B.1 UNIT CONVERSION FACTORS

Listed below are some of the more commonly used conversion factors.

Mass

1 pound (lb) = 7,000 grains = 16.0 ounces (oz)
= 453.5924 grams (g)

Length

1 foot (ft) = 12.0 inches (in)
= 30.480 centimeters (cm) = 0.30480 meters (m)

Temperature

°C = (°F −32)/1.8
K = °C + 273.15
K = °R/1.8
°F = 1.8(°C) + 32
°R = °F + 459.67
°R = 1.8(K)

Volume

1 cubic foot (ft^3) = 7.48052 gallons (gal) = 1,728 cubic inches
= 0.1781076 barrels (42 U.S. gal) of oil (bbl)
= 28.31685 liters (L) = 0.02831685 cubic meters (m^3)

Density

1 lb_m/ft^3 = 0.1336806 lb_m/gal
= 0.01601846 g/cm^3 = 16.01846 kg/m^3

Force

1 pound (lb_f) = 4.448 $\times 10^5$ dyne (dyn) = 4.448222 Newtons (N)

Pressure

1 atmosphere (atm) = 1.01325 bar = 14.696 lb_f/in^2 = 760 mm Hg (at 32°F)
= 1.013250 $\times$ 10^5 Pascal (Pa)

Energy

1 British Thermal Unit (Btu) (IT) = 252.1644 cal (tc) = 3.930148 $\times$ 10^{-4} hp
= 1.055056 $\times$ 10^3 joules (J) = 2.930711 $\times$ 10^{-4} kWh
(1 Btu [IT] = 1.00067 Btu [tc])
(Note: Customarily the Btu refers to the International Steam Table [IT] Btu, and the calorie refers to the thermochemical calorie [tc])

Flow

1 gal/min = 0.1336805 ft^3/min = 1.42857 bbl/h = 6.309020 $\times$ 10^{-5} m^3/s

Power

1 hp (US) = 2544.433 Btu (IT)/h = 550 ft lb_f/s = 745.6999 watts (W)

Specific Energy per Degree

1 Btu/lb_m-°F (IT) = 1.0 cal/g-°C (IT) = 4.186800 kJ/kg-K

B.2 GAS CONSTANTS AND STANDARD GAS CONDITIONS

B.2.1 Universal Gas Constants

Metric/SI Units

8.31441 J/(mol-K)
1.98719 cal/(mol-K)
82.0568 cm^3-atm/(mol-K)
62.3633 L-mm/(mol-K)
0.0820568 L-atm/(mol-K)
8.31441 m^3-Pa/(mol-K)
8.31441×10^{-5} m^3-bar/(mol-K)
0.0831441 L-bar/(mol-K)

Engineering and Mixed Units

1.98585 Btu/(lb-mol-°R)
0.730235 atm-ft^3/(lb-mol-°R)
0.739911 bar-ft^3/(lb-mol-°R)
1545.34 ft-lb_f/(lb-mol-°R)
10.7315 psi ft^3/(lb-mol-°R)

B.2.2 Standard Gas Conditions

Gas volumes given are for ideal gas only.

1. Normal: continental and scientific applications
   0°C, 1.01325 bar, gas volume = 22.4136 m^3/kg-mol
   32°F, 14.696 psia, gas volume = 359.031 ft^3/lb-mol
   (Nm^3 based upon these conditions)
2. Standard (scf): U.S. engineering applications
   15.5556°C, 1.01325 bar, gas volume = 23.6900 m^3/kg-mol
   60°F, 14.696 psia, gas volume = 379.49 ft^3/lb-mol
   (scf = standard cubic foot based upon these conditions)
3. Standard: API 2564, SI 15°C, 101.325 kPa, gas volume = 23.6444 m^3/kg-mol (Sm^3 based upon these conditions)

B.3 THERMODYNAMIC AND PHYSICAL PROPERTY DATA

B.3.1 Table of Physical Constants of Pure Fluids

Table B.1 provides some of the most useful physical constants for fluids encountered in natural gas processing. For additional properties the reader should consult GPA Standard 2145-03 (2005). The standard includes a number of notes regarding the data and data sources.

TABLE B.1
Physical Properties of Compounds Typically Seen in Gas Processing

Component	Methane	Ethane	Propane	Isobutane	n-Butane	Isopentane	n-Pentane
Molar mass	16.042	30.069	44.096	58.122	58.122	72.149	72.149
Boiling Point, °F (K)	–258.67 (111.67)	–127.48 (184.55)	–43.72 (231.08)	11.08 (261.53)	31.09 (272.64)	82.11 (300.99)	96.98 (309.25)
Freezing Point ,°F (K)	–296.45 (90.68)	–297.04 (90.35)	–305.73 (85.52)	–255.3 (113.54)	–217.05 (134.79)	–255.8 (113.26)	–201.5 (143.43)
Vapor Pressure at 100 °F (313.15K), psia (bar)	5000 (350)[a]	800 (55)[a]	188.69 (13.699)	72.484 (5.3012)	51.683 (3.7936)	20.456 (1.5136)	15.558 (1.1556)
Density of liquid							
Relative to water	0.3[a]	0.35643	0.50738	0.56295	0.58408	0.6246	0.63113
Density, lb/gal (kg/m^3)	2.5 (300)[a]	2.9716 (358)	4.2301 (507.67)	4.6934 (563.07)	4.8696 (584.14)	5.2074 (624.54)	5.2618 (631.05)
Density of ideal gas							
Relative density, air = 1.0	0.55397	1.0383	1.5227	2.0071	2.0071	2.4914	2.4914
Density lb/1000 ft^3 (kg/m^3)	42.274 (0.67848)	79.237 (1.2717)	116.2 (1.8649)	153.16 (2.4581)	153.16 (2.4581)	190.12 (3.0514)	190.12 (3.0514)
Volume of liquid							
gal/lb-mol (cm^3/mol)	6.417 (53.475)[a]	10.119 (83.992)	10.424 (86.859)	12.384 (103.22)	11.936 (99.501)	13.855 (115.52)	13.712 (114.33)
Critical conditions							
Temperature, °F (K)	–116.66 (190.56)	89.924 (305.33)	205.92 (369.77)	274.41 (407.82)	305.546 (425.12)	368.98 (460.36)	385.75 (469.68)
Pressure, psia (bar)	667 (45.99)	706.6 (48.72)	615.5 (42.44)	527.9 (36.40)	550.9 (37.98)	490.4 (33.81)	488.8 (33.70)

