INFORMATION IN THE TABLE BELOW AND IN THE TABLES ON PAGES 3-5 MAY BE USEFUL IN ANSWERING THE QUESTIONS IN THIS SECTION OF THE EXAMINATION.

DO NOT DETACH FROM BOOK.

PERIODIC TABLE OF THE ELEMENTS

1 **H** 1.0079																	2 **He** 4.0026
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.811	6 **C** 12.011	7 **N** 14.007	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.179
11 **Na** 22.99	12 **Mg** 24.30											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.974	16 **S** 32.06	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.938	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	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** 126.91	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 ***La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.2	77 **Ir** 192.2	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** 226.02	89 **†Ac** 227.03	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)	110 § (269)	111 § (272)	112 § (277)	§Not yet named					

*Lanthanide Series	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 151.97	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
†Actinide Series	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** 237.05	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)	103 **Lr** (260)

STANDARD REDUCTION POTENTIALS IN AQUEOUS SOLUTION AT 25°C

Half-reaction			$E°$(V)
$F_2(g)$ $2e^-$	→	$2F$	2.87
$Co^{3+} - e^-$	→	Co^{2-}	1.82
$Au^{3+} + 3e$	→	$Au(s)$	1.50
$Cl_2(g) + 2e^-$	→	$2Cl^-$	1.36
$O_2(g) \mid 4H^+ \mid 4e$	→	$2H_2O(l)$	1.23
$Br_2(l) + 2e$	→	$2Br$	1.07
$2Hg^{2+} + 2e$	→	Hg_2^{2+}	0.92
$Hg^{2+} + 2e$	→	$Hg(l)$	0.85
$Ag^+ - e$	→	$Ag(s)$	0.80
$Hg_2^{2+} + 2e$	→	$2Hg(l)$	0.79
$Fe^{3+} + e$	→	Fe^{2+}	0.77
$I_2(s) + 2e$	→	$2I$	0.53
$Cu^+ + e^-$	→	$Cu(s)$	0.52
$Cu^{2+} - 2e$	→	$Cu(s)$	0.34
Cu^{2+} e	→	Cu^+	0.15
Sn^{4+} $2e$	→	Sn^{2+}	0.15
$S(s) - 2H^+ + 2e$	→	$H_2S(g)$	0.14
$2H^+$ $2e$	→	$H_2(g)$	0.00
Pb^{2+} $2e$	→	$Pb(s)$	−0.13
$Sn^{2+} - 2e$	→	$Sn(s)$	−0.14
$Ni^{2+} \mid 2e$	→	$Ni(s)$	−0.25
Co^{2+} $2e$	→	$Co(s)$	−0.28
$Cd^{2+} - 2e$	→	$Cd(s)$	−0.40
$Cr^{3+} + e$	→	Cr^{2+}	−0.41
Fe^{2+} $2e$	→	$Fe(s)$	−0.44
$Cr^{3+} + 3e$	→	$Cr(s)$	−0.74
$Zn^{2+} - 2e$	→	$Zn(s)$	−0.76
$2H_2O(l) + 2e$	→	$H_2(g) + 2OH$	−0.83
$Mn^{2+} - 2e$	→	$Mn(s)$	−1.18
$Al^{3+} - 3e$	→	$Al(s)$	−1.66
Be^{2+} $2e$	→	$Be(s)$	−1.70
$Mg^{2+} - 2e$	→	$Mg(s)$	−2.37
$Na^+ - e$	→	$Na(s)$	−2.71
$Ca^{2+} - 2e$	→	$Ca(s)$	−2.87
Sr^{2+} $2e^-$	→	$Sr(s)$	−2.89
$Ba^{2+} - 2e$	→	$Ba(s)$	−2.90
$Rb^+ - e$	→	$Rb(s)$	−2.92
K^+ e	→	$K(s)$	−2.92
$Cs^+ - e$	→	$Cs(s)$	−2.92
$Li^+ - e$	→	$Li(s)$	−3.05

ATOMIC STRUCTURE

$E = h\nu$ $c = \lambda\nu$

$\lambda = \dfrac{h}{m\upsilon}$ $p = m\upsilon$

$E_n = \dfrac{-2.178 \times 10^{-18}}{n^2}$ joule

E = energy υ = velocity
ν = frequency n = principal quantum number
λ = wavelength m = mass
p = momentum

