Topics in the June 2014 Exam Paper for CHEM1101

Click on the links for resources on each topic.

2014-J-2:

- Atomic Electronic Spectroscopy
- Band Theory - MO in Solids
- Ionic Bonding

2014-J-3:

- VSEPR
- Types of Intermolecular Forces

2014-J-4:

- Nuclear and Radiation Chemistry

2014-J-5:

- Bonding - MO theory (H_2)
- Bonding - MO theory (larger molecules)

2014-J-6:

- Shape of Atomic Orbitals and Quantum Numbers
- Filling Energy Levels in Atoms Larger than Hydrogen

2014-J-7:

- Lewis Structures
- VSEPR

2014-J-8:

- Thermochemistry

2014-J-9:

- Chemical Equilibrium
- First and Second Law of Thermodynamics

2014-J-10:

- Chemical Equilibrium

2014-J-11:

- First and Second Law of Thermodynamics
- Gas Laws

2014-J-12:

- Equilibrium and Thermochemistry in Industrial Processes

2014-J-13:

- Electrolytic Cells

2014-J-14:

- Electrochemistry

2014-J-15:

- Electrochemistry

2205(a) THE UNIVERSITY OF SYDNEY

CHEMISTRY 1A - CHEM1101

CONFIDENTIAL

FIRST SEMESTER EXAMINATION

JUNE 2014 **TIME ALLOWED: THREE HOURS**

GIVE THE FOLLOWING INFORMATION IN BLOCK LETTERS

FAMILY NAME		**SID NUMBER**	
OTHER NAMES		**TABLE NUMBER**	

INSTRUCTIONS TO CANDIDATES

- All questions are to be attempted. There are 22 pages of examinable material.
- Complete the written section of the examination paper in **INK.**
- Read each question carefully. Report the appropriate answer and show all relevant working in the space provided.
- The total score for this paper is 100. The possible score per page is shown in the adjacent tables.
- Each new short answer question begins with a •.
- Only non-programmable, University-approved calculators may be used.
- Students are warned that credit may not be given, even for a correct answer, where there is insufficient evidence of the working required to obtain the solution.
- Numerical values required for any question, standard electrode reduction potentials, a Periodic Table and some useful formulas may be found on the separate data sheets.
- Pages 13, 17, 20, 22 and 28 are for rough working only.

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Multiple choice section

	Marks	
Pages	Max	Gained
2-9	30	

Short answer section

Page	Marks			Marker
	Max	Gained		
10	6			
11	5			
12	7			
14	6			
15	5			
16	6			
18	3			
19	3			
21	4			
23	6			
24	4			
25	6			
26	6			
27	3			
Total	70			
Check total				

Marks

- An atomic absorption spectrometer with a path length of 1.0 cm is used to measure the concentrations of copper in tap water. The results are shown below. The standard solution contains 5.0 ppm Cu. **3**

Sample	Absorbance reading
Standard solution (5.0 ppm Cu)	22.3
Unknown tap water	14.5

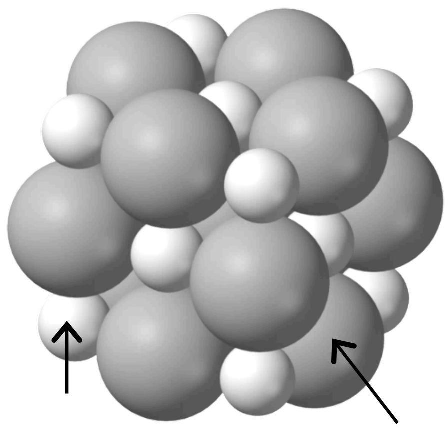
Assuming the Beer-Lambert Law is applicable, what is the concentration of Cu in the unknown tap water?

Answer:

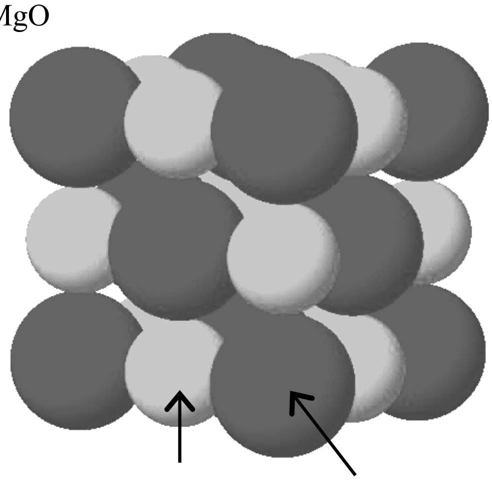
What is the absorption process that AAS measures?

