Ch. 7. Entropy and free energy

It is common sense that some natural phenomena happen spontaneously in nature, without any help, in nature whereas others do not. For example, one would expect a ball on a hill to roll down instead of rolling up. How does common sense apply in chemistry? Why some reactions happen spontaneously whereas others do not. For example, methane (CH_4) spontaneously burns with oxygen (O_2), producing carbon dioxide, and water. Differently, if we mix water and carbon dioxide, CH_4 is not spontaneously produced. Thermodynamics helps make sense of spontaneity in physics and chemistry. In particular, three thermodynamic properties–enthalpy, entropy, and Gibbs free energy–are commonly used to predict different aspects of spontaneity. At the same time, spontaneity in chemistry is indeed related to equilibrium and these properties can be translated into equilibrium constants.

Table 7.1 Standard thermodynamic functions at 1atm and 298K.*

Substance	ΔH_f° (KJ/mol)	ΔG_f° (KJ/mol)	ΔS° (J/mol· K)
Al			
$Al_{(s)}$	0	0	28.3
$Al^{3+}_{(g)}$	5483.9	NA†	149.9
$Al_{(aq)}$	-524.7	-481.2	——
$AlF_{3(s)}$	-1504.1	-1425.1	66.4
$AlCl_{3(s)}$	-704.2	-628.9	110.7
$AlCl_3 \cdot 6\,H_2O_{(s)}$	-2691.6	NA†	NA†
$AlBr_{3(s)}$	-527.2	-488.4	163.2
$AlI_{3(s)}$	-313.8	-300.8	159.0
$Al_2O_{3(s)}$	-1675.7	-1582.4	50.9
$Al(OH)_{3(s)}$	-1287.4	-1149.8	85.4
$Al(NO_3)_3 \cdot 6\,H_2O_{(s)}$	-2850.5	-2203.9	467.8
$Al_2S_{3(s)}$	-723.8	NA†	decomp.
$Al_2(SO_4)_{3(s)}$	-3440.0	-3100.1	239.3
$Al_2(SO_4)_3 \cdot 6\,H_2O_{(s)}$	-5311.7	-4622.6	469.0
$Al_2(SO_4)_3 \cdot 18\,H_2O_{(s)}$	-8878.9	-7437.5	——
Sb			
$Sb^{3+}_{(g)}$	2703.3	NA†	168.7
$SbH_{3(g)}$	145.1	147.7	232.7
$SbF_{3(s)}$	-915.5	-807.0	105.4
$SbCl_{3(s)}$	-382.2	-323.7	184.0
$SbCl_{5(l)}$	-440.2	-350.2	301.0
$Sb_4O_{6(s)}$	-1440.6	-1268.2	220.9
$Sb_2S_3(black)_{(s)}$	-174.9	-173.6	182.0
$Sb_2(SO_4)_{3(s)}$	-2402.5	NA†	
As			
$As_{(s)}$	0	0	35.1
$As^{3+}_{(g)}$	5950.2	NA†	162.3
$AsH_{3(g)}$	66.4	68.9	222.7
$AsF_{3(l)}$	-956.3	-909.1	181.2
$AsF_{3(g)}$	-920.6	-905.7	289.0
$AsCl_{3(l)}$	-305.0	-259.4	216.3
$AsBr_{3(s)}$	-197.5	-169.0	161.1
$As_2O_{3(s)}$	-653.0	-571.0	117.0
$As_2O_{5(s)}$	-924.9	-782.4	105.4
$As_2O_{3(s)}$	-169.0	-168.6	163.6
$As_4O_{6(s)}$	-1314.0	-1153.0	223.0
Ba			
$Ba_{(s)}$	0	0	66.9
$Ba^{2+}_{(g)}$	1660.5	NA†	170.2
$Ba^{2+}_{(aq)}$	-537.0	-560.8	9.6
$BaH_{2(s)}$	-178.7	-132.2	NA†
$BaF_{2(s)}$	-1207.1	-1156.9	96.4
$BaCl_{2(s)}$	-858.6	-810.4	123.7
$BaCl_2 \cdot 2\,H_2O_{(s)}$	-1406.1	-1296.5	202.9
$Ba(ClO_3)_{2(s)}$	-762.7	-556.9	231.0
$Ba(ClO_3)_2 \cdot H_2O_{(s)}$	-1069.0	—NA†	0.125
$Ba(ClO_4)_{2(s)}$	-800.0	-535.1	249.0
$BaBr_{2(s)}$	-757.3	-736.8	146.0
$BaBr_2 \cdot 2\,HO_{(s)}$	-1366.1	-1230.5	226.0
$Ba(BrO_3)_{2(s)}$	-752.7	-577.4	243.0
$Ba(BrO_3)_2 \cdot H_2O_{(s)}$	-1054.8	-824.6	292.5
$BaI_{2(s)}$	-602.1	-609.0	167.0
$BaI_2 \cdot 2\,H_2O_{(s)}$	-1216.7	NA†	0.63
$Ba(IO_3)_{2(s)}$	-1027.2	-864.8	249.0
$Ba(IO_3)_2 \cdot H_2O_{(s)}$	-1322.1	-1104.2	297.0
$BaO_{(s)}$	-553.5	-525.1	70.4
$BaO_{2(s)}$	-634.3	-572.0	65.7
$Ba(OH)_{2(s)}$	-944.7	-855.2	99.7
$BaCO_{3(s)}$	-1216.3	-1137.6	112.1
$Ba(HCO_3)_{2(s)}$	-1921.6	-1734.3	192.0
$Ba(NO_3)_{2(s)}$	-992.1	-796.7	213.8
$BaS_{(s)}$	-460.0	-456.0	78.2
$BaSO_{4(s)}$	-1473.2	-1362.3	151.9
$BaCrO_{4(s)}$	-1428.0	-1338.8	132.2
$BaC_2O_{4(s)}$	-1368.6	NA†	5.2×10^{-5}
$BaC_2O_4 \cdot 2\,H_2O_{(s)}$	-1971.1	NA†	5.20×10^{-5}
Be			
$Be_{(s)}$	0	0	9.5
$Be^{2+}_{(s)}$	2993.0	NA†	136.2
$BeF_{2(s)}$	-1026.8	-979.5	53.2
$BeCl_{2(s)}$	-490.4	-445.6	82.7
$BeCl_2 \cdot 4\,H_2O_{(s)}$	-1808.3	-1563.0	243.1
$BeBr_{2(s)}$	-353.5	-354.0	112.1
$BeO_{(s)}$	-609.6	-580.3	14.1
$Be(OH)_{2(s)}$	-902.4	-815.0	51.9
