Appendix C | Thermodynamic Quantities for Substances and Ions at 25°C

Substance or Ion	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol·K)
$e^-(g)$	0	0	20.87
Aluminum			
$Al(s)$	0	0	28.28
$Al^{3+}(aq)$	−531	−485	−321.7
$AlCl_3(s)$	−705.6	−630.0	109.3
$Al_2O_3(s)$	−1675.7	−1582.3	50.95
Barium			
$Ba(g)$	179.1	147.0	170.1
$Ba(s)$	0	0	62.48
$Ba^{2+}(aq)$	−537.6	−560.7	9.6
$BaCO_3(s)$	−1216.3	−1137.6	112.1
$BaCl_2(s)$	−858.6	−810.3	123.7
$Ba(NO_3)_2(aq)$	−952.4	−783.4	302.5
$Ba(OH)_2(s)$	−946.3	−859.3	107.1
$Ba(OH)_2 \cdot 8H_2O(s)$	−3342.2	−2793	427
$BaSO_4(s)$	−1473.2	−1362.3	132.2
Beryllium			
$Be(s)$	0	0	9.440
$BeO(s)$	−608.4	−579.1	13.77
$Be(OH)_2(s)$	−905.8	−817.9	50.21
Boron			
$B(s)$	0	0	5.834
$BCl_3(l)$	−427.2	−387.4	206
$BF_3(g)$	−1135.6	−1119.0	254.2
$B_2O_3(s)$	−1271.9	−1192.8	53.95
Bromine			
$Br(g)$	111.9	82.40	174.9
$Br^-(aq)$	−121.5	−104.0	82.4
$Br^-(g)$	−219.0	−238.8	163.4
$Br_2(g)$	30.91	3.159	245.3
$Br_2(l)$	0	0	152.2
$HBr(g)$	−36.44	−53.50	198.6
Calcium			
$Ca(g)$	177.8	144.1	154.8
$Ca(s)$	0	0	41.59
$Ca^+(g)$	773.8	732.1	160.5
$Ca^{2+}(aq)$	−542.8	−553.5	−53.1
$Ca^{2+}(g)$	1925.9	—	—
$CaCO_3(s,$ calcite)	−1206.9	−1128.8	92.9
$CaCl_2(s)$	−795.8	−748.1	104.6
$CaF_2(s)$	−1225.9	−1173.5	68.57
$CaO(s)$	−635.1	−603.5	38.21
$Ca(OH)_2(s)$	−986.1	−898.4	83.39
$Ca_3(PO_4)_2(s)$	−4120.8	−3884.8	236.0
$CaSO_4(s)$	−1434.1	−1321.9	106.7
Carbon			
$C(g)$	716.7	671.3	158.0
$C(s,$ diamond)	1.897	2.900	2.377
$C(s,$ graphite)	0	0	5.740
$CCl_4(g)$	−95.98	−53.65	309.7
$CCl_4(l)$	−135.4	−65.27	216.4
$CF_4(g)$	−933.2	−888.5	261.3
$CN^-(aq)$	151	166	118
$CO(g)$	−110.5	−137.2	197.5
$CO_2(g)$	−393.5	−394.4	213.7
$CO_3^{2-}(aq)$	−677.1	−527.9	−56.9
$CS_2(g)$	116.9	66.85	237.9
$CS_2(l)$	89.70	65.27	151.3
$COCl_2(g)$	−220.1	−205.9	283.9
$HCN(aq)$	150.6	172.4	94.1
$HCN(g)$	135.1	124.7	201.7
$HCN(l)$	108.9	124.9	112.8
$HCO_3^-(aq)$	−692.0	−586.8	91.2
Hydrocarbons			
$CH_4(g)$	−74.87	−50.80	186.1
$C_2H_2(g)$	226.7	209.2	200.9
$C_2H_4(g)$	52.47	68.39	219.2
$C_2H_6(g)$	−84.68	−32.89	229.5
$C_3H_8(g)$	−104.7	−23.6	270.2
$C_4H_{10}(g)$	−125.6	−17.2	310.1
$C_6H_6(g)$	82.6	129.7	269.2
$C_6H_6(l)$	49.0	124.4	173.4
Alcohols			
$CH_3OH(g)$	−200.7	−162.0	239.7
$CH_3OH(l)$	−238.7	−166.4	126.8
$C_2H_5OH(g)$	−235.1	−168.6	282.6
$C_2H_5OH(l)$	−277.7	−174.9	160.7
Aldehydes			
$HCHO(g)$	−117	−113	219.0
$CH_3CHO(g)$	−166.1	−133.4	246.4
$CH_3CHO(l)$	−191.8	−128.3	160.4
Carboxylic acids and ions			
