

# Thermodynamic Quantities

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Substance	$\Delta H_f^\circ$ (kJ/mole)	$\Delta G_f^\circ$ (kJ/mole)	S(J/moleK)	Substance	$\Delta H_f^\circ$ (kJ/mole)	$\Delta G_f^\circ$ (kJ/mole)	S(J/moleK)
<b>Aluminum</b>				<b>CO</b>			
Al(s)	0	0	+28.32	CO(g)	-110.5	-137.2	+197.9
Al <sup>3+</sup> (aq)	-538.4		-325	CO <sub>2</sub> (g)	-393.5	-394.4	+213.6
AlCl <sub>3</sub> (s)	-705.6	-630.0	+109.3	HC <sub>2</sub> H <sub>3</sub> O <sub>2</sub> (L)	-487.0	-392.4	+159.8
Al <sub>2</sub> O <sub>3</sub> (s)	-1669.8	-1576.5	+51.00	<b>Cesium</b>			
<b>Barium</b>				Cs(g)	+76.50	+49.53	+175.6
Ba(s)	0	0	+63.2	Cs(L)	+2.09	+0.03	+92.07
Ba <sup>2+</sup> (aq)	-537.6			Cs(s)	0	0	+85.15
BaCO <sub>3</sub> (s)	-1216.3	-1137.6	+112.1	CsCl(s)	-442.8	-414.4	+101.2
BaO(s)	-553.5	-525.1	+70.42	<b>Chlorine</b>			
<b>Beryllium</b>				Cl(g)	+121.7	+105.7	+165.2
Be(s)	0	0	+9.44	Cl <sup>-</sup> (aq)	-167.2	-131.2	+56.5
BeO(s)	-608.4	-579.1	+13.77	ClO <sub>3</sub> <sup>-1</sup> (aq)	-104.0		
Be(OH) <sub>2</sub> (s)	-905.8	-817.9	+50.21	ClO <sub>4</sub> <sup>-1</sup> (aq)	-129.3		
<b>Bromine</b>				Cl <sub>2</sub> (g)	0	0	+222.96
Br(g)	111.8	82.38	+174.9	HCl(aq)	+167.2	-131.2	+56.5
Br <sup>-1</sup> (aq)	-120.9	-102.8	+80.71	HCl(g)	-92.30	-95.27	+186.69
Br <sub>2</sub> (g)	+30.71	+3.14	+245.3	<b>Chromium</b>			
Br <sub>2</sub> (L)	0	0	+152.3	Cr(g)	+397.5	+352.6	+174.2
HBr(g)	-36.23	-53.22	+198.49	Cr(s)	0	0	+23.6
<b>Calcium</b>				CrO <sub>4</sub> <sup>-2</sup> (aq)	-881.2		
Ca(g)	+179.3	+145.5	+154.8	Cr <sub>2</sub> O <sub>7</sub> <sup>-2</sup> (aq)	-1490.3		
Ca(s)	0	0	+41.4	Cr <sub>2</sub> O <sub>3</sub> (s)	-1139.7	-1058.1	+81.2
Ca <sup>2+</sup> (aq)	-542.8		-56.2	<b>Cobalt</b>			
CaCO <sub>3</sub> (s, calcite)	-1207.1	-1128.76	+92.88	Co(g)	+439	+393	+179
CaCl <sub>2</sub> (s)	-795.8	-748.1	+104.6	Co(s)	0	0	+28.4
CaF <sub>2</sub> (s)	-1219.6	-1167.3	+68.87	<b>Copper</b>			
CaO(s)	-635.5	-604.17	+39.75	Cu(g)	+338.4	+298.6	+166.3
Ca(OH) <sub>2</sub> (s)	-986.2	-898.5	+83.4	Cu(s)	0	0	+33.30
CaSO <sub>4</sub> (s)	-1434.0	-1321.8	+106.7	Cu <sup>1+</sup> (aq)	+71.7		
<b>Cadmium</b>				Cu <sup>2+</sup> (aq)	+64.8		-98
Cd <sup>2+</sup> (aq)	-75.9		-72.8	CuCl <sub>2</sub> (s)	-205.9	-161.7	+108.1
<b>Carbon</b>				CuO(s)	-156.1	-128.3	+42.59
C(g)	+718.4	+672.9	+158.0	Cu <sub>2</sub> O(s)	-170.7	-147.9	+92.36
C(s, diamond)	+1.88	+2.84	+2.43	<b>Fluorine</b>			
C(s, graphite)	0	0	+5.69	F(g)	+80.0	+61.9	+158.7