$Be(NO_3)_2 \cdot 3\,H_2O_{(s)}$	-787.8	NA†	0.804
$BeS_{(s)}$	-234.3	-232.0	35.0
$BeSO_{4(s)}$	-1205.2	-1093.9	77.9
$BeSO_4 \cdot 4\,H_2O_{(s)}$	-2423.7	-2080.7	234.0
Bi			
$Bi_{(s)}$	0	0	56.9
$Bi^{3+}_{(g)}$	5005.7	NA†	
$BiCl_{3(s)}$	-379.1	-315.1	177.0
$Bi(ClO)_{3(s)}$	-366.9	-322.2	120.5
$BiI_{3(s)}$	-105.0	-175.3	233.9
$Bi_2O_{3(s)}$	-573.9	-493.7	151.5
$Bi_2S_{3(s)}$	-143.1	-140.6	200.46
$Bi_2(SO_4)_{3(s)}$	-2544.3	-2583.6	NA†
B			
$B_{(s)}$	0	0	5.9
$B^{3+}_{(s)}$	7468.0	NA†	138.5
$B_2H_{6(g)}$	35.6	86.6	232.0
$BF_{3(g)}$	-137.0	-1120.3	254.0
$BCl_{3(l)}$	-427.2	-387.4	206.3
$BCl_{3(g)}$	-403.7	-388.7	290.0
$BI_{3(g)}$	71.1	20.8	349.1
$B_2O_{3(s)}$	-1272.8	-1193.7	54.0
$B_2O_{3(l)}$	-1254.5	-1182.4	77.8
$B(OH)_{3(s)}$	-1094.0	-969.0	88.8
$BN_{(s)}$	-254.4	-228.4	14.8
$B_2S_{3(s)}$	-240.6	-229.0	57.4
Br			
$Br_{2(l)}$	0	0	152.2
$Br_{2(g)}$	30.9	3.1	245.4
$Br^{-1}_{(g)}$	-233.9	-238.7	163.4
Cd			
$Cd_{(s)}$	0	0	51.8
$Cd^{2+}_{(g)}$	2623.5	NA†-	167.7
$CdF_{2(s)}$	-700.4	-647.7	77.4
$CdCl_{2(s)}$	-391.5	-344.0	115.3
$CdCl_2 \cdot H_2O_{(s)}$	-688.4	-587.1	167.8
$Cd(ClO_4)_{2(aq)}$	-334.6	-94.8	290.8
$Cd(ClO_4)_2 \cdot 6\,H_2O_{(s)}$	-2052.7	NA†	
$CdBr_{2(s)}$	-316.2	-296.3	137.2
$CdI_{2(s)}$	-203.3	-201.4	161.1
$Cd(IO_3)_{2(s)}$	NA†-	377.1	NA†–
$CdO_{(s)}$	-258.2	-228.4	54.8
$Cd(OH)_{2(s)}$	-560.7	-473.6	96.0
$Cd(CN)_{2(s)}$	162.2	207.9	104.2
$Cd(NO_3)_{2(s)}$	-456.3	-259.0	197.9
$Cd(NO_3)_2 \cdot 2\,H_2O_{(s)}$	-1055.6	-748.9	NA†
$Cd(NO_3)_2 \cdot 4\,H_2O_{(s)}$	-1649.0	-1217.1	NA†
$CdS_{(s)}$	-161.9	-156.5	64.8
$CdSO_{4(s)}$	-933.3	-822.8	123.0
$CdSO_4 \cdot 2.67\,H_2O_{(s)}$	-1729.4	-1465.3	229.6
Cs			
$Cs_{(s)}$	0	0	
$Cs^{1+}_{(g)}$	458.0	NA†	169.7
$CsF_{(s)}$	-553.5	-525.5	92.8
$CsCl_{(s)}$	-443.0	-414.5	101.2
$CsClO_{3(s)}$	-411.7	-307.9	156.1
$CsClO_{4(s)}$	-443.1	-314.3	175.1
$CsBr_{(s)}$	-405.8	-391.4	113.1
$CsI_{(s)}$	-346.0	-340.6	123.1
$CsIO_{4(s)}$	NA†	-380.7	184.0
$Cs_2O_{(s)}$	-345.8	-308.2	146.9
$CsOH_{(s)}$	-417.2	-359.0	86.0
$CsHCO_{3(s)}$	-966.1	-831.8	130.0
$CsNO_{3(s)}$	-506.0	-406.6	155.2
$Cs_2SO_{4(s)}$	-1443.0	-1323.7	211.9
Ca			
$Ca_{(s)}$	0	0	41.4
$Ca^{2+}_{(g)}$	1925.0	NA†	154.8
$CaH_{2(s)}$	-186.2	-147.3	42.0
$CaF_{2(s)}$	-1219.6	-1167.3	68.9
$CaCl_{2(s)}$	-795.8	-748.1	104.6
$CaCl_2 \cdot H_2O_{(s)}$	-1109.2	-1010.9	NA†
$CaCl_2 \cdot 2\,H_2O_{(s)}$	-1402.9	NA†	0.665
$CaCl_2 \cdot 4\,H_2O_{(s)}$	-2009.6	-1724.0	212.6
$CaCl_2 \cdot 6\,H_2O_{(s)}$	-2607.9	-2205.0	284.9
$Ca(ClO_4)_{2(s)}$	-736.8	NA†	233.0
$Ca(ClO_4)_2 \cdot 4\,H_2O_{(s)}$	-1948.9	-1476.8	433.5
$CaBr_{2(s)}$	-682.8	-663.6	130.0
$CaBr_2 \cdot 6\,H_2O_{(s)}$	-2506.2	-2153.1	410.0
$Ca(BrO_3)_{2(s)}$	-718.8	NA†	227.6
$CaI_{2(s)}$	-533.5	-528.9	142.0
$CaI_2 \cdot 8\,H_2O_{(s)}$	-2929.6	NA†	
$Ca(IO_3)_{2(s)}$	-1002.5	-893.3	230.1
$Ca(IO_3)_2 \cdot H_2O_{(s)}$	-1293.3	NA†	
$Ca(IO_3)_2 \cdot 6\,H_2O_{(s)}$	-2780.7	-2267.7	451.9
$CaO_{(s)}$	-635.1	-604.0	39.7
$Ca(OH)_{2(s)}$	-986.1	-898.6	83.4
$CaC_{2(s)}$	-59.1	-64.8	69.9
$CaCO_{3(s),calcite}$	-1206.9	-1128.8	92.9
$CaCO_{3(s),aragonite}$	-1207.1	-1127.8	88.7
$Ca(NO_3)_{2(s)}$	-635.1	-743.2	193.3
$Ca(NO_3)_2 \cdot 2\,H_2O_{(s)}$	-1540.8	-1229.3	269.4
$Ca(NO_3)_2 \cdot 3\,H_2O_{(s)}$	-1838.0	-1471.9	319.2
$Ca(NO_3)_2 \cdot 4\,H_2O_{(s)}$	-2132.3	-1713.5	375.3
$CaS_{(s)}$	-482.4	-477.4	56.5
$CaSO_{3(s)}$	-1156.0	NA†	
$CaSO_{4(s)}$	-1431.1	-1321.9	106.7
$CaSO_4 \cdot 0.5\,H_2O_{(s)}$	-1576.7	-1436.8	130.5
$CaSO_4 \cdot 2\,H_2O_{(s)}$	-2022.6	-1797.4	194.1
$Ca_3(PO_4)_{2(s)}$	-4120.8	-3884.8	236.0
$CaCrO_4 \cdot 2\,H_2O$	-1379.0	-1277.4	133.9
$CaC_2O_{4(s)}$	-1360.6	NA†	NA†
$CaC_2O_4 \cdot H_2O_{(s)}$	-1674.9	-1514.0	156.5
$CaSi_{2(s)}$	-151.0	NA†	decomp.
