Formulas, Constants, Conversion Factors, etc.

Ideal Gas Law: $PV = nRT$

$v_{mp} = \sqrt{\frac{2k_BT}{m}}$ $\quad < v > = \sqrt{\frac{8k_BT}{\pi m}}$ $\quad v_{rms} = \sqrt{\frac{3k_BT}{m}} = \sqrt{\frac{3RT}{M}}$

$< KE >$ (per mole) $= \frac{3}{2}RT$ $\quad < KE >$ (per molecule) $= \frac{3}{2}k_BT$; $\quad KE = \frac{1}{2}mv^2$

$1\ J = 1\frac{kg\ m^2}{s^2}$ $\quad 1\ amu = 1.66 \times 10^{-27} kg$

$K_p = K_C(RT)^{\Delta n}$

$K_w = K_aK_b = 1.0 \times 10^{-14}$ at 25°C $\quad pH = -\log[H_3O^+]$; $pOH = -\log[OH^-]$

Solution to the quadratic equation $ax^2 + bx + c = 0$: $x = \frac{-b \pm (b^2 - 4ac)^{1/2}}{2a}$

Henderson-Hasselbalch Equation: $pH = pK_a - \log_{10}\left(\frac{[HA]_o}{[A^-]_o}\right)$

Heat Capacities for an Ideal Monatomic Gas: $C_P = (5/2)R$ $\quad C_V = (3/2)R$

work (against constant P_{ext}): $w = -P_{ext}\Delta V$

work (reversible and isothermal): $w = -nRT \ln\left(\frac{V_2}{V_1}\right)$

In general: $\Delta U = q + w$

In general: $\Delta H = \Delta U + \Delta(PV) = \Delta U + \Delta(nRT)$

In general: $\Delta U = nC_v\Delta T$

In general: $\Delta H = nC_P\Delta T$

At constant P: $q = \Delta H$

At constant V: $q = \Delta U$

For a reversible adiabatic expansion: $C_V \ln\left(\frac{T_2}{T_1}\right) = -R\ln\left(\frac{V_2}{V_1}\right) = R\ln\left(\frac{V_1}{V_2}\right)$

At constant T: $\Delta S = \frac{q_{rev}}{T}$

Formulas, Constants, Conversion Factors, etc. (continued)

At constant T: $\Delta S = nR\ln\left(\frac{V_2}{V_1}\right)$

For phase changes at constant P: $\Delta S = \frac{\Delta H}{T}$

At constant P: $\Delta S = nC_P\ln\left(\frac{T_2}{T_1}\right)$

At constant V: $\Delta S = nC_V\ln\left(\frac{T_2}{T_1}\right)$

Boltzmann's Equation: $S = k_B \ln \Omega$

At constant T and P: $\Delta G = \Delta H - T\Delta S$

Kirchoff's Law: $\Delta H^\circ_{T_2} = \Delta H^\circ_{T_1} + \Delta C_p(T_2 - T_1)$

$$\Delta S^\circ_{T_2} = \Delta S^\circ_{T_1} + \Delta C_p \ln\left(\frac{T_2}{T_1}\right)$$

$\Delta G = \Delta G^o + RT \ln Q$

$\Delta G^o = -RT \ln K$

$\ln K = -\frac{\Delta H^\circ}{RT} + \frac{\Delta S^\circ}{R}$ Van't Hoff: $\ln\left(\frac{K_2}{K_1}\right) = \frac{-\Delta H^\circ}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$

$\Delta G^\circ = -nF\Delta\varepsilon^\circ_{cell} = -nF\Delta E^\circ_{cell}$

Nernst equation: $\Delta\varepsilon_{cell}$ (or ΔE_{cell}) $= \Delta\varepsilon^\circ_{cell}$ (or ΔE°_{cell}) $- \frac{RT}{nF}\ln Q$

At 298 K the Nernst equation simplifies to:

