RAFFLES INSTITUTION
2016 YEAR 6 PRELIMINARY EXAMINATION

Higher 1

CANDIDATE NAME			
CLASS		INDEX NUMBER	

CHEMISTRY 8872/02

Paper 2 **14 September 2016**
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.
The use of an approved scientific calculator is expected, where appropriate.
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.

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

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

At the end of the examination, fasten all your work securely together.
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 in Section B)	**A1**	/ 5
	A2	/ 5
	A3	/ 10
	A4	/ 20
	B5	/ 20
	B6	/ 20
	B7	/ 20
Sub-total		/ 80
Total		**/ 110**

Section A (40 marks)

For examiner's use

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

1 Elements of the third period in the Periodic Table show various trends.

(a) Describe and explain the trend in atomic radius of the elements from sodium to chlorine.

……

……

……

……

……

……

……

……[3]

(b) The oxides, MgO, Al_2O_3 and SiO_2, exist as white powdered solids with high melting points. Describe two chemical reactions you could carry out on a sample of white powder to determine the identity of the oxide.

……

……

……

……

……

……[2]

[Total: 5]

For examiner's use

2 When concentrated sodium chloride is added to blue aqueous copper(II) ions, the following equilibrium is established:

$$[Cu(H_2O)_6]^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons [Cu(Cl)_4]^{2-}(aq) + 6H_2O(l)$$
blue yellow

Aqueous copper complexes containing $CuCl_4^{2-}$ ions are yellow in colour.

(a) (i) Write a K_c expression for this equilibrium.

[1]

(ii) A solution is prepared in which the initial concentration of $[Cu(H_2O)_6]^{2+}(aq)$ ions and $Cl^-(aq)$ ions are 1 mol dm^{-3} and 4 mol dm^{-3} respectively. After equilibrium is reached, the concentration of $[Cu(Cl)_4]^{2-}(aq)$ ions is 0.95 mol dm^{-3}.

Calculate the value of K_c for this equilibrium and state its units.

K_c = ... units = ... [2]

(b) If the container containing $[Cu(H_2O)_6]^{2+}(aq)$ ions and $[Cu(Cl)_4]^{2-}(aq)$ ions in equilibrium is cooled, the solution becomes more blue and less yellow.

Deduce whether the equilibrium as written is exothermic or endothermic, explaining your answer briefly.

.....

.....

.....

.....

