



**SERANGOON JUNIOR COLLEGE**  
**General Certificate of Education Advanced Level**  
**Higher 1**

Candidate Name

Class

**CHEMISTRY**  
**JC2 Preliminary Examination**  
**Paper 2**

**8872/02**  
**14<sup>th</sup> Sep 2017 (AM)**  
**2 hours**

Additional Materials: Data Booklet

**READ THESE INSTRUCTIONS FIRST**

Write your name and class on all the work you hand in.  
Write in dark or blue pen.  
You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

**Section A**

Answer **all** the questions

**Section B**

Answer **two** questions on a 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		
P1 (MCQ)		30
P2	Section A	
	1	15
	2	15
	3	10
	Section B	
		20
		20
Total		110

## Section A

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

- 1 (a) An excess of water was added to 3.9 g of unknown phosphorus chloride,  $PCl_x$ , and the resulting solution was made up to 250 cm<sup>3</sup> in a standard flask. 25.0 cm<sup>3</sup> of this solution was titrated with 0.40 mol dm<sup>-3</sup> NaOH and required 37.40 cm<sup>3</sup> for neutralisation.

- (i) Write equations, for the reactions of  $PCl_5$  and  $PCl_3$  with water. [1]



- (ii) Calculate the total amount, in moles, of  $H^+$  ions present in the 250 cm<sup>3</sup> standard flask. [2]

$$n(H^+) \text{ in } 25.0 \text{ cm}^3 = n(NaOH) = 0.40 \times 37.40/1000 = 0.01496 \text{ mol [1]}$$

$$n(H^+) \text{ in } 250 \text{ cm}^3 = 0.01496 \times 250/25 = 0.1496 \text{ mol [1]}$$

- (iii) Hence, calculate the numerical value of x. [2]

Assuming it is  $PCl_5$ :

$$8 \times n(PCl_5) = n(H^+) \text{ [1]}$$

$$n(PCl_5) = 0.1496/8 = 1.87 \times 10^{-2} \text{ mol}$$

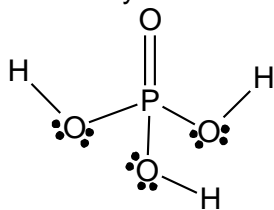
$$n(PCl_5) = 3.9/208.2 = 1.87 \times 10^{-2} \text{ mol}$$

$$x = 5 \text{ [1]}$$

Identify of phosphorus chloride =  $PCl_5$

The amounts would not match if you assumed it to be  $PCl_3$

- (iv) Draw out the Lewis structure of  $H_3PO_4$ . State the bond angles and shape about any central atoms. [3]



[1] show all bond angles and lp.

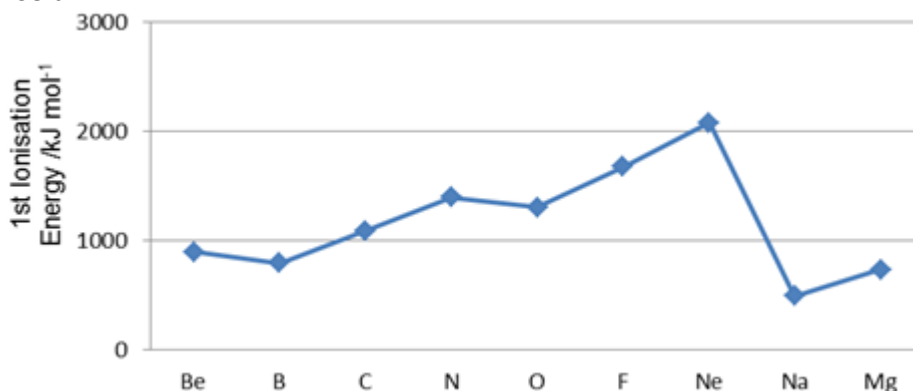
P: tetrahedral, 109.5° [1]

O: Bent, 104.5° [1]

- (v) Explain why  $PCl_5$  exist but not  $NCI_5$ . [1]

$PCl_5$  belongs to period 3 and is able to expand octet configuration [1]  
due to energetically accessible 3d orbitals.

- (b) The graph below shows the first ionisation energy of the elements beryllium to magnesium.



