





















Appendix II: Useful Data

A. Atomic Colors

| | | | | | | | |
|----------------|---|---|---|---|--|---|---|
| Atomic number: | 1 | 4 | 5 | 6 | 7 | 8 | 9 |
| |  |  |  |  |  |  |  |
| Atomic symbol: | H | Be | B | C | N | O | F |
| Atomic number: | 11 | 12 | 14 | 15 | 16 | 17 | 19 |
| |  |  |  |  |  |  |  |
| Atomic symbol: | Na | Mg | Si | P | S | Cl | K |
| Atomic number: | 20 | 29 | 30 | 35 | 53 | 54 | |
| |  |  |  |  |  |  | |
| Atomic symbol: | Ca | Cu | Zn | Br | I | Xe | |

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

| Substance | ΔH_f° (kJ/mol) | ΔG_f° (kJ/mol) | S° (J/mol · K) | Substance | ΔH_f° (kJ/mol) | ΔG_f° (kJ/mol) | S° (J/mol · K) |
|------------------------------------|-----------------------------|-----------------------------|-----------------------|------------------------------------|-----------------------------|-----------------------------|-----------------------|
| Aluminum | | | | Beryllium | | | |
| Al(s) | 0 | 0 | 28.32 | Be(s) | 0 | 0 | 9.5 |
| Al(g) | 330.0 | 289.4 | 164.6 | BeO(s) | -609.4 | -580.1 | 13.8 |
| Al ³⁺ (aq) | -538.4 | -483 | -325 | Be(OH) ₂ (s) | -902.5 | -815.0 | 45.5 |
| AlCl ₃ (s) | -704.2 | -628.8 | 109.3 | Bismuth | | | |
| Al ₂ O ₃ (s) | -1675.7 | -1582.3 | 50.9 | Bi(s) | 0 | 0 | 56.7 |
| Barium | | | | BiCl ₃ (s) | -379.1 | -315.0 | 177.0 |
| Ba(s) | 0 | 0 | 62.5 | Bi ₂ O ₃ (s) | -573.9 | -493.7 | 151.5 |
| Ba(g) | 180.0 | 146.0 | 170.2 | Bi ₂ S ₃ (s) | -143.1 | -140.6 | 200.4 |
| Ba ²⁺ (aq) | -537.6 | -560.8 | 9.6 | Boron | | | |
| BaCO ₃ (s) | -1213.0 | -1134.4 | 112.1 | B(s) | 0 | 0 | 5.9 |
| BaCl ₂ (s) | -855.0 | -806.7 | 123.7 | B(g) | 565.0 | 521.0 | 153.4 |
| BaO(s) | -548.0 | -520.3 | 72.1 | BCl ₃ (g) | -403.8 | -388.7 | 290.1 |
| Ba(OH) ₂ (s) | -944.7 | | | BF ₃ (g) | -1136.0 | -1119.4 | 254.4 |
| BaSO ₄ (s) | -1473.2 | -1362.2 | 132.2 | B ₂ H ₆ (g) | 36.4 | 87.6 | 232.1 |

(continued on the next page)

A-6 Appendix II: Useful Data

| Substance | ΔH_f° (kJ/mol) | ΔG_f° (kJ/mol) | S° (J/mol · K) |
|---|-----------------------------|-----------------------------|-----------------------|
| B ₂ O ₃ (s) | -1273.5 | -1194.3 | 54.0 |
| H ₃ BO 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 ₃ Cl(g) | -81.9 | -60.2 | 234.6 |
| CH ₂ Cl ₂ (g) | -95.4 | | 270.2 |
| CH ₂ Cl 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 ₃ O(g) | -108.6 | -102.5 | 218.8 |
| CH ₃ O ₂ (l, formic acid) | -425.0 | -361.4 | 129.0 |
| CH ₃ NH ₂ (g, methylamine) | -22.5 | 32.7 | 242.9 |
| CH ₃ OH(l) | -238.6 | -166.6 | 126.8 |
| CH ₃ OH(g) | -201.0 | -162.3 | 239.9 |

| Substance | ΔH_f° (kJ/mol) | ΔG_f° (kJ/mol) | S° (J/mol · K) |
|---|-----------------------------|-----------------------------|-----------------------|
| C ₂ H ₂ (g) | 227.4 | 209.9 | 200.9 |
| C ₂ H ₄ (g) | 52.4 | 68.4 | 219.3 |
| C ₂ H ₆ (g) | -84.68 | -32.0 | 229.2 |
| C ₂ H ₅ OH(l) | -277.6 | -174.8 | 160.7 |
| C ₂ H ₅ OH(g) | -234.8 | -167.9 | 281.6 |
| C ₂ H ₃ Cl (g, vinyl chloride) | 37.2 | 53.6 | 264.0 |
| C ₂ H ₄ Cl ₂ (l, dichloroethane) | -166.8 | -79.6 | 208.5 |
| C ₂ H ₄ O (g, acetaldehyde) | -166.2 | -133.0 | 263.8 |
| C ₂ H ₄ O ₂ (l, acetic acid) | -484.3 | -389.9 | 159.8 |
| C ₃ H ₈ (g) | -103.85 | -23.4 | 270.3 |
| C ₃ H ₆ O (l, acetone) | -248.4 | -155.6 | 199.8 |
| C ₃ H ₇ OH (l, isopropanol) | -318.1 | | 181.1 |
| C ₄ H ₁₀ (l) | -147.3 | -15.0 | 231.0 |
| C ₄ H ₁₀ (g) | -125.7 | -15.71 | 310.0 |
| C ₆ H ₆ (l) | 49.1 | 124.5 | 173.4 |
| C ₆ H ₅ NH ₂ (l, aniline) | 31.6 | 149.2 | 191.9 |
| C ₆ H ₅ OH (s, phenol) | -165.1 | -50.4 | 144.0 |
| C ₆ H 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 ₂ CO 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 |

