

12.6: Appendix 2- Selected Thermodynamic Values

Selected Thermodynamic Values (at 298.15 K)

Substance	ΔH_f° (kJ/mol)	S° (J/K·mol)	ΔG_f° (kJ/mol)
Aluminum			
Al(s)	0	28.3	0
AlCl ₃ (s)	-704.2	110.67	-628.8
Al ₂ O ₃ (s)	-1675.7	50.92	-1582.3
Barium			
BaCl ₂ (s)	-858.6	123.68	-810.4
BaCl ₂ • 2 H ₂ O (s)	-1460.1	203	-1296.5
BaO(s)	-553.5	70.42	-525.1
Ba(OH) ₂ • 8 H ₂ O (s)	-3342	427	-2793
BaSO ₄ (s)	-1473.2	132.2	-1362.2
Beryllium			
Be(s)	0	9.5	0
Be(OH) ₂ (s)	-902.5	51.9	-815
Bromine			
Br(g)	111.884	175.022	82.396
Br ₂ (liq)	0	152.2	0
Br ₂ (g)	30.907	245.463	3.11
BrF ₃ (g)	-255.6	292.53	-229.43
HBr(g)	-36.4	198.695	-53.45
Calcium			
Ca(s)	0	41.42	0
Ca(g)	178.2	158.884	144.3
Ca ₂ ⁺ (g)	1925.9		
CaC ₂ (s)	-59.8	69.96	-64.9
CaCO ₃ (s; calcite)	-1206.92	92.9	-1128.79
CaCl ₂ (s)	-795.8	104.6	-748.1
CaF ₂ (s)	-1219.6	68.87	-1167.3
CaH ₂ (s)	-186.2	42	-147.2
CaO(s)	-635.09	39.75	-604.03
CaS(s)	-482.4	56.5	-477.4
Ca(OH) ₂ (s)	-986.09	83.39	-898.49
Ca(OH) ₂ (aq)	-1002.82	-74.5	-868.07

CaSO ₄ (s)	-1434.11	106.7	-1321.79
Carbon			
C(s, graphite)	0	5.74	0
C(s, diamond)	1.895	2.377	2.9
C(g)	716.682	158.096	671.257
CCl ₄ (liq)	-135.44	216.4	-65.21
CCl ₄ (g)	-102.9	309.85	-60.59
CHCl ₃ (liq)	-134.47	201.7	-73.66
CHCl ₃ (g)	-103.14	295.71	-70.34
CH ₄ (g, methane)	-74.81	186.264	-50.72
C ₂ H ₂ (g, ethyne)	226.73	200.94	209.2
C ₂ H ₄ (g, ethene)	52.26	219.56	68.15
C ₂ H ₆ (g, ethane)	-84.68	229.6	-32.82
C ₃ H ₈ (g, propane)	-103.8	269.9	-23.49
C ₄ H ₁₀ (g, butane)	-888.0		
C ₆ H ₆ (liq, benzene)	49.03	172.8	124.5
C ₆ H ₁₄ (liq)	-198.782	296.018	-4.035
C ₈ H ₁₈ (liq)	-249.952	361.205	6.707
CH ₃ OH(liq, methanol)	-238.66	126.8	-166.27
CH ₃ OH(g, methanol)	-200.66	239.81	-161.96
C ₂ H ₅ OH(liq, ethanol)	-277.69	160.7	-174.78
C ₂ H ₅ OH(g, ethanol)	-235.1	282.7	-168.49
CH ₃ COOH(liq)	-276.981	160.666	-173.991
CO(NH ₂) ₂ (s, urea)	-333.5	104.6	-197.4
CO(g)	-110.525	197.674	-137.168
CO ₂ (g)	-393.509	213.74	-394.359
CS ₂ (g)	117.36	237.84	67.12
COCl ₂ (g)	-218.8	283.53	-204.6
Cesium			
Cs(s)	0	85.23	0
Cs ⁺ (g)	457.964		
CsCl(s)	-443.04	101.17	-414.53
Chlorine			
Cl(g)	121.679	165.198	105.68
Cl ⁻ (g)	-233.13		

