

FUNDAMENTALS OF CHEMISTRY 1A - CHEM1001FIRST 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.

OFFICIAL USE ONLY**Multiple choice section**

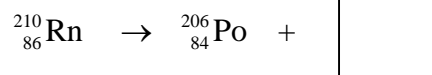
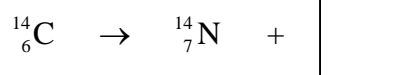
	Marks	
Pages	Max	Gained
2-12	43	

Short answer section

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

Marks
2

- Balance the following nuclear reactions by identifying the missing nuclear particle.

**2**

- 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.

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

Marks
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:

Marks
3

- 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.

Answer:

3

- 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?

Answer:

Marks
5

- 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.

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
4

- In the chlor-alkali electrolysis of aqueous NaCl solution, 1000 g of NaOH was produced. What mass of Cl₂(g) was formed?

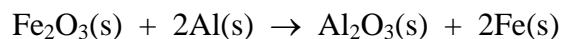
3

- Briefly describe the following ideas or phenomena.
Dynamic equilibrium

The difference between Q and K

Effect of a catalyst on equilibrium

- 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:



Write a balanced equation for the reduction of $\text{CuO}(\text{s})$ to the base metal by $\text{Al}(\text{s})$.

Marks
5

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

Compound	ΔH_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
3

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

It has a relatively constant voltage.

It needs no salt bridge.

It can be recharged.

- Consider the following cell reaction.



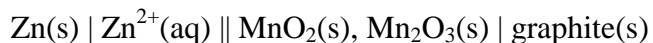
Use the Nernst equation to calculate the ratio of cation concentrations for which the cell potential, $E = 0$. (See the data sheet for a table of standard reduction potentials.)

3

Answer:

Marks
4

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



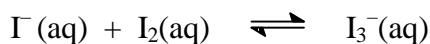
Which component of the battery is the anode?

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.



A solution of KI (0.100 M) dissolves 12.5 g of iodine per litre, most of which is converted to $\text{I}_3^{-}(\text{aq})$. Assuming that the concentration of I_2 in all saturated solutions is the same, calculate the equilibrium constant for the above reaction.

4

Answer:

CHEM1001 – FUNDAMENTALS OF CHEMISTRY 1A**DATA SHEET***Physical constants*

Avogadro constant, $N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$

Faraday constant, $F = 96485 \text{ C mol}^{-1}$

Planck constant, $h = 6.626 \times 10^{-34} \text{ J s}$

Speed of light in vacuum, $c = 2.998 \times 10^8 \text{ m s}^{-1}$

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

Gas constant, $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$
 $= 0.08206 \text{ L atm K}^{-1} \text{ mol}^{-1}$

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 m³

1 Å = 10⁻¹⁰ m

1 eV = 1.602 × 10⁻¹⁹ J

1 Ci = 3.70 × 10¹⁰ 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

CHEM1001 – FUNDAMENTALS OF CHEMISTRY 1A*Standard Reduction Potentials, E°*

Reaction	E° / V
$\text{Cl}_2 + 2\text{e}^- \rightarrow 2\text{Cl}^-(\text{aq})$	+1.36
$\text{O}_2 + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}$	+1.23
$\text{Pd}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Pd}(\text{s})$	+0.92
$\text{Ag}^+(\text{aq}) + \text{e}^- \rightarrow \text{Ag}(\text{s})$	+0.80
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$	+0.34
$\text{Sn}^{4+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Sn}^{2+}(\text{aq})$	+0.15
$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$	0 (by definition)
$\text{Fe}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Fe}(\text{s})$	-0.04
$\text{Pb}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Pb}(\text{s})$	-0.13
$\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Sn}(\text{s})$	-0.14
$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Ni}(\text{s})$	-0.24
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Fe}(\text{s})$	-0.44
$\text{Cr}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Cr}(\text{s})$	-0.74
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Zn}(\text{s})$	-0.76
$2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$	-0.83
$\text{Cr}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cr}(\text{s})$	-0.89
$\text{Al}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Al}(\text{s})$	-1.68
$\text{Mg}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Mg}(\text{s})$	-2.36
$\text{Na}^+(\text{aq}) + \text{e}^- \rightarrow \text{Na}(\text{s})$	-2.71

CHEM1001 – FUNDAMENTALS OF CHEMISTRY 1A

*Useful formulas***Quantum Chemistry**

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

$$\lambda = h/mu$$

$$4.5k_B T = hc/\lambda$$

Kinetics

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

$$t_{1/2} = \ln 2/k$$

$$\ln[A] = \ln[A]_0 - kt$$

Colligative properties

$$\pi = cRT$$

$$p = kc$$

$$\Delta T_f = K_f m$$

$$\Delta T_b = K_b m$$

Electrochemistry

$$\Delta G^\circ = -nFE^\circ$$

$$\text{Moles of } e^- = It/F$$

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

$$E^\circ = (RT/nF) \times 2.303 \log K$$

$$E = E^\circ - \frac{0.0592}{n} \log Q \text{ (at } 25^\circ\text{C)}$$

Polymers

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

Mathematics

$$\ln x = 2.303 \log x$$

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

Gas Laws

$$PV = nRT$$

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

Radioactivity

$$A = \lambda N$$

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

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

Acids and Bases

$$pK_w = \text{pH} + \text{pOH} = 14.00$$

$$pK_w = \text{p}K_a + \text{p}K_b = 14.00$$

$$\text{pH} = \text{p}K_a + \log\{[A^-] / [HA]\}$$

Thermodynamics & Equilibrium

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$\Delta G = \Delta G^\circ + RT \ln Q$$

$$\Delta G^\circ = -RT \ln K$$

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

PERIODIC TABLE OF THE ELEMENTS

June 2004

CHEM1001 – FUNDAMENTALS OF CHEMISTRY 1A

22/01(b)

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 YTRIUM 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 BERKELIUM 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]		