| Substance | ΔH_f° (kJ/mol) | ΔG_f° (kJ/mol) | S° (J/mol · K) |
|---|-----------------------------|-----------------------------|-----------------------|
| CsF(s) | -553.5 | -525.5 | 92.8 |
| CsI(s) | -342 | -337 | 127 |
| 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 ₂ O(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 ₂ O ₃ (s) | -1139.7 | -1058.1 | 81.2 |
| Cr ₂ O 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 ₂ O(s) | -168.6 | -146.0 | 93.1 |
| Cu ₂ S(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 |

| Substance | ΔH_f° (kJ/mol) | ΔG_f° (kJ/mol) | S° (J/mol · K) |
|---------------------------------------|-----------------------------|-----------------------------|-----------------------|
| H ⁺ (g) | 1536.3 | 1517.1 | 108.9 |
| H ₂ (g) | 0 | 0 | 130.7 |
| 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 ₂ O ₃ (s) | -824.2 | -742.2 | 87.4 |
| Fe ₃ O 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 ₂ O(s) | -597.9 | -561.2 | 37.6 |

(continued on the next page)

A-8 Appendix II: Useful Data

| Substance | ΔH_f° (kJ/mol) | ΔG_f° (kJ/mol) | S° (J/mol · K) |
|--------------------------------------|-----------------------------|-----------------------------|-----------------------|
| 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 |
| 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 ₃ N 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 ₂ Cl 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 ₄ Br(s) | -270.8 | -175.2 | 113.0 |
| NH ₄ Cl(s) | -314.4 | -202.9 | 94.6 |
| NH ₄ CN(s) | 0.4 | | |
| NH ₄ F(s) | -464.0 | -348.7 | 72.0 |
| NH ₄ HCO ₃ (s) | -849.4 | -665.9 | 120.9 |
| NH ₄ I(s) | -201.4 | -112.5 | 117.0 |
| NH ₄ NO ₃ (s) | -365.6 | -183.9 | 151.1 |
| NH ₄ NO ₃ (aq) | -339.9 | -190.6 | 259.8 |

| Substance | ΔH_f° (kJ/mol) | ΔG_f° (kJ/mol) | S° (J/mol · K) |
|--|-----------------------------|-----------------------------|-----------------------|
| 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 ₂ H ₄ (l) | 50.6 | 149.3 | 121.2 |
| N ₂ H ₄ (g) | 95.4 | 159.4 | 238.5 |
| N ₂ O(g) | 81.6 | 103.7 | 220.0 |
| N ₂ O ₄ (l) | -19.5 | 97.5 | 209.2 |
| N ₂ O ₄ (g) | 9.16 | 99.8 | 304.4 |
| N ₂ O ₅ (s) | -43.1 | 113.9 | 178.2 |
| N ₂ O 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 ₂ O(l) | -285.8 | -237.1 | 70.0 |
| H ₂ O(g) | -241.8 | -228.6 | 188.8 |
| H ₂ O ₂ (l) | -187.8 | -120.4 | 109.6 |
| H ₂ O 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 ₃ (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 ₂ PO ₄ ⁻ (aq) | -1296.3 | -1130.2 | 90.4 |
| H ₃ PO ₄ (s) | -1284.4 | -1124.3 | 110.5 |
| H ₃ PO ₄ (aq) | -1288.3 | -1142.6 | 158.2 |
| P ₄ O ₆ (s) | -1640.1 | | |
| P ₄ O ₁₀ (s) | -2984 | -2698 | 228.9 |
| Platinum | | | |
| Pt(s) | 0 | 0 | 41.6 |
| Pt(g) | 565.3 | 520.5 | 192.4 |

| Substance | ΔH_f° (kJ/mol) | ΔG_f° (kJ/mol) | S° (J/mol · K) |
|------------------------------------|-----------------------------|-----------------------------|-----------------------|
| 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 |
| 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 ₂ CO ₃ (s) | -1151.0 | -1063.5 | 155.5 |
| K ₂ O(s) | -361.5 | -322.1 | 94.14 |
| K ₂ O ₂ (s) | -494.1 | -425.1 | 102.1 |
| K ₂ SO 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 ₂ Se(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 ₂ H 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 |

| Substance | ΔH_f° (kJ/mol) | ΔG_f° (kJ/mol) | S° (J/mol · K) |
|-------------------------------------|-----------------------------|-----------------------------|-----------------------|
| 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 ₂ O(s) | -31.1 | -11.2 | 121.3 |
| Ag ₂ S(s) | -32.6 | -40.7 | 144.0 |
| Ag ₂ SO 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 |
| 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 ₂ CO ₃ (s) | -1130.7 | -1044.4 | 135.0 |
| Na ₂ O(s) | -414.2 | -375.5 | 75.1 |
| Na ₂ O ₂ (s) | -510.9 | -447.7 | 95.0 |
| Na ₂ SO ₄ (s) | -1387.1 | -1270.2 | 149.6 |
| Na ₃ PO 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 |

