TABLE 2.1 Heat Capacities at Constant Pressure, 1 atm, of Various Substances Near 25°C

Substance	$\overline{C}_P$	Substance	$\overline{C}_P$	Substance	C_P*
Gases	**Molar heat capacities ($J\,K^{-1}\,mol^{-1}$)**	**Liquids**	**Molar heat capacities ($J\,K^{-1}\,mol^{-1}$)**	**Solids**	**Specific heat capacities ($J\,K^{-1}\,kg^{-1}$)**
He	20.8	Hg	28.0	Au	129
H_2	28.8	H_2O	75.2	Fe	452
O_2	29.4	Ethanol	111.4	C (diamond)	510
N_2	29.1	Benzene	136.1	Glass (Pyrex)	840
H_2O	33.6	*n*-Hexane	195.0	Brick	~800
CH_4	35.8			Al	902
CO_2	37.1			Glucose	1250
				Urea	2199
				H_2O (0°C)	2100
				Wood	~2000

TABLE 2.2 Physical Properties of Water, H_2O (mol wt = 18.016), at 1 atm*

Solid H_2O = ice
(at 0°C)

Density = 0.915 g cm^{-3}; specific volume = 1.093 $cm^3\,g^{-1}$
Vapor pressure = 4.579 torr
Heat of melting = 333.4 kJ kg^{-1} = 6.007 kJ mol^{-1}
Absolute molar entropy = 41.0 J $K^{-1}\,mol^{-1}$
Specific heat capacity = 2.113 kJ $K^{-1}\,kg^{-1}$
Molar heat capacity = 38.07 J $K^{-1}\,mol^{-1}$

Liquid H_2O

Temperature (°C)	Density (g cm^{-3})	Surface tension (mN m^{-1})	Vapor pressure (Torr)	Heat of vaporization (kJ kg^{-1})	Viscosity (mPa s)
0	0.9999	75.64	4.579	2493	1.7921
20	0.9982	72.75	17.535	2447	1.0050
40	0.9922	69.56	55.324	2402	0.6560
60	0.9832	66.18	149.38	2356	0.4688
80	0.9718	62.61	355.1	2307	0.3565
100	0.9584	58.85	760.00	2257	0.2838

Absolute molar entropy = 63.2 J $K^{-1}\,mol^{-1}$ at 0°C
= 87.0 J $K^{-1}\,mol^{-1}$ at 100°C
Specific heat capacity = 4.18 kJ $K^{-1}\,kg^{-1}$ between 0 and 100°C
Molar heat capacity = 75.4 J $K^{-1}\,mol^{-1}$
Heat of freezing = −333.4 kJ kg^{-1} at 0°C

Gaseous H_2O = steam
(at 100°C)

Density = 5.880×10^{-4} g cm^{-3}; specific volume = 1701 $cm^3\,g^{-1}$
Absolute molar entropy = 196.2 J $K^{-1}\,mol^{-1}$
Specific heat capacity at constant pressure = 1.874 kJ $K^{-1}\,kg^{-1}$
Molar heat capacity at constant pressure = 33.76 J $K^{-1}\,mol^{-1}$
Heat of condensation = −2257 kJ kg^{-1} = −40.66 kJ mol^{-1}

*Some of the properties listed will be defined and discussed in later chapters.

TABLE A.5 Inorganic Compounds*

	$\Delta H_f^0 \equiv \bar{H}^0$ (kJ mol^{-1})	$\bar{S}^0$ (J K^{-1} mol^{-1})	$\Delta G_f^0 \equiv \bar{G}^0$ (kJ mol^{-1})
Ag(*s*)	0	42.55	0
Ag^+(*aq*)†	105.579	72.68	77.107
AgCl(*s*)	−127.068	96.2	−109.789
C(*g*)	716.682	158.096	671.257
C(*s*, graphite)	0	5.740	0
C(*s*, diamond)	1.895	2.377	2.900
Ca(*s*)	0	41.42	0
$CaCO_3$(*s*, calcite)	−1206.92	92.9	−1128.79
Cl_2(*g*)	0	223.066	0
Cl^-(*aq*)	−167.159	56.5	−131.228
CO(*g*)	−110.525	197.674	−137.168
CO_2(*g*)	−393.509	213.74	−394.359
CO_2(*aq*)	−413.80	117.6	−385.98
HCO_3^-(*aq*)	−691.99	91.2	−586.77
CO_3^{2-}(*aq*)	−677.14	−56.9	−527.81
Fe(*s*)	0	27.28	0
Fe_2O_3(*s*)	−824.2	87.40	−742.2
H_2(*g*)	0	130.684	0
H_2O(*g*)	−241.818	188.825	−228.572
H_2O(*l*)	−285.830	69.91	−237.129
H^+(*aq*)	0	0	0
OH^-(*aq*)	−229.994	−10.75	−157.244
H_2O_2(*aq*)	−191.17	143.9	−134.03
H_2S(*g*)	−20.63	205.79	−33.56
N_2(*g*)	0	191.61	0
NH_3(*g*)	−46.11	192.45	−16.45
NH_3(*aq*)	−80.29	111.3	−26.50
NH_4^+(*aq*)	−132.51	113.4	−79.31
NO(*g*)	90.25	210.761	86.55
NO_2(*g*)	33.18	240.06	51.31
NO_3^-(*aq*)	−205.0	146.4	−108.74
Na^+(*aq*)	−240.12	59.0	−261.905
NaCl(*s*)	−411.153	72.13	−384.138
NaCl(*aq*)	−407.27	115.5	−393.133
NaOH(*s*)	−425.609	64.455	−379.494
O_2(*g*)	0	205.138	0
O_3(*g*)	142.7	238.93	163.2
S(rhombic)	0	31.80	0
SO_2(*g*)	−296.830	248.22	−300.194
SO_3(*g*)	−395.72	256.76	−371.06

