APPENDIX C

TABLES OF SELECTED DATA

TABLE C.1 Thermodynamic Data for Selected Elements, Compounds, and Ions (25 °C)

Substance	ΔH_f°(kJ mol^{-1})	S°(J mol^{-1} K^{-1})	ΔG_f°(kJ mol^{-1})
Aluminum			
$Al(s)$	0	28.3	0
$Al^{3+}(aq)$	−524.7		−481.2
$AlCl_3(s)$	−704	110.7	−629
$Al_2O_3(s)$	−1669.8	51.0	−1576.4
$Al_2(SO_4)_3(s)$	−3441	239	−3100
Arsenic			
$As(s)$	0	35.1	0
$AsH_3(g)$	+66.4	223	+68.9
$As_4O_6(s)$	−1314	214	−1153
$As_2O_5(s)$	−925	105	−782
$H_3AsO_3(aq)$	−742.2		
$H_3AsO_4(aq)$	−902.5		
Barium			
$Ba(s)$	0	66.9	0
$Ba^{2+}(aq)$	−537.6	9.6	−560.8
$BaCO_3(s)$	−1219	112	−1139
$BaCrO_4(s)$	−1428.0		
$BaCl_2(s)$	−860.2	125	−810.8
$BaO(s)$	−553.5	70.4	−525.1
$Ba(OH)_2(s)$	−998.22	−8	−875.3
$Ba(NO_3)_2(s)$	−992	214	−795
$BaSO_4(s)$	−1465	132	−1353
Beryllium			
$Be(s)$	0	9.50	0
$BeCl_2(s)$	−468.6	89.9	−426.3
$BeO(s)$	−611	14	−582
Bismuth			
$Bi(s)$	0	56.9	0
$BiCl_3(s)$	−379	177	−315
$Bi_2O_3(s)$	−576	151	−497
Boron			
$B(s)$	0	5.87	0
$BCl_3(g)$	−404	290	−389
$B_2H_6(g)$	+36	232	+87
$B_2O_3(s)$	−1273	53.8	−1194
$B(OH)_3(s)$	−1094	88.8	−969
Bromine			
$Br_2(l)$	0	152.2	0
$Br_2(g)$	+30.9	245.4	+3.11
$HBr(g)$	−36	198.5	+53.1
$Br^-(aq)$	−121.55	82.4	−103.96
Cadmium			
$Cd(s)$	0	51.8	0
$Cd^{2+}(aq)$	−75.90	−73.2	−77.61
$CdCl_2(s)$	−392	115	−344
$CdO(s)$	−258.2	54.8	−228.4
$CdS(s)$	−162	64.9	−156
$CdSO_4(s)$	−933.5	123	−822.6
Calcium			
$Ca(s)$	0	41.4	0
$Ca^{2+}(aq)$	−542.83	−53.1	−553.58
$CaCO_3(s)$	−1207	92.9	−1128.8
$CaF_2(s)$	−741	80.3	−1166
$CaCl_2(s)$	−795.0	114	−750.2
$CaBr_2(s)$	−682.8	130	−663.6
$CaI_2(s)$	−535.9	143	
$CaO(s)$	−635.5	40	−604.2
$Ca(OH)_2(s)$	−986.59	76.1	−896.76
$Ca_3(PO_4)_2(s)$	−4119	241	−3852
$CaSO_3(s)$	−1156		
$CaSO_4(s)$	−1433	107	−1320.3
$CaSO_4 \cdot \frac{1}{2}H_2O(s)$	−1575.2	131	−1435.2
$CaSO_4 \cdot 2H_2O(s)$	−2021.1	194.0	−1795.7
Carbon			
C(s, graphite)	0	5.69	0
C(s, diamond)	+1.88	2.4	+2.9
$CCl_4(l)$	−134	214.4	−65.3
$CO(g)$	−110.5	197.9	−137.3
$CO_2(g)$	−393.5	213.6	−394.4
$CO_2(aq)$	−413.8	117.6	−385.98
$H_2CO_3(aq)$	−699.65	187.4	−623.08
$HCO_3^-(aq)$	−691.99	91.2	−586.77
$CO_3^{2-}(aq)$	−677.14	−56.9	−527.81
$CS_2(l)$	+89.5	151.3	+65.3
$CS_2(g)$	+117	237.7	+67.2
$HCN(g)$	+135.1	201.7	+124.7
$CN^-(aq)$	+150.6	94.1	+172.4
$CH_4(g)$	−74.848	186.2	−50.79
$C_2H_2(g)$	+226.75	200.8	+209
$C_2H_4(g)$	+52.284	219.8	+68.12
$C_2H_6(g)$	−84.667	229.5	−32.9
$C_3H_8(g)$	−104	269.9	−23
$C_4H_{10}(g)$	−126	310.2	−17.0
$C_6H_6(l)$	+49.0	173.3	+124.3
$CH_3OH(l)$	−238.6	126.8	−166.2
$C_2H_5OH(l)$	−277.63	161	−174.8
$HCHO_2(g)$	−363	251	+335
$HC_2H_3O_2(l)$	−487.0	160	−392.5
$HCHO(g)$	−108.6	218.8	−102.5
$CH_3CHO(g)$	−167	250	−129

(Continued)

TABLE C.1 Thermodynamic Data for Selected Elements, Compounds, and Ions (25 °C) *(Continued)*