(continued on the next page)

A-10 Appendix II: Useful Data

| Substance | ΔH_f° (kJ/mol) | ΔG_f° (kJ/mol) | S° (J/mol · K) |
|--|-----------------------------|-----------------------------|-----------------------|
| H ₂ S(g) | -20.6 | -33.4 | 205.8 |
| H ₂ S(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 ₂ SO ₄ (l) | -814.0 | -690.0 | 156.9 |
| H ₂ SO ₄ (aq) | -909.3 | -744.6 | 18.5 |
| S ₂ O 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(l) | 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 |
| 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 |

| Substance | ΔH_f° (kJ/mol) | ΔG_f° (kJ/mol) | S° (J/mol · K) |
|-----------------------|-----------------------------|-----------------------------|-----------------------|
| 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_{a1} | K_{a2} | K_{a3} |
|-----------------|---|-----------------------|-----------------------|-----------------------|
| Acetic | HC ₂ H ₃ O ₂ | 1.8×10^{-5} | | |
| Acetylsalicylic | HC ₉ H ₇ O ₄ | 3.3×10^{-4} | | |
| Adipic | H ₂ C ₆ H ₈ O ₄ | 3.9×10^{-5} | 3.9×10^{-6} | |
| Arsenic | H ₃ AsO ₄ | 5.5×10^{-3} | 1.7×10^{-7} | 5.1×10^{-12} |
| Arsenous | H ₃ AsO ₃ | 5.1×10^{-10} | | |
| Ascorbic | H ₂ C ₆ H ₆ O ₆ | 8.0×10^{-5} | 1.6×10^{-12} | |
| Benzoic | HC ₇ H ₅ O ₂ | 6.5×10^{-5} | | |
| Boric | H ₃ BO ₃ | 5.4×10^{-10} | | |
| Butanoic | HC ₄ H ₇ O ₂ | 1.5×10^{-5} | | |
| Carbonic | H ₂ CO ₃ | 4.3×10^{-7} | 5.6×10^{-11} | |
| Chloroacetic | HC ₂ H ₃ O ₂ Cl | 1.4×10^{-3} | | |
| Chlorous | HClO ₂ | 1.1×10^{-2} | | |
| Citric | H ₃ C ₆ H ₅ O 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} | | |

| Name | Formula | K_{a1} | K_{a2} | K_{a3} |
|-----------------------|---|-----------------------|-----------------------|----------|
| Hydrocyanic | HCN | 4.9×10^{-10} | | |
| Hydrofluoric | HF | 3.5×10^{-4} | | |
| Hydrogen chromate ion | HCrO ₄ ⁻ | 3.0×10^{-7} | | |
| Hydrogen peroxide | H ₂ O ₂ | 2.4×10^{-12} | | |
| Hydrogen selenate ion | HSeO ₄ ⁻ | 2.2×10^{-2} | | |
| Hydrosulfuric | H ₂ S | 8.9×10^{-8} | 1×10^{-19} | |
| Hydrotelluric | H ₂ Te | 2.3×10^{23} | 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 ₃ H ₅ O ₃ | 1.4×10^{-4} | | |
| Maleic | H ₂ C ₄ H ₂ O ₄ | 1.2×10^{-2} | 5.9×10^{-7} | |
| Malonic | H ₂ C ₃ H ₂ O ₄ | 1.5×10^{-3} | 2.0×10^{-6} | |

| Name | Formula | K_{s1} | K_{s2} | K_{s3} |
|----------------|---|-----------------------|----------------------|-----------------------|
| Nitrous | HNO ₂ | 4.6×10^{-4} | | |
| Oxalic | H ₂ C ₂ O ₄ | 6.0×10^{-2} | 6.1×10^{-5} | |
| Paraperiodic | H ₃ O ₆ | 2.8×10^{-2} | 5.3×10^{-9} | |
| Phenol | HC ₆ H ₅ O | 1.3×10^{-10} | | |
| Phosphoric | H ₃ PO ₄ | 7.5×10^{-3} | 6.2×10^{-8} | 4.2×10^{-13} |
| Phosphorous | H ₃ PO ₃ | 5×10^{-2} | 2.0×10^{-7} | |
| Propanoic | HC ₃ H ₅ O ₂ | 1.3×10^{-5} | | |
| Pyruvic | HC ₃ H ₃ O ₃ | 4.1×10^{-3} | | |
| Pyrophosphoric | H ₄ P ₂ O ₇ | 1.2×10^{-1} | 7.9×10^{-3} | 2.0×10^{-7} |

| Name | Formula | K_{s1} | K_{s2} | K_{s3} |
|----------------------|---|----------------------|----------------------|----------|
| Selenous | H ₂ SeO ₃ | 2.4×10^{-3} | 4.8×10^{-9} | |
| Succinic | H ₂ C ₄ H ₄ O ₄ | 6.2×10^{-5} | 2.3×10^{-6} | |
| Sulfuric | H ₂ SO ₄ | Strong acid | 1.2×10^{-2} | |
| Sulfurous | H ₂ SO ₃ | 1.6×10^{-2} | 6.4×10^{-8} | |
| Tartaric | H ₂ C ₄ H ₄ O ₆ | 1.0×10^{-3} | 4.6×10^{-5} | |
| Trichloroacetic | HC ₂ Cl ₃ O ₂ | 2.2×10^{-1} | | |
| Trifluoroacetic acid | HC ₂ F ₃ O ₂ | 3.0×10^{-1} | | |

