

SELECTED THERMODYNAMIC VALUES AT 298.15 K (continued)

Species	ΔH_f^0 (kJ/mol)	S^0 (J/mol·K)	ΔG_f^0 (kJ/mol)	Species	ΔH_f^0 (kJ/mol)	S^0 (J/mol·K)	ΔG_f^0 (kJ/mol)
<i>Lithium</i>				<i>Rubidium</i>			
Li(s)	0	28.0	0	Rb(s)	0	76.78	0
LiOH(s)	-487.23	50	-443.9	RbOH(aq)	-481.16	110.75	-441.24
LiOH(aq)	-508.4	4	-451.1	<i>Silicon</i>			
<i>Magnesium</i>				Si(s)	0	18.8	0
Mg(s)	0	32.5	0	SiBr ₄ (l)	-457.3	277.8	-443.9
MgCl ₂ (s)	-641.8	89.5	-592.3	SiC(s)	-65.3	16.6	-62.8
MgO(s)	-601.8	27	-569.6	SiCl ₄ (g)	-657.0	330.6	-617.0
Mg(OH) ₂ (s)	-924.7	63.14	-833.7	SiH ₄ (g)	34.3	204.5	56.9
MgS(s)	-347	—	—	SiF ₄ (g)	-1615	282.4	-1573
<i>Mercury</i>				SiI ₄ (g)	-132	—	—
Hg(l)	0	76.02	0	SiO ₂ (s)	-910.9	41.84	-856.7
HgCl ₂ (s)	-224	146	-179	H ₂ SiO ₃ (s)	-1189	134	-1092
HgO(s, red)	-90.83	70.29	-58.56	Na ₂ SiO ₃ (s)	-1079	—	—
HgS(s, red)	-58.2	82.4	-50.6	H ₂ SiF ₆ (aq)	-2331	—	—
<i>Nickel</i>				<i>Silver</i>			
Ni(s)	0	30.1	0	Ag(s)	0	42.55	0
Ni(CO) ₄ (g)	-602.9	410.4	-587.3	<i>Sodium</i>			
NiO(s)	-244	38.6	-216	Na(s)	0	51.0	0
<i>Nitrogen</i>				Na(g)	108.7	153.6	78.11
N ₂ (g)	0	191.5	0	Na ⁺ (g)	601	—	—
N ₂ (g)	472.704	153.19	455.579	NaBr(s)	-359.9	—	—
NH ₃ (g)	-46.11	192.3	-16.5	NaCl(s)	-411.0	72.38	-384
N ₂ H ₄ (l)	50.63	121.2	149.2	NaCl(aq)	-407.1	115.5	-393.0
(NH ₄) ₂ AsO ₄ (aq)	-1268	—	—	Na ₂ CO ₃ (s)	-1131	136	-1048
NH ₄ Cl(s)	-314.4	94.6	-201.5	NaOH(s)	-426.7	—	—
NH ₄ Cl(aq)	-300.2	—	—	NaOH(aq)	-469.6	49.8	-419.2
NH ₄ I(s)	-201.4	117	-113	<i>Sulfur</i>			
NH ₄ NO ₃ (s)	-365.6	151.1	-184.0	S(s, rhombic)	0	31.8	0
NO(g)	90.25	210.7	86.57	S(g)	278.8	167.8	238.3
NO ₂ (g)	33.2	240.0	51.30	S ₂ Cl ₂ (g)	-18	331	-31.8
N ₂ O(g)	82.05	219.7	104.2	SF ₆ (g)	-1209	291.7	-1105
N ₂ O ₄ (g)	9.16	304.2	97.82	H ₂ S(g)	-20.6	205.7	-33.6
N ₂ O ₅ (g)	11	356	115	SO ₂ (g)	-296.8	248.1	-300.2
N ₂ O ₅ (s)	-43.1	178	114	SO ₃ (g)	-395.6	256.6	-371.1
NOCl(g)	52.59	264	66.36	SOCl ₂ (l)	-206	—	—
HNO ₂ (l)	-174.1	155.6	-80.79	SO ₂ Cl ₂ (l)	-389	—	—
HNO ₃ (g)	-135.1	266.2	-74.77	H ₂ SO ₄ (l)	-814.0	156.9	-690.1
HNO ₃ (aq)	-206.6	146	-110.5	H ₂ SO ₄ (aq)	-907.5	17	-742.0
<i>Oxygen</i>				<i>Tin</i>			
O(g)	249.2	161.0	231.8	Sn(s, white)	0	51.55	0
O ₂ (g)	0	205.0	0	Sn(s, grey)	-2.09	44.1	0.13
O ₃ (g)	143	238.8	163	SnCl ₂ (s)	-350	—	—
OF ₂ (g)	23	246.6	41	SnCl ₄ (l)	-511.3	258.6	-440.2
<i>Phosphorus</i>				SnCl ₄ (g)	-471.5	366	-432.2
P(g)	314.6	163.1	278.3	SnO ₂ (s)	-580.7	52.3	-519.7
P ₄ (s, white)	0	177	0	<i>Titanium</i>			
P ₄ (s, red)	-73.6	91.2	-48.5	TiCl ₄ (l)	-804.2	252.3	-737.2
PCl ₃ (g)	-306.4	311.7	-286.3	TiCl ₄ (g)	-763.2	354.8	-726.8
PCl ₅ (g)	-398.9	353	-324.6	<i>Tungsten</i>			
PH ₃ (g)	5.4	210.1	13	W(s)	0	32.6	0
P ₄ O ₁₀ (s)	-2984	228.9	-2698	WO ₃ (s)	-842.9	75.90	-764.1
H ₃ PO ₄ (s)	-1281	110.5	-1119	<i>Zinc</i>			
<i>Potassium</i>				ZnO(s)	-348.3	43.64	-318.3
K(s)	0	63.6	0	ZnS(s)	-205.6	57.7	-201.3
KCl(s)	-436.5	82.6	-408.8				
KClO ₃ (s)	-391.2	143.1	-289.9				
KI(s)	-327.9	106.4	-323.0				
KOH(s)	-424.7	78.91	-378.9				
KOH(aq)	-481.2	92.0	-439.6				

