Name: _____ **Class: 13**_____ **Reg Number:** _____

MERIDIAN JUNIOR COLLEGE
JC 2 Preliminary Exam
Higher 1

Chemistry 8872/02

Paper 2 Structured and Free Response **17 September 2014**

2 hours

Additional Materials: Data Booklet
Writing Papers
Graph Paper

READ THESE INSTRUCTIONS FIRST

Write your name, class and register number in the spaces at the top of this page.

This booklet contains Section **A** and Section **B**.

Section A : Pg 2 to 10

Answer **all** questions in Section A in the **spaces provided on the question paper**. You are advised to spend about **1 hour** on Section **A**.

Section B : Pg 11 to 16

You are advised to spend about **1 hour** on Section **B**.

Hand in Section **B *separately*** from Section **A.**

Fasten your answers for Section **B** behind the given **Cover Page**. Detach the **Cover Page** from the last page behind this booklet.

INFORMATION FOR CANDIDATES

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

Examiner's Use		
Paper 1	**MCQ**	**/ 30**
		/ 33 %
Paper 2 Section A	**Q1**	**/ 7**
	Q2	**/ 7**
	Q3	**/ 15**
	Q4	**/ 11**
Paper 2 Section B		**/ 40**
Paper 2 Total		**/ 80**
		/ 67 %
Grand Total		**/ 100 %**
Grade		

This document consists of **16** printed pages (*excluding the cover page for answer scripts*).

Section A : Structured Questions

You are advised to spend no more than 1 hour on this section.

1 Pyrolusite is a mineral, which contains manganese dioxide. It is used for the large scale production of potassium manganate(VII), $KMnO_4$. The process involves two steps:

Step 1: The pyrolusite is reacted with KOH and heated in the presence of excess oxygen at room temperature and pressure to form potassium manganate(VI), K_2MnO_4, and water.

$$MnO_2 + 2OH^- + \frac{1}{2}O_2 \rightarrow MnO_4^{2-} + H_2O$$

Step 2: Potassium manganate(VI) is then oxidised to potassium manganate(VII).

$$MnO_4^{2-} \rightarrow MnO_4^- + e^-$$

To determine the percentage composition of MnO_2 in pyrolusite, a sample of pyrolusite that weighed 5.20 g was treated accordingly as stated in **Step 1** and **2**. The potassium manganate(VII) formed was reacted with ethanedioate solution, $C_2O_4^{2-}$. Upon complete reaction, 5.53 dm^3 of CO_2 was liberated at room temperature and pressure.

(a) Define what is meant by '*one mole of a substance*'.

[1]

(b) Write a balanced ionic equation for the reaction of potassium manganate(VII) with $C_2O_4^{2-}$.

[1]

(c) Calculate the number of moles of MnO_2 reacted. Hence, calculate the percentage composition of manganese dioxide in pyrolusite.

[2]

(d) In another experiment, 25.00 cm^3 of 0.15 mol dm^{-3} acidified potassium manganate(VII) solution is needed to completely react with 9.38 x 10^{-3} mole of vanadium(II) ions, V^{2+}.

(i) Calculate the final oxidation state of the vanadium ion.

(ii) Suggest a reason why hydrochloric acid is not suitable to acidify $KMnO_4$.

[3]

[Total: 7]

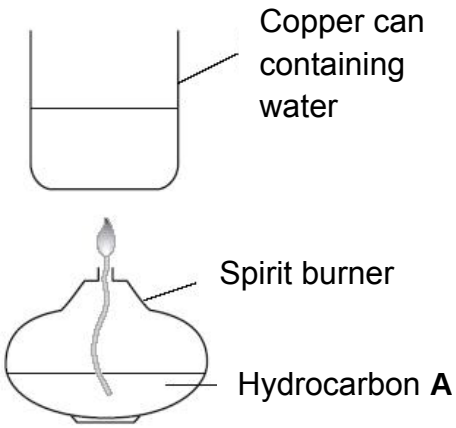
2 An **unsaturated** hydrocarbon **A** is an important intermediate used in the petrochemical industry and is often used in the production of fuel additives that improve the combustion in engines.

