RAFFLES INSTITUTION
2014 YEAR 6 PRELIMINARY EXAMINATION

Higher 1

CANDIDATE NAME			
CLASS		INDEX NUMBER	

CHEMISTRY 8872/02

Paper 2 Structured Questions **17 September 2014**
2 hours

Candidates answer Section A on the Question Paper.

Additional Materials: Answer paper
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number in the spaces provided at the top of this page.
Write in dark blue or black pen in the spaces provided.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** the questions on the question paper.

Section B
Answer **two** questions on separate answer paper.

A Data Booklet is provided. Do not write anything on it.
You are reminded of the need for good English and clear presentation in your answers.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use		
Paper 1		/ 30
Paper 2 (circle the questions you have answered)	**A1**	/ 10
	A2	/ 10
	A3	/ 8
	A4	/ 12
	B5	/ 20
	B6	/20
	B7	/20
Total		/ 100

This document consists of **17** printed pages.

For Examiner's Use

Section A (40 marks)

Answer **all** the questions in this section in the spaces provided.

A1 This question focuses on chlorine and chlorine-containing compounds.

(a) A sample of chlorine gas from the planet Xanadu was analysed in a mass spectrometer. The sample was initially bombarded with electrons so that an electron is knocked out of each species generated. The resulting ions $^{35}Cl^+$, $^{37}Cl^+$, $^{35}Cl_2^+$, $^{37}Cl_2^+$ and $(^{35}Cl^{37}Cl)^+$ were then separated by the introduction of an electric field.

The ratio of abundance of $^{35}Cl^+$ ions to $^{37}Cl^+$ ions is 4:1.

(i) Define the term *relative atomic mass* of C*l* atom.

.....

.....

(ii) Write a balanced equation to illustrate the electron bombardment of chlorine molecules to form $^{35}Cl_2^+$ ions.

.....

.....

(iii) Write the electronic configuration of $^{37}Cl^+$ ion.

.....

.....

(iv) Suggest why the energy required to remove one mole of electrons each from one mole of ^{35}Cl and one mole of ^{37}Cl gaseous atoms separately is the same.

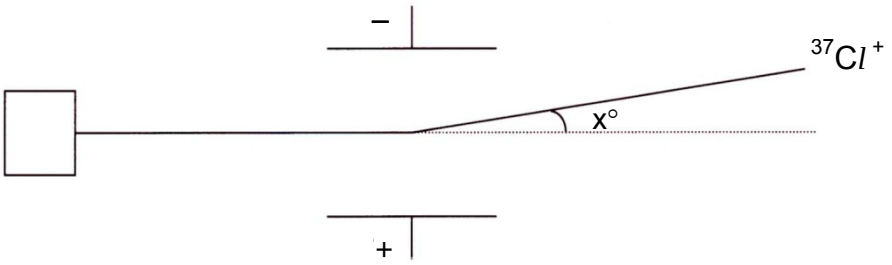
.....

.....

.....

[4]

(v) Under an electric field, the angle of deflection for $^{37}Cl^+$ ion is x°.



Calculate, in terms of x, the angle of deflection for $^{35}Cl_2^+$.

[1]

(b) **(i)** By quoting suitable data from the *Data Booklet*, suggest explanations for the following observations.

compound	*pH of a 1.0 mol dm^{-3} solution in water*
$NaCl$	7.0
$MgCl_2$	6.5
$AlCl_3$	3.0

.....

.....

.....

.....

.....

(ii) Write equations to show why the reaction between $MgCl_2$ and water gives a pH of 6.5.

.....

.....

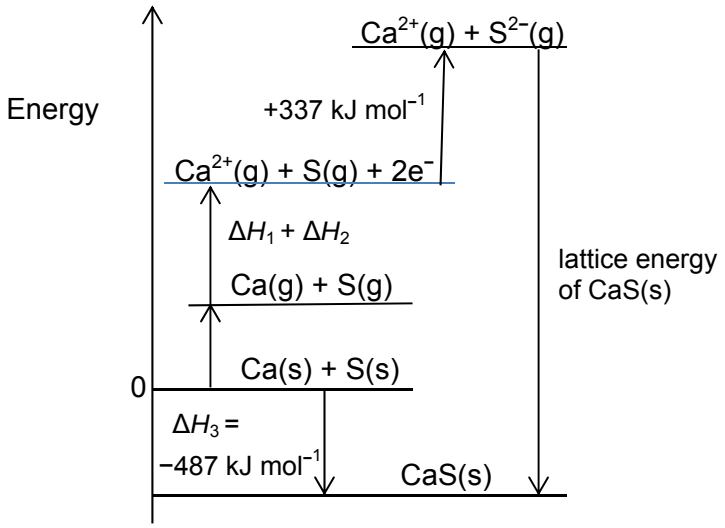
[5]
[Total: 10]

For Examiner's Use

A2 **(a)** Calcium sulphide, CaS, is an ionic compound.
Draw a dot-and-cross diagram to show the bonding in CaS.