APPENDIX K

SELECTED THERMODYNAMIC VALUES AT 298.15 K

Species	ΔH_f° (kJ/mol)	S° (J/mol·K)	ΔG_f° (kJ/mol)	Species	ΔH_f° (kJ/mol)	S° (J/mol·K)	ΔG_f° (kJ/mol)
<i>Aluminum</i>				<i>Cesium</i>			
Al(s)	0	28.3	0	Cs ⁺ (aq)	-248	133	-282.0
AlCl ₃ (s)	-704.2	110.7	-628.9	CsF(aq)	-568.6	123	-558.5
Al ₂ O ₃ (s)	-1676	50.92	-1582	<i>Chlorine</i>			
<i>Barium</i>				Cl(g)	121.7	165.1	105.7
BaCl ₂ (s)	-860.1	126	-810.9	Cl ⁻ (g)	-226	—	—
BaSO ₄ (s)	-1465	132	-1353	Cl ₂ (g)	0	223.0	0
<i>Beryllium</i>				HCl(g)	-92.31	186.8	-95.30
Be(s)	0	9.54	0	HCl(aq)	-167.4	55.10	-131.2
Be(OH) ₂ (s)	-907.1	—	—	<i>Chromium</i>			
<i>Bromine</i>				Cr(s)	0	23.8	0
Br(g)	111.8	174.9	82.4	(NH ₄) ₂ Cr ₂ O ₇ (s)	-1807	—	—
Br ₂ (l)	0	152.23	0	<i>Copper</i>			
Br ₂ (g)	30.91	245.4	3.14	Cu(s)	0	33.15	0
BrF ₃ (g)	-255.6	292.4	-229.5	CuO(s)	-157	42.63	-130
HBr(g)	-36.4	198.59	-53.43	<i>Fluorine</i>			
<i>Calcium</i>				F ⁻ (g)	-322	—	—
Ca(s)	0	41.6	0	F ⁻ (aq)	-332.6	—	-278.8
Ca(g)	192.6	154.8	158.9	F(g)	78.99	158.6	61.92
Ca ²⁺ (g)	1920	—	—	F ₂ (g)	0	202.7	0
CaC ₂ (s)	-62.8	70.3	-67.8	HF(g)	-271	173.7	-273
CaCO ₃ (s)	-1207	92.9	-1129	HF(aq)	-320.8	—	-296.8
CaCl ₂ (s)	-795.0	114	-750.2	<i>Hydrogen</i>			
CaF ₂ (s)	-1215	68.87	-1162	H(g)	218.0	114.6	203.3
CaH ₂ (s)	-189	42	-150	H ₂ (g)	0	130.6	0
CaO(s)	-635.5	40	-604.2	H ₂ O(l)	-285.8	69.91	-237.2
CaS(s)	-482.4	56.5	-477.4	H ₂ O(g)	-241.8	188.7	-228.6
Ca(OH) ₂ (s)	-986.6	76.1	-896.8	H ₂ O ₂ (l)	-187.8	109.6	-120.4
Ca(OH) ₂ (aq)	-1002.8	76.15	-867.6	<i>Iodine</i>			
CaSO ₄ (s)	-1433	107	-1320	I(g)	106.6	180.66	70.16
<i>Carbon</i>				I ₂ (s)	0	116.1	0
C(s, graphite)	0	5.740	0	I ₂ (g)	62.44	260.6	19.36
