

Appendix B

Standard Thermodynamic Values*

Substance or Ion	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol·K)	Substance or Ion	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol·K)
$e^-(g)$	0	0	20.87	$CaCO_3(s)$	-1206.9	-1128.8	92.9
Aluminum				$CaO(s)$	-635.1	-603.5	38.2
$Al(s)$	0	0	28.3	$Ca(OH)_2(s)$	-986.09	-898.56	83.39
$Al^{3+}(aq)$	-524.7	-481.2	-313	$Ca_3(PO_4)_2(s)$	-4138	-3899	263
$AlCl_3(s)$	-704.2	-628.9	110.7	$CaSO_4(s)$	-1432.7	-1320.3	107
$Al_2O_3(s)$	-1676	-1582	50.94	Carbon			
Barium				$C(\text{graphite})$	0	0	5.686
$Ba(s)$	0	0	62.5	$C(\text{diamond})$	1.896	2.866	2.439
$Ba(g)$	175.6	144.8	170.28	$C(g)$	715.0	669.6	158.0
$Ba^{2+}(g)$	1649.9	—	—	$CO(g)$	-110.5	-137.2	197.5
$Ba^{2+}(aq)$	-538.36	-560.7	13	$CO_2(g)$	-393.5	-394.4	213.7
$BaCl_2(s)$	-806.06	-810.9	126	$CO_2(aq)$	-412.9	-386.2	121
$BaCO_3(s)$	-1219	-1139	112	$CO_3^{2-}(aq)$	-676.26	-528.10	-53.1
$BaO(s)$	-548.1	-520.4	72.07	$HCO_3^-(aq)$	-691.11	587.06	95.0
$BaSO_4(s)$	-1465	-1353	132	$H_2CO_3(aq)$	-698.7	-623.42	191
Boron				$CH_4(g)$	-74.87	-50.81	186.1
$B(\beta\text{-rhombohedral})$	0	0	5.87	$C_2H_2(g)$	227	209	200.85
$BF_3(g)$	-1137.0	-1120.3	254.0	$C_2H_4(g)$	52.47	68.36	219.22
$BCl_3(g)$	-403.8	-388.7	290.0	$C_2H_6(g)$	-84.667	-32.89	229.5
$B_2H_6(g)$	35	86.6	232.0	$C_3H_8(g)$	-105	-24.5	269.9
$B_2O_3(s)$	-1272	-1193	53.8	$C_4H_{10}(g)$	-126	-16.7	310
$H_3BO_3(s)$	-1094.3	-969.01	88.83	$C_6H_6(l)$	49.0	124.5	172.8
Bromine				$CH_3OH(g)$	-201.2	-161.9	238
$Br_2(l)$	0	0	152.23	$CH_3OH(l)$	-238.6	-166.2	127
$Br_2(g)$	30.91	3.13	245.38	$HCHO(g)$	-116	-110	219
$Br(g)$	111.9	82.40	174.90	$HCOO^-(aq)$	-410	-335	91.6
$Br^-(g)$	-218.9	—	—	$HCOOH(l)$	-409	-346	129.0
$Br^-(aq)$	-120.9	-102.82	80.71	$HCOOH(aq)$	-410	-356	164
$HBr(g)$	-36.3	-53.5	198.59	$C_2H_5OH(g)$	-235.1	-168.6	282.6
Cadmium				$C_2H_5OH(l)$	-277.63	-174.8	161
$Cd(s)$	0	0	51.5	$CH_3CHO(g)$	-166	-133.7	266
$Cd(g)$	112.8	78.20	167.64	$CH_3COOH(l)$	-487.0	-392	160
$Cd^{2+}(aq)$	-72.38	-77.74	-61.1	$C_6H_{12}O_6(s)$	-1273.3	-910.56	212.1