$CaSiO_{3(s)}$	-1634.9	-1549.7	81.9
$Ca_2SiO_{4(s)}$	-2307.5	-2192.8	127.7
C(s), graphite	0	0	5.7
C(s), diamond	1.9	2.9	2.4
$C_{(g)}$	716.7	671.3	158.0
$C_{2(g)}$	836.8	780.4	199.3
$C_{3(g)}$	793.5	773.1	212.1
$CCl_{4(l)}$	-134.0	-65.3	214.4
$CO_{(g)}$	-110.5	-137.2	197.6
$CO_{2(g)}$	-393.5	-394.4	213.6
$CO_{2(aq)}$	-413.8	-386.0	117.6
$CO_3^{2-}{}_{(aq)}$	-677.1	-527.8	-56.9
$C_2N_{2(g)}$	307.9	296.3	242.1
$CS_{2(l)}$	98.7	65.2	151.3
$CS_{2(g)}$	117.0	67.2	237.7
Cl			
$Cl_{2(g)}$	0	0	233.0
$Cl^{-1}_{(g)}$	-246.0	-240.0	153.1
$Cl_2O_{(g)}$	80.3	97.9	266.1
$ClO_{2(g)}$	102.5	120.5	256.7

* Adapted from: https://issr.edu.kh/science/Reference_Tables_and_Values/10545-Nuffield%20Advance%20Science%20Book%20of%20Data.pdf

Table 7.1 (continued) Standard thermodynamic functions at 1atm and 298K.

Substance	ΔH_f° (KJ/mol)	ΔG_f° (KJ/mol)	ΔS° (J/mol· K)
Cr			
$Cr_{(s)}$	0	0	23.8
$Cr^{3+}_{(aq)}$	-232.0	–NA†	
$CrF_{3(s)}$	-1159.0	-1088.0	93.9
$CrCl_{2(s)}$	-326.0	-282.0	115.0
$CrCl_{3(s)}$	-556.5	-486.2	115.3
$CrO_2Cl_{2(l)}$	-579.5	-510.9	221.8
$CrI_{3(s)}$	-205.0	-202.5	NA†
$Cr_2O_{3(s)}$	-1139.7	-1058.1	81.2
$CrO_{3(s)}$	-598.5	-501.0	NA†
$Cr_2(SO_4)_{3(s)}$	-3025.0	NA†	0.163
$Cr_2(SO_4)_3 \cdot 18\,H_2O_{(s)}$	-8339.0	NA†	0.167
$Cr(CO)_{6(s)}$	-1076.9	-975.0	NA†
Co			
$Co_{(s)}$	0	0	30.0
$Co^{2+}_{(g)}$	2841.6	NA†	178.8
$CoF_{3(g)}$	-810.9	-707.0	94.6
$CoCl_{2(s)}$	-312.5	-269.9	109.2
$CoCl_2 \cdot 2\,H_2O_{(s)}$	-923.0	-764.8	188.0
$CoCl_2 \cdot 6\,H_2O_{(s)}$	-2115.4	-1725.5	343.0
$Co(ClO_4)_{2(aq)}$	-316.7	-71.5	251.0
$Co(ClO_4)_2 \cdot 6\,H_2O_{(s)}$	-2038.4	NA†	0.707
$CoBr_{2(s)}$	-220.0	-210.0	135.6
$CoBr_2 \cdot 6\,H_2O_{(s)}$	-2020.0	NA†	
$CoI_{2(s)}$	-88.7	-101.3	158.2
$Co(IO_3)_{2(aq)}$	-500.8	-310.4	125.5
$Co(IO_3)_2 \cdot 2\,H_2O_{(s)}$	-1081.9	-795.8	267.8
$CoO_{(s)}$	-237.9	-214.2	53.0
$Co_3O_{4(s)}$	-891.0	-774.0	102.5
$Co(OH)_{2(s)}$	-539.7	-454.4	79.0
$Co(NO_3)_{2(s)}$	-420.5	-237.0	192.0
$Co(NO_3)_2 \cdot 2\,H_2O_{(s)}$	-1021.7	NA†	
$Co(NO_3)_2 \cdot 3\,H_2O_{(s)}$	-1325.9	NA†	
$Co(NO_3)_2 \cdot 4\,H_2O_{(s)}$	-1630.5	NA†	
$Co(NO_3)_2 \cdot 6\,H_2O_{(s)}$	-2211.2	-1655.6	NA†
$CoS_{(s)}$	-80.8	-82.8	67.4
$CoSO_{4(s)}$	-888.3	-782.4	118.0
$CoSO_4 \cdot 7\,H_2O_{(s)}$	-2979.9	-2473.8	406.1
Cu			
$Cu_{(s)}$	0	0	33.2
$Cu^{2+}_{(g)}$	3054.0	NA†	179.0
$CuF_{2(s)}$	-542.7	-481.0	88.0
$CuF_2 \cdot 2\,H_2O_{(s)}$	NA†	-981.6	NA†
$CuCl_{(s)}$	-137.2	-119.9	86.2
$CuCl_{2(s)}$	-220.1	-175.7	108.1
$Cu(ClO_4)_{2(aq)}$	-193.1	48.3	264.4
$Cu(ClO_4)_2 \cdot 6\,H_2O_{(s)}$	-1928.4	NA†	very
$CuBr_{2(s)}$	-141.8	-108.7	118.0
$CuBr_2 \cdot 4\,H_2O_{(s)}$	-1326.3	-1081.1	293.7
$CuI_{(s)}$	-67.7	-69.5	96.7
$Cu(IO_3)_{2(aq)}$	-377.8	-190.4	137.2
$Cu(IO_3)_2 \cdot H_2O_{(s)}$	-692.0	-468.6	247.2
$Cu_2O_{(s)}$	-168.6	-146.0	93.1
$CuO_{(s)}$	-157.3	-129.7	42.6
$Cu(OH)_{2(s)}$	-449.8	-359.4	75.0
$Cu(NO_3)_{2(s)}$	-302.9	-118.2	193.0
$Cu(NO_3)_2 \cdot 3\,H_2O_{(s)}$	-1217.1	NA†	0.570
$Cu(NO_3)_2 \cdot 6\,H_2O_{(s)}$	-2110.8	NA†	0.824
$Cu_2S_{(s)}$	-79.0	-86.2	120.9
$CuS_{(s)}$	-53.1	-53.6	66.5
$CuSO_{4(s)}$	-771.4	-661.9	109.0
$CuSO_4 \cdot 5\,H_2O_{(s)}$	-2279.6	-1880.1	300.4
F			
$F_{2(g)}$	0	0	202.7
$F^{-1}_{(g)}$	-270.7	-266.6	145.4
$F_2O_{(g)}$	-21.7	-4.7	247.3
Ga			
$Ga^{3+}_{(g)}$	5816.0	NA†	161.6
$GaF_{3(s)}$	-1163.0	-1085.3	84.0
$GaCl_{3(s)}$	-524.7	-454.8	142.0
$GaBr_{3(s)}$	-386.6	-359.8	180.0
$GaI_{3(s)}$	-238.9	-217.6	49.0
$Ga_2O_{3(s)}$	-1089.1	-998.3	85.0
Ge			
$Ge^{4+}_{(g)}$	10412.3	NA†	
$GeF_{4(g)}$	-NA†	302.8	decomp.