The standard enthalpy change of combustion of **A** is –2718 kJ mol^{-1}.

(a) Define the term *standard enthalpy change of combustion.*

[1]

(b) 0.500 g of **A** was completely burnt in an experiment and the heat produced was used to raise the temperature of 200 g of water. The process was known to be only 80% efficient. The experimental data collected is shown in the table below.



Mass of **A** used / g	0.500
Mass of water in copper can / g	200
Initial temperature of water / °C	25.0
Final temperature of water / °C	48.2
Specific heat capacity of water / J g^{-1} K^{-1}	4.18

(i) Suggest **one** improvement that can be made to improve the efficiency of the above experiment.

(ii) Calculate the amount of heat released by combustion of hydrocarbon **A**.

(iii) Use the data above and your answer in **(b)(ii)** to calculate the relative molecular mass of **A**, giving your answer to the nearest **whole number**.

(iv) Deduce the molecular formula of **A**. Given that **A** does **not** exhibit geometric isomerism, draw a possible structure of **A**.

[6]

[Total: 7]

3 The elements in Period 3 range from metals on the left of the Periodic Table to non–metals on the right.

(a) Both sodium and magnesium react with chlorine to give white solids. However, the respective white solids formed differ in the way they react with water.

(i) Explain the difference for the action of water on these white solids. Write equations for any reaction that occur, and suggest the pH of each solution formed.

(ii) Give the **full** electronic configuration of the anion in the white solids.

(iii) By quoting data from the *Data Booklet*, explain the relative sizes of the ionic and atomic radii of sodium.

[8]

(b) Aluminum oxide is amphoteric.

(i) Write **two** equations which demonstrate the amphoteric behavior of aluminum oxide.

(ii) Suggest a polyatomic ion that is isoelectronic with aluminum ion.

[2]

(c) Silicon occurs naturally as silicon(VI) oxide, SiO_2, which is widely used to make ceramics.
Explain why SiO_2 is a solid whereas CO_2 is a gas at room temperature.

[3]

(d) Suggest, with an explanation, if the second ionisation energy of sulfur is lower or higher than the second ionisation energy of chlorine.

[2]

[Total: 15]

4 The following equilibrium is established when propanoic acid reacts with ethanol to form an organic product and water.

$$CH_3CH_2CO_2H(l) + CH_3CH_2OH(l) \rightleftharpoons CH_3CH_2CO_2CH_2CH_3(l) + H_2O(l)$$

To prepare the organic product, a student followed a procedure found in an old textbook:

- Add 1.2 cm^3 of ethanol to 1.48 g of propanoic acid in a round–bottom flask. Mix well.
- Carefully add 0.50 g of concentrated sulfuric acid.
- Place the round–bottomed flask in a heating mantle, and attach a reflux condenser to the top of the flask.
- Turn on the heating mantle to heat the mixture at 45 °C for 16 hours.
- Allow the mixture to cool.
- Rearrange the apparatus for distillation. Collect the product as the distillate.

The boiling points of the reactants and products in the above equilibrium are given in the table below.

Compound	Boiling point / °C
$CH_3CH_2CO_2H$	141
CH_3CH_2OH	78
$CH_3CH_2CO_2CH_2CH_3$	99
water	100

(a) Name the organic product formed and state its functional group.

[1]

(b) (i) Sketch a graph of the rates of the forward and backward reactions against time.

(ii) Explain, in terms of the position of the equilibrium, why concentrated sulfuric acid is added to the flask.

(iii) Using the data given, explain the temperature chosen for the heating of the reaction mixture.

[4]

(c) The amount of propanoic acid present at equilibrium was determined by means of titration with aqueous sodium hydroxide with phenolphthalein as indicator. It was found that 0.0100 moles of NaOH is required to completely react with propanoic acid present at equilibrium.

