VICTORIA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATIONS
Higher 1

CANDIDATE NAME ……

CT GROUP ……

CHEMISTRY 8872/02

Paper 2 **13 September 2016**

Candidates answer Section A on the Question Paper. **2 hours**

Additional Materials: Answer Paper
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and CT group on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
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.

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

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

FOR EXAMINER'S USE			
Section A		**Section B**	
A1		**B4**	
A2		**B5**	
A3		**B6**	
		Total	**/ 80**

This document consists of **14** printed pages and **0** blank page.

Section A

Answer **all** questions in the space provided.

1 A 2.00 g salt contains a mixture of potassium iodate, KIO_3, and potassium iodide, KI. Dissolving this mixture in the presence of acid will lead to formation of iodine in a redox reaction as shown:

$$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O$$

(a) (i) Identify the oxidising and reducing agent in this reaction and state its change in oxidation number.

Oxidising agent:	Change in oxidation number:
Reducing agent:	Change in oxidation number:

[2]

(ii) 2.00 g of this mixture was dissolved in a 250 cm^3 solution containing excess acidified potassium iodide solution. The iodine produced in this reaction reacts with sodium thiosulfate, $Na_2S_2O_3$ as shown below.

$$2S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2I^-$$

10.0 cm^3 of the resultant solution requires 22.35 cm^3 of 2.50 x 10^{-2} mol dm^{-3} thiosulfate to completely react with the iodine formed. Determine the percentage composition by mass of potassium iodide and potassium iodate in the mixture.

[3]

When a colourless solution containing KIO_3 and starch is mixed with acidified sodium hydrogensulfite, $NaHSO_3$, the resultant mixture is initially colourless but turned to blue–black after some time. The blue–black colouration is only formed when the concentration of iodine in the solution is sufficiently high.

(b) (i) When iodate ions are first mixed with hydrogensulfite ions, iodide and sulfate(VI) ions are formed. Write two half–equations and hence a balanced equation for this redox reaction.

……...

……...

……[2]

(ii) The iodate in excess will oxidise the iodide generated above to form iodine. However, the iodine is reduced immediately back to iodide by hydrogensulfite.

Write two half–equations and hence a balanced equation for the reaction between iodine and hydrogensulfite.

……...

……...

……[2]

(iii) With reference to the reaction between iodide and iodate as well as your answers to **(b)(i)** and **(b)(ii)**, explain why a blue–black colouration is formed after some time when a colourless solution containing KIO_3 and starch is mixed with acidified sodium hydrogensulfite, $NaHSO_3$.

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……[2]

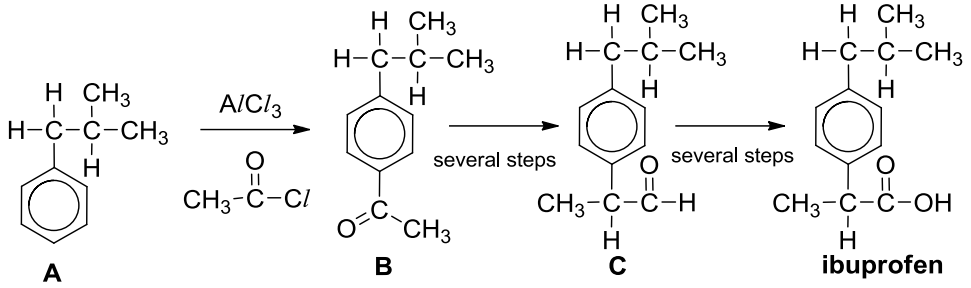
(c) 20 cm^3 of a gaseous mixture containing gaseous ethanol, carbon monoxide and excess oxygen was burned completely. There was a contraction of 1 cm^3. When the product mixture was passed through sodium hydroxide, there was a further contraction of 6 cm^3. All gas volumes are measured at 400 K and 1 atm.

Determine the molar composition of the ethanol and carbon monoxide in this gaseous mixture.

