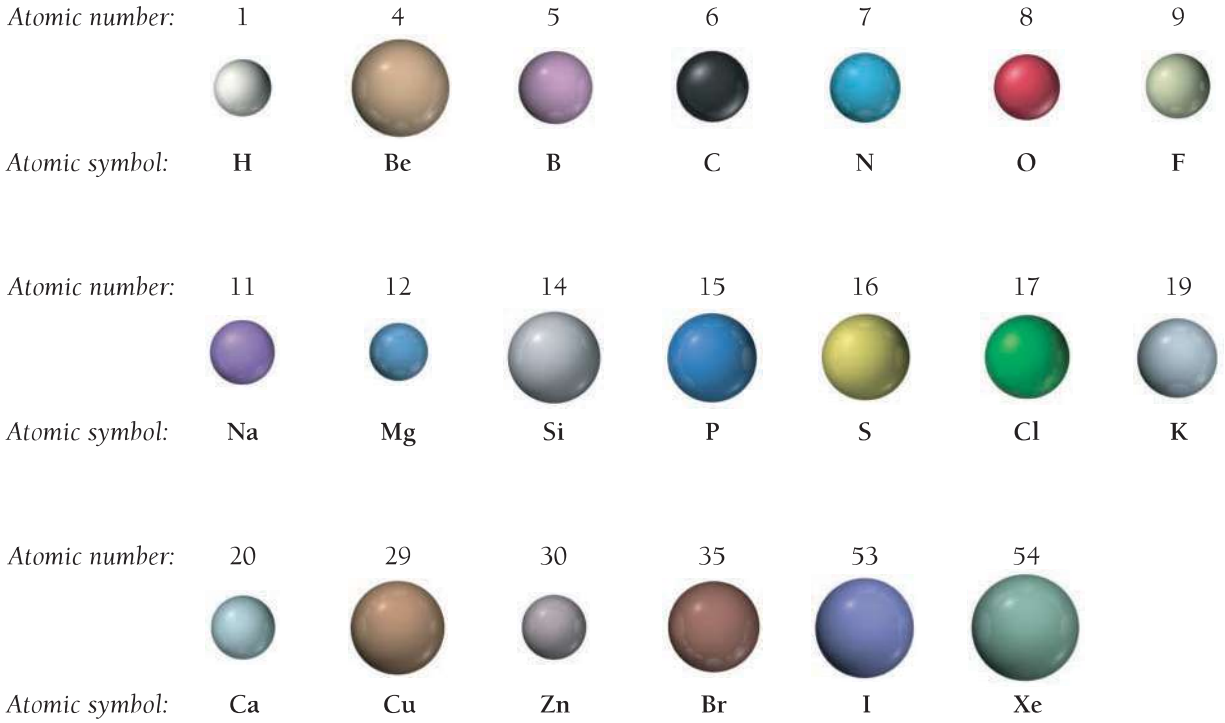
APPENDIX II Useful Data

A. Atomic Colors



B. Standard Thermodynamic Quantities for Selected Substances at 25 °C

Substance	ΔH_f°(kJ/mol)	ΔG_f°(kJ/mol)	S°(J/mol · K)
Aluminum			
Al(*s*)	0	0	28.32
Al(*g*)	330.0	289.4	164.6
$Al^{3+}(aq)$	−538.4	−483	−325
$AlCl_3(s)$	−704.2	−628.8	109.3
$Al_2O_3(s)$	−1675.7	−1582.3	50.9
Barium			
Ba(*s*)	0	0	62.5
Ba(*g*)	180.0	146.0	170.2
$Ba^{2+}(aq)$	−537.6	−560.8	9.6
$BaCO_3(s)$	−1213.0	−1134.4	112.1
$BaCl_2(s)$	−855.0	−806.7	123.7
BaO(*s*)	−548.0	−520.3	72.1
$Ba(OH)_2(s)$	−944.7		
$BaSO_4(s)$	−1473.2	−1362.2	132.2

Substance	ΔH_f°(kJ/mol)	ΔG_f°(kJ/mol)	S°(J/mol · K)
Beryllium			
Be(*s*)	0	0	9.5
BeO(*s*)	−609.4	−580.1	13.8
$Be(OH)_2(s)$	−902.5	−815.0	45.5
Bismuth			
Bi(*s*)	0	0	56.7
$BiCl_3(s)$	−379.1	−315.0	177.0
$Bi_2O_3(s)$	−573.9	−493.7	151.5
$Bi_2S_3(s)$	−143.1	−140.6	200.4
Boron			
B(*s*)	0	0	5.9
B(*g*)	565.0	521.0	153.4
$BCl_3(g)$	−403.8	−388.7	290.1
$BF_3(g)$	−1136.0	−1119.4	254.4
$B_2H_6(g)$	36.4	87.6	232.1

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Substance	ΔH_f°(kJ/mol)	ΔG_f°(kJ/mol)	S°(J/mol · K)
$B_2O_3(s)$	−1273.5	−1194.3	54.0
$H_3BO_3(s)$	−1094.3	−968.9	90.0
Bromine			
$Br(g)$	111.9	82.4	175.0
$Br_2(l)$	0	0	152.2
$Br_2(g)$	30.9	3.1	245.5
$Br^-(aq)$	−121.4	−102.8	80.71
$HBr(g)$	−36.3	−53.4	198.7
Cadmium			
$Cd(s)$	0	0	51.8
$Cd(g)$	111.8	77.3	167.7
$Cd^{2+}(aq)$	−75.9	−77.6	−73.2
$CdCl_2(s)$	−391.5	−343.9	115.3
$CdO(s)$	−258.4	−228.7	54.8
$CdS(s)$	−161.9	−156.5	64.9
$CdSO_4(s)$	−933.3	−822.7	123.0
Calcium			
$Ca(s)$	0	0	41.6
$Ca(g)$	177.8	144.0	154.9
$Ca^{2+}(aq)$	−542.8	−553.6	−53.1
$CaC_2(s)$	−59.8	−64.9	70.0
$CaCO_3(s)$	−1207.6	−1129.1	91.7
$CaCl_2(s)$	−795.4	−748.8	108.4
$CaF_2(s)$	−1228.0	−1175.6	68.5
$CaH_2(s)$	−181.5	−142.5	41.4
$Ca(NO_3)_2(s)$	−938.2	−742.8	193.2
$CaO(s)$	−634.9	−603.3	38.1
$Ca(OH)_2(s)$	−985.2	−897.5	83.4
$CaSO_4(s)$	−1434.5	−1322.0	106.5
$Ca_3(PO_4)_2(s)$	−4120.8	−3884.7	236.0
Carbon			
C(*s*, graphite)	0	0	5.7
C(*s*, diamond)	1.88	2.9	2.4
$C(g)$	716.7	671.3	158.1
$CH_4(g)$	−74.6	−50.5	186.3
$CH_3Cl(g)$	−81.9	−60.2	234.6
$CH_2Cl_2(g)$	−95.4		270.2
$CH_2Cl_2(l)$	−124.2	−63.2	177.8
$CHCl_3(l)$	−134.1	−73.7	201.7
$CCl_4(g)$	−95.7	−62.3	309.7
$CCl_4(l)$	−128.2	−66.4	216.4
$CH_2O(g)$	−108.6	−102.5	218.8
CH_2O_2 (*l*, formic acid)	−425.0	−361.4	129.0
CH_3NH_2 (*g*, methylamine)	−22.5	32.7	242.9
$CH_3OH(l)$	−238.6	−166.6	126.8
$CH_3OH(g)$	−201.0	−162.3	239.9
$C_2H_2(g)$	227.4	209.9	200.9
$C_2H_4(g)$	52.4	68.4	219.3
$C_2H_6(g)$	−84.68	−32.0	229.2
$C_2H_5OH(l)$	−277.6	−174.8	160.7
$C_2H_5OH(g)$	−234.8	−167.9	281.6
C_2H_3Cl (*g*, vinyl chloride)	37.2	53.6	264.0
$C_2H_4Cl_2$ (*l*, dichloroethane)	−166.8	−79.6	208.5
C_2H_4O (*g*, acetaldehyde)	−166.2	−133.0	263.8
$C_2H_4O_2$ (*l*, acetic acid)	−484.3	−389.9	159.8
$C_3H_8(g)$	−103.85	−23.4	270.3
C_3H_6O (*l*, acetone)	−248.4	−155.6	199.8
C_3H_7OH (*l*, isopropanol)	−318.1		181.1
$C_4H_{10}(l)$	−147.3	−15.0	231.0
$C_4H_{10}(g)$	−125.7	−15.71	310.0
$C_6H_6(l)$	49.1	124.5	173.4
$C_6H_5NH_2$ (*l*, aniline)	31.6	149.2	191.9
C_6H_5OH (*s*, phenol)	−165.1	−50.4	144.0
$C_6H_{12}O_6$ (*s*, glucose)	−1273.3	−910.4	212.1
$C_{10}H_8$ (*s*, naphthalene)	78.5	201.6	167.4
$C_{12}H_{22}O_{11}$ (*s*, sucrose)	−2226.1	−1544.3	360.24
$CO(g)$	−110.5	−137.2	197.7
$CO_2(g)$	−393.5	−394.4	213.8
$CO_2(aq)$	−413.8	−386.0	117.6
$CO_3^{2-}(aq)$	−677.1	−527.8	−56.9
$HCO_3^-(aq)$	−692.0	−586.8	91.2
$H_2CO_3(aq)$	−699.7	−623.2	187.4
$CN^-(aq)$	151	166	118
$HCN(l)$	108.9	125.0	112.8
$HCN(g)$	135.1	124.7	201.8
$CS_2(l)$	89.0	64.6	151.3
$CS_2(g)$	116.7	67.1	237.8
$COCl_2(g)$	−219.1	−204.9	283.5
$C_{60}(s)$	2327.0	2302.0	426.0
Cesium			
$Cs(s)$	0	0	85.2
$Cs(g)$	76.5	49.6	175.6
$Cs^+(aq)$	−258.0	−292.0	132.1
$CsBr(s)$	−400	−387	117
$CsCl(s)$	−438	−414	101.2
$CsF(s)$	−553.5	−525.5	92.8
$CsI(s)$	−342	−337	127

