Appendix I

Definitions of the SI Base Units

Metre (m): The metre, symbol m, is the SI unit of length. It is defined by taking the fixed numerical value of the speed of light in vacuum c to be 299792458 when expressed in the unit ms-1, where the second is defined in terms of the caesium frequency.

Kilogram (k): The kilogram, symbol kg, is the SI unit of mass. It is defined by taking the fixed numerical value of the planck constant *h* to be $6.62607015 \times 10^{-34}$ when expressed in the unit Js, which is equal to kgm2s-1, where the metre and the second are defined in terms of c and Δ *Vcs*.

Second (s): The symbol s, is the SI unit of time. It is defined by taking the fixed numerical value of the caesium frequency Δ *Vcs*, the unperturbed ground-state hyperfine transition frequency of the caesium-133 atom, to be 9192631770 when expressed in the unit Hz, which is equal to s^{-1}.

Ampere (A): The ampere, symbol A, is the SI unit of electric current. It is defined by taking the fixed numerical value of the elementary charge e to be $1.602176634 \times 10^{-19}$ when expressed in the unit C, which is equal to A s, where the second is defined in terms of.

Kelvin (K): The Kelvin, symbol K, is the SI unit of thermodynamic temperature. It is defined by taking the fixed numerical value of the Boltzmann constant *K* to be 1.380649×10^{-23} when expressed in the unit JK^{-1}, which is equal to $kgm^2s^{-2}K^{-1}$, where the kilogram, metre and second are defined in terms of *h*, *c* and Δ *Vcs*.

Mole (mol): The mole, symbol mol, is the SI unit of amount of substance. One mole contains exactly $6.02214076 \times 10^{23}$ elementary entities. This number is the fixed numerical value of the Avogadro constant, N_A, when expressed in the unit mol^{-1} and is called the Avogadro number. The amount of substance, symbol n, of a system is a measure of the number of specified elementary entities. An elementary entity may be an atom, a molecule, an ion, an electron, any other particle or specified group of particles.

Candela (cd): The candela, symbol cd is the SI unit of luminous intensity in a given direction. It is defined by taking the fixed numerical value of the luminous efficacy of monochromatic radiation of frequency 540×10^{12} Hz, K_{cd}, to be 683 when expressed in the unit $lm \cdot W^{-1}$, which is equal to $cd \cdot sr \cdot W^{-1}$, or cd sr $kg^{-1}m^{-2}s^3$, where the kilogram, metre and second are defined in terms of *h*, *c* and Δ *Vcs*.

(The symbols listed here are internationally agreed and should not be changed in other languages and scripts.

Appendix II

Elements, their Atomic Number and Molar Mass

Element	Symbol	Atomic Number	Molar mass/ (g mol^{-1})
Actinium	Ac	89	227.03
Aluminium	Al	13	26.98
Americium	Am	95	(243)
Antimony	Sb	51	121.75
Argon	Ar	18	39.95
Arsenic	As	33	74.92
Astatine	At	85	210
Barium	Ba	56	137.34
Berkelium	Bk	97	(247)
Beryllium	Be	4	9.01
Bismuth	Bi	83	208.98
Bohrium	Bh	107	(264)
Boron	B	5	10.81
Bromine	Br	35	79.91
Cadmium	Cd	48	112.40
Caesium	Cs	55	132.91
Calcium	Ca	20	40.08
Californium	Cf	98	251.08
Carbon	C	6	12.01
Cerium	Ce	58	140.12
Chlorine	Cl	17	35.45
Chromium	Cr	24	52.00
Cobalt	Co	27	58.93
Copper	Cu	29	63.54
Curium	Cm	96	247.07
Dubnium	Db	105	(263)
Dysprosium	Dy	66	162.50
Einsteinium	Es	99	(252)
Erbium	Er	68	167.26
Europium	Eu	63	151.96
Fermium	Fm	100	(257.10)
Fluorine	F	9	19.00
Francium	Fr	87	(223)
Gadolinium	Gd	64	157.25
Gallium	Ga	31	69.72
Germanium	Ge	32	72.61
Gold	Au	79	196.97
Hafnium	Hf	72	178.49
Hassium	Hs	108	(269)
Helium	He	2	4.00
Holmium	Ho	67	164.93
Hydrogen	H	1	1.0079
Indium	In	49	114.82
Iodine	I	53	126.90
Iridium	Ir	77	192.2
Iron	Fe	26	55.85
Krypton	Kr	36	83.80
Lanthanum	La	57	138.91
Lawrencium	Lr	103	(262.1)
Lead	Pb	82	207.19
Lithium	Li	3	6.94
Lutetium	Lu	71	174.96
Magnesium	Mg	12	24.31
Manganese	Mn	25	54.94
Meitneium	Mt	109	(268)
Mendelevium	Md	101	258.10