[3]

[Total: 14]

2 Ibuprofen is one of the most commonly used nonsteroidal anti-inflammatory drugs and can be made from the following process:



(a) State the type of reaction for the conversion of **A to B**.

…….....[1]

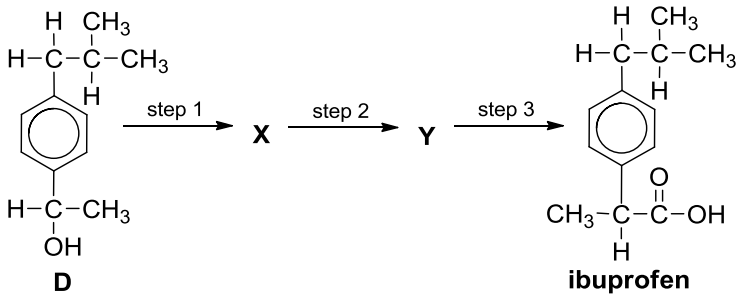
(b) Describe a simple chemical test to distinguish between **A** and **B**, giving the reagents and conditions, observations, and balanced equation for the positive test.

[2]

(c) Suggest reagents and conditions that can be used to convert compound **C** to Ibuprofen in one step in the laboratory.

…….....[1]

(d) A student commented that ibuprofen can be produced via a 3-step synthesis in the laboratory starting from compound **D**, as shown below.



State the reagents and conditions for steps 1, 2 and 3. Give the structures of the intermediates **X** and **Y**.

X:	**Y:**

Step 1: ……..

Step 2: ……..

Step 3: ……. [4]

(e) Ibuprofen can be also synthesised when compound **D** reacts with carbon monoxide over palladium catalyst.

Use the concept of activation energy, together with an appropriate sketch of the Boltzmann distribution, to explain why the addition of a suitable catalyst speeds up a chemical reaction.

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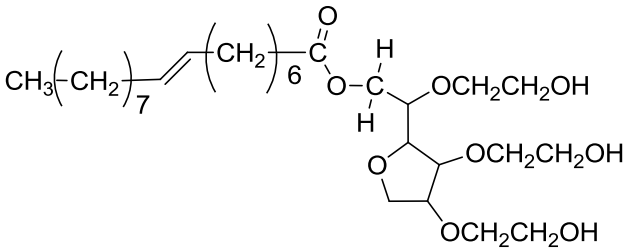
……[3]

(f) Young children can find it difficult to swallow tablets or pills. As a result, ibuprofen is supplied as an "infant formula" emulsion, which is a homogeneous mixture of two or more liquids (e.g. oil and water) that are immiscible.

To prevent the liquids from separating, an emulsifier is used and one such emulsifier is polysorbate 80. Its structure is given below.



polysorbate 80

Explain why this molecule acts as an emulsifier.

……

……

……[1]

(g) The decomposition of ibuprofen follows a first order kinetics with a half-life of 1.5 hours. Calculate the mass of the drug that remains in the blood for a dosage of 400 mg after 6 hours.

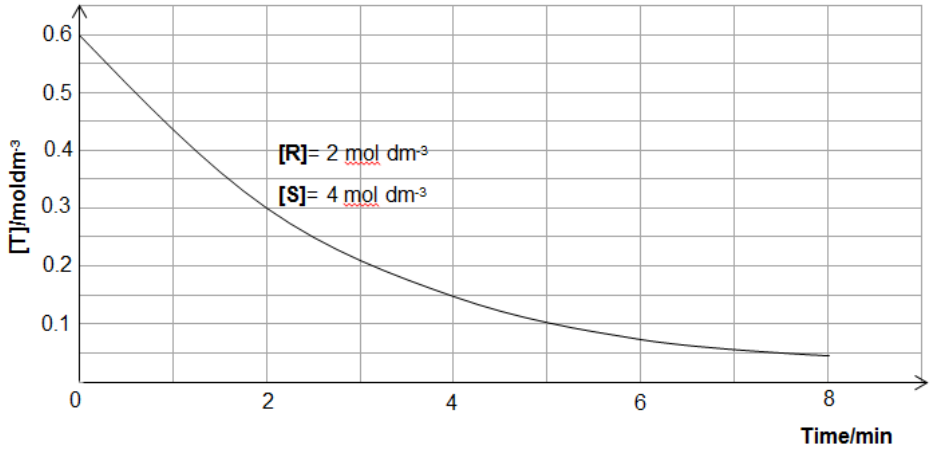
[1]