Substance	ΔH_f°(kJ/mol)	ΔG_f°(kJ/mol)	S°(J/mol · K)
Chlorine			
$Cl(g)$	121.3	105.3	165.2
$Cl_2(g)$	0	0	223.1
$Cl^-(aq)$	−167.1	−131.2	56.6
$HCl(g)$	−92.3	−95.3	186.9
$HCl(aq)$	−167.2	−131.2	56.5
$ClO_2(g)$	102.5	120.5	256.8
$Cl_2O(g)$	80.3	97.9	266.2
Chromium			
$Cr(s)$	0	0	23.8
$Cr(g)$	396.6	351.8	174.5
$Cr^{3+}(aq)$	−1971		
$CrO_4^{2-}(aq)$	−872.2	−717.1	44
$Cr_2O_3(s)$	−1139.7	−1058.1	81.2
$Cr_2O_7^{2-}(aq)$	−1476	−1279	238
Cobalt			
$Co(s)$	0	0	30.0
$Co(g)$	424.7	380.3	179.5
$CoO(s)$	−237.9	−214.2	53.0
$Co(OH)_2(s)$	−539.7	−454.3	79.0
Copper			
$Cu(s)$	0	0	33.2
$Cu(g)$	337.4	297.7	166.4
$Cu^+(aq)$	51.9	50.2	−26
$Cu^{2+}(aq)$	64.9	65.5	−98
$CuCl(s)$	−137.2	−119.9	86.2
$CuCl_2(s)$	−220.1	−175.7	108.1
$CuO(s)$	−157.3	−129.7	42.6
$CuS(s)$	−53.1	−53.6	66.5
$CuSO_4(s)$	−771.4	−662.2	109.2
$Cu_2O(s)$	−168.6	−146.0	93.1
$Cu_2S(s)$	−79.5	−86.2	120.9
Fluorine			
$F(g)$	79.38	62.3	158.75
$F_2(g)$	0	0	202.79
$F^-(aq)$	−335.35	−278.8	−13.8
$HF(g)$	−273.3	−275.4	173.8
Gold			
$Au(s)$	0	0	47.4
$Au(g)$	366.1	326.3	180.5
Helium			
$He(g)$	0	0	126.2
Hydrogen			
$H(g)$	218.0	203.3	114.7
$H^+(aq)$	0	0	0
$H^-(aq)$	1536.3	1517.1	108.9
$H_2(g)$	0	0	130.7

Substance	ΔH_f°(kJ/mol)	ΔG_f°(kJ/mol)	S°(J/mol · K)
Iodine			
$I(g)$	106.76	70.2	180.79
$I_2(s)$	0	0	116.14
$I_2(g)$	62.42	19.3	260.69
$I^-(aq)$	−56.78	−51.57	106.45
$HI(g)$	26.5	1.7	206.6
Iron			
$Fe(s)$	0	0	27.3
$Fe(g)$	416.3	370.7	180.5
$Fe^{2+}(aq)$	−87.9	−84.94	−113.4
$Fe^{3+}(aq)$	−47.69	−10.54	−293.3
$FeCO_3(s)$	−740.6	−666.7	92.9
$FeCl_2(s)$	−341.8	−302.3	118.0
$FeCl_3(s)$	−399.5	−334.0	142.3
$FeO(s)$	−272.0	−255.2	60.75
$Fe(OH)_3(s)$	−823.0	−696.5	106.7
$FeS_2(s)$	−178.2	−166.9	52.9
$Fe_2O_3(s)$	−824.2	−742.2	87.4
$Fe_3O_4(s)$	−1118.4	−1015.4	146.4
Lead			
$Pb(s)$	0	0	64.8
$Pb(g)$	195.2	162.2	175.4
$Pb^{2+}(aq)$	0.92	−24.4	18.5
$PbBr_2(s)$	−278.7	−261.9	161.5
$PbCO_3(s)$	−699.1	−625.5	131.0
$PbCl_2(s)$	−359.4	−314.1	136.0
$PbI_2(s)$	−175.5	−173.6	174.9
$Pb(NO_3)_2(s)$	−451.9		
$PbO(s)$	−217.3	−187.9	68.7
$PbO_2(s)$	−277.4	−217.3	68.6
$PbS(s)$	−100.4	−98.7	91.2
$PbSO_4(s)$	−920.0	−813.0	148.5
Lithium			
$Li(s)$	0	0	29.1
$Li(g)$	159.3	126.6	138.8
$Li^+(aq)$	−278.47	−293.3	12.24
$LiBr(s)$	−351.2	−342.0	74.3
$LiCl(s)$	−408.6	−384.4	59.3
$LiF(s)$	−616.0	−587.7	35.7
$LiI(s)$	−270.4	−270.3	86.8
$LiNO_3(s)$	−483.1	−381.1	90.0
$LiOH(s)$	−487.5	−441.5	42.8
$Li_2O(s)$	−597.9	−561.2	37.6
Magnesium			
$Mg(s)$	0	0	32.7
$Mg(g)$	147.1	112.5	148.6
$Mg^{2+}(aq)$	−467.0	−455.4	−137
$MgCl_2(s)$	−641.3	−591.8	89.6
$MgCO_3(s)$	−1095.8	−1012.1	65.7
$MgF_2(s)$	−1124.2	−1071.1	57.2

