methyl formate	$C_2H_4O_2$	107-31-3	60.052	6.9755E-06	0.3154	1034.5		174.15	5.117E-06	1000	3.029E-05
225	Methylisobutyl ether	$C_5H_{12}O$	625-44-5	88.148	1.5035E-07	0.7338	108.5		150.00	3.448E-06	1000	2.157E-05
226	Methylisobutyl ketone	$C_6H_{12}O$	108-10-1	100.159	9.4257E-08	0.7845	90.183		189.15	3.901E-06	1000	1.951E-05
227	Methyl Isocyanate	C_2H_3NO	624-83-9	57.051	3.1573E-07	0.66404	173.59		256.15	7.481E-06	1000	2.642E-05
228	Methylisopropyl ether	$C_4H_{10}O$	598-53-8	74.122	1.925E-07	0.7091	109		127.93	3.242E-06	1000	2.327E-05
229	Methylisopropyl ketone	$C_5H_{10}O$	563-80-4	86.132	1.0826E-07	0.77382	93.349		180.15	3.968E-06	1000	2.076E-05
230	Methylisopropyl sulfide	$C_4H_{10}S$	1551-21-9	90.187	8.6077E-08	0.81669	71.294		171.64	4.065E-06	1000	2.265E-05
231	Methyl mercaptan	CH_4S	74-93-1	48.107	1.637E-07	0.76706	107.97		150.18	4.450E-06	1000	2.956E-05
232	Methyl methacrylate	$C_5H_8O_2$	80-62-6	100.116	4.889E-07	0.6096	342.23		224.95	5.265E-06	1000	2.456E-05
233	2-Methyloctanoic acid	$C_9H_{18}O_2$	3004-93-1	158.238	7.2131E-08	0.80319	99.437		240.00	4.162E-06	1000	1.685E-05
234	2-Methylpentane	C_6H_{14}	107-83-5	86.175	1.1164E-06	0.4537	374.74		119.55	2.366E-06	1000	1.865E-05
235	Methyl pentyl ether	$C_6H_{14}O$	628-80-8	102.175	1.0546E-07	0.77106	93.745		176.00	3.707E-06	1000	1.983E-05
236	2-Methylpropane	C_4H_{10}	75-28-5	58.122	1.0871E-07	0.78135	70.639		150.00	3.707E-06	1000	2.242E-05
237	2-Methyl-2-propanol	$C_4H_{10}O$	75-65-0	74.122	9.605E-07	0.4856	381		298.97	6.727E-06	600	1.312E-05
238	2-Methyl propene	C_4H_8	115-11-7	56.106	9.0981E-07	0.49288	260.08		132.81	3.423E-06	1000	2.174E-05
239	Methyl propionate	$C_4H_8O_2$	554-12-1	88.105	3.5642E-07	0.6327	232.2		185.65	4.316E-06	1000	2.288E-05
240	Methylpropyl ether	$C_4H_{10}O$	557-17-5	74.122	4.4941E-08	0.90199			133.97	3.725E-06	1000	2.284E-05

241	Methylpropyl sulfide	$C_4H_{10}S$	3877-15-4	90.187	5.8223E-08	0.88057	48.298		160.17	3.908E-06	1000	2.434E-05
242	Methylsilane	CH_6Si	992-94-9	46.144	3.8926E-07	0.63159	169.45		116.34	3.196E-06	1000	5.762E-13
243	alpha-Methyl styrene	C_9H_{10}	98-83-9	118.176	7.1455E-07	0.49832	303.31		249.95	5.057E-06	1000	1.714E-05
244	Methyl *tert*-butyl ether	$C_5H_{12}O$	1634-04-4	88.148	1.571E-07	0.733	111.578		164.55	3.944E-06	1000	2.235E-05
245	Methyl vinyl ether	C_3H_6O	107-25-5	58.079	7.646E-07	0.5476	284		278.65	8.264E-06	1000	2.616E-05
246	Naphthalene	$C_{10}H_8$	91-20-3	128.171	6.4318E-07	0.5389	400.16		353.43	7.125E-06	1000	1.900E-05
247	Neon	Ne	7440-01-9	20.180	7.19E-07	0.6659	5.3		30.00	5.884E-06	3273.1	1.573E-04
248	Nitroethane	$C_2H_5NO_2$	79-24-3	75.067	2.4391E-07	0.702	280		183.63	3.752E-06	1000	2.432E-05
249	Nitrogen	N_2	7727-37-9	28.013	6.5592E-07	0.6081	54.714		63.15	4.372E-06	1970	6.432E-05
250	Nitrogen trifluoride	F_3N	7783-54-2	71.002	8.2005E-07	0.61423	114.58		66.46	3.964E-06	1000	1.975E-12
251	Nitromethane	CH_3NO_2	75-52-5	61.040	4.070E-07	0.6485	367.5		244.60	5.756E-06	1000	2.625E-05
252	Nitrous oxide	N_2O	10024-97-2	44.013	2.115E-06	0.4642	305.7		182.30	8.854E-06	1000	4.000E-05
253	Nitric oxide	NO	10102-43-9	30.006	1.467E-06	0.5123	125.4		110.00	7.618E-06	1500	5.737E-05
254	Nonadecane	$C_{19}H_{40}$	629-92-5	268.521	3.0465E-07	0.62218	705.34		305.04	3.231E-06	1000	1.314E-05
255	Nonanal	$C_9H_{18}O$	124-19-6	142.239	7.1902E-08	0.8013	92.051		255.15	4.483E-06	1000	1.669E-05
256	Nonane	C_9H_{20}	111-84-2	128.255	1.0344E-07	0.77301	220.47		219.66	3.335E-06	1000	1.767E-05
257	Nonanoic acid	$C_9H_{18}O_2$	112-05-0	158.238	7.0165E-08	0.8062	100.36		285.65	4.957E-06	1000	1.672E-05
258	1-Nonanol	$C_9H_{20}O$	143-08-8	144.255	1.20E-07	0.74	180		268.15	4.499E-06	1000	1.688E-05
259	2-Nonanol	$C_9H_{20}O$	628-99-9	144.255	7.0111E-08	0.80701	89.582		238.15	4.219E-06	1000	1.697E-05
260	1-Nonene	C_9H_{18}	124-11-8	126.239	6.6329E-08	0.82027	76.204		191.91	3.542E-06	1000	1.781E-05
261	Nonyl mercaptan	$C_9H_{20}S$	1455-21-6	160.320	3.8673E-08	0.91142	50.646		253.05	4.995E-06	1000	1.996E-05
262	1-Nonyne	C_9H_{16}	3452-09-3	124.223	6.1447E-07	0.50705	287.19		223.15	4.170E-06	1000	1.585E-05
263	Octadecane	$C_{18}H_{38}$	593-45-3	254.494	3.2095E-07	0.61839	709.09		301.31	3.266E-06	1000	1.345E-05
264	Octanal	$C_8H_{16}O$	124-13-0	128.212	1.0321E-07	0.7589	121.26		246.00	4.510E-06	1000	1.741E-05
265	Octane	C_8H_{18}	111-65-9	114.229	3.1191E-08	0.92925	55.092		216.38	3.677E-06	1000	1.813E-05
266	Octanoic acid	$C_8H_{16}O_2$	124-07-2	144.211	7.9611E-08	0.7948	106.6		289.65	5.267E-06	1000	1.743E-05
267	1-Octanol	$C_8H_{18}O$	111-87-5	130.228	1.752E-07	0.6941	206.8		257.65	4.583E-06	1000	1.755E-05
268	2-Octanol	$C_8H_{18}O$	123-96-6	130.228	8.1701E-08	0.79241	97.709		241.55	4.498E-06	1000	1.774E-05
269	2-Octanone	$C_8H_{16}O$	111-13-7	128.212	8.0901E-08	0.79062	99.338		252.85	4.611E-06	1000	1.733E-05
270	3-Octanone	$C_8H_{16}O$	106-68-3	128.212	6.1515E-11	1.8808			255.55	2.075E-06	1000	2.700E-05
271	1-Octene	C_8H_{16}	111-66-0	112.213	5.0324E-05	0.077611	3604.6		171.45	3.406E-06	1000	1.868E-05
272	Octyl mercaptan	$C_8H_{18}S$	111-88-6	146.294	3.3253E-08	0.9351	32.426		223.95	4.579E-06	1000	2.057E-05
273	1-Octyne	C_8H_{14}	629-05-0	110.197	5.7084E-07	0.52446	271.76		193.55	3.758E-06	1000	1.681E-05
274	Oxalic acid	$C_2H_2O_4$	144-62-7	90.035	1.1453E-07	0.7968	126.34		462.65	1.196E-05	1000	2.498E-05
275	Oxygen	O_2	7782-44-7	31.999	1.101E-06	0.5634	96.3		54.35	3.773E-06	1500	6.371E-05
276	Ozone	O_3	10028-15-6	47.998	1.196E-07	0.84797			80.15	4.922E-06	1000	4.184E-05
277	Pentadecane	$C_{15}H_{32}$	629-62-9	212.415	4.0828E-08	0.8766	212.68		283.07	3.288E-06	1000	1.436E-05
278	Pentanal	$C_5H_{10}O$	110-62-3	86.132	2.27E-07	0.6767	191.74		182.00	3.740E-06	1000	2.042E-05
279	Pentane	C_5H_{12}	109-66-0	72.149	6.3412E-08	0.84758	41.718		143.42	3.305E-06	1000	2.124E-05
280	Pentanoic acid	$C_5H_{10}O_2$	109-52-4	102.132	9.4314E-08	0.7932	98.279		239.15	5.150E-06	1000	2.058E-05
281	1-Pentanol	$C_5H_{12}O$	71-41-0	88.148	1.8903E-07	0.7031	175.9		410.95	9.111E-06	1000	2.068E-05
282	2-Pentanol	$C_5H_{12}O$	6032-29-7	88.148	1.1749E-07	0.7649	103.78		200.00	4.452E-06	1000	2.098E-05
283	2-Pentanone	$C_5H_{10}O$	107-87-9	86.132	2.463E-07	0.6653	208.7		196.29	4.003E-06	1000	2.019E-05
284	3-Pentanone	$C_5H_{10}O$	96-22-0	86.132	1.164E-07	0.7615	107.94		234.18	5.079E-06	1000	2.023E-05
285	1-Pentene	C_5H_{10}	109-67-1	70.133	1.6378E-06	0.44337	636.11	–26,218	108.02	2.813E-06	1000	2.176E-05
286	2-Pentyl mercaptan	$C_5H_{12}S$	2084-19-7	104.214	8.8646E-08	0.81492	85.198		160.75	3.638E-06	1000	2.275E-05
287	Pentyl mercaptan	$C_5H_{12}S$	110-66-7	104.214	2.7467E-08	0.97555			197.45	4.766E-06	1000	2.320E-05
288	1-Pentyne	C_5H_8	627-19-0	68.117	4.1022E-08	0.90585			167.45	4.242E-06	1000	2.141E-05
289	2-Pentyne	C_5H_8	627-21-4	68.117	5.765E-07	0.53498	235.2		163.83	3.621E-06	1000	1.879E-05
290	Phenanthrene	$C_{14}H_{10}$	85-01-8	178.229	4.3478E-07	0.5272	238.27		372.38	6.010E-06	1000	1.340E-05
291	Phenol	C_6H_6O	108-95-2	94.111	1.0094E-07	0.799	103.1		314.06	7.514E-06	1000	2.283E-05
292	Phenyl isocyanate	C_7H_5NO	103-71-9	119.121	8.536E-08	0.80872	88.273		243.15	5.324E-06	1000	2.093E-05
293	Phthalic anhydride	$C_8H_4O_3$	85-44-9	148.116	4.3511E-08	0.908	102.73		404.15	8.072E-06	1000	2.090E-05
294	Propadiene	C_3H_4	463-49-0	40.064	6.0758E-07	0.53845	173.45		136.87	3.788E-06	1000	2.135E-05
295	Propane	C_3H_8	74-98-6	44.096	4.9054E-08	0.90125			85.47	2.702E-06	1000	2.480E-05
296	1-Propanol	C_3H_8O	71-23-8	60.095	7.942E-07	0.5491	415.8		200.00	4.732E-06	1000	2.490E-05
297	2-Propanol	C_3H_8O	67-63-0	60.095	1.2003E-06	0.494	479.78		187.35	4.471E-06	1000	2.461E-05
298	Propenylcyclohexene	C_9H_{14}	13511-13-2	122.207	5.4749E-07	0.53893	283.52		199.00	3.914E-06	1000	1.765E-05
299	Propionaldehyde	C_3H_6O	123-38-6	58.079	1.7526E-07	0.72691	119.93		170.00	4.297E-06	1000	2.373E-05
300	Propionic acid	$C_3H_6O_2$	79-09-4	74.079	1.61E-07	0.7457	159.3		252.45	6.105E-06	1000	2.397E-05
301	Propionitrile	C_3H_5N	107-12-0	55.079	1.0111E-07	0.7821	89.5		180.26	3.927E-06	1000	2.060E-05
302	Propyl acetate	$C_5H_{10}O_2$	109-60-4	102.132	2.1372E-07	0.6894	178.57		178.15	3.802E-06	1000	2.122E-05
303	Propyl amine	C_3H_9N	107-10-8	59.110	1.62E-07	0.7285	117		188.36	4.540E-06	1000	2.223E-05

TABLE 2-312 Vapor Viscosity of Inorganic and Organic Substances (Pa·s) (*Concluded*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	T_{min}, K	Viscosity at T_{min}	T_{max}, K	Viscosity at T_{max}
304	Propylbenzene	C_9H_{12}	103-65-1	120.192	3.0387E-07	0.61945	210.35		173.55	3.351E-06	1000	1.812E-05
305	Propylene	C_3H_6	115-07-1	42.080	7.3919E-07	0.5423	263.73		87.89	2.093E-06	1000	2.477E-05
306	Propyl formate	$C_4H_8O_2$	110-74-7	88.105	6.0741E-07	0.5863	367.29		180.25	4.203E-06	1000	2.550E-05
307	2-Propyl mercaptan	C_3H_8S	75-33-2	76.161	3.5532E-08	0.95654			142.61	4.085E-06	1000	2.632E-05
308	Propyl mercaptan	C_3H_8S	107-03-9	76.161	7.9457E-08	0.84656	65.878		159.95	4.132E-06	1000	2.583E-05
309	1,2-Propylene glycol	$C_3H_8O_2$	57-55-6	76.094	4.543E-08	0.9173	61		213.15	4.832E-06	1000	2.418E-05
310	Quinone	$C_6H_4O_2$	106-51-4	108.095	1.1085E-07	0.8008	152.51		388.85	9.439E-06	1000	2.429E-05
311	Silicon tetrafluoride	F_4Si	7783-61-1	104.079	2.1671E-07	0.76757	16.28		250.00	1.410E-05	500	2.475E-05
312	Styrene	C_8H_8	100-42-5	104.149	6.3863E-07	0.5254	295.1		242.54	5.158E-06	1000	1.858E-05
313	Succinic acid	$C_4H_6O_4$	110-15-6	118.088	2.273E-07	0.6845	229.8		460.65	1.009E-05	1000	2.091E-05
314	Sulfur dioxide	O_2S	7446-09-5	64.064	6.863E-07	0.6112	217		197.67	8.280E-06	1000	3.844E-05
315	Sulfur hexafluoride	F_6S	2551-62-4	146.055	5.3986E-07	0.6349	34.5	19,000	205.15	9.790E-06	5000	1.195E-04
316	Sulfur trioxide	O_3S	7446-11-9	80.063	3.9067E-06	0.3845	470.1		297.93	1.355E-05	694.19	2.883E-05
317	Terephthalic acid	$C_8H_6O_4$	100-21-0	166.131	2.2452E-08	0.97631			700.15	1.346E-05	1000	1.906E-05
318	*o*-Terphenyl	$C_{18}H_{14}$	84-15-1	230.304	7.0859E-07	0.51971	652.24		329.35	4.837E-06	1000	1.554E-05
319	Tetradecane	$C_{14}H_{30}$	629-59-4	198.388	5.1567E-09	1.1561			279.01	3.465E-06	1000	1.516E-05
320	Tetrahydrofuran	C_4H_8O	109-99-9	72.106	3.778E-07	0.6533	271.01		164.65	4.006E-06	1000	2.710E-05
321	1,2,3,4-Tetrahydronaphthalene	$C_{10}H_{12}$	119-64-2	132.202	5.0784E-07	0.5614	328.55		237.38	4.592E-06	1000	1.847E-05
322	Tetrahydrothiophene	C_4H_8S	110-01-0	88.171	8.5988E-08	0.82841	68.172		176.99	4.520E-06	1000	2.461E-05
323	2,2,3,3-Tetramethylbutane	C_8H_{18}	594-82-1	114.229	8.1458E-07	0.50257	380.29		373.96	7.930E-06	1000	1.900E-05
324	Thiophene	C_4H_4S	110-02-1	84.140	1.03E-06	0.5497	569.4		234.94	6.049E-06	1000	2.926E-05
325	Toluene	C_7H_8	108-88-3	92.138	8.7268E-07	0.49397	323.79		178.18	4.008E-06	1000	2.000E-05
326	1,1,2-Trichloroethane	$C_2H_3Cl_3$	79-00-5	133.404	2.7081E-07	0.6955	187.93		236.50	6.756E-06	1000	2.782E-05
327	Tridecane	$C_{13}H_{28}$	629-50-5	184.361	3.5585E-08	0.8987	165.3		267.76	3.344E-06	1000	1.517E-05
328	Triethyl amine	$C_6H_{15}N$	121-44-8	101.190	2.411E-07	0.6845	223		158.45	3.210E-06	1000	2.230E-05
329	Trimethyl amine	C_3H_9N	75-50-3	59.110	1.2434E-06	0.4832	447.7		156.08	3.689E-06	1000	2.418E-05
330	1,2,3-Trimethylbenzene	C_9H_{12}	526-73-8	120.192	7.8498E-07	0.49855	362.79		247.79	4.975E-06	1000	1.803E-05
331	1,2,4-Trimethylbenzene	C_9H_{12}	95-63-6	120.192	6.8812E-07	0.51063	330.88		229.33	4.520E-06	1000	1.760E-05
332	2,2,4-Trimethylpentane	C_8H_{18}	540-84-1	114.229	1.107E-07	0.746	72.4		165.78	3.488E-06	1000	1.786E-05
333	2,3,3-Trimethylpentane	C_8H_{18}	560-21-4	114.229	8.2418E-07	0.4931	371.44		387.91	7.958E-06	1000	1.812E-05
334	1,3,5-Trinitrobenzene	$C_6H_3N_3O_6$	99-35-4	213.105	3.4066E-08	0.95252	43.528		398.40	9.208E-06	1000	2.352E-05
335	2,4,6-Trinitrotoluene	$C_7H_5N_3O_6$	118-96-7	227.131	2.8471E-08	0.96571	30.83		354.00	7.581E-06	1000	2.179E-05
336	Undecane	$C_{11}H_{24}$	1120-21-4	156.308	3.594E-08	0.9052	125		247.57	3.506E-06	1000	1.660E-05
337	1-Undecanol	$C_{11}H_{24}O$	112-42-5	172.308	5.9537E-08	0.81842	90.245		288.45	4.677E-06	1000	1.558E-05
338	Vinyl acetate	$C_4H_6O_2$	108-05-4	86.089	1.388E-07	0.7599	98		180.35	4.660E-06	1000	2.407E-05
339	Vinyl acetylene	C_4H_4	689-97-4	52.075	6.7484E-07	0.5304	230.17		173.15	4.459E-06	1000	2.140E-05
340	Vinyl chloride	C_2H_3Cl	75-01-4	62.498	2.379E-07	0.71517	102.84		119.36	3.907E-06	1000	1.263E-12
341	Vinyl trichlorosilane	$C_2H_3Cl_3Si$	75-94-5	161.490	3.6429E-08	0.95924			178.35	5.260E-06	1000	2.749E-05
342	Water	H_2O	7732-18-5	18.015	1.7096E-08	1.1146			273.16	8.882E-06	1073.15	4.082E-05
343	*m*-Xylene	C_8H_{10}	108-38-3	106.165	6.8293E-07	0.52199	324.17		225.30	4.735E-06	1000	1.899E-05
344	*o*-Xylene	C_8H_{10}	95-47-6	106.165	8.3436E-07	0.49713	365.86		247.98	5.225E-06	1000	1.894E-05
345	*p*-Xylene	C_8H_{10}	106-42-3	106.165	9.3485E-07	0.47683	371.96		286.41	6.037E-06	1000	1.836E-05

The vapor viscosity is calculated by

$$\mu = \frac{C1T^{C2}}{1 + C3/T + C4/T^2}$$

where μ is the viscosity in Pa·s and T is the temperature in K. Viscosities are at either 1 atm or the vapor pressure, whichever is lower. All substances are listed by chemical family in Table 2-6 and by formula in Table 2-7.

Values in this table were taken from the Design Institute for Physical Properties (DIPPR) of the American Institute of Chemical Engineers (AIChE), copyright 2007 AIChE and reproduced with permission of AICHE and of the DIPPR Evaluated Process Design Data Project Steering Committee. Their source should be cited as R. L. Rowley, W. V. Wilding, J. L. Oscarson, Y. Yang, N. A. Zundel, T. E. Daubert, R. P. Danner, DIPPR® Data Compilation of Pure Chemical Properties, Design Institute for Physical Properties, AIChE, New York (2007).

The number of digits provided for values at T_{min} and T_{max} was chosen for uniformity of appearance and formatting; these do not represent the uncertainties of the physical quantities, but are the result of calculations from the standard thermophysical property formulations within a fixed format.

TABLE 2-313 Viscosity of Inorganic and Organic Liquids (Pa·s)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	C5	T_{min}, K	Viscosity at T_{min}	T_{max}, K	Viscosity at T_{max}
1	Acetaldehyde	C_2H_4O	75-07-0	44.053	–5.895	668.21	–0.84323			150.15	3.446E-03	294.00	2.216E-04
2	Acetamide	C_2H_5NO	60-35-5	59.067	1.5525	1376.4	–2.0126			353.33	1.728E-03	494.30	2.895E-04
3	Acetic acid	$C_2H_4O_2$	64-19-7	60.052	–9.03	1212.3	–0.322			289.81	1.265E-03	391.05	3.890E-04
4	Acetic anhydride	$C_4H_6O_3$	108-24-7	102.089	–14.164	1350.3	0.4492			210.00	4.834E-03	412.70	2.783E-04
5	Acetone	C_3H_6O	67-64-1	58.079	–14.918	1023.4	0.5961			190.00	1.655E-03	329.44	2.351E-04
6	Acetonitrile	C_2H_3N	75-05-8	41.052	–10.906	872.02				229.32	8.220E-04	436.40	1.350E-04
7	Acetylene	C_2H_2	74-86-2	26.037	6.224	–151.8	–2.6554			193.15	1.958E-04	273.15	9.819E-05
8	Acrolein	C_3H_4O	107-02-8	56.063	–12.032	867.34	0.19534			185.45	1.773E-03	353.22	2.181E-04
9	Acrylic acid	$C_3H_4O_2$	79-10-7	72.063	–28.12	2280.2	2.3956			286.15	1.359E-03	460.00	2.086E-04
10	Acrylonitrile	C_3H_3N	107-13-1	53.063	2.019	239.7	–1.8975			220.00	8.040E-04	350.50	2.215E-04
11	Air	Mixture	132259-10-0	28.960	–20.077	285.15	1.784	–6.2382E-22	10	59.15	3.430E-04	130.00	4.276E-05
12	Ammonia	H_3N	7664-41-7	17.031	–6.743	598.3	–0.7341	–3.69E-27	10	195.41	5.240E-04	393.15	4.858E-05
13	Anisole	C_7H_8O	100-66-3	108.138	–15.407	1518.7	0.60172			235.65	3.429E-03	426.73	2.736E-04
14	Argon	Ar	7440-37-1	39.948	–8.8685	204.29	–0.38305	–1.2937E-22	10	83.78	2.950E-04	150.00	3.823E-05
15	Benzamide	C_7H_7NO	55-21-0	121.137	–12.632	2668.2				403.00	2.451E-03	563.15	3.730E-04
16	Benzene	C_6H_6	71-43-2	78.112	7.5117	294.68	–2.794			278.68	7.761E-04	545.00	7.106E-05
17	Benzenethiol	C_6H_6S	108-98-5	110.177	–8.4562	1024.4	–0.30635			258.27	2.047E-03	442.29	3.333E-04
18	Benzoic acid	$C_7H_6O_2$	65-85-0	122.121	–12.947	2557.9				395.52	1.530E-03	600.80	1.680E-04
19	Benzonitrile	C_7H_5N	100-47-0	103.121	–20.236	1737.4	1.3531			270.00	1.977E-03	450.00	3.009E-04
20	Benzophenone	$C_{13}H_{10}O$	119-61-9	182.218	13.354	–232.91	–3.2685	1.7488E+20	–8.052	321.35	6.100E-03	664.00	2.660E-04
21	Benzyl alcohol	C_7H_8O	100-51-6	108.138	–14.152	2652				257.85	2.092E-02	478.60	1.821E-04
22	Benzyl ethyl ether	$C_9H_{12}O$	539-30-0	136.191	–11.46	1497	–0.043397			275.65	1.887E-03	458.15	2.121E-04
23	Benzyl mercaptan	C_7H_8S	100-53-8	124.203	–11.459	1334.4	0.00049694			243.95	2.513E-03	472.03	1.788E-04
24	Biphenyl	$C_{12}H_{10}$	92-52-4	154.208	–9.9265	1576.3	–0.21119			342.20	1.427E-03	723.15	1.076E-04
25	Bromine	Br_2	7726-95-6	159.808	16.775	–314	–3.9763			265.85	1.353E-03	350.00	6.021E-04
26	Bromobenzene	C_6H_5Br	108-86-1	157.008	–20.611	1656.5	1.4415			242.43	2.842E-03	429.24	3.310E-04
27	Bromoethane	C_2H_5Br	74-96-4	108.965	–10.015	823.43	–0.11122			154.55	5.260E-03	311.50	3.321E-04
28	Bromomethane	CH_3Br	74-83-9	94.939	–8.103	570.8	–0.32958			179.47	1.316E-03	276.71	3.732E-04
29	1,2-Butadiene	C_4H_6	590-19-2	54.090	–10.143	472.79	–0.028241			136.95	1.081E-03	284.00	1.773E-04
30	1,3-Butadiene	C_4H_6	106-99-0	54.090	17.844	–310.2	–4.5058			250.00	2.547E-04	400.00	4.880E-05
31	Butane	C_4H_{10}	106-97-8	58.122	–7.2471	534.82	–0.57469	–4.6625E-27	10	134.86	2.243E-03	420.00	3.566E-05
32	1,2-Butanediol	$C_4H_{10}O_2$	584-03-2	90.121	–393.86	19042	59.978	–0.049479	1	220.00	2.020E+02	544.00	3.440E-04
33	1,3-Butanediol	$C_4H_{10}O_2$	107-88-0	90.121	–390.03	18609	60.014	–0.055844	1	196.15	4.410E+04	540.80	2.890E-04
34	1-Butanol	$C_4H_{10}O$	71-36-3	74.122	0.87669	1602.9	–2.1475	3.3866E+22	–9.9231	190.00	3.237E-01	391.90	3.877E-04
35	2-Butanol	$C_4H_{10}O$	78-92-2	74.122	–16.323	3141.7				158.45	3.327E+01	372.90	3.715E-04
36	1-Butene	C_4H_8	106-98-9	56.106	–10.773	591.61				87.80	1.770E-02	335.60	1.220E-04
37	*cis*-2-Butene	C_4H_8	590-18-1	56.106	–10.346	522.3	–0.011847			134.26	1.483E-03	276.87	1.982E-04
38	*trans*-2-Butene	C_4H_8	624-64-6	56.106	–10.335	521.39	–0.013184			167.62	6.810E-04	274.03	2.022E-04
39	Butyl acetate	$C_6H_{12}O_2$	123-86-4	116.158	–17.488	1478.2	0.91828			250.00	1.496E-03	399.26	2.521E-04
40	Butylbenzene	$C_{10}H_{14}$	104-51-8	134.218	–23.802	1887.2	1.8479			200.00	1.030E-02	456.46	2.359E-04
41	Butyl mercaptan	$C_4H_{10}S$	109-79-5	90.187	–10.807	966.74	–0.014851			157.46	8.717E-03	373.15	2.475E-04
42	*sec*-Butyl mercaptan	$C_4H_{10}S$	513-53-1	90.187	–10.903	932.82	0.023034			133.02	2.288E-02	358.13	2.851E-04
43	1-Butyne	C_4H_6	107-00-6	54.090	–3.4644	334.5	–1.0811			147.43	1.369E-03	373.15	1.271E-04
44	Butyraldehyde	C_4H_8O	123-72-8	72.106	–10.057	903.73	–0.13186			176.75	3.602E-03	348.05	2.660E-04
45	Butyric acid	$C_4H_8O_2$	107-92-6	88.105	–9.817	1388	–0.238			267.95	2.561E-03	436.42	3.087E-04
46	Butyronitrile	C_4H_7N	109-74-0	69.105	–10.136	1006.4	–0.1337			161.25	1.031E-02	390.75	2.344E-04
47	Carbon dioxide	CO_2	124-38-9	44.010	18.775	–402.92	–4.6854	–6.9171E-26	10	216.58	2.488E-04	303.15	5.652E-05
48	Carbon disulfide	CS_2	75-15-0	76.141	–10.306	703.01				161.58	2.590E-03	441.60	1.640E-04
49	Carbon monoxide	CO	630-08-0	28.010	–4.9735	97.67	–1.1088			68.15	2.689E-04	131.37	6.515E-05
50	Carbon tetrachloride	CCl_4	56-23-5	153.823	–8.0738	1121.1	–0.4726			250.00	2.032E-03	455.00	2.030E-04
51	Carbon tetrafluoride	CF_4	75-73-0	88.004	–9.9212	300.5				89.56	1.408E-03	145.10	3.897E-04
52	Chlorine	Cl_2	7782-50-5	70.906	–9.5412	456.62				172.12	1.020E-03	333.72	2.820E-04
53	Chlorobenzene	C_6H_5Cl	108-90-7	112.557	0.15772	540.5	–1.6075			250.00	1.422E-03	540.00	1.291E-04
54	Chloroethane	C_2H_5Cl	75-00-3	64.514	–10.216	702	–0.072			150.00	2.748E-03	373.15	1.567E-04
55	Chloroform	$CHCl_3$	67-66-3	119.378	–14.109	1049.2	0.5377			209.63	1.970E-03	353.20	3.410E-04
56	Chloromethane	CH_3Cl	74-87-3	50.488	–25.132	1381.9	2.0811	–4.4999E-27	10	175.43	1.501E-03	403.15	5.951E-05
57	1-Chloropropane	C_3H_7Cl	540-54-5	78.541	–13.994	949.4	0.50223	–6.163E-17	6	150.35	5.728E-03	423.15	1.154E-04
58	2-Chloropropane	C_3H_7Cl	75-29-6	78.541	–15.458	1086	0.654			250.00	5.515E-04	308.85	2.767E-04
59	*m*-Cresol	C_7H_8O	108-39-4	108.138	59.686	–3517.9	–9.838	9.0312E+12	–5	273.15	8.670E-02	564.68	1.630E-04

TABLE 2-313 Viscosity of Inorganic and Organic Liquids (Pa·s) (*Continued*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	C5	T_{min}, K	Viscosity at T_{min}	T_{max}, K	Viscosity at T_{max}
60	*o*-Cresol	C_7H_8O	95-48-7	108.138	−0.033937	390.77	−1.4547	5.0187E+12	−5	293.15	9.600E-03	558.04	2.160E-04
61	*p*-Cresol	C_7H_8O	106-44-5	108.138	−1.6355	1052.9	−1.3891	3.6844E+17	−7	273.15	9.770E-02	563.72	1.940E-04
62	Cumene	C_9H_{12}	98-82-8	120.192	−24.988	1807.9	2.0556			200.00	6.363E-03	400.00	2.881E-04
63	Cyanogen	C_2N_2	460-19-5	52.035	−12.086	994.23				245.25	3.250E-04	320.12	1.260E-04
64	Cyclobutane	C_4H_8	287-23-0	56.106	−3.4968	397.94	−1.1087			182.48	8.345E-04	367.94	1.278E-04
65	Cyclohexane	C_6H_{12}	110-82-7	84.159	−33.763	2497.2	3.2236			279.69	1.260E-03	443.04	2.070E-04
66	Cyclohexanol	$C_6H_{12}O$	108-93-0	100.159	280.87	−31869	−38.837	3,994,500	−2.002	296.60	6.330E-02	520.08	1.650E-04
67	Cyclohexanone	$C_6H_{10}O$	108-94-1	98.143	−44.877	3227.7	4.887			242.00	8.960E-03	428.58	4.402E-04
68	Cyclohexene	C_6H_{10}	110-83-8	82.144	−11.641	1154.3	0.066511			200.00	4.018E-03	373.15	2.877E-04
69	Cyclopentane	C_5H_{10}	287-92-3	70.133	−3.2612	614.16	−1.156			225.00	1.122E-03	325.00	3.167E-04
70	Cyclopentene	C_5H_8	142-29-0	68.117	−4.1508	599.77	−1.0308			138.13	7.531E-03	405.60	1.416E-04
71	Cyclopropane	C_3H_6	75-19-4	42.080	−3.524	342.54	−1.1599			145.59	9.601E-04	318.40	1.080E-04
72	Cyclohexyl mercaptan	$C_6H_{12}S$	1569-69-3	116.224	−11.338	1304.1	0.000092396			189.64	1.155E-02	431.95	2.440E-04
73	Decanal	$C_{10}H_{20}O$	112-31-2	156.265	−10.115	1111.9	−0.015659			267.15	2.381E-03	488.15	3.583E-04
74	Decane	$C_{10}H_{22}$	124-18-5	142.282	−9.6489	1181.1	−0.24367	9.0522E+34	−15	240.05	2.780E-03	494.16	1.550E-04
75	Decanoic acid	$C_{10}H_{20}O_2$	334-48-5	172.265	−12.305	2324.1	−0.055494			304.55	6.798E-03	543.15	2.304E-04
76	1-Decanol	$C_{10}H_{22}O$	112-30-1	158.281	−69.985	5818.8	8.0715			285.00	1.937E-02	503.00	2.727E-04
77	1-Decene	$C_{10}H_{20}$	872-05-9	140.266	−15.868	1434.8	0.68071			206.89	4.975E-03	443.75	2.064E-04
78	Decyl mercaptan	$C_{10}H_{22}S$	143-10-2	174.347	−11.464	1510.1	−0.012754			247.56	4.364E-03	512.35	1.848E-04
79	1-Decyne	$C_{10}H_{18}$	764-93-2	138.250	−2.3633	791.93	−1.2272			229.15	3.786E-03	505.60	2.167E-04
80	Deuterium	D_2	7782-39-0	4.032	0.000001348					20.35	1.348E-06	20.35	1.348E-06
81	1,1-Dibromoethane	$C_2H_4Br_2$	557-91-5	187.861	−10.457	1101.1	−0.0031354			210.15	5.331E-03	381.15	5.071E-04
82	1,2-Dibromoethane	$C_2H_4Br_2$	106-93-4	187.861	−17.582	1635.4	0.9932			282.85	2.042E-03	404.51	5.120E-04
83	Dibromomethane	CH_2Br_2	74-95-3	173.835	−10.013	921.31				220.60	2.920E-03	488.80	2.950E-04
84	Dibutyl ether	$C_8H_{18}O$	142-96-1	130.228	10.027	206	−3.1607			175.30	5.931E-03	414.15	1.989E-04
85	*m*-Dichlorobenzene	$C_6H_4Cl_2$	541-73-1	147.002	−1.9265	387.67	−1.1335	1.5037E+14	−6	248.39	2.540E-03	547.16	2.340E-04
86	*o*-Dichlorobenzene	$C_6H_4Cl_2$	95-50-1	147.002	−30.6	2153.4	2.9371			256.15	2.727E-03	453.57	3.761E-04
87	*p*-Dichlorobenzene	$C_6H_4Cl_2$	106-46-7	147.002	31.63	−1080	−6.114			326.14	8.543E-04	447.21	3.039E-04
88	1,1-Dichloroethane	$C_2H_4Cl_2$	75-34-3	98.959	−8.991	870.2	−0.2805			176.19	4.076E-03	330.45	3.407E-04
89	1,2-Dichloroethane	$C_2H_4Cl_2$	107-06-2	98.959	15.312	−41.12	−3.919			237.49	1.839E-03	400.00	2.557E-04
90	Dichloromethane	CH_2Cl_2	75-09-2	84.933	−13.071	940.03	0.3733			208.38	1.407E-03	373.93	2.374E-04
91	1,1-Dichloropropane	$C_3H_6Cl_2$	78-99-9	112.986	−10.872	1033.1	−0.00067435			200.00	3.312E-03	361.25	3.301E-04
92	1,2-Dichloropropane	$C_3H_6Cl_2$	78-87-5	112.986	−11.269	1195.3	0.012736			172.71	1.381E-02	369.52	3.495E-04
93	Diethanol amine	$C_4H_{11}NO_2$	111-42-2	105.136	−375.21	17177	66.66	−3.6367	0.5	293.15	8.130E-01	589.28	1.090E-04
94	Diethyl amine	$C_4H_{11}N$	109-89-7	73.137	−17.57	1385.7	0.85647			223.35	1.191E-03	329.10	2.260E-04
95	Diethyl ether	$C_4H_{10}O$	60-29-7	74.122	10.197	−63.8	−3.226			200.00	7.359E-04	373.15	1.141E-04
96	Diethyl sulfide	$C_4H_{10}S$	352-93-2	90.187	−5.135	667.5	−0.8553			225.00	1.113E-03	365.25	2.354E-04
97	1,1-Difluoroethane	$C_2H_4F_2$	75-37-6	66.050	10.501	−52.181	−3.3459			154.56	1.229E-03	343.15	1.026E-04
98	1,2-Difluoroethane	$C_2H_4F_2$	624-72-6	66.050	−10.072	710.48	−0.14677			215.00	5.231E-04	283.65	2.257E-04
99	Difluoromethane	CH_2F_2	75-10-5	52.023	−17.723	850.2	1.0601	−1.1719E-18	7	137.00	1.830E-03	343.15	6.050E-05
100	Di-isopropyl amine	$C_6H_{15}N$	108-18-9	101.190	−1.7366	599.8	−1.4237			250.00	7.479E-04	357.05	2.193E-04
101	Di-isopropyl ether	$C_6H_{14}O$	108-20-3	102.175	−11.5	993	0.022			187.65	2.259E-03	341.45	2.110E-04
102	Di-isopropyl ketone	$C_7H_{14}O$	565-80-0	114.185	−15.097	1426.9	0.51512			204.81	4.569E-03	397.55	2.194E-04
103	1,1-Dimethoxyethane	$C_4H_{10}O_2$	534-15-6	90.121	−10.968	885.49				159.95	4.375E-03	337.45	2.378E-04
104	1,2-Dimethoxypropane	$C_5H_{12}O_2$	7778-85-0	104.148	−10.631	1086.4				226.10	2.950E-03	366.15	4.695E-04
105	Dimethyl acetylene	C_4H_6	503-17-3	54.090	0.10842	300.2	−1.6831			240.91	3.796E-04	371.00	1.186E-04
106	Dimethyl amine	C_2H_7N	124-40-3	45.084	−10.93	699.5				200.00	5.917E-04	308.15	1.734E-04
107	2,3-Dimethylbutane	C_6H_{14}	79-29-8	86.175	7.2565	221.4	−2.7946			220.00	1.103E-03	331.13	2.509E-04
108	1,1-Dimethylcyclohexane	C_8H_{16}	590-66-9	112.213	−10.716	1140.5	−0.047736			239.66	1.992E-03	392.70	3.045E-04
109	*cis*-1,2-Dimethylcyclohexane	C_8H_{16}	2207-01-4	112.213	−11.796	1463.5				223.16	5.310E-03	484.92	1.540E-04
110	*trans*-1,2-Dimethylcyclohexane	C8H16	6876-23-9	112.213	−11.344	1168.9	0.04513			184.99	8.315E-03	396.58	2.956E-04
111	Dimethyl disulfide	$C_2H_6S_2$	624-92-0	94.199	−10.577	1172.6	−0.14244			188.44	6.093E-03	382.90	2.336E-04
112	Dimethyl ether	C_2H_6O	115-10-6	46.068	−10.62	448.99	0.000083967			131.65	7.398E-04	248.31	1.490E-04
113	*N*,*N*-Dimethyl formamide	C_3H_7NO	68-12-2	73.094	−20.425	1515.5	1.4444			240.00	2.041E-03	425.15	2.981E-04
114	2,3-Dimethylpentane	C_7H_{16}	565-59-3	100.202	−12.08	1112.2	0.09654			160.00	9.669E-03	362.93	2.147E-04
115	Dimethyl phthalate	$C_{10}H_{10}O_4$	131-11-3	194.184	16.961	−423.16	−3.8178	1.362E+15	−6	274.18	6.030E-02	612.80	2.730E-04
116	Dimethylsilane	C_2H_8Si	1111-74-6	60.170									
117	Dimethyl sulfide	C_2H_6S	75-18-3	62.134	−17.641	1067.5	1.0317			225.00	6.696E-04	310.48	2.528E-04
118	Dimethyl sulfoxide	C_2H_6OS	67-68-5	78.133	−37.347	2835	3.7937			291.67	2.253E-03	464.00	3.547E-04

119	Dimethyl terephthalate	$C_{10}H_{10}O_4$	120-61-6	194.184	−11.488	1922.6				413.80	1.068E-03	561.15	3.154E-04
120	1,4-Dioxane	$C_4H_8O_2$	123-91-1	88.105	−46.166	3086.2	5.104			284.95	1.525E-03	374.65	4.610E-04
121	Diphenyl ether	$C_{12}H_{10}O$	101-84-8	170.207	−12.373	2017.5				293.15	4.120E-03	613.44	1.130E-04
122	Dipropyl amine	$C_6H_{15}N$	142-84-7	101.190	−15.404	1390	0.5564			260.00	9.454E-04	382.35	2.118E-04
123	Dodecane	$C_{12}H_{26}$	112-40-3	170.335	−7.8244	1191.9	−0.49963	3.9572E+23	−10	262.15	3.020E-03	526.40	1.680E-04
124	Eicosane	$C_{20}H_{42}$	112-95-8	282.547	−18.315	2283.5	0.95485			309.58	4.243E-03	616.93	2.078E-04
125	Ethane	C_2H_6	74-84-0	30.069	−7.0046	276.38	−0.6087	−3.1108E-18	7	90.35	1.247E-03	300.00	3.587E-05
126	Ethanol	C_2H_6O	64-17-5	46.068	7.875	781.98	−3.0418			200.00	1.315E-02	440.00	1.416E-04
127	Ethyl acetate	$C_4H_8O_2$	141-78-6	88.105	14.354	−154.6	−3.7887			220.00	1.132E-03	473.15	9.061E-05
128	Ethyl amine	C_2H_7N	75-04-7	45.084	19.822	−0.12598	−4.9793			192.15	1.727E-03	289.73	2.236E-04
129	Ethylbenzene	C_8H_{10}	100-41-4	106.165	−13.563	1208.6	0.377			178.20	8.012E-03	413.10	2.326E-04
130	Ethyl benzoate	$C_9H_{10}O_2$	93-89-0	150.175	−40.706	3035	4.2655			250.00	6.643E-03	486.55	3.109E-04
131	2-Ethyl butanoic acid	$C_6H_{12}O_2$	88-09-5	116.158	−12.24	1836.4	0.021868			258.15	6.705E-03	466.95	2.822E-04
132	Ethyl butyrate	$C_6H_{12}O_2$	105-54-4	116.158	−15.485	1325.6	0.6432			250.00	1.319E-03	394.65	2.533E-04
133	Ethylcyclohexane	C_8H_{16}	1678-91-7	112.213	−22.11	1673	1.641			200.00	6.406E-03	404.94	2.956E-04
134	Ethylcyclopentane	C_7H_{14}	1640-89-7	98.186	−6.894	818.6	−0.5941			253.15	9.605E-04	378.15	2.599E-04
135	Ethylene	C_2H_4	74-85-1	28.053	1.8878	78.865	−2.1554			104.00	6.334E-04	250.00	6.143E-05
136	Ethylenediamine	$C_2H_8N_2$	107-15-3	60.098	−53.908	4030.8	5.9704			284.29	2.487E-03	483.15	1.723E-04
137	Ethylene glycol	$C_2H_6O_2$	107-21-1	62.068	−20.515	2468.5	1.2435	2.4998E+12	−5	260.15	1.340E-01	576.00	2.520E-04
138	Ethyleneimine	C_2H_5N	151-56-4	43.068	−11.012	967.4				250.00	7.909E-04	329.00	3.123E-04
139	Ethylene oxide	C_2H_4O	75-21-8	44.053	−8.521	634.2	−0.3314			160.65	1.918E-03	283.85	2.863E-04
140	Ethyl formate	$C_3H_6O_2$	109-94-4	74.079	−9.8417	876.4	−0.1708			245.00	7.435E-04	345.00	2.486E-04
141	2-Ethyl hexanoic acid	$C_8H_{16}O_2$	149-57-5	144.211	−13.037	2346				235.00	4.717E-02	510.10	2.165E-04
142	Ethylhexyl ether	$C_8H_{18}O$	5756-43-4	130.228	−11.311	1337.2	−0.02982			180.00	1.765E-02	417.15	2.522E-04
143	Ethylisopropyl ether	$C_5H_{12}O$	625-54-7	88.148	−11.331	908.46	0.00042478			140.00	7.908E-03	326.15	1.949E-04
144	Ethylisopropyl ketone	$C_6H_{12}O$	565-69-5	100.159	−11.452	1172.7	−0.00010095			204.15	3.319E-03	386.55	2.207E-04
145	Ethyl mercaptan	C_2H_6S	75-08-1	62.134	−9.7574	729.43	−0.14912			125.26	9.520E-03	308.15	2.626E-04
146	Ethyl propionate	$C_5H_{10}O_2$	105-37-3	102.132	−8.9215	950.8	−0.32687			250.00	9.848E-04	372.25	2.480E-04
147	Ethylpropyl ether	$C_5H_{12}O$	628-32-0	88.148	0.7109	386.51	−1.7754			200.00	1.156E-03	337.01	2.086E-04
148	Ethyltrichlorosilane	$C_2H_5Cl_3Si$	115-21-9	163.506	7.8744	−106.34	−2.6884	4.2757E+13	−6	167.55	1.010E-02	447.96	1.550E-04
149	Fluorine	F_2	7782-41-4	37.997	8.18	−75.6	−3.5148			53.48	7.317E-04	140.00	5.954E-05
150	Fluorobenzene	C_6H_5F	462-06-6	96.102	−10.064	1058.7	−0.17162			232.15	1.599E-03	453.15	1.542E-04
151	Fluoroethane	C_2H_5F	353-36-6	48.060	−10.758	558.81	−0.016459			129.95	1.448E-03	235.45	2.087E-04
152	Fluoromethane	CH_3F	593-53-3	34.033	−10.501	427.78	0.0086309			131.35	7.450E-04	194.82	2.587E-04
153	Formaldehyde	CH_2O	50-00-0	30.026	−11.24	751.69	−0.024579			181.15	7.331E-04	254.05	2.210E-04
154	Formamide	CH_3NO	75-12-7	45.041	40.153	−912.39	−7.5664	1.6873E+24	−10	273.15	7.408E-03	493.00	1.821E-04
155	Formic acid	CH_2O_2	64-18-6	46.026	−48.529	3394.7	5.3903			281.45	2.319E-03	373.71	5.444E-04
156	Furan	C_4H_4O	110-00-9	68.074	−10.923	894.63	−0.00068418			200.00	1.575E-03	304.50	3.392E-04
157	Helium-4	He	7440-59-7	4.003	−9.6312	−3.841	−1.458	−1.065E-08	10	2.20	3.628E-06	5.10	2.532E-06
158	Heptadecane	$C_{17}H_{36}$	629-78-7	240.468	−19.991	2245.1	1.1982			295.13	3.814E-03	575.30	2.088E-04
159	Heptanal	$C_7H_{14}O$	111-71-7	114.185	−10.443	1063.2	−0.031488			229.80	2.510E-03	425.95	2.924E-04
160	Heptane	C_7H_{16}	142-82-5	100.202	−9.4622	877.07	−0.23445	1.4022E+22	−10	180.15	4.420E-03	432.16	1.430E-04
161	Heptanoic acid	$C_7H_{14}O_2$	111-14-8	130.185	−40.543	3328.3	4.1804			265.83	9.242E-03	496.15	3.754E-04
162	1-Heptanol	$C_7H_{16}O$	111-70-6	116.201	−66.654	5325.8	7.66	−2.2512E-28	9.9041	239.15	8.805E-02	448.60	3.190E-04
163	2-Heptanol	$C_7H_{16}O$	543-49-7	116.201	11.225	25.319	−3.2694	1.0082E+11	−4.3444	230.00	4.036E-01	432.90	2.723E-04
164	3-Heptanone	$C_7H_{14}O$	106-35-4	114.185	−9.3874	1204.9	−0.32618			234.15	2.427E-03	421.15	2.040E-04
165	2-Heptanone	$C_7H_{14}O$	110-43-0	114.185	−13.929	1321.9	0.40382			250.00	1.642E-03	424.18	2.318E-04
166	1-Heptene	C_7H_{14}	592-76-7	98.186	−10.819	841.33				154.12	4.700E-03	429.92	1.420E-04
167	Heptyl mercaptan	$C_7H_{16}S$	1639-09-4	132.267	−11.812	1291.9	0.076469			229.92	3.097E-03	450.09	2.087E-04
168	1-Heptyne	C_7H_{12}	628-71-7	96.170	−2.7947	563.86	−1.1636			192.22	2.528E-03	447.20	1.777E-04
169	Hexadecane	$C_{16}H_{34}$	544-76-3	226.441	−20.182	2203.5	1.2289			291.31	3.536E-03	564.15	2.054E-04
170	Hexanal	$C_6H_{12}O$	66-25-1	100.159	−10.745	1021.4	−0.000055427			217.15	2.378E-03	401.45	2.744E-04
171	Hexane	C_6H_{14}	110-54-3	86.175	−6.3276	640	−0.694	5.6884E+21	−10	174.65	2.400E-03	406.08	1.340E-04
172	Hexanoic acid	$C_6H_{12}O_2$	142-62-1	116.158	−46.402	3448.6	5.0849			269.25	5.854E-03	478.85	4.019E-04
173	1-Hexanol	$C_6H_{14}O$	111-27-3	102.175	−39.324	3841	3.6933	−2.1166E-30	10.485	250.00	2.822E-02	429.90	3.343E-04
174	2-Hexanol	$C_6H_{14}O$	626-93-7	102.175	−82.705	7404.9	6.4721	1.5016	0.41014	223.00	4.919E-01	412.40	3.274E-04
175	2-Hexanone	$C_6H_{12}O$	591-78-6	100.159	−11.445	1187.2	0.0029076			217.35	2.561E-03	400.70	2.108E-04
176	3-Hexanone	$C_6H_{12}O$	589-38-8	100.159	−13.684	1283.4	0.33755			217.50	2.563E-03	396.65	2.185E-04
177	1-Hexene	C_6H_{12}	592-41-6	84.159	−10.36	775.85	−0.082348			133.39	7.108E-03	336.63	1.966E-04
178	3-Hexyne	C_6H_{10}	928-49-4	82.144	−4.2684	647.6	−1.0087			170.05	3.550E-03	432.00	1.377E-04
179	Hexyl mercaptan	$C_6H_{14}S$	111-31-9	118.240	−10.073	1123.3	−0.16515			192.62	6.035E-03	425.81	2.172E-04
180	1-Hexyne	C_6H_{10}	693-02-7	82.144	−4.7263	594.43	−0.86247			141.25	8.332E-03	412.00	2.083E-04
181	2-Hexyne	C_6H_{10}	764-35-2	82.144	−3.7464	624.2	−1.084			183.65	2.483E-03	435.00	1.368E-04

TABLE 2-313 Viscosity of Inorganic and Organic Liquids (Pa·s) (*Continued*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	C5	T_{min}, K	Viscosity at T_{min}	T_{max}, K	Viscosity at T_{max}
182	Hydrazine	H_4N_2	302-01-2	32.045	−75.781	4175.4	9.6508	−7.27E-09	3	274.69	1.450E-03	522.52	2.190E-04
183	Hydrogen	H_2	1333-74-0	2.016	−11.661	24.7	−0.261	−4.1E-16	10	13.95	2.546E-05	33.00	3.906E-06
184	Hydrogen bromide	HBr	10035-10-6	80.912	−11.633	316.38	0.56191			185.15	9.207E-04	206.45	8.206E-04
185	Hydrogen chloride	HCl	7647-01-0	36.461	−116.34	3834.6	16.864	−2.5875E-10	4	158.97	1.000E-03	318.15	5.780E-05
186	Hydrogen cyanide	CHN	74-90-8	27.025	−21.927	1266.5	1.5927			259.83	2.754E-04	298.85	1.821E-04
187	Hydrogen fluoride	HF	7664-39-3	20.006	353.99	13928	−41.717	−2,962	−0.5	189.79	1.550E-03	368.92	1.190E-04
188	Hydrogen sulfide	H_2S	7783-06-4	34.081	−10.905	762.11	−0.11863			187.68	5.726E-04	350.00	8.089E-05
189	Isobutyric acid	$C_4H_8O_2$	79-31-2	88.105	−11.497	1365.7	0.036966			250.00	2.938E-03	450.00	2.649E-04
190	Isopropyl amine	C_3H_9N	75-31-0	59.110	−31.157	1926	2.925			250.00	6.737E-04	453.15	1.214E-04
191	Malonic acid	$C_3H_4O_4$	141-82-2	104.061	−19.834	2784.5	1.1161			404.15	1.939E-03	580.00	3.593E-04
192	Methacrylic acid	$C_4H_6O_2$	79-41-4	86.089	−14.527	1497.7	0.51747			288.15	1.664E-03	434.15	3.582E-04
193	Methane	CH_4	74-82-8	16.042	−6.1572	178.15	−0.95239	−9.0606E-24	10	90.69	2.063E-04	188.00	2.263E-05
194	Methanol	CH_4O	67-56-1	32.042	−25.317	1789.2	2.069			175.47	1.193E-02	337.85	3.442E-04
195	*N*-Methyl acetamide	C_3H_7NO	79-16-3	73.094	−4.648	1832	−1.2191			301.15	3.995E-03	478.15	2.392E-04
196	Methyl acetate	$C_3H_6O_2$	79-20-9	74.079	13.557	−187.3	−3.6592			250.00	6.135E-04	425.00	1.198E-04
197	Methyl acetylene	C_3H_4	74-99-7	40.064	−2.8737	301.35	−1.2271			170.45	6.045E-04	373.15	8.846E-05
198	Methyl acrylate	$C_4H_6O_2$	96-33-3	86.089	10.848	75	−3.297			275.00	6.126E-04	400.00	1.636E-04
199	Methyl amine	CH_5N	74-89-5	31.057	−17.044	1074	0.84203			179.69	1.236E-03	273.15	2.275E-04
200	Methyl benzoate	$C_8H_8O_2$	93-58-3	136.148	−21.971	2267.4	1.4173			288.15	2.299E-03	472.65	2.149E-04
201	3-Methyl-1,2-butadiene	C_5H_8	598-25-4	68.117	−10.481	648.37	−0.041947			159.53	1.321E-03	314.00	1.739E-04
202	2-Methylbutane	C_5H_{12}	78-78-4	72.149	−12.596	889.11	0.20469			150.00	3.542E-03	310.00	1.928E-04
203	2-Methylbutanoic acid	$C_5H_{10}O_2$	116-53-0	102.132	−1.035	1048.5	−1.5474			298.15	1.774E-03	450.15	2.859E-04
204	3-Methyl-1-butanol	$C_5H_{12}O$	123-51-3	88.148	−25.882	3359.4	1.5787			155.95	3.776E+01	404.15	3.051E-04
205	2-Methyl-1-butene	C_5H_{10}	563-46-2	70.133	−10.755	705.48	−0.011113			135.58	3.675E-03	304.30	2.034E-04
206	2-Methyl-2-butene	C_5H_{10}	513-35-9	70.133	−8.4453	639.21	−0.38409			139.39	3.164E-03	311.70	1.841E-04
207	2-Methyl-1-butene-3-yne	C_5H_6	78-80-8	66.101	−3.6585	441.1	−1.0547			160.15	1.915E-03	390.15	1.476E-04
208	Methylbutyl ether	$C_5H_{12}O$	628-28-4	88.148	−11.278	949.12	−0.00012343			157.48	5.239E-03	343.31	2.006E-04
209	Methylbutyl sulfide	$C_5H_{12}S$	628-29-5	104.214	−10.97	1067.3	−0.017484			175.30	6.930E-03	396.58	2.286E-04
210	3-Methyl-1-butyne	C_5H_8	598-23-2	68.117	−1.8842	433.58	−1.3238			183.45	1.628E-03	364.00	2.035E-04
211	Methyl butyrate	$C_5H_{10}O_2$	623-42-7	102.132	−12.206	1141.7	0.15014			200.00	3.339E-03	375.90	2.539E-04
212	Methylchlorosilane	CH_5ClSi	993-00-0	80.589	−12.002	1009.7				139.05	8.730E-03	353.60	1.070E-04
213	Methylcyclohexane	C_7H_{14}	108-87-2	98.186	−11.358	1213.1				146.58	4.590E-02	457.68	1.650E-04
214	1-Methylcyclohexanol	$C_7H_{14}O$	590-67-0	114.185	−6.1534	3219	−1.4494			299.15	2.584E-02	548.80	8.026E-05
215	*cis*-2-Methylcyclohexanol	$C_7H_{14}O$	7443-70-1	114.185	−6.6904	3150.5	−1.392			280.15	3.729E-02	491.20	1.360E-04
216	*trans*-2-Methylcyclohexanol	$C_7H_{14}O$	7443-52-9	114.185	−6.6915	3173.2	−1.3046			269.15	1.107E-01	493.60	2.356E-04
217	Methylcyclopentane	C_6H_{12}	96-37-7	84.159	−1.8553	612.62	−1.3774			248.15	9.288E-04	353.15	2.742E-04
218	1-Methylcyclopentene	C_6H_{10}	693-89-0	82.144	−4.8515	679.07	−0.93238			146.62	7.669E-03	433.60	1.301E-04
219	3-Methylcyclopentene	C_6H_{10}	1120-62-3	82.144	−6.7424	788.86	−0.69862			115.00	4.086E-02	420.80	1.129E-04
220	Methyldichlorosilane	CH_4Cl_2Si	75-54-7	115.034	−10.517	745.32				275.00	4.070E-04	314.70	2.891E-04
221	Methylethyl ether	C_3H_8O	540-67-0	60.095	−11.104	627.18	0.036581			160.00	9.133E-04	280.50	1.731E-04
222	Methylethyl ketone	C_4H_8O	78-93-3	72.106	−1.0598	520.68	−1.4961			186.48	2.266E-03	535.50	7.577E-05
223	Methylethyl sulfide	C_3H_8S	624-89-5	76.161	−10.842	863.65	−0.00074603			167.23	3.409E-03	339.80	2.474E-04
224	Methyl formate	$C_2H_4O_2$	107-31-3	60.052	−39.641	2113.3	4.308			250.00	6.104E-04	304.90	3.134E-04
225	Methylisobutyl ether	$C_5H_{12}O$	625-44-5	88.148	−11.27	888.42	0.024736			150.00	5.390E-03	331.70	2.143E-04
226	Methylisobutyl ketone	$C_6H_{12}O$	108-10-1	100.159	−11.394	1168.7	−0.007539			189.15	5.222E-03	389.15	2.170E-04
227	Methyl Isocyanate	C_2H_3NO	624-83-9	57.051									
228	Methylisopropyl ether	$C_4H_{10}O$	598-53-8	74.122	−11.216	737.75	0.019308			127.93	4.722E-03	303.92	1.703E-04
229	Methylisopropyl ketone	$C_5H_{10}O$	563-80-4	86.132	−11.272	1048.9	0.00030493			180.15	4.305E-03	367.55	2.212E-04
230	Methylisopropyl sulfide	$C_4H_{10}S$	1551-21-9	90.187	−11.075	990.72				171.64	4.977E-03	553.10	9.292E-05
231	Methyl mercaptan	CH_4S	74-93-1	48.107	−10.628	645	0.025885			150.18	2.023E-03	279.11	2.827E-04
232	Methyl methacrylate	$C_5H_8O_2$	80-62-6	100.116	−0.099	496	−1.5939			260.00	8.635E-04	400.00	2.229E-04
233	2-Methyloctanoic acid	$C_9H_{18}O_2$	3004-93-1	158.238	−12.579	2224.2				240.00	3.646E-02	518.15	2.519E-04
234	2-Methylpentane	C_6H_{14}	107-83-5	86.175	−12.86	946.91	0.26191			119.55	2.506E-02	333.41	2.038E-04
235	Methyl pentyl ether	$C_6H_{14}O$	628-80-8	102.175	−11.391	1090.8	1.0752E-07			176.00	5.554E-03	372.00	2.120E-04
236	2-Methylpropane	C_4H_{10}	75-28-5	58.122	−13.912	797.09	0.45308			110.00	1.072E-02	310.95	1.588E-04
237	2-Methyl-2-propanol	$C_4H_{10}O$	75-65-0	74.122	51.356	−1249.5	−9.4593	3.694E+24	−9.8759	295.56	5.440E-03	451.21	1.010E-04
238	2-Methyl propene	C_4H_8	115-11-7	56.106	−10.385	599.59	−0.046088			132.81	2.253E-03	266.25	2.270E-04
239	Methyl propionate	$C_4H_8O_2$	554-12-1	88.105	−4.841	696.7	−0.9194			250.00	8.002E-04	352.60	2.593E-04
240	Methylpropyl ether	$C_4H_{10}O$	557-17-5	74.122	−10.705	788.94	−0.048383			133.97	6.390E-03	312.20	2.127E-04

241	Methylpropyl sulfide	$C_4H_{10}S$	3877-15-4	90.187	–10.569	952.38	–0.063873			160.17	7.103E-03	368.69	2.333E-04
242	Methylsilane	CH_6Si	992-94-9	46.144									
243	alpha-Methyl styrene	C_9H_{10}	98-83-9	118.176	–11.632	1251.6	0.071692			249.95	1.972E-03	438.65	2.382E-04
244	Methyl *tert*-butyl ether	$C_5H_{12}O$	1634-04-4	88.148	–6.921	790.773	–0.654			164.55	4.284E-03	450.00	1.052E-04
245	Methyl vinyl ether	C_3H_6O	107-25-5	58.079	–10.34	519.61	–0.013899			151.15	9.377E-04	278.65	1.929E-04
246	Naphthalene	$C_{10}H_8$	91-20-3	128.171	–19.308	1822.5	1.218			353.43	9.077E-04	633.15	1.892E-04
247	Neon	Ne	7440-01-9	20.180	–17.945	115.57	1.428	–2.14E-17	10	25.09	1.602E-04	44.13	2.706E-05
248	Nitroethane	$C_2H_5NO_2$	79-24-3	75.067	–4.438	746.5	–0.9385			200.00	3.421E-03	387.22	3.027E-04
249	Nitrogen	N_2	7727-37-9	28.013	16.004	–181.61	–5.1551			63.15	2.633E-04	124.00	3.331E-05
250	Nitrogen trifluoride	F_3N	7783-54-2	71.002									
251	Nitromethane	CH_3NO_2	75-52-5	61.040	–9.5556	981.64	–0.19453			244.60	1.344E-03	374.35	3.078E-04
252	Nitrous oxide	N_2O	10024-97-2	44.013	19.329	–381.68	–4.8618			210.00	2.065E-04	283.09	7.730E-05
253	Nitric oxide	NO	10102-43-9	30.006	–246.65	3150.3	49.98	–0.22541	1	109.50	3.858E-04	180.05	3.791E-05
254	Nonadecane	$C_{19}H_{40}$	629-92-5	268.521	–16.403	2119.5	0.6881			305.04	4.012E-03	603.15	2.068E-04
255	Nonanal	$C_9H_{18}O$	124-19-6	142.239	–12.94	1257.6	0.37191			255.15	2.606E-03	468.15	3.468E-04
256	Nonane	C_9H_{20}	111-84-2	128.255	–68.54	3165.3	9.0919	–0.000013519	2	218.15	3.310E-03	593.15	5.000E-05
257	Nonanoic acid	$C_9H_{18}O_2$	112-05-0	158.238	–48.851	4095	5.294			285.55	1.030E-02	528.75	3.670E-04
258	1-Nonanol	$C_9H_{20}O$	143-08-8	144.255	–39.863	4089	3.7631			280.00	1.733E-02	485.20	2.852E-04
259	2-Nonanol	$C_9H_{20}O$	628-99-9	144.255	–98.854	7183.8	12.283			238.15	2.310E-01	471.70	3.334E-04
260	1-Nonene	C_9H_{18}	124-11-8	126.239	–21.921	1603.9	1.5971			191.91	5.699E-03	420.02	2.127E-04
261	Nonyl mercaptan	$C_9H_{20}S$	1455-21-6	160.320	–11.319	1428	–0.022545			253.05	3.026E-03	492.95	1.913E-04
262	1-Nonyne	C_9H_{16}	3452-09-3	124.223	–2.3409	715.52	–1.222			223.15	3.206E-03	487.20	2.172E-04
263	Octadecane	$C_{18}H_{38}$	593-45-3	254.494	–22.688	2466	1.5703			301.31	3.926E-03	589.86	2.057E-04
264	Octanal	$C_8H_{16}O$	124-13-0	128.212	–10.191	1072.4	–0.030553			246.00	2.479E-03	447.15	3.425E-04
265	Octane	C_8H_{18}	111-65-9	114.229	–7.556	881.09	–0.52502	4.6342E+22	–10	211.15	2.660E-03	454.96	1.460E-04
266	Octanoic acid	$C_8H_{16}O_2$	124-07-2	144.211	–60.795	4617.8	7.028			289.65	6.652E-03	512.85	3.576E-04
267	1-Octanol	$C_8H_{18}O$	111-87-5	130.228	–19.907	2791.7	0.94296	2.3041E+24	–10.09	280.00	1.569E-02	468.35	2.901E-04
268	2-Octanol	$C_8H_{18}O$	123-96-6	130.228	16.792	1353.6	–4.6357	2.6663E+31	–13.039	241.55	4.576E-01	452.90	1.899E-04
269	2-Octanone	$C_8H_{16}O$	111-13-7	128.212	–11.736	1415.2	0.0003618			252.85	2.161E-03	446.15	1.913E-04
270	3-Octanone	$C_8H_{16}O$	106-68-3	128.212	–20.804	1834.6	1.3403			255.55	2.039E-03	440.65	2.075E-04
271	1-Octene	C_8H_{16}	111-66-0	112.213	–11.19	1057.4				171.45	6.590E-03	453.52	1.420E-04
272	Octyl mercaptan	$C_8H_{18}S$	111-88-6	146.294	–11.498	1362.1	0.015575			223.95	4.837E-03	472.19	2.000E-04
273	1-Octyne	C_8H_{14}	629-05-0	110.197	–3.8552	684.22	–1.0071			193.55	3.614E-03	468.00	1.868E-04
274	Oxalic acid	$C_2H_2O_4$	144-62-7	90.035									
275	Oxygen	O_2	7782-44-7	31.999	–4.1476	94.04	–1.207			54.36	7.170E-04	150.00	6.990E-05
276	Ozone	O_3	10028-15-6	47.998	–10.94	415.96				77.55	3.790E-03	208.80	1.300E-04
277	Pentadecane	$C_{15}H_{32}$	629-62-9	212.415	–19.299	2088.6	1.1091			283.07	3.486E-03	543.84	2.091E-04
278	Pentanal	$C_5H_{10}O$	110-62-3	86.132	–10.846	980.01	–0.0054565			182.00	4.129E-03	376.15	2.553E-04
279	Pentane	C_5H_{12}	109-66-0	72.149	–53.509	1836.6	7.1409	–0.000019627	2	143.42	3.529E-03	465.15	4.796E-05
280	Pentanoic acid	$C_5H_{10}O_2$	109-52-4	102.132	–37.067	2856.7	3.7344			270.00	3.773E-03	458.65	3.516E-04
281	1-Pentanol	$C_5H_{12}O$	71-41-0	88.148	–36.561	3542.2	3.3364	–8.0487E-37	12.84	253.15	1.649E-02	410.90	3.844E-04
282	2-Pentanol	$C_5H_{12}O$	6032-29-7	88.148	–410.49	18371	61.985	–0.0095612	1.2201	200.00	3.823E+01	392.20	5.828E-04
283	2-Pentanone	$C_5H_{10}O$	107-87-9	86.132	–11.055	1005.3	0.0039301			250.00	9.009E-04	375.46	2.354E-04
284	3-Pentanone	$C_5H_{10}O$	96-22-0	86.132	–2.8695	596.32	–1.2025			234.18	1.024E-03	375.14	2.232E-04
285	1-Pentene	C_5H_{10}	109-67-1	70.133	–10.667	659.56				108.02	1.045E-02	303.22	2.051E-04
286	2-Pentyl mercaptan	$C_5H_{12}S$	2084-19-7	104.214	–6.9168	818.76	–0.59628			220.00	1.643E-03	385.15	2.385E-04
287	Pentyl mercaptan	$C_5H_{12}S$	110-66-7	104.214	–11.677	1091.2	0.10658			197.45	3.746E-03	399.79	2.463E-04
288	1-Pentyne	C_5H_8	627-19-0	68.117	–1.7273	424.34	–1.342			167.45	2.323E-03	378.00	1.898E-04
289	2-Pentyne	C_5H_8	627-21-4	68.117	–3.7241	516.54	–1.1167			163.83	1.902E-03	415.20	9.980E-05
290	Phenanthrene	$C_{14}H_{10}$	85-01-8	178.229	–22.472	2566.9	1.5749			372.38	1.920E-03	610.03	2.849E-04
291	Phenol	C_6H_6O	108-95-2	94.111	–43.335	3881.7	4.3983	3.0548E+24	–10	291.45	1.270E-02	555.40	1.940E-04
292	Phenyl isocyanate	C_7H_5NO	103-71-9	119.121	–11.31	1280				243.15	2.370E-03	522.40	1.420E-04
293	Phthalic anhydride	$C_8H_4O_3$	85-44-9	148.116	195.25	–11072	–29.084			404.15	1.229E-03	557.65	1.986E-04
294	Propadiene	C_3H_4	463-49-0	40.064	–6.3528	240.85	–0.58229			136.87	5.772E-04	298.15	1.416E-04
295	Propane	C_3H_8	74-98-6	44.096	–17.156	646.25	1.1101	–7.3439E-11	4	85.47	9.458E-03	360.00	4.275E-05
296	1-Propanol	C_3H_8O	71-23-8	60.095	23.467	116.07	–5.3372	2.8801E+09	–4.0267	146.95	2.069E+01	370.35	4.735E-04
297	2-Propanol	C_3H_8O	67-63-0	60.095	–8.8918	2357.6	–0.91376			185.26	3.917E-01	355.30	4.892E-04
298	Propenylcyclohexene	C_9H_{14}	13511-13-2	122.207	–11.208	1079.8				199.00	3.080E-03	508.80	1.130E-04
299	Propionaldehyde	C_3H_6O	123-38-6	58.079	–9.9177	839.53	–0.16735			170.00	2.912E-03	321.15	2.562E-04
300	Propionic acid	$C_3H_6O_2$	79-09-4	74.079	–23.931	1834.6	1.9124			252.45	2.275E-03	414.32	3.430E-04
301	Propionitrile	C_3H_5N	107-12-0	55.079	–5.7136	703.62	–0.78123			250.00	7.372E-04	370.50	2.171E-04
302	Propyl acetate	$C_5H_{10}O_2$	109-60-4	102.132	17.797	–252.43	–4.291			250.00	1.002E-03	473.15	1.045E-04
303	Propyl amine	C_3H_9N	107-10-8	59.110	–9.8074	1010.4	–0.25697			188.36	3.060E-03	321.00	2.908E-04

TABLE 2-313 Viscosity of Inorganic and Organic Liquids (Pa·s) (*Concluded*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	C5	T_{min}, K	Viscosity at T_{min}	T_{max}, K	Viscosity at T_{max}
304	Propylbenzene	C_9H_{12}	103-65-1	120.192	–18.282	1549.7	1.0454			200.00	6.774E-03	432.39	2.357E-04
305	Propylene	C_3H_6	115-07-1	42.080	–92.082	1907.3	15.639	–0.043098	1	87.90	1.550E-02	333.15	5.150E-05
306	Propyl formate	$C_4H_8O_2$	110-74-7	88.105	–73.735	2668.2	10.993	–0.018364	1	180.25	5.852E-03	353.97	2.810E-04
307	2-Propyl mercaptan	C_3H_8S	75-33-2	76.161	–5.7244	638.2	–0.76415			142.61	6.477E-03	325.71	2.784E-04
308	Propyl mercaptan	C_3H_8S	107-03-9	76.161	–10.153	840.71	–0.093763			159.95	4.641E-03	340.87	2.656E-04
309	1,2-Propylene glycol	$C_3H_8O_2$	57-55-6	76.094	–804.54	30487	130.79	–0.15449	1	213.15	9.500E+02	500.80	3.310E-04
310	Quinone	$C_6H_4O_2$	106-51-4	108.095	–14.846	1829.4	0.3729			388.85	3.643E-04	454.00	1.965E-04
311	Silicon tetrafluoride	F_4Si	7783-61-1	104.079									
312	Styrene	C_8H_8	100-42-5	104.149	–22.675	1758	1.6701			242.54	1.919E-03	418.31	2.268E-04
313	Succinic acid	$C_4H_2O_4$	110-15-6	118.088	–13.422	3431.8				460.65	2.550E-03	644.80	3.040E-04
314	Sulfur dioxide	O_2S	7446-09-5	64.064	46.223	–1378	–8.7475			225.00	6.900E-04	400.00	6.557E-05
315	Sulfur hexafluoride	F_6S	2551-62-4	146.055	3.8305	41.21	–2.1342			223.15	5.388E-04	318.69	2.383E-04
316	Sulfur trioxide	O_3S	7446-11-9	80.063	–88.793	6400.7	10.709			289.95	2.477E-03	318.15	9.456E-04
317	Terephthalic acid	$C_8H_6O_4$	100-21-0	166.131									
318	*o*-Terphenyl	$C_{18}H_{14}$	84-15-1	230.304	–215.09	11612	31.849	–0.026882	1	329.35	1.736E-02	723.15	1.522E-04
319	Tetradecane	$C_{14}H_{30}$	629-59-4	198.388	–14.493	1710.8	0.4417	3.0895E+28	–12	277.65	3.350E-03	554.40	1.810E-04
320	Tetrahydrofuran	C_4H_8O	109-99-9	72.106	–10.321	900.92	–0.069128			164.65	5.505E-03	373.15	2.446E-04
321	1,2,3,4-Tetrahydronaphthalene	C10H12	119-64-2	132.202	–11.167	1193.2	0.096226	9.5986E+11	-5	237.40	1.300E-02	576.00	2.100E-04
322	Tetrahydrothiophene	C_4H_8S	110-01-0	88.171	–10.843	1165.2				293.15	1.040E-03	303.15	9.125E-04
323	2,2,3,3-Tetramethylbutane	C_8H_{18}	594-82-1	114.229	5.5351	632.38	–2.6576			373.96	1.999E-04	454.00	8.859E-05
324	Thiophene	C_4H_4S	110-02-1	84.140	–16.671	1342.5	0.8388			250.00	1.269E-03	393.15	2.625E-04
325	Toluene	C_7H_8	108-88-3	92.138	–226.08	6805.7	37.542	–0.060853	1	178.18	1.569E-02	383.78	2.428E-04
326	1,1,2-Trichloroethane	$C_2H_3Cl_3$	79-00-5	133.404	0.388	736.5	–1.7063			236.50	2.955E-03	387.00	3.798E-04
327	Tridecane	$C1_3H_{28}$	629-50-5	184.361	–4.1103	1005.3	–1.0188	1.0017E+19	–8	267.67	3.450E-03	540.00	1.740E-04
328	Triethyl amine	$C_6H_{15}N$	121-44-8	101.190	–3.7067	585.78	–1.0926			250.00	6.135E-04	359.05	2.028E-04
329	Trimethyl amine	C_3H_9N	75-50-3	59.110	10.142	–130.41	–3.2199			200.00	5.156E-04	308.15	1.612E-04
330	1,2,3-Trimethylbenzene	C_9H_{12}	526-73-8	120.192	–11.756	1483.1	–0.040387			247.79	2.495E-03	449.27	1.663E-04
331	1,2,4-Trimethylbenzene	C_9H_{12}	95-63-6	120.192	–9.6461	1281.2	–0.29478			229.33	3.477E-03	442.53	1.942E-04
332	2,2,4-Trimethylpentane	C_8H_{18}	540-84-1	114.229	–12.928	1137.5	0.25725	–3.6929E-28	10	165.78	8.636E-03	541.15	4.530E-05
333	2,3,3-Trimethylpentane	C_8H_{18}	560-21-4	114.229	–4.0309	990.76	–1.1771			172.22	1.305E-02	387.91	2.049E-04
334	1,3,5-Trinitrobenzene	$C_6H_3N_3O_6$	99-35-4	213.105	–10.707	1818.5				398.40	2.150E-03	676.80	3.290E-04
335	2,4,6-Trinitrotoluene	$C_7H_5N_3O_6$	118-96-7	227.131	–11.504	3301	–0.39102			353.15	1.167E-02	625.00	1.601E-04
336	Undecane	$C_{11}H_{24}$	1120-21-4	156.308	52.176	–4951.9	–8.5676	570,980	–2	247.57	3.240E-03	511.20	1.570E-04
337	1-Undecanol	$C_{11}H_{24}O$	112-42-5	172.308	–69.778	5905.2	8.0214			288.45	2.089E-02	590.15	1.856E-04
338	Vinyl acetate	$C_4H_6O_2$	108-05-4	86.089	–22.407	1462.8	1.7006			225.00	1.237E-03	345.65	2.654E-04
339	Vinyl acetylene	C_4H_4	689-97-4	52.075	–2.2333	320.37	–1.2915			173.15	8.764E-04	364.00	1.273E-04
340	Vinyl chloride	C_2H_3Cl	75-01-4	62.498	0.26297	276.55	–1.7282			130.00	2.425E-03	400.00	8.272E-05
341	Vinyl trichlorosilane	$C_2H_3Cl_3Si$	75-94-5	161.490	–10.37	823.31				178.35	3.170E-03	434.52	2.090E-04
342	Water	H_2O	7732-18-5	18.015	–52.843	3703.6	5.866	–5.879E-29	10	273.16	1.702E-03	646.15	5.028E-05
343	*m*-Xylene	C_8H_{10}	108-38-3	106.165	–11.91	1094.9	0.13825			225.30	1.834E-03	413.10	2.189E-04
344	*o*-Xylene	C_8H_{10}	95-47-6	106.165	–15.489	1393.5	0.63711			247.98	1.735E-03	418.10	2.459E-04
345	*p*-Xylene	C_8H_{10}	106-42-3	106.165	–7.381	911.7	–0.54152			286.41	7.021E-04	413.10	2.169E-04

The liquid viscosity is calculated by

$$\mu = \exp(C1 + C2/T + C3 \ln T + C4T^{c5})$$

where μ is the viscosity in Pa·s and T is the temperature in K. Viscosities are at either 1 atm or the vapor pressure, whichever is higher. All substances are listed by chemical family in Table 2-6 and by formula in Table 2-7.