Cl ₂ (g)	0	223.066	0
HCl(g)	-92.307	186.908	-95.299
HCl(aq)	-167.159	56.5	-131.228
Chromium			
Cr(s)	0	23.77	0
Cr ₂ O ₃ (s)	-1139.7	81.2	-1058.1
CrCl ₃ (s)	-556.5	123	-486.1
Copper			
Cu(s)	0	33.15	0
CuO(s)	-157.3	42.63	-129.7
CuCl ₂ (s)	-220.1	108.07	-175.7
Fluorine			
F ₂ (g)	0	202.78	0
F(g)	78.99	158.754	61.91
F ⁻ (g)	-255.39		
F ⁻ (aq)	-332.63	-13.8	-278.79
HF(g)	-271.1	173.779	-273.2
HF(aq)	-332.63	-13.8	-278.79
Hydrogen			
H ₂ (g)	0	130.684	0
H(g)	217.965	114.713	203.247
H ⁺ (g)	1536.202		
H ₂ O(liq)	-285.83	69.91	-237.129
H ₂ O(g)	-241.818	188.825	-228.572
H ₂ O ₂ (liq)	-187.78	109.6	-120.35
Iodine			
I ₂ (s)	0	116.135	0
I ₂ (g)	62.438	260.69	19.327
I(g)	106.838	180.791	70.25
I ⁻ (g)	-197		
ICl(g)	17.78	247.551	-5.46
Iron			
Fe(s)	0	27.78	0
FeO(s)	-272		
Fe ₂ O ₃ (s, hematite)	-824.2	87.4	-742.2

$\text{Fe}_3\text{O}_4(\text{s, magnetite})$	-1118.4	146.4	-1015.4
$\text{FeCl}_2(\text{s})$	-341.79	117.95	-302.3
$\text{FeCl}_3(\text{s})$	-399.49	142.3	-344
$\text{FeS}_2(\text{s, pyrite})$	-178.2	52.93	-166.9
$\text{Fe}(\text{CO})_5(\text{liq})$	-774	338.1	-705.3
Lead			
$\text{Pb}(\text{s})$	0	64.81	0
$\text{PbCl}_2(\text{s})$	-359.41	136	-314.1
$\text{PbO}(\text{s, yellow})$	-217.32	68.7	-187.89
$\text{PbS}(\text{s})$	-100.4	91.2	-98.7
Lithium			
$\text{Li}(\text{s})$	0	29.12	0
$\text{Li}^+(\text{g})$	685.783		
$\text{LiOH}(\text{s})$	-484.93	42.8	-438.95
$\text{LiOH}(\text{aq})$	-508.48	2.8	-450.58
$\text{LiCl}(\text{s})$	-408.701	59.33	-384.37
Magnesium			
$\text{Mg}(\text{s})$	0	32.68	0
$\text{MgCl}_2(\text{g})$	-641.32	89.62	-591.79
$\text{MgO}(\text{s})$	-601.7	26.94	-569.43
$\text{Mg}(\text{OH})_2(\text{s})$	-924.54	63.18	-833.51
$\text{MgS}(\text{s})$	-346	50.33	-341.8
Mercury			
$\text{Hg}(\text{liq})$	0	29.87	0
$\text{HgCl}_2(\text{s})$	-224.3	146	-178.6
$\text{HgO}(\text{s, red})$	-90.83	70.29	-58.539
$\text{HgS}(\text{s, red})$	-58.2	82.4	-50.6
Nickel			
$\text{Ni}(\text{s})$	0	29.87	0
$\text{NiO}(\text{s})$	-239.7	37.99	-211.7
$\text{NiCl}_2(\text{s})$	-305.332	97.65	-259.032
Nitrogen			
$\text{N}_2(\text{g})$	0	191.61	0
$\text{N}(\text{g})$	472.704	153.298	455.563
$\text{NH}_3(\text{g})$	-46.11	192.45	-16.45

$\text{N}_2\text{H}_4(\text{liq})$	50.63	121.21	149.34
$\text{NH}_4\text{Cl}(\text{s})$	-314.43	94.6	-202.87
$\text{NH}_4\text{Cl}(\text{aq})$	-299.66	169.9	-210.52
$\text{NH}_4\text{NO}_3(\text{s})$	-365.56	151.08	-183.87
$\text{NH}_4\text{NO}_3(\text{aq})$	-339.87	259.8	-190.56
$\text{NO}(\text{g})$	90.25	210.76	86.55
$\text{NO}_2(\text{g})$	33.18	240.06	51.31
$\text{N}_2\text{O}(\text{g})$	82.05	219.85	104.2
$\text{N}_2\text{O}_4(\text{g})$	9.16	304.29	97.89
$\text{NOCl}(\text{g})$	51.71	261.69	66.08
$\text{HNO}_3(\text{liq})$	-174.1	155.6	-80.71
$\text{HNO}_3(\text{g})$	-135.06	266.38	-74.72
$\text{HNO}_3(\text{aq})$	-207.36	146.4	-111.25
Oxygen			
$\text{O}_2(\text{g})$	0	205.138	0
$\text{O}(\text{g})$	249.17	161.055	231.731
$\text{O}_3(\text{g})$	142.7	238.93	163.2
Phosphorus			
$\text{P}_4(\text{s, white})$	0	164.36	0
$\text{P}_4(\text{s, red})$	-70.4	91.2	-48.4
$\text{P}(\text{g})$	314.64	163.193	278.25
$\text{PH}_3(\text{g})$	5.4	310.23	13.4
$\text{PCl}_3(\text{g})$	-287	311.78	-267.8
$\text{P}_4\text{O}_{10}(\text{s})$	-2984	228.86	-2697.7
$\text{H}_3\text{PO}_4(\text{s})$	-1279	110.5	-1119.1
Potassium			
$\text{K}(\text{s})$	0	64.18	0
$\text{KCl}(\text{s})$	-436.747	82.59	-409.14
$\text{KClO}_3(\text{s})$	-397.73	143.1	-296.25
$\text{KI}(\text{s})$	-327.9	106.32	-324.892
$\text{KOH}(\text{s})$	-424.764	78.9	-379.08
$\text{KOH}(\text{aq})$	-482.37	91.6	-440.5
Silicon			
$\text{Si}(\text{s})$	0	18.83	0
$\text{SiBr}_4(\text{liq})$	-457.3	277.8	-443.8