$CdS(s)$	-144	-141	71	$C_{12}H_{22}O_{11}(s)$	-2221.7	-1544.3	360.24
Calcium				$CN^-(aq)$	151	166	118
$Ca(s)$	0	0	41.6	$HCN(g)$	135	125	201.7
$Ca(g)$	192.6	158.9	154.78	$HCN(l)$	105	121	112.8
$Ca^{2+}(g)$	1934.1	—	—	$HCN(aq)$	105	112	129
$Ca^{2+}(aq)$	-542.96	-553.04	-55.2	$CS_2(g)$	117	66.9	237.79
$CaF_2(s)$	-1215	-1162	68.87	$CS_2(l)$	87.9	63.6	151.0
$CaCl_2(s)$	-795.0	-750.2	114	$CH_3Cl(g)$	-83.7	-60.2	234
				$CH_2Cl_2(l)$	-117	-63.2	179

CHCl ₃ (l)	-132	-71.5	203	Fe ²⁺ (aq)	-87.9	-84.94	113
CCl ₄ (g)	-96.0	-53.7	309.7	FeCl ₂ (s)	-341.8	-302.3	117.9
CCl ₄ (l)	-139	-68.6	214.4	FeCl ₃ (s)	-399.5	-334.1	142
COCl ₂ (g)	-220	-206	283.74	FeO(s)	-272.0	-251.4	60.75
Cesium				Fe ₂ O ₃ (s)	-825.5	-743.6	87.400
Cs(s)	0	0	85.15	Fe ₃ O ₄ (s)	-1121	-1018	145.3
Cs(g)	76.7	49.7	175.5	Lead			
Cs ⁺ (g)	458.5	427.1	169.72	Pb(s)	0	0	64.785
Cs ⁺ (aq)	-248	-282.0	133	Pb ²⁺ (aq)	1.6	-24.3	21
CsF(s)	-554.7	-525.4	88	PbCl ₂ (s)	-359	-314	136
CsCl(s)	-442.8	-414	101.18	PbO(s)	-218	-198	68.70
CsBr(s)	-395	-383	121	PbO ₂ (s)	-276.6	-219.0	76.6
CsI(s)	-337	-333	130	PbS(s)	-98.3	-96.7	91.3
Chlorine				PbSO ₄ (s)	-918.39	-811.24	147
Cl ₂ (g)	0	0	223.0	Lithium			
Cl(g)	121.0	105.0	165.1	Li(s)	0	0	29.10
Cl ⁻ (g)	-234	-240	153.25	Li(g)	161	128	138.67
Cl ⁻ (aq)	-167.46	-131.17	55.10	Li ⁺ (g)	687.163	649.989	132.91
HCl(g)	-92.31	-95.30	186.79	Li ⁺ (aq)	-278.46	-293.8	14
HCl(aq)	-167.46	-131.17	55.06	LiF(s)	-616.9	-588.7	35.66
ClO ₂ (g)	102	120	256.7	LiCl(s)	-408	-384	59.30
Cl ₂ O(g)	80.3	97.9	266.1	LiBr(s)	-351	-342	74.1
Chromium				LiI(s)	-270	-270	85.8
Cr(s)	0	0	23.8	Magnesium			
Cr ³⁺ (aq)	-1971	-	-	Mg(s)	0	0	32.69
CrO ₄ ²⁻ (aq)	-863.2	-706.3	38	Mg(g)	150	115	148.55
Cr ₂ O ₇ ²⁻ (aq)	-1461	-1257	214	Mg ²⁺ (g)	2351	-	-
Copper				Mg ²⁺ (aq)	-461.96	-456.01	118
Cu(s)	0	0	33.1	MgCl ₂ (s)	-641.6	-592.1	89.630
Cu(g)	341.1	301.4	166.29	MgCO ₃ (s)	-1112	-1028	65.86
Cu ⁺ (aq)	51.9	50.2	-26	MgO(s)	-601.2	-569.0	26.9
Cu ²⁺ (aq)	64.39	64.98	-98.7	Mg ₃ N ₂ (s)	-461	-401	88