Values in this table were taken from the Design Institute for Physical Properties (DIPPR) of the American Institute of Chemical Engineers (AIChE), copyright 2007 AIChE and reproduced with permission of AICHE and of the DIPPR Evaluated Process Design Data Project Steering Committee. Their source shold be cited as R. L. Rowley, W. V. Wilding, J. L. Oscarson, Y. Yang, N. A. Zundel, T. E. Daubert, R. P. Danner, DIPPR® Data Compilation of Pure Chemical Properties, Design Institute for Physical Properties, AIChE, New York (2007).

The number of digits provided for values at T_{min} and T_{max} was chosen for uniformity of appearance and formatting; these do not represent the uncertainties of the physical quantities, but are the result of calculations from the standard thermophysical property formulations within a fixed format.

TABLE 2-314 Vapor Thermal Conductivity of Inorganic and Organic Substances [W/(m·K)]

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	T_{min}, K	Thermal cond. at T_{min}	T_{max}, K	Thermal cond. at T_{max}
1	Acetaldehyde	C_2H_4O	75-07-0	44.05	3.7272E-07	1.8129			273.15	0.00973	994	0.10124
2	Acetamide	C_2H_5NO	60-35-5	59.07	0.00013195	0.97	728.3		494.30	0.02189	1000	0.06206
3	Acetic acid	$C_2H_4O_2$	64-19-7	60.05	0.000001691	1.6692	658	–95,400	294.70	0.01049	686.88	0.05236
4	Acetic anhydride	$C_4H_6O_3$	108-24-7	102.09	0.00042004	0.8066	439.37	142,620	412.70	0.01864	1000	0.06981
5	Acetone	C_3H_6O	67-64-1	58.08	–26.8	0.9098	–126500000		329.44	0.01363	1000	0.11362
6	Acetonitrile	C_2H_3N	75-05-8	41.05	4.901E-08	2.1091			354.75	0.01170	994.75	0.10298
7	Acetylene	C_2H_2	74-86-2	26.04	0.000075782	1.0327	–36.227	31,432	189.35	0.01011	1000	0.09545
8	Acrolein	C_3H_4O	107-02-8	56.06	0.024098	0.3285	1325.3	577,830	325.84	0.01534	1000	0.08028
9	Acrylic acid	$C_3H_4O_2$	79-10-7	72.06	0.0009265	0.7035	627.58	112,460	414.15	0.02027	1000	0.06867
10	Acrylonitrile	C_3H_3N	107-13-1	53.06	0.0013784	1.2093	50594		350.50	0.01133	990.5	0.11107
11	Air	Mixture	132259-10-0	28.96	0.00031417	0.7786	–0.7116	2,121.7	70.00	0.00603	2000	0.11675
12	Ammonia	H_3N	7664-41-7	17.03	9.6608E-06	1.3799			200.00	0.01446	900	0.11523
13	Anisole	C_7H_8O	100-66-3	108.14	0.00059858	0.7527	354.04	241,830	426.73	0.01809	1000	0.06796
14	Argon	Ar	7440-37-1	39.95	0.000633	0.6221	70		90.00	0.00585	3273.1	0.09525
15	Benzamide	C_7H_7NO	55-21-0	121.14	0.025389	0.28547	1018.3	1,228,600	563.15	0.02317	1000	0.05618
16	Benzene	C_6H_6	71-43-2	78.11	0.00001652	1.3117	491		339.15	0.01407	1000	0.09542
17	Benzenethiol	C_6H_6S	108-98-5	110.18	0.00047951	0.7818	463.4	189,410	442.29	0.01861	1000	0.06427
18	Benzoic acid	$C_7H_6O_2$	65-85-0	122.12	0.0001163	0.9705	740		522.40	0.02090	1000	0.05452
19	Benzonitrile	C_7H_5N	100-47-0	103.12	0.00015674	0.95503	711.32		464.15	0.02180	1000	0.06713
20	Benzophenone	$C_{13}H_{10}O$	119-61-9	182.22	0.0001235	0.9495	778.7		579.24	0.02213	1000	0.04899
21	Benzyl alcohol	C_7H_8O	100-51-6	108.14	0.00023476	0.8639	187.8	193,840	478.60	0.02167	1000	0.06636
22	Benzyl ethyl ether	$C_9H_{12}O$	539-30-0	136.19	0.00096451	0.69225	519.99	278,930	458.15	0.01936	1000	0.06398
23	Benzyl mercaptan	C_7H_8S	100-53-8	124.20	0.00015525	0.9446	715.78		472.03	0.02071	1000	0.06171
24	Biphenyl	$C_{12}H_{10}$	92-52-4	154.21	2.8646E-06	1.4098	–391.35	156,820	373.15	0.01123	1000	0.06347
25	Bromine	Br_2	7726-95-6	159.81	1.0404E-06	1.4685			300.00	0.00452	500	0.00956
26	Bromobenzene	C_6H_5Br	108-86-1	157.01	0.00027085	0.7932	278.33	165,880	429.24	0.01302	1000	0.04495
27	Bromoethane	C_2H_5Br	74-96-4	108.97	0.00019745	0.8824	647		311.50	0.01018	1000	0.05321
28	Bromomethane	CH_3Br	74-83-9	94.94	0.000038314	1.0484	287.38		273.00	0.00669	1000	0.04158
29	1,2-Butadiene	C_4H_6	590-19-2	54.09	0.000088221	1.0273	75.316	99,063	284.00	0.01172	1000	0.09071
30	1,3-Butadiene	C_4H_6	106-99-0	54.09	–20,890	0.9593	–9.382E+10		268.74	0.01281	1000	0.16809
31	Butane	C_4H_{10}	106-97-8	58.12	0.051094	0.45253	5455.5	1,979,800	272.65	0.01357	1000	0.13799
32	1,2-Butanediol	$C_4H_{10}O_2$	584-03-2	90.12	–295.44	–0.21463	91602	–7.6032E+08	469.57	0.02426	1000	0.10046
33	1,3-Butanediol	$C_4H_{10}O_2$	107-88-0	90.12	–918.39	–0.21199	334420	–2.8842E+09	481.38	0.02110	1000	0.08332
34	1-Butanol	$C_4H_{10}O$	71-36-3	74.12	0.0011484	0.87647	3253.7		370.70	0.02097	712.94	0.06536
35	2-Butanol	$C_4H_{10}O$	78-92-2	74.12	4.5894E-06	1.4484			372.90	0.02435	1000	0.10161
36	1-Butene	C_4H_8	106-98-9	56.11	0.000096809	1.1153	781.82		266.91	0.01252	1000	0.12049
37	*cis*-2-Butene	C_4H_8	590-18-1	56.11	0.000067737	1.0709	–65.881	129,390	273.15	0.01105	1273.15	0.13926
38	*trans*-2-Butene	C_4H_8	624-64-6	56.11	0.000078576	1.0565	14.63	105,920	274.03	0.01200	1257	0.13704
39	Butyl acetate	$C_6H_{12}O_2$	123-86-4	116.16	5.86E-09	2.376	–401.32	69,280	273.00	0.00783	800	0.07634
40	Butylbenzene	$C_{10}H_{14}$	104-51-8	134.22	0.1807	0.0082225	–129.42	1,691,500	456.46	0.02151	1000	0.07465
41	Butyl mercaptan	$C_4H_{10}S$	109-79-5	90.19	0.00097826	0.78643	1531.5	67,115	371.61	0.01832	1000	0.08610
42	*sec*-Butyl mercaptan	$C_4H_{10}S$	513-53-1	90.19	0.9719	–0.111	1167.2	3,163,200	358.13	0.01749	1000	0.08470
43	1-Butyne	C_4H_6	107-00-6	54.09	0.000037269	1.1427	–43.844	79,421	281.22	0.01268	1000	0.09644
44	Butyraldehyde	C_4H_8O	123-72-8	72.11	1138.6	0.95596	7.5086E+09		347.95	0.01419	1000	0.11186
45	Butyric acid	$C_4H_8O_2$	107-92-6	88.11	0.002751	0.2734	–314.55		436.40	0.05192	526.32	0.03792
46	Butyronitrile	C_4H_7N	109-74-0	69.11	5.2879E-07	1.6715	–381.9	95,650	273.00	0.00706	1000	0.07660
47	Carbon dioxide	CO_2	124-38-9	44.01	3.69	–0.3838	964	1,860,000	194.67	0.00887	1500	0.09025
48	Carbon disulfide	CS_2	75-15-0	76.14	0.0003467	0.7345	479		273.15	0.00776	1000	0.03745
49	Carbon monoxide	CO	630-08-0	28.01	0.00059882	0.6863	57.13	501.92	70.00	0.00576	1500	0.08724
50	Carbon tetrachloride	CCl_4	56-23-5	153.82	0.00016599	0.94375	1449.6		349.79	0.00812	1000	0.04595
51	Carbon tetrafluoride	CF_4	75-73-0	88.00	0.000092004	1.0164	270.83		145.10	0.00505	1000	0.08108
52	Chlorine	Cl_2	7782-50-5	70.91	0.0009993	0.5472	458.6		200.00	0.00551	1000	0.03002
53	Chlorobenzene	C_6H_5Cl	108-90-7	112.56	0.0004783	0.8994	1845.5	163,000	400.00	0.01579	1000	0.07935
54	Chloroethane	C_2H_5Cl	75-00-3	64.51	–19.283	0.20238	–715050	–271,300,000	273.15	0.00960	1000	0.07920
55	Chloroform	$CHCl_3$	67-66-3	119.38	0.00043073	0.83878	1874.5		334.33	0.00854	1000	0.04920
56	Chloromethane	CH_3Cl	74-87-3	50.49	–22136	0.7666	–4.8749E+10		213.15	0.00590	750	0.05448
57	1-Chloropropane	C_3H_7Cl	540-54-5	78.54	0.00004861	1.1407	593		319.67	0.01225	1000	0.08065
58	2-Chloropropane	C_3H_7Cl	75-29-6	78.54	0.00009154	1.0681	746.6		308.85	0.01222	1000	0.08389

TABLE 2-314 Vapor Thermal Conductivity of Inorganic and Organic Substances [W/(m·K)] (*Continued*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	T_{min}, K	Thermal cond. at T_{min}	T_{max}, K	Thermal cond. at T_{max}
59	*m*-Cresol	C_7H_8O	108-39-4	108.14	0.00019307	0.9248	710		475.43	0.02316	1000	0.06716
60	*o*-Cresol	C_7H_8O	95-48-7	108.14	0.00018648	0.9302	709.37		464.15	0.02230	1000	0.06736
61	*p*-Cresol	C_7H_8O	106-44-5	108.14	0.00019063	0.9282	716.91		475.13	0.02319	1000	0.06762
62	Cumene	C_9H_{12}	98-82-8	120.19	1.6743E-07	1.8369	−449.46	112,760	380.00	0.01534	1000	0.08181
63	Cyanogen	C_2N_2	460-19-5	52.03	0.000026933	1.137	28.119		252.00	0.01302	1000	0.06749
64	Cyclobutane	C_4H_8	287-23-0	56.11	−449,910	0.27364	−1.0001E+10	−9.8654E+12	285.66	0.01356	1000	0.14994
65	Cyclohexane	C_6H_{12}	110-82-7	84.16	0.000000859	1.7709	243		325.00	0.01380	1000	0.14198
66	Cyclohexanol	$C_6H_{12}O$	108-93-0	100.16	0.0032207	0.5991	608.69	509,290	434.00	0.02399	1000	0.09535
67	Cyclohexanone	$C_6H_{10}O$	108-94-1	98.14	−1,095.5	−0.023408	498,780	−7.8355E+09	428.58	0.02291	1000	0.12704
68	Cyclohexene	C_6H_{10}	110-83-8	82.14	0.0000901	1.0897	655		356.12	0.01914	1000	0.10116
69	Cyclopentane	C_5H_{10}	287-92-3	70.13	9.5461E-06	1.4641	632.62		273.00	0.01061	1000	0.14429
70	Cyclopentene	C_5H_8	142-29-0	68.12	0.0010949	0.71644	175.55	346,040	317.38	0.01360	1000	0.10148
71	Cyclopropane	C_3H_6	75-19-4	42.08	−91.383	0.89718	−283,310,000		240.37	0.01061	1000	0.15854
72	Cyclohexyl mercaptan	$C_6H_{12}S$	1569-69-3	116.22	0.0000813	1.0674	697.6		431.95	0.02022	1000	0.07629
73	Decanal	$C_{10}H_{20}O$	112-31-2	156.27	−4.9825	0.04928	−1107	−67,349,000	488.15	0.02381	1000	0.10382
74	Decane	$C_{10}H_{22}$	124-18-5	142.28	−668.4	0.9323	−4.071E+09		447.30	0.02173	1000	0.10286
75	Decanoic acid	$C_{10}H_{20}O_2$	334-48-5	172.27	0.00017047	0.9313	757.67		543.15	0.02508	1000	0.06034
76	1-Decanol	$C_{10}H_{22}O$	112-30-1	158.28	−0.3072	0.489	−67,500	−29,400,000	504.07	0.02591	1000	0.09389
77	1-Decene	$C_{10}H_{20}$	872-05-9	140.27	0.000027232	1.257	751.7		443.75	0.02149	1000	0.09175
78	Decyl mercaptan	$C_{10}H_{22}S$	143-10-2	174.35	0.00012058	1.0111	740		512.35	0.02709	1000	0.07482
79	1-Decyne	$C_{10}H_{18}$	764-93-2	138.25	0.000016707	1.2128	−206.08	153,850	447.15	0.02092	1000	0.07667
80	Deuterium	D_2	7782-39-0	4.03	0.00028527	0.9874	−200.51	21,807	233.15	0.11474	1500	0.44547
81	1,1-Dibromoethane	$C_2H_4Br_2$	557-91-5	187.86	0.00021231	0.8052	649.51		381.15	0.00940	1000	0.03351
82	1,2-Dibromoethane	$C_2H_4Br_2$	106-93-4	187.86	0.00015878	0.8636	659.5		404.51	0.01077	1000	0.03729
83	Dibromomethane	CH_2Br_2	74-95-3	173.83	0.00021302	0.8719	1,620		370.10	0.00687	1000	0.03356
84	Dibutyl ether	$C_8H_{18}O$	142-96-1	130.23	0.0032694	0.58633	1259.9	300,890	323.15	0.01244	1000	0.07330
85	*m*-Dichlorobenzene	$C_6H_4Cl_2$	541-73-1	147.00	−1,067.8	0.754	−3.0361E+09		446.23	0.01561	1000	0.06430
86	*o*-Dichlorobenzene	$C_6H_4Cl_2$	95-50-1	147.00	−1,420	0.7614	−4.5040E+09		453.57	0.01507	1000	0.06066
87	*p*-Dichlorobenzene	$C_6H_4Cl_2$	106-46-7	147.00	−1,520.8	0.754	−4.3328E+09		447.21	0.01564	1000	0.06417
88	1,1-Dichloroethane	$C_2H_4Cl_2$	75-34-3	98.96	0.0001315	1.0113	1,023.8		330.45	0.01132	1000	0.07025
89	1,2-Dichloroethane	$C_2H_4Cl_2$	107-06-2	98.96	0.00021054	0.9574	1,414		356.59	0.01177	1000	0.06498
90	Dichloromethane	CH_2Cl_2	75-09-2	84.93	0.0014796	0.69531	2,657.4		312.90	0.00847	1000	0.04931
91	1,1-Dichloropropane	$C_3H_6Cl_2$	78-99-9	112.99	0.000057603	1.1148	849.98		361.25	0.01220	1000	0.06881
92	1,2-Dichloropropane	$C_3H_6Cl_2$	78-87-5	112.99	0.000062435	1.103	913.43		369.52	0.01222	1000	0.06647
93	Diethanol amine	$C_4H_{11}NO_2$	111-42-2	105.14	−11,633	0.4621	−3.7939E+09		541.54	0.03044	1000	0.07463
94	Diethyl amine	$C_4H_{11}N$	109-89-7	73.14	0.00001706	1.248	−112.8	77,960	273.15	0.01148	1000	0.09804
95	Diethyl ether	$C_4H_{10}O$	60-29-7	74.12	−0.0044894	0.6155	−3266.3		200.00	0.00764	600	0.05181
96	Diethyl sulfide	$C_4H_{10}S$	352-93-2	90.19	0.0018097	0.67406	1179.7	174,850	365.25	0.01743	1000	0.08089
97	1,1-Difluoroethane	$C_2H_4F_2$	75-37-6	66.05	0.000059249	1.0713	101.84	45,974	248.95	0.01016	1000	0.08447
98	1,2-Difluoroethane	$C_2H_4F_2$	624-72-6	66.05	2.4194E-06	1.4456			303.65	0.00938	993.65	0.05206
99	Difluoromethane	CH_2F_2	75-10-5	52.02	0.000013015	1.1897			221.50	0.00803	1000	0.04826
100	Di-isopropyl amine	$C_6H_{15}N$	108-18-9	101.19	0.00051305	0.8076	360.19	154,510	357.05	0.01836	1000	0.08967
101	Di-isopropyl ether	$C_6H_{14}O$	108-20-3	102.17	0.00019879	0.9423	306.8	106,230	328.05	0.01598	1000	0.09444
102	Di-isopropyl ketone	$C_7H_{14}O$	565-80-0	114.19	−8.5357	−0.0056423	1882.1	−65,622,000	397.55	0.02015	1000	0.13085
103	1,1-Dimethoxyethane	$C_4H_{10}O_2$	534-15-6	90.12	0.00046265	0.81968	539.34	104,530	337.45	0.01554	1000	0.08099
104	1,2-Dimethoxypropane	$C_5H_{12}O_2$	7778-85-0	104.15	3.7962E-06	1.4462			366.15	0.01936	1000	0.08279
105	Dimethyl acetylene	C_4H_6	503-17-3	54.09	0.00021761	0.9187	217	132,070	300.13	0.01288	1000	0.09199
106	Dimethyl amine	C_2H_7N	124-40-3	45.08	1.6085	−0.1103	2160.3	2,989,300	280.03	0.01845	1000	0.12209
107	2,3-Dimethylbutane	C_6H_{14}	79-29-8	86.18	0.000034741	1.1646	−99.956	130,820	331.13	0.01581	1000	0.10506
108	1,1-Dimethylcyclohexane	C_8H_{16}	590-66-9	112.21	0.008856	0.4215	−50.645	764,580	392.70	0.01884	1000	0.09500
109	*cis*-1,2-Dimethylcyclohexane	C_8H_{16}	2207-01-4	112.21	0.013298	0.3692	0.1027	852,540	402.94	0.01948	1000	0.09196
110	*trans*-1,2-Dimethylcyclohexane	C_8H_{16}	6876-23-9	112.21	0.012144	0.3854	52.191	803,590	396.58	0.01952	1000	0.09376
111	Dimethyl disulfide	$C_2H_6S_2$	624-92-0	94.20	0.00022578	0.892	697		382.90	0.01613	1000	0.06310
112	Dimethyl ether	C_2H_6O	115-10-6	46.07	0.059975	0.2667	1,018.6	1,098,800	248.31	0.01139	1500	0.19458
113	*N,N*-Dimethyl formamide	C_3H_7NO	68-12-2	73.09	0.014449	0.3612	595.22	728,130	425.15	0.02001	1000	0.07539
114	2,3-Dimethylpentane	C_7H_{16}	565-59-3	100.20	0.000022421	1.2137	−146.91	131,830	362.93	0.01797	1000	0.09962
115	Dimethyl phthalate	$C_{10}H_{10}O_4$	131-11-3	194.18	0.00012822	0.9324	752.5		556.85	0.01981	1000	0.04587
116	Dimethylsilane	C_2H_8Si	1111-74-6	60.17	0.0011808	0.742	1131	6,400	253.55	0.01291	1000	0.09296

117	Dimethyl sulfide	C_2H_6S	75-18-3	62.13	0.00023614	0.9204	638		310.48	0.01520	1000	0.08319
118	Dimethyl sulfoxide	C_2H_6OS	67-68-5	78.13	0.00064761	0.7716	1013.3	82,563	462.15	0.02059	1000	0.06379
119	Dimethyl terephthalate	$C_{10}H_{10}O_4$	120-61-6	194.18	–25,190	0.3639	–6,869,000,000		561.15	0.02060	1000	0.04529
120	1,4-Dioxane	$C_4H_8O_2$	123-91-1	88.11	6.4032E-07	1.7194			337.85	0.01427	768.01	0.05855
121	Diphenyl ether	$C_{12}H_{10}O$	101-84-8	170.21	0.00014629	0.9377	745.89		531.46	0.02188	1000	0.05449
122	Dipropyl amine	$C_6H_{15}N$	142-84-7	101.19	0.0001123	0.9958	183.2	98,000	279.65	0.01055	1000	0.08515
123	Dodecane	$C_{12}H_{26}$	112-40-3	170.33	0.000005719	1.4699	579.4		489.47	0.02354	1000	0.09301
124	Eicosane	$C_{20}H_{42}$	112-95-8	282.55	–375.32	1.0708	–8,783,600,000		616.93	0.02563	1000	0.06968
125	Ethane	C_2H_6	74-84-0	30.07	0.000073869	1.1689	500.73		184.55	0.00886	1000	0.15807
126	Ethanol	C_2H_6O	64-17-5	46.07	–0.010109	0.6475	–7,332	–268,000	293.15	0.01475	1000	0.13417
127	Ethyl acetate	$C_4H_8O_2$	141-78-6	88.11	1.3575E-07	1.9681			273.15	0.00847	990.21	0.10682
128	Ethyl amine	C_2H_7N	75-04-7	45.08	0.3935	0.0131	1,380	1,710,000	289.73	0.01622	1000	0.10532
129	Ethylbenzene	C_8H_{10}	100-41-4	106.17	0.000017537	1.3144	560.65		409.35	0.02007	1000	0.09859
130	Ethyl benzoate	$C_9H_{10}O_2$	93-89-0	150.17	0.00002012	1.1513	–89.583	125,410	486.55	0.01855	1000	0.05524
131	2-Ethyl butanoic acid	$C_6H_{12}O_2$	88-09-5	116.16	0.00017727	0.9428	712.4		466.95	0.02306	1000	0.06973
132	Ethyl butyrate	$C_6H_{12}O_2$	105-54-4	116.16	829.29	1.0156	8,955,300,000		394.65	0.01583	1000	0.10314
133	Ethylcyclohexane	C_8H_{16}	1678-91-7	112.21	0.0000748	1.1103	686		404.95	0.02180	1000	0.09505
134	Ethylcyclopentane	C_7H_{14}	1640-89-7	98.19	0.0043244	0.5429	333.67	570,470	376.62	0.01832	1000	0.09659
135	Ethylene	C_2H_4	74-85-1	28.05	8.6806E-06	1.4559	299.72	–29,403	170.00	0.00879	590.92	0.06613
136	Ethylenediamine	$C_2H_8N_2$	107-15-3	60.10	0.1655	0.1798	3,827.9	1,600,000	390.41	0.02272	1000	0.08915
137	Ethylene glycol	$C_2H_6O_2$	107-21-1	62.07	–8,145,800	–0.30502	1,832,500,000	–1.1842E+13	470.45	0.02513	1000	0.09896
138	Ethyleneimine	C_2H_5N	151-56-4	43.07	0.00077079	0.7713	446.16	197,930	329.00	0.01610	1000	0.09659
139	Ethylene oxide	C_2H_4O	75-21-8	44.05	–0.0003788	1.115	–5,641		273.15	0.01004	1000	0.18063
140	Ethyl formate	$C_3H_6O_2$	109-94-4	74.08	508	0.9023	2,170,000,000		327.46	0.01426	1000	0.11921
141	2-Ethyl hexanoic acid	$C_8H_{16}O_2$	149-57-5	144.21	2.5804E-06	1.4669			500.66	0.02353	1000	0.06492
142	Ethylhexyl ether	$C_8H_{18}O$	5756-43-4	130.23	0.0052833	0.52982	1,415.7	378,180	417.15	0.01967	1000	0.07348
143	Ethylisopropyl ether	$C_5H_{12}O$	625-54-7	88.15	0.00021652	0.94192	632.16		326.15	0.01717	1000	0.08882
144	Ethylisopropyl ketone	$C_6H_{12}O$	565-69-5	100.16	–152,400	–0.049106	80,955,000	–9.3122E+11	386.55	0.01889	1000	0.12768
145	Ethyl mercaptan	C_2H_6S	75-08-1	62.13	0.0015251	0.70243	1,347.5	35,085	308.15	0.01487	1000	0.08195
146	Ethyl propionate	$C_5H_{10}O_2$	105-37-3	102.13	1.0507E-07	1.9854			400.00	0.01540	1000	0.09499
147	Ethylpropyl ether	$C_5H_{12}O$	628-32-0	88.15	5.8174E-08	2.0116	–372.68	57,690	273.15	0.01133	550	0.03690
148	Ethyltrichlorosilane	$C_2H_5Cl_3Si$	115-21-9	163.51	2.9354E-06	1.4153			373.15	0.01281	573.15	0.02352
149	Fluorine	F_2	7782-41-4	38.00	0.00012144	0.93831			70.00	0.00654	700	0.05675
150	Fluorobenzene	C_6H_5F	462-06-6	96.10	0.000053432	1.1576	760.75		357.88	0.01546	600	0.03874
151	Fluoroethane	C_2H_5F	353-36-6	48.06	0.0004104	0.8333	723		235.45	0.00955	1000	0.07531
152	Fluoromethane	CH_3F	593-53-3	34.03	0.003959	0.4834	997.4		194.82	0.00827	1000	0.05589
153	Formaldehyde	CH_2O	50-00-0	30.03	44.847	–0.7096	–3,493.5	5,353,200	254.05	0.01256	994.05	0.11532
154	Formamide	CH_3NO	75-12-7	45.04	0.00025893	0.9083	723.6		493.00	0.02930	1000	0.07973
155	Formic acid	CH_2O_2	64-18-6	46.03	0.0003754	0.8459	674.4		373.71	0.02008	1000	0.07733
156	Furan	C_4H_4O	110-00-9	68.07	–644,950	0.2862	–1.6794E+10	–1.7372E+13	304.50	0.01367	1000	0.13631
157	Helium-4	He	7440-59-7	4.00	0.00226	0.7305	–18.63	440	30.00	0.03124	2000	0.58820
158	Heptadecane	$C_{17}H_{36}$	629-78-7	240.47	–114.41	1.0566	–2,211,400,000		575.30	0.02454	1000	0.07649
159	Heptanal	$C_7H_{14}O$	111-71-7	114.19	1,556.7	1.0284	17,049,000,000		425.95	0.01967	1000	0.11110
160	Heptane	C_7H_{16}	142-82-5	100.20	–0.070028	0.38068	–7,049.9	–2,400,500	339.15	0.01583	1000	0.11493
161	Heptanoic acid	$C_7H_{14}O_2$	111-14-8	130.19	0.00019376	0.92434	739.56		496.15	0.02413	1000	0.06605
162	1-Heptanol	$C_7H_{16}O$	111-70-6	116.20	-0.061993	0.2792	–3,336	–1,642,000	449.45	0.02345	1000	0.10722
163	2-Heptanol	$C_7H_{16}O$	543-49-7	116.20	0.00017569	0.97218	686.56		432.90	0.02484	1000	0.08596
164	3-Heptanone	$C_7H_{14}O$	106-35-4	114.19	1,348.6	1.0313	14,832,000,000		420.55	0.01943	1000	0.11287
165	2-Heptanone	$C_7H_{14}O$	110-43-0	114.19	2,049.3	1.0323	22,983,000,000		424.18	0.01951	1000	0.11145
166	1-Heptene	C_7H_{14}	592-76-7	98.19	0.00002133	1.2885	487.8		366.79	0.01845	1000	0.10518
167	Heptyl mercaptan	$C_7H_{16}S$	1639-09-4	132.27	0.0083145	0.51862	2,253	532,590	450.09	0.02289	1000	0.07899
168	1-Heptyne	C_7H_{12}	628-71-7	96.17	0.000060732	1.0586	–102.79	143,140	372.93	0.01827	1000	0.08751
169	Hexadecane	$C_{16}H_{34}$	544-76-3	226.44	0.000004438	1.4949	682		560.01	0.02568	1000	0.08055
170	Hexanal	$C_6H_{12}O$	66-25-1	100.16	–7,157,100	–0.05819	4,089,000,000	–4.5826E+13	401.45	0.01842	1000	0.11472
171	Hexane	C_6H_{14}	110-54-3	86.18	–650.5	0.8053	–1,412,100,000		339.09	0.01704	1000	0.12003
172	Hexanoic acid	$C_6H_{12}O_2$	142-62-1	116.16	0.00021014	0.91616	727.64		478.85	0.02381	1000	0.06816
173	1-Hexanol	$C_6H_{14}O$	111-27-3	102.17	–4,935,500	–0.1653	1,563,100,000	–1.5752E+13	429.90	0.02220	1000	0.11104
174	2-Hexanol	$C_6H_{14}O$	626-93-7	102.18	0.00018361	0.97199	677.05		412.40	0.02421	1000	0.09022
175	2-Hexanone	$C_6H_{12}O$	591-78-6	100.16	–1.2158	0.026637	–1,711.6	–13,176,000	273.00	0.00775	1000	0.10523
176	3-Hexanone	$C_6H_{12}O$	589-38-8	100.16	–0.33262	0.12054	–2,472.6	–5,493,400	273.00	0.00800	1000	0.10980
177	1-Hexene	C_6H_{12}	592-41-6	84.16	0.000064256	1.1355	445.15	64,810	336.63	0.01644	1000	0.10850
178	3-Hexyne	C_6H_{10}	928-49-4	82.14	6.9682E-06	1.347	–214.35	110,480	354.35	0.01485	1000	0.08546
179	Hexyl mercaptan	$C_6H_{14}S$	111-31-9	118.24	0.074318	0.30035	4,470.1	1,775,800	425.81	0.02151	1000	0.08167

TABLE 2-314 Vapor Thermal Conductivity of Inorganic and Organic Substances [W/(m·K)] (*Continued*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	T_{min}, K	Thermal cond. at T_{min}	T_{max}, K	Thermal cond. at T_{max}
180	1-Hexyne	C_6H_{10}	693-02-7	82.14	0.000058116	1.0724	−77.165	123,900	344.48	0.01679	1000	0.09155
181	2-Hexyne	C_6H_{10}	764-35-2	82.14	0.000011631	1.2753	−202.84	122,990	357.67	0.01506	1000	0.08466
182	Hydrazine	H_4N_2	302-01-2	32.05	0.00043196	0.86603	641.48		386.65	0.02828	1000	0.10430
183	Hydrogen	H_2	1333-74-0	2.02	0.002653	0.7452	12		22.00	0.01718	1600	0.64299
184	Hydrogen bromide	HBr	10035-10-6	80.91	0.00049725	0.63088	331.62		206.45	0.00551	600	0.01812
185	Hydrogen chloride	HCl	7647-01-0	36.46	0.001865	0.49755	358		190.00	0.00880	700	0.03213
186	Hydrogen cyanide	CHN	74-90-8	27.03	4.6496E-06	1.3669	−210.76	58,295	273.15	0.00985	673.15	0.04185
187	Hydrogen fluoride	HF	7664-39-3	20.01	0.000034629	1.1224	18.744		350.00	0.02356	450	0.03160
188	Hydrogen sulfide	H_2S	7783-06-4	34.08	1.381E-07	1.8379	−352.09	46,041	212.80	0.00724	600	0.03258
189	Isobutyric acid	$C_4H_8O_2$	79-31-2	88.11	0.000214	0.9248	698		427.85	0.02206	1000	0.07497
190	Isopropyl amine	C_3H_9N	75-31-0	59.11	0.00028183	0.92094	619.17		304.92	0.01804	1000	0.10081
191	Malonic acid	$C_3H_4O_4$	141-82-2	104.06	0.00033075	0.81895	777.75		580.00	0.02590	1000	0.05327
192	Methacrylic acid	$C_4H_6O_2$	79-41-4	86.09	0.00019847	0.9284	678.69		434.15	0.02176	1000	0.07210
193	Methane	CH_4	74-82-8	16.04	8.3983E-06	1.4268	−49.654		111.63	0.01263	600	0.08425
194	Methanol	CH_4O	67-56-1	32.04	5.7992E-07	1.7862			273.00	0.01303	684.37	0.06726
195	*N*-Methyl acetamide	C_3H_7NO	79-16-3	73.09	0.034177	0.3312	2,070	1,195,600	478.15	0.02498	1000	0.07895
196	Methyl acetate	$C_3H_6O_2$	79-20-9	74.08	−25,343	−0.1934	11,164,000	−67,259,000,000	330.09	0.01415	1000	0.11878
197	Methyl acetylene	C_3H_4	74-99-7	40.06	0.00026544	0.8921	222.19	79,869	249.94	0.01154	1000	0.09675
198	Methyl acrylate	$C_4H_6O_2$	96-33-3	86.09	0.4734	−0.1111	533.57	1,649,600	353.35	0.01569	1000	0.06904
199	Methyl amine	CH_5N	74-89-5	31.06	−55.13	1.065	−448,200,000		266.82	0.01259	650	0.07917
200	Methyl benzoate	$C_8H_8O_2$	93-58-3	136.15	0.000023963	1.1308	−67.272	125,720	472.65	0.01784	1000	0.05588
201	3-Methyl-1,2-butadiene	C_5H_8	598-25-4	68.12	0.0002509	0.899	253.4	149,500	314.00	0.01326	1000	0.08902
202	2-Methylbutane	C_5H_{12}	78-78-4	72.15	0.0008968	0.7742	456	230,640	273.15	0.01198	1000	0.11176
203	2-Methylbutanoic acid	$C_5H_{10}O_2$	116-53-0	102.13	0.0001799	0.9457	704.6		450.15	0.02266	1000	0.07253
204	3-Methyl-1-butanol	$C_5H_{12}O$	123-51-3	88.15	2,053.4	0.90109	8,755,500,000		404.15	0.02116	1000	0.11843
205	2-Methyl-1-butene	C_5H_{10}	563-46-2	70.13	0.00019098	0.9341	84.07	155,720	304.30	0.01348	1000	0.09771
206	2-Methyl-2-butene	C_5H_{10}	513-35-9	70.13	0.00021736	0.9171	112.3	177,690	311.71	0.01320	1000	0.09504
207	2-Methyl-1-butene-3-yne	C_5H_6	78-80-8	66.10	0.00015498	0.9364	15.366	137,400	305.40	0.01304	1000	0.08664
208	Methylbutyl ether	$C_5H_{12}O$	628-28-4	88.15	0.000023993	1.1976	58.59	35,667	273.15	0.01173	1000	0.08586
209	Methylbutyl sulfide	$C_5H_{12}S$	628-29-5	104.21	0.079414	0.23442	2,671.9	1,366,100	396.58	0.01966	1000	0.07960
210	3-Methyl-1-butyne	C_5H_8	598-23-2	68.12	0.000065855	1.072	−36.369	106,430	302.15	0.01468	1000	0.10120
211	Methyl butyrate	$C_5H_{10}O_2$	623-42-7	102.13	1,333.1	0.9962	12,317,000,000		375.90	0.01495	1000	0.10543
212	Methylchlorosilane	CH_5ClSi	993-00-0	80.59	0.00037057	0.81367	609.17		281.85	0.01155	1000	0.06357
213	Methylcyclohexane	C_7H_{14}	108-87-2	98.19	0.0000719	1.1274	667		374.08	0.02056	1000	0.10399
214	1-Methylcyclohexanol	$C_7H_{14}O$	590-67-0	114.19	0.00011359	1.0311	709.27		441.15	0.02322	1000	0.08238
215	*cis*-2-Methylcyclohexanol	$C_7H_{14}O$	7443-70-1	114.19	0.069565	0.1633	208.7	1,209,500	438.15	0.02415	1000	0.08888
216	*trans*-2-Methylcyclohexanol	$C_7H_{14}O$	7443-52-9	114.19	0.075448	0.155	218.44	1,252,500	440.15	0.02435	1000	0.08908
217	Methylcyclopentane	C_6H_{12}	96-37-7	84.16	0.0024385	0.61774	223.01	477,570	344.96	0.01592	1000	0.10227
218	1-Methylcyclopentene	C_6H_{10}	693-89-0	82.14	0.0040082	0.54462	242.12	559,040	348.64	0.01544	1000	0.09578
219	3-Methylcyclopentene	C_6H_{10}	1120-62-3	82.14	0.0019845	0.6393	227.11	434,120	338.05	0.01501	1000	0.09888
220	Methyldichlorosilane	CH_4Cl_2Si	75-54-7	115.03	0.00041077	0.75688	591.5		314.70	0.01109	1000	0.04813
221	Methylethyl ether	C_3H_8O	540-67-0	60.10	0.00024036	0.93177	588.14		273.00	0.01419	1000	0.09447
222	Methylethyl ketone	C_4H_8O	78-93-3	72.11	−4,202,700	−0.1524	2,084,600,000	−1.4577E+13	352.79	0.01546	1000	0.11740
223	Methylethyl sulfide	C_3H_8S	624-89-5	76.16	0.0034805	0.61906	1,810.8	166,290	339.80	0.01653	1000	0.08415
224	Methyl formate	$C_2H_4O_2$	107-31-3	60.05	−800,040	−0.2285	248,100,000	−1.5034E+12	300.00	0.01369	1000	0.13148
225	Methylisobutyl ether	$C_5H_{12}O$	625-44-5	88.15	0.00020053	0.95381	644.42		331.70	0.01729	1000	0.08863
226	Methylisobutyl ketone	$C_6H_{12}O$	108-10-1	100.16	−2,483,300	−0.046517	1,313,100,000	−1.5798E+13	389.65	0.01869	1000	0.12433
227	Methyl Isocyanate	C_2H_3NO	624-83-9	57.05	0.0026136	0.62	1,631.7	126,720	312.00	0.01221	1000	0.06864
228	Methylisopropyl ether	$C_4H_{10}O$	598-53-8	74.12	2.1191	−0.19015	1,453.4	3,575,500	303.92	0.01606	1000	0.09451
229	Methylisopropyl ketone	$C_5H_{10}O$	563-80-4	86.13	−5,935,000	−0.089497	3,098,800,000	−2.7994E+13	367.55	0.01760	1000	0.12847
230	Methylisopropyl sulfide	$C_4H_{10}S$	1551-21-9	90.19	0.0071536	0.53907	2,700.7	241,730	171.64	0.00459	1000	0.07516
231	Methyl mercaptan	CH_4S	74-93-1	48.11	0.00002653	1.1631	29.996	32,519	273.15	0.01171	1000	0.07704
232	Methyl methacrylate	$C_5H_8O_2$	80-62-6	100.12	0.00072502	0.7395	365.68	204,360	373.45	0.01680	1000	0.07637
233	2-Methyloctanoic acid	$C_9H_{18}O_2$	3004-93-1	158.24	0.0001813	0.92912	793.45		518.15	0.02383	1000	0.06195
234	2-Methylpentane	C_6H_{14}	107-83-5	86.18	0.000061119	1.0861	−59.592	141,260	333.41	0.01606	1000	0.10242
235	Methyl pentyl ether	$C_6H_{14}O$	628-80-8	102.17	0.93312	−0.1172	1,154.3	2,961,700	372.00	0.01828	1000	0.08117
236	2-Methylpropane	C_4H_{10}	75-28-5	58.12	0.089772	0.18501	639.23	1,114,700	261.43	0.01273	1000	0.11701
237	2-Methyl-2-propanol	$C_4H_{10}O$	75-65-0	74.12	1.1776E-06	1.6618			333.82	0.01839	766.87	0.07325

238	2-Methyl propene	C_4H_8	115-11-7	56.11	−488.1	0.8877	−1,448,500,000		266.25	0.01276	1000	0.15513
239	Methyl propionate	$C_4H_8O_2$	554-12-1	88.11	−200.9	−0.1321	104,000	−846,000,000	350.00	0.01402	1000	0.10886
240	Methylpropyl ether	$C_4H_{10}O$	557-17-5	74.12	0.011136	0.4831	2,170.3	281,220	312.20	0.01648	1000	0.09079
241	Methylpropyl sulfide	$C_4H_{10}S$	3877-15-4	90.19	0.0023574	0.67434	1,804.1	155,660	368.69	0.01802	1000	0.08398
242	Methylsilane	CH_6Si	992-94-9	46.14	12.248	−0.5611	−1,067	2,715,200	216.25	0.01108	1000	0.09590
243	alpha-Methyl styrene	C_9H_{10}	98-83-9	118.18	0.21276	−0.022299	−194.68	1,708,700	438.65	0.01969	1000	0.07255
244	Methyl tert-butyl ether	$C_5H_{12}O$	1634-04-4	88.15	0.0002084	0.93034	364.832	73,041	273.00	0.01161	1000	0.08958
245	Methyl vinyl ether	C_3H_6O	107-25-5	58.08	0.00032359	0.8892	623.22		278.65	0.01493	1000	0.09273
246	Naphthalene	$C_{10}H_8$	91-20-3	128.17	0.000091828	1.0345	731.78		491.14	0.02243	1000	0.06730
247	Neon	Ne	7440-01-9	20.18	0.0011385	0.6646	8.7		30.00	0.00846	3273.1	0.24616
248	Nitroethane	$C_2H_5NO_2$	79-24-3	75.07	0.0011282	0.6895	679.11	238,800	387.22	0.01580	1000	0.06887
249	Nitrogen	N_2	7727-37-9	28.01	0.00033143	0.7722	16.323	373.72	63.15	0.00602	2000	0.11638
250	Nitrogen trifluoride	F_3N	7783-54-2	71.00	2.1443	−0.30545	1,860.3	1,216,700	144.09	0.00648	1000	0.06377
251	Nitromethane	CH_3NO_2	75-52-5	61.04	0.00003135	1.1119	−91.6	128,000	374.35	0.01365	1000	0.06553
252	Nitrous oxide	N_2O	10024-97-2	44.01	0.001096	0.667	540		182.30	0.00891	1000	0.07133
253	Nitric oxide	NO	10102-43-9	30.01	0.0004096	0.7509	45.6		121.38	0.01094	750	0.05567
254	Nonadecane	$C_{19}H_{40}$	629-92-5	268.52	0.000049571	1.2652	3,332.3		603.05	0.02502	1000	0.07147
255	Nonanal	$C_9H_{18}O$	124-19-6	142.24	−11.621	0.025653	2,248.3	−135,100,000	468.15	0.02228	1000	0.10522
256	Nonane	C_9H_{20}	111-84-2	128.26	−0.065771	0.27198	−3,482.3	−1,580,300	423.97	0.02130	1000	0.10597
257	Nonanoic acid	$C_9H_{18}O_2$	112-05-0	158.24	0.000178	0.9288	753		528.75	0.02484	1000	0.06209
258	1-Nonanol	$C_9H_{20}O$	143-08-8	144.25	−30.715	−0.1075	8,107	−156,830,000	485.20	0.02436	1000	0.09895
259	2-Nonanol	$C_9H_{20}O$	628-99-9	144.26	0.00016337	0.97256	709.74		471.70	0.02599	1000	0.07905
260	1-Nonene	C_9H_{18}	124-11-8	126.24	0.000021269	1.2943	662.21		420.02	0.02051	1000	0.09771
261	Nonyl mercaptan	$C_9H_{20}S$	1455-21-6	160.32	0.047041	0.29733	2,460.6	1,367,200	492.95	0.02559	1000	0.07598
262	1-Nonyne	C_9H_{16}	3452-09-3	124.22	0.000016681	1.218	−199.41	144,580	423.85	0.01981	1000	0.07956
263	Octadecane	$C_{18}H_{38}$	593-45-3	254.49	−291.08	1.0615	−6,019,900,000		589.86	0.02491	1000	0.07395
264	Octanal	$C_8H_{16}O$	124-13-0	128.21	−110.89	−0.000042988	51,384	−1.0701E+09	447.15	0.02117	1000	0.10893
265	Octane	C_8H_{18}	111-65-9	114.23	−8,758	0.8448	−2.7121E+10		339.00	0.01503	1000	0.11053
266	Octanoic acid	$C_8H_{16}O_2$	124-07-2	144.21	0.00018263	0.9283	741.3		513.05	0.02450	1000	0.06391
267	1-Octanol	$C_8H_{18}O$	111-87-5	130.23	−0.0030238	0.8745	−13,352		468.35	0.02380	1000	0.10288
268	2-Octanol	$C_8H_{18}O$	123-96-6	130.23	0.00016915	0.97238	698.55		452.90	0.02545	1000	0.08229
269	2-Octanone	$C_8H_{16}O$	111-13-7	128.21	−0.0020184	1.0027	−20,406		446.15	0.02046	1000	0.10597
270	3-Octanone	$C_8H_{16}O$	106-68-3	128.21	8.1833E-08	2.0418			440.65	0.02050	1000	0.10923
271	1-Octene	C_8H_{16}	111-66-0	112.21	0.0000133	1.3554	504.59		394.41	0.01926	1000	0.10295
272	Octyl mercaptan	$C_8H_{18}S$	111-88-6	146.29	−3,965.5	0.5213	−1,851,900,000		472.19	0.02505	1000	0.07845
273	1-Octyne	C_8H_{14}	629-05-0	110.20	0.000060734	1.0516	−124.91	158,300	399.35	0.01967	1000	0.08394
274	Oxalic acid	$C_2H_2O_4$	144-62-7	90.03	0.05881	0.278	14,815		569.00	0.01269	1000	0.02537
275	Oxygen	O_2	7782-44-7	32.00	0.00044994	0.7456	56.699		80.00	0.00691	2000	0.12655
276	Ozone	O_3	10028-15-6	48.00	0.0043147	0.47999	700.09		161.85	0.00931	1000	0.06990
277	Pentadecane	$C_{15}H_{32}$	629-62-9	212.41	4.7796E-06	1.4851	643.13		543.84	0.02529	1000	0.08299
278	Pentanal	$C_5H_{10}O$	110-62-3	86.13	−4,918,700	−0.10297	2,691,100,000	−2.3179E+13	376.15	0.01705	1000	0.11788
279	Pentane	C_5H_{12}	109-66-0	72.15	−684.4	0.764	−1,055,000,000		273.15	0.01288	1000	0.12707
280	Pentanoic acid	$C_5H_{10}O_2$	109-52-4	102.13	0.00024601	0.8946	696.42		458.65	0.02349	1000	0.07002
281	1-Pentanol	$C_5H_{12}O$	71-41-0	88.15	2,896	0.8985	12,735,000,000		410.90	0.02084	990.95	0.11087
282	2-Pentanol	$C_5H_{12}O$	6032-29-7	88.15	0.00019575	0.9692	664.04		392.20	0.02372	1000	0.09509
283	2-Pentanone	$C_5H_{10}O$	107-87-9	86.13	−0.01719	0.4832	−3,798	−1,235,000	273.00	0.00877	1000	0.12002
284	3-Pentanone	$C_5H_{10}O$	96-22-0	86.13	22.775	1.0019	191,000,000		273.00	0.00898	1000	0.12082
285	1-Pentene	C_5H_{10}	109-67-1	70.13	2.7081E-06	1.5493	41.075	8,301.3	303.22	0.01546	1000	0.11472
286	2-Pentyl mercaptan	$C_5H_{12}S$	2084-19-7	104.21	0.00022307	0.93358	794.16		385.15	0.01890	1000	0.07858
287	Pentyl mercaptan	$C_5H_{12}S$	110-66-7	104.21	0.00011261	1.034	693.05		399.79	0.02019	1000	0.08412
288	1-Pentyne	C_5H_8	627-19-0	68.12	0.000052415	1.0948	−51.09	101,160	313.33	0.01517	1000	0.09608
289	2-Pentyne	C_5H_8	627-21-4	68.12	0.00025623	1.0073	1,423.7		329.27	0.01653	1000	0.11119
290	Phenanthrene	$C_{14}H_{10}$	85-01-8	178.23	0.00010167	0.988	797		610.03	0.02490	1000	0.05208
291	Phenol	C_6H_6O	108-95-2	94.11	0.038846	0.2392	985.81	937,170	454.99	0.02183	1000	0.06936
292	Phenyl isocyanate	C_7H_5NO	103-71-9	119.12	0.00016675	0.91777	730.1		439.43	0.01669	1000	0.05461
293	Phthalic anhydride	$C_8H_4O_3$	85-44-9	148.12	0.0000593	1.046	765.5		557.65	0.01864	1000	0.04615
294	Propadiene	C_3H_4	463-49-0	40.06	0.000061629	1.0731	1.8579	70,128	238.65	0.00980	1000	0.09526
295	Propane	C_3H_8	74-98-6	44.10	−1.12	0.10972	−9,834.6	−7,535,800	231.11	0.01114	1000	0.14599
296	1-Propanol	C_3H_8O	71-23-8	60.10	−613.84	0.7927	−1,157,400,000		370.35	0.02135	720.25	0.07034
297	2-Propanol	C_3H_8O	67-63-0	60.10	7.3907E-07	1.7419			355.30	0.02049	1000	0.12428
298	Propenylcyclohexene	C_9H_{14}	13511-13-2	122.21	0.00010242	1.0486	701.56		431.65	0.02262	1000	0.08421
299	Propionaldehyde	C_3H_6O	123-38-6	58.08	1,165.1	0.90419	5,472,900,000		321.15	0.01263	1000	0.10983
300	Propionic acid	$C_3H_6O_2$	79-09-4	74.08	0.00022286	0.91704	678.21		414.32	0.02124	1000	0.07487

TABLE 2-314 Vapor Thermal Conductivity of Inorganic and Organic Substances [W/(m·K)] (*Concluded*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	T_{min}, K	Thermal cond. at T_{min}	T_{max}, K	Thermal cond. at T_{max}
301	Propionitrile	C_3H_5N	107-12-0	55.08	0.001321	1.2202	51,822		370.50	0.01278	990.5	0.11209
302	Propyl acetate	$C_5H_{10}O_2$	109-60-4	102.13	1,325.3	1	12,235,000,000		374.65	0.01520	1000	0.10832
303	Propyl amine	C_3H_9N	107-10-8	59.11	0.2833	0.055046	1,325.9	1,817,600	321.00	0.01709	1000	0.10000
304	Propylbenzene	C_9H_{12}	103-65-1	120.19	0.16992	0.021288	−54.484	1,624,800	432.39	0.02022	1000	0.07658
305	Propylene	C_3H_6	115-07-1	42.08	0.0000449	1.2018	421		225.45	0.01054	1000	0.12737
306	Propyl formate	$C_4H_8O_2$	110-74-7	88.11	740.1	0.9732	5,646,000,000		353.97	0.01403	1000	0.10893
307	2-Propyl mercaptan	C_3H_8S	75-33-2	76.16	0.00018367	0.9627	646.01		325.71	0.01616	1000	0.08624
308	Propyl mercaptan	C_3H_8S	107-03-9	76.16	0.0087425	0.51733	2,358.1	334,590	340.87	0.01654	1000	0.08439
309	1,2-Propylene glycol	$C_3H_8O_2$	57-55-6	76.09	0.0001666	0.9765	706		460.75	0.02624	1000	0.08302
310	Quinone	$C_6H_4O_2$	106-51-4	108.09	–5,678,600	–0.045252	2,615,700,000	−3.5415E+13	454.00	0.02593	1000	0.12665
311	Silicon tetrafluoride	F_4Si	7783-61-1	104.08	0.0000955	0.928	63.6		333.55	0.01761	702.45	0.03837
312	Styrene	C_8H_8	100-42-5	104.15	0.010048	0.4033	553.74	685,570	418.31	0.01837	1000	0.07276
313	Succinic acid	$C_4H_6O_4$	110-15-6	118.09	0.00032875	0.8172	740.97		591.00	0.02685	1000	0.05342
314	Sulfur dioxide	O_2S	7446-09-5	64.06	10.527	–0.7732	−1,333	1,506,400	250.00	0.00745	900	0.03969
315	Sulfur hexafluoride	F_6S	2551-62-4	146.06	0.00048883	0.6518	−117.08	78,863	273.15	0.01163	1000	0.04587
316	Sulfur trioxide	O_3S	7446-11-9	80.06	1.0702	–0.2348	2,010.4	1,277,000	317.90	0.01386	1000	0.04930
317	Terephthalic acid	$C_8H_6O_4$	100-21-0	166.13	0.00017531	0.8901	909.56		832.00	0.03328	1000	0.04297
318	*o*-Terphenyl	$C_{18}H_{14}$	84-15-1	230.30	0.000078652	0.95174	−282.82	289,490	373.15	0.00950	1000	0.05598
319	Tetradecane	$C_{14}H_{30}$	629-59-4	198.39	−163.62	0.9193	−1.0876E+09		526.73	0.02517	1000	0.08615
320	Tetrahydrofuran	C_4H_8O	109-99-9	72.11	9.5521E-06	1.4561	662.22		339.12	0.01564	1000	0.13419
321	1,2,3,4-Tetrahydronaphthalene	$C_{10}H_{12}$	119-64-2	132.20	0.00007754	1.0778	729		480.77	0.02395	1000	0.07676
322	Tetrahydrothiophene	C_4H_8S	110-01-0	88.17	0.00085604	0.7297	531.99	213,840	394.27	0.01801	1000	0.07579
323	2,2,3,3-Tetramethylbutane	C_8H_{18}	594-82-1	114.23	0.000015235	1.2816	−111.88	124,120	379.44	0.01964	1000	0.10528
324	Thiophene	C_4H_4S	110-02-1	84.14	0.00013384	0.98115	645.95		357.31	0.01525	1000	0.07139
325	Toluene	C_7H_8	108-88-3	92.14	0.00002392	1.2694	537		383.78	0.01901	1000	0.10007
326	1,1,2-Trichloroethane	$C_2H_3Cl_3$	79-00-5	133.40	0.0000952	1.0423	1,243.3		387.00	0.01125	1000	0.05684
327	Tridecane	$C_{13}H_{28}$	629-50-5	184.36	5.3701E-06	1.4751	599.09		508.62	0.02422	1000	0.08942
328	Triethyl amine	$C_6H_{15}N$	121-44-8	101.19	0.000106	1.0161	91	132,900	273.15	0.01018	1000	0.09680
329	Trimethyl amine	C_3H_9N	75-50-3	59.11	0.00027648	0.901	167.68	132,200	273.15	0.01280	1000	0.10734
330	1,2,3-Trimethylbenzene	C_9H_{12}	526-73-8	120.19	0.000098408	1.0452	720.49		449.27	0.02238	1000	0.07816
331	1,2,4-Trimethylbenzene	C_9H_{12}	95-63-6	120.19	0.00008498	1.061	708		442.53	0.02098	1000	0.07583
332	2,2,4-Trimethylpentane	C_8H_{18}	540-84-1	114.23	0.00001758	1.3114	392.9		355.15	0.01846	1000	0.10847
333	2,3,3-Trimethylpentane	C_8H_{18}	560-21-4	114.23	0.000020248	1.2284	−174.72	147,800	387.91	0.02001	1000	0.10079
334	1,3,5-Trinitrobenzene	$C_6H_3N_3O_6$	99-35-4	213.10	0.00020544	0.87137	807.3		629.60	0.02474	1000	0.04675
335	2,4,6-Trinitrotoluene	$C_7H_5N_3O_6$	118-96-7	227.13	0.00018189	0.88744	803.39		625.00	0.02410	1000	0.04635
336	Undecane	$C_{11}H_{24}$	1120-21-4	156.31	0.038012	0.68615	34,663	8,721,900	469.08	0.02259	1000	0.09798
337	1-Undecanol	$C_{11}H_{24}O$	112-42-5	172.31	2,498.8	0.95209	2.0167E+10		520.30	0.02486	1000	0.08899
338	Vinyl acetate	$C_4H_6O_2$	108-05-4	86.09	–3,279,500	–0.12941	1.7104E+09	−1.2727E+13	345.65	0.01515	1000	0.12177
339	Vinyl acetylene	C_4H_4	689-97-4	52.07	0.000054197	1.0632	−70.589	9,0617	278.25	0.01123	1000	0.08222
340	Vinyl chloride	C_2H_3Cl	75-01-4	62.50	−229.41	0.59582	−169,430,000		259.25	0.00963	1000	0.08300
341	Vinyl trichlorosilane	$C_2H_3Cl_3Si$	75-94-5	161.49	3510.8	0.225	401,720,000		363.85	0.01198	1000	0.04135
342	Water	H_2O	7732-18-5	18.02	6.2041E-06	1.3973			273.16	0.01574	1073.15	0.10652
343	*m*-Xylene	C_8H_{10}	108-38-3	106.17	3.0593E-09	2.4182	−569.28	121,060	320	0.00867	1000	0.09965
344	*o*-Xylene	C_8H_{10}	95-47-6	106.17	4.9707E-06	1.3787	−225.64	66,786	320	0.01492	1000	0.08084
345	*p*-Xylene	C_8H_{10}	106-42-3	106.17	9.9305E-08	1.9229	−469.93	113,460	320	0.01019	1000	0.09060

The vapor thermal conductivity is calculated by

$$k = \frac{\mathrm{C1}T^{C2}}{1 + \mathrm{C3}/T + \mathrm{C4}/T^2}$$

where k is the thermal conductivity in W/(m·K) and T is the temperature in K. Thermal conductivites are at either 1 atm or the vapor pressure, whichever is lower. All substances are listed by chemical family in Table 2-6 and by formula in Table 2-7.

Values in this table were taken from the Design Institute for Physical Properties (DIPPR) of the American Institute of Chemical Engineers (AIChE), copyright 2007 AIChE and reproduced with permission of AICHE and of the DIPPR Evaluated Process Design Data Project Steering Committee. Their source shold be cited as R. L. Rowley, W. V. Wilding, J. L. Oscarson, Y. Yang, N. A. Zundel, T. E. Daubert, R. P. Danner, DIPPR® Data Compilation of Pure Chemical Properties, Design Institute for Physical Properties, AIChE, New York (2007) .

The number of digits provided for values at T_{min} and T_{max} was chosen for uniformity of appearance and formatting; these do not represent the uncertainties of the physical quantities, but are the result of calculations from the standard thermophysical property formulations within a fixed format.

TABLE 2-315 Thermal Conductivity of Inorganic and Organic Liquids [W/(m·K)]

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	C5	T_{min}, K	Thermal cond. at T_{min}	T_{max}, K	Thermal cond. at T_{max}
1	Acetaldehyde	C_2H_4O	75-07-0	44.05	0.311	–0.000436				150.15	0.2455	294.00	0.1828
2	Acetamide	C_2H_5NO	60-35-5	59.07	0.39363	–0.00037053				353.33	0.2627	494.30	0.2105
3	Acetic acid	$C_2H_4O_2$	64-19-7	60.05	0.214	–0.0001834				289.81	0.1609	391.05	0.1423
4	Acetic anhydride	$C_4H_6O_3$	108-24-7	102.09	0.23638	–0.00024263				200.15	0.1878	412.70	0.1363
5	Acetone	C_3H_6O	67-64-1	58.08	0.2878	–0.000427				178.45	0.2116	343.15	0.1413
6	Acetonitrile	C_2H_3N	75-05-8	41.05	0.33192	–0.00043243				229.32	0.2328	349.32	0.1809
7	Acetylene	C_2H_2	74-86-2	26.04	0.33363	–0.00083655				192.40	0.1727	250.00	0.1245
8	Acrolein	C_3H_4O	107-02-8	56.06	0.2703	–0.0003764				185.45	0.2005	325.84	0.1477
9	Acrylic acid	$C_3H_4O_2$	79-10-7	72.06	0.2441	–0.0002904				286.15	0.1610	484.50	0.1034
10	Acrylonitrile	C_3H_3N	107-13-1	53.06	0.28941	–0.00041691				189.63	0.2104	350.50	0.1433
11	Air	Mixture	132259-10-0	28.96	0.28472	–0.0017393				75.00	0.1543	125.00	0.0673
12	Ammonia	H_3N	7664-41-7	17.03	1.169	–0.002314				195.41	0.7168	400.05	0.2433
13	Anisole	C_7H_8O	100-66-3	108.14	0.23494	–0.00026477				235.65	0.1726	512.50	0.0992
14	Argon	Ar	7440-37-1	39.95	0.1819	–0.0003176	–0.00000411			83.78	0.1264	150.00	0.0418
15	Benzamide	C_7H_7NO	55-21-0	121.14	0.28485	–0.00025225				403.00	0.1832	563.15	0.1428
16	Benzene	C_6H_6	71-43-2	78.11	0.23444	–0.00030572				278.68	0.1492	413.10	0.1082
17	Benzenethiol	C_6H_6S	108-98-5	110.18	0.20996	–0.0002146				258.27	0.1545	442.29	0.1150
18	Benzoic acid	$C_7H_6O_2$	65-85-0	122.12	0.2391	–0.0002325				395.45	0.1472	596.00	0.1005
19	Benzonitrile	C_7H_5N	100-47-0	103.12	0.21284	–0.00021587				260.40	0.1566	464.15	0.1126
20	Benzophenone	$C_{13}H_{10}O$	119-61-9	182.22	0.25867	–0.00022516				321.35	0.1863	664.00	0.1092
21	Benzyl alcohol	C_7H_8O	100-51-6	108.14	0.17847	–0.000065843				257.85	0.1615	478.60	0.1470
22	Benzyl ethyl ether	$C_9H_{12}O$	539-30-0	136.19	0.2029	–0.0002226				275.65	0.1415	528.60	0.0852
23	Benzyl mercaptan	C_7H_8S	100-53-8	124.20	0.20316	–0.00019912				243.95	0.1546	472.03	0.1092
24	Biphenyl	$C_{12}H_{10}$	92-52-4	154.21	0.19053	–0.00015145				342.20	0.1387	723.15	0.0810
25	Bromine	Br_2	7726-95-6	159.81	–0.2185	0.0042143	–0.000017753	3.1041E-08	–2.0108E-11	266.00	0.1299	584.00	0.0316
26	Bromobenzene	C_6H_5Br	108-86-1	157.01	0.16983	–0.0001981				242.43	0.1218	429.24	0.0848
27	Bromoethane	C_2H_5Br	74-96-4	108.97	0.1799	–0.000262				154.55	0.1394	414.14	0.0714
28	Bromomethane	CH_3Br	74-83-9	94.94	0.1912	–0.000299				179.47	0.1375	370.10	0.0805
29	1,2-Butadiene	C_4H_6	590-19-2	54.09	0.21966	–0.0003436				136.95	0.1726	284.00	0.1221
30	1,3-Butadiene	C_4H_6	106-99-0	54.09	0.22231	–0.0003664				164.25	0.1621	268.74	0.1238
31	Butane	C_4H_{10}	106-97-8	58.12	0.27349	–0.00071267	5.1555E-07			134.86	0.1868	400.00	0.0709
32	1,2-Butanediol	$C_4H_{10}O_2$	584-03-2	90.12	0.064621	0.00067625	–1.0491E-06			220.00	0.1626	469.57	0.1509
33	1,3-Butanediol	$C_4H_{10}O_2$	107-88-0	90.12	–0.0032865	0.0011463	–1.5525E-06			196.15	0.1618	481.38	0.1888
34	1-Butanol	$C_4H_{10}O$	71-36-3	74.12	0.2136	–0.0002034				183.85	0.1762	391.90	0.1339
35	2-Butanol	$C_4H_{10}O$	78-92-2	74.12	0.22787	–0.00030727				158.45	0.1792	372.90	0.1133
36	1-Butene	C_4H_8	106-98-9	56.11	0.22153	–0.00035023				87.80	0.1908	266.91	0.1281
37	*cis*-2-Butene	C_4H_8	590-18-1	56.11	0.21378	–0.00035445				134.26	0.1662	276.87	0.1156
38	*trans*-2-Butene	C_4H_8	624-64-6	56.11	0.21153	–0.00035056				167.62	0.1528	274.03	0.1155
39	Butyl acetate	$C_6H_{12}O_2$	123-86-4	116.16	0.21721	–0.00026563				199.65	0.1642	453.75	0.0967
40	Butylbenzene	$C_{10}H_{14}$	104-51-8	134.22	0.18707	–0.00020037				185.30	0.1499	473.15	0.0923
41	Butyl mercaptan	$C_4H_{10}S$	109-79-5	90.19	0.21143	–0.000258				157.46	0.1708	371.61	0.1156
42	*sec*-Butyl mercaptan	$C_4H_{10}S$	513-53-1	90.19	0.2069	–0.0002568				133.02	0.1727	358.13	0.1149
43	1-Butyne	C_4H_6	107-00-6	54.09	0.22334	–0.0003515				147.43	0.1715	281.22	0.1245
44	Butyraldehyde	C_4H_8O	123-72-8	72.11	0.21915	–0.00024846				176.75	0.1752	382.15	0.1242
45	Butyric acid	$C_4H_8O_2$	107-92-6	88.11	0.1967	–0.000168				267.95	0.1517	573.15	0.1004
46	Butyronitrile	C_4H_7N	109-74-0	69.11	0.2597	–0.00031				161.25	0.2097	390.75	0.1386
47	Carbon dioxide	CO_2	124-38-9	44.01	0.4406	–0.0012175				216.58	0.1769	300.00	0.0754
48	Carbon disulfide	CS_2	75-15-0	76.14	0.2333	–0.000275				161.11	0.1890	319.37	0.1455
49	Carbon monoxide	CO	630-08-0	28.01	0.2855	–0.001784				68.15	0.1639	125.00	0.0625
50	Carbon tetrachloride	CCl_4	56-23-5	153.82	0.1589	–0.0001987				250.33	0.1092	349.79	0.0894
51	Carbon tetrafluoride	CF_4	75-73-0	88.00	0.20771	–0.00078883				89.56	0.1371	145.10	0.0933
52	Chlorine	Cl_2	7782-50-5	70.91	0.2246	–0.000064	–0.000000788			172.12	0.1902	410.00	0.0659
53	Chlorobenzene	C_6H_5Cl	108-90-7	112.56	0.1841	–0.0001917				227.95	0.1404	404.87	0.1065
54	Chloroethane	C_2H_5Cl	75-00-3	64.51	0.2438	–0.000419				134.80	0.1873	373.15	0.0875
55	Chloroform	$CHCl_3$	67-66-3	119.38	0.1778	–0.0002023				209.63	0.1354	400.00	0.0969
56	Chloromethane	CH_3Cl	74-87-3	50.49	0.41067	–0.0008478				175.43	0.2619	350.00	0.1139
57	1-Chloropropane	C_3H_7Cl	540-54-5	78.54	0.20143	–0.00028925				150.35	0.1579	400.95	0.0855
58	2-Chloropropane	C_3H_7Cl	75-29-6	78.54	0.21232	–0.0003149				155.97	0.1632	386.70	0.0905

TABLE 2-315 Thermal Conductivity of Inorganic and Organic Liquids [W/(m·K)] (*Continued*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	C5	T_{min}, K	Thermal cond. at T_{min}	T_{max}, K	Thermal cond. at T_{max}
59	*m*-Cresol	C_7H_8O	108-39-4	108.14	0.18241	–0.00011109				285.39	0.1507	475.43	0.1296
60	*o*-Cresol	C_7H_8O	95-48-7	108.14	0.19186	–0.0001303				304.19	0.1522	464.15	0.1314
61	*p*-Cresol	C_7H_8O	106-44-5	108.14	0.17971	–0.00012037				307.93	0.1426	475.13	0.1225
62	Cumene	C_9H_{12}	98-82-8	120.19	0.1855	–0.00020895				177.14	0.1485	413.15	0.0992
63	Cyanogen	C_2N_2	460-19-5	52.03	0.4685	–0.00086594				245.25	0.2561	252.00	0.2503
64	Cyclobutane	C_4H_8	287-23-0	56.11	0.22262	–0.00034082				182.48	0.1604	285.66	0.1253
65	Cyclohexane	C_6H_{12}	110-82-7	84.16	0.19813	–0.0002505				279.69	0.1281	353.87	0.1095
66	Cyclohexanol	$C_6H_{12}O$	108-93-0	100.16	0.1715	–0.0001255				296.60	0.1343	563.15	0.1008
67	Cyclohexanone	$C_6H_{10}O$	108-94-1	98.14	0.17557	–0.00012392				242.00	0.1456	428.58	0.1225
68	Cyclohexene	C_6H_{10}	110-83-8	82.14	0.20926	–0.00026037				169.67	0.1651	356.12	0.1165
69	Cyclopentane	C_5H_{10}	287-92-3	70.13	0.2066	–0.0002696				179.28	0.1583	322.40	0.1197
70	Cyclopentene	C_5H_8	142-29-0	68.12	0.21776	–0.00027783				138.13	0.1794	333.15	0.1252
71	Cyclopropane	C_3H_6	75-19-4	42.08	0.24348	–0.00042568				145.59	0.1815	240.37	0.1412
72	Cyclohexyl mercaptan	$C_6H_{12}S$	1569-69-3	116.22	0.18374	–0.0001925				189.64	0.1472	431.95	0.1006
73	Decanal	$C_{10}H_{20}O$	112-31-2	156.27	0.20383	–0.0002				267.15	0.1504	488.15	0.1062
74	Decane	$C_{10}H_{22}$	124-18-5	142.28	0.2063	–0.00025				243.51	0.1454	447.30	0.0945
75	Decanoic acid	$C_{10}H_{20}O_2$	334-48-5	172.27	0.206	–0.0002				304.75	0.1451	543.15	0.0974
76	1-Decanol	$C_{10}H_{22}O$	112-30-1	158.28	0.228	–0.000223				280.05	0.1656	503.00	0.1158
77	1-Decene	$C_{10}H_{20}$	872-05-9	140.27	0.20237	–0.00024187				206.89	0.1523	443.75	0.0950
78	Decyl mercaptan	$C_{10}H_{22}S$	143-10-2	174.35	0.20134	–0.00020826				247.56	0.1498	512.35	0.0946
79	1-Decyne	$C_{10}H_{18}$	764-93-2	138.25	0.20839	–0.00023622				229.15	0.1543	447.15	0.1028
80	Deuterium	D_2	7782-39-0	4.03	1.264					20.40	1.2640	20.40	1.2640
81	1,1-Dibromoethane	$C_2H_4Br_2$	557-91-5	187.86	0.1426	–0.00016402				210.15	0.1081	498.40	0.0609
82	1,2-Dibromoethane	$C_2H_4Br_2$	106-93-4	187.86	0.13622	–0.0001179				282.85	0.1029	404.51	0.0885
83	Dibromomethane	CH_2Br_2	74-95-3	173.83	0.17558	–0.00022499				220.60	0.1260	370.10	0.0923
84	Dibutyl ether	$C_8H_{18}O$	142-96-1	130.23	0.19418	–0.00022246				175.30	0.1552	523.15	0.0778
85	*m*-Dichlorobenzene	$C_6H_4Cl_2$	541-73-1	147.00	0.16694	–0.0001667				248.39	0.1255	446.23	0.0926
86	*o*-Dichlorobenzene	$C_6H_4Cl_2$	95-50-1	147.00	0.16994	–0.0001637				262.87	0.1269	351.71	0.1124
87	*p*-Dichlorobenzene	$C_6H_4Cl_2$	106-46-7	147.00	0.16977	–0.0001799				326.14	0.1111	548.00	0.0712
88	1,1-Dichloroethane	$C_2H_4Cl_2$	75-34-3	98.96	0.18881	–0.00026083				176.19	0.1429	416.90	0.0801
89	1,2-Dichloroethane	$C_2H_4Cl_2$	107-06-2	98.96	0.214	–0.000266				253.15	0.1467	356.59	0.1192
90	Dichloromethane	CH_2Cl_2	75-09-2	84.93	0.23847	–0.00033366				178.01	0.1791	325.00	0.1300
91	1,1-Dichloropropane	$C_3H_6Cl_2$	78-99-9	112.99	0.18	–0.00023144				200.00	0.1337	438.00	0.0786
92	1,2-Dichloropropane	$C_3H_6Cl_2$	78-87-5	112.99	0.19653	–0.00025012				172.71	0.1533	457.60	0.0821
93	Diethanol amine	$C_4H_{11}NO_2$	111-42-2	105.14	0.0218	0.0010315	–0.000001355			301.15	0.2096	673.15	0.1022
94	Diethyl amine	$C_4H_{11}N$	109-89-7	73.14	0.2587	–0.00054343	4.2097E-07			223.35	0.1583	453.15	0.0989
95	Diethyl ether	$C_4H_{10}O$	60-29-7	74.12	0.2495	–0.000407				156.85	0.1857	433.15	0.0732
96	Diethyl sulfide	$C_4H_{10}S$	352-93-2	90.19	0.21065	–0.0002623				169.20	0.1663	365.25	0.1148
97	1,1-Difluoroethane	$C_2H_4F_2$	75-37-6	66.05	0.27019	–0.000661	3.443E-07			154.56	0.1763	363.15	0.0756
98	1,2-Difluoroethane	$C_2H_4F_2$	624-72-6	66.05	0.23171	–0.00038503				215.00	0.1489	372.80	0.0882
99	Difluoromethane	CH_2F_2	75-10-5	52.02	0.37296	–0.00088707	2.5762E-07			136.95	0.2563	302.56	0.1282
100	Di-isopropyl amine	$C_6H_{15}N$	108-18-9	101.19	0.1844	–0.000239				176.85	0.1421	357.05	0.0991
101	Di-isopropyl ether	$C_6H_{14}O$	108-20-3	102.17	0.19162	–0.0002762				187.65	0.1398	400.10	0.0811
102	Di-isopropyl ketone	$C_7H_{14}O$	565-80-0	114.19	0.22076	–0.00027624				204.81	0.1642	460.00	0.0937
103	1,1-Dimethoxyethane	$C_4H_{10}O_2$	534-15-6	90.12	0.22078	–0.00031271				159.95	0.1708	337.45	0.1153
104	1,2-Dimethoxypropane	$C_5H_{12}O_2$	7778-85-0	104.15	0.22998	–0.00030372				226.10	0.1613	366.15	0.1188
105	Dimethyl acetylene	C_4H_6	503-17-3	54.09	0.22773	–0.00034804				240.91	0.1439	300.13	0.1233
106	Dimethyl amine	C_2H_7N	124-40-3	45.08	0.2454	–0.000338				180.96	0.1842	403.15	0.1091
107	2,3-Dimethylbutane	C_6H_{14}	79-29-8	86.18	0.1774	–0.0002436				145.19	0.1420	331.15	0.0967
108	1,1-Dimethylcyclohexane	C_8H_{16}	590-66-9	112.21	0.1807	–0.0002177				239.66	0.1285	392.70	0.0952
109	*cis*-1,2-Dimethylcyclohexane	C_8H_{16}	2207-01-4	112.21	0.18092	–0.0002108				223.16	0.1339	402.94	0.0960
110	*trans*-1,2-Dimethylcyclohexane	C_8H_{16}	6876-23-9	112.21	0.17675	–0.0002077				184.99	0.1383	596.15	0.0529
111	Dimethyl disulfide	$C_2H_6S_2$	624-92-0	94.20	0.21373	–0.0002447				188.44	0.1676	382.90	0.1200
112	Dimethyl ether	C_2H_6O	115-10-6	46.07	0.31174	–0.0005638				131.65	0.2375	320.03	0.1313
113	*N*,*N*-Dimethyl formamide	C_3H_7NO	68-12-2	73.09	0.26	–0.000255				250.00	0.1963	425.15	0.1516
114	2,3-Dimethylpentane	C_7H_{16}	565-59-3	100.20	0.17964	–0.000246				160.00	0.1403	362.93	0.0904
115	Dimethyl phthalate	$C_{10}H_{10}O_4$	131-11-3	194.18	0.13905	0.0001509	–3.978E-07			273.15	0.1506	556.85	0.0997