C(s, diamond)	1.897	2.38	2.900	ICl(g)	17.78	247.4	-5.52
C(g)	716.7	158.0	671.3	HI(g)	26.5	206.5	1.72
CCl ₄ (l)	-135.4	216.4	-65.27	<i>Iron</i>			
CCl ₄ (g)	-103	309.7	-60.63	Fe(s)	0	27.3	0
CHCl ₃ (l)	-134.5	202	-73.72	FeO(s)	-272	—	—
CHCl ₃ (g)	-103.1	295.6	-70.37	Fe ₂ O ₃ (s, hematite)	-824.2	87.40	-742.2
CH ₄ (g)	-74.81	186.2	-50.75	Fe ₃ O ₄ (s, magnetite)	-1118	146	-1015
C ₂ H ₂ (g)	226.7	200.8	209.2	FeS ₂ (s)	-177.5	122.2	-166.7
C ₂ H ₄ (g)	52.26	219.5	68.12	Fe(CO) ₅ (l)	-774.0	338	-705.4
C ₂ H ₆ (g)	-84.86	229.5	-32.9	Fe(CO) ₅ (g)	-733.8	445.2	-697.3
C ₃ H ₈ (g)	-103.8	269.9	-23.49	<i>Lead</i>			
C ₆ H ₆ (l)	49.03	172.8	124.5	Pb(s)	0	64.81	0
C ₈ H ₁₈ (l)	-268.8	—	—	PbCl ₂ (s)	-359.4	136	-314.1
C ₂ H ₅ OH(l)	-277.7	161	-174.9	PbO(s, yellow)	-217.3	68.70	-187.9
C ₂ H ₅ OH(g)	-235.1	282.6	-168.6	Pb(OH) ₂ (s)	-515.9	88	-420.9
CO(g)	-110.5	197.6	-137.2	PbS(s)	-100.4	91.2	-98.7
CO ₂ (g)	-393.5	213.6	-394.4				
CS ₂ (g)	117.4	237.7	67.15				
COCl ₂ (g)	-223.0	289.2	-210.5				

TABLE 15-2 *Approximate Bond Energies (kJ/mol) of Single Bonds*

H	C	N	O	F	Si	P	S	Cl	Br	I	
436	413	391	358	565	352	322	377	432	366	299	H
	346	305	270	485	293			339	285	213	C
		163	201	283				192			N
			146			335		218	201	201	O
				155	352	490	377	253	249	278	F
					293		293	381	310	234	Si
						201		326		184	P
							226	255			S
								242		208	Cl
									193	175	Br
										151	I

TABLE 15-3 *Approximate Bond Energies (kJ/mol) of Double and Triple Bonds*

Single Bonds		Double Bonds		Triple Bonds	
C—C	346	C=C	602	C≡C	835
N—N	163	N=N	418	N≡N	945
O—O	146	O=O	498		
C—N	305	C=N	615	C≡N	887
C—O	358	C=O	732*	C≡O	1072

*Except in CO_2 , where it is 799 kJ/mol.