* Standard thermodynamic values at 25°C (298 K) and 1 atm pressure. Values for ions refer to an aqueous solution at unit activity on the molarity scale. Standard enthalpy of formation, ΔH_f^0, third-law entropies, S^0, and standard Gibbs free energy of formation, ΔG_f^0, are given.

† The standard state for all ions and for species labeled (*aq*) is that of a solute on the molarity scale.

SOURCE: Data from *The NBS Tables of Thermodynamic Properties, D. D. Wagman et al., eds., J. Phys. Chem. Ref. Data, 11,* Suppl. 2 (1982).

TABLE A.6 Hydrocarbons*

	$\Delta H_f^0 \equiv \bar{H}^0$ (kJ mol^{-1})	$\bar{S}^0$ (J K^{-1} mol^{-1})	$\Delta G_f^0 \equiv \bar{G}^0$ (kJ mol^{-1})
Acetylene, $C_2H_2(g)$	226.73	200.94	209.20
Benzene, $C_6H_6(g)$	82.93	269.20	129.66
Benzene, $C_6H_6(l)$	49.04	173.26	124.35
n-Butane, $C_4H_{10}(g)$	−126.15	310.12	−17.15
Cyclohexane, $C_6H_{12}(g)$	−123.14	298.24	31.76
Ethane, $C_2H_6(g)$	−84.68	229.60	−32.82
Ethylene, $C_2H_4(g)$	52.26	219.56	68.15
n-Heptane, $C_7H_{16}(g)$	−187.78	427.90	7.99
n-Hexane, $C_6H_{14}(g)$	−167.19	388.40	−0.25
Isobutane, $C_4H_{10}(g)$	−134.52	294.64	−20.88
Methane, $CH_4(g)$	−74.81	186.264	−50.72
Napthalene, $C_{10}H_8(g)$	150.96	335.64	223.59
n-Octane, $C_8H_{18}(g)$	−208.45	466.73	16.40
n-Pentane, $C_5H_{12}(g)$	−146.44	348.95	−8.37
Propane, $C_3H_8(g)$	−103.85	269.91	−23.47
Propylene, $C_3H_6(g)$	20.42	266.94	62.72

* Standard thermodynamic values at 25°C (298 K) and 1 atm pressure. Standard enthalpy of formation, ΔH_f^0, third-law entropies, S^0, and standard Gibbs free energy of formation, ΔG_f^0, are given.

SOURCE: Data from D. R. Stull, E. F. Westrum, Jr., and G. C. Sinke, *The Chemical Thermodynamics of Organic Compounds*, John Wiley, New York (1969).

