# THERMODYNAMIC QUANTITIES FOR SELECTED SUBSTANCES AT 298.15 K (25 °C)

| Substance | $\Delta H_f^\circ$ (kJ/mol) | $\Delta G_f^\circ$ (kJ/mol) | $S^\circ$ (J/mol-K) |
|---|---|---|---|
| Aluminum | | | |
| $Al(s)$ | 0 | 0 | 28.32 |
| $AlCl_3(s)$ | −705.6 | −630.0 | 109.3 |
| $Al_2O_3(s)$ | −1669.8 | −1576.5 | 51.00 |
| Barium | | | |
| $Ba(s)$ | 0 | 0 | 63.2 |
| $BaCO_3(s)$ | −1216.3 | −1137.6 | 112.1 |
| $BaO(s)$ | −553.5 | −525.1 | 70.42 |
| Beryllium | | | |
| $Be(s)$ | 0 | 0 | 9.44 |
| $BeO(s)$ | −608.4 | −579.1 | 13.77 |
| $Be(OH)_2(s)$ | −905.8 | −817.9 | 50.21 |
| Bromine | | | |
| $Br(g)$ | 111.8 | 82.38 | 174.9 |
| $Br^-(aq)$ | −120.9 | −102.8 | 80.71 |
| $Br_2(g)$ | 30.71 | 3.14 | 245.3 |
| $Br_2(l)$ | 0 | 0 | 152.3 |
| $HBr(g)$ | −36.23 | −53.22 | 198.49 |
| Calcium | | | |
| $Ca(g)$ | 179.3 | 145.5 | 154.8 |
| $Ca(s)$ | 0 | 0 | 41.4 |
| $CaCO_3(s,$ calcite) | −1207.1 | −1128.76 | 92.88 |
| $CaCl_2(s)$ | −795.8 | −748.1 | 104.6 |
| $CaF_2(s)$ | −1219.6 | −1167.3 | 68.87 |
| $CaO(s)$ | −635.5 | −604.17 | 39.75 |
| $Ca(OH)_2(s)$ | −986.2 | −898.5 | 83.4 |
| $CaSO_4(s)$ | −1434.0 | −1321.8 | 106.7 |
| Carbon | | | |
| $C(g)$ | 718.4 | 672.9 | 158.0 |
| $C(s,$ diamond) | 1.88 | 2.84 | 2.43 |
| $C(s,$ graphite) | 0 | 0 | 5.69 |
| $CCl_4(g)$ | −106.7 | −64.0 | 309.4 |
| $CCl_4(l)$ | −139.3 | −68.6 | 214.4 |
| $CF_4(g)$ | −679.9 | −635.1 | 262.3 |
| $CH_4(g)$ | −74.8 | −50.8 | 186.3 |
| $C_2H_2(g)$ | 226.77 | 209.2 | 200.8 |
| $C_2H_4(g)$ | 52.30 | 68.11 | 219.4 |
| $C_2H_6(g)$ | −84.68 | −32.89 | 229.5 |
| $C_3H_8(g)$ | −103.85 | −23.47 | 269.9 |
| $C_4H_{10}(g)$ | −124.73 | −15.71 | 310.0 |
| $C_4H_{10}(l)$ | −147.6 | −15.0 | 231.0 |
| $C_6H_6(g)$ | 82.9 | 129.7 | 269.2 |
| $C_6H_6(l)$ | 49.0 | 124.5 | 172.8 |
| $CH_3OH(g)$ | −201.2 | −161.9 | 237.6 |
| $CH_3OH(l)$ | −238.6 | −166.23 | 126.8 |
| $C_2H_5OH(g)$ | −235.1 | −168.5 | 282.7 |
| $C_2H_5OH(l)$ | −277.7 | −174.76 | 160.7 |
| $C_6H_{12}O_6(s)$ | −1273.02 | −910.4 | 212.1 |
| $CO(g)$ | −110.5 | −137.2 | 197.9 |
| $CO_2(g)$ | −393.5 | −394.4 | 213.6 |
| $CH_3COOH(l)$ | −487.0 | −392.4 | 159.8 |
| Cesium | | | |
| $Cs(g)$ | 76.50 | 49.53 | 175.6 |
| $Cs(l)$ | 2.09 | 0.03 | 92.07 |
| $Cs(s)$ | 0 | 0 | 85.15 |
| $CsCl(s)$ | −442.8 | −414.4 | 101.2 |
| Chlorine | | | |
| $Cl(g)$ | 121.7 | 105.7 | 165.2 |
| $Cl(aq)$ | −167.2 | −131.2 | 56.5 |
| $Cl_2(g)$ | 0 | 0 | 222.96 |