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Substance	ΔH_f°(kJ/mol)	ΔG_f°(kJ/mol)	S°(J/mol · K)
$MgO(s)$	−601.6	−569.3	27.0
$Mg(OH)_2(s)$	−924.5	−833.5	63.2
$MgSO_4(s)$	−1284.9	−1170.6	91.6
$Mg_3N_2(s)$	−461	−401	88
Manganese			
$Mn(s)$	0	0	32.0
$Mn(g)$	280.7	238.5	173.7
$Mn^{2+}(aq)$	−219.4	−225.6	−78.8
$MnO(s)$	−385.2	−362.9	59.7
$MnO_2(s)$	−520.0	−465.1	53.1
$MnO_4^-(aq)$	−529.9	−436.2	190.6
Mercury			
$Hg(l)$	0	0	75.9
$Hg(g)$	61.4	31.8	175.0
$Hg^{2+}(aq)$	170.21	164.4	−36.19
$Hg_2^{2+}(aq)$	166.87	153.5	65.74
$HgCl_2(s)$	−224.3	−178.6	146.0
$HgO(s)$	−90.8	−58.5	70.3
$HgS(s)$	−58.2	−50.6	82.4
$Hg_2Cl_2(s)$	−265.4	−210.7	191.6
Nickel			
$Ni(s)$	0	0	29.9
$Ni(g)$	429.7	384.5	182.2
$NiCl_2(s)$	−305.3	−259.0	97.7
$NiO(s)$	−239.7	−211.7	37.99
$NiS(s)$	−82.0	−79.5	53.0
Nitrogen			
$N(g)$	472.7	455.5	153.3
$N_2(g)$	0	0	191.6
$NF_3(g)$	−132.1	−90.6	260.8
$NH_3(g)$	−45.9	−16.4	192.8
$NH_3(aq)$	−80.29	−26.50	111.3
$NH_4^+(aq)$	−133.26	−79.31	111.17
$NH_4Br(s)$	−270.8	−175.2	113.0
$NH_4Cl(s)$	−314.4	−202.9	94.6
$NH_4CN(s)$	0.4		
$NH_4F(s)$	−464.0	−348.7	72.0
$NH_4HCO_3(s)$	−849.4	−665.9	120.9
$NH_4I(s)$	−201.4	−112.5	117.0
$NH_4NO_3(s)$	−365.6	−183.9	151.1
$NH_4NO_3(aq)$	−339.9	−190.6	259.8
$HNO_3(g)$	−133.9	−73.5	266.9
$HNO_3(aq)$	−207	−110.9	146
$NO(g)$	91.3	87.6	210.8
$NO_2(g)$	33.2	51.3	240.1
$NO_3^-(aq)$	−206.85	−110.2	146.70
$NOBr(g)$	82.2	82.4	273.7
$NOCl(g)$	51.7	66.1	261.7
$N_2H_4(l)$	50.6	149.3	121.2
$N_2H_4(g)$	95.4	159.4	238.5
$N_2O(g)$	81.6	103.7	220.0
$N_2O_4(l)$	−19.5	97.5	209.2
$N_2O_4(g)$	9.16	99.8	304.4
$N_2O_5(s)$	−43.1	113.9	178.2
$N_2O_5(g)$	13.3	117.1	355.7
Oxygen			
$O(g)$	249.2	231.7	161.1
$O_2(g)$	0	0	205.2
$O_3(g)$	142.7	163.2	238.9
$OH^-(aq)$	−230.02	−157.3	−10.90
$H_2O(l)$	−285.8	−237.1	70.0
$H_2O(g)$	−241.8	−228.6	188.8
$H_2O_2(l)$	−187.8	−120.4	109.6
$H_2O_2(g)$	−136.3	−105.6	232.7
Phosphorus			
P(s, white)	0	0	41.1
P(s, red)	−17.6	−12.1	22.8
$P(g)$	316.5	280.1	163.2
$P_2(g)$	144.0	103.5	218.1
$P_4(g)$	58.9	24.4	280.0
$PCl_3(l)$	−319.7	−272.3	217.1
$PCl_3(g)$	−287.0	−267.8	311.8
$PCl_5(s)$	−443.5		
$PCl_5(g)$	−374.9	−305.0	364.6
$PF_5(g)$	−1594.4	−1520.7	300.8
$PH_3(g)$	5.4	13.5	210.2
$POCl_3(l)$	−597.1	−520.8	222.5
$POCl_3(g)$	−558.5	−512.9	325.5
$PO_4^{3-}(aq)$	−1277.4	−1018.7	−220.5
$HPO_4^{2-}(aq)$	−1292.1	−1089.2	−33.5
$H_2PO_4^-(aq)$	−1296.3	−1130.2	90.4
$H_3PO_4(s)$	−1284.4	−1124.3	110.5
$H_3PO_4(aq)$	−1288.3	−1142.6	158.2
$P_4O_6(s)$	−1640.1		
$P_4O_{10}(s)$	−2984	−2698	228.9
Platinum			
$Pt(s)$	0	0	41.6
$Pt(g)$	565.3	520.5	192.4
Potassium			
$K(s)$	0	0	64.7
$K(g)$	89.0	60.5	160.3
$K^+(aq)$	−252.14	−283.3	101.2
$KBr(s)$	−393.8	−380.7	95.9
$KCN(s)$	−113.0	−101.9	128.5
$KCl(s)$	−436.5	−408.5	82.6
$KClO_3(s)$	−397.7	−296.3	143.1
$KClO_4(s)$	−432.8	−303.1	151.0
$KF(s)$	−567.3	−537.8	66.6
$KI(s)$	−327.9	−324.9	106.3
$KNO_3(s)$	−494.6	−394.9	133.1

Substance	ΔH_f°(kJ/mol)	ΔG_f°(kJ/mol)	S°(J/mol · K)
KOH(*s*)	−424.6	−379.4	81.2
KOH(*aq*)	−482.4	−440.5	91.6
KO_2(*s*)	−284.9	−239.4	116.7
K_2CO_3(*s*)	−1151.0	−1063.5	155.5
K_2O(*s*)	−361.5	−322.1	94.14
K_2O_2(*s*)	−494.1	−425.1	102.1
K_2SO_4(*s*)	−1437.8	−1321.4	175.6
Rubidium			
Rb(*s*)	0	0	76.8
Rb(*g*)	80.9	53.1	170.1
Rb^+(*aq*)	−251.12	−283.1	121.75
RbBr(*s*)	−394.6	−381.8	110.0
RbCl(*s*)	−435.4	−407.8	95.9
$RbClO_3$(*s*)	−392.4	−292.0	152
RbF(*s*)	−557.7		
RbI(*s*)	−333.8	−328.9	118.4
Scandium			
Sc(*s*)	0	0	34.6
Sc(*g*)	377.8	336.0	174.8
Selenium			
Se(*s*, gray)	0	0	42.4
Se(*g*)	227.1	187.0	176.7
H_2Se(*g*)	29.7	15.9	219.0
Silicon			
Si(*s*)	0	0	18.8
Si(*g*)	450.0	405.5	168.0
$SiCl_4$(*l*)	−687.0	−619.8	239.7
SiF_4(*g*)	−1615.0	−1572.8	282.8
SiH_4(*g*)	34.3	56.9	204.6
SiO_2(*s*, quartz)	−910.7	−856.3	41.5
Si_2H_6(*g*)	80.3	127.3	272.7
Silver			
Ag(*s*)	0	0	42.6
Ag(*g*)	284.9	246.0	173.0
Ag^+(*aq*)	105.79	77.11	73.45
AgBr(*s*)	−100.4	−96.9	107.1
AgCl(*s*)	−127.0	−109.8	96.3
AgF(*s*)	−204.6	−185	84
AgI(*s*)	−61.8	−66.2	115.5
$AgNO_3$(*s*)	−124.4	−33.4	140.9
Ag_2O(*s*)	−31.1	−11.2	121.3
Ag_2S(*s*)	−32.6	−40.7	144.0
Ag_2SO_4(*s*)	−715.9	−618.4	200.4
Sodium			
Na(*s*)	0	0	51.3
Na(*g*)	107.5	77.0	153.7
Na^+(*aq*)	−240.34	−261.9	58.45
NaBr(*s*)	−361.1	−349.0	86.8
NaCl(*s*)	−411.2	−384.1	72.1
NaCl(*aq*)	−407.2	−393.1	115.5