[1]

(b) **(i)** The diagram below shows a Born-Haber cycle involving CaS.



In the Born-Haber cycle above, name the enthalpy changes represented as:

$\Delta H_1 + \Delta H_2$: ……

ΔH_3: ……

For Examiner's Use

(ii) The standard enthalpy changes of atomisation of an element is defined as the energy absorbed to form one mole of gaseous atoms from the element in its standard state at 298 K and 1 atm.

The enthalpy change of atomisation of two elements are given below.

$\Delta H_a^{\ominus}$ of calcium = +178 kJ mol $^{-1}$
$\Delta H_a^{\ominus}$ of sulfur = +279 kJ mol $^{-1}$

Using the Born-Haber cycle in **(b)(i),** together with the above enthalpy changes and suitable data from the *Data Booklet*, calculate the lattice energy of CaS.

[4]

(c) The constituents of cement include approximately 65% calcium oxide, CaO, and 25% silicon dioxide, SiO_2.

(i) Suggest and explain how you would expect the value of the lattice energy of calcium oxide, CaO, to compare with the lattice energy of CaS.

……

……

……

……

(ii) With reference to structure and bonding, explain the higher electrical conductivity of molten CaO as compared to molten SiO_2.

……

……

……

[3]

For Examiner's Use

(d) Lattice energies can be calculated from figures obtained experimentally using Born-Haber cycles. They can also be calculated theoretically based on knowledge of the distances between the cations and anions in the crystal structure, and the charge on each ion.

The table gives the experimental and theoretical values of lattice energies for the silver halides.

compound	experimental value / kJ mol^{-1}	theoretical value / kJ mol^{-1}
AgF	+967	+953
AgC*l*	+915	+864
AgBr	+904	+830
AgI	+889	+808

(i) Suggest a reason why the experimental and theoretical values of the lattice energy of AgF are very close.

……

……

(ii) Explain why the difference between the experimental and theoretical values increases from AgF to AgI.

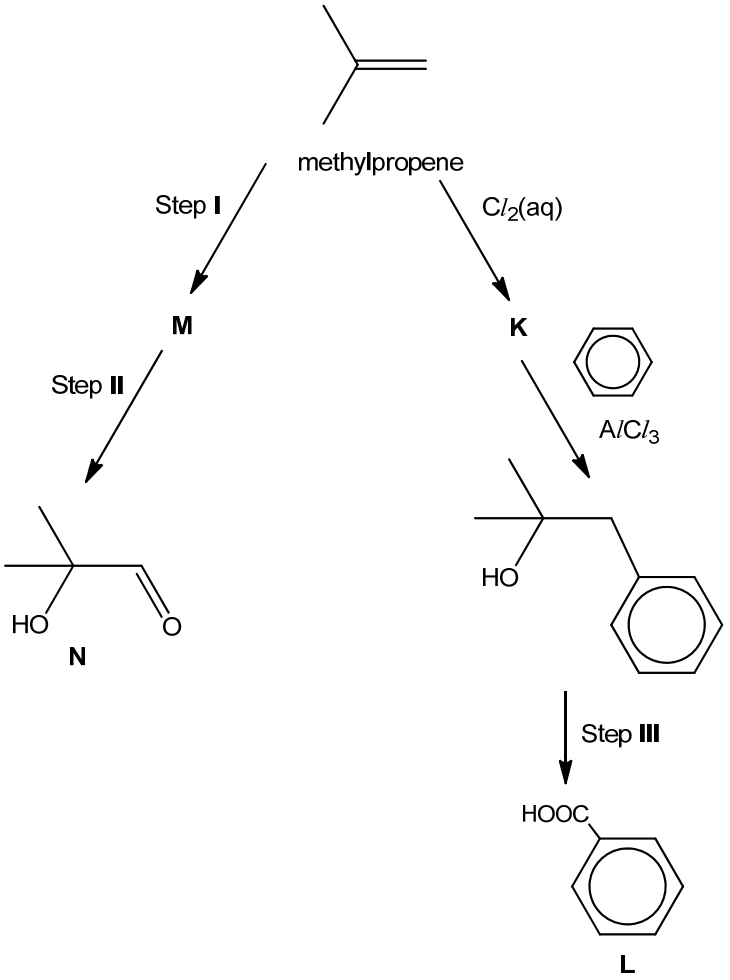
……

……

[2]
[Total : 10]

For Examiner's Use

A3 Compounds **N** and **L** can be made from methylpropene in the reaction scheme below.