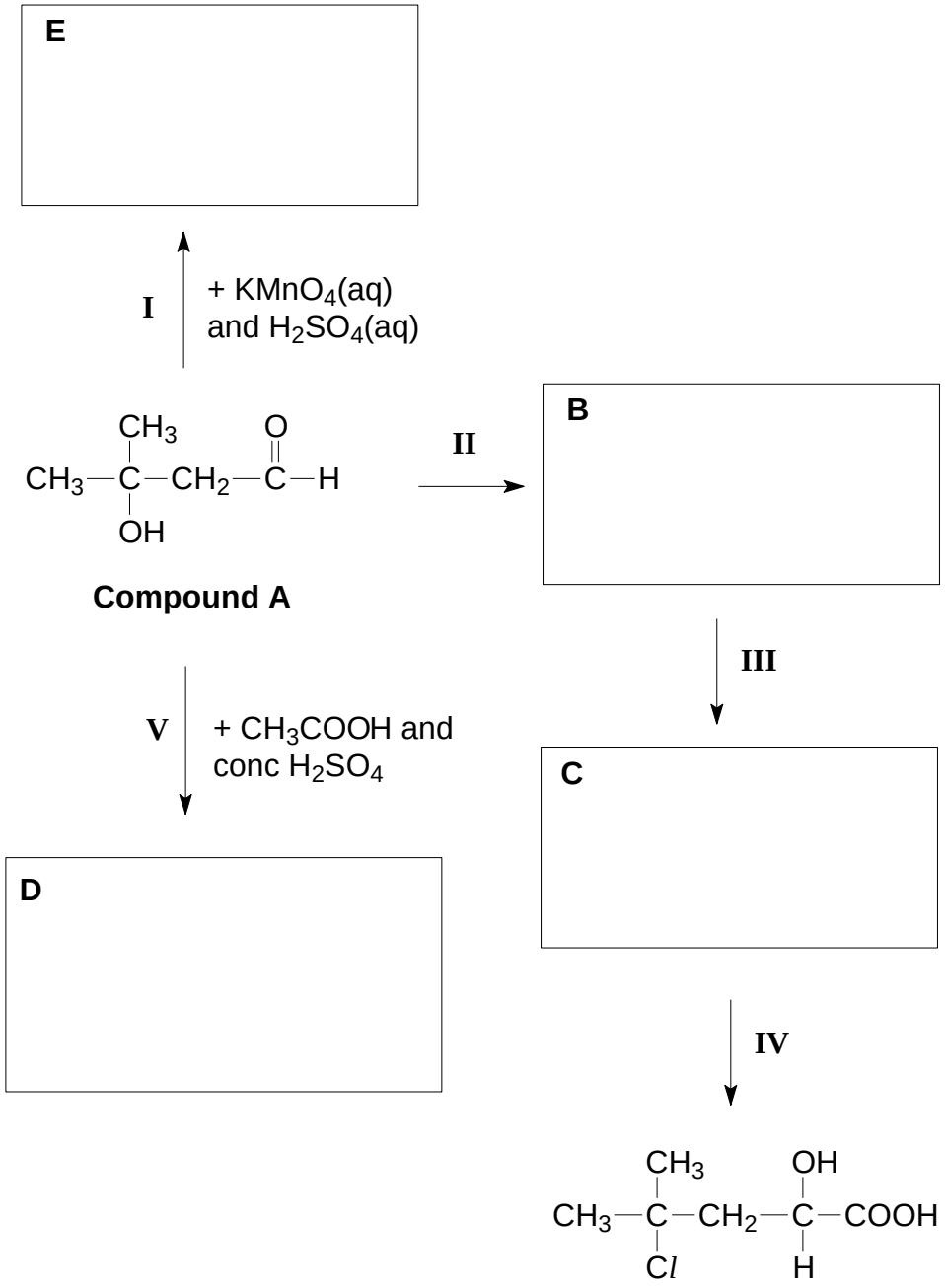
.....

.....[2]

[Total: 5]

3 Study the reaction scheme shown below.

For examiner's use



(a) State the functional groups present in compound **A**.

……..……..……..…….....[1]

(b) In the appropriate boxes, draw the structures of compounds **B**, **C**, **D** and **E**. [4]

For examiner's use

(c) For the reactions shown in the scheme above, state

(i) the reagents and conditions for reaction **II**,

……

(ii) the reagents and conditions for reaction **III**,

……

(iii) the type of reaction in reaction **V**.

……..…….....[3]

Esters are commonly used in perfumes and fruit flavours. Esters can be hydrolysed under suitable conditions.

(d) Write a balanced equation for the hydrolysis of propyl ethanoate in

(i) acidic conditions,

……

(ii) basic conditions.

……..…….....[2]
[Total: 10]