(i) Calculate the amount (in moles) of propanoic acid and ethanol placed in the flask initially. (Density of ethanol = 0.789 g cm^{-3})

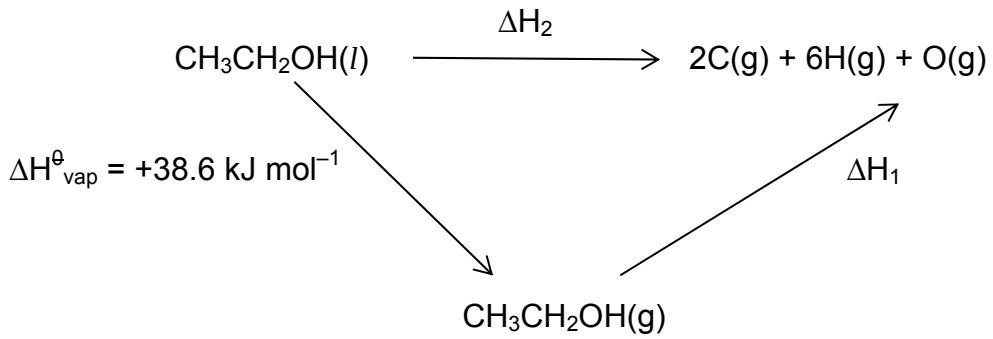
(ii) Use the information given and your answers in **(i)** to complete the table below.

	$CH_3CH_2CO_2H(l)$ + $CH_3CH_2OH(l)$ $\rightleftharpoons$ $CH_3CH_2CO_2CH_2CH_3(l)$ + $H_2O(l)$			
Initial amount/ mol				
Equilibrium amount/ mol				

(iii) Write an expression for the equilibrium constant K_c for the reaction. Using your answers in **(c)(ii)**, calculate the value of K_c.

[4]

(d) Using the energy cycle given below, and the bond energy values in the *Data Booklet*, calculate ΔH_1. Hence, calculate the enthalpy change of atomisation of ethanol, ΔH_2.



[2]

[Total: 11]

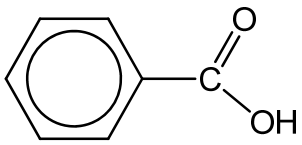
**** End of Section A ****

Section B : Free Response Questions

*Answer **two** out of three questions on writing paper provided.*
You are advised to spend no more than 1 hour on this section.

5 Benzoic acid occurs naturally in many plants and it serves as an important precursor to produce other useful chemicals.

Benzoic acid is an aromatic carboxylic acid as shown in the structure below.



(a) It is found that an aqueous solution of benzoic acid of 0.10 mol dm^{-3} has pH 2.6. By using calculation, explain why benzoic acid is a weak acid. [1]

(b) A sample of 20.0 cm^3 aqueous solution of 0.100 mol dm^{-3} benzoic acid was titrated with 0.15 mol dm^{-3} potassium hydroxide solution.

(i) Calculate the pH of the 0.15 mol dm^{-3} potassium hydroxide solution.

(ii) Calculate the volume of potassium hydroxide required for neutralisation with the benzoic acid.

(iii) Suggest a suitable indicator for this titration.

[3]

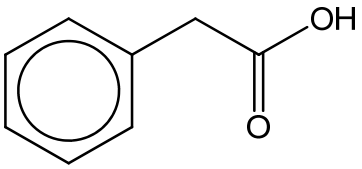
(c) A buffer containing potassium benzoate and benzoic acid was formed during the titration in **(b)**.

(i) With the aid of **one** equation, explain how a solution of the buffer can control pH when a small amount of NaOH is added.

(ii) In terms of chemical bonding, explain why both potassium benzoate is very soluble in water whereas benzoic acid is not very soluble in water.

[3]

(d) The structure of phenylethanoic acid is shown below.