Element	Symbol	Atomic Number	Molar mass/ (g mol^{-1})
Mercury	Hg	80	200.59
Molybdenum	Mo	42	95.94
Neodymium	Nd	60	144.24
Neon	Ne	10	20.18
Neptunium	Np	93	(237.05)
Nickel	Ni	28	58.71
Niobium	Nb	41	92.91
Nitrogen	N	7	14.0067
Nobelium	No	102	(259)
Osmium	Os	76	190.2
Oxygen	O	8	16.00
Palladium	Pd	46	106.4
Phosphorus	P	15	30.97
Platinum	Pt	78	195.09
Plutonium	Pu	94	(244)
Polonium	Po	84	210
Potassium	K	19	39.10
Praseodymium	Pr	59	140.91
Promethium	Pm	61	(145)
Protactinium	Pa	91	231.04
Radium	Ra	88	(226)
Radon	Rn	86	(222)
Rhenium	Re	75	186.2
Rhodium	Rh	45	102.91
Rubidium	Rb	37	85.47
Ruthenium	Ru	44	101.07
Rutherfordium	Rf	104	(261)
Samarium	Sm	62	150.35
Scandium	Sc	21	44.96
Seaborgium	Sg	106	(266)
Selenium	Se	34	78.96
Silicon	Si	14	28.08
Silver	Ag	47	107.87
Sodium	Na	11	22.99
Strontium	Sr	38	87.62
Sulphur	S	16	32.06
Tantalum	Ta	73	180.95
Technetium	Tc	43	(98.91)
Tellurium	Te	52	127.60
Terbium	Tb	65	158.92
Thallium	Tl	81	204.37
Thorium	Th	90	232.04
Thulium	Tm	69	168.93
Tin	Sn	50	118.69
Titanium	Ti	22	47.88
Tungsten	W	74	183.85
Ununbium	Uub	112	(277)
Ununnilium	Uun	110	(269)
Unununium	Uuu	111	(272)
Uranium	U	92	238.03
Vanadium	V	23	50.94
Xenon	Xe	54	131.30
Ytterbium	Yb	70	173.04
Yttrium	Y	39	88.91
Zinc	Zn	30	65.37
Zirconium	Zr	40	91.22

The value given in parenthesis is the molar mass of the isotope of largest known half-life.

Appendix III

A. Specific and Molar Heat Capacities for Some Substances at 298 K and one Atmospheric Pressure

Substance	Specific Heat Capacity (J/g)	Molar Heat Capacity (J/mol)
air	0.720	20.8
water (liquid)	4.184	75.4
ammonia (gas)	2.06	35.1
hydrogen chloride	0.797	29.1
hydrogen bromide	0.360	29.1
ammonia (liquid)	4.70	79.9
ethyl alcohol (liquid)	2.46	113.16
ethylene glycol (liquid)	2.42	152.52
water (solid)	2.06	37.08
carbon tetrachloride (liquid)	0.861	132.59
chlorofluorocarbon (CCl_2F_2)	0.5980	72.35
ozone	0.817	39.2
neon	1.03	20.7
chlorine	0.477	33.8
bromine	0.473	75.6
iron	0.460	25.1
copper	0.385	24.7
aluminium	0.902	24.35
gold	0.128	25.2
graphite	0.720	8.65

B. Molar Heat Capacities for Some Gases (J/mol)

Gas	C_p	C_v	$C_p - C_v$	C_p / C_v
Monatomic*				
helium	20.9	12.8	8.28	1.63
argon	20.8	12.5	8.33	1.66
iodine	20.9	12.6	8.37	1.66
mercury	20.8	12.5	8.33	1.66
Diatomic†				
hydrogen	28.6	20.2	8.33	1.41
oxygen	29.1	20.8	8.33	1.39
nitrogen	29.0	20.7	8.30	1.40
hydrogen chloride	29.6	21.0	8.60	1.39
carbon monoxide	29.0	21.0	8.00	1.41
Triatomic†				
nitrous oxide	39.0	30.5	8.50	1.28
carbon dioxide	37.5	29.0	8.50	1.29
Polyatomic†				
ethane	53.2	44.6	8.60	1.19

*Translational kinetic energy only.
†Translational, vibrational and rotational energy.

Appendix IV

Physical Constants

Quantity	Symbol	Traditional Units	SI Units
Acceleration of gravity	g	980.6 cm/s	9.806 m/s
Atomic mass unit (1/12 the mass of ^{12}C atom)	amu or u	1.6606×10^{-24} g	1.6606×10^{-27} kg
Avogadro constant	N_A	6.022×10^{23} particles/mol	6.022×10^{23} particles/mol
Bohr radius	a_o	0.52918 Å 5.2918×10^{-9} cm	5.2918×10^{-11} m
Boltzmann constant	k	1.3807×10^{-16} erg/K	1.3807×10^{-23} J/K
Charge-to-mass ratio of electron	e/m	1.758820×10^{8} coulomb/g	1.7588×10^{11} C/kg
Electronic charge	e	1.602176×10^{-19} coulomb 4.8033×10^{-19} esu	1.60219×10^{-19} C
Electron rest mass	m_e	9.109382×10^{-28} g 0.00054859 u	9.10952×10^{-31} kg
Faraday constant	F	96,487 coulombs/eq 23.06 kcal/volt. eq	96,487 C/mol e^- 96,487 J/V.mol e^-
Gas constant	R	$0.8206 \frac{\text{L atm}}{\text{mol K}}$ $1.987 \frac{\text{cal}}{\text{mol K}}$	$8.3145 \frac{\text{kPa dm}^3}{\text{mol K}}$ 8.3145 J/mol.K
Molar volume (STP)	V_m	22.710981 L/mol	22.710981×10^{-3} m^3/mol 22.710981 dm^3/mol
Neutron rest mass	m_n	1.674927×10^{-24} g 1.008665 u	1.67495×10^{-27} kg
Planck constant	h	6.6262×10^{-27} ergs	6.6262×10^{-34} J s
Proton rest mass	m_p	$1.6726216 \times 10^{-24}$ g 1.007277 u	1.6726×10^{-27} kg
Rydberg constant	R_∞	3.289×10^{15} cycles/s 2.1799×10^{-11} erg	1.0974×10^{7} m^{-1} 2.1799×10^{-18} J
Speed of light (in a vacuum)	c	2.9979×10^{10} cm/s (186,281 miles/second)	2.9979×10^{8} m/s