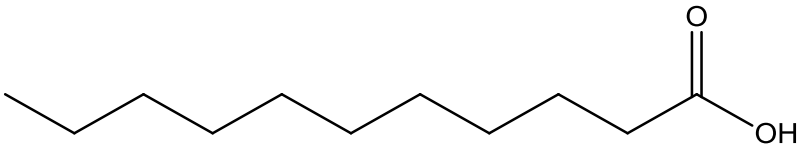
For examiner's use

4 Coconut, olive and soybean oil are vegetable oils that are commonly used for cooking.

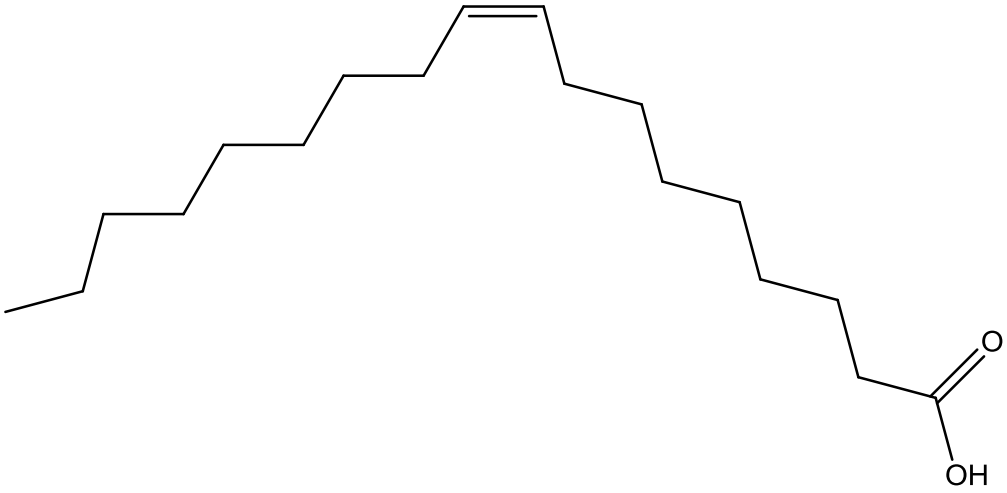
Table 4.1

Type of vegetable oil	**Coconut**	**Olive**	**Soybean**
Saturated fatty acid (%)	91	14	16
Mono-unsaturated (%)	6	72	23
Poly-unsaturated (%)	3	14	61
Iodine value	**x**	80 – 88	120 –136
Heat content / kJ g^{-1}	36.1	37.0	18.7

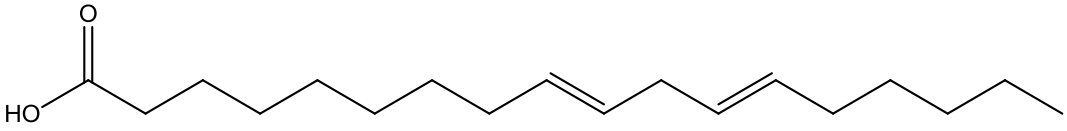
A fatty acid is a carboxylic acid with a long aliphatic chain which is either saturated or unsaturated. Examples of fatty acids are lauric acid, oleic acid and linoleic acid.



lauric acid



oleic acid



linoleic acid

For examiner's use

(a) Oleic acid was burned in a spirit burner under a beaker of water. The experimental results obtained are shown below:

Table 4.2

Mass of water / g	250
Original temperature of water / °C	25.0
Final temperature of water / °C	100.0
Original mass of oleic acid + burner / g	52.64
Final mass of oleic acid + burner / g	50.64
Molar mass of oleic acid / g mol^{-1}	282

(i) Calculate the enthalpy change of combustion of liquid oleic acid in kJ mol^{-1}.

$\Delta H_c^{\ominus}$ ..... [3]

(ii) The data for some enthalpy changes of formation are given in the table below.

Table 4.3

compound	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$CO_2(g)$	– 394
$H_2O(l)$	– 286

The combustion of liquid oleic acid can be represented as follows:

$$C_{18}H_{34}O_2(l) + 25½O_2(g) \rightarrow 18CO_2(g) + 17H_2O(l)$$

Using **Table 4.3** and your answer to **(a)(i)**, calculate the enthalpy change of formation of liquid oleic acid.

[2]

(iii) Suggest why the heat content of a vegetable oil, e.g. coconut oil, is always quoted in kJ g^{-1} instead of kJ mol^{-1}.

.....

.....[1]

For examiner's use

(b) **(i)** What type of intermolecular force will operate between the hydrocarbon chains of the fatty acids?

……[1]

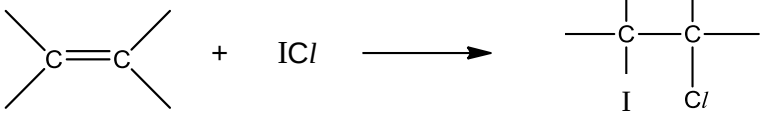
(ii) Hence, suggest a reason why fatty acids are insoluble in water.