(a) **(i)** State the reagents and conditions for the following steps.

Step **I**: .....

Step **II**: .....

Step **III**: .....

(ii) In the boxes below, draw the displayed formulae of **K** and **M**.

K	**M**

[5]

For Examiner's Use

(b) **(i)** State the reagents and conditions for a simple chemical test that could be used to distinguish between **L** and **N**. You should state the observations of how each of **L** and **N** react.

Test: ……

……

……

Observations: ……

……

……

(ii) Explain why **L** is insoluble in water.

……

……

……

[3]
[Total : 8]

For Examiner's Use

A4 Atmospheric nitrogen gas is highly unreactive, thus it cannot be used by plants directly. Nitrogen fixation is the process that converts atmospheric nitrogen gas into ammonia or oxides of nitrogen. The major industrial source of fixed nitrogen in the form of ammonia is the Haber Process. Fertilisers generated from ammonia sustain one third of the world's population.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \text{ .....(1)}$$

Figure 1 below shows how the percentage of ammonia in the equilibrium mixture varies with pressure at 500 °C and 700 °C respectively.

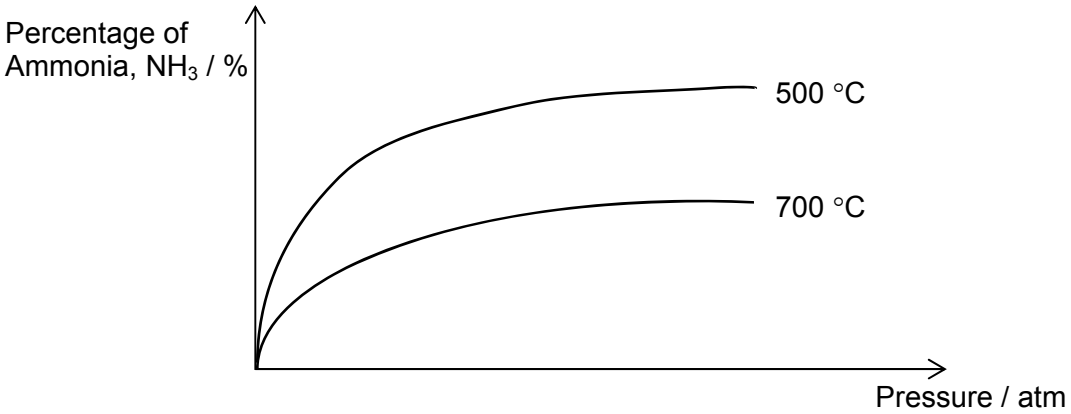


Figure 1: Graph of percentage of ammonia against pressure

(a) **(i)** Use Figure 1 to deduce whether the production of ammonia gas from the Haber process is an endothermic or exothermic process.

Explain your answer.

.....

.....

.....

.....

(ii) State the conditions used in Haber process and the reasons that these particular conditions are chosen.

.....

.....

.....

.....

.....

.....

.....

.....

[5]

The hydrogen gas required for this reaction is obtained by steam reforming as shown in equation 2.

$$CH_4(g) + H_2O(g) \longrightarrow CO(g) + 3H_2(g) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

(b) **(i)** Given that the bond energy in CO is 1074 kJ mol^{-1}, use the *Data Booklet* to calculate the enthalpy change of the reaction in equation (2).

(ii) Explain why this reaction can have undesirable biological effect.

.....

.....

[3]

For Examiner's Use

(c) An efficient and milder method for fixating atmospheric nitrogen gas will result in considerable energy savings. One alternative is the electrochemical method. In this method, nitrogen gas is reduced to ammonia gas while water is oxidised to oxygen gas. The half equations are as follows.

$$N_2 + 6H^+ + 6e^- \rightleftharpoons 2NH_3$$

$$O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O$$

(i) Use the half-equations to construct an equation for the overall reaction that takes place in the electrochemical synthesis of ammonia.