Cu ₂ O(s)	-168.6	-146.0	93.1	Manganese			
CuO(s)	-157.3	-130	42.63	Mn(s, α)	0	0	31.8
Cu ₂ S(s)	-79.5	-86.2	120.9	Mn ²⁺ (aq)	-219	-223	-84
CuS(s)	-53.1	-53.6	66.5	MnO ₂ (s)	-520.9	-466.1	53.1
Fluorine				MnO ₄ ⁻ (aq)	-518.4	-425.1	190
F ₂ (g)	0	0	202.7	Mercury			
F(g)	78.9	61.8	158.64	Hg(l)	0	0	76.027
F ⁻ (g)	-255.6	-262.5	145.47	Hg(g)	61.30	31.8	174.87
F ⁻ (aq)	-329.1	-276.5	-9.6	Hg ²⁺ (aq)	171	164.4	-32
HF(g)	-273	-275	173.67	Hg ₂ ²⁺ (aq)	172	153.6	84.5
Hydrogen				HgCl ₂ (s)	-230	-184	144
H ₂ (g)	0	0	130.6	Hg ₂ Cl ₂ (s)	-264.9	-210.66	196
H(g)	218.0	203.30	114.60	HgO(s)	-90.79	-58.50	70.27
H ⁺ (aq)	0	0	0	Nitrogen			
H ⁺ (g)	1536.3	1517.1	108.83	N ₂ (g)	0	0	191.5
Iodine				N(g)	473	456	153.2
I ₂ (s)	0	0	116.14	N ₂ O(g)	82.05	104.2	219.7
I ₂ (g)	62.442	19.38	260.58	NO(g)	90.29	86.60	210.65
I(g)	106.8	70.21	180.67	NO ₂ (g)	33.2	51	239.9
I ⁻ (g)	-194.7	-	-	N ₂ O ₄ (g)	9.16	97.7	304.3
I ⁻ (aq)	-55.94	-51.67	109.4	N ₂ O ₅ (g)	11	118	346
HI(g)	25.9	1.3	206.33	N ₂ O ₅ (s)	-43.1	114	178
Iron				NH ₃ (g)	-45.9	-16	193
Fe(s)	0	0	27.3	NH ₃ (aq)	-80.83	26.7	110
Fe ³⁺ (aq)	-47.7	-10.5	-293	N ₂ H ₄ (l)	50.63	149.2	121.2

NO ₃ ⁻ (aq)	-206.57	-110.5	146	AgF(s)	-203	-185	84
HNO ₃ (l)	-173.23	-79.914	155.6	AgCl(s)	-127.03	-109.72	96.11
HNO ₃ (aq)	-206.57	-110.5	146	AgBr(s)	-99.51	-95.939	107.1
NF ₃ (g)	-125	-83.3	260.6	AgI(s)	-62.38	-66.32	114
NOCl(g)	51.71	66.07	261.6	AgNO ₃ (s)	-45.06	19.1	128.2
NH ₄ Cl(s)	-314.4	-203.0	94.6	Ag ₂ S(s)	-31.8	-40.3	146
Oxygen				Sodium			
O ₂ (g)	0	0	205.0	Na(s)	0	0	51.446
O(g)	249.2	231.7	160.95	Na(g)	107.76	77.299	153.61
O ₃ (g)	143	163	238.82	Na ⁺ (g)	609.839	574.877	147.85
OH ⁻ (aq)	-229.94	-157.30	-10.54	Na ⁺ (aq)	-239.66	-261.87	60.2
H ₂ O(g)	-241.826	-228.60	188.72	NaF(s)	-575.4	-545.1	51.21
H ₂ O(l)	-285.840	-237.192	69.940	NaCl(s)	-411.1	-384.0	72.12
H ₂ O ₂ (l)	-187.8	-120.4	110	NaBr(s)	-361	-349	86.82
H ₂ O ₂ (aq)	-191.2	-134.1	144	NaOH(s)	-425.609	-379.53	64.454
Phosphorus				Na ₂ CO ₃ (s)	-1130.8	-1048.1	139
P ₄ (s, white)	0	0	41.1	NaHCO ₃ (s)	-947.7	-851.9	102
