Topics in the June 2007 Exam Paper for CHEM1001

Click on the links for resources on each topic.

2007-J-2:

- Elements and Atoms
- Chemical Equations
- Stoichiometry

2007-J-3:

- Lewis Model of Bonding
- VSEPR
- Elements and Atoms

2007-J-4:

- Stoichiometry
- Chemical Equations

2007-J-5:

- Chemical Equations
- Stoichiometry

2007-J-6:

- Thermochemistry
- Chemical Equilibrium

2007-J-7:

- Introduction to Electrochemistry
- Electrochemistry
- First Law of Thermodynamics

2007-J-8:

- Electrolytic Cells
- Introduction to Electrochemistry
- Electrochemistry
- Batteries and Corrosion

2007-J-9:

- Chemical Equilibrium

2007-J-10:

- Gas Laws

22/01(a) # The University of Sydney

FUNDAMENTALS OF CHEMISTRY 1A - CHEM1001

FIRST SEMESTER EXAMINATION

CONFIDENTIAL

JUNE 2007 **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 20 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 •.
- Electronic calculators, including programmable calculators, may be used. Students are warned, however, 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 sheet.
- Pages 17, 21 and 24 are for rough working only.

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Multiple choice section

	Marks	
Pages	Max	Gained
2-12	40	

Short answer section

Page	Marks			Marker
	Max	Gained		
13	9			
14	11			
15	8			
16	7			
18	5			
19	4			
20	7			
22	4			
23	5			
Total	60			
Check Total				

Marks

- Write balanced equations for the following nuclear reactions. **4**

Naturally occurring thorium 232 undergoes alpha decay.	
A nuclide undergoes beta decay and produces caesium 133.	

- A cook uses a microwave oven to heat up a meal. The wavelength of the radiation is 0.012 m. Calculate the frequency and energy of a photon of this radiation. **2**

Frequency:	Energy:

- What mass of calcium chloride is required to make 250 mL of a 0.1 M solution? **3**

Answer:

What amount of chloride ions (in mol) is present in 30.0 mL of this solution?

Answer:

Marks

- Complete the following table. **9**

Molecular formula	SF_6		NH_3
Name		chlorine trifluoride	
Lewis structure			
Number of bonding electron pairs on central atom			
Number of non-bonding electron pairs on central atom			
Molecular shape			

- Silicon is essential to the computer industry as a major component of chips. It has three naturally occurring isotopes, the relative abundance of each being given below. Calculate the atomic mass of silicon. **2**

Isotope	Mass of isotope (a.m.u.)	Relative abundance
^{28}Si	27.9769	92.23%
^{29}Si	28.9765	4.67%
^{30}Si	29.9738	3.10%

Answer:

Marks

- The complete combustion of butane, C_4H_{10}, in air gives water and carbon dioxide as the products. Write a balanced equation for this reaction. **4**

What mass of oxygen is required for the complete combustion of 454 g of butane and what masses of carbon dioxide and water are produced?

- During physical activity, lactic acid forms in the muscle tissue and is responsible for muscle soreness. Elemental analysis shows that it contains by mass 40.0% C, 6.71% H and 53.3% O. Determine the empirical formula of lactic acid. **4**

Answer:

Given that lactic acid has a molar mass of 90.08 g mol^{-1}, determine its molecular formula.

Answer:

Marks

- If 50 mL of a 0.10 M solution of $AgNO_3$ is mixed with 50 mL of a 0.40 M solution of Na_2CO_3, what mass of Ag_2CO_3 will precipitate from the reaction? **4**

Answer:

What is the final concentration of CO_3^{2-} ions in the solution after the above reaction?

Answer:

- Give balanced ionic equations for the reactions that occur in each of the following cases. **3**

Sodium metal is added to excess water.
Solutions of cobalt(II) nitrate and sodium phosphate are mixed.
Solid calcium carbonate is dissolved in dilute nitric acid.

Marks

- A 60.0 g piece of Ag metal is heated to 90.0 °C and dropped into 120.0 g of water at 25.0 °C in a well insulated container. The final temperature of the Ag-H_2O mixture is 26.7 °C. Calculate the specific heat of silver.
  Data: The specific heat of water is 4.18 J g^{-1} K^{-1}. **3**

Answer:

- Determine K_c for the reaction $\frac{1}{2}O_2(g) + Na_2O(s) \rightleftharpoons Na_2O_2(s)$ at 25 °C. **2**

  Data:

  $Na_2O(s) \rightleftharpoons 2Na(s) + \frac{1}{2}O_2(g)$ $K_c = 2 \times 10^{-25}$ at 25 °C.

  $Na_2O_2(s) \rightleftharpoons 2Na(s) + O_2(g)$ $K_c = 5 \times 10^{-29}$ at 25 °C.

Answer:

Marks

- Consider a cell composed of the following half-reactions. **2**

$$Ag^{+}(aq) + e^{-} \rightarrow Ag(s)$$

$$Cr(s) \rightarrow Cr^{3+}(aq) + 3e^{-}$$

What is the balanced equation for the spontaneous reaction?

What is the value of $E°$ for the cell? Relevant standard reduction potentials are on the data sheet.

