22/01(a)

The University of Sydney

FUNDAMENTALS OF CHEMISTRY 1A - CHEM1001

FIRST SEMESTER EXAMINATION

CONFIDENTIAL

JUNE 2005

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, 20 and 24 are for rough working only.

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Multiple choice section

	Marks	
Pages	Max	Gained
2-11	37	

Short answer section

Page	Marks (Max)	Marks (Gained)		Marker
12	8			
13	9			
14	4			
15	8			
17	7			
18	6			
19	3			
21	7			
22	7			
23	4			
Total	63			
Check Total				

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

${}^{14}_{6}\mathrm{C} \rightarrow \square + {}^{0}_{-1}\mathrm{e}$
${}^{243}_{95}\mathrm{Am} \rightarrow \square + {}^{4}_{2}\mathrm{He}$

• Briefly explain the concept of resonance in Lewis structures. Include an example of a species that displays resonance. **3**

• What element has the ground state electronic arrangement of $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$? **1**

• Calculate the frequency and energy of yellow light of wavelength 570 nm. **2**

Frequency =	Energy =

Marks

- Iodine is a soft, low-melting point solid while diamond is very hard and has an extremely high melting point. How does the bonding in each element account for these differences in properties?

3

- Draw Lewis diagrams of the following species. Give the arrangement of the valence shell electron pairs (both bonding and, where present, non-bonding) around the underlined atom and predict the geometry of each species.

6

Species	Lewis diagram	Arrangement of electron pairs	Geometry of species
$H_2\underline{O}$	$H-\ddot{\underset{..}{O}}-H$	tetrahedral	bent
$\underline{N}H_4^+$			
$\underline{B}F_3$			
$\underline{O}F_2$			

Marks

- The element boron forms a series of hydrides, which includes B_2H_6, B_4H_{10}, B_5H_9, B_6H_{10} and $B_{10}H_{14}$. Which one of these hydrides consists of 85.63% boron by mass? **2**

Answer:

- Complete the following table. **2**

Formula	Name
K_2SO_4	
	copper(II) chloride
SF_4	
	potassium chromate

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

Marks

- Balance the following equation: **2**

$$Fe_2O_3(s) + CO(g) \rightarrow Fe(s) + CO_2(g)$$

- Calculate the mass of sodium hydroxide required to make 500 mL of a 0.200 M aqueous solution. **6**

Answer:

What volume of the above solution would be required to neutralise 50.0 mL of 0.100 M hydrochloric acid solution?

Answer:

Marks

- A 0.50 g sample of ammonium nitrate, $NH_4NO_3(s)$, was dissolved in 35.0 g of water in a coffee cup calorimeter. The temperature of the solution dropped from 22.7 to 21.6 °C. Write a balanced equation to describe the reaction in the calorimeter. **5**

Describe this process as either endothermic or exothermic.

Assuming a perfect calorimeter what is the heat of solution of ammonium nitrate, expressed in kJ mol^{-1}? Assume the density of the solution is 1.00 g mL^{-1} and that the heat capacity of the solution is 4.18 J K^{-1} g^{-1}.

- Heat radiating fins are used to dissipate heat and prevent damage to electronic components. Is it better to make the fins out of aluminium or iron? Give reasons for your answer. **2**

  Data: Specific heat of Al = 0.900 J K^{-1} g^{-1} Specific heat of Fe = 0.444 J K^{-1} g^{-1}

Marks

- Aluminium acts as a reducing agent in the thermite reaction where Fe_2O_3 is reduced to metallic iron. Write a balanced equation for the thermite reaction. **4**

What is the maximum theoretical mass of Fe that can be produced when 270 g of Al reacts with excess Fe_2O_3 in the thermite reaction?