| $HCl(aq)$ | −167.2 | −131.2 | 56.5 |
| $HCl(g)$ | −92.30 | −95.27 | 186.69 |
| Chromium | | | |
| $Cr(g)$ | 397.5 | 352.6 | 174.2 |
| $Cr(s)$ | 0 | 0 | 23.6 |
| $Cr_2O_3(s)$ | −1139.7 | −1058.1 | 81.2 |
| Cobalt | | | |
| $Co(g)$ | 439 | 393 | 179 |
| $Co(s)$ | 0 | 0 | 28.4 |
| Copper | | | |
| $Cu(g)$ | 338.4 | 298.6 | 166.3 |
| $Cu(s)$ | 0 | 0 | 33.30 |

| Substance | $\Delta H_f^\circ$ (kJ/mol) | $\Delta G_f^\circ$ (kJ/mol) | $S^\circ$ (J/mol-K) |
|---|---|---|---|
| $CuCl_2(s)$ | −205.9 | −161.7 | 108.1 |
| $CuO(s)$ | −156.1 | −128.3 | 42.59 |
| $Cu_2O(s)$ | −170.7 | −147.9 | 92.36 |
| Fluorine | | | |
| $F(g)$ | 80.0 | 61.9 | 158.7 |
| $F(aq)$ | −332.6 | −278.8 | −13.8 |
| $F_2(g)$ | 0 | 0 | 202.7 |
| $HF(g)$ | −268.61 | −270.70 | 173.51 |
| Hydrogen | | | |
| $H(g)$ | 217.94 | 203.26 | 114.60 |
| $H^+(aq)$ | 0 | 0 | 0 |
| $H^+(g)$ | 1536.2 | 1517.0 | 108.9 |
| $H_2(g)$ | 0 | 0 | 130.58 |
| Iodine | | | |
| $I(g)$ | 106.60 | 70.16 | 180.66 |
| $I^-(aq)$ | −55.19 | −51.57 | 111.3 |
| $I_2(g)$ | 62.25 | 19.37 | 260.57 |
| $I_2(s)$ | 0 | 0 | 116.73 |
| $HI(g)$ | 25.94 | 1.30 | 206.3 |
| Iron | | | |
| $Fe(g)$ | 415.5 | 369.8 | 180.5 |
| $Fe(s)$ | 0 | 0 | 27.15 |
| $Fe^{2+}(aq)$ | −87.86 | −84.93 | 113.4 |
| $Fe^{3+}(aq)$ | −47.69 | −10.54 | 293.3 |
| $FeCl_2(s)$ | −341.8 | −302.3 | 117.9 |
| $FeCl_3(s)$ | −400 | −334 | 142.3 |
| $FeO(s)$ | −271.9 | −255.2 | 60.75 |
| $Fe_2O_3(s)$ | −822.16 | −740.98 | 89.96 |
| $Fe_3O_4(s)$ | −1117.1 | −1014.2 | 146.4 |
| $FeS_2(s)$ | −171.5 | −160.1 | 52.92 |
| Lead | | | |
| $Pb(s)$ | 0 | 0 | 68.85 |
| $PbBr_2(s)$ | −277.4 | −260.7 | 161 |
| $PbCO_3(s)$ | −699.1 | −625.5 | 131.0 |
| $Pb(NO_3)_2(aq)$ | −421.3 | −246.9 | 303.3 |
| $Pb(NO_3)_2(s)$ | −451.9 | — | — |
| $PbO(s)$ | −217.3 | −187.9 | 68.70 |
| Lithium | | | |
| Li(g) | 159.3 | 126.6 | 138.8 |
| $Li(s)$ | 0 | 0 | 29.09 |
| $Li^+(aq)$ | −278.5 | −273.4 | 12.2 |
| $Li^+(g)$ | 685.7 | 648.5 | 133.0 |
| $LiCl(s)$ | −408.3 | −384.0 | 59.30 |
| Magnesium | | | |
| $Mg(g)$ | 147.1 | 112.5 | 148.6 |
| $Mg(s)$ | 0 | 0 | 32.51 |
| $MgCl_2(s)$ | −641.6 | −592.1 | 89.6 |
| $MgO(s)$ | −601.8 | −569.6 | 26.8 |
| $Mg(OH)_2(s)$ | −924.7 | −833.7 | 63.24 |
| Manganese | | | |
| $Mn(g)$ | 280.7 | 238.5 | 173.6 |
| $Mn(s)$ | 0 | 0 | 32.0 |
| $MnO(s)$ | −385.2 | −362.9 | 59.7 |
| $MnO_2(s)$ | −519.6 | −464.8 | 53.14 |
| $MnO_4^-(aq)$ | −541.4 | −447.2 | 191.2 |