Substance	ΔH_f°(kJ/mol)	ΔG_f°(kJ/mol)	S°(J/mol · K)
$NaClO_3$(*s*)	−365.8	−262.3	123.4
NaF(*s*)	−576.6	−546.3	51.1
$NaHCO_3$(*s*)	−950.8	−851.0	101.7
$NaHSO_4$(*s*)	−1125.5	−992.8	113.0
NaI(*s*)	−287.8	−286.1	98.5
$NaNO_3$(*s*)	−467.9	−367.0	116.5
$NaNO_3$(*aq*)	−447.5	−373.2	205.4
NaOH(*s*)	−425.8	−379.7	64.4
NaOH(*aq*)	−470.1	−419.2	48.2
NaO_2(*s*)	−260.2	−218.4	115.9
Na_2CO_3(*s*)	−1130.7	−1044.4	135.0
Na_2O(*s*)	−414.2	−375.5	75.1
Na_2O_2(*s*)	−510.9	−447.7	95.0
Na_2SO_4(*s*)	−1387.1	−1270.2	149.6
Na_3PO_4(*s*)	−1917	−1789	173.8
Strontium			
Sr(*s*)	0	0	55.0
Sr(*g*)	164.4	130.9	164.6
Sr^{2+}(*aq*)	−545.51	−557.3	−39
$SrCl_2$(*s*)	−828.9	−781.1	114.9
$SrCO_3$(*s*)	−1220.1	−1140.1	97.1
SrO(*s*)	−592.0	−561.9	54.4
$SrSO_4$(*s*)	−1453.1	−1340.9	117.0
Sulfur			
S(*s*, rhombic)	0	0	32.1
S(*s*, monoclinic)	0.3	0.096	32.6
S(*g*)	277.2	236.7	167.8
S_2(*g*)	128.6	79.7	228.2
S_8(*g*)	102.3	49.7	430.9
S^{2-}(*aq*)	41.8	83.7	22
SF_6(*g*)	−1220.5	−1116.5	291.5
HS^-(*aq*)	−17.7	12.4	62.0
H_2S(*g*)	−20.6	−33.4	205.8
H_2S(*aq*)	−39.4	−27.7	122
$SOCl_2$(*l*)	−245.6		
SO_2(*g*)	−296.8	−300.1	248.2
SO_3(*g*)	−395.7	−371.1	256.8
SO_4^{2-}(*aq*)	−909.3	−744.6	18.5
HSO_4^-(*aq*)	−886.5	−754.4	129.5
H_2SO_4(*l*)	−814.0	−690.0	156.9
H_2SO_4(*aq*)	−909.3	−744.6	18.5
$S_2O_3^{2-}$(*aq*)	−648.5	−522.5	67
Tin			
Sn(*s*, white)	0	0	51.2
Sn(*s*, gray)	−2.1	0.1	44.1
Sn(*g*)	301.2	266.2	168.5
$SnCl_4$(*l*)	−511.3	−440.1	258.6
$SnCl_4$(*g*)	−471.5	−432.2	365.8
SnO(*s*)	−280.7	−251.9	57.2
SnO_2(*s*)	−577.6	−515.8	49.0

—(Continued on the next page)

Substance	ΔH_f°(kJ/mol)	ΔG_f°(kJ/mol)	S°(J/mol · K)
Titanium			
Ti(*s*)	0	0	30.7
Ti(*g*)	473.0	428.4	180.3
$TiCl_4(l)$	−804.2	−737.2	252.3
$TiCl_4(g)$	−763.2	−726.3	353.2
$TiO_2(s)$	−944.0	−888.8	50.6
Tungsten			
W(*s*)	0	0	32.6
W(*g*)	849.4	807.1	174.0
$WO_3(s)$	−842.9	−764.0	75.9
Uranium			
U(*s*)	0	0	50.2
U(*g*)	533.0	488.4	199.8
$UF_6(s)$	−2197.0	−2068.5	227.6
$UF_6(g)$	−2147.4	−2063.7	377.9
$UO_2(s)$	−1085.0	−1031.8	77.0
Vanadium			
V(*s*)	0	0	28.9
V(*g*)	514.2	754.4	182.3
Zinc			
Zn(*s*)	0	0	41.6
Zn(*g*)	130.4	94.8	161.0
$Zn^{2+}(aq)$	−153.39	−147.1	−109.8
$ZnCl_2(s)$	−415.1	−369.4	111.5
ZnO(*s*)	−350.5	−320.5	43.7
ZnS (*s*, zinc blende)	−206.0	−201.3	57.7
$ZnSO_4(s)$	−982.8	−871.5	110.5