Answer:

- What does the superscript "o" mean in the symbol ΔH_f°? **1**

- Briefly describe what is meant by "Dynamic Equilibrium"? **1**

Marks

- A sealed 1.000 L flask at 30 °C contains air at a pressure of 1.000 atm. A 5.00 g sample of liquid water is injected into the flask and the flask heated to a temperature of 150 °C, causing the water to vaporise. What is the final pressure in the flask? **3**

Answer:

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

Marks

- Consider the following reaction. **4**

$$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l) \qquad \Delta E = -10909 \text{ kJ mol}^{-1}$$

A mixture of C_8H_{18} (10.00 g) and O_2 (30.00 g) is allowed to react. Assuming that the reaction goes to completion, how much energy will be produced?

Answer:

- The half reactions describing the discharge of a silver-zinc cell are: **3**

$$Zn(s) + 2OH^-(aq) \rightarrow ZnO(s) + H_2O(l) + 2e^-$$

$$Ag_2O(s) + H_2O(l) + 2e^- \rightarrow 2Ag(s) + 2OH^-(aq)$$

List the chemical species that will be consumed as the battery discharges.

Why is a saturated solution of KOH used in the battery?

Why is the voltage in the silver-zinc cell constant during discharge?

Marks

3

- Consider the following cell reaction.

$$Cr^{2+}(aq) + Zn(s) \rightleftharpoons Cr(s) + Zn^{2+}(aq)$$

Use the Nernst equation to calculate the ratio of cation concentrations at 298 K for which the cell potential, E = 0 V.

Answer:

4

- A lead-acid battery has the following shorthand notation:

$$Pb(s), PbSO_4(s) \mid H^+(aq), SO_4^{2-}(aq) \parallel H^+(aq), SO_4^{2-}(aq) \mid PbO_2(s), PbSO_4(s)$$

Which component of the battery is the anode?

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

Which component of the battery is the cathode?

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

Marks
4

- At 800 °C, the value of the equilibrium constant, K_c, for the following equation is 1.245×10^3 L mol^{-1}.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$$

What is the equilibrium concentration of NO(g) at 800 °C if, at equilibrium, $[O_2(g)] = 0.0012$ M and $[NO_2(g)] = 0.055$ M?

Answer:

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

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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}

Rydberg constant, $E_R = 2.18 \times 10^{-18}$ J

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}

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}

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
$Co^{3+}(aq) + e^{-} \rightarrow Co^{2+}(aq)$	+1.82
$Ce^{4+}(aq) + e^{-} \rightarrow Ce^{3+}(aq)$	+1.72
$Cl_2(g) + 2e^{-} \rightarrow 2Cl^{-}(aq)$	+1.36
$O_2(g) + 4H^{+}(aq) + 4e^{-} \rightarrow 2H_2O(l)$	+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
$Cu^{+}(aq) + e^{-} \rightarrow Cu(s)$	+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
$Co^{2+}(aq) + 2e^{-} \rightarrow Co(s)$	–0.28
$Fe^{2+}(aq) + 2e^{-} \rightarrow Fe(s)$	–0.44
$Cr^{3+}(aq) + 3e^{-} \rightarrow Cr(s)$	–0.74
$Zn^{2+}(aq) + 2e^{-} \rightarrow Zn(s)$	–0.76
$2H_2O(l) + 2e^{-} \rightarrow H_2(g) + 2OH^{-}(aq)$	–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 $E = h\nu = hc/\lambda$ $\lambda = h/mv$ $4.5k_BT = hc/\lambda$ $E = Z^2E_R(1/n^2)$	**Radioactivity** $t_{½} = \ln 2/\lambda$ $A = \lambda N$ $\ln(N_0/N_t) = \lambda t$ ^{14}C age = 8033 $\ln(A_0/A_t)$
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 $\pi = cRT$ $P_{solution} = X_{solvent} \times P°_{solvent}$ $p = kc$ $\Delta T_f = K_fm$ $\Delta T_b = K_bm$	**Kinetics** $t_{½} = \ln 2/k$ $k = Ae^{-Ea/RT}$ $\ln[A] = \ln[A]_o - kt$ $\ln\frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$
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)	**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 $R_g = \sqrt{\frac{nl_0^2}{6}}$	**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]									

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]