Substance	ΔH_f°(kJ mol^{-1})	S°(J mol^{-1} K^{-1})	ΔG_f°(kJ mol^{-1})
$(CH_3)_2CO(l)$	−248.1	200.4	−155.4
$C_6H_5CO_2H(s)$	−385.1	167.6	−245.3
$CO(NH_2)_2(s)$	−333.19	104.6	−197.2
$CO(NH_2)_2(aq)$	−391.2	173.8	−203.8
$CH_2(NH_2)CO_2H(s)$	−532.9	103.5	−373.4
Chlorine			
$Cl_2(g)$	0	223.0	0
$Cl^-(aq)$	−167.2	56.5	−131.2
$HCl(g)$	−92.30	186.7	−95.27
$HCl(aq)$	−167.2	56.5	−131.2
$HClO(aq)$	−131.3	106.8	−80.21
Chromium			
$Cr(s)$	0	23.8	0
$Cr^{3+}(aq)$	−232		
$CrCl_2(s)$	−326	115	−282
$CrCl_3(s)$	−563.2	126	−493.7
$Cr_2O_3(s)$	−1141	81.2	−1059
$CrO_3(s)$	−585.8	72.0	−506.2
$(NH_4)_2Cr_2O_7(s)$	−1807		
$K_2Cr_2O_7(s)$	−2033.01		
Cobalt			
$Co(s)$	0	30.0	0
$Co^{2+}(aq)$	−59.4	−110	−53.6
$CoCl_2(s)$	−325.5	106	−282.4
$Co(NO_3)_2(s)$	−422.2	192	−230.5
$CoO(s)$	−237.9	53.0	−214.2
$CoS(s)$	−80.8	67.4	−82.8
Copper			
$Cu(s)$	0	33.15	0
$Cu^{2+}(aq)$	+64.77	−99.6	+65.49
$CuCl(s)$	−137.2	86.2	−119.87
$CuCl_2(s)$	−172	119	−131
$Cu_2O(s)$	−168.6	93.1	−146.0
$CuO(s)$	−155	42.6	−127
$Cu_2S(s)$	−79.5	121	−86.2
$CuS(s)$	−53.1	66.5	−53.6
$CuSO_4(s)$	−771.4	109	−661.8
$CuSO_4 \cdot 5H_2O(s)$	−2279.7	300.4	−1879.7
Fluorine			
$F_2(g)$	0	202.7	0
$F^-(aq)$	−332.6	−13.8	−278.8
$HF(g)$	−271	173.5	−273
Gold			
$Au(s)$	0	47.7	0
$Au_2O_3(s)$	+80.8	125	+163
$AuCl_3(s)$	−118	148	−48.5
Hydrogen			
$H_2(g)$	0	130.6	0
$H_2O(l)$	−285.9	69.96	−237.2
$H_2O(g)$	−241.8	188.7	−228.6
$H_2O_2(l)$	−187.6	109.6	−120.3
$H_2Se(g)$	+76	219	+62.3
$H_2Te(g)$	+154	234	+138
Iodine			
$I_2(s)$	0	116.1	0
$I_2(g)$	+62.4	260.7	+19.3
$HI(g)$	+26.6	206	+1.30
Iron			
$Fe(s)$	0	27	0
$Fe^{2+}(aq)$	−89.1	−137.7	−78.9
$Fe^{3+}(aq)$	−48.5	−315.9	−4.7
$Fe_2O_3(s)$	−822.2	90.0	−741.0
$Fe_3O_4(s)$	−1118.4	146.4	−1015.4
$FeS(s)$	−100.0	60.3	−100.4
$FeS_2(s)$	−178.2	52.9	−166.9
Lead			
$Pb(s)$	0	64.8	0
$Pb^{2+}(aq)$	−1.7	10.5	−24.4
$PbCl_2(s)$	−359.4	136	−314.1
$PbO(s)$	−219.2	67.8	−189.3
$PbO_2(s)$	−277	68.6	−219
$Pb(OH)_2(s)$	−515.9	88	−420.9
$PbS(s)$	−100	91.2	−98.7
$PbSO_4(s)$	−920.1	149	−811.3
Lithium			
$Li(s)$	0	28.4	0
$Li^+(aq)$	−278.6	10.3	
$LiF(s)$	−611.7	35.7	−583.3
$LiCl(s)$	−408	59.29	−383.7
$LiBr(s)$	−350.3	66.9	−338.87
$Li_2O(s)$	−596.5	37.9	−560.5
$Li_3N(s)$	−199	37.7	−155.4
Magnesium			
$Mg(s)$	0	32.5	0
$Mg^{2+}(aq)$	−466.9	−138.1	−454.8
$MgCO_3(s)$	−1113	65.7	−1029
$MgF_2(s)$	−1124	79.9	−1056
$MgCl_2(s)$	−641.8	89.5	−592.5
$MgCl_2 \cdot 2H_2O(s)$	−1280	180	−1118
$Mg_3N_2(s)$	−463.2	87.9	−411
$MgO(s)$	−601.7	26.9	−569.4
$Mg(OH)_2(s)$	−924.7	63.1	−833.9
Manganese			
$Mn(s)$	0	32.0	0
$Mn^{2+}(aq)$	−223	−74.9	−228
$MnO_4^-(aq)$	−542.7	191	−449.4
$KMnO_4(s)$	−813.4	171.71	−713.8
$MnO(s)$	−385	60.2	−363
$Mn_2O_3(s)$	−959.8	110	−882.0
$MnO_2(s)$	−520.9	53.1	−466.1

(Continued)

TABLE C.1 Thermodynamic Data for Selected Elements, Compounds, and Ions (25 °C) *(Continued)*