[Total: 13]

3 (a) Substances **R**, **S** and **T** react according to the following equation:

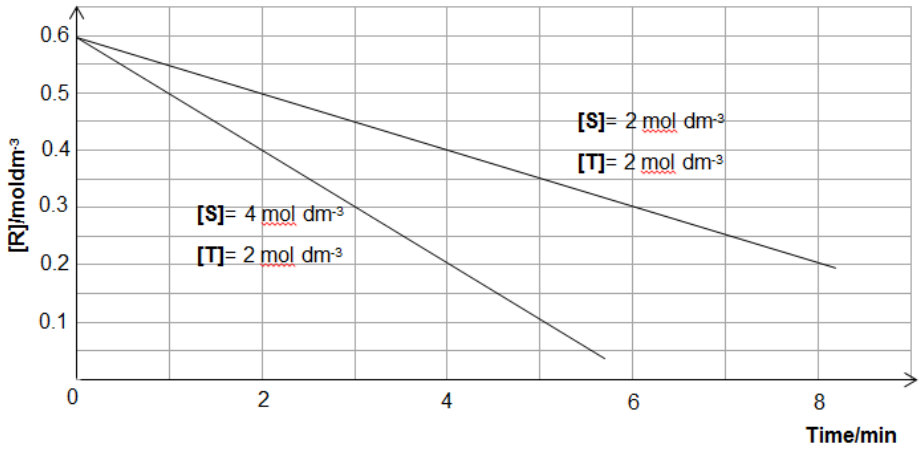
$$\mathbf{R}(aq) + 2\mathbf{S}(aq) + \mathbf{T}(aq) \rightarrow 2\mathbf{U}(aq) + \mathbf{V}(aq)$$

To find the rate equation for the above reaction, separate experiments were performed. The results are shown below.



(i) By showing your working clearly on the graph above, prove that the order of reaction with respect to **T** is first order.

[1]



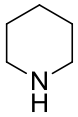
(ii) Deduce the order of reaction with respect to **R** and **S**.

[2]

(iii) Write the rate equation for the reaction. Hence, calculate a value for the rate constant, giving its units.

[2]

(b) Piperidine is a monoacidic base and is widely used building block and chemical reagent in the synthesis of organic compounds.



piperidine

(i) The pH of an aqueous solution of piperidine is 10.1. Calculate the concentration of hydroxide ions in the solution.

[1]

(ii) In a titration, 25 cm^3 of the aqueous solution of piperidine in **(b)(i)** was found to react completely with 30 cm^3 of 0.15 mol dm^{-3} of HC*l* (aq). Calculate the concentration of piperidine solution.

[1]

(iii) With reference to your answers to **(b)(i)** and **(b)(ii)**, explain why piperidine is a weak base.

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……...

……[1]

(iv) Which of the indicators from the table below could you use for this titration in **(b)(ii)**? Explain your answer.

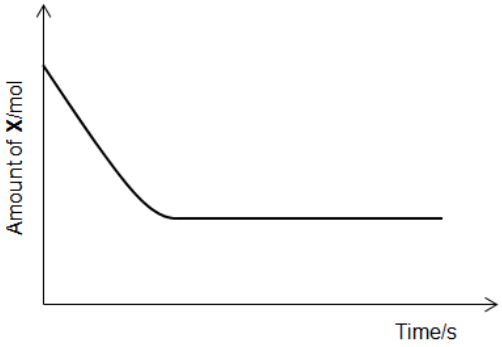
Indicator	**Working range**	**Low pH color**	**High pH color**
Tetrabromophenol blue	3.0 – 4.6	yellow	blue
Thymolphthalein	9.3 – 10.5	colorless	blue

……...