C. Aqueous Equilibrium Constants

1. Dissociation Constants for Acids at 25 °C

Name	Formula	K_{a_1}	K_{a_2}	K_{a_3}
Acetic	$HC_2H_3O_2$	1.8×10^{-5}		
Acetylsalicylic	$HC_9H_7O_4$	3.3×10^{-4}		
Adipic	$H_2C_6H_8O_4$	3.9×10^{-5}	3.9×10^{-6}	
Arsenic	H_3AsO_4	5.5×10^{-3}	1.7×10^{-7}	5.1×10^{-12}
Arsenous	H_3AsO_3	5.1×10^{-10}		
Ascorbic	$H_2C_6H_6O_6$	8.0×10^{-5}	1.6×10^{-12}	
Benzoic	$HC_7H_5O_2$	6.5×10^{-5}		
Boric	H_3BO_3	5.4×10^{-10}		
Butanoic	$HC_4H_7O_2$	1.5×10^{-5}		
Carbonic	H_2CO_3	4.3×10^{-7}	5.6×10^{-11}	
Chloroacetic	$HC_2H_2O_2Cl$	1.4×10^{-3}		
Chlorous	$HClO_2$	1.1×10^{-2}		
Citric	$H_3C_6H_5O_7$	7.4×10^{-4}	1.7×10^{-5}	4.0×10^{-7}
Cyanic	HCNO	2×10^{-4}		
Formic	$HCHO_2$	1.8×10^{-4}		
Hydrazoic	HN_3	2.5×10^{-5}		
Hydrocyanic	HCN	4.9×10^{-10}		
Hydrofluoric	HF	6.8×10^{-4}		
Hydrogen chromate ion	$HCrO_4^-$	3.0×10^{-7}		
Hydrogen peroxide	H_2O_2	2.4×10^{-12}		
Hydrogen selenate ion	$HSeO_4^-$	2.2×10^{-2}		
Hydrosulfuric	H_2S	8.9×10^{-8}	1×10^{-19}	
Hydrotelluric	H_2Te	2.3×10^{-3}	1.6×10^{-11}	
Hypobromous	HBrO	2.8×10^{-9}		
Hypochlorous	HClO	2.9×10^{-8}		
Hypoiodous	HIO	2.3×10^{-11}		
Iodic	HIO_3	1.7×10^{-1}		
Lactic	$HC_3H_5O_3$	1.4×10^{-4}		
Maleic	$H_2C_4H_2O_4$	1.2×10^{-2}	5.9×10^{-7}	
Malonic	$H_2C_3H_2O_4$	1.5×10^{-3}	2.0×10^{-6}	
Nitrous	HNO_2	4.6×10^{-4}		
Oxalic	$H_2C_2O_4$	6.0×10^{-2}	6.1×10^{-5}	
Paraperiodic	H_5IO_6	2.8×10^{-2}	5.3×10^{-9}	
Phenol	HC_6H_5O	1.3×10^{-10}		
Phosphoric	H_3PO_4	7.5×10^{-3}	6.2×10^{-8}	4.2×10^{-13}
Phosphorous	H_3PO_3	5×10^{-2}	2.0×10^{-7}	
Propanoic	$HC_3H_5O_2$	1.3×10^{-5}		
Pyruvic	$HC_3H_3O_3$	4.1×10^{-3}		
Pyrophosphoric	$H_4P_2O_7$	1.2×10^{-1}	7.9×10^{-3}	2.0×10^{-7}
Selenous	H_2SeO_3	2.4×10^{-3}	4.8×10^{-9}	
Succinic	$H_2C_4H_4O_4$	6.2×10^{-5}	2.3×10^{-6}	
Sulfuric	H_2SO_4	Strong acid	1.2×10^{-2}	
Sulfurous	H_2SO_3	1.6×10^{-2}	6.4×10^{-8}	
Tartaric	$H_2C_4H_4O_6$	1.0×10^{-3}	4.6×10^{-5}	
Trichloroacetic	$HC_2Cl_3O_2$	2.2×10^{-1}		
Trifluoroacetic acid	$HC_2F_3O_2$	3.0×10^{-1}		

2. Dissociation Constants for Hydrated Metal Ions at 25 °C

Cation	Hydrated Ion	K_a
Al^{3+}	$Al(H_2O)_6^{3+}$	1.4×10^{-5}
Be^{2+}	$Be(H_2O)_6^{2+}$	3×10^{-7}
Co^{2+}	$Co(H_2O)_6^{2+}$	1.3×10^{-9}
Cr^{3+}	$Cr(H_2O)_6^{3+}$	1.6×10^{-4}
Cu^{2+}	$Cu(H_2O)_6^{2+}$	3×10^{-8}
Fe^{2+}	$Fe(H_2O)_6^{2+}$	3.2×10^{-10}
Fe^{3+}	$Fe(H_2O)_6^{3+}$	6.3×10^{-3}
Ni^{2+}	$Ni(H_2O)_6^{2+}$	2.5×10^{-11}
Pb^{2+}	$Pb(H_2O)_6^{2+}$	3×10^{-8}
Sn^{2+}	$Sn(H_2O)_6^{2+}$	4×10^{-4}
Zn^{2+}	$Zn(H_2O)_6^{2+}$	2.5×10^{-10}

3. Dissociation Constants for Bases at 25 °C

Name	Formula	K_b
Ammonia	NH_3	1.76×10^{-5}
Aniline	$C_6H_5NH_2$	3.9×10^{-10}
Bicarbonate ion	HCO_3^-	2.3×10^{-8}
Carbonate ion	CO_3^{2-}	1.8×10^{-4}
Codeine	$C_{18}H_{21}NO_3$	1.6×10^{-6}
Diethylamine	$(C_2H_5)_2NH$	6.9×10^{-4}
Dimethylamine	$(CH_3)_2NH$	5.4×10^{-4}
Ethylamine	$C_2H_5NH_2$	5.6×10^{-4}
Ethylenediamine	$C_2H_8N_2$	8.3×10^{-5}
Hydrazine	H_2NNH_2	1.3×10^{-6}
Hydroxylamine	$HONH_2$	1.1×10^{-8}
Ketamine	$C_{13}H_{16}ClNO$	3×10^{-7}
Methylamine	CH_3NH_2	4.4×10^{-4}
Morphine	$C_{17}H_{19}NO_3$	1.6×10^{-6}
Nicotine	$C_{10}H_{14}N_2$	1.0×10^{-6}
Piperidine	$C_5H_{10}NH$	1.33×10^{-3}
Propylamine	$C_3H_7NH_2$	3.5×10^{-4}
Pyridine	C_5H_5N	1.7×10^{-9}
Strychnine	$C_{21}H_{22}N_2O_2$	1.8×10^{-6}
Triethylamine	$(C_2H_5)_3N$	5.6×10^{-4}
Trimethylamine	$(CH_3)_3N$	6.4×10^{-5}

4. Solubility Product Constants for Compounds at 25 °C

Compound	Formula	K_{sp}
Aluminum hydroxide	$Al(OH)_3$	1.3×10^{-33}
Aluminum phosphate	$AlPO_4$	9.84×10^{-21}
Barium carbonate	$BaCO_3$	2.58×10^{-9}
Barium chromate	$BaCrO_4$	1.17×10^{-10}
Barium fluoride	BaF_2	2.45×10^{-5}
Barium hydroxide	$Ba(OH)_2$	5.0×10^{-3}
Barium oxalate	BaC_2O_4	1.6×10^{-6}
Barium phosphate	$Ba_3(PO_4)_2$	6×10^{-39}
Barium sulfate	$BaSO_4$	1.07×10^{-10}
Cadmium carbonate	$CdCO_3$	1.0×10^{-12}
Cadmium hydroxide	$Cd(OH)_2$	7.2×10^{-15}
Cadmium sulfide	CdS	8×10^{-28}
Calcium carbonate	$CaCO_3$	4.96×10^{-9}
Calcium chromate	$CaCrO_4$	7.1×10^{-4}
Calcium fluoride	CaF_2	1.46×10^{-10}
Calcium hydroxide	$Ca(OH)_2$	4.68×10^{-6}
Calcium hydrogen phosphate	$CaHPO_4$	1×10^{-7}
Calcium oxalate	CaC_2O_4	2.32×10^{-9}
Calcium phosphate	$Ca_3(PO_4)_2$	2.07×10^{-33}
Calcium sulfate	$CaSO_4$	7.10×10^{-5}
Chromium(III) hydroxide	$Cr(OH)_3$	6.3×10^{-31}
Cobalt(II) carbonate	$CoCO_3$	1.0×10^{-10}
Cobalt(II) hydroxide	$Co(OH)_2$	5.92×10^{-15}
Cobalt(II) sulfide	CoS	5×10^{-22}
Copper(I) bromide	$CuBr$	6.27×10^{-9}
Copper(I) chloride	$CuCl$	1.72×10^{-7}
Copper(I) cyanide	$CuCN$	3.47×10^{-20}
Copper(II) carbonate	$CuCO_3$	2.4×10^{-10}
Copper(II) hydroxide	$Cu(OH)_2$	2.2×10^{-20}
Copper(II) phosphate	$Cu_3(PO_4)_2$	1.40×10^{-37}
Copper(II) sulfide	CuS	1.27×10^{-36}
Iron(II) carbonate	$FeCO_3$	3.07×10^{-11}