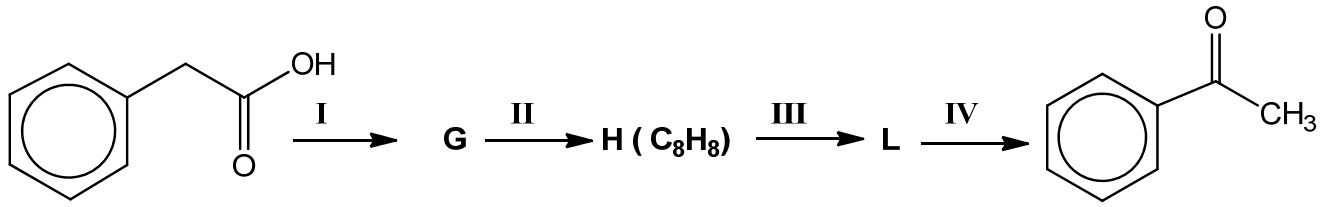
Phenylethanoic acid

(i) Suggest the reagents and conditions used to synthesise benzoic acid from phenylethanoic acid.

(ii) Explain, in terms of its structure, why phenylethanoic acid is acidic.

[3]

(e) The following shows how phenylethanone can be synthesised from phenylethanoic acid.



phenylethanoic acid phenylethanone

(i) Compound **H** decolourises aqueous Br_2.

Draw the structures of **G**, **H** and **L**. State the reagents and conditions for step **I** to **IV**.

(ii) Describe one distinguishing tests that allow visible observation for phenylethanone but not for phenylethanoic acid. State clearly the observation seen.

[7]

(f) Phenylethanone can react with HCN in cold condition with trace amount of NaCN.

(i) Name the type of reaction as described above.

(ii) Draw the structure of the product formed from the reaction.

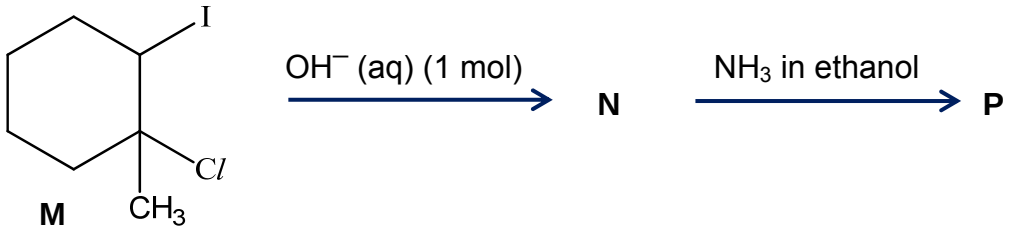
[2]

[Total: 20]

6 Halogenoalkanes are used widely in the industry to produce organic compounds commercially. Halogenoalkanes can also undergo hydrolysis with sodium hydroxide to produce alcohol commercially.

(a) (i) Using monohalogenohexanes, $C_6H_{13}X$ as an example, describe and explain the relative reactivity of chloro and iodo–compounds with respect to hydrolysis.

(ii) Hence, predict the outcome of the following transformation on reagent **M**, a dihalogeno compound, by drawing the structures of the intermediate **N** and product **P**.



(iii) Suggest a suitable alkene and the reagents and conditions needed to form **M** in **(a)(ii)**.

[6]

(b) Halogenoalkanes can also be synthesised from alkanes. Suggest with reasoning why this method of synthesis is not reliable. [1]

(c) A series of experiments were conducted to investigate the kinetics of the reaction between 2–bromohexane and sodium hydroxide.

(i) In Experiment 1, 0.010 mol dm^{-3} of 2–bromohexane was mixed with 0.10 mol dm^{-3} of NaOH. The [NaOH] in the resulting mixture can be assumed to remain virtually constant.

The following results were obtained when an aliquot of the reaction mixture was drawn at regular time interval, placed in an ice bath before excess aqueous silver nitrate is added to precipitate silver bromide.

If the reaction is to reach completion, the maximum amount of AgBr that can be precipitated is 0.0100 mole.

Time / min	Amount of AgBr obtained / mol
0	0.0000
40	0.0021
80	0.0038
120	0.0051
160	0.0062
200	0.0070
240	0.0076

Plot these data on suitable axes and use your graph to confirm that the order of reaction with respect to 2–bromohexane is **one.**

(ii) In Experiment 2 and 3, different initial [NaOH] and [$C_6H_{13}Br$] were reacted.