SiC(s)	-65.3	16.61	-62.8
SiCl ₄ (g)	-657.01	330.73	-616.98
SiH ₄ (g)	34.3	204.62	56.9
SiF ₄ (g)	-1614.94	282.49	-1572.65
SiO ₂ (s, quartz)	-910.94	41.84	-856.64
Silver			
Ag(s)	0	42.55	0
Ag ₂ O(s)	-31.05	121.3	-11.2
AgCl(s)	-127.068	96.2	-109.789
AgNO ₃ (s)	-124.39	140.92	-33.41
Sodium			
Na(s)	0	51.21	0
Na(g)	107.32	153.712	76.761
Na ⁺ (g)	609.358		
NaBr(s)	-361.062	86.82	-348.983
NaCl(s)	-411.153	72.13	-384.138
NaCl(g)	-176.65	229.81	-196.66
NaCl(aq)	-407.27	115.5	-393.133
NaOH(s)	-425.609	64.455	-379.484
NaOH(aq)	-470.114	48.1	-419.15
Na ₂ CO ₃ (s)	-1130.68	134.98	-1044.44
Sulfur			
S(s, rhombic)	0	31.8	0
S(g)	278.805	167.821	238.25
S ₂ Cl ₂ (g)	-18.4	331.5	-31.8
SF ₆ (g)	1209	291.82	-1105.3
H ₂ S(g)	-20.63	205.79	-33.56
SO ₂ (g)	-296.83	248.22	-300.194
SO ₃ (g)	-395.72	256.76	-371.06
SOCl ₂ (g)	-212.5	309.77	-198.3
H ₂ SO ₄ (liq)	-813.989	156.904	-690.003
H ₂ SO ₄ (aq)	-909.27	20.1	-744.53
Tin			
Sn(s, white)	0	51.55	0
Sn(s, gray)	-2.09	44.14	0.13

$\text{SnCl}_4(\text{liq})$	-511.3	248.6	-440.1
$\text{SnCl}_4(\text{g})$	-471.5	365.8	-432.2
$\text{SnO}_2(\text{s})$	-580.7	52.3	-519.6
Titanium			
$\text{Ti}(\text{s})$	0	30.63	0
$\text{TiCl}_4(\text{liq})$	-804.2	252.34	-737.2
$\text{TiCl}_4(\text{g})$	-763.2	354.9	-726.7
$\text{TiO}_2(\text{s})$	-939.7	49.92	-884.5
Zinc			
$\text{Zn}(\text{s})$	0	41.63	0
$\text{ZnCl}_2(\text{s})$	-415.05	111.46	-369.398
$\text{ZnO}(\text{s})$	-348.28	43.64	-318.3
$\text{ZnS}(\text{s, sphalerite})$	-205.98	57.7	-201.29
Aqueous Ions and Molecules			
$\text{Ca}^{2+}(\text{aq})$	-542.96	-55.2	-553.04
$\text{CO}_3^{2-}(\text{aq})$	-676.26	-53.1	-528.1
$\text{CO}_2(\text{aq})$	-413.8	117.6	-386.0
$\text{Cl}^-(\text{aq})$	-167.16	56.5	-131.26
$\text{H}^+(\text{aq})$	0		0
$\text{HCO}_2^-(\text{aq})$	-410	91.6	-335
$\text{HCO}_2\text{H}(\text{aq})$	-410	164	-356
$\text{HCO}_3^-(\text{aq})$	-691.11	95	-587.06
$\text{H}_2\text{CO}_3(\text{aq})$	-698.7	191	-623.42
$\text{NH}_3(\text{aq})$	-80.29	111	-26.6
$\text{OH}^-(\text{aq})$	-229.94	-10.54	-157.3
$\text{Ag}^+(\text{aq})$	105.58	72.68	77.124

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