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Compound	Formula	K_{sp}
Iron(II) hydroxide	$Fe(OH)_2$	4.87×10^{-17}
Iron(II) sulfide	FeS	3.72×10^{-19}
Iron(III) hydroxide	$Fe(OH)_3$	2.79×10^{-39}
Lanthanum fluoride	LaF_3	2×10^{-19}
Lanthanum iodate	$La(IO_3)_3$	7.50×10^{-12}
Lead(II) bromide	$PbBr_2$	4.67×10^{-6}
Lead(II) carbonate	$PbCO_3$	7.40×10^{-14}
Lead(II) chloride	$PbCl_2$	1.17×10^{-5}
Lead(II) chromate	$PbCrO_4$	2.8×10^{-13}
Lead(II) fluoride	PbF_2	3.3×10^{-8}
Lead(II) hydroxide	$Pb(OH)_2$	1.43×10^{-20}
Lead(II) iodide	PbI_2	9.8×10^{-9}
Lead(II) phosphate	$Pb_3(PO_4)_2$	1×10^{-54}
Lead(II) sulfate	$PbSO_4$	1.82×10^{-8}
Lead(II) sulfide	PbS	9.04×10^{-29}
Magnesium carbonate	$MgCO_3$	6.82×10^{-6}
Magnesium fluoride	MgF_2	5.16×10^{-11}
Magnesium hydroxide	$Mg(OH)_2$	2.06×10^{-13}
Magnesium oxalate	MgC_2O_4	4.83×10^{-6}
Manganese(II) carbonate	$MnCO_3$	2.24×10^{-11}
Manganese(II) hydroxide	$Mn(OH)_2$	1.6×10^{-13}
Manganese(II) sulfide	MnS	2.3×10^{-13}
Mercury(I) bromide	Hg_2Br_2	6.40×10^{-23}
Mercury(I) carbonate	Hg_2CO_3	3.6×10^{-17}
Mercury(I) chloride	Hg_2Cl_2	1.43×10^{-18}
Mercury(I) chromate	Hg_2CrO_4	2×10^{-9}
Mercury(I) cyanide	$Hg_2(CN)_2$	5×10^{-40}

Compound	Formula	K_{sp}
Mercury(I) iodide	Hg_2I_2	5.2×10^{-29}
Mercury(II) hydroxide	$Hg(OH)_2$	3.1×10^{-26}
Mercury(II) sulfide	HgS	1.6×10^{-54}
Nickel(II) carbonate	$NiCO_3$	1.42×10^{-7}
Nickel(II) hydroxide	$Ni(OH)_2$	5.48×10^{-16}
Nickel(II) sulfide	NiS	3×10^{-20}
Silver bromate	$AgBrO_3$	5.38×10^{-5}
Silver bromide	AgBr	5.35×10^{-13}
Silver carbonate	Ag_2CO_3	8.46×10^{-12}
Silver chloride	AgCl	1.77×10^{-10}
Silver chromate	Ag_2CrO_4	1.12×10^{-12}
Silver cyanide	AgCN	5.97×10^{-17}
Silver iodide	AgI	8.51×10^{-17}
Silver phosphate	Ag_3PO_4	8.89×10^{-17}
Silver sulfate	Ag_2SO_4	1.20×10^{-5}
Silver sulfide	Ag_2S	6×10^{-51}
Strontium carbonate	$SrCO_3$	5.60×10^{-10}
Strontium chromate	$SrCrO_4$	3.6×10^{-5}
Strontium phosphate	$Sr_3(PO_4)_2$	1×10^{-31}
Strontium sulfate	$SrSO_4$	3.44×10^{-7}
Tin(II) hydroxide	$Sn(OH)_2$	5.45×10^{-27}
Tin(II) sulfide	SnS	1×10^{-26}
Zinc carbonate	$ZnCO_3$	1.46×10^{-10}
Zinc hydroxide	$Zn(OH)_2$	3×10^{-17}
Zinc oxalate	ZnC_2O_4	2.7×10^{-8}
Zinc sulfide	ZnS	2×10^{-25}

5. Complex Ion Formation Constants in Water at 25 °C

Complex Ion	K_f
$[Ag(CN)_2]^-$	1×10^{21}
$[Ag(EDTA)]^{3-}$	2.1×10^{7}
$[Ag(en)_2]^+$	5.0×10^{7}
$[Ag(NH_3)_2]^+$	1.7×10^{7}
$[Ag(SCN)_4]^{3-}$	1.2×10^{10}
$[Ag(S_2O_3)_2]^{3-}$	2.8×10^{13}
$[Al(EDTA)]^-$	1.3×10^{16}
$[AlF_6]^{3-}$	7×10^{19}
$[Al(OH)_4]^-$	3×10^{33}
$[Al(ox)_3]^{3-}$	2×10^{16}
$[CdBr_4]^{2-}$	5.5×10^{3}
$[Cd(CN)_4]^{2-}$	3×10^{18}

Complex Ion	K_f
$[CdCl_4]^{2-}$	6.3×10^{2}
$[Cd(en)_3]^{2+}$	1.2×10^{12}
$[CdI_4]^{2-}$	2×10^{6}
$[Co(EDTA)]^{2-}$	2.0×10^{16}
$[Co(EDTA)]^-$	1×10^{36}
$[Co(en)_3]^{2+}$	8.7×10^{13}
$[Co(en)_3]^{3+}$	4.9×10^{48}
$[Co(NH_3)_6]^{2+}$	1.3×10^{5}
$[Co(NH_3)_6]^{3+}$	2.3×10^{33}
$[Co(OH)_4]^{2-}$	5×10^{9}
$[Co(ox)_3]^{4-}$	5×10^{9}
$[Co(ox)_3]^{3-}$	1×10^{20}

Complex Ion	K_f
$[Co(SCN)_4]^{2-}$	1×10^{3}
$[Cr(EDTA)]^{-}$	1×10^{23}
$[Cr(OH)_4]^{-}$	8.0×10^{29}
$[CuCl_3]^{2-}$	5×10^{5}
$[Cu(CN)_4]^{2-}$	1.0×10^{25}
$[Cu(EDTA)]^{2-}$	5×10^{18}
$[Cu(en)_2]^{2+}$	1×10^{20}
$[Cu(NH_3)_4]^{2+}$	1.7×10^{13}
$[Cu(ox)_2]^{2-}$	3×10^{8}
$[Fe(CN)_6]^{4-}$	1.5×10^{35}
$[Fe(CN)_6]^{3-}$	2×10^{43}
$[Fe(EDTA)]^{2-}$	2.1×10^{14}
$[Fe(EDTA)]^{-}$	1.7×10^{24}
$[Fe(en)_3]^{2+}$	5.0×10^{9}
$[Fe(ox)_3]^{4-}$	1.7×10^{5}
$[Fe(ox)_3]^{3-}$	2×10^{20}
$[Fe(SCN)]^{2+}$	8.9×10^{2}
$[Hg(CN)_4]^{2-}$	1.8×10^{41}
$[HgCl_4]^{2-}$	1.1×10^{16}
$[Hg(EDTA)]^{2-}$	6.3×10^{21}
$[Hg(en)_2]^{2+}$	2×10^{23}
$[HgI_4]^{2-}$	2×10^{30}