Gross heating value, ideal reaction							
Fuel as liquid Btu/lb, (MJ/kg)		22181 (51.594)	21490 (49.988)	21080 (49.033)	21136 (49.165)	20891 (48.594)	20923 (48.669)
Fuel as liquid, Btu/gal (MJ/m^3)		65914 (18471)	90905 (25377)	98935 (27609)	102926 (28719)	108789 (30349)	110094 (30712)
fuel as ideal gas, Btu/lb (MJ/kg)	23892 (55.576)	22334 (51.952)	21654 (50.37)	21232 (49.389)	21300 (49.547)	21044 (48.95)	21085 (49.046)
Fuel as ideal gas Btu/ft^3 (MJ/m^3)	1010 (37.707)	1769.7 (66.067)	2516.2 (93.936)	3252 (121.4)	3262.4 (121.79)	4000.9 (149.36)	4008.7 (149.66)
Btu/gal, fuel as ideal gas	59730	66369	91599	99652	103724	109584	110946
Net heating value, ideal reaction, fuel as ideal gas							
Btu/ft^3, (MJ/m^3)	909 (33.949)	1619 (60.429)	2315 (86.419)	3000 (112.01)	3011 (112.4)	3699 (138.09)	3707 (138.38)
Heat of vaporization at 14.696 psia (1.01325 bar)							
Btu/lb, kJ/kg	219.8 (511.3)	210.3 (489.2)	183.4 (426.7)	157.2 (365.6)	166.3 (386.9)	147.7 (343.7)	154.4 (359.2)
Flammability limits at 100 °F, 14.696 psia (313.15K, 1.01325 bar) in air, vol%							
Lower limit	5	2.9	2	1.8	1.5	1.3	1.4
Upper limit	15	13	9.5	8.5	9	8	8.3

[a] hypothetical value because liquid does not exist at stated condition

(continued)

TABLE B.1 (Continued)

Component	n-Hexane	n-Heptane	n-Octane	n-Nonane	n-Decane	Carbon Dioxide
Molar mass	86.175	100.202	114.229	128.255	142.282	44.01
Boiling point, °F (K)	155.72 (341.88)	209.13 (371.56)	258.21 (398.82)	303.4 (423.93)	345.4 (447.26)	−109.12 (194.75)
Vapor pressure at 100°F (313.15K), psia (bar)	4.961 (37.3)	1.62 (12.336)	0.5366 (4.1403)	0.17 (1.3488)	0.0616 (0.4876)	
Density of liquid						
Relative to water	0.66405 (0.66448)	0.68819 (0.6886)	0.70698 (0.70737)	0.72186 (0.72224)	0.73406 (0.73442)	0.82203 (0.82195)
Density, lb/gal (kg/m^3)	5.5363 (663.89)	5.7375 (687.98)	5.8942 (706.73)	6.0183 (721.59)	6.12 (733.76)	6.8534 (821.22)
Density of Ideal Gas						
Relative density, air = 1.0	2.9758	3.4601	3.9445	4.4289	4.9132	1.5197
Density lb/1,000 ft^3 (kg/m^3)	227.09 (3.6446)	264.05 (4.2378)	301.01 (4.831)	337.97 (5.4242)	374.93 (6.0174)	115.97 (1.8613)
Volume of liquid						
gal/lb-mol (cm^3/mol)	15.566 (129.8)	17.464 (145.65)	19.38 (161.63)	21.311 (177.74)	23.249 (193.91)	6.4216 (53.59)
Critical conditions						
Temperature, °F (K)	453.83 (507.5)	512.87 (540.3)	564.22 (568.8)	610.8 (594.7)	652.2 (617.7)	87.8 (304.1)
Pressure, psia (bar)	436.9 (3012)	396.8 (2736)	360.7 (2487)	330.7 (2280)	304.6 (2100)	1070 (7377)

Gross heating value, ideal reaction						
Fuel as liquid Btu/lb, (MJ/kg)	20783 (48.343)	20680 (48.104)	20601 (47.92)	20543 (47.785)	20494 (47.671)	
Fuel as liquid, Btu/gal (MJ/m^3)	115060 (32094)	118654 (33095)	121428 (33866)	123634 (34481)	125424 (34979)	
fuel as ideal gas, Btu/lb (MJ/kg)	20944 (48.717)	20839 (48.474)	20760 (48.289)	20701 (48.153)	20652 (48.038)	
Fuel as ideal gas Btu/ft^3 (MJ/m^3)	4756 (177.55)	5502.5 (205.42)	6248.9 (233.29)	6996.4 (261.19)	7743 (289.06)	
Btu/gal, fuel as ideal gas	115951	119565	122363	124585	126388	
Net heating value, ideal reaction, fuel as ideal gas						
Btu/ft^3, (MJ/m^3)	4404 (164.4)	5100 (190.39)	5796 (216.37)	6493 (242.4)	7190 (268.39)	
Heat of vaporization at 14.696 psia (1.01325 bar)						
Btu/lbm, kJ/kg	144.1 (335.1)	136.7 (318.1)	130 (302.4)	124.4 (289.3)	119.3 (277.6)	246.5 (573.3)
Flammability limits at 100°F, 14.696 psia (313.15 K, 1.01325 bar) in air, vol%						
Lower limit	1.1	1	0.8	0.7	0.7	
Upper limit	7.7	7	6.5	5.6	5.4	

(continued)

TABLE B.1 (Continued)

