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

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examination
Higher 1

Chemistry 8872/02

Paper 2

17 September 2013

2 hours

Additional Materials: *Data Booklet*
Writing Papers

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 13

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

Section B : Pg 14 to 20

Answer **2 out of 3** questions in Section B. You are advised to spend about **1 h** 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 m**
		/ 33 %
Paper 2 Section A	**Q1**	**/ 12 m**
	Q2	**/ 17 m**
	Q3	**/ 11 m**
Paper 2 Section B		**/ 40 m**
Paper 2 Total		**/ 80 m**
		/ 67 %
Grand Total		**/ 100 %**
Grade		

This document consists of **20** printed pages (including this cover page)

Section A : Structured Questions

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

1 An early Periodic Table devised by Mendeleev listed the elements known then in order of their relative atomic mass.

(a) **(i)** When Mendeleev created the table, there were uncertainties regarding the relative atomic mass of tellurium. It is now known that there are eight isotopes of tellurium. Complete the following table. Give your answers to **four** significant figures.

isotope	percentage abundance	isotopic mass x percentage abundance
tellurium-120	0.09	11.00
tellurium-122	2.46	300.0
tellurium-123	0.87	107.0
tellurium-124	4.61	572.0
tellurium-125	6.99	874.0
tellurium-126	18.71	2357
tellurium-128	31.79	
tellurium-130		

Hence, calculate the relative atomic mass of tellurium to **1 decimal place.**

(ii) The electronic configuration of tellurium and antimony are as follows:

Te: $[Kr]5s^2 5p^4$

Sb: $[Kr]5s^2 5p^3$

Explain why the first ionisation energy of tellurium is lower than that of antimony.

……

……

……**[4]**

(b) Tellurium (IV) chloride, $TeCl_4$, exists as a vapour at 380°C. Gaseous $TeCl_4$ has a structure similar to sulfur tetrafluoride, SF_4.

(i) Draw a dot-and-cross diagram of $TeCl_4$.

(ii) Predict, with reasoning, the shape of $TeCl_4$.

……

……

……

……

……

(iii) The compound $TeCl_4$ exists, but OCl_4 does not.

By considering the possible types of bonding in the two compounds, suggest a reason for this difference. (Assume that Te and O atoms occupy a central position in each of these molecules.)

……

……

……**[4]**

(c) Tellurium resembles silicon in many aspects. For example, both are metalloids and are used as semiconductors. Tellurium (IV) chloride, $TeCl_4$, dissolves in water in the same way as silicon (IV) chloride, $SiCl_4$.

Describe the reaction, if any, of the chlorides of aluminium and tellurium with water. Give equations for any reactions and suggest the pH values of the resulting solution.

……

……

……

……

……

……

……

……

……

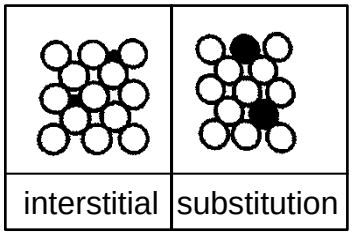
……

……

……**[4]**

[Total : 12]

2 Steel is an *interstitial* alloy, as carbon atoms fit in between iron atoms in the lattice. Brass is a *substitution* alloy, as zinc atoms replace the copper atoms in the lattice. Stainless steel is a combination of interstitial and substitution alloys, because carbon atoms fit into the interstices, but some of the iron atoms are replaced with nickel atoms.



The alloy's structure will determine properties such as *hardness*, which measures the material's resistance to permanent shape change when a force is applied. These properties rely on how much electrostatic attraction is present between ions and electrons in any given volume of the lattice.

$$\text{Lattice Strength } \alpha \frac{q^+}{r^+}$$

(a) The ionic radius and ionic charge of the following element are given in the following table.

Element	**C**	**V**	**Cr**	**Fe**	**Ni**	**Cu**	**Zn**	**W**
Ionic radius (10^{-12} m)	16	64	62	64	60	73	74	66
Ionic charge	+4	+3	+3	+3	+3	+2	+2	+4

(i) Adding a small amount of which **metallic** element is likely to increase the lattice strength of iron most? Give a reason for your answer.

……

……

(ii) From the table above, suggest another element that can be added to iron to form a substitution alloy.

……**[2]**

(b) The hardness of iron is enhanced when carbon atoms are added to iron atoms in the lattice. Explain how adding carbon atoms enhance the hardness of iron in steel.

