Thermodynamic Properties of Selected Substances

All of the values in this table are for one mole of material at 298 K and 1 bar. Following the chemical formula is the form of the substance, either solid (s), liquid (l), gas (g), or aqueous solution (aq). When there is more than one common solid form, the mineral name or crystal structure is indicated. Data for aqueous solutions are at a standard concentration of 1 mole per kilogram water. The enthalpy and Gibbs free energy of formation, $\Delta_f H$ and $\Delta_f G$, represent the changes in H and G upon forming one mole of the material starting with elements in their most stable pure states (e.g., C (graphite), O_2 (g), etc.). To obtain the value of ΔH or ΔG for another reaction, subtract Δ_f of the reactants from Δ_f of the products. For ions in solution there is an ambiguity in dividing thermodynamic quantities between the positive and negative ions; by convention, H^+ is assigned the value zero and all others are chosen to be consistent with this value. Data from Atkins (1998), Lide (1994), and Anderson (1996). Please note that, while these data are sufficiently accurate and consistent for the examples and problems in this textbook, not all of the digits shown are necessarily significant; for research purposes you should always consult original literature to determine experimental uncertainties.

Substance (form)	$\Delta_f H$ (kJ)	$\Delta_f G$ (kJ)	S (J/K)	C_P (J/K)	V (cm^3)
Al (s)	0	0	28.33	24.35	9.99
Al_2SiO_5 (kyanite)	−2594.29	−2443.88	83.81	121.71	44.09
Al_2SiO_5 (andalusite)	−2590.27	−2442.66	93.22	122.72	51.53
Al_2SiO_5 (sillimanite)	−2587.76	−2440.99	96.11	124.52	49.90
Ar (g)	0	0	154.84	20.79	
C (graphite)	0	0	5.74	8.53	5.30
C (diamond)	1.895	2.900	2.38	6.11	3.42
CH_4 (g)	−74.81	−50.72	186.26	35.31	
C_2H_6 (g)	−84.68	−32.82	229.60	52.63	
C_3H_8 (g)	−103.85	−23.49	269.91	73.5	
C_2H_5OH (l)	−277.69	−174.78	160.7	111.46	58.4
$C_6H_{12}O_6$ (glucose)	−1273	−910	212	115	
CO (g)	−110.53	−137.17	197.67	29.14	
CO_2 (g)	−393.51	−394.36	213.74	37.11	
H_2CO_3 (aq)	−699.65	−623.08	187.4		
HCO_3^- (aq)	−691.99	−586.77	91.2		
Ca^{2+} (aq)	−542.83	−553.58	−53.1		
$CaCO_3$ (calcite)	−1206.9	−1128.8	92.9	81.88	36.93
$CaCO_3$ (aragonite)	−1207.1	−1127.8	88.7	81.25	34.15
$CaCl_2$ (s)	−795.8	−748.1	104.6	72.59	51.6
Cl_2 (g)	0	0	223.07	33.91	
Cl^- (aq)	−167.16	−131.23	56.5	−136.4	17.3
Cu (s)	0	0	33.150	24.44	7.12
Fe (s)	0	0	27.28	25.10	7.11

Substance (form)	$\Delta_f H$ (kJ)	$\Delta_f G$ (kJ)	S (J/K)	C_P (J/K)	V (cm^3)
H$_2$ (g)	0	0	130.68	28.82	
H (g)	217.97	203.25	114.71	20.78	
H$^+$ (aq)	0	0	0	0	
H$_2$O (l)	-285.83	-237.13	69.91	75.29	18.068
H$_2$O (g)	-241.82	-228.57	188.83	33.58	
He (g)	0	0	126.15	20.79	
Hg (l)	0	0	76.02	27.98	14.81
N$_2$ (g)	0	0	191.61	29.12	
NH$_3$ (g)	-46.11	-16.45	192.45	35.06	
Na$^+$ (aq)	-240.12	-261.91	59.0	46.4	-1.2
NaCl (s)	-411.15	-384.14	72.13	50.50	27.01
NaAlSi$_3$O$_8$ (albite)	-3935.1	-3711.5	207.40	205.10	100.07
NaAlSi$_2$O$_6$ (jadeite)	-3030.9	-2852.1	133.5	160.0	60.40
Ne (g)	0	0	146.33	20.79	
O$_2$ (g)	0	0	205.14	29.38	
O$_2$ (aq)	-11.7	16.4	110.9		
OH$^-$ (aq)	-229.99	-157.24	-10.75	-148.5	
Pb (s)	0	0	64.81	26.44	18.3
PbO$_2$ (s)	-277.4	-217.33	68.6	64.64	
PbSO$_4$ (s)	-920.0	-813.0	148.5	103.2	
SO$_4^{2-}$ (aq)	-909.27	-744.53	20.1	-293	
HSO$_4^-$ (aq)	-887.34	-755.91	131.8	-84	
SiO$_2$ (α quartz)	-910.94	-856.64	41.84	44.43	22.69
H$_4$SiO$_4$ (aq)	-1449.36	-1307.67	215.13	468.98	