116	Dimethylsilane	C_2H_8Si	1111-74-6	60.17	0.25547	–0.0004411			122.93	0.2013	253.55	0.1436
117	Dimethyl sulfide	C_2H_6S	75-18-3	62.13	0.23942	–0.0003311			174.88	0.1815	310.48	0.1366
118	Dimethyl sulfoxide	C_2H_6OS	67-68-5	78.13	0.3142	–0.00030809			291.67	0.2243	464.00	0.1713
119	Dimethyl terephthalate	$C_{10}H_{10}O_4$	120-61-6	194.18	0.21593	–0.00020805			413.80	0.1298	561.15	0.0992
120	1,4-Dioxane	$C_4H_8O_2$	123-91-1	88.11	0.3027	–0.0004827			284.95	0.1652	374.47	0.1219
121	Diphenyl ether	$C_{12}H_{10}O$	101-84-8	170.21	0.18686	–0.00014953			300.03	0.1420	531.46	0.1074
122	Dipropyl amine	$C_6H_{15}N$	142-84-7	101.19	0.2224	–0.000314			210.15	0.1564	382.00	0.1025
123	Dodecane	$C_{12}H_{26}$	112-40-3	170.33	0.2047	–0.0002326			263.57	0.1434	489.47	0.0908
124	Eicosane	$C_{20}H_{42}$	112-95-8	282.55	0.2178	–0.0002233			309.58	0.1487	616.93	0.0800
125	Ethane	C_2H_6	74-84-0	30.07	0.35758	–0.0011458	6.1866E-07		90.35	0.2591	300.00	0.0695
126	Ethanol	C_2H_6O	64-17-5	46.07	0.2468	–0.000264			159.05	0.2048	353.15	0.1536
127	Ethyl acetate	$C_4H_8O_2$	141-78-6	88.11	0.2501	–0.0003563			189.60	0.1826	350.21	0.1253
128	Ethyl amine	C_2H_7N	75-04-7	45.08	0.30059	–0.000581	6.602E-07		192.15	0.2133	293.15	0.1870
129	Ethylbenzene	C_8H_{10}	100-41-4	106.17	0.1999	–0.00023823			178.20	0.1575	413.10	0.1015
130	Ethyl benzoate	$C_9H_{10}O_2$	93-89-0	150.17	0.20771	–0.00021265			238.45	0.1570	549.40	0.0909
131	2-Ethyl butanoic acid	$C_6H_{12}O_2$	88-09-5	116.16	0.2175	–0.0002407			258.15	0.1554	516.50	0.0932
132	Ethyl butyrate	$C_6H_{12}O_2$	105-54-4	116.16	0.21043	–0.00024903			175.15	0.1668	453.15	0.0976
133	Ethylcyclohexane	C_8H_{16}	1678-91-7	112.21	0.17662	–0.0002014			161.84	0.1440	404.94	0.0951
134	Ethylcyclopentane	C_7H_{14}	1640-89-7	98.19	0.18334	–0.0002228			134.71	0.1533	376.62	0.0994
135	Ethylene	C_2H_4	74-85-1	28.05	0.4194	–0.001591	0.000001306		104.00	0.2681	280.00	0.0763
136	Ethylenediamine	$C_2H_8N_2$	107-15-3	60.10	0.36434	–0.0004433			284.29	0.2383	390.41	0.1913
137	Ethylene glycol	$C_2H_6O_2$	107-21-1	62.07	0.088067	0.00094712	–1.3114E-06		260.15	0.2457	470.45	0.2434
138	Ethyleneimine	C_2H_5N	151-56-4	43.07	0.3097	–0.0004023			195.20	0.2312	329.00	0.1773
139	Ethylene oxide	C_2H_4O	75-21-8	44.05	0.26957	–0.0003984			160.65	0.2056	283.85	0.1565
140	Ethyl formate	$C_3H_6O_2$	109-94-4	74.08	0.2587	–0.00033			193.55	0.1948	433.15	0.1158
141	2-Ethyl hexanoic acid	$C_8H_{16}O_2$	149-57-5	144.21	0.20954	–0.00022251			235.00	0.1573	500.66	0.0981
142	Ethylhexyl ether	$C_8H_{18}O$	5756-43-4	130.23	0.19356	–0.00024102			180.00	0.1502	466.40	0.0811
143	Ethylisopropyl ether	$C_5H_{12}O$	625-54-7	88.15	0.21928	–0.00032568			140.00	0.1737	391.20	0.0919
144	Ethylisopropyl ketone	$C_6H_{12}O$	565-69-5	100.16	0.22873	–0.0002913			204.15	0.1693	450.10	0.0976
145	Ethyl mercaptan	C_2H_6S	75-08-1	62.13	0.23392	–0.0003206			125.26	0.1938	308.15	0.1351
146	Ethyl propionate	$C_5H_{10}O_2$	105-37-3	102.13	0.2137	–0.0002515			199.25	0.1636	495.00	0.0892
147	Ethylpropyl ether	$C_5H_{12}O$	628-32-0	88.15	0.22717	–0.0003298			145.65	0.1791	400.07	0.0952
148	Ethyltrichlorosilane	$C_2H_5Cl_3Si$	115-21-9	163.51	0.19769	–0.00017713	–1.5448E-07		167.55	0.1637	371.05	0.1107
149	Fluorine	F_2	7782-41-4	38.00	0.2758	–0.0016297			53.48	0.1886	130.00	0.0639
150	Fluorobenzene	C_6H_5F	462-06-6	96.10	0.20962	–0.00028034			238.15	0.1429	353.15	0.1106
151	Fluoroethane	C_2H_5F	353-36-6	48.06	0.2595	–0.0005008			129.95	0.1944	292.59	0.1130
152	Fluoromethane	CH_3F	593-53-3	34.03	0.445	–0.001023			131.35	0.3106	283.15	0.1553
153	Formaldehyde	CH_2O	50-00-0	30.03	0.37329	–0.00065			204.00	0.2407	234.00	0.2212
154	Formamide	CH_3NO	75-12-7	45.04	0.3847	–0.0001065			275.70	0.3553	493.00	0.3322
155	Formic acid	CH_2O_2	64-18-6	46.03	0.302	–0.000108			281.45	0.2716	373.71	0.2616
156	Furan	C_4H_4O	110-00-9	68.07	0.2198	–0.00031405			187.55	0.1609	304.50	0.1242
157	Helium-4	He	7440-59-7	4.00	–0.013833	0.022913	–0.0054872	0.0004585	2.20	0.0149	4.80	0.0204
158	Heptadecane	$C_{17}H_{36}$	629-78-7	240.47	0.20926	–0.0002215			295.13	0.1439	575.30	0.0818
159	Heptanal	$C_7H_{14}O$	111-71-7	114.19	0.21816	–0.0003015	1.033E-07		229.80	0.1543	553.15	0.0830
160	Heptane	C_7H_{16}	142-82-5	100.20	0.215	–0.000303			182.57	0.1597	371.58	0.1024
161	Heptanoic acid	$C_7H_{14}O_2$	111-14-8	130.19	0.202	–0.0002			265.83	0.1488	496.15	0.1028
162	1-Heptanol	$C_7H_{16}O$	111-70-6	116.20	0.2239	–0.000226			239.15	0.1699	573.15	0.0944
163	2-Heptanol	$C_7H_{16}O$	543-49-7	116.20	0.21134	–0.00024776			230.00	0.1544	432.90	0.1041
164	3-Heptanone	$C_7H_{14}O$	106-35-4	114.19	0.2026	–0.0002234			234.15	0.1503	553.15	0.0790
165	2-Heptanone	$C_7H_{14}O$	110-43-0	114.19	0.2108	–0.000246			238.15	0.1522	424.05	0.1065
166	1-Heptene	C_7H_{14}	592-76-7	98.19	0.19664	–0.00016623	–2.5241E-07		154.12	0.1650	366.79	0.1017
167	Heptyl mercaptan	$C_7H_{16}S$	1639-09-4	132.27	0.2037	–0.0002252			229.92	0.1519	450.09	0.1023
168	1-Heptyne	C_7H_{12}	628-71-7	96.17	0.21098	–0.00026652			192.22	0.1598	372.93	0.1116
169	Hexadecane	$C_{16}H_{34}$	544-76-3	226.44	0.20749	–0.00021917			291.31	0.1436	560.01	0.0848
170	Hexanal	$C_6H_{12}O$	66-25-1	100.16	0.22196	–0.00032053	1.1554E-07		217.15	0.1578	533.15	0.0839
171	Hexane	C_6H_{14}	110-54-3	86.18	0.22492	–0.0003533			177.83	0.1621	370.00	0.0942
172	Hexanoic acid	$C_6H_{12}O_2$	142-62-1	116.16	0.1855	–0.000146			269.25	0.1462	603.15	0.0974
173	1-Hexanol	$C_6H_{14}O$	111-27-3	102.17	0.2193	–0.00022			228.55	0.1690	575.00	0.0928
174	2-Hexanol	$C_6H_{14}O$	626-93-7	102.18	0.21391	–0.00026042			223.00	0.1558	412.40	0.1065
175	2-Hexanone	$C_6H_{12}O$	591-78-6	100.16	0.21076	–0.00024			217.35	0.1586	400.85	0.1146
176	3-Hexanone	$C_6H_{12}O$	589-38-8	100.16	0.23493	–0.0002912			217.50	0.1716	466.00	0.0992
177	1-Hexene	C_6H_{12}	592-41-6	84.16	0.19112	–0.000083519	–5.1407E-07		133.39	0.1708	336.63	0.1048
178	3-Hexyne	C_6H_{10}	928-49-4	82.14	0.20996	–0.0002692			170.05	0.1642	354.35	0.1146

TABLE 2-315 Thermal Conductivity of Inorganic and Organic Liquids [W/(m·K)] (*Continued*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	C5	T_{min}, K	Thermal cond. at T_{min}	T_{max}, K	Thermal cond. at T_{max}
179	Hexyl mercaptan	$C_6H_{14}S$	111-31-9	118.24	0.2058	–0.0002324				192.62	0.1610	425.81	0.1068
180	1-Hexyne	C_6H_{10}	693-02-7	82.14	0.21492	–0.0002899				141.25	0.1740	344.48	0.1151
181	2-Hexyne	C_6H_{10}	764-35-2	82.14	0.2119	–0.00027048				183.65	0.1622	357.67	0.1152
182	Hydrazine	H_4N_2	302-01-2	32.05	1.3675	–0.0015895				274.69	0.9309	623.15	0.3770
183	Hydrogen	H_2	1333-74-0	2.02	–0.0917	0.017678	–0.000382	–3.3324E-06	1.0266E-07	13.95	0.0754	31.00	0.0847
184	Hydrogen bromide	HBr	10035-10-6	80.91	0.234	–0.0004636				185.15	0.1482	290.62	0.0993
185	Hydrogen chloride	HCl	7647-01-0	36.46	0.8045	–0.002102				273.15	0.2303	323.15	0.1252
186	Hydrogen cyanide	CHN	74-90-8	27.03	0.43454	–0.0007008				259.83	0.2525	298.85	0.2251
187	Hydrogen fluoride	HF	7664-39-3	20.01	0.7516	–0.0010874				189.79	0.5452	394.45	0.3227
188	Hydrogen sulfide	H_2S	7783-06-4	34.08	0.4842	–0.001184				193.15	0.2555	292.42	0.1380
189	Isobutyric acid	$C_4H_8O_2$	79-31-2	88.11	0.21668	–0.0002556				227.15	0.1586	482.75	0.0933
190	Isopropyl amine	C_3H_9N	75-31-0	59.11	0.237	–0.000332				177.95	0.1779	305.55	0.1356
191	Malonic acid	$C_3H_4O_4$	141-82–2	104.06	0.28918	–0.0002614				407.95	0.1825	644.00	0.1208
192	Methacrylic acid	$C_4H_6O_2$	79-41–4	86.09	0.2306	–0.00025201				288.15	0.1580	530.00	0.0970
193	Methane	CH_4	74-82-8	16.04	0.41768	–0.0024528	3.5588E-06			90.69	0.2245	180.00	0.0915
194	Methanol	CH_4O	67-56-1	32.04	0.2837	–0.000281				175.47	0.2344	337.85	0.1888
195	*N*-Methyl acetamide	C_3H_7NO	79-16-3	73.09	0.23743	–0.0002362				301.15	0.1663	478.15	0.1245
196	Methyl acetate	$C_3H_6O_2$	79-20-9	74.08	0.2777	–0.000417				175.15	0.2047	386.15	0.1167
197	Methyl acetylene	C_3H_4	74-99-7	40.06	0.23648	–0.00041639				170.45	0.1655	249.94	0.1324
198	Methyl acrylate	$C_4H_6O_2$	96-33-3	86.09	0.26082	–0.0003506				196.32	0.1920	421.00	0.1132
199	Methyl amine	CH_5N	74-89-5	31.06	0.33446	–0.00067427	8.033E-07			179.69	0.2392	283.15	0.2079
200	Methyl benzoate	$C_8H_8O_2$	93-58-3	136.15	0.22142	–0.00022759				260.75	0.1621	547.90	0.0967
201	3-Methyl-1,2-butadiene	C_5H_8	598-25-4	68.12	0.1983	–0.0002822				159.53	0.1533	314.00	0.1097
202	2-Methylbutane	C_5H_{12}	78-78-4	72.15	0.21246	–0.00033581				113.25	0.1744	368.13	0.0888
203	2-Methylbutanoic acid	$C_5H_{10}O_2$	116-53-0	102.13	0.22284	–0.0002516				357.15	0.1330	480.90	0.1019
204	3-Methyl-1-butanol	$C_5H_{12}O$	123-51-3	88.15	0.17471	–0.0001256				155.95	0.1551	404.15	0.1239
205	2-Methyl-1-butene	C_5H_{10}	563-46-2	70.13	0.19447	–0.0002901				135.58	0.1551	304.30	0.1062
206	2-Methyl-2-butene	C_5H_{10}	513-35-9	70.13	0.19636	–0.000291				139.39	0.1558	311.70	0.1057
207	2-Methyl-1-butene-3-yne	C_5H_6	78-80-8	66.10	0.20385	–0.0002874				160.15	0.1578	305.40	0.1161
208	Methylbutyl ether	$C_5H_{12}O$	628-28-4	88.15	0.22235	–0.0003044				157.48	0.1744	463.15	0.0814
209	Methylbutyl sulfide	$C_5H_{12}S$	628-29-5	104.21	0.20698	–0.00024439				175.30	0.1641	396.58	0.1101
210	3-Methyl-1-butyne	C_5H_8	598-23-2	68.12	0.20348	–0.0003106				183.45	0.1465	302.15	0.1096
211	Methyl butyrate	$C_5H_{10}O_2$	623-42-7	102.13	0.21748	–0.00025913				187.35	0.1689	493.15	0.0897
212	Methylchlorosilane	CH_5ClSi	993-00-0	80.59	0.24683	–0.00038854				139.05	0.1928	281.85	0.1373
213	Methylcyclohexane	C_7H_{14}	108-87-2	98.19	0.1791	–0.0002291				273.15	0.1165	374.08	0.0934
214	1-Methylcyclohexanol	$C_7H_{14}O$	590-67-0	114.19	0.21558	–0.00022728				299.15	0.1476	548.80	0.0908
215	*cis*-2-Methylcyclohexanol	$C_7H_{14}O$	7443-70-1	114.19	0.21839	–0.00025776				280.15	0.1462	484.20	0.0936
216	*trans*-2-Methylcyclohexanol	$C_7H_{14}O$	7443-52-9	114.19	0.21828	–0.0002557				269.15	0.1495	484.80	0.0943
217	Methylcyclopentane	C_6H_{12}	96-37-7	84.16	0.1929	–0.0002492				130.73	0.1603	344.95	0.1069
218	1-Methylcyclopentene	C_6H_{10}	693-89-0	82.14	0.20023	–0.00025581				146.62	0.1627	348.64	0.1110
219	3-Methylcyclopentene	C_6H_{10}	1120-62-3	82.14	0.1994	–0.00026149				115.00	0.1693	338.05	0.1110
220	Methyldichlorosilane	CH_4Cl_2Si	75-54-7	115.03	0.21956	–0.00032153				182.55	0.1609	314.70	0.1184
221	Methylethyl ether	C_3H_8O	540-67-0	60.10	0.27304	–0.0004518				160.00	0.2008	341.34	0.1188
222	Methylethyl ketone	C_4H_8O	78-93-3	72.11	0.2197	–0.0002505				186.48	0.1730	352.79	0.1313
223	Methylethyl sulfide	C_3H_8S	624-89-5	76.16	0.22136	–0.00028938				167.23	0.1730	339.80	0.1230
224	Methyl formate	$C_2H_4O_2$	107-31-3	60.05	0.3246	–0.000468				174.15	0.2431	373.15	0.1500
225	Methylisobutyl ether	$C_5H_{12}O$	625-44-5	88.15	0.222	–0.00032217				150.00	0.1737	390.00	0.0964
226	Methylisobutyl ketone	$C_6H_{12}O$	108-10-1	100.16	0.2301	–0.00028899				189.15	0.1754	451.42	0.0996
227	Methyl isocyanate	C_2H_3NO	624-83-9	57.05	0.2822	–0.00042037				256.15	0.1745	312.00	0.1510
228	Methylisopropyl ether	$C_4H_{10}O$	598-53-8	74.12	0.24154	–0.0003774				127.93	0.1933	370.00	0.1019
229	Methylisopropyl ketone	$C_5H_{10}O$	563-80-4	86.13	0.2332	–0.0003044				180.15	0.1784	435.90	0.1005
230	Methylisopropyl sulfide	$C_4H_{10}S$	1551-21-9	90.19	0.20978	–0.00026468				171.64	0.1644	357.91	0.1151
231	Methyl mercaptan	CH_4S	74-93-1	48.11	0.26119	–0.00038345				150.18	0.2036	279.11	0.1542
232	Methyl methacrylate	$C_5H_8O_2$	80-62-6	100.12	0.2583	–0.000379				290.15	0.1483	363.45	0.1206
233	2-Methyloctanoic acid	$C_9H_{18}O_2$	3004-93-1	158.24	0.20911	–0.00021852				208.20	0.1636	555.20	0.0878
234	2-Methylpentane	C_6H_{14}	107-83-5	86.18	0.19334	–0.00028038				119.55	0.1598	389.25	0.0842
235	Methyl pentyl ether	$C_6H_{14}O$	628-80-8	102.17	0.21698	–0.00028998				176.00	0.1659	432.30	0.0916
236	2-Methylpropane	C_4H_{10}	75-28-5	58.12	0.20455	–0.00036589				113.54	0.1630	400.00	0.0582

237	2-Methyl-2-propanol	$C_4H_{10}O$	75-65-0	74.12	0.21258	–0.00029864				298.97	0.1233	404.96	0.0916
238	2-Methyl propene	C_4H_8	115-11-7	56.11	0.2802	–0.000786	6.516E-07			132.81	0.1873	395.20	0.0713
239	Methyl propionate	$C_4H_8O_2$	554-12-1	88.11	0.22534	–0.0002683				185.65	0.1755	475.00	0.0979
240	Methylpropyl ether	$C_4H_{10}O$	557-17-5	74.12	0.24817	–0.0003774				133.97	0.1976	373.00	0.1074
241	Methylpropyl sulfide	$C_4H_{10}S$	3877-15-4	90.19	0.21103	–0.00025985				160.17	0.1694	368.69	0.1152
242	Methylsilane	CH_6Si	992-94-9	46.14	0.2774	–0.00054608				116.34	0.2139	216.25	0.1593
243	α-Methyl styrene	C_9H_{10}	98-83-9	118.18	0.19657	–0.0002118				249.95	0.1436	438.65	0.1037
244	Methyl *tert*-butyl ether	$C_5H_{12}O$	1634-04-4	88.15	0.2253	–0.00037273	1.1728E-07			164.55	0.1671	328.18	0.1156
245	Methyl vinyl ether	C_3H_6O	107-25-5	58.08	0.28035	–0.0004646				151.15	0.2101	341.10	0.1219
246	Naphthalene	$C_{10}H_8$	91-20-3	128.17	0.17096	–0.00010059				353.43	0.1354	646.97	0.1059
247	Neon	Ne	7440-01-9	20.18	0.2971	–0.017356	0.0005911	–0.000007421		25.00	0.1167	44.00	0.0457
248	Nitroethane	$C_2H_5NO_2$	79-24-3	75.07	0.247	–0.0002814				183.63	0.1953	387.22	0.1380
249	Nitrogen	N_2	7727-37-9	28.01	0.2654	–0.001677				63.15	0.1595	124.00	0.0575
250	Nitrogen trifluoride	F_3N	7783-54-2	71.00									
251	Nitromethane	CH_3NO_2	75-52-5	61.04	0.3276	–0.000405				244.60	0.2285	374.35	0.1760
252	Nitrous oxide	N_2O	10024-97-2	44.01	0.10112					277.59	0.1011	277.59	0.1011
253	Nitric oxide	NO	10102-43-9	30.01	0.1878	0.0010293	–0.00000943			110.00	0.1869	176.40	0.0759
254	Nonadecane	$C_{19}H_{40}$	629-92-5	268.52	0.21229	–0.00022				305.04	0.1452	603.05	0.0796
255	Nonanal	$C_9H_{18}O$	124-19-6	142.24	0.21523	–0.0002799	9.572E-08			255.15	0.1501	593.15	0.0829
256	Nonane	C_9H_{20}	111-84-2	128.26	0.209	–0.000264				219.66	0.1510	423.97	0.0971
257	Nonanoic acid	$C_9H_{18}O_2$	112-05-0	158.24	0.204	–0.0002				285.55	0.1469	528.75	0.0983
258	1-Nonanol	$C_9H_{20}O$	143-08-8	144.25	0.2292	–0.00023				268.15	0.1675	578.65	0.0961
259	2-Nonanol	$C_9H_{20}O$	628-99-9	144.26	0.20829	–0.00022922				238.15	0.1537	471.70	0.1002
260	1-Nonene	C_9H_{18}	124-11-8	126.24	0.20468	–0.00025738				191.91	0.1553	420.02	0.0966
261	Nonyl mercaptan	$C_9H_{20}S$	1455-21-6	160.32	0.20244	–0.00021343				253.05	0.1484	492.95	0.0972
262	1-Nonyne	C_9H_{16}	3452-09-3	124.22	0.20954	–0.00024588				223.15	0.1547	423.85	0.1053
263	Octadecane	$C_{18}H_{38}$	593-45-3	254.49	0.2137	–0.0002252				301.31	0.1458	589.86	0.0809
264	Octanal	$C_8H_{16}O$	124-13-0	128.21	0.20143	–0.00021102				246.00	0.1495	573.15	0.0805
265	Octane	C_8H_{18}	111-65-9	114.23	0.2156	–0.00029483				216.38	0.1518	398.83	0.0980
266	Octanoic acid	$C_8H_{16}O_2$	124-07-2	144.21	0.203	–0.0002				289.65	0.1451	512.85	0.1004
267	1-Octanol	$C_8H_{18}O$	111-87-5	130.23	0.2316	–0.0002407				257.65	0.1696	570.15	0.0944
268	2-Octanol	$C_8H_{18}O$	123-96-6	130.23	0.20955	–0.00023733				241.55	0.1522	452.90	0.1021
269	2-Octanone	$C_8H_{16}O$	111-13-7	128.21	0.2132	–0.0002494				252.85	0.1501	499.00	0.0887
270	3-Octanone	$C_8H_{16}O$	106-68-3	128.21	0.21732	–0.00024969				255.55	0.1535	440.65	0.1073
271	1-Octene	C_8H_{16}	111-66-0	112.21	0.20467	–0.0002675				171.45	0.1588	394.41	0.0992
272	Octyl mercaptan	$C_8H_{18}S$	111-88-6	146.29	0.2012	–0.0002142				223.95	0.1532	472.19	0.1001
273	1-Octyne	C_8H_{14}	629-05-0	110.20	0.2095	–0.00025334				193.55	0.1605	399.35	0.1083
274	Oxalic acid	$C_2H_2O_4$	144-62-7	90.03	0.3074	–0.00028101				462.65	0.1774	643.20	0.1267
275	Oxygen	O_2	7782-44-7	32.00	0.2741	–0.00138				60.00	0.1913	150.00	0.0671
276	Ozone	O_3	10028-15-6	48.00	0.17483	0.00075288	–2.5228E-06			77.35	0.2180	161.85	0.2306
277	Pentadecane	$C_{15}H_{32}$	629-62-9	212.41	0.20649	–0.00021911				283.07	0.1445	543.84	0.0873
278	Pentanal	$C_5H_{10}O$	110-62-3	86.13	0.22697	–0.00033227	1.177E-07			182.00	0.1704	513.15	0.0875
279	Pentane	C_5H_{12}	109-66-0	72.15	0.2537	–0.000576	0.000000344			143.42	0.1782	445.00	0.0655
280	Pentanoic acid	$C_5H_{10}O_2$	109-52-4	102.13	0.1848	–0.0001434				239.15	0.1505	458.65	0.1190
281	1-Pentanol	$C_5H_{12}O$	71-41-0	88.15	0.2006	–0.0001603				273.15	0.1568	353.15	0.1440
282	2-Pentanol	$C_5H_{12}O$	6032-29-7	88.15	0.21875	–0.00027849				200.00	0.1631	392.20	0.1095
283	2-Pentanone	$C_5H_{10}O$	107-87-9	86.13	0.2161	–0.00024866				196.29	0.1673	375.46	0.1227
284	3-Pentanone	$C_5H_{10}O$	96-22-0	86.13	0.21569	–0.00024081				234.18	0.1593	375.14	0.1254
285	1-Pentene	C_5H_{10}	109-67-1	70.13	0.21361	–0.00030777				108.02	0.1804	303.22	0.1203
286	2-Pentyl mercaptan	$C_5H_{12}S$	2084-19-7	104.21	0.20597	–0.00024518				160.75	0.1666	385.15	0.1115
287	Pentyl mercaptan	$C_5H_{12}S$	110-66-7	104.21	0.2086	–0.00024536				197.45	0.1602	399.79	0.1105
288	1-Pentyne	C_5H_8	627-19-0	68.12	0.22102	–0.000322				167.45	0.1671	313.33	0.1201
289	2-Pentyne	C_5H_8	627-21-4	68.12	0.21282	–0.0002856				163.83	0.1660	329.27	0.1188
290	Phenanthrene	$C_{14}H_{10}$	85-01-8	178.23	0.13753	–0.000025247				372.38	0.1281	610.03	0.1221
291	Phenol	C_6H_6O	108-95-2	94.11	0.18831	–0.0001				314.06	0.1569	454.99	0.1428
292	Phenyl isocyanate	C_7H_5NO	103-71-9	119.12	0.16326	–0.00017777				243.15	0.1200	439.43	0.0851
293	Phthalic anhydride	$C_8H_4O_3$	85-44-9	148.12	0.22946	–0.00021345				404.15	0.1432	557.65	0.1104
294	Propadiene	C_3H_4	463-49-0	40.06	0.23081	–0.0004078				136.87	0.1750	238.65	0.1335
295	Propane	C_3H_8	74-98-6	44.10	0.26755	–0.00066457	2.774E-07			85.47	0.2128	350.00	0.0689
296	1-Propanol	C_3H_8O	71-23-8	60.10	0.2203	–0.0002155				200.00	0.1772	370.35	0.1405
297	2-Propanol	C_3H_8O	67-63-0	60.10	0.20161	–0.00021529				185.26	0.1617	425.00	0.1101
298	Propenylcyclohexene	C_9H_{14}	13511-13-2	122.21	0.1831	–0.00020275				199.00	0.1428	431.65	0.0956
299	Propionaldehyde	C_3H_6O	123-38-6	58.08	0.2498	–0.00030075				170.00	0.1987	453.15	0.1135

TABLE 2-315 Thermal Conductivity of Inorganic and Organic Liquids [W/(m·K)] (*Concluded*)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	C5	T_{min}, K	Thermal cond. at T_{min}	T_{max}, K	Thermal cond. at T_{max}
300	Propionic acid	$C_3H_6O_2$	79-09-4	74.08	0.1954	–0.000164				252.45	0.1540	543.15	0.1063
301	Propionitrile	C_3H_5N	107-12-0	55.08	0.26626	–0.0003307				180.26	0.2067	370.50	0.1437
302	Propyl acetate	$C_5H_{10}O_2$	109-60-4	102.13	0.2332	–0.0003096				178.15	0.1780	434.82	0.0986
303	Propyl amine	C_3H_9N	107-10-8	59.11	0.2632	–0.0004278	0.000000412			188.36	0.1972	333.15	0.1664
304	Propylbenzene	C_9H_{12}	103-65-1	120.19	0.18707	–0.00019846				173.55	0.1526	583.15	0.0713
305	Propylene	C_3H_6	115-07-1	42.08	0.24719	–0.00048824				87.89	0.2043	340.49	0.0809
306	Propyl formate	$C_4H_8O_2$	110-74-7	88.11	0.2247	–0.000264				180.25	0.1771	483.15	0.0971
307	2-Propyl mercaptan	C_3H_8S	75-33-2	76.16	0.21706	–0.00028952				142.61	0.1758	325.71	0.1228
308	Propyl mercaptan	C_3H_8S	107-03-9	76.16	0.2202	–0.00028535				159.95	0.1746	340.87	0.1229
309	1,2-Propylene glycol	$C_3H_8O_2$	57-55-6	76.09	0.2152	–0.0000497				213.15	0.2046	460.75	0.1923
310	Quinone	$C_6H_4O_2$	106-51-4	108.09	0.26524	–0.00028676				388.85	0.1537	545.00	0.1090
311	Silicon tetrafluoride	F_4Si	7783-61-1	104.08									
312	Styrene	C_8H_8	100-42-5	104.15	0.20215	–0.0002201				242.54	0.1488	418.31	0.1101
313	Succinic acid	$C_4H_6O_4$	110-15-6	118.09	0.28215	–0.0002585				460.65	0.1631	642.00	0.1162
314	Sulfur dioxide	O_2S	7446-09-5	64.06	0.38218	–0.0006254				197.67	0.2586	400.00	0.1320
315	Sulfur hexafluoride	F_6S	2551-62-4	146.06	0.2544	–0.0006595				223.15	0.1072	318.69	0.0442
316	Sulfur trioxide	O_3S	7446-11-9	80.06	0.92882	–0.0030803	0.00000266			289.95	0.2593	481.47	0.0624
317	Terephthalic acid	$C_8H_6O_4$	100-21-0	166.13									
318	*o*-Terphenyl	$C_{18}H_{14}$	84-15-1	230.30	0.16853	–0.00010817				329.35	0.1329	723.15	0.0903
319	Tetradecane	$C_{14}H_{30}$	629-59-4	198.39	0.20293	–0.00021798				279.01	0.1421	526.73	0.0881
320	Tetrahydrofuran	C_4H_8O	109-99-9	72.11	0.19428	–0.000249				164.65	0.1533	339.12	0.1098
321	1,2,3,4-Tetrahydronaphthalene	$C_{10}H_{12}$	119-64-2	132.20	0.14563	–0.0000536				237.38	0.1329	480.77	0.1199
322	Tetrahydrothiophene	C_4H_8S	110-01-0	88.17	0.20414	–0.00021217				176.98	0.1666	394.27	0.1205
323	2,2,3,3-Tetramethylbutane	C_8H_{18}	594-82-1	114.23	0.17835	–0.00023704				373.96	0.0897	426.00	0.0774
324	Thiophene	C_4H_4S	110-02-1	84.14	0.20571	–0.00020028				234.94	0.1587	357.31	0.1342
325	Toluene	C_7H_8	108-88-3	92.14	0.20463	–0.00024252				178.18	0.1614	474.85	0.0895
326	1,1,2-Trichloroethane	$C_2H_3Cl_3$	79-00-5	133.40	0.20731	–0.00024997				236.50	0.1482	482.00	0.0868
327	Tridecane	$C_{13}H_{28}$	629-50-5	184.36	0.20447	–0.00022612				267.76	0.1439	508.62	0.0895
328	Triethyl amine	$C_6H_{15}N$	121-44-8	101.19	0.1918	–0.0002453				158.45	0.1529	483.15	0.0733
329	Trimethyl amine	C_3H_9N	75-50-3	59.11	0.23813	–0.00038397				156.08	0.1782	276.02	0.1322
330	1,2,3-Trimethylbenzene	C_9H_{12}	526-73-8	120.19	0.18854	–0.0001963				247.79	0.1399	449.27	0.1004
331	1,2,4-Trimethylbenzene	C_9H_{12}	95-63-6	120.19	0.19216	–0.0002105				229.33	0.1439	442.53	0.0990
332	2,2,4-Trimethylpentane	C_8H_{18}	540-84-1	114.23	0.1659	–0.00022686				165.78	0.1283	372.39	0.0814
333	2,3,3-Trimethylpentane	C_8H_{18}	560-21-4	114.23	0.16815	–0.00020535				172.22	0.1328	387.91	0.0885
334	1,3,5-Trinitrobenzene	$C_6H_3N_3O_6$	99-35-4	213.10	0.18421	–0.00016097				398.40	0.1201	629.60	0.0829
335	2,4,6-Trinitrotoluene	$C_7H_5N_3O_6$	118-96-7	227.13	–1.5128	0.0079553	–0.000010066			357.20	0.0445	393.20	0.0590
336	Undecane	$C_{11}H_{24}$	1120-21-4	156.31	0.20515	–0.00023933				247.57	0.1459	469.08	0.0929
337	1-Undecanol	$C_{11}H_{24}O$	112-42-5	172.31	0.21211	–0.00021815				288.45	0.1492	561.20	0.0897
338	Vinyl acetate	$C_4H_6O_2$	108-05-4	86.09	0.256	–0.0003542				180.35	0.1921	410.00	0.1108
339	Vinyl acetylene	C_4H_4	689-97-4	52.07	0.22838	–0.00035173				173.15	0.1675	278.25	0.1305
340	Vinyl chloride	C_2H_3Cl	75-01-4	62.50	0.2333	–0.00039223				119.36	0.1865	345.60	0.0977
341	Vinyl trichlorosilane	$C_2H_3Cl_3Si$	75-94-5	161.49	0.21831	–0.00029122				178.35	0.1664	434.52	0.0918
342	Water	H_2O	7732-18-5	18.02	–0.432	0.0057255	–0.000008078	1.861E-09		273.16	0.5672	633.15	0.4272
343	*m*-Xylene	C_8H_{10}	108-38-3	106.17	0.20044	–0.00023544				225.30	0.1474	413.10	0.1032
344	*o*-Xylene	C_8H_{10}	95-47-6	106.17	0.19989	–0.0002299				247.98	0.1429	417.58	0.1039
345	*p*-Xylene	C_8H_{10}	106-42-3	106.17	0.20003	–0.00023573				286.41	0.1325	413.10	0.1027

The liquid thermal conductivity is calculated by

$$k = \mathrm{C1} + \mathrm{C2}T + \mathrm{C3}T^2 + \mathrm{C4}T^3 + \mathrm{C5}T^4.$$

where k is the thermal conductivity in W/(m·K) and T is the temperature in K. Thermal conductivites are at either 1 atm or the vapor pressure, whichever is higher. All substances are listed by chemical family in Table 2-6 and by formula in Table 2-7.

Values in this table were taken from the Design Institute for Physical Properties (DIPPR) of the American Institute of Chemical Engineers (AIChE), copyright 2007 AIChE and reproduced with permission of AICHE and of the DIPPR Evaluated Process Design Data Project Steering Committee. Their source should be cited as R. L. Rowley, W. V. Wilding, J. L. Oscarson, Y. Yang, N. A. Zundel, T. E. Daubert, R. P. Danner, DIPPR® Data Compilation of Pure Chemical Properties, Design Institute for Physical Properties, AIChE, New York (2007).

The number of digits provided for values at T_{min} and T_{max} was chosen for uniformity of appearance and formatting; these do not represent the uncertainties of the physical quantities, but are the result of calculations from the standard thermophysical property formulations within a fixed format.

TABLE 2-316 Transport Properties of Selected Gases at Atmospheric Pressure*

	Thermal conductivity, W/(m·K) Temperature, K					Viscosity, 10^{-4} Pa·s Temperature, K					Prandtl number, dimensionless Temperature, K			
Substance	250	300	400	500	600	250	300	400	500	600	250	300	400	500
Acetone	0.0080	0.0115	0.0201	0.0310			0.077	0.101	0.128	0.156				
Acetylene	0.0162	0.0213	0.0332	0.0452	0.0561		0.104	0.135	0.164					
Benzene	0.0077	0.0104	0.0195	0.0335	0.0524		0.076	0.101	0.127	0.154				
Bromine	0.0038	0.0048	0.0067					0.203	0.260	0.291				
CCl_4	0.0053	0.0067	0.0099	0.0126			0.101	0.131	0.162	0.191				
Chlorine	0.0071	0.0089	0.0124	0.0156	0.0190		0.136	0.178	0.218	0.259				
Deuterium	0.122	0.141	0.176			0.111	0.126	0.153	0.178	0.201				
Propylene	0.0114	0.0168	0.0226	0.0430	0.0580	0.073	0.087	0.115	0.141		0.860	0.797	0.762	
R 11		0.0078	0.0119			0.094	0.110	0.144				0.814	0.761	
R 12	0.0072	0.0097	0.0151	0.0208		0.108	0.126	0.162			0.827	0.781	0.745	0.708
R 13	0.0091	0.0121	0.0185	0.0248		0.123	0.145	0.190			0.796	0.766	0.759	0.757
R 21		0.0088	0.0135	0.0181		0.100	0.115	0.154				0.779	0.773	
R 22	0.0080	0.0109	0.0170	0.0230	0.0290	0.109	0.129	0.168			0.820	0.771	0.760	
SO_2	0.0078	0.0096	0.0143	0.0200	0.0256		0.129	0.175	0.217	0.256				

*An approximate interpolation scheme is to plot the logarithm of the viscosity or the thermal conductivity versus the logarithm of the absolute temperature. At 250 K the viscosity of gaseous argon is to be read as 1.95×10^{-5} Pa·s = 0.0000195 N·s/m^2.

TABLE 2-317 Lower and Upper Flammability Limits, Flash Point, and Autoignition Temperature for Selected Hydrocarbons

Compound	CAS no.	Formula	LFL	LFL rating	UFL	UFL rating	Flash point °C	Flash point rating	Autoignition *T* °C	Autoignition rating
Paraffin hydrocarbons										
Methane	74828	CH_4	5.00	12	15.00	12	−187.15	4	536.85	11
Ethane	74840	C_2H_6	2.90	12	13.00	12	−130.15	4	471.85	11
Propane	74986	C_3H_8	2.00	12	9.50	12	−104.00	4	449.85	11
Butane	106978	C_4H_{10}	1.50	12	9.00	12	−69.00	6	287.85	11
Isobutane	75285	C_4H_{10}	1.80	12	8.40	12	−82.59	5	460.00	11
Pentane	109660	C_5H_{12}	1.30	14	8.00	14	−40.00	11	242.85	11
Isopentane	78784	C_5H_{12}	1.30	12	8.00	12	−56.00	11	420.00	11
2,2-Dimethylpropane	463821	C_5H_{12}	1.40	11	7.50	11	−72.15	4	450.00	11
Hexane	1100543	C_6H_{14}	1.05	13	7.68	13	−21.65	11	224.85	11
Heptane	142825	C_7H_{16}	1.00	14	7.00	14	−4.15	11	203.85	11
2,3-Dimethylpentane	565593	C_7H_{16}	1.12	4	6.75	4	−6.00	4	335.00	11
Octane	111659	C_8H_{18}	0.80	12	6.50	12	12.85	11	205.85	11
Isooctane	540841	C_8H_{18}	0.95	11	6.00	11	−12.22	11	411.00	11
Nonane	111842	C_9H_{20}	0.70	12	5.60	12	30.85	11	204.85	11
Decane	124185	$C_{10}H_{22}$	0.70	12	5.40	12	45.85	11	200.85	11
Olefins										
Ethylene	74851	C_2H_4	2.70	11	36.00	11	−146.15	4	450.00	11
Propylene	115071	C_3H_6	2.00	11	11.00	11	−108.15	11	455.00	11
1- Butene	106989	C_4H_8	1.60	11	9.30	11	−79.81	5	383.85	11
2- Butene	107017	C_4H_8	1.70	8	9.70	8	<−34.00	1	325.00	8
1-Pentene	109671	C_5H_{10}	1.50	11	8.70	11	−18.15	11	272.85	11
Acetylenes										
Acetylene	74862	C_2H_2	2.50	12	80.00	12	−18.15	11	305.00	11
Vinylacetylene	689974	C_4H_4	1.80	6	100.00	4	−66.15	4	310.00	6
Methylacetylene	613878	C_3H_4	1.70	11	16.80	11	−86.15	4	340.00	11
Aromatics										
Benzene	71432	C_6H_6	1.40	11	7.10	11	−11.15	11	561.85	11
Toluene	108883	C_7H_8	1.20	11	7.10	11	4.85	11	535.85	11
o-Xylene	95476	C_8H_{10}	1.00	11	6.00	11	16.85	11	463.85	11
Ethylbenzene	100414	C_8H_{10}	1.00	11	6.70	11	15.00	11	431.85	11
Isopropylbenzene (Cumene)	98828	C_9H_{12}	0.88	12	6.50	12	31.00	12	423.85	11
Anthracene	120127	$C_{14}H_{10}$	0.65	8	5.46	4	120.85	4	540.00	8
Cyclic hydrocarbons										
Cyclopropane	75194	C_3H_6	2.40	12	10.40	12	92.00	4	497.85	11
Furan	110009	C_4H_4O	2.30	11	14.30	11	−36.15	11	510.00	6
Cyclopentadiene	542927	C_5H_6	1.62	4	7.70	4	−28.15	4	429.85	4
Cyclohexane	110827	C_6H_{12}	1.30	8	7.80	8	−18.15	4	245.00	11
Methylcyclohexane	108872	C_7H_{14}	1.10	11	6.70	11	−6.00	11	250.00	11
Phenol	108952	C_6H_6O	1.52	6	8.76	6	79.85	11	714.85	11
Dicyclopentadiene	77736	$C_{10}H_{12}$	1.00	4	6.76	4	26.00	4	505.00	5
Alcohols										
Methyl alcohol	67561	CH_4O	7.30	11	36.00	11	10.85	11	463.85	11
Ethyl alcohol	64175	C_2H_6O	3.30	8	19.00	8	12.85	4	356.00	8
2-propen-1-ol	107186	C_3H_6O	2.50	11	18.00	11	20.85	11	377.85	11
n-Propyl alcohol	71238	C_3H_8O	2.10	8	13.50	8	24.63	5	440.00	8
Isopropyl alcohol	67630	C_3H_8O	2.20	8	12.00	8	21.85	4	399.00	5
n-Butyl alcohol	71363	$C_4H_{10}O$	1.40	8	11.20	8	37.19	5	359.00	5
2-Butanol	78922	$C_4H_{10}O$	1.68	4	9.80	4	23.85	4	405.00	8
2-Methyl-l-propanol	78831	$C_4H_{10}O$	1.70	11	10.90	11	27.85	11	408.00	11
2-Methyl-2-propanol	75650	$C_4H_{10}O$	1.90	4	9.00	4	10.85	4	480.00	8
Cyclohexanol	108930	$C_6H_{12}O$	1.20	11	9.30	10	67.85	11	300.00	11
Aldehydes										
Formaldehyde	50000	CH_2O	7.00	11	73.00	11	−52.96	3	430.00	11
Acetaldehyde	75070	C_2H_4O	4.00	11	60.00	11	−38.15	11	175.00	8
Acrolein	107028	C_3H_4O	2.80	11	31.00	11	−26.00	11	233.85	11
Propionaldehyde	123386	C_3H_6O	2.60	11	16.10	11	−30.00	11	206.85	11
Crotonic aldehyde	123739	C_4H_6O	2.10	11	15.50	11	8.00	11	231.85	11
Crotonaldehyde	4170303	C_4H_6O	2.10	8	15.50	8	13.00	6	232.00	5
Isobutyraldehyde	78842	C_4H_8O	1.60	4	10.60	4	−18.15	4	204.85	11
Butyraldehyde	123728	C_4H_8O	2.50	8	12.50	4	− 7.15	4	215.76	5
2-Furancarboxaldehyde	98011	$C_5H_4O_2$	2.10	8	19.30	4	72.85	4	316.00	5
Ethers										
Dimethyl ether	115106	C_2H_6O	3.30	11	27.30	11	−41.15	11	350.00	11
Vinyl methyl ether	107255	C_3H_6O	2.60	11	39.00	11	−56.00	11	287.00	11
Diethyl ether	60297	$C_4H_{10}O$	1.90	11	48.00	11	−45.00	11	160.00	11
Diphenyl ether	101848	$C_{12}H_{10}O$	0.80	11	1.50	11	95.85	11	618.00	11
Ketones										
Acetone	67641	C_3H_6O	2.60	8	13.00	8	−18.15	4	465.00	8
Methylethyl ketone	78933	C_4H_8O	1.80	11	10.00	11	−6.15	11	515.85	11
Methyl phenyl ketone	98862	C_8H_8O	1.10	8	6.89	4	82.00	8	571.11	11
Acids										
Acetic acid	64197	$C_2H_4O_2$	4.05	8	16.00	4	42.85	11	426.85	11
Hydrocyanic acid	74908	HCN	6.00	11	41.00	11	−18.00	6	537.85	11
Formic acid	64186	CH_2O_2	15.70	10	38.00	11	48.00	12	480.00	11
Esters										
Methyl formate	107313	$C_2H_4O_2$	5.90	11	20.00	11	−19.15	11	455.85	11
Ethyl formate	109944	$C_3H_6O_2$	2.80	8	16.00	8	−19.50	6	455.00	8

Methyl acetate	79209	$C_3H_6O_2$	3.20	8	16.00	8	−15.50	6	476.85	14
Vinyl acetate	108054	$C_4H_6O_2$	2.60	11	13.40	11	−8.15	11	426.85	11
Ethyl acetate	141786	$C_4H_8O_2$	2.20	11	11.40	11	−4.15	11	426.85	11
Propyl acetate	109604	$C_5H_{10}O_2$	2.05	5	8.00	4	–	–	450.00	4
Isopropyl acetate	108214	$C_5H_{10}O_2$	2.00	5	7.80	4	4.50	6	460.00	4
Butyl acetate	123864	$C_6H_{12}O_2$	1.70	8	7.60	8	21.85	4	425.00	8
Isobutyl acetate	110190	$C_6H_{12}O_2$	1.30	11	10.50	11	17.85	11	422.85	11
Amyl acetate	628637	$C_7H_{14}O_2$	1.10	11	7.50	11	23.00	11	360.00	11
Inorganic										
Hydrogen	1333740	H_2	4.00	11	75.00	11	−260.15	4	400.00	11
Ammonia	7664417	NH_3	16.00	11	25.00	11	Gas	3	650.85	11
Cyanogen	460195	C_2N_2	6.00	11	32.00	11	−62.15	4	661.85	4
Oxides										
Carbon monoxide	630380	CO	12.50	11	74.00	11	−206.15	4	608.85	11
Ethylene oxide	75218	C_2H_4O	3.00	11	100.00	8	−19.81	5	428.85	11
Propylene oxide	75569	C_3H_6O	2.10	11	21.50	11	−37.15	11	465.00	11
Dioxan	123911	$C_4H_8O_2$	2.00	11	22.00	11	11.85	11	180.00	11
Mesityl oxide	141797	$C_6H_{10}O$	1.30	4	7.20	4	30.00	4	344.85	4
Styrene oxide	100425	C_8H_8O	1.10	11	–	–	31.85	11	463.00	11
Peroxides										
Di-*tert*-butyl peroxide	110054	$C_8H_{18}O_2$	1.00	6	7.05	4	1.00	–	79.85	4
Sulfur containing										
Carbon disulfide	75150	CS_2	1.30	11	50.00	11	−30.00	–	90.00	11
Hydrogen sulfide	7783064	H_2S	4.30	14	45.50	14	−107.15	–	260.00	11
Carbon oxysulfide	463581	COS	12.00	11	29.00	11	−88.15	–	250.00	6
Dimethyl sulfide	75183	C_2H_6S	2.20	8	19.70	8	−36.00	–	205.00	11
Chlorine containing										
Methyl chloride	74873	CH_3Cl	8.10	11	17.20	11	−70.15	4	631.85	11
Ethyl chloride	75003	C_2H_5Cl	3.80	11	15.40	11	−50.00	11	518.85	11
Isopropyl chloride	75296	C_3H_7Cl	2.80	11	10.70	11	−35.00	11	592.85	11
Ethylene dichloride	107062	$C_2H_2Cl_2$	6.20	11	16.00	6	12.85	11	412.85	11
Propylene dichloride	78875	$C_3H_6Cl_2$	3.40	11	14.50	11	13.00	11	556.85	11
Dichloromethane	75092	CH_2Cl_2	14.00	6	22.00	4	− 9.15	4	615.00	11
2-Chloroethanol	107073	C_2H_5ClO	4.90	11	15.90	11	40.55	12	425.00	11
Trichloroethylene	79016	C_2HCl_3	8.00	11	40.00	5	32.22	11	410.00	11
Hexachlorobutadiene	87683	C_4Cl_6	2.90	1	15.70	1	121.85	10	610.00	11
Vinyl chloride	75014	C_2H_3Cl	3.60	11	33.00	11	−78.15	11	471.85	11
Chlorobenzene	108907	C_6H_5Cl	1.30	11	7.10	11	31.85	11	637.85	11
Benzyl chloride	100447	C_7H_7Cl	1.10	11	8.00	4	60.00	11	585.00	11
Bromides										
Methyl bromide	74839	CH_3Br	10.00	11	15.00	11	−48.15	4	537.22	11
Glycols										
Ethylene glycol	107211	$C_2H_6O_2$	3.20	11	33.00	10	110.85	11	395.85	11
Diethylene glycol	111466	$C_4H_{10}O_3$	2.00	10	17.10	10	123.85	11	223.85	11
Triethylene glycol	112276	$C_6H_{14}O_4$	0.90	11	9.20	11	156.00	11	370.85	11
Amines										
Methyl amine	74895	CH_5N	4.90	11	20.70	11	−62.00	7	430.00	11
Ethyl amine	75047	C_2H_7N	3.50	8	14.00	8	−39.00	6	383.85	7
Dimethyl amine	124403	C_2H_7N	2.80	11	14.40	11	−57.00	7	400.00	11
Isopropylamine	75310	C_3H_7N	2.00	11	10.40	11	−37.00	11	400.00	12
Trimethylamine	75503	C_3H_9N	2.00	11	11.60	11	− 7.15	11	190.00	11
Isopropylamine	75310	C_3H_9N	2.00	11	10.40	11	−37.00	11	400.00	12
Allylamine	107119	C_3H_7N	2.20	11	22.00	11	−28.89	11	373.89	11
Diethyl amine	109897	$C_4H_{11}N$	1.70	12	10.10	12	−39.00	11	310.00	12
tert-Butylamine	75349	$C_4H_{11}N$	1.70	11	8.90	11	− 9.00	11	380.00	5
Triethyl amine	121448	$C_6H_{15}N$	1.20	11	8.00	11	−12.15	12	231.85	10
Cyclohexylamine	108918	$C_6H_{13}N$	0.66	11	8.42	4	31.00	13	293.00	11
Monoethanolamine	141435	C_2H_7NO	3.02	4	24.06	4	85.00	11	410.00	5
Diethanolamine	111422	$C_4H_{11}NO_2$	1.69	4	16.25	4	151.85	11	661.85	11
Dimethylethanolamine	108010	$C_4H_{11}NO$	1.67	4	11.36	4	41.00	11	295.00	11
Miscellaneous										
Acrylonitrile	107131	C_3H_3N	2.42	11	17.34	13	0.00	11	480.85	11
Aniline	62533	$C_6H_{15}N$	1.30	11	11.00	11	70.00	11	616.85	11
Diborane	19287457	B_2H_6	0.90	11	98.00	11	−148.15	4	51.85	11
Methyl methacrylate	80626	$C_5H_8O_2$	2.10	11	12.50	11	11.00	11	435.85	11
Naptha	8030306	–	0.80	8	5.00	8	−6.00	4	290.00	4
Styrene	100425	C_8H_8	1.10	11	6.10	11	31.85	11	490.00	11
Biphenyl	92524	$C_{12}H_{10}$	0.60	11	5.80	11	113.00	11	540.00	11
Methyl acrylate	96333	$C_4H_6O_2$	2.80	4	25.00	4	5.85	4	468.00	5
Phthalic anhydride	85449	$C_8H_4O_3$	1.70	8	10.50	4	151.85	6	583.85	11

LFL and UFL are lower and upper flammability limits respectively in volume percent fuel in air. Values in this table were taken from the Design Institute for Physical Properties (DIPPR) of the American Institute of Chemical Engineers (AIChE), copyright 2007 AIChE and reproduced with permission of AIChE, the DIPPR Environmental Safety Property Data and Estimations Steering Committee and of the DIPPR Evaluated Process Design Data Project Steering Committee. Their source should be cited as T. N. Rogers, D. A. Zei, R. L. Rowley, W. V. Wilding, J. L. Oscarson, Y. Yang, N. A. Zundel, T. E. Daubert, R. P. Danner, DIPPR® Data Compilation of Pure Chemical Properties, Design Institute for Physical Properties, AIChE, New York (2007). Flammability limits are from B. Lewis and G. Von Elbe, *Combustion, Flames and Explosions of Gases*, New York: Harcourt Brace Jovanovich (1987). Flash point data are from N. I. Sax, *Dangerous Properties of Industrial Materials*, 6th ed., New York: Van Nostrand Reinhold (1984). Autoignition data are from I. Glassman, *Combustion*, 3d ed., New York: Academic Press (1996). The ratings reflect DIPPR® ESP's effort to provide a critical evaluation and quality assessment of each data point with 15 being the highest score possible. The rating is not directly correlated with the estimated experimental uncertainty.

TABLE 2-318 Viscosities of Liquids: Coordinates for Use with Fig. 2-32

Liquid	*X*	*Y*	Liquid	*X*	*Y*
Acetaldehyde	15.2	4.8	Freon-113	12.5	11.4
Acetic acid, 100%	12.1	14.2	Glycerol, 100%	2.0	30.0
Acetic acid, 70%	9.5	17.0	Glycerol, 50%	6.9	19.6
Acetic anhydride	12.7	12.8	Heptane	14.1	8.4
Acetone, 100%	14.5	7.2	Hexane	14.7	7.0
Acetone, 35%	7.9	15.0	Hydrochloric acid, 31.5%	13.0	16.6
Acetonitrile	14.4	7.4	Iodobenzene	12.8	15.9
Acrylic acid	12.3	13.9	Isobutyl alcohol	7.1	18.0
Allyl alcohol	10.2	14.3	Isobutyric acid	12.2	14.4
Allyl bromide	14.4	9.6	Isopropyl alcohol	8.2	16.0
Allyl iodide	14.0	11.7	Isopropyl bromide	14.1	9.2
Ammonia, 100%	12.6	2.0	Isopropyl chloride	13.9	7.1
Ammonia, 26%	10.1	13.9	Isopropyl iodide	13.7	11.2
Amyl acetate	11.8	12.5	Kerosene	10.2	16.9
Amyl alcohol	7.5	18.4	Linseed oil, raw	7.5	27.2
Aniline	8.1	18.7	Mercury	18.4	16.4
Anisole	12.3	13.5	Methanol, 100%	12.4	10.5
Arsenic trichloride	13.9	14.5	Methanol, 90%	12.3	11.8
Benzene	12.5	10.9	Methanol, 40%	7.8	15.5
Brine, $CaCl_2$, 25%	6.6	15.9	Methyl acetate	14.2	8.2
Brine, NaCl, 25%	10.2	16.6	Methyl acrylate	13.0	9.5
Bromine	14.2	13.2	Methyl *i*-butyrate	12.3	9.7
Bromotoluene	20.0	15.9	Methyl *n*-butyrate	13.2	10.3
Butyl acetate	12.3	11.0	Methyl chloride	15.0	3.8
Butyl acrylate	11.5	12.6	Methyl ethyl ketone	13.9	8.6
Butyl alcohol	8.6	17.2	Methyl formate	14.2	7.5
Butyric acid	12.1	15.3	Methyl iodide	14.3	9.3
Carbon dioxide	11.6	0.3	Methyl propionate	13.5	9.0
Carbon disulfide	16.1	7.5	Methyl propyl ketone	14.3	9.5
Carbon tetrachloride	12.7	13.1	Methyl sulfide	15.3	6.4
Chlorobenzene	12.3	12.4	Napthalene	7.9	18.1
Chloroform	14.4	10.2	Nitric acid, 95%	12.8	13.8
Chlorosulfonic acid	11.2	18.1	Nitric acid, 60%	10.8	17.0
Chlorotoluene, ortho	13.0	13.3	Nitrobenzene	10.6	16.2
Chlorotoluene, meta	13.3	12.5	Nitrogen dioxide	12.9	8.6
Chlorotoluene, para	13.3	12.5	Nitrotoluene	11.0	17.0
Cresol, meta	2.5	20.8	Octane	13.7	10.0
Cyclohexanol	2.9	24.3	Octyl alcohol	6.6	21.1
Cyclohexane	9.8	12.9	Pentachloroethane	10.9	17.3
Dibromomethane	12.7	15.8	Pentane	14.9	5.2
Dichloroethane	13.2	12.2	Phenol	6.9	20.8
Dichloromethane	14.6	8.9	Phosphorus tribromide	13.8	16.7
Diethyl ketone	13.5	9.2	Phosphorus trichloride	16.2	10.9
Diethyl oxalate	11.0	16.4	Propionic acid	12.8	13.8
Diethylene glycol	5.0	24.7	Propyl acetate	13.1	10.3
Diphenyl	12.0	18.3	Propyl alcohol	9.1	16.5
Dipropyl ether	13.2	8.6	Propyl bromide	14.5	9.6
Dipropyl oxalate	10.3	17.7	Propyl chloride	14.4	7.5
Ethyl acetate	13.7	9.1	Propyl formate	13.1	9.7
Ethyl acrylate	12.7	10.4	Propyl iodide	14.1	11.6
Ethyl alcohol, 100%	10.5	13.8	Sodium	16.4	13.9
Ethyl alcohol, 95%	9.8	14.3	Sodium hydroxide, 50%	3.2	25.8
Ethyl alcohol, 40%	6.5	16.6	Stannic chloride	13.5	12.8
Ethyl benzene	13.2	11.5	Succinonitrile	10.1	20.8
Ethyl bromide	14.5	8.1	Sulfur dioxide	15.2	7.1
2-Ethyl butyl acrylate	11.2	14.0	Sulfuric acid, 110%	7.2	27.4
Ethyl chloride	14.8	6.0	Sulfuric acid, 100%	8.0	25.1
Ethyl ether	14.5	5.3	Sulfuric acid, 98%	7.0	24.8
Ethyl formate	14.2	8.4	Sulfuric acid, 60%	10.2	21.3
2-Ethyl hexyl acrylate	9.0	15.0	Sulfuryl chloride	15.2	12.4
Ethyl iodide	14.7	10.3	Tetrachloroethane	11.9	15.7
Ethyl propionate	13.2	9.9	Thiophene	13.2	11.0
Ethyl propyl ether	14.0	7.0	Titanium tetrachloride	14.4	12.3
Ethyl sulfide	13.8	8.9	Toluene	13.7	10.4
Ethylene bromide	11.9	15.7	Trichloroethylene	14.8	10.5
Ethylene chloride	12.7	12.2	Triethylene glycol	4.7	24.8
Ethylene glycol	6.0	23.6	Turpentine	11.5	14.9
Ethylidene chloride	14.1	8.7	Vinyl acetate	14.0	8.8
Fluorobenzene	13.7	10.4	Vinyl toluene	13.4	12.0
Formic acid	10.7	15.8	Water	10.2	13.0
Freon-11	14.4	9.0	Xylene, ortho	13.5	12.1
Freon-12	16.8	5.6	Xylene, meta	13.9	10.6
Freon-21	15.7	7.5	Xylene, para	13.9	10.9
Freon-22	17.2	4.7			

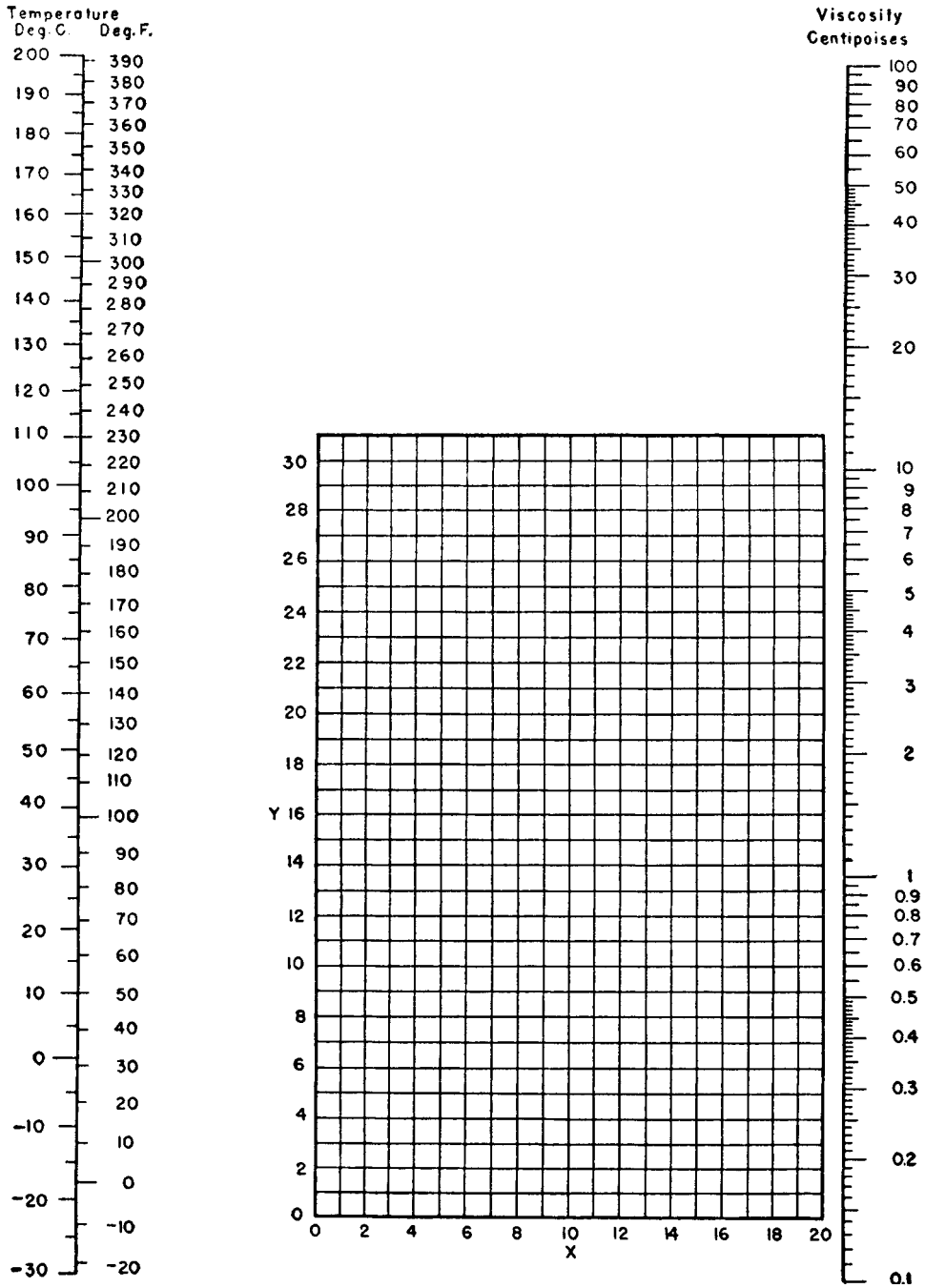

FIG. 2-32 Nomograph for viscosities of liquids at 1 atm. For coordinates see Table 2-318. To convert centipoises to pascal-seconds, multiply by 0.001.

TABLE 2-320

No.	Compound	Range, °C	Exp pt	% Avg abs devi
31	Acetaldehyde	0 – 30	2	0.4
40	Acetic acid	18 – 79	5	0.1
29	Acetone	0 – 40	3	0.4
20	Aniline	0 – 93	6	1.3
2	Benzaldehyde	16 – 68	4	0.7
13	Benzene	20 – 116	5	0.6
47	n-Butane	– 21 – 0	2	0.2
16	n-Butanol	0 – 102	7	0.4
48	i-Butanol	0 – 20	2	0.6
49	s-Butanol	0 – 65	3	0.2
18	t-Butanol	20 – 77	3	2.5
28	Butyl acetate	0 – 38	4	1.1
23	Carbon tetrachloride	– 20 – 25	4	1.1
25	Chlorobenzene	– 40 – 80	6	0.5
42	Chloroform	0 – 40	3	1.3
19	m-Cresol	20 – 80	2	0.2
11	Cyclohexane	20 – 38	2	0.4
7	n-Decane	20 – 76	5	1.0
30	Diethyl ether	0 – 25	3	0.7
9	2,3-Dimethylbutane	32 – 49	2	0.3
38	n-Dodecane	0 – 63	6	1.1
15	Ethanol	17 – 77	7	0.5
27	Ethyl acetate	6 – 160	9	1.6
14	Ethylbenzene	0 – 80	3	0.7
24	Ethyl bromide	0 – 30	3	0.3
4	n-Heptane	0 – 60	3	0.3
3	n-Hexane	17 – 40	5	1.4
26	Iodobenzene	– 20 – 80	4	0.7
41	Methanol	20 – 62	6	0.2
39	Methyl acetate	4 – 21	2	0.4
12	Methylcyclopentane	20 – 38	2	0.1
22	Methylene chloride	– 20 – 20	3	0.9
8	2-Methylpentane	32 – 49	2	0.5
6	n-Nonane	16 – 77	5	2.0
5	n-Octane	0 – 77	3	0.3
10	i-Octane	20 – 77	4	1.6
17	n-Octanol	20 – 212	3	1.3
43	n-Pentanol	0 – 38	3	0.4
1	Propane	– 60 – 50	4	1.6
32	n-Propanol	16 – 66	6	0.6
21	Propionic acid	12 – 30	3	1.7
44	n-Propyl acetate	0 – 38	2	0.1
33	i-Propylbenzene	0 – 38	4	0.2
45	Refrigerant-11, $CFCl_3$	0 – 20	4	0.5
46	Refrigerant-12, CF_2Cl_2	– 42 – 70	4	1.8
50	Refrigerant-13, CF_3Cl	– 20 – 20	4	1.7
51	Refrigerant-22, CHF_2Cl	– 65 – 60	7	2.5
52	Refrigerant-113, $C_2F_3Cl_3$	0 – 20	4	0.7
53	Refrigerant-114, $C_2F_4Cl_2$	– 25 – 20	4	0.8
54	Refrigerant-142, $C_2H_3F_2Cl$	0 – 90	2	0.9
34	Toluene	– 70 – 200	5	1.8
55	n-Tridecane	20 – 228	5	2.4
36	m-Xylene	0 – 208	5	1.0
35	o-Xylene	0 – 208	5	0.7
37	p-Xylene	0 – 251	5	1.4

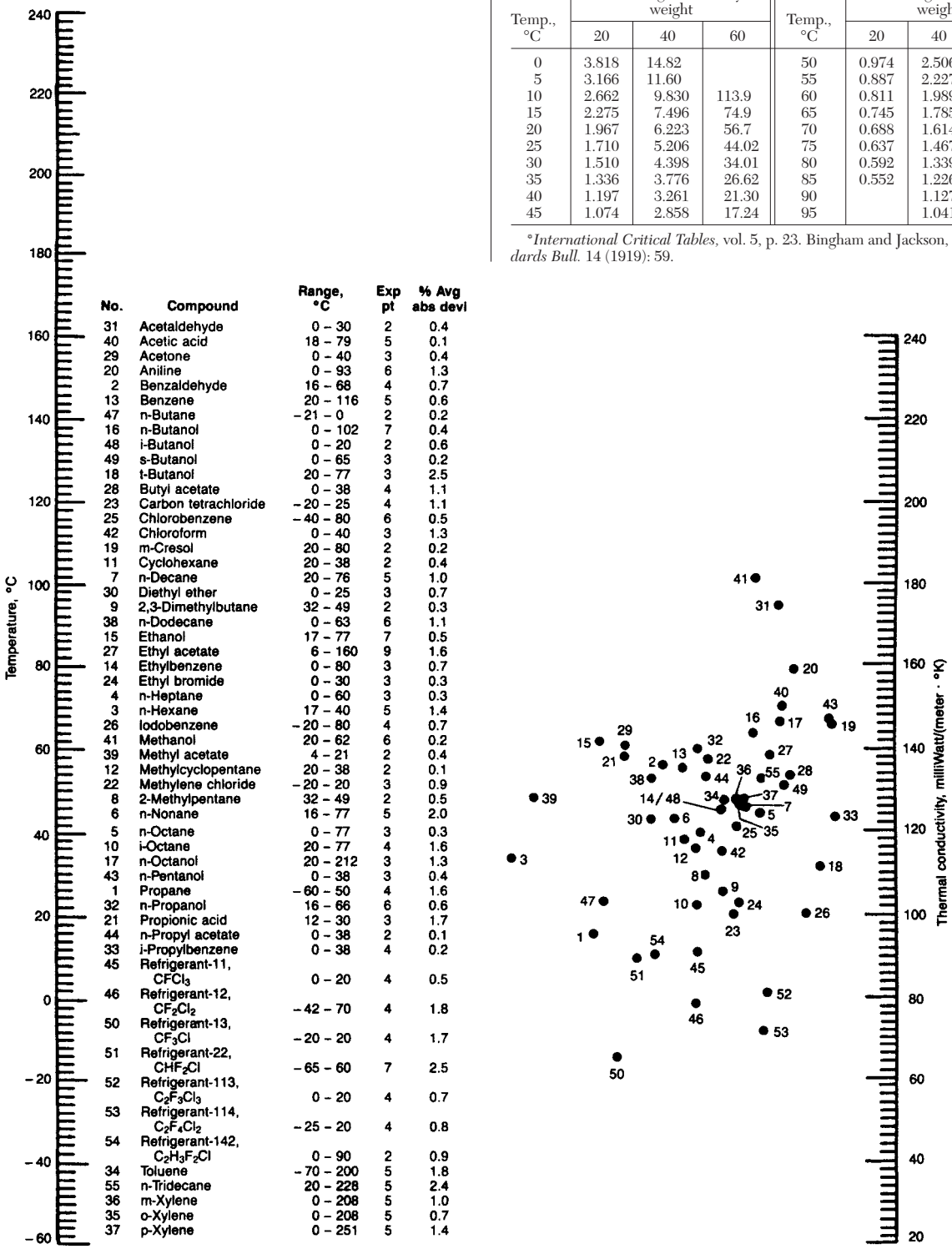

FIG. 2-33 and TABLE 2-320 Nomograph (*right*) for thermal conductivity of organic liquids. (*From Mallu and Rao, Hydroc. Proc. 78, 1988.*)

TABLE 2-319 Viscosity of Sucrose Solutions*

Viscosity in centipoises

Temp., °C	Percentage sucrose by weight			Temp., °C	Percentage sucrose by weight		
	20	40	60		20	40	60
0	3.818	14.82		50	0.974	2.506	14.06
5	3.166	11.60		55	0.887	2.227	11.71
10	2.662	9.830	113.9	60	0.811	1.989	9.87
15	2.275	7.496	74.9	65	0.745	1.785	8.37
20	1.967	6.223	56.7	70	0.688	1.614	7.18
25	1.710	5.206	44.02	75	0.637	1.467	6.22
30	1.510	4.398	34.01	80	0.592	1.339	5.42
35	1.336	3.776	26.62	85	0.552	1.226	4.75
40	1.197	3.261	21.30	90		1.127	4.17
45	1.074	2.858	17.24	95		1.041	3.73

**International Critical Tables,* vol. 5, p. 23. Bingham and Jackson, *Bur. Standards Bull.* 14 (1919): 59.

TABLE 2-321 Prandtl Number of Air*

Temperature, K	Pressure, bar											
	1	5	10	20	30	40	50	60	70	80	90	100
80	mix	2.31	2.32	2.35	2.37	2.40	2.42	2.45	2.48	2.51	2.54	2.57
90	0.796	1.76	1.77	1.78	1.79	1.81	1.82	1.83	1.85	1.87	1.89	1.91
100	0.786	0.872	1.54	1.53	1.53	1.53	1.53	1.53	1.53	1.54	1.54	1.55
120	0.773	0.813	0.89	1.44	1.65	1.54	1.48	1.43	1.40	1.38	1.36	1.34
140	0.763	0.782	0.82	0.94	1.20	1.59	2.14	2.43	2.07	1.78	1.62	1.52
160	0.754	0.765	0.78	0.84	0.92	1.03	1.13	1.25	1.37	1.65	1.83	1.72
180	0.745	0.754	0.763	0.792	0.830	0.876	0.932	1.00	1.07	1.14	1.20	1.25
200	0.738	0.743	0.749	0.766	0.788	0.812	0.841	0.87	0.90	0.95	0.97	1.00
240	0.724	0.727	0.729	0.737	0.746	0.756	0.767	0.78	0.80	0.81	0.81	0.82
280	0.710	0.711	0.713	0.717	0.721	0.726	0.731	0.737	0.742	0.75	0.75	0.76
300	0.705	0.707	0.708	0.712	0.715	0.717	0.721	0.725	0.728	0.732	0.737	0.742
350	0.699	0.699	0.699	0.701	0.703	0.705	0.707	0.709	0.711	0.712	0.714	0.716
400	0.694	0.694	0.694	0.695	0.696	0.697	0.698	0.699	0.700	0.701	0.703	0.704
450	0.691	0.691	0.691	0.691	0.692	0.692	0.693	0.693	0.694	0.695	0.695	0.696
500	0.689	0.689	0.689	0.689	0.689	0.690	0.690	0.690	0.690	0.691	0.691	0.691
600	0.690	0.690	0.690	0.689	0.689	0.689	0.689	0.689	0.689	0.690	0.690	0.690
700	0.696	0.696	0.695	0.695	0.695	0.695	0.695	0.695	0.695	0.695	0.695	0.695
800	0.705	0.704	0.704	0.704	0.704	0.703	0.703	0.703	0.703	0.702	0.702	0.702
900	0.709	0.709	0.708	0.708	0.708	0.708	0.708	0.708	0.708	0.708	0.708	0.708
1000	0.711	0.711	0.711	0.711	0.711	0.710	0.710	0.710	0.710	0.709	0.709	0.709

*Compiled by P. E. Liley from tables of specific heat at constant pressure, thermal conductivity, and viscosity given in SI units for integral kelvin temperatures and pressures in bars by Vasserman. *Thermophysical Properties of Air and Its Components* and *Thermophysical Properties of Liquid Air and Its Components.* Nauka, Moscow, and in translated form by the National Bureau of Standards, Washington. The number of significant figures given above reflects the similar numbers appearing for the constituent properties in the source references. While reasonable agreement occurs for atmospheric pressure with some other works, the fragmentary data available for the saturated, etc., states show large deviations.

TABLE 2-322 Prandtl Number of Liquid Refrigerants*

Refrigerant	No.	Temperature, K										
		180	200	220	240	260	280	300	320	340	360	380
Trichlorofluoromethane	11		11.9	8.64	6.73	5.33	4.74	4.18				
Dichlorodifluoromethane	12	7.00	5.25	4.27	3.65	3.27	3.08	3.04	3.19	3.44	4.00	
Chlorotrifluoromethane	13		2.96	2.67	2.69	3.05	3.57		—	—	—	—
Bromotrifluoromethane	13B1	4.80	3.75	3.27	2.94	2.83	3.03	3.61	4.52		—	—
Dichlorofluoromethane	21			5.72	4.50	3.87	3.48	3.25	3.16	3.17		
Chlorodifluoromethane	22	4.68	3.76	3.23	2.93	2.79	2.77	2.87	3.18	3.54		—
Methyl chloride	40			2.53	2.42	2.40	2.45	2.60	2.85			
Trichlorotrifluoroethane	113	—	—	—					7.04	6.23	5.61	5.18
Dichlorotetrafluoroethane	114	25.7	15.13	11.18	8.59	6.94	5.77	5.06	4.78	4.82		
Chloropentafluoroethane	115	—	7.85	6.16	5.21	4.67	4.40	4.46	4.90		—	—
Ethane	170	2.55	2.29	2.22	2.40	2.70			—	—	—	—
Propane	290	5.28	4.46	3.88	3.44	3.16	3.02	3.16				
Octafluorocyclobutane	C318	—	—	—	11.2	8.74	7.35	6.37	5.87	5.96		—
Dichlorodifluoromethane/difluoroethane	500		5.78	4.23	3.40	3.13	3.01	3.13	3.35	3.72		—
Chlorodifluoromethane/chloropentafluoroethane	502		5.73	4.71	4.13	3.81					—	—
Trifluoromethane/chlorotrifluoromethane	503	2.10	2.09	2.24	2.43	2.89		—	—	—	—	—
Methylene fluoride/chloropentafluoroethane	504		4.90	3.60	3.04	2.79	2.69	2.85	3.30	—	—	—
Butane	600	8.35	6.19	5.20	4.44	3.83	3.44	3.22	3.07	3.02		
Isobutane (2-methyl propane)	600a		8.26	6.36	5.18	4.49	3.93	3.66	3.53	3.53	3.77	4.68
Ammonia	717	—			1.97	1.76	1.54	1.40	1.29	1.24	1.25	1.34
Water	718	—	—	—	—	—	10.3	5.69	3.65	2.60	1.99	1.59
Ethylene	1150	1.85	1.74	1.78	2.07	2.70	4.4	—	—	—	—	—
Propylene	1270	3.80	2.24	1.88	1.71	1.71	1.88	2.24	3.91	4.73		—

*Dashes indicate inaccessible states. Average uncertainty is about 20 percent. Values derived from formulations for thermal conductivity, specific heat at constant pressure, and viscosity contained in *Thermophysical Properties of Refrigerants.* American Society of Heating, Refrigerating and Air-Conditioning Engineers, New York, 1976. For further details see M. W. Johnson, M.S.M.E. thesis, Purdue University, West Lafayette, Ind., 1976.