$GeCl_{2(s)}$	—NA†	NA†-	
$GeCl_{4(l)}$	-531.8	-462.8	245.6
$GeBr_{4(l)}$	-347.7	-331.4	280.7
$GeBr_{4(g)}$	-300.0	-318.0	396.1
$GeO_{(s)}$	-212.1	-237.2	50.0
$GeO_{2(s)}$	-551.0	-497.1	55.3
$GeS_{(s)}$	-69.0	-71.5	71.0
$GeS_{2(s)}$	-189.5	—NA†-	0.00329
Au			
$Au_{(s)}$	0	0	47.7
$Au^{1+}_{(g)}$	1262.4	NA†–	174.7
$AuH_{(g)}$	294.9	265.7	211.0
$AuF_{3(s)}$	-363.0	-297.5	210.9
$AuCl_{3(s)}$	-117.6	-55.2	147.3
$AuCl_3 \cdot 2\,H_2O_{(s)}$	-715.0	-519.0	226.0
$AuBr_{3(s)}$	-53.3	-31.0	100.0
$AuI_{(s)}$	0.0	-0.2	119.2
$Au_2O_{3(s)}$	-3.3	76.2	NA†–
H			
$H_{2(g)}$	0	0	130.6
$HF_{(g)}$	-271.1	-273.2	173.7
$HCl_{(g)}$	-92.3	-95.2	186.8
$HCl_{(aq)}$	-167.2	-131.2	56.5
$HClO_{(aq)}$	-131.3	-80.2	106.8
$HBr_{(g)}$	-36.4	-53.4	198.6
$HI_{(g)}$	26.5	1.7	206.5
$HIO_{3(s)}$	-230.1	-144.3	118.0
$H_2O_{(l)}$	-285.8	-237.2	69.9
$H_2O_{(g)}$	-241.8	-228.6	188.7
$H_2O_{2(l)}$	-187.8	-120.4	109.6
$H_3AsO_{3(aq)}$	-742.2	-NA†	
$H_3AsO_{4(aq)}$	-902.5	NA†	
$HCN_{(l)}$	108.9	124.9	112.8
$HCN_{(g)}$	135.1	124.7	201.7
$H_2CO_{3(aq)}$	-699.6	-623.3	187.4
$HCO_3^{-1}{}_{(aq)}$	-692.0	-586.8	91.2
$HNO_{3(l)}$	-174.1	-80.8	266.3
$H_2S_{(g)}$	-20.6	-33.6	205.7
$H_2S_{(aq)}$	-39.7	-27.9	121.3
$H_2S_{2(l)}$	-23.1	NA†	decomp.
$H_2Se_{(g)}$	76.0	62.3	219.0
$H_2SO_{4(l)}$	-814.0	-690.1	156.9
$H_2SO_{4(aq)}$	-909.3	-744.5	20.1
$H_2Te_{(g)}$	154.0	138.0	234.0
$H_3PO_{4(s)}$	-1279.0	-1119.2	110.5
$H_3BO_{3(s)}$	-1094.3	-969.0	88.8
$H_3O_1{}^{+}{}_{(g)}$	979.9	NA†	
$OH^+_{(g)}$	1328.4	NA†	
$OH^-_{(g)}$	-140.9	NA†	
$H_2S^+_{(aq)}$	995.0	NA†	
I			
$I_{2(s)}$	0	0	116.1
$I_{2(g)}$	62.4	19.4	260.6
$IF_{(g)}$	-95.6	-118.5	236.1
$I_2{}^{+}{}_{(g)}$	967.5	NA†	
$ICl_{(s)}$	-35.1	NA†	decomp.
$ICl_{3(s)}$	-89.5	-22.3	167.4
$IBr_{(s)}$	-10.5	NA†	138.1
$I_2O_{5(s)}$	-158.1	-38.0	NA†
$I^{-1}_{(g)}$	-196.6	-221.9	169.1
Fe			
$Fe_{(s)}$	0	0	27.0
$Fe^{2+}_{(g)}$	2752.2	NA†	177.2
$Fe^{2+}_{(aq)}$	-89.1	-78.9	137.7
$Fe^{3+}_{(g)}$	-48.5	-4.7	315.9
$FeF_{2(s)}$	-686.0	-644.0	87.0
$FeF_{3(aq)}$	-1046.4	-841.0	357.0
$FeCl_{2(s)}$	-341.8	-302.3	117.9
$FeCl_2 \cdot 2\,H_2O_{(s)}$	-953.1	-797.5	NA†
$FeCl_2 \cdot 4\,H_2O_{(s)}$	-1549.3	-1275.7	NA†
$FeCl_{3(s)}$	-399.5	-334.1	142.3
$FeCl_3 \cdot 6\,H_2O_{(s)}$	-2223.8	-1812.9	NA†
$Fe(ClO_4)_{2(aq)}$	-347.7	-96.1	226.4
$Fe(ClO_4)_2 \cdot 6\,H_2O_{(s)}$	-2086.6	NA†	0.270
$FeBr_{2(s)}$	-249.8	-236.0	140.7
$FeI_{2(s)}$	-113.0	-128.4	77.0
$FeI_{3(g)}$	71.0	NA†	
$FeO_{(s)}$	-271.9	-245.4	58.5
$Fe_2O_{3(s)}$	-824.2	-742.2	87.4
$Fe_3O_{4(s)}$	-1118.4	-1015.5	146.4
$Fe(OH)_{2(s)}$	-569.0	-486.6	88.0
$Fe(OH)_{3(s)}$	-823.0	-696.6	106.7
$FeCO_{3(s)}$	-740.6	-666.7	92.9
$Fe(CO)_{5(l)}$	-774.0	-705.4	338.1
$FeS_{(s)}$	-100.0	-100.4	60.3
$FeS_{2(s)}$	-178.2	-166.9	52.9
$FeSO_{4(s)}$	-928.4	-820.9	107.5
$FeSO_4 \cdot 7\,H_2O_{(s)}$	-3014.6	-2510.3	409.2
$Fe_{2(s)4)3(s)}$	-2581.5	NA†	261.7
$Fe(NO_3)_{3(aq)}$	-674.9	NA†	
Li			
$Li_{(s)}$	0	0	28.4
$Li^+_{(g)}$	679.6	650.0	132.9
$Li^+_{(aq)}$	-278.6	NA†	10.3
$LiH_{(s)}$	-90.5	-68.4	20.3
$Li_3H_{4(s)}$	NA†	NA†	decomp.
$LiF_{(s)}$	-616.0	-587.7	35.6
$LiCl_{(s)}$	-408.6	-384.4	59.3
$LiClO_{3(s)}$	-369.0	NA†	5.531
$LiClO_{4(s)}$	-381.0	NA†	0.564
$LiClO_4 \cdot H_2O_{(s)}$	-697.1	-509.6	155.2
$LiClO_4 \cdot 3\,H_2O_{(s)}$	-1298.0	-1001.3	254.8
$LiBr_{(s)}$	-351.2	-342.0	74.3
$LiBr \cdot H_2O_{(s)}$	-662.6	-594.3	109.6
$Pb_{(s)}$	0	0	64.8
$Pb^{2+}_{(g)}$	916.8	NA†	175.3
$Pb^{2+}_{(aq)}$	-1.7	-24.4	10.5
$PbF_{2(s)}$	-664.0	-617.1	110.5
$PbCl_{2(s)}$	-359.4	-314.1	136.0
$PbCl_{4(l)}$	-329.2	-259.0	NA†
$PbBr_{2(s)}$	-278.7	-261.9	161.5
$Pb(BrO_3)_{2(s)}$	-134.0	-50.0	NA†
$PbI_{2(s)}$	-175.5	-173.6	174.5
$PbO_{(s)}$	-217.3	-187.9	68.7
$PbO_{2(s)}$	-277.4	-217.4	68.6
$Pb(OH)_{2(s)}$	-515.9	-420.9	88.0
$Pb_3O_{4(s)}$	-718.4	-601.2	211.3
$PbCO_{3(s)}$	-700.0	-626.3	131.0
$Pb(NO_3)_{2(s)}$	-451.9	-251.0	213.0
$PbS_{(s)}$	-100.4	-98.7	91.2
$PbSO_{4(s)}$	-919.0	-813.2	148.6
$PbCrO_{4(s)}$	-899.6	-819.6	152.7
$Pb(CH_3COO)_2 \cdot 3\,H_2O_{(s)}$	-1851.0	-NA†	0.204
$Pb(C_2H_5)_{4(l)}$	52.7	336.4	472.5

Table 7.1 (continued) Standard thermodynamic functions at 1atm and 298K.