……

……

……**[1]**

(c) Addition of a minimum 13% chromium by mass into steel will form stainless steel which is resistant to oxidation. Suggest how adding chromium helps to prevent oxidation of the metal.

……..……

……**[1]**

(d) With the aid of a labelled diagram, describe the structure and bonding in copper.

……..……

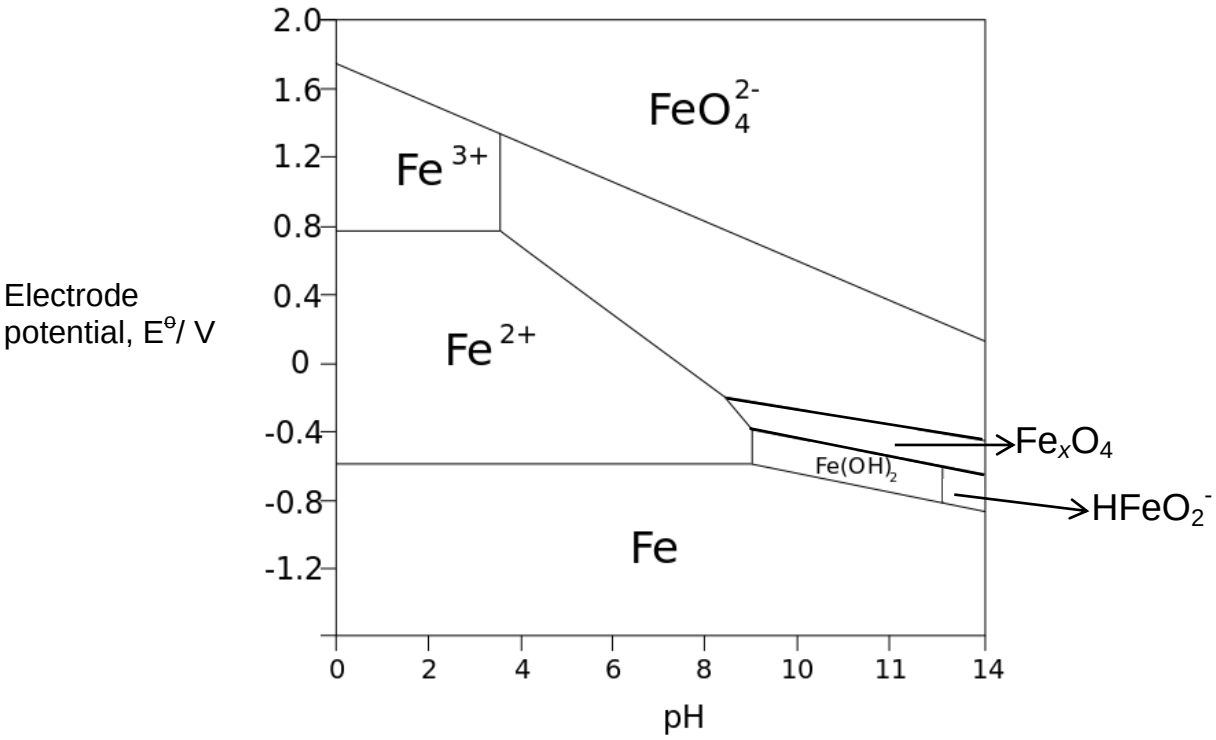
……..……

……...**[2]**

(e) The diagram below is a Pourbaix diagram of iron. Any point on the Pourbaix diagram will give **most stable form** of the element for that electrode potential, $E^{\ominus}$ and pH. The lines in the Pourbaix diagram show the equilibrium conditions where the activities are equal for the species on each side of that line.

A positive value of $E^{\ominus}$ denotes a strongly oxidising environment where iron is oxidised. For example, at pH 14 and $E^{\ominus}$ 0.8 V, Fe will be oxidised to FeO_4^{2-}.

Pourbaix diagrams are useful in predicting the predominant species of that element in different environments.



(i) Use the Pourbaix diagram to answer the following questions:

1 Which species of iron is the strongest oxidising agent?

……

2 What is the range of the $E^{\ominus}$ values when oxidation of $Fe(OH)_2$ to Fe_xO_4 take places from pH 9 to 14?

……...

(ii) A lake containing FeO_4^{2-} (aq) is very well aerated with oxygen at a pH of 5. However, due to continuous NaOH discharge from a chemical industry, reddish brown sediments of Fe_2O_3 is observed in the lake.