Substance	ΔH_f°(kJ mol^{-1})	S°(J mol^{-1} K^{-1})	ΔG_f°(kJ mol^{-1})
$Mn_3O_4(s)$	−1387	149	−1280
$MnSO_4(s)$	−1064	112	−956
Mercury			
$Hg(l)$	0	76.1	0
$Hg(g)$	+61.32	175	+31.8
$Hg_2Cl_2(s)$	−265.2	192.5	−210.8
$HgCl_2(s)$	−224.3	146.0	−178.6
$HgO(s)$	−90.83	70.3	−58.54
$HgS(s,red)$	−58.2	82.4	−50.6
Nickel			
$Ni(s)$	0	30	0
$NiCl_2(s)$	−305	97.5	−259
$NiO(s)$	−244	38	−216
$NiO_2(s)$			−199
$NiSO_4(s)$	−891.2	77.8	−773.6
$NiCO_3(s)$	−664.0	91.6	−615.0
$Ni(CO)_4(g)$	−220	399	−567.4
Nitrogen			
$N_2(g)$	0	191.5	0
$NH_3(g)$	−46.19	192.5	−16.7
$NH_4^+(aq)$	−132.5	113	−79.37
$N_2H_4(g)$	+95.40	238.4	+159.3
$N_2H_4(l)$	+50.6	121.2	+149.4
$NH_4Cl(s)$	−315.4	94.6	−203.9
$NO(g)$	+90.37	210.6	+86.69
$NO_2(g)$	+33.8	240.5	+51.84
$N_2O(g)$	+81.57	220.0	+103.6
$N_2O_4(g)$	+9.67	304	+98.28
$N_2O_5(g)$	+11	356	+115
$HNO_3(l)$	−173.2	155.6	−79.91
$NO_3^-(aq)$	−205.0	146.4	−108.74
Oxygen			
$O_2(g)$	0	205.0	0
$O_3(g)$	+143	238.8	+163
$OH^-(aq)$	−230.0	−10.75	−157.24
Phosphorus			
$P(s,white)$	0	41.09	0
$P_4(g)$	+314.6	163.2	+278.3
$PCl_3(g)$	−287.0	311.8	−267.8
$PCl_5(g)$	−374.9	364.6	−305.0
$PH_3(g)$	+5.4	210.2	+12.9
$P_4O_6(s)$	−1640		
$POCl_3(g)$	−1109.7	646.5	−1019
$POCl_3(l)$	−1186	26.36	−1035
$P_4O_{10}(s)$	−2984	228.9	−2698
$H_3PO_4(s)$	−1279	110.5	−1119
Potassium			
$K(s)$	0	64.18	0
$K^+(aq)$	−252.4	102.5	−283.3
$KF(s)$	−567.3	66.6	−537.8
$KCl(s)$	−435.89	82.59	−408.3
$KBr(s)$	−393.8	95.9	−380.7
$KI(s)$	−327.9	106.3	−324.9
$KOH(s)$	−424.8	78.9	−379.1
$K_2O(s)$	−361	98.3	−322
$K_2SO_4(s)$	−1433.7	176	−1316.4
Silicon			
$Si(s)$	0	19	0
$SiH_4(g)$	+33	205	+52.3
$SiO_2(s,alpha)$	−910.0	41.8	−856
Silver			
$Ag(s)$	0	42.55	0
$Ag^+(aq)$	+105.58	72.68	+77.11
$AgCl(s)$	−127.0	96.2	−109.7
$AgBr(s)$	−100.4	107.1	−96.9
$AgNO_3(s)$	−124	141	−32
$Ag_2O(s)$	−31.1	121.3	−11.2
Sodium			
$Na(s)$	0	51.0	0
$Na^+(aq)$	−240.12	59.0	−261.91
$NaF(s)$	−571	51.5	−545
$NaCl(s)$	−411.0	72.38	−384.0
$NaBr(s)$	−360	83.7	−349
$NaI(s)$	−288	91.2	−286
$NaHCO_3(s)$	−947.7	102	−851.9
$Na_2CO_3(s)$	−1131	136	−1048
$Na_2O_2(s)$	−510.9	94.6	−447.7
$Na_2O(s)$	−510	72.8	−376
$NaOH(s)$	−426.8	64.18	−382
$Na_2SO_4(s)$	−1384.49	149.49	−1266.83
Sulfur			
$S(s,\ rhombic)$	0	31.9	0
$SO_2(g)$	−296.9	248.5	−300.4
$SO_3(g)$	−395.2	256.2	−370.4
$H_2S(g)$	−20.6	206	−33.6
$H_2SO_4(l)$	−811.32	157	−689.9
$H_2SO_4(aq)$	−909.3	20.1	−744.5
$SF_6(g)$	−1209	292	−1105
Tin			
$Sn(s,white)$	0	51.6	0
$Sn^{2+}(aq)$	−8.8	−17	−27.2
$SnCl_4(l)$	−511.3	258.6	−440.2
$SnO(s)$	−285.8	56.5	−256.9
$SnO_2(s)$	−580.7	52.3	−519.6
Zinc			
$Zn(s)$	0	41.6	0
$Zn^{2+}(aq)$	−153.9	−112.1	−147.06
$ZnCl_2(s)$	−415.1	111	−369.4
$ZnO(s)$	−348.3	43.6	−318.3
$ZnS(s)$	−205.6	57.7	−201.3
$ZnSO_4(s)$	−982.8	120	−874.5

TABLE C.2 Heats of Formation of Gaseous Atoms from Elements in Their Standard States

Element	ΔH_f°(kJ mol^{-1})*	Element	ΔH_f°(kJ mol^{-1})*
Group IA		***Group IVA***	
H	217.89	C	716.67
Li	161.5	Si	450
Na	107.8	***Group VA***	
K	89.62	N	472.68
Rb	82.0	P	332.2
Cs	78.2	***Group VIA***	
Group IIA		O	249.17
Be	324.3	S	276.98
Mg	146.4	***Group VIIA***	
Ca	178.2	F	79.14
Sr	163.6	Cl	121.47
Ba	177.8	Br	112.38
Group IIIA		I	107.48
B	560		
Al	329.7		

*All values in this table are positive because forming the gaseous atoms from the elements is endothermic: it involves bond breaking.