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

| Cation | Hydrated Ion | K_h |
|------------------|---|-----------------------|
| Al ³⁺ | Al(H ₂ O) ₆ ³⁺ | 1.4×10^{-5} |
| Be ²⁺ | Be(H ₂ O) ₆ ²⁺ | 3×10^{-7} |
| Co ²⁺ | Co(H ₂ O) ₆ ²⁺ | 1.3×10^{-9} |
| Cr ³⁺ | Cr(H ₂ O) ₆ ³⁺ | 1.6×10^{-4} |
| Cu ²⁺ | Cu(H ₂ O) ₆ ²⁺ | 3×10^{-8} |
| Fe ²⁺ | Fe(H ₂ O) ₆ ²⁺ | 3.2×10^{-10} |

| Cation | Hydrated Ion | K_h |
|------------------|---|-----------------------|
| Fe ³⁺ | Fe(H ₂ O) ₆ ³⁺ | 6.3×10^{-3} |
| Ni ²⁺ | Ni(H ₂ O) ₆ ²⁺ | 2.5×10^{-11} |
| Pb ²⁺ | Pb(H ₂ O) ₆ ²⁺ | 3×10^{-8} |
| Sn ²⁺ | Sn(H ₂ O) ₆ ²⁺ | 4×10^{-4} |
| Zn ²⁺ | Zn(H ₂ O) 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 ₆ H ₅ NH 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 ₂ H ₅) ₂ NH | 6.9×10^{-4} |
| Dimethylamine | (CH ₃) ₂ NH | 5.4×10^{-4} |
| Ethylamine | C ₂ H ₅ NH ₂ | 5.6×10^{-4} |
| Ethylenediamine | C ₂ H ₈ N ₂ | 8.3×10^{-5} |
| Hydrazine | H ₂ NNH ₂ | 1.3×10^{-6} |
| Hydroxylamine | HONH ₂ | 1.1×10^{-8} |

| Name | Formula | K_b |
|----------------|---|-----------------------|
| Ketamine | C ₁₃ H ₁₆ ClNO | 3×10^{-7} |
| Methylamine | CH ₃ NH 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 ₆ H ₁₀ NH | 1.33×10^{-3} |
| Propylamine | C ₃ H ₇ NH ₂ | 3.5×10^{-4} |
| Pyridine | C ₅ H ₅ N | 1.7×10^{-9} |
| Strychnine | C ₂₂ H ₂₂ N ₂ O ₂ | 1.8×10^{-6} |
| Triethylamine | (C ₂ H ₅) ₃ N | 5.6×10^{-4} |
| Trimethylamine | (CH ₃) ₃ N | 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 ₂ O ₄ | 1.6×10^{-6} |
| Barium phosphate | Ba ₃ (PO ₄) ₂ | 6×10^{-39} |
| Barium sulfate | BaSO ₄ | 1.07×10^{-10} |

| Compound | Formula | K_{sp} |
|----------------------------|---------------------|------------------------|
| 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} |

(continued on the next page)