……...[1]

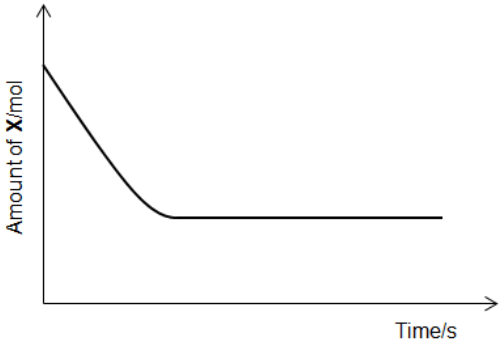
(c) When 1 mole of **X** is mixed with 1 mole of **Y**, the results were as shown:

$$\mathbf{X}(g) + \mathbf{Y}(g) \rightleftharpoons \mathbf{Z}(g) + \mathbf{E}(l)$$



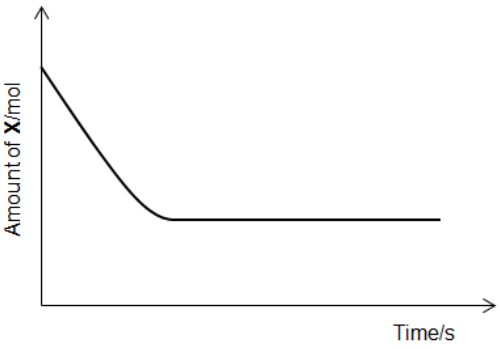
(i) Experiments were carried out on the above equilibrium with changes in the conditions. Plot and indicate on the graph (using dotted lines) the variation of **X** with time for each experiment.

(I) Experiment 1: Lower pressure



[1]

(II) Experiment 2: More **X** used initially



[1]

(ii) Explain the shape of the graph obtained for experiment 1 in **(c)(i)**.

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……...

……[2]

[Total: 13]

Section B

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

4

(a) Describe the bonding in benzene in terms of orbital overlap. You may draw a diagram to illustrate your answer. [3]

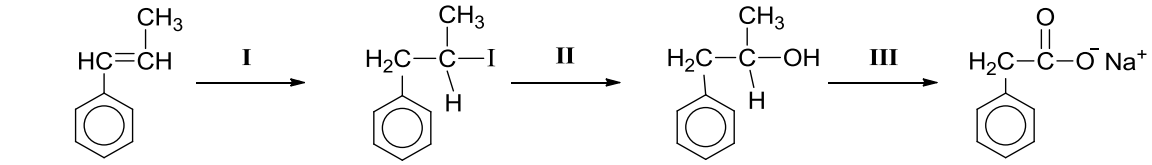
(b) The successive ionisation energies in kJ mol^{-1} of the elements, **X** and **Y**, are given below.

	1st	2nd	3rd	4th	5th	6th	7th	8th
X	580	1817	2745	11577	14842	19379	23326	27465
Y	1000	2252	3357	4556	7004	8496	27107	31719

(i) Deduce the group that element **X** and **Y** belongs to. [2]

(ii) Hence, give the formula of the compound formed between **X** and **Y**. [1]

(c) Beta-methylstyrene undergoes the reactions shown below:



Beta-methylstyrene

(i) State the reagents and conditions required for reactions **I** to **III**. [3]

(ii) Beta-methylstyrene exists naturally as a pair of geometric isomers. Draw the structures of the isomers, clearly labelling each isomer. [2]

(d) I_2 is not very soluble in water. However when I_2 reacts with KI(aq), it forms highly soluble KI_3.

Draw the dot and cross diagram of the I_3^- ion (including all lone pairs of electrons), and deduce its shape and bond angle. [2]

(e) The standard enthalpy change of vapourisation ($\Delta H^{\ominus}_{vap}$), is defined as the energy required to convert 1 mol of a compound into the gaseous state.