TABLE A.7 Organic Compounds*

	$\Delta H_f^0 \equiv \bar{H}^0$ (kJ mol^{-1})	$\bar{S}^0$ (J K^{-1} mol^{-1})	$\Delta G_f^0 \equiv \bar{G}^0$ (kJ mol^{-1})	$\Delta G_f^0 \equiv \bar{G}^0$ (1 M activity, aq) (kJ mol^{-1})
Acetaldehyde $CH_3CHO(g)$	−166.36	264.22	−133.30	−139.24
Acetate$^-$(aq)	—	—	—	−372.334
Acetic acid $CH_3CO_2H(l)$	−484.1	159.83	−389.36	−396.60
Acetone $CH_3COCH_3(l)$	−248.1	200.4	−155.39	−161.00
Adenine $C_5H_5N_5(s)$	95.98	151.00	299.49	—
L-Alanine $CH_3CHNH_2COOH(s)$	−562.7	129.20	−370.24	−371.71
L-Alanylglycine $C_5H_{10}N_2O_3(s)$	−826.42	195.05	−532.62	—
L-Aspartate^{+--}(aq)	—	—	—	−698.69
Aspartic acid $C_4H_7NO_4(s)$	−973.37	170.12	−730.23	−719.98
Butyric acid $C_3H_7COOH(s)$	−533.9	226.4	−377.69	—
Citrate^{3-}(aq) $C_6H_5O_7$	—	—	—	−1168.34
Creatine $C_4H_9N_3O_2(s)$	−537.18	189.5	−264.93	—
L-Cysteine $HSCH_2CHNH_2COOH(s)$	−533.9	169.9	−343.97	−340.33
L-Cystine $C_6H_{12}N_2O_4S_2(s)$	−1051.9	280.58	−693.33	−674.29
Ethanol $C_2H_5OH(l)$	−276.98	160.67	−174.14	−180.92
Formaldehyde $CH_2O(g)$	−115.90	218.78	−109.91	−130.5
Formamide $HCONH_2(g)$	−186.2	248.45	−141.04	—
Formic acid $HCOOH(l)$	−424.76	128.95	−361.46	—
Fumarate$^-$(aq)	—	—	—	−604.21
Fumaric acid *trans*-$(=CHCOOH)_2(s)$	−811.07	166.1	−653.67	−646.05
α-D-Galactose $C_6H_{12}O_6(s)$	−1285.37	205.4	−919.43	−924.58
α-D-Glucose $C_6H_{12}O_6(s)$	−1274.4	212.1	−910.52	−917.47
L-Glutamate^{+--}(aq)	—	—	—	−694.00
L-Glutamic acid $C_5H_9NO_4(s)$	−1009.68	118.20	−731.28	−722.70
Glycerol $HOCH_2CHOHCH_2OH(l)$	−668.6	204.47	−477.06	−488.52
Glycine $H_2CNH_2COOH(s)$	−537.2	103.51	−377.69	−379.9
Glycylglycine $C_4H_8N_2O_3(s)$	−745.25	189.95	−490.57	—

TABLE A.7 Organic Compounds* *(cont.)*

	$\Delta H_f^0 \equiv \bar{H}^0$ (kJ mol^{-1})	$\bar{S}^0$ (J K^{-1} mol^{-1})	$\Delta G_f^0 \equiv \bar{G}^0$ (kJ mol^{-1})	$\Delta G_f^0 \equiv \bar{G}^0$ (1 *M* activity, *aq*) (kJ mol^{-1})
Guanine $C_5H_5N_5O(s)$	−183.93	160.2	47.40	—
L-Isoleucine $C_6H_{13}NO_2(s)$	−638.1	207.99	−347.15	—
Lactate$^-$(*aq*)	—	—	—	−517.812
L-Lactic acid $CH_3CHOHCOOH(s)$	−694.08	142.26	−522.92	—
β-Lactose $C_{12}H_{22}O_{11}(s)$	−2236.72	386.2	−1566.99	−1569.92
L-Leucine $C_6H_{13}NO_2(s)$	−646.8	211.79	−357.06	−353.09
Maleic acid *cis*-$(=CHCOOH)_2(s)$	−790.61	159.4	−631.20	—
Methanol $CH_3OH(l)$	−238.57	126.8	−166.23	−175.23
L-Methionine $C_5H_{11}NO_2S(s)$	−758.6	231.08	−505.76	—
Oxalic acid $(-COOH)_2(s)$	−829.94	120.08	−701.15	—
Oxaloacetate^{--}(*aq*) $C_4H_2O_5$	—	—	—	−797.18
L-Phenylalanine $C_9H_{11}NO_2(s)$	−466.9	213.63	−211.59	—
Pyruvate$^-$(*aq*)	—	—	—	−474.33
Pyruvic acid $CH_3COCOOH(l)$	−584.5	179.5	−463.38	—
L-Serine $HOCH_2CHNH_2COOH(s)$	−726.3	149.16	−509.19	—
Succinate^{2-}(*aq*)	—	—	—	−690.23
Succinic acid $(-CH_2COOH)_2(s)$	−940.90	175.7	−747.43	−746.22
Sucrose $C_{12}H_{22}O_{11}(s)$	−2222.1	360.2	−1544.65	−1551.76
L-Tryptophan $C_{11}H_{12}N_2O(s)$	−415.0	251.04	−119.41	—
L-Tyrosine $C_9H_{11}NO_3(s)$	−671.5	214.01	−385.68	−370.83
Urea $NH_2CONH_2(s)$	−333.17	104.60	−197.15	−203.84
L-Valine $C_5H_{11}NO_2(s)$	−617.98	178.86	−358.99	—

* Standard thermodynamic values at 25°C (298 K) and 1 atm pressure. Values for ions refer to an aqueous solution at unit activity on the molarity scale. Standard enthalpy of formation, ΔH_f^0, third-law entropies, S^0, and standard Gibbs free energy of formation, ΔG_f^0, are given.

SOURCES: Data from D. R. Stull, E. F. Westrum, Jr., and G. C. Sinke, *The Chemical Thermodynamics of Organic Compounds,* John Wiley, New York (1969) and from J. T. Edsall and J. Wyman, Biophysical Chemistry, Vol. 1, Academic Press, New York (1958).