- (i) Define the term *first ionisation energy*. [1]

First ionisation energy is the energy required to remove one mole of electrons from one mole of gaseous atoms to form one mole of singly positively-charged gaseous ions. [1]

- (ii) Account for the increasing ionisation energy from beryllium to neon. [2]

Across the period,

Nuclear charge increases.

Shielding effect is similar [1] since successive elements in the period have an additional electron in the same valence shell.

Effective nuclear charge increases. More energy is required to overcome the stronger electrostatic forces of attraction between the nucleus and the valence electron to be removed. [1]

- (iii) Explain why the first ionisation energy decreases from beryllium to boron and nitrogen to oxygen. [2]

Be :  $1s^2 2s^2$

B :  $1s^2 2s^2 2p^1$

The 2p electron to be removed from B is at a higher energy level compared to the 2s electron to be removed from Be. Less energy is required to overcome the weaker electrostatic forces of attraction between the nucleus and the valence 2p electron in B. [1]

N :  $1s^2 2s^2 2p^3$

O :  $1s^2 2s^2 2p^4$

There is interelectronic repulsion between the pair of electrons in the doubly-filled 2p orbital of O.

Less energy is required to overcome the weaker electrostatic forces of attraction between the nucleus and the paired valence 2p electron in O compared to the unpaired valence 2p electron in N. [1]

- (iv) Explain why the first ionisation energy decreases sharply from neon to sodium. [1]

Sodium (Na) is in period 3 while neon (Ne) is in period 2.

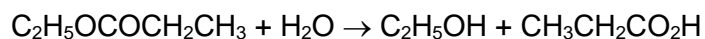
Na:  $1s^2 2s^2 2p^6 3s^1$

Ne:  $1s^2 2s^2 2p^6$

The number of filled principal quantum shells increases. The valence electrons in Na are further from the nucleus. Less energy is required to overcome the weaker electrostatic forces of attraction between the nucleus and the valence electron to be removed. [1]

[Total: 15]

- 2 Ethyl propanoate can be hydrolysed according to the following equation.



The kinetics of the above hydrolysis may be investigated by measuring the concentration of propanoic acid produced. In this investigation, 0.240 moles of the ester was mixed with a suitable catalyst in 1 dm<sup>3</sup> of water and the mixture was kept at a constant temperature of 35 °C.

10 cm<sup>3</sup> samples were withdrawn periodically at hourly intervals and rapidly cooled by the addition of cold water. The resulting solution was then titrated against a solution of standard sodium hydroxide every hour over a period of four hours. The following results were obtained.

Time / h	Concentration of propanoic acid / mol dm <sup>-3</sup>
0	0.000
1	0.084
2	0.140
3	0.178
4	0.195

- (a) (i) Identify the role of the cold water used prior to the titration and explain why it is necessary. [2]

The cold water is a quenching agent [1].

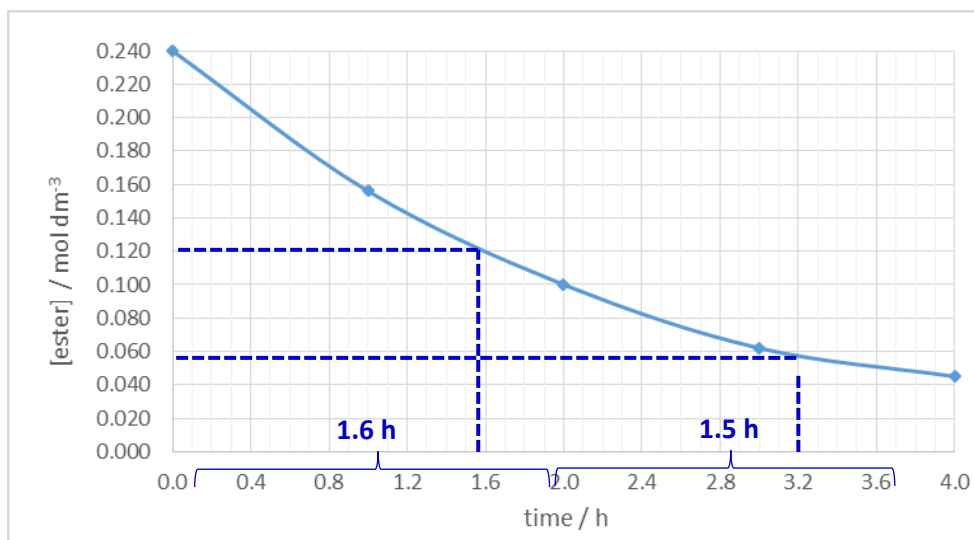
It is necessary to slow down the reaction significantly (by lowering concentration and temperature of the reaction) so that the reaction is considered to have stopped at that instant. [1]