$\pi = 3.1416$

$e = 2.71828$

$\ln X = 2.303 \log X$

$2.303\ R = 4.576$ cal/mol K $= 19.15$ J/mol K

$2.303\ RT$ (at 25°C) = 1364 cal/mol = 5709 J/mol

Appendix V

Some Useful Conversion Factors

Common Unit of Mass and Weight
1 pound = 453.59 grams

1 pound = 453.59 grams = 0.45359 kilogram
1 kilogram = 1000 grams = 2.205 pounds
1 gram = 10 decigrams = 100 centigrams
= 1000 milligrams
1 gram = 6.022×10^{23} atomic mass units or u
1 atomic mass unit = 1.6606×10^{-24} gram
1 metric tonne = 1000 kilograms
= 2205 pounds

Common Unit of Volume
1 quart = 0.9463 litre
1 litre = 1.056 quarts

1 litre = 1 cubic decimetre = 1000 cubic centimetres = 0.001 cubic metre
1 millilitre = 1 cubic centimetre = 0.001 litre
= 1.056×10^{-3} quart
1 cubic foot = 28.316 litres = 29.902 quarts
= 7.475 gallons

Common Units of Energy
1 joule = 1×10^7 ergs

1 thermochemical calorie**
= 4.184 joules
= 4.184×10^7 ergs
= 4.129×10^{-2} litre-atmospheres
= 2.612×10^{19} electron volts
1 ergs = 1×10^{-7} joule = 2.3901×10^{-8} calorie
1 electron volt = 1.6022×10^{-19} joule
= 1.6022×10^{-12} erg
= 96.487 kJ/mol†
1 litre-atmosphere = 24.217 calories
= 101.32 joules
= 1.0132×10^9 ergs
1 British thermal unit = 1055.06 joules
= 1.05506×10^{10} ergs
= 252.2 calories

Common Units of Length
1 inch = 2.54 centimetres (exactly)

1 mile = 5280 feet = 1.609 kilometres
1 yard = 36 inches = 0.9144 metre
1 metre = 100 centimetres = 39.37 inches
= 3.281 feet
= 1.094 yards
1 kilometre = 1000 metres = 1094 yards
= 0.6215 mile
1 Angstrom = 1.0×10^{-8} centimetre
= 0.10 nanometre
= 1.0×10^{-10} metre
= 3.937×10^{-9} inch

Common Units of Force* and Pressure

1 atmosphere = 760 millimetres of mercury
= 1.013×10^5 pascals
= 14.70 pounds per square inch
1 bar = 10^5 pascals
1 torr = 1 millimetre of mercury
1 pascal = 1 kg/ms^2 = 1 N/m^2

Temperature
SI Base Unit: Kelvin (K)

K = -273.15°C
K = °C + 273.15
°F = 1.8(°C) + 32

$$°C = \frac{°F - 32}{1.8}$$

* Force: 1 newton (N) = 1 kg m/s^2, i.e., the force that, when applied for 1 second, gives a 1-kilogram mass a velocity of 1 metre per second.
** The amount of heat required to raise the temperature of one gram of water from 14.5°C to 15.5°C.
† Note that the other units are per particle and must be multiplied by 6.022×10^{23} to be strictly comparable.