Write a half-equation to explain the observation above.

[3]

(f) Oxides of iron can exist in several forms: FeO, Fe_2O_3 or Fe_xO_4.

A sample of Fe_xO_4 is oxidised to Fe^{3+} (aq) using 10.0 cm^3 of 0.0860 mol dm^{-3} of acidified $KMnO_4$ solution. 25.85 cm^3 of 0.500 mol dm^{-3} potassium iodide solution was needed to reduce all the Fe^{3+} (aq) to Fe^{2+} (aq).

(i) Calculate the number of moles of Fe^{3+}.

(ii) Hence, or otherwise, calculate the value of *x* in Fe_xO_4.

The following mole ratio is given: $KMnO_4 \equiv 5\ Fe_xO_4$

(iii) From your answer in **(f)(ii)**, the average oxidation number of an iron atom in Fe_xO_4 is not a whole number. Hence, suggest the oxidation states of the iron atoms in Fe_xO_4.

……**[4]**

(g) Cations of some of the metals such as Fe and Cu can act as catalysts for specific reactions. Using the concept of activation energy together with an appropriate sketch of the Maxwell-Boltzmann distribution, explain how the catalysis reaction increases the rate of reaction.

……

……

……

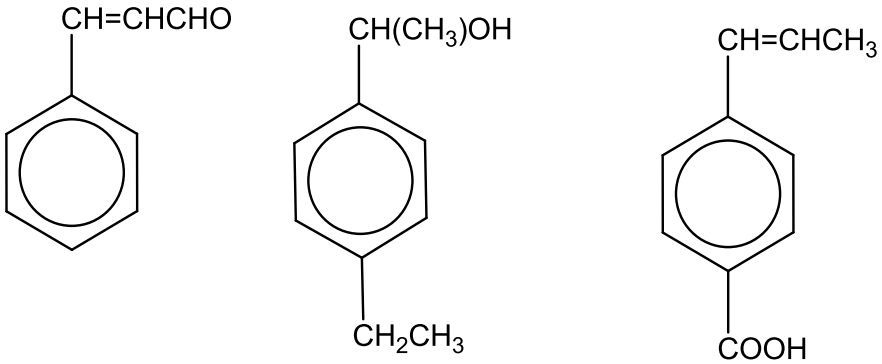
……

……**[4]**

[Total: 17]

3 The spice cinnamon has been used as a medicine for many hundreds of years. However, recent research has suggested that cinnamon could also be an effective pesticide against the larvae of mosquitoes, thus helping in the fight against malaria.

Each of the following four compounds, which are present in cinnamon, appears to be effective as a pesticide.



A **B** **C**

(a) Only **one** of the compounds **A**, **B** or **C** will react with **each** of the following reagents under suitable conditions. In **each** case, identify the compound concerned and draw the structural formula of the organic product formed.

Each compound may be used once, more than once, or not at all.

Reagent	Compound **A**, **B** or **C**	Structural formula of the organic product
Na_2CO_3 (aq)		
2,4-DNPH		

Reagent	Compound **A**, **B** or **C**	Structural formula of the organic product
Tollens' reagent		

[5]

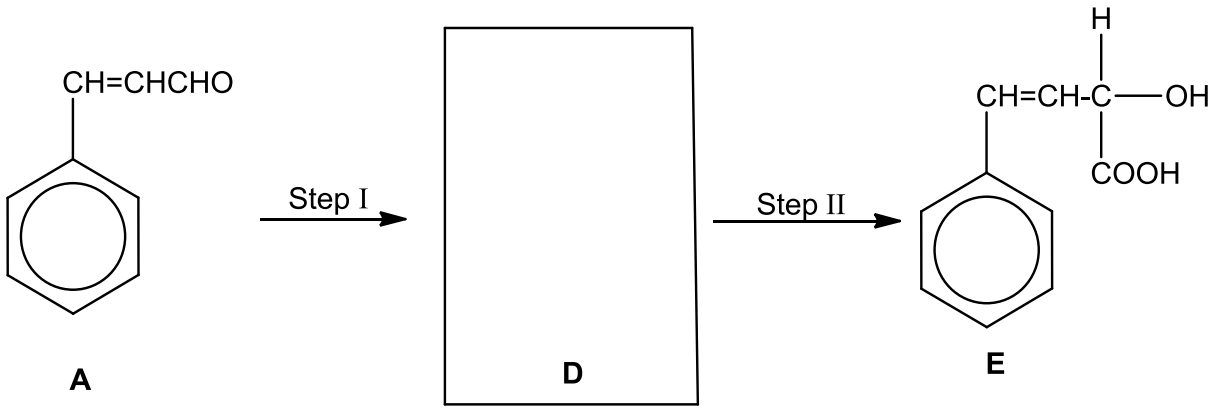
(b) Draw the structural formulae of the organic compounds formed when

(i) compound **B** is heated with aqueous iodine in sodium hydroxide;

(ii) compound **C** is heated under reflux with hot acidified concentrated manganate (VII) ions.