Complex Ion	K_f
$[Hg(ox)_2]^{2-}$	9.5×10^{6}
$[Ni(CN)_4]^{2-}$	2×10^{31}
$[Ni(EDTA)]^{2-}$	3.6×10^{18}
$[Ni(en)_3]^{2+}$	2.1×10^{18}
$[Ni(NH_3)_6]^{2+}$	2.0×10^{8}
$[Ni(ox)_3]^{4-}$	3×10^{8}
$[PbCl_3]^{-}$	2.4×10^{1}
$[Pb(EDTA)]^{2-}$	2×10^{18}
$[PbI_4]^{2-}$	3.0×10^{4}
$[Pb(OH)_3]^{-}$	8×10^{13}
$[Pb(ox)_2]^{2-}$	3.5×10^{6}
$[Pb(S_2O_3)_3]^{4-}$	2.2×10^{6}
$[PtCl_4]^{2-}$	1×10^{16}
$[Pt(NH_3)_6]^{2+}$	2×10^{35}
$[Sn(OH)_3]^{-}$	3×10^{25}
$[Zn(CN)_4]^{2-}$	2.1×10^{19}
$[Zn(EDTA)]^{2-}$	3×10^{16}
$[Zn(en)_3]^{2+}$	1.3×10^{14}
$[Zn(NH_3)_4]^{2+}$	2.8×10^{9}
$[Zn(OH)_4]^{2-}$	2×10^{15}
$[Zn(ox)_3]^{4-}$	1.4×10^{8}

D. Standard Electrode Potentials at 25 °C

Half-Reaction	$E°$(V)
$F_2(g) + 2\ e^- \longrightarrow 2\ F^-(aq)$	2.87
$O_3(g) + 2\ H^+(aq) + 2\ e^- \longrightarrow O_2(g) + H_2(l)$	2.08
$Ag^{2+}(aq) + e^- \longrightarrow Ag^+(aq)$	1.98
$Co^{3+}(aq) + e^- \longrightarrow Co^{2+}(aq)$	1.82
$H_2O_2(aq) + 2\ H^+(aq) + 2\ e^- \longrightarrow 2\ H_2O(l)$	1.78
$PbO_2(s) + 4\ H^+(aq) + SO_4^{2-}aq) + 2\ e^- \longrightarrow PbSO_4(s) + 2\ H_2O(l)$	1.69
$MnO_4^-(aq) + 4\ H^+(aq) + 3\ e^- \longrightarrow MnO_2(s) + 2\ H_2O(l)$	1.68
$2\ HClO(aq) + 2\ H^+(aq) + 2\ e^- \longrightarrow Cl_2(g) + 2\ H_2O(l)$	1.61
$MnO_4^-(aq) + 8\ H^+(aq) + 5\ e^- \longrightarrow Mn^{2+}(aq) + 4\ H_2O(l)$	1.51
$Au^{3+}(aq) + 3\ e^- \longrightarrow Au(s)$	1.50
$2\ BrO_3^-(aq) + 12\ H^+(aq) + 10\ e^- \longrightarrow Br_2(l) + 6\ H_2O(l)$	1.48
$PbO_2(s) + 4\ H^+(aq) + 2\ e^- \longrightarrow Pb^{2+}(aq) + 2\ H_2O(l)$	1.46
$Cl_2(g) + 2\ e^- \longrightarrow 2\ Cl^-(aq)$	1.36

Half-Reaction	$E°$(V)
$Cr_2O_7^{2-}(aq) + 14\ H^+(aq) + 6\ e^- \longrightarrow 2\ Cr^{3+}(aq) + 7\ H_2O(l)$	1.33
$O_2(g) + 4\ H^+(aq) + 4\ e^- \longrightarrow 2\ H_2O(l)$	1.23
$MnO_2(s) + 4\ H^+(aq) + 2\ e^- \longrightarrow Mn^{2+}(aq) + 2\ H_2O(l)$	1.21
$IO_3^-(aq) + 6\ H^+(aq) + 5\ e^- \longrightarrow \frac{1}{2}\ I_2(aq) + 3\ H_2O(l)$	1.20
$Br_2(l) + 2\ e^- \longrightarrow 2\ Br^-(aq)$	1.09
$AuCl_4^-(aq) + 3\ e^- \longrightarrow Au(s) + 4\ Cl^-(aq)$	1.00
$VO_2^+(aq) + 2\ H^+(aq) + e^- \longrightarrow VO^{2+}(aq) + H_2O(l)$	1.00
$HNO_2(aq) + H^+(aq) + e^- \longrightarrow NO(g) + 2\ H_2O(l)$	0.98
$NO_3^-(aq) + 4\ H^+(aq) + 3\ e^- \longrightarrow NO(g) + 2\ H_2O(l)$	0.96
$ClO_2(g) + e^- \longrightarrow ClO_2^-(aq)$	0.95
$2\ Hg^{2+}(aq) + 2\ e^- \longrightarrow 2\ Hg_2^{2+}(aq)$	0.92
$Ag^+(aq) + e^- \longrightarrow Ag(s)$	0.80
$Hg_2^{2+}(aq) + 2\ e^- \longrightarrow 2\ Hg(l)$	0.80

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Half-Reaction	$E°$(V)
$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$	0.77
$PtCl_4^{2-}(aq) + 2\ e^- \longrightarrow Pt(s) + 4\ Cl^-(aq)$	0.76
$O_2(g) + 2\ H^+(aq) + 2\ e^- \longrightarrow H_2O_2(aq)$	0.70
$MnO_4^-(aq) + e^- \longrightarrow MnO_4^{2-}(aq)$	0.56
$I_2(s) + 2\ e^- \longrightarrow 2\ I^-(aq)$	0.54
$Cu^+(aq) + e^- \longrightarrow Cu(s)$	0.52
$O_2(g) + 2\ H_2O(l) + 4\ e^- \longrightarrow 4\ OH^-(aq)$	0.40
$Cu^{2+}(aq) + 2\ e^- \longrightarrow Cu(s)$	0.34
$BiO^+(aq) + 2\ H^+(aq) + 3\ e^- \longrightarrow Bi(s) + H_2O(l)$	0.32
$Hg_2Cl_2(s) + 2\ e^- \longrightarrow 2\ Hg(l) + 2\ Cl^-(aq)$	0.27
$AgCl(s) + e^- \longrightarrow Ag(s) + Cl^-(aq)$	0.22
$SO_4^{2-}(aq) + 4\ H^+(aq) + 2\ e^- \longrightarrow H_2SO_3(aq) + H_2O(l)$	0.20
$Cu^{2+}(aq) + e^- \longrightarrow Cu^+(aq)$	0.16
$Sn^{4+}(aq) + 2\ e^- \longrightarrow Sn^{2+}(aq)$	0.15
$S(s) + 2\ H^+(aq) + 2\ e^- \longrightarrow H_2S(g)$	0.14
$AgBr(s) + e^- \longrightarrow Ag(s) + Br^-(aq)$	0.071
$2\ H^+(aq) + 2\ e^- \longrightarrow H_2(g)$	0.00
$Fe^{3+}(aq) + 3\ e^- \longrightarrow Fe(s)$	−0.036
$Pb^{2+}(aq) + 2\ e^- \longrightarrow Pb(s)$	−0.13
$Sn^{2+}(aq) + 2\ e^- \longrightarrow Sn(s)$	−0.14
$AgI(s) + e^- \longrightarrow Ag(s) + I^-(aq)$	−0.15