Substance	ΔH_f° (KJ/mol)	ΔG_f° (KJ/mol)	ΔS° (J/mol· K)
$LiBr \cdot 2\,H_2O_{(s)}$	-962.7	-840.6	162.3
$LiBrO_{3(s)}$	-347.0	NA†	
$LiI_{(s)}$	-270.4	-270.3	86.8
$LiI \cdot H_2O_{(s)}$	-590.3	-531.4	123.0
$LiI \cdot 2\,H_2O_{(s)}$	-890.4	-780.3	184.0
$LiI \cdot 3\,H_2O_{(s)}$	-1192.1	NA†	0.804
$LiIO_{3(s)}$	-503.4	NA†	0.442
$Li_2O_{(s)}$	-597.9	-561.2	37.6
$LiOH_{(s)}$	-484.4	-439.0	42.8
$LiOH \cdot H_2O_{(s)}$	-788.0	-681.0	71.2
$Li_2CO_{3(s)}$	-1215.9	-1132.1	90.4
$LiHCO_{3(s)}$	-969.6	-880.9	123.4
$Li_3N_{(s)}$	-199.0	-155.4	37.7
$LiNO_{3(s)}$	-483.1	-381.2	90.0
$LiNO_3 \cdot 3\,H_2O_{(s)}$	-1374.4	-1103.7	223.4
$Li_2SO_{4(s)}$	-1436.5	-1321.8	115.1
$Li_2SO_4 \cdot H_2O_{(s)}$	-1735.5	-1565.7	163.6
$Li_3PO_{4(s)}$	-2095.8	NA†	0.000257
$LiAlH_{4(s)}$	-116.3	-44.8	78.7
Mg			
$Mg_{(s)}$	0	0	32.5
$Mg^{2+}_{(aq)}$	-466.9	-454.8	-138.1
$MgF_{2(s)}$	-1123.4	-1070.3	57.2
$MgCl_{2(s)}$	-641.3	-591.8	89.6
$MgCl_2 \cdot H_2O_{(s)}$	-966.6	-861.8	137.2
$MgCl_2 \cdot 2\,H_2O_{(s)}$	-1279.7	-1118.1	179.9
$MgCl_2 \cdot 4\,H_2O_{(s)}$	-1898.9	-1623.5	264.0
$MgCl_2 \cdot 6\,H_2O_{(s)}$	-2499.0	-2115.0	366.1
$Mg(ClO_4)_{2(s)}$	-568.9	-432.2	213.0
$Mg(ClO_4)_2 \cdot 2\,H_2O_{(s)}$	-1218.7	NA†	
$Mg(ClO_4)_2 \cdot 4\,H_2O_{(s)}$	-1837.2	NA†	
$Mg(ClO_4)_2 \cdot 6\,H_2O_{(s)}$	-2445.5	-1863.1	520.9
$MgBr_{2(s)}$	-524.3	-503.8	117.2
$MgBr_2 \cdot 6\,H_2O_{(s)}$	-2410.0	-2056.0	397.0
$MgI_{2(s)}$	-364.0	-358.2	129.7
$MgO_{(s)}$	-601.7	-569.4	26.9
$Mg(OH)_{2(s)}$	-924.5	-833.6	63.2
$MgCO_{3(s)}$	-1095.8	-1012.1	65.7
$Mg_3N_{2(s)}$	-460.7	-406.0	90.0
$Mg(NO_3)_{2(s)}$	-790.7	-589.5	164.0
$Mg(NO_3)_2 \cdot 2\,H_2O_{(s)}$	-1409.2	NA†	soluble
$Mg(NO_3)_2 \cdot 6\,H_2O_{(s)}$	-2613.3	-2080.7	452.0
$MgS_{(s)}$	-346.0	-341.8	50.3
$MgSO_{4(s)}$	-1284.9	-1170.7	91.6
$MgSO_4 \cdot 2\,H_2O_{(s)}$	-1896.2	-1376.5	NA†
$MgSO_4 \cdot 4\,H_2O_{(s)}$	-2496.6	-2138.9	NA†
$MgSO_4 \cdot 6\,H_2O_{(s)}$	-3086.9	-2632.2	348.1
$MgSO_4 \cdot 7\,H_2O_{(s)}$	-3388.7	-2871.9	372.0
$Mg_3(PO_4)_2 \cdot 2\,H_2O_{(s)}$	-4022.9	NA†	7.61×10^{-5}
$Mg_2Si_{(s)}$	-77.8	-75.0	75.0
$MgSiO_{3(s)}$	-1549.0	-11462.1	67.7
$Mg_2SiO_{4(s)}$	-2174.0	-2055.2	95.1
Mn			
$Mn_{(s)}$	0	0	32.0
$Mn^{2+}_{(g)}$	2519.0	NA†	173.6
$Mn^{2+}_{(aq)}$	-233.0	-228.0	-74.6
$MnCl_{2(s)}$	-481.3	-440.5	118.2
$MnCl_2 \cdot H_2O_{(s)}$	-789.9	-696.2	174.1
$MnCl_2 \cdot 2\,H_2O_{(s)}$	-1092.0	-942.2	218.8
$MnCl_2 \cdot 4\,H_2O_{(s)}$	-1687.4	-1423.8	303.3
$MnBr_{2(s)}$	-384.9	-365.7	138.0
$MnBr_2 \cdot H_2O_{(s)}$	-705.0	NA†	
$MnBr_2 \cdot 4\,H_2O_{(s)}$	-1590.3	-1292.4	291.6
$MnI_{2(aq)}$	-331.0	-250.6	152.7
$MnI_2 \cdot 2\,H_2O_{(s)}$	-842.7	NA†	NA†
$MnI_2 \cdot 4\,H_2O_{(s)}$	-1438.9	NA†	NA†
$MnO_{(s)}$	-385.2	-362.9	59.7
$MnO_4{}^{-1}{}_{(aq)}$	-542.7	-449.4	191.0
$Mn_3O_{4(s)}$	-1387.8	-1283.2	155.6
$Mn_2O_{3(s)}$	-959.0	-881.2	110.5
$MnO_{2(s),pyrolusite}$	-520.0	-465.2	53.1
$Mn(OH)_{2(s)}$	-695.4	-615.0	99.2
$MnCO_{3(s)}$	-894.1	-816.7	85.8
$Mn(NO_3)_{2(s)}$	-576.3	-503.3	168.6
$Mn(NO_3)_2 \cdot 6\,H_2O_{(s)}$	-2371.9	-1809.6	NA†
$MnS_{(s)}$	-214.2	-218.4	78.2
$MnSO_{4(s)}$	-1065.2	-957.4	112.1
$MnSO_4 \cdot H_2O_{(s)}$	-1376.5	-1214.6	NA†
$MnSO_4 \cdot 4\,H_2O_{(s)}$	-2258.1	-1908.3	NA†
$MnSO_4 \cdot 5\,H_2O_{(s)}$	-2553.1	-2140.0	NA†
Hg			
$Hg_{(l)}$	0	0	76.1
$Hg_{(g)}$	61.32	-178.6	146.0
$Hg^{2+}_{(g)}$	2890.4	NA†	174.9
$Hg_2{}^{2+}{}_{(aq)}$	172.3	153.6	84.5
$Hg_2F_{2(s)}$	-485.0	-435.6	160.7
$Hg_2Cl_{2(s),calomel}$	-265.2	-210.8	192.5
$HgCl_{2(s)}$	-224.3	-178.7	146.0
$Hg_2Br_{2(s)}$	-206.9	-181.1	218.0
$HgBr_{2(s)}$	-170.7	-153.1	172.0
$Hg_2I_{2(s)}$	-121.3	-111.0	233.5
$HgI_{2(s)}$	red	-105.4	-101.7