……

……[1]

The interhalogen compound, IC*l*, reacts faster with alkenes than the pure halogens, so IC*l* can be used to determine volumetrically the unsaturation in fatty acids and oils. This unsaturation is in the form of C=C bonds.

Reaction I



Reaction II $ICl + KI \longrightarrow KCl + I_2$

Reaction III $I_2 + 2S_2O_3^{2-} \longrightarrow 2I^- + S_4O_6^{2-}$

(c) **(i)** Name the type of reaction occurring in reaction **I**.

……[1]

(ii) Suggest why IC*l* reacts with alkenes faster than the pure halogens, Cl_2, Br_2 and I_2.

……

……[1]

(d) Give the oxidation states of iodine and sulfur in reactions **II** and **III**.

(i) iodine in IC*l* and I_2 in reaction **II**

IC*l* ……..

I_2 …….. [1]

(ii) sulfur in $S_2O_3^{2-}$ and $S_4O_6^{2-}$ in reaction **III**

$S_2O_3^{2-}$ ……

$S_4O_6^{2-}$ …… [1]

For examiner's use

(e) A student was given a sample of an unknown fatty acid **y**, which is either linoleic acid or oleic acid.

To determine the unsaturation in this sample of fatty acid, 0.100 g of fatty acid **y** was dissolved in 20 cm^3 of 1,1,1-trichloroethane solvent. 25 cm^3 of 0.100 mol dm^{-3} IC*l* was added to the fatty acid solution.

The unreacted IC*l* was added to an excess of potassium iodide solution and titrated against 0.200 mol dm^{-3} sodium thiosulfate solution. The volume required is 17.85 cm^3.

(i) Calculate the number of moles of sodium thiosulfate reacted in reaction **III**.

[1]

(ii) Calculate the number of moles of iodine produced in reaction **II**.

[1]

(iii) Hence, calculate the number of moles of interhalogen, IC*l* that reacted with 0.100 g fatty acid **y** in reaction **I**.

[2]

(iv) Calculate the mass of fatty acid per mole of IC*l* reacted.

[1]

For examiner's use

Table 4.4

Fatty acid	Molecular formula	Molar mass / g mol^{-1}	Number of C=C bonds (n)	$\frac{\text{molar mass}}{\text{n}}$
linoleic acid	$C_{18}H_{32}O_2$	280	2	140
oleic acid	$C_{18}H_{34}O_2$	282	1	282

(v) The identity of the fatty acid **y** can be obtained by using the following equation:

$$\frac{\text{mass of fatty acid}}{\text{amount of IC}l \text{ reacted}} = \frac{\text{molar mass of fatty acid}}{\text{n}}$$

Using **Table 4.4** and your answer to **(e)(iv)**, determine the identity of fatty acid **y**.

[1]

(f) Iodine values are often used to determine the amount of unsaturation in fatty acids.

Predict if the iodine value of coconut oil, **x**, in **Table 4.1**, will be higher or lower than that of olive acid and explain why.

……

……..…[2]

[Total: 20]

Section B (40 marks)

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

5 (a) Ethanoic acid is commonly found in vinegar. Explain, in terms of its structure, why ethanoic acid is acidic. [2]

(b) When carbon dioxide dissolves in water it produces carbonic acid, in equilibrium.

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

Carbonic acid is used in the making of carbonated drinks and also plays an important role in maintaining the pH of blood.

(i) Carbonic acid is described as a *weak acid*. What is meant by this term? Illustrate your answer with an equation. [2]

A 20 cm^3 solution of carbonic acid (pH = 2.40) was titrated against 0.1 mol dm^{-3} of NaOH. It was found that 25 cm^3 of the NaOH was needed for complete reaction.

(ii) Calculate the concentration of carbonic acid in the solution. Hence or otherwise, show that carbonic acid is a weak acid. [3]

(iii) Suggest an indicator for the above titration. [1]

(iv) With the aid of equations, explain how carbonic acid helps "*in maintaining the pH of blood.*" [2]

(c) Halogenoalkanes can undergo two different types of reaction with hydroxide ions.