Appendix VI

Thermodynamic Data at 298 K

INORGANIC SUBSTANCES

Substance	Enthalpy of formation, $\Delta_f H^\ominus$ / (kJ mol^{-1})	Gibbs Energy of formation, $\Delta_f G^\ominus$ / (kJ mol^{-1})	Entropy,* $S^\ominus$/(J K^{-1} mol^{-1})
Aluminium			
Al(s)	0	0	28.33
Al^{3+}(aq)	– 524.7	–481.2	–321.7
Al_2O_3(s)	–1675.7	–1582.3	50.92
$Al(OH)_3$(s)	–1276	—	—
$AlCl_3$(s)	–704.2	–628.8	110.67
Antimony			
SbH_3(g)	145.11	147.75	232.78
$SbCl_3$(g)	–313.8	–301.2	337.80
$SbCl_5$(g)	–394.34	–334.29	401.94
Arsenic			
As(s), gray	0	0	35.1
As_2S_3(s)	–169.0	–168.6	163.6
AsO_4^{3-}(aq)	–888.14	–648.41	–162.8
Barium			
Ba(s)	0	0	62.8
Ba^{2+}(aq)	–537.64	–560.77	9.6
BaO(s)	–553.5	–525.1	70.42
$BaCO_3$(s)	–1216.3	–1137.6	112.1
$BaCO_3$(aq)	–1214.78	–1088.59	–47.3
Boron			
B(s)	0	0	5.86
B_2O_3(s)	–1272.8	–1193.7	53.97
BF_3(g)	–1137.0	–1120.3	254.12
Bromine			
Br_2(l)	0	0	152.23
Br_2(g)	30.91	3.11	245.46
Br(g)	111.88	82.40	175.02
Br^-(aq)	–121.55	–103.96	82.4
HBr(g)	–36.40	–53.45	198.70
BrF_3(g)	–255.60	–229.43	292.53
Calcium			
Ca(s)	0	0	41.42
Ca(g)	178.2	144.3	154.88
Ca^{2+}(aq)	–542.83	–553.58	–53.1

(continued)

Substance	Enthalpy of formation, $\Delta_f H^\ominus$/ (kJ mol^{-1})	Gibbs Energy of formation, $\Delta_f G^\ominus$/ (kJ mol^{-1})	Entropy,* $S^\ominus$/(J K^{-1} mol^{-1})
Calcium (continued)			
CaO(s)	–635.09	–604.03	39.75
$Ca(OH)_2$(s)	–986.09	–898.49	83.39
$Ca(OH)_2$(aq)	–1002.82	–868.07	–74.5
$CaCO_3$(s), calcite	–1206.92	–1128.8	92.9
$CaCO_3$(s), aragonite	–1207.1	–1127.8	88.7
$CaCO_3$(aq)	–1219.97	–1081.39	–110.0
CaF_2(s)	–1219.6	–1167.3	68.87
CaF_2(aq)	–1208.09	–1111.15	–80.8
$CaCl_2$(s)	–795.8	–748.1	104.6
$CaCl_2$(aq)	–877.1	–816.0	59.8
$CaBr_2$(s)	–682.8	–663.6	130
CaC_2(s)	–59.8	–64.9	69.96
CaS(s)	–482.4	–477.4	56.5
$CaSO_4$(s)	–1434.11	–1321.79	106.7
$CaSO_4$(aq)	–1452.10	–1298.10	–33.1
*Carbon***			
C(s), graphite	0	0	5.740
C(s), diamond	1.895	2.900	2.377
C(g)	716.68	671.26	158.10
CO(g)	–110.53	–137.17	197.67
CO_2(g)	–393.51	–394.36	213.74
CO_3^{2-}(aq)	–677.14	–527.81	–56.9
CCl_4(l)	–135.44	–65.21	216.40
CS_2(l)	89.70	65.27	151.34
HCN(g)	135.1	124.7	201.78
HCN(l)	108.87	124.97	112.84
Cerium			
Ce(s)	0	0	72.0
Ce^{3+}(aq)	–696.2	–672.0	–205
Ce^{4+}(aq)	–537.2	–503.8	–301
Chlorine			
Cl_2(g)	0	0	223.07
Cl(g)	121.68	105.68	165.20
Cl^-(aq)	–167.16	–131.23	56.5
HCl(g)	–92.31	–95.30	186.91
HCl(aq)	–167.16	–131.23	56.5
Copper			
Cu(s)	0	0	33.15
Cu^+(aq)	71.67	49.98	40.6
Cu^{2+}(aq)	64.77	65.49	–99.6
Cu_2O(aq)	–168.6	–146.0	93.14
CuO(s)	–157.3	–129.7	42.63
$CuSO_4$(s)	–771.36	–661.8	109
$CuSO_4.5H_2O$(s)	–2279.7	–1879.7	300.4

(continued)