The table below shows the $\Delta H^{\ominus}_{vap}$ of NH_3 and NI_3.

Compound	Standard enthalpy change of vapourisation, $\Delta H^{\ominus}_{vap}$ / kJ mol^{-1}
NH_3	+23.35
NI_3	+ 28.29

(i) Explain why the $\Delta H^{\ominus}_{vap}$ of NI_3 is more endothermic than NH_3. [2]

AlI_3 has a simple molecular structure. In the gas phase, it dimerises readily to form the dimer Al_2I_6. The two species are related by equilibrium (I) shown below:

$$Al_2I_6(g) \rightleftharpoons 2AlI_3(g) \quad \text{------ (I)} \qquad \Delta H > 0$$

(ii) A 10.0 g sample of Al_2I_6 was allowed to vapourise in a 2 dm^3 vessel at 400 ^{o}C. Given that the degree of dissociation (α) of Al_2I_6 was 0.35, find the K_c value for equilibrium (I) at 400 ^{o}C. [3]

(iii) Explain what happens to the position of equilibrium (I) for each of the changes below.

(I) The reaction was carried out at 500 ^{o}C.
(II) A sample of Ar(g) was introduced into a 1 dm^3 vessel containing AlI_3(g) and Al_2I_6(g) at 400 ^{o}C. [2]

[Total: 20]

5 **(a)** Describe the carbon atom, ^{12}C, as fully as you can, including the nature and location of the sub-atomic particles, and sketch the shapes of the filled valence orbitals. [3]

(b) Predict, with reasons, how the radius of carbon atom would compare with

(i) C^- ion; [1]

(ii) C^+ ion [1]

(c) Esters of carboxylic acids are often used as components of synthetic fruit flavours. Ethyl butanoate, **P**, $CH_3CH_2CH_2CO_2CH_2CH_3$, is a major component of strawberry flavourings.

(i) Name the reagents and state conditions needed to synthesise **P** from butanoic acid. [1]

(ii) Write an equation for the formation of **P** from butanoic acid. [1]

(d) $CH_3CH_2CH(NH_2)CH_3$ can be synthesized from $CH_3CH_2CH_2CH_2OH$ through a 3-step reaction route.

$$CH_3CH_2CH_2CH_2OH \xrightarrow{\text{step 1}} \mathbf{X} \xrightarrow{\text{step 2}} \mathbf{Y} \xrightarrow{\text{step 3}} CH_3CH_2CH(NH_2)CH_3$$

Suggest reagents and conditions for each step, showing the structural formulae of the intemediates produced. [4]

(e) Compound **A**, $C_4H_{10}O_2$, reacts with sodium metal but is insoluble in aqueous sodium hydroxide, and does not form pale yellow precipitate with alkaline aqueous iodine. On treatment with hot acidified sodium manganate(VII), **A** gives **B**, $C_4H_8O_3$, which is soluble in aqueous sodium hydroxide. On treatment of **B** with phosphorus pentachloride, a compound **C**, $C_4H_6OCl_2$ is obtained. On warming **B** with concentrated sulfuric acid, **D**, $C_8H_{12}O_4$ is obtained.

(i) From the observations provided above, suggest the identity of the compounds, **A** to **D**, giving your reasons and explain the reactions. [8]

(ii) Compound **E**, an isomer of compound **A**, can also react with sodium metal but forms a pale yellow precipitate with alkaline aqueous iodine. Suggest a structure for compound **E.** [1]

[Total: 20]

6 **(a)** Magnesium, silicon and phosphorus are elements in the third period of the Periodic Table. Arrange the elements in order of increasing melting point. Explain your answer in terms of structure and bonding. [4]

(b) There is said to be a 'diagonal relationship' between beryllium and aluminium as they show similar chemical behaviour due to their similarities in electronegativity and charge density.

(i) When a few drops of water are added to solid beryllium chloride, steamy white fumes are evolved and a white solid remains, which is insoluble in water.