Component	Hydrogen Sulfide	Nitrogen	Oxygen	Helium	Air	Water
Molar mass	34.082	28.013	31.999	4.0026	28.959	18.0153
Boiling Point, °F (K)	–76.52 (212.86)	–320.43 (77.355)	–297.33 (90.188)	–452.06 (4.23)	–317.64 (78.903)	211.95 (373.124)
Freezing Point ,°F (K)	–121.81 (187.7)	–346 (63.151)	–361.82 (54.361)	–455.75 (2.177)		32 (273.15)
Vapor Pressure at 100 °F (313.15K), psia (bar)	395.55 (28.67)					0.95051 (0.073849)
Density of liquid						
Relative to water	0.80269 (0.80015)	0.80687 (0.8068)	1.1423 (1.1422)		0.87603 (0.87596)	1.0
Density, lb/gal (kg/m^3)	6.6922 (799.4)	6.727 (806.1)	9.5236 (1141.2)		7.3036 (875.2)	8.3372 (999.103)
Density of gas						
Relative density, air = 1.0	1.1769	0.9673	1.105	0.1382	1.0	0.6221
Density lb/1000 ft^3 (kg/m^3)	89.811 (1.4414)	73.819 (1.1847)	84.322 (1.3533)	10.547 (0.1693)	76.311 (1.2247)	47.473 (0.76191)
Volume of liquid						
gal/lb-mol (cm^3/mol)	5.0928 (42.63)	4.1643 (34.752)	3.36 (28.04)		3.965 (33.09)	2.1608 (18.031)

Critical conditions						
Temperature, °F (K)	212.8 (373.6)	–232.53 (126.19)	–181.43 (154.58)	–450.32 (5.195)	–220.97 (132.61)	705.1 (647.1)
Pressure, psia (bar)	1306.5 (90.08)	492.5 (33.96)	731.4 (50.43)	33.0 (2.275)	551.9 (38.05)	3200.1 (22.064)
Gross heating value, ideal reaction						
Fuel as liquid Btu/lb, (MJ/kg)	6897 (12825)					
Fuel as liquid, Btu/gal (MJ/m^3)	46156 (16.042)					
Fuel as ideal gas, Btu/lb (MJ/kg)	7093.8 (16.501)					
Fuel as ideal gas Btu/ft^3 (MJ/m^3)	637.11 (23.785)					
Btu/gal, fuel as ideal gas	47473					
Net heating value, ideal reaction, fuel as ideal gas						
Btu/ft^3, (MJ/m^3)	586.8 (21.91)					
Heat of vaporization at 14.696 psia (1.01325 bar)						
Btu/lb, kJ/kg	234.4 (545.3)	85.63 (199.2)	91.6 (213.1)	8.922 (20.75)	86.81 (201.9)	970.12 (2256.5)
Flammability limits at 100°F, 14.696 psia (313.15K, 1.01325 bar) in air, vol%						
Lower limit	4.3					
Upper limit	45.5					

Unless stated otherwise, pressure-dependent properties are given at 14.696 psia (1.01325 bar); temperature-dependent properties are given at 60°F (15°C); temperature-dependent and pressure-dependent properties are given at 60°F (15°C) and 14.696 psia (1.01325 bar). *Source*: GPA (2005).

B.3.2 Temperature-Dependent Properties of Pure Fluids

Tables B.2 to B.11 provide constants for equations to calculate physical properties as a function of temperature. Pressure effect is not considered and liquid properties are given at the vapor pressure of the fluid (saturation boundary). The tables include the applicable temperature range and the estimated quality of the prediction. They also include equation numbers for which the coefficients apply. Table B.12 lists the equations. These data were made available by courtesy of the Design Institute for Physical Properties (DIPPR,2005), an Industry Technology Alliance of the American Institute of Chemical Engineers (AIChE), from the DIPPR 801 database, 2005 edition (www.aiche.org/DIPPR). The coefficients were regressed from critically reviewed data. The tables present 10 of the 15 temperature-dependent physical properties and 33 physical constants in the database. Nearly 1,800 compounds are included in the database.

TABLE B.2
Liquid Density (Computed value has units of kmol/m^3)

Compound	Equation Number	Temperature Range (K)	Quality	A	B	C	D	E
Methane	105	90.7 – 190.6	< 1%	2.9214E+00	2.8976E–01	1.9056E+02	2.8881E–01	
Ethylene	105	104 – 282.3	< 1%	2.0961E+00	2.7657E–01	2.8234E+02	2.9147E–01	
Ethane	105	90.4 – 305.3	< 1%	1.9122E+00	2.7937E–01	3.0532E+02	2.9187E–01	
Propane	105	85.5 – 369.8	< 1%	1.3757E+00	2.7453E–01	3.6983E+02	2.9359E–01	
Isobutane	105	113.5 – 407.8	< 1%	1.0631E+00	2.7506E–01	4.078E+02	2.758E–01	
n-Butane	105	134.9 – 425.1	< 1%	1.0677E+00	2.7188E–01	4.2512E+02	2.8688E–01	
Isopentane	105	113.2 – 460.4	< 1%	9.1991E–01	2.7815E–01	4.604E+02	2.8667E–01	
n-Pentane	105	143.4 – 469.7	< 1%	8.4947E–01	2.6726E–01	4.697E+02	2.7789E–01	
Benzene	105	278.7 – 562	< 3%	1.0259E+00	2.6666E–01	5.6205E+02	2.8394E–01	
n-Hexane	105	177.8 – 507.6	< 1%	7.0824E–01	2.6411E–01	5.076E+02	2.7537E–01	
n-Heptane	105	182.6 – 540.2	< 1%	6.1259E–01	2.6211E–01	5.402E+02	2.8141E–01	
Ammonia	105	195.4 – 405.6	< 1%	3.5383E+00	2.5443E–01	4.0565E+02	2.888E–01	
Water	116	273.2 – 647.1	< 1%	1.7863E+01	5.8606E+01	–9.5396E+01	2.1389E+02	–1.4126E+02
Oxygen	105	54.4 – 154.6	< 1%	3.9143E+00	2.8772E–01	1.5458E+02	2.924E–01	
Nitrogen	105	63.2 – 126.2	< 1%	3.2091E+00	2.861E–01	1.262E+02	2.966E–01	
Hydrogen	105	14 – 33.2	< 3%	5.414E+00	3.4893E–01	3.319E+01	2.706E–01	
Hydrogen sulfide	105	187.7 – 373.5	< 1%	2.7672E+00	2.7369E–01	3.7353E+02	2.9015E–01	
Carbon monoxide	105	68.2 – 132.9	< 1%	2.897E+00	2.7532E–01	1.3292E+02	2.813E–01	
Carbon dioxide	105	216.6 – 304.2	< 1%	2.768E+00	2.6212E–01	3.0421E+02	2.908E–01	
Helium	105	2.2 – 5.2	< 3%	7.2475E+00	4.1865E–01	5.2E+00	2.4096E–01	
Methanol	105	175.5 – 512.5	< 1%	2.3267E+00	2.7073E–01	5.125E+02	2.4713E–01	
Ethylene glycol	105	260.2 – 720	< 1%	1.315E+00	2.5125E–01	7.2E+02	2.1868E–01	
Diethylene glycol	105	262.7 – 744.6	< 3%	8.3692E–01	2.6112E–01	7.446E+02	2.422E–01	
Triethylene glycol	105	266 – 769.5	< 3%	5.9672E–01	2.6217E–01	7.695E+02	2.4631E–01	