A-12 Appendix II: Useful Data

| Compound | Formula | K_{sp} | Compound | Formula | K_{sp} |
|-------------------------|------------------------------|------------------------|-------------------------|------------------------------|------------------------|
| Calcium oxalate | CaC_2O_4 | 2.32×10^{-9} | Manganese(II) carbonate | MnCO_3 | 2.24×10^{-11} |
| Calcium phosphate | $\text{Ca}_3(\text{PO}_4)_2$ | 2.07×10^{-33} | Manganese(II) hydroxide | $\text{Mn}(\text{OH})_2$ | 1.6×10^{-13} |
| Calcium sulfate | CaSO_4 | 7.10×10^{-5} | Manganese(II) sulfide | MnS | 2.3×10^{-13} |
| Chromium(III) hydroxide | $\text{Cr}(\text{OH})_3$ | 6.3×10^{-31} | Mercury(I) bromide | Hg_2Br_2 | 6.40×10^{-23} |
| Cobalt(II) carbonate | CoCO_3 | 1.0×10^{-10} | Mercury(I) carbonate | Hg_2CO_3 | 3.6×10^{-17} |
| Cobalt(II) hydroxide | $\text{Co}(\text{OH})_2$ | 5.92×10^{-15} | Mercury(I) chloride | Hg_2Cl_2 | 1.43×10^{-18} |
| Cobalt(II) sulfide | CoS | 5×10^{-22} | Mercury(I) chromate | Hg_2CrO_4 | 2×10^{-9} |
| Copper(I) bromide | CuBr | 6.27×10^{-9} | Mercury(I) cyanide | $\text{Hg}_2(\text{CN})_2$ | 5×10^{-40} |
| Copper(I) chloride | CuCl | 1.72×10^{-7} | Mercury(I) iodide | Hg_2I_2 | 5.2×10^{-29} |
| Copper(I) cyanide | CuCN | 3.47×10^{-20} | Mercury(II) hydroxide | $\text{Hg}(\text{OH})_2$ | 3.1×10^{-26} |
| Copper(II) carbonate | CuCO_3 | 2.4×10^{-10} | Mercury(II) sulfide | HgS | 1.6×10^{-54} |
| Copper(II) hydroxide | $\text{Cu}(\text{OH})_2$ | 2.2×10^{-20} | Nickel(II) carbonate | NiCO_3 | 1.42×10^{-7} |
| Copper(II) phosphate | $\text{Cu}_3(\text{PO}_4)_2$ | 1.40×10^{-37} | Nickel(II) hydroxide | $\text{Ni}(\text{OH})_2$ | 5.48×10^{-16} |
| Copper(II) sulfide | CuS | 1.27×10^{-36} | Nickel(II) sulfide | NiS | 3×10^{-20} |
| Iron(II) carbonate | FeCO_3 | 3.07×10^{-11} | Silver bromate | AgBrO_3 | 5.38×10^{-5} |
| Iron(II) hydroxide | $\text{Fe}(\text{OH})_2$ | 4.87×10^{-17} | Silver bromide | AgBr | 5.35×10^{-13} |
| Iron(II) sulfide | FeS | 3.72×10^{-19} | Silver carbonate | Ag_2CO_3 | 8.46×10^{-12} |
| Iron(III) hydroxide | $\text{Fe}(\text{OH})_3$ | 2.79×10^{-39} | Silver chloride | AgCl | 1.77×10^{-10} |
| Lanthanum fluoride | LaF_3 | 2×10^{-19} | Silver chromate | Ag_2CrO_4 | 1.12×10^{-12} |
| Lanthanum iodate | $\text{La}(\text{IO}_3)_3$ | 7.50×10^{-12} | Silver cyanide | AgCN | 5.97×10^{-17} |
| Lead(II) bromide | PbBr_2 | 4.67×10^{-6} | Silver iodide | AgI | 8.51×10^{-17} |
| Lead(II) carbonate | PbCO_3 | 7.40×10^{-14} | Silver phosphate | Ag_3PO_4 | 8.89×10^{-17} |
| Lead(II) chloride | PbCl_2 | 1.17×10^{-5} | Silver sulfate | Ag_2SO_4 | 1.20×10^{-5} |
| Lead(II) chromate | PbCrO_4 | 2.8×10^{-13} | Silver sulfide | Ag_2S | 6×10^{-51} |
| Lead(II) fluoride | PbF_2 | 3.3×10^{-8} | Strontium carbonate | SrCO_3 | 5.60×10^{-10} |
| Lead(II) hydroxide | $\text{Pb}(\text{OH})_2$ | 1.43×10^{-20} | Strontium chromate | SrCrO_4 | 3.6×10^{-5} |
| Lead(II) iodide | PbI_2 | 9.8×10^{-9} | Strontium phosphate | $\text{Sr}_3(\text{PO}_4)_2$ | 1×10^{-31} |
| Lead(II) phosphate | $\text{Pb}_3(\text{PO}_4)_2$ | 1×10^{-54} | Strontium sulfate | SrSO_4 | 3.44×10^{-7} |
| Lead(II) sulfate | PbSO_4 | 1.82×10^{-8} | Tin(II) hydroxide | $\text{Sn}(\text{OH})_2$ | 5.45×10^{-27} |
| Lead(II) sulfide | PbS | 9.04×10^{-29} | Tin(II) sulfide | SnS | 1×10^{-26} |
| Magnesium carbonate | MgCO_3 | 6.82×10^{-6} | Zinc carbonate | ZnCO_3 | 1.46×10^{-10} |
| Magnesium fluoride | MgF_2 | 5.16×10^{-11} | Zinc hydroxide | $\text{Zn}(\text{OH})_2$ | 3×10^{-17} |
| Magnesium hydroxide | $\text{Mg}(\text{OH})_2$ | 2.06×10^{-13} | Zinc oxalate | ZnC_2O_4 | 2.7×10^{-8} |
| Magnesium oxalate | MgC_2O_4 | 4.83×10^{-6} | Zinc sulfide | ZnS | 2×10^{-25} |

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

| Complex Ion | K_f | Complex Ion | K_f |
|---|----------------------|---------------------------------|----------------------|
| $[\text{Ag}(\text{CN})_2]^-$ | 1×10^{21} | $[\text{Al}(\text{OH})_4]^-$ | 3×10^{33} |
| $[\text{Ag}(\text{EDTA})]^{3-}$ | 2.1×10^7 | $[\text{Al}(\text{ox})_3]^{3-}$ | 2×10^{16} |
| $[\text{Ag}(\text{en})_2]^+$ | 5.0×10^7 | $[\text{CdBr}_4]^{2-}$ | 5.5×10^3 |
| $[\text{Ag}(\text{NH}_3)_2]^+$ | 1.7×10^7 | $[\text{Cd}(\text{CN})_4]^{2-}$ | 3×10^{18} |
| $[\text{Ag}(\text{SCN})_4]^{3-}$ | 1.2×10^{10} | $[\text{CdCl}_4]^{2-}$ | 6.3×10^2 |
| $[\text{Ag}(\text{S}_2\text{O}_3)_2]^-$ | 2.8×10^{13} | $[\text{Cd}(\text{en})_3]^{2+}$ | 1.2×10^{12} |
| $[\text{Al}(\text{EDTA})]^-$ | 1.3×10^{16} | $[\text{CdI}_4]^{2-}$ | 2×10^6 |
| $[\text{AlF}_6]^{3-}$ | 7×10^{19} | $[\text{Co}(\text{EDTA})]^{2-}$ | 2.0×10^{16} |