$HgO_{(s),red}$	-90.8	-58.6	70.26
$Hg(OH)_{2(aq)}$	-355.2	-274.9	142.3
$Hg_2(NO_3)_2 \cdot 2\,H_2O_{(s)}$	-868.2	-563.2	NA†
$HgS_{(s),black}$	-53.6	-47.7	88.3
$HgS_{(s),red}$	-58.2	-50.6	82.4
$Hg_2SO_{4(s)}$	-743.1	-625.9	200.7
$HgSO_{4(s)}$	-707.5	-590.0	145.0
Ni			
$NH_4OH_{(l)}$	-361.2	-254.1	165.6
$NH_4NO_{3(s)}$	-365.6	-184.0	151.1
$(NH_4)_2SO_{4(s)}$	-1180.9	-901.9	220.1
$NH_4VO_{3(s)}$	-1053.1	-888.3	140.6
O			
$O_{2(g)}$	0	0	
$O_{3(g)}$ ozone	142.7	163.2	238.8
$OH^{-1}_{(aq)}$	-230.0	-157.2	-10.8
P			
$P_{(s),white}$	0	0	41.1
$P_{4(g)}$	314.5	278.3	163.2
$PH_{3(g)}$	5.4	13.4	210.1
$PH_4I_{(s)}$	-69.9	0.8	123.0
$PF_{3(g)}$	-918.8	-897.5	273.1
$PF_{5(g)}$	-1595.8	NA†	281.0
$PCl_{3(l)}$	-319.7	-272.4	217.1
$PCl_{5(s)}$	-443.5	NA†	166.5
$POCl_{3(l)}$	-597.1	-520.9	222.5
$PBr_{3(l)}$	-184.5	-175.7	240.2
$PBr_{5(s)}$	-269.9	-NA†	decomp.
$POBr_{3(s)}$	-458.6	-430.5	NA†
$P_4O_{6(s)}$	-1640.1	NA†	decomp.
$P_4O_{10(s)}$	-2984.0	-2697.8	228.9
$P_2S_{5(s)}$	251.0	NA†	insoluble
K			
$K_{(s)}$	0	0	64.2
$K^+_{(g)}$	514.3	481.2	154.4
$KF_{(s)}$	-567.3	-537.8	66.6
$KF \cdot 2\,H_2O_{(s)}$	-1163.6	-1021.6	155.2
$KCl_{(s)}$	-436.7	-409.2	82.6
$KClO_{3(s)}$	-397.7	-296.3	143.1
$KClO_{4(s)}$	-432.8	-303.2	151.0
$KBr_{(s)}$	-393.8	-380.7	95.9
$KBrO_{3(s)}$	-360.2	-271.2	149.2
$KBrO_{4(s)}$	-287.9	-174.5	170.1
$KI_{(s)}$	-327.9	-324.9	106.3
$KIO_{3(s)}$	-501.4	-418.4	151.5
$KIO_{4(s)}$	-467.2	-361.4	176.0
$K_2O_{(s)}$	-361.4	NA†	NA†
$KO_{2(s)}$	-284.9	-239.5	116.7
$KOH_{(s)}$	-424.8	-379.1	78.9
$KOH \cdot 2\,H_2O_{(s)}$	-1051.0	-887.4	151.0
$K_2CO_{3(s)}$	-1151.0	-1063.6	155.5
$KHCO_{3(s)}$	-963.2	-863.6	115.5
$KNO_{2(s)}$	-369.8	-306.6	152.1
$KNO_{3(s)}$	-494.6	-349.9	133.1
$KCN_{(s)}$	-113.0	-101.9	128.5
$KSCN_{(s)}$	-200.2	-178.3	124.3
$K_2S_{(s)}$	-380.7	-364.0	104.6
$K_2SO_{4(s)}$	-1437.8	-1321.4	175.6
$KHSO_{4(s)}$	-1160.6	-1031.4	138.1
$KH_2PO_{4(s)}$	-1568.3	-1415.9	134.9
$KMnO_{4(s)}$	-837.2	-737.6	171.7
$K_2CrO_{4(s)}$	-1403.7	-1295.8	200.1
$K_2Cr_2O_{7(s)}$	-2061.4	-1882.0	291.2
$KAl(SO_4)_{2(s)}$	-2470.2	-2240.1	204.6
$KAl(SO_4)_2 \cdot 12\,H_2O_{(s)}$	-6061.8	-5141.7	687.4
$KCr(SO_4)_2 \cdot 12\,H_2O_{(s)}$	-5777.3	NA†	0.0441
$K_3Fe(CN)_{6(s)}$	-249.8	-129.7	426.1
$K_4Fe(CN)_{6(s)}$	-594.1	-453.1	418.8
$K_4Fe(CN)_6 \cdot 3\,H_2O_{(s)}$	-1466.5	-1169.0	593.7
Rb			
$Rb^+_{(g)}$	490.1	NA†	164.2
$RbH_{(s)}$	-52.1	-32.2	NA†
$RbF_{(s)}$	-557.7	-523.4	82.1
$RbCl_{(s)}$	-435.3	-407.8	95.9
$RbClO_{3(s)}$	-402.9	-300.4	151.9
$RbClO_{4(s)}$	-437.2	-307.7	164.0
$RbBr_{(s)}$	-394.6	-381.8	110.0
$RbBrO_{3(s)}$	-367.3	-278.1	161.1
$RbI_{(s)}$	-333.8	-328.9	118.4
$RbIO_{3(s)}$	NA†	-426.3	NA†
$RbOH_{(s)}$	-418.2	NA†	84.1
$RbOH \cdot H_2O_{(s)}$	-748.9	NA†	
$RbOH \cdot 2\,H_2O_{(s)}$	-1053.2	NA†	
$Rb_2CO_{3(s)}$	-1136.0	-1051.0	181.4
$RbHCO_{3(s)}$	-936.2	-893.6	121.3
$RbNO_{3(s)}$	-495.1	-395.8	147.3
$Rb_2S_{(s)}$	-360.7	-339.0	134.0
$Rb_2SO_{4(s)}$	-1435.6	-1317.0	197.4
$RbHSO_{4(s)}$	-1158.9	-1030.1	NA†
Sc			
$Sc^{3+}_{(g)}$	4627.0	NA†	156.3
$ScF_{3(s)}$	-1629.2	-1555.6	92.0
$ScCl_{3(s)}$	-925.1	-858.0	127.2
$Sc_2O_{3(s)}$	-1908.8	-1819.4	77.0
Si			
$Si_{(s)}$	0	0	19.0
$SiH_{4(g)}$	34.3	56.9	204.5
$SiF_{4(g)}$	-1614.9	-1572.7	282.4
$SiCl_{4(l)}$	-687.0	-619.9	239.7
$SiCl_{4(g)}$	-657.0	-617.0	330.6
$SiBr_{4(l)}$	-457.3	-443.9	277.8
$SiBr_{4(g)}$	-415.4	-431.8	377.8
$SiO_{(g)}$	-99.6	-126.3	211.5
$SiO_{2(s),quartz}$	-910.9	-856.7	41.8
$SiO_{2(s)}$	-909.5	-855.9	42.7
$SiO_{2(s)}$	-909.1	-855.3	43.5
$SiC_{(s)}$	-62.8	-60.2	16.5
$SiS_{2(s)}$	-207.1	-175.3	66.9

Table 7.1 (continued) Standard thermodynamic functions at 1atm and 298K.