CO <sub>3</sub> <sup>-2</sup> (aq)	-677.1		-50	F <sup>-1</sup> (aq)	-332.6	-278.8	+13.8
HCO <sub>3</sub> <sup>-1</sup> (aq)	-692.0			F <sub>2</sub> (g)	0	0	+202.7
CCl <sub>4</sub> (g)	-106.7	-64.0	+309.4	HF(g)	-268.61	-270.70	+173.51
CCl <sub>4</sub> (L)	-139.3	-68.6	+214.4	<b>Hydrogen</b>			
CF <sub>4</sub> (g)	-679.9	-635.1	+262.3	H(g)	+217.94	+203.26	+114.60
CH <sub>4</sub> (g)	-74.8	-50.8	+186.3	H <sup>1+</sup> (aq)	0	0	0
C <sub>2</sub> H <sub>2</sub> (g)	+226.7	+209.2	+200.8	H <sup>1+</sup> (g)	+1536.2	+1517.0	+108.9
C <sub>2</sub> H <sub>4</sub> (g)	+52.30	+68.11	+219.4	H <sub>2</sub> (g)	0	0	+130.58
C <sub>2</sub> H <sub>6</sub> (g)	-84.68	-32.89	+229.5	<b>Iodine</b>			
C <sub>3</sub> H <sub>8</sub> (g)	-103.85	-23.47	+269.9	I(g)	+106.60	+70.16	+180.66
C <sub>4</sub> H <sub>10</sub> (g)	-124.73	-15.71	+310.0	I <sup>-1</sup> (aq)	-55.19	-51.57	+111.3
C <sub>4</sub> H <sub>10</sub> (L)	-147.6	-15.0	+231.0	I <sub>2</sub> (g)	+62.25	+19.37	+260.57
C <sub>6</sub> H <sub>6</sub> (g)	+82.9	+129.7	+269.2	I <sub>2</sub> (s)	0	0	+116.73
C <sub>6</sub> H <sub>6</sub> (L)	+49.0	+124.5	+172.8	HI(g)	+25.94	+1.30	+206.3
CH <sub>3</sub> OH(g)	-201.2	-161.9	+237.6				
CH <sub>3</sub> OH(L)	-238.6	-166.23	+126.8				
C <sub>2</sub> H <sub>5</sub> OH(g)	-235.1	-168.5	+282.7				
C <sub>2</sub> H <sub>5</sub> OH(L)	-277.7	-174.76	+160.7				
C <sub>6</sub> H <sub>12</sub> O <sub>6</sub> (s)	-1273.02	-910.4	+212.1				

# Thermodynamic Quantities

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Substance	$\Delta H_f^\circ$ (kJ/mole)	$\Delta G_f^\circ$ (kJ/mole)	S(J/moleK)	Substance	$\Delta H_f^\circ$ (kJ/mole)	$\Delta G_f^\circ$ (kJ/mole)	S(J/moleK)
<b>Iron</b>				<b>Nitrogen</b>			
Fe(g)	+415.5	+369.8	+180.66	N(g)	+472.7	+455.5	+153.3
Fe(s)	0	0	+27.15	N <sub>2</sub> (g)	0	0	+191.50
Fe <sup>2+</sup> <sub>(aq)</sub>	-87.86	-84.93	+113.4	NH <sub>3</sub> (aq)	-80.29	-26.50	+111.3
Fe <sup>3+</sup> <sub>(aq)</sub>	-47.69	-10.54	+293.3	NH <sub>3</sub> (g)	-46.19	-16.66	+192.5
FeCl <sub>2</sub> (s)	-341.8	-302.3	+117.9	NH <sub>4</sub> <sup>+</sup> <sub>(aq)</sub>	-132.5	-79.31	+113.4
FeCl <sub>3</sub> (s)	-400	-334	+142.3	N <sub>2</sub> H <sub>4</sub> (g)	+95.40	+159.4	+238.5
FeO(s)	-271.9	-255.2	+60.75	NH <sub>4</sub> CN(s)	0.0		
Fe <sub>2</sub> O <sub>3</sub> (s)	-822.16	-740.98	+89.96	NH <sub>4</sub> Cl(s)	-314.4	-203.0	+94.6