| Complex Ion | K_f |
|-----------------------------------|----------------------|
| $[\text{Co}(\text{EDTA})]^-$ | 1×10^{36} |
| $[\text{Co}(\text{en})_3]^{2+}$ | 8.7×10^{13} |
| $[\text{Co}(\text{en})_3]^{3+}$ | 4.9×10^{48} |
| $[\text{Co}(\text{NH}_3)_6]^{2+}$ | 1.3×10^5 |
| $[\text{Co}(\text{NH}_3)_6]^{3+}$ | 2.3×10^{33} |
| $[\text{Co}(\text{OH})_4]^{2-}$ | 5×10^9 |
| $[\text{Co}(\alpha)_3]^{4-}$ | 5×10^9 |
| $[\text{Co}(\alpha)_3]^{3-}$ | 1×10^{20} |
| $[\text{Co}(\text{SCN})_4]^{2-}$ | 1×10^3 |
| $[\text{Cr}(\text{EDTA})]^-$ | 1×10^{23} |
| $[\text{Cr}(\text{OH})_4]^-$ | 8.0×10^{29} |
| $[\text{CuCl}_2]^{2-}$ | 5×10^5 |
| $[\text{Cu}(\text{CN})_4]^{2-}$ | 1.0×10^{25} |
| $[\text{Cu}(\text{EDTA})]^{2-}$ | 5×10^{18} |
| $[\text{Cu}(\text{en})_2]^{2+}$ | 1×10^{20} |
| $[\text{Cu}(\text{NH}_3)_4]^{2+}$ | 1.7×10^{13} |
| $[\text{Cu}(\alpha)_2]^{2-}$ | 3×10^8 |
| $[\text{Fe}(\text{CN})_6]^{4-}$ | 1.5×10^{35} |
| $[\text{Fe}(\text{CN})_6]^{3-}$ | 2×10^{43} |
| $[\text{Fe}(\text{EDTA})]^{2-}$ | 2.1×10^{14} |
| $[\text{Fe}(\text{EDTA})]^-$ | 1.7×10^{24} |
| $[\text{Fe}(\text{en})_3]^{2+}$ | 5.0×10^9 |
| $[\text{Fe}(\alpha)_3]^{4-}$ | 1.7×10^5 |
| $[\text{Fe}(\alpha)_3]^{3-}$ | 2×10^{20} |
| $[\text{Fe}(\text{SCN})]^{2+}$ | 8.9×10^2 |
| $[\text{Hg}(\text{CN})_4]^{2-}$ | 1.8×10^{41} |

| Complex Ion | K_f |
|--|----------------------|
| $[\text{HgCl}_4]^{2-}$ | 1.1×10^{16} |
| $[\text{Hg}(\text{EDTA})]^{2-}$ | 6.3×10^{21} |
| $[\text{Hg}(\text{en})_2]^{2+}$ | 2×10^{23} |
| $[\text{HgI}_4]^{2-}$ | 2×10^{30} |
| $[\text{Hg}(\alpha)_2]^{2-}$ | 9.5×10^6 |
| $[\text{Ni}(\text{CN})_4]^{2-}$ | 2×10^{31} |
| $[\text{Ni}(\text{EDTA})]^{2-}$ | 3.6×10^{18} |
| $[\text{Ni}(\text{en})_3]^{2+}$ | 2.1×10^{18} |
| $[\text{Ni}(\text{NH}_3)_6]^{2+}$ | 2.0×10^8 |
| $[\text{Ni}(\alpha)_3]^{4-}$ | 3×10^8 |
| $[\text{PbCl}_2]^-$ | 2.4×10^1 |
| $[\text{Pb}(\text{EDTA})]^{2-}$ | 2×10^{18} |
| $[\text{PbI}_4]^{2-}$ | 3.0×10^4 |
| $[\text{Pb}(\text{OH})_3]^-$ | 8×10^{13} |
| $[\text{Pb}(\alpha)_2]^{2-}$ | 3.5×10^6 |
| $[\text{Pb}(\text{S}_2\text{O}_3)_3]^{4-}$ | 2.2×10^6 |
| $[\text{PtCl}_4]^{2-}$ | 1×10^{16} |
| $[\text{Pt}(\text{NH}_3)_4]^{2+}$ | 2×10^{35} |
| $[\text{Sn}(\text{OH})_3]^-$ | 3×10^{25} |
| $[\text{Zn}(\text{CN})_4]^{2-}$ | 2.1×10^{19} |
| $[\text{Zn}(\text{EDTA})]^{2-}$ | 3×10^{16} |
| $[\text{Zn}(\text{en})_3]^{2+}$ | 1.3×10^{14} |
| $[\text{Zn}(\text{NH}_3)_4]^{2+}$ | 2.8×10^9 |
| $[\text{Zn}(\text{OH})_4]^{2-}$ | 2×10^{15} |
| $[\text{Zn}(\alpha)_3]^{4-}$ | 1.4×10^8 |

