22/01(a)

The University of Sydney

FUNDAMENTALS OF CHEMISTRY 1A - CHEM1001

FIRST SEMESTER EXAMINATION

CONFIDENTIAL

JUNE 2004

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 19 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 15, 19, 22 and 24 are for rough working only.

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Multiple choice section

	Marks	
Pages	Max	Gained
2-12	43	

Short answer section

Page	Marks Max	Gained		Marker
13	6			
14	12			
16	6			
17	7			
18	7			
20	5			
21	6			
23	8			
Total	57			
Check Total				

- Balance the following nuclear reactions by identifying the missing nuclear particle. **Marks 2**

$$^{14}_{6}\text{C} \rightarrow {}^{14}_{7}\text{N} + \square$$

$$^{210}_{86}\text{Rn} \rightarrow {}^{206}_{84}\text{Po} + \square$$

- Ionising radiation is defined as radiation that has energy greater than 1.93×10^{-18} J per photon. Using this criterion, determine whether UV light of $\nu = 1.00 \times 10^{16}$ Hz would be ionising. **2**

- The atoms in both iodine and diamond are joined by covalent bonds. However, iodine is a soft, low-melting point solid while diamond is very hard and has an extremely high melting point. Account for these differences in properties. **2**

Marks

- Give the formula and name of a binary ionic compound formed from the following elements. **6**

	Formula	Name
magnesium and oxygen		
barium and bromine		
sodium and nitrogen		
potassium and oxygen		

- Explain why some ionic compounds are soluble in water and usually insoluble in hydrocarbon solvents such as kerosene. **2**

- Draw Lewis diagrams for the following species. Show both bonding and non-bonding pairs of valence electrons. Give the geometry of the species. **4**

NH_4^+	SO_2
Geometry:	Geometry:

- Solid sodium hydroxide reacts with carbon dioxide to produce sodium carbonate and water. Calculate the mass of sodium hydroxide required to prepare 53.0 g of sodium carbonate.

Marks
3

Answer:

- Analysis of an unknown compound returned the following percentage composition by weight:

  nitrogen: 26.2%; chlorine: 66.4% hydrogen 7.5%

  What is the empirical formula of this compound?

3

Answer:

Marks

- Water solutions of NaOH (100 mL, 2.0 M) and HCl (100 mL, 2.0 M), both at 24.6 °C, were mixed together in a coffee cup calorimeter. The temperature of the solution rose to 38.0 °C during the reaction process. Write a balanced chemical equation to describe the reaction in the calorimeter.

5

Is the process an endothermic or exothermic reaction?

Assuming a perfect calorimeter, determine the standard enthalpy change for the neutralisation reaction. Assume the density of water is 1.00 g mL^{-1}. The heat capacity of water is 4.18 J K^{-1} g^{-1}.

- Explain why aluminium metal cannot be produced by the electrolysis of aqueous solutions of aluminium salts.

2

	Marks
• In the chor-alkali electrolysis of aqueous NaCl solution, 1000 g of NaOH was produced. What mass of $Cl_2(g)$ was formed?	**4**
• Briefly describe the following ideas or phenomena. Dynamic equilibrium	**3**
The difference between *Q* and *K*	
Effect of a catalyst on equilibrium	

Marks 5

- Aluminium metal is a very effective agent for reducing oxides to their elements. For example, it is used as a component of the solid fuel in the space shuttle, and in the thermite reaction shown in lectures:

$$Fe_2O_3(s) + 2Al(s) \rightarrow Al_2O_3(s) + 2Fe(s)$$

Write a balanced equation for the reduction of CuO(s) to the base metal by Al(s).

Given the following thermochemical data, evaluate the enthalpy change per gram of reactant for the CuO and Fe_2O_3 reactions above.

Compound	$\Delta H_f°$ (kJ mol^{-1})
Fe_2O_3	-821
Al_2O_3	-1668
CuO	-157

Answer:

Which would make the best rocket fuel on the basis of most energy provided per mass of fuel (*i.e.* biggest "bounce per ounce")?

Marks

- Explain the following features of the lead acid storage battery. **3**

It has a relatively constant voltage.

It needs no salt bridge.

It can be recharged.

- Consider the following cell reaction. **3**

$$Pb(s) + Sn^{2+}(aq) \rightleftharpoons Pb^{2+}(aq) + Sn(s)$$

Use the Nernst equation to calculate the ratio of cation concentrations for which the cell potential, $E = 0$. (See the data sheet for a table of standard reduction potentials.)

Answer:

Marks

- The standard dry cell (battery) has the following shorthand notation:

$$Zn(s) \mid Zn^{2+}(aq) \parallel MnO_2(s), Mn_2O_3(s) \mid graphite(s)$$

4

Which component of the battery is the anode?

Give the balanced half equation that takes place at the anode.

Which component of the battery is the cathode?

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

- A saturated solution of iodine, I_2, in water contains 0.330 g I_2 per litre, but more than this amount can dissolve in a KI solution because of the following equilibrium.

$$I^-(aq) + I_2(aq) \rightleftharpoons I_3^-(aq)$$

4

A solution of KI (0.100 M) dissolves 12.5 g of iodine per litre, most of which is converted to $I_3^-(aq)$. Assuming that the concentration of I_2 in all saturated solutions is the same, calculate the equilibrium constant for the above reaction.

Answer:

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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}

Boltzmann constant, $k_B = 1.381 \times 10^{-23}$ J K^{-1}

Gas constant, $R = 8.314$ J K^{-1} mol^{-1}

$= 0.08206$ L atm K^{-1} mol^{-1}

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}

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

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Standard Reduction Potentials, E°

Reaction	*E°* / V
$Cl_2 + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$O_2 + 4H^+(aq) + 4e^- \rightarrow 2H_2O$	+1.23
$Pd^{2+}(aq) + 2e^- \rightarrow Pd(s)$	+0.92
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+0.80
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+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
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–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

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Useful formulas

Quantum Chemistry

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

$\lambda = h/mu$

$4.5k_BT = hc/\lambda$

Gas Laws

$PV = nRT$

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

Kinetics

$k = Ae^{-Ea/RT}$

$t_{½} = \ln 2/k$

$\ln[A] = \ln[A]_o - kt$

Radioactivity

$A = \lambda N$

$\ln(N_0/N_t) = \lambda t$

^{14}C age $= 8033 \ln(A_0/A_t)$

Colligative properties

$\pi = cRT$

$p = kc$

$\Delta T_f = K_f m$

$\Delta T_b = K_b m$

Acids and Bases

$pK_w = pH + pOH = 14.00$

$pK_w = pK_a + pK_b = 14.00$

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

Electrochemistry

$\Delta G° = -nFE°$

Moles of $e^- = It/F$

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

$E° = (RT/nF) \times 2.303 \log K$

$E = E° - \dfrac{0.0592}{n} \log Q$ (at 25 °C)

Thermodynamics & Equilibrium

$\Delta G° = \Delta H° - T\Delta S°$

$\Delta G = \Delta G° + RT \ln Q$

$\Delta G° = -RT \ln K$

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

Polymers

$R_g = \sqrt{\dfrac{nl_0^2}{6}}$

Mathematics

$\ln x = 2.303 \log x$

If $ax^2 + bx + c = 0$, then $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

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]									

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]