$\Delta\varepsilon_{cell}$ (or ΔE_{cell}) $= \Delta\varepsilon^\circ_{cell}$ (or ΔE°_{cell}) $- \frac{0.0592}{n}\log_{10} Q = \Delta\varepsilon^\circ_{cell}$ (or ΔE°_{cell}) $- \frac{0.0257}{n}\ln Q$

Q (Charge) = I t

For first-order reactions of the type A ⟶ products , $\ln [A] = -kt + \ln[A]_0$

For second-order reactions of the type 2A ⟶ products , $\frac{1}{[A]} = 2kt + \frac{1}{[A]_0}$

$k = Ae^{-E_a/RT}$ Arrhenius: $\ln\left(\frac{k_2}{k_1}\right) = \frac{-E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$

1 Joule = 1 Coulomb • Volt 1 Amp = 1 Coulomb/sec

Formulas, Constants, Conversion Factors, etc. (continued)

$\Delta G^\circ_{vap} = -RT \ln P^* = -RT \ln P^\bullet$ where P^* or $P^\bullet$ is the pure vapor pressure of a liquid

Clausius-Clapeyron: $\ln\left(\frac{P_2}{P_1}\right) = \frac{-\Delta H^o_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$

Raoult's Law: $P_A = \chi_A^{liq} P_A^* = \chi_A^{liq} P_A^\bullet$

Dalton's Law: $P_A = \chi_A^{vap} P_{Total}$

Henry's Law: $P_A = \chi_A k_A$ where k_A = Henry's constant

$\Delta P = \chi_{solute} P^*_{solvent} = \chi_{solute} P^\bullet_{solvent}$

$\Delta T_b = k_b\, m_{solute}$ $\qquad k_b = \frac{RT_b^2(MW_{solvent})}{1000\Delta H^\circ_{vap}}$

$\Delta T_f = -k_f\, m_{solute}$ $\qquad k_f = \frac{RT_f^2(MW_{solvent})}{1000\Delta H^\circ_{fus}}$

$P_{column} = \rho g h$

$\Pi = cRT$

Formulas, Constants, Conversion Factors, etc.

vector quantities are given in **bold**

$\mathbf{F} = m\mathbf{a}$

$\mathbf{v} = \Delta x/\Delta t$ (if $\mathbf{v}$ is constant)

$\mathbf{a} = \Delta \mathbf{v}/\Delta t$ (if $\mathbf{a}$ is constant)

$\mathbf{F} = m\mathbf{g}$

$\mathbf{F} = q\mathbf{E}$

$V(\mathrm{r}) = \frac{q_1 q_2}{4\pi\varepsilon_0 r} = \frac{q_1 q_2}{\alpha r}$

$\alpha = 4\pi\varepsilon_0 = 1.11 \times 10^{-10}\ \frac{\mathrm{C}^2}{\mathrm{J\ m}}$

$\mathrm{F}(r) = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$

At fixed time, $\mathrm{A(x)} = \mathrm{A_{max}} \sin\left(\frac{2\pi \mathrm{x}}{\lambda}\right)$;

At fixed position, $\mathrm{A(t)} = \mathrm{A_{max}} \sin(2\pi\nu \mathrm{t})$

For the Bohr model, $\mathrm{KE} = \mathrm{E}_K = -\frac{1}{2}\mathrm{V}$

Circumference = $2\pi \mathrm{r}$

$\mathrm{KE} = \mathrm{E_K} = m\mathrm{v}^2/2$

$E = h\nu$

speed = $\lambda\nu$

$c = \nu\lambda$

$\mathrm{KE} = \mathrm{E_K} = h\nu - \phi$

$E_n = (-2.18 \times 10^{-18}\ \mathrm{J})\, Z^2/n^2$
$= (-13.6\ \mathrm{eV})\, Z^2/n^2$

$\mathrm{r_n} = \frac{\mathrm{n}^2 \mathrm{a_0}}{Z}$; $\mathrm{a_0} = 52.9\ \mathrm{pm}$