……

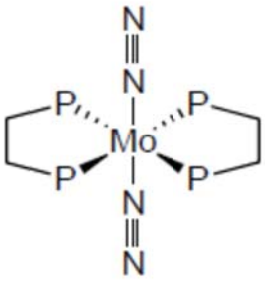
……

(ii) Given that nitrogen gas makes up 78% of atmospheric air, calculate the minimum volume of air required to synthesise 1 mol of ammonia using the electrochemical method at room temperature and pressure.

[3]

For Examiner's Use

Biological fixation, an alternative to Haber process, is performed with bacteria that live in parts of a plant or in the soil. The bacteria reduce atmospheric nitrogen gas to ammonia and this process is catalysed by nitrogenase enzymes. Such enzymes are highly complex protein structures which contain a molybdenum central atom. A simplified structural formula of an enzyme is shown below in Figure 2.



where  $= Ph_2PCH_2CH_2PPh_2$

Figure 2: Structural formula of a nitrogenase enzyme being to nitrogen gas

(d) Explain how nitrogen gas bonds to a molybdenum atom in Figure 2.

.....

.....

[1]

[Total: 12]

Section B (40 marks)

Answer any **two** questions from this section on separate answer paper.

B5 This question is about the chemistry of Period 3 elements and their compounds.

A student investigated the rate of reaction between sodium and ethanol. A freshly cut piece of sodium was weighed and added to a large excess of ethanol.

(a) **(i)** Write an equation for the reaction between sodium and ethanol.

(ii) Explain why sodium needs to be freshly cut.

[2]

The total volume of gas liberated was recorded every minute. The results are tabulated below.

time / min	0	1	2	3	4	5	6	7
total volume of gas / cm^3	0	23.0	36.5	46.0	51.0	54.5	57.0	58.5

(b) **(i)** Plot a graph of total volume of gas against time on a graph paper.

(ii) Explain, as fully as you can, why your graph in **(b)(i)** indicates that the overall kinetics are first order.

(iii) In this experiment, the kinetics appear to be zero order with respect to ethanol. Suggest a reason for this.

[4]

(c) **(i)** Assuming that the reaction was completed at 7 min, calculate how many moles of gas were produced in the experiment, conducted at room temperature and pressure.

(ii) Calculate the mass of sodium weighed out at the start of the experiment.

[2]

The student wishes to modify the experiment by changing the concentration of ethanol.

(d) **(i)** Explain, with the aid of an equation, why water should not be used to dilute ethanol.

(ii) Suggest a suitable solvent the student could use to dilute ethanol.

[2]

In each of the following reactions, describe the ways in which the oxide of the named element is reacting and discuss whether its behaviour is what you would expect from the position of the element in the Periodic Table:

(e) **(i)** silicon ; $CaO + SiO_2 \longrightarrow CaSiO_3$

(ii) bismuth ; $Bi_2O_3 + 6HNO_3 \rightarrow 2Bi(NO_3)_3 + 3H_2O$ **[4]**

Carbon and silicon each form a tetrachloride. CCl_4 has no reaction with water; $SiCl_4$ reacts violently with water.

(f) **(i)** Write a balanced equation for the reaction of $SiCl_4$ with water.

(ii) Suggest an explanation for the inertness of CCl_4 to water.

(g) Ozone, O_3, is a molecule that contains a dative covalent bond.

(i) Draw a dot-and-cross diagram to show the bonding in an ozone molecule.

(ii) State the bond angle in the molecule and explain in detail how this angle arises.

[6]
[Total: 20]

B6 Vinegar is a liquid consisting mainly of ethanoic acid, CH_3COOH. White vinegar, which is used in cooking and baking, contains 0.800 mol dm^{-3} ethanoic acid.

(a) The percentage dissociation of ethanoic acid in white vinegar is 0.473%.

(i) What is the hydrogen ion concentration in a sample of white vinegar?

(ii) Find the pH of the white vinegar.

(iii) Write an expression for the acid dissociation constant, K_a, of CH_3COOH and calculate the K_a of the acid.

[4]

(b) 25 cm^3 solution of white vinegar was mixed with 25 cm^3 of 1.00 mol dm^{-3} NaOH and the temperature of the mixture rose by 5.2 °C.

(i) If 4.3 J is required to raise the temperature of 1 cm^3 of solution by 1 °C, calculate the amount of heat involved in the above experiment.

(ii) Calculate ΔH_{neut} for this reaction.

(iii) When white vinegar was replaced by a solution of 0.800 mol dm^{-3} HCl, ΔH_{neut} was calculated to be -57.3 kJ mol^{-1}. Suggest a reason for the difference between this value and your answer in **(b)(ii)**.