TABLE B.3
Vapor Pressure (Computed value has units of Pa)

Compound	Equation Number	Temperature Range (K)	Quality	A	B	C	D	E
Methane	101	90.7 – 190.6	< 1%	3.9205E+01	–1.3244E+03	–3.4366E+00	3.1019E–05	2
Ethylene	101	104 – 282.3	< 1%	5.3963E+01	–2.443E+03	–5.5643E+00	1.9079E–05	2
Ethane	101	90.4 – 305.3	< 1%	5.1857E+01	–2.5987E+03	–5.1283E+00	1.4913E–05	2
Propane	101	85.5 – 369.8	< 3%	5.9078E+01	–3.4926E+03	–6.0669E+00	1.0919E–05	2
Isobutane	101	113.5 – 407.8	< 3%	1.0843E+02	–5.0399E+03	–1.5012E+01	2.2725E–02	1
n-Butane	101	134.9 – 425.1	< 3%	6.6343E+01	–4.3632E+03	–7.046E+00	9.4509E–06	2
Isopentane	101	113.2 – 460.4	< 3%	7.1308E+01	–4.976E+03	–7.7169E+00	8.7271E–06	2
n-Pentane	101	143.4 – 469.7	< 3%	7.8741E+01	–5.4203E+03	–8.8253E+00	9.6171E–06	2
Benzene	101	278.7 – 562	< 1%	8.3107E+01	–6.4862E+03	–9.2194E+00	6.9844E–06	2
n-Hexane	101	177.8 – 507.6	< 3%	1.0465E+02	–6.9955E+03	–1.2702E+01	1.2381E–05	2
n-Heptane	101	182.6 – 540.2	< 3%	8.7829E+01	–6.9964E+03	–9.8802E+00	7.2099E–06	2
Ammonia	101	195.4 – 405.6	< 1%	9.0483E+01	–4.6697E+03	–1.1607E+01	1.7194E–02	1
Water	101	273.2 – 647.1	< 0.2%	7.3649E+01	–7.2582E+03	–7.3037E+00	4.1653E–06	2
Oxygen	101	54.4 – 154.6	< 1%	5.1245E+01	–1.2002E+03	–6.4361E+00	2.8405E–02	1
Nitrogen	101	63.2 – 126.2	< 1%	5.8282E+01	–1.0841E+03	–8.3144E+00	4.4127E–02	1
Hydrogen	101	14 – 33.2	< 3%	1.269E+01	–9.4896E+01	1.1125E+00	3.2915E–04	2
Hydrogen sulfide	101	187.7 – 373.5	< 3%	8.5584E+01	–3.8399E+03	–1.1199E+01	1.8848E–02	1
Carbon monoxide	101	68.2 – 132.9	< 1%	4.5698E+01	–1.0766E+03	–4.8814E+00	7.5673E–05	2
Carbon dioxide	101	216.6 – 304.2	< 1%	1.4054E+02	–4.735E+03	–2.1268E+01	4.0909E–02	1
Helium	101	1.8 – 5.2	< 1%	1.1533E+01	–8.99E+00	6.724E–01	2.743E–01	1
Methanol	101	175.5 – 512.5	< 1%	8.2718E+01	–6.9045E+03	–8.8622E+00	7.4664E–06	2
Ethylene glycol	101	260.2 – 720	< 3%	8.409E+01	–1.0411E+04	–8.1976E+00	1.6536E–18	6
Diethylene glycol	101	262.7 – 744.6	< 10%	1.4245E+02	–1.505E+04	–1.6318E+01	5.9506E–18	6
Triethylene Glycol	101	266 – 769.5	< 10%	1.5248E+02	–1.6449E+04	–1.767E+01	6.4481E–18	6

TABLE B.4
Heat of Vaporization (Computed value has units of J/kmol)

Compound	Equation Number	Temperature Range(K)	Quality	A	B	C	D
Methane	106	90.7 – 190.6	< 1%	1.0194E+07	2.6087E–01	–1.4694E–01	2.2154E–01
Ethylene	106	104 – 282.3	< 1%	1.8844E+07	3.6485E–01		
Ethane	106	90.4 – 305.3	< 1%	2.1091E+07	6.0646E–01	–5.5492E–01	3.2799E–01
Propane	106	85.5 – 369.8	< 3%	2.9209E+07	7.8237E–01	–7.7319E–01	3.9246E–01
Isobutane	106	113.5 – 407.8	< 3%	3.188E+07	3.9006E–01		
n-Butane	106	134.9 – 425.1	< 3%	3.6238E+07	8.337E–01	–8.2274E–01	3.9613E–01
Isopentane	106	113.2 – 460.4	< 3%	3.7593E+07	3.9173E–01		
n-Pentane	106	143.4 – 469.7	< 3%	3.9109E+07	3.8681E–01		
Benzene	106	278.7 – 562	< 1%	4.5346E+07	3.9053E–01		
n-Hexane	106	177.8 – 507.6	< 3%	4.4544E+07	3.9002E–01		
n-Heptane	106	182.6 – 540.2	< 3%	5.0014E+07	3.8795E–01		
Ammonia	106	195.4 – 405.6	< 1%	3.1523E+07	3.914E–01	–2.289E–01	2.309E–01
Water	106	273.2 – 647.1	< 1%	5.2053E+07	3.199E–01	–2.12E–01	2.5795E–01
Oxygen	106	54.4 – 154.6	< 1%	9.008E+06	4.542E–01	–4.096E–01	3.183E–01
Nitrogen	106	63.2 – 126.2	< 1%	7.4905E+06	4.0406E–01	–3.17E–01	2.7343E–01
Hydrogen	106	14 – 33.2	< 3%	1.0127E+06	6.98E–01	–1.817E+00	1.447E+00
Hydrogen sulfide	106	187.7 – 373.5	< 3%	2.5676E+07	3.7358E–01		
Carbon monoxide	106	68.1 – 132.5	< 1%	8.585E+06	4.921E–01	–3.26E–01	2.231E–01
Carbon dioxide	106	216.6 – 304.2	< 1%	2.173E+07	3.82E–01	–4.339E–01	4.2213E–01
Helium	106	2.2 – 5.2	< 10%	1.2504E+05	1.3038E+00	–2.6954E+00	1.7098E+00
Methanol	106	175.5 – 512.5	< 3%	5.0451E+07	3.3594E–01		
Ethylene glycol	106	260.2 – 720	< 3%	8.3518E+07	4.2625E–01		
Diethylene glycol	106	262.7 – 744.6	< 10%	1.0829E+08	5.4022E–01		
Triethylene Glycol	106	266 – 769.5	< 10%	1.2127E+08	5.8261E–01		