TABLE 2-323 Thermophysical Properties of Miscellaneous Saturated Liquids

Substance	Property	Temperature, °C															
		–50	–40	–30	–20	–10	0	10	20	30	40	50	60	70	80	90	100
Acetaldehyde	ρ (kg/m³)	863	852	840	828	816	804	794	783								
	c_p(kJ/kg·K)	2.05	2.08	2.11	2.14	2.17	2.20	2.24	2.28								
	μ (10^{-6}Pa·s)	460	404	358	321	290	263	241	222								
	k (W/m·K)	0.211	0.206	0.200	0.195	0.189	0.184	0.182	0.180								
	Pr	4.47	4.08	3.78	3.52	3.33	3.14	2.97	2.81								
Acetic acid	ρ (kg/m³)								1049	1039	1028	1018	1006	995	984	972	960
	c_p (kJ/kg·K)								2.031								
	μ (10^{-6}Pa·s)								1210	1102	1010	795	600				
	k (W/m·K)								0.173	0.170	0.168	0.167	0.165	0.163	0.161		
	Pr								14.2								
Aniline	ρ (kg/m³)	—	—	—	—	—	1039	1030	1022	1013	1005	996	987	978	969	960	951
	c_p(kJ/kg·K)	—	—	—	—	—	2.024	2.047	2.071	2.093	2.113	2.132	2.17	2.20	2.23	2.27	2.32
	μ (10^{-6}Pa·s)	—	—	—	—	—	10200	6500	4400	3160	2370	1850	1510	1270	1090	935	825
	k (W/m·K)	—	—	—	—	—	0.186	0.184	0.182	0.180	0.177	0.174	0.171	0.169	0.168	0.167	0.167
	Pr	—	—	—	—	—	111	72	50	36.7	28.3	22.7	19.2	16.5	14.5	12.7	11.5
Butanol	ρ (kg/m³)	845	841	837	833	829	825	817	810	803	797	791	784	776	768	760	753
	c_p(kJ/kg·K)	1.947	1.996	2.046	2.100	2.153	2.202	2.262	2.345	2.437	2.524	2.621					
	μ (10^{-6}Pa·s)	34700	22400	14700	10300	7400	5190	3870	2950	2300	1780	1410	1140	930	760	630	535
	k (W/m·K)	0.175	0.174	0.173	0.172	0.171	0.170	0.168	0.167	0.166	0.165	0.164	0.163	0.162	0.161	0.160	0.159
	Pr	3860	2570	1740	1260	930	670	120	41	33.8	27.2	22.5					
Carbon disulfide	ρ (kg/m³)	1362	1348	1334	1320	1306	1292	1278	1263								
	c_p(kJ/kg·K)	0.988	0.989	0.990	0.991	0.993	0.996	1.004	1.017								
	μ (10^{-6}Pa·s)	630	580	535	496	463	435	405	375	350	330						
	k (W/m·K)	0.194	0.190	0.186	0.182	0.178	0.174	0.170	0.166	0.161	0.158	0.156	0.154	0.152	0.150		
	Pr	3.21	3.02	2.85	2.70	2.58	2.49	2.39	2.30								
Cyclohexane	ρ (kg/m³)	—	—	—	—	—	—	789	779	769	759	750	740	731	721		
	c_p(kJ/kg·K)	—	—	—	—	—	—	2.068	2.081	2.094	2.106	2.119					
	μ (10^{-6}Pa·s)	—	—	—	—	—	—	1175	980	820	710	605	540				
	k (W/m·K)	—	—	—	—	—	—	0.122	0.120	0.119	0.118	0.117	0.116	0.114	0.112		
	Pr	—	—	—	—	—	—	19.9	17.0	14.4	12.7	11.0					
Ethanol	ρ (kg/m³)						806	798	789	781	776	763	754	745	735	725	716
	c_p(kJ/kg·K)	2.01	2.04	2.08	2.13	2.19	2.27	2.35	2.43	2.52	2.62	2.73	2.83	2.93	3.03	3.19	3.30
	μ (10^{-6}Pa·s)	6400	4790	3650	2825	2220	1770	1470	1200	1000	835	700	590	500	435	370	314
	k (W/m·K)	0.188	0.186	0.184	0.181	0.179	0.177	0.175	0.173	0.171	0.168	0.165	0.162	0.159	0.156	0.153	0.151
	Pr	68.4	52.5	41.3	33.2	27.2	22.7	19.7	16.9	14.7	13.0	11.6	10.3	9.2	8.4	7.7	6.9
Ethyl acetate	ρ (kg/m³)				947	935	924	912	901	888	876	863	851	838	825	811	797
	c_p(kJ/kg·K)								2.01								
	μ (10^{-6}Pa·s)	1090					580	510	455	400	370	345	310	280	250	230	220
	k (W/m·K)								0.145	0.142	0.139	0.136	0.133	0.130	0.127	0.123	0.119
	Pr								6.3								
Ethylamine	ρ (kg/m³)	761	750	739	729	718	707	695	683	671	658	646	633	620	607		
	c_p(kJ/kg·K)	2.95	2.97	2.98	3.00	3.01	3.03										
	μ (10^{-6}Pa·s)	580	500	435	390	350	320										
	k (W/m·K)	0.204	0.201	0.199	0.196	0.194	0.191										
	Pr	8.39	7.39	6.51	5.97	5.43	5.08										
Ethyl ether	ρ (kg/m³)	790	780	769	758	747	736	725	714	702	689	676	666	653	640	625	611
	c_p(kJ/kg·K)	2.135	2.156	2.179	2.205	2.233	2.265	2.299	2.332	2.36	2.39	2.43	2.47	2.51			
	μ (10^{-6}Pa·s)	550	470	410	365	330	290	265	233	214	197	181	166	153	140	129	118
	k (W/m·K)	0.159	0.155	0.151	0.147	0.144	0.140	0.139	0.134	0.129	0.125	0.120	0.116	0.112			
	Pr	7.39	6.54	5.92	5.48	5.12	4.69	4.38	4.05	3.92	3.77	3.67	3.54	3.43			
Ethyl iodide	ρ (kg/m³)																
	c_p(kJ/kg·K)			0.656	0.663	0.670	0.677	0.684	0.691	0.698	0.705	0.712	0.718	0.724			
	μ (10^{-6}Pa·s)						730	655	590	539	495	455	420	390			
	k (W/m·K)						0.092	0.090	0.088	0.086	0.085	0.083	0.081	0.080			
	Pr						5.37	4.98	4.63	4.30	4.11	3.90	3.72	3.53			
Ethylene glycol	ρ (kg/m³)						1127	1120	1113	1106	1099	1092	1085	1077	1070	1063	1056
	c_p(kJ/kg·K)						2.272	2.327	2.381	2.431	2.484	2.536	2.586	2.636	2.685	2.734	2.779
	μ (10^{-6}Pa·s)						57000	33300	20200	13400	9100	7070	4000	3450	3000	2440	2000
	k (W/m·K)						0.254	0.255	0.256	0.258	0.259	0.260					
	Pr						510	305	190	126	87.3	69.0					
Formic acid	ρ (kg/m³)						1241	1231	1220	1209	1196	1184	1170	1156	1140	1124	1108
	c_p(kJ/kg·K)																
	μ (10^{-6}Pa·s)							2260	1800	1470	1220	1030	890	780	680	615	550
	k (W/m·K)						0.265	0.261	0.257	0.257	0.253	0.250	0.246	0.243	0.240	0.236	0.232
	Pr																

TABLE 2-323 Thermophysical Properties of Miscellaneous Saturated Liquids (*Concluded*)

Substance	Property	Temperature, °C															
		–50	–40	–30	–20	–10	0	10	20	30	40	50	60	70	80	90	100
Gasoline	ρ (kg/m^3)				784	775	767	759	751	743	735	721	717	708	699	690	681
	c_p(kJ/kg·K)				1.88	1.92	1.97	2.02	2.06	2.11	2.15	2.20	2.25	2.30	2.35	2.41	2.46
	μ (10^{-6}Pa·s)	1710	1400	1170	990	850	735	645	530	464	410	367	330	298	270	246	225
	k (W/m·K)	0.131	0.128	0.125	0.123	0.121	0.120	0.118	0.116	0.114	0.112	0.110	0.108	0.106	0.104	0.102	0.100
	Pr				15.1	13.5	12.1	11.0	9.41	8.59	7.87	7.34	6.88	6.47	6.10	5.81	5.54
Glycerol	ρ (kg/m^3)	—	—	—	—	—	1276	1270	1260	1254	1248	1242					
	c_p(kJ/kg·K)								2.393	2.406	2.457	2.504	2.548	2.588	2.625	2.657	2.686
	μ (10^{-6}Pa·s)						1.2.+7	4.0.+6	1.5.+6								
	k (W/m·K)								0.284	0.285	0.287	0.288	0.289	0.291	0.293	0.294	0.295
	Pr								12650								
Kerosene	ρ (kg/m^3)						781	774	767	760	754	748	742				
	c_p(kJ/kg·K)						1.91	1.96	2.02	2.07	2.13	2.18	2.23	2.28	2.32	2.35	2.38
	μ (10^{-6}Pa·s)	1150	725	500	360	275	215	173	149	126	108	95	83	73	66	60	55
	k (W/m·K)						0.140	0.139	0.139	0.138	0.138	0.137	0.137				
	Pr						2.93	2.44	2.17	1.89	1.67	1.51	1.35				
Methanol	ρ (kg/m^3)									783	774	766	756	746	736	725	711
	c_p(kJ/kg·K)	2.30	2.32	2.35	2.37	2.40	2.42	2.45	2.47	2.49	2.52	2.55	2.65	2.78	2.94	3.13	3.30
	μ (10^{-6}Pa·s)	2305	1800	1410	1170	975	820	692	590	510	455	400	355	315	271	240	218
	k(W/m·K)	0.225	0.222	0.219	0.216	0.212	0.209	0.206	0.203	0.199	0.195	0.192	0.189	0.187	0.184	0.182	0.180
	Pr	23.6	18.8	15.1	12.9	11.0	9.53	8.23	7.18	6.38	5.88	5.31	4.98	4.68	4.34	4.13	3.99
Methyl formate	ρ (kg/m^3)	1069	1056	1043	1030	1017	1003	989	975	960	944	929	913	897	880	863	845
	c_p(kJ/kg·K)	1.84	1.86	1.88	1.90	1.92	1.95	1.99	2.03	2.08							
	μ (10^{-6}Pa·s)	830	711	618	544	481	430	380	345	315							
	k (W/m·K)	0.217	0.213	0.209	0.205	0.200	0.195	0.191	0.186	0.180							
	Pr	7.04	6.21	5.56	5.04	4.62	4.30	3.96	3.77	3.64							
Oil, castor	ρ (kg/m^3)																
	c_p(kJ/kg·K)																
	μ (10^{-6}Pa·s)							2,420,000	986,000	451,000	231,000	125,000	74,000	43,000			
	k (W/m·K)							0.182	0.181	0.180	0.179	0.178	0.177	0.176	0.175	0.174	0.17
	Pr																
Oil, olive	ρ (kg/m^3)								914								
	c_p(kJ/kg·K)								1.633								
	μ (10^{-6}Pa·s)							138,000	84,000	52,000	36,300	24,500	17,000	12,400			
	k (W/m·K)							0.170	0.169	0.168	0.167	0.166	0.166	0.165	0.165	0.164	0.164
	Pr								810								
Pentane	ρ (kg/m^3)	693	684	674	665	656	646	636	626	616	606	596	585	574	562	550	538
	c_p(kJ/kg·K)	2.060	2.084	2.110	2.137	2.167	2.206	2.239	2.273								
	μ (10^{-6}Pa·s)	489	428	379	339	307	279	254	234	209	190	175	161	148	137	124	113
	k (W/m·K)	0.142	0.139	0.136	0.132	0.128	0.125	0.122	0.119	0.115	0.112	0.108	0.105	0.101	0.098	0.095	0.091
	Pr	7.14	6.42	5.88	5.49	5.20	4.92	4.66	4.47								
Propanol	ρ (kg/m^3)	849					819	811	814	796	788	779	770	761	752	747	743
	c_p(kJ/kg·K)	1.955					2.219										
	μ (10^{-6}Pa·s)	20,200	13,500	9500	6900	5110	3900	2900	2245	1720	1400	1130	921	760	630	508	447
	k (W/m·K)	0.167	0.166	0.165						0.171	0.169	0.168	0.167	0.165	0.164	0.163	0.162
	Pr	236															
Sulfuric acid	ρ (kg/m^3)								1834								
	c_p(kJ/kg·K)								1.382								
	μ (10^{-6}Pa·s)						48,400	35,200	25,400	15,700	11,500	8820	7220	6090	5190		
	k (W/m·K)						0.314										
	Pr																
Toluene	ρ (kg/m^3)	932	923	913	904	895	886	876	867	858	848	839	829	820	810	800	790
	c_p(kJ/kg·K)	1.514	1.535	1.556	1.579	1.602	1.633	1.652	1.675	1.701	1.73	1.76	1.80	1.83	1.87	1.92	1.97
	μ (10^{-6}Pa·s)	2120	1670	1345	1100	915	770	670	590	520	470	420	380	355	325	295	270
	k (W/m·K)	0.152	0.149	0.147	0.144	0.142	0.139	0.137	0.134	0.132	0.129	0.126	0.124	0.122	0.119	0.117	0.114
	Pr	21.1	17.8	14.2	12.1	10.3	9.0	8.1	7.4	6.7	6.3	5.9	5.5	5.3	5.1	4.8	4.7
Turpentine	ρ (kg/m^3)																
	c_p(kJ/kg·K)						1.72	1.76	1.80			1.93					
	μ (10^{-6}Pa·s)						2250	1780	1490	1270	1070	925	820	730	675		
	k (W/m·K)						0.130	0.129	0.128	0.127	0.126	0.125					
	Pr						29.8	24.3	20.9	18.4	16.1	14.3					

TABLE 2-324 Diffusivities of Pairs of Gases and Vapors (1 atm)

D_v in cm^2/s

Substance	Temp., °C	Air	A	H_2	O_2	N_2	CO_2	N_2O	CH_4	C_2H_6	C_2H_4	n-C_4H_{10}	i-C_4H_{10}	Ref.
Acetic acid	0	0.1064		0.416			0.0716							8
Acetone	0	.109		.361										6, 16
n-Amyl alcohol	0	.0589		.235			.0422							8
sec-Amyl alcohol	30	.072												5
Amyl butyrate	0	.040												8
Amyl formate	0	.0543												8
i-Amyl formate	0	.058												8
Amyl isobutyrate	0	.0419		.171										8
Amyl propionate	0	.046		.1914			.0347							8
Aniline	0	.0610												8
	30	.075												5
Anthracene	0	.0421												8
Argon	20					0.194								18
Benzene	0	.077		.306	0.0797		.0528							8, 15
Benzidine	0	.0298												8
Benzyl chloride	0	.066												8
n-Butyl acetate	0	.058												8
i-Butyl acetate	0	.0612		.2364			.0425							8
n-Butyl alcohol	0	.0703		.2716			.0476							8
	30	.088												5
i-Butyl alcohol	0	.0727		.2771			.0483							8
Butyl amine	0	.0821												8
i-Butyl amine	0	.0853												8
i-Butyl butyrate	0	.0468		.185			.0327							8
i-Butyl formate	0	.0705												8
i-Butyl isobutyrate	0	.0457		.191			.0364							8
i-Butyl proprionate	0	.0529		.203			.0366							8
i-Butyl valerate	0	.0424		.173			.0308							8
Butyric acid	0	.067		.264			.0476							8
i-Butyric acid	0	.0679		.271			.0471							8
Cadmium	0					.17								13
Caproic acid	0	.050												8
i-Caproic acid	0	.0513												8
Carbon dioxide	0	.138		.550	.139			0.096	0.153					8
	20					.163								19
	25							.0996*	.00215†					1, 9
	500‡				.9									18
Carbon disulfide	0	.0892		.369			.063							8
Carbon monoxide	0			.651	.185		.137				0.116			8
	450‡				1.0									18
Carbon tetrachloride	0			.293	0.0636									16, 17
Chlorobenzene	30	.075												5
Chloroform	0	.091												6
Chloropicrin	25	.088												10
m-Chlorotoluene	0	.054												8
o-Chlorotoluene	0	.059												8
p-Chlorotoluene	0	.051												8
Cyanogen chloride	0	.111												10
Cyclohexane	15		0.0719	.319	.0744	.0760								3
	45	.086												6
n-Decane	90			.306		.0841								3
Diethylamine	0	.0884												8
2,3-Dimethyl butane	15		.0657	.301	.0753	.0751								3
Diphenyl	0	.0610												8
n-Dodecane	126			.308		.0813								3
Ethane	0			.459										8
Ethanol	0			.377			.0686							20
Ether (diethyl)	0	.0778		.298			.0546							7, 8
Ethyl acetate	0	.0715		.273			.0487							8
	30	.089												5
Ethyl alcohol	0	.102		.375			.0685							8
Ethyl benzene	0	.0658												8
Ethyl *n*-butyrate	0	.0579		.224			.0407							8
Ethyl *i*-butyrate	0	.0591		.229			.0413							8
Ethylene	0			.486										8
Ethyl formate	0	.0840		.337			.0573							8
Ethyl propionate	0	.068		.236			.0450							4, 8
Ethyl valerate	0	.0512		.205			.0367							8
Eugenol	0	.0377												8
Formic acid	0	.1308		.510			.0874							8
Helium	0		.641											8
	20					.705								19
n-Heptane	38								.066§					
n-Hexane	15		.0663	.290	.0753	.0757								3
Hexyl alcohol	0	.0499		.200			.0351							8
Hydrogen	0	.611			.697	.674	.550	.535	.625	0.459	0.486	0.272	0.277	8
	25						.646			.537	.726			2
	500				4.2									18

TABLE 2-324 Diffusivities of Pairs of Gases and Vapors (1 atm) (*Concluded*)
D_v in cm^2/s

Substance	Temp., °C	Air	A	H_2	O_2	N_2	CO_2	N_2O	CH_4	C_2H_6	C_2H_4	n-C_4H_{10}	i-C_4H_{10}	Ref.
Hydrogen cyanide	0	0.173												10
Hydrogen peroxide	60	.188												11
Iodine	0	.07				0.070								8, 12, 14
Mercury	0	.112		0.53		.13								8, 12, 13
Mesitylene	0	.056												8
Methane	500				1.1									18
Methyl acetate	0	.084		.333			0.0567							8
Methyl alcohol	0	.132		.506			.0879							8
Methyl butyrate	0	.0633		.242			.0446							8
Methyl i-butyrate	0	.0639		.257			.0451							8
Methyl cyclopentane	15		0.0731	.318	0.0742	0.0758								3
Methyl formate	0	.0872												8
Methyl propionate	0	.0735		.295			.0528							8
Methyl valerate	0	0.0569												8
Naphthalene	0	.0513												8
Nitrogen	0				0.181									8
	25						0.165			0.148	0.163	0.0960	0.0908	2
Nitrous oxide	0			0.535			.096							8
n-Octane	0	.0505												8
	30		0.0642	.271	0.0705	0.0710								3
Oxygen	0	.178		.697		0.181	.139							8
Phosgene	0	.095												10
Propionic acid	0	.0829		.330			.0588							8
Propyl acetate	0	.067												8
n-Propyl alcohol	0	.085		.315			.0577							8
i-Propyl alcohol	0	.0818												8
	30	.101												5
n-Propyl benzene	0	.0481												8
i-Propyl benzene	0	.0489												8
n-Propyl bromide	0	.085												8
i-Propyl bromide	0	.0902												8
Propyl butyrate	0	.0530		.206			.0364							8
Propyl formate	0	.0712		.281			.0490							8
n-Propyl iodide	0	.079												8
i-Propyl iodide	0	.0802												8
n-Propyl isobutyrate	0	.0549		.212			.0388							8
i-Propyl isobutyrate	0	.059												8
Propyl propionate	0	.057		.212			.0395							8
Propyl valerate	0	.0466		.189			.0341							8
Safrol	0	.0434												8
i-Safrol	0	.0455												8
Sulfur hexafluoride	25			.418										2
Toluene	0	.076	0.071											4, 8
	30	.088												5
Trimethyl carbinol	0	.087												8
2,2,4-Trimethyl pentane	30		0.0618	.288	0.0688	0.0705								3
2,2,3-Trimethyl heptane	90			.270		0.0684								3
n-Valeric acid	0	0.050												8
i-Valeric acid	0	0.0544		.212			.0376							8
Water	0	0.220		.75			.138							8, 20
	450				1.3									18

* 320 mmHg.
† 40 atm.
‡ Also at other temperatures.
§ Strong function of concentration.

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In this table are a representative selection of diffusion coefficients. The subsection "Prediction and Correlation of Physical Properties" should be consulted for estimation techniques. As general references, the works by Hirschfelder, Curtiss, and Bird, *Molecular Theory of Gases and Liquids,* Wiley, New York, 1964; Chapman and Cowling, *The Mathematical Theory of Non-Uniform Gases,* Cambridge, New York, 1970; Reid and Sherwood, *The Properties of Gases and Liquids,* McGraw-Hill, New York, 1964; and Bretsznajder, *Prediction of Transport and Other Physical Properties of Fluids,* Pergamon, New York, 1971, may be found useful. The most exhaustive recent compilation for gases is by Mason and Marrero, *J. Phys. Chem. Ref. Data,* 1 (1972). Unfortunately, the Mason and Marrero work cites only equations and equation constants and not direct tabulations. For these, the Landolt-Börnstein series is suggested.

TABLE 2-325 Diffusivities in Liquids (25 °C)

Dilute solutions and 1 atm unless otherwise noted; use $D_L\mu/T$ = constant to estimate effect of temperature; ° indicates that reference gives effect of concentration.

Solute	Solvent	$D_L \times 10^5$, sq cm/sec	Estimated possible, error, ± %1	Ref.
Acetal°	Ethanol	1.25	5	11
Acetamide°	Ethanol	0.68	5	11
Acetamide°	Water	1.19	3	11
Acetic acid	Acetone	3.31		4
Acetic acid	Benzene	2.11		1, 4
Acetic acid	Carbon tetrachloride	1.49		4
Acetic acid	Ethylene glycol	0.13		4
Acetic acid	Toluene	2.26		4
Acetic acid°	Water	1.24	3	11
Acetonitrile	Water	1.66	5	11
Acetylene	Water	1.78, 2.11		1, 24
Allyl alcohol°	Ethanol	1.06	5	11
Allyl alcohol	Water	1.19	6	11
Ammonia°	Water	1.7, 2.0, 2.3		1, 11
i-Amyl alcohol°	Ethanol	0.87	5	11
i-Amyl alcohol	Water	1.0	8	11, 25
Benzene	Carbon tetrachloride	1.53		7
Benzene (50 mole %)	*n*-Decane	1.72		26
Benzene (50 mole %)	2,4-Dimethyl pentane	2.49		26
Benzene (50 mole %)	*n*-Dodecane	1.40		26
Benzene (50 mole %)	*n*-Heptane	2.47		26
Benzene (50 mole %)	*n*-Hexadecane	0.96		26
Benzene (50 mole %)	*n*-Octadecane	0.86		26
Benzoic acid	Acetone	2.62		4
Benzoic acid	Benzene	1.38		4
Benzoic acid	Carbon tetrachloride	0.91		4
Benzoic acid	Ethylene glycol	0.043		4
Benzoic acid	Toluene	1.49		4
Bromine	Benzene	2.7		11
Bromine	Carbon disulfide	4.1		11
Bromine	Water	1.3		11
Bromobenzene	Benzene	2.30		25
Bromoform°	Acetone	2.90		11
Bromoform	*i*-Amyl alcohol	0.53		11
Bromoform	Ethanol	1.08	5	11
Bromoform°	Ethyl ether	3.62		11
Bromoform	Methanol	2.20		23
Bromoform	*n*-Propanol	0.94		11
n-Butanol	Water	0.96	5	1, 11, 18, 25
Caffeine	Water	0.63	6	11
Carbon dioxide	Ethanol	4.0	6	11
Carbon dioxide	Water	1.96	1	1, 3, 5, 20, 24, 28
Carbon disulfide (50 mole %, 200 atm.)	*n*-Butanol	3.57		14
Carbon disulfide (50 mole %, 200 atm.)	*i*-Butanol	2.42		14
Carbon disulfide (50 mole %, 218 atm.)	Chlorobenzene	3.00		14
Carbon disulfide (50 mole %, 200 atm.)	2,4-Dimethyl pentane	3.63		14
Carbon disulfide (50 mole %, 100 atm.)	*n*-Heptane	3.0		14
Carbon disulfide (50 mole %, 50 atm.)	Methyl cyclohexane	3.5		14
Carbon disulfide (50 mole %, 200 atm.)	*n*-Octane	3.10		14
Carbon disulfide (50 mole %)	Toluene	2.06		14
Carbon tetrachloride	Benzene	2.04	3	7, 9
Carbon tetrachloride°	Cyclohexane	1.49	2	9, 10°
Carbon tetrachloride	Decalin	0.776	2	9
Carbon tetrachloride	Dioxane	1.02	2	9
Carbon tetrachloride°	Ethanol	1.50	2	9, 10°
Carbon tetrachloride	*n*-Heptane	3.17	2	9
Carbon tetrachloride	Kerosene	0.961	2	9
Carbon tetrachloride	Methanol	2.30	2	9
Carbon tetrachloride	*i*-Octane	2.57	2	9
Carbon tetrachloride	Tetralin	0.735	2	9
Chloral°	Ethanol	0.68	5	11
Chloral hydrate	Water	0.77	7	11

TABLE 2-325 Diffusivities in Liquids (25 °C) (*Continued*)

Dilute solutions and 1 atm unless otherwise noted; use $D_L\mu/T$ = constant to estimate effect of temperature; ° indicates that reference gives effect of concentration.

Solute	Solvent	$D_L \times 10^5$, sq cm/sec	Estimated possible, error, ± %1	Ref.
Chlorine	Water	1.44	4	1, 28
Chlorobenzene	Benzene	2.66		25
Chloroform	Benzene	2.50	6	1, 25
Chloroform	Ethanol	1.38	3	11
Cinnamic acid	Acetone	2.41		4
Cinnamic acid	Benzene	1.12		4
Cinnamic acid	Carbon tetrachloride	0.76		4
Cinnamic acid	Toluene	2.41		4
1,1′-Dichloropropanol	Water	1.0	6	11
Dicyanodiamide°	Water	1.18	4	11
Diethyl ether	Benzene	2.73		25
Diethyl ether	Water	0.85		2
2,4-Dimethyl pentane (50 mole %)	*n*-Dodecane	1.44		26
2,4-Dimethyl pentane (50 mole %)	*n*-Hexadecane	0.88		26
Ethanol°	Water	1.28	4	1, 7, 9,° 11,° 22
Ethyl acetate	Ethyl benzoate	0.94		6
Ethylene dichloride	Benzene	2.8		1, 25
Formic acid	Acetone	3.77		4
Formic acid	Benzene	2.28		4
Formic acid	Carbon tetrachloride	1.89		4
Formic acid	Ethylene glycol	0.094		4
Formic acid	Toluene	2.65		
Formic acid	Water	1.37	10	11
Glucose	Water	0.69	6	11
Glycerol	*i*-Amyl alcohol	0.12		11
Glycerol	Ethanol	0.56		11
Glycerol°	Water	0.94	6	1, 11°
n-Heptane (50 mole %)	*n*-Dodecane	1.58		26
n-Heptane (50 mole %)	*n*-Hexadecane	1.00		26
n-Heptane (50 mole %)	*n*-Octadecane	0.92		26
n-Heptane (50 mole %)	*n*-Tetradecane	1.29		26
Hexamethylene tetramine	Water	0.67		11
Hydrogen chloride°	Water	3.10	3	4, 11,° 12°
Hydrogen	Water	5.85 (4.4)		1, 11, 24(?)
Hydrogen sulfide	Water	1.61		1
Hydroquinone°	Ethanol	0.53	5	11
Hydroquinone°	Water	0.88, 1.12		2, 11°
Iodine	Acetic acid	1.13		11
Iodine	Anisole	1.25		11
Iodine	Benzene	1.98		9, 19, 23
Iodine	Bromobenzene	1.25	10	4, 11, 19
Iodine	Carbon disulfide	3.2		11, 19, 23
Iodine	Carbon tetrachloride	1.45	8	9, 11, 19
Iodine	Chloroform	2.30	3	11, 23
Iodine	Cyclohexane	1.80		4
Iodine	Dioxane	1.07		9
Iodine°	Ethanol	1.30		4, 11°
Iodine	Ethyl acetate	2.2		11, 19
Iodine	Ethyl ether	3.61		11
Iodine	Ethylene bromide	0.93		11
Iodine	*n*-Heptane	3.4, 2.5		9, 11, 19
Iodine	*n*-Hexane	4.15		4, 9
Iodine	Mesitylene	1.49		9
Iodine	Methanol	1.74		19
Iodine	Methyl cyclohexane	2.1		4
Iodine	*n*-Octane	2.76		4
Iodine	Tetrabromoethane	2.0		11
Iodine	*n*-Tetradecane	0.96		4
Iodine	Toluene	2.1		11
Iodine	*m*-Xylene	1.82		9, 11
Iodobenzene	Ethanol	1.09	3	11
Lactose°	Water	0.49	5	11
Maltose°	Water	0.48	5	11
Mannitol°	Water	0.65	5	11
Methanol	Water	1.6		1, 7, 11
Nicotine°	Water	0.60	8	11
Nitric acid°	Water	2.98	2	11
Nitrobenzene	Carbon tetrachloride	1.00		7
Nitrogen	Water	1.9		1, 24
Nitrous oxide	Water	1.8		1, 11
Oxalic acid°	Water	1.61	2	11

TABLE 2-325 Diffusivities in Liquids (25 °C) (*Concluded*)

Dilute solutions and 1 atm unless otherwise noted; use $D_L\mu/T$ = constant to estimate effect of temperature; ° indicates that reference gives effect of concentration.

Solute	Solvent	$D_L \times 10^5$, sq cm/sec	Estimated possible, error, ± %1	Ref.
Oxygen	Glycerol°-water (106 poise)	0.24		13
Oxygen	Sucrose°-water (125 poise)	0.25		13
Oxygen	Water	2.5	20	1, 3, 15, 21, 24
Pentaerythritol°	Water	0.77	4	11
Phenol	*i*-Amyl alcohol	0.2		11
Phenol	Benzene	1.68		1
Phenol	Carbon disulfide	3.7		11
Phenol	Chloroform	2.0		11
Phenol	Ethanol	0.89		11
Phenol	Ethyl ether	3.9		11
n-Propanol	Water	1.1		1, 7, 11
Pyridine°	Ethanol	1.24	3	11
Pyridine	Water	0.76	7	11
Pyrogallol	Water	0.74	7	11
Raffinose°	Water	0.41	4	11
Resorcinol°	Ethanol	0.46	5	11
Resorcinol°	Water	0.87	4	11
Saccharose°	Water	0.49	4	11
Stearic acid°	Ethanol	0.65	5	11
Succinic acid°	Water	0.94		11
Sucrose	Water	0.56	6	2, 27
Sulfur dioxide	Water	1.7		15, 17
Sulfuric acid°	Water	1.97	3	11
Tartaric acid°	Water	0.80	10	11
1,1,2,2-Tetrabromoethane	1,1,2,2-Tetra-chloroethane	0.61	4	11
Toluene	*n*-Decane	2.09		4
Toluene	*n*-Dodecane	1.38		4
Toluene	*n*-Heptane	3.72		4
Toluene	*n*-Hexane	4.21		4
Toluene	*n*-Tetradecane	1.02		4
Urea	Ethanol	0.73		11
Urea	Water	1.37	2	8, 11
Urethane	Water	1.06		11, 25
Water	Glycerol	0.021		16

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TABLE 2-326 Thermal Conductivities of Some Building and Insulating Materials*

k = Btu/(h·ft²)(°F/ft)

Material	Apparent density ρ, lb/ft³ at room temperature	t, °C	k
Aerogel, silica, opacified	8.5	120	0.013
		290	.026
Asbestos-cement boards	120	20	.43
Asbestos sheets	55.5	51	.096
Asbestos slate	112	0	.087
	112	60	.114
Asbestos	29.3	–200	.043
	29.3	0	.090
	36	0	.087
	36	100	.111
	36	200	.120
	36	400	.129
	43.5	–200	.090
	43.5	0	.135
Aluminum foil (7 air spaces per 2.5 in.)	0.2	38	.025
		177	.038
Ashes, wood		0–100	.041
Asphalt	132	20	.43
Boiler scale (Note 1)			
Bricks:			
Alumina (92–99% Al_2O_3 by wt.) fused		427	1.8
Alumina (64–65% Al_2O_3 by wt.)		1315	2.7
(See also Bricks, fire clay)	115	800	0.62
	115	1100	.63
Building brick work		20	.4
Carbon	96.7		3.0
Chrome brick (32% Cr_2O_3 by wt.)	200	200	.67
	200	650	.85
	200	1315	1.0
Diatomaceous earth, natural, across strata (Note 2)	27.7	204	0.051
	27.7	871	.077
Diatomaceous, natural, parallel to strata (Note 2)	27.7	204	.081
	27.7	871	.106
Diatomaceous earth, molded and fired (Note 2)	38	204	.14
	38	871	.18
Diatomaceous earth and clay, molded and fired (Note 2)	42.3	204	.14
	42.3	871	.19
Diatomaceous earth, high burn, large pores (Note 3)	37	200	.13
	37	1000	.34
Fire clay (Missouri)		200	.58
		600	.85
		1000	.95
		1400	1.02
Kaolin insulating brick (Note 3)	27	500	0.15
	27	1150	.26
Kaolin insulating firebrick (Note 4)	19	200	.050
	19	760	.113
Magnesite (86.8% MgO, 6.3% Fe_2O_3, 3% CaO, 2.6% SiO_2 by wt.)	158	204	2.2
	158	650	1.6
	158	1200	1.1
Silicon carbide brick, recrystallized (Note 3)	129	600	10.7
	129	800	9.2
	129	1000	8.0
	129	1200	7.0
	129	1400	6.3
Calcium carbonate, natural	162	30	1.3
White marble			1.7
Chalk	96		0.4
Calcium sulfate ($4H_2O$), artificial	84.6	40	.22
plaster (artificial)	132	75	.43
(building)	77.9	25	.25
Cambric (varnished)		38	.091
Carbon, gas		0–100	2.0
Carbon stock	94	–184	0.55
		0	3.6
Cardboard, corrugated			0.037
Cotton wool	5	30	0.024
Cork board	10	30	.025
Cork (regranulated)	8.1	30	.026
(ground)	9.4	30	.025
Diatomaceous earth powder, coarse (Note 2)	20.0	38	.036
	20.0	871	.082
fine (Note 2)	17.2	204	.040
	17.2	871	.074
molded pipe covering (Note 2)	26.0	204	.051
	26.0	871	.088
4 vol. calcined earth and 1 vol. cement, poured and fired (Note 2)	61.8	204	.16
	61.8	871	.23
Dolomite	167	50	1.0
Ebonite			0.10
Enamel, silicate	38		0.5–0.75
Felt, wool	20.6	30	0.03
Fiber insulating board	14.8	21	.028
Fiber, red	80.5	20	.27
(with binder, baked)		20–97	.097
Gas carbon		0–100	2.0
Glass			0.2–0.73
Borosilicate type	139	30–75	0.63
Window glass			0.3–0.61
Soda glass			0.3–0.44
Granite			1.0–2.3
Graphite, longitudinal		20	95
powdered, through 100 mesh	30	40	0.104
Gypsum (molded and dry)	78	20	.25
Hair felt (perpendicular to fibers)	17	30	.021
Ice	57.5	0	1.3
Infusorial earth, see diatomaceous earth			
Kapok	0.88	20	0.020
Lampblack	10	40	.038
Lava			.49
Leather, sole	62.4		.092
Limestone (15.3 vol. % H_2O)	103	24	.54
Linen		30	.05
Magnesia (powdered)	49.7	47	.35
Magnesia (light carbonate)	13	21	0.034
Magnesium oxide (compressed)	49.9	20	.32
Marble			1.2–1.7
Mica (perpendicular to planes)		50	0.25
Mill shavings			0.033–0.05
Mineral wool	9.4	30	0.0225
	19.7	30	.024
Paper			.075
Paraffin wax		0	.14
Petroleum coke		100	3.4
		500	2.9
Porcelain		200	0.88
Portland cement, see concrete		90	.17
Pumice stone		21–66	.14
Pyroxylin plastics			.075
Rubber (hard)	74.8	0	.087
(para)		21	.109
(soft)		21	0.075–0.092
Sand (dry)	94.6	20	0.19
Sandstone	140	40	1.06
Sawdust	12	21	0.03
Scale (Note 1)			
Silk	6.3		.026
varnished		38	.096
Slag, blast furnace		24–127	.064
Slag wool	12	30	.022
Slate		94	.86
Snow	34.7	0	.27
Sulfur (monoclinic)		100	0.09–0.097
(rhombic)		21	0.16
Wall board, insulating type	14.8	21	.028
Wall board, stiff paste board	43	30	.04
Wood shavings	8.8	30	.034

TABLE 2-326 Thermal Conductivities of Some Building and Insulating Materials* (*Concluded*)

k = Btu/(h·ft²)(°F/ft)

Material	Apparent density ρ, lb/ft³ at room temperature	t, °C	k	Material	Apparent density ρ, lb/ft³ at room temperature	t, °C	k
Celluloid	87.3	30	.12	Wood (across grain):			
Charcoal flakes	11.9	80	.043	Balsa	7–8	30	0.025–0.03
	15	80	.051	Oak	51.5	15	0.12
Clinker (granular)		0–700	.27	Maple	44.7	50	.11
Coke, petroleum		100	3.4	Pine, white	34.0	15	.087
		500	2.9	Teak	40.0	15	.10
Coke, petroleum (20–100 mesh)	62	400	0.55	White fir	28.1	60	.062
Coke (powdered)		0–100	.11	Wood (parallel to grain):			
Concrete (cinder)			.20	Pine	34.4	21	.20
(stone)			.54	Wool, animal	6.9	30	.021
(1:4 dry)			.44				

*Marks, *Mechanical Engineers' Handbook,* 4th ed., McGraw-Hill, New York, 1941. *International Critical Tables,* McGraw-Hill, 1929, and other sources.

Note 1: B. Kamp [*Z. tech. Physik,* **12,** 30 (1931)] shows the effect of increased porosity in decreasing thermal conductivity of boiler scale. Partridge [University of Michigan, *Eng. Research Bull.,* **15,** 1930] has published a 170-page treatise on Formation and Properties of Boiler Scale.

Note 2: Townshend and Williams, *Chem. & Met.,* **39,** 219 (1932).

Note 3: Norton, *Refractories,* 2d ed., McGraw-Hill, New York, 1942.

Note 4: Norton, private communication.

TABLE 2-327 Thermal-Conductivity-Temperature Table for Metals*

Thermal conductivities tabulated in watts per meter-kelvin

Substance	Temperature, K														
	10	20	40	60	80	100	200	300	400	500	600	800	1000	1200	1400
Alumina	7	32	121	174	160	125	55	36	26	20	16	10	8	7	6
Aluminum	38,000	13,500	2,300	850	380	300	237	273	240	237	232	220	93	99	105
Antimony	470	230	110	80	60	48	32	26	22	20					
Beryllium oxide	47	196	810	1,400	1,650	1,490	480	272	196	146	111	70	47	33	25
Bismuth	240	100	45	31	24	22	18	16	14	12					
Boron	165	305	400	327	230	170	45	25	15	12					
Cadmium	900	250	150	120	110	110	105	104	101	99					
Chromium	400	570	450	250	180	158	111	90	87	85	81	71	65	62	61
Cobalt	250	450	380	250	190	160	120	100	85	70					
Constantan	4	9	16	18	19	20	23	25	27	30					
Copper	19,000	10,700	2,100	850	570	483	413	398	392	388	383	371	357	342	
Gallium	2,200	640	250	200	170	140	100	85							
Gold	2,800	1,500	520	380	350	345	327	315	312	309	304	292	278	262	
Graphite†	27	108	135	81	54	39	15	10	7	5	4	3	3	2	2
Graphite‡	81	420	1,630	2,980	4,290	4,980	3,250	2,000	1,460	1,140	930	680	530	440	370
Hastelloy	1	3	4	5	6	7	9	10	11	13					
Inconel	2	4	8	10	11	11	14	15							
Iridium	1,300	1,900	750	360	230	172	147	145	143	140					
Iron	710	1,000	560	270	170	132	94	80	69	61	55	43	33	28	31
Lead	175	57	43	42	41	40	37	35	34	33	31	19	22	24	26
Magnesium	1,200	1,300	620	290	190	169	159	156	153	151	149	146	84	98	112
Magnesium oxide	1,100	3,100	2,200	950	460	260	75	48	36	27	21	13	10	8	7
Manganese	2	2	4	5	5	6	7	8	9	9					
Manganin	2	4	9	11	13	13	17	22	28	34	40				
Mercury	54	40	35	33	33	32	32	8	10	11	12	13	14		
Molybdenum	150	280	350	250	210	179	143	138	134	130	126	118	112	105	100
Nickel	2,600	1,700	570	290	200	158	106	91	80	72	66	67	72	76	80
Nylon	0.04	0.10	0.17	0.20	0.23	0.25	0.28	0.30							
Palladium	1,200	610	160	100	88	80	78	78	78	80					
Platinum	1,200	490	130	92	82	79	75	73	72	72	72	73	78	78	81
PTFE§	0.94	1.43	1.94	2.1	2.15	2.16	2.20	2.25	2.3	2.5					
Pyrex	0.12	0.20	0.33	0.42	0.51	0.57	0.88	1.1	1.6	2.1					
Quartz	1,200	480	82	40	30										
Rhodium	2,900	3,900	1,000	370	250	190	160	150	145	140					
Rubber			0.13	0.15	0.16	0.17	0.20	0.22	0.24	0.25					
Selenium (axis)	140	57	25	15	10	8	6	4	3	2					
Silica								1.34	1.52	1.70	1.87	2.22	2.60		
Silver	16,500	5,200	1,100	630	500	430	425	424	420	413	405	389	374	358	
Tantalum	108	146	88	68	62	59	58	57	58	58	59	59	60	61	62
Tellurium	300	93	29	17	13	11	6	4	3	3					
Tin		320	130	101	90	84	72	67	62	60					
Titanium	14	28	39	37	33	31	26	21	20	20	19				
Tungsten			880	330	310	280	190	180	170	150	140				
Uranium				20	22	23	26	28	30	32					
Zinc				150	135	130	123	120	116	110	110				
Zirconium	100	110	59	42	38	34	25	23	22	21	21				

*Especially at low temperatures, the thermal conductivity can often be markedly reduced by even small traces of impurities. This table, for the highest-purity specimens available, should thus be used with caution in applications with commercial materials. From Perry, *Engineering Manual,* 3d ed., McGraw-Hill, New York, 1976. A more detailed table appears as Section 5.5.6 in the *Heat Exchanger Design Handbook,* Hemisphere Pub. Corp., Washington, DC, 1983.

† Parallel to basal plane.

‡ Perpendicular to basal plane.

§ Also known as Teflon, etc.

TABLE 2-328 Thermal Conductivity of Chromium Alloys*

k = Btu/(h·ft²)(°F/ft)

American Iron and Steel Institute Type No.	k at 212 °F	k at 932 °F
301, 302, 302B, 303, 304, 316†	9.4	12.4
308	8.8	12.5
309, 310	8.0	10.8
321, 347	9.3	12.8
403, 406, 410, 414, 416†	14.4	16.6
430, 430F†	15.1	15.2
442	12.5	14.2
501, 502†	21.2	19.5

*Table 3-322 is based on information from manufacturers.

† Shelton and Swanger (National Bureau of Standards), *Trans. Am. Soc. Steel Treat.*, 21, 1061–1078 (1933).

TABLE 2-329 Thermal Conductivity of Some Alloys at High Temperature*

	Thermal conductivity, Btu/(ft)(hr)(°R)					
°R	Kovar	Advance	Monel	Hastelloy A	Inconel	Nichrome V
500	7.8		9.0	5.6	6.0	5.5
600	8.3	11.4	10.2	6.2	6.5	6.1
700	8.6	12.6	11.2	6.8	7.0	6.7
800	8.7	13.9	12.3	7.3	7.6	7.3
900	8.7	15.1	13.4	7.8	8.1	7.8
1000	8.9	16.4	14.4	8.4	8.6	8.4
1100	9.2	17.6	15.4	9.0	9.1	9.0
1200	9.5	18.8	16.5	9.5	9.7	9.5
1300	9.8	20.0	17.6	10.1	10.2	10.1
1400	10.2	21.2	18.7	10.7	10.8	10.7
1500	10.5	22.5	19.8	11.3	11.3	11.3
1600	10.8	23.8	20.8	11.8	11.8	11.9
1700	11.1	25.0	21.9	12.3	12.4	12.4
1800	11.3	26.2	23.0	12.9	13.0	13.0
1900	11.5	27.4	24.0	13.4	13.6	13.5
2000	11.8	28.7	25.1	14.0	14.0	14.1
2100	12.1	30.0	26.1	14.6	14.5	14.7
2200	12.3		27.2	15.1	15.0	15.3

*Silverman, *J. Metals*, **5,** 631 (1953). Copyright American Institute of Mining, Metallurgical and Petroleum Engineers, Inc.

TABLE 2-330 Thermal Conductivities of Some Materials for Refrigeration and Building Insulation*

k = Btu/(h·ft²)(°F/ft) at approximately room temperature

Material	Apparent density, lb/cu ft room temp.	k
Soft flexible materials in sheet form:		
Chemically treated wood fiber	2.2	0.023
Eel grass between paper	3.4–4.6	0.021–0.022
Felted cattle hair	11–13	0.022
Flax fibers between paper	4.9	.023
Hair and asbestos fibers, felted	7.8	.023
Insulating hair, and jute	6.1–6.3	0.022–0.023
Jute and asbestos fibers, felted	10.0	0.031
Loose materials:		
Cork, regranulated, fine particles	8–9	.025
Charcoal, 6 mesh	15.2	.031
Diatomaceous earth, powdered	10.6	.026
Glass wool, curled	4–10	.024
Gypsum in powdered form	26–34	0.043–0.05
Mineral wool, fibrous	6	0.0217
	10	.0225
	14	.0233
	18	.0242
Sawdust	12	.034
Wood shavings, from planer	8.8	.034
Semiflexible materials in sheet form:		
Flax fiber	13.0	.026
Semirigid materials in board form:		
Corkboard	7.0	.0225
	10.6	.025
Mineral wool, block, with binder	16.7	.031
Stiff fibrous materials in sheet form:		
Wood pulp	16.2–16.9	.028
Sugar-cane fiber	13.2–14.8	.028
Cellular gypsum	8	.029
	12	.037
	18	.049
	24	.064
	30	.083

*Abstracted from *U.S. Bur. Standards Letter Circ.* **227,** Apr. 19, 1927.

TABLE 2-331 Thermal Conductivities of Insulating Materials at High Temperatures*

k = Btu/(h·ft²)(°F/ft)

Material	For temperatures, °F up to	Mean temperatures, °F									
		100	200	300	400	500	600	800	1000	1500	2000
Laminated asbestos felt (approx. 40 laminations per in)	700	0.033	0.037	0.040	0.044	0.048					
Laminated asbestos felt (approx. 20 laminations per in)	500	.045	.050	.055	.060	.065					
Corrugated asbestos (4 plies per in)	300	.050	.058	.069							
85% magnesia (density, 13 lb/ft³)	600	.034	.036	.038	.040						
Diatomaceous earth, asbestos and bonding material	1600	.045	.047	.049	.050	.053	0.055	0.060	0.065		
Diatomaceous earth brick	1600	.054	.056	.058	.060	.063	.065	.069	.073		
Diatomaceous earth brick	2000	.127	.130	.133	.137	.140	.143	.150	.158	0.176	
Diatomaceous earth brick	2500	.128	.131	.135	.139	.143	.148	.155	.163	.183	0.203
Diatomaceous earth powder (density, 18 lb/ft³)		.039	.042	.044	.048	.051	.054	.061	.068		
Rock wool		.030	.034	.039	.044	.050	.057				

Asbestos cement, 1.2; 85% magnesia cement, 0.05; asbestos and rock wool cement, 0.075 approx.

*Marks, *Mechanical Engineers' Handbook*, 4th ed., McGraw-Hill, New York, 1941.

TABLE 2-332 Thermal Conductivities of Insulating Materials at Moderate Temperatures (Nusselt)*

k = Btu/(h·ft²)(°F/ft)

Material	Weight, lb/cu ft	Temperatures, °F						
		32	100	200	300	400	600	800
Asbestos	36.0	0.087	0.097	0.110	0.117	0.121	0.125	0.130
Burned infusorial earth for pipe coverings	12.5	.043	.046	.052	.057	.062	.073	.085
Insulating composition (loose)	25.0	.040	.046	.050	.053	.055		
Cotton	5.0	.032	.035	.039				
Silk hair	9.1	.026	.030	.034				
Silk	6.3	.025	.028	.034				
Wool	8.5	.022	.027	.033				
Pulverized cork	10.0	.021	.026	.032				
Infusorial earth (loose)	22.0	.035	.039	.045	.047	.050	.053	

*Marks, *Mechanical Engineers' Handbook,* 4th ed., McGraw-Hill, New York, 1941.

TABLE 2-333 Thermal Conductivities of Insulating Materials at Low Temperatures (Gröber)*

k = Btu/(h·ft²)(°F/ft)

Material	Weight, lb/cu ft	Temperatures, °F				
		32	–50	–100	–200	–300
Asbestos	44.0	0.135	0.132	0.130	0.125	0.100
Asbestos	29.0	.0894	.0860	.0820	.0720	.0545
Cotton	5.0	.0325	.0302	.0276	.0235	.0198
Silk	6.3	.0290	.0256	.0235	.0196	.0155

*Marks, *Mechanical Engineers' Handbook,* 4th ed., McGraw-Hill, New York, 1941.

TABLE 2-334 Thermal Diffusivity (m²/s) of Selected Elements*

Element	Temperature, K									
	20	40	60	80	100	200	400	600	800	1000
Aluminum	0.50	0.012	0.0014	4.4. – 4	2.3. – 4	1.1. – 4	9.4. – 5	8.4. – 5	7.4. – 5	6.6. – 5
Beryllium					0.0036	1.5. – 4	4.0. – 5	2.6. – 5	2.1. – 5	1.7. – 5
Chromium	0.038	0.0037	5.9. – 4	2.0. – 4	1.2. – 4	4.1. – 5	2.6. – 5	2.0. – 5	1.7. – 5	1.4. – 5
Copper	0.16	0.0040	6.9. – 4	3.1. – 4	2.2. – 4	1.3. – 4	1.1. – 4	1.0. – 4	9.0. – 5	9.0. – 5
Gold	0.005	4.5. – 4	2.3. – 4	1.8. – 4	1.5. – 4	1.3. – 4	1.2. – 4	1.2. – 4	1.1. – 4	9.8. – 5
Iridium	0.046				8.4. – 5	5.6. – 5	4.8. – 5	4.4. – 5	4.1. – 5	3.5. – 5
Iron	0.043	3.2. – 3	4.9. – 4	1.6. – 4	8.2. – 5	3.1. – 5	1.8. – 5	1.3. – 5	1.1. – 5	1.0. – 5
Lead	9.3. – 5	3.9. – 5	3.3. – 5	3.1. – 5	2.9. – 5	2.6. – 5	2.3. – 5	2.0. – 5	1.3. – 5	1.5. – 5
Molybdenum	0.0095	0.0014	4.0. – 4	2.0. – 4	1.3. – 4	6.3. – 5	5.1. – 5	4.5. – 5	4.2. – 5	3.8. – 5
Nickel	0.033	0.0017	3.1. – 4	1.3. – 4	8.0. – 5	3.1. – 5	1.9. – 5	1.3. – 5	1.4. – 5	1.5. – 5
Platinum	0.0029	1.6. – 4	6.3. – 5	4.3. – 5	3.6. – 5	2.7. – 5	2.5. – 5	2.5. – 5	2.5. – 5	2.5. – 5
Silver	0.031	0.0013	4.5. – 4	2.8. – 4	2.3. – 4	1.8. – 4	1.7. – 4	1.6. – 4	1.5. – 4	1.4. – 4
Zinc	0.0046	3.1. – 4	1.0. – 4	7.0. – 5	5.5. – 5	4.7. – 5	3.9. – 5	3.4. – 5	1.8. – 5	2.2. – 5

*Tables for up to 24 temperatures for 47 elements appear in the *Handbook of Heat Transfer,* 2d ed., McGraw-Hill, New York, 1984. The notation 3.2. – 4 signifies 2.3×10^{-4}.

TABLE 2-335 Thermophysical Properties of Selected Nonmetallic Solid Substances

Material	Density, kg/m^3	Emissivity	Specific heat, kJ/(kg·K)	Thermal conductivity, W/(m·K)	Thermal diffusivity, m^2/s × 10^6
Alumina	3975		0.765	36	11.9
Asphalt	2110		0.920	0.06	0.03
Bakelite	1300		1.465	1.4	0.74
Beryllia	3000	0.82	1.030	270	88
Brick	1925	0.93	0.835	0.72	0.45
Brick, fireclay	2640	0.93	0.960	1.0	0.39
Carbon, amorphous	1950	0.86	0.724	1.6	1.13
Clay	1460	0.91	0.880	1.3	1.01
Coal	1350	0.80	1.26	0.26	0.15
Cotton	80		1.30	0.06	0.58
Diamond	3500		0.509	2300	1290
Granite	2630		0.775	2.79	1.37
Hardboard	1000		1.38	0.15	0.11
Magnesite	3025	0.38	1.13	4.0	1.2
Magnesia	3635	0.72	0.943	48	14
Oak	770	0.90	2.38	0.18	0.10
Paper	930	0.83	1.34	0.011	0.01
Pine	525	0.84	2.75	0.12	0.54
Plaster board	800	0.91		0.17	
Plywood	540		1.22	0.12	0.18
Pyrex	2250	0.92	0.835	1.4	0.74
Rubber	1150	0.92	2.00	0.2	0.09
Rubber, foam	70	0.90		0.03	
Salt		0.34	0.854	7.1	
Sandstone	2150	0.59	0.745	2.9	1.8
Silica		0.79	0.743	1.3	
Sapphire	3975	0.48	0.765	46	15
Silicon carbide	3160	0.86	0.675	110	230
Soil	2050	0.38	1.84	0.52	0.14
Teflon	2200	0.92	0.35	0.26	0.34
Thoria	4160	0.28	0.71	14	4.7
Urethane foam	70		1.05	0.03	0.36
Vermiculite	120		0.84	0.06	0.60

NOTE: Difficulties of accurately characterizing many of the specimens mean that many of the values presented here must be regarded as being of order of magnitude only. For some materials, actual measurement may be the only way to obtain data of the required accuracy. To convert kilograms per cubic meter to pounds per cubic foot, multiply by 0.062428; to convert kilojoules per kilogram-kelvin to British thermal units per pound-degree Fahrenheit, multiply by 0.23885.

PREDICTION AND CORRELATION OF PHYSICAL PROPERTIES*

INTRODUCTION

Physical property values, sufficiently accurate for many engineering applications, can be estimated in the absence of reliable experimental data. The purpose of this subsection is to provide a set of recommended prediction methods for general engineering use; it is not a comprehensive review, and many alternative methods are available in the literature. Methods recommended were selected on the basis of accuracy, generality, and, in most cases, simplicity. They generally correspond to the methods tested and given priority in the DIPPR® 801 database project.†

Properties included in this subsection are divided into 10 categories: (1) physical constants: critical properties, normal melting and boiling points, acentric factor, radius of gyration, and dipole moment; (2) vapor pressure: liquid and solid; (3) thermal properties: enthalpy and Gibbs' energy of formation and ideal gas entropy; (4) latent enthalpy: vaporization, fusion, and sublimation; (5) heat capacity: ideal gas, gas, liquid, and solid; (6) density: gas, liquid, and solid; (7) viscosity: gas and liquid; (8) thermal conductivity: gas and liquid; (9) surface tension; and (10) flammability properties: flash point, flammability limits, and autoignition temperature. Each of the 10 subsections provides a definition of the relevant properties and a description of one or more recommended prediction methods. Each description lists the type of method, its uncertainty, its limitations, and the expected uncertainty of the predicted value. A numerical example is also given to illustrate use of the method. For brevity, symbols used for physical properties and for variables and constants in the equations are defined under Nomenclature and are not generally defined after their use except where doing so clarifies usage. A list of equation and table numbers in which variables appear is included in the Nomenclature section for quick cross-referencing. Although emphasis is on pure-component properties, some mixture estimation techniques have been included for physical constants, density, viscosity, thermal conductivity, surface tension, and flammability. Correlation and estimation of properties that are inherently multicomponent (e.g., diffusion coefficients, mixture excess properties, activity coefficients, etc.) are treated elsewhere in the Handbook.

*Some material in this subsection has been retained from the corresponding subsection in the Seventh Edition, which was coauthored by Thomas E. Daubert and Evan Buck.

†The Design Institute for Physical Properties (DIPPR®) is an industrial consortium under the auspices of AIChE; Project 801, Evaluated Process Design Data, is a pure-component database of industrially important compounds.

UNITS

The International Metric System (SI) of units has been used throughout this subsection. Where possible, the estimation equations are set up in dimensionless groups. This makes transparent any conversion factors that should be applied to obtain the property in a desired set of units and eliminates the requirement of specific units for variables. For example, rather than use P_c as a variable with defined units, the dimensionless group P_c/ Pa is used. When a value for P_c expressed in any units (say, P_c = 6.53 MPa) is inserted into this group, the result is dimensionless with an explicit indication of conversion factors that must be included:

$$\frac{P_C}{\text{Pa}} = \frac{6.53\ \text{MPa}}{\text{Pa}} = \left(\frac{6.53\ \text{MPa}}{\text{Pa}}\right)\left(\frac{10^6\ \text{Pa}}{\text{MPa}}\right) = 6.53 \times 10^6$$

Section 1 of this handbook should be used for appropriate unit conversion factors.

Nomenclature

Physical constants	Definition	Value
h	Planck's constant	6.626×10^{-34} J·s
k	Boltzmann's constant	1.3806×10^{-23} J/(molecule·K)
N_A	Avogadro's number	6.022×10^{26} molecule/kmol
R	Gas constant	8.3143 Pa·m^3/(kmol·K)
Properties	**Definition**	**Typical units**
A, B, C	Molecular principal moments of inertia	kg·m^2
$B, B(T)$	Second virial coefficient	m^3/kmol
B_m	Second virial coefficient for a mixture	m^3/kmol
C_p	Constant-pressure molar heat capacity	J/(kmol·K)
C_p^o	Ideal gas constant-pressure molar heat capacity	J/(kmol·K)
C_v	Constant-volume molar heat capacity	J/(kmol·K)
H_i	Enthalpy of compound i	J/kmol
k	Thermal conductivity	W/(m·K)
k_b	Thermal conductivity at T_b	W/(m·K)
LFL	Lower flammability limit	%
M	Molecular weight	kg/kmol
P	Pressure	Pa
P	Parachor	unitless
P_c	Critical pressure	Pa
P_r	Reduced pressure; $P_r = P/P_c$	unitless
P^*	Vapor pressure	Pa
P^*_{meas}	Measured vapor pressure value	Pa
P^*_r	Reduced vapor pressure; $P^*_r = P^*/P_c$	unitless
P^*_t	Vapor pressure at triple point	Pa
R_g	Radius of gyration	m
S^o	Ideal gas entropy	J/(kmol·K)
S^s	Standard state entropy	J/(kmol·K)
S_r	Rotational contribution to entropy	J/(kmol·K)
S_{vib}	Vibrational contribution to entropy	J/(kmol·K)
T	Temperature	K
T_b	Normal boiling point temperature	K
T_{br}	Reduced temperature at T_b; $T_{br} = T_b/T_c$	unitless
T_c	Critical temperature	K
T_m	Melting temperature	K
T_{meas}	T at which a dependent property was measured	K
T_r	Reduced temperature; $T_r = T/T_c$	unitless
T_t	Triple point temperature	K
UFL	Upper flammability limit	%
V	Molar volume	m^3/kmol
V_m	Mixture molar volume	m^3/kmol
V_r	Reduced volume; $V_r = ZT_r/P_r$	unitless
w_i	Mass fraction of component i	unitless
x_i	Mole fraction of component i	unitless
y_i	Mole fraction of component i in vapor phase	unitless
Z	Compressibility factor; $Z = PV/RT$	unitless
Z_c	Critical compressibility factor; $Z_c = P_cV_c/RT_c$	unitless
Z_i	Compressibility factor of reference fluid i	unitless
ΔG_f^o	Ideal gas standard Gibbs energy of formation	J/kmol
ΔG_f^s	Standard state Gibbs energy of formation	J/kmol
ΔH_f^o	Ideal gas standard enthalpy of formation	J/kmol
ΔH_f^s	Standard state enthalpy of formation	J/kmol
ΔH_{fus}	Enthalpy of fusion	J/kmol
ΔH_{rxn}	Enthalpy change per mole of reaction as written	J/kmol
ΔH_{sub}	Enthalpy of sublimation	J/kmol
ΔH_v	Enthalpy of vaporization	J/kmol
ΔS_f^s	Standard state entropy of formation	J/(kmol·K)
ΔS_f^o	Ideal gas entropy of formation	J/(kmol·K)
ΔS_{fus}	Latent entropy of fusion	J/(kmol·K)
ΔZ_v	Change in compressibility factor upon vaporization	unitless
ρ	Molar density; $\rho = V^{-1}$	kmol/m^3
ρ_c	Critical molar density; $\rho_c = V_c^{-1}$	kmol/m^3

Nomenclature (*Continued*)

Properties	Definition	Typical units
ρ_r	Reduced molar density; $\rho_r = \rho/\rho_c$	unitless
ω	Acentric factor	unitless
η	Viscosity	Pa·s
η^o	Viscosity at low pressure	Pa·s
σ	Surface tension	mN/m
σ_m	Surface tension of mixture	mN/m
τ	Complementary reduced temperature (= $1 - T_r$)	unitless
τ_b	Complementary reduced normal boiling temperature (= $1 - T_{br}$)	unitless
μ	Dipole moment	D
μ_r	Reduced dipole moment [defined in Eq. (2-62)]	unitless

Eq. variables	Definition	(Equations), [Tables]
a	EoS constant	(2-66), [2-354]
$a, b, c, \ldots$	GC values for C_p and η	(2-51), (2-52), (2-53), (2-97), [2-356]
a, b, c	Correlation coefficients	(2-21), (2-23)
a_i	GC values	(2-43), (2-97), [2-346, 2-356]
a, b	Terms in second virial correlation	(2-61)
a, b	Chickos correlation parameters	(2-39), (2-40), (2-41)
a_i, b_i, d_i	GC values for liquid C_p	(2-51), [2-348]
$\bar{a}$ $\bar{\alpha}$	EoS constant for mixture	(2-76)
$A, B, C, \ldots$	Correlation constants/parameters	(2-2), (2-20), (2-22), (2-34), (2-36), (2-50), (2-65), (2-68), (2-83), (2-85), (2-87), (2-88), (2-95), (2-96), (2-101), above (2-114)
A	Factor in liquid k correlation	(2-108), [2-358]
A_i	Constants in C_p^o correlation	(2-45), (2-46)
b	EoS constant	(2-66), [2-354]
$b_i, c_i, \ldots$	Reference EoS constants	(2-65), [2-353]
b_j	GC value for AIT	(2-124), [2-363, 2-364]
$\bar{b}$	EoS constant for mixture	(2-75)
$B^{(i)}$	Second virial expansion terms	(2-58), (2-59), (2-60), (2-61)
C	Number of components in mixture	(2-55), (2-72), (2-73), (2-74), (2-75), (2-76), (2-77), (2-80), (2-81), (2-82), (2-98), (2-113), (2-119)
C_i	GC values for T_b or η	(2-15), (2-87), [2-341, 2-355]
$C_{i,int}$	Sum of intramolecular group-group interactions	(2-16)
C_{ij}	Group-group intramolecular interaction pair	(2-16), [2-342]
$(C_p^o)_i$	GC values for ideal gas heat capacity	(2-49), [2-347]
Cs_j	Chickos: GC value for C—H group	(2-41), [2-344]
Ct_j	Chickos: GC value for functional group	(2-41), [2-345]
f_i	Halogen correction for ΔH_{sub} correlation	(2-43), [2-346]
$f^{(i)}$	Vapor pressure deviation function	(2-25)
F	Factor in surface tension equation	(2-116), (2-117)
G_{ij}	Adjustable mixture viscosity parameter	(2-98)
g_c^E	UNIFAC combinatorial excess Gibbs energy	(2-99)
g_r^E	UNIFAC residual excess Gibbs energy	(2-99)
h	Parameter in Riedel vapor pressure equation	following (2-24)
K	Parameter in Riedel vapor pressure equation	following (2-24)
LFL_i	GC contribution	(2-122), [2-361, 2-362]
n	Number of nonhydrogen atoms	(2-15)
n_A	Number of atoms in molecule	(2-1), (2-30), (2-31), (2-48)
n_E	Number of occurrnces of element E in compound	(2-54)
n_i	Number of occurrences of group i	(2-27), (2-43), (2-49), (2-51), (2-53), (2-87), (2-109), (2-115), (2-122), (2-123), (2-124)
n_f	Chickos: no. of different functional groups	(2-41)
n_s	Chickos: no. of different nonring or aromatic C—H groups bonded to functional groups	(2-41)
n_x	Total no. of halogen and H atoms attached to C and Si atoms for ΔH_{sub} correlation	(2-43)
N	Total number of groups in molecule	(2-12), (2-15) (2-16), (2-43), (2-49), (2-51), (2-53), (2-54), (2-87), (2-97), (2-109), (2-115)
N_C	Number of C atoms	(2-121)
Nf_i	Chickos: no. of functional groups of type i	(2-41)
Ng_i	Chickos: no. of C—H groups of type i bonded to other C atoms	(2-41)
N_H	Number of H atoms	(2-121)

Nomenclature (*Continued*)

Eq. variables	Definition	(Equations), [Tables]
N_{CR}	Chickos: no. of CH_2 groups in nonaromatic ring to form cyclic paraffin of same ring size	(2-40)
N_O	Chickos: Number of O atoms	(2-121)
N_R	Chickos: no. of nonaromatic rings	(2-40)
N_S	Chickos: Number of S atoms	(2-121)
Ns_i	Chickos: no. of C—H groups of type i bonded to at least one functional group	(2-41)
N_X	Number of halogen atoms	(2-121)
P_c	Pseudocritical pressure for mixture	(2-73)
$P_{c,ij}$	Cross term in mixing rule	(2-79)
q	Rackett equation power for Z_c	(2-69), (2-70), (2-81)
q_i	UNIFAC molecular surface area	following (2-100)
Q_k	UNIFAC group surface area	following (2-100)
r_i	UNIFAC molecular volume	following (2-100)
r^*	Dimensionless separation distance	(2-4)
R_k	UNIFAC group volume	following (2-100)
$(S^o)_i$	GC value for entropy	(2-27), [2-343]
t	Chickos: total no. of functional groups	(2-41)
$t_{m1,i}$	First-order GC contribution for T_m	(2-13), [2-339]
$t_{m2,i}$	Second-order GC contribution for T_m	(2-13), [2-340]
T_c	Pseudocritical temperature for mixture	(2-72), (2-73), (2-80)
$T_{c,ij}$	Cross term in mixing rule	(2-78), (2-80)
x_P	Term in Pailhes method = log(1 atm/P)	(2-14)
U^*	Dimensionless intermolecular potential	(2-4)
UFL_i	GC contribution	(2-123), [2-361, 2-362]
$V_{c,ij}$	Cross term in mixing rule	(2-78), (2-79)
$Z^{(0)}$	Compressibility factor of simple fluid	(2-63), (2-64), [2-351]
$Z^{(1)}$	Acentric deviation term for Z	(2-63), (2-64), [2-352]
$Z_{c,ij}$	Cross term in mixing rule	(2-78), (2-79)
Z_{RA}	Modified Rackett correlation parameter	(2-70)
$\bar{Z}_{RA}$	Modified Rackett parameter for mixture	(2-82)
$\alpha, \beta, \gamma, \ldots$	Correlation parameters for k	(2-106), (2-107), (2-108), (2-109), [2-358]
$\alpha(T_r)$	EoS temperature-dependent function	(2-66), [2-354]
α_c	Parameter in Riedel vapor pressure equation	following (2-24)
α_{mn}	Viscosity group-group interactions	(2-100), [2-357]
β	Reference EoS constant	(2-65), [2-353]
β	Stoichiometric coefficient in FP correlation	(2-120), (2-121)
β_i	Nonlinear correction term in correlation	(2-43), (2-53), [2-346, 2-349]
γ	Reference EoS constant	(2-65), [2-353]
δ	= 0 for nonlinear molecules; = 1 for linear	(2-1), (2-48)
δ	EoS parameter	(2-66), [2-354]
Δ_E	Contribution of element E to heat capacity	(2-54), [2-350]
Δ_P	GC contribution to P_c	(2-7), (2-10), [2-336, 2-337]
Δ_T	GC contribution to T_c	(2-6), (2-9), [2-336, 2-337]
Δ_V	GC contribution to V_c	(2-8), (2-11), [2-336, 2-337]
$(\Delta H_f^o)_i$	GC value for enthalpy of formation	(2-27), [2-343]
Δk_i	GC for thermal conductivity at T_b	(2-109), [2-359]
$\Delta \mathbf{P}_i$	GC for parachor	(2-115), [2-360]
Δs_i	Chickos: GC value for group i	(2-41), [2-344, 2-345]
ε	Lennard-Jones well depth parameter	following (2-4)
ε	EoS parameter	(2-66), [2-354]
ϕ	UNIFAC molecular volume fraction	following (2-100)
ϕ_i	Volume fraction of component i	(2-80), following (2-100), (2-113)
ν_i	Stoichiometric coefficient (+ for product and – for reactant) for compound i in reaction	(2-28), (2-29), (2-30)
ν_j	Frequency of vibrational mode j	(2-47)
θ	UNIFAC molecular surface fraction	following (2-100)
Θ	UNIFAC group surface fraction	following (2-100)
$\Theta_A, \Theta_B, \Theta_C$	Characteristic rotational T of molecule	before and following (2-31)
Θj	Characteristic vibrational T of mode j	(2-1), (2-31), (2-48)
σ	Lennard-Jones size parameter	(2-4)
σ	Rotational external symmetry number	following (2-31)
μ_r^*	Modified reduced dipole moment	(2-85), (2-86)
ψ	Parameter in Riedel vapor pressure equation	following (2-24)
Ψ	Parameter in correlation of k for gases	(2-106)
Ψ_{mn}	UNIFAC interaction factor	(2-100)
ξ	Viscosity dedimensionalizing factor	(2-89), (2-90), (2-91), (2-92), (2-93), (2-94)
$\bar{\omega}$	Pseudoacentric factor for mixture	(2-74)
ω_{ij}	Cross term in mixing rule	(2-79)

Acronyms and abbreviations	Definition
CC	Computational chemistry
CS	Corresponding states
DIPPR®	Design Institute for Physical Properties
EoS	Equation of state

Nomenclature (*Concluded*)

Acronyms and abbreviations	Definition
GC	Group contributions
LJ	Lennard-Jones
MC	Monte Carlo
MD	Molecular dynamics
QSPR	Quantitative structure-property relationships
TRC	Thermodynamics Research Center

General References

(a) Prediction methods:

[PGL4] Reid, R. C., J. M. Prausnitz, and B. E. Poling, *The Properties of Gases and Liquids*, 4th ed., McGraw-Hill, New York, 1987.

[PGL5] Poling, B. E., J. M. Prausnitz, and J. P. O'Connell, *The Properties of Gases and Liquids*, 5th ed., McGraw-Hill, New York, 2001.

(b) Property databases:

[DIPPR] Rowley, R. L., et al., *DIPPR® Data Compilation of Pure Chemicals Properties*, Design Institute for Physical Properties, AIChE, New York, 2007.

[TRC] *TRC Thermodynamic Tables—Non-Hydrocarbons*, Thermodynamics Research Center, The Texas A&M University System, College Station, Tex., extant 2004; *TRC Thermodynamic Tables—Hydrocarbons*, Thermodynamics Research Center, The Texas A&M University System, College Station, Tex., extant 2004.

[JANAF] Chase, M. W., Jr., et al., "JANAF Thermochemical Tables," *J. Phys. Chem. Ref. Data*, **14**, suppl. 1, 1985.

[SWS] Stull, D. R., F. F. Westrum, Jr., and G. C. Sinke, *The Chemical Thermodynamics of Organic Compounds*, John Wiley & Sons, New York, 1969.

CLASSIFICATION OF ESTIMATION METHODS

Physical property estimation methods may be classified into six general areas: (1) theory and empirical extension of theory, (2) corresponding states, (3) group contributions, (4) computational chemistry, (5) empirical and quantitative structure property relations (QSPR) correlations, and (6) molecular simulation. A quick overview of each class is given below to provide context for the methods and to define the general assumptions, accuracies, and limitations inherent in each.

Theory and Empirical Extension of Theory Methods based on theory generally provide better extrapolation capability than empirical fits of experimental data. Assumptions required to simplify the theory to a manageable equation suggest accuracy limitations and possible improvements, if necessary. For example, the ideal gas isobaric heat capacity, rigorously obtained from statistical mechanics under the assumption of independent harmonic vibrational modes, is [Rowley, R. L., *Statistical Mechanics for Thermophysical Property Calculations*, Prentice-Hall, Englewood Cliffs, N.J., 1994]

$$\frac{C_P^o}{R} = \frac{8-\delta}{2} + \sum_{j=1}^{3n_A-6+\delta} \left(\frac{\Theta_j}{T}\right)^2 \frac{e^{\Theta_j/T}}{(e^{\Theta_j/T}-1)^2}$$

$$\delta = \begin{cases} 0 & \text{nonlinear molecules} \\ 1 & \text{linear molecules} \end{cases} \qquad (2\text{-}1)$$

where Θ_j is the characteristic temperature for the jth vibrational frequency in a molecule of n_A atoms. The temperature dependence of this equation is exact to the extent that the frequencies are harmonic. Corrections for anharmonicity can be applied (albeit with difficulty) where warranted.

Extension of theory often requires introduction of empirical models and parameters in lieu of terms that cannot be rigorously calculated. Good accuracy is expected in the region where the model parameters were fitted to experimental data, but only limited accuracy when an empirical model is extrapolated to other conditions. For example, a simplified theory suggests that vapor pressure should have the form

$$\ln P^* = A - \frac{B}{T} \qquad (2\text{-}2)$$

where the empirical parameter B is given by

$$B = \frac{\Delta H_v}{R \Delta Z_v} \qquad (2\text{-}3)$$

and ΔH_v and ΔZ_v are differences between the vapor and liquid enthalpies and compressibility factors, respectively. Vapor pressures over a narrow temperature range can be effectively correlated using Eq. (2-2), but this equation should not be used to extrapolate vapor pressures over a wide range of temperatures.

Corresponding States (CS) The principle of CS applies to conformal fluids [Leland, T. L., Jr., and P. S. Chappelear, *Ind. Eng. Chem.*, **60** (1968): 15]. Two fluids are conformal if their intermolecular interactions are equivalent when scaled in dimensionless form. For example, the Lennard-Jones (LJ) intermolecular pair potential energy U can be written in dimensionless form as

$$U^* = 4[(r^{*-12} - r^{*-6})] \qquad (2\text{-}4)$$

where $r^* = r/\sigma$, $U^* = U/\varepsilon$, σ is the LJ size parameter, and ε is the LJ attractive well depth parameter. At equivalent scaled temperatures kT/ε (k is Boltzmann's constant) and pressures $P\sigma^3/\varepsilon$, all LJ fluids will have identical dimensionless properties because the molecules interact through the identical scaled intermolecular potential given by Eq. (2-4). Generalization of this scaling principle is commonly done using critical temperature T_c and critical pressure P_c as scaling factors. At the same reduced coordinates ($T_r = T/T_c$ and $P_r = P/P_c$) all conformal fluids will have the same dimensionless properties; for example, $Z = Z(T_r, P_r)$ where the compressibility factor is defined as $Z = PV/RT$. A correlation of experimental data for one fluid can be used as the reference for the properties of all conformal fluids. Nonconformality is the main accuracy limitation. For instance, interactions between nonspherical or polar molecules may not be adequately represented by Eq. (2-4), and so the scaled properties of these fluids will not conform to those of a fluid with interactions well represented by Eq. (2-4). A correction for nonconformality is usually made by the addition of one or more reference fluids whose deviations from the first reference fluid are used to characterize the effect of nonconformality. For example, in the Lee-Kesler method [Lee, B. I., and M. G. Kesler, *AIChE J.*, **21** (1975): 510] *n*-octane is used as a second, nonspherical reference fluid, and deviations of *n*-octane scaled properties from those of the spherical reference fluid at equivalent reduced conditions are assumed to be a linear function of the acentric factor. An extended Lee-Kesler method [Wilding, W. V., and R. L. Rowley, *Int. J. Thermophys.*, **7** (1986): 525] uses three reference fluids: *n*-octane to correct for size-shape nonconformality relative to methane and water to correct for polar effects. Some CS methods [e.g., Teja, A., S. I. Sandler, and N. C. Patel, *Chem. Eng. J.*, **21** (1981): 21] utilize different reference fluids for different classes of fluids to maintain close conformality between the fluid whose properties are to be estimated and the reference fluids.

Group Contributions (GC) Chemical and physical properties generally correlate well with molecular structure. GC methods assume a summative behavior of the structural groups of the constituent molecules. For example, ethanol (CH_3—CH_2—OH) properties would be obtained as the sum of contributions from the —CH_3,—CH_2, and —OH groups. The contribution of each group is obtained by regression of experimental data that include as many different compounds containing that group as possible. Structural groups must be used exactly as defined in the original correlation. A general priniciple in deciding how to make the groupings is to give the more specific group priority. For example, although the structural piece —$COOCH_3$ is ambiguous in a methyl ester, a more specific group value available for an ester —COO— would take precedence over a combination the two smaller groups —(C═O)— and

—O— whose values were most likely regressed only from ketone and ether data, respectively. Excellent accuracy can usually be expected from GC methods when group values were regressed from large quantities of experimental data. However, if the ratio of number of groups to regressed experimental data is large, significant errors can result when the method is applied to new compounds (extrapolation). Such excessive specificity in the group definitions leads to poor extrapolation capabilities even though the fit of the regressed data may be excellent.

Computational Chemistry (CC) Commercial software is available that solves the Schrödinger equation for approximate forms of the wave function. Various levels of sophistication (termed *model chemistry*) for the wave function can be chosen at the expense of computational time. Results include structural information (bond lengths, bond angles, dihedral angles, etc.), electron/charge distribution information, internal vibrational modes (for ideal gas properties), and energy of the molecule, valid for the chosen model chemistry. Because calculations are performed on individual molecules, they are primarily suited for ideal gas properties. Relative energies for the same model chemistry are more accurately obtained than absolute energies, so enthalpies and entropies of reaction are common industrial uses of CC predictions in addition to individual structural and ideal gas properties.

Empirical QSPR Correlations In quantitative structure property relationship (QSPR) methods, physical properties are correlated with molecular descriptors that characterize the molecular and electronic structure of the molecule. Large amounts of experimental data are used to statistically determine the most significant descriptors to be used in the correlation and their contributions. The resultant correlations are simple to apply if the descriptors are available. Descriptors must generally be generated by the user with computational chemistry software, although the DIPPR® 801 database now contains a table of molecular descriptors for most of the compounds in it. QSPR methods are often very accurate for specific families of compounds for which the correlation was developed, but extrapolation problems are even more of an issue than with GC methods.

Molecular Simulations Molecular simulations are useful for predicting properties of bulk fluids and solids. Molecular dynamics (MD) simulations solve Newton's equations of motion for a small number (on the order of 10^3) of molecules to obtain the time evolution of the system. MD methods can be used for equilibrium and transport properties. Monte Carlo (MC) simulations use a model for the potential energy between molecules to simulate configurations of the molecules in proportion to their probability of occurrence. Statistical averages of MC configurations are useful for equilibrium properties, particularly for saturated densities, vapor pressures, etc. Property estimations using molecular simulation techniques are not illustrated in the remainder of this section as commercial software implementations are not generally available at this time.

PHYSICAL CONSTANTS

Critical Properties The critical temperature T_c, pressure P_c, and volume V_c of a compound are important, widely used constants. They are important in determining the phase boundaries of a compound and (particularly T_c and P_c) are required input parameters for most thermal and volumetric property calculations of the equilibrium phases using CS or analytical equations of state. Most estimation methods employ weighted group, atom, or bond contributions.

The critical temperature of a compound is the temperature above which a liquid phase cannot be formed, no matter the pressure of the system. The critical pressure is the vapor pressure of the compound at the critical temperature. The critical volume is the volume occupied by a set amount of a compound (typically 1 mol) at its critical temperature and pressure.

The critical compressibility factor Z_c is determined from the experimental or predicted values of the critical properties by the definition

$$Z_c = \frac{P_c V_c}{R T_c} \tag{2-5}$$

Recommended Methods

Organic molecules: The Ambrose method is recommended for all three critical properties of hydrocarbons and *n*-alcohols. The Joback method is recommended for T_c and P_c of all other organic molecules. Fedors' method is recommended for V_c of these compounds, but the Joback method can also be used.