| Mercury | | | |
| $Hg(g)$ | 60.83 | 31.76 | 174.89 |
| $Hg(l)$ | 0 | 0 | 77.40 |
| $HgCl_2(s)$ | −230.1 | −184.0 | 144.5 |
| $Hg_2Cl_2(s)$ | −264.9 | −210.5 | 192.5 |
| Nickel | | | |
| $Ni(g)$ | 429.7 | 384.5 | 182.1 |
| $Ni(s)$ | 0 | 0 | 29.9 |
| $NiCl_2(s)$ | −305.3 | −259.0 | 97.65 |
| $NiO(s)$ | −239.7 | −211.7 | 37.99 |
| Nitrogen | | | |
| $N(g)$ | 472.7 | 455.5 | 153.3 |
| $N_2(g)$ | 0 | 0 | 191.50 |
| $NH_3(aq)$ | −80.29 | −26.50 | 111.3 |
| $NH_3(_g)$ | −46.19 | −16.66 | 192.5 |
| $NH_4^+(aq)$ | −132.5 | −79.31 | 113.4 |
| $N_2H_4(g)$ | 95.40 | 159.4 | 238.5 |
| $NH_4CN(s)$ | 0.0 | — | — |
| $NH_4Cl(s)$ | −314.4 | −203.0 | 94.6 |
| $NH_4NO_3(s)$ | −365.6 | −184.0 | 151 |
| $NO(g)$ | 90.37 | 86.71 | 210.62 |
| $NO_2(g)$ | 33.84 | 51.84 | 240.45 |
| $N_2O(g)$ | 81.6 | 103.59 | 220.0 |
| $N_2O_4(g)$ | 9.66 | 98.28 | 304.3 |
| $NOCl(g)$ | 52.6 | 66.3 | 264 |
| $HNO_3(aq)$ | −206.6 | −110.5 | 146 |
| $HNO_3(g)$ | −134.3 | −73.94 | 266.4 |
| Oxygen | | | |
| $O(g)$ | 247.5 | 230.1 | 161.0 |
| $O_2(g)$ | 0 | 0 | 205.0 |
| $O_3(g)$ | 142.3 | 163.4 | 237.6 |
| $OH^-(aq)$ | −230.0 | −157.3 | −10.7 |
| $H_2O(g)$ | −241.82 | −228.57 | 188.83 |
| $H_2O(l)$ | −285.83 | −237.13 | 69.91 |
| $H_2O_2(g)$ | −136.10 | −105.48 | 232.9 |
| $H_2O_2(l)$ | −187.8 | −120.4 | 109.6 |
| Phosphorus | | | |
| $P(g)$ | 316.4 | 280.0 | 163.2 |
| $P_2(g)$ | 144.3 | 103.7 | 218.1 |

| Substance | $\Delta H_f^\circ$ (kJ/mol) | $\Delta G_f^\circ$ (kJ/mol) | $S^\circ$ (J/mol-K) |
|---|---|---|---|
| $P_4(g)$ | 58.9 | 24.4 | 280 |
| $P_4(s$, red) | −17.46 | −12.03 | 22.85 |
| $P_4(s$, white) | 0 | 0 | 41.08 |
| $PCl_3(g)$ | −288.07 | −269.6 | 311.7 |
| $PCl_3(l)$ | −319.6 | −272.4 | 217 |
| $PF_5(g)$ | −1594.4 | −1520.7 | 300.8 |
| $PH_3(g)$ | 5.4 | 13.4 | 210.2 |
| $P_4O_6(s)$ | −1640.1 | — | — |
| $P_4O_{10}(s)$ | −2940.1 | −2675.2 | 228.9 |
| $POCl_3(g)$ | −542.2 | −502.5 | 325 |
| $POCl_3(l)$ | −597.0 | −520.9 | 222 |
| $H_3PO_4(aq)$ | −1288.3 | −1142.6 | 158.2 |
| Potassium | | | |
| $K(g)$ | 89.99 | 61.17 | 160.2 |
| $K(s)$ | 0 | 0 | 64.67 |
| $KCl(s)$ | −435.9 | −408.3 | 82.7 |
| $KClO_3(s)$ | −391.2 | −289.9 | 143.0 |
| $KClO_3(aq)$ | −349.5 | −284.9 | 265.7 |
| $K_2CO_3(s)$ | −1150.18 | −1064.58 | 155.44 |
| $KNO_3(s)$ | −492.70 | −393.13 | 132.9 |
| $K_2O(s)$ | −363.2 | −322.1 | 94.14 |
| $KO_2(s)$ | −284.5 | −240.6 | 122.5 |
| $K_2O_2(s)$ | −495.8 | −429.8 | 113.0 |