Write a balanced equation for this reaction. [1]

(ii) When a large amount of water is added to solid beryllium chloride, a clear, weakly acidic solution is obtained. Explain. [1]

(iii) At 750 ^{o}C, the relative molecular mass of gaseous beryllium chloride corresponds to the formula $BeCl_2$. At 550 ^{o}C, gaseous beryllium chloride exists as a mixture of $BeCl_2$ and **Y** (relative molecular mass of **Y** is 160).

Determine the molar composition of gaseous beryllium chloride at 550 ^{o}C which has a relative molecular mass of 100. Draw a diagram to illustrate the nature of the bonding in **Y** and indicate the value of the bond angle about Be. [2]

(c) A solid mixture contains two oxides of Period 3 elements. To separate the oxides, water was added to the mixture, followed by filtration. Effervescence was observed when sodium carbonate was added to the filtrate. The residue does not react with dilute acid and dilute alkali.

(i) Identify the two oxides present in the mixture. [1]

(ii) Hence, write an equation for the oxide that reacts with water. [1]

(d) **(i)** Write an equation, with state symbols, to define the C*l*–F bond energy in ClF_3. [1]

(ii) The following reaction occurs in the gas phase.

$$3F_2(g) + Cl_2(g) \rightarrow 2ClF_3(g), \quad \Delta H^{\ominus}_r = -328 \text{ kJ mol}^{-1}$$

Use these and other data from the *Data Booklet* to calculate the average bond energy of the C*l*–F bond in ClF_3. [2]

(e) An experiment is conducted to determine the enthalpy change of neutralisation between methanoic acid (HCO_2H) and aqueous sodium hydroxide. Some methanoic acid is added to excess sodium hydroxide solution. The changes in temperature and amount of reagents mixed are recorded as follows.

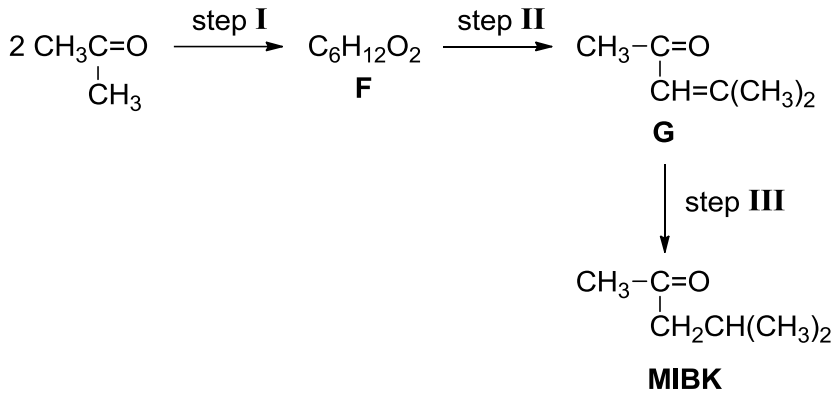
Initial temperature / ^{o}C	24.0
Final temperature / ^{o}C	34.0
Mass of HCO_2H added / g	1.84
Volume of 1 mol dm^{-3} NaOH(aq) used / cm^3	50.0

(i) Define standard enthalpy change of neutralisation with respect to methanoic acid and aqueous sodium hydroxide. [1]

(ii) Use the above data to calculate the enthalpy change of neutralisation, assuming that 4.2 J is required to raise the temperature of 1 cm^3 solution by 1°C. [2]

(iii) The magnitude of enthalpy change of neutralisation between aqueous nitric acid and aqueous sodium hydroxide is found to be larger than the value calculated in **(e)(ii)**. Explain why this is so. [1]

(f) Propanone, CH_3COCH_3, an important industrial solvent, can be converted into another industrially important solvent, MIBK, by the following sequence.



(i) When **F** is formed in step **I**, no other compound is produced. Suggest a structural formula for **F**, which contains one –OH group. [1]

(ii) Name the types of reaction occurring in steps **I** and **III**. [1]

(iii) **G** is formed from **F** in step **II**. Suggest the reagent and condition for step **II**. [1]

[Total: 20]