Fe <sub>3</sub> O <sub>4</sub> (s)	-1117.1	-1014.2	+146.4	NH <sub>4</sub> NO <sub>3</sub> (s)	-365.6	-184.0	+151
FeS <sub>2</sub> (s)	-171.5	-160.1	+52.92	NO(g)	+90.37	+86.71	+210.62
<b>Lead</b>				NO <sub>2</sub> (g)	+33.84	+51.84	+240.45
Pb(s)	0	0	+68.85	NO <sub>2</sub> <sup>-1</sup> <sub>(aq)</sub>	-104.6		
Pb <sup>2+</sup> <sub>(aq)</sub>	-1		18.5	NO <sub>3</sub> <sup>-1</sup> <sub>(aq)</sub>	-205.0		+147
PbBr <sub>2</sub> (s)	-227.4	-260.7	+161	N <sub>2</sub> O <sub>4</sub> (g)	+9.66	+98.28	+304.3
PbCO <sub>3</sub> (s)	-699.1	-625.5	+131.0	NOCl(g)	+52.6	+66.3	+264
Pb(NO <sub>3</sub> ) <sub>2</sub> (aq)	-421.3	-246.9	+303.3	HNO <sub>3</sub> (aq)	-206.6	-110.5	+146
Pb(NO <sub>3</sub> ) <sub>2</sub> (aq)	-451.9			HNO <sub>3</sub> (g)	-134.3	-73.94	+266.4
PbO(s)	-217.3	-187.9	+68.70	<b>Oxygen</b>			
<b>Lithium</b>				O(g)	+247.5	+230.1	+161.0
Li(g)	+159.3	+126.6	+138.8	O <sub>2</sub> (g)	0	0	+205.0
Li(s)	0	0	+29.09	O <sub>3</sub> (g)	142.3	163.4	+237.6
Li <sup>+</sup> <sub>(aq)</sub>	-278.5	-273.4	+12.2	OH <sup>-1</sup> <sub>(aq)</sub>	-230.0	-157.3	+10.7
Li <sup>+</sup> <sub>(g)</sub>	+685.7	+648.5	+133.0	H <sub>2</sub> O(g)	-241.82	-228.57	+188.83
LiCl(s)	-408.3	-384.0	+59.30	H <sub>2</sub> O(L)	-285.83	-237.13	+69.91
<b>Magnesium</b>				H <sub>2</sub> O <sub>2</sub> (g)	-136.10	-105.48	+232.9
Mg(g)	+147.1	+112.5	+148.6	H <sub>2</sub> O <sub>2</sub> (L)	-187.8	-120.4	+109.6
Mg(s)	0	0	+32.51	<b>Phosphorus</b>			
Mg <sup>2+</sup> <sub>(aq)</sub>	-466.8		-137	P(g)	+316.4	+280.0	+163.2
MgCl <sub>2</sub> (s)	-641.6	-592.1	+89.6	P <sub>2</sub> (g)	+144.3	+103.7	+218.1
MgO(s)	-601.8	-569.6	+26.8	P <sub>4</sub> (g)	+58.9	+24.4	+280
Mg(OH) <sub>2</sub> (s)	-924.7	-833.7	+63.24	P <sub>4</sub> (s, red)	-17.46	-12.03	+22.85
MgSO <sub>4</sub> (s)	-1284.9	-1170.6	+96.5	P <sub>4</sub> (s, white)	0	0	+41.08
<b>Manganese</b>				PCl <sub>3</sub> (g)	-288.07	-269.6	+311.4
Mn(g)	+280.7	+238.5	+173.6	PCl <sub>3</sub> (L)	-319.6	-272.4	+217
Mn(s)	0	0	+32.0	PF <sub>5</sub> (g)	-1594.4	-1520.7	+300.8
Mn <sup>2+</sup> <sub>(aq)</sub>	-220.8			PH <sub>3</sub> (g)	+5.4	+13.4	+210.2
MnO(s)	-385.2	-362.9	+59.7	P <sub>4</sub> O <sub>6</sub> (s)	-1640.1		
MnO <sub>2</sub> (s)	-519.6	-464.8	+53.14	P <sub>4</sub> O <sub>10</sub> (s)	-2940.1	-2675.2	+228.9
MnO <sub>4</sub> <sup>-1</sup> <sub>(aq)</sub>	-541.4			POCl <sub>3</sub> (g)	-542.2	-502.5	+325
Mg(OH) <sub>2</sub> (s)	-924.7	-833.7	+63.24	POCl <sub>3</sub> (L)	-597.0	-520.9	+222