TABLE C.3 Average Bond Energies

Bond	Bond Energy (kJ mol^{-1})	Bond	Bond Energy (kJ mol^{-1})
C—C	348	C—Br	276
C=C	612	C—I	238
C≡C	960	H—H	436
C—H	412	H—F	565
C—N	305	H—Cl	431
C=N	613	H—Br	366
C≡N	890	H—I	299
C—O	360	H—N	388
C=O	743	H—O	463
C—F	484	H—S	338
C—Cl	338	H—Si	376

TABLE C.4 Vapor Pressure of Water as a Function of Temperature

Temp (°C)	Vapor Pressure (torr)	Temp (°C)	Vapor Pressure (torr)	Temp (°C)	Vapor Pressure (torr)	Temp (°C)	Vapor Pressure (torr)
0	4.58	11	9.84	22	19.8	33	37.7
1	4.93	12	10.5	23	21.1	34	39.9
2	5.29	13	11.2	24	22.4	35	41.2
3	5.68	14	12.0	25	23.8	36	44.6
4	6.10	15	12.8	26	25.2	37	47.1
5	6.54	16	13.6	27	26.7	38	49.7
6	7.01	17	14.5	28	28.3	39	52.4
7	7.51	18	15.5	29	30.0	40	55.3
8	8.04	19	16.5	30	31.8	41	58.3
9	8.61	20	17.5	31	33.7	42	61.5
10	9.21	21	18.7	32	35.7	43	64.8

(Continued)

TABLE C.4 Vapor Pressure of Water as a Function of Temperature *(Continued)*

Temp (°C)	Vapor Pressure (torr)	Temp (°C)	Vapor Pressure (torr)	Temp (°C)	Vapor Pressure (torr)	Temp (°C)	Vapor Pressure (torr)
44	68.3	59	142.6	74	277.2	89	506.1
45	71.9	60	149.4	75	289.1	90	525.8
46	75.6	61	156.4	76	301.4	91	546.0
47	79.6	62	163.8	77	314.1	92	567.0
48	83.7	63	171.4	78	327.3	93	588.6
49	88.0	64	179.3	79	341.0	94	610.9
50	92.5	65	187.5	80	355.1	95	633.9
51	97.2	66	196.1	81	369.7	96	657.6
52	102.1	67	205.0	82	384.9	97	682.1
53	107.2	68	214.2	83	400.6	98	707.3
54	112.5	69	223.7	84	416.8	99	733.2
55	118.0	70	233.7	85	433.6	100	760.0
56	123.8	71	243.9	86	450.9		
57	129.8	72	254.6	87	468.7		
58	136.1	73	265.7	88	487.1		

TABLE C.5 Solubility Product Constants

Salt	K_{sp}	Salt	K_{sp}
Fluorides		***Hydroxides***	
MgF_2	6.6×10^{-9}	$Mg(OH)_2$	7.1×10^{-12}
CaF_2	3.9×10^{-11}	$Ca(OH)_2$	6.5×10^{-6}
SrF_2	2.9×10^{-9}	$Mn(OH)_2$	1.6×10^{-13}
BaF_2	1.7×10^{-6}	$Fe(OH)_2$	7.9×10^{-16}
LiF	1.7×10^{-3}	$Fe(OH)_3$	1.6×10^{-39}
PbF_2	3.6×10^{-8}	$Co(OH)_2$	1×10^{-15}
		$Co(OH)_3$	3×10^{-45}
Chlorides		$Ni(OH)_2$	6×10^{-16}
CuCl	1.9×10^{-7}	$Cu(OH)_2$	4.8×10^{-20}
AgCl	1.8×10^{-10}	$V(OH)_3$	4×10^{-35}
Hg_2Cl_2	1.2×10^{-18}	$Cr(OH)_3$	2×10^{-30}
TlCl	1.8×10^{-4}	Ag_2O	1.9×10^{-8}
$PbCl_2$	1.7×10^{-5}	$Zn(OH)_2$	3.0×10^{-16}
$AuCl_3$	3.2×10^{-25}	$Cd(OH)_2$	5.0×10^{-15}
		$Al(OH)_3$ (alpha form)	3×10^{-34}
Bromides			
CuBr	5×10^{-9}	***Cyanides***	
AgBr	5.0×10^{-13}	AgCN	1.2×10^{-16}
Hg_2Br_2	5.6×10^{-23}	$Zn(CN)_2$	3×10^{-16}
$HgBr_2$	1.3×10^{-19}		
$PbBr_2$	2.1×10^{-6}	***Sulfites***	
		$CaSO_3$	3×10^{-7}
Iodides		Ag_2SO_3	1.5×10^{-14}
CuI	1×10^{-12}	$BaSO_3$	8×10^{-7}
AgI	8.3×10^{-17}		
Hg_2I_2	4.7×10^{-29}	***Sulfates***	
HgI_2	1.1×10^{-28}	$CaSO_4$	2.4×10^{-5}
PbI_2	7.9×10^{-9}	$SrSO_4$	3.2×10^{-7}

(Continued)

