RAFFLES INSTITUTION
2015 YEAR 6 PRELIMINARY EXAMINATION

Higher 1

CANDIDATE NAME	
CLASS	INDEX NUMBER

CHEMISTRY 8872/02

Paper 2 Structured Questions **September 2015**
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**	/ 15
	A2	/ 10
	A3	/ 15
	B4	/ 20
	B5	/ 20
	B6	/ 20
	/ 80	
Total		

This document consists of **13** printed pages.

Section A (40 marks)

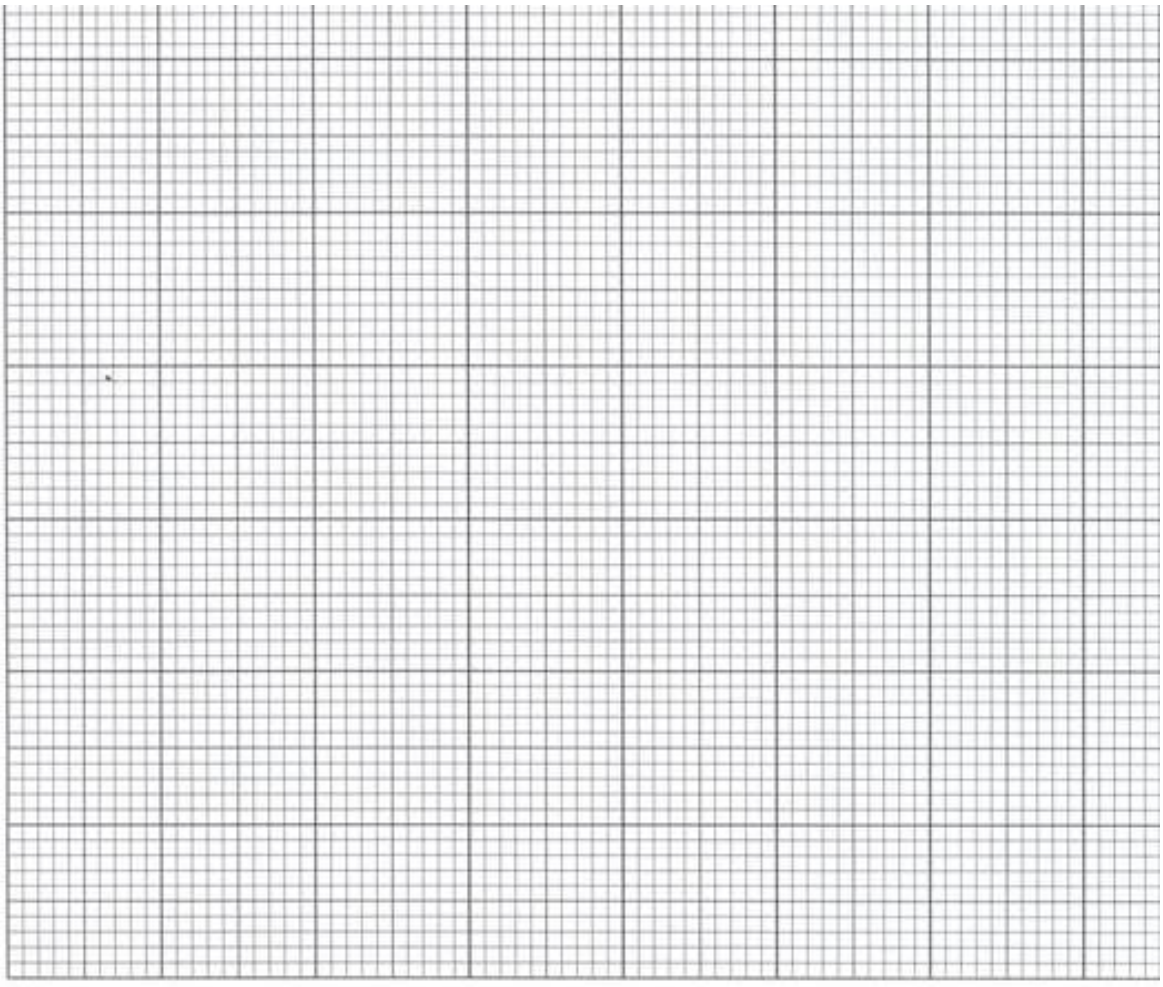
1 **(a)** Dinitrogen pentoxide, N_2O_5, decomposes to NO_2 and O_2 at relatively low temperatures according to the following equation:

$$2N_2O_5(org) \longrightarrow 4NO_2(org) + O_2(g)$$

A student investigated the rate of decomposition of N_2O_5 and carried out the reaction in a CCl_4 solution at 45 °C. 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	59.0

(i) Plot the experimental results on the grid below.