Half-Reaction	$E°$(V)
$N_2(g) + 5\ H^+(aq) + 4\ e^- \longrightarrow N_2H_5^+(aq)$	−0.23
$Ni^{2+}(aq) + 2\ e^- \longrightarrow Ni(s)$	−0.23
$Co^{2+}(aq) + 2\ e^- \longrightarrow Co(s)$	−0.28
$PbSO_4(s) + 2\ e^- \longrightarrow Pb(s) + SO_4^{2-}(aq)$	−0.36
$Cd^{2+}(aq) + 2\ e^- \longrightarrow Cd(s)$	−0.40
$Fe^{2+}(aq) + 2\ e^- \longrightarrow Fe(s)$	−0.45
$2\ CO_2(g) + 2\ H^+(aq) + 2\ e^- \longrightarrow H_2C_2O_4(aq)$	−0.49
$Cr^{3+}(aq) + e^- \longrightarrow Cr^{2+}(aq)$	−0.50
$Cr^{3+}(aq) + 3\ e^- \longrightarrow Cr(s)$	−0.73
$Zn^{2+}(aq) + 2\ e^- \longrightarrow Zn(s)$	−0.76
$2\ H_2O(l) + 2\ e^- \longrightarrow H_2(g) + 2\ OH^-(aq)$	−0.83
$Mn^{2+}(aq) + 2\ e^- \longrightarrow Mn(s)$	−1.18
$Al^{3+}(aq) + 3\ e^- \longrightarrow Al(s)$	−1.66
$H_2(g) + 2\ e^- \longrightarrow 2\ H^-(aq)$	−2.23
$Mg^{2+}(aq) + 2\ e^- \longrightarrow Mg(s)$	−2.37
$La^{3+}(aq) + 3\ e^- \longrightarrow La(s)$	−2.38
$Na^+(aq) + e^- \longrightarrow Na(s)$	−2.71
$Ca^{2+}(aq) + 2\ e^- \longrightarrow Ca(s)$	−2.76
$Ba^{2+}(aq) + 2\ e^- \longrightarrow Ba(s)$	−2.90
$K^+(aq) + e^- \longrightarrow K(s)$	−2.92
$Li^+(aq) + e^- \longrightarrow Li(s)$	−3.04

E. Vapor Pressure of Water at Various Temperatures

T (°C)	P (torr)	T (°C)	P (torr)	T (°C)	P (torr)	T (°C)	P (torr)
0	4.58	21	18.65	35	42.2	92	567.0
5	6.54	22	19.83	40	55.3	94	610.9
10	9.21	23	21.07	45	71.9	96	657.6
12	10.52	24	22.38	50	92.5	98	707.3
14	11.99	25	23.76	55	118.0	100	760.0
16	13.63	26	25.21	60	149.4	102	815.9
17	14.53	27	26.74	65	187.5	104	875.1
18	15.48	28	28.35	70	233.7	106	937.9
19	16.48	29	30.04	80	355.1	108	1004.4
20	17.54	30	31.82	90	525.8	110	1074.6

APPENDIX III Answers to Selected Exercises

Chapter 1

33. **a.** theory **b.** observation **c.** law **d.** observation

35. Several answers possible

37. **a.** mixture, homogeneous
b. pure substance, compound
c. pure substance, element
d. mixture, heterogeneous

39.

Substance	Pure or Mixture	Type
Aluminum	Pure	Element
Apple juice	Mixture	Homogeneous
Hydrogen peroxide	Pure	Compound
Chicken soup	Mixture	Heterogeneous

41. **a.** pure substance, compound
b. mixture, heterogeneous
c. mixture, homogeneous
d. pure substance, element

43. physical, chemical, physical, physical, physical

45. **a.** chemical **b.** physical **c.** physical **d.** chemical

47. **a.** chemical **b.** physical **c.** chemical **d.** chemical

49. **a.** physical **b.** chemical **c.** physical

51. **a.** 0 °C **b.** −321 °F **c.** −78.3 °F **d.** 310.2 K

53. −89.2 °C, 184.0 K

55. **a.** 1.2 nm **b.** 22 fs **c.** 1.5 Gg **d.** 3.5 ML

57. **a.** 4.5×10^{-9} s **b.** 1.8×10^{-14} s **c.** 1.28×10^{-10} m **d.** 3.5×10^{-5} m

59.

1245 kg	1.245×10^{6} g	1.245×10^{9} mg
515 km	5.15×10^{6} dm	5.15×10^{7} cm
122.355 s	1.22355×10^{5} ms	0.122355 ks
3.345 kJ	3.345×10^{3} J	3.345×10^{6} mJ

61. **e.** 254.998 km **f.** 2.54998×10^{-1} Mm **g.** 254998×10^{3} mm **h.** 254998×10^{2} cm

63. 10,000 1 cm squares

65. no

67. 1.26 g/cm^3

69. **a.** 463 g **b.** 3.7 L

71. $201. \times 10^{3}$ g

73. **a.** 73.7 mL **b.** 88.2 °C **c.** 647 mL

75. **a.** 1,050,501 **b.** 0.0020 **c.** 0.0000000000002 **d.** 0.001090

77. **a.** 3 **b.** ambiguous; without more information, assume three significant figures. **c.** 3 **d.** 5 **e.** ambiguous; without more information, assume one significant figure.

79. **a.** not exact **b.** exact **c.** not exact **d.** exact

81. **a.** 156.9 **b.** 156.8 **c.** 156.8 **d.** 156.9

83. **a.** 1.84 **b.** 0.033 **c.** 0.500 **d.** 34

85. **a.** 41.4 **b.** 133.5 **c.** 73.0 **d.** 0.42

87. **a.** 391.3 **b.** 1.1×10^{4} **c.** 5.96 **d.** 5.93×10^{4}

89. 0.74 g/mL

91. **a.** 2.78×10^{4} cm^3 **b.** 1.898×10^{-3} kg **c.** 1.98×10^{7} cm

93. **a.** 60.6 in **b.** 3.14×10^{3} g **c.** 3.7 qt **d.** 4.29 in

95. 5.0×10^{1} min

97. 4.0×10^{1} mi/gal

99. **a.** 1.95×10^{-4} km^2 **b.** 1.95×10^{4} dm^2 **c.** 1.95×10^{6} cm^2

101. 0.680 mi^2

103. 0.95 mL

105. 3.1557×10^{7} s/solar year

107. **a.** extensive **b.** intensive **c.** intensive **d.** intensive **e.** extensive

109. −34 °F

111. $F = \text{kg}(\text{m/s}^2) = \text{N}$ (for newton), kN, pN

113. **a.** 2.2×10^{-6} **b.** 0.0159 **c.** 6.9×10^{4}

115. **a.** mass of can of gold $= 1.9 \times 10^{4}$ g
mass of can of sand $= 3.0 \times 10^{3}$ g
b. Yes, the thief sets off the trap because the can of sand is lighter than the gold cylinder.

117. 22 in^3

119. 7.6 g/cm^3

121. 3.11×10^{5} lb

123. 3.3×10^{2} km

125. 6.8×10^{-15}

127. 2.4×10^{19} km

129. 488 grams

131. 0.661 Ω

133. 0.492

135. 18.2 atm

137. $1\text{ J} = 1\text{ kg m}^2/\text{s}^2$
$m = \text{kg}, v^2 = (\text{m/s})^2\ mv = \text{kg m}^2/\text{s}^2$
$P = \text{N/m}^2 = \text{kg m/s}^2/\text{m}^2 = \text{kg/m s}^2$
$V = \text{m}^2\ PV = \text{kg m}^3/\text{m s}^2 = \text{kg m}^2/\text{s}^2$

139. 9.0×10^{1} mg CO

141. 13% increase

143. No. Since the container is sealed, the atoms and molecules can move around, but they cannot leave. If no atoms or molecules can leave, the mass must be constant.