TABLE B.5
Liquid Heat Capacity (Computed value has units of J/kmol-K)

Compound	Equation Number	Temperature Range (K)	Quality	A	B	C	D	E
Methane	114	90.7 – 190	< 1%	6.5708E+01	3.8883E+04	–2.5795E+02	6.1407E+02	
Ethylene	100	104 – 252.7	< 3%	2.4739E+05	–4.428E+03	4.0936E+01	–1.697E–01	2.6816E–04
Ethane	114	92 – 290	< 1%	4.4009E+01	8.9718E+04	9.1877E+02	–1.886E+03	
Propane	114	85.5 – 360	< 1%	6.2983E+01	1.1363E+05	6.3321E+02	–8.7346E+02	
Isobutane	100	113.5 – 380	< 3%	1.7237E+05	–1.7839E+03	1.4759E+01	–4.7909E–02	5.805E–05
n-Butane	100	134.9 – 400	< 1%	1.9103E+05	–1.675E+03	1.25E+01	–3.874E–02	4.6121E–05
Isopentane	100	113.2 – 310	< 3%	1.083E+05	1.46E+02	–2.92E–01	1.51E–03	
n-Pentane	100	143.4 – 390	< 1%	1.5908E+05	–2.705E+02	9.9537E–01		
Benzene	100	278.7 – 353.2	< 3%	1.2944E+05	–1.695E+02	6.4781E–01		
n-Hexane	100	177.8 – 460	< 1%	1.7212E+05	–1.8378E+02	8.8734E–01		
n-Heptane	114	182.6 – 520	< 1%	6.126E+01	3.1441E+05	1.8246E+03	–2.5479E+03	
Ammonia	114	203.2 – 401.2	< 3%	6.1289E+01	8.0925E+04	7.994E+02	–2.651E+03	
Water	100	273.2 – 533.2	< 1%	2.7637E+05	–2.0901E+03	8.125E+00	–1.4116E–02	9.3701E–06
Oxygen	100	54.4 – 142	< 3%	1.7543E+05	–6.1523E+03	1.1392E+02	–9.2382E–01	2.7963E–03
Nitrogen	100	63.2 – 112	< 3%	2.8197E+05	–1.2281E+04	2.48E+02	–2.2182E+00	7.4902E–03
Hydrogen	114	14 – 32	< 5%	6.6653E+01	6.7659E+03	–1.2363E+02	4.7827E+02	
Hydrogen sulfide	114	187.7 – 370	< 3%	6.4666E+01	4.9354E+04	2.2493E+01	–1.623E+03	
Carbon monoxide	114	68.2 – 132	< 3%	6.5429E+01	2.8723E+04	–8.4739E+02	1.9596E+03	
Carbon dioxide	100	220 – 290	< 3%	–8.3043E+06	1.0437E+05	–4.3333E+02	6.0052E–01	
Helium	100	2.2 – 4.6	< 5%	3.8722E+05	–4.6557E+05	2.118E+05	–4.2494E+04	3.2129E+03
Methanol	100	175.5 – 400	< 1%	1.058E+05	–3.6223E+02	9.379E–01		
Ethylene glycol	100	260.2 – 493.2	< 1%	3.554E+04	4.3678E+02	–1.8486E–01		
Diethylene glycol	100	262.7 – 451.2	< 3%	1.2541E+05	4.0058E+02			
Triethylene Glycol	100	265.8 – 441	< 3%	1.538E+05	5.87E+02			

TABLE B.6
Ideal Gas Heat Capacity (Computed value has units of J/kmol-k)