(ii) Explain what is meant by the term *overall order of reaction*.

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(iii) Explain, as fully as you can, why the experimental results indicate that the overall kinetics are first order, and hence write the rate equation.

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(iv) Calculate the rate constant and state its units.

[7]

(b) Nitrogen and hydrogen react together to form ammonia in the Haber process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

(i) Describe the conditions of pressure and temperature used in this process and for each one, explain why that condition is chosen.

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At high temperatures, the particles of a finely divided catalyst tend to fuse together and the powder may “cake”, forming a solid mass. Steps must be taken to avoid this. One way is to add another substance, known as a *promoter*.

When iron is used as the catalyst in the Haber Process, aluminium oxide is added as a *promoter* and acts as a barrier to the fusion of the metal particles.

(ii) Explain why steps must be taken to avoid the finely divided catalyst from “caking”.

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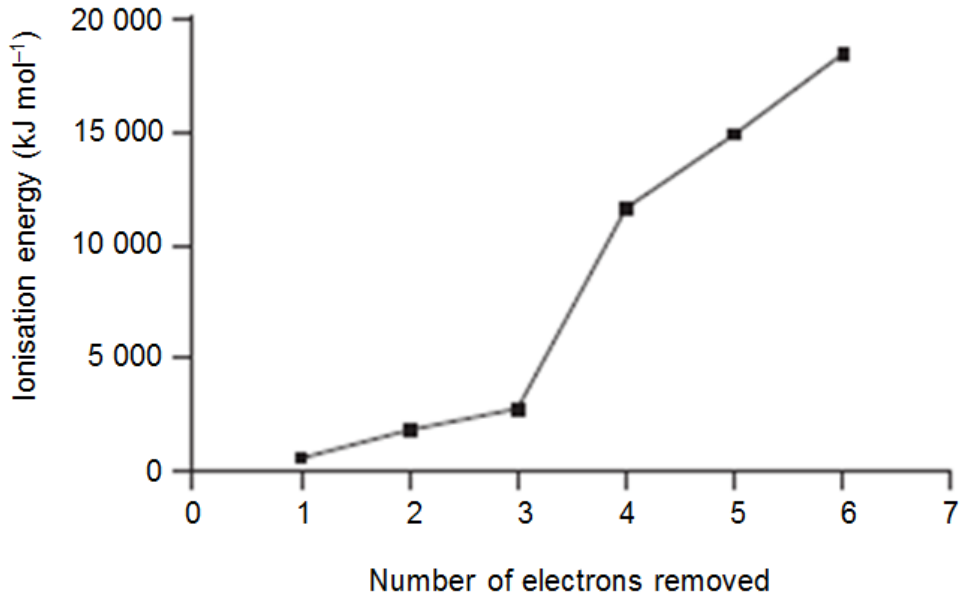
(iii) The graph below shows the first six successive ionisation energies of aluminium.

Comment and explain on the shape of the graph.



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(iv) *The use of the Data Booklet is relevant to this question.*

Write the full electronic configuration of aluminium in aluminium oxide.

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[8]

[Total:15]

2 **(a)** Both diamond and graphite are allotropes of carbon with different structures and physical properties.

Explain, in terms of structure and bonding, the differences between the electrical conductivities of diamond and graphite.

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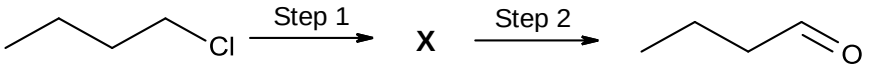
(b) Butanal is a solvent that can be made from chlorobutane, a possible synthesis pathway is shown below.



(i) Suggest the reagents and conditions for Step 2 and the structure for **X**.

Reagents and conditions: ……..……..…….

Structure of **X**:

(ii) Both butanal and butanone are carbonyl compounds that have similar chemical reactions. Suggest a chemical test that will distinguish between the two compounds.

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(iii) How would the rates of reaction differ when both butanal and butanone react with HCN, in the presence of KCN? Explain.

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[5]

(c) Chlorobutane and chlorobenzene can be distinguished by reacting with hot NaOH followed by the addition of $AgNO_3$. State and explain your observations for the above reactions.

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..... [2]

[Total: 10]

3 The chemical analysis of water provides considerable insight into the health of lakes, rivers and oceans.

The concentrations of ions found in a sample of sea-water, measured in mg dm^{-3}, are found in the table below.

1 mg = 1×10^{-3} g

Ions	Sample concentrations/ mg dm^{-3}
Cl^-	18980
Na^+	10540
SO_4^{2-}	2460
Mg^{2+}	1270
Ca^{2+}	400
K^+	380
HCO_3^-	140
Br^-	60

(a) Hydrogencarbonate ions, HCO_3^-, are also found in blood plasma. Together with carbonic acid, H_2CO_3, they play an important role in maintaining pH in the body.