Inorganic molecules: The simple correlation $T_c = 1.64 T_b$ is recommended if the normal boiling point is known. Critical pressure P_c is best obtained by extrapolating vapor pressure data to T_c, and V_c is best obtained from a correlation of liquid density extrapolated to T_c.

Other recent methods including the Wilson-Jasperson (Wilson, G. M., and L.V. Jasperson, *Critical Constants T_c, P_c, Estimation Based on Zero, First and Second Order Methods,* AIChE Spring Meeting, New Orleans, La., 1996) and Marrero-Pardillo [Marrero-Morejon, J., and E. Pardillo-Fontdevila, *AIChE J.*, **45** (1999): 615] methods have proved to be as good as or better for some classes of compounds than the methods presented here; however, their application is more difficult.

Method: Ambrose method.

Reference: Ambrose, D., Correlation and Estimation of Vapour-Liquid Critical Properties. I. Critical Temperatures of Organic Compounds, *Natl. Phys. Lab. Report Chem.* **92** (1978); Correlation and Estimation of Vapour-Liquid Critical Properties. II. Critical Pressures and Volumes of Organic Compounds, *Natl. Phys. Lab Report Chem.* **98** (1979).

Classification: Group contributions.

Expected uncertainty: ~6 K for T_c (about 1 percent), ~2 bar for P_c (about 5 percent), ~8 cm³/mol for V_c (about 3 percent).

Applicability: Organic compounds.

Input data: T_b, M, group contributions Δ_T, Δ_P, and Δ_V from Table 2-336.

Description: A GC method with first-order contributions and corrections (delta Platt number) for branched alkanes. Variables T_c, P_c, and V_c are given by the following relations:

$$T_c = T_b\left[1 + \left(1.242 + \sum \Delta_T\right)^{-1}\right] \tag{2-6}$$

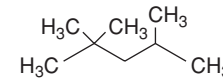
$$\frac{P_c}{\text{bar}} = \frac{M}{\text{kg/kmol}}\left(0.339 + \sum \Delta_P\right)^{-2} \tag{2-7}$$

$$\frac{V_c}{\text{cm}^3/\text{mol}} = 40 + \sum \Delta_V \tag{2-8}$$

Example Use the Ambrose method to estimate the critical constants of 2,2,4-trimethylpentane.

Required data: From the DIPPR® 801 database, $T_b = 372.39$ K and M = 114.229 kg/kmol.

Structure:



Group contributions from Table 2-336:

Group	n_i	Δ_T	Δ_P	Δ_V
Alkyl carbons	8	0.138	0.226	55.1
>CH— (correction)	1	–0.043	–0.006	–8
>C< (correction)	1	–0.120	–0.030	–17
Delta Platt no.	0	–0.023	–0.026	—

Calculations using Eqs. (2-6), (2-7), and (2-8):

$$\sum \Delta_T = (8)(0.138) + (1)(-0.043) + (1)(-0.120) = 0.941$$

$$T_c = T_b(1.4581) = (372.39\text{ K})(1.4581) = 543.0\text{ K}$$

$$\sum \Delta_P = (8)(0.226) + (1)(-0.006) + (1)(-0.030) = 1.772$$

$$\frac{P_c}{\text{bar}} = \frac{M}{\text{kg/kmol}}\left(0.339 + \sum \Delta_P\right)^{-2} = \frac{114.229}{(0.339 + 1.772)^2} = 25.63$$

$$P_c = 25.63\text{ bar}$$

TABLE 2-336 Ambrose Group[a] Contributions for Critical Constants

Group	Δ_T	Δ_P	Δ_V
Carbon atoms in alkyl groups	0.138	0.226	55.1
Corrections			
>CH— (each)	–0.043	–0.006	–8
>C< (each)	–0.120	–0.030	–17
Double bonds (nonaromatic)	–0.050	–0.065	–20
Triple bonds	–0.200	–0.170	–40
Delta Platt number,[b] multiply by	–0.023	–0.026	—
Aliphatic functional groups:			
—O—	0.138	0.160	20
>CO	0.220	0.282	60
—CHO	0.220	0.220	55
—COOH	0.578	0.450	80
—CO—O—OC—	1.156	0.900	160
—CO—O—	0.330	0.470	80
—NO_2—	0.370	0.420	78
—NH_2	0.208	0.095	30
—NH—	0.208	0.135	30
>N—	0.088	0.170	30
—CN	0.423	0.360	80
—S—	0.105	0.270	55
—SH	0.090	0.270	55
—SiH_3	0.200	0.460	119
—O—$Si(CH_3)_2$	0.496	—	—
—F	0.055	0.223	14
—Cl	0.055	0.318	45
—Br	0.055	0.500	67
—I	0.055	—	90
Halogen correction in aliphatic compounds:			
F is present	0.125		
F is absent, but Cl, Br, I are present	0.055		
Aliphatic alcohols[c]	[d]	[e]	15
Ring compound increments (listed only when different from aliphatic values):			
—CH_2—, >CH—, >C<	0.090	0.182	44.5
>CH— in fused ring	0.030	0.182	44.5
Double bond	–0.030	—	–15
—O—	0.090	—	10
—NH—	0.090	—	—
—S—	0.090	—	30
Aromatic compounds:			
Benzene	0.448	0.924	[f]
Pyridine	0.448	0.850	
C_4H_4 (fused as in naphthalene)	0.220	0.515	
—F	0.080	0.183	
—Cl	0.080	0.318	
—Br	0.080	0.600	
—I	0.080	0.850	
—OH	0.198	–0.025	
Corrections for nonhalogenated substitutions:			
First	0.010	0	
Each subsequent	0.030	0.020	
Ortho pairs containing —OH	–0.080	–0.050	
Ortho pairs with no —OH	–0.040	–0.050	
Highly fluorinated aliphatic compounds:			
—CF_3, —CF_2—, >CF—	0.200	0.550	
—CF_2—, >CF— (ring)	0.140	0.420	
>CF— (in fused ring)	0.030	—	
—H (monosubstitution)	–0.050	–0.350	
Double bond (nonring)	–0.150	–0.500	
Double bond (ring)	–0.030	—	
(other increments as in nonfluorinated compounds)			

[a]Ambrose, D., Correlation and Estimation of Vapour-Liquid Critical Properties. I. Critical Temperatures of Organic Compounds, *Natl. Phys. Lab Report Chem.* **92** (1978); Correlation and Estimation of Vapour-Liquid Critical Properties. II. Critical Pressures and Volumes of Organic Compounds, *Natl. Phys. Lab Report Chem.* **98** (1979).

[b]The delta Platt number is defined as the Platt number of the isomer minus the Platt number of the corresponding alkane. (For *n*-alkanes the Platt number is $n - 3$.) The Platt number is the total number of groups of four carbon atoms three bonds apart [Platt, J. R., *J. Chem. Phys.*, **15**(1947): 419; **56**(1952): 328]. This correction is used only for branched alkanes.

[c]Includes naphthenic alcohols and glycols but not aromatic alcohols such as xylenol.

[d]First determine the hydrocarbon homomorph, i.e., substitute —CH_3 for each —OH and calculate $\sum\Delta_T$ for this compound. Subtract 0.138 from $\sum\Delta_T$ for each —OH substituted. Next, add $0.87 - 0.11n + 0.003n^2$ where $n = [T_b/\text{K (alcohol)} - 314]/19.2$. Exceptions include methanol ($\sum\Delta_T = 0$), ethanol ($\sum\Delta_T = 0.939$), and any alcohol whose value of n exceeds 10.

[e]Determine the hydrocarbon homomorph as in footnote *d*. Calculate $\sum\Delta_P$ and subtract 0.226 for each —OH substituted. Add $0.100 - 0.013n$, where n is computed as in footnote *d*.

[f]When estimating the critical volumes of aromatic substances, use ring compound values, if available, and correct for double bonds.

$$\sum \Delta_V = (8)(55.1) + (1)(-8) + (1)(-17) = 415.8$$

$$V_c = (40 + 415.8)\ \text{cm}^3/\text{mol} = 455.8\ \text{cm}^3/\text{mol}$$

Results:

Property	DIPPR® recommended value	Ambrose estimation	% Difference
T_c/K	543.8	543.0	–0.15
P_c/bar	25.70	25.63	0.27
V_c/(cm³/mol)	468.0	455.8	–2.6

Method: Joback method.

Reference: Joback, K. G., M.S. Thesis in Chemical Engineering, Massachusetts Institute of Technology, Cambridge, Mass., June 1984.

Classification: Group contributions.

Expected uncertainty: 7 K (~1 percent) for T_c; 2 bar (~5 percent) for P_c.

Applicability: Organic compounds.

Input data: T_b, group contributions Δ_T, Δ_P, Δ_V from Table 2-337, and the number of atoms in the molecule n_A.

Description: A GC method with first-order contributions. Variables T_c, P_c, and V_c are given by the following relations:

$$T_c = T_b\left[0.584 + 0.965\sum \Delta_T - \left(\sum \Delta_T\right)^2\right]^{-1} \quad (2\text{-}9)$$

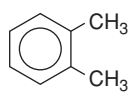
$$\frac{P_c}{\text{bar}} = \left(0.113 + 0.0032 n_A - \sum \Delta_P\right)^{-2} \quad (2\text{-}10)$$

$$\frac{V_c}{\text{cm}^3/\text{mol}} = 17.5 + \sum \Delta_V \quad (2\text{-}11)$$

where Δ_T, Δ_P, Δ_V are group contributions from Table 2-337 and n_A is the number of atoms in the molecule.

Example Estimate the critical constants of *o*-xylene by using the Joback method.

Structure:



Required input data: From the DIPPR® 801 database, T_b = 417.58 K. From Table 2-337:

Group	n_i	Δ_T	Δ_P	Δ_V
═CH— (ring)	4	0.0082	0.0011	41
═C < (ring)	2	0.0143	0.0008	32
—CH_3	2	0.0141	–0.0012	65

From Eqs. (2-9), (2-10), and (2-11):

$$\sum \Delta_T = (4)(0.0082) + (2)(0.0143) + (2)(0.0141) = 0.0896$$

$$T_c = T_b[0.584 + 0.965\ (0.896) - (0.896)^2]^{-1}$$

$$T_c = T_b(1.5096) = (417.58\ \text{K})(1.5096) = 630.37\ \text{K}$$

$n_A = 18$ $\quad \sum \Delta_P = (4)(0.0011) + (2)(0.0008) + (2)(-0.0012) = 0.00360$

$$\frac{P_c}{\text{bar}} = \left(0.113 + 0.0032 n_A - \sum \Delta_P\right)^{-2} = [0.113 + (0.0032)(18) - 0.0036]^{-2} = 35.86$$

$$P_c = 35.86\ \text{bar}$$

$$\sum \Delta_V = (4)(41) + (2)(32) + (2)(65) = 358$$

$$V_c = (17.5 + 358)\ \text{cm}^3/\text{mol} = 375.5\ \text{cm}^3/\text{mol}$$

TABLE 2-337 Joback * Group Contributions for Critical Constants

Group	Δ_T	Δ_P	Δ_V
Nonring increments:			
—CH_3	0.0141	–0.0012	65
>CH_2	0.0189	0	56
>CH—	0.0164	0.0020	41
>C<	0.0067	0.0043	27
═CH_2	0.0113	–0.0028	56
═CH—	0.0129	–0.0006	46
═C<	0.0117	0.0011	38
═C═	0.0026	0.0028	36
≡CH	0.0027	–0.0008	46
≡C—	0.0020	0.0016	37
Ring increments:			
—CH_2—	0.0100	0.0025	48
>CH—	0.0122	0.0004	38
>C<	0.0042	0.0061	27
═CH—	0.0082	0.0011	41
═C<	0.0143	0.0008	32
Halogen increments:			
—F	0.0111	–0.0057	27
—Cl	0.0105	–0.0049	58
—Br	0.0133	0.0057	71
—I	0.0068	–0.0034	97
Oxygen increments:			
—OH (alcohol)	0.0741	0.0112	28
—OH (phenol)	0.0240	0.0184	–25
—O— (nonring)	0.0168	0.0015	18
—O— (ring)	0.0098	0.0048	13
>C═O (nonring)	0.0380	0.0031	62
>C═O (ring)	0.0284	0.0028	55
—CH═O (aldehyde)	0.0379	0.0030	82
—COOH (acid)	0.0791	0.0077	89
—COO— (ester)	0.0481	0.0005	82
═O (except as above)	0.0143	0.0101	36
Nitrogen increments:			
—NH_2	0.0243	0.0109	38
>NH (nonring)	0.0295	0.0077	35
>NH (ring)	0.0130	0.0114	29
>N— (nonring)	0.0169	0.0074	9
—N═ (nonring)	0.0255	–0.0099	—
—N═ (ring)	0.0085	0.0076	34
—CN	0.0496	–0.0101	91
—NO_2	0.0437	0.0064	91
Sulfur increments:			
—SH	0.0031	0.0084	63
—S— (nonring)	0.0119	0.0049	54
—S— (ring)	0.0019	0.0051	38

*Joback, K. G., M.S. thesis in chemical engineering, Massachusetts Institute of Technology, Cambridge, Mass., June 1984.

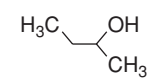
Results:

Property	DIPPR® 801 recommendation	Joback estimation	% Difference
T_c/K	630.3	630.37	0.00
P_c/bar	37.32	35.86	–3.92
V_c/(cm³/mol)	370	375.5	1.49

Example Estimate the critical constants of *sec*-butanol by using the Joback method.

Required input data: From DIPPR® 801 database, T_b = 372.7 K, M = 74.1216 kg/kmol.

Structure:



Group contributions from Table 2-337:

Group	n_i	Δ_T	Δ_P	Δ_V
—CH_3	2	0.0141	–0.0012	65
>CH_2	1	0.0189	0	56
>CH—	1	0.0164	0.0020	41
—OH (alcohol)	1	0.0741	0.0112	28

From Eqs. (2-9), (2-10), and (2-11):

TABLE 2-338 Fedors* Method Atomic and Structural Contributions

Atomic increments		Structural increments	
Atom	Δ_V	Feature	Δ_V
C	34.426	Three-member ring	–15.824
H	9.172	Four-member ring	–17.247
O	20.291	Five-member ring	–39.126
O (alcohols)	18.000	Six-member ring	–39.508
N	48.855	Double bond	5.028
N (amines)	47.422	Triple bond	0.797
F	22.242	Ring attached to another	35.524
Cl	52.801		
Br	71.774		
I	96.402		
S	50.866		

*Fedors, R. F., *AIChE J.*, **25** (1979): 202.

$$\sum \Delta_T = (2)(0.0141) + (1)(0.0189) + (1)(0.0164) + (1)(0.0741) = 0.1376$$

$$T_c = T_b(1.4330) = (372.7\ \text{K})(1.4330) = 534.1\ \text{K}$$

$$\sum \Delta_P = (2)(-0.0012) + (1)(0.0020) + (1)(0.0112) = 0.0108 \qquad n_A = 15$$

$$\frac{P_c}{\text{bar}} = (0.1022 + 0.0032 n_A)^{-2} = \left[\frac{1}{0.1022 + (0.0032)(15)}\right]^2 = 44.33$$

$$P_c = 44.33\ \text{bar}$$

$$\sum \Delta_V = (2)(65) + (1)(56) + (1)(41) + (1)(28) = 255$$

$$V_c = (17.5 + 255)\ \text{cm}^3/\text{mol} = 272.5\ \text{cm}^3/\text{mol}$$

Results:

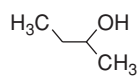
Property	DIPPR® 801 recommendation	Joback estimation	% Difference
T_c/K	536.2	534.1	–0.39
P_c/bar	42.02	44.33	5.50
V_c/(cm^3/mol)	269	272.5	1.30

Method: Fedor method.
Reference: Fedors, R. F., *AIChE J.*, **25** (1979): 202.
Classification: Atom/structure contributions.
Expected uncertainty: ~8 cm^3/mol (3 percent).
Applicability: Organic compounds.
Input data: Molecular structure, atom and structural increments, Δ_V in Table 2-238.
Description: An atom contribution method with structural increments for V_c, given by

$$\frac{V_c}{\text{cm}^3/\text{mol}} = 26.6 + \sum_{i=1}^{N} n_i \Delta_V \tag{2-12}$$

where Δ_V are structural contributions from Table 2-238.

Example Use Fedors' method to estimate the critical volume of *sec*-butanol.
Group contributions from Table 2-238:



Group	n_i	Δ_V
C	4	34.426
H	10	9.172
O (alcohol)	1	18.000

Calculation using Eq. (2-12):

$$\sum \Delta_V = (4)(34.426) + (10)(9.172) + (1)(18.000) = 247.4$$

$$V_c = (26.6 + 247.4)\ \text{cm}^3/\text{mol} = 274.0\ \text{cm}^3/\text{mol}$$

This value differs from the DIPPR® 801 recommended value of 269 cm^3/mol by 1.9 percent.

Mixtures Application of CS methods and analytical equations of state (EoS) to mixtures typically requires pseudocritical temperatures and pressures. These values are obtained from the pure-component critical properties by applying mixing rules specific to the method under consideration. While pseudocritical values should be used for mixture CS and EoS applications, the values are usually quite different from the mixture's true critical properties. A variety of methods are available for estimating true critical properties for mixtures (see PGL4), but only modest accuracy can be expected.

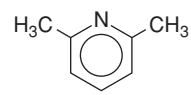
Normal Melting Point The *normal melting point* is defined as the temperature at which melting occurs at atmospheric pressure. Methods to estimate the melting point have not been particularly effective because the melting point depends strongly on solid crystal structure and that structure is not effectively correlated with standard GC or CS methods. If the triple point temperature is known, then the melting point is best estimated as being equal to the triple point temperature. However, rarely is the triple point temperature available if the melting point has not also been determined.

Recommended Method The method of Constantinou and Gani is recommended with caution.
Reference: Constantinou, L., and R. Gani, *AIChE J.*, **40** (1994): 1697.
Classification: Group contributions.
Expected uncertainty: 25 percent.
Applicability: Organic compounds.
Input data: First-order and second-order group contributions from molecular structure.
Description: A group contribution method given by

$$T_m = (102.425\ \text{K}) \cdot \ln\left(\sum_i N_i t_{m1,i} + \sum_j N_j t_{m2,j}\right) \tag{2-13}$$

where N_i, N_j = number of first- and second-order groups, respectively
$t_{m1,i}$ = first-order group contributions from Table 2-339
$t_{m2,i}$ = second-order group contributions from Table 2-340

Example Estimate the melting point of 2,6-dimethylpyridine.
Structure and group contributions:



Group	N_i	$t_{m1,i}$	$t_{m2,i}$
–CH$_3$	2	0.4640	
–C$_5$H$_3$(N)–	1	12.6275	
Six-member ring	1		1.5656

Calculation using Eq. (2-13):

$$T_m = (102.425\ \text{K}) \ln[(2)(0.4640) + 12.6275 + 1.5656] = 278\ \text{K}$$

The predicted value is 4 percent higher than the recommended experimental value of 267 K in the DIPPR® 801 database.

Normal Boiling Point The normal boiling temperature T_b is the temperature at which the vapor pressure of the liquid equals 101.325 kPa (1.0 atm). In some (usually older) literature sources, T_b values were reported at ambient pressures rather than at 101.325 kPa. If two or more such values are available, they can be be used to obtain T_b by using Eq. (2-2) to linearly interpolate $\ln P^*$ vs. $1/T$ values.

If there are sufficient vapor pressure data available, then T_b may be found from a regression of the data using an appropriate vapor pressure equation [e.g., Eqs. (2-21)–(2-26)]. If one or a few vapor pressure data at low pressure are available, a common occurrence, then the method of Pailhes can be used to estimate T_b. The most accurate method for prediction of normal boiling temperatures without experimental data is the Nannoolal method.

TABLE 2-339 First-Order Groups and Their Contributions for Melting Point*

Group	$t_{m1,i}$	Group	$t_{m1,i}$	Group	$t_{m1,i}$
—CH_3	0.4640	—$COOCH_2$—	3.5572	—CCl_3	10.2337
>CH_2	0.9246	—OOCH	4.2250	>ACCl	2.7336
>CH—	0.3557	—OCH_3	2.9248	—CH_2NO_2	5.5424
>C<	1.6479	—OCH_2—	2.0695	>$CHNO_2$	4.9738
—CH=CH_2	1.6472	—OCH<	4.0352	>$ACNO_2$	8.4724
—CH=CH—	1.6322	—OCH_2F	4.5047	—CH_2SH	3.0044
>C=CH_2	1.7899	—CH_2NH_2	6.7684	—I	4.6089
>C=CH—	2.0018	>$CHNH_2$	4.1187	—Br	3.7442
>C=C<	5.1175	—$NHCH_3$	4.5341	—C≡CH	3.9106
—CH=C=CH_2	3.3439	—CH_2NH—	6.0609	—C≡C—	9.5793
>ACH	1.4669	>CHNH—	3.4100	>C=CCl—	1.5598
>AC—	0.2098	>NCH_3	4.0580	>ACF	2.5015
>$ACCH_3$	1.8635	—NCH_2—	0.9544	—CF_3	3.2411
>$ACCH_2$—	0.4177	>$ACNH_2$	10.1031	—COO—	3.4448
>ACCH<	–1.7567	—$C_5H_3(N)$—	12.6275	—CCl_2F	7.4756
—OH	3.5979	—CH_2CN	4.1859	—$CClF_2$	2.7523
>ACOH	13.7349	—COOH	11.5630	—F (other)	1.9623
—$COCH_3$	4.8776	—CH_2Cl	3.3376	—$CONH_2$	31.2786
—$COCH_2$—	5.6622	>CHCl	2.9933	—$CON(CH_3)_2$	11.3770
—CHO	4.2927	>CCl—	9.8409	—CH_3S	5.0506
—$COOCH_3$	4.0823	—$CHCl_2$	5.1638	>CH_2S	3.1468

*Constantinou, L., and R. Gani, *AIChE J.*, **40** (1994): 1697.

Recommended Method Pailhes method.
Classification: Group contributions.
Expected uncertainty: 3 K (~1 to 2 percent).
Applicability: Organic compounds.
Reference: Pailhes, F., *Fluid Phase Equilib.*, **41** (1988): 97.
Input data: Molecular structure and one measured vapor pressure value P^*_{meas}, (often at a low pressure). The method requires estimation of T_c and P_c using a group contribution method. The original Pailhes method used the Lyderson method [Lydersen, A. L., *AIChE J.*, **21** (1975): 510], but the Joback method is illustrated here for consistency with the previous examples on critical constant estimation.

Description: A simple group contribution method given by

$$T_b = T_{meas}\frac{\log(P_c/\text{bar}) + (1 - T_{br})x_P}{\log(P_c/\text{bar})} - 3x_P - 1.49x_P^2 \qquad (2\text{-}14)$$

where T_b = estimate of normal boiling point
P_c = critical pressure estimated from group contributions
T_{br} = reduced normal boiling point estimated from Eq. (2-9)
$x_P = \log(1\ \text{atm}/P^*_{meas})$
T_{meas} = temperature at which experimental vapor pressure is known

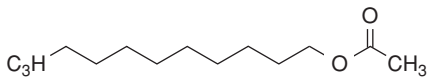
TABLE 2-340 Second-Order Groups and Their Contributions for Melting Point*

Group	$t_{m2,i}$	Group	$t_{m2,i}$
—$CH(CH_3)_2$	0.0381	CHCOOH; CCOOH	–3.1034
—$C(CH_3)_3$	–0.2355	ACCOOH	28.4324
—$CH(CH_3)CH(CH_3)$—	0.4401	CH_3COOCH; CH_3COOC	0.4838
—$CH(CH_3)C(CH_3)_2$—	–0.4923	$COCH_2COO$ or COCHCOO or COCCOO	0.0127
—$C(CH_3)_2C(CH_3)_2$—	6.0650	CO—O—CO	–2.3598
Three-member ring	1.3772	ACCOO	–2.0198
Five-member ring	0.6824	CHOH	–0.5480
Six-member ring	1.5656	COH	0.3189
Seven-member ring	6.9709	$CH_m(OH)CH_n(OH)$ [$m, n = 0, 1, 2$]	0.9124
CH_n=CH_m—CH_p=CH_k [$k, n, m, p = 0, 1, 2$]	1.9913	$CH_{m\ cyclic}$—OH [$m = 0, 1$]	9.5209
CH_3CH_m=CH_n [$m, n = 0, 1, 2$]	0.2476	$CH_m(OH)CH_n(NH_p)$ [$m, n, p = 0, 1, 2, 3$]	2.7826
CH_2CH_m=CH_n [$m, n = 0, 1, 2$]	–0.5870	$CH_m(NH_2)CH_n(NH_2)$ [$m, n = 0, 1, 2$]	2.5114
$CHCH_m$=CH_n or CCH_m=CH_n [$m, n = 0, 1, 2$]	–0.2361	$CH_{m\ cyclic}$—NH_p—$CH_{n\ cyclic}$ [$m, n, p = 0, 1, 2$]	1.0729
Alicyclic side chain: $C_{cyclic}C_m$ [$m > 1$]	–2.8298	CH_m—O—CH_n=CH_p [$m, n, p = 0, 1, 2$]	0.2476
CH_3CH_3	1.4880	AC—O—CH_m [$m = 0, 1, 2, 3$]	0.1175
CHCHO; CCHO	2.0547	$CH_{m\ cyclic}$—S—$CH_{n\ cyclic}$ [$m, n = 0, 1, 2$]	–0.2914
CH_3COCH_2	–0.2951	CH_m=CH_n—F [$m, n = 0, 1, 2$]	–0.0514
CH_3COCH; CH_3COC	–0.2986	CH_m=CH_n—Br [$m, n = 0, 1, 2$]	–1.6425
C_{cyclic}(=O)	0.7143	ACBr	2.5832
ACCHO	–0.6697	ACl	–1.5511

*Constantinou, L., and R. Gani, *AIChE J.*, **40** (1994): 1697.

Example The vapor pressure of *n*-decylacetate at 348.65 K is 106.66 Pa. Estimate the normal boiling point of this compound.

Structure and group contributions from Table 2-337:



Group	n_i	Δ_T	Δ_P
—CH3	2	0.0141	–0.0012
>CH_2	9	0.0189	0
—COO— (ester)	1	0.0481	0.0005

Group contribution calculations using Eqs. (2-9) and (2-10):

$$\sum \Delta_T = (2)(0.0141) + (9)(0.0189) + (1)(0.0481) = 0.2464$$

$$T_{br} = 0.584 + 0.965(0.2464) - (0.2464)^2 = 0.76106$$

$$\sum \Delta_P = (2)(-0.0012) + (1)(0.0005) = -0.0019$$

$n_A = 38 \qquad P_c = (0.113 + 0.0032n_A + 0.0019)^{-2}\,\text{bar} = 17.88\ \text{bar} = 17.65\ \text{atm}$

Calculation of auxiliary quantities:

$$x_P = \log \frac{1\ \text{atm}}{P^*_{\text{meas}}} = \log \frac{101325\ \text{Pa}}{106.66\ \text{Pa}} = 2.9777$$

Calculation of normal boiling point using Eq. (2-14):

$$\frac{T_b}{\text{K}} = 348.65 \frac{\log 17.88 + (1 - 0.76016)(2.9777)}{\log 17.88} - 3(2.9777) - 1.49(2.9777)^2$$

$$T_b = 525.3\ \text{K}$$

The estimated value is 1.6 percent higher than the DIPPR® 801 recommended value of 517.15 K.

Recommended Method Nannoolal method.

Reference: Nannoolal, Y., et al., *Fluid Phase Equilib.*, **226** (2004): 45.

Classification: Group contributions.

Expected uncertainty: 7 K (on the order of 2 percent).

Applicability: Organic compounds for which group values are available.

Input data: GC values C_i in Table 2-341; intramolecular group-group interactions C_{ij} in Table 2-342.

Description: A GC method that includes second-order corrections for steric effects and intramolecular interactions. Variable T_b is found from

$$\frac{T_b}{K} = \frac{\sum_{i=1}^{N} n_i \cdot C_i}{n^{0.6583} + 1.6868} + 84.3395 \qquad (2\text{-}15)$$

where n = number of nonhydrogen atoms
n_i = number of occurrences of group i
N = number of groups
C_i = group contribution from Table 2-341 or Eq. (2-16)

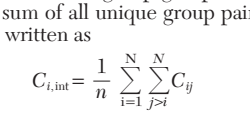
Corrections for intramolecular group-group interactions $C_{i,\text{int}}$ are made by dividing the sum of all unique group pairs within the molecule by n. This can be written as

$$C_{i,\text{int}} = \frac{1}{n} \sum_{i=1}^{N} \sum_{j>i}^{N} C_{ij} \qquad (2\text{-}16)$$

or thought of as the sum of terms in the upper half (above and to the right of the diagonal) of the square matrix formed by listing each group in the molecule along the row and column. The values for the interactions are shown in this format in Table 2-342.

Example Estimate the normal boiling point of di-isopropanolamine by using the Nannoolal method.

Structure:



Group contributions and values:

Group	n_i	C_i	Group total
—CH3	2	177.3066	354.6132
>C(c)<(e)	4	266.8769	1067.508
—OH sec	2	390.2446	780.4892
—NH—	1	223.0992	223.0992
Corrections			
—OH::—OH	1/9	291.7985	32.42206
—OH::—NH—	2/9	286.9698	63.77107
		Total	2521.902

Note that there are three interacting groups (—OH, —OH, —NH—) in the molecule which gives two —OH::—NH— interactions and one —OH::—OH interaction which are then divided by n (= 9) as in Eq. (2-16) to give the frequency.

Calculation using Eq. (2-15):

$$\frac{T_b}{K} = \frac{2521.902}{9^{0.6583} + 1.6868} + 84.3395 = 509.3 \qquad T_b = 509.3\ \text{K}$$

The calculated value differs by –2.4 percent from the DIPPR® 801 recommended value of 521.9 K.

Characterizing and Correlating Constants

Acentric Factor The acentric factor of a compound ω is defined in terms of the reduced vapor pressure evaluated at a reduced temperature of 0.7 as

$$\omega = -\log P_r^* \big|_{T_r = 0.7} - 1.0000 \qquad (2\text{-}17)$$

It is primarily used as a third parameter (beyond T_c and P_c) in CS predictions as a measure of deviations from nonspherical molecular shape, hence the name, suggesting molecular interactions that are not between centers of molecules. However, as defined in Eq. (2-17), ω also contains polarity information, and ω increases slightly with increasing polarity for molecules of similar size and shape. The value of ω is close to zero for small, spherically shaped, nonpolar molecules (argon, methane, etc.). It increases in value with larger deviations of molecular shape from spherical (longer chain lengths, less chain branching, etc.) and with increasing molecular polarity. When possible, ω should be obtained from experimental vapor pressure correlations by using Eq. (2-17), but an accurate estimation of ω can be made by using the critical constants and a single vapor pressure point by application of CS vapor pressure equations.

Recommended Method Ambrose-Walton modification of Lee-Kesler vapor pressure equations.

References: Ambrose, D., and J. Walton, *Pure & Appl. Chem.*, **61** (1989): 1395; Lee, B. I., and M. G. Kesler, *AIChE J.*, **21** (1975): 510.

Classification: Corresponding states.

Expected uncertainty: Generally within 5 percent.

Applicability: Most organic compounds.

Input data: T_c, P_c, and a single vapor pressure point (e.g., the normal boiling point).

Description: See Eq. (2-25) for the equations used in this method. The vapor pressure equation is inverted to obtain the acentric factor from a single experimental vapor pressure point.

Example Calculate the acentric factor of chlorobenzene with a known value for T_b.

Input information: From the DIPPR® 801 database, T_b = 404.87 K, T_c = 632.35 K, and P_c = 45.1911 bar.

Calculation of auxiliary quantities:

$$T_{br} = \frac{T_b}{T_c} = \frac{404.87}{632.35} = 0.64 \qquad \tau = 1 - 0.64 = 0.36$$

$$f^{(0)} = \frac{(-5.97616)(0.36) + (1.29874)(0.36)^{1.5} - (0.60394)(0.36)^{2.5} - (1.06841)(0.36)^5}{0.64}$$

$$= -3.0034$$

$$f^{(1)} = \frac{(-5.03365)(0.36) + (1.11505)(0.36)^{1.5} - (5.41217)(0.36)^{2.5} - (7.46628)(0.36)^5}{0.64}$$

$$= -3.1788$$

TABLE 2-341 Group Contributions for the Nannoolal* Method for Normal Boiling Point

Table-specific nomenclature: (e) = connected to N, O, F, Cl; (ne) = not connected to N, O, F, Cl; (r) = in a ring; (c) = in a chain; (a) = aromatic, not necessarily carbon; (Ca) = aromatic carbon; b = any nonhydrogen atom

ID	Group	Description	Value
1	CH_3—(ne)	CH_3— not connected to N, O, F, or Cl	177.3066
2	CH_3—(e)	CH_3— connected to N, O, F, or Cl	251.8338
3	CH_3—(a)	CH_3— connected to an aromatic atom (not necessarily C)	157.9527
4	—C(c)H_2—	—CH_2— in a chain	239.4531
5	>C(c)H—	>CH— in a chain	240.6785
6	>C(c)<	>C< in a chain	249.5809
7	>C(c)<(e)	>C< in a chain connected to at least one F, Cl, N, or O	266.8769
8	>C(c)<(Ca)	>C< in a chain connected to at least one aromatic carbon	201.0115
9	—C(r)H_2—	—CH_2— in a ring	239.4957
10	>C(r)H—	>CH— in a ring	222.1163
11	>C(r)<	>C< in a ring	209.9749
12	>C(r)<(e, c)	>C< in a ring; connected to at least one N, O, Cl, or F which are not part of the ring	250.9584
13	>C(r)<(e, r)	>C< in a ring connected to at least one N or O which are part of the ring	291.2291
14	>C(r)<(Ca)	>C< in a ring connected to at least one aromatic carbon	244.3581
15	═C(a)H—	aromatic ═CH—	235.3462
16	═C(a)<(ne)	aromatic ═C< not connected to O, N, Cl, or F	315.4128
17	═C(a)<(e)	aromatic ═C< connected to O, N, Cl, or F	348.2779
18	(a)═C(a)<2(a)	aromatic ═C< with three aromatic neighbors	367.9649
19	F—(C, Si)	F— connected to C or Si	106.5492
20	—CF═C<	F— on a C═C (vinylfluoride)	49.2701
21	F—(C,Si)(F)(2b)	F— connected to C or Si already substituted with at least one F and two other atoms	53.1871
22	F—(C,Si)([F, Cl])(b)	F— connected to a C or Si already substituted with one F or Cl and one other atom	78.7578
23	F—(C,Si)([F, Cl]2)	F— connected to C or Si already substituted with two F or Cl atoms	103.5672
24	F—(Ca)	F— connected to an aromatic carbon	–19.5575
25	Cl—(C,Si)	Cl— connected to C or Si not already substituted with F or Cl	330.9117
26	Cl—(C,Si)([F, Cl])	Cl— connected to C or Si already substituted with one F or Cl	287.1863
27	Cl—(C, Si)([F, Cl]2)	Cl— connected to C or Si already substituted with at least two F or Cl	267.4170
28	Cl—(Ca)	Cl— connected to aromatic C	205.7363
29	—CCl═C<	Cl— on a C═C (vinylchloride)	292.5816
30	Br—(C,Si)	Br— connected to a nonaromatic C or Si	419.4959
31	Br—(Ca)	Br— connected to an aromatic C	377.6775
32	I—(C, Si)	I— connected to C or Si	556.3944
33	—OH *tert*	—OH connected to tertiary carbon	349.9409
34	HO—(C,Si) *sec*	—OH connected to secondary C or Si	390.2446
35	HO—(C,Si) long	—OH connected to primary C or Si; chain > 4 C or Si	443.8712
36	HO—(C,Si) short	—OH connected to primary C or Si; chain < 5 C or Si	488.0819
37	—OH (Ca)	—OH connected to an aromatic C (phenols)	361.4775
38	(C,Si)—O—(C,Si)	ether —O— connected to two C or Si	146.4836
39	>(OC_2)<	>(OC_2)< (epoxide)	820.7118
40	NH_2—(C, Si)	NH_2— connected to either C or Si	321.1759
41	NH_2—(Ca)	NH_2— connected to an aromatic C	441.4388
42	(C,Si)—NH—(C,Si)	—NH— connected to two C or Si (secondary amine)	223.0992
43	(C,Si)2>N—(C,Si)	>N— connected to three C or Si (tertiary amine)	126.2952
44	COOH—(C)	—COOH connected to C	1080.3139
45	(C)—COO—(C)	—COO— connected to two C (ester)	636.2020
46	HCOO—(C)	HCOO— connected to C (formic acid ester)	642.0427
47	—C(c)OO—	—COO— in ring, C is connected to C (lactone)	1142.6119
48	—CON<	—CON< disubstituted amide	1052.6072
49	—CONH—	—CONH— (monosubstituted amide)	1364.5333
50	—$CONH_2$	—$CONH_2$ (amide)	1487.4109
51	O═C<(Can)2	—CO— connected to two nonaromatic C (ketones)	618.9782
52	CHO—(Can)	CHO— connected to nonaromatic C (aldehydes)	553.8090
53	SH—(C)	—SH connected to C (thioles)	434.0811
54	(C)—S—(C)	—S— connected to two C	461.5784
55	(C)—S—S—(C)	—S—S— (disulfide) connected to two C	864.5074
56	—S(a)—	—S— in an aromatic ring	304.3321
57	(C)—C≡N	—C≡N (cyanide) connected to C	719.2462
58	>C(c)═C(c)<	>C═C< (both C have at least one non-H neighbor)	475.7958
59	>C(c)═C(c)<(Ca)	noncyclic >C═C< connected to at least one aromatic C	586.1413
60	—(e)C(c)═C(c)<	noncyclic >C═C< with at least one F, Cl, N, or O	500.2434
61	H_2C(c)═C<	H_2C═C< (1-ene)	412.6276
62	>C(r)═C(r)<	cyclic >C═C<	475.9623
63	—C≡C—	—C≡C—	512.2893
64	HC≡C—	HC≡C— (1-yne)	422.2307
65	(Ca)—O(a)—(Ca)	—O— in an aromatic ring with aromatic C neighbors	37.1936
66	═N(a)—(r5)	aromatic —N— in a five-member ring, free electron pair	453.3397
67	═N(a)—(r6)	aromatic ═N— in a six-member ring	306.7139
68	NO_2—(C)	NO_2— connected to aliphatic C	866.5843
69	NO_2—(Ca)	NO_2— connected to aromatic C	821.4141
70	>Si<	>Si<	282.0181
71	>Si<(O)	>Si< connected to at least one O	207.9312
72	NO_3—	nitrate (esters of nitric acid)	920.3617
73	PO_4—	phosphates	1153.1344
74	O═N—O—(C)	nitrites (esters of nitrous acid)	494.2668

TABLE 2-341 Group Contributions for the Nannoolal* Method for Normal Boiling Point (*Concluded*)

Table-specific nomenclature: (e) = connected to N, O, F, Cl; (ne) = not connected to N, O, F, Cl; (r) = in a ring; (c) = in a chain; (a) = aromatic, not necessarily carbon; (Ca) = aromatic carbon; b = any nonhydrogen atom

ID	Group	Description	Value
75	ONC—	ONC— (oxime)	1041.0851
76	—C═O—O—C═O—	anhydride connected to two C	1251.2675
77	COCl—	COCl— connected to C (acid chloride)	778.9151
78	>Si<(F,Cl)	>Si< connected to at least one F or Cl	540.0895
79	O═C(—O—)2	noncyclic carbonate	879.7062
80	OCN—	OCN— connected to C or Si (cyanate)	660.4645
81	SCN—(C)	SCN— (thiocyanate) connected to C	1018.4865
82	(C)—SO_2—(C)	noncyclic sulfone connected to two C (sulfones)	1559.9840
83	(C)2>Sn<(C)2	>Sn< connected to four carbons	510.4223
84	$AsCl_2$—	$AsCl_2$ connected to C	1149.9670
85	$GeCl_3$—	$GeCl_3$— connected to carbons	1209.2972
86	(C)2>Ge<(C)2	>Ge< connected to four carbons	347.7717
87	>C═C═C<	cumulated double bond	664.0903
88	>C═C—C═C<(r)	conjugated double bond in a ring	957.6388
89	>C═C—C═C<(c)	conjugated double bond in a chain	928.9954
90	CHO—(Ca)	CHO— connected to aromatic C (aldehydes)	560.1024
91	(C,Si)═N—	double-bonded amine connected to at least one C or Si	229.2288
92	(O═C< (C)2)a	—CO— connected to two C with at least one aromatic C (ketones)	606.1797
94	—O—O—	peroxide	273.1755
95	—C≡C—C≡C—	conjugated triple bond	1218.1878
96	(—C═O—O—C═O—)r	cyclic anhydride connected to two C	2082.3288
97	(C,Si)a—NH—(Ca,Si)a	—NH— connected to two C or Si with at least one aromatic (secondary amines)	201.3224
99	—OCON<	—CO connected to O and N (carbamate)	886.7613
100	>N—(C═O)—N<	—CO connected to two N (urea)	1045.0343
101	(C,Si)2>N< (C,Si)2	Quaternary amine connected to four C or Si	–109.6269
102	F—(C,Si)(Cl)(b)2	F— connected to C or Si already substituted with at least one Cl and two other atoms	111.0590
103	—OCOO—	—CO connected to two O (carbonates)	1573.3769
104	$>SO_4$	$S(=O)_2$ connected to two O (sulfates)	1483.1289
105	—SO_2N<	—$S(=O)_2$ connected to N	1506.8136
106	···═CNC═NC═···	imadizole	484.6371
107	>S═O	sulfoxide	1379.4485
108	(S)—C≡N	—C≡N (cyanide) connected to S	659.7336
109	>N(C═O)	—CO connected to N	492.0707
111	(N)—C≡N	—C≡N (cyanide) connected to N	971.0365
113	>P<	phosphorus connected to at least 1 C or S (phosphine)	428.8911
115	—ON═(C,Si)	—ON═ connected to C or Si (isoazole)	612.9506
116	>Se<	>Se< connected to at least one C or Si	562.1791
117	>Al<	>Al< connected to at least one C or Si	761.6006
		Corrections	
118	C═C—C═O	—C═O connected to sp_2 carbon	40.4205
119	(C═O)—C([F,Cl]2,3)	carbonyl connected to C with two or more halogens	–82.2328
120	(C═O)—C([F,Cl]2,3)2	carbonyl connected to two C, each with at least two halogens	–247.8893
121	C—[F,Cl]3	carbon with three halogens	–20.3996
122	(C)2—C—[F,Cl]2	secondary carbon with two halogens	15.4720
123	No hydrogen	component has no hydrogen	–172.4201
124	One-hydrogen	component has one hydrogen	–99.8035
125	(3,4) ring	a three- or four-member nonaromatic ring	–62.3740
126	5-ring	a five-member nonaromatic ring	–40.0058
127	*Ortho* pair(s)	*Ortho*- position counted only once and only if there are no *meta* or *para* pairs	–27.2705
128	*Meta* pair(s)	*Meta*- position counted only once and only if there are no *para* or *ortho* pairs	–3.5075
129	*Para* pair(s)	*Para*- position counted only once and only if there are no *meta* or *ortho* pairs	16.1061
130	((C═)(C)C—CC3)	carbon with four carbon neighbors and one double-bonded carbon neighbor	25.8348
131	C2C—CC2	carbon with four carbon neighbors, two on each side	35.8330
132	C3C—CC2	carbon with five carbon neighbors	51.9098
133	C3C—CC3	carbon with six carbon neighbors	111.8372

*Nannoolal, Y., et al., *Fluid Phase Equilib*. **226** (2004): 45.

$$f^{(2)} = \frac{(-0.64771)(0.36) + (2.41539)(0.36)^{1.5} - (4.26979)(0.36)^{2.5} + (3.25259)(0.36)^{5}}{0.64}$$

$$= -0.037$$

Calculation using Eq. (2-25) at the normal boiling point:

$$\ln \frac{1.01325}{45.1911} = -3.798 = f^{(0)} + \omega f^{(1)} + \omega f^{(2)} = 3.0034 + 3.1788\omega + 0.037\omega^2$$

$$\omega = 0.249$$

The value obtained from the Ambrose-Walton-Lee-Kesler method compares favorably with the value of 0.2499 recommended in the DIPPR® 801 database (obtained from the vapor pressure correlation).

Radius of Gyration The radius of gyration R_g is a measure of the mass distribution about the center of mass of a molecule. Radius R_g increases with molecular size. It is useful in CS applications to separate molecular size and shape effects from polar effects. It is defined in terms of the principal moments of inertia of a molecule (A, B, and C) as

$$R_g = \sqrt{\frac{(AB)^{1/2} N_A}{M}} \tag{2-18}$$

for planar molecules and as

$$R_g = \sqrt{\frac{2\pi (ABC)^{1/3} N_A}{M}} \tag{2-19}$$

TABLE 2-342 Intermolecular Interaction Corrections for the Nannoolal et al.* Method for Normal Boiling Point

	—OH	—OH(a)	—COOH	—O—	>(OC_2)<	—COOC—	—CO—	—CHO
—OH	291.7985	0	146.7286	135.3991	226.4980	211.6814	46.3754	0
—OH(a)		288.6155	−1477.9671	130.3742	0	−1184.9784	0	43.9722
—COOH			117.2044	612.8821	0	−183.2986	−55.9871	0
—O—				91.4997	178.7845	322.5671	15.6980	17.0400
>(OC_2)<					1006.388	0	22.5208	163.5475
—COOC—						431.0990	22.5208	0
—CO—							−303.9653	−391.3690
—CHO								582.1763

	—O(a)—	—S(na)—	—S(a)—	—SH	—NH_2	>NH	—OCN	—CN
—OH	435.0923	−74.0193	0	38.6974	314.6126	286.9698	0	306.3979
—OH(a)	0	0	0	0	797.4327	0	0	0
—COOH	0	0	0	0	0	0	0	0
—O—	329.0050	394.5505	0	0	124.3549	101.8475	0	293.5974
>(OC_2)<	0	0	0	0	0	0	0	0
—COOC—	707.9404	0	0	0	182.6291	317.0200	0	517.0677
—CO—	176.5481	0	381.0107	0	0	−215.3532	0	−574.2230
—CHO	674.6858	0	397.575	0	0	0	0	0
—O(a)—	0	0	0	0	395.4093	0	0	0
—S(na)—		−11.9406	0	0	−562.306	0	0	0
—S(a)—			0	0	0	0	0	−101.232
—SH				217.6360	0	0	0	0
—NH_2					174.0258	510.3473	0	0
>NH						239.8076	0	0
—OCN							−356.5017	0
—CN								0

	Nitrate	═N(a)—(r5)	═N(a)—(r6)
—OH	0	0	1334.6747
—OH(a)	−1048.124	0	−614.3624
—COOH	0	0	0
—O—	963.6518	0	0
>(OC_2)<	0	0	0
—COOC—	−205.6165	0	0
—CO—	−3628.903	0	124.1943
—CHO	140.9644	0	0
—O(a)—	0	−888.612	0
—S(na)—	0	0	0
—S(a)—	0	−348.740	0
—SH	0	0	0
—NH_2	663.8009	0	27.2735
>NH	0	0	758.9855
—OCN	−263.0807	0	0
—CN	0	0	−370.9729
Nitrate	65.1432	0	0
═N(a)–(r5)		0	0
═N(a)–(r6)			−271.9449

*Nannoolal, Y., et al., *Fluid Phase Equilib.*, **226** (2004): 45.

for nonplanar molecules. Radii of gyration can be calculated from these defining equations and principal moments of inertia obtained from spectral data or from computational chemistry software.

Recommended Method Principal moments of inertia.

Classification: Computational chemistry.

Expected uncertainty: Less than 5 percent.

Applicability: All molecules.

Input data: M and molecular structure.

Description: Computational chemistry software is used to optimize the geometry of the molecule and obtain the principal moments of inertia to be used in Eqs. (2-18) and (2-19).

Example Calculate the radius of gyration for hydrazine.

Input information: From the DIPPR® 801 database, $M = 32.0452$ kg/kmol. The structure of hydrazine is

$$H_2N—NH_2$$

Calculation of the principal moments of inertia: Optimizing hydrazine with HF/6-31G model chemistry gives the following principal moments of inertia:

$$A = 12.24050 \text{ amu}\cdot\text{Bohr}^2 \qquad B = 72.41081 \text{ amu}\cdot\text{Bohr}^2$$
$$C = 79.16893 \text{ amu}\cdot\text{Bohr}^2$$

Conversion from atomic units to SI gives

$$A = (12.24050 \text{ amu}\cdot\text{Bohr}^2)\left(\frac{5.29177\times10^{-11}\text{ m}}{\text{Bohr}}\right)^2\left(\frac{1.66054\times10^{-27}\text{ kg}}{\text{amu}}\right)$$
$$= 5.692\times10^{-47}\text{ kg}\cdot\text{m}^2$$

$$B = (72.41081 \text{ amu}\cdot\text{Bohr}^2)\left(\frac{4.65010^{-48}\text{ kg}\cdot\text{m}^2}{\text{amu}\cdot\text{Bohr}^2}\right) = 3.367\times10^{-46}\text{ kg}\cdot\text{m}^2$$

$$C = (79.16893 \text{ amu}\cdot\text{Bohr}^2)\left(\frac{4.65010^{-48}\text{ kg}\cdot\text{m}^2}{\text{amu}\cdot\text{Bohr}^2}\right) = 3.681\times10^{-46}\text{ kg}\cdot\text{m}^2$$

Calculation using Eq. (2-19):

$$(ABC)^{1/3} = [(5.692\times10^{-47})(3.367\times10^{-46})(3.681\times10^{-46})]^{1/3}\text{ kg}\cdot\text{m}^2$$
$$= 1.918\times10^{-46}\text{ kg}\cdot\text{m}^2$$

$$R_g = \sqrt{\frac{2\pi(1.918\times10^{-46}\ \text{kg}\cdot\text{m}^2)(6.022\cdot10^{26}\ \text{kmol}^{-1})}{32.0452\ \text{kg/kmol}}} = 1.505\times10^{-10}\ \text{m}$$

This is 3.8 percent below the DIPPR® 801 database value of 1.564×10^{-10} m which was obtained from spectral principal moments of inertia.

Dipole Moment The dipole moment of a molecule is the first moment of the electric charge density expansion. All normal paraffins have a value of zero. Charge separation within the molecule due to electronegativity differences between bonded atoms increases the dipole moment. Computational chemistry software uses the electron density distribution of the optimized molecule to calculate dipole moments.

Recommended Method Electron density distribution.
Classification: Computational chemistry.
Expected uncertainty: Uncertainty varies depending upon the model chemistry chosen, but it can be as large as 60 percent.
Applicability: All molecules.
Input data: Molecular structure.

Example Calculate the dipole moment for methanol.
Draw structure and optimize molecule using computational chemistry software: The dipole moment obtained from a geometry optimized with the HF/6-31G model chemistry for methanol is 2.288 D. This value is 35 percent larger than the experimental gas-phase value of 1.700 D in the DIPPR® 801 database.

VAPOR PRESSURE

Liquids Vapor pressure is the most important of the basic thermodynamic properties of fluids. It is the pressure of equilibrium, coexisting liquid and vapor phases at a specified temperature. The vapor pressure curve is a monotonic function of temperature from its minimum value (the triple point pressure) at the triple point temperature T_t to its maximum value (the critical pressure) at T_c.

Liquid vapor pressure data over a limited temperature range can be correlated with the Antoine [Antoine, C, *C.R.*, **107** (1888): 681, 836] equation

$$\ln\frac{P^*}{\text{Pa}} = A - \frac{B}{\text{T/K} + C} \qquad (2\text{-}20)$$

Data from the triple point to the critical point can be correlated with either a modified form of the Wagner equation [Wagner, W., *"A New Correlation Method for Thermodynamic Data Applied to the Vapor-Pressure Curve of Argon, Nitrogen, and Water,"* J.T.R. Watson (trans. and ed.), IUPAC Thermodynamic Tables Project Centre, London, 1977; Ambrose, D., *J. Chem. Thermodyn.*, **18** (1986): 45; Ambrose, D., and N. B. Ghiassee, *J. Chem. Thermodyn.*, **19** (1987): 903, 911]

$$\ln P_r^* = \frac{a\tau + b\tau^{1.5} + c\tau^{2.5} + d\tau^5}{1-\tau} \qquad \text{where } \tau \equiv 1 - T_r \qquad (2\text{-}21)$$

or the Riedel [Riedel, L., *Chem. Ing. Tech.*, **26** (1954): 679] equation

$$\ln\frac{P^*}{\text{Pa}} = A + \frac{B}{T/\text{K}} + C\ln\frac{T}{\text{K}} + D\left(\frac{T}{\text{K}}\right)^E \qquad (2\text{-}22)$$

Generally, E in Eq. (2-22) is assigned a value of 6, but values of 2 or 1 have also been used, particularly when correlating low-temperature data. While the Wagner equation can be used to correlate most fluids over the whole liquid range, a fifth term is often required for alcohols [Poling, B. E., *Fluid Phase Equil.*, **116** (1996): 102]:

$$\ln P_r^* = \frac{a\tau + b\tau^{1.5} + c\tau^{2.5} + d\tau^5 + e\tau^6}{1-\tau} \qquad \text{(for alcohols)} \qquad (2\text{-}23)$$

Correlation of experimental data within a few tenths of a percent over the entire fluid range can usually be obtained with either the Wagner or Riedel equations.

Two prediction methods are recommended for liquid vapor pressure. The first method is based on the Riedel equation; the second is a CS method. Both methods require T_c and P_c as input, but these can be estimated by the methods shown earlier if experimental values are unavailable.

Recommended Method 1 Riedel method.
Reference: Riedel, L., *Chem. Ing. Tech.*, **26** (1954): 679
Classification: Empirical extension of theory and corresponding states.
Expected uncertainty: Varies strongly depending upon relative T, but 1 percent or less above T_b is typical with uncertainties of 5 to 30 percent near the triple point.
Applicability: Most organic compounds.
Input data: T_b, T_c, P_c.
Description: Equation (2-22) in reduced form

$$\ln P_r = A + \frac{B}{T_r} + C\ln T_r + DT_r^6 \qquad (2\text{-}24)$$

Constants for this equation are determined from the following set of relationships:

$$\psi = -35 + \frac{36}{T_{br}} + 42\ln T_{br} - T_{br}^6 \qquad \alpha_c = \frac{3.758K\psi + \ln(P_c/1.01325\ \text{bar})}{K\psi - \ln T_{br}}$$

$$h = T_{br}\frac{\ln(P_c/1.01325\ \text{bar})}{1-T_{br}} \qquad D = K(\alpha_c - 3.758)$$

$$C = \alpha_c - 42D \qquad B = -36D \qquad A = 35D$$

Values of the constant K [Vetere, A., *Ind. Eng. Chem Res.*, **30** (1991): 2487]:

Class	Value
Acids	$K = -0.120 + 0.025h$
Alcohols	$K = 0.373 - 0.030h$
All other organic compounds	$K = 0.0838$

Example Estimate the vapor pressure of chlorobenzene at 50 K intervals from 300 to 600 K.
Input information: From the DIPPR® 801 database, T_b = 404.87 K, T_c = 632.35 K, and P_c = 45.1911 bar.
Auxiliary Quantities:

$$K = 0.0838 \qquad T_{br} = 404.87/632.35 = 0.640$$

$$\psi = -35 + \frac{36}{0.640} + 42\ln 0.640 - (0.640)^6 = 2.431$$

$$\alpha_c = \frac{(3.758)(0.0838)(2.431) + \ln(45.191/1.01325)}{(0.0838)(2.431) - \ln(0.640)} = 7.0248$$

$$D = (0.0838)(7.0248 - 3.758) = 0.2738 \qquad C = 7.0248 - (42)(0.2738) = -4.4729$$

$$B = -(36)(0.2738) = -9.8552 \qquad A = -(35)(0.2738) = 9.5814$$

Calculation using Eq. (2-24) at each T (detailed calculation shown for T = 500 K):

$$T_r = 500/632.35 = 0.7907$$

$$\ln P_r = 9.5814 - \frac{9.8552}{0.7907} - 4.4729\ln 0.7907 + (0.2738)(0.7907)^6 = -1.7651$$

$$P_r = \exp(-1.7651) = 0.1712 \qquad P = P_rP_c = (0.1712)(45.1911\ \text{bar}) = 7.74\ \text{bar}$$

T/K	T_r	$\ln P_r$	P/bar	P_{DIPPR}/bar	% Error
300	0.4744	–7.8532	0.0176	0.0175	0.3
350	0.5535	–5.5704	0.172	0.172	0.1
400	0.6326	–3.9323	0.886	0.880	0.6
450	0.7116	–2.7101	3.01	2.98	0.9
500	0.7907	–1.7651	7.74	7.67	0.9
550	0.8698	–1.0067	16.51	16.39	0.8
600	0.9488	–0.3705	31.20	31.11	0.3

Recommended Method 2 Ambrose-Walton method.
References: Ambrose, D., and J. Walton, *Pure & Appl. Chem.*, **61** (1989): 1395; Lee, B. I., and M. G. Kesler, *AIChE J.*, **21** (1975): 510.

Classification: Corresponding states.

Expected uncertainty: Varies strongly with relative T, but less than 1 percent is typical above T_b if the acentric factor is known.

Applicability: Most organic compounds.

Input data: T_b, T_c, P_c, and ω.

Description: The acentric factor is used to linearly interpolate within the simple-fluid and deviation terms for the $\ln P^*$ values of the reference fluids, which themselves have been correlated with the Wagner vapor pressure equation.

$$\ln P_r^\circ = f^{(0)} + \omega f^{(1)} + \omega^2 f^{(2)}$$

$$f^{(0)} = \frac{-5.97616\tau + 1.29874\tau^{1.5} - 0.60394\tau^{2.5} - 1.06841\tau^5}{1-\tau}$$

$$f^{(1)} = \frac{-5.03365\tau + 1.11505\tau^{1.5} - 5.41217\tau^{2.5} - 7.46628\tau^5}{1-\tau} \qquad (2\text{-}25)$$

$$f^{(2)} = \frac{-0.64771\tau + 2.41539\tau^{1.5} - 4.26979\tau^{2.5} + 3.25259\tau^5}{1-\tau}$$

where $\tau = 1 - T_r$.

Example Repeat the calculation of the liquid vapor pressure of chlorobenzene at 50 K intervals from 300 to 600 K.

Input information: From the DIPPR® 801 database, T_c = 632.35 K, P_c = 45.1911 bar, and ω = 0.249857.

Auxiliary quantities:

$$T_r = 500/632.35 = 0.7907 \qquad \tau = 1 - 0.7907 = 0.2093$$

Simple-fluid and deviation vapor pressure terms at each T (shown for T = 500 K):

$$f^{(0)} = \frac{(-5.97616)(0.2093) + (1.29874)(0.2093)^{1.5} - (0.60394)(0.2093)^{2.5} - (1.06841)(0.2093)^5}{0.7907} = -1.4405$$

$$f^{(1)} = \frac{(-5.03365)(0.2093) + (1.11505)(0.2093)^{1.5} - (5.41217)(0.2093)^{2.5} - (7.46628)(0.2093)^5}{0.7907} = -1.3383$$

$$f^{(2)} = \frac{(-0.64771)(0.2093) + (2.41539)(0.2093)^{1.5} - (4.26979)(0.2093)^{2.5} + (3.25259)(0.2093)^5}{0.7907} = 0.0145$$

Calculation using Eq. (2-25):

$\ln P_r^\circ = -1.4405 + (0.249857)(-1.3383) + (0.249857)^2(0.0145) = -1.774$

$P^* = (45.1911 \text{ bar})[\exp(-1.774)] = 7.667 \text{ bar}$

T	τ	$f^{(0)}$	$f^{(1)}$	$f^{(2)}$	$\ln P_r^\circ$	P^*/bar	P^*_{DIPPR}/bar	% Error
300	0.5256	−5.9228	−7.5966	−0.3050	−7.840	0.0178	0.0175	1.4
350	0.4465	−4.3006	−5.0017	−0.1439	−5.559	0.174	0.172	1.5
400	0.3674	−3.1036	−3.3106	−0.0437	−3.933	0.885	0.880	0.5
450	0.2884	−2.1800	−2.1576	0.0043	−2.719	2.98	2.98	0.0
500	0.2093	−1.4405	−1.3383	0.0145	−1.774	7.67	7.67	0.0
550	0.1302	−0.8289	−0.7318	0.0036	−1.012	16.43	16.39	0.3
600	0.0512	−0.3068	−0.2612	−0.0081	−0.373	31.14	31.11	0.1

Solids Below the triple point, the pressure at which the solid and vapor phases of a pure component are in equilibrium at any given temperature is the vapor pressure of the solid. It is a monotonic function of temperature with a maximum at the triple point. Solid vapor pressures can be correlated with the same equations used for liquids. Estimation of solid vapor pressure can be made from the integrated form of the Clausius-Clapeyron equation

$$\ln \frac{P^*}{P_t^*} = \frac{\Delta H_{\text{sub}}}{RT_t}\left(1 - \frac{T_t}{T}\right) \qquad (2\text{-}26)$$

where T_t = triple point temperature
P_t^* = triple point pressure
ΔH_{sub} = enthalpy of sublimation

The liquid and solid vapor pressures are identical at the triple point. A good vapor pressure correlation that is valid at the triple point may be used to obtain the triple point pressure. Estimating solid vapor pressures by using Eq. (2-26) generally requires an estimation of ΔH_{sub}, and so the illustrative example is combined with the example on enthalpy of sublimation in the section on latent enthalpy.

THERMAL PROPERTIES

Enthalpy of Formation The standard enthalpy (heat) of formation is the enthalpy change upon formation of 1 mol of the compound in its standard state from its constituent elements in their standard states. Two different standard enthlapies of formation are commonly defined based on the chosen standard state. The standard state enthalpy of formation ΔH_f^s uses the naturally occurring phase at 298.15 K and 1 bar as the standard state; the ideal gas standard enthalpy (heat) of formation ΔH_f^o uses the compound in the ideal gas state at 298.15 K and 1 bar as the standard state. In both cases, the standard state for the elements is their naturally occurring state of aggregation at 298.15 K and 1 atm. Sources for data include DIPPR®, TRC, SWS, JANAF, and Daubert, T. E., and R. P. Danner, *Technical Data Book—Petroleum Refining*, 5th ed., American Petroleum Institute, Washington, extant 1994. The Domalski-Hearing method is the most accurate general method for estimating either ΔH_f^s or ΔH_f^o if the appropriate GC values are available, but a CC method is also as accurate for estimating ΔH_f^o if an isodesmic reaction can be formulated and used. The Domalski-Hearing method also applies to entropies, and the entropy predictive equations are listed in this section for convenience because they are equivalent in form to the enthalpy equations. However, discussion and illustration of the estimation methods for entropy are delayed to the next subsection.

Recommended Method Domalski-Hearing method.

Reference: Domalski, E. S., and E. D. Hearing, *J. Phys. Chem. Ref. Data*, **22** (1993): 805.

Classification: Group contributions.

Expected uncertainty: 3 percent.

Applicability: Organic compounds for which group contributions have been regressed.

Input data: Molecular structure.

Description: GC values from Table 2-343 are directly additive for both enthalpy of formation and absolute third-law entropies:

$$\frac{\Delta H_f^\circ}{\text{kJ/mol}} = \sum_{i=1}^{N} n_i (\Delta H_f^\circ)_i \qquad \frac{S^\circ}{\text{J}\cdot\text{mol}^{-1}\text{K}^{-1}} = \sum_{i=1}^{N} n_i (S^\circ)_i \qquad (2\text{-}27)$$

where $(\Delta H_f^o)_i$ = enthalpy of formation GC value from Table 2-343 and $(S^o)_i$ = entropy GC value from Table 2-343.

Group values in Table 2-343 are defined by the central, nonhydrogen group and the atoms bonded to that group. Thus, C—(2H)(2C) represents a C atom to which 2 H and 2 C atoms are bonded. For example, propane (CH_3—CH_2—CH_3) is composed of three groups: two C—(3H)(C) and one C—(2H)(2C).

Example Estimate the standard and ideal gas enthalpies of formation of *o*-toluidine.

Input information: The melting point (256.8 K) and boiling point (473.49 K) given for *o*-toluidine in the DIPPR® 801 database bracket 298.15 K, and so the standard state phase at 298.15 K and 1 bar must be liquid.

Structure:

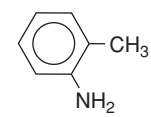


TABLE 2-343 Domalski-Hearing* Group Contribution Values for Standard State Thermal Properties

This table is a partial listing of GC values available from the original Domalski-Hearing tables. Table-specific nomenclature: Cd = carbon with double bond; Ct = carbon with triple bond; Cb = carbon in benzene ring; Ca = allenic carbon; corr = correction term; Cbf = fused benzene ring; N_A = azo nitrogen; N_I = imino nitrogen.

Group	ΔH_f^o	S^o	ΔH_f^s liq.	S^s liq.	ΔH_f^s solid	S^s solid
			CH Groups			
C—(3H)(C)	–42.26	127.32	–47.61	83.30	–46.74	56.69
C—(2H)(2C)	–20.63	39.16	–25.73	32.38	–29.41	23.01
C—(H)(3C)	–1.17	–53.60	–4.77	–23.89	–5.98	–16.89
—$CH_{3\ corr}$ (tertiary)	–2.26	0.00	–2.18	0.00	–2.34	0.00
C—(4C)	19.20	–149.49	17.99	–98.65	12.47	–33.19
—$CH_{3\ corr}$ (quaternary)	–4.56	0.00	–4.39	0.00	–4.35	0.00
—$CH_{3\ corr}$ (tert/quat)	–1.80	0.00	–1.77	0.00	–2.70	0.00
—$CH_{3\ corr}$ (quat/quat)	–0.64	0.00	–0.64	0.00	–2.24	0.00
Cd—(2H)	–26.32	115.52	21.75	86.19	22.43	
Cd—(H)(C)	36.32	33.05	31.05	28.58	25.48	
Cd—(2C)	44.14	–50.84	39.16	–29.83	32.97	
Cd—(H)(Cd)	28.28	27.74	22.18	13.30	17.53	21.75
Cd—(C)(Cd)	36.78	–61.33	30.42	–41.92	27.91	
Cd—(Cd)(Cb)					56.07	
Cd—(H)(Cb)	28.28	27.74	22.18	13.30	17.53	21.75
Cd—(C)(Cb)	37.95	–51.97	38.58			
Cd—(H)(Ct)	28.28	27.74	22.18	13.30	17.53	21.75
C—(4H), Methane	–74.48	206.92				
Cd—(2Cb)	32.88		30.83		49.91	
C—(2H)(C)(Cd)	–20.88	38.20	–25.73	31.67	–24.35	
C—(H)(2C)(Cd)	–1.63	–50.38	–5.02	–28.07	–6.49	
—$CH_{3\ corr}$ (tertiary)	–2.26	0.00	–2.18	0.00	–2.34	0.00
C—(3C)(Cd)	22.13	–150.23	20.79	–108.20	12.51	
—$CH_{3\ corr}$ (quaternary)	–4.56	0.00	–4.39	0.00	–4.35	0.00
C—(H)(C)(2Cd)	–1.17	–53.60	–4.77	–23.89	–5.98	–16.89
C—(2H)(2Cd)	–18.92	42.08	–24.43	19.32	–21.60	
C—(2H)(Cd)(Cb)			–24.73			
C—(H)(C)(Cd)(Cb)			–6.90			
cis (unsat)$_{corr}$	4.85	5.06	5.27	0.00	5.73	0.00
tert—Butyl *cis*$_{corr}$	17.24	0.00	17.48	0.00	17.57	0.00
Ct—(H)	113.50	101.96	104.47	67.57	110.34	
Ct—(C)	115.10	26.32	107.15	14.25	101.66	
Ct—(Cd)	121.42	39.92	114.77			
Ct—(Cb)	120.76	17.77	119.00		103.28	
Ct—(Ct)	120.76	25.94	104.80		103.28	
C—(2H)(C)(Ct)	–19.70	42.80	–22.13	32.36	–29.41	
C—(H)(2C)(Ct)	–3.16	–45.69				
—$CH_{3\ corr}$ (tertiary)	–2.26	0.00	–2.18	0.00	–2.34	0.00
C—(3C)(Ct)			22.83		26.38	
—$CH_{3\ corr}$ (quaternary)	–4.56	0.00	–4.39	0.00	–4.35	0.00
C—(2H)(2Ct)	–41.14		–39.08			
C—(2C)(2Ct)			20.67			
Ca	142.67	26.28	134.68	14.39	131.08	
Cb—(H)(2Cb)	13.81	48.31	8.16	28.87	6.53	22.75
Cb—(C)(2Cb)	23.64	–35.61	19.16	–19.50	13.90	–5.50
Cb—(Cd)(2Cb)	24.17	–33.85	19.12	–9.04	20.27	–10.00
Cb—(Ct)(2Cb)	24.17	–33.85	19.12	–9.04	20.07	–10.00
Cb—(3Cb)	21.66	–36.57	17.21		17.03	–6.00
C—(2C)(2Cb)					52.81	
C—(2H)(C)(Cb)	–21.34	42.59	–24.81	47.40	–22.10	26.90
C—(H)(2C)(Cb)	–4.52	–48.00	–5.82	–13.90	–3.50	
C—(Cb)(3C)	18.28	–147.19	18.70	–96.10	21.57	
C—(2H)(2Cb)	–46.43		–26.50	51.97	–21.44	22.85
C—(H)(C)(2Cb)			–21.47	28.12	16.40	
C—(H)(3Cb)	–6.86				34.48	–12.62
C—(3Cb)(C)					116.25	
C—(4Cb)	27.04				64.89	
Cbf—(Cbf)(2Cb)	20.10	0.00	15.83	–5.54	14.10	–6.00
Cbf—(Cb)(2Cbf)	16.00		11.50		12.00	2.00
Cbf—(3Cbf)	3.59		–0.90		1.94	7.00
Cb—(2Cb)(Cbf)					–8.77	
Cb—(Cb)(2Cbf)	22.46				47.93	
ortho$_{corr}$ hydrocarbons	1.26	–2.50	3.26	0.00	5.00	0.00
meta$_{corr}$ hydrocarbons	–0.63	0.00	0.00	0.00	2.00	0.00
Cyclopropane rsc (unsub)	115.15	134.86	111.58			
Cyclobutane rsc	110.89	126.04	106.64	51.48	114.43	
Cyclopentane rsc (unsub)	26.75	116.22	22.84	42.24	34.00	
Cyclohexane rsc (unsub)	0.68	78.18	–1.77	10.07	10.94	
Cycloheptane rsc	26.34	73.97	23.50	15.89		
Cyclooctane rsc	40.65	70.78	38.10	2.96		
Cyclononane rsc	52.91		50.40			
Cyclodecane rsc	51.99		50.61			

TABLE 2-343 Domalski-Hearing* Group Contribution Values for Standard State Thermal Properties (*Continued*)

This table is a partial listing of GC values available from the original Domalski-Hearing tables. Table-specific nomenclature: Cd = carbon with double bond; Ct = carbon with triple bond; Cb = carbon in benzene ring; Ca = allenic carbon; corr = correction term; Cbf = fused benzene ring; N_A = azo nitrogen; N_I = imino nitrogen.

Group	ΔH_f^o	S^o	ΔH_f^s liq.	S^s liq.	ΔH_f^s solid	S^s solid
			CHO Groups			
CO—(2H), formaldehyde	−108.60	224.54				
CO—(C)(CO)	−121.29		−135.04		−140.75	
CO—(H)(CO)	−105.98					
CO—(CO)(Cb)	−112.30				−117.75	
CO—(O)(CO)	−123.75		−123.30		−120.81	
CO—(Cd)(O)	−136.73	62.59	−155.56		−134.10	32.90
CO—(C)(O)	−137.24	62.59	−149.37	32.72	−153.60	32.13
CO—(H)(O)	−124.39	147.03	−142.42	94.68		
CO—(2O)	−111.88		−122.00		−123.00	−42.92
CO—(H)(Cd)	−126.96		−153.05			
CO—(2Cb)	−110.00		−119.00		−116.00	
CO—(C)(Cb)	−148.82		−145.22		−143.70	23.72
CO—(H)(Cb)	−121.35		−138.12		−160.18	
CO—(O)(Cb)	−125.00		−140.00		−145.00	32.13
CO—(2C)	−132.67	64.31	−152.76	33.81	−157.95	
CO—(H)(C)	−124.39	147.03	−142.42	93.55		
CO—(C)(Cd)						
O—(2CO), aliphatic	−214.50	34.16	−230.50		−235.00	
O—(2CO), aromatic	−238.30		−220.90		−207.00	
O—(Cd)(CO)	−198.03		−201.42			
O—(C)(CO)	−188.87	36.03	−196.02	38.28	−210.60	12.09
O—(H)(CO)	−254.30	101.71	−285.64	38.28	−282.15	21.78
O—(Cb)(CO)	−167.00		−165.50		−170.00	45.32
O—(C)(O)	−20.75		−23.50		−30.20	
O—(H)(O)	−72.26		−101.75		−105.30	
O—(2Cd)	−139.29		−137.32			
O—(H)(Cd)						
O—(C)(Cd)	−129.33		−133.72			
O—(2Cb)	−77.66		−85.27	23.31	−96.20	3.14
O—(C)(Cb)	−92.55		−104.85		−122.87	
O—(H)(Cb)	−160.30	121.50	−191.75	43.89	−199.25	28.62
O—(2C)	−101.42	29.33	−110.83	26.78	−119.00	
O—(H)(C)	−159.33	121.50	−191.50	43.89	−199.66	28.62
Cd—(H)(CO)	32.30	35.19	26.61		7.82	27.53
Cd—(C)(CO)						
Cd—(O)(Cd)	36.78	−61.34	30.42	−41.92	27.91	
Cd—(O)(C)	44.14	−50.84	39.08	−29.83	32.97	
Cd—(O)(H)	36.32	33.05	31.05	28.58	25.48	
Ct—(CO)					144.52	
Cb—(CO)(2Cb)	15.50		10.50		8.15	0.08
Cb—(O)(2Cb)	−4.75	−43.72	−5.61	−10.59	1.00	1.59
C—(2H)(2CO)	−30.74		−23.06		−19.10	
C—(CO)(3C)	23.93		26.15	−85.98	24.02	
C—(H)(CO)(2C)	−0.25		−3.89	−24.52	−9.83	
C—(2H)(CO)(C)	−21.84	39.58	−24.14	39.87	−27.90	24.73
C—(3H)(CO)	−42.26	127.32	−47.61	83.30	−46.74	56.69
C—(2H)(CO)(Cd)	−16.95		−19.62			
C—(2H)(CO)(Ct)	−25.48		−26.61			
C—(2H)(CO)(Cb)	−16.20		−11.67			
C—(H)(CO)(C)(Cb)					14.81	
C—(H)(O)(CO)(C)	126.63		123.43	−46.71	−14.39	8.08
C—(4O)	−152.46		−133.34			
C—(H)(3O)	−113.97		−107.74			
C—(3O)(C)	−114.39		−99.54			
C—(2O)(2C)	−53.56		−41.30			
C—(H)(2O)(C)	−57.78		−51.42			
C—(2H)(2O)	−62.22		−62.89	23.85		
C—(2H)(O)(Cb)	−33.76		−29.17			
C—(2H)(O)(Cd)	−27.49	37.49	−28.62			
C—(H)(CO)(C)(Cb)					−14.39	
C—(H)(CO)(2Cb)					3.72	
C—(O)(3Cb)					60.46	
C—(O)(3C) (ethers, esters)	9.50	−141.92	0.79	−94.68	−0.50	
C—(H)(O)(2C) (ethers, esters)	−19.46	−52.80	−21.00	−25.31	−20.08	
C—(O)(3C) (alcohols, peroxides)	−13.50	−144.60	−11.13	−122.48	−12.25	−14.77
C—(H)(O)(2C) (alcohols, peroxides)	−26.10	−43.05	−27.60	−29.83	−29.08	6.95
C—(2H)(O)(C)	−32.90	43.43	−35.80	32.59	−33.00	24.73
C—(3H)(O)	−42.26	127.32	−47.61	83.30	−46.74	56.69
O—(CO)(O)	−88.00		−90.00		−80.50	
C—(2C)(O)(Cb)	15.30		25.80		29.30	
C—(H)(C)(2O)					−52.50	

TABLE 2-343 Domalski-Hearing* Group Contribution Values for Standard State Thermal Properties (*Continued*)

This table is a partial listing of GC values available from the original Domalski-Hearing tables. Table-specific nomenclature: Cd = carbon with double bond; Ct = carbon with triple bond; Cb = carbon in benzene ring; Ca = allenic carbon; corr = correction term; Cbf = fused benzene ring; N_A = azo nitrogen; N_I = imino nitrogen.