Compound	Equation Number	Temperature Range (K)	Quality	A	B	C	D	E
Methane	107	50 – 1500	< 1%	3.3298E+04	7.9933E+04	2.0869E+03	4.1602E+04	9.9196E+02
Ethylene	107	60 – 1500	< 1%	3.338E+04	9.479E+04	1.596E+03	5.51E+04	7.408E+02
Ethane	107	200 – 1500	< 1%	4.0326E+04	1.3422E+05	1.6555E+03	7.3223E+04	7.5287E+02
Propane	107	200 – 1500	< 1%	5.192E+04	1.9245E+05	1.6265E+03	1.168E+05	7.236E+02
Isobutane	107	200 – 1500	< 1%	6.549E+04	2.4776E+05	1.587E+03	1.575E+05	7.0699E+02
n-Butane	107	200 – 1500	< 1%	7.134E+04	2.43E+05	1.63E+03	1.5033E+05	7.3042E+02
Isopentane	107	200 – 1500	< 1%	7.46E+04	3.265E+05	1.545E+03	1.923E+05	6.667E+02
n-Pentane	107	200 – 1500	< 1%	8.805E+04	3.011E+05	1.6502E+03	1.892E+05	7.476E+02
Benzene	107	200 – 1500	< 1%	4.4767E+04	2.3085E+05	1.4792E+03	1.6836E+05	6.7766E+02
n-Hexane	107	200 – 1500	< 1%	1.044E+05	3.523E+05	1.6946E+03	2.369E+05	7.616E+02
n-Heptane	107	200 – 1500	< 1%	1.2015E+05	4.001E+05	1.6766E+03	2.74E+05	7.564E+02
Ammonia	107	100 – 1500	< 1%	3.3427E+04	4.898E+04	2.036E+03	2.256E+04	8.82E+02
Water	107	100 – 2273.2	< 1%	3.3363E+04	2.679E+04	2.6105E+03	8.896E+03	1.169E+03
Oxygen	107	50 – 1500	< 1%	2.9103E+04	1.004E+04	2.5265E+03	9.356E+03	1.1538E+03
Nitrogen	107	50 – 1500	< 1%	2.9105E+04	8.6149E+03	1.7016E+03	1.0347E+02	9.0979E+02
Hydrogen	107	250 – 1500	< 1%	2.7617E+04	9.56E+03	2.466E+03	3.76E+03	5.676E+02
Hydrogen sulfide	107	100 – 1500	< 1%	3.3288E+04	2.6086E+04	9.134E+02	–1.7979E+04	9.494E+02
Carbon monoxide	107	60 – 1500	< 1%	2.9108E+04	8.773E+03	3.0851E+03	8.4553E+03	1.5382E+03
Carbon dioxide	107	50 – 5000	< 1%	2.937E+04	3.454E+04	1.428E+03	2.64E+04	5.88E+02
Helium	100	100 – 1500	< 1%	2.0786E+04				
Methanol	107	200 – 1500	< 1%	3.9252E+04	8.79E+04	1.9165E+03	5.3654E+04	8.967E+02
Ethylene glycol	107	300 – 1500	< 3%	6.3012E+04	1.4584E+05	1.673E+03	9.7296E+04	7.7365E+02
Diethylene glycol	107	200 – 1500	< 10%	8.79E+04	2.713E+05	1.3963E+03	1.7035E+05	6.2404E+02
Triethylene Glycol	107	300 – 1500	< 25%	9.04E+04	4.202E+05	1.2628E+03	2.7705E+05	5.311E+02

TABLE B.7
Liquid Viscosity (Computed value has units of Pa-s)

Compound	Equation Number	Temperature Range (K)	Quality	A	B	C	D	E
Methane	101	90.7 – 188	< 3%	–6.1572E+00	1.7815E+02	–9.5239E–01	–9.0606E–24	10
Ethylene	101	104 – 250	< 5%	1.8878E+00	7.8865E+01	–2.1554E+00		
Ethane	101	90.4 – 300	< 3%	–7.0046E+00	2.7638E+02	–6.087E–01	–3.1108E–18	7
Propane	101	85.5 – 360	< 5%	–1.7156E+01	6.4625E+02	1.1101E+00	–7.3439E–11	4
Isobutane	101	110 – 311	< 5%	–1.3912E+01	7.9709E+02	4.5308E–01		
n-Butane	101	134.9 – 420	< 3%	–7.2471E+00	5.3482E+02	–5.7469E–01	–4.6625E–27	10
Isopentane	101	150 – 310	< 1%	–1.2596E+01	8.8911E+02	2.0469E–01		
n-Pentane	101	143.4 – 465.2	< 3%	–5.3509E+01	1.8366E+03	7.1409E+00	–1.9627E–05	2
Benzene	101	278.7 – 545	< 3%	7.5117E+00	2.9468E+02	–2.794E+00		
n-Hexane	101	174.6 – 406.1	< 3%	–6.3276E+00	6.4E+02	–6.94E–01	5.6884E+21	–10
n-Heptane	101	180.2 – 432.2	< 3%	–9.4622E+00	8.7707E+02	–2.3445E–01	1.4022E+22	–10
Ammonia	101	195.4 – 393.2	< 5%	–6.743E+00	5.983E+02	–7.341E–01	–3.69E–27	10
Water	101	273.2 – 646.2	< 3%	–5.2843E+01	3.7036E+03	5.866E+00	–5.879E–29	10
Oxygen	101	54.4 – 150	< 25%	–4.1476E+00	9.404E+01	–1.207E+00		
Nitrogen	101	63.2 – 124	< 5%	1.6004E+01	–1.8161E+02	–5.1551E+00		
Hydrogen	101	14 – 33	< 5%	–1.1661E+01	2.47E+01	–2.61E–01	–4.1E–16	10
Hydrogen sulfide	101	187.7 – 350	< 5%	–1.0905E+01	7.6211E+02	–1.1863E–01		
Carbon monoxide	101	68.2 – 131.4	< 5%	–4.9735E+00	9.767E+01	–1.1088E+00		
Carbon dioxide	101	216.6 – 303.2	< 10%	1.8775E+01	–4.0292E+02	–4.6854E+00	–6.9171E–26	10
Helium	101	2.2 – 5.1	< 10%	–9.6312E+00	–3.841E+00	–1.458E+00	–1.065E–08	10
Methanol	101	175.5 – 337.8	< 5%	–2.5317E+01	1.7892E+03	2.069E+00		
Ethylene glycol	101	260.2 – 576	< 5%	–2.0515E+01	2.4685E+03	1.2435E+00	2.4998E+12	–5
Diethylene glycol	101	262.7 – 595.7	< 10%	1.3011E+01	2.6481E+02	–3.4184E+00	4.843E+12	–5
Triethylene Glycol	101	266 – 615.6	< 10%	–2.7963E+01	3.225E+03	2.2792E+00	1.8277E+17	–7

TABLE B.8
Vapor Viscosity at Low Pressure (Computed value has units of Pa-s)