- Below are fragments of the ionic crystals of LiCl and MgO (not to scale). On the diagrams, label the ions for each structure. **3**

LiCl



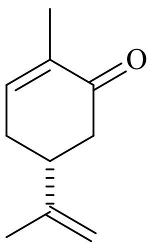
MgO



LiCl and MgO both adopt the same crystal lattice structure. Which of the two ionic compounds has the higher melting point? Why?

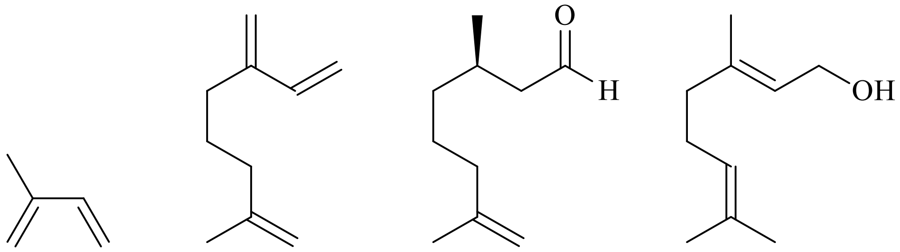
Marks
5

- (*R*)-Carvone is a typical terpene, a class of compounds widely distributed in nature. On the structure of (*R*)-carvone below, circle all of the carbon atoms with trigonal planar geometry.



(*R*)-carvone

All terpenes are derived from isoprene and many, such as myrcene, (*R*)-citronellal and geraniol, are used in the perfume industry.



isoprene	myrcene	(*R*)-citronellal	geraniol
b.p. 34 °C	b.p. 167 °C	b.p. 201 °C	b.p. 230 °C

Explain the differences in boiling points of these four compounds in terms of the type and size of the intermolecular forces present.

Marks
7

- Technetium-99m is an important radionuclide for medical imaging. It is produced from molybdenum-99. Fill in the box below to give a balanced nuclear equation for the production of Tc-99m from Mo-99.

$${}^{99}_{42}\text{Mo} \rightarrow {}^{99m}_{43}\text{Tc} + \boxed{}$$

The half-life of Tc-99m is 6.0 hours. Calculate the decay constant, λ, in s^{-1}.

Answer:

Calculate the molar activity in Bq mol^{-1}.

Answer:

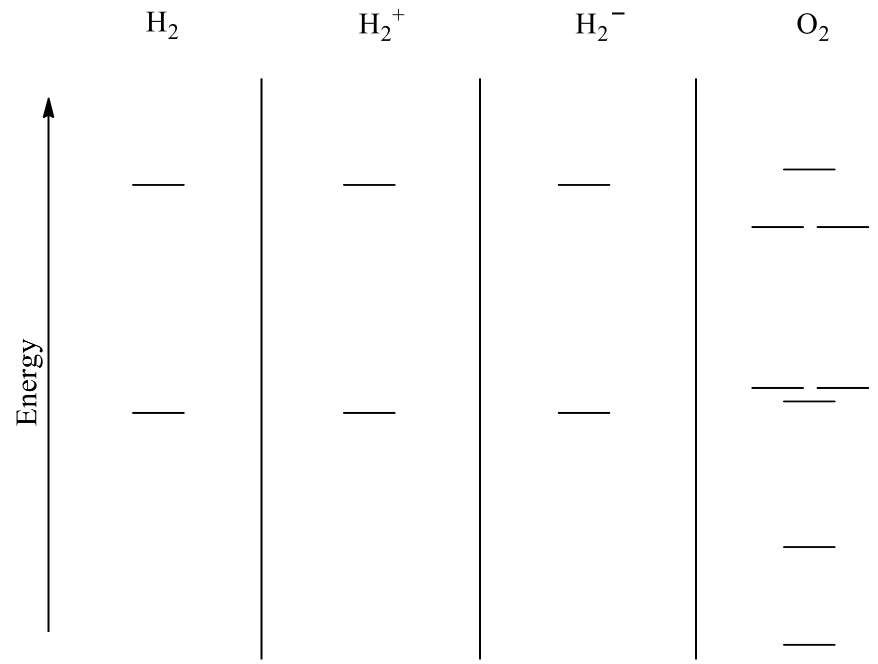
Calculate the time in hours for 90% of the activity of a sample of Tc-99m to decay.