$1\ \text{Å} = 10^{-10}\ \mathrm{m}$

$\mathbf{p} = \mathrm{h}/\lambda$

$\mathbf{p} = \mathrm{m}\mathbf{v}$

$\lambda = \frac{\mathrm{h}}{\mathrm{mv}} = \frac{h}{p}$

$(\Delta \mathrm{p})(\Delta \mathrm{x}) \geq \mathrm{h}/(4\pi)$

$\mathrm{L} = \mathrm{n}\lambda/2$

$\Psi_\mathrm{n}(\mathrm{x}) = \sqrt{\frac{2}{\mathrm{L}}} \sin \frac{\mathrm{n}\pi \mathrm{x}}{\mathrm{L}}$

$\mathrm{KE_n} = \frac{\mathrm{n^2 h^2}}{8\mathrm{mL}^2}$

$\Psi_{\mathrm{n_x n_y}}(\mathrm{x,y}) = \sqrt{\frac{4}{\mathrm{L_x L_y}}} \sin\left(\frac{\mathrm{n_x}\pi \mathrm{x}}{\mathrm{L_x}}\right) \sin\left(\frac{\mathrm{n_y}\pi \mathrm{y}}{\mathrm{L_y}}\right)$

$\mathrm{KE_{n_x,n_y}} = \frac{\mathrm{h}^2}{8\mathrm{m}}\left(\frac{\mathrm{n_x}^2}{\mathrm{L_x}^2} + \frac{\mathrm{n_y}^2}{\mathrm{L_y}^2}\right)$

$\Psi_{\mathrm{n_x n_y n_z}}(\mathrm{x,y,z}) = \sqrt{\frac{8}{\mathrm{L_x L_y L_z}}} \sin\left(\frac{\mathrm{n_x}\pi \mathrm{x}}{\mathrm{L_x}}\right) \sin\left(\frac{\mathrm{n_y}\pi \mathrm{y}}{\mathrm{L_y}}\right) \sin\left(\frac{\mathrm{n_z}\pi \mathrm{z}}{\mathrm{L_z}}\right)$

$\mathrm{KE_{n_x,n_y,n_z}} = \frac{\mathrm{h}^2}{8\mathrm{m}}\left(\frac{\mathrm{n_x}^2}{\mathrm{L_x}^2} + \frac{\mathrm{n_y}^2}{\mathrm{L_y}^2} + \frac{\mathrm{n_z}^2}{\mathrm{L_z}^2}\right)$

$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$\mathrm{E}_{\mathrm{n},\ell} = -2.18 \times 10^{-18}\ \mathrm{J}\left(\frac{\mathrm{Z^{*2}}}{\mathrm{n^2}}\right) = -13.6\ \mathrm{eV}\left(\frac{\mathrm{Z^{*2}}}{\mathrm{n^2}}\right) = -1313\ \frac{\mathrm{kJ}}{\mathrm{mol}}\left(\frac{\mathrm{Z^{*2}}}{\mathrm{n^2}}\right)$

$\mathrm{I_j} = 2.18 \times 10^{-18}\ \mathrm{J}\left(\frac{\mathrm{Z^{*2}}}{\mathrm{n^2}}\right) = 13.6\ \mathrm{eV}\left(\frac{\mathrm{Z^{*2}}}{\mathrm{n^2}}\right) = 1313\ \frac{\mathrm{kJ}}{\mathrm{mol}}\left(\frac{\mathrm{Z^{*2}}}{\mathrm{n^2}}\right)$

Formulas, Constants, Conversion Factors, etc.

vector quantities are given in **bold**

$PV = nRT$

$P_i = \chi_i P_T = x_i P_T$

$$\chi_i = x_i = \frac{n_i}{n_T}$$

$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$$

$$P = \frac{nRT}{V - nb} - \frac{an^2}{V^2}$$

Formulas, Constants, Conversion Factors, etc.