Group	ΔH_f^o	S^o	ΔH_f^s liq.	S^s liq.	ΔH_f^s solid	S^s solid
CHN and CHNO Groups						
C—(3H)(N)	–42.26	127.32	–47.61	83.30	–46.74	56.69
C—(2H)(C)(N)	–28.30	42.26	–30.80	32.38	–34.00	23.01
C—(H)(2C)(N)	–16.70	–63.55	–14.65	–20.00	–13.90	
—$CH_{3\ corr}$ (tertiary)	–2.26	0.00	–2.18	0.00	–2.34	0.00
C—(3C)(N)	0.29	–152.59	5.10	–87.99	1.00	
—$CH_{3\ corr}$ (quaternary)	–4.56	0.00	–4.39	0.00	–4.35	0.00
C—(2H)(2N)	–30.00				–26.00	
C—(2H)(Cb)(N)	–24.14		–26.09		–33.31	
N—(2H)(C) (first, amino acids)	19.25	124.40	0.33	71.71	–6.30	39.00
N—(2H)(C) (second, amino acids)	19.25	126.90	0.33	71.71	–46.00	48.75
N—(H)(2C)	67.55	33.96	51.50	32.09	47.80	
N—(3C)	116.50	–61.71	112.00	–38.62	101.00	
N—(2H)(N)	47.70	122.18	25.30	60.58	18.97	
N—(H)(C)(N)	89.16		75.00	22.05		
N—(2C)(N)	120.71		119.00	–26.94		
N—(2Cb)(N)					137.35	
N—(H)(Cb)(N)	87.50		73.40		66.90	
N—(2CO)(N)					73.62	
N—(H)(2Cd)	83.55		50.50		45.40	
N—(C)(2Cd)	120.64		97.38		88.92	
N—(2H)(Cb)	19.25	126.90	–11.00	71.71	–21.60	70.00
N—(H)(C)(Cb)	59.00		26.25		36.55	
N—(2C)(Cb)	126.40		109.40		96.50	
N—(C)(2Cb)	120.44		97.38		89.30	
N—(H)(2Cb)	83.55		50.50		45.40	
N—(3Cb)	123.15		121.80		107.50	
N_I—(C)	81.46		73.68			
N_I—(Cb)	69.00	47.01	54.50	36.40	57.00	
N_A—(C)	109.50		104.85		103.00	
N_A—(Cb)	109.50		104.85		103.00	
N_A—(oxide)(C)	40.80		22.65			
C—(2H)(C)(N_A)	–20.70		–25.70		–29.41	
C—(H)(2C)(N_A)	–2.66		–5.42			
C—(3C)(N_A)	11.50		15.50		10.50	
Cd—(H)(N)	–16.00		–15.50		–13.00	
Cd—(C)(N)	–5.74		–5.62		–3.95	
Cb—(N)(2Cb)	–1.30	–43.53	1.50	–24.43	9.75	–37.57
Cb—(NO)(2Cb)	21.50				23.00	
Cb—(NO_2)(2Cb)	–1.45		–28.30	79.95	–32.50	110.46
Cb—(CNO)(2Cb)	–177.63				155.69	
Cb—(CN)(2Cb)	151.00	85.25	122.38	64.75	121.20	50.45
Cb—(N_A)(2Cb)	22.55		20.08		18.65	
Cb—(H)(2N_I)	6.30				0.25	
CO—(H)(N)	–124.39	147.03	–188.00	93.55		
CO—(C)(N)	–133.26	56.70	–185.00		–194.60	40.00
CO—(Cb)(N) (amides)					–177.75	
CO—(Cb)(N) (amino acids)					–177.75	
CO—(Cd)(N)	–171.80					
CO—(2N)	–111.00	96.00	–190.50		–203.10	69.00
N—(2H)(CO) (amides, ureas)	–63.00	88.25	–63.90		–65.25	18.00
N—(2H)(CO) (amino acids)	–63.00		–63.90		–59.75	33.03
N—(H)(C)(CO) (amides, ureas)	–16.28		–17.10		–9.80	
N—(H)(C)(CO) (amino acids)	–16.28		–17.10		5.50	
N—(2C)(CO)	45.00		62.00		55.00	
N—(H)(Cb)(CO)	–20.84				–3.50	
N—(H)(2CO)	–91.00				–30.80	
N—(C)(2CO)	–11.64		56.20		64.00	
N—(Cb)(2CO)	9.12					
N–(2Cb)(CO)					60.85	
N—(C)(Cb)(CO)					72.00	
C—(3H)(CN), acetonitrile	74.04	252.60	40.56	149.62		
C—(2H)(C)(CN)	94.52	167.25	66.07	106.02	69.85	96.15
C—(H)(2C)(CN)	113.50	67.86	81.50		69.00	
C—(3C)(CN)	137.96		116.20	–17.91	102.07	
C—(2C)(2CN)						74.57
C—(2H)(Cd)(CN)	95.31		66.40			
Cd—(H)(CN)	146.65	158.41	117.28	92.72		
Ct—(CN)	264.60		250.20			
C—(3H)(NO_2), nitromethane	–74.86	284.14	–112.60	171.75		
C—(2H)(2NO_2), dinitromethane	–58.90		–104.90			
C—(H)(3NO_2), trinitromethane	–0.30		–32.80		–48.00	
C—(4NO_2), tetranitromethane	82.30		38.30			
C—(2H)(C)(NO_2)	–60.50	203.60	–93.50		–99.00	

TABLE 2-343 Domalski-Hearing* Group Contribution Values for Standard State Thermal Properties (*Continued*)

This table is a partial listing of GC values available from the original Domalski-Hearing tables. Table-specific nomenclature: Cd = carbon with double bond; Ct = carbon with triple bond; Cb = carbon in benzene ring; Ca = allenic carbon; corr = correction term; Cbf = fused benzene ring; N_A = azo nitrogen; N_I = imino nitrogen.

Group	ΔH_f^o	S^o	ΔH_f^s liq.	S^s liq.	ΔH_f^s solid	S^s solid
			CHN and CHNO Groups			
C—(H)(2C)(NO_2)	−53.00	115.32	−82.50		−89.00	
C—(3C)(NO_2)	−36.65		−61.20		−76.55	
C—(2H)(Cb)(NO_2)	−62.00		−82.76		−81.00	
C—(H)(C)($2NO_2$)	−36.80		−88.80		−91.50	
C—(2C)($2NO_2$)	−28.50		−77.20		−90.30	
C—(H)(C)(CO)(N)	−18.70				−11.65	−4.00
C—(2H)(CO)(N)	−3.10				−30.95	24.00
C—(H)(Cb)(CO)(N)						
O—(C)(NO)	−24.23	166.11	−46.50			
O—(C)(NO_2)	−79.71	191.92	−108.96	127.50	−124.00	
N—(H)(C)(NO_2)					16.50	
N—(H)(Cb)(NO_2)						
N—(H)(CO)(NO_2)					−14.00	
N—(C)($2NO_2$)	100.30		53.50			
N—(C)(Cb)(NO_2)	183.00		167.00		150.50	
N—(2C)(NO)	90.00		59.00		55.00	
N—(2C)(NO_2)	88.00		50.00		40.00	
C—(2H)(C)(N_3)			321.70			
C—(H)(2C)(N_3)	274.00		255.00			
C—(2H)(Cb)(N_3)	347.00		327.40			
C—(3Cb)(N_3)	328.60				346.50	
Cb—(N_3)(2Cb)	320.00		303.50			
			CHS and CHSO Groups			
C—(3H)(S)	−42.26	127.32	−47.61	83.30	−46.74	56.69
C—(2H)(C)(S)	−23.17	41.87	−26.77	41.09		
C—(H)(2C)(S)	−5.88	−47.36	−6.07	−16.61		
—$CH_{3\ corr}$ (tertiary)	−2.26	0.00	−2.18	0.00	−2.34	0.00
C—(3C)(S)	13.52	−145.38	16.69	−86.86		
—$CH_{3\ corr}$ (quaternary)	−4.56	0.00	−4.39	0.00	−4.35	0.00
—$CH_{3\ corr}$ (tert/quat)	−1.80	0.00	−1.77	0.00	−2.70	0.00
—$CH_{3\ corr}$ (quat/quat)	−0.64	0.00	−0.64	0.00	−2.24	0.00
C—(2H)(Cb)(S)	−18.53		−23.82			
C—(2H)(Cd)(S)	−25.93		−32.44			
C—(2H)(2S)	−25.10					
Cb—(S)(2Cb)	−4.75	43.72	−5.61	−10.59	1.00	1.59
Cd—(H)(S)	36.32	33.05	31.05	28.58	25.48	
Cd—(C)(S)	45.73	−51.92				
S—(C)(H)	18.64	137.67	0.06	85.95		
S—(Cb)(H)	48.10	57.34	28.51	89.04		
S—(2C)	46.99	55.19	29.82	29.80		
S—(H)(Cd)	25.52					
S—(C)(Cd)	54.39					
S—(2Cd)	102.60	68.59				
S—(Cb)(C)	76.21		58.20	35.44	42.00	
S—(C)(S)	27.62	50.50	14.36	30.84		
S—(Cb)(S)	57.45				40.60	
S—(2S)	12.59	56.07				
S—(2Cb)	102.60	68.59	93.02			
S—(H)(S)	7.95					
S—(H)(CO)	−5.90	130.54				
CO—(C)(S)	−132.67	64.31	−152.76	33.81		
C—(3H)(SO)	−42.26	127.32	−47.61	83.30	−46.74	56.69
C—(2H)(C)(SO)	−29.16		−36.88			
C—(H)(2C)(SO)						
—$CH_{3\ corr}$ (tertiary)	−2.26	0.00	−2.18	0.00	−2.34	0.00
C—(3C)(SO)	4.56		0.97			
—$CH_{3\ corr}$ (quaternary)	−4.56	0.00	−4.39	0.00	−4.35	0.00
C—(2H)(Cd)(SO)	−27.56		−32.63			
cis correction	4.11	5.06	5.27	0.00	5.73	0.00
Cb—(SO)(2Cb)	15.48		25.44		7.55	0.08
O—(SO)(H)	−158.60					
O—(C)(SO)	−92.60					
SO—(2C)	−66.78	75.73	−108.98	22.18		
SO—(2Cb)	−62.26					
SO—(2O)	−213.00					
SO—(C)(Cb)	−72.00					
C—(3H)(SO_2)	−42.26	127.32	−47.61	83.30	−46.74	56.69
C—(2H)(C)(SO_2)	−27.03		−33.76		−35.96	
C—(H)(2C)(SO_2)	−14.00					
—$CH_{3\ corr}$ (tertiary)	−2.26	0.00	−2.18	0.00	−2.34	0.00
C—(3C)(SO_2)	1.52		2.00		3.78	
—$CH_{3\ corr}$ (quaternary)	−4.56	0.00	−4.39	0.00	−4.35	0.00

TABLE 2-343 Domalski-Hearing* Group Contribution Values for Standard State Thermal Properties (*Continued*)

This table is a partial listing of GC values available from the original Domalski-Hearing tables. Table-specific nomenclature: Cd = carbon with double bond; Ct = carbon with triple bond; Cb = carbon in benzene ring; Ca = allenic carbon; corr = correction term; Cbf = fused benzene ring; N_A = azo nitrogen; N_I = imino nitrogen.

Group	ΔH_f^o	S^o	ΔH_f^s liq.	S^s liq.	ΔH_f^s solid	S^s solid
CHN and CHNO Groups						
—$CH_{3\ corr}$ (quat/quat)	–0.64		–0.64		–2.24	
C—(2H)(Cd)(SO_2)	–29.49		–49.05			
C—(H)(C)(Cd)(SO_2)	–71.99					
C—(2H)(Cb)(SO_2)	–29.80					
C—(2H)(Ct)(SO_2)	16.36					
Cb—(SO_2)(2Cb)	15.48		25.44		7.55	0.08
Cd—(H)(SO_2)	51.58					
Cd—(C)(SO_2)	64.01					
Ct—(SO_2)	177.10					
SO_2—(Cd)(Cb)	–291.55					
SO_2—(2Cd)	–306.70					
SO_2—(2C)	–288.58	87.37	–341.14		–356.62	32.10
SO_2—(C)(Cb)	–289.10					
SO_2—(2Cb)	–287.76				–305.40	
SO_2—(SO_2)(Cb)	–325.18				–361.75	
SO_2—(2O)	–417.30					
SO_2—(C)(Cd)	–316.80					
SO_2—(Ct)(Cb)	–296.30					
O—(SO_2)(H)	–158.60					
O—(C)(SO_2)	–91.40					
CHX and CHXO Groups						
C—(3H)(F), methyl fluoride	–247.00	231.93				
C—(3H)(Cl), methyl chloride	–81.90	243.60				
C—(3H)(Br), methyl bromide	–37.66	254.94	–61.10			
C—(3H)(I), methyl iodide	14.30	263.14	–11.70			
C—(C)(3F)	–673.81	178.22	–709.07	135.56		
C—(2H)(C)(F)	–221.12	146.80				
C—(H)(2C)(F)	–204.46	55.76				
C—(3C)(F)	–202.92					
C—(H)(C)(2F)	–454.74	164.32	–487.23			
C—(2C)(2F)	–411.39	74.48	–400.37		–428.77	
C—(C)(Cl)(2F)	–462.70	169.45	–466.00	138.31		
C—(H)(C)(Cl)(F)	–271.14					
C—(C)(3Cl)	–81.98	202.14	–112.93	145.91		
C—(H)(C)(2Cl)	–79.10	183.28	–102.60	128.45		
C—(2H)(C)(Cl)	–69.45	159.24	–86.90	104.27	–85.65	
C—(2C)(2Cl)	–79.56	95.41	–101.80			
C—(H)(2C)(Cl)	–55.61	71.34	–71.17			
C—(3C)(Cl)	–43.70	–24.26	–56.78			
C—(C)(3Br)		233.05				
C—(H)(C)(2Br)						
C—(2H)(C)(Br)	–21.78	173.31	–42.65	113.00		
C—(2C)(2Br)						
C—(H)(2C)(Br)	–10.75	84.69	–27.31			
C—(3C)(Br)	7.26	–13.46	–7.40			
C—(C)(3I)						
C—(H)(C)(2I)	108.78	228.45				
C—(2H)(C)(I)	33.54	177.78	4.14		3.65	
C—(2C)(2I)						
C—(H)(2C)(I)	48.74	88.10	24.78			
C—(3C)(I)	68.46	–3.21	48.60			
C—(H)(C)(Br)(Cl)	–18.45	191.21				
N—(C)(2F)	–32.64					
C—(H)(C)(Cl)(O)	–90.37	66.53				
C—(2H)(I)(O)	15.90	170.29				
C—(C)(2Cl)(F)	–322.54		–343.87	141.71		
C—(C)(Br)(2F)	–394.55			149.70		
C—(C)(2Br)(F)						
C—(Br)(Cl)(F)						
Cd—(H)(F)	–165.12	137.24				
Cd—(H)(Cl)	4.37	147.85	–12.67			
Cd—(H)(Br)	50.94	159.91				
Cd—(H)(I)	102.36	169.45				
Cd—(C)(Cl)	–5.06	62.76	–2.23			
Cd—(2F)	–329.90	155.63				
Cd—(2Cl)	–11.51	175.41	–32.08	115.35		
Cd—(2Br)		199.16				
Cd—(2I)						
Cd—(Cl)(F)	–235.10	175.61				
Cd—(Br)(F)		177.82				
Cd—(Cl)(Br)		188.70				
Ct—(F)						

TABLE 2-343 Domalski-Hearing* Group Contribution Values for Standard State Thermal Properties (*Concluded*)

This table is a partial listing of GC values available from the original Domalski-Hearing tables. Table-specific nomenclature: Cd = carbon with double bond; Ct = carbon with triple bond; Cb = carbon in benzene ring; Ca = allenic carbon; corr = correction term; Cbf = fused benzene ring; N_A = azo nitrogen; N_I = imino nitrogen.

Group	ΔH_f^o	S^o	ΔH_f^s liq.	S^s liq.	ΔH_f^s solid	S^s solid
CHX and CHXO Groups						
Ct—(Cl)		140.00				
Ct—(Br)		151.30				
Ct—(I)	35.53					
Cb—(F)(2Cb)	–181.26	67.52	–191.20	54.19	–194.00	39.79
Cb—(Cl)(2Cb)	–17.03	77.08	–32.20	55.47	–32.00	43.37
Cb—(Br)(2Cb)	36.35	88.60	19.90	74.85	13.50	54.45
Cb—(I)(2Cb)	94.50	98.26	73.70	61.08	70.40	
cis $_{corr}$—(I)(I)	3.00	0.00	0.00	0.00	0.00	0.00
C—(2H)(CO)(Cl)	–44.26		–58.41		–74.75	
C—(H)(CO)(2Cl)	–40.40		–55.11			
CO—(C)(F)	–379.84		–419.59			
C—(Cb)(3F)	–691.79	179.08	–696.66			
C—(2H)(Cb)(Br)	–29.49		–44.06			
C—(2H)(Cb)(I)	7.31		–7.24			
C—(2H)(Cb)(Cl)	–73.79		–92.56			
CO—(C)(Cl)	–200.54	176.66	–225.29			
CO—(Cb)(Cl)			–216.67		–212.99	
CO—(C)(Br)	–148.54		–175.49			
CO—(C)(I)	–83.94		–117.09			
C—(H)(C)(CO)(Cl)	–39.88		–35.46			
C—(C)(CO)(2Cl)						
ortho $_{corr}$—(I)(I)	7.56	0.00	6.96	0.00	5.50	0.00
ortho $_{corr}$—(F)(F)	20.90	0.00	25.00	0.00	25.50	0.00
ortho $_{corr}$—(Cl)(Cl)	9.50	0.00	14.00	0.00	8.50	0.00
ortho $_{corr}$—(alkyl)(X)	2.51	0.00	6.30	0.00	0.00	0.00
cis $_{corr}$—(Cl)(Cl)	–4.00	0.00	0.00	0.00	0.00	0.00
cis $_{corr}$—(CH_3)(Br)	–4.00	0.00	0.00	0.00	0.00	0.00
ortho $_{corr}$—(F)(Cl)	13.50	0.00	18.50	0.00	19.50	0.00
ortho $_{corr}$—(F)(Br)	37.25	0.00	40.60	0.00	42.50	0.00
ortho $_{corr}$—(F)(I)	85.40	0.00	83.55	0.00	85.20	0.00
meta $_{corr}$—(I)(I)	0.00	0.00	0.00	0.00	20.08	0.00
meta $_{corr}$—(COCl)(COCl)	0.00	0.00	0.00	0.00	16.06	0.00
ortho $_{corr}$—(COCl)(COCl)	0.00	0.00	0.00	0.00		0.00
ortho $_{corr}$—(F)(CF_3)	111.00	0.00	112.00	0.00	0.00	0.00
meta $_{corr}$—(F)(CF_3)	2.00	0.00	6.00	0.00	0.00	0.00
ortho $_{corr}$—(F)(CH_3)	–3.30	0.00	–6.00	0.00	0.00	0.00
ortho $_{corr}$—(F)(F')	8.00	0.00	8.00	0.00	8.00	0.00
ortho $_{corr}$—(Cl)(Cl')	8.00	0.00	8.00	0.00	8.00	0.00
meta $_{corr}$—(F)(F)	0.00	0.00	6.00	0.00	8.50	0.00
meta $_{corr}$—(Cl)(Cl)	–5.00	0.00	10.00	0.00	4.00	0.00
ortho $_{corr}$—(Cl)(CHO)	–6.75	0.00	8.50	0.00	0.00	0.00
ortho $_{corr}$—(F)(COOH)	20.00	0.00	0.00	0.00	20.00	0.00
ortho $_{corr}$—(Cl)(COCl)	0.00	0.00	34.43	0.00	0.00	0.00
ortho $_{corr}$—(F)(OH)	25.50	0.00	23.00	0.00	20.00	0.00
ortho $_{corr}$—(Cl)(COOH)	0.00	0.00	0.00	0.00	20.00	0.00
ortho $_{corr}$—(Br)(COOH)	0.00	0.00	0.00	0.00	20.00	0.00
ortho $_{corr}$—(I)(COOH)	0.00	0.00	0.00	0.00	20.00	0.00
ortho $_{corr}$—(NH_2)(NH_2)	–10.00	0.00	0.00	0.00	0.00	0.00
meta $_{corr}$—(NH_2)(NH_2)	0.00	0.00	0.00	0.00	14.00	0.00
ortho $_{corr}$—(OH)(Cl)	7.50	0.00	0.00	0.00	11.00	0.00
cis $_{corr}$—(CH_3)(I)	–4.00	0.00	0.00	0.00	0.00	0.00

*Domalski, E. S, and E. D. Hearing, *J. Phys. Chem. Ref. Data*, **22** (1993): 805

Group contributions:

Group	n_i	ΔH_f° gas	ΔH_f° liq.	S° gas	S^s liq.
Cb—(H)(2Cb)	4	13.81	8.16	48.31	28.87
Cb—(C)(2Cb)	1	23.64	19.16	–35.61	–19.50
Cb—(N)(2Cb)	1	–1.30	1.50	–43.53	–24.43
C—(3H)(C)	1	–42.26	–47.61	127.32	83.30
N—(2H)(Cb)	1	19.25	–11.00	126.90	71.71
	Total	54.57	–5.31	368.32	226.56

Calculation from Eq. (2-27):

$$\frac{\Delta H_f^o}{\text{kJ/mol}} = 54.57 \qquad \frac{\Delta H_f^s}{\text{kJ/mol}} = -5.31$$

$$\frac{S^o}{\text{J/(mol·K)}} = 368.32 \qquad \frac{S^o}{\text{J/(mol·K)}} = 226.56$$

The recommended DIPPR® 801 standard enthalpies of formation are ΔH_f^o = 53.20 kJ/mol and ΔH_f^s = – 4.72 kJ/mol; the estimated values are higher than the recommended values by 2.6 and 12.5 percent, respectively. The recommended DIPPR® 801 standard entropies are S^o = 355.8 J/(mol·K) and S^s = 231.2 J/(mol·K). The estimated values differ from these by 3.5 and – 2.0 percent, respectively.

Recommended Method Isodesmic reaction.

Reference: Foresman, J. B., and A. Frisch, *Exploring Chemistry with Electronic Structure Methods*, 2d ed., Gaussian Inc., Pittsburgh, Pa., 1996.

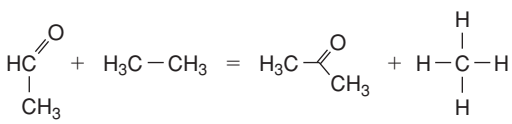
Classification: Computational chemistry.

Expected uncertainty: 5 to 10 percent depending upon the level of theory and basis set size used.

Applicability: Compounds for which an isodesmic reaction can be formulated.

Input data: Experimental ΔH_f^o values for all *other* participants in the isodesmic reaction.

Description: While *ab initio* calculations of absolute enthalpies are not currently as accurate as GC methods, *relative* enthalpies of molecules calculated with the same level of theory and basis set can be very accurate, as in the case of isodesmic reactions. An isodesmic reaction is one in which the number and type of bonds are preserved during the reaction. For example, the reaction of acetaldehyde with ethane to form acetone and methane



is isodesmic with 12 single bonds and 1 double bond in both reactants and products. To use this method, one devises an isodesmic reaction involving the compound for which ΔH_f^o is to be determined and other compounds for which experimental ΔH_f^o values are available. *Ab initio* calculations are performed on all the participating compounds, all at the same level of theory and basis set size, to obtain the enthalpy for each at 298.15 K. The enthalpy of reaction is then calculated from

$$\Delta H_{rxn} = \sum \nu_i H_i \tag{2-28}$$

where ν_i = stoichiometric coefficient of i (+ for products, − for reactants). The enthalpy of reaction is also related to ΔH_f^o by

$$\Delta H_{\text{rxn}} = \sum \nu_i (\Delta H_f^o)_i \tag{2-29}$$

With experimental values available for all ΔH_f^o except the desired compound, its value can be back-calculated from Eq. (2-29).

Example Estimate the standard ideal gas enthalpy of formation of acetaldehyde.

Input information: The isodesmic reaction shown above will be used. The recommended ΔH_f^o values from DIPPR® 801 for the other three compounds are

Acetone	Methane	Ethane
–215.70 kJ/mol	–74.52 kJ/mol	–83.82 kJ/mol

Ab initio calculations of enthalpy: With structures optimized using HF/6-31G(d) model chemistry and energies calculated with B3LYP/6-311 + G(3df,2p), the following enthalpies are obtained (including the zero point energy):

Acetone	Methane	Ethane	Acetaldehyde
-5.071×10^5 kJ/mol	-1.063×10^5 kJ/mol	-2.095×10^5 kJ/mol	-4.039×10^5 kJ/mol

Calculation using Eq. (2-28):

$$\Delta H_{\text{rxn}} = (-1.063 - 5.071 + 2.095 + 4.039) \times 10^5 \text{ kJ/mol} = -41.67 \text{ kJ/mol}$$

Calculation using Eq. (2-29):

$$\Delta H^o_{f,\text{acetaldehyde}} = \Delta H^o_{f,\text{acetone}} + \Delta H^o_{f,\text{methane}} - \Delta H^o_{f,\text{ethane}} - \Delta H_{rxn}$$

$$\Delta H^o_{f,\text{acetaldehyde}} = (-215.70 - 74.52 + 83.82 + 41.67)\ \frac{\text{kJ}}{\text{mol}} = -164.73\ \frac{\text{kJ}}{\text{mol}}$$

The estimated value is 1.0 percent above the DIPPR® 801 recommended value of –166.40 kJ/mol.

Entropy Absolute or third-law entropies (relative to a perfectly ordered crystal at 0 K) of a compound in its standard state S^s or of an ideal gas S^o at 298.15 K and 1 bar can be found in various literature sources (DIPPR, JANAF, TRC, SWS, and Daubert, T. E., and R. P. Danner, *Technical Data Book-Petroleum Refining*, 5th ed., American Petroleum Institute, Washington, extant 1994). Very good estimates for S^s or S^o can be obtained by using the Domalski-Hearing method. Excellent S^o values can also be obtained from statistical mechanics by using experimental vibrational frequencies or values of the frequencies generated from computational chemistry.

The standard state ΔS_f^s and standard ideal gas ΔS_f^o entropies of formation at 298.15 K and 1 bar are related to the standard entropies by

$$\Delta S_f^s = S^s_{\text{compound}} - \sum_{i=1}^{n_A} \nu_i S^s_{\text{element},i} \qquad \Delta S_f^o = S^o_{\text{compound}} - \sum_{i=1}^{n_A} \nu_i S^s_{\text{element},i} \tag{2-30}$$

where $S^s_{\text{element},i}$ is the absolute entropy of element i in its standard state at 298.15 K and 1 bar.

Recommended Method Domalski-Hearing method.

Reference: Domalski, E. S., and E. D. Hearing, *J. Phys. Chem. Ref. Data*, **22** (1993): 805.

Classification: Group contributions.

Expected uncertainty: 3 percent.

Applicability: Organic compounds for which group contributions have been regressed.

Input data: Molecular structure.

Description: See description given under Enthalpy of Formation above.

Example Estimate the standard and ideal gas entropies of formation of *o*-toluidine.

Standard state entropies: Estimation of S^s and S^o using the Domalski-Hearing method was illustrated above in the Enthalpy of Formation section. The standard entropies of formation can be obtained from the values determined in that example.

Formula: C_7H_9N. The standard state entropies of the elements from the DIPPR® 801 database are as follows:

Compound:	N_2	H_2	C, graphite
ν_i:	1/2	9/2	7
S_i^o/[J(kmol·K)]:	1.9151×10^5	1.3057×10^5	5740

Entropies of formation can be calculated from these values by using Eq. (2-30):

$$\Delta S_f^s = \left[0.22656 - \left(\frac{1}{2}\right)(1.9151) - \left(\frac{9}{2}\right)(1.3057) - (7)(0.0574)\right] \frac{10^5 \text{J}}{\text{kmol·K}}$$

$$= -7.008 \cdot 10^5 \frac{\text{J}}{\text{kmol·K}}$$

$$\Delta S_f^o = \left[0.36832 - \left(\frac{1}{2}\right)(1.9151) - \left(\frac{9}{2}\right)(1.3057) - (7)(0.0574)\right] \frac{10^5 \text{J}}{\text{kmol·K}}$$

$$= -6.867 \cdot 10^5 \frac{\text{J}}{\text{kmol·K}}$$

Recommended Method Statistical mechanics.

Classification: Theory and computational chemistry.

Expected uncertainty: 0.2 percent if vibrational frequencies (or their characteristic temperatures) are experimentally available; uncertainty depends upon model chemistry if frequencies are determined from computational chemistry, but generally within about 5 percent.

Applicability: Ideal gases.

Input data: M; σ (external symmetry number); characteristic rotational temperature(s) (Θ_A for linear molecules; Θ_A, Θ_B, and Θ_C for nonlinear molecules); and $3n_A - 6 + \delta$ characteristic vibrational temperatures Θ_j.

Description: For harmonic frequencies, the rigorous temperature dependence of S^o is given by

$$\frac{S^o}{R} = \frac{3}{2} \ln\left(6175 \frac{M}{\text{kg/kmol}}\right) + \frac{S_r}{R} + \sum_{j=1}^{3n_A - 6 + \delta} \left[\left(\frac{\Theta_j}{T}\right)(e^{\Theta_j/T} - 1)^{-1} - \ln\left(1 - e^{-\Theta_j/T}\right)\right] \tag{2-31}$$

where $\delta = \begin{cases} 0 & \text{nonlinear} \\ 1 & \text{linear} \end{cases}$

$$\frac{S_r}{R} = \begin{cases} \ln\left[\frac{1}{\sigma}\left(\frac{\pi T^3 e^3}{\Theta_A\Theta_B\Theta_C}\right)^{1/2}\right] & \text{nonlinear} \\ \ln\left[\left(\frac{Te}{\sigma\Theta_A}\right)^{1/2}\right] & \text{linear} \end{cases}$$

$T = 298.15$ K

Example Calculate S^o for ammonia.

Structure: NH_3.

Input data: M = 17 kg/kmol. McQuarrie [McQuarrie, D. A., *Statistical Mechanics*, Harper & Row, New York, 1976] gives the following $3m - 6 + \delta = 12 - 6 + 0 = 6$ characteristic vibrational temperatures (K): 1360, 2330, 2330, 4800, 4880, 4880. The characteristic rotational temperatures given by McQuarrie are $\Theta_A = 13.6$ *K*, $\Theta_B = 13.6$ *K*, and $\Theta_C = 8.92$ *K*. For NH_3, $\sigma = 3$.

Vibrational contribution: The table below shows a spreadsheet calculation of the vibrational terms inside the summation sign in Eq. (2-31).

$\Theta j/K$	$\Theta j/T$	S_{vib}
1207.91	4.051	0.08929
1850.16	6.205	0.01457
1850.16	6.205	0.01457
3688.19	12.370	0.00006
3821.36	12.817	0.00004
3821.36	12.817	0.00004
	Sum	0.1186

Rotational contribution:

$$\frac{S_r}{R} = \ln\left\{\frac{1}{3}\cdot\left[\frac{(298.15\text{ K})^3\pi c^3}{(13.6\text{ K})(13.6\text{ K})(8.92\text{ K})}\right]^{1/2}\right\} = 5.81593$$

Calculation using Eq. (2-31):

$$\frac{S^o_{298}}{R} = \frac{3}{2}\ln(6175\cdot 17) + 5.81593 + 0.1186 = 23.277 \quad \Delta H_{rxn} = \sum \nu_i(\Delta H^o_f)_i$$

$$S^o_{298} = 1.935 \times 10^5 \frac{\text{J}}{\text{kmol}\cdot\text{K}}$$

The calculated value differs from the DIPPR® 801 recommended value of 1.9266×10^5 J/(kmol·K) by 0.5 percent.

Gibbs' Energy of Formation The standard Gibbs energy of formation is the Gibbs energy change upon formation of 1 mol of the compound in its standard state from its constituent elements in their standard states. The standard state Gibbs energy of formation ΔG^s_f uses the naturally occurring phase at 298.15 K and 1 bar as the standard state, while the ideal gas Gibbs energy of formation ΔG^o_f uses the compound in the ideal gas state at 298.15 K and 1 bar as the standard state. In both cases, the standard state for the elements is their naturally occurring state of aggregation at 298.15 K and 1 atm. Sources for data include DIPPR, TRC, JANAF, and Daubert and Danner, (Daubert, T. E., and R. P. Danner *Technical Data Book—Petroleum Refining*, 5th ed., American Petroleum Institute, Washington, extant 1994). The Gibbs energies of formation are related to the corresponding enthalpies and entropies of formation by

$$\Delta G^o_f = \Delta H^o_f - T\Delta S^o_f \qquad \text{and} \qquad \Delta G^s_f = \Delta H^s_f - T\Delta S^s_f \qquad (2\text{-}32)$$

and predicted values of ΔG^s_f and ΔG^o_f are obtained from Eq. (2-32) by estimating the enthalpies and entropies of formation as shown above.

LATENT ENTHALPY

Enthalpy of Vaporization The enthalpy (heat) of vaporization ΔH_v is the difference between the molar enthalpies of the saturated vapor and saturated liquid at a temperature between the triple point and critical point (at the corresponding vapor pressure). Variable ΔH_v is related to the vapor pressure P^* by the thermodynamically exact Clapeyron equation

$$\Delta H_v = -R\,\Delta Z_v \frac{d\ln P^*}{d(1/T)} = RT^2\Delta Z_v \frac{d\ln P^*}{dT} \qquad (2\text{-}33)$$

where $\Delta Z_v = Z_G - Z_L$
$Z_G = Z$ of saturated vapor
$Z_L = Z$ of saturated liquid

Experimental heats of vaporization can be effectively correlated with

$$\Delta H_v = A(1 - T_r)^{B + CT_r + DT_r^2 + ET_r^3} \qquad (2\text{-}34)$$

A simple method for obtaining ΔH_v at one temperature from a known value at a reference temperature, say, at the normal boiling point, is to truncate Eq. (2-34) after the B term, set $B = 0.38$, and take a ratio of the ΔH_v values at the two conditions to give the Watson [Thek, R. E., and L. I. Stiel, *AIChE J.*, **12** (1966): 599; 13(1967): 626] correlation

$$\Delta H_v = \Delta H_{v,\text{ref}}\left(\frac{1 - T_r}{1 - T_{r,\text{ref}}}\right)^{0.38} \qquad (2\text{-}35)$$

If an accurate correlation for P^* and accurate values for Z_G and Z_L are available, Eq. (2-33) is the preferred method for obtaining enthalpies of vaporization. Otherwise, the CS methods shown below should be used.

Recommended Method 1 Vapor pressure correlation.

Classification: Extension of theory.

Expected uncertainty: Varies significantly with temperature and with the quality and temperature range of the vapor pressure data used in the correlation.

Applicability: Organic compounds for which group contributions have been regressed.

Input data: Correlations for P^*, Z_G, and Z_L. If $T_r < 0.8$, then Z_G can be set to 1.

Description: An expression for ΔH_v can be obtained from Eq. (2-33) by using an appropriate vapor pressure correlation. If one differentiates the Riedel vapor pressure correlation, Eq. (2-22), in accordance with Eq. (2-33), one obtains the heat of vaporization as

$$\Delta H_v = R\,\Delta Z_v\,(-B + CT + DET^{E+1}) \qquad (2\text{-}36)$$

The Z_G and Z_L values can be evaluated by using the methods given in the subsection on densities below.

Example Calculate ΔH_v for anisole at 452 K.

Input data: The vapor pressure coefficients in the DIPPR® 801 database, based on Eq. (2-22), are

$A = 128.06$ $B = -9307.7$ $C = -16.693$ $D = 0.014919$ $E = 1$

The vapor pressure at 452 K is

$$\ln\frac{P^*}{\text{Pa}} = 128.06 - \frac{9307.7}{452} - 16.693\ln 452 + 0.014919(452)^1 = 12.155$$

$$P^* = \exp(12.155)\cdot\text{Pa} = 1.901 \times 10^5\text{Pa}$$

Determine ΔZ*:* Required data from the DIPPR® 801 database for this calculation are $T_c = 645.6$ K, $P_c = 4.25$ MPa, and $\omega = 0.35017$. These values are used to determine the reduced conditions and the values of Z_G and Z_L from the Lee-Kesler corresponding states method as discussed in the subsection on density.

$$T_r = \frac{452}{645.6} = 0.7 \qquad P_r = \frac{0.1901}{4.25} = 0.045$$

Interpolation of the P_r values in Tables 2-351 and 2-352 at a T_r of 0.7 gives

$$Z_G^{(0)} = 0.9904 + \frac{0.045 - 0.010}{0.050 - 0.010}(0.9504 - 0.9904) = 0.9554$$

$$Z_G^{(1)} = -0.0064 + \frac{0.045 - 0.010}{0.050 - 0.010}(-0.0507 + 0.0064) = -0.0452$$

$$Z_G = Z_G^{(0)} + \omega Z_G^{(1)} = 0.9554 + (0.35017)(-0.0452) = 0.94$$

At this low pressure, Z_L is very small compared to Z_G and may be neglected; so

$$\Delta Z_V = Z_G - Z_L = 0.94$$

Calculation using Eq. (2-36):

$$\Delta H_v = \left(8.314 \frac{\text{J}}{\text{mol·K}}\right)(0.94)[9307.7 - (16.693)(452) + (0.014919)(1)(452)^2]$$

$$= 37.59 \frac{\text{kJ}}{\text{mol·K}}$$

This value is 0.2 percent higher than the value of 37.51 kJ/(mol·K) obtained from the DIPPR® 801 database.

Recommended Method 2 Corresponding states correlation.
Reference: PGL5, p. 7.18.
Classification: Corresponding states.
Expected uncertainty: Less than about 6 percent.
Applicability: Organic compounds.
Input data: T_c, P_c, and ω.
Description: The following correlation is used:

$$\frac{\Delta H_v}{RT_c} = 7.08\tau^{0.354} + 10.95\omega\tau^{0.456} \qquad \text{where } \tau = 1 - T_r \qquad (2\text{-}37)$$

Example Repeat the above calculation for anisole's ΔH_v at 452 K.
Input data: $T_c = 645.6$ K, $P_c = 4.25$ MPa, and $\omega = 0.35017$.
Auxiliary quantities: From the previous example, the reduced temperature is

$$T_r = 0.7 \qquad \tau = 1 - 0.7 = 0.3$$

Calculation using Eq. (2-37):

$$\frac{\Delta H_v}{RT_c} = 7.08(0.3)^{0.354} + 10.95(0.35017)(0.3)^{0.456} = 6.838$$

$$\Delta H_v = (6.838)\left(8.314 \frac{\text{J}}{\text{mol·K}}\right)(645.6 \text{ K}) = 36.70 \frac{\text{kJ}}{\text{mol·K}}$$

This value is 2.2 percent below the DIPPR® 801 recommended value of 37.51 kJ/(mol·K).

Recommended Method 3 Vetere method for ΔH_v at T_b.
Reference: Vetere, A., *Fluid Phase Equilib.*, **106** (1995): 1.
Classification: Corresponding states.
Expected uncertainty: About 4 percent.
Applicability: Valid only at the normal boiling point.
Input data: T_c, P_c, and T_b.
Description: The following correlation is used:

$$\frac{\Delta H_v}{RT_b} = \frac{\tau_b^{0.38}\left[\ln(P_c/\text{bar}) - 0.513 + \dfrac{0.5066 \cdot \text{bar}}{P_c T_{br}^2}\right]}{\tau_b + F(1 - \tau_b^{0.38}) \ln T_{br}} \qquad (2\text{-}38)$$

where $\tau_b = 1 - T_{br}$

For most compounds, $F = 1$; compounds that dimerize (e.g., SO_2, NO, NO_2) and alcohols with more than two C atoms are assigned $F = 1.05$.

Example Calculate ΔH_v at the normal boiling point for acetaldehyde.
Input data: Recommended values from the DIPPR® 801 database are $T_c = 466.0$ K, $P_c = 5.55$ MPa, and $T_b = 294.0$ K.
Auxiliary quantities: From the previous example, the reduced temperature is

$$T_{br} = \frac{294}{466} = 0.631 \qquad \tau_b = 1 - T_{br} = 0.369 \qquad F = 1$$

Calculation using Eq. (2-38):

$$\frac{\Delta H_v}{RT_b} = \frac{(0.369)^{0.38}\left[\ln 55.5 - 0.513 + 0.5066/(55.5)(0.631)^2\right]}{(0.369) + [1 - (0.369)^{0.38}] \ln 0.631} = 10.785$$

$$\Delta H_v = (10.785)\left(8.314 \frac{\text{J}}{\text{mol·K}}\right)(294 \text{ K}) = 26.36 \frac{\text{kJ}}{\text{mol·K}}$$

This value is 2.4 percent above the DIPPR® 801 recommended value of 25.73 kJ/(mol·K).

Enthalpy of Fusion The enthalpy (heat) of fusion ΔH_{fus} is the difference between the molar enthalpies of the equilibrium liquid and solid at the melting temperature and 1.0 atm pressure. There is no generally applicable, high-accuracy estimation method for ΔH_{fus}, but the GC method of Chickos can be used to obtain approximate results if the melting temperature is known.

Recommended Method Chickos method.
Reference: Chickos, J. S., et al., *J. Org. Chem.*, **56** (1991): 927.
Classification: QSPR and group contributions.
Expected uncertainty: Considerable variation but generally less than 50 percent.
Applicability: Only valid at the melting temperature. The method is based on the ΔS_{fus} between a solid at 0 K and the liquid at the T_m so no solid-solid transitions are taken into account. Values of ΔH_{fus} will be overestimated if there are solid-solid transitions for the actual material.
Input data: T_m and molecular structure.
Description:

$$\frac{\Delta H_{\text{fus}}}{\text{J/mol}} = \frac{\Delta S_{\text{fus}}}{\text{J/(mol·K)}}\left(\frac{T_m}{\text{K}}\right) = (T_m/\text{K})(a + b) \qquad (2\text{-}39)$$

$$a = \begin{cases} 0 & \text{no nonaromatic rings} \\ 35.19N_R + 4.289(N_{CR} - 3N_R) & \text{nonaromatic rings} \end{cases} \qquad (2\text{-}40)$$

$$b = \sum_{i=1}^{n_g} Ng_i \, \Delta s_i + \sum_{j=1}^{n_s} Ns_j Cs_j \, \Delta s_j + \sum_{k=1}^{nf} Nf_k Ct_k \, \Delta s_k \qquad (2\text{-}41)$$

where Ng_i = number of C—H groups of type i bonded to other carbon atoms
n_g = number of different nonring or aromatic C—H groups bonded to other carbon atoms
Ns_j = number of C—H groups of type j bonded to at least one functional group or atom
n_s = number of different nonring or aromatic C—H groups bonded to at least one functional group or atom
Nf_k = number of functional groups of type k
n_f = number of different functional groups or atoms
t = total number of functional groups or atoms with the exception that F atoms count as one regardless of number of occurences
Cs_j = value from Table 2-344 for C—H group j bonded to at least one functional group or atom
Ct_k = value from Table 2-345 for functional group k
N_R = number of nonaromatic rings
N_{CR} = number of —CH_2— groups in nonaromatic ring(s) required to form cyclic paraffin of same ring size(s)
Δs_i = contribution from Table 2-344 for group i
Δs_k = contribution from Table 2-345 for group k

TABLE 2-344 Cs (C—H) Group Values for Chickos Estimation* of ΔH_{fus}

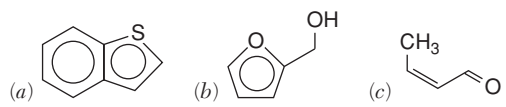
Group	Description	*Cs*	Δ*s*	Group	Description	*Cs*	Δ*s*
—CH_3	methyl	1.0	18.33	—CH_{Ar}	aromatic C	1.0	6.44
>CH_2	methylene	1.0	9.41	—C_{Ar}—	ar. C bonded to paraffinic C	1.0	–10.33
>CH—	secondary C	0.69	–16.91	—C_{Ar}—	ar. C bonded to olefinic C or non-C group	1.0	–4.27
>C <	tertiary C	0.67	–38.70	—C_{Ar}—	ar. C bonded to acetylinic C	1.0	–2.51
CH_2=	terminal alkene	1.0	14.56	>C_rH—	ring structure	0.76	–15.98
—CH=	alkene	3.23	4.85	>C_r <	ring structure	1.0	–32.97
>C=	subst. alkene	1.0	–11.38	—C_rH=	ring structure	0.62	–4.35
≡CH	term. alkyne	1.0	10.88	>C_r=	ring structure	0.86	–11.72
≡C—	alkyne	1.0	2.18	≡C_r— or =C_r=	ring structure	1.0	–5.36

*Chickos, J. S., et al., *J. Org. Chem.*, **56** (1991): 927.

Note that nonaromatic ring —CH_2 groups are accounted for in the *a* term and are *not* included in the *b* term.

Example Calculate ΔH_{fus} at the melting point for (*a*) benzothiophene, (*b*) furfuryl alcohol, and (*c*) *cis*-crotonaldehyde.

Structures:



(*a*) (*b*) (*c*)

(*a*) $t = 1$ (1 total "functional group"), so the C_1 column in Table 2-345 is used.

$N_R = 1$ $N_{CR} = 5$ $a = 35.19 + (5 - 3)(4.289) = 43.77$

Group	Description	N	C	Δs	Total
=CH—	aromatic (*Ng* type)	4	1	6.44	25.76
=C—	ring (*Ng* type)	1	1	–11.72	–11.72
=C—	ring (*Ns* type)	1	0.86	–11.72	–10.08
=CH—	ring (*Ng* type)	1	1	–4.35	–4.35
=CH—	ring (*Ns* type)	1	0.62	–4.35	–2.70
—S—	ring	1	1	2.18	2.18
				Total	–0.91

TABLE 2-345 Ct (Functional) Group Values for Chickos Estimation* of ΔH_{fus}

Group	Description	C_1	C_2	C_3	C_4	Δ*s*
—OH	alcohol	1.0	12.6	18.9	26.4	1.13
—OH	phenol	1.0	1.0	1.0	1.0	16.57
—O—	nonring ether	1.0	1.0	1.0	1.0	1.09
—O—	ring ether	1.0	1.0	1.0	1.0	1.34
>C=O	nonring ketone	1.0	1.0			3.14
>C=O	ring ketone	1.0	1.0			–1.88
—CHO	aldehyde	1.0	1.0			19.66
—COOH	acid	1.0	1.83	1.88	1.72	14.90
—COO—	ester	1.0	1.0	1.0	1.0	3.68
—NH_2	aliphatic	1.0	1.0			16.23
—NH_2	aromatic	1.0	1.0			15.48
>NH	nonring	1.0	1.0			–2.18
>NH	ring	1.0	1.0			1.84
>N—	nonring	1.0	1.0			–15.90
>N—	ring	1.0	1.0			–17.07
=N—	ring	1.0	1.0			1.67
=N—	aromatic	1.0	1.0	1.0		7.32
—CN	nitrile	1.0	1.4			9.62
—NO_2	nitro	1.0	1.0	1.0		17.36
—$CONH_2$	primary amide	1.0	1.0			26.19
—CONH—	secondary amide	1.0	1.0			–0.42
—SH		1.0	1.0			17.99
—S—	nonring	1.0	1.0		0.36	7.20
—S—	ring	1.0	1.0			2.18
—SO_2	nonring	1.0	1.0			3.26
—F	on aliph. C	1.0	1.0	1.0	1.0	14.73
—F	on olefinic C	1.0	1.0	1.0	1.0	13.01
—F	on ring C	1.0	1.0	1.0	1.0	15.90
—Cl		1.0	2.0	2.0	1.93	8.37
—Br		1.0	1.0	1.0	0.82	17.95
—I		1.0	1.0			16.95

*Chickos, J. S., et al., *J. Org. Chem.*, **56** (1991): 927.

$T_m = 304.5$ K from DIPPR® 801 database

$\Delta H_{fus} = (T_m/\text{K})(a + b)$ J/mol = (304.5)(43.77 – 0.91) J/mol = 13.05 kJ/mol

This value is 10 percent higher than the DIPPR® 801 recommended value of 11.83 kJ/mol.

(*b*) $t = 2$ (2 total "functional groups"), so the C_2 column in Table 2-345 is used.

$N_R = 1$ $N_{CR} = 5$ $a = 35.19 + (5 - 3)(4.289) = 43.77$

Group	Description	N	C	Δs	Total
=CH—	ring (*Ng* type)	2	1	–4.35	–8.70
=CH—	ring (*Ns* type)	1	0.62	–4.35	–2.70
=C<	ring (*Ns* type)	1	0.86	–11.72	–10.08
=O—	ring ether	1	1	1.34	1.34
—CH_2—	*Ns* type	1	1	9.41	9.41
—OH	alcohol	1	12.6	1.13	14.24
				Total	3.51

$T_m = 258.52$ K from DIPPR® 801 database

$\Delta H_{fus} = (T_m/\text{K})(a + b)$ J/mol = (258.52)(43.77 + 3.51) J/mol = 12.22 kJ/mol

This value is 7 percent lower than the DIPPR® 801 recommended value of 13.13 kJ/mol.

(*c*) $t = 1$ $N_R = 0$ $a = 0$

Group	Description	*N*	*C*	Δs	Total
—CH_3	nonring (*Ng* type)	1	1	18.33	18.33
=CH–	nonring (*Ng* type)	1	1	4.85	4.85
=CH–	nonring (*Ns* type)	1	3.23	4.85	15.67
—CHO	aldehyde	1	1	19.66	19.66
				Total	58.51

$T_m = 158.38$ K from DIPPR® 801 database

$\Delta H_{fus} = (T_m/\text{K})(a + b)$ J/mol = (158.38)(0 + 58.51) J/mol = 9.27 kJ/mol

This value is 5 percent higher than the DIPPR® 801 recommended value of 8.86 kJ/mol.

Enthalpy of Sublimation The enthalpy (heat) of sublimation ΔH_{fus} is the difference between the molar enthalpies of the equilibrium vapor and solid along the sublimation curve below the triple point. The effects of pressure on ΔH_{fus} and melting temperature are very small so that T_t and the normal melting point are nearly equal and

$$\Delta H_{sub}(T_t) = \Delta H_v(T_t) + \Delta H_{fus}(T_t) \tag{2-42}$$

Equation (2-42) can be used to estimate ΔH_{sub} at the triple point if ΔH_v is accurately known at T_t. Because ΔH_v is usually obtained from Eq. (2-33), $\Delta H_v(T)$ correlations may be less accurate near T_t where $P^*(T_t)$ is very small and difficult to measure. In this case, it is better to estimate ΔH_{sub} directly by using the following recommended

method. Although Eqs. (2-33) and (2-34) apply to T_t, ΔH_{sub} is only a weak function of temperature and can generally be taken as a constant from the triple point temperature down to the first solid-solid phase transition.

Recommended Method Goodman method.

Reference: Goodman, B., et al., *Int. J. Thermophys.* **25** (2004): 337.

Classification: QSPR and group contributions.

Expected uncertainty: 6 percent.

Applicability: Organic compounds for which group contributions have been regressed.

Input data: Molecular structure and radius of gyration R_G.

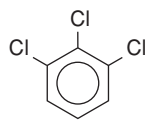
Description:

$$\frac{\Delta H_{sub}(T_t)}{R\ \mathrm{K}} = 698.04 + 3.83798\times 10^{12}\left(\frac{R_G}{\mathrm{m}}\right) + \sum_{i=1}^{N} n_i a_i + \sum_{i=1}^{N} n_i^2 \beta_i + \sum_{i=1}^{N} \frac{n_i}{n_x} f_i \qquad (2\text{-}43)$$

where a_i = GC values from Table 2-346
β_i = nonlinear corrections for >CH_2 and Ar—CH = groups
f_i = halogen corrections
n_x = total number of all halogen and hydrogen atoms attached to C and Si atoms

Example Calculate ΔH_{sub} and the solid vapor pressure for 1,2,3-trichlorobenzene at 301.15 K.

Structure:



Group contributions:

Linear groups			Nonlinear and correction terms			
Group	n_i	a_i	Group	n_i	β_i	f_i
Ar—CH=	3	626.7621	Ar—CH=	3	−2.21614	
Ar >C=	3	348.8092	—Cl	3		−1543.66
—Cl	3	1243.445	n_x	6		
	$\sum_i n_i a_i$	6657.049				

Input data: The value of R_G from the DIPPR® 801 database is 4.455×10^{-10} m.

Calculation using Eq. (2-43):

$$\frac{\Delta H_{sub}(T_t)}{R\ \mathrm{K}} = 698.04 + (3.83798\times 10^{12})(4.455\times 10^{-10}) + 6657.049 + (3^2)(-2.21614) + \left(\frac{3}{6}\right)(-1543.66)$$

$$\Delta H_{sub}(T_t) = (8273.134\ \mathrm{K})\left(0.008314\frac{\mathrm{kJ}}{\mathrm{mol\cdot K}}\right) = 68.78\frac{\mathrm{kJ}}{\mathrm{mol}}$$

The estimated value is 5.6 percent above the DIPPR® 801 recommended value of 65.11 kJ/mol.

Estimate the solid vapor pressure from Eq. (2-26): The solid vapor pressure at 301.15 K can be calculated from Eq. (2-26) by using the estimated ΔH_{sub}. Recommended values for T_t and P^*_t from the DIPPR® 801 database are 325.65 K and 182.957 Pa, respectively.

$$\ln\frac{P^*}{182.957\ \mathrm{Pa}} = \frac{68.78\mathrm{kJ/mol}}{[0.008314\ \mathrm{kJ/(mol\cdot K)}](325.65\ \mathrm{K})}\left(1-\frac{325.65}{301.15}\right) = -2.067$$

$$P^* = (182.957\ \mathrm{Pa})[\exp(-2.067)] = 23.16\ \mathrm{Pa}$$

The estimated value is 0.3 percent above the DIPPR® 801 recommended value of 23.09 Pa.

HEAT CAPACITY

Heat capacity C_P is defined as the energy required to change the temperature of a unit mass (specific heat) or mole (molar heat capacity) of the material by one degree. Typical units are J/(kg·K).

Gases The heat capacity of a gas is related rigorously to the ideal gas heat capacity C_P^o by

$$C_P = C_P^o - T\int_0^P \left(\frac{\partial^2 V}{\partial T^2}\right)_P dP \qquad (2\text{-}44)$$

The second term, giving the deviation of the real fluid heat capacity from the ideal gas value, can be neglected at low to moderate pressures, or it can be calculated directly from an appropriate EoS.

Ideal gas heat capacities are available from several sources (DIPPR, JANAF, TRC, and SWS). Two common correlating equations for C_P^o are the Aly-Lee [Aly, F. A., and L. L. Lee, *Fluid Phase Equilib.*, **6**

TABLE 2-346 Group Contributions and Corrections* for ΔH_{sub}

Group	Description	a_i	Group	Description	a_i
—CH_3	methyl	736.5889	>C=O	ketone	1816.093
>CH_2	methylene	561.3543	—COO—	ester	2674.525
>CH—	secondary C	111.0344	—COOH	acid	5006.188
>C<	tertiary C	−800.517	—NH_2	primary amine	2219.148
CH_2=	terminal alkene	572.6245	—NH—	sec. amine	1561.222
—CH=	alkene	541.2918	>N—	tertiary amine	325.9442
>C=	substituted alkene	117.9504	—NO_2	nitro	3661.233
Ar—CH=	aromatic C	626.7621	—SH	thiol/mercaptan	1921.097
Ar >C=	subst. aromatic C	348.8092	—S—	sulfide	1930.84
Ar—O—	furan O	763.284	—SS—	disulfide	2782.054
Ar—N=	pyridine N	1317.056	—F	fluoride	626.4494
Ar—S—	thiophene S	911.2903	—Cl	chloride	1243.445
—O—	ether	970.4474	—Br	bromide	669.9302
—OH	alcohol	3278.446	>Si<	silane	−83.7034
—COH	aldehyde	2402.093	>Si(O—)—	siloxane	−16.0597
Nonlinear terms		β_i	**Halogen correction terms**		f_i
>CH_2	methylene	9.5553	—F	F fraction	−1397.4
Ar—CH=	aromatic C	−2.21614	—Cl	Cl fraction	−1543.66
			—Br	Br fraction	5812.49

*Goodman, B., et al., *Int. J. Thermophys.*, **25** (2004): 337.

(1981): 169] equation

$$C_P^o = A_o + A_1\left[\frac{A_2/T}{\sinh(A_2/T)}\right]^2 + A_3\left[\frac{A_4/T}{\cosh(A_4/T)}\right]^2 \qquad (2\text{-}45)$$

and a polynomial form (generally fourth-order)

$$C_P^o = \sum_{i=0}^{4} A_i T^i \qquad (2\text{-}46)$$

Ideal gas heat capacities may also be estimated from several techniques, of which two of the most accurate and commonly used are recommended here.

Recommended Method 1 Statistical mechanics.

Reference: Rowley, R. L., *Statistical Mechanics for Thermophysical Property Calculations,* Prentice-Hall, Englewood Cliffs, N.J., 1994.

Classification: Theory and computational chemistry.

Expected uncertainty: 0.2 percent if vibrational frequencies (or their characteristic temperatures) are experimentally available; accuracy depends upon model chemistry if frequencies are determined from computational chemistry, but generally within 3 percent.

Applicability: Ideal gases.

Input data: $3n_A - 6 + \delta$ vibrational frequencies ν_j, or the corresponding characteristic vibrational temperatures Θ_j. The two are related by

$$\Theta_j = h\nu_j/k \qquad (2\text{-}47)$$

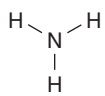
where n_A = number of atoms in molecule and $\delta = 1$ for linear molecules and 0 for nonlinear molecules.

Description: For harmonic frequencies, the rigorous temperature dependence of C_P^o is given by

$$\frac{C_P^o}{R} = \frac{8-\delta}{2} + \sum_{j=1}^{3n_A-6+\delta}\left(\frac{\Theta_j}{T}\right)^2\left[\frac{e^{\Theta_j/T}}{(e^{\Theta_j/T}-1)^2}\right] \qquad \delta = \begin{cases} 0 & \text{nonlinear} \\ 1 & \text{linear} \end{cases} \qquad (2\text{-}48)$$

Example Calculate the ideal gas heat capacity of ammonia at 300 K.

Structure:



Input data: McQuarrie (McQuarrie, D. A., *Statistical Mechanics*, Harper & Row, New York, 1976) gives the following $3m - 6 + \delta = 12 - 6 + 0 = 6$ characteristic vibrational temperatures (K): 1360, 2330, 2330, 4800, 4880, and 4880. Alternatively, a computational chemistry package gives the following *scaled* frequencies for HF/6-31G+ model chemistry (10^{13} Hz): 3.24, 4.97, 4.97, 9.90, 10.26, and 10.26.

Calculation: The table on the left uses the experimental Θ values to determine the individual terms in the summation of Eq. (2-48); the table on the right uses the scaled frequencies from computational chemistry software and Eq. (2-47) to obtain Θ values and the individual terms in Eq. (2-48).

From experimental frequencies:

$$C_P^0 = \left(\frac{8}{2} + 0.2769\right)R = (4.2769)\left(8.3143\,\frac{\text{J}}{\text{mol·K}}\right) = 35.56\,\frac{\text{J}}{\text{mol·K}}$$

From computational chemistry frequencies:

$$C_P^0 = \left(\frac{8}{2} + 0.197\right)R = (4.197)\left(8.3143\,\frac{\text{J}}{\text{mol·K}}\right) = 34.90\,\frac{\text{J}}{\text{mol·K}}$$

The value calculated from experimental frequencies is 0.1 percent lower than the DIPPR® 801 recommended value of 35.61 J/(mol·K); the value calculated from frequencies generated from computational chemistry software is 2.0 percent lower than the DIPPR® 801 value.

Recommended Method 2 Benson method as implemented in CHETAH program.

References: Benson, S. W., et al., *Chem. Rev.*, **69** (1969): 279; CHETAH Version 8.0: *The ASTM Computer Program for Chemical Thermodynamic and Energy Release Evaluation (NIST Special Database 16).*

Classification: Group contributions.

Expected uncertainty: 4 percent.

Applicability: Ideal gases of organic compounds.

Input data: Table 2-347 group values at the seven specified temperatures.

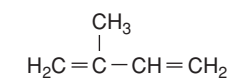
Description: Groups are summed at each individual temperature:

$$C_P^o = \sum_{i=1}^{N} n_i \cdot (C_p^o)_i \qquad (2\text{-}49)$$

where n_i = number of occurrences of group i and $(C_p^o)_i$ = individual group contribution. Either Eq. (2-45) or Eq. (2-46) can be used to interpolate between the discrete temperatures.

Example Calculate the ideal gas heat capacity of isoprene (2-methyl-1,3-butadiene) at 400 K.

Structure:



Group identification and values:

Group	No.	Value, J/(mol·K)	Contribution, J/(mol·K)
$=CH_2$	2	26.62	53.24
$=C-(2C)$	1	19.3	19.3
$-CH_3-(=C)$	1	32.82	32.82
$=CH-(C)$	1	21.05	21.05
		Total	126.41

The value of 126.4 J/(mol·K) is 3.1 percent below the DIPPR® 801 recommended value of 130.4 J/(mol·K).

Liquids Liquid heat capacity increases with increasing temperature, although a minimum occurs near the triple point for many compounds. Usually liquid heat capacity is correlated as a function of temperature with a polynomial equation. A cubic equation is usually adequate.

Estimation of liquid heat capacity can be done by using a number of methods [Ruzicka, V., and E. S. Domalski, *J. Phys. Chem. Ref. Data*, **22** (1993): 597, 619; Chueh, C. F., and A. C. Swanson, *Chem. Eng.*

Experimental frequencies		
Θ/K	Θ/(300 K)	Term
1360	4.533	0.2256
2330	7.767	0.0256
2330	7.767	0.0256
4800	16.000	0.0000
4880	16.267	0.0000
4880	16.267	0.0000
	Sum	0.2769

HF/6-31G + scaled frequencies			
ν_{scaled}/Hz	Θ/K	Θ/(300 K)	Term
3.24	1555.0	5.183	0.1524
4.97	2385.3	7.951	0.0223
4.97	2385.3	7.951	0.0223
9.90	4751.4	15.838	0.0000
10.26	4924.2	16.414	0.0000
10.26	4924.2	16.414	0.0000
		Sum	0.1970

NOTE: Empirical scaling factors have been developed for each model chemistry to help correct theoretical frequencies for anharmonic effects [Scott, A. P., and L. Radom, *J. Phys. Chem.*, **100** (1996): 16502].

TABLE 2-347 Benson* and CHETAH† Group Contributions for Ideal Gas Heat Capacity

Table-specific nomenclature: Cb = carbon in benzene ring; Ct = carbon with a triple bond, (═C) = carbon with a double bond; Cp = carbon in fused ring; Naz = azide; Nim = imino.

Group	298 K	400 K	500 K	600 K	800 K	1000 K	1500 K
			CH_3 Groups				
CH_3—(Cb)	25.91	32.82	39.35	45.17	54.5	61.83	73.59
CH_3—(CO)	25.91	32.82	39.35	45.17	54.5	61.83	73.59
CH_3—(Ct)	25.91	32.82	39.35	45.17	54.5	61.83	73.59
CH_3—(C)	25.91	32.82	39.35	45.17	54.5	61.83	73.59
CH_3—(N)	25.95	32.65	39.35	45.21	54.42	61.95	73.67
CH_3—(O)	25.91	32.82	39.35	45.17	54.54	61.83	73.59
CH_3—(PO)	25.91	32.82	39.35	45.17	54.54	61.83	73.59
CH_3—(P)	25.91	32.82	39.35	45.17	54.54	61.83	73.59
CH_3—(P═N)	25.91	32.82	39.35	45.17	54.54	61.83	73.59
CH_3—(Si)	25.91	32.82	39.35	45.17	54.5	61.83	73.59
CH_3—(SO_2)	25.91	32.82	39.35	45.17	54.5	61.83	
CH_3—(SO)	25.91	32.82	39.35	45.17	54.5	61.83	
CH_3—(S)	25.91	32.82	39.35	45.17	54.5	61.83	
CH_3—(═C)	25.91	32.82	39.35	45.17	54.5	61.83	73.59
			Ct Groups				
Ct—(Cb)	10.76	14.82	14.65	20.59	22.35	23.02	24.28
Ct—(Ct)	14.82	16.99	18.42	19.42	20.93	21.89	23.32
Ct—(C)	13.1	14.57	15.95	17.12	19.25	20.59	26.58
Ct—(═C)	10.76	14.82	14.65	20.59	22.35	23.02	24.28
CtBr	34.74	36.42	37.67	38.51	39.77	40.6	
CtCl	33.07	35.16	36.42	37.67	39.35	40.18	
CtF	28.55	31.65	33.99	35.79	38.3	39.85	41.77
CtH	22.06	25.07	27.17	28.76	31.27	33.32	37.04
CtI	35.16	36.84	38.09	38.93	40.18	41.02	
Ct(CN)	43.11	47.3	50.65	53.16	56.93	59.86	64.04
			CH_2 Groups				
CH_2—(2CO)	16.03	26.66	32.15	37.8	45.46	51.74	
CH_2—(2C)	23.02	29.09	34.53	39.14	46.34	51.65	59.65
CH_2—(2O)	11.85	21.18	31.48	38.17	43.2	47.26	
CH_2—(2═C)	19.67	28.46	35.16	40.18	47.3	52.74	60.28
CH_2—(Cb,O)	15.53	26.26	34.66	40.98	49.35	55.25	
CH_2—(Cb,SO_2)	15.53	27.5	34.66	40.98	49.77	55.25	
CH_2—(Cb,S)	38.09	49.02	57.43	63.71	72.58	78.82	
CH_2—(Cb,═C)	19.67	28.46	35.16	40.18	47.3	52.74	60.28
CH_2—(C,Cb)	24.45	31.85	37.59	41.9	48.1	52.49	57.6
CH_2—(C,CO)	25.95	32.23	36.42	39.77	46.46	51.07	
CH_2—(C,Ct)	20.72	27.46	33.19	38.01	45.46	51.03	59.44
CH_2—(C,N)	21.77	28.88	34.74	39.35	46.46	51.49	
CH_2—(C,O)	20.89	28.67	34.74	39.47	46.5	51.61	61.11
CH_2—(C,SO_2)	17.12	24.99	31.56	36.84	44.58	49.94	
CH_2—(C,SO)	19.05	26.87	33.28	38.34	45.84	51.15	
CH_2—(C,S)	22.52	29.64	36	41.73	51.32	59.23	
CH_2—(C,═C)	21.43	28.71	34.83	39.72	46.97	52.24	60.11
CH_2—(═C,O)	19.51	29.18	36.21	41.36	48.3	53.29	
CH_2—(═C,SO_2)	20.34	28.51	34.95	40.1	47.17	52.49	
CH_2—(═C,SO)	18.42	26.62	29.05	38.72	45.92	51.28	
CH_2—(═C,S)	22.23	28.59	34.45	40.85	50.98	59.48	
			CH Groups				
CH—(2C,Cb)	20.43	27.88	33.07	36.63	40.73	42.9	44.7
CH—(2C,CO)	18.96	25.87	30.89	35.12	41.11	43.99	
CH—(2C,Ct)	16.7	23.48	28.67	32.57	38.09	41.44	46.55
CH—(2C,N)	19.67	26.37	31.81	35.16	40.18	42.7	
CH—(2C,O)	20.09	27.79	33.91	36.54	41.06	43.53	
CH—(2C,SO_2)	18.5	26.16	31.65	35.5	40.35	43.11	
CH—(2C,S)	20.3	27.25	32.57	36.38	41.44	44.24	
CH—(2C,═C)	17.41	24.74	30.72	34.28	39.6	42.65	47.22
CH—(3C)	19	25.12	30.01	33.7	38.97	42.07	46.76
CH—(C,2O)	22.02	23.06	27.67	31.77	35.41	38.97	
			C Groups				
C—(2C,2O)	19.25	19.25	23.02	25.53	27.63	28.46	
C—(3C,Cb)	19.72	28.42	33.86	36.75	38.47	37.51	31.94
C—(3C,CO)	9.71	18.33	23.86	27.17	30.43	31.69	
C—(3C,Ct)	0.33	7.33	14.36	19.97	25.2	26.71	
C—(3C,N)	18.42	25.95	30.56	33.07	35.58	35.58	
C—(3C,O)	18.12	25.91	30.35	32.23	34.32	34.49	
C—(3C,SO_2)	9.71	18.33	23.86	27.17	30.43	31.23	
C—(3C,SO)	12.81	19.17	20.26	27.63	31.56	33.32	
C—(3C,S)	19.13	26.25	31.18	34.11	36.5	33.91	
C—(3C,═C)	16.7	25.28	31.1	34.58	37.34	37.51	34.45
C—(4C)	18.29	25.66	30.81	33.99	36.71	36.67	33.99

TABLE 2-347 Benson* and CHETAH† Group Contributions for Ideal Gas Heat Capacity (*Continued*)

Table-specific nomenclature: Cb = carbon in benzene ring; Ct = carbon with a triple bond, (═C) = carbon with a double bond; Cp = carbon in fused ring; Naz = azide; Nim = imino.

Group	298 K	400 K	500 K	600 K	800 K	1000 K	1500 K
			Aromatic (Cb and Cp Groups)				
Cb—(Cb)	13.94	17.66	20.47	22.06	24.11	24.91	25.32
Cb—(CO)	11.18	13.14	15.4	17.37	20.76	22.77	
Cb—(Ct)	15.03	16.62	18.33	19.76	22.1	23.48	24.07
Cb—(C)	11.18	13.14	15.4	17.37	20.76	22.77	25.03
Cb—(N)	16.53	21.81	24.86	26.45	27.33	27.46	
Cb—(O)	16.32	22.19	25.95	27.63	28.88	28.88	
Cb—(Si)	11.18	13.14	15.4	17.37	20.76	22.77	25.03
Cb—(SO_2)	11.18	13.14	15.4	17.37	20.76	22.77	
Cb—(SO)	11.18	13.14	15.4	17.37	20.76	22.77	
Cb—(S)	16.32	22.19	25.95	27.63	28.88	28.88	
Cb—(═C)	15.03	16.62	18.33	19.76	22.1	23.48	24.07
Cb—(═Nim)	16.53	21.81	24.86	26.45	27.33	27.46	
CbBr	32.65	36.42	39.35	41.44	43.11	43.95	
CbCl	30.98	35.16	38.51	40.6	42.7	43.53	
CbF	26.37	31.81	35.58	38.09	41.02	42.7	
CbH	13.56	18.59	22.85	26.37	31.56	35.2	40.73
CbI	33.49	37.25	40.18	41.44	43.11	43.95	
Cb(CHN_2)	47.3						
Cb(CN)	41.86	48.14	52.74	55.67	59.86	62.79	
Cb(N_3)	34.74						
Cb(NCO)	55.25	64.04	70.32	74.51	79.95	82.88	85.81
Cb(NCS)	32.23						
Cb(NO_2)	38.93	50.23	59.44	66.56	76.18	80.37	
Cb(SO_2OH)	65.42	79.49	84.51	97.61	109.25	113.31	
Cp—(2Cb,Cp)	12.56	15.49	17.58	19.25	21.77	23.02	
Cp—(3Cp)	8.37	12.14	14.65	16.74	19.67	21.35	
Cp—(Cb,2Cp)	12.56	15.49	17.58	19.25	21.77	23.02	
			═C═, ═C—, ═CH— Groups				
═C—(2C)	17.16	19.3	20.89	22.02	24.28	25.45	26.62
═C—(CO,O)	23.4	29.3	31.31	32.44	33.57	34.03	
═C—(C,Cb)	18.42	22.48	24.82	25.87	27.21	27.71	28.13
═C—(C,CO)	22.94	29.22	31.02	31.98	33.53	34.32	
═C—(C,O)	17.16	19.3	20.89	22.02	24.28	25.45	
═C—(C,SO_2)	15.49	26.04	33.32	38.51	44.62	47.47	
═C—(C,S)	14.65	14.94	16.03	17.12	18.46	20.93	
═C—(C,═C)	18.42	22.48	24.82	25.87	27.21	27.71	28.13
═CC—(═C,O)	18.42	22.9	24.82	26.29	27.21	27.71	
═CH—(Cb)	18.67	24.24	28.25	31.06	34.95	37.63	41.77
═CH—(CO)	31.73	37.04	38.8	40.31	43.45	46.21	
═CH—(Ct)	18.67	24.24	28.25	31.06	34.95	37.63	41.77
═CH—(C)	17.41	21.05	24.32	27.21	32.02	35.37	40.27
═CH—(O)	17.41	21.05	24.32	27.21	32.02	35.37	40.27
═CH—(SO_2)	12.72	19.55	24.82	28.63	32.94	36.29	
═CH—(S)	17.41	21.05	24.32	27.21	32.02	35.37	
═CH—(═C)	18.67	24.24	28.25	31.06	34.95	37.63	41.77
═CH_2	21.35	26.62	31.44	35.58	42.15	47.17	55.21
═C═	16.32	18.42	19.67	20.93	22.19	23.02	23.86
			Oxygen Groups				
O—(2C)	14.23	15.49	15.49	15.91	18.42	19.25	
O—(2O)	15.49	15.49	15.49	15.49	17.58	17.58	20.09
O—(2═C)	14.02	16.32	17.58	18.84	21.35	22.6	
O—(Cb,CO)	8.62	11.3	13.02	14.32	16.24	17.5	
O—(CO,O)	1.51	6.28	9.63	11.89	15.28	17.33	
O—(C,Cb)	2.6	3.01	4.94	7.45	11.89	14.99	
O—(C,CO)	11.64	15.86	18.33	19.8	20.55	21.05	
O—(C,O)	15.49	15.49	15.49	15.49	17.58	17.58	20.09
O—(C,═C)	12.72	13.9	14.65	15.49	17.54	18.96	
O—(═C,CO)	6.03	12.47	16.66	18.79	20.8	21.77	
OH—(Cb)	18	18.84	20.09	21.77	25.12	27.63	
OH—(CO)	15.95	20.85	24.28	26.54	30.01	32.44	37.34
OH—(C)	18.12	18.63	20.18	21.89	25.2	27.67	33.65
OH—(O)	21.64	24.24	26.29	27.88	29.93	31.44	34.2
O(CN)—(Cb)	34.74						
O(CN)—(C)	41.86						
O(CN)—(═C)	54.42						
O(NO_2)—(C)	39.93	48.3	55.5	65.3	68.61	72.75	
O(NO)—(C)	38.09	43.11	46.88	50.23	55.67	58.18	60.69
(CO)Cl—(C)	42.28	46.04	49.39	51.9	55.67	57.76	
(CO)H—(Cb)	33.53	44.2	48.77	59.48	68.56	74.01	
(CO)H—(CO)	28.13	32.78	37.25	41.4	47.84	50.73	

TABLE 2-347 Benson* and CHETAH† Group Contributions for Ideal Gas Heat Capacity (*Continued*)

Table-specific nomenclature: Cb = carbon in benzene ring; Ct = carbon with a triple bond, (═C) = carbon with a double bond; Cp = carbon in fused ring; Naz = azide; Nim = imino.

Group	298 K	400 K	500 K	600 K	800 K	1000 K	1500 K
			Oxygen Groups				
(CO)H—(C)	29.43	32.94	36.92	40.52	46.71	51.07	
(CO)H—(N)	29.43	32.94	36.92	40.52	46.71	51.07	
(CO)H—(O)	29.43	32.94	36.92	40.52	46.71	51.07	
(CO)H—(═C)	24.32	30.22	39.77	48.77	63.12	74.68	
CO—(Cb)(O)	9.12	11.51	16.65	21.05	26.32	29.54	
			Halide Groups				
CBr—(3C)	39.35	47.72	52.74	55.25	56.93	56.09	
CBr_3—(C)	72.12	78.65	82.92	85.64	88.66	89.66	
CCl—(3C)	36.96	43.87	47.72	49.52	52.07	53.12	
CCl_2—(2C)	51.07	62.29	66.76	68.98	70.99	71.24	
CCl_3—(C)	68.23	75.35	79.95	82.88	86.23	87.9	
$CClF_2$—(C)	57.35	67.39	73.25	77.86	82.88	85.39	
CF—(3C)	28.46	37.09	42.7	46.71	52.03	53.24	
CF_2—(2C)	39.01	46.97	53.24	57.85	63.46	65.84	
CF_3—(Cb)	52.32	64.04	72	77.44	84.14	87.9	
CF_3—(C)	53.16	62.79	68.65	74.93	80.79	83.72	
CF_3—(S)	41.36	54.46	62.08	68.52	76.06	79.99	
CH_2Br—(Cb)	30.51	46.46	52.2	57.3	65.26	69.95	
CH_2Br—(C)	38.09	46.04	52.74	57.35	64.88	70.32	
CH_2Br—(═C)	40.6	47.72	54.42	59.86	67.81	73.67	
CH_2Cl—(C)	37.25	44.79	51.49	56.09	64.04	69.9	
CH_2F—(C)	33.91	41.86	50.23	54.42	63.62	69.49	
CH_2I—(Cb)	33.91	45.17	53.7	59.9	68.15	73.8	
CH_2I—(C)	38.51	46.04	54	58.18	66.14	72	
CH_2I—(O)	34.41	43.91	51.19	56.72	64.25	69.36	
CHBr—(2C)	37.38	44.62	50.06	53.75	58.81	61.62	
CHBrCl—(C)	51.9	58.6	63.3	68.23	74.93	79.53	
CHCl—(2C)	35.45	42.7	48.89	53.41	59.82	64.38	
CHCl—(C,O)	37.67	41.44	43.95	46.88			
$CHCl_2$—(C)	50.65	58.6	64.46	69.07	74.93	78.28	
CHF—(2C)	30.56	37.84	43.83	48.39	54.83	58.64	
CHF_2—(C)	41.44	50.23	57.35	63.21	69.9	74.51	
CHI—(2C)	38.64	45.67	50.9	54.42	59.31	61.95	
CHI_2—(C)	56.93	63.42	69.61	74.17	79.7	81.58	
CI—(3C)	41.15	49.18	54.08	56.3	57.72	56.93	
═CBr_2	51.49	55.25	58.18	59.86	62.37	63.62	
═CBrCl	50.65	53.16	56.51	59.02	61.53	62.79	
═CBrF	45.21	50.23	53.58	56.51	59.86	61.53	
═CCl_2	47.72	52.32	55.67	58.18	61.11	62.79	
═CClF	43.11	48.97	52.74	55.67	59.44	61.53	
═CF_2	40.6	46.04	50.23	53.16	57.76	60.69	
═CHBr	33.91	39.77	44.37	47.72	51.9	55.25	
═CHCl	33.07	38.51	43.11	46.88	51.49	54.83	
═CHF	28.46	35.16	39.77	43.95	49.39	53.16	
═CHI	36.84	41.86	45.63	48.56	52.74	55.67	
			Nitrogen Groups				
$CH_2(N_3)$—(C)	64.46						
═$CH(N_3)$	54.42						
N—(2C,Cb)	2.6	8.46	13.69	17.29	21.89	23.4	
N—(2C,CO)	13.02	19.17	23.52	26.16	28.42	28.76	
N—(2C,SO_2)	25.2	26.58	31.56	34.45	37.8	38.47	
N—(2C,SO)	17.58	24.61	25.62	27.33	28.59	34.91	
N—(2C,S)	15.99	21.64	25.99	29.05	30.93	38.68	
N—(3C)	14.57	19.09	22.73	24.99	27.46	27.92	27.21
N—(Cb,2CO)	4.1	12.81	17.71	20.3	22.1	22.14	
N—(C,2CO)	4.48	12.99	18.04	20.93	22.94	27.08	
Nb pyrid—N	10.88	13.48	15.95	17.66	20.05	21.43	
NF_2—(C)	26.5	34.58	40.9	45.63	50.9	53.54	
NH—(2Cb)	9.04	13.06	17.29	21.35	28.3	32.98	
NH—(2CO)	15.03	23.19	28.05	30.93	33.28	34.28	
NH—(2C)	17.58	21.81	25.66	28.59	33.07	36.21	39.97
NH—(Cb,CO)	2.39	6.32	9.96	13.94	16.91	18.21	
NH—(C,Cb)	15.99	20.47	23.9	26.29	30.1	32.36	
NH—(C,CO)	2.76	6.49	10.3	14.57	17.75	18.96	
NH—(C,N)	20.09	24.28	27.21	29.3	32.65	34.74	37.67
NH_2—(Cb)	23.94	27.25	30.64	33.78	39.39	43.83	51.4
NH_2—(CO)	17.04	24.03	29.85	34.7	41.69	46.97	
NH_2—(C)	23.94	27.25	30.64	33.78	39.39	43.83	51.4
NH_2—N	25.53	30.98	35.16	38.93	43.95	48.14	55.25
═Naz—(C)	11.3	17.16	20.59	22.35	23.82	23.9	
═Naz—(N)	8.87	17.5	23.06	28.34	28.71	29.51	

TABLE 2-347 Benson* and CHETAH† Group Contributions for Ideal Gas Heat Capacity (*Continued*)

Table-specific nomenclature: Cb = carbon in benzene ring; Ct = carbon with a triple bond, (═C) = carbon with a double bond; Cp = carbon in fused ring; Naz = azide; Nim = imino.