<b>Mercury</b>				H <sub>3</sub> PO <sub>4</sub> (aq)	-1288.3	-1142.6	+158.2
Hg(g)	+60.83	+31.76	+174.89	PO <sub>4</sub> <sup>-4</sup> <sub>(aq)</sub>	-1277.4		
Hg(L)	0	0	+77.40	HPO <sub>4</sub> <sup>-2</sup> <sub>(aq)</sub>	-1292.1		
Hg <sup>2+</sup> <sub>(aq)</sub>	+167		65.7	H <sub>2</sub> PO <sub>4</sub> <sup>-1</sup> <sub>(aq)</sub>	-1296.3		
HgCl <sub>2</sub> (s)	-230.1	-184.0	+144.5	<b>Nickel</b>			
Hg <sub>2</sub> Cl <sub>2</sub> (s)	-264.9	-210.5	+192.5	Ni(g)	+429.7	+384.5	+182.1
<b>Nickel</b>				Ni(s)	0	0	+29.9
Ni(g)	+429.7	+384.5	+182.1	Ni <sup>2+</sup> <sub>(aq)</sub>	-54.0		
Ni(s)	0	0	+29.9	NiCl <sub>2</sub> (s)	-305.3	-259.0	+97.65
Ni <sup>2+</sup> <sub>(aq)</sub>	-54.0			NiO(s)	-239.7	-211.7	+37.99
NiCl <sub>2</sub> (s)	-305.3	-259.0	+97.65				
NiO(s)	-239.7	-211.7	+37.99				

# Thermodynamic Quantities

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Substance	$\Delta H_f^\circ$ (kJ/mole)	$\Delta G_f^\circ$ (kJ/mole)	S(J/moleK)	Substance	$\Delta H_f^\circ$ (kJ/mole)	$\Delta G_f^\circ$ (kJ/mole)	S(J/moleK)
<b>Potassium</b>				<b>Sulfur</b>			
K <sub>(g)</sub>	+89.99	+61.17	+160.2	S <sub>(s, rhombic)</sub>	0	0	+31.88
K <sub>(s)</sub>	0	0	+64.67	S <sup>-2</sup> <sub>(aq)</sub>	+33.1		
K <sup>+</sup> <sub>(aq)</sub>	-252.4		101.2	S <sub>8(g)</sub>	+102.3	+49.7	+430.9
KCl <sub>(s)</sub>	-435.9	-408.3	+82.7	SO <sub>2(g)</sub>	-296.9	-300.4	+248.5
KClO <sub>3(s)</sub>	-391.2	-289.9	+143.0	SO <sub>3(g)</sub>	-395.2	-370.4	+256.2
KClO <sub>3(aq)</sub>	-349.5	-284.9	+265.7	SO <sub>4</sub> <sup>-2</sup> <sub>(aq)</sub>	-909.3	-744.5	+18.5
K <sub>2</sub> CO <sub>3(s)</sub>	-1150.18	-1064.58	+155.44	SOCl <sub>2(L)</sub>	-245.6		
KNO <sub>3(s)</sub>	-492.70	-393.13	+288.1	H <sub>2</sub> S <sub>(g)</sub>	-20.17	-33.01	+205.6
K <sub>2</sub> O <sub>(s)</sub>	-363.2	-322.1	+94.14	H <sub>2</sub> SO <sub>4(aq)</sub>	-909.3	-744.5	+20.1
KO <sub>2(s)</sub>	-284.5	-240.6	+122.5	H <sub>2</sub> SO <sub>4(L)</sub>	-814.0	-689.9	+156.1
K <sub>2</sub> O <sub>2(s)</sub>	-495.8	-429.8	+113.0	HSO <sub>4</sub> <sup>-2</sup> <sub>(aq)</sub>	-887.3		
KOH <sub>(s)</sub>	-424.7	-378.9	+78.91	<b>Tin</b>			
KOH <sub>(aq)</sub>	-482.4	-440.5	+91.6	Sn <sup>+2</sup> <sub>(aq)</sub>	-8.8		-16.7
<b>Rubidium</b>				<b>Titanium</b>			
Rb <sub>(g)</sub>	+85.8	+55.8	+170.0	Ti <sub>(g)</sub>	+468	+422	+180.3
Rb <sub>(s)</sub>	0	0	+78.78	Ti <sub>(s)</sub>	0	0	+30.76
RbCl <sub>(s)</sub>	-430.5	-412.0	+92	TiCl <sub>4(g)</sub>	-763.2	-726.8	+354.9