Answer:

Why is Tc-99m suitable for medical imaging? Give two reasons.

Marks 6

- The molecular orbital energy level diagrams for H_2, H_2^+, H_2^- and O_2 are shown below. Fill in the valence electrons for each species in its ground state and label the types of orbitals (σ, σ*, π, π*).



Give the bond order of each species.

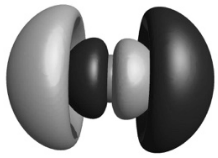
H_2:	H_2^+:	H_2^-:	O_2:

Which of the four species are paramagnetic?

The bond lengths of H_2^+ and H_2^- are different. Which do you expect to be longer? Explain your answer.

Marks

- A schematic representation of a *p* orbital is shown below. The central sphere (mostly obscured) represents the atomic nucleus. **2**



How many spherical and planar nodes does this orbital have? Label them on the diagram above.

Number of spherical nodes:	Number of planar nodes:

What is the principal quantum number, n, of this orbital? Explain your answer.

- Shielding is important in multi-electron atoms. Briefly explain the concept of shielding. **3**

Give one example of a consequence of shielding.

Marks

- Complete the following table for the molecules NCl_3 and ICl_3. **3**

Molecule	Total number of valence electrons	Lewis structure	Shape of molecule
NCl_3			
ICl_3			

- Thionyl chloride ($SOCl_2$) is a common chlorinating agent in organic chemistry. Draw two possible Lewis structures for this molecule, assigning formal charges where appropriate. **3**

Which is the more stable resonance form? Give a reason for your answer.

Marks
3

- A 1.0 kg sample of copper metal is heated to 100.0 °C. The copper sample is immersed in a volume of water initially at 25.0 °C. What volume of water is required so that the final temperature of the copper is 40.0 °C? Show all working.

  Data: Specific heat capacity of Cu(s) is 0.39 J K^{-1} g^{-1}.
  Specific heat capacity of H_2O(l) is 4.184 J K^{-1} g^{-1}.
  The density of water is 1.0 g mL^{-1}.

Answer:

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

Marks

- Use the following equilibria: **2**

$$2CH_4(g) \rightleftharpoons C_2H_6(g) + H_2(g) \qquad K_1 = 9.5 \times 10^{-13}$$

$$CH_4(g) + H_2O(g) \rightleftharpoons CH_3OH(g) + H_2(g) \qquad K_2 = 2.8 \times 10^{-21}$$

to calculate the equilibrium constant, K_3, for the following reaction:

$$2CH_3OH(g) + H_2(g) \rightleftharpoons C_2H_6(g) + 2H_2O(g).$$

Show all working.

Answer:

- The Second Law states that all observable processes must involve a net increase in entropy. When liquid water freezes into ice at 0 °C, the entropy of the water decreases. Since the freezing of water is certainly observable, the processes must still satisfy the Second Law. Provide a brief explanation of how this is so. **1**

Page Total:

Marks
4

- Consider the following reaction.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad K_c = 4.61 \times 10^{-3} \text{ at } 25\ °C$$

A 0.086 mol sample of NO_2 is allowed to come to equilibrium with N_2O_4 in a 0.50 L container at 25 °C. Calculate the amount (in mol) of NO_2 and N_2O_4 present at equilibrium. Show all working.

Amount of NO_2:	Amount of N_2O_4:

Page Total:

Marks

- Give the balanced chemical equation for the combustion of butane gas, C_4H_{10}, in oxygen to produce CO_2 and water. **3**

Use the standard enthalpies of formation provided to calculate the molar heat of combustion of butane gas. Show all working.