- (ii) By using a suitable graphical method, determine the half-life of the reaction and hence show that the hydrolysis reaction is first order with respect to the ester. [4]

Time / h	Concentration of propanoic acid / mol dm <sup>-3</sup>	Concentration of ester / mol dm <sup>-3</sup>
0	0.000	0.240
1	0.084	0.156
2	0.140	0.100
3	0.178	0.062
4	0.195	0.045

[Reactant]-time graph

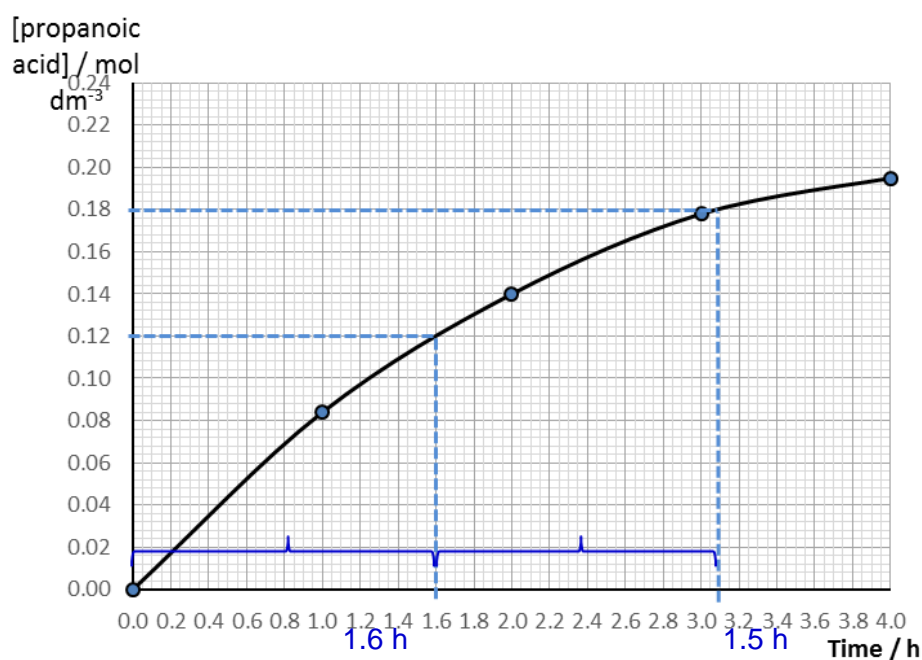
**Correct labelled axis and plotted points: 1m; Show at least 2  $t_{1/2}$  : 1m; Smooth curve: 1m**



The half life is constant [1] hence it is first order with respect to the ester. **Accept :  $1.45 \text{ h} < t_{1/2} < 1.75 \text{ h}$**

OR

[Product]-time graph



Assuming the reaction goes into completion, the  $0.24 \text{ mol dm}^{-3}$  of the ester would form  $0.24 \text{ mol dm}^{-3}$  of propanoic acid.

The first half-life of a product-time graph would be the time taken to form half the total amount of propanoic acid ( $0.12 \text{ mol dm}^{-3}$ ) and the time subsequently taken to form  $3/4$  of the total amount of propanoic acid ( $0.18 \text{ mol dm}^{-3}$ ).

- (b) The ester, ethyl propanoate, can also undergo base hydrolysis and the reaction is monitored using the initial rates method. The initial rate of the hydrolysis reaction between the ester and NaOH(aq) was measured in three separate experiments at a constant temperature.