TABLE C.5 Solubility Product Constants *(Continued)*

Salt	K_{sp}	Salt	K_{sp}
$BaSO_4$	1.1×10^{-10}	Ag_2CO_3	8.1×10^{-12}
$RaSO_4$	4.3×10^{-11}	Hg_2CO_3	8.9×10^{-17}
Ag_2SO_4	1.5×10^{-5}	$ZnCO_3$	1.0×10^{-10}
Hg_2SO_4	7.4×10^{-7}	$CdCO_3$	1.8×10^{-14}
$PbSO_4$	6.3×10^{-7}	$PbCO_3$	7.4×10^{-14}
Chromates		***Phosphates***	
$BaCrO_4$	2.1×10^{-10}	$Ca_3(PO_4)_2$	2.0×10^{-29}
$CuCrO_4$	3.6×10^{-6}	$Mg_3(PO_4)_2$	6.3×10^{-26}
Ag_2CrO_4	1.2×10^{-12}	$SrHPO_4$	1.2×10^{-7}
Hg_2CrO_4	2.0×10^{-9}	$BaHPO_4$	4.0×10^{-8}
$CaCrO_4$	7.1×10^{-4}	$LaPO_4$	3.7×10^{-23}
$PbCrO_4$	1.8×10^{-14}	$Fe_3(PO_4)_2$	1×10^{-36}
Carbonates		Ag_3PO_4	2.8×10^{-18}
$MgCO_3$	3.5×10^{-8}	$FePO_4$	4.0×10^{-27}
$CaCO_3$	4.5×10^{-9}	$Zn_3(PO_4)_2$	5×10^{-36}
$SrCO_3$	9.3×10^{-10}	$Pb_3(PO_4)_2$	3.0×10^{-44}
$BaCO_3$	5.0×10^{-9}	$Ba_3(PO_4)_2$	5.8×10^{-38}
$MnCO_3$	5.0×10^{-10}	***Ferrocyanides***	
$FeCO_3$	2.1×10^{-11}	$Zn_2[Fe(CN)_6]$	2.1×10^{-16}
$CoCO_3$	1.0×10^{-10}	$Cd_2[Fe(CN)_6]$	4.2×10^{-18}
$NiCO_3$	1.3×10^{-7}	$Pb_2[Fe(CN)_6]$	9.5×10^{-19}
$CuCO_3$	2.5×10^{-10}		

TABLE C.6 Formation Constants of Complexes (25 °C)

Complex Ion Equilibrium	K_{form}	Complex Ion Equilibrium	K_{form}
Halide Complexes		$Hg^{2+} + 4NH_3 \rightleftharpoons [Hg(NH_3)_4]^{2+}$	1.8×10^{19}
$Al^{3+} + 6F^- \rightleftharpoons [AlF_6]^{3-}$	1×10^{20}	$Co^{2+} + 6NH_3 \rightleftharpoons [Co(NH_3)_6]^{2+}$	5.0×10^{4}
$Al^{3+} + 4F^- \rightleftharpoons [AlF_4]^-$	2.0×10^{8}	$Co^{3+} + 6NH_3 \rightleftharpoons [Co(NH_3)_6]^{3+}$	4.6×10^{33}
$Be^{2+} + 4F^- \rightleftharpoons [BeF_4]^{2-}$	1.3×10^{13}	$Cd^{2+} + 6NH_3 \rightleftharpoons [Cd(NH_3)_6]^{2+}$	2.6×10^{5}
$Sn^{4+} + 6F^- \rightleftharpoons [SnF_6]^{2-}$	1×10^{25}	$Ni^{2+} + 6NH_3 \rightleftharpoons [Ni(NH_3)_6]^{2+}$	2.0×10^{8}
$Cu^+ + 2Cl^- \rightleftharpoons [CuCl_2]^-$	3×10^{5}	***Cyanide Complexes***	
$Ag^+ + 2Cl^- \rightleftharpoons [AgCl_2]^-$	1.8×10^{5}	$Fe^{2+} + 6CN^- \rightleftharpoons [Fe(CN)_6]^{4-}$	1.0×10^{24}
$Pb^{2+} + 4Cl^- \rightleftharpoons [PbCl_4]^{2-}$	2.5×10^{15}	$Fe^{3+} + 6CN^- \rightleftharpoons [Fe(CN)_6]^{3-}$	1.0×10^{31}
$Zn^{2+} + 4Cl^- \rightleftharpoons [ZnCl_4]^{2-}$	1.6	$Ag^+ + 2CN^- \rightleftharpoons [Ag(CN)_2]^-$	5.3×10^{18}
$Hg^{2+} + 4Cl^- \rightleftharpoons [HgCl_4]^{2-}$	5.0×10^{15}	$Cu^+ + 2CN^- \rightleftharpoons [Cu(CN)_2]^-$	1.0×10^{16}
$Cu^+ + 2Br^- \rightleftharpoons [CuBr_2]^-$	8×10^{5}	$Cd^{2+} + 4CN^- \rightleftharpoons [Cd(CN)_4]^{2-}$	7.7×10^{16}
$Ag^+ + 2Br^- \rightleftharpoons [AgBr_2]^-$	1.7×10^{7}	$Au^+ + 2CN^- \rightleftharpoons [Au(CN)_2]^-$	2×10^{38}
$Hg^{2+} + 4Br^- \rightleftharpoons [HgBr_4]^{2-}$	1×10^{21}	***Complexes with Other Monodentate Ligands***	
$Cu^+ + 2I^- \rightleftharpoons [CuI_2]^-$	8×10^{8}	***Methylamine*** **(CH_3NH_2)**	
$Ag^+ + 2I^- \rightleftharpoons [AgI_2]^-$	1×10^{11}	$Ag^+ + 2CH_3NH_2 \rightleftharpoons [Ag(CH_3NH_2)_2]^+$	7.8×10^{6}
$Pb^{2+} + 4I^- \rightleftharpoons [PbI_4]^{2-}$	3×10^{4}	***Thiocyanate ion*** **(SCN^-)**	
$Hg^{2+} + 4I^- \rightleftharpoons [HgI_4]^{2-}$	1.9×10^{30}	$Cd^{2+} + 4SCN^- \rightleftharpoons [Cd(SCN)_4]^{2-}$	1×10^{3}
Ammonia Complexes		$Cu^{2+} + 2SCN^- \rightleftharpoons [Cu(SCN)_2]$	5.6×10^{3}
$Ag^+ + 2NH_3 \rightleftharpoons [Ag(NH_3)_2]^+$	1.6×10^{7}	$Fe^{3+} + 3SCN^- \rightleftharpoons [Fe(SCN)_3]$	2×10^{6}
$Zn^{2+} + 4NH_3 \rightleftharpoons [Zn(NH_3)_4]^{2+}$	7.8×10^{8}	$Hg^{2+} + 4SCN^- \rightleftharpoons [Hg(SCN)_4]^{2-}$	5.0×10^{21}
$Cu^{2+} + 4NH_3 \rightleftharpoons [Cu(NH_3)_4]^{2+}$	1.1×10^{13}		