Answer:

- Calculate the standard heat of reaction for the following reaction. **2**

$$Zn(s) + 2Cu^{+}(aq) \rightarrow 2Cu(s) + Zn^{2+}(aq)$$

Data: ΔH_f^o = +51.9 kJ mol^{-1} for $Cu^{+}(aq)$

ΔH_f^o = –152.4 kJ mol^{-1} for $Zn^{2+}(aq)$

Answer:

Marks

- An electrolytic cell contains a solution of MCl_3. A total charge of 3600 C is passed through the cell, depositing 0.65 g of the metal, M, at the cathode. What is the identity of the metal, M? **4**

Answer:

- A metal-metal hydride battery has the following shorthand notation: **3**

$$MH(s), M(s) \mid OH^-(aq) \parallel OH^-(aq) \mid NiO(OH)(s), Ni(OH)_2(s)$$

Which component of the battery is the cathode?

Give the balanced half equation of the reaction that takes place at the cathode.

Why is it important that all redox active species are solids in this reaction?

Marks
4

- K_p = 7.0 for the reaction $Br_2(g) + Cl_2(g) \rightleftharpoons 2BrCl(g)$ at 400 K.

  Suppose a 1.0 L flask is filled with 0.30 atm $Br_2(g)$ and 0.30 atm $Cl_2(g)$ at 400 K. Find the pressures of all three gases at equilibrium.

$p(Br_2)$:	$p(Cl_2)$:	$p(BrCl)$:

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

Marks

- The *Voyager I* spacecraft determined that the atmospheric pressure at the surface of Saturn's moon, Titan, is 1.6 times that of earth and that the atmosphere contains 6.0 mol % methane, CH_4. What is the partial pressure of methane on Titan in mmHg? **2**

Answer:

- Many gases are available for use in compressed gas cylinders, in which they are stored at high pressures. Calculate the mass of O_2 that can be stored at 20 °C and 170 atm pressure in a cylinder with a volume of 60.0 L. **3**

Answer:

What volume would this mass of oxygen occupy at 1.00 atm pressure and 20 °C?

Answer:

CHEM1001 – FUNDAMENTALS OF 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 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	

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

CHEM1001 – FUNDAMENTALS OF 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
$Pd^{2+}(aq) + 2e^- \rightarrow Pd(s)$	+0.92
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+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
$Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$	+0.15
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0 (by definition)
$Fe^{3+}(aq) + 3e^- \rightarrow Fe(s)$	–0.04
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	–0.13
$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$	–0.14
$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$	–0.24
$Cd^{2+}(aq) + 2e^- \rightarrow Cd(s)$	–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
$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$	–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

CHEM1001 – FUNDAMENTALS OF CHEMISTRY 1A

Useful formulas

Quantum Chemistry $E = h\nu = hc/\lambda$ $\lambda = h/mv$ $4.5k_BT = hc/\lambda$ $E = -Z^2E_R(1/n^2)$ $\Delta x \cdot \Delta(mv) \geq h/4\pi$ $q = 4\pi r^2 \times 5.67 \times 10^{-8} \times T^4$	**Electrochemistry** $\Delta G° = -nFE°$ $Moles\ of\ e^- = It/F$ $E = E° - (RT/nF) \times 2.303 \log Q$ $= E° - (RT/nF) \times \ln Q$ $E° = (RT/nF) \times 2.303 \log K$ $= (RT/nF) \times \ln K$ $E = E° - \frac{0.0592}{n} \log Q$ (at 25 °C)
Acids and Bases $pK_w = pH + pOH = 14.00$ $pK_w = pK_a + pK_b = 14.00$ $pH = pK_a + \log\{[A^-] / [HA]\}$	**Gas Laws** $PV = nRT$ $(P + n^2a/V^2)(V - nb) = nRT$
Colligative properties $\pi = cRT$ $P_{solution} = X_{solvent} \times P°_{solvent}$ $p = kc$ $\Delta T_f = K_f m$ $\Delta T_b = K_b m$	**Kinetics** $t_{½} = \ln 2/k$ $k = Ae^{-Ea/RT}$ $\ln[A] = \ln[A]_o - kt$ $\ln\frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$
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	**Thermodynamics & Equilibrium** $\Delta G° = \Delta H° - T\Delta S°$ $\Delta G = \Delta G° + RT \ln Q$ $\Delta G° = -RT \ln K$ $K_p = K_c (RT)^{\Delta n}$
Miscellaneous $A = -\log 10 \frac{I}{I_0}$ $A = \varepsilon cl$ $E = -A \frac{e^2}{4\pi\varepsilon_0 r} N_A$	**Mathematics** If $ax^2 + bx + c = 0$, then $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ $\ln x = 2.303 \log x$

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** [261]	105 DUBNIUM **Db** [262]	106 SEABORGIUM **Sg** [266]	107 BOHRIUM **Bh** [262]	108 HASSIUM **Hs** [265]	109 MEITNERIUM **Mt** [266]	110 DARMSTADTIUM **Ds** [271]	111 ROENTGENIUM **Rg** [272]							

LANTHANIDES	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
ACTINIDES	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]