[4]

(c) Buffered vinegar is used to increase the shelf-life of ground beef and reduce the growth of pathogens such as salmonella.

(i) What is meant by the term *buffer solution*?

(ii) Suggest a reagent that could be added to vinegar to create a buffer solution.

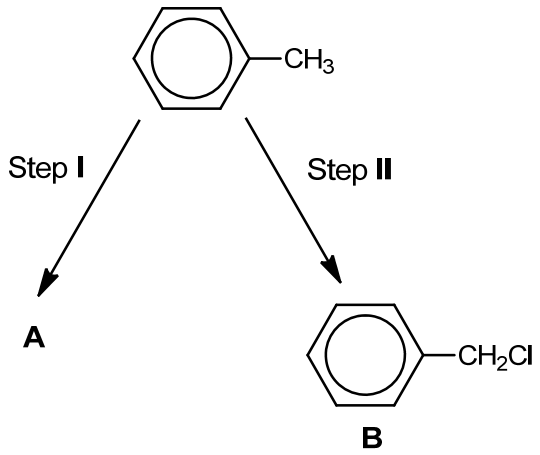
(iii) Write ionic equations for the reactions that occur when $H^+(aq)$ ions, and $OH^-(aq)$ ions respectively, are added to buffered vinegar.

[4]

(d) In a non-aqueous solvent like pentane, ethanoic acid is found to have an M_r value of 120. With the aid of a suitable diagram, explain this observation.

[2]

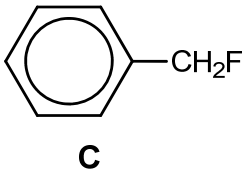
(e) Methylbenzene reacts with chlorine gas under different conditions to give two isomeric chlorine-containing compounds, **A** and **B**.



(i) Suggest the structure of compound **A**, and suggest the reagents and conditions required for steps **I** and **II**.

(ii) Compounds **B** and **C** can be differentiated from each other by carrying out the following:

I Heat the samples separately with aqueous sodium hydroxide.
II Cool the reaction mixtures.
III Acidify the mixture with dilute nitric acid.
IV Add dilute aqueous silver nitrate



C

State the expected observations for both compounds.

(iii) The bond energy of the C-F bond is 485 kJ mol^{-1}.
Compare this value with another relevant value from the *Data Booklet* to explain the difference in the observations in **(e)(ii)**.

[6]
[Total: 20]

B7 **(a)** An organic compound **A** exhibits geometric isomerism. It has the following composition by mass: C, 62.1%; H, 10.3%; O, 27.6% and has a relative molecular mass of 116.

1 mol of **A** reacts with anhydrous PCl_5 to give 2 mol of HC*l* gas. When **A** is heated with acidified potassium manganate(VII), **B**, $C_4H_6O_3$, is produced together with evolution of carbon dioxide gas.

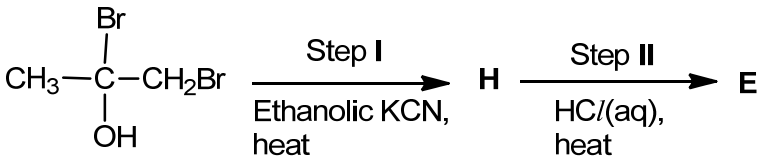
When warmed with an alkaline solution of iodine, **B** yielded a yellow precipitate, **C** and a solution which gave propane-1,3-dioic acid after acidification.

Treating **B** with HCN and a trace amount of NaCN gives compound **D**.

Deduce the structural formulae of **A**, **B**, and **D**. With the aid of suitable equations, explain how you arrive at your answers.

[8]

(b) When **D** is heated under reflux with dilute H_2SO_4, **E** is formed. Compound **E** can be generated as indicated in the following reaction scheme.



Treatment of 1 mol of **E** with 2 mol of ethanol in the presence of concentrated sulfuric acid gave compound **F** that has a fruity smell. **E** does not cause any colour change upon heating with acidified $K_2Cr_2O_7$. Heating **E** under reflux with a mixture of NaBr and concentrated H_2SO_4 gives **G**. Heating **G** under reflux with ethanolic KOH give 3 isomeric alkenedioic acids, $C_5H_6O_4$.

(i) Deduce the structural formulae of **E**, **F**, **G, H** and the 3 isomeric alkenedioic acids. Explain the chemistry involved in the reactions.

(ii) Write the balanced equations for steps **I** and **II**.

[12]
[Total: 20]

END OF PAPER