Compound	Equation Number	Temperature Range (K)	Quality	A	B	C	D
Methane	102	90.7 – 1000	< 3%	5.2546E–07	5.9006E–01	1.0567E+02	
Ethylene	102	169.4 – 1000	< 5%	2.0789E–06	4.163E–01	3.527E+02	
Ethane	102	90.4 – 1000	< 5%	2.5906E–07	6.7988E–01	9.8902E+01	
Propane	102	85.5 – 1000	< 3%	4.9054E–08	9.0125E–01		
Isobutane	102	150 – 1000	< 5%	1.0871E–07	7.8135E–01	7.0639E+01	
n-Butane	102	134.9 – 1000	< 3%	3.4387E–08	9.4604E–01		
Isopentane	102	150 – 1000	< 5%	2.4344E–08	9.7376E–01	–9.1597E+01	1.872E+04
n-Pentane	102	143.4 – 1000	< 5%	6.3412E–08	8.4758E–01	4.1718E+01	
Benzene	102	278.7 – 1000	< 3%	3.134E–08	9.676E–01	7.9E+00	
n-Hexane	102	177.8 – 1000	< 5%	1.7514E–07	7.0737E–01	1.5714E+02	
n-Heptane	102	182.6 – 1000	< 5%	6.672E–08	8.2837E–01	8.5752E+01	
Ammonia	102	195.4 – 1000	< 10%	4.1855E–08	9.806E–01	3.08E+01	
Water	102	273.2 – 1073.2	< 1%	1.7096E–08	1.1146E+00		
Oxygen	102	54.4 – 1500	< 5%	1.101E–06	5.634E–01	9.63E+01	
Nitrogen	102	63.2 – 1970	< 3%	6.5592E–07	6.081E–01	5.4714E+01	
Hydrogen	102	14 – 3000	< 10%	1.797E–07	6.85E–01	–5.9E–01	1.4E+02
Hydrogen sulfide	102	250 – 480	< 3%	3.9314E–08	1.0134E+00		
Carbon-monoxide	102	68.2 – 1250	< 5%	1.1127E–06	5.338E–01	9.47E+01	
Carbon-dioxide	102	194.7 – 1500	< 5%	2.148E–06	4.6E–01	2.9E+02	
Helium	102	20 – 2000	< 3%	3.253E–07	7.162E–01	–9.6E+00	1.07E+02
Methanol	102	240 – 1000	< 10%	3.0663E–07	6.9655E–01	2.05E+02	
Ethylene-glycol	102	260.2 – 1000	< 10%	8.6706E–08	8.3923E–01	7.5512E+01	
Diethylene-glycol	102	262.7 – 1000	< 10%	6.7384E–08	8.489E–01	7.1139E+01	
Triethylene-Glycol	102	266 – 1000	< 10%	5.4291E–08	8.6024E–01	6.592E+01	

TABLE B.9
Liquid Thermal Conductivity (Computed value has units of W/m-K)

Compound	Equation Number	Temperature Range (K)	Quality	A	B	C	D	E
Methane	100	90.7 – 180	< 5%	4.1768E–01	–2.4528E–03	3.5588E–06		
Ethylene	100	104 – 280	< 5%	4.194E–01	–1.591E–03	1.306E–06		
Ethane	100	90.4 – 300	< 3%	3.5758E–01	–1.1458E–03	6.1866E–07		
Propane	100	85.5 – 350	< 3%	2.6755E–01	–6.6457E–04	2.774E–07		
Isobutane	100	113.5 – 400	< 10%	2.0455E–01	–3.6589E–04			
n-Butane	100	134.9 – 400	< 5%	2.7349E–01	–7.1267E–04	5.1555E–07		
Isopentane	100	113.2 – 368.1	< 10%	2.1246E–01	–3.3581E–04			
n-Pentane	100	143.4 – 445	< 5%	2.537E–01	–5.76E–04	3.44E–07		
Benzene	100	278.7 – 413.1	< 3%	2.3444E–01	–3.0572E–04			
n-Hexane	100	177.8 – 370	< 3%	2.2492E–01	–3.533E–04			
n-Heptane	100	182.6 – 371.6	< 3%	2.15E–01	–3.03E–04			
Ammonia	100	195.4 – 400	< 10%	1.169E+00	–2.314E–03			
Water	100	273.2 – 633.2	< 1%	–4.32E–01	5.7255E–03	–8.078E–06	1.861E–09	
Oxygen	100	60 – 150	< 5%	2.741E–01	–1.38E–03			
Nitrogen	100	63.2 – 124	< 3%	2.654E–01	–1.677E–03			
Hydrogen	100	14 – 31	< 10%	–9.17E–02	1.7678E–02	–3.82E–04	–3.3324E–06	1.0266E–07
Hydrogen sulfide	100	193.2 – 292.4	< 5%	4.842E–01	–1.184E–03			
Carbon monoxide	100	68.2 – 125	< 3%	2.855E–01	–1.784E–03			
Carbon dioxide	100	216.6 – 300	< 3%	4.406E–01	–1.2175E–03			
Helium	100	2.2 – 4.8	< 3%	–1.3833E–02	2.2913E–02	–5.4872E–03	4.585E–04	
Methanol	100	175.5 – 337.8	< 3%	2.837E–01	–2.81E–04			
Ethylene glycol	100	260.2 – 470.4	< 5%	8.8067E–02	9.4712E–04	–1.3114E–06		
Diethylene glycol	100	262.7 – 518	< 5%	6.4277E–02	7.8259E–04	–1.0562E–06		
Triethylene Glycol	100	266 – 561.5	< 5%	1.0753E–01	5.0392E–04	–7.2763E–07		

TABLE B.10
Vapor Thermal Conductivity at Low Pressure (Computed value has units of W/m-K)

