Topics in the June 2009 Exam Paper for CHEM1001

Click on the links for resources on each topic.

2009-J-2:

- Molecules and Ions
- Atomic Energy Levels

2009-J-3:

- Lewis Model of Bonding
- VSEPR

2009-J-4:

- Types of Intermolecular Forces

2009-J-5:

- Chemical Equations
- Stoichiometry

2009-J-6:

- Elements and Atoms
- Chemical Equations
- Stoichiometry

2009-J-7:

- Stoichiometry
- Gas Laws
- Introduction to Electrochemistry
- Electrochemistry

2009-J-8:

- Electrolytic Cells

2009-J-9:

- Chemical Equilibrium

2009-J-10:

- First Law of Thermodynamics
- Chemical Equilibrium
- Thermochemistry

2009-J-11:

- Thermochemistry
- Types of Intermolecular Forces
- Chemical Equilibrium

2009-J-12:

- Types of Intermolecular Forces

22/01(a)

The University of Sydney

FUNDAMENTALS OF CHEMISTRY 1A - CHEM1001

FIRST SEMESTER EXAMINATION

CONFIDENTIAL

JUNE 2009 **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 16, 21 and 24 are for rough working only.

OFFICIAL USE ONLY

Multiple choice section

	Marks	
Pages	Max	Gained
2-10	31	

Short answer section

Page	Marks Max	Gained		Marker
11	9			
12	10			
13	7			
14	5			
15	6			
17	7			
18	3			
19	6			
20	4			
22	6			
23	6			
Total	69			
Check Total				

Marks

- Complete the following table. **4**

Formula	Systematic name
$CaBr_2$	
	potassium hydrogencarbonate
$KMnO_4$	
$Fe(NO_3)_3$	

- Consider the elements **W**, **X**, **Y** and **Z** from the same period, *n*, with the following valence electron configurations. **3**

W $ns^2\ np^3$ **X** ns^2 **Y** $ns^2\ np^5$ **Z** $ns^2\ np^6$

Which element will conduct electricity in the solid state?	
Which element will be the most electronegative?	
Which element will possess the largest atomic radius?	

- Write the electronic configuration of lowest energy for the following species. Na is given as an example. **2**

Na	$1s^2\ 2s^2\ 2p^6\ 3s^1$
Al^{3+}	
Cl	

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

- Complete the following table.

Marks 10

Species	Lewis structure	Arrangement of the electron pairs around the underlined atom	Geometry of species
$\underline{N}H_3$			
$\underline{S}F_6$			
$\underline{B}F_4^-$			
$\underline{C}O_2$			
$\underline{I}Cl_3$			

	Marks
• Manganese(II) chloride and manganese(II) sulfate are both soluble in water. Manganese(II) carbonate, manganese(II) hydroxide and manganese(II) phosphate are all insoluble. Describe, using equations where appropriate, how to convert solid manganese(II) chloride into solid manganese(II) sulfate.	**4**
• Sodium chloride is soluble in water, magnesium oxide is not. Using your understanding of the intermolecular forces involved, explain why this is so.	**3**

Marks 5

- A solution is prepared by dissolving lead(II) nitrate (33.12 g) in 1.00 L of water. Write the balanced ionic equation for this dissolution reaction.

When a 100.0 mL portion of this solution is mixed with a solution of potassium iodide (0.300 M, 150.0 mL), a bright yellow precipitate of lead(II) iodide forms. Write the balanced ionic equation for this precipitation reaction.

What mass of lead(II) iodide is formed?

Answer:

What is the final concentration of $I^-(aq)$ ions remaining in solution after the reaction is complete?

Answer:

	Marks
• Direct damage to the DNA of skin cells can be brought about by exposure to ultraviolet radiation of wavelength 300 nm. What are the frequency and energy (in kJ mol^{-1}) of this radiation?	**4**

Frequency:	Energy:

• Three different oxides of lead are known. The oxide that is red in colour is found to consist of 90.67 % lead. What is its empirical formula?	**2**

	Answer:

- Propane, C_3H_8, is commonly used in barbecue gas cylinders, its complete combustion yielding water and carbon dioxide as the only products. What volume of CO_2 is produced at 0 ^oC and 1.0 atm from the complete combustion of 15.0 L of propane at a pressure of 4.5 atm and a temperature of 25 ^oC?

Marks 3

Answer:

- The following cell has a potential of 0.55 V at 25 ^oC:

$$Pt(s) \mid H_2(1.0\ atm) \mid H^+(x\ M) \parallel Cl^-(1.0\ M) \mid Hg_2Cl_2(s) \mid Hg(l)$$

What is the concentration of H^+ in the anode compartment?

Data: $Hg_2Cl_2(s) + 2e^- \rightarrow 2Hg(l) + 2Cl^-(aq)$ $\quad E^o = 0.28$ V

4

Answer:

Marks 3

- Adiponitrile, a key intermediate in the manufacture of nylon, is prepared by the reduction of acrylonitrile.