Group	298 K	400 K	500 K	600 K	800 K	1000 K	1500 K
Nitrogen Groups							
═NazH	18.33	20.47	22.77	24.86	28.34	31.06	35.33
═Nim—(Cb)	12.56						
═Nim—(C)	10.38	13.98	16.53	17.96	19.21	19.25	
═NimH	12.35	19.17	27	32.27	38.22	41.52	
Sulfur Groups							
S—(2Cb)	8.37	8.41	9.38	11.47	15.91	19.72	
S—(2C)	20.89	20.76	21.01	21.22	22.65	23.98	
S—(2S)	19.67	20.93	21.35	21.77	22.19	22.6	
S—(2═C)	20.05	23.36	23.15	26.33	33.24	40.73	
S—(Cb,S)	12.1	14.19	15.57	17.37	20.01	21.35	
S—(C,Cb)	12.64	14.19	15.53	16.91	19.34	20.93	
S—(C,S)	21.89	22.69	23.06	23.06	22.52	21.43	
S—(C,═C)	17.66	21.26	23.27	24.15	24.57	24.57	
SH—(Cb)	21.43	22.02	23.32	25.24	29.26	32.82	
SH—(CO)	31.94	33.86	33.99	34.2	35.58	34.49	
SH—(C)	24.53	25.95	27.25	28.38	30.56	32.27	
SO—(2Cb)	23.94	38.05	40.6	47.93	47.97	47.09	
SO—(2C)	37.17	41.98	43.95	45.17	45.96	46.76	
SO_2—(2Cb)	34.99	46.17	56.72	62.54	66.39	66.81	
SO_2—(2C)	48.22	50.1	55.88	59.77	64.38	66.47	
SO_2—(2═C)	48.22	50.1	55.88	59.77	64.38	66.47	
SO_2—(Cb,SO_2)	41.06	48.14	56.59	61.66	65.76	67.1	
SO_2—(Cb,═C)	41.4	48.14	55.88	61.16	65.8	66.64	
SO_2—(C,Cb)	41.61	48.14	56.3	60.74	65.38	66.64	
S(CN)—(Cb)	39.77						
S(CN)—(C)	46.88						
S(CN)—(═C)	59.44						
Boron and Silicon Groups							
Si—(4C)	113.23	134.95	154.5	171.2	198.62	219.72	252.91
SiH_3—(C)	–39.64						
Monovalent Ligands							
CH_2(CN)—(C)	47.72	56.93	64.04	70.74	80.79	85.81	
CH_2(NCS)—(C)	61.95						
CH_2(NO_2)—(C)	52.7	66.22	77.52	86.48	99.58	108.41	
CH(CN)—(2C)	45.21	54	60.69	66.14	72	79.11	
CH(NO_2)—(2C)	50.19	63.67	74.17	82.08	92.84	99.2	
CH(NO_2)$_2$—(C)	80.79	101.3	117.2	129.76	146.09	156.13	
C(CN)—(3C)	36.21	46.71	53.96	58.81	64.92	67.77	
C(CN)$_2$—(2C)	61.62	74.47	83.72	90.46	99.54	104.48	
C(NO_2)—(3C)	41.4	55.84	66.39	73.75	82.92	87.32	
═CH(CHN_2)	72.42						
═CH(CN)	43.11	50.23	56.09	61.11	68.65	73.67	
═CH(NCS)	51.90						
═CH(NO_2)	51.49	63.21	72.83	80.37	90.41	97.11	105.9
═C(CN)$_2$	56.93	69.28	78.19	84.76	93.51	98.74	
3,4 Member Ring Corrections							
cyclobutane ring	–19.3	–16.28	–13.14	–11.05	–7.87	–5.78	–2.8
cyclobutene ring	–10.59	–9.17	–7.91	–7.03	–6.2	–5.57	–5.11
cyclopropane ring	–12.77	–10.59	–8.79	–7.95	–7.41	–6.78	–6.36
ethylene oxide ring	–8.37	–11.72	–12.56	–10.88	–9.63	–8.63	
ethylene sulfide ring	–11.93	–10.84	–11.13	–12.64	18.09	24.35	
thietane ring	–19.21	–17.5	–16.37	–16.37	–19.25	–23.86	
trimethylene oxide ring	–19.25	–20.93	–17.58	–14.56	–10.88	0.84	
5,6 Member Ring Corrections							
1,4 dioxane ring	–19.21	–20.8	–15.91	–10.97	–6.4	–1.8	
cyclohexane ring	–24.28	–17.16	–12.14	–5.44	4.6	9.21	13.81
cyclohexene ring	–17.92	–12.72	–8.29	–5.99	–1.21	0.33	3.39
cyclopentadiene ring	–14.44	–11.85	–8.96	–6.91	–5.36	–4.35	
cyclopentane ring	–27.21	–23.02	–18.84	–15.91	–11.72	–8.08	–1.55
cylopentene ring	–25.03	–22.39	–20.47	–17.33	–12.26	–9.46	–4.52
furan ring	–20.51	–18	–15.07	–12.56	–10.88	–10.05	
piperidine ring	–24.7	–19.67	–12.14	–3.77	9.21	17.58	
pyrrolidine ring	–25.83	–23.36	–20.09	–16.74	–12.01	–9.08	
tetrahydrofuran ring	–25.12	–24.28	–20.09	–15.91	–11.3	–7.53	
thiacyclohexane ring	–26.04	–17.83	–9.38	–2.89	3.6	5.4	
thiolane ring	–20.51	–19.55	–15.4	–15.32	–18.46	–23.32	
thiophene ring	–20.51	–19.55	–15.4	–15.32	–18.46	–23.32	

TABLE 2-347 Benson* and CHETAH† Group Contributions for Ideal Gas Heat Capacity (*Concluded*)

Table-specific nomenclature: Cb = carbon in benzene ring; Ct = carbon with a triple bond, (═C) = carbon with a double bond; Cp = carbon in fused ring; Naz = azide; Nim = imino.

Group	298 K	400 K	500 K	600 K	800 K	1000 K	1500 K
7 and 8 Member Ring Corrections							
cycloheptane ring	–38.01						
cyclooctane ring	–44.16						
Gauche and 1,5 Repulsion Corrections							
but-2-ene structure C—C═C—C	–5.61	–4.56	–3.39	–2.55	–1.63	–1.09	
but-3-ene structure C—C—C═C	–5.61	–4.56	–3.39	–2.55	–1.63	–1.09	
cis- between 2 t-butyl groups	–5.61	–4.56	–3.39	–2.55	–1.63	–1.09	
cis- involving 1 t-butyl group	–5.61	–4.56	–3.39	–2.55	–1.63	–1.09	
cis-(not with t-butyl group)	–5.61	–4.56	–3.39	–2.55	–1.63	–1.09	
ortho- between Cl atoms	–2.09	5.02	2.09	–2.51	–1.26		
ortho- between F atoms		–0.84	–0.42	1.26	2.93		
other *ortho*- (nonpolar-nonpolar)	4.69	5.65	5.44	4.9	3.68	2.76	–0.21

*Benson, S. W., et al., *Chem. Rev.*, **69** (1969): 279.
†CHETAH Version 8.0: *The ASTM Computer Program for Chemical Thermodynamic and Energy Release Evaluation (NIST Special Database 16).*

Prog., **69**, 7 (1973): 83; Lee, B. I., and M. G. Kesler, *AIChE J.*, **21** (1975): 510; Tarakad, R. R., and R. P. Danner, *AIChE J.*, **23** (1977): 944] and thermodynamic differentiation. The most accurate and generally applicable method is that by Ruzicka and Domalski.

Recommended Method Ruzicka-Domalski.

References: Ruzicka, V., and E. S. Domalski, *J. Phys. Chem. Ref. Data*, **22** (1993): 597, 619.

Classification: Group contributions.

Expected Uncertainty: 4 percent.

Applicability: Organic compounds for which group values are available.

Input data: Molecular structure and Table 2-348 values.

Description: Groups are summed to find the temperature coefficients for a cubic polynomial correlation:

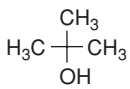
$$\frac{C_p}{R} = A + B\left(\frac{T}{100\ \text{K}}\right) + D\left(\frac{T}{100\ \text{K}}\right)^2 \qquad (2\text{-}50)$$

$$A = \sum_{i=1}^{N} n_i a_i \qquad B = \sum_{i=1}^{N} n_i b_i \qquad D = \sum_{i=1}^{N} n_i d_i \qquad (2\text{-}51)$$

where n_i = number of occurrences of group i and a_i, b_i, d_i = individual group contributions.

Example Estimate the liquid heat capacity for 2-methyl-2-propanol at 340 K.

Structure:



Group contributions:

Group	n_i	a_i	b_i	d_i
C—(3C,O) (alcohol)	1	–44.690	31.769	–4.8791
O—(H)(C)	1	12.952	–10.145	2.6261
C—(3H)(C)	3	3.8452	–0.33997	0.19489
	Sum	–20.202	20.604	–1.668

$$C_p = \left(8.3143\ \frac{\text{J}}{\text{mol·K}}\right)\left[-20.202 + 20.604\left(\frac{340}{100}\right) - 1.668\left(\frac{340}{100}\right)^2\right]$$

$$= 254.16\ \frac{\text{J}}{\text{mol·K}}$$

This value is 0.7 percent higher than the DIPPR® 801 recommended value of 252.40 J/(mol·K).

Solids Solid heat capacity increases with increasing temperature and is proportional to T^3 near absolute zero. The heat capacity at a solid-solid phase transition becomes large, and there can be a substantial difference in the heat capacity of the two equilibrium solid phases that exist on either side of the transition temperature. The heat capacity generally rises steeply with increasing temperature near the triple point.

For a quick estimation of solid heat capacity specifically at 298.15 K, the very simple modification of Kopp's rule [Kopp, H., *Ann. Chem. Pharm.* (*Liebig*), **126** (1863): 362] by Hurst and Harrison [Hurst, J. E., and B. K. Harrison, *Chem. Eng. Comm.*, **112** (1992): 21] can be used. At other temperatures and to obtain the temperature dependence of the solid heat capacity, the method given below by Goodman et al. should be used.

Recommended Method 1 Goodman method.

Reference: Goodman, B. T., et al., *J. Chem. Eng. Data*, **49** (2004): 24.

Classification: Group contributions.

Expected uncertainty: 10 percent.

Applicability: Organic compounds for which group values are available.

Input data: Molecular structure and Table 2-349 group values.

Description:

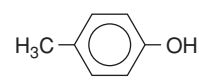
$$\frac{C_P}{\text{J/(mol·K)}} = \frac{A}{1000}\left(\frac{T}{\text{K}}\right)^{0.79267} \qquad (2\text{-}52)$$

$$A = \exp\left(6.7796 + \sum_{i=1}^{N} n_i a_i + \sum_{i=1}^{N} n_i^2 \beta_i\right) \qquad (2\text{-}53)$$

where n_i = number of occurences of group i
a_i = individual group contribution
β_i = nonlinear correction terms for chain and aromatic carbons

Example Estimate the solid heat capacity for *p*-cresol at 307.93 K.

Structure:



Group contributions:

Group	n_i	a_i	β_i
—CH_3	1	0.20184	0
Ar—CH═	4	0.082478	–0.00033
Ar >C═	2	0.012958	0
—OH	1	0.10341	0

From Eq. (2-53):

$$A = \exp[6.7796 + 0.20184 + (4)(0.082478) + (2)(0.012958) + 0.10341 + (4)^2(-0.00033)] = 1694.9$$

TABLE 2-348 Liquid Heat Capacity Group Parameters for Ruzicka-Domalski Method*

Table-specific nomenclature: Ct refers to a carbon atom with a triple bond; Cb refers to a carbon atom in benzene ring; ═C refers to a carbon atom with a double bond; Cp refers to a carbon atom in a fused benzene ring; ═C═ refers to an allenic carbon atom.

Group Definition	*a*	*b*	*d*	*T* range (K)
Hydrocarbon Groups				
C—(3H,C)	3.8452	–0.33997	0.19489	80–490
C—(2H,2C)	2.7972	–0.054967	0.10679	80–490
C—(H,3C)	–0.42867	0.93805	0.0029498	85–385
C—(4C)	–2.9353	1.4255	–0.085271	145–395
═C—(2H)	4.1763	–0.47392	0.099928	90–355
═C—(H,C)	4.0749	–1.0735	0.21413	90–355
═C—(2C)	1.9570	–0.31938	0.11911	140–315
═C—(H,═C)	3.6968	–1.6037	0.55022	130–305
═C—(C,═C)	1.0679	–0.50952	0.33607	130–305
C—(3H,═C)	3.8452	–0.33997	0.19489	80–490
C—(2H,C,═C)	2.0268	–0.20137	0.11624	90–355
C—(H,2C,═C)	–0.87558	0.82109	0.18415	110–300
C—(3C,═C)	–4.8006	2.6004	–0.040688	165–295
C—(2H,2═C)	1.4973	–0.46017	0.52861	130–300
Ct—(H)	9.1633	–4.6695	1.1400	150–275
Ct—(C)	1.4822	1.0770	–0.19489	150–285
═C═	3.0880	–0.62917	0.25779	140–315
Ct—(Cb)	12.377	–7.5742	1.3760	230–550
Cb—(H)	2.2609	–0.2500	0.12592	180–670
Cb—(C)	1.5070	–0.13366	0.011799	180–670
Cb—(═C)	–5.7020	5.8271	–1.2013	230–550
Cb—(Cb)	5.8685	–0.86054	–0.063611	295–670
C—(2H,C,Ct)	2.0268	–0.20137	0.11624	90–355
C—(3H,Ct)	3.8452	–0.33997	0.19489	80–490
C—(3H,Cb)	3.8452	–0.33997	0.19489	80–490
C—(2H,C,Cb)	1.4142	0.56919	0.0053465	180–470
C—(H,2C,Cb)	–0.10495	1.0141	–0.071918	180–670
C—(3C,Cb)	1.2367	–1.3997	0.41385	220–295
C—(2H,2Cb)	–18.583	11.344	–1.4108	300–420
C—(H,3Cb)	–46.611	24.987	–3.0249	375–595
═C—(H,Cb)	3.6968	–1.6037	0.55022	130–305
═C—(C,Cb)	1.0679	–0.50952	0.33607	130–305
Cp—(Cp,2Cb)	–3.5572	2.8308	–0.39125	250–510
Cp—(2Cp,Cb)	–11.635	6.4068	–0.78182	370–510
Cp—(3Cp)	26.164	–11.353	1.2756	385–480
Halogen Groups				
C—(C,3F)	15.423	–9.2464	2.8647	125–345
C—(2C,2F)	–8.9527	10.550	–1.9986	125–345
C—(C,3Cl)	8.5430	2.6966	–0.42564	245–310
C—(H,C,2Cl)	10.880	–0.35391	0.08488	180–355
C—(2H,C,Cl)	9.6663	–1.8601	0.41360	140–360
C—(2H,═C,Cl)	9.6663	–1.8601	0.41360	140–360
C—(H,2C,Cl)	–2.0600	5.3281	–0.82721	275–360
C—(2H,C,Br)	6.3944	–0.10298	0.19403	168–360
C—(H,2C,Br)	10.784	–2.4754	0.33288	190–420
C—(2H,C,I)	0.037620	5.6204	–0.92054	245–340
C—(C,2Cl,F)	13.532	–3.2794	0.80145	240–420
C—(C,Cl,2F)	7.2295	0.41759	0.15892	180–420
C—(C,Br,2F)	8.7956	–0.19165	0.24596	165–415
═C—(H,Cl)	7.1564	–0.84442	0.27199	120–300
═C—(2F)	7.6646	–2.0750	0.82003	120–240
═C—(2Cl)	9.3249	–1.2478	0.44241	155–300
═C—(Cl,F)	7.8204	–0.69005	0.19165	120–240
Cb—(F)	3.0794	0.46959	–0.0055745	210–365
Cb—(Cl)	4.5479	0.22250	–0.0097873	230–460
Cb—(Br)	2.2857	2.2573	–0.40942	245–370
Cb—(I)	2.9033	2.9763	–0.62960	250–320
C—(Cb,3F)	7.4477	–0.92230	0.39346	210–365
C—(2H,Cb,Cl)	16.752	–6.7938	1.2520	245–345
Nitrogen Groups				
C—(3H,N)	3.8452	–0.33997	0.19489	80–490
C–(2H,C,N)	2.4555	1.0431	–0.24054	190–375
C—(2H,Cb,N)	2.4555	1.0431	–0.24054	190–375
C—(H,2C,N)	2.6322	–2.0135	0.45109	240–370
C—(3C,N)	1.9630	–1.7235	0.31086	255–375
N—(2H,C)	8.2758	–0.18365	0.035272	185–455
N—(2H,Cb)	8.2758	–0.18365	0.035272	185–455

Group Definition	*a*	*b*	*d*	*T* range (K)
Nitrogen Groups				
N—(H,2C)	–0.10987	0.73024	0.89325	170–400
N—(3C)	4.5942	–2.2134	0.55316	160–360
N—(H,C,Cb)	0.49631	3.4617	–0.57161	240–380
N—(2C,Cb)	–0.23640	16.260	–2.5258	285–390
N—(C,2Cb)	4.5942	–2.2134	0.55316	160–360
Cb—(N)	–0.78169	1.5059	–0.25287	240–455
N—(2H,N)	6.8050	–0.72563	0.15634	215–465
N—(H,C,N)	1.1411	3.5981	–0.69350	205–300
N—(2C,N)	–1.0570	4.0038	–0.71494	205–300
N—(H,Cb,N)	–0.74531	3.6258	–0.53306	295–385
C—(2H,C,CN)	11.976	–2.4886	0.52358	185–345
C—(3C,CN)	2.5774	3.5218	–0.58466	295–345
═C—(H,CN)	9.0789	–0.86929	0.32986	195–345
Cb—(CN)	1.9389	3.0269	–0.47276	265–480
C—(2H,C,NO_2)	18.520	–5.4568	1.05080	190–300
O—(C,NO_2)	–2.0181	10.505	–1.83980	180–350
Cb—(NO_2)	15.277	–4.4049	0.71161	280–415
N—(H,2Cb) (pyrrole)	–7.3662	6.3622	–0.68137	255–450
Nb—(2Cb)	0.84237	1.25560	–0.20336	210–395
Oxygen Groups				
O—(H,C)	12.952	–10.145	2.6261	155–505
O—(H,C) (diol)	5.2302	–1.5124	0.54075	195–475
O—(H,Cb) (diol)	5.2302	–1.5124	0.54075	195–475
O—(H,Cb)	–7.9768	8.10450	–0.87263	285–400
C–(3H,O)	3.8452	–0.33997	0.19489	80–490
C–(2H,C,O)	1.4596	1.4657	–0.27140	135–505
C–(2H,Cb,O)	–35.127	28.409	–4.9593	260–460
C–(2H,═C,O)	–35.127	28.409	–4.9593	260–460
C—(H,2C,O) (alcohol)	2.2209	–1.4350	0.69508	185–460
C—(H,2C,O) (ether, ester)	0.98790	0.39403	–0.016124	130–170
C—(3C,O) (alcohol)	–44.690	31.769	–4.8791	200–355
C—(3C,O) (ether, ester)	–3.3182	2.6317	–0.44354	170–310
O—(2C)	5.0312	–1.5718	0.37860	130–350
O—(C,Cb)	–22.5240	13.1150	–1.44210	320–350
O—(2Cb)	–4.5788	0.94150	0.31655	300–535
C—(2H,2O)	1.0852	1.5402	–0.31693	170–310
C—(2C,2O)	–12.955	9.10270	–1.53670	275–335
Cb—(O)	–1.0686	3.52210	–0.79259	285–530
C—(3H,CO)	3.8452	–0.33997	0.19489	80–490
C—(2H,C,CO)	6.6782	–2.44730	0.47121	180–465
C—(H,2C,CO)	3.92380	–2.12100	0.49646	185–375
C—(3C,CO)	–2.2681	1.75580	–0.25674	225–360
CO—(H,C)	–3.82680	7.67190	–1.27110	180–430
CO—(H,═C)	–8.00240	3.63790	–0.15377	220–430
CO—(H,Cb)	–8.00240	3.63790	–0.15377	220–430
CO—(2C)	5.4375	0.72091	–0.18312	185–380
CO—(C,═C)	41.507	–32.632	6.0326	275–355
CO—(C,Cb)	–47.21100	24.36800	–2.82740	300–465
CO—(H,O)	13.11800	16.12000	–5.12730	280–340
CO—(C,O)	29.24600	3.42610	–2.89620	180–445
CO—(═C,O)	41.61500	–12.78900	0.53631	195–350
CO—(O,CO)	23.99000	6.25730	–3.24270	320–345
O—(C,CO)	–21.43400	–4.01640	3.05310	175–440
O—(H,CO)	–27.58700	–0.16485	2.74830	230–500
═C—(H,CO)	–9.01080	15.14800	–3.04360	195–355
═C—(C,CO)	–12.81800	15.99700	–3.05670	195–430
Cb—(CO)	12.15100	–1.67050	–0.12758	175–500
CO—(Cb,O)	16.58600	5.44910	–2.68490	175–500
Sulfur Groups				
C—(3H,S)	3.84520	–0.33997	0.19489	80–490
C—(2H,C,S)	1.54560	0.88228	–0.08349	130–390
C—(H,2C,S)	–1.64300	2.30700	–0.31234	150–390
C—(3C,S)	–5.38250	4.50230	–0.72356	190–365
Cb—(S)	–4.45070	4.43240	–0.75674	260–375
S—(H,C)	10.99400	–3.21130	0.47368	130–380
S—(H,Cb)	10.99400	–3.21130	0.47368	130–380
S—(2C)	9.23060	–3.00870	0.45625	165–390
S—(2Cb)	9.23060	–3.00870	0.45625	165–390
S—(C,S)	6.65900	–1.35570	0.17938	170–350
S—(Cb,S)	9.23060	–3.00870	0.45625	165–390
S—(2Cb) (thiophene)	3.84610	0.36718	–0.06131	205–345

TABLE 2-348 Liquid Heat Capacity Group Parameters for Ruzicka-Domalski Method* (*Concluded*)

Table-specific nomenclature: Ct refers to a carbon atom with a triple bond; Cb refers to a carbon atom in benzene ring; ═C refers to a carbon atom with a double bond; Cp refers to a carbon atom in a fused benzene ring; ═C═ refers to an allenic carbon atom.

Group Definition	*a*	*b*	*d*	*T* range (K)
Ring Strain Contributions				
Hydrocarbons (ring strain)				
cyclopropane	4.4297	–4.3392	1.0222	155–240
cyclobutane	1.2313	–2.8988	0.75099	140–300
cyclopentane (unsub)	–0.33642	–2.8663	0.70123	180–300
cyclopentane (sub)	0.21983	–1.5118	0.28172	135–365
cyclohexane	–2.0097	–0.72656	0.14758	145–485
cycloheptane	–11.460	4.9507	–0.74754	270–300
cyclooctane	–4.1696	0.52991	–0.018423	295–320
spiropentane	5.9700	–3.7965	0.74612	175–310
cyclopentene	0.21433	–2.5214	0.63136	140–300
cyclohexene	–1.2086	–1.5041	0.42863	160–320
cycloheptene	–5.6817	1.5073	–0.19810	220–300
cyclooctene	–14.885	7.4878	–1.0879	260–330
cyclohexadiene	–8.9683	6.4959	–1.5272	170–300
cyclooctadiene	–7.2890	3.1119	–0.43040	205–320
cycloheptatriene	–8.7885	8.2530	–2.4573	200–310
cyclooctatetraene	–12.914	13.583	–4.0230	275–330
indan	–6.1414	3.5709	–0.48620	170–395
1H-indene	–3.6501	2.4707	–0.60531	280–375
tetrahydronaphthalene	–6.3861	2.6257	–0.19578	250–320
decahydronaphthalene	–6.8984	0.66846	–0.070012	235–485
hexahydroindan	–3.9271	–0.29239	0.048561	210–425
dodecahydrofluorene	–19.687	8.8265	–1.4031	315–485
tetradecahydrophenanthrene	–0.67632	–1.4753	–0.13087	315–485
hexadecahydropyrene	61.213	–30.927	3.2269	310–485
Nitrogen compounds				
ethyleneimine	15.281	–2.3360	–0.13720	195–330
pyrrolidine	12.703	1.3109	–1.18130	170–400
piperidine	25.681	–7.0966	0.14304	265–370
Oxygen compounds				
ethylene oxide	6.8459	–5.8759	1.2408	135–325
trimethylene oxide	–7.0148	7.3764	–2.1901	185–300
1, 3-dioxolane	–2.3985	–0.48585	0.10253	175–300
furan	9.6704	–2.8138	0.11376	190–305
tetrahydrofuran	3.2842	–5.8260	1.2681	160–320
tetrahydropyran	–13.017	3.7416	–0.15622	295–325
Sulfur compounds				
thiacyclobutane	–0.73127	–1.3426	0.40114	200–320
thiacyclopentane	–3.2899	0.38399	0.089358	170–390
thiacyclohexane	–12.766	5.2886	–0.59558	295–340

*Ruzicka, V., and E. S. Domalski, *J. Phys. Chem. Ref. Data*, **22** (1993): 597, 619.

From Eq. (2-52):

$$C_P = \frac{1694.9}{1000}(307.93)^{0.79267}\frac{\text{J}}{\text{mol·K}} = 159.1\frac{\text{J}}{\text{mol·K}}$$

This value is 2.5 percent higher than the DIPPR® 801 recommended value of 155.2 J/(mol·K).

Recommended Method 2 Modified Kopp's rule.

Reference: Kopp, H., *Ann. Chem. Pharm.* (*Liebig*), **126** (1863): 362; Hurst, J. E., and B. K. Harrison, *Chem. Eng. Comm.*, **112** (1992): 21.

Classification: Group contributions.

Expected uncertainty: 10 percent.

Applicability: 298.15 K; organic compounds that are solids at 298.15 K.

Input data: Compound chemical formula and element contributions of Table 2-350.

Description:

$$\frac{C_P}{\text{J/(mol·K)}} = \sum_{E=1}^{N} n_E \Delta_E \qquad (2\text{-}54)$$

where N = number of different elements in compound
n_E = number of occurrences of element E in compound
Δ_E = contribution of element E from Table 2-350

Example Estimate the solid heat capacity at 298.15 K for dibenzothiophene.

Structure: $C_{12}H_8S$.

Group values from Table 2-350:

$$\Delta_C = 10.89 \qquad \Delta_H = 7.56 \qquad \Delta_S = 12.36$$

Calculation using Eq. (2-54):

$$C_p = (12)(10.89) + (8)(7.56) + (1)(12.36) = 203.52 \text{ J/(mol·K)}$$

This value is 2.5 percent higher than the DIPPR® 801 recommended value of 198.45 J/(mol·K).

Mixtures The heat capacity of liquid and vapor mixtures can be estimated as mole fraction averages of the pure-component values

$$C_{p,m} = \sum_{i=1}^{C} x_i C_{p,i} \qquad (2\text{-}55)$$

This neglects the excess heat capacity, which if available can be added to the mole fraction average to improve the estimated value.

DENSITY

Density is defined as the mass of a substance per unit volume. Density is given in kg/m^3 in SI units, but lb$_m$/ft^3 and g/cm^3 are common AES and cgs units, respectively. Other commonly used forms of density include *molar density* (density divided by molecular weight) in kmol/m^3, *relative density* (density relative to water at 15°C), and the older term *specific gravity* (density relative to water at 60°F). Often the inverse of density, *specific volume*, and the inverse of molar density, *molar volume*, are correlated and used to convey equivalent information.

Gases Gases/vapors are compressible and their densities are strong functions of both temperature and pressure. Equations of state (EoS) are commonly used to correlate molar densities or molar volumes. The most accurate EoS are those developed for specific fluids with parameters regressed from all available data for that fluid. Super EoS are available for some of the most industrially important gases and may contain 50 or more constants specific to that chemical. Different predictive methods may be used for gas densities depending upon the conditions:

1. At *very low densities* (high temperatures, generally above the critical, and very low pressures, generally below a few bar), the ideal gas EoS

$$Z \equiv \frac{PV}{RT} = 1 \qquad (2\text{-}56)$$

may be applied.

2. At *moderate densities* (below 40 percent of the critical density), the virial equation truncated after the second virial coefficient

$$Z = 1 + \frac{B(T)}{V} \qquad (2\text{-}57)$$

may be used. Second virial coefficients $B(T)$ are available in the DIPPR® 801 database for many chemicals and can be estimated for others by using the Tsonopoulos method.

TABLE 2-349 Group Values and Nonlinear Correction Terms for Estimation of Solid Heat Capacity with the Goodman et al.* Method

Group	Description	a_i	Group	Description	a_i
—CH_3	methyl	0.20184	—CO_3—	carbonate	0.2517
>CH_2	methylene	0.11644	—NH_2	primary amine	0.056138
>CH—	secondary C	0.030492	>NH	secondary amine	–0.00717
>C<	tertiary C	–0.04064	>N—	tertiary amine	–0.01661
CH_2==	terminal alkene	0.18511	==NH	double-bond NH	0.17689
—CH==	alkene	0.11224	#N	nitrile	0.015355
>C==	subst. alkene	0.028794	—N==N—	diazide	0.3687
==C==	allene	0.053464	—NO_2	nitro	0.23327
#CH	terminal alkyne	–0.02914	—N==C==O	isocyanate	0.2698
#C—	alkyne	0.13298	—SH	thiol/mercaptan	0.21123
Ar —CH==	arom. C	0.082478	—S—	sulfide	0.14232
Ar >C==	subst. arom. C	0.012958	—SS—	disulfide	0.31457
Ar —O—	furan O	0.066027	==S	sulfur double bond	0.13753
Ar —N==	pyridine N	0.056641	>S==O	sulfoxide	0.040002
Ar >N—	subst. pyrrole N	0.008938	—F	fluoride	0.15511
Ar —NH—	pyrrole N	–0.05246	—Cl	chloride	0.16995
Ar —S—	thiophene S	0.090926	—Br	bromide	0.19112
—O—	ether	0.064068	—I	iodide	0.11318
—OH	alcohol	0.10341	>Si<	silane	0.12213
—COH	aldehyde	0.15699	>Si(O—)—	linear siloxane	0.10125
>C==O	ketone	0.12939	cyc >Si(O—)—	cyclic siloxane	0.063438
—COO—	ester	0.13686	P(==O)$(O—)_3$	phosphate	0.15016
—COOH	acid	0.21019	>P—	phosphine	0.069602
—COOCO—	anhydride	0.33091	>P(==O)—	phospine oxide	0.21875

Nonlinear Terms

Groups	β_i	Usage
>CH_2	–0.00188	Methylene
Ar==CH—	–0.00033	Aromatic carbon

*Goodman, B. T., W. V. Wilding, J. L. Oscarson, and R. L. Rowley, *J. Chem. Eng. Data*, **49** (2004): 24

Recommended Method Tsonopoulos method.

Reference: Tsonopoulos, C., *AIChE J.*, **20** (1974): 263; **21** (1975): 827; **24** (1978): 1112.

Classification: Corresponding states.

Expected uncertainty: 8 percent for $B(T)$.

Applicability: Nonpolar organic compounds and some classes of polar compounds.

Input data: Class of fluid, ω, P_c, T_c, and μ.

Description:

$$\frac{BP_c}{RT_c} = B^{(0)} + \omega B^{(1)} + B^{(2)} \tag{2-58}$$

where ω = acentric factor
P_c = critical pressure
T_c = critical temperature

$$B^{(0)} = 0.1445 - \frac{0.330}{T_r} - \frac{0.1385}{T_r^2} - \frac{0.0121}{T_r^3} - \frac{0.000607}{T_r^8} \tag{2-59}$$

TABLE 2-350 Element Contributions to Solid Heat Capacity for the Modified Kopp's Rule*†

Element	Δ_E	Element	Δ_E	Element	Δ_E
C	10.89	Ba	32.37	Mo	29.44
H	7.56	Be	12.47	Na	26.19
O	13.42	Ca	28.25	Ni	25.46
N	18.74	Co	25.71	Pb	31.60
S	12.36	Cu	26.92	Si	17.00
F	26.16	Fe	29.08	Sr	28.41
Cl	24.69	Hg	27.87	Ti	27.24
Br	25.36	K	28.78	V	29.36
I	25.29	Li	23.25	W	30.87
Al	18.07	Mg	22.69	Zr	26.82
B	10.10	Mn	28.06	All others	26.63

*Kopp, H., *Ann. Chem. Pharm.* (*Liebig*), **126** (1863): 362.
†Hurst, J. E., and B. K. Harrison, *Chem. Eng. Comm.*, **112** (1992): 21.

$$B^{(1)} = 0.0637 + \frac{0.331}{T_r^2} - \frac{0.423}{T_r^3} - \frac{0.008}{T_r^8} \tag{2-60}$$

$$B^{(2)} = \frac{a}{T_r^6} - \frac{b}{T_r^8} \tag{2-61}$$

$$\mu_r = \left(\frac{\mu}{\text{D}}\right)^2 \left(\frac{P_c}{\text{bar}}\right) \left(\frac{T_c}{\text{K}}\right)^{-2} \tag{2-62}$$

where μ = dipole moment. The values of a and b used in Eq. (2-61) depend upon the class of fluid, as given in the table below:

Class	a	b
Nonpolar fluids	0	0
Ketones, aldehydes, nitriles, ethers, esters, NH_3, H_2S, HCN	$-21.4\mu_r - 4.308 \times 10^{19}\mu_r^8$	0
Monoalkylhalides, mercaptans, sulfides	$-2.188 \times 10^{16}\mu_r^4 - 7.831 \times 10^{19}\mu_r^8$	0
1-Alcohols except methanol	0.0878	$0.00908 + 69.57\mu_r$
Methanol	0.0878	0.0525

Example Estimate the molar volume of ammonia at 430 K and 2.82 MPa.

Input properties: Recommended values from the DIPPR® 801 database are T_c = 405.65 K, P_c = 11.28 MPa, μ = 1.469 D, and ω = 0.252608.

Reduced conditions:

$$T_r = (430\text{ K})/(405.65\text{ K}) = 1.06$$

$$P_r = (2.82\text{ MPa})/(11.28\text{ MPa}) = 0.25$$

$$\mu_r = (1.469)^2(112.8)/(405.65)^2 = 0.0014793$$

Second virial coefficient from Eqs. (2-59) to (2-61):

$$B^{(0)} = 0.1445 - 0.330/1.06 - 0.1385/(1.06)^2 - 0.0121/(1.06)^3$$

$$-0.000607/(1.06)^8 = -0.301$$

$$B^{(1)} = 0.0637 + 0.331/(1.06)^2 - 0.423/(1.06)^3 - 0.008/(1.06)^8 = -0.00189$$

$$a = (-21.4)(0.0014793) - (4.308 \times 10^{19})(0.0014793)^8 = -0.033$$

$$b = 0$$

$$B^{(2)} = (-0.033)/(1.06)^6 = -0.023$$

From Eq. (2-58):

$$BP_c/(RT_c) = -0.301 - (0.252608)(0.00189) - 0.023 = -0.324$$

$$B = (-0.324)[0.008314\ \text{m}^3\cdot\text{MPa}/(\text{kmol}\cdot\text{K})](405.65\ \text{K})/(11.28\ \text{MPa})$$

$$= -0.097\ \text{m}^3/\text{kmol}$$

Molar volume from Eq. (2-56):

$$V = \frac{RT}{P}\left(1 + \frac{B}{V}\right) = \frac{\left(0.0083143\ \frac{\text{m}^3\cdot\text{MPa}}{\text{kmol}\cdot\text{K}}\right)(430\ K)}{2.82\ \text{MPa}}\left(1 + \frac{-0.097\ \frac{\text{m}^3}{\text{kmol}}}{V}\right)$$

$$= 1.162\ \text{m}^3/\text{kmol}$$

Note that the ideal gas value, 1.268 m^3/kmol, deviates by 9.1 percent from this more accurate value. The truncated virial EoS should be valid for this density since $\rho = V^{-1} = 0.86$ kmol/m^3 is much less than 40 percent of the critical density (the DIPPR® 801 recommended value for the critical density is 13.8 kmol/m^3).

3. For *higher gas densities*, the Lee-Kesler method described below provides excellent predictions for nonpolar and slightly polar fluids. Extended four-parameter corresponding-states methods are available for polar and slightly associating compounds.

Recommended Method Lee-Kesler method.
Reference: Lee, B. I., and M. G. Kesler, *AIChE J.*, **21** (1975): 510.
Classification: Corresponding states.
Expected uncertainty: 1 percent except near the critical point where errors can be up to 30 percent.
Applicability: Nonpolar and moderately polar compounds. An extended Lee-Kesler method, not described here, may be used for polar and slightly associating compounds [Wilding, W. V., and R. L. Rowley, *Int. J. Thermophys.*, **8** (1986): 525].
Input data: T_c, P_c, ω, $Z^{(0)}$,$Z^{(1)}$.
Description:

$$Z = Z^{(0)} + \omega Z^{(1)} \tag{2-63}$$

where Z = compressibility factor
$Z^{(0)}$ = compressibility factor of simple fluid obtained from Table 2-351.
$Z^{(1)}$ = deviation from simple fluid obtained from Table 2-352.

Analytical expressions for $Z^{(0)}$ and $Z^{(1)}$ can also be generated by using

$$Z^{(0)} = Z_0 \qquad Z^{(1)} = \frac{Z_1 - Z_0}{0.3978} \tag{2-64}$$

where Z_0 and Z_1 are determined from

$$Z_i = \frac{P_r V_r}{T_r} = 1 + \frac{B}{V_r} + \frac{C}{V_r^2} + \frac{D}{V_r^5} + \frac{c_4}{T_r^3 V_r^2}\left(\beta + \frac{\gamma}{V_r^2}\right)\exp\left(\frac{-\gamma}{V_r^2}\right) \tag{2-65}$$

$$B = b_1 - \frac{b_2}{T_r} - \frac{b_3}{T_r^2} - \frac{b_4}{T_r^3}$$

$$C = c_1 - \frac{c_2}{T_r} + \frac{c_3}{T_r^2}$$

$$D = d_1 + \frac{d_2}{T_r}$$

as applied to the simple reference fluid and to the acentric reference fluid (*n*-octane), respectively. The constants for Eq. (2-65) for the two reference fluids are given in Table 2-353.

Example Estimate the molar volume of saturated decane vapor at 540.5 K.
Input properties: Recommended values from the DIPPR® 801 database are T_c = 617.7 K, P_c = 2.11 MPa, P^*(540.5 K) = 0.6799 MPa (vapor pressure), and ω = 0.492328.
Reduced conditions:

$$T_r = (540.5\ \text{K})/(617.7\ \text{K}) = 0.875$$

$$P_r = (0.6799\ \text{MPa})/(2.11\ \text{MPa}) = 0.322$$

LK compressiblity factor: Since vapor phase values are needed, the appropriate values from Tables 2-351 and 2-352 that can be used to double-interpolate are

$Z^{(0)}$

$T_r \backslash P_r$	0.2	0.4
0.85	0.8810	(0.7222)
0.90	0.9015	0.7800

$Z^{(1)}$

$T_r \backslash P_r$	0.2	0.4
0.85	–0.0715	(–0.1503)
0.90	–0.0442	–0.1118

Double linear interpolation within these values gives $Z^{(0)} = 0.8058$ and $Z^{(1)} = -0.1025$.

From Eq. (2-63):

$$Z = 0.8058 + (0.492328)(-0.1025) = 0.7553$$

Note: If the analytical form available in Eq. (2-65) is used, the following more accurate values are obtained: $Z^{(0)} = 0.8131$, $Z^{(1)} = -0.1067$, and Z = 0.7606.

Molar volume:

$$V = \frac{ZRT}{P} = \frac{(0.7553)\left(0.0083143\ \frac{\text{m}^3\cdot\text{MPa}}{\text{kmol}\cdot\text{K}}\right)(540.5\ \text{K})}{0.6799\ \text{MPa}} = 4.992\ \frac{\text{m}^3}{\text{kmol}}$$

4. *Cubic EoS* can be used to obtain both vapor and liquid densities as an alternative method to those mentioned above.

Recommended Method Cubic EoS.
Classification: Empirical extension of theory.
Expected uncertainty: Varies depending upon compound and conditions, but a general expectation is perhaps 10 to 20 percent.
Applicability: Nonpolar and moderately polar compounds.
Input data: T_c, P_c, ω.
Description: The more common cubic EoS can be written in the form

$$Z = \frac{V}{V-b} - \frac{V}{V^2 + \delta V + \varepsilon}\frac{a\,\alpha(T_r)}{RT} \tag{2-66}$$

where a, b, δ, and ε are constants that depend upon the model EoS chosen, as does the temperature dependence of the function $\alpha(T_r)$. Definitions of these constants and $\alpha(T_r)$ for some of the more commonly used EoS models are shown in Table 2-354. The corresponding relations for many other EoS models in this same form are available [Soave, G., *Chem. Eng. Sci.*, **27** (1972): 1197]. The independent parameters a and b in these models can be regressed from experimental data to correlate densities or obtained from known critical constants to predict density data. In the latter case, the relationships between a and b and the critical constants shown in Table 2-354 were obtained from the critical point requirements

$$\left(\frac{\partial P}{\partial V}\right)_T\Big|_{T=T_c} = 0 = \left(\frac{\partial^2 P}{\partial V^2}\right)_T\Big|_{T=T_c} \tag{2-67}$$

TABLE 2-351 Simple Fluid Compressibility Factors $Z^{(0)}$

Values in parentheses are for the opposite phase and may be used to interpolate to or near the phase boundary [PGL4; Wilding, W. V., J. K. Johnson, and R. L. Rowley, *Int. J. Thermophys.*, **8**(1987):717].

$Tr \backslash Pr$	0.010	0.050	0.100	0.200	0.400	0.600	0.800	1.000	1.200	1.500	2.000	3.000	5.000	7.000	10.000
0.30	0.0029	0.0145	0.0290	0.0579	0.1158	0.1737	0.2315	0.2892	0.3470	0.4335	0.5775	0.8648	1.4366	2.0048	2.8507
0.35	0.0026	0.0130	0.0261	0.0522	0.1043	0.1564	0.2084	0.2604	0.3123	0.3901	0.5195	0.7775	1.2902	1.7987	2.5539
0.40	0.0024	0.0119	0.0239	0.0477	0.0953	0.1429	0.1904	0.2379	0.2853	0.3563	0.4744	0.7095	1.1758	1.6373	2.3211
0.45	0.0022 (0.9648)	0.0110	0.0221	0.0442	0.0882	0.1322	0.1762	0.2200	0.2638	0.3294	0.4384	0.6551	1.0841	1.5077	2.1338
0.50	0.0021 (0.9741)	0.0103 (0.8699)	0.0207	0.0413	0.0825	0.1236	0.1647	0.2056	0.2465	0.3077	0.4092	0.6110	1.0094	1.4017	1.9801
0.55	0.9804 (0.0020)	0.0098 (0.9000)	0.0195 (0.7995)	0.0390	0.0778	0.1166	0.1553	0.1939	0.2323	0.2899	0.3853	0.5747	0.9475	1.3137	1.8520
0.60	0.9849 (0.0019)	0.0093 (0.9211)	0.0186 (0.8405)	0.0371	0.0741	0.1109	0.1476	0.1842	0.2207	0.2753	0.3657	0.5446	0.8959	1.2398	1.7440
0.65	0.9881 (0.0018	0.9377 (0.0089)	0.0178 (0.8707)	0.0356 (0.7367)	0.0710	0.1063	0.1415	0.1765	0.2113	0.2634	0.3495	0.5197	0.8526	1.1773	1.6519
0.70	0.9904	0.9504 (0.0086)	0.8958 (0.0172)	0.0344 (0.7805)	0.0687	0.1027	0.1366	0.1703	0.2038	0.2538	0.3364	0.4991	0.8161	1.1241	1.5729
0.75	0.9922	0.9598 (0.0085)	0.9165 (0.0169)	0.0336 (0.8181)	0.0670 (0.6122)	0.1001	0.1330	0.1656	0.1981	0.2464	0.3260	0.4823	0.7854	1.0787	1.5047
0.80	0.9935	0.9669	0.9319 (0.0168)	0.8539 (0.0332)	0.0661 (0.6659)	0.0985 (0.4746)	0.1307	0.1626	0.1942	0.2411	0.3182	0.4690	0.7598	1.0400	1.4456
0.85	0.9946	0.9725	0.9436	0.8810 (0.0336)	0.0661 (0.7222)	0.0983 (0.5346)	0.1301	0.1614	0.1924	0.2382	0.3132	0.4591	0.7388	1.0071	1.3943
0.90	0.9954	0.9768	0.9528	0.9015 (0.0364)	0.7800 (0.0685)	0.1006 (0.6040)	0.1321 (0.4034)	0.1630	0.1935	0.2383	0.3114	0.4527	0.7220	0.9793	1.3496
0.93	0.9959	0.9790	0.9573	0.9115	0.8059 (0.7350)	0.6635 (0.1047)	0.1359 (0.4499)	0.1664	0.1963	0.2405	0.3122	0.4507	0.7138	0.9648	1.3257
0.95	0.9961	0.9803	0.9600	0.9174	0.8206 (0.0822)	0.6967 (0.1116)	0.1410 (0.4853)	0.1705	0.1998	0.2432	0.3138	0.4501	0.7092	0.9561	1.3108
0.97	0.9963	0.9815	0.9625	0.9227	0.8338	0.7240 (0.1312)	0.5580 (0.1532)	0.1779	0.2055	0.2474	0.3164	0.4504	0.7052	0.9480	1.2968
0.98	0.9965	0.9821	0.9637	0.9253	0.8398	0.7360	0.5887 (0.1703)	0.1844	0.2097	0.2503	0.3182	0.4508	0.7035	0.9442	1.2901
0.99	0.9966	0.9826	0.9648	0.9277	0.8455	0.7471	0.6138 (0.2324)	0.1959	0.2154	0.2538	0.3204	0.4514	0.7018	0.9406	1.2835
1.00	0.9967	0.9832	0.9659	0.9300	0.8509	0.7574	0.6353	0.2901	0.2237	0.2583	0.3229	0.4522	0.7004	0.9372	1.2772
1.01	0.9968	0.9837	0.9669	0.9322	0.8561	0.7671	0.6542	0.4648	0.2370	0.2640	0.3260	0.4533	0.6991	0.9339	1.2710
1.02	0.9969	0.9842	0.9679	0.9343	0.8610	0.7761	0.6710	0.5146	0.2629	0.2715	0.3297	0.4547	0.6980	0.9307	1.2650
1.05	0.9971	0.9855	0.9707	0.9401	0.8743	0.8002	0.7130	0.6026	0.4437	0.3131	0.3452	0.4604	0.6956	0.9222	1.2481
1.10	0.9975	0.9874	0.9747	0.9485	0.8930	0.8323	0.7649	0.6880	0.5984	0.4580	0.3953	0.4770	0.6950	0.9110	1.2232
1.15	0.9978	0.9891	0.9780	0.9554	0.9081	0.8576	0.8032	0.7443	0.6803	0.5798	0.4760	0.5042	0.6987	0.9033	1.2021
1.20	0.9981	0.9904	0.9808	0.9611	0.9205	0.8779	0.8330	0.7858	0.7363	0.6605	0.5605	0.5425	0.7069	0.8990	1.1844
1.30	0.9985	0.9926	0.9852	0.9702	0.9396	0.9083	0.8764	0.8438	0.8111	0.7624	0.6908	0.6344	0.7358	0.8998	1.1580
1.40	0.9988	0.9942	0.9884	0.9768	0.9534	0.9298	0.9062	0.8827	0.8595	0.8256	0.7753	0.7202	0.7761	0.9112	1.1419
1.50	0.9991	0.9954	0.9909	0.9818	0.9636	0.9456	0.9278	0.9103	0.8933	0.8689	0.8328	0.7887	0.8200	0.9297	1.1339
1.60	0.9993	0.9964	0.9928	0.9856	0.9714	0.9575	0.9439	0.9308	0.9180	0.9000	0.8738	0.8410	0.8617	0.9518	1.1320
1.70	0.9994	0.9971	0.9943	0.9886	0.9775	0.9667	0.9563	0.9463	0.9367	0.9234	0.9043	0.8809	0.8984	0.9745	1.1343
1.80	0.9995	0.9977	0.9955	0.9910	0.9823	0.9739	0.9659	0.9583	0.9511	0.9413	0.9275	0.9118	0.9297	0.9961	1.1391
1.90	0.9996	0.9982	0.9964	0.9929	0.9861	0.9796	0.9735	0.9678	0.9624	0.9552	0.9456	0.9359	0.9557	1.0157	1.1452
2.00	0.9997	0.9986	0.9972	0.9944	0.9892	0.9842	0.9796	0.9754	0.9715	0.9664	0.9599	0.9550	0.9772	1.0328	1.1516
2.20	0.9998	0.9992	0.9983	0.9967	0.9937	0.9910	0.9886	0.9865	0.9847	0.9826	0.9806	0.9827	1.0094	1.0600	1.1635
2.40	0.9999	0.9996	0.9991	0.9983	0.9969	0.9957	0.9948	0.9941	0.9936	0.9935	0.9945	1.0011	1.0313	1.0793	1.1728
2.60	1.0000	0.9998	0.9997	0.9994	0.9991	0.9990	0.9990	0.9993	0.9998	1.0010	1.0040	1.0137	1.0463	1.0926	1.1792
2.80	1.0000	1.0000	1.0001	1.0002	1.0007	1.0013	1.0021	1.0031	1.0042	1.0063	1.0106	1.0223	1.0565	1.1016	1.1830
3.00	1.0000	1.0002	1.0004	1.0008	1.0018	1.0030	1.0043	1.0057	1.0074	1.0101	1.0153	1.0284	1.0635	1.1075	1.1848
3.50	1.0001	1.0004	1.0008	1.0017	1.0035	1.0055	1.0075	1.0097	1.0120	1.0156	1.0221	1.0368	1.0723	1.1138	1.1834
4.00	1.0001	1.0005	1.0010	1.0021	1.0043	1.0066	1.0090	1.0115	1.0140	1.0179	1.0249	1.0401	1.0741	1.1136	1.1773

Table 2-352 Acentric Deviations $Z^{(1)}$ from the Simple Fluid Compressibility Factor

Values in parentheses are for the opposite phase and may be used to interpolate to or near the phase boundary [PGL4; Wilding, W. V., J. K. Johnson, and R. L. Rowley, *Int. J. Thermophys.*, 8(1987):717].

$Ti\backslash Pr$	0.010	0.050	0.100	0.200	0.400	0.600	0.800	1.000	1.200	1.500	2.000	3.000	5.000	7.000	10.000
0.30	−0.0008	−0.0040	−0.0081	−0.0161	−0.0323	−0.0484	−0.0645	−0.0806	−0.0966	−0.1207	−0.1608	−0.2407	−0.3996	−0.5572	−0.7915
0.35	−0.0009	−0.0046	−0.0093	−0.0185	−0.0370	−0.0554	−0.0738	−0.0921	−0.1105	−0.1379	−0.1834	−0.2738	−0.4523	−0.6279	−0.8863
0.40	−0.0010	−0.0048	−0.0095	−0.0190	−0.0380	−0.0570	−0.0758	−0.0946	−0.1134	−0.1414	−0.1879	−0.2799	−0.4603	−0.6365	−0.8936
0.45	−0.0009 (−0.0740)	−0.0047	−0.0094	−0.0187	−0.0374	−0.0560	−0.0745	−0.0929	−0.1113	−0.1387	−0.1840	−0.2734	−0.4475	−0.6162	−0.8606
0.50	−0.0009 (−0.0457)	−0.0045 (−0.2270)	−0.0090	−0.0181	−0.0360	−0.0539	−0.0716	−0.0893	−0.1069	−0.1330	−0.1762	−0.2611	−0.4253	−0.5831	−0.8099
0.55	−0.0314 (−0.0009)	−0.0043 (−0.1438)	−0.0086 (−0.2864)	−0.0172	−0.0343	−0.0513	−0.0682	−0.0849	−0.1015	−0.1263	−0.1669	−0.2465	−0.3991	−0.5446	−0.7521
0.60	−0.0205 (0.0008)	−0.0041 (0.0949)	−0.0082 (−0.1857)	−0.0164	−0.0326	−0.0487	−0.0646	−0.0803	−0.0960	−0.1192	−0.1572	−0.2312	−0.3718	−0.5047	−0.6928
0.65	−0.0137 (−0.0008)	−0.0772 (0.0039)	−0.0078 (−0.1262)	−0.0156 (−0.2424)	−0.0309	−0.0461	−0.0611	−0.0759	−0.0906	−0.1122	−0.1476	−0.2160	−0.3447	−0.4653	−0.6346
0.70	−0.0093	−0.0507 (−0.0038)	−0.1161 (−0.0075)	−0.0148 (−0.1685)	−0.0294	−0.0438	−0.0579	−0.0718	−0.0855	−0.1057	−0.1385	−0.2013	−0.3184	−0.4270	−0.5785
0.75	−0.0064	−0.0339 (−0.0037)	−0.0744 (−0.0072)	−0.0143 (−0.1298)	−0.0282 (−0.2203)	−0.0417	−0.0550	−0.0681	−0.0808	−0.0996	−0.1298	−0.1872	−0.2929	−0.3901	−0.5250
0.80	−0.0044	−0.0228	−0.0487 (−0.0073)	−0.1160 (−0.0139)	−0.0272 (−0.1682)	−0.0401 (−0.2185)	−0.0526	−0.0648	−0.0767	−0.0940	−0.1217	−0.1736	−0.2682	−0.3545	−0.4740
0.85	−0.0029	−0.0152	−0.0319	−0.0715 (−0.0144)	−0.0268 (−0.1503)	−0.0391 (−0.1692)	−0.0509	−0.0622	−0.0731	−0.0888	−0.1138	−0.1602	−0.2439	−0.3201	−0.4254
0.90	−0.0019	−0.0099	−0.0205	−0.0442 (−0.0179)	−0.1118 (−0.0286)	−0.0396 (−0.1580)	−0.0503 (−0.1464)	−0.0604	−0.0701	−0.0840	−0.1059	−0.1463	−0.2195	−0.2862	−0.3788
0.93	−0.0015	−0.0075	−0.0154	−0.0326	−0.0763 (−0.0340)	−0.1662 (−0.0424)	−0.0514 (−0.1418)	−0.0602	−0.0687	−0.0810	−0.1007	−0.1374	−0.2045	−0.2661	−0.3516
0.95	−0.0012	−0.0062	−0.0126	−0.0262	−0.0589 (−0.0444)	−0.1110 (−0.0490)	−0.0540 (−0.1532)	−0.0607	−0.0678	−0.0788	−0.0967	−0.1310	−0.1943	−0.2526	−0.3339
0.97	−0.0010	−0.0050	−0.0101	−0.0208	−0.0450	−0.0770 (−0.0714)	−0.1647 (−0.0643)	−0.0623	−0.0669	−0.0759	−0.0921	−0.1240	−0.1837	−0.2391	−0.3163
0.98	−0.0009	−0.0044	−0.0090	−0.0184	−0.0390	−0.0641	−0.1100 (−0.0828)	−0.0641	−0.0661	−0.0740	−0.0893	−0.1202	−0.1783	−0.2322	−0.3075
0.99	−0.0008	−0.0039	−0.0079	−0.0161	−0.0335	−0.0531	−0.0796 (−0.1621)	−0.0680	−0.0646	−0.0715	−0.0861	−0.1162	−0.1728	−0.2254	−0.2989
1.00	−0.0007	−0.0034	−0.0069	−0.0140	−0.0285	−0.0435	−0.0588	−0.0879	−0.0609	−0.0678	−0.0824	−0.1118	−0.1672	−0.2185	−0.2902
1.01	−0.0006	−0.0030	−0.0060	−0.0120	−0.0240	−0.0351	−0.0429	−0.0223	−0.0473	−0.0621	−0.0778	−0.1072	−0.1615	−0.2116	−0.2816
1.02	−0.0005	−0.0026	−0.0051	−0.0102	−0.0198	−0.0277	−0.0303	−0.0062	0.0227	−0.0524	−0.0722	−0.1021	−0.1556	−0.2047	−0.2731
1.05	−0.0003	−0.0015	−0.0029	−0.0054	−0.0092	−0.0097	−0.0032	0.0220	0.1059	0.0451	−0.0432	−0.0838	−0.1370	−0.1835	−0.2476
1.10	0.0000	0.0000	0.0001	0.0007	0.0038	0.0106	0.0236	0.0476	0.0897	0.1630	0.0698	−0.0373	−0.1021	−0.1469	−0.2056
1.15	0.0002	0.0011	0.0023	0.0052	0.0127	0.0237	0.0396	0.0625	0.0943	0.1548	0.1667	0.0332	−0.0611	−0.1084	−0.1642
1.20	0.0004	0.0019	0.0039	0.0084	0.0190	0.0326	0.0499	0.0719	0.0991	0.1477	0.1990	0.1095	−0.0141	−0.0678	−0.1231
1.30	0.0006	0.0030	0.0061	0.0125	0.0267	0.0429	0.0612	0.0819	0.1048	0.1420	0.1991	0.2079	0.0875	0.0176	−0.0423
1.40	0.0007	0.0036	0.0072	0.0147	0.0306	0.0477	0.0661	0.0857	0.1063	0.1383	0.1894	0.2397	0.1737	0.1008	0.0350
1.50	0.0008	0.0039	0.0078	0.0158	0.0323	0.0497	0.0677	0.0864	0.1055	0.1345	0.1806	0.2433	0.2309	0.1717	0.1058
1.60	0.0008	0.0040	0.0080	0.0162	0.0330	0.0501	0.0677	0.0855	0.1035	0.1303	0.1729	0.2381	0.2631	0.2255	0.1673
1.70	0.0008	0.0040	0.0081	0.0163	0.0329	0.0497	0.0667	0.0838	0.1008	0.1259	0.1658	0.2305	0.2788	0.2628	0.2179
1.80	0.0008	0.0040	0.0081	0.0162	0.0325	0.0488	0.0652	0.0816	0.0978	0.1216	0.1593	0.2224	0.2846	0.2871	0.2576
1.90	0.0008	0.0040	0.0079	0.0159	0.0318	0.0477	0.0635	0.0792	0.0947	0.1173	0.1532	0.2144	0.2848	0.3017	0.2876
2.00	0.0008	0.0039	0.0078	0.0155	0.0310	0.0464	0.0617	0.0767	0.0916	0.1133	0.1476	0.2069	0.2819	0.3097	0.3096
2.20	0.0007	0.0037	0.0074	0.0147	0.0293	0.0437	0.0579	0.0719	0.0857	0.1057	0.1374	0.1932	0.2720	0.3135	0.3355
2.40	0.0007	0.0035	0.0070	0.0139	0.0276	0.0411	0.0544	0.0675	0.0803	0.0989	0.1285	0.1812	0.2602	0.3089	0.3459
2.60	0.0007	0.0033	0.0066	0.0131	0.0260	0.0387	0.0512	0.0634	0.0754	0.0929	0.1207	0.1706	0.2484	0.3009	0.3475
2.80	0.0006	0.0031	0.0062	0.0124	0.0245	0.0365	0.0483	0.0598	0.0711	0.0876	0.1138	0.1613	0.2372	0.2915	0.3443
3.00	0.0006	0.0029	0.0059	0.0117	0.0232	0.0345	0.0456	0.0565	0.0672	0.0828	0.1076	0.1529	0.2268	0.2817	0.3385
3.50	0.0005	0.0026	0.0052	0.0103	0.0204	0.0303	0.0401	0.0497	0.0591	0.0728	0.0949	0.1356	0.2042	0.2584	0.3194
4.00	0.0005	0.0023	0.0046	0.0091	0.0182	0.0270	0.0357	0.0443	0.0527	0.0651	0.0849	0.1219	0.1857	0.2378	0.2994

TABLE 2-353 Constants for the Two Reference Fluids Used in Lee-Kesler Method*

Constant	Simple reference fluid	Acentric reference fluid
b_1	0.1181193	0.2026579
b_2	0.265728	0.331511
b_3	0.154790	0.027655
b_4	0.030323	0.203488
c_1	0.0236744	0.0313385
c_2	0.0186984	0.0503618
c_3	0.0	0.016901
c_4	0.042724	0.041577
$d_1 \times 10^4$	0.155488	0.48736
$d_2 \times 10^4$	0.623689	0.0740336
β	0.65392	1.226
γ	0.060167	0.03754

*Lee, B. I., and M. G. Kesler, *AIChE J.*, **21** (1975): 510.

Of the cubic EoS given in Table 2-354, the Soave and Peng-Robinson are the most accurate, but there is no general rule for which EoS produces the best estimated volumes for specific fluids or conditions. The Peng-Robinson equation has been better tuned to liquid densities, while the Soave equation has been better tuned to vapor-liquid equilibrium and vapor densities. In solving the cubic equation for volume, a convenient initial guess to find the vapor root is the ideal gas value, while an initial value of 1.05*b* is convenient to locate the liquid root.

Example Estimate the molar density of liquid and vapor saturated ammonia at 353.15 K, using the Soave and Peng-Robinson EoS.

Required properties: Recommended values in the DIPPR® 801 database are

$$T_c = 405.65 \text{ K} \qquad P_c = 112.8 \text{ bar} \qquad \omega = 0.252608$$

$$P^s\,(353.15 \text{ K}) = 41.352 \text{ bar (vapor pressure at 353.15 K)}$$

EoS parameters (shown for Soave EoS):

$$a = \frac{0.42748(RT_c)^2}{P_c} = \frac{0.42748\left[\left(83.145\,\frac{\text{bar}\cdot\text{cm}^3}{\text{mol}\cdot\text{K}}\right)(405.65 \text{ K})\right]^2}{112.8 \text{ bar}}$$

$$= 4.311 \times 10^6\,\frac{\text{cm}^6\cdot\text{bar}}{\text{mol}^2}$$

$$b = \frac{0.08664(RT_c)}{P_c} = \frac{0.08664\left(83.145\,\frac{\text{bar}\cdot\text{cm}^3}{\text{mol}\cdot\text{K}}\right)(405.65 \text{ K})}{112.8 \text{ bar}}$$

$$= 25.906\ \frac{\text{cm}^3}{\text{mol}}$$

$$T_r = (353.15 \text{ K})/(405.65 \text{ K}) = 0.871$$

$$\alpha = \{1 + [0.48 + (1.574)(0.252608) - (0.176)(0.252608)^2][1 - (0.871)^{0.5}]\}^2 = 1.119$$

Rearrange and solve Eq. (2-66) for V:

$$P = \frac{RT}{V-b} - \frac{a\alpha}{V(V+b)} \qquad \text{or} \qquad PV^3 - RTV^2 + (a\alpha - bRT - Pb^2)V - ab\alpha = 0$$

$$41.352\left(\frac{V}{\text{m}^3/\text{mol}}\right)^3 - \left(0.029\,\frac{\text{m}^3}{\text{mol}}\right)\left(\frac{V}{\text{m}^3/\text{mol}}\right)^2 + \left(4.037 \times 10^{-6}\ \frac{\text{m}^6}{\text{mol}^2}\right) \times \left(\frac{V}{\text{m}^3/\text{mol}}\right) - 1.25 \times 10^{-10} = 0$$

Vapor root (initial guess of $V = 7.1 \times 10^{-7}$ m³/mol from ideal gas equation):

$$V_{vap} = 5.395 \times 10^{-4} \text{ m}^3/\text{mol} \qquad \text{and} \qquad \rho_{vap} = 1/V_{vap} = 1.854 \text{ kmol/m}^3$$

Liquid root (initial guess of $V = 2.72 \times 10^{-5}$ m³/mol from 1.05b):

$$V_{liq} = 4.441 \times 10^{-5} \text{ m}^3/\text{mol} \qquad \text{and} \qquad \rho_{liq} = 1/V_{liq} = 22.516 \text{ kmol/m}^3$$

The corresponding values and equation for the Peng-Robinson EoS are

$$a = 4.611 \times 10^6 \text{ cm}^6\cdot\text{bar/mol}^2 \qquad b = 23.262 \text{ cm}^3/\text{mol}$$

$$\alpha = 1.103$$

$$P = \frac{RT}{V-b} - \frac{a\alpha}{V^2 + 2bV - b^2}$$

or

$$PV^3 + (bP - RT)V^2 + (a\alpha - 2bRT - 3Pb^2)V + (bP^3 + RTb^2 - ab\alpha) = 0$$

$$41.352\left(\frac{V}{\text{m}^3/\text{mol}}\right)^3 - \left(0.0284\,\frac{\text{m}^3}{\text{mol}}\right)\left(\frac{V}{\text{m}^3/\text{mol}}\right)^2 + \left(3.651 \times 10^{-6}\ \frac{\text{m}^6}{\text{mol}^2}\right) \times \left(\frac{V}{\text{m}^3/\text{mol}}\right) - 1.018 \times 10^{-10} = 0$$

$$V_{vap} = 5.286 \times 10^{-4} \text{ m}^3/\text{mol and } \rho_{vap} = 1.892 \text{ kmol/m}^3$$

$$V_{liq} = 3.914 \times 10^{-5} \text{ m}^3/\text{mol and } \rho_{liq} = 25.55 \text{ kmol/m}^3$$

The liquid density calculated from the Soave EoS is 24.2 percent below the DIPPR® 801 recommended value of 29.69 kmol/m³, while that calculated from the Peng-Robinson EoS is 13.9 percent below the recommended value.

TABLE 2-354 Relationships for Eq. (2-66) for Common Cubic EoS

EoS	δ	ε	$\alpha(T_r)$	$aP_c/(RT_c)^2$	$bP_c/(RT_c)$
van der Waals*	0	0	1	0.42188	0.125
Relich-Kwong†	0	0	$T_r^{-0.5}$	0.42748	0.08664
Soave‡	b	0	$[1 + (0.48 + 1.574\omega - 0.176\omega^2)(1 - T_r^{0.5})]^2$	0.42748	0.08664
Peng-Robinson§	$2b$	$-b^2$	$[1 + (0.37464 + 1.54226\omega - 0.2699\omega^2)(1 - T_r^{0.5})]^2$	0.45724	0.0778

*van der Waal, J. H., *Z. Phys. Chem.*, **5** (1890): 133.
†Redlich, O., and J. N. S. Kwong, *Chem. Rev.*, **44** (1949): 233.
‡Soave, G., *Chem. Eng. Sci.*, **27** (1972): 1197.
§Peng, D. Y., and D. B. Robinson, *Ind. Eng. Chem. Fundam.*, **15** (1976): 59.

Liquids For most liquids, the saturated molar liquid density ρ can be effectively correlated with

$$\rho = \frac{A}{B^{[1+(1-T/C)^D]}} \tag{2-68}$$

adapted from the Rackett prediction equation [Rackett, H. G., *J. Chem. Eng. Data*, **15** (1970): 514]. The regression constants *A*, *B*, and *D* are determined from the nonlinear regression of available data, while *C* is usually taken as the critical temperature. The liquid density decreases approximately linearly from the triple point to the normal boiling point and then nonlinearly to the critical density (the reciprocal of the critical volume). A few compounds such as water cannot be fit with this equation over the entire range of temperature.

The recommended method for estimation of saturated liquid density for pure organic compounds is the Rackett prediction method.

Recommended Method Rackett method.

Reference: Rackett, H. G., *J. Chem. Eng. Data*, **15** (1970): 514.

Classification: Corresponding states.

Expected uncertainty: 8 percent as purely predictive equation; 2 percent if Z_{RA} (see Description below) or some liquid density data are available.

Applicability: Saturated liquid densities of organic compounds.

Input data: T_c, P_c, and Z_c (or, equivalently, V_c).

Description: A predictive form of the equation is given by

$$\frac{1}{\rho} = V = \left(\frac{RT_c}{P_c}\right) Z_c^q \qquad \text{where } q = 1.0 + (1.0 - T_r)^{2/7} \tag{2-69}$$

A modification of the Rackett method by Spencer and Danner [Spencer, C. F., and R. P. Danner, *J. Chem. Eng. Data*, **17** (1972): 236] replaces Z_c with an adjustable parameter Z_{RA}

$$\frac{1}{\rho} = V = \left(\frac{RT_c}{P_c}\right) Z_{RA}^q \tag{2-70}$$

to provide better estimations of liquid density away from the critical point [Eq. (2-70) gives the correct critical density only when $Z_{RA} = Z_c$]. An alternative to this modification when several liquid density data points are available is to replace the 2/7 power in *q* of Eq. (2-69) with an adjustable parameter. This generally provides good agreement with the experimental values and permits accurate extrapolation of the densities all the way to the critical point.

Example Estimate the saturated liquid density of acetonitrile at 376.69 K.

Required properties: The recommended values from the DIPPR® 801 database are

$$T_c = 545.5 \text{ K} \qquad P_c = 4.83 \text{ MPa} \qquad Z_c = 0.184$$

Calculate supporting quantities:

$$T_r = (376.69 \text{ K})/(545.5 \text{ K}) = 0.691$$
$$q = 1 + (1 - 0.691)^{2/7} = 1.715$$

Calculate saturated liquid density from Eq. (2-69):

$$\rho = \left[\frac{4.83 \times 10^6 \text{ Pa}}{\left(8.314 \dfrac{\text{Pa·m}^3}{\text{mol·K}}\right)(545.5 \text{ K})}\right](0.184)^{-1.715} = 19.42 \ \frac{\text{kmol}}{\text{m}^3}$$

This estimated value is 16.1 percent above the DIPPR® 801 recommended value of 16.726 kmol/m³.

Calculate ρ_{sat} from Eq. (2-70): Kratzke [Kratzke, H., and S. Muller, *J. Chem. Thermo.*, **17** (1985): 151] reported an experimental density of 18.919 kmol/m³ at 298.08 K. Use of this experimental value in Eq. (2-70) to calculate Z_{RA} gives

$$T_r = (298.08 \text{ K})/(545.5 \text{ K}) = 0.546 \qquad q = 1 + (1 - 0.546)^{2/7} = 1.798$$

$$Z_{RA} = \left[\frac{4.83 \times 10^6 \text{ Pa}}{\left(8314 \dfrac{\text{Pa·m}^3}{\text{kmol·K}}\right)(545.5 \text{ K})\left(18.919 \dfrac{\text{kmol}}{\text{m}^3}\right)}\right]^{1/1.798} = 0.202$$

$$\rho = \left[\frac{4.83 \times 10^6 \text{ Pa}}{\left(8.314 \dfrac{\text{Pa·m}^3}{\text{mol·K}}\right)(545.5 \text{ K})}\right](0.202)^{-1.715} = 16.577 \ \frac{\text{kmol}}{\text{m}^3}$$

The value obtained by the modified Rackett method is 0.9 percent below the DIPPR® 801 recommended value. Note, however, that with $Z_{RA} = 0.202$, Eq. (2-70) gives $\rho_c = 5.28$ kmol/m³ as opposed to the DIPPR® 801 recommended value of 5.79 kmol/m³. If the power is regressed from the Kratzke density, one obtains $q_1 = 0.452$ and $\rho = 15.68$ kmol/m³ (4 percent below the experimental value), while still retaining $\rho_c = 5.79$ kmol/m³.

Solids Solid density data are sparse and usually available only within a narrow temperature range. For most solids, density decreases approximately linearly with increasing temperature. Prediction of solid densities is an inexact science, but reasonable correlation has been found between the density of the liquid phase at the triple point and the solid that is stable at the triple point conditions.

Recommended Method Goodman method.

Reference: Goodman, B. T., et al., *J. Chem. Eng. Data*, **49** (2004): 1512.

Classification: Empirical correlation.

Expected uncertainty: 6 percent.

Applicability: Organic compounds; applicable to the stable solid phase at the triple point temperature T_t, to either the next solid-phase transition temperature or to approximately $0.3T_t$.

Input data: Liquid density at the triple point.

Description: The density for the solid phase that is stable at the triple point has been correlated as a function of temperature and the liquid density at T_t:

$$\rho_s = \left(1.28 - 0.16\frac{T}{T_t}\right) \rho_L(T_t) \tag{2-71}$$

Example Estimate the density of solid naphthalene at 281.46 K.

Required properties: The recommended values from the DIPPR® 801 database for T_t and the liquid density at T_t are

$$T_t = 353.43 \text{ K} \qquad \rho_L(T_t) = 7.6326 \text{ kmol/m}^3$$

From Eq. (2-71):

$$\rho_s = \left(1.28 - 0.16\frac{281.46 \text{ K}}{353.43 \text{ K}}\right)\left(7.6326 \frac{\text{kmol}}{\text{m}^3}\right) = 8.797 \ \frac{\text{kmol}}{\text{m}^3}$$

The estimated value is 4.3 percent lower than the DIPPR® 801 recommended value of 9.1905 kmol/m³.

Mixtures Both liquid and vapor densities can be estimated using pure-component CS and EoS methods by treating the fluid as a pseudo-pure component with effective parameters calculated from the pure-component parameters and using ad hoc mixing rules.

To apply the Lee-Kesler CS method to mixtures, pseudo-pure fluid constants are required. One of the simplest set of mixing rules for these quantities is [Prausnitz, J. M., and R. D. Gunn, *AIChE J.*, **4** (1958): 430, 494; Joffe, J., *Ind. Eng. Chem. Fundam.*, **10** (1971): 532]:

$$\overline{T}_c = \sum_{i=1}^{C} x_i T_{c,i} \tag{2-72}$$

$$\overline{P}_c = \frac{\sum_{i=1}^{C} x_i Z_{c,i}}{\sum_{i=1}^{C} x_i V_{c,i}} R\overline{T}_c \qquad (2\text{-}73)$$

$$\overline{\omega} = \sum_{i=1}^{C} x_i \omega_i \qquad (2\text{-}74)$$

The procedures are identical to those for pure components with the replacement of T_c, P_c, and ω with the effective mixture values calculated by using these equations.

To use a cubic EoS for a mixture, mixing rules are used to calculate effective mixture parameters in terms of the pure-component values. Although there are more complex mixing rules available that may improve prediction accuracy, the simplest forms are recommended here for their simplicity and reasonable accuracy without adjustable parameters:

$$\overline{b} = \sum_{i=1}^{C} x_i b_i \qquad (2\text{-}75)$$

$$\overline{a\alpha} = \left[\sum_{i=1}^{C} x_i (a_i \alpha_i)^{1/2}\right]^2 \qquad (2\text{-}76)$$

Mixture calculations are then identical to the pure-component calculations using these effective mixture parameters for the pure-component $a\alpha$ and b values.

The actual mixture second virial coefficient B_m is related to the pure-component values by

$$B_m = \sum_{i=1}^{C}\sum_{j=1}^{C} x_i x_j B_{ij} \qquad \text{where} \qquad B_{ii} = B_i \qquad (2\text{-}77)$$

This requires calculation of all possible binary pair interaction virials (B_{ij}, $i \neq j$) for the mixture. Again the pure-component methods can be used to provide estimates of these values by using the following combining rules:

$$T_{c,ij} = \sqrt{T_{c,i} T_{c,j}} \qquad V_{c,ij} = \left(\frac{V_{c,i}^{1/3} + V_{c,j}^{1/3}}{2}\right)^3 \qquad Z_{c,ij} = \frac{Z_{c,i} + Z_{c,j}}{2} \qquad (2\text{-}78)$$

$$\omega_{ij} = \frac{\omega_i + \omega_j}{2} \qquad P_{c,ij} = \frac{Z_{c,ij} R T_{c,ij}}{V_{c,ij}} \qquad (2\text{-}79)$$

These interaction parameters are used in place of the corresponding pure-component parameters to determine the B_{ij} values.

The modified Rackett method has also been extended to liquid mixtures [Spencer, C. F., and R. P. Danner, *J. Chem. Eng. Data*, **17** (1972): 236] using the following combining and mixing rules as modified by Li [Li, C. C., *Can. J. Chem. Eng.*, **19** (1971): 709]:

$$T_{c,ij} = \sqrt{T_{c,i} T_{c,j}} \qquad \phi_i = \frac{x_i V_{c,i}}{\sum_{j=1}^{C} x_j V_{c,j}} \qquad \overline{T}_c = \sum_{i=1}^{C}\sum_{j=1}^{C} \phi_i \phi_j T_{c,ij} \qquad (2\text{-}80)$$

Recommended Method Spencer-Danner-Li mixing rules with Rackett equation.

References: Spencer, C. F., and R. P. Danner, *J. Chem. Eng. Data*, **17** (1972): 236; Li, C. C., *Can. J. Chem. Eng.*, **19** (1971): 709.

Classification: Corresponding states.

Expected uncertainty: About 7 percent on average; higher near the T_c of any of the components.

Applicability: Saturated (at the bubble point) liquid mixtures.

Input data: T_c, V_c, and x_i.

Description: The predictive form of the equation is given by

$$\frac{1}{\rho} = V = R\left(\sum_{i=1}^{C} \frac{x_i T_{c,i}}{P_{c,i}}\right)\overline{Z}_{RA}^{q} \qquad q = 1.0 + (1.0 - T_r)^{2/7} \qquad (2\text{-}81)$$

where

$$\overline{Z}_{RA} = 0.29056 - 0.08775 \sum_{i=1}^{C} x_i \omega_i \qquad \text{and} \qquad T_r = \frac{T}{\overline{T}_c} \qquad (2\text{-}82)$$

Example Estimate the saturated liquid density of a liquid mixture of 50 mol % ethane(1) and 50 mol % *n*-decane(2) at 377.6 K.