** For organic compounds, a separate table is provided in continuation.

Substance	Enthalpy of formation, $\Delta_f H^\ominus$/ (kJ mol^{-1})	Gibbs Energy of formation, $\Delta_f G^\ominus$/ (kJ mol^{-1})	Entropy,* $S^\ominus$/(J K^{-1} mol^{-1})
Deuterium			
$D_2(g)$	0	0	144.96
$D_2O(g)$	–249.20	–234.54	198.34
$D_2O(l)$	–294.60	–243.44	75.94
Fluorine			
$F_2(g)$	0	0	202.78
$F^-(aq)$	–332.63	–278.79	–13.8
HF(g)	–271.1	–273.2	173.78
HF(aq)	–332.63	–278.79	–13.8
Hydrogen (see also Deuterium)			
$H_2(g)$	0	0	130.68
H(g)	217.97	203.25	114.71
$H^+(aq)$	0	0	0
$H_2O(l)$	–285.83	–237.13	69.91
$H_2O(g)$	–241.82	–228.57	188.83
$H_2O_2(l)$	–187.78	–120.35	109.6
$H_2O_2(aq)$	–191.17	–134.03	143.9
Iodine			
$I_2(s)$	0	0	116.14
$I_2(g)$	62.44	19.33	260.69
$I^-(aq)$	–55.19	–51.57	111.3
HI(g)	26.48	1.70	206.59
Iron			
Fe(s)	0	0	27.28
$Fe^{2+}(aq)$	–89.1	–78.90	–137.7
$Fe^{3+}(aq)$	–48.5	–4.7	–315.9
$Fe_3O_4(s)$, magnetite	–1118.4	–1015.4	146.4
$Fe_2O_3(s)$, haematite	–824.2	–742.2	87.40
FeS(s,α)	–100.0	–100.4	60.29
FeS(aq)	—	6.9	—
$FeS_2(s)$	–178.2	–166.9	52.93
Lead			
Pb(s)	0	0	64.81
$Pb^{2+}(aq)$	–1.7	–24.43	10.5
$PbO_2(s)$	–277.4	–217.33	68.6
$PbSO_4(s)$	–919.94	–813.14	148.57
$PbBr_2(s)$	–278.7	–261.92	161.5
$PbBr_2(aq)$	–244.8	–232.34	175.3
Magnesium			
Mg(s)	0	0	32.68
Mg(g)	147.70	113.10	148.65
$Mg^{2+}(aq)$	–466.85	–454.8	–138.1
MgO(s)	–601.70	–569.43	26.94
$MgCO_3(s)$	–1095.8	–1012.1	65.7
$MgBr_2(s)$	–524.3	–503.8	117.2

(continued)

Substance	Enthalpy of formation, $\Delta_f H^\ominus$ / (kJ mol^{-1})	Gibbs Energy of formation, $\Delta_f G^\ominus$ / (kJ mol^{-1})	Entropy,* $S^\ominus$ /(J K^{-1} mol^{-1})
Mercury			
Hg(1)	0	0	76.02
Hg(g)	61.32	31.82	174.96
HgO(s)	–90.83	–58.54	70.29
Hg_2Cl_2(s)	–265.22	–210.75	192.5
Nitrogen			
N_2(g)	0	0	191.61
NO(g)	90.25	86.55	210.76
N_2O(g)	82.05	104.20	219.85
NO_2(g)	33.18	51.31	240.06
N_2O_4(g)	9.16	97.89	304.29
HNO_3(1)	–174.10	–80.71	155.60
HNO_3(aq)	–207.36	–111.25	146.4
NO_3^-(aq)	–205.0	–108.74	146.4
NH_3(g)	–46.11	–16.45	192.45
NH_3(aq)	–80.29	–26.50	111.3
NH_4^+(aq)	–132.51	–79.31	113.4
NH_2OH(s)	–114.2	—	—
HN_3(g)	294.1	328.1	238.97
N_2H_4(1)	50.63	149.34	121.21
NH_4NO_3(s)	–365.56	–183.87	151.08
NH_4Cl(s)	–314.43	–202.87	94.6
NH_4ClO_4(s)	–295.31	–88.75	186.2
Oxygen			
O_2(g)	0	0	205.14
O_3(g)	142.7	163.2	238.93
OH^-(aq)	–229.99	–157.24	–10.75
Phosphorus			
P(s), white	0	0	41.09
P_4(g)	58.91	24.44	279.98
PH_3(g)	5.4	13.4	210.23
P_4O_{10}(s)	–2984.0	–2697.0	228.86
H_3PO_3(aq)	–964.8	—	—
H_3PO_4(1)	–1266.9	—	—
H_3PO_4(aq)	–1277.4	–1018.7	—
PCl_3(1)	–319.7	–272.3	217.18
PCl_3(g)	–287.0	–267.8	311.78
PCl_5(g)	–374.9	–305.0	364.6
Potassium			
K(s)	0	0	64.18
K(g)	89.24	60.59	160.34
K^+(aq)	–252.38	–283.27	102.5
KOH(s)	–424.76	–379.08	78.9
KOH(aq)	–482.37	–440.50	91.6
KF(s)	–567.27	–537.75	66.57

(continued)