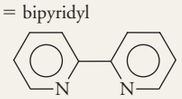
(Continued)

TABLE C.6 Formation Constants of Complexes (25 °C) *(Continued)*

Complex Ion Equilibrium	K_{form}
***Hydroxide ion* (OH^-)**	
$Cu^{2+} + 4OH^- \rightleftharpoons [Cu(OH)_4]^{2-}$	1.3×10^{16}
$Zn^{2+} + 4OH^- \rightleftharpoons [Zn(OH)_4]^{2-}$	2×10^{20}
Complexes with Bidentate Ligands*	
$Mn^{2+} + 3\ en \rightleftharpoons [Mn(en)_3]^{2+}$	6.5×10^{5}
$Fe^{2+} + 3\ en \rightleftharpoons [Fe(en)_3]^{2+}$	5.2×10^{9}
$Co^{2+} + 3\ en \rightleftharpoons [Co(en)_3]^{2+}$	1.3×10^{14}
$Co^{3+} + 3\ en \rightleftharpoons [Co(en)_3]^{3+}$	4.8×10^{48}
$Ni^{2+} + 3\ en \rightleftharpoons [Ni(en)_3]^{2+}$	4.1×10^{17}
$Cu^{2+} + 2\ en \rightleftharpoons [Cu(en)_2]^{2+}$	3.5×10^{19}
$Mn^{2+} + 3\ bipy \rightleftharpoons [Mn(bipy)_3]^{2+}$	1×10^{6}
$Fe^{2+} + 3\ bipy \rightleftharpoons [Fe(bipy)_3]^{2+}$	1.6×10^{17}
$Ni^{2+} + 3\ bipy \rightleftharpoons [Ni(bipy)_3]^{2+}$	3.0×10^{20}
$Co^{2+} + 3\ bipy \rightleftharpoons [Co(bipy)_3]^{2+}$	8×10^{15}
$Mn^{2+} + 3\ phen \rightleftharpoons [Mn(phen)_3]^{2+}$	2×10^{10}
$Fe^{2+} + 3\ phen \rightleftharpoons [Fe(phen)_3]^{2+}$	1×10^{21}
$Co^{2+} + 3\ phen \rightleftharpoons [Co(phen)_3]^{2+}$	6×10^{19}
$Ni^{2+} + 3\ phen \rightleftharpoons [Ni(phen)_3]^{2+}$	2×10^{24}
$Co^{2+} + 3C_2O_4^{2-} \rightleftharpoons [Co(C_2O_4)_3]^{4-}$	4.5×10^{6}
$Fe^{3+} + 3C_2O_4^{2-} \rightleftharpoons [Fe(C_2O_4)_3]^{3-}$	3.3×10^{20}
Complexes of Other Polydentate Ligands*	
$Zn^{2+} + EDTA^{4-} \rightleftharpoons [Zn(EDTA)]^{2-}$	3.8×10^{16}
$Mg^{2+} + 2NTA^{3-} \rightleftharpoons [Mg(NTA)_2]^{4-}$	1.6×10^{10}
$Ca^{2+} + 2NTA^{3-} \rightleftharpoons [Ca(NTA)_2]^{4-}$	3.2×10^{11}

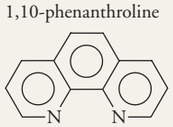
*en = ethylenediamine

bipy = bipyridyl



bipyridyl

phen = 1,10-phenanthroline



1,10-phenanthroline

$EDTA^{4-}$ = ethylenediaminetetraacetate ion

NTA^{3-} = nitrilotriacetate ion

TABLE C.7 Ionization Constants of Weak Acids and Bases (Alternative Formulas in Parentheses)

Monoprotic Acid	Name	K_a
$HC_2O_2Cl_3$ (Cl_3CCO_2H)	trichloroacetic acid	2.2×10^{-1}
HIO_3	iodic acid	1.69×10^{-1}
$HC_2HO_2Cl_2$ (Cl_2CHCO_2H)	dichloroacetic acid	5.0×10^{-2}
$HC_2H_2O_2Cl$ (ClH_2CCO_2H)	chloroacetic acid	1.36×10^{-3}
HNO_2	nitrous acid	7.1×10^{-4}
HF	hydrofluoric acid	6.8×10^{-4}
HOCN	cyanic acid	3.5×10^{-4}
$HCHO_2$ (HCO_2H)	formic acid	1.8×10^{-4}
$HC_3H_5O_3$ [$CH_3CH(OH)CO_2H$]	lactic acid	1.38×10^{-4}
$HC_4H_3N_2O_3$	barbituric acid	9.8×10^{-5}
$HC_7H_5O_2$ ($C_6H_5CO_2H$)	benzoic acid	6.28×10^{-5}
$HC_4H_7O_2$ ($CH_3CH_2CH_2CO_2H$)	butanoic acid	1.52×10^{-5}
HN_3	hydrazoic acid	1.8×10^{-5}
$HC_2H_3O_2$ (CH_3CO_2H)	acetic acid	1.8×10^{-5}
$HC_3H_5O_2$ ($CH_3CH_2CO_2H$)	propanoic acid	1.34×10^{-5}
$HC_2H_4NO_2$	nicotinic acid (niacin)	1.4×10^{-5}
HOCl	hypochlorous acid	3.0×10^{-8}
HOBr	hypobromous acid	2.1×10^{-9}