Table B-2 Derived Units in Sl:

Quantity	Unit	Symbol	Definition
Energy	Joule	J	$kg\ m^2\ s^{-2}$
Force	Newton	N	$kg\ m\ s^{-2} = J\ m^{-1}$
Power	Watt	W	$kg\ m^2\ s^{-3} = J\ s^{-1}$
Pressure	Pascal	Pa	$kg\ m^{-1}\ s^{-2} = N\ m^{-2}$
Electric charge	Coulomb	C	A s
Electric potential difference	Volt	V	$kg\ m^2\ s^{-3}\ A^{-1} = J\ C^{-1}$
Magnetic field strength	Tesla	T	$kg\ C^{-1}\ s^{-1} = V\ s\ m^{-2}$

Table B-3 Prefixes in Sl:

Fraction	Prefix	Symbol	Factor	Prefix	Symbol
10^{-1}	*deci-*	d	10	*deca-*	da
10^{-2}	*centi-*	c	10^2	*hecto-*	h
10^{-3}	*milli-*	m	10^3	*kilo-*	k
10^{-6}	*micro-*	μ	10^6	*mega-*	M
10^{-9}	*nano-*	n	10^9	*giga-*	G
10^{-12}	*pico-*	p	10^{12}	*tera-*	T
10^{-15}	*femto-*	f			
10^{-18}	*atto-*	a			

Table of Standard Reduction Potentials (25°C)

Reaction			E° or ε° (V)
$F_2 + 2e^-$	→	$2F^-$	+2.87
$Co^{3+} + e^-$	→	Co^{2+}	+1.82
$Au^+(aq) + e^-$	→	$Au(s)$	+1.68
$Ce^{4+} + e^-$	→	Ce^{3+}	+1.61
$MnO_4^- + 8H_3O^+ + 5e^-$	→	$Mn^{2+} + 12H_2O(l)$	+1.49
$Au^{3+} + 3e^-$	→	$Au(s)$	+1.42
$Cl_2 + 2e^-$	→	$2Cl^-$	+1.36
$Cr_2O_7^{2-} + 14H_3O^+ + 6e^-$	→	$2Cr^{3+} + 21H_2O(l)$	+1.33
$O_2 + 4H_3O^+ + 4e^-$	→	$6H_2O(l)$	+1.23
			+0.82 @ pH=7
$Br_2 + 2e^-$	→	$2Br^-$	+1.07
$NO_3^- + 4H^+ + 3e^-$	→	$NO(g) + H_2O(l)$	+0.96
$Hg^{2+} + 2e^-$	→	$Hg(l)$	+0.85
$Ag^+ + e^-$	→	$Ag(s)$	+0.80
$Fe^{3+} + e^-$	→	Fe^{2+}	+0.77
$I_2 + 2e^-$	→	$2I^-$	+0.54
$O_2 + 2H_2O + 4e^-$	→	$4OH^-$	+0.40
			+0.82 @ pH=7
$Cu^{2+} + 2e^-$	→	$Cu(s)$	+0.34
$AgCl(s) + e^-$	→	$Ag(s) + Cl^-$	+0.22
$Sn^{4+} + 2e^-$	→	Sn^{2+}	+0.15
$AgBr(s) + e^-$	→	$Ag(s) + Br^-$	+0.07
$2H_3O^+ + 2e^-$	→	$H_2 + 2H_2O$	0.00
$Pb^{2+} + 2e^-$	→	$Pb(s)$	–0.13
$Sn^{2+} + 2e^-$	→	$Sn(s)$	–0.14
$AgI(s) + e^-$	→	$Ag(s) + I^-$	–0.15
$Ni^{2+} + 2e^-$	→	$Ni(s)$	–0.26
$Co^{2+} + 2e^-$	→	$Co(s)$	–0.28
$Se + 2H^+ + 2e^-$	→	H_2Se	–0.40
$Cd^{2+} + 2e^-$	→	$Cd(s)$	–0.40
$Cr^{3+} + e^-$	→	Cr^{2+}	–0.41
$Fe^{2+} + 2e^-$	→	$Fe(s)$	–0.45
$Ag_2S(s) + 2e^-$	→	$2Ag + S^{2-}$	–0.69
$Zn^{2+} + 2e^-$	→	$Zn(s)$	–0.76
$2H_2O + 2e^-$	→	$H_2 + 2OH^-$	–0.83
			–0.42 @ pH=7
$Cr^{2+} + 2e^-$	→	$Cr(s)$	–0.91
$Mn^{2+} + 2e^-$	→	$Mn(s)$	–1.18
$Al^{3+} + 3e^-$	→	$Al(s)$	–1.71
$Mg^{2+} + 2e^-$	→	$Mg(s)$	–2.37
$Na^+ + e^-$	→	$Na(s)$	–2.71
$Ca^{2+} + 2e^-$	→	$Ca(s)$	–2.76
$Ba^{2+} + 2e^-$	→	$Ba(s)$	–2.91
$K^+ + e^-$	→	$K(s)$	–2.93
$Li^+ + e^-$	→	$Li(s)$	–3.04