Explain how blood plasma can buffer the pH change when acid is released into the blood.

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..... [1]

(b) Water described as "hard" is high in dissolved minerals, specifically calcium and magnesium.

The removal of Ca^{2+} and Mg^{2+} ions can be achieved by adding precipitating water softeners which form insoluble precipitates with Ca^{2+} and Mg^{2+} ions.

An example of one such reagent is sodium carbonate, Na_2CO_3.

Excess solid Na_2CO_3 was added to 100 cm^3 of the sea-water. Calculate the maximum combined mass of $CaCO_3$ and $MgCO_3$ precipitated.

[3]

(c) Suggest a reagent that a student could use to confirm the presence of SO_4^{2-} ions in the sea-water.

State what he would observe.

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..... [2]

(d) The Winkler test is used to determine the concentration of dissolved oxygen in water samples. In this procedure, oxygen reacts with Mn^{2+} under alkaline conditions to produce a precipitate of MnO_2.

(i) Write the balanced equation when oxygen reacts with Mn^{2+} under alkaline conditions to form MnO_2.

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The precipitate is then dissolved in acid and reacted with iodide, forming iodine and Mn^{2+}.

$$MnO_2(s) + 2I^-(aq) + 4H^+(aq) \longrightarrow Mn^{2+}(aq) + I_2(aq) + 2H_2O(l)$$

Finally, the amount of iodine produced is determined by reaction with thiosulfate.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \longrightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

(ii) A 50 cm^3 sample of sea-water was prepared for titration using the Winkler method. A standard 0.020 mol dm^{-3} sodium thiosulfate solution was used to titrate the sample and an end point was achieved at 5.50 cm^3. Calculate the concentration of dissolved oxygen in mg dm^{-3}.

[5]

(e) Sea ice is formed when ocean water is cooled below its freezing temperature.

Explain, in terms of structure and bonding, why ice has a lower density than liquid water.

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..... [2]

(f) Magnesium oxide is made by heating magnesium salts at high temperatures. One main source of magnesium salts is by precipitation of magnesium ions from seawater.

Describe the action of water on magnesium oxide and write equations for any reactions that occur.

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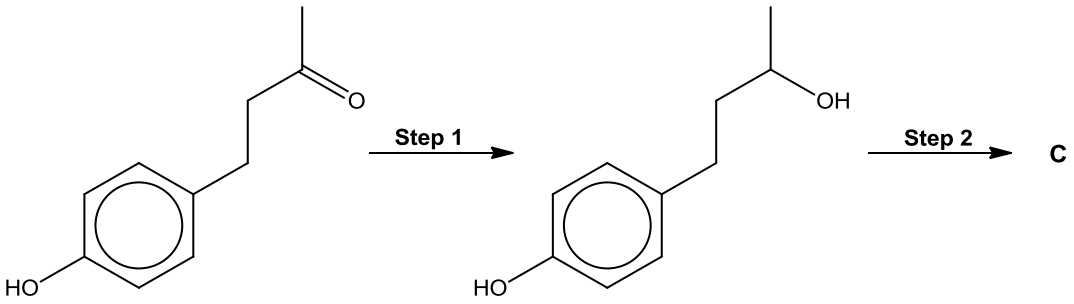
..... [2]

[Total: 15]

Section B (40 marks)

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

4 **(a)** Compound **A** is responsible for the aroma of raspberries. It can be converted into alkene **C** via a 2-step synthesis as shown.



A **B**

(i) Other than the phenolic group, name the other functional group present in each of the compounds **A** and **B**.

(ii) Compound **B** has two K_a values, K_{a1} and K_{a2}, as shown in **Figure 1**.

Explain why K_{a1} is higher than K_{a2}.

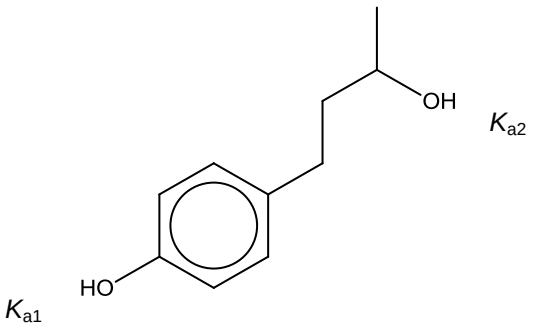


Figure 1

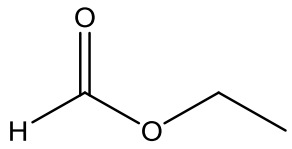
(iii) State the reagents and conditions for **Step 2**, and hence, the structure of compound **C** formed.

(iv) State the type of isomerism compound **C** displays, and explain how this isomerism arises.