Data:

Compound	$H_2O(l)$	$CO_2(g)$	$C_4H_{10}(g)$
$\Delta_f H^\circ$ / kJ mol^{-1}	–285.8	–393.5	–125.6

Answer:

- Calculate the volume change when 20.0 g of solid trinitrotoluene $C_7H_5N_3O_6(s)$ explosively decomposes via the following process at 2000. °C and 2.0 atm. **3**

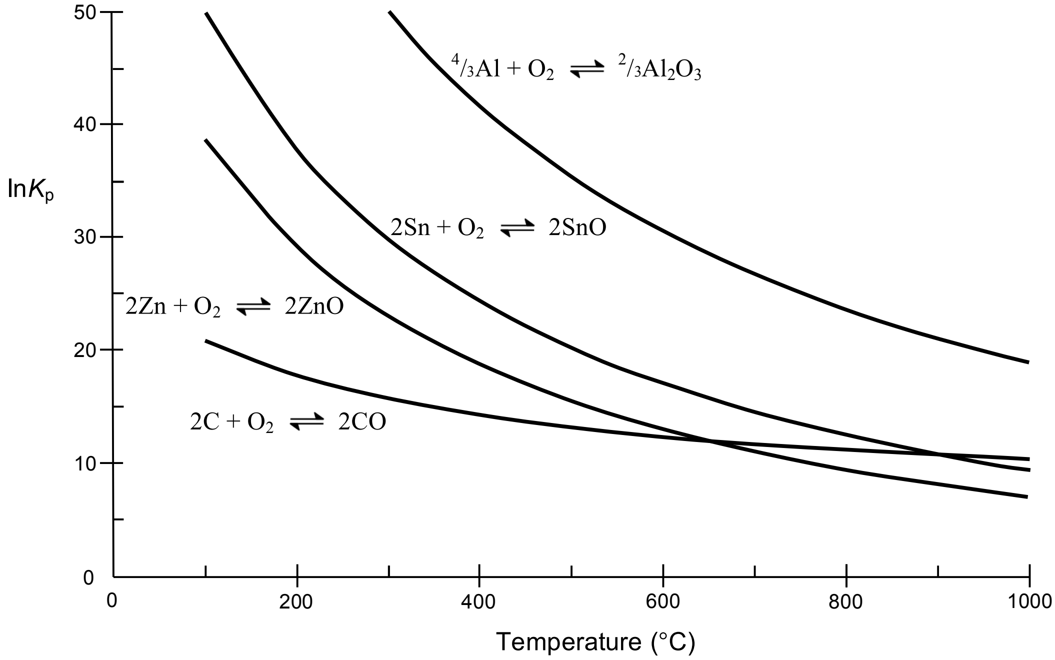
$$2C_7H_5N_3O_6(s) \rightarrow 12CO(g) + 5H_2(g) + 3N_2(g) + 2C(s)$$

Assume all gases behave as ideal gases and neglect the volume of any solid phases. Show all working.

Answer:

Marks
4

- The diagram below represents the equilibrium constant K_p associated with the formation of the four oxides indicated.



Using the equilibrium constant data above, describe the reaction that proceeds under the following conditions. If you think no reaction will occur, write 'no reaction'.

CO and Sn are combined at 400 °C
Al and SnO are combined at 400 °C
C and ZnO are mixed at 900 °C

Which oxide has the largest (most negative) enthalpy of formation?

Marks
6

- An aqueous solution of 1 M $CuSO_4$ undergoes electrolysis. At the minimum voltage necessary for a reaction to proceed, what products form at the anode and the cathode? Explain your answer.

Write a balanced overall reaction for the electrolytic cell.

Assuming no overpotential, what would be the minimum voltage required to drive the overall reaction at a pH of 0?

Answer:

At a pH of 7, would a higher or lower voltage be required to drive the reaction? Explain your answer.

Marks
6

- An electrochemical cell consists of an Fe^{2+}/Fe half cell with unknown [Fe^{2+}] and a Sn^{2+}/Sn half-cell with [Sn^{2+}] = 1.10 M. The electromotive force (electrical potential) of the cell was measured at 25 °C to be 0.35 V. What is the concentration of Fe^{2+} in the Fe^{2+}/Fe half-cell?