The results are obtained below:

Experiment	Temperature / °C	Initial [NaOH] / mol dm <sup>-3</sup>	Initial [ester] / mol dm <sup>-3</sup>	Initial rate / mol dm <sup>-3</sup> s <sup>-1</sup>
1	T <sub>1</sub>	0.020	0.015	2.70 x 10 <sup>-3</sup>
2	T <sub>1</sub>	0.030	0.015	4.05 x 10 <sup>-3</sup>
3	T <sub>1</sub>	0.060	0.020	<i>r</i> <sub>1</sub>
4	T <sub>2</sub>	0.120	0.020	4.32 x 10 <sup>-2</sup>

- (i) Deduce the order of reaction with respect to NaOH. [2]

Comparing expt 1 and 2, when **[OH<sup>-</sup>]** increased **1.5 times** while keeping **[ester] constant**, **initial rate increased 1.5 times**. [1]

Hence, **order of reaction wrt [OH<sup>-</sup>]** is **1**. [1]

- (ii) Given that the reaction is first order with respect to the ester, calculate the initial rate of reaction, *r*<sub>1</sub>, for Experiment 3. [1]

$$\text{rate} = k [\text{NaOH}] [\text{ester}]$$

Comparing expts 2 and 3,

$$\frac{r_1}{4.05 \times 10^{-3}} = \frac{k(0.06)(0.02)}{k(0.03)(0.015)}$$

$$r_1 = \underline{0.0108} \text{ mol dm}^{-3} \text{ s}^{-1} \text{ [1] allow ecf}$$

- (iii) Calculate the value of the rate constant in experiment 1 and experiment 4, specifying the correct unit. Hence, deduce whether T<sub>1</sub> or T<sub>2</sub> is higher. [3]

$$\text{For experiment 1: } 2.70 \times 10^{-3} = k (0.020) (0.015)$$

$$\underline{k = 9} \text{ mol}^{-1} \text{ dm}^3 \text{ s}^{-1} \text{ [1] allow ecf}$$

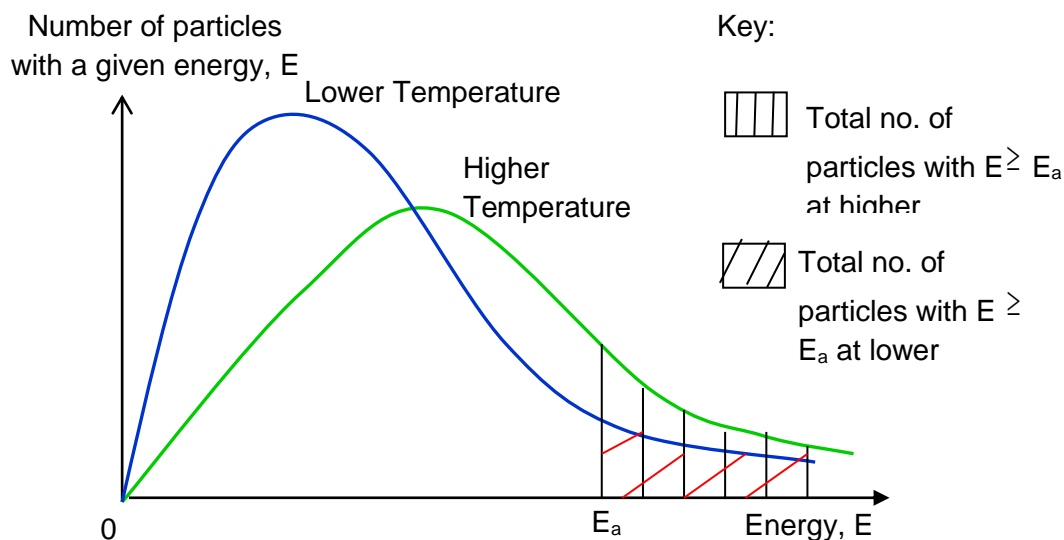
$$\text{For experiment 2: } 4.32 \times 10^{-2} = k (0.120) (0.020)$$

$$\underline{k = 18} \text{ mol}^{-1} \text{ dm}^3 \text{ s}^{-1} \text{ [1] allow ecf}$$

**T<sub>2</sub> is higher** [1] as the rate constant for Experiment 4 is **larger** than that of Experiment 1. **Increasing the temperature increases the value of the rate constant.**

- (iv) Draw the Maxwell-Boltzmann distribution curve, explain how the increase in temperature increases the rate of reaction. [3]