Required properties: The recommended values from the DIPPR® 801 database for the required properties are as follows:

	T_c/K	V_c/(m^3·kmol^{-1})	P_c/ bar	ω
Ethane	305.32	0.1455	48.72	0.0995
Decane	617.7	0.617	21.1	0.4923

Auxiliary quantities from Eq. (2-80):

$$\phi_1 = \frac{(0.5)(0.1455)}{(0.5)(0.1455) + (0.5)(0.617)} = 0.191; \qquad \phi_2 = 0.809$$

$$T_{c,12} = \sqrt{(305.32\text{ K})(617.7\text{ K})} = 434.3\text{ K}$$

$$\frac{\overline{T}_c}{\text{K}} = \phi_1^2 T_{c,1} + 2\phi_1\phi_2 T_{c,12} + \phi_2^2 T_{c,2}$$

$$= (0.191)^2(305.32) + (2)(0.191)(0.809)(434.3) + (0.809)^2(617.7)$$

$$\overline{T}_c = 549.68\text{ K}$$

Calculations from Eqs. (2-81) and (2-82):

$$T_r = (377.6\text{ K})/(549.63\text{ K}) = 0.687$$

$$q = 1 + (1 - 0.687)^{2/7} = 1.718$$

$$\overline{Z}_{RA} = 0.29056 - 0.08775[(0.5)(0.0995) + (0.5)(0.4923)] = 0.2646$$

$$V = \left(0.08314\ \frac{\text{m}^3\cdot\text{bar}}{\text{K}\cdot\text{kmol}}\right)\left[\frac{(0.5)(305.32\text{ K})}{48.72\text{ bar}} + \frac{(0.5)(617.7\text{ K})}{21.1\text{ bar}}\right](0.2646)^{1.718}$$

$$= 0.151\ \frac{\text{m}^3}{\text{kmol}}$$

The experimental value [Reamer, H. H., and B. H. Sage, *J. Chem. Eng. Data*, **7** (1962): 161] is 0.149 m^3/kmol, and the error in the estimated value is 1.3 percent.

VISCOSITY

Viscosity is defined as the shear stress per unit area at any point in a confined fluid, divided by the velocity gradient in the direction perpendicular to the direction of flow. The *absolute viscosity* η is the shear stress at a point, divided by the velocity gradient at that point. The SI unit of viscosity is Pa·s [1 kg/(m·s)], but the cgs unit of poise (P) [1 g/(cm·s)] is also commonly used. Because many common fluids have viscosities on the order of 0.01 P, the unit of centipoise (cP) is also frequently used (1 cP =1 mPa·s). The *kinematic viscosity* ν is defined as the ratio of the absolute viscosity to density at the same temperature and pressure. The SI unit for ν is m^2/s, but again cgs units are very common and ν is often given in stokes (St) (1 cm^2/s) or centistokes (cSt) (0.01 cm^2/s).

Gases Experimental data for gases and vapors at low density are often correlated with

$$\eta^o = \frac{AT^B}{1 + C/T + D/T^2} \qquad (2\text{-}83)$$

Over smaller temperature ranges, parameters C and D may not be necessary as ln η is often reasonably linear with ln T. Care should be taken in extrapolating using Eq. (2-83) as there can be unintended mathematical poles where the denominator approaches zero.

Numerous methods have been developed for estimation of vapor viscosity. For nonpolar vapors, the Yoon-Thodos CS method works well, but for polar fluids the Reichenberg method is preferred. Both methods are illustrated below.

Recommended Method Yoon-Thodos method.
Reference: Yoon, P., and G. Thodos, *AIChE J.*, **16** (1970): 300.
Classification: Corresponding states.
Expected uncertainty: 5 percent.
Applicability: Nonpolar and slightly polar organic vapors.
Input data: T_c, P_c, and M.
Description: The correlation for viscosity as a function of reduced temperature is

$$\frac{\eta^o}{\text{Pa·s}} = \frac{46.1T_r^{0.618} - 20.4\exp(-0.449T_r) + 19.4\exp(-4.058T_r) + 1}{2.173424\times10^{11}(T_c/\text{K})^{1/6}(\text{M/g·mol})^{-1}(P_c/\text{Pa})^{-2/3}} \tag{2-84}$$

Example Estimate the low-pressure vapor viscosity of propane at 353 K.
Required constants: The DIPPR® 801 database recommends the following values:

$T_c = 369.83$ K $\quad P_c = 4.248$ MPa $\quad M = 44.0956$ g/mol

Reduced temperature:

$$T_r = (353\text{ K})/(369.83\text{ K}) = 0.9545$$

Calculation using Eq. (2-84):

$$\frac{\eta^o}{\text{Pa}\cdot\text{s}} = \frac{(46.1)(0.9545)^{0.618} - 20.4\exp[-0.449)(0.9545)] + 19.4\exp[-4.058(0.9545)] + 1}{(2.173424\times10^{11})(369.83)^{-1/2}(44.0956)^{-1/2}(4.248\times10^{6})^{-2/3}}$$

$$= 9.84\times10^{-6}$$

The estimated value is 1.5 percent higher than the DIPPR® 801 recommended value of 9.70×10^{-6} Pa·s.

Recommended Method Reichenberg method.
Reference: Reichenberg, D., *AIChE J.*, **21** (1975): 181.
Classification: Group contributions and corresponding states.
Expected uncertainty: 5 percent.
Applicability: Nonpolar and polar organic and inorganic vapors.
Input data: T_c, P_c, M, μ, and molecular structure.
Description: The temperature dependence of the viscosity is given by

$$\frac{\eta^o}{\text{Pa·s}} = \frac{AT_r^2}{[1+0.36T_r(T_r-1)]^{1/6}}\left[\frac{1+270(\mu_r^*)^4}{T_r+270(\mu_r^*)^4}\right] \tag{2-85}$$

where the parameter A is determined from group contributions and the modified reduced dipole μ_r^* is found from

$$\mu_r^* = 52.46\mu_r \tag{2-86}$$

and Eq. (2.62).

For organic compounds, A is found from the group values C_i, listed in Table 2-355, using

$$A = 10^{-7}\frac{\left[\dfrac{M}{(\text{kg/kmol})}\right]^{1/2}(T_c/\text{K})}{\sum_{i=1}^{N} n_i C_i} \tag{2-87}$$

For inorganic gases, A is obtained from

$$A = 1.6104\times10^{-10}\left[\left(\frac{M}{\text{g/mol}}\right)^{1/2}\left(\frac{P_c}{\text{Pa}}\right)^{2/3}\left(\frac{T_c}{\text{K}}\right)^{-1/6}\right] \tag{2-88}$$

TABLE 2-355 Reichenberg* Group Contribution Values

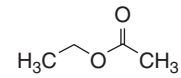
Group	C_i	Group	C_i
—CH_3	9.04	—F	4.46
>CH_2	6.47	—Cl	10.06
>CH—	2.67	—Br	12.83
>C<	−1.53	—OH alcohol	7.96
═CH_2	7.68	>O	3.59
═CH—	5.53	>C═O	12.02
>C═	1.78	—CHO	14.02
≡CH	7.41	—COOH	18.65
≡C—	5.24	—COO— or HCOO—	13.41
>CH_2 ring	6.91	—NH_2	9.71
>CH— ring	1.16	>NH	3.68
>C< ring	0.23	═N— ring	4.97
═CH— ring	5.90	—CN	18.13
>C═ ring	3.59	>S ring	8.86

*Reichenberg, D., *AIChE J.*, **21** (1975): 181.

Example Estimate the low-pressure vapor viscosity of ethyl acetate at 401.25 K.
Required constants: The DIPPR® 801 database recommends the following values:

$M = 88.1051$ g/mol $\quad T_c = 523.3$ K $\quad P_c = 3.88$ MPa $\quad \mu = 1.78$ *D*

Supporting quantities:
Structural groups:



Group	n_i	C_i	Contribution
–CH_3	2	9.04	18.08
>CH_2	1	6.47	6.47
—COO—	1	13.41	13.41
		Total	37.96

$$T_r = (401.25\text{ K})/(523.3\text{ K}) = 0.767$$

From Eqs. (2-62) and (2-86):

$$\mu_r^* = 52.46\frac{(1.78)^2(38.8)}{(523.3)^2} = 0.024$$

From Eq. (2-87):

$$A = 10^{-7}\frac{(88.1051)^{1/2}(523.3)}{37.96} = 1.294\times10^{-5}$$

Calculation using Eq. (2-84):

$$\frac{\eta^o}{\text{Pa·s}} = \frac{(1.294\times10^{-5})(0.767)^2}{[1+(0.36)(0.767)(0.767-1)]^{1/6}}\frac{1+(270)(0.024)^4}{0.767+(270)(0.024)^4} = 1.003\times10^{-5}$$

The estimated value is 1.5 percent lower than the DIPPR® 801 recommended value of 1.018×10^{-5} Pa·s.

The dependence of viscosity upon pressure is principally a density effect. Estimation of vapor viscosity at elevated pressures is commonly done by correlating density deviations from the low-pressure values, which are in turn estimated by using the procedures mentioned above. Several methods are available, but the method developed by Jossi et al. and extended to polar fluids by Stiel and Thodos is relatively accurate and easy to apply.

Recommended Method Jossi-Stiel-Thodos Method.
References: Stiel, L. I., and G. Thodos, *AIChE J.*, **10** (1964): 26; Jossi, J. A., L. I. Stiel, and G. Thodos, *AIChE J.*, **8** (1962): 59.
Classification: Empirical correlation and corresponding states.
Expected uncertainty: 9 percent—often less for nonpolar gases, larger for polar gases.
Applicability: Nonassociating gases; $\rho_r < 2.6$.
Input data: M, T_c, P_c, Z_c, μ, η^o (low-pressure viscosity at same T may be estimated by using methods given above), and ρ (may be calculated from T and P by using density methods given above).

Description: Deviation of η from the low-pressure value η^o is given by one of the following correlations depending upon its polarity and reduced density range:

For nonpolar gases, $0.1 < \rho r < 3.0$:

$$\left[\left(\frac{\eta-\eta^o}{\text{mPa·s}}\right)\xi+1\right]^{1/4} = 1.0230 + 0.23364\rho_r + 0.58533\rho_r^2 - 0.40758\rho_r^3 + 0.093324\rho_r^4 \quad (2\text{-}89)$$

For polar gases, $\rho_r \le 0.1$:

$$\left(\frac{\eta-\eta^o}{\text{mPa·s}}\right)\xi = 1.656\rho_r^{1.111} \quad (2\text{-}90)$$

For polar gases, $0.1 < \rho_r \le 0.9$:

$$\left(\frac{\eta-\eta^o}{\text{mPa·s}}\right)\xi = 0.0607(9.045\rho_r + 0.63)^{1.739} \quad (2\text{-}91)$$

For polar gases, $0.9 < \rho_r \le 2.2$:

$$\log\left\{4 - \log\left[\left(\frac{\eta-\eta^o}{\text{mPa·s}}\right)\xi\right]\right\} = 0.6439 - 0.1005\rho_r \quad (2\text{-}92)$$

For polar gases, $2.2 < \rho r \le 2.6$:

$$\log\left\{4 - \log\left[\left(\frac{\eta-\eta^o}{\text{mPa·s}}\right)\xi\right]\right\} = 0.6439 - 0.1005\rho_r - 0.000475(\rho_r^3 - 10.65)^2 \quad (2\text{-}93)$$

where $\rho_c = P_c/(Z_cRT_c)$ and

$$\xi = 2173.4\left(\frac{T_c}{\text{K}}\right)^{1/6}\left(\frac{M}{\text{kg/kmol}}\right)^{-1/2}\left(\frac{P_c}{\text{MPa}}\right)^{-2/3} \quad (2\text{-}94)$$

Example Estimate the vapor viscosity of CO_2 at 350 K and 20 MPa if $\eta^o = 0.0174$ mPa·s and $Z = 0.4983$ (estimated from Lee-Kesler method, see section on density).

Required properties: From the DIPPR® 801 database,

$M = 44.01$ kg/kmol $\quad T_c = 304.21$ K $\quad P_c = 7.383$ MPa

$Z_c = 0.274 \quad \mu = 0$ D (nonpolar)

Auxiliary quantities:

$$\xi = 2173.4(304.21)^{1/6}(44.01)^{-1/2}(7.383)^{-2/3} = 224.1$$

$$\rho_c = \frac{7.383\text{ MPa}}{0.274[8.314\text{ m}^3\text{Pa/(K·mol)}](304.21\text{ K})} = 10.654\ \frac{\text{kmol}}{\text{m}^3}$$

$$\rho_r = \frac{\rho}{\rho_c} = \frac{P}{ZRT\rho_c} = \frac{20\text{ MPa}}{0.4983[8.314\text{ m}^3\text{·Pa/(K·mol)}](350\text{ K})(10.654\text{ m}^3\text{·kmol})} = 1.295$$

Calculation using Eq. (2-89) for nonpolar fluids:

$$\left[224.1\left(\frac{\eta-\eta^o}{\text{mPa·s}}\right)+1\right]^{1/4} = 1.0230 + 0.23364(1.295) + 0.58533(1.295)^2 - 0.40758(1.295)^3 + 0.093324(1.295)^4 = 1.684$$

$$\eta = \frac{1.684^4 - 1}{224.1}\text{ mPa·s} + 0.0174\text{ mPa·s} = 0.0489\text{ mPa·s}$$

This differs from the experimental value of 0.0473 mPa·s by 3.4 percent.

Liquids Liquid viscosity can be correlated as a function of temperature for low pressures. Usually the correlation is based on the Andrade equation [Andrade, E. N. da C., *Nature*, **125** (1930): 309]

$$\ln\eta = A + \frac{B}{T} \quad (2\text{-}95)$$

or an extension of it. For example, the DIPPR® 801 database uses the equation

$$\ln\eta = A + \frac{B}{T} + C\ln T + DT^E \quad (2\text{-}96)$$

which is analogous to the Riedel [Riedel, L., *Chem. Ing. Tech.*, **26** (1954): 83] vapor pressure equation.

Currently the most accurate method for predicting pure liquid viscosity is the following GC method.

Recommended Method Hsu method.

Reference: Hsu, H.-C., Y.-W. Sheu, and C.-H. Tu, *Chem. Eng. J.*, **88** (2002): 27.

Classification: Group contributions.

Expected uncertainty: 20 percent.

Applicability: Organic liquids; $T_r < 0.75$.

Input data: P_c and molecular structure.

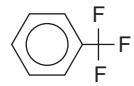
Description: The temperature dependence of the liquid viscosity is given by

$$\ln\left(\frac{\eta}{\text{mPa·s}}\right) = \sum_{i=1}^{N} a_i + T\sum_{i=1}^{N} b_i + \frac{\sum_{i=1}^{N} c_i}{T^2} + \left(\sum_{i=1}^{N} d_i\right)\ln\left(\frac{P_c}{\text{bar}}\right) \quad (2\text{-}97)$$

where P_c is critical pressure and the coefficients a, b, c, and d are the sum of the group contributions obtained from Table 2-356.

Example Estimate the liquid viscosity of benzotrifluoride at 303.15 K.

Structural information:



Group	Number	a	$100b$	$0.0001c$	d
>C<	1	1.0031	–0.3677	–6.0316	1.1972
(═CH—)$_A$	5	–0.8570	–0.0098	2.4376	0.1311
(═C<)$_A$	1	0.7896	–0.0231	–0.9222	0.1928
(—F)$_3$	1	1.5394	0.8465	17.8121	–2.9915
	Total	–0.9529	0.4067	23.0463	–0.9460

Supporting values:

$P_c = 32.1$ MPa

Calculation using Eq. (2-97):

$$\frac{\eta}{\text{mPa·s}} = \exp\left[-0.9529 + (0.004067)(303.15) + \frac{230463}{(303.15)^2} - 0.9460\ln 32.1\right] = 0.610$$

The estimated value is 20 percent higher than the DIPPR® 801 recommended value of 0.509 mPa·s.

Liquid Mixtures Almost all methods for estimating liquid mixture viscosity interpolate between the pure-component values at the same temperature. The Grunberg-Nissan [Grunberg, L., and A. H. Nissan, *Nature*, **164** (1949): 799] equation

$$\ln\eta = \sum_{i}^{C} x_i\ln\eta_i + \frac{1}{2}\sum_{i=1}^{C}\sum_{j=1}^{C} x_i x_j G_{ij} \quad (2\text{-}98)$$

is commonly used for nonaqueous mixtures. The parameter G_{ij} generally must be regressed from an experimental mixture viscosity. However, in the case of hydrocarbon mixtures G_{ij} can be set to zero with expected errors in the mixture viscosity of about 15 percent.

TABLE 2-356 Group Contributions for the Hsu et al. Method*

Table-specific nomenclature: R = in nonaromatic ring, A = in aromatic ring, RC = attached to nonaromatic ring, AC = attached to aromatic ring, X = halogen, $(-X)_n = n$ X atoms attached to same C atom

Group	a	$100b$	$0.0001c$	d
		C, H Groups		
CH_4	–1.7296	–1.0563	0.8928	–0.0019
—CH_3	0.0570	–0.2382	0.7556	–0.1765
—CH_2—	–0.1497	0.0060	1.4157	0.0751
>CH—	–2.2942	0.4028	4.5094	0.6679
>C<	1.0031	–0.3677	–6.0316	1.1972
═CH_2	0.9256	–0.2656	0.9860	–0.4417
═CH—	1.3365	0.1612	1.9408	0.2507
═C<	–3.5020	0.4305	3.1287	1.0465
≡CH	87.6040	–0.1106	4.4245	–24.1836
≡C—	–91.6154	–0.0111	0.3265	25.0542
$(—CH_2—)_R$	6.0416	–0.1778	0.8437	–1.5184
$(>CH—)_R$	–33.8745	0.7637	7.2433	8.5951
$(═CH—)_R$ cycloalkene	1.2028	–0.0120	2.0143	–0.3677
$(>C<)_R$ spirocyclane	–56.2158	1.7694	19.0452	13.3885
$(═CH—)_A$	–0.8570	–0.0098	2.4376	0.1311
$(═C<)_A$ cycloalkene	0.7896	–0.0231	–0.9222	0.1928
$(═C<)_A$ bi/terphenyl	2.0973	0.0444	8.1690	–0.4351
$(═C<)_A$ naphthalene	0.4392	0.0683	8.8426	–0.1685
$(═C<)_A$ turpentine	27.3350	1.2165	34.2857	–11.6500
$(═C<)_A$ tetralin	14.2586	–0.8665	–14.7474	–2.7574
		O, S Groups		
—OH primary for C<3	5.7852	–0.5310	9.5499	–1.0300
—OH primary for C>2	1.4351	–1.0010	13.8366	0.3418
—OH secondary	–2.6895	–0.3645	29.8404	0.4246
—OH tertiary	–18.5630	2.4275	78.5417	0.9650
$(—OH)_{RC}$	16.7808	0.8509	77.1759	–6.9285
—OH polyhydric	–0.0125	–0.3634	23.2329	–0.0172
$(—OH)_{AC}$	–2.0856	0.6362	50.0840	–1.0539
—OH alkoxyalcohol	–2.6991	–0.4377	17.2243	0.7139
—O—	–0.7185	0.0985	2.9405	0.1149
$(—O—)_R$	–29.8045	–0.2847	–4.3145	8.3131
$(—O—)_{AC}$	–2.3454	0.0872	6.4296	0.5389
—CHO	–0.8288	–0.2612	3.7241	0.2386
>CO	–2.6622	0.1142	6.7008	0.7348
$(>CO)_R$	45.9143	–0.2405	3.8828	–12.4994
HCOOH	–2.7291	0.0413	27.4079	0.0002
—COOH for C<7	–4.0451	–0.1841	12.6878	1.1139
—COOH for C>6	–0.6721	–0.1693	20.0309	0.0279
HCOO—	–3.3731	–0.0113	9.4694	0.6071
—COO— for C<8	–0.0635	–0.2162	1.9325	0.4686
—COO— for C>7	–2.5390	0.0006	5.4231	0.8717
>CHO—	–5.4872	1.5834	34.5474	–0.4244
—(CO)—O—(CO)— anhydride	–11.8236	0.0111	7.2831	3.6587
—O—(CO)—O— carbonate	–8.0314	0.2848	9.3746	2.1486
$(>NO)_R$	–16.9531	1.0614	49.1049	2.8583
—NO_2	–13.0333	0.1801	12.9392	2.8987
═$CHNO_2$	–1.9653	0.1322	15.8672	–0.0701
$(—NO_2)_{AC}$	–1.2954	0.0427	12.1837	–0.0948
—S—	–3.2767	0.0779	4.4123	0.9549
—SH primary	–2.1030	–0.0965	6.0066	0.3464
—SH secondary	–0.2481	–0.3285	1.9387	0.1148
—SH tertiary	–12.3498	1.2621	23.1473	1.3950
—CSO— for C<13	–15.2678	0.5248	14.2694	3.7646
—CSO— for C>12	3.7475	–1.2592	–23.9353	0.8329
>SO	–32.8607	0.6232	27.5184	7.7525
		N, X Groups		
—NH_2	–1.1345	–0.2126	7.0544	0.1336
—NH—	–6.9489	–0.1723	5.7804	1.6467
—N<	–2.1403	0.4842	6.1893	0.4718
$(—NH_2)_{AC}$	–6.3646	–0.0180	23.2752	1.0653
$(—NH—)_{AC}$	–1.7592	0.2208	14.9707	0.1171
$(—N<)_{AC}$	–1.2982	0.5975	14.0415	–0.0031
$HCONH_2$	–1.5435	–0.2774	31.8007	0.0001
HCONH—	–8.1097	0.0432	20.9135	1.8795
HCON<	–122.3280	26.4615	394.1670	0.3530
—$CONH_2$	–6.7363	0.1316	45.5193	1.2172
—CONH—	8.9977	1.5664	60.8742	–4.6399
—$COONH_2$	17.8400	–4.5188	–62.0987	1.2353
—COONH—	–10.1316	0.6712	37.9465	1.9199
$(>NH)_R$	–0.1589	0.1910	12.0578	–0.0276

TABLE 2-356 Group Contributions for the Hsu et al. Method* (*Concluded*)

Table-specific nomenclature: R = in nonaromatic ring, A = in aromatic ring, RC = attached to nonaromatic ring, AC = attached to aromatic ring, X = halogen, $(-X)_n = n$ X atoms attached to same C atom

Group	a	$100b$	$0.0001c$	d
N, X Groups				
$(=N-)_R$	−4.7601	0.1120	6.98437	0.9719
$-C\equiv N$	−2.7194	−0.1324	7.7955	0.6293
$(-C\equiv N)_{AC}$	0.9435	−0.0086	8.6310	−0.6443
—Cl primary	−1.7997	−0.3851	3.0118	0.5524
$=CHCl$	1.5851	−0.1934	3.7798	−0.4748
$(-Cl)_2$	−3.0561	−1.0770	0.1882	1.2223
$(-Cl)_3$	−1.3357	−0.3220	8.8683	0.1702
$(-Cl)_4$	4.2070	−0.4130	13.3194	−1.1972
$(-Cl)_{AC}$	−0.3083	−0.0623	4.1382	−0.2644
—F primary	−9.4982	0.2607	11.3406	1.8461
$(-F)_2$	−10.3980	−1.1189	1.3134	2.6681
$(-F)_3$	1.5394	0.8465	17.8121	−2.9915
$(-F)_{AC}$	0.4079	−0.2352	−0.1505	−0.2893
(—F)(—Cl)	−0.8565	−0.3682	4.6451	−0.0751
(—F)$(-Cl)_2$	−3.4552	−0.5629	3.6831	0.3613
$(-F)_2$(—Cl)	54.2824	0.0109	5.9474	−14.5771
$(-F)_2(-Cl)_2$	−2.1710	0.1403	10.3743	−1.1972
—Br primary	−0.7586	−0.6623	−2.4228	0.7385
—Br secondary	−279.0030	−0.3420	1.4253	73.6293
$(-Br)_{AC}$	−8.1919	−0.1635	3.0150	0.0621
—I primary	−1.4672	−0.2787	4.3362	0.5635
$(-I)_{AC}$	70.9918	−0.0245	7.2061	−18.9106
—(CO)—Cl	−2.3300	−0.0470	8.2815	0.4485

*Hsu, H.-C., Y.-W. Sheu, and C.-H. Tu, *Chem. Eng. J.*, **88** (2002): 27

Estimation of liquid mixture viscosity without any mixture data is difficult because the viscosity is strongly affected by large molecular size differences and strong cross interactions between the different types of molecules. Viscosity-composition plots for aqueous mixtures can have maxima or minima, and viscosities for these mixtures are particularly difficult to estimate. The UNIFAC-VISCO method described below can be used to predict liquid viscosity of organic mixtures without any mixture data. It is relatively successful even for large differences in molecular size, but it is currently limited in scope by the small number of group contributions available.

Recommended Method UNIFAC-VISCO method.

Reference: Chevalier, J. L., P. Petrino, and Y. Gaston-Bonhomme, *Chem. Eng. Sci.*, **43** (1988): 1303; Gaston-Bonhomme, Y., P. Petrino, and J. L. Chevalier, *Chem. Eng. Sci.*, **49** (1994): 1799.

Classification: Group contributions.

Expected uncertainty: 20 percent.

Applicability: Organic liquids.

Input data: Molecular structure; pure-component molar volumes and viscosities at the mixture temperature.

Description: The equations for this method are

$$\ln\left(\frac{\eta}{\text{mPa·s}}\right) = \sum_{i=1}^{\text{comp}} x_i \ln\left(\frac{\eta_i}{\text{mPa·s}} \cdot \frac{V_i}{V_m}\right) + \frac{g_c^E}{RT} - \frac{g_r^E}{RT} \qquad (2\text{-}99)$$

where V_m is the mixture molar volume and V_i is the pure-component molar volume of component i. The combinatorial and residual excess Gibbs energies are calculated exactly as in the UNIFAC method (see Sec. 13) with the exception that the group interactions ψ_{mn} are calculated by using

$$\Psi_{mn} = \exp\left(-\frac{\alpha_{mn}}{298.15}\right) \qquad (2\text{-}100)$$

The interaction parameters α_{mn} are obtained from Table 2-357.

Example Estimate the viscosity of a mixture of 51.13 mol % ethanol(1) and 48.87 mol % benzene(2) at 298.15 K.

Required input: Values from the DIPPR® 801 database for the pure components at 298.15 K are $\eta_1 = 1.0774$ mPa·s, $\eta_2 = 0.5997$ mPa·s, $V_1 = 0.05862$ m³/kmol, and $V_2 = 0.08948$ m³/kmol.

Groups, area fractions, volume fractions:

Group	R	Q	N_1	N_2
CH_3	0.9011	0.8480	1	0
CH_2	0.6744	0.5400	1	0
CH_{ar}	0.5313	0.4000	0	6
OH	1.0000	1.2000	1	0
Group	r_1	q_1	r_2	q_2
CH_3	0.9011	0.848	0	0
CH_2	0.6744	0.54	0	0
CH_{ar}	0	0	3.1878	2.4
OH	1	1.2	0	0
Total	2.5755	2.588	3.1878	2.4

where in the above table

$$q_i = \sum_{k=1}^{N} N_{i,k} Q_k \qquad \text{and} \qquad r_i = \sum_{k=1}^{N} N_{i,k} R_k$$

$$\theta_1 = \frac{x_1 q_1}{\sum_{i=1}^{4} x_i q_i} = \frac{(0.5113)(2.588)}{(0.5113)(2.588) + (0.4887)(2.4)} = 0.53 \qquad \theta_2 = 0.47$$

$$\phi_1 = \frac{x_1 r_1}{\sum_{i=1}^{4} x_i r_i} = \frac{(0.5113)(2.5755)}{(0.5113)(2.5755) + (0.4887)(3.1878)} = 0.458 \qquad \phi_2 = 0.542$$

UNIFAC combinatorial term:

$$\frac{g_C^E}{RT} = \sum_{i=1}^{2} x_i \ln\frac{\phi_i}{x_i} + 5\sum_{i=1}^{2} x_i q_i \ln\frac{\theta_i}{\phi_i} = 0.124$$

TABLE 2-357 UNIFAC-VISCO* Group Interaction Parameters α_{mn}

m/n	CH_2	CH_3	CH_{2cy}	CH_{ar}	Cl	CO	COO	OH	CH_3OH
CH_2	0	66.53	224.9	406.7	60.30	859.5	1172.0	498.6	−219.7
CH_3	−709.5	0	−130.7	−119.5	82.41	11.86	−172.4	594.4	−228.7
CH_{2cy}	−538.1	187.3	0	8.958	251.4	−125.4	−165.7	694.4	−381.53
CH_{ar}	−623.7	237.2	50.89	0	177.2	128.4	−49.85	419.3	−88.81
Cl	−710.3	375.3	−163.3	−139.8	0	−404.3	−525.4	960.2	−165.4
CO	586.2	−21.56	740.6	−117.9	−4.145	0	29.20	221.5	55.52
COO	541.6	−44.25	416.2	−36.17	240.5	22.92	0	186.8	69.62
OH	−634.5	1209.0	−138	197.7	195.7	664.1	68.35	0	416.4
CH_3OH	−526.1	653.1	751.3	51.31	−140.9	−22.59	−286.2	−23.91	0

*Chevalier, J. L., P. Petrino, and Y. Gaston-Bonhomme, *Chem. Eng. Sci.*, **43** (1988): 1303; Gaston-Bonhomme, Y., P. Petrino, and J. L. Chevalier, *Chem. Eng. Sci.*, **49** (1994): 1799.

Group interactions:

m/n	α_{mn}			
group	CH_3	CH_2	CH_{ar}	OH
CH_3	0	−709.5	−119.5	594.4
CH_2	66.53	0	406.7	498.6
CH_{ar}	237.2	−623.7	0	419.3
OH	1209	−634.5	197.7	0

m/n	Ψ_{mn}			
group	CH_3	CH_2	CH_{ar}	OH
CH_3	1.000	10.801	1.493	0.136
CH_2	0.800	1.000	0.256	0.188
CH_{ar}	0.451	8.100	1.000	0.245
OH	0.017	8.399	0.515	1.000

The α_{mn} values were obtained from Table 2-357, and Ψ_{mn} values were calculated from Eq. (2-100).

Group fractions in the mixture:

Group	*N*	*X*	*XQ*	Θ	$ln\gamma$
CH_3	0.5113	0.1145	0.097083	0.17370	0.293
CH_2	0.5113	0.1145	0.061822	0.11061	−0.873
CH_{ar}	2.9322	0.6565	0.262618	0.46988	0.066
OH	0.5113	0.1145	0.137382	0.24581	1.077
Sum	4.4661		0.558905		

Here $\Theta_m = \dfrac{X_m Q_m}{\sum_{i=1}^{4} X_i Q_i}$

and

$$\ln \gamma_m = Q_m \left[1 - \ln \left(\sum_{i=1}^{4} \Theta_i \Psi_{i,m} \right) - \sum_{i=1}^{4} \frac{\Theta_i \Psi_{m,i}}{\sum_{j=1}^{4} \Theta_j \Psi_{j,i}} \right]$$

Group fractions in pure components:

	Ethanol				
Group	*N*	*X*	*XQ*	Θ	ln γ
CH_3	1	0.3333	0.283	0.3277	0.5306
CH_2	1	0.3333	0.180	0.2087	−0.9405
CH_{ar}	0	0.0000	0.000	0.0000	0.2095
OH	1	0.3333	0.400	0.4637	0.6179
Sum	3		0.863		

	Benzene				
Group	*N*	*X*	*XQ*	Θ	ln γ
CH_3	0	0	0	0	0.257
CH_2	0	0	0	0	−0.728
CH_{ar}	6	1	0.4	1	0.000
OH	0	0	0	0	2.270
Sum	6		0.4		

Here Θ and ln γ are defined by the same equations shown above for the mixture groups.

UNIFAC residual term:

$$\frac{g_r^E}{RT} = \sum_{i=1}^{2} x_i \left[\sum_{m=1}^{4} N_{m,i} \left(\ln \gamma_m - \ln \gamma_{m,i} \right) \right] = 0.3425$$

where N_m and ln γ_m refer to the mixture and $N_{m,i}$ and ln $\gamma_{m,i}$ refer to the pure-component values.

Mixture volume:

$$V_m = \sum_{i=1}^{2} x_i V_i = 0.5113 \left(0.05862 \ \frac{\text{m}^3}{\text{kmol}} \right) + 0.4887 \left(0.08948 \ \frac{\text{m}^3}{\text{kmol}} \right)$$

$$= 0.07370 \ \frac{\text{m}^3}{\text{kmol}}$$

Using Eq. (2-99):

$$\ln \left(\frac{\eta}{\text{mPa·s}} \right) = 0.5113 \ln \left[1.0774 \left(\frac{0.05862}{0.07370} \right) \right] + 0.4887$$

$$\ln \left[0.5997 \left(\frac{0.08948}{0.07370} \right) \right] + 0.124 - 0.3425 = -0.4523$$

$$\eta = \exp(-0.4523) \text{ mPa·s} = 0.636 \text{ mPa·s}$$

The estimated value is 6.6 percent below the reported experimental value of 0.681 mPa·s [Kouris, S., and C. Panayiotou, *J. Chem. Eng. Data,* **34** (1989): 200].

THERMAL CONDUCTIVITY

Thermal conductivity k is a measure of the rate at which heat conducts through the material and is defined as the proportionality constant in Fourier's law of heat conduction that relates the gradient of temperature to the heat flux or flow per unit area. In SI units, it has the units of W/(m·K). The conduction mechanism in low-density media, gases,

is primarily via molecular collisions, and k increases with increasing temperature (increasing molecular velocity). In dense media such as liquids, the energy transfer by conduction occurs more efficiently through the attractive intermolecular potential wells between the molecules than through collisions. As a result, liquid thermal conductivity generally decreases with increasing temperature (except for water, aqueous solutions, and a few multihydroxy and multiamine compounds), corresponding to the decrease in density with increased temperature. Below or near the normal boiling point, the temperature dependence of liquid thermal conductivity is nearly linear for modest temperature ranges and can be represented by

$$k = A - BT \tag{2-101}$$

where B is generally in the range of 1×10^{-4} to 3×10^{-4} W/(m·K^2).

Gases Methods for estimating low-pressure gas thermal conductivities are based on kinetic theory and generally correlate the dimensionless group $kM/\eta C_v$ (M = molecular weight, η = viscosity, C_v = isochoric heat capacity) known as the Eucken factor. The method of Stiel and Thodos is recommended for pure nonpolar compounds, and the method of Chung is recommended for pure polar compounds.

Recommended Method Stiel-Thodos method.
Reference: Stiel, L. I., and G. Thodos, *AIChE J.*, **10** (1964): 26.
Classification: Empirical extension of theory.
Expected uncertainty: 15 percent.
Applicability: Pure nonpolar gases at low pressure.
Input data: M, T_c, η, and C_v.
Description: The following equations may be used depending upon the molecular shape:

$$\frac{kM}{\eta C_v} = 2.5 \qquad \text{monatomic} \tag{2-102}$$

$$\frac{kM}{\eta C_v} = 1.30 + \left(\frac{R}{C_v}\right)\left(1.7614 - \frac{0.3523}{T_r}\right) \qquad \text{linear molecules} \tag{2-103}$$

$$\frac{kM}{\eta C_v} = 1.15 + 2.033\left(\frac{R}{C_v}\right) \qquad \text{nonlinear molecules} \tag{2-104}$$

where η = viscosity at same conditions as desired for k. *Note:* Because this method is only applicable at low pressures, C_v may be calculated as $C_p^o - R$, where C_p^o is the ideal gas isobaric heat capacity.

Example Estimate the low-pressure thermal conductivity of toluene vapor at 500 K.
Required properties from the DIPPR® 801 database:

$T_c = 591.75$ K $\quad M = 92.138$ g/mol $\quad \eta\,(500\text{ K}) = 1.1408 \times 10^{-5}$ Pa·s

$C_v = C_p - R = (170.78 - 8.314)$ J/(mol·K) $= 162.47$ J/(mol·K)

Auxiliary quantities:

$T_r = 500/591.75 = 0.845 \quad R/C_v = (8.314)/(162.47) = 0.0512$

From Eq. (2-104):

$$k = [1.15 + (2.033)(0.0512)]\left[\frac{(1.1408 \times 10^{-5}\text{Pa·s})\left(162.47\ \frac{\text{J}}{\text{mol·K}}\right)}{92.138\ \frac{\text{g}}{\text{mol}}}\right]$$

$$= 25.2\ \frac{\text{mW}}{\text{m·K}}$$

The estimated value is 18 percent below the DIPPR® 801 recommended value of 30.76 mW/(m·K).

Recommended Method Chung-Lee-Starling method.
Reference: Chung, T.-H., L. L. Lee, and K. E. Starling, *Ind. Eng. Chem. Fundam.*, **23** (1984): 8.
Classification: Corresponding states.
Expected uncertainty: 15 percent.
Applicability: Pure organic gases at low pressure.
Input data: C_v, ω, T_c, M, and η.
Description: The following equations apply:

$$\frac{kM}{\eta C_v} = 3.75\,\Psi\left(\frac{R}{C_v}\right) \tag{2-105}$$

$$\Psi = 1 + \alpha\left(\frac{0.215 + 0.28288\alpha - 1.061\beta + 0.26665\gamma}{0.6366 + \beta\gamma + 1.061\alpha\beta}\right) \tag{2-106}$$

$$\alpha = \frac{C_v}{R} - 1.5 \qquad \beta = 0.7862 - 0.7109\omega + 1.3168\omega^2$$
$$\gamma = 2.0 + 10.5T_r^2 \tag{2-107}$$

Example Estimate the low-pressue thermal conductivity of naphthalene vapor at 500 K.
Required properties from the DIPPR® 801 database:

$T_c = 748.4$ K $\quad M = 128.17$ g/mol $\quad \omega = 0.30203$

$\eta(500\text{ K}) = 1.0173 \times 10^{-5}$ Pa·s

$C_v = C_p - R = (219.82 - 8.314)$ J/(mol·K) $= 211.51$ J/(mol·K)

Auxiliary quantities [Eqs. (2-106) and(2-107)]:

$T_r = 500/748.4 = 0.6681 \qquad R/C_v = (8.314)/(211.51) = 0.0393$

$\gamma = 2.0 + (10.5)(0.6681)^2 = 6.6866 \qquad \alpha = (0.0393)^{-1} - 1.5 = 23.9388$

$\beta = 0.7862 - (0.7109)(0.30203) + (1.3168)(0.30203)^2 = 0.6916$

$$\Psi = 1 + 23.9388 \times \left[\frac{0.215 + 0.28288(23.9388) - 1.061(0.6916) + 0.26665(6.6866)}{0.6366 + 0.6916(6.6866) + 1.061(23.9388)(0.6916)}\right]$$

$$= 9.4273$$

From Eq. (2-105):

$$k = (3.75)(9.4273)\left[\frac{(1.1408 \times 10^{-5}\text{Pa·s})\left(8.314\ \frac{\text{J}}{\text{mol·K}}\right)}{128.17\ \frac{\text{g}}{\text{mol}}}\right] = 23.33\ \frac{\text{mW}}{\text{m·K}}$$

The estimated value is 1.0 percent above the DIPPR® 801 recommended value of 23.09 mW/(m·K).

Liquids The Baroncini method provides accurate liquid thermal conductivity estimates if the compound clearly belongs to one of the specific families designated by the correlation. The Sastri-Rao method is recommended for other specific families as listed in the discussion of the method given below. As a general method for estimating thermal conductivity of pure liquids at ambient pressure for all other compounds, the Missenard method is recommended.

Recommended Method Baroncini method.
Reference: Baroncini, C., et al., *Int. J. Thermophys.*, **2** (1981): 21.
Classification: Empirical correlation.
Expected uncertainty: 10 percent.
Applicability: Particularly accurate for the following families: acetates, aliphatic ethers, halogenated compounds, dicarboxylic acids, ketones, aliphatic alcohols, aliphatic acids, propionates and butyrates, and unsaturated aliphatic esters.
Input data: M, T_b (normal boiling point), T_c.
Description:

$$\frac{k}{\text{W/(m·K)}} = A\left(\frac{T_b}{K}\right)^{\alpha}\left(\frac{M}{\text{g/mol}}\right)^{-\beta}\left(\frac{T_c}{K}\right)^{-\gamma}\frac{(1 - T_r)^{0.38}}{T_r^{1/6}} \tag{2-108}$$

where A, α, β, and γ are obtained from Table 2-358.

TABLE 2-358 Correlation Parameters for Baroncini et al. Method* for Estimation of Thermal Conductivity

Family	A	α	β	γ
Saturated hydrocarbons	0.00350	1.2	0.5	0.167
Olefins	0.0361	1.2	1	0.167
Cycloparaffins	0.0310	1.2	1	0.167
Aromatics	0.0346	1.2	1	0.167
Alcohols	0.00339	1.2	0.5	0.167
Organic acids	0.00319	1.2	0.5	0.167
Ketones	0.00383	1.2	0.5	0.167
Esters	0.0415	1.2	1	0.167
Ethers	0.0385	1.2	1	0.167
Refrigerants				
R20, R21, R22, R23	0.562	0	0.5	–0.167
Others	0.494	0	0.5	–0.167

*Baroncini, C., et al., *Int. J. Thermophys.*, **2** (1981): 21.

Example Estimate the thermal conductivity of liquid *p*-cresol at 400 K.
Required properties from DIPPR® 801 database:

$$M = 108.1378 \text{ g/mol} \qquad T_c = 704.65 \text{ K} \qquad T_b = 475.133 \text{ K}$$

Auxiliary properties:

$$T_r = T/T_c = (400 \text{ K})/(704.65 \text{ K}) = 0.5677$$

From Table 2-358 for alcohols:

$$A = 0.00339 \qquad \alpha = 1.2 \qquad \beta = \frac{1}{2} \qquad \gamma = 0.167$$

From Eq. (2-108):

$$\frac{k}{\text{W/(m·K)}} = (0.00339)(475.13)^{1.2}(108.1378)^{-1/2}(704.65)^{-0.167}$$

$$\frac{(1 - 0.5677)^{0.38}}{0.5677^{1/6}} = 0.142$$

The estimated value is 7.6 percent higher than the DIPPR® 801 recommended value of 0.132 W/(m·K).

Recommended Method Sastri-Rao method.
Reference: Sastri, S. R. S., and K. K. Rao, *Chem. Eng. J.*, **74** (1999): 161.
Classification: Group contributions and corresponding states.
Expected uncertainty: 10 percent.
Applicability: Particularly accurate for the following families: alkanes, alkenes, aromatic alcohols, cycloalkanes, epoxides, aliphatic acids, condensed rings.
Input data: T_c , T_b (normal boiling point), and molecular structure.
Description: The thermal conductivity at the normal boiling point k_b is calculated from the sum of the group contributions given in Table 2-359. This value is then scaled to the desired reduced temperature by using a factor α^β in which the power β is related to the fractional reduced temperature distance between the normal boiling point and the critical point as shown in the following equations:

$$k_b = \sum_{i=1}^{N} n_i \Delta k_i \qquad \beta = 1 - \left(\frac{1 - T_r}{1 - T_{br}}\right)^{\gamma} \qquad k = k_b \alpha^\beta \quad (2\text{-}109)$$

where $\gamma = 1.23$ for alcohols and 0.2 for all other compounds and $\alpha = 0.856$ for alcohols and 0.16 for all other compounds.

TABLE 2-359 Sastri-Rao* Group Contributions for Liquid Thermal Conductivity at the Normal Boiling Point

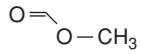
Group	Δk_i (W/m·K)	Group	Δk_i (W/m·K)
Hydrocarbons		—COOH	0.0650
—CH_3	0.0545	—NH_2	0.0880
—CH_2—	–0.0008	—NH—	0.0065
>CH—	–0.0600	—NH— ring	0.0450
>C<	–0.1230	>N—	–0.0605
═CH_2	0.0545	>N— ring	0.0135
═CH—	0.0020	—CN	0.0645
═C<	–0.0630	—NO_2	0.0700
═*C*═	0.1200	—S	0.0100
ring[a]	0.1130	—F perfluoro	0.0568
Nonhydrocarbons		—F other	0.0510
—O—	0.0100	—Cl	0.0550
—OH primary[b]	0.0830	—Br	0.0415
—OH other	0.0680	—I	0.0245
>CO	0.0175	—H[c]	0.0675
>CHO	0.0730	3-ring	0.1500
—COO—	0.0070	other ring[d]	0.1100

Corrections for multigroup interactions

Hydrocarbons with 4 or fewer carbon atoms	[e]$0.0150(5 - nC)$
Single CH_3 group + nonhydrocarbon groups other than COOH, Br, I[f]	0.0600
Two hydrocarbon + nonhydrocarbon groups other than COOH, Br, I[f]	0.0285
Unsaturated aliphatic compounds with three hydrocarbon groups	0.0285
Special groups $Cl(CH_2)_nCl$	0.0350
More than one nonhydrocarbon group with hydrocarbon groups	0.0095
Nonhydrocarbon groups but no hydrocarbon groups	0.1165

[a]All rings are treated as separate rings in polycyclic compounds.
[b]Used only for aliphatic primary alcohols and phenols having no branch chains.
[c]Used in methane, formic acid, formates, etc.
[d]Used for all rings in polycyclic compounds with at least one nonhydrocarbon ring.
[e]The number of carbon atoms is *nC*.
[f]Aliphatic nonhydrocarbon liquids such as methylformate, aceticanhydride, and ethylformate, having more than one type of nonhydrocarbon group and (1) one or two methyl groups or (2) one ethyl group only, require two correction factors. One is due to the hydrocarbon groups, and one is due to the presence of more than one type of nonhydrocarbon group
*SOURCE: Sastri, S. R. S., and K. K. Rao, *Chem. Eng. J.*, **74** (1999): 161.

Example Estimate the thermal conductivity of liquid methyl formate at 323 K.
Molecular structure:



Group contributions from Table 2-359:

Group	n_i	Δki	$n_i \Delta k_i$
—CH_3	1	0.0545	0.0545
—COO—	1	0.0070	0.0070
—H	1	0.0675	0.0675
Corrections for multigroup interactions			
Single CH3 group + nonhydrocarbon groups			0.0600
More than one nonhydrocarbon with hydrocarbon groups			0.0095
		Total	0.1985

Required input properties from DIPPR® 801 recommended values:

$T_c = 487.2$ K $\quad T_b = 304.9$ K

$T_r = T/T_c = 323/487.2 = 0.6630 \quad T_{br} = 304.9/487.2 = 0.6258$

From Eq. (2-109):

$\alpha = 0.16 \quad \gamma = 0.2$ (nonalcohol values)

$$\beta = 1 - \left(\frac{1 - 0.633}{1 - 0.6257}\right)^{0.2} = 0.0207 \qquad k_b = 0.1985 \text{ W/(m·K)}$$

$$k = [0.1985 \text{ W/(m·K)}]\,(0.16)^{0.0207} = 0.1911 \text{ W/(m·K)}$$

The estimated value is 10.2 percent above the DIPPR® 801 recommended value of 0.1734 W/(m·K).

Recommended Method Missenard method.
Reference: Missenard, A., *Comptes Rendus*, **260** (1965): 5521.
Classification: Corresponding states.
Expected uncertainty: 20 percent.
Applicability: Organic compounds; nonassociating.
Input data: T_c, m (number of atoms in molecule), ρ_{273} (liquid density at 273.15 K), T_b, M, $C_{p,273}$ (liquid heat capacity at 273.15 K).
Description:

$$\frac{k_{273}}{\text{mW/(m·K)}} = \frac{8.4}{m^{1/4}} \cdot \left(\frac{T_b}{\text{K}}\right)^{1/2} \left(\frac{\rho_{273}}{\text{g/m}^3}\right)^{1/2} \left(\frac{M}{\text{g/mol}}\right)^{-1/2} \times \left[\frac{C_{p,273}}{\text{J/(mol·K)}}\right] \tag{2-110}$$

$$k = \frac{k_{273}[3 + 20(1 - T_r)^{2/3}]}{3 + 20(1 - T_{r,273})^{2/3}} \tag{2-111}$$

where $T_{r,273} = (273 \text{ K})/T_c$.

Example Estimate the thermal conductivity of *m*-xylene at 350 K.
Required properties from DIPPR® 801 database:

$T_c = 617$ K $\quad m = 18 \quad \rho_{273} = 7.6812$ kmol/m^3

$T_b = 412.27$ K $\quad M = 106.165$ kg/kmol $\quad C_{p,273} = 200.64$ kJ/(kmol·K)

Auxiliary properties:

$T_r = 350/617 = 0.5673 \quad T_{br} = 412.27/617 = 0.6682$

$T_{r,273} = 273/617 = 0.4425$

From Eq. (2-110):

$$\left(\frac{k_{273}}{\text{mW/(m·K)}}\right) = (8.4)(412.27)^{1/2}(0.007681)^{1/2}(106.165)^{-1/2}(200.64)(18)^{-0.25} = 141.3$$

From Eq. (2-111):

$$k = \frac{k_{273}[3 + 20(1 - T_r)^{2/3}]}{3 + 20(1 - T_{r,273})^{2/3}} = \frac{\left(141.3 \dfrac{\text{mW}}{\text{m·K}}\right)[3 + 20(1 - 0.5673)^{2/3}]}{3 + 20\,(1 - 0.4425)^{2/3}}$$

$$= 123.3 \frac{\text{mW}}{\text{m·K}}$$

The estimated value is 4.5 percent above the DIPPR® 801 recommended value of 118.0 mW/(m·K).

Liquid Mixtures The thermal conductivity of liquid mixtures generally shows a modest negative deviation from a linear mass-fraction-weighted average of the pure-component values. Although more complex methods with some improved accuracy are available, two simple methods are recommended here that require very little additional information. The first method applies only to binary mixtures while the second can be used for multiple components.

Recommended Method Filippov correlation.
References: Filippov, L. P., *Vest. Mosk. Univ., Ser. Fiz. Mat. Estestv. Nauk*, **10** (1955): 67; Filippov, L. P., and N. S. Novoselova, Sugden, *Vest. Mosk. Univ., Ser. Fiz. Mat. Estestv. Nauk*, **10** (1955): 37.
Classification: Empirical correlation.
Expected uncertainty: 4 to 8 percent.
Applicability: Binary liquid mixtures.
Input data: Pure-component thermal conductivities k_i at mixture conditions; w_i.
Description: The mixture thermal conductivity is calculated from the pure-component values using

$$k = w_1 k_1 + w_2 k_2 - 0.72 w_1 w_2 |k_2 - k_1| \tag{2-112}$$

where w_i is the mass fraction of pure fluid *i*.

Recommended Method Li correlation.
References: Li, C. C., *AIChE J.*, **22** (1976): 927.
Classification: Empirical correlation.
Expected uncertainty: 4 to 8 percent.
Applicability: Liquid mixtures.
Input data: Pure-component thermal conductivities k_i at mixture conditions; $\rho_{L,i}$
Description: The mixture thermal conductivity is correlated as a function of the mixture volume fractions ϕ_i:

$$k = \sum_{i=1}^{C} \sum_{j=1}^{C} \phi_i \phi_j \frac{2k_i k_j}{k_i + k_j} \tag{2-113}$$

$$\text{where } \phi_i = \frac{x_i \rho_{L,i}^{-1}}{\sum_{j=1}^{C} x_j \rho_{L,j}^{-1}}$$

Example Estimate the thermal conductivity of a mixture containing 30.2 mol % diethyl ether(1) and 69.8 mol % methanol(2) at 273.15 K and 0.1 MPa, using the Filippov and Li correlations.
Auxiliary data: The pure-component thermal conductivities and molar densities at 273.15 K recommended in the DIPPR® 801 database are

$k_1 = 0.1383$ W/(m·K) $\quad \rho_1 = 9.9335$ kmol/m^3 $\quad M_1 = 74.1216$ kg/kmol

$k_2 = 0.2069$ W/(m·K) $\quad \rho_2 = 25.371$ kmol/m^3 $\quad M_2 = 32.0419$ kg/kmol

The mass fractions corresponding to the mole fractions given above are

$w_1 = 0.5 \quad w_2 = 0.5$

The volume fractions are

$$\phi_1 = \frac{(0.302)(9.9335)^{-1}}{(0.302)(9.9335)^{-1} + (0.698)(25.371)^{-1}} = 0.525 \qquad \phi_2 = 0.475$$

Calculation using Eq. (2-112):

$$k = [(0.5)(0.1383) + (0.5)(0.2069) - (0.72)(0.5)(0.5)|0.2069 - 0.1383|]\ \frac{\text{W}}{\text{m·K}}$$

$$= 0.160\ \text{W/(m·K)}$$

Calculation using Eq. (2-113):

$$k = \left[(0.525)^2(0.1383) + 2\cdot\frac{(0.525)(0.475)(2)(0.1383)(0.2069)}{0.1383 + 0.2069} + (0.475)^2(0.2069)\right]\frac{\text{W}}{\text{m·K}}$$

$$= 0.167\ \text{W/(m·K)}$$

The Filippov value is 7.5 percent lower than the experimental value of 0.173 W/(m·K) [Jamieson, D. T., and B. K. Hastings, *Thermal Conductivity, Proceedings of the Eighth Conference,* C. Y. Ho and R. E. Taylor, eds., Plenum Press, New York, 1969]; the Li value is 3.5 percent lower than the experimental value.

Solids There is no reliable method for estimating solid thermal conductivity at this time.

SURFACE TENSION

The surface layer at a vapor-liquid interface is in tension and will contract to minimize the surface area. Qualitatively, the surface tension is due to the larger attractive forces that molecules at the interface experience from molecules in the dense liquid phase than from those in the low-density gas phase. Quantitatively, *surface tension* is defined as the force in the surface plane per unit length. Jasper [Jasper, J. J., *J. Phys. Chem. Ref. Data*, **1** (1972): 841] has made a critical evaluation of experimental surface tension data for approximately 2200 pure chemicals and correlated surface tension σ (mN/m = dyn/cm) with temperature as

$$\sigma = A - BT$$

Jasper's evaluation also includes values of A and B for most of the tabulated chemicals. Surface tension decreases with increasing temperature and increasing pressure.

Pure Liquids An approach suggested by Macleod [Macleod, D. B., *Trans. Faraday Soc.*, **19** (1923): 38] and modified by Sugden [Sugden, S. J., *Chem. Soc.*, **125** (1924): 32] relates σ to the liquid and vapor *molar* densities and a temperature-independent parameter called the parachor **P**

$$\frac{\sigma}{\text{mN/m}} = \left[\mathbf{P}\cdot\left(\frac{\rho_L - \rho_V}{10^3\ \text{kmol/m}^3}\right)\right]^4 \qquad (2\text{-}114)$$

where ρ_L and ρ_V are the saturated molar liquid and vapor densities, respectively. At low temperatures, where $\rho_L >> \rho_V$, the vapor density can be neglected, but at higher temperatures the density of both phases must be calculated. At the critical point the surface tension is zero as $\rho_L = \rho_V$. Quayle [Quayle, O. R., *Chem. Rev.*, **53** (1953): 439] proposed a group contribution method for estimating **P** that has been improved in recent years by Knotts et al. [Knotts, T. A., et. al., *J. Chem. Eng. Data*, **46** (2001): 1007]. This method using **P** is recommended when groups are available; otherwise, the Brock-Bird [Brock, J. R., and R. B. Bird, *AIChE J.*, **1** (1955): 174] corresponding-states method as modified by Miller [Miller, D. G., *Ind. Eng. Chem. Fundam.*, **2** (1963): 78] may be used to estimate surface tension for compounds that are not strongly polar or associating.

Recommended Method Parachor method.

References: Macleod, D. B., *Trans. Faraday Soc.*, **19** (1923): 38; Sugden, S. J., *Chem. Soc.*, **125** (1924): 32; Knotts, T. A., et al., *J. Chem. Eng. Data*, **46** (2001): 1007.

Classification: Group contributions and QSPR.

Expected uncertainty: 4 percent.

Applicability: Organic compounds for which group values are available.

Input Data: ρ_L, molecular structure, and Table 2-360.

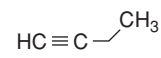
Description: Equation (2-114) is used with **P** calculated from

$$\mathbf{P} = \sum_{i=1}^{N} n_i\,\Delta\mathbf{P}_i \qquad (2\text{-}115)$$

Group values for the parachor are given in Table 2-360.

Example Estimate the surface tension of ethylacetylene at 237.45 K.

Structure:



Group	n_i	$\Delta\mathbf{P}_i$	$n_i\,\Delta\mathbf{P}_i$
≡ CH	1	43.64	43.64
≡ C—	1	28.64	28.64
>CH_2 (n = 1–11)	1	39.92	39.92
CH_3	1	55.25	55.25
		Total	167.45

Required properties: The DIPPR® 801 database gives $\rho_L = 13.2573$ kmol/m^3 at 237.45 K.

Calculation using Eq. (2-114):

$$\sigma = \left[(167.45)\left(\frac{13.2573}{1000}\right)\right]^4\ \frac{\text{mN}}{\text{m}} = 0.02429\ \frac{\text{N}}{\text{m}}$$

The estimated value is 0.9 percent above the DIPPR® 801 recommended value of 0.02407 N/m.

Recommended Method Brock-Bird method.

Reference: Brock, J. R., and R. B. Bird, *AIChE J.*, **1** (1955): 174; Miller, D. G., *Ind. Eng. Chem. Fundam.*, **2** (1963): 78.

Classification: Corresponding states.

Expected uncertainty: 5 percent.

Applicability: Nonpolar and moderately polar organic compounds.

Input data: T_c, P_c, and T_b.

Description:

$$\frac{\sigma}{\text{mN/m}} = (5.553\times10^{-5})\left(\frac{P_c}{\text{Pa}}\right)^{2/3}\left(\frac{T_c}{\text{K}}\right)^{1/3}F(1-T_r)^{11/9} \qquad (2\text{-}116)$$

where

$$F = \frac{T_{br}[\ln(P_c/\text{Pa}) - 11.5261]}{1 - T_{br}} - 1.3281 \qquad (2\text{-}117)$$

Example Estimate the surface tension for ethyl mercaptan at 303.15 K.

Required properties from DIPPR® 801:

$T_c = 499.15$ K $\quad P_c = 5.49\times10^6$ Pa $\quad T_b = 308.15$ K

Supporting quantities:

$T_r = (303.15\ \text{K})/(499.15\ \text{K}) = 0.6073$

$T_{br} = (308.15\ \text{K})/(499.15\ \text{K}) = 0.6173$

$F = \{0.6173[\ln(5.49\times10^6) - 11.5261]/(1 - 0.6173)\} - 1.3281 = 5.113$

[from Eq. (2-117)]

From Eq. (2-116):

$$\sigma = (5.553\times10^{-5})(5.49\times10^6)^{2/3}(499.15)^{1/3}(5.113)(1-0.6073)^{11/9}\ \text{mN/m}$$

$$= 22.36\ \text{mN/m}$$

The estimated value is 1.4 percent lower than the DIPPR® 801 recommended value of 22.68 mN/m.

TABLE 2-360 Knotts* Group Contributions for the Parachor in Estimating Surface Tension

Group	ΔP_i	Group	ΔP_i
(a) Nonring C		**(e) Nitrogen groups**	
—CH_3	55.25	R—NH_2 (primary R)	44.98
>CH_2 (n = 1–11)	39.92	R—NH_2 (sec R)	44.63
>CH_2 (n = 12–20)	40.11	R—NH_2 (tert R)	46.44
>CH_2 (n > 20)	40.51	A—NH_2 (attached to arom ring)	46.53
>CH—	28.90	>NH (nonring)	29.04
>C<	15.76	>NH (ring)	31.97
═CH_2	49.76	>NH (in arom ring)	33.92
═CH—	34.57	>N- (nonring)	10.77
═C<	24.50	>N- (ring)	15.71
═C═	24.76	—N═ (nonring)	23.24
≡CH	43.64	>N (aromatic)	26.49
≡C—	28.64	HC≡N (hyd cyanide)	80.94
Branch corrections		—C≡N	65.23
Per branch	–6.02	—C≡N (aromatic)	67.54
sec-sec adjacency	–2.73	**(f) Nitrogen and oxygen groups**	
sec-tert adjacency	–3.61	—C═ONH_2 (amides)	93.43
tert-tert adjacency	–6.10	—C═ONH- (amides)	73.64
(b) Nonaromatic ring C		—C═ON< (amides)	57.05
—CH_2—	39.21	—NHCHO	91.69
>CH—	23.94	>NCHO	77.12
>C<	7.19	—N═O	64.32
═CH—	34.07	—NO_2	73.86
═C<	18.85	—NO_2 (aromatic)	75.05
>CH— (fused ring)	22.05	**(g) Sulfur groups**	
Ring corrections		R-SH (primary R)	66.89
Three-member ring	12.67	R-SH (sec R)	63.34
Four-member ring	15.76	R-SH (tert R)	65.33
Five-member ring	7.04	—SH (aromatic)	68.30
Six-member ring	5.19	—S— (nonring)	51.37
Seven-member ring	3.00	—S— (ring)	51.75
(c) Aromatic ring C		—S— (aromatic)	51.47
>CH	34.36	>S═O (nonring)	72.21
>C—	16.07	>SO_2 (nonring)	93.20
—C— (fused arom/arom)	19.73	>SO_2 (ring)	90.13
—C— (fused arom/aliph)	14.41	**(h) Halogen groups**	
Arom ring corr		—F	21.81
ortho	–0.60	—Cl	26.24
para	3.40	—Br	51.16
meta	2.24	—I	54.56
subst. naphthalene corr	–7.07	—F (aromatic)	66.30
(d) Oxygen groups		—Cl (aromatic)	70.39
—OH (alc, primary)	31.42	—Br (aromatic)	90.84
—OH (alc, sec)	22.68	—I (aromatic)	92.04
—OH (alc, tertiary)	20.66	**(i) Si groups**	
—OH (phenol)	30.32	SiH_4	105.11
—O— (nonring)	20.61	>SiH—	54.50
—O— (ring)	21.67	>Si<	44.93
—O— (aromatic)	23.54	>Si< (ring)	28.64
>C═O (nonring)	47.02	**(j) Other inorganic groups**	
>C═O (ring)	50.04	—PO_4	115.59
O═CH— (aldehyde)	66.06	>P—	48.84
CHOOH (formic)	94.01	>B—	22.65
—COOH (acid)	74.57	>Al—	25.06
—OCHO (formate)	82.29	—ClO_3	106.03
—COO— (ester)	64.97		
—COOCO— (acid anhyd)	115.07		
—OC(═O)O— (ring)	84.05		

*Knotts, T. A., et al., *J. Chem. Eng. Data*, **46** (2001): 1007.

Liquid Mixtures Compositions at the liquid-vapor interface are not the same as in the bulk liquid, and so simple (bulk) composition-weighted averages of the pure-fluid values do not provide quantitative estimates of the surface tension at the vapor-liquid interface of a mixture. The behavior of aqueous mixtures is more difficult to correlate and estimate than that of nonpolar mixtures because small amounts of organic material can have a pronounced effect upon the surface concentrations and the resultant surface tension. These effects are usually modeled with thermodynamic methods that account for the activity coefficients. For example, a UNIFAC method [Suarez, J. T. C. Torres-Marchal, and P. Rasmussen, *Chem. Eng. Sci.,* **44** (1989): 782] is recommended and illustrated in PGL5. For nonaqueous systems the extension of the parachor method, used above for pure fluids, is a simple and reasonably effective method for estimating σ for mixtures.

Recommended Method Parachor correlation.

Reference: Hugill, J. A., and A. J. van Welsenes, *Fluid Phase Equil.,* **29** (1986): 383; Macleod, D. B., *Trans. Faraday Soc.*, **19** (1923): 38; Sugden, S. J., *Chem. Soc.*, **125** (1924).

Classification: Corresponding states.

Expected uncertainty: 3 to 10 percent.

Applicability: Nonaqueous mixtures.

Input data: Liquid and vapor ρ at mixture T; parachors of pure components; x_i.

Description:

$$\frac{\sigma_m}{\text{mN/m}} = \left(\mathbf{P}_{L,m} \frac{\rho_{L,m}}{10^3 \text{kmol/m}^3} - \mathbf{P}_{V,m} \frac{\rho_{V,m}}{10^3 \text{kmol/m}^3} \right)^4 \qquad (2\text{-}118)$$

where σ_m = surface tension of the mixture

$\mathbf{P}_{L,m}$ = parachor of liquid mixture

$\mathbf{P}_{V,m}$ = parachor of vapor mixture

$\rho_{L,m}$ = liquid mixture molar density

$\rho_{V,m}$ = vapor mixture molar density

The following definitions are used for the liquid and vapor mixture parachors:

$$P_{L,m} = \frac{1}{2}\sum_{i=1}^{C}\sum_{j=1}^{C} x_i x_j (\mathbf{P}_i + \mathbf{P}_j) \qquad \mathbf{P}_{V,m} = \frac{1}{2}\sum_{i=1}^{C}\sum_{j=1}^{C} y_i y_j (\mathbf{P}_i + \mathbf{P}_j) \quad (2\text{-}119)$$

where x_i is the mole fraction of component i in the liquid and y_i is the mole fraction of component i in the vapor.

Note that ρ_V is generally very small compared to ρ_L at temperatures substantially lower than T_c and can often be neglected.

Example Estimate the surface tension for a 16.06 mol % *n*-pentane(1) + 83.94 mol % dichloromethane(2) mixture at 298.15 K.

Required properties from DIPPR® 801:

	P	ρ_L/(kmol·m^{-3}) at 298.15 K
n-Pentane	231.1	8.6173
Dichloromethane	146.6	15.5211

Mixture parachor from Eq. (2-119) and mixture density:

$$\mathbf{P}_{L,m} = (0.1606)^2(231.1) + (0.1606)(0.8394)(231.1 + 146.6) + (0.8394)^2(146.6) = 160.17$$

$$\rho_{L,m} = \left(\sum_{i=1}^{C}\frac{x_i}{\rho_i}\right)^{-1} = \left(\frac{0.1606}{8.6173} + \frac{0.8394}{15.5211}\right)^{-1}\frac{\text{kmol}}{\text{m}^3} = 13.752\,\frac{\text{kmol}}{\text{m}^3}$$

Calculation using Eq. (2-118): Because the temperature is low, the density of the vapor can be neglected, and

$$\frac{\sigma_m}{\text{mN/m}} = [(160.17)(0.013752)]^4 = 23.54\,\frac{\text{mN}}{\text{m}}$$

The estimated value is 2.9 percent below the experimental value of 24.24 mN/m reported by De Soria et al. [De Soria, M. L. G., et al., *J. Colloid Interface Sci.*, **103** (1985): 354].

FLAMMABILITY PROPERTIES

Flash points, lower and upper *flammability limits*, and *autoignition temperature* are important properties for determining safe operating limits when processing organic compounds. As with any property, experimental values are preferable to predicted values, and prediction techniques for these properties are only modestly accurate.

The flash point is the lowest temperature at which a liquid gives off sufficient vapor to form an ignitable mixture with air near the surface of the liquid or within the vessel used. ASTM test methods include procedures using a closed-cup apparatus (ASTM D 56, ASTM D 93, and ASTM D 3828), which is preferred, and an open-cup apparatus (ASTM D 92 and ASTM D 1310). Closed-cup values are typically lower than open-cup values. When several values are available, the lowest reasonable temperature is usually accepted in order to ensure safe operations.

The lower and upper flammability limits are the boundary-line equilibrium mixtures of vapor or gas with air, which if ignited will just propagate a flame away from the ignition source. Each of these limits has a temperature at which the flammability limits are reached. The lower flammability limit temperature corresponds approximately to the flash point, but since the flash point is determined with downward flame propagation and nonuniform mixtures and the lower flammability temperature is determined with upward flame propagation and unifrom vapor mixtures, the measured lower flammability temperature is often somewhat lower than the flash point.

The autoignition temperature is the minimum temperature for a substance to initiate self-combustion in air in the absence of an ignition source.

Recommended Methods Flash point: Thornton method.

Reference: As described by N. Y. Shebeko, A. V. Ivanov, and E. N. Alekhina, "Calculation of Flash Points and Ignition Temperatures of Organic Compounds," *Soviet Chem. Ind.* **16**(1984):1371.

Classification: Atomic contributions.

Expected uncertainty: 5 K.

Applicability: Organic compounds.

Input data: Number of carbon, hydrogen, sulfur, halogen, and oxygen atoms; vapor pressure correlation.

Description: A simple atom contribution method is given by

$$P^* - \frac{P_{sys}}{1 + 4.76(2\beta - 1)} = 0 \quad (2\text{-}120)$$

where P^* = vapor pressure at flash point temperature

P_{sys} = total system pressure, typically 1.01325×10^5 Pa

β = stoichiometric coefficient, defined by

$$\beta = N_C + N_S + \frac{N_H - N_X}{4} - \frac{N_O}{2} \quad (2\text{-}121)$$

where N_C = number of carbon atoms in compound

N_S = number of sulfur atoms in compound

N_H = number of hydrogen atoms in compound

N_X = number of halogen atoms in compound

N_O = number of oxygen atoms in compound

Procedure:

Step 1. Determine the number of carbon, sulfur, hydrogen, halogen, and oxygen atoms in the compound.

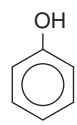
Step 2. Calculate β from Eq. (2-121).

Step 3. Substitute a temperature-dependent expression for vapor pressure in Eq. (2-120) for P^*.

Step 4. Solve Eq. (2-120) for temperature. This temperature is the flash point estimate.

Example Estimate the flash point of phenol.

Structure:



Atomic contributions:

Atom type	Number
C	6
H	6
O	1

$$\beta = 6 + \frac{6}{4} - \frac{1}{2} = 7$$

The DIPPR® 801 correlation for the vapor pressure of phenol is

$$P^* = \exp\left(95.444 - \frac{10{,}113}{T} - 10.09\ln T + 6.7603 \times 10^{-18}T^6\right)$$

When this expression is used in Eq. (2-120) and solved for temperature, one obtains T_{FP} = 348.7 K, which is 1.2 percent below the DIPRR recommended value of 353 K.

Recommended Method Flammability limits: Pintar method.

Reference: Pintar, A. J., Technical Support Document DIPPR Project 912, Michigan Technological University, Houghton, 1996.

Classification: Group contributions.

Expected uncertainty: 25 percent.

TABLE 2-361 Group Contributions for Pintar* Flammability Limits Method for Organic Compounds

Group	LFL_i	UFL_i	Group	LFL_i	UFL_i
—CH_3	17.2750	3.8461	>NH	3.2709	–1.9112
>CH_2	13.7022	1.4959	—N═	–7.2149	–2.3309
>CH—	10.0000	0.2183	—CN	8.0990	3.6918
>C<	5.5291	–0.8422	═C═N—	2.5963	–1.1463
—H	2.7250	2.8206	═N—NH_2	–3.5071	–0.29897
—OH	2.1797	0.5856	>N—NH_2	0.5861	2.4811
—O—	–3.0156	–2.2427	—NO_2	–3.1507	0.8011
—O—O—	–6.0312	–4.4854	—SH	7.9424	0.5344
═C═O	4.6752	0.6009	—S—	11.0079	–1.9832
—CHO	10.3801	–1.2148	—SO—	3.9115	–4.1834
—COOH	4.8890	1.6121	—SO_2—	5.5400	—
—COO—	1.2955	–1.1840	—SO_3—	2.8600	—
—CO—O—CO—	4.6740	2.4751	—SO_4—	0.1800	—
—C_6H_5	73.8338	9.6661	—CO_3—	2.4103	–3.4894
m-C_6H_4	57.4447	7.6126	—OPO_2—	7.1419	—
o-C_6H_4	57.4447	7.2450	—P═	47.6909	—
p-C_6H_4	57.4447	7.9291	—PO—	7.1515	—
Arom. ring	45.0633	–5.9925	—PO_4═	–11.5096	–6.0260
═	4.2821	2.0269	Si—C†	–2.2855	–3.0576
≡	17.5470	0.7842	Si—O†	2.5034	1.4282
—Cl	–2.9697	1.4008	Si—H†	8.3130	–24.4160
—Cl_2	–5.9764	3.1943	Si—Cl†	4.1010	9.7131
—Cl_3	–8.0982	4.2024	Si—N†	15.8960	1.6577
—F	–1.2615	0.3984	Si—Si	—	—
—F_2	–2.1224	0.6847	Al	—	—
—F_3	–5.1300	1.1952	B	47.3806	—
—Br	–8.0405	4.0018	Cr	—	—
—Br_2	–16.0809	8.0036	Na	—	—
—Br_3	–21.9000	12.0054	*cis*	–6.8350	1.8040
—I	–22.0000	11.4300	*trans*	0.5821	0.9183
—I_2	–44.0000	22.8600	Nonarom·ring	2.9082	3.7760
—I_3	–60.0000	34.2900	Add'l·ring	14.2712	3.1127
—NH_2	3.7078	1.8802			

*Pintar, A. J., Technical Support Document DIPPR Project 912, Michigan Technological University, Houghton, 1996.
†Does not include contribution of atoms attached to silicon.

TABLE 2-362 Group Contributions for Pintar* Flammability Limits Method for Inorganic Compounds

Group	LFL_i	UFL_i	Group	LFL_i	UFL_i
B	24.5190	–1.3818	>N—NH_2	0.5861	–0.2990
Br	—	—	O	–24.3242	2.2990
C	32.0745	–0.6259	P	24.8302	—
Cl	14.2658	–1.4231	S	26.6776	1.3171
F	—	—	Si—C†	–2.2855	–3.0576
Fe	—	—	Si—O†	2.5034	1.4282
H	10.3452	0.6500	Si—H†	8.3130	–24.4160
N	–24.5487	1.8453	Si—Cl†	4.1010	9.7131
Na	—	—	Si—N†	15.8960	1.6577
Ni	—	—	Si—Si	—	—

*Pintar, A. J., Technical Support Document DIPPR Project 912, Michigan Technological University, Houghton, 1996.
†Does not include contribution of atoms attached to silicon.

Applicability: Organic and inorganic compounds.
Input data: Group contributions from Tables 2-361 and 2-362.
Description: A simple GC method with first-order contributions with lower flammability limit (LFL) and upper flammability limit (UFL) in volume % given by

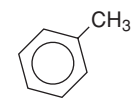
$$LFL = \frac{100\%}{\sum n_i LFL_i} \tag{2-122}$$

$$UFL = \frac{100\%}{\sum n_i UFL_i} \tag{2-123}$$

where n_i = number of groups of type i in molecule
LFL_i = contribution of group i to LFL
UFL_i = contribution of group i to UFL

Example Estimate the lower and upper flammability limits of toluene.

Structure:



Group contributions:

Group	LFL	UFL
—CH_3	17.2750	3.8461
—C_6H_5	73.8338	9.6661

Calculations using Eqs. (2-122) and (2-123):

$$LFL = \frac{100\%}{17.2750 + 73.8338} = 1.10\%$$

$$UFL = \frac{100\%}{3.8461 + 9.6661} = 7.40\%$$

TABLE 2-363 Group Contributions for Pintar*Autoignition Temperature Method for Organic Compounds

Group	b_i	Group	b_i	Group	b_i
—CH_3	301.91	—Cl_3	1073.47	—SO_3—	—
>CH_2	–10.86	—F	360.60	—SO_4—	–31.71
>CH—	–275.17	—F_2	755.54	—CO_3—	442.26
>C<	–570.43	—F_3	1082.00	—P═	–334.91
—H	391.48	—Br	420.96	—PO—	–549.59
—OH	324.10	—Br_2	607.69	—OPO_2—	—
—O—	–18.60	—Br_3	1260.00	—PO_4═	–329.45
—O—O—	–397.61	—I	310.53	Si—C†	–147.69
═C═O	57.65	—I_2	—	Si—O†	–136.99
—CHO	195.20	—I_3	—	Si—H†	–310.52
—COOH	370.75	—NH_2	354.11	Si—Cl†	–200.88
—COO—	43.90	>NH	9.88	Si—N†	—
—CO—O—CO—	46.11	—N═	–249.91	Si—Si	—
—C_6H_5	380.27	—CN	469.67	Al	—
m—C_6H_4	153.15	═C═N—	–273.70	B	—
o—C_6H_4	77.48	═N—NH_2	378.27	Cr	—
p—C_6H_4	99.87	>N—NH_2	–215.02	Na	534.29
Aromatic ring	–1339.65	—NO_2	292.57	*cis*	–29.19
═	578.72	—SH	273.84	*trans*	–38.31
≡	1116.50	—S—	–60.75	Nonarom.ring	605.97
—Cl	347.39	—SO—	–91.10	Add'l.ring	565.11
—Cl_2	726.03	—SO_2—	—	Zn	349.02

*Pintar, A. J., *Estimation of Autoignition Temperature,* Technical Support Document DIPPR Project 912, Michigan Technological University, Houghton, 1996.
†Does not include contribution of atoms attached to silicon.

TABLE 2-364 Group Contributions for Pintar*Autoignition Temperature Method for Inorganic Compounds

Group	b_i	Group	b_i	Group	b_i
B	–457.14	N	0.71	Si—C†	–147.69
Br	—	Na	—	Si—O†	–136.99
C	489.19	Ni	–1595.10	Si—H†	–310.52
Cl	395.42	>N—NH_2	–215.02	Si—Cl†	–200.88
F	—	O	–13.39	Si—N†	—
Fe	–2050.90	P	108.45	Si—Si	—
H	204.55	S	–3.57		

*Pintar, A. J., *Estimation of Autoignition Temperature,* Technical Support Document DIPPR Project 912, Michigan Technological University, Houghton, 1996.
†Does not include contribution of atoms attached to silicon.

The values recommended in the DIPPR® 801 database are 1.2 and 7.1 percent, respectively.

Flammability temperatures are found by determining the temperature at which the vapor pressure equals the partial pressure corresponding to the LFL or UFL.

Recommended Methods Autoignition temperature: Pintar method.

Reference: Pintar, A. J., *Estimation of Autoignition Temperature,* Technical Support Document DIPPR Project 912, Michigan Technological University, Houghton, 1996.

Classification: Group contributions.

Expected uncertainty: 25 percent.

Applicability: Organic and inorganic compounds.

Input data: Group contributions from Tables 2-363 and 2-364.

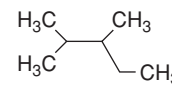
Description: A simple GC method with first-order contributions is given by

$$\text{AIT} = \sum n_i b_i \qquad (2\text{-}124)$$

where n_i is the number of groups of type i in the molecule and b_i is the contribution of group i to the autoignition temperature. A more accurate but somewhat more complicated logarithmic GC method was also developed by Pintar in the same reference cited here.

Example Estimate the autoignition temperature of 2,3-dimethylpentane.

Structure and group information:



Group	n_i	b_i
—CH_3	4	301.91
>CH_2	1	–10.86
>CH—	2	–275.17

Calculation using Eq. (2-124):

$$\text{AIT} = 4(301.91) - 10.86 + 2(-275.17) = 646.4 \text{ K}$$

The estimated value is 6.3 percent above the DIPPR® 801 recommended value of 608.15 K.

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