D. Standard Electrode Potentials at 25 °C

| Half-Reaction | $E^\circ(\text{V})$ |
|--|---------------------|
| $\text{F}_2(\text{g}) + 2 \text{e}^- \longrightarrow 2 \text{F}^-(\text{aq})$ | 2.87 |
| $\text{O}_3(\text{g}) + 2 \text{H}^+(\text{aq}) + 2 \text{e}^- \longrightarrow \text{O}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$ | 2.08 |
| $\text{Ag}_2^{2+}(\text{aq}) + \text{e}^- \longrightarrow \text{Ag}^+(\text{aq})$ | 1.98 |
| $\text{Co}^{3+}(\text{aq}) + \text{e}^- \longrightarrow \text{Co}^{2+}(\text{aq})$ | 1.82 |
| $\text{H}_2\text{O}_2(\text{aq}) + 2 \text{H}^+(\text{aq}) + 2 \text{e}^- \longrightarrow 2 \text{H}_2\text{O}(\text{l})$ | 1.78 |
| $\text{PbO}_2(\text{s}) + 4 \text{H}^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{PbSO}_4(\text{s}) + 2 \text{H}_2\text{O}(\text{l})$ | 1.69 |
| $\text{MnO}_4^-(\text{aq}) + 4 \text{H}^+(\text{aq}) + 3 \text{e}^- \longrightarrow \text{MnO}_2(\text{s}) + 2 \text{H}_2\text{O}(\text{l})$ | 1.68 |
| $2 \text{HClO}(\text{aq}) + 2 \text{H}^+(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Cl}_2(\text{g}) + 2 \text{H}_2\text{O}(\text{l})$ | 1.61 |
| $\text{MnO}_4^-(\text{aq}) + 8 \text{H}^+(\text{aq}) + 5 \text{e}^- \longrightarrow \text{Mn}^{2+}(\text{aq}) + 4 \text{H}_2\text{O}(\text{l})$ | 1.51 |
| $\text{Au}^{3+}(\text{aq}) + 3 \text{e}^- \longrightarrow \text{Au}(\text{s})$ | 1.50 |
| $2 \text{BrO}_3^-(\text{aq}) + 12 \text{H}^+(\text{aq}) + 10 \text{e}^- \longrightarrow \text{Br}_2(\text{l}) + 6 \text{H}_2\text{O}(\text{l})$ | 1.48 |
| $\text{PbO}_2(\text{s}) + 4 \text{H}^+(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Pb}^{2+}(\text{aq}) + 2 \text{H}_2\text{O}(\text{l})$ | 1.46 |

| Half-Reaction | $E^\circ(\text{V})$ |
|--|---------------------|
| $\text{Cl}_2(\text{g}) + 2 \text{e}^- \longrightarrow 2 \text{Cl}^-(\text{aq})$ | 1.36 |
| $\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14 \text{H}^+(\text{aq}) + 6 \text{e}^- \longrightarrow 2 \text{Cr}^{3+}(\text{aq}) + 7 \text{H}_2\text{O}(\text{l})$ | 1.33 |
| $\text{O}_2(\text{g}) + 4 \text{H}^+(\text{aq}) + 4 \text{e}^- \longrightarrow 2 \text{H}_2\text{O}(\text{l})$ | 1.23 |
| $\text{MnO}_2(\text{s}) + 4 \text{H}^+(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Mn}^{2+}(\text{aq}) + 2 \text{H}_2\text{O}(\text{l})$ | 1.21 |
| $\text{IO}_3^-(\text{aq}) + 6 \text{H}^+(\text{aq}) + 5 \text{e}^- \longrightarrow \frac{1}{2} \text{I}_2(\text{aq}) + 3 \text{H}_2\text{O}(\text{l})$ | 1.20 |
| $\text{Br}_2(\text{l}) + 2 \text{e}^- \longrightarrow 2 \text{Br}^-(\text{aq})$ | 1.09 |
| $\text{AuCl}_4^-(\text{aq}) + 3 \text{e}^- \longrightarrow \text{Au}(\text{s}) + 4 \text{Cl}^-(\text{aq})$ | 1.00 |
| $\text{VO}_2^+(\text{aq}) + 2 \text{H}^+(\text{aq}) + \text{e}^- \longrightarrow \text{VO}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$ | 1.00 |
| $\text{HNO}_2(\text{aq}) + \text{H}^+(\text{aq}) + \text{e}^- \longrightarrow \text{NO}(\text{g}) + 2 \text{H}_2\text{O}(\text{l})$ | 0.98 |
| $\text{NO}_2^-(\text{aq}) + 4 \text{H}^+(\text{aq}) + 3 \text{e}^- \longrightarrow \text{NO}(\text{g}) + 2 \text{H}_2\text{O}(\text{l})$ | 0.96 |
| $\text{ClO}_2(\text{g}) + \text{e}^- \longrightarrow \text{ClO}_2^-(\text{aq})$ | 0.95 |
| $2 \text{Hg}_2^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow 2 \text{Hg}_2^{2+}(\text{aq})$ | 0.92 |

(continued on the next page)