**Marking point: [Any 2 mistakes minus 1m]**



**-Correctly labelled axis & origin**

**-Correctly labelled curve &  $E_a$**

**-Correct legend & shading**

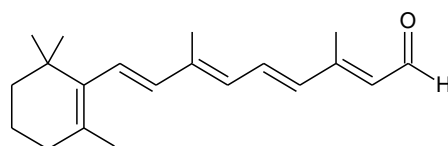
When temperature of the reaction increases,

- average kinetic energy of the reactant particles increases
- more reactant particles with energy  $\geq E_a$
- more effective collisions
- Since rate of reaction is proportional to the frequency of effective collisions, rate of reaction increases [1]

[Total: 15]

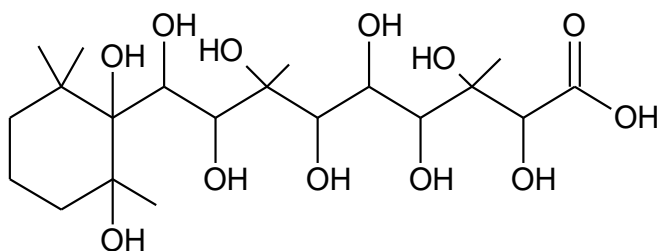
- 3 This question revolves around carbonyl compounds involved in biological applications in living things.

- (a) Retinal is one of the many forms of vitamin A, bound to proteins called opsins. It is the chemical basis of vision in animals and humans as well as allowing certain microorganisms to convert light into metabolic energy.



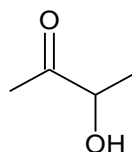
**Retinal**

- (i) State the number of geometrical isomers for retinal. [1]  
 $2^4 = 16$  isomers [1]
- (ii) Draw all the organic products formed when retinal is reacted with cold acidified potassium manganate(VII). [1]



[1]

- (b) Acetoin is a colorless or pale yellow liquid with a pleasant buttery odour. It is a neutral, four-carbon molecule used as an external energy store by a number of fermentive bacteria.



Acetoin

- (i) Suggest a chemical test to **positively** distinguish acetoin from retinal, including relevant chemical equations. [3]

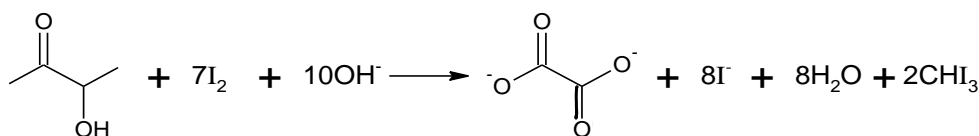
Test:

Add aqueous iodine and sodium hydroxide to both samples and heat.

[1]

Observation:

Acetoin would decolourise the brown iodine solution and yellow precipitate of tri-iodomethane would be formed, but retinal no decolourisation and no yellow ppt. [1]



[1]

- (ii) Compound **F** is an isomer of acetoin and contains an aldehyde and a tertiary alcohol. **F** was reacted in a sequential procedure as shown below.

Step 1:

It is reacted with aqueous hydrogen cyanide at low temperatures.

Step 2:

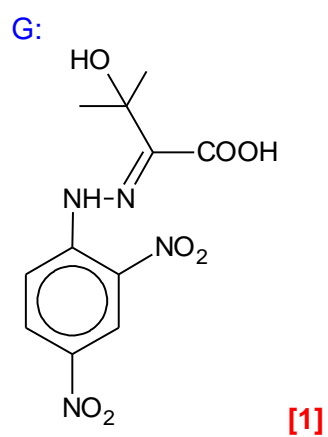
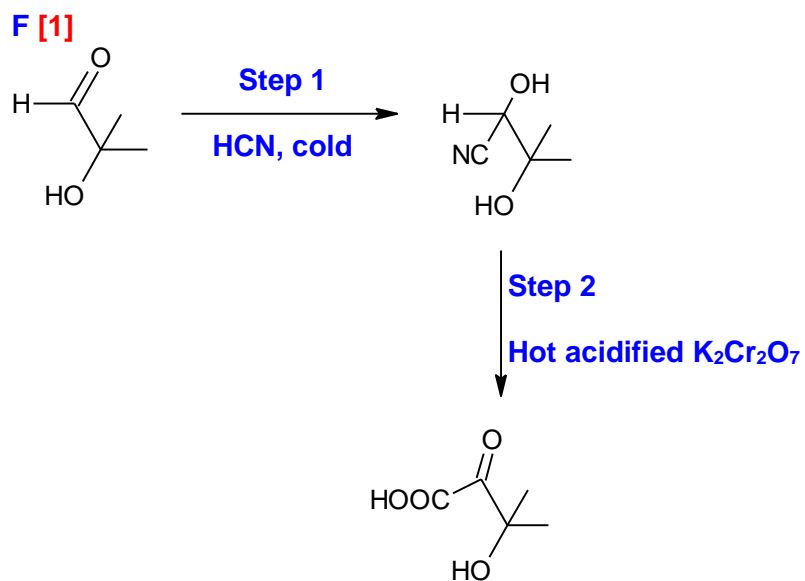
Hot acidified potassium dichromate(VI) added to product formed earlier