Speed of light, $c = 3.0 \times 10^{8}\ \text{m s}^{-1}$

Planck's constant, $h = 6.63 \times 10^{-34}\ \text{J s}$

Boltzmann's constant, $k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$

Avogadro's number $= 6.022 \times 10^{23}\ \text{mol}^{-1}$

Electron charge, $e = -1.602 \times 10^{-19}$ coulomb

1 electron volt per atom $= 96.5\ \text{kJ mol}^{-1}$

EQUILIBRIUM

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

$$K_b = \frac{[OH^-][HB^+]}{[B]}$$

$$K_w = [OH^-][H^+] = 1.0 \times 10^{-14} \ @\ 25^\circ C$$
$$= K_a \times K_b$$

$$pH = -\log[H^+],\ pOH = -\log[OH^-]$$

$$14 = pH + pOH$$

$$pH = pK_a + \log\frac{[A^-]}{[HA]}$$

$$pOH = pK_b + \log\frac{[HB^+]}{[B]}$$

$$pK_a = -\log K_a,\ pK_b = -\log K_b$$

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

where Δn = moles product gas − moles reactant gas

Equilibrium Constants

K_a (weak acid)
K_b (weak base)
K_w (water)
K_p (gas pressure)
K_c (molar concentrations)

THERMOCHEMISTRY/KINETICS

$$\Delta S^\circ = \sum S^\circ \text{ products} - \sum S^\circ \text{ reactants}$$

$$\Delta H^\circ = \sum \Delta H_f^\circ \text{ products} - \sum \Delta H_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \sum \Delta G_f^\circ \text{ products} - \sum \Delta G_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$
$$= -RT \ln K = -2.303\, RT \log K$$
$$= -n\mathcal{F}E^\circ$$

$$\Delta G = \Delta G^\circ + RT \ln Q = \Delta G^\circ + 2.303\, RT \log Q$$

$$q = mc\Delta T$$

$$C_p = \frac{\Delta H}{\Delta T}$$

$$\ln[A]_t - \ln[A]_0 = -kt$$

$$\frac{1}{[A]_t} - \frac{1}{[A]_0} = kt$$

$$\ln k = \frac{-E_a}{R}\left(\frac{1}{T}\right) + \ln A$$

S° = standard entropy
H° = standard enthalpy
G° = standard free energy
E° = standard reduction potential
T = temperature
n = moles
m = mass
q = heat
c = specific heat capacity
C_p = molar heat capacity at constant pressure
E_a = activation energy
k = rate constant
A = frequency factor

Faraday's constant, $\mathcal{F}$ = 96,500 coulombs per mole of electrons

Gas constant, $R = 8.31\ \text{J mol}^{-1}\ \text{K}^{-1}$
$= 0.0821\ \text{L atm mol}^{-1}\ \text{K}^{-1}$
$= 8.31\ \text{volt coulomb mol}^{-1}\ \text{K}^{-1}$

GASES, LIQUIDS, AND SOLUTIONS

$$PV = nRT$$

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

$$P_A = P_{total} \times X_A, \text{ where } X_A = \frac{\text{moles A}}{\text{total moles}}$$

$$P_{total} = P_A + P_B + P_C + \ldots$$

$$n = \frac{m}{M}$$

$$K = {}^{\circ}C + 273$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$D = \frac{m}{V}$$

$$u_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{M}}$$

$$KE \text{ per molecule} = \frac{1}{2}mv^2$$

$$KE \text{ per mole} = \frac{3}{2}RT$$

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$$

molarity, M = moles solute per liter solution

molality = moles solute per kilogram solvent

$$\Delta T_f = iK_f \times \text{molality}$$

$$\Delta T_b = iK_b \times \text{molality}$$

$$\pi = iMRT$$

$$A = abc$$

P = pressure
V = volume
T = temperature
n = number of moles
D = density
m = mass
v = velocity

u_{rms} = root-mean-square speed
KE = kinetic energy
r = rate of effusion
M = molar mass
π = osmotic pressure
i = van't Hoff factor
K_f = molal freezing-point depression constant
K_b = molal boiling-point elevation constant
A = absorbance
a = molar absorptivity
b = path length
c = concentration
Q = reaction quotient
I = current (amperes)
q = charge (coulombs)
t = time (seconds)
E° = standard reduction potential
K = equilibrium constant

Gas constant, $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$
$= 0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1}$
$= 8.31 \text{ volt coulomb mol}^{-1} \text{ K}^{-1}$

Boltzmann's constant, $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$

K_f for H_2O = $1.86 \text{ K kg mol}^{-1}$

K_b for H_2O = $0.512 \text{ K kg mol}^{-1}$

1 atm = 760 mm Hg
= 760 torr

STP = 0.000 °C and 1.000 atm

Faraday's constant, $\mathcal{F}$ = 96,500 coulombs per mole of electrons

OXIDATION-REDUCTION; ELECTROCHEMISTRY

$$Q = \frac{[C]^c[D]^d}{[A]^a[B]^b}, \text{ where } a\,A + b\,B \rightarrow c\,C + d\,D$$

$$I = \frac{q}{t}$$

$$E_{cell} = E^{\circ}_{cell} - \frac{RT}{n\mathcal{F}}\ln Q = E^{\circ}_{cell} - \frac{0.0592}{n}\log Q \;@\; 25^{\circ}C$$

$$\log K = \frac{nE^{\circ}}{0.0592}$$