A-14 Appendix II: Useful Data

| Half-Reaction | E°(V) | Half-Reaction | E°(V) |
|--|--------|--|-------|
| $\text{Ag}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Ag}(\text{s})$ | 0.80 | $\text{Ag}(\text{s}) + \text{e}^- \longrightarrow \text{Ag}(\text{s}) + \Gamma^-(\text{aq})$ | -0.15 |
| $\text{Hg}_2^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow 2 \text{Hg}(\text{l})$ | 0.80 | $\text{N}_2(\text{g}) + 5 \text{H}^+(\text{aq}) + 4 \text{e}^- \longrightarrow \text{N}_2\text{H}_5^+(\text{aq})$ | -0.23 |
| $\text{Fe}^{3+}(\text{aq}) + \text{e}^- \longrightarrow \text{Fe}^{2+}(\text{aq})$ | 0.77 | $\text{Ni}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Ni}(\text{s})$ | -0.23 |
| $\text{PtCl}_4^{2-}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Pt}(\text{s}) + 4 \text{Cl}^-(\text{aq})$ | 0.76 | $\text{Co}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Co}(\text{s})$ | -0.28 |
| $\text{O}_2(\text{g}) + 2 \text{H}^+(\text{aq}) + 2 \text{e}^- \longrightarrow \text{H}_2\text{O}_2(\text{aq})$ | 0.70 | $\text{PbSO}_4(\text{s}) + 2 \text{e}^- \longrightarrow \text{Pb}(\text{s}) + \text{SO}_4^{2-}(\text{aq})$ | -0.36 |
| $\text{MnO}_4^-(\text{aq}) + \text{e}^- \longrightarrow \text{MnO}_4^{2-}(\text{aq})$ | 0.56 | $\text{Cd}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Cd}(\text{s})$ | -0.40 |
| $\text{I}_2(\text{s}) + 2 \text{e}^- \longrightarrow 2 \text{I}^-(\text{aq})$ | 0.54 | $\text{Fe}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Fe}(\text{s})$ | -0.45 |
| $\text{Cu}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Cu}(\text{s})$ | 0.52 | $2 \text{CO}_2(\text{g}) + 2 \text{H}^+(\text{aq}) + 2 \text{e}^- \longrightarrow \text{H}_2\text{C}_2\text{O}_4(\text{aq})$ | -0.49 |
| $\text{O}_2(\text{g}) + 2 \text{H}_2\text{O}(\text{l}) + 4 \text{e}^- \longrightarrow 4 \text{OH}^-(\text{aq})$ | 0.40 | $\text{Cr}^{3+}(\text{aq}) + \text{e}^- \longrightarrow \text{Cr}^{2+}(\text{aq})$ | -0.50 |
| $\text{Cu}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Cu}(\text{s})$ | 0.34 | $\text{Cr}^{3+}(\text{aq}) + 3 \text{e}^- \longrightarrow \text{Cr}(\text{s})$ | -0.73 |
| $\text{BiO}^+(\text{aq}) + 2 \text{H}^+(\text{aq}) + 3 \text{e}^- \longrightarrow \text{Bi}(\text{s}) + \text{H}_2\text{O}(\text{l})$ | 0.32 | $\text{Zn}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Zn}(\text{s})$ | -0.76 |
| $\text{Hg}_2\text{Cl}_2(\text{s}) + 2 \text{e}^- \longrightarrow 2 \text{Hg}(\text{l}) + 2 \text{Cl}^-(\text{aq})$ | 0.27 | $2 \text{H}_2\text{O}(\text{l}) + 2 \text{e}^- \longrightarrow \text{H}_2(\text{g}) + 2 \text{OH}^-(\text{aq})$ | -0.83 |
| $\text{AgCl}(\text{s}) + \text{e}^- \longrightarrow \text{Ag}(\text{s}) + \text{Cl}^-(\text{aq})$ | 0.22 | $\text{Mn}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Mn}(\text{s})$ | -1.18 |
| $\text{SO}_4^{2-}(\text{aq}) + 4 \text{H}^+(\text{aq}) + 2 \text{e}^- \longrightarrow \text{H}_2\text{SO}_3(\text{aq}) + \text{H}_2\text{O}(\text{l})$ | 0.20 | $\text{Al}^{3+}(\text{aq}) + 3 \text{e}^- \longrightarrow \text{Al}(\text{s})$ | -1.66 |
| $\text{Cu}^{2+}(\text{aq}) + \text{e}^- \longrightarrow \text{Cu}^+(\text{aq})$ | 0.16 | $\text{H}_2(\text{g}) + 2 \text{e}^- \longrightarrow 2 \text{H}^-(\text{aq})$ | -2.23 |
| $\text{Sn}^{4+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Sn}^{2+}(\text{aq})$ | 0.15 | $\text{Mg}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Mg}(\text{s})$ | -2.37 |
| $\text{S}(\text{s}) + 2 \text{H}^+(\text{aq}) + 2 \text{e}^- \longrightarrow \text{H}_2\text{S}(\text{g})$ | 0.14 | $\text{La}^{3+}(\text{aq}) + 3 \text{e}^- \longrightarrow \text{La}(\text{s})$ | -2.38 |
| $\text{AgBr}(\text{s}) + \text{e}^- \longrightarrow \text{Ag}(\text{s}) + \text{Br}^-(\text{aq})$ | 0.071 | $\text{Na}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Na}(\text{s})$ | -2.71 |
| $2 \text{H}^+(\text{aq}) + 2 \text{e}^- \longrightarrow \text{H}_2(\text{g})$ | 0.00 | $\text{Ca}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Ca}(\text{s})$ | -2.76 |
| $\text{Fe}^{3+}(\text{aq}) + 3 \text{e}^- \longrightarrow \text{Fe}(\text{s})$ | -0.036 | $\text{Ba}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Ba}(\text{s})$ | -2.90 |
| $\text{Pb}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Pb}(\text{s})$ | -0.13 | $\text{K}^+(\text{aq}) + \text{e}^- \longrightarrow \text{K}(\text{s})$ | -2.92 |
| $\text{Sn}^{2+}(\text{aq}) + 2 \text{e}^- \longrightarrow \text{Sn}(\text{s})$ | -0.14 | $\text{Li}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Li}(\text{s})$ | -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 |