Substance	ΔH_f° (KJ/mol)	ΔG_f° (KJ/mol)	ΔS° (J/mol· K)
$Si^{4+}_{(g)}$	10428.5	NA†	229.8
Ag			
$Ag_{(s)}$	0	0	42.6
$Ag^{+}_{(g)}$	1019.2	NA†	167.2
$Ag^{+}_{(aq)}$	105.2	77.1	72.7
$AgF_{(s)}$	-204.6	-186.6	80.1
$AgF \cdot 2\,H_2O_{(s)}$	-800.8	-671.1	174.9
$AgF \cdot 4\,H_2O_{(s)}$	-1388.3	-1147.3	268.0
$AgCl_{(s)}$	-127.1	-109.8	96.2
$AgClO_{3(s)}$	-25.5	61.7	149.4
$AgClO_{4(s)}$	-31.1	77.0	NA†
$AgBr_{(s)}$	-100.4	-96.9	107.1
$AgBrO_{3(s)}$	-27.2	54.4	152.7
$AgI_{(s)}$	-61.8	-66.2	115.5
$Ag_2O_{(s)}$	-31.0	-11.2	121.3
$Ag_2CO_{3(s)}$	-505.8	-436.8	167.4
$AgNO_{3(s)}$	-124.4	-33.5	140.9
$AgCN_{(s)}$	146.0	156.9	107.2
$Ag_2S_{(s)}$	-29.4	-39.5	150.6
$Ag_2SO_{4(s)}$	-715.9	-618.5	200.4
$Ag_2CrO_{4(s)}$	-712.1	-621.7	216.7
Na			
$Na_{(s)}$	0	0	51.0
$Na^{+}_{(g)}$	609.0	NA†	147.9
$Na^{+}_{(aq)}$	-240.1	-261.9	59.0
$NaH_{(s)}$	-56.1	-33.5	40.0
$NaF_{(s)}$	-573.6	-543.5	51.5
$NaCl_{(s)}$	-411.2	-384.2	72.1
$NaClO_{3(s)}$	-365.8	-262.2	123.4
$NaClO_{4(s)}$	-383.3	-254.9	142.3
$NaBr_{(s)}$	-361.1	-349.0	86.8
$NaBr \cdot H_2O_{(s)}$	-951.9	-828.4	179.1
$NaBrO_{3(s)}$	-344.1	-242.8	128.9
$NaI_{(s)}$	-287.8	-286.1	98.5
$NaIO_{3(s)}$	-481.8	NA†	135.1
$NaIO_3 \cdot H_2O_{(s)}$	-779.5	-634.1	162.3
$NaIO_3 \cdot 5\,H_2O_{(s)}$	-1952.3	NA†	
$Na_2O_{(s)}$	-414.5	-375.5	75.1
$Na_2O_{2(s)}$	-510.9	-447.7	95.0
$NaOH_{(s)}$	-425.6	-379.5	64.5
$NaOH \cdot H_2O_{(s)}$	-734.5	-629.4	99.5
$Na_2CO_{3(s)}$	-1130.7	-1044.5	135.0
$Na_2CO_3 \cdot 10\,H_2O_{(s)}$	-4081.3	-3428.2	564.0
$NaHCO_{3(s)}$	-950.8	-851.0	101.7
$NaNO_{2(s)}$	-358.7	-284.6	103.8
$NaCN_{(s)}$	-87.5	-76.4	115.6
$Na_2S_{(s)}$	-364.8	-349.8	83.7
$Na_2SO_{4(s)}$	-1387.1	-1270.2	149.6
$Na_2SO_4 \cdot 10\,H_2O_{(s)}$	-4327.3	-3647.4	592.0
$NaHSO_{4(s)}$	-1125.5	-992.9	113.0
$Na_2S_2O_{3(s)}$	-1123.0	-1028.0	155.0
$Na_2S_2O_3 \cdot 5\,H_2O_{(s)}$	-2607.9	-2230.1	372.4
$Na_3PO_{4(s)}$	-1917.4	-1788.9	173.8
$Na_2SiO_{3(s)}$	-1554.9	-1461.0	113.8
$Na_2B_4O_{7(s)}$	-3291.1	-3096.2	189.2
$Na_2B_4O_7 \cdot 10\,H_2O_{(s)}$	-6288.6	-5516.6	585.5
$NaNH_{2(s)}$	-123.8	-64.0	76.9
Sr			
$Sr^{2+}_{(g)}$	1790.6	NA†	164.6
$SrF_{2(s)}$	-1216.3	-1164.8	82.1
$SrCl_{2(s)}$	-828.9	-781.2	114.9
$SrCl_2 \cdot H_2O_{(s)}$	-1136.8	-1036.4	172.0
$SrCl_2 \cdot 2\,H_2O_{(s)}$	-1438.0	-1282.0	218.0
$SrCl_2 \cdot 6\,H_2O_{(s)}$	-2623.8	-2241.2	390.8
$Sr(ClO_4)_{2(s)}$	-762.8	NA†	247.1
$SrBr_{2(s)}$	-717.6	-697.1	135.1
$SrI_{2(s)}$	-558.1	-562.3	159.0
$SrI_2 \cdot H_2O_{(s)}$	-886.0	NA†	
$SrI_2 \cdot 2\,H_2O_{(s)}$	-1182.4	NA†	
$SrI_2 \cdot 6\,H_2O_{(s)}$	-2388.6	NA†	
$Sr(IO_3)_{2(s)}$	-1019.2	-855.2	234.0
$SrO_{(s)}$	-592.0	-561.9	54.4
$Sr(OH)_{2(s)}$	-959.0	-869.4	88.0
$Sr(OH)_2 \cdot 8\,H_2O_{(s)}$	-3352.2	NA†	0.00655
$SrCO_{3(s)}$	-1220.1	-1104.4	97.1
$Sr(HCO_3)_{2(aq)}$	-1927.9	-1731.3	150.6
$Sr(NO_3)_{2(s)}$	-978.2	-780.1	194.6
$Sr(NO_3)_2 \cdot 4\,H_2O_{(s)}$	-2154.8	-1730.7	369.0
$SrS_{(s)}$	-453.1	-448.5	68.2
$SrSO_{4(s)}$	-1453.1	-1341.0	117.0
S			
$S_{(s),rhombic}$	0	0	31.8
$S^{2-}_{(aq)}$	33.1	85.8	-14.6
$SF_{4(g)}$	-774.9	-731.4	291.9
$SF_{6(g)}$	-1209.0	-1105.4	291.7
$SCl_{2(g)}$	-19.7	NA†	282.2
$SCl_{4(l)}$	-56.1	NA†	decomp.