(Continued)

TABLE C.7 Ionization Constants of Weak Acids and Bases (Alternative Formulas in Parentheses) *(Continued)*

Monoprotic Acid	Name	K_a
HCN	hydrocyanic acid	6.2×10^{-10}
HC_6H_5O	phenol	1.3×10^{-10}
HOI	hypoiodous acid	2.3×10^{-11}
H_2O_2	hydrogen peroxide	1.8×10^{-12}

Polyprotic Acid	Name	K_{a_1}	K_{a_2}	K_{a_3}
H_2SO_4	sulfuric acid	large	1.0×10^{-2}	
H_2CrO_4	chromic acid	5.0	1.5×10^{-6}	
$H_2C_2O_4$	oxalic acid	5.6×10^{-2}	5.4×10^{-5}	
H_3PO_3	phosphorous acid	3×10^{-2}	1.6×10^{-7}	
$H_2S(aq)$	hydrosulfuric acid	9.5×10^{-8}	1×10^{-19}	
H_2SO_3	sulfurous acid	1.2×10^{-2}	6.6×10^{-8}	
H_2SeO_4	selenic acid	large	1.2×10^{-2}	
H_2SeO_3	selenous acid	4.5×10^{-3}	1.1×10^{-8}	
H_6TeO_6	telluric acid	2×10^{-8}	1×10^{-11}	
H_2TeO_3	tellurous acid	3.3×10^{-3}	2.0×10^{-8}	
$H_2C_3H_2O_4$ ($HO_2CCH_2CO_2H$)	malonic acid	1.4×10^{-3}	2.0×10^{-6}	
$H_2C_8H_4O_4$	phthalic acid	1.1×10^{-3}	3.9×10^{-6}	
$H_2C_4H_4O_6$	tartaric acid	9.2×10^{-4}	4.3×10^{-5}	
$H_2C_6H_6O_6$	ascorbic acid	6.8×10^{-5}	2.7×10^{-12}	
H_2CO_3	carbonic acid	4.3×10^{-7}	4.7×10^{-11}	
H_3PO_4	phosphoric acid	7.1×10^{-3}	6.3×10^{-8}	4.5×10^{-13}
H_3AsO_4	arsenic acid	5.6×10^{-3}	1.7×10^{-7}	4.0×10^{-12}
$H_3C_6H_5O_7$	citric acid	7.1×10^{-4}	1.7×10^{-5}	6.3×10^{-6}

Weak Base	Name	K_b
$(CH_3)_2NH$	dimethylamine	9.6×10^{-4}
$C_4H_9NH_2$	butylamine	5.9×10^{-4}
CH_3NH_2	methylamine	4.4×10^{-4}
$CH_3CH_2NH_2$	ethylamine	4.3×10^{-4}
$(CH_3)_3N$	trimethylamine	7.4×10^{-5}
NH_3	ammonia	1.8×10^{-5}
$C_{21}H_{22}N_2O_2$	strychnine	1.0×10^{-6}
N_2H_4	hydrazine	9.6×10^{-7}
$C_{17}H_{19}NO_3$	morphine	7.5×10^{-7}
NH_2OH	hydroxylamine	6.6×10^{-9}
C_5H_5N	pyridine	1.5×10^{-9}
$C_6H_5NH_2$	aniline	4.1×10^{-10}
PH_3	phosphine	10^{-28}

TABLE C.8 Standard Reduction Potentials (25 °C)