$HCOOH(aq)$	−425.6	−351.0	92
$HCOOH(l)$	−424.7	−361.4	129

Substance or Ion	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol·K)
$Li^+(aq)$	−278.5	−293.3	13.4
$Li^+(g)$	685.7	648.5	132.9
$LiBr(s)$	−350.9	−341.6	74.06
$LiCl(s)$	−408.3	−384.0	59.30
$LiF(s)$	−616.9	−588.7	35.66
$LiI(s)$	−270.1	−269.7	85.77
Magnesium			
$Mg(g)$	147.1	112.6	148.5
$Mg(s)$	0	0	32.67
$Mg^+(g)$	891.0	848.6	154.3
$Mg^{2+}(aq)$	−466.9	−454.8	−138.1
$Mg^{2+}(g)$	2351	—	—
$MgCO_3(s)$	−1111.7	−1028.1	65.85
$MgCl_2(s)$	−641.6	−592.1	89.63
$Mg_3N_2(s)$	−461.1	−400.9	87.86
$MgO(s)$	−601.2	−568.9	26.92
$Mg(OH)_2(s)$	−924.7	−833.7	63.24
Manganese			
$Mn(g)$	283.3	241.0	173.6
$Mn(s)$	0	0	32.01
$MnO(s)$	−385.2	−362.9	59.71
$MnO_2(s)$	−520.0	−465.2	53.05
$MnO_4^-(aq)$	−541.4	−447.3	191.2
Mercury			
$Hg(g)$	61.38	31.91	174.9
$Hg(l)$	0	0	76.03
$Hg^{2+}(aq)$	171.1	164.4	−32.2
$Hg_2^{2+}(aq)$	172.3	153.6	84.5
$HgCl_2(s)$	−230.1	−184.0	144.5
$Hg_2Cl_2(s)$	−265.2	−210.8	192.4
$HgO(s)$	−90.79	−58.49	70.27
Nickel			
$Ni(g)$	430.1	384.7	182.1
$Ni(s)$	0	0	29.87
$Ni^{2+}(aq)$	−54.0	−45.6	−128.9
$NiCl_2(s)$	−304.9	−258.8	98.16
$NiO(s)$	−239.7	−211.7	37.99
Nitrogen			
$N(g)$	472.7	455.6	153.2
$N_2(g)$	0	0	191.6
$NH_3(aq)$	−80.29	−26.57	111.3
$NH_3(g)$	−45.90	−16.40	192.7
$NH_4^+(aq)$	−132.5	−79.37	113.4
$N_2H_4(g)$	95.35	159.2	238.6
$N_2H_4(l)$	50.63	149.4	121.4
$NH_4Cl(s)$	−314.6	−203.1	94.86
$NH_4NO_3(s)$	−365.6	−184.0	151.1
$NO(g)$	90.29	86.60	210.6
$NO_2(g)$	33.10	51.24	239.9
$NO_3^-(aq)$	−207.4	−111.3	146.4
$N_2O(g)$	82.05	104.2	219.9
$N_2O_4(g)$	9.079	97.72	304.3
$N_2O_4(l)$	−19.56	97.52	209.2
$NOCl(g)$	51.71	66.08	261.6
$HNO_3(aq)$	−207.4	−111.3	146.4
$HNO_3(g)$	−134.3	−73.99	266.3
$HNO_3(l)$	−174.1	−80.79	155.6
Oxygen			
$O(g)$	249.2	231.8	160.9
$O_2(g)$	0	0	205.0
$O_3(g)$	142.7	163.2	238.8
$OH^-(aq)$	−230.0	−157.3	−10.75
Phosphorus			
$P(g)$	316.4	280.0	163.1
$P(s, \text{red})$	−17.46	−12.03	22.85
$P(s, \text{white})$	0	0	41.08
$P_2(g)$	143.7	103.1	218.0
$P_4(g)$	58.91	24.45	279.9
$PCl_3(g)$	−288.7	−269.6	311.6
$PCl_5(g)$	−360.2	−290.3	364.2
$PF_5(g)$	−1594.4	−1520.7	300.7
$PH_3(g)$	5.439	7.175	210.1
$P_4O_{10}(s)$	−3009.9	−2723.3	228.8
$PO_4^{3-}(aq)$	−1277.4	−1018.8	−222
$POCl_3(g)$	−559.8	−514.3	325.3
$POCl_3(l)$	−597.1	−520.9	222.5
$P_4S_3(s)$	−224.6	−206.9	200.8
$HPO_4^{2-}(aq)$	−1281	−1082	−36
$H_2PO_4^-(aq)$	−1285	−1135	89.1
$H_3PO_4(aq)$	−1288.3	−1142.6	158.2
Potassium			
$K(g)$	89.00	60.51	160.2
$K(s)$	0	0	64.67