P(g)	314.6	278.3	163.1	NaI(s)	-288	-285	98.5
P(s, red)	-17.6	-12.1	22.8	Strontium			
P ₂ (g)	144	104	218	Sr(s)	0	0	54.4
P ₄ (g)	58.9	24.5	280	Sr(g)	164	110	164.54
PCl ₃ (g)	-287	-268	312	Sr ²⁺ (g)	1784	-	-
PCl ₃ (l)	-320	-272	217	Sr ²⁺ (aq)	-545.51	-557.3	-39
PCl ₅ (g)	-402	-323	353	SrCl ₂ (s)	-828.4	-781.2	117
PCl ₅ (s)	-443.5	-	-	SrCO ₃ (s)	-1218	-1138	97.1
P ₄ O ₁₀ (s)	-2984	-2698	229	SrO(s)	-592.0	-562.4	55.5
PO ₄ ³⁻ (aq)	-1266	-1013	-218	SrSO ₄ (s)	-1445	-1334	122
HPO ₄ ²⁻ (aq)	-1281	-1082	-36	Sulfur			
H ₂ PO ₄ ⁻ (aq)	-1285	-1135	89.1	S(rhombic)	0	0	31.9
H ₃ PO ₄ (aq)	-1277	-1019	228	S(monoclinic)	0.3	0.096	32.6
Potassium				S(g)	279	239	168
K(s)	0	0	64.672	S ₂ (g)	129	80.1	228.1
K(g)	89.2	60.7	160.23	S ₈ (g)	101	49.1	430.211
K ⁺ (g)	514.197	481.202	154.47	S ²⁻ (aq)	41.8	83.7	22
K ⁺ (aq)	-251.2	-282.28	103	HS ⁻ (aq)	-17.7	12.6	61.1
KF(s)	-568.6	-538.9	66.55	H ₂ S(g)	-20.2	-33	205.6
KCl(s)	-436.7	-409.2	82.59	H ₂ S(aq)	-39	-27.4	122
KBr(s)	-394	-380	95.94	SO ₂ (g)	-296.8	-300.2	248.1
KI(s)	-328	-323	106.39	SO ₃ (g)	-396	-371	256.66
KOH(s)	-424.8	-379.1	78.87	SO ₄ ²⁻ (aq)	-907.51	-741.99	17
KClO ₃ (s)	-397.7	-296.3	143.1	HSO ₄ ⁻ (aq)	-885.75	-752.87	126.9
KClO ₄ (s)	-432.75	-303.2	151.0	H ₂ SO ₄ (l)	-813.989	-690.059	156.90
Rubidium				H ₂ SO ₄ (aq)	-907.51	-741.99	17
Rb(s)	0	0	69.5	Tin			
Rb(g)	85.81	55.86	169.99	Sn(white)	0	0	51.5
Rb ⁺ (g)	495.04	-	-	Sn(gray)	3	4.6	44.8
Rb ⁺ (aq)	-246	-282.2	124	SnCl ₄ (l)	-545.2	-474.0	259
RbF(s)	-549.28	-	-	SnO ₂ (s)	-580.7	-519.7	52.3
RbCl(s)	-435.35	-407.8	95.90	Titanium			
RbBr(s)	-389.2	-378.1	108.3	Ti(s)	0	0	30.7
RbI(s)	-328	-326	118.0	TiCl ₄ (l)	-804.2	-737.2	252.3
Silicon				TiO ₂ (s)	-944.0	-888.8	50.6
Si(s)	0	0	18.0	Zinc			
SiF ₄ (g)	-1614.9	-1572.7	282.4	Zn(s)	0	0	41.6
SiO ₂ (s)	-910.9	-856.5	41.5	Zn(g)	130.5	94.93	160.9
Silver				Zn ²⁺ (aq)	-152.4	-147.21	-106.5
Ag(s)	0	0	42.702	ZnO(s)	-348.0	-318.2	43.9
Ag(g)	289.2	250.4	172.892	ZnS(s, zinc blende)	-203	-198	57.7
Ag ⁺ (aq)	105.9	77.111	73.93				

*All values at 298K.