Substance	Enthalpy of formation, $\Delta_f H^\ominus$ / (kJ mol^{-1})	Gibbs Energy of formation, $\Delta_f G^\ominus$ / (kJ mol^{-1})	Entropy,* $S^\ominus$/(J K^{-1} mol^{-1})
Potassium (continued)			
KCl(s)	–436.75	–409.14	82.59
KBr(s)	–393.80	–380.66	95.90
KI(s)	–327.90	–324.89	106.32
$KClO_3$(s)	–397.73	–296.25	143.1
$KClO_4$(s)	–432.75	–303.09	151.0
K_2S(s)	–380.7	–364.0	105
K_2S(aq)	–471.5	–480.7	190.4
Silicon			
Si(s)	0	0	18.83
SiO_2(s,α)	–910.94	–856.64	41.84
Silver			
Ag(s)	0	0	42.55
Ag^+(aq)	105.58	77.11	72.68
Ag_2O(s)	–31.05	–11.20	121.3
AgBr(s)	–100.37	–96.90	107.1
AgBr(aq)	–15.98	–26.86	155.2
AgCl(s)	–127.07	–109.79	96.2
AgCl(aq)	–61.58	–54.12	129.3
AgI(s)	–61.84	–66.19	115.5
AgI(aq)	50.38	25.52	184.1
$AgNO_3$(s)	–124.39	–33.41	140.92
Sodium			
Na(s)	0	0	51.21
Na(g)	107.32	76.76	153.71
Na^+(aq)	–240.12	–261.91	59.0
NaOH(s)	–425.61	–379.49	64.46
NaOH(aq)	–470.11	–419.15	48.1
NaCl(s)	–411.15	–384.14	72.13
NaCl(aq)	–407.3	–393.1	115.5
NaBr(s)	–361.06	–348.98	86.82
NaI(s)	–287.78	–286.06	98.53
$NaHCO_3$(s)	–947.7	–851.9	102.1
Na_2CO_3(s)	–1130.9	–1047.7	136.0
Sulphur			
S(s), rhombic	0	0	31.80
S(s), monoclinic	0.33	0.1	32.6
S^{2-}(aq)	33.1	85.8	–14.6
SO_2(g)	–296.83	–300.19	248.22
SO_3(g)	–395.72	–371.06	256.76
H_2SO_4(l)	–813.99	–690.00	156.90
H_2SO_4(aq)	–909.27	–744.53	20.1
SO_4^{2-}(aq)	–909.27	–744.53	20.1
H_2S(g)	–20.63	–33.56	205.79
H_2S(aq)	–39.7	–27.83	121
SF_6(g)	–1209	–1105.3	291.82

(continued)

Substance	Enthalpy of formation, $\Delta_f H^\ominus$ / (kJ mol^{-1})	Gibbs Energy of formation, $\Delta_f G^\ominus$ / (kJ mol^{-1})	Entropy,* $S^\ominus$/(J K^{-1} mol^{-1})
Tin			
Sn(s), white	0	0	51.55
Sn(s), gray	–2.09	0.13	44.14
SnO(s)	–285.8	–256.9	56.5
SnO_2(s)	–580.7	–519.6	52.3
Zinc			
Zn(s)	0	0	41.63
Zn^{2+}(aq)	–153.89	–147.06	–112.1
ZnO(s)	–348.28	–318.30	43.64
Zn(g)	+130.73	+95.14	160.93

*The entropies of individual ions in solution are determined by setting the entropy of H^+ in water equal to 0 and then defining the entropies of all other ions relative to this value; hence a negative entropy is one that is lower than the entropy of H^+ in water.

ORGANIC COMPOUNDS

Substance	Enthalpy of combustion, $\Delta_c H^\ominus$ / (kJ mol^{-1})	Enthalpy of formation, $\Delta_f H^\ominus$ / (kJ mol^{-1})	Gibbs Energy of formation, $\Delta_f G^\ominus$ / (kJ mol^{-1})	Entropy, $S^\ominus$/(J K^{-1} mol^{-1})
Hydrocarbons				
CH_4(g), methane	–890	–74.81	–50.72	186.26
C_2H_2(g), ethyne (acetylene)	–1300	226.73	209.20	200.94
C_2H_4(g), ethene(ethylene)	–1411	52.26	68.15	219.56
C_2H_6(g), ethane	–1560	–84.68	–32.82	229.60
C_3H_6(g), propene (propylene)	–2058	20.42	62.78	266.6
C_3H_6(g), cyclopropane	–2091	53.30	104.45	237.4
C_3H_8(g), propane	–2220	–103.85	–23.49	270.2
C_4H_{10}(g), butane	–2878	–126.15	–17.03	310.1
C_5H_{12}(g), pentane	–3537	–146.44	–8.20	349
C_6H_6(l), benzene	–3268	49.0	124.3	173.3
C_6H_6(g)	–3302	—	—	—
C_7H_8(l), toluene	–3910	12.0	113.8	221.0
C_7H_8(g)	–3953	—	—	—
C_6H_{12}(l), cyclohexane	–3920	–156.4	26.7	204.4
C_6H_{12}(g),	–3953	—	—	—
C_8H_{18}(l), octane	–5471	–249.9	6.4	358
Alcohols and phenols				
CH_3OH(l), methanol	–726	–238.86	–166.27	126.8
CH_3OH(g)	–764	–200.66	–161.96	239.81
C_2H_5OH(l), ethanol	–1368	–277.69	–174.78	160.7
C_2H_5OH(g)	–1409	–235.10	–168.49	282.70
C_6H_5OH(s), phenol	–3054	–164.6	–50.42	144.0

(continued)