(i) Use 1-bromobutane to illustrate two types of reactions that halogenoalkanes undergo with NaOH. For **each** one, write an equation for the reaction, give the conditions needed and identify the type of reaction that occurs. [6]

(ii) In **(c)(i)**, each reaction gave one organic product. Suggest a simple chemical test to distinguish between the two organic products. Include in your test the reagents and conditions, and a balanced chemical equation. [3]

(iii) Briefly describe how CFCs are an environmental concern. [1]

[Total: 20]

6 **(a)** Boron trichloride, BCl_3, is a highly reactive halide that is used in the refining of metals. It reacts with water in a similar manner as phosphorus trichloride, PCl_3, to form only 2 products: boric acid, H_3BO_3, and an acidic gas.

(i) Name the type of reaction between boron trichloride and water. [1]

(ii) Identify the acidic gas, and hence, write a balanced equation for this reaction. [2]

(iii) State the observations for this reaction. [1]

(b) As boron trichloride is highly reactive, it is often first reacted with dimethyl sulfide, $(CH_3)_2S$, to form a solid addition compound that is much safer to use.

(i) Draw the dot-and-cross electron diagrams for boron trichloride and dimethyl sulfide. By considering the numbers of bonding and non-bonding electron pairs, state the shape of each compound about the central atom. [4]

(ii) Boron trichloride and dimethyl sulfide forms an addition compound when they react in a 1:1 ratio. Suggest the type of bond formed between boron trichloride and dimethyl sulfide and explain your reasoning clearly. [2]

(iii) Draw the shape of the addition compound formed in **(b)(ii)**. Indicate clearly the bond angles with respect to both boron and sulfur atoms.
You may use $-CH_3$ to represent the methyl group. [3]

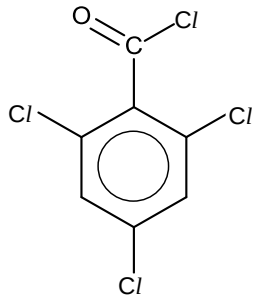
(c) Write the full electronic configuration of the following species:
(i) Mg atom
(ii) Br^- ion

[2]

(d) With the aid of a balanced equation, explain what is meant by the *lattice energy of magnesium chloride*. Deduce whether the magnitude of the lattice energy of magnesium chloride will be larger or smaller than that of sodium bromide. [5]

[Total:20]

7 2,4,6-trichlorobenzoyl chloride, which is also known as the Yamaguchi reagent, is a compound that can be used to make an ester.

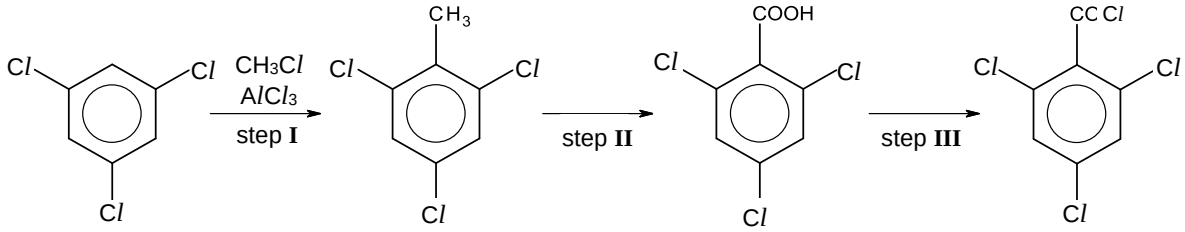


Yamaguchi reagent

(a) Copy the above structure onto your answer script.

Circle the most polar C–C*l* bond in a molecule of the Yamaguchi reagent and explain why a reaction is most likely to occur at this carbon atom. [2]

The following reaction scheme shows how the Yamaguchi reagent may be prepared from 1,3,5-trichlorobenzene.



1,3,5-trichlorobenzene Yamaguchi reagent

(b) **(i)** Name the type of reaction which occurred in step **I**. [1]

(ii) Suggest the reagents and conditions for step **II**.
Write a balanced equation for step **II**, using displayed formulae for all organic compounds. [2]

Step **III** may be carried out by reacting 2,4,6-trichlorobenzoic acid with thionyl chloride, $SOCl_2$. The products of the reaction are sulfur dioxide, hydrogen chloride and the Yamaguchi reagent.