  Anode: $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

  Cathode: $2CH_2{=}CHCN + 2H^+ + 2e^- \rightarrow NC(CH_2)_4CN$

  Write a balanced equation for the overall electrochemical reaction.

What mass of adiponitrile (in kg) is produced in 10.0 hours in a cell that has a constant current of 3.00×10^3 A?

Answer:

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

- Write a balanced equation for the following reaction:

$$WO_3(s) + H_2(g) \rightarrow W(s) + H_2O(g)$$

Marks 3

What is the equilibrium constant expression, K_p, for the above reaction?

What is the equilibrium constant, K_c, for the above reaction, in terms of K_p?

- Fe_2O_3 can be reduced by carbon monoxide according to the following equation. **3**

$$Fe_2O_3(s) + 3CO(g) \rightleftharpoons 2Fe(s) + 3CO_2(g) \qquad K_p = 19.9 \text{ at } 1000 \text{ K}$$

At 1000 K, what are the equilibrium partial pressures of CO and CO_2 if the only gas initially present is CO at a partial pressure of 0.978 atm?

$p(CO)$ =	$p(CO_2)$ =

- Calculate the standard-free energy change for the oxidation of ammonia to nitric oxide and water, according to the following equation.

Marks 3

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(l)$$

Data: $\Delta_f G°(NO(g)) = 87.6 \text{ kJ mol}^{-1}$

$\Delta_f G°(NH_3(g)) = -16.5 \text{ kJ mol}^{-1}$

$\Delta_f G°(H_2O(l)) = -237.2 \text{ kJ mol}^{-1}$

Answer:

Is the reaction spontaneous under standard conditions? Give a reason for your answer.

- How much heat is evolved, in kJ, when 5.00 g of Al reacts with a stoichiometric amount of Fe_2O_3 according to the following equation?

1

$$2Al(s) + Fe_2O_3(s) \rightarrow 2Fe(s) + Al_2O_3(s) \qquad \Delta H^o = -852 \text{ kJ mol}^{-1}$$

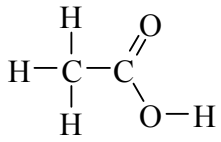
Answer:

- The specific heat of Si is 0.71 J g^{-1} K^{-1}. How much heat is required to heat a Si wafer weighing 0.45 g from 20.0 °C to 26.0 °C?

Marks 1

Answer:

- The structural formula of acetic acid is shown on the right. Acetic acid forms dimers (*i.e.* pairs of molecules) in the gas phase. Draw the dimer showing the H-bonding that occurs.



1

- Heating $SbCl_5$ causes it to decompose according to the following equation.

$$SbCl_5(g) \rightleftharpoons SbCl_3(g) + Cl_2(g)$$

A sample of 0.50 mol of $SbCl_5$ is placed in a 1.0 L flask and heated to 450 ºC. When the system reaches equilibrium there is 0.10 mol of Cl_2 present. Calculate the value of the equilibrium constant, K_c, at 450 °C.

4

Answer:

	Marks
• Which of acetone, $(CH_3)_2CO$, and water will have the greater surface tension. Why?	**2**
• Melting points of the hydrogen halides increase in the order HCl < HBr < HF < HI. Explain this trend.	**2**
• Why is the solubility of chloroform ($CHCl_3$) in water 10 times greater than that of carbon tetrachloride (CCl_4) in water?	**2**

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

0 °C = 273 K

1 L = 10^{-3} m^3

1 Å = 10^{-10} m

1 eV = 1.602×10^{-19} J

1 Ci = 3.70×10^{10} Bq

1 Hz = 1 s^{-1}

1 tonne = 10^3 kg

1 W = 1 J s^{-1}

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
$NO_3^-(aq) + 4H^+(aq) + 3e^- \rightarrow NO(g) + 2H_2O$	+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

$E = h\nu = hc/\lambda$

$\lambda = h/mv$

$E = -Z^2 E_R(1/n^2)$

$\Delta x \cdot \Delta(mv) \geq h/4\pi$

$q = 4\pi r^2 \times 5.67 \times 10^{-8} \times T^4$

$T\lambda = 2.898 \times 10^6$ K nm

Electrochemistry

$\Delta G° = -nFE°$

Moles of $e^- = It/F$

$E = E° - (RT/nF) \times 2.303 \log Q$

$= E° - (RT/nF) \times \ln Q$

$E° = (RT/nF) \times 2.303 \log K$

$= (RT/nF) \times \ln K$

$E = E° - \frac{0.0592}{n} \log Q$ (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

$PV = nRT$

$(P + n^2a/V^2)(V - nb) = nRT$

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

$\Pi = cRT$

$P_{solution} = X_{solvent} \times P°_{solvent}$

$c = kp$

$\Delta T_f = K_f m$

$\Delta T_b = K_b m$

Thermodynamics & Equilibrium

$\Delta G° = \Delta H° - T\Delta S°$

$\Delta G = \Delta G° + RT \ln Q$

$\Delta G° = -RT \ln K$

$\Delta_{univ} S° = R \ln K$

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

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** [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]							

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]