In these experiments, the time taken for the maximum amount of silver bromide to be collected was recorded. The results are shown in the table below.

Experiment	[NaOH] / mol dm^{-3}	[$C_6H_{13}Br$] / mol dm^{-3}	Time taken for maximum amount of AgBr to be collected / min
2	0.050	0.010	620
3	0.100	0.020	155

Using the data provided, state the order of reaction with respect to NaOH.

(iii) Using information from **(c)(i)** and your answer in **(c)(ii)**, write the rate law for the reaction between 2–bromohexane and sodium hydroxide. State the units for the rate constant.

(iv) Rate of the reaction between 2–bromohexane and sodium hydroxide increases when temperature is raised. With the aid of a well–labelled energy distribution curve, explain this observation.

[10]

(d) Halogenoarenes on the other hand, has generated much less commercial interest due to its limited reactivity.

(i) Suggest why C_6H_5Br is less reactive then $C_6H_{13}Br$ towards sodium hydroxide.

(ii) State the reagents and conditions required to synthesise C_6H_5Br from C_6H_6.

[3]

[Total: 20]

7 Concentrated sulfuric acid is a common reagent used in many organic and inorganic chemistry reactions. Reactions in this question involve the use of concentrated sulfuric acid.

(a) At a crime scene, preliminary investigations led the homicide detectives to believe that concentrated sulfuric acid was used to hurt the victim.

Some samples of blood and fibres were collected from the victim and sent to the forensic laboratory. Upon analysis, the fibres were found to contain sodium oxide and another unknown oxide of element **Q**.

Like sodium, **Q** is an element in Period 3 of the Periodic Table and the following is known about the two elements and their corresponding oxides:

- Sodium reacts very vigorously with oxygen and burns with a yellow flame to form sodium oxide. Sodium oxide has a melting point of 1275^{o}C and it dissolves readily in water.

- **Q** reacts vigorously with oxygen and burns with a brilliant yellow flame to form its corresponding oxide. The oxide of **Q** has a melting point of 24^{o}C and it dissolves readily in water.

(i) Draw a dot-and-cross diagram for sodium oxide.

(ii) Write an equation, with state symbols, for the reaction of sodium oxide with water. Give the approximate pH of the resulting solution formed. What is the effect of adding universal indicator to the solution?

(iii) Sodium oxide has different electrical conductivity in different states. Account for this difference.

(iv) Apart from the oxides of sodium and **Q**, one other substance was found in the samples collected from the victim. This is formed when sodium oxide reacts with sulfuric acid. Write an equation to illustrate the formation of this substance.

(v) Identify the oxide of **Q**. Write an equation for the reaction of oxide of **Q** with water.

[8]

(b) **R, X, Y** and **Z** are four isomers with the molecular formula $C_4H_{10}O$.

(i) Alcohol **R** reacts with concentrated sulfuric acid to give three compounds **S, T** and **U**.

When compounds **S**, **T** and **U** were separately reacted with hot acidified potassium manganate (VII), the following was observed:

- Compounds **T** and **U** formed the same products.
- Effervescence was observed only for the reaction involving **S**.
- All 3 compounds **S**, **T** and **U** formed products that reacted with sodium carbonate.

Draw the structures of **R**, **S**, **T** and **U**.

(ii) Compound **X** was reacted with a limited supply of chlorine gas under intense light and formed only a single mono-substituted product C_4H_9OCl.

On the other hand, when **Y** and **Z** were separately heated with acidified potassium dichromate solution under distillation, each of the two resulting products forms silver mirror with Tollens' reagent. Compound **Y** has a higher boiling point than **Z**.

1. Identify the compounds **X, Y, Z**, and explain clearly the chemistry involved in the reactions.

2. Using structure and bonding, explain why **Y** has a higher boiling point than **Z**.

[12]

[Total: 20]

End of Paper 2