(iii) Use the information given to write a balanced equation for step **III**. [1]

(iv) Calculate the total volume of gases that would be produced at r.t.p. if 1.0 g of thionyl chloride reacted with 10.0 g of 2,4,6-trichlorobenzoic acid. [4]

A student investigated the kinetics of the acid-catalysed reaction between propanone and iodine.

$$CH_3COCH_3 + I_2 \xrightarrow{H^+} CH_3COCH_2I + HI$$

The following results were obtained for an experiment in which the concentrations of I_2 and H^+ were kept virtually constant at 0.100 mol dm^{-3}.

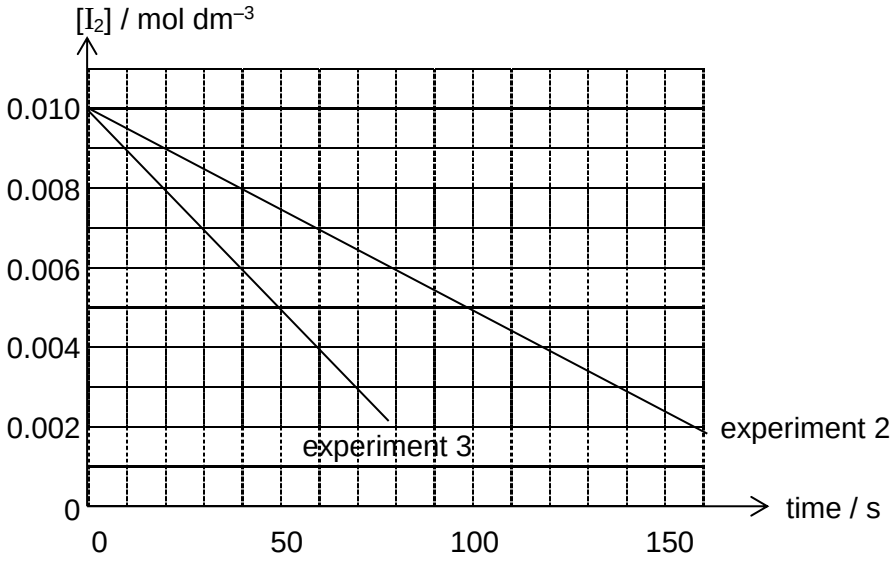
time / s	0	40	80	120	160	200	240
[CH_3COCH_3] / mol dm^{-3}	0.0100	0.0079	0.0062	0.0049	0.0038	0.0030	0.0024

(c) (i) Plot the data on suitable axes and use your graph to determine the order of reaction with respect to CH_3COCH_3. [3]

Two more experiments were carried out to investigate how the initial rate of reaction varied with the concentrations of I_2 and H^+.

experiment number	[CH_3COCH_3] / mol dm^{-3}	[I_2] / mol dm^{-3}	[H^+] / mol dm^{-3}
2	0.100	0.010	0.010
3	0.100	0.010	0.020

The following graphs were obtained.



(ii) Use the graphs to deduce the orders of reaction with respect to I_2 and H^+. Show clearly how you arrived at your answers. [2]

(iii) Use your answers to **(c)(i)** and **(c)(ii)** to write a rate equation for the reaction. [1]

H^+ ions are a catalyst for the reaction between propanone and iodine.

(d) **(i)** What is meant by the term *catalyst*? [1]

(ii) Although H^+ ions are regenerated at the end of each experiment, the concentration of H^+ at the end of each experiment might still be greater than that at the start of each experiment.

Suggest a reason why this might be so. [1]

The enthalpy change of the reaction between propanone and iodine is –38 kJ mol^{-1}. The activation energy of the acid-catalysed reaction is 92 kJ mol^{-1}.

(e) Draw a fully labelled reaction pathway diagram, showing on it both the catalysed and uncatalysed pathways. [2]

[Total:20]

END OF PAPER