RbClO <sub>3(s)</sub>	-392.4	-292.0	+152	TiCl <sub>4(L)</sub>	-804.2	-728.1	+221.9
<b>Scandium</b>				<b>Vanadium</b>			
Sc <sub>(g)</sub>	+377.8	+336.1	+74.7	V <sub>(g)</sub>	+514.2	+453.1	+182.2
Sc <sub>(s)</sub>	0	0	+34.6	V <sub>(s)</sub>	0	0	+28.9
<b>Selenium</b>				<b>Zinc</b>			
H <sub>2</sub> Se <sub>(g)</sub>	+29.7	+15.9	+219.0	Zn <sub>(g)</sub>	+130.7	+95.2	+160.9
<b>Silicon</b>				Zn <sub>(s)</sub>	0	0	+41.63
Si <sub>(g)</sub>	+368.2	+323.9	+167.8	Zn <sup>+2</sup> <sub>(aq)</sub>	-153.9		
Si <sub>(s)</sub>	0	0	+18.7	ZnCl <sub>2(s)</sub>	-415.1	-369.4	+111.5
SiC <sub>(s)</sub>	-73.22	-70.85	+16.61	ZnO <sub>(s)</sub>	-348.0	-318.2	+43.9
SiCl <sub>4(L)</sub>	-640.1	-572.8	+239.3				
SiO <sub>2(s, quartz)</sub>	-910.9	-856.5	+41.84				
<b>Silver</b>							
Ag <sub>(s)</sub>	0	0	+42.55				
Ag <sup>+</sup> <sub>(aq)</sub>	+105.90	+77.11	+73.93				
AgCl <sub>(s)</sub>	-127.0	-109.70	+96.11				
Ag <sub>2</sub> O <sub>(s)</sub>	-31.05	-11.20	+121.3				
AgNO <sub>3(s)</sub>	-124.4	-33.41	+140.9				
Na <sub>(g)</sub>	107.7	+77.3	+153.7				
Na <sub>(s)</sub>	0	0	+51.45				
Na <sup>+</sup> <sub>(aq)</sub>	-240.1	-261.9	+59.0				
Na <sup>+</sup> <sub>(g)</sub>	+609.3	+574.3	+148.0				
NaBr <sub>(aq)</sub>	-360.6	-364.7	+141.0				
NaBr <sub>(s)</sub>	-361.4	-349.3	+86.82				
Na <sub>2</sub> CO <sub>3(s)</sub>	-1130.9	-1047.7	+136.0				
NaCl <sub>(aq)</sub>	-407.1	-393.0	+115.5				
NaCl <sub>(s)</sub>	-410.9	-384.0	+72.33				
NaHCO <sub>3(s)</sub>	-947.7	-851.8	+102.1				
NaNO <sub>3(aq)</sub>	-446.2	-372.4	+207				
NaNO <sub>3(s)</sub>	-467.9	-367.0	+116.5				
NaOH <sub>(aq)</sub>	-469.6	-419.2	+49.8				
NaOH <sub>(s)</sub>	-425.6	-379.5	+64.46				
<b>Strontium</b>							
SrO <sub>(s)</sub>	-592.0	-561.9	+54.9				
Sr <sub>(g)</sub>	+164.4	+110.0	+164.6				

# Thermodynamic Quantities

Average Bond Enthalpies (kJ/mole)							
Single Bonds							
C—H	413	N—H	391	O—H	463	F—F	155
C—C	348	N—N	163	O—O	146		
C—N	293	N—O	201	O—F	190	Cl—F	253
C—O	358	N—F	272	O—Cl	203	Cl—Cl	242
C—F	485	N—Cl	200	O—I	234		
C—Cl	328	N—Br	243			Br—F	237
C—Br	276			S—H	339	Br—Cl	218
C—I	240	H—H	436	S—F	327	Br—Br	193
C—S	259	H—F	567	S—Cl	253		
		H—Cl	431	S—Br	218	I—Cl	208
Si—H	323	H—Br	366	S—S	266	I—Br	175
Si—Si	226	H—I	299			I—I	151
Si—C	301						
Si—O	368						
Si—Cl	464						
Multiple Bonds							
C=C	614	N=N	418	O=O	495		
C≡C	839	N≡N	941				
C=N	615	N=O	607	S=O	523		
C≡N	891			S=S	418		
C=O	799						
C≡O	1072						