Substance	Enthalpy of combustion, $\Delta_c H^\ominus$/ (kJ mol^{-1})	Enthalpy of formation, $\Delta_f H^\ominus$/ (kJ mol^{-1})	Gibbs Energy of formation, $\Delta_f G^\ominus$/ (kJ mol^{-1})	Entropy, $S^\ominus$/(J K^{-1} mol^{-1})
Carboxylic acid				
HCOOH(l), formic acid	–255	–424.72	–361.35	128.95
CH_3COOH(l), acetic acid	–875	–484.5	–389.9	159.8
CH_3COOH (aq)	—	–485.76	–396.64	86.6
$(COOH)_2$(s), oxalic acid	–254	–827.2	–697.9	120
C_6H_5COOH(s), benzoic acid	–3227	–385.1	–245.3	167.6
Aldehydes and ketones				
HCHO(g), methanal (formaldehyde)	–571	–108.57	–102.53	218.77
CH_3CHO(l), ethanal (acetaldehyde)	–1166	–192.30	–128.12	160.2
CH_3CHO(g)	–1192	–166.19	–128.86	250.3
CH_3COCH_3(l), propanone (acetone)	–1790	–248.1	–155.4	200
Sugars				
$C_6H_{12}O_6$(s), glucose	–2808	–1268	–910	212
$C_6H_{12}O_6$(aq)	—	—	–917	—
$C_6H_{12}O_6$(s), fructose	–2810	–1266	—	—
$C_{12}H_{22}O_{11}$(s), sucrose	–5645	–2222	–1545	360
Nitrogen compounds				
$CO(NH_2)_2$(s), urea	–632	–333.51	–197.33	104.60
$C_6H_5NH_2$(l), aniline	–3393	31.6	149.1	191.3
NH_2CH_2COOH(s), glycine	–969	–532.9	–373.4	103.51
CH_3NH_2(g), methylamine	–1085	–22.97	32.16	243.41

Appendix VII

Standard potentials at 298 K in electrochemical order

Reduction half-reaction	$E^\ominus$/V	Reduction half-reaction	$E^\ominus$/V
$H_4XeO_6 + 2H^+ + 2e^- \longrightarrow XeO_3 + 3H_2O$	+3.0	$Cu^+ + e^- \longrightarrow Cu$	+0.52
$F_2 + 2e^- \longrightarrow 2F-$	+2.87	$NiOOH + H_2O + e^- \longrightarrow Ni(OH)_2 + OH^-$	+0.49
$O_3 + 2H^+ + 2e^- \longrightarrow O_2 + H_2O$	+2.07	$Ag_2CrO_4 + 2e^- \longrightarrow 2Ag + CrO_4^{2-}$	+0.45
$S_2O_8^{2-} + 2e^- \longrightarrow 2SO_4^{2-}$	+2.05	$O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$	+0.40
$Ag^+ + e^- \longrightarrow Ag^+$	+1.98	$ClO_4^- + H_2O + 2e^- \longrightarrow ClO^-_3 + 2OH^-$	+0.36
$Co^{3+} + e^- \longrightarrow Co^{2+}$	+1.81	$[Fe(CN)_6]^{3-} + e^- \longrightarrow [Fe(CN)_6]^{4-}$	+0.36
$H_2O_2 + 2H^+ + 2e^- \longrightarrow 2H_2O$	+1.78	$Cu^{2+} + 2e^- \longrightarrow Cu$	+0.34
$Au^+ + e^- \longrightarrow Au$	+1.69	$Hg_2Cl_2 + 2e^- \longrightarrow 2Hg + 2Cl^-$	+0.27
$Pb^{4+} + 2e^- \longrightarrow Pb^{2+}$	+1.67	$AgCl + e^- \longrightarrow Ag + Cl^-$	+0.27
$2HClO + 2H^+ + 2e^- \longrightarrow Cl_2 + 2H_2O$	+1.63	$Bi^{3+} + 3e^- \longrightarrow Bi$	+0.20
$Ce^{4+} + e^- \longrightarrow Ce^{3+}$	+1.61	$SO_4^{2-} + 4H^+ + 2e^- \longrightarrow H_2SO_3 + H_2O$	+0.17
$2HBrO + 2H^+ + 2e^- \longrightarrow Br_2 + 2H_2O$	+1.60	$Cu^{2+} + e^- \longrightarrow Cu^+$	+0.16
$MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$	+1.51	$Sn^{4+} + 2e^- \longrightarrow Sn^{2+}$	+0.15
$Mn^{3+} + e^- \longrightarrow Mn^{2+}$	+1.51	$AgBr + e^- \longrightarrow Ag + Br^-$	+0.07
$Au^{3+} + 3e^- \longrightarrow Au$	+1.40	$Ti^{4+} + e^- \longrightarrow Ti^{3+}$	0.00
$Cl_2 + 2e^- \longrightarrow 2Cl^-$	+1.36	$2H^+ + 2e- \longrightarrow H_2$	0.0 by definition
$Cr_2O_7^{2-} + 14H^+ + 6e^- \longrightarrow 2Cr^{3+} + 7H_2O$	+1.33	$Fe^{3+} + 3e^- \longrightarrow Fe$	–0.04
$O_3 + H_2O + 2e^- \longrightarrow O_2 + 2OH^-$	+1.24	$O_2 + H_2O + 2e^- \longrightarrow HO_2^- + OH^-$	–0.08
$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$	+1.23	$Pb^{2+} + 2e^- \longrightarrow Pb$	–0.13
$ClO_4^- + 2H^+ + 2e^- \longrightarrow ClO^-_3 + 2H_2O$	+1.23	$In^+ + e^- \longrightarrow In$	–0.14
$MnO_2 + 4H^+ + 2e^- \longrightarrow Mn^{2+} + 2H_2O$	+1.23	$Sn^{2+} + 2e^- \longrightarrow Sn$	–0.14
$Pt^{2+} + 2e^- \longrightarrow Pt$	+1.20	$AgI + e^- \longrightarrow Ag + I^-$	–0.15
$Br_2 + 2e^- \longrightarrow 2Br^-$	+1.09	$Ni^{2+} + 2e^- \longrightarrow Ni$	–0.23
$Pu^{4+} + e^- \longrightarrow Pu^{3+}$	+0.97	$V^{3+} + e^- \longrightarrow V^{2+}$	–0.26
$NO^-_3 + 4H^+ + 3e^- \longrightarrow NO + 2H_2O$	+0.96	$Co^{2+} + 2e^- \longrightarrow Co$	–0.28
$2Hg^{2+} + 2e^- \longrightarrow Hg_2^{2+}$	+0.92	$In^{3+} + 3e^- \longrightarrow In$	–0.34
$ClO^- + H_2O + 2e^- \longrightarrow Cl^- + 2OH^-$	+0.89	$Tl^+ + e^- \longrightarrow Tl$	–0.34
$Hg^{2+} + 2e^- \longrightarrow Hg$	+0.86	$PbSO_4 + 2e^- \longrightarrow Pb + SO_4^{2-}$	–0.36
$NO_3^- + 2H^+ + e^- \longrightarrow NO_2 + H_2O$	+0.80	$Ti^{3+} + e^- \longrightarrow Ti^{2+}$	–0.37
$Ag^+ + e^- \longrightarrow Ag$	+0.80	$Cd^{2+} + 2e^- \longrightarrow Cd$	–0.40
$Hg_2^{2+} + 2e^- \longrightarrow 2Hg$	+0.79	$In^{2+} + e^- \longrightarrow In^+$	–0.40
$Fe^{3+} + e^- \longrightarrow Fe^{2+}$	+0.77	$Cr^{3+} + e^- \longrightarrow Cr^{2+}$	–0.41
$BrO^- + H_2O + 2e^- \longrightarrow Br^- + 2OH^-$	+0.76	$Fe^{2+} + 2e^- \longrightarrow Fe$	–0.44
$Hg_2SO_4 + 2e^- \longrightarrow 2Hg + SO_4^{2-}$	+0.62	$In^{3+} + 2e^- \longrightarrow In^+$	–0.44
$MnO_4^{2-} + 2H_2O + 2e^- \longrightarrow MnO_2 + 4OH^-$	+0.60	$S + 2e^- \longrightarrow S^{2-}$	–0.48
$MnO_4^- + e^- \longrightarrow MnO_4^{2-}$	+0.56	$In^{3+} + e^- \longrightarrow In^{2+}$	–0.49
$I_2 + 2e^- \longrightarrow 2I^-$	+0.54	$U^{4+} + e^- \longrightarrow U^{3+}$	–0.61
$I_3^- + 2e^- \longrightarrow 3I^-$	+0.53	$Cr^{3+} + 3e^- \longrightarrow Cr$	–0.74
		$Zn^{2+} + 2e^- \longrightarrow Zn$	–0.76