Answer:

Calculate the equilibrium constant for the reaction at 25 °C.

Answer:

Calculate the standard Gibbs free energy change for the reaction at 25 °C.

Answer:

Marks 3

- A concentration cell is constructed from two beakers containing 1 M $NiCl_2$ and 0.002 M $NiCl_2$. Describe the overall change that occurs as the concentration cell runs.

What would be the major driving force for the overall reaction, enthalpy or entropy? Explain your answer.

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

CHEM1101 - CHEMISTRY 1A

DATA SHEET

Physical constants

Avogadro constant, $N_A = 6.022 \times 10^{23}$ mol^{-1}
Faraday constant, $F = 96485$ C mol^{-1}
Planck constant, $h = 6.626 \times 10^{-34}$ J s
Speed of light in vacuum, $c = 2.998 \times 10^{8}$ m s^{-1}
Rydberg constant, $E_R = 2.18 \times 10^{-18}$ J
Boltzmann constant, $k_B = 1.381 \times 10^{-23}$ J K^{-1}
Permittivity of a vacuum, $\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 J^{-1} m^{-1}
Gas constant, $R = 8.314$ J K^{-1} mol^{-1}
= 0.08206 L atm K^{-1} mol^{-1}
Charge of electron, $e = 1.602 \times 10^{-19}$ C
Mass of electron, $m_e = 9.1094 \times 10^{-31}$ kg
Mass of proton, $m_p = 1.6726 \times 10^{-27}$ kg
Mass of neutron, $m_n = 1.6749 \times 10^{-27}$ kg

Properties of matter

Volume of 1 mole of ideal gas at 1 atm and 25 °C = 24.5 L
Volume of 1 mole of ideal gas at 1 atm and 0 °C = 22.4 L
Density of water at 298 K = 0.997 g cm^{-3}

Conversion factors

1 atm = 760 mmHg = 101.3 kPa = 1.013 bar	1 Ci = 3.70×10^{10} Bq
0 °C = 273 K	1 Hz = 1 s^{-1}
1 L = 10^{-3} m^3	1 tonne = 10^3 kg
1 Å = 10^{-10} m	1 W = 1 J s^{-1}
1 eV = 1.602×10^{-19} J	1 J = 1 kg m^2 s^{-2}

Decimal fractions

Fraction	Prefix	Symbol
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Decimal multiples

Multiple	Prefix	Symbol
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T

CHEM1101 - CHEMISTRY 1A

Standard Reduction Potentials, E°

Reaction	*E*° / V
$Co^{3+}(aq) + e^- \rightarrow Co^{2+}(aq)$	+1.82
$Ce^{4+}(aq) + e^- \rightarrow Ce^{3+}(aq)$	+1.72
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O$	+1.51
$Au^{3+}(aq) + 3e^- \rightarrow Au(s)$	+1.50
$Cl_2 + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$O_2 + 4H^+(aq) + 4e^- \rightarrow 2H_2O$	+1.23
$Pt^{2+}(aq) + 2e^- \rightarrow Pt(s)$	+1.18
$MnO_2(s) + 4H^+(aq) + e^- \rightarrow Mn^{3+} + 2H_2O$	+0.96
$NO_3^-(aq) + 4H^+(aq) + 3e^- \rightarrow NO(g) + 2H_2O$	+0.96
$Pd^{2+}(aq) + 2e^- \rightarrow Pd(s)$	+0.92
$NO_3^-(aq) + 10H^+(aq) + 8e^- \rightarrow NH_4^+(aq) + 3H_2O$	+0.88
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+0.80
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$Cu^+(aq) + e^- \rightarrow Cu(s)$	+0.53
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+0.34
$BiO^+(aq) + 2H^+(aq) + 3e^- \rightarrow Bi(s) + H_2O$	+0.32
$Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$	+0.15
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0 (by definition)
$Fe^{3+}(aq) + 3e^- \rightarrow Fe(s)$	–0.04
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	–0.126
$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$	–0.136
$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$	–0.24
$Co^{2+}(aq) + 2e^- \rightarrow Co(s)$	–0.28
$Cd^{2+}(aq) + 2e^- \rightarrow Cd(s)$	–0.40
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–0.44
$Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$	–0.74
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	–0.76
$2H_2O + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$	–0.83
$Cr^{2+}(aq) + 2e^- \rightarrow Cr(s)$	–0.89
$Al^{3+}(aq) + 3e^- \rightarrow Al(s)$	–1.68
$Sc^{3+}(aq) + 3e^- \rightarrow Sc(s)$	–2.09
$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$	–2.36
$Na^+(aq) + e^- \rightarrow Na(s)$	–2.71
$Ca^{2+}(aq) + 2e^- \rightarrow Ca(s)$	–2.87
$Li^+(aq) + e^- \rightarrow Li(s)$	–3.04