| $KOH(s)$ | −424.7 | −378.9 | 78.91 |
| $KOH(aq)$ | −482.4 | −440.5 | 91.6 |
| Rubidium | | | |
| $Rb(g)$ | 85.8 | 55.8 | 170.0 |
| $Rb(s)$ | 0 | 0 | 76.78 |
| $RbCl(s)$ | −430.5 | −412.0 | 92 |
| $RbClO_3(s)$ | −392.4 | −292.0 | 152 |
| Scandium | | | |
| $Sc(g)$ | 377.8 | 336.1 | 174.7 |
| $Sc(s)$ | 0 | 0 | 34.6 |
| Selenium | | | |
| $H_2Se(g)$ | 29.7 | 15.9 | 219.0 |
| Silicon | | | |
| $Si(g)$ | 368.2 | 323.9 | 167.8 |
| $Si(s)$ | 0 | 0 | 18.7 |
| $SiC(s)$ | −73.22 | −70.85 | 16.61 |
| $SiCl_4(l)$ | −640.1 | −572.8 | 239.3 |
| $SiO_2(s$, quartz) | −910.9 | −856.5 | 41.84 |
| Silver | | | |
| $Ag(s)$ | 0 | 0 | 42.55 |
| $Ag^+(aq)$ | 105.90 | 77.11 | 73.93 |
| $AgCl(s)$ | −127.0 | −109.70 | 96.11 |
| $Ag_2O(s)$ | −31.05 | −11.20 | 121.3 |
| $AgNO_3(s)$ | −124.4 | −33.41 | 140.9 |
| Sodium | | | |
| $Na(g)$ | 107.7 | 77.3 | 153.7 |
| $Na(s)$ | 0 | 0 | 51.45 |
| $Na^+(aq)$ | −240.1 | −261.9 | 59.0 |
| $Na^+(g)$ | 609.3 | 574.3 | 148.0 |
| $NaBr(aq)$ | −360.6 | −364.7 | 141.00 |
| $NaBr(s)$ | −361.4 | −349.3 | 86.82 |
| $Na_2CO_3(s)$ | −1130.9 | −1047.7 | 136.0 |
| $NaCl(aq)$ | −407.1 | −393.0 | 115.5 |
| $NaCl(g)$ | −181.4 | −201.3 | 229.8 |
| $NaCl(s)$ | −410.9 | −384.0 | 72.33 |
| $NaHCO_3(s)$ | −947.7 | −851.8 | 102.1 |
| $NaNO_3(aq)$ | −446.2 | −372.4 | 207 |
| $NaNO_3(s)$ | −467.9 | −367.0 | 116.5 |
| $NaOH(aq)$ | −469.6 | −419.2 | 49.8 |
| $NaOH(s)$ | −425.6 | −379.5 | 64.46 |
| $Na_2SO_4(s)$ | −1387.1 | −1270.2 | 149.6 |
| Strontium | | | |
| $SrO(s)$ | −592.0 | −561.9 | 54.9 |
| $Sr(g)$ | 164.4 | 110.0 | 164.6 |
| Sulfur | | | |
| $S(s$, rhombic) | 0 | 0 | 31.88 |
| $S_8(g)$ | 102.3 | 49.7 | 430.9 |
| $SO_2(g)$ | −296.9 | −300.4 | 248.5 |
| $SO_3(g)$ | −395.2 | −370.4 | 256.2 |
| $SO_4^{2-}(aq)$ | −909.3 | −744.5 | 20.1 |
| $SOCl_2(l)$ | −245.6 | — | — |
| $H_2S(g)$ | −20.17 | −33.01 | 205.6 |
| $H_2SO_4(aq)$ | −909.3 | −744.5 | 20.1 |
| $H_2SO_4(l)$ | −814.0 | −689.9 | 156.1 |
| Titanium | | | |
| $Ti(g)$ | 468 | 422 | 180.3 |
| $Ti(s)$ | 0 | 0 | 30.76 |
| $TiCl_4(g)$ | −763.2 | −726.8 | 354.9 |
| $TiCl_4(l)$ | −804.2 | −728.1 | 221.9 |
| $TiO_2(s)$ | −944.7 | −889.4 | 50.29 |
| Vanadium | | | |
| $V(g)$ | 514.2 | 453.1 | 182.2 |
| $V(s)$ | 0 | 0 | 28.9 |
| Zinc | | | |
| $Zn(g)$ | 130.7 | 95.2 | 160.9 |
| $Zn(s)$ | 0 | 0 | 41.63 |
| $ZnCl_2(s)$ | −415.1 | −369.4 | 111.5 |
| $ZnO(s)$ | −348.0 | −318.2 | 43.9 |