Formulas, Constants, Conversion Factors, etc.

Physical Constants:

Standard acceleration of terrestrial gravity	$g = 9.80665$ m s^{-2} (exactly)
Avogadro's number	$N_0 = 6.022137 \times 10^{23}$
Bohr radius	$a_0 = 0.52917725$ Å $= 5.2917725 \times 10^{-11}$ m
Boltzmann's constant	$k_B = 1.38066 \times 10^{-23}$ J K^{-1}
Electron charge	$q_e = e = 1.6021773 \times 10^{-19}$ C
Faraday constant	F = 96,485.31 C mol^{-1}
Masses of fundamental particles:	
Electron	$m_e = 9.109390 \times 10^{-31}$ kg = 0.00054857990 u
Proton	$m_p = 1.67263 \times 10^{-27}$ kg = 1.00727647 u
Neutron	$m_n = 1.674929 \times 10^{-27}$ kg = 1.00866490 u
Ratio of proton mass to electron mass	$m_p/m_e = 1836.15270$
Permittivity of vacuum	$\varepsilon_0 = 8.8541878 \times 10^{-12}$ C^2 J^{-1} m^{-1}
Planck's constant	$h = 6.626076 \times 10^{-34}$ J s
Speed of light in a vacuum	$c = 2.99792458 \times 10^8$ m s^{-1} (exactly)
Universal gas constant	$R = 8.31451$ J mol^{-1} K^{-1}
	= 0.0820578 L atmmol^{-1} K^{-1}

Conversion Factors:

Standard atmosphere	1 atm = 1.01325×10^5 Pa = 1.01325×10^5 kg m^{-1} s^{-2} (exactly)
Atomic mass unit	1 u = 1.660540×10^{-27} kg
	1 u = 1.492419×10^{-10} J = 931.4943 MeV
	(energy equivalent from $E = mc^2$)
Calorie	1 cal = 4.184 J (exactly)
Electron volt	1 eV = $1.6021773 \times 10^{-19}$ J = 96.48531 kJ mol^{-1}
Foot	1 ft = 12 in = 0.3048 m (exactly)
Gallon (U.S.)	1 gallon = 4 quarts = 3.78541 L (exactly)
Liter-atmosphere	1 L atm = 101.325 J (exactly)
Metric ton	1 metric ton = 1000 kg (exactly)
Pound	1 lb = 16 oz = 0.45359237 kg (exactly)

PERIODIC TABLE OF THE ELEMENTS

1 **H** 1.0079																	2 **He** 4.0026
3 **Li** 6.941	4 **Be** 9.0122											5 **B** 10.811	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.180
11 **Na** 22.990	12 **Mg** 24.305											13 **Al** 26.982	14 **Si** 28.086	15 **P** 30.974	16 **S** 32.066	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.88	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.847	27 **Co** 58.933	28 **Ni** 58.69	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.61	33 **As** 74.922	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	71 **Lu** 174.97	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.2	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	103 **Lr** (260)	104 **Unq** (261)	105 **Unp** (262)	106 **Unh** (263)	107 **Uns** (262)	108 **Uno** (265)	109 **Une** (266)	110 **Uun** (269)	111 **Uuu** (272)							

57 **La** 138.9	58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0
89 **Ac** (227)	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)