$K^+(aq)$	−252.4	−283.3	102.5
$K^+(g)$	514.0	481.0	154.5
$KBr(s)$	−393.8	−380.4	95.94
$KCl(s)$	−436.7	−408.8	82.55
$KF(s)$	−568.6	−538.9	66.55
$KI(s)$	−327.9	−323.0	106.4
$KClO_3(s)$	−397.7	−296.3	143.1

Substance or Ion	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol·K)
$K_2CO_3(s)$	−1150.2	−1064.5	155.5
$KNO_3(s)$	−494.6	−394.9	133.1
$K_2O(s)$	−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
Rubidium			
$Rb(g)$	80.90	53.11	170.0
$Rb(s)$	0	0	76.78
$RbBr(s)$	−394.6	−381.8	110.0
$RbCl(s)$	−435.5	−407.8	95.90
$RbF(s)$	−549.4	—	75.3
$RbI(s)$	−333.8	−328.9	118.4
Silicon			
$Si(g)$	450.0	405.6	167.9
$Si(s)$	0	0	18.82
$SiC(s)$	−65.3	−62.8	16.61
$SiCl_4(l)$	−687.0	−619.9	239.7
$SiF_4(g)$	−1614.9	−1572.7	282.7
$SiO_2(s,$ quartz)	−910.9	−856.4	41.46
Silver			
$Ag(g)$	284.6	245.7	172.9
$Ag(s)$	0	0	42.55
$Ag^+(aq)$	105.6	77.12	72.68
$AgBr(s)$	−100.4	−96.90	107.1
$AgCl(s)$	−127.1	−109.8	96.2
$AgF(s)$	−204.6	—	83.7
$AgI(s)$	−61.84	−66.19	115.5
$Ag_2O(s)$	−31.05	−11.21	121.3
$Ag_2S(s)$	−32.59	−40.67	144.0
$AgNO_3(s)$	−124.4	−33.47	140.9
Sodium			
$Na(g)$	107.3	76.86	153.6
$Na(s)$	0	0	51.46
$Na^+(aq)$	−240.1	−261.9	59.1
$Na^+(g)$	609.3	574.4	147.8
$NaBr(s)$	−361.4	−349.3	86.82
$Na_2CO_3(s)$	−1130.8	−1048.0	138.8
$NaCl(s)$	−411.1	−384.0	72.12
$NaF(s)$	−575.4	−545.1	51.21
$NaHCO_3(s)$	−950.8	−851.0	101.7
$NaI(s)$	−287.9	−284.6	98.50
$NaNO_3(s)$	−467.9	−367.1	116.5
$NaOH(s)$	−425.9	−379.7	64.44
Strontium			
$Sr(g)$	164.0	131.6	164.5
$Sr(s)$	0	0	55.69
$Sr^+(g)$	719.7	679.3	170.3
$Sr^{2+}(aq)$	−545.8	−559.4	−32.6
$Sr^{2+}(g)$	1790.6	—	—
$SrCO_3(s)$	−1220.1	−1140.1	97.1
$SrCl_2(s)$	−828.9	−781.2	114.9
$SrO(s)$	−592.0	−561.4	55.52
$SrSO_4(s)$	−1453.1	−1341.0	117
Sulfur			
$S(g)$	277.0	236.5	167.7
$S(s,$ monoclinic)	0.360	0.070	33.03
$S(s,$ rhombic)	0	0	32.06
$S^{2-}(aq)$	41.8	83.7	22
$S_2(g)$	128.6	79.7	228.1
$S_8(g)$	100.4	48.61	430.2
$SO_2(g)$	−296.8	−300.1	248.1
$SO_3(g)$	−395.8	−371.0	256.7
$SO_4^{2-}(aq)$	−909.3	−744.6	20.1
$HS^-(aq)$	−17.7	12.6	61.1
$H_2S(aq)$	−39	−27.4	122
$H_2S(g)$	−20.50	−33.33	205.6
$HSO_4^-(aq)$	−887.3	−756.0	131.8
$H_2SO_4(l)$	−814.0	−689.9	156.9
Tin			
$Sn(s,$ gray)	−2.09	0.13	44.14
$Sn(s,$ white)	0	0	51.55
$SnCl_4(l)$	−511.3	−440.2	258.6
$SnO_2(s)$	−580.7	−519.7	52.3
Zinc			
$Zn(g)$	130.4	94.89	160.9
$Zn(s)$	0	0	41.72
$Zn^{2+}(aq)$	−153.9	−147.0	−112.1
$ZnCl_2(s)$	−415.1	−369.4	111.5
$ZnO(s)$	−348.3	−318.3	43.64
$ZnS(s,$ sphalerite)	−206.0	−201.3	−57.7