$S_2Cl_{2(s)}$	-59.4	4.2	NA†
$SOCl_{2(l)}$	-245.6	-197.9	307.9
$SO_2Cl_{2(l)}$	-394.1	-305.0	216.7
$SO_{2(g)}$	-296.8	-300.2	248.1
$SO_{3(l)}$	-441.0	-368.4	95.6
$SO_{3(g)}$	-396.0	-370.0	256.0
$S_{(g)}$	278.8	238.3	167.8
$S_{2(g)}$	128.4	79.3	228.1
$S_{8(g)}$	102.3	49.7	430.9
Sn			
$Sn_{(s,white)}$	0	0	51.6
$Sn^{2+}_{(g)}$	2434.9	NA†	168.4
$Sn^{2+}_{(aq)}$	-8.8	-27.2	-17.0
$Sn^{4+}_{(g)}$	9323.2	NA†	168.4
$SnH_{4(g)}$	162.8	188.2	227.6
$SnCl_{2(s)}$	-325.1	NA†	1.42
$SnCl_2 \cdot 2\,H_2O_{(s)}$	-921.3	-787.8	NA†
$SnCl_{4(l)}$	-511.3	-440.2	258.6
$SnBr_{2(s)}$	-243.5	-250.6	146.0
$SnBr_{4(s)}$	-377.4	-350.2	264.4
$SnBr_4 \cdot 8\,H_2O_{(s)}$	-276.8	NA†	
$SnI_{2(s)}$	-143.5	-145.2	168.6
$SnO_{(s)}$	-285.8	-256.9	56.5
$SnO_{2(s)}$	-580.7	-519.7	52.3
$SnS_{(s)}$	-100.0	-98.3	77.0
$Sn(SO_4)_{2(s)}$	-1629.2	-1443.0	155.2
Ti			
$Ti^{2+}_{(g)}$	2450.6	NA†	
$Ti^{3+}_{(g)}$	9290.2	NA†	
$TiH_{2(s)}$	-119.7	-80.3	29.1
$TiCl_{2(s)}$	-513.8	-464.4	87.4
$TiCl_{3(s)}$	-720.9	-653.5	139.7
$TiCl_{4(s)}$	-804.2	-737.2	252.3
$TiBr_{2(s)}$	-402.0	-375.0	130.1
$TiBr_{3(s)}$	-548.5	-523.8	176.6
$TiBr_{4(s)}$	-616.7	-589.5	243.5
$TiI_{2(s)}$	-263.0	-270.1	147.7
$TiI_{4(s)}$	-375.7	-371.5	249.4
$TiO_{2(s)}$	-939.7	-884.5	49.9
$Ti_2O_{3(s)}$	-1520.9	-1434.3	78.9
W			
$W^{+}_{(g)}$	1625.9	NA†	
$WF_{6(l)}$	-1747.7	-1631.4	251.5
$WCl_{2(s)}$	-255.0	-213.6	130.2
$WCl_{4(s)}$	-467.0	-303.1	344.5
$WCl_{6(s)}$	-682.5	-548.9	254.0
$WBr_{6(s)}$	-348.5	-328.0	472.0
$WO_{3(s),wolfamite}$	-842.9	-764.1	75.9
$WS_{2(s)}$	-209.0	NA†	84.0
$WC_{(s)}$	-40.5	-40.2	35.6
U			
$UF_{6(g)}$	-2112.9	-2029.3	379.7
$UCl_{2(s)}$	-75.3	-80.3	79.0
$UCl_2O_{2(s)}$	-1263.1	-1159.0	150.5
$UO_{2(s)}$	-1129.7	-1075.3	77.8
$UO_{3(s)}$	-1263.6	-1184.1	98.6
$U_2C_{3(s)}$	-205.0	-201.0	105.0
$UO_2(NO_3)_{2(s)}$	-1377.4	-1142.7	276.1
$UO_2(NO_3)_2 \cdot 6\,H_2O_{(s)}$	-3197.8	-2615.0	505.6
$US_{2(s)}$	-502.0	-531.7	110.5
V			
$V^{2+}_{(g)}$	2590.5	NA†	169.4
$V^{3+}_{(g)}$	5430.5	NA†	171.5
$V^{4+}_{(g)}$	9943.3	NA†	169.3
$VF_{4(s)}$	-1403.3	NA†	
$VF_{5(l)}$	-1480.3	-1373.2	175.7
$VF_{5(g)}$	-1433.8	-1369.8	320.8
$VCl_{2(s)}$	-452.0	-406.0	97.1
$VCl_{3(s)}$	-580.7	-511.3	131.0
$VCl_{4(l)}$	-569.4	-503.7	255.2
$VBr_{2(s)}$	-365.3	NA†	126.0
$VBr_{3(s)}$	-433.5	NA†	142.0
$VBr_{4(g)}$	-336.8	NA†	335.0
$VI_{2(s)}$	-251.5	NA†	143.1
$VO_{(s)}$	-431.8	-404.2	38.9
$V_2O_{3(s)}$	-1228.0	-1139.3	98.3
$V_2O_{5(s)}$	-1550.6	-1419.6	131.0
Xe			
$XeF_{2(s)}$	-133.9	-62.8	133.9
$XeF_{4(s)}$	-261.5	-121.3	146.4
$XeF_{6(s)}$	-380.7	NA†	
$XeO_{3(s)}$	401.7	NA†	
Zn			
$Zn_{(s)}$	0	0	41.6
$Zn^{2+}_{(g)}$	2782.7	NA†	160.9
$Zn^{2+}_{(aq)}$	-153.9	-147.1	-112.1
$ZnF_{2(s)}$	-764.4	-449.5	73.7
$ZnCl_{2(s)}$	-415.1	-369.4	111.5
$ZnBr_{2(s)}$	-328.7	-312.1	138.5
$ZnI_{2(s)}$	-208.0	-208.9	161.1
$ZnO_{(s)}$	-348.3	-318.3	43.6
$ZnCO_{3(s)}$	-812.8	-731.6	82.4
$Zn(NO_3)_{2(s)}$	-483.7	NA†	
$Zn(NO_3)_2 \cdot 6\,H_2O_{(s)}$	-2306.6	-1773.1	456.9
$ZnS_{(s),wurtzite}$	-192.6	-187.0	57.7
$ZnS_{(s),blende}$	-206.0	-201.3	65.3
$ZnSO_{4(s)}$	-982.8	-874.5	119.7
$ZnSO_4 \cdot 7\,H_2O_{(s)}$	-3077.8	-2563.1	388.7