$E°$ (Volts)	Half-Cell Reaction
+2.87	$F_2(g) + 2e^- \rightleftharpoons 2F^-(aq)$
+2.08	$O_3(g) + 2H^+(aq) + 2e^- \rightleftharpoons O_2(g) + H_2O$
+2.01	$S_2O_8^{2-}(aq) + 2e^- \rightleftharpoons 2SO_4^{2-}(aq)$
+1.82	$Co^{3+}(aq) + e^- \rightleftharpoons Co^{2+}(aq)$
+1.77	$H_2O_2(aq) + 2H^+(aq) + 2e^- \rightleftharpoons 2H_2O$
+1.695	$MnO_4^-(aq) + 4H^+(aq) + 3e^- \rightleftharpoons MnO_2(s) + 2H_2O$
+1.69	$PbO_2(s) + HSO_4^-(aq) + 3H^+(aq) + 2e^- \rightleftharpoons PbSO_4(s) + 2H_2O$
+1.63	$2HOCl(aq) + 2H^+(aq) + 2e^- \rightleftharpoons Cl_2(g) + 2H_2O$
+1.51	$Mn^{3+}(aq) + e^- \rightleftharpoons Mn^{2+}(aq)$
+1.51	$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O$
+1.46	$PbO_2(s) + 4H^+(aq) + 2e^- \rightleftharpoons Pb^{2+}(aq) + 2H_2O$
+1.44	$BrO_3^-(aq) + 6H^+(aq) + 6e^- \rightleftharpoons Br^-(aq) + 3H_2O$
+1.42	$Au^{3+}(aq) + 3e^- \rightleftharpoons Au(s)$
+1.36	$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$
+1.33	$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O$
+1.24	$O_3(g) + H_2O + 2e^- \rightleftharpoons O_2(g) + 2OH^-(aq)$
+1.23	$MnO_2(s) + 4H^+(aq) + 2e^- \rightleftharpoons Mn^{2+}(aq) + 2H_2O$
+1.23	$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O$
+1.20	$Pt^{2+}(aq) + 2e^- \rightleftharpoons Pt(s)$
+1.07	$Br_2(aq) + 2e^- \rightleftharpoons 2Br^-(aq)$
+0.96	$NO_3^-(aq) + 4H^+(aq) + 3e^- \rightleftharpoons NO(g) + 2H_2O$
+0.94	$NO_3^-(aq) + 3H^+(aq) + 2e^- \rightleftharpoons HNO_2(aq) + H_2O$
+0.91	$2Hg^{2+}(aq) + 2e^- \rightleftharpoons Hg_2^{2+}(aq)$
+0.87	$HO_2^-(aq) + H_2O + 2e^- \rightleftharpoons 3OH^-(aq)$
+0.80	$NO_3^-(aq) + 4H^+(aq) + 2e^- \rightleftharpoons 2NO_2(g) + 2H_2O$
+0.80	$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$
+0.77	$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$
+0.69	$O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons H_2O_2(aq)$
+0.54	$I_2(s) + 2e^- \rightleftharpoons 2I^-(aq)$
+0.49	$NiO_2(s) + 2H_2O + 2e^- \rightleftharpoons Ni(OH)_2(s) + 2OH^-(aq)$
+0.45	$SO_2(aq) + 4H^+(aq) + 4e^- \rightleftharpoons S(s) + 2H_2O$
+0.401	$O_2(g) + 2H_2O + 4e^- \rightleftharpoons 4OH^-(aq)$
+0.34	$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$
+0.27	$Hg_2Cl_2(s) + 2e^- \rightleftharpoons 2Hg(l) + 2Cl^-(aq)$
+0.25	$PbO_2(s) + H_2O + 2e^- \rightleftharpoons PbO(s) + 2OH^-(aq)$
+0.2223	$AgCl(s) + e^- \rightleftharpoons Ag(s) + Cl^-(aq)$
+0.172	$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightleftharpoons H_2SO_3(aq) + H_2O$
+0.169	$S_4O_6^{2-}(aq) + 2e^- \rightleftharpoons 2S_2O_3^{2-}(aq)$
+0.16	$Cu^{2+}(aq) + e^- \rightleftharpoons Cu^+(aq)$
+0.15	$Sn^{4+}(aq) + 2e^- \rightleftharpoons Sn^{2+}(aq)$
+0.14	$S(s) + 2H^+(aq) + 2e^- \rightleftharpoons H_2S(g)$
+0.07	$AgBr(s) + e^- \rightleftharpoons Ag(s) + Br^-(aq)$
0 (exactly)	$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$
−0.13	$Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$

(Continued)

TABLE C.8 Standard Reduction Potentials (25 °C) *(Continued)*

$E°$ (Volts)	Half-Cell Reaction
−0.14	$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$
−0.15	$AgI(s) + e^- \rightleftharpoons Ag(s) + I^-(aq)$
−0.25	$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$
−0.28	$Co^{2+}(aq) + 2e^- \rightleftharpoons Co(s)$
−0.34	$In^{3+}(aq) + 3e^- \rightleftharpoons In(s)$
−0.34	$Tl^+(aq) + e^- \rightleftharpoons Tl(s)$
−0.36	$PbSO_4(s) + H^+(aq) + 2e^- \rightleftharpoons Pb(s) + HSO_4^-(aq)$
−0.40	$Cd^{2+}(aq) + 2e^- \rightleftharpoons Cd(s)$
−0.44	$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$
−0.56	$Ga^{3+}(aq) + 3e^- \rightleftharpoons Ga(s)$
−0.58	$PbO(s) + H_2O + 2e^- \rightleftharpoons Pb(s) + 2OH^-(aq)$
−0.74	$Cr^{3+}(aq) + 3e^- \rightleftharpoons Cr(s)$
−0.76	$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$
−0.81	$Cd(OH)_2(s) + 2e^- \rightleftharpoons Cd(s) + 2OH^-(aq)$
−0.83	$2H_2O + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$
−0.88	$Fe(OH)_2(s) + 2e^- \rightleftharpoons Fe(s) + 2OH^-(aq)$
−0.91	$Cr^{2+}(aq) + e^- \rightleftharpoons Cr(s)$
−1.16	$N_2(g) + 4H_2O + 4e^- \rightleftharpoons N_2O_4(aq) + 4OH^-(aq)$
−1.18	$V^{2+}(aq) + 2e^- \rightleftharpoons V(s)$
−1.216	$ZnO_2^-(aq) + 2H_2O + 2e^- \rightleftharpoons Zn(s) + 4OH^-(aq)$
−1.63	$Ti^{2+}(aq) + 2e^- \rightleftharpoons Ti(s)$
−1.66	$Al^{3+}(aq) + 3e^- \rightleftharpoons Al(s)$
−1.79	$U^{3+}(aq) + 3e^- \rightleftharpoons U(s)$
−2.02	$Sc^{3+}(aq) + 3e^- \rightleftharpoons Sc(s)$
−2.36	$La^{3+}(aq) + 3e^- \rightleftharpoons La(s)$
−2.37	$Y^{3+}(aq) + 3e^- \rightleftharpoons Y(s)$
−2.37	$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$
−2.71	$Na^+(aq) + e^- \rightleftharpoons Na(s)$
−2.76	$Ca^{2+}(aq) + 2e^- \rightleftharpoons Ca(s)$
−2.89	$Sr^{2+}(aq) + 2e^- \rightleftharpoons Sr(s)$
−2.90	$Ba^{2+}(aq) + 2e^- \rightleftharpoons Ba(s)$
−2.92	$Cs^+(aq) + e^- \rightleftharpoons Cs(s)$
−2.92	$K^+(aq) + e^- \rightleftharpoons K(s)$
−2.93	$Rb^+(aq) + e^- \rightleftharpoons Rb(s)$
−3.05	$Li^+(aq) + e^- \rightleftharpoons Li(s)$