(v) Describe a simple chemical test that could be used to distinguish between **A** and **B**. Draw the structures of the products of any reactions that occur, and the observations you would make.

[12]

(b) Compound **D**, with the following structure, is one of the chemicals that contributes to the flavour of raspberries. It can undergo hydrolysis with 0.20 mol dm^{-3} HC*l*(aq) to form two organic molecules.



Compound **D**

(i) Name compound **D**.

(ii) Write an equation to show how compound **D** undergoes acidic hydrolysis.

(iii) One of the products obtained from **(b)(ii)**, is a *weak* acid whereas HC*l* is a *strong* acid. Using the Bronsted-Lowry theory, state the difference between a *weak* and *strong* acid.

(iv) Calculate the pH of the HC*l* used for the hydrolysis.

[4]

(c) Compound **K**, C_8H_{10}, reacts with concentrated nitric acid in concentrated sulfuric acid to form two isomers **L** and **M**. When **K** is heated with acidified potassium manganate(VII), it forms a white solid **N**, $C_7H_6O_2$. Identify the compounds **K** to **N**.

[4]

[Total: 20]

5 **(a)** **(i)** Aluminium, silicon and phosphorus are consecutive elements in Period 3 of the Periodic Table. Describe and explain the variations in atomic radius for these three elements.

(ii) The chlorides of aluminium, silicon and phosphorus all dissolve in, or react with, water.
Describe and explain the reactions of these three chlorides when separate samples are added to excess water. Give equations for any reactions that occur.

[8]

(b) Draw a 'dot-and-cross' diagram to show the bonding in phosphorus trichloride. State and explain the shape of this molecule and the bond angles it contains.

[5]

(c) Define the term *lattice energy*.

Explain why the magnitude of the lattice energy of magnesium chloride (–2526 kJ mol^{-1}) is much larger than that of sodium chloride (–787 kJ mol^{-1}).

[3]

(d) **(i)** Consider the following reaction between oxides of nitrogen.

$$N_2O(g) + NO_2(g) \longrightarrow 3NO(g) \quad \Delta H_r$$

Use the following data to calculate ΔH_r.

$N_2(g) + O_2(g) \longrightarrow 2NO(g)$ $\Delta H = +181$ kJ
$2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$ $\Delta H = -113$ kJ
$2N_2O(g) \longrightarrow 2N_2(g) + O_2(g)$ $\Delta H = -163$ kJ

(ii) Some of the above reactions occur in an internal combustion engine as undesirable side-reactions. State the environmental damage some of these products may cause.

[4]

[Total: 20]

6 **(a)** Natural gas has many impurities such as CH_4 and H_2S, which can react to give the following equilibrium.

$$CH_4(g) + 2H_2S(g) \rightleftharpoons CS_2(g) + 4H_2(g)$$

In a 250 cm^3 vessel at 960 ^oC, 1.0 mol of CH_4, 2.0 mol of H_2S, 1.0 mol of CS_2 and 2.0 mol of H_2 were allowed to reach equilibrium. The equilibrium concentration of CH_4 is 5.56 mol dm^{-3}.

(i) Calculate the value of K_c.

(ii) Define *Le Chatelier's Principle*.

(iii) Predict and explain what happens to the position of equilibrium when pressure is increased.

[6]

(b) Ethanol can be used as a fuel.

(i) Write the equation for the combustion of ethanol.

(ii) A beaker of 200 cm^3 of water was brought to a temperature of 80 ^oC from 25 ^oC using ethanol as a fuel. 1.75 g of fuel was used for the experiment. Given that specific heat capacity of water is 4.2 J K^{-1} g^{-1}. Calculate the enthalpy change of combustion of ethanol for this experiment.

(iii) The literature value for the enthalpy of combustion of ethanol is -1368 kJ mol^{-1}. Using your answer in **(b)(ii)**, calculate the percentage efficiency of the combustion and suggest a reason for the difference.

[6]

(c) Cracking is a chemical reaction that breaks larger hydrocarbons into smaller hydrocarbons.

Dodecane is a straight chain alkane with the formula $C_{10}H_{22}$. When one molecule of dodecane is cracked, hexane and one other compound are formed.

Draw the displayed formulae of all the structural isomers of the other compound, excluding any cyclic compounds.

[2]

(d) Hydrocarbons can also exist in ring structures. Two such compounds are methylbenzene and cyclohexene.

(i) Methylbenzene can react with chlorine to give two different compounds depending on the conditions of the reaction.

Draw the two compounds, clearly stating the reagents and conditions required.

(ii) Give the structural formulae of the organic products in the following reactions with cyclohexene.

- HBr
- cold acidified potassium maganate(VII)

[6]

[Total: 20]

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