[2]

(c) Compound **E** may be synthesised from compound **A** via a two-stage process as shown below.



A **D** **E**

(i) What is the structural formula of the intermediate, **D**, in this conversion?

(ii) For each step, in the reaction sequence, give reagent(s) and conditions.

Step **I**

Reagent(s): ……

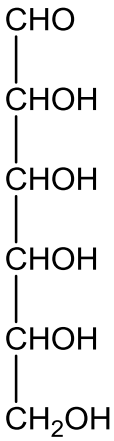
Conditions: ……

Step **II**

Reagent(s): ……

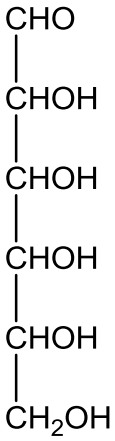
Conditions: ……..**[3]**

(d) Unlike compound **B**, glucose is very soluble in water.



Glucose

Draw a labelled diagram to show the interaction between a molecule of glucose and a molecule of water. You can illustrate your answer on the sketch given below.



[1]

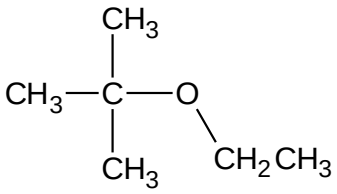
[Total: 11]

End of Section A

Section B : Free Response Questions

*Answer **two** of the following three questions.*
Answer these questions on separate answer papers.

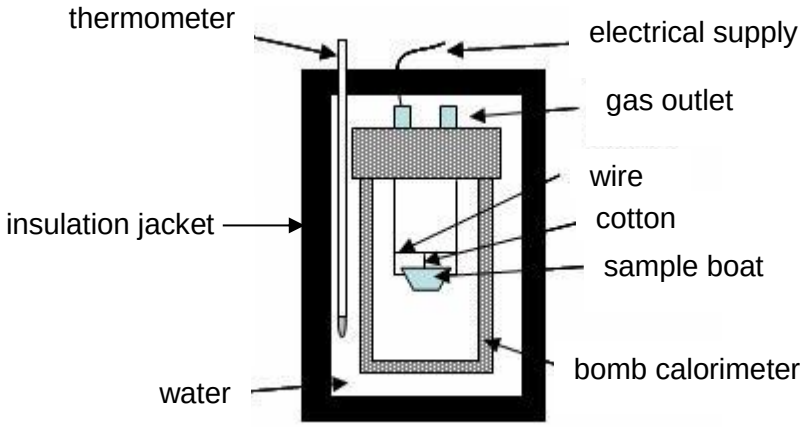
4 Gasoline is the petroleum fraction used as motor car fuel. Gasoline additives are often added to increase its octane rating and to reduce pollution. One such additive is liquid ethyl-tertiary-butyl ether (*ETBE)*.



Ethyl-tertiary-butyl ether (*ETBE*)

(a) Define *standard enthalpy change of formation*. **[1]**

(b) While the enthalpy change of formation of *ETBE* cannot be determined experimentally, the enthalpy change of combustion of *ETBE* can be determined using a bomb calorimeter. The experimental set-up is as shown.



A known volume of water was added and *ETBE* was introduced into the sample boat. A spark was produced when the electrical supply was switched on. The temperature was recorded at every 1 minute interval for 20 minutes. At the end of the experiment, the apparatus was allowed to cool.