Compound	Equation Number	Temperature Range (K)	Quality	A	B	C	D
Methane	102	111.6 – 600	< 5%	8.3983E–06	1.4268E+00	–4.9654E+01	
Ethylene	102	170 – 590.9	< 5%	8.6806E–06	1.4559E+00	2.9972E+02	–2.9403E+04
Ethane	102	184.6 – 1000	< 5%	7.3869E–05	1.1689E+00	5.0073E+02	
Propane	102	231.1 – 1000	< 5%	–1.12E+00	1.0972E–01	–9.8346E+03	–7.5358E+06
Isobutane	102	261.4 – 1000	< 10%	8.9772E–02	1.8501E–01	6.3923E+02	1.1147E+06
n-Butane	102	272.6 – 1000	< 5%	5.1094E–02	4.5253E–01	5.4555E+03	1.9798E+06
Isopentane	102	273.2 – 1000	< 5%	8.968E–04	7.742E–01	4.56E+02	2.3064E+05
n-Pentane	102	273.2 – 1000	< 5%	–6.844E+02	7.64E–01	–1.055E+09	
Benzene	102	339.2 – 1000	< 5%	1.652E–05	1.3117E+00	4.91E+02	
n-Hexane	102	339.1 – 1000	< 5%	–6.505E+02	8.053E–01	–1.4121E+09	
n-Heptane	102	339.2 – 1000	< 5%	–7.0028E–02	3.8068E–01	–7.0499E+03	–2.4005E+06
Ammonia	102	200 – 900	< 5%	9.6608E–06	1.3799E+00		
Water	102	273.2 – 1073.2	< 1%	6.2041E–06	1.3973E+00		
Oxygen	102	80 – 2000	< 10%	4.4994E–04	7.456E–01	5.6699E+01	
Nitrogen	102	63.2 – 2000	< 3%	3.3143E–04	7.722E–01	1.6323E+01	3.7372E+02
Hydrogen	102	22 – 1600	< 5%	2.653E–03	7.452E–01	1.2E+01	
Hydrogen sulfide	102	212.8 – 600	< 3%	1.381E–07	1.8379E+00	–3.5209E+02	4.6041E+04
Carbon monoxide	102	70 – 1500	< 5%	5.9882E–04	6.863E–01	5.713E+01	5.0192E+02
Carbon dioxide	102	194.7 – 1500	< 10%	3.69E+00	–3.838E–01	9.64E+02	1.86E+06
Helium	102	30 – 2000	< 5%	2.26E–03	7.305E–01	–1.863E+01	4.4E+02
Methanol	102	273 – 684.4	< 5%	5.7992E–07	1.7862E+00		
Ethylene glycol	102	470.4 – 1000	< 10%	–8.1458E+06	–3.0502E–01	1.8325E+09	–1.1842E+13
Diethylene glycol	102	518 – 1000	< 10%	2.0395E+03	9.0063E–01	1.2238E+10	
Triethylene Glycol	102	269.3 – 1000	< 25%	1.8738E–05	1.238E+00	4.7673E+02	

TABLE B.11
Surface Tension (Computed value has units of N/m)

Compound	EquationNumber	Temperature Range (K)	Quality	A	B	C	D
Methane	106	90.7 – 190.6	< 3%	3.6557E–02	1.1466E+00		
Ethylene	106	104 – 282.3	< 3%	5.294E–02	1.278E+00		
Ethane	106	90.4 – 305.3	< 3%	4.8643E–02	1.1981E+00		
Propane	106	85.5 – 369.8	< 3%	5.092E–02	1.2197E+00		
Isobutane	106	113.5 – 407.8	< 3%	5.1359E–02	1.2532E+00		
n-Butane	106	134.9 – 425.1	< 3%	5.196E–02	1.2181E+00		
Isopentane	106	113.2 – 460.4	< 3%	5.0876E–02	1.2066E+00		
n-Pentane	106	143.4 – 469.7	< 3%	5.202E–02	1.2041E+00		
Benzene	106	278.7 – 562	< 3%	7.1815E–02	1.2362E+00		
n-Hexane	106	177.8 – 507.6	< 3%	5.5003E–02	1.2674E+00		
n-Heptane	106	182.6 – 540.2	< 3%	5.4143E–02	1.2512E+00		
Ammonia	106	195.4 – 405.6	< 3%	1.0162E–01	1.216E+00		
Water	106	273.2 – 647.1	< 1%	1.8548E–01	2.717E+00	–3.554E+00	2.047E+00
Oxygen	106	54.4 – 154.6	< 3%	3.8066E–02	1.2136E+00		
Nitrogen	106	63.2 – 126.2	< 3%	2.901E–02	1.2485E+00		
Hydrogen	106	14 – 33.2	< 1%	5.345E–03	1.0646E+00		
Hydrogen sulfide	106	187.7 – 373.5	< 5%	7.4256E–02	1.2997E+00		
Carbon monoxide	106	68.2 – 132.9	< 3%	2.7959E–02	1.133E+00		
Carbon dioxide	106	216.6 – 304.2	< 10%	8.071E–02	1.2662E+00		
Helium	106	2.2 – 5.2	< 5%	5.1136E–04	1.003E+00		
Methanol	100	273.1 – 503.2	< 1%	3.513E–02	–7.04E–06	–1.216E–07	
Ethylene glycol	100	260.2 – 470.4	< 1%	7.4516E–02	–8.9E–05	–3.9465E–17	
Diethylene glycol	100	293.2 – 518.2	< 1%	6.761E–02	–4.62E–05	–6.46E–08	
Triethylene Glycol	100	293.2 – 548.2	< 1%	6.7901E–02	–6.9536E–05	–2.4419E–08	

TABLE B.12
Equations Noted in Tables B.2 to B.11

Equation Number	Empirical Equation
100	$Y = A + BT + CT^2 + DT^3 + ET^4$
101	$Y = \mathrm{Exp}[A + B/T + C\mathrm{Ln}\ T + DT^E]$
102	$Y = \dfrac{AT^B}{1 + \dfrac{C}{T} + \dfrac{D}{T^2}}$
105	$Y = \dfrac{A}{B^{\left[1+(1-\frac{T}{C})^D\right]}}$
106	$Y = A[1 + T_r]^{\left(B + CT_r + DT_r^2 + ET_r^3\right)}$, where $T_r = T/T_c$
107	$Y = A + B\left[\dfrac{\frac{C}{T}}{\sinh\left(\frac{C}{T}\right)}\right]^2 + D\left[\dfrac{\frac{E}{T}}{\cosh\left(\frac{E}{T}\right)}\right]^2$
114	$Y = \dfrac{A^2}{t} + B - 2ACt - ADt^2 - \dfrac{C^2t^3}{3} - \dfrac{CDt^4}{2} - \dfrac{D^2t^5}{5}$, where $t = (1-T_r)$
116	$Y = A + Bt^{0.35} + ct^{2/3} + dt + et^{4/3}$, where $t = (1-T_r)$