(continued)

Appendix continued

Reduction half-reaction	$E^{\ominus}$**/V**	**Reduction half-reaction**	$E^{\ominus}$**/V**
$Cd(OH)_2 + 2e^- \longrightarrow Cd + 2OH^-$	–0.81	$La^{3+} + 3e^- \longrightarrow La$	–2.52
$2H_2O + 2e^- \longrightarrow H_2 + 2OH^-$	–0.83	$Na^+ + e^- \longrightarrow Na$	–2.71
$Cr^{2+} + 2e^- \longrightarrow Cr$	–0.91	$Ca^{2+} + 2e^- \longrightarrow Ca$	–2.87
$Mn^{2+} + 2e^- \longrightarrow Mn$	–1.18	$Sr^{2+} + 2e^- \longrightarrow Sr$	–2.89
$V^{2+} + 2e^- \longrightarrow V$	–1.19	$Ba^{2+} + 2e^- \longrightarrow Ba$	–2.91
$Ti^{2+} + 2e^- \longrightarrow Ti$	–1.63	$Ra^{2+} + 2e^- \longrightarrow Ra$	–2.92
$Al^{3+} + 3e^- \longrightarrow Al$	–1.66	$Cs^+ + e^- \longrightarrow Cs$	–2.92
$U^{3+} + 3e^- \longrightarrow U$	–1.79	$Rb^+ + e^- \longrightarrow Rb$	–2.93
$Sc^{3+} + 3e^- \longrightarrow Sc$	–2.09	$K^+ + e^- \longrightarrow K$	–2.93
$Mg^{2+} + 2e^- \longrightarrow Mg$	–2.36	$Li^+ + e^- \longrightarrow Li$	–3.05
$Ce^{3+} + 3e^- \longrightarrow Ce$	–2.48		