The following results were recorded:

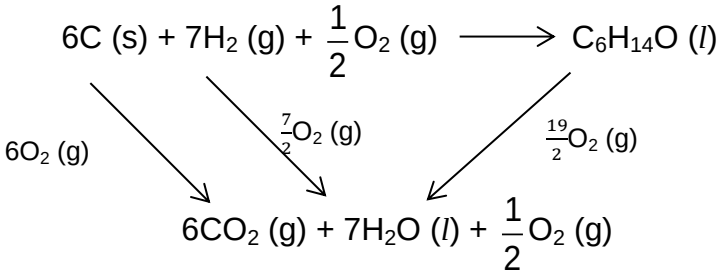
Mass of sample boat + *ETBE* (start of experiment) / g	108.01
Mass of sample boat + *ETBE* (after leaving to cool) / g	102.51
Volume of water heated / cm^3	500
Initial temperature / °C	28.0
Final maximum temperature / °C	95.5

The instrumentation manual of the calorimeter states that the efficiency factor is 70%.

Calculate the enthalpy change of combustion of *ETBE*. Assume that the specific heat capacity of water is 4.18 J g^{-1} K^{-1}. Express your answers to the appropriate number of significant figures.

[4]

(c) Using your answer in part **(b)**, the energy cycle below and the data provided, calculate the enthalpy change of formation of *ETBE.*



Data provided: $\Delta H_f(CO_2)$ = -393 kJ mol^{-1}, $\Delta H_f(H_2O)$ = -286 kJ mol^{-1}

[1]

(d) When gasoline burns in an internal combustion engine, there are some undesirable exhaust gases emitted such as nitrogen monoxide. Briefly explain how nitrogen oxide is formed in an internal combustion engine and state the environmental damage it causes. **[2]**

(e) Compound **K** is a structural isomer of *ETBE*. **K** produces a yellow precipitate with warm alkaline iodine solution and produces effervescence with sodium metal. When **K** is heated under reflux conditions with concentrated sulfuric acid, two isomeric compounds **L** and **M** are obtained. Upon reaction with hot acidified potassium manganate (VII), **L** produces **N,** C_4H_8O. **N** gives a precipitate when treated with 2,4-dinitrophenylhydrazine but not with Tollen's reagent.

(i) Deduce the structures of **K**, **L**, **M** and **N**. Explain the chemistry of the reactions involved.

(ii) State the type of structural isomerism between *ETBE* and **K**.

[7]

The oil refineries and petrochemical industry demand high performance refractory products. Magnesium and aluminium oxides are commonly used as refractory materials as they are both physically and chemically stable at high temperatures.

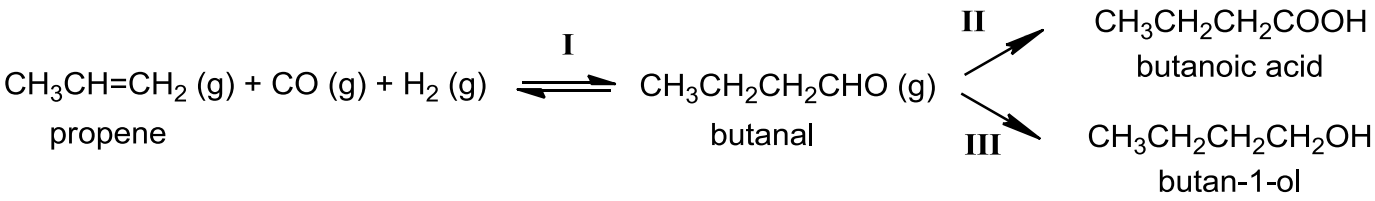
(f) The acid-base behavior of aluminium oxide, Al_2O_3, shows similarities to that of magnesium oxide, MgO, on the one hand, and phosphorus (V) oxide, P_4O_{10}, on the other.

Describe what these similarities are, and explain why aluminum oxide occupies this in-between position. Write equations for all the reactions you choose to illustrate your answer.

[5]

[Total: 20]

5 The "OXO" reaction (reaction **I** in the scheme below) is industrially important for synthesis of alcohols, aldehydes and carboxylic acids. For example, butan-1-ol, butanal and butanoic acid can all be synthesised from propene, C_3H_6, according to the following scheme.



(a) Write an expression for K_c for reaction **I**, stating its units.

[2]

(b) 10 g of H_2 is mixed with C_3H_6 and CO in a 1: 1: 1 mole ratio in a vessel of 800 cm^3 at 500 K. At equilibrium, the concentration of butanal is found to be 3.00 mol dm^{-3}.

(i) Calculate the equilibrium concentrations of C_3H_6, CO and H_2.

(ii) Hence, calculate the value for K_c at 500 K.