CHEM1101 - CHEMISTRY 1A

Useful formulas

Quantum Chemistry $E = h\nu = hc/\lambda$ $\lambda = h/mv$ $E = -Z^2E_R(1/n^2)$ $\Delta x \cdot \Delta(mv) \geq h/4\pi$ $q = 4\pi r^2 \times 5.67 \times 10^{-8} \times T^4$ $T\lambda = 2.898 \times 10^6$ K nm	**Electrochemistry** $\Delta G° = -nFE°$ $Moles\ of\ e^- = It/F$ $E = E° - (RT/nF) \times \ln Q$ $E° = (RT/nF) \times \ln K$ $E = E° - \frac{0.0592}{n}\log Q$ (at 25 °C)
Acids and Bases $pH = -\log[H^+]$ $pK_w = pH + pOH = 14.00$ $pK_w = pK_a + pK_b = 14.00$ $pH = pK_a + \log\{[A^-] / [HA]\}$	**Gas Laws** $PV = nRT$ $(P + n^2a/V^2)(V - nb) = nRT$ $E_k = ½mv^2$
Radioactivity $t_{½} = \ln 2/\lambda$ $A = \lambda N$ $\ln(N_0/N_t) = \lambda t$ ^{14}C age = 8033 $\ln(A_0/A_t)$ years	**Kinetics** $t_{½} = \ln 2/k$ $k = Ae^{-Ea/RT}$ $\ln[A] = \ln[A]_o - kt$ $\ln\frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$
Colligative Properties & Solutions $\Pi = cRT$ $P_{solution} = X_{solvent} \times P°_{solvent}$ $c = kp$ $\Delta T_f = K_f m$ $\Delta T_b = K_b m$	**Thermodynamics & Equilibrium** $\Delta G° = \Delta H° - T\Delta S°$ $\Delta G = \Delta G° + RT\ln Q$ $\Delta G° = -RT\ln K$ $\Delta_{univ}S° = R\ln K$ $K_p = K_c\left(\frac{RT}{100}\right)^{\Delta n}$
Miscellaneous $A = -\log\frac{I}{I_0}$ $A = \varepsilon cl$ $E = -A\frac{e^2}{4\pi\varepsilon_0 r}N_A$	**Mathematics** If $ax^2 + bx + c = 0$, then $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ $\ln x = 2.303 \log x$ Area of circle = πr^2 Surface area of sphere = $4\pi r^2$

PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 HYDROGEN **H** 1.008																	2 HELIUM **He** 4.003
3 LITHIUM **Li** 6.941	4 BERYLLIUM **Be** 9.012											5 BORON **B** 10.81	6 CARBON **C** 12.01	7 NITROGEN **N** 14.01	8 OXYGEN **O** 16.00	9 FLUORINE **F** 19.00	10 NEON **Ne** 20.18
11 SODIUM **Na** 22.99	12 MAGNESIUM **Mg** 24.31											13 ALUMINIUM **Al** 26.98	14 SILICON **Si** 28.09	15 PHOSPHORUS **P** 30.97	16 SULFUR **S** 32.07	17 CHLORINE **Cl** 35.45	18 ARGON **Ar** 39.95
19 POTASSIUM **K** 39.10	20 CALCIUM **Ca** 40.08	21 SCANDIUM **Sc** 44.96	22 TITANIUM **Ti** 47.88	23 VANADIUM **V** 50.94	24 CHROMIUM **Cr** 52.00	25 MANGANESE **Mn** 54.94	26 IRON **Fe** 55.85	27 COBALT **Co** 58.93	28 NICKEL **Ni** 58.69	29 COPPER **Cu** 63.55	30 ZINC **Zn** 65.39	31 GALLIUM **Ga** 69.72	32 GERMANIUM **Ge** 72.59	33 ARSENIC **As** 74.92	34 SELENIUM **Se** 78.96	35 BROMINE **Br** 79.90	36 KRYPTON **Kr** 83.80
37 RUBIDIUM **Rb** 85.47	38 STRONTIUM **Sr** 87.62	39 YTTRIUM **Y** 88.91	40 ZIRCONIUM **Zr** 91.22	41 NIOBIUM **Nb** 92.91	42 MOLYBDENUM **Mo** 95.94	43 TECHNETIUM **Tc** [98.91]	44 RUTHENIUM **Ru** 101.07	45 RHODIUM **Rh** 102.91	46 PALLADIUM **Pd** 106.4	47 SILVER **Ag** 107.87	48 CADMIUM **Cd** 112.40	49 INDIUM **In** 114.82	50 TIN **Sn** 118.69	51 ANTIMONY **Sb** 121.75	52 TELLURIUM **Te** 127.60	53 IODINE **I** 126.90	54 XENON **Xe** 131.30
55 CAESIUM **Cs** 132.91	56 BARIUM **Ba** 137.34	57-71	72 HAFNIUM **Hf** 178.49	73 TANTALUM **Ta** 180.95	74 TUNGSTEN **W** 183.85	75 RHENIUM **Re** 186.2	76 OSMIUM **Os** 190.2	77 IRIDIUM **Ir** 192.22	78 PLATINUM **Pt** 195.09	79 GOLD **Au** 196.97	80 MERCURY **Hg** 200.59	81 THALLIUM **Tl** 204.37	82 LEAD **Pb** 207.2	83 BISMUTH **Bi** 208.98	84 POLONIUM **Po** [210.0]	85 ASTATINE **At** [210.0]	86 RADON **Rn** [222.0]
87 FRANCIUM **Fr** [223.0]	88 RADIUM **Ra** [226.0]	89-103	104 RUTHERFORDIUM **Rf** [263]	105 DUBNIUM **Db** [268]	106 SEABORGIUM **Sg** [271]	107 BOHRIUM **Bh** [274]	108 HASSIUM **Hs** [270]	109 MEITNERIUM **Mt** [278]	110 DARMSTADTIUM **Ds** [281]	111 ROENTGENIUM **Rg** [281]	112 COPERNICIUM **Cn** [285]		114 FLEROVIUM **Fl** [289]		116 LIVERMORIUM **Lv** [293]		

LANTHANOIDS	57 LANTHANUM **La** 138.91	58 CERIUM **Ce** 140.12	59 PRASEODYMIUM **Pr** 140.91	60 NEODYMIUM **Nd** 144.24	61 PROMETHIUM **Pm** [144.9]	62 SAMARIUM **Sm** 150.4	63 EUROPIUM **Eu** 151.96	64 GADOLINIUM **Gd** 157.25	65 TERBIUM **Tb** 158.93	66 DYSPROSIUM **Dy** 162.50	67 HOLMIUM **Ho** 164.93	68 ERBIUM **Er** 167.26	69 THULIUM **Tm** 168.93	70 YTTERBIUM **Yb** 173.04	71 LUTETIUM **Lu** 174.97
ACTINOIDS	89 ACTINIUM **Ac** [227.0]	90 THORIUM **Th** 232.04	91 PROTACTINIUM **Pa** [231.0]	92 URANIUM **U** 238.03	93 NEPTUNIUM **Np** [237.0]	94 PLUTONIUM **Pu** [239.1]	95 AMERICIUM **Am** [243.1]	96 CURIUM **Cm** [247.1]	97 BERKELLIUM **Bk** [247.1]	98 CALIFORNIUM **Cf** [252.1]	99 EINSTEINIUM **Es** [252.1]	100 FERMIUM **Fm** [257.1]	101 MENDELEVIUM **Md** [256.1]	102 NOBELIUM **No** [259.1]	103 LAWRENCIUM **Lr** [260.1]