(iii) Hence, draw a fully labelled graph for the reaction above, showing how the concentration of the reactants and product change from the time the gases are mixed to the time the reaction reaches equilibrium at time ***t***.

(iv) An approximate value for ΔH can be calculated using bond energy values. Taking the bond energy for the C≡O bond in carbon monoxide to be 1077 kJ mol^{-1}, and using other appropriate bond energies given in the *Data Booklet*, calculate the value of ΔH for reaction **I**.

(v) Suggest, with a reason, whether a high temperature would favour the formation of butanal.

[8]

(c) **(i)** State the reagents and conditions needed for

- reaction **II**,
- reaction **III**.

(ii) State the reagents and conditions needed in the conversion of butan-1-ol into

- 1-chlorobutane
- 2-chlorobutane (in two steps)

[5]

(d) The compound 2-chlorobutane is a useful intermediate for making other organic compounds.

(i) It forms butan-2-ol by heating with NaOH (aq).

How would you expect the rate of this reaction to compare to that of the reaction of 2-iodobutane with NaOH (aq)? Explain your answer.

(ii) State, with the help of relevant equations, how 2-chlorobutane could be distinguished by a simple chemical test from butan-2-ol through a **positive** test for 2-chlorobutane.

[4]

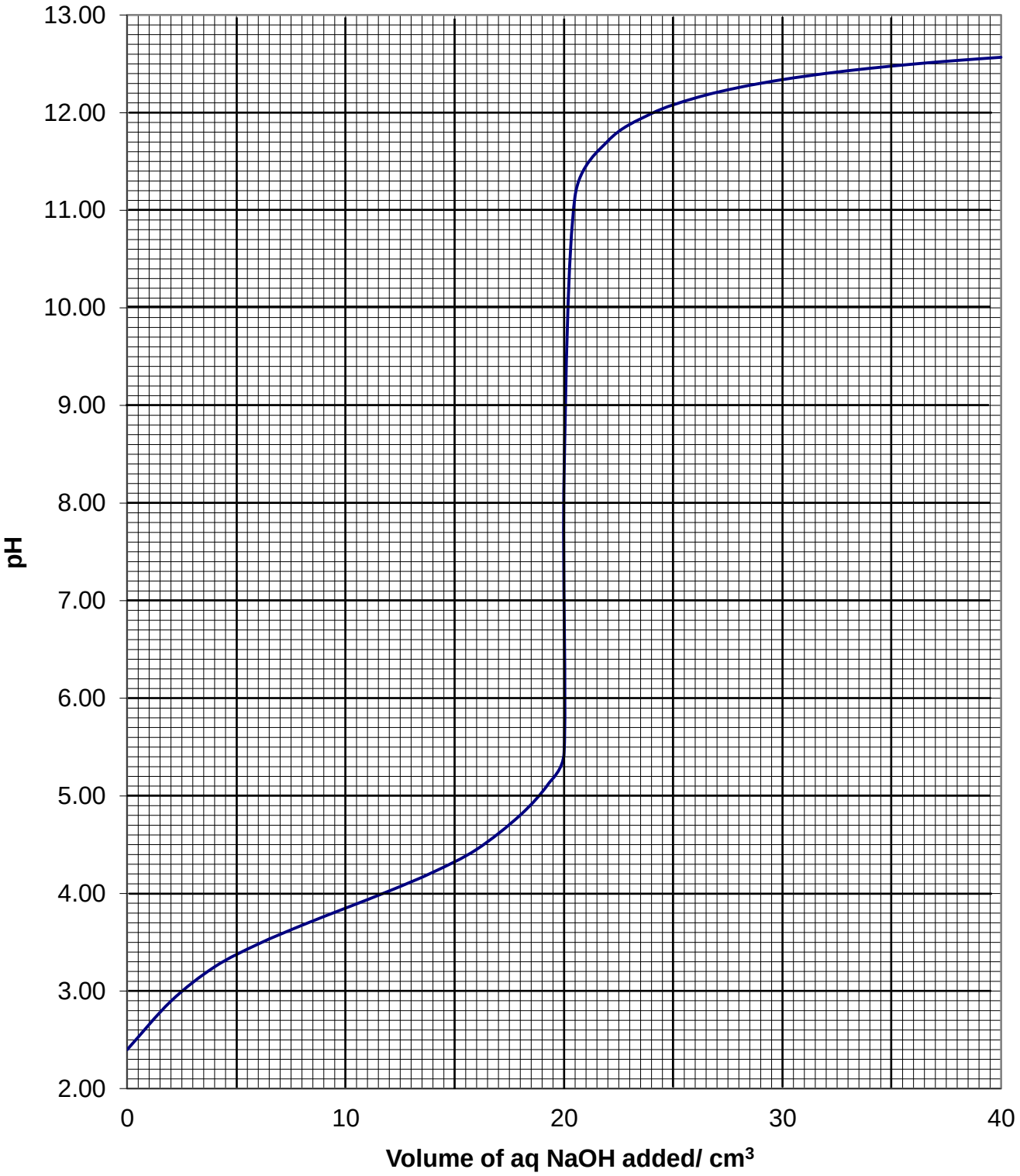
(e) When butane is treated with a small quantity of chlorine in the presence of ultraviolet light, both 1-chlorobutane and 2-chlorobutane are produced. Suggest the approximate ratio in which they are formed.

[1]

[Total: 20]

6 Lactic acid (2-hydroxypropanoic acid), $CH_3CH(OH)CO_2H$, is present in milk. It is a chemical compound that plays a role in several biochemical processes. A chemistry student conducted the following experiment in the laboratory.

(a) 25.0 cm^3 of an aqueous solution of lactic acid is titrated against 0.120 mol dm^{-3} of aqueous sodium hydroxide and the following graph is obtained.



(i) Calculate the concentration of the lactic acid used.

(ii) Determine the initial concentration of H^+ dissociated from lactic acid and hence calculate the acid dissociation constant of lactic acid.

(iii) The student is provided with some acid-base indicators.

Indicator	pH range at which colour change occurs
Methyl violet	0.5 – 1.5
Chlorophenol red	4.8 – 6.4
Alizarin Yellow	10.1 – 12.0

His classmate suggested that they could use chlorophenol red to detect the end-point of this titration.

Explain whether chlorophenol red is a suitable indicator for this titration.

(iv) Explain, with the aid of equations, how a mixture of lactic acid and its conjugate base, $CH_3CH(OH)COO^-$ acts as a buffer on the addition of small amounts of acid and bases. **[7]**

(b) When lactic acid is refluxed with a catalytic amount of concentrated sulfuric acid, a neutral compound **D** with the molecular formula of $C_6H_8O_4$ is formed. Compound **D** does not react with sodium. Deduce the structural formula of **D**, giving reasons for your answer. **[3]**

(c) **E** is an isomer of lactic acid. It reacts with Fehling's solution to give a brick red precipitate. 0.01 mol of **E** reacts with sodium to give 0.24 dm^3 of hydrogen gas under room temperature and pressure conditions. One mole of **E** reacts with two moles of PCl_5.

(i) Suggest a structural formula of **E**, giving reasons for your answer.

(ii) Explain why lactic acid is more acidic than **E**.

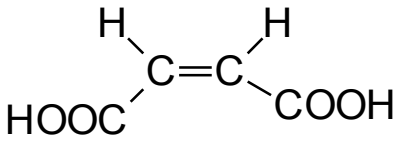
[6]

(d) Maleic acid and fumaric acid are naturally occurring acids found in fruits. They have the following features:

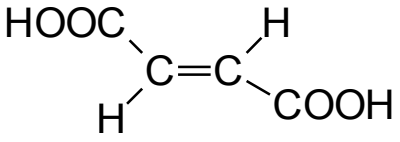
- Same molecular formula of $C_4H_4O_4$
- Are dibasic acids
- Are *cis-trans* isomers of each other
- Fumaric acid has a higher boiling point than maleic acid

(i) What do you understand by the term *cis-trans* isomers?

(ii) The following are the structural formula of maleic acid and fumaric acid.



maleic acid



fumaric acid

Using bonding and structure, account for the differences in the boiling points observed.

[4]

[Total: 20]

End of Section B

Cover Page for Section B

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

Meridian Junior College
2013 JC2 Preliminary Examinations

H1 Chemistry 8872

17 September 2013

INSTRUCTION TO CANDIDATES

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

Circle the two questions that you have attempted

Fasten your answers for Section **B** behind this Cover Page.

You are advised to spend about **1 h for Section B**.

INFORMATION FOR CANDIDATES

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

You are reminded the need for good English and clear presentation in your answers.

Examiner's Use		
Section B	**Q4**	**/ 20 m**
	Q5	**/ 20 m**
	Q6	**/ 20 m**
Total		**/ 40 m**