Step 3:

2,4-dinitrophenylhydrazine added to product formed in step 2 to form compound **G**.

Draw the structures of compounds **F** and **G** and state the types of reactions taken place. [5]





Step 1: Nucleophilic Addition  
 Step 2: Oxidation and acidic hydrolysis  
 Step 3: Condensation [1 each]

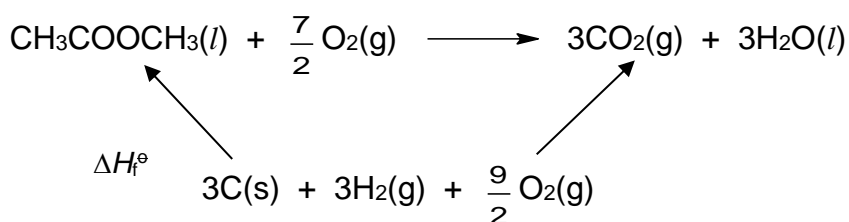
[Total: 10]

## Section B

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

- 1 (a) (i) Define standard enthalpy change of formation. [1]  
 Standard enthalpy change of formation ( $\Delta H_f^\ominus$ ) of a substance is the energy change when one mole of the substance is formed from its elements under standard conditions. [1]
- (ii) Use the energy cycle below and the standard enthalpy changes of combustion,  $\Delta H_c^\ominus$ , in the table to calculate the standard enthalpy change of formation,  $\Delta H_f^\ominus$ , of methyl ethanoate,  $\text{CH}_3\text{COOCH}_3$ . [2]

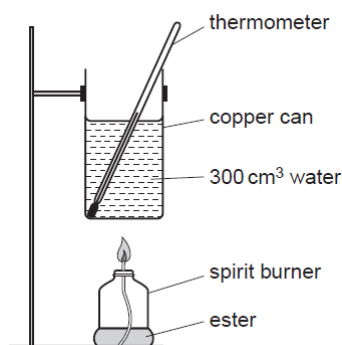
	$\Delta H_c^\ominus / \text{kJ mol}^{-1}$
carbon	-393.5
hydrogen	-285.8
methyl ethanoate	-1592.1



By Hess's law,

$$\begin{aligned} \Delta H_f^\ominus(\text{CH}_3\text{COOCH}_3) &= 3\Delta H_f^\ominus(\text{CO}_2) + 3\Delta H_f^\ominus(\text{H}_2\text{O}) - \Delta H_c^\ominus(\text{CH}_3\text{COOCH}_3) \\ &= 3(-393.5) + 3(-285.8) - (-1592.1) \quad [\text{M1}] \\ &= -445.8 \approx \underline{-446 \text{ kJ mol}^{-1}} \quad [1] \end{aligned}$$

- (b) A student used the apparatus shown to carry out experiments to determine the standard enthalpy change of combustion of methyl ethanoate,  $\text{CH}_3\text{COOCH}_3$ .



Mass of copper can = 250 g

An initial experiment was carried out using methyl ethanoate. This ester was burnt in a spirit burner underneath a copper can so that the flame from the burner heated 300 cm³ of water in the can. It was found that 0.980 g of ester was required to raise the temperature of the water in the can by 10.0 °C.

- (i) Calculate the heat gain by the water given that the specific heat capacity of water is  $4.18 \text{ J g}^{-1} \text{ K}^{-1}$ . Take the density of water to be  $1.00 \text{ g cm}^{-3}$ . [1]

$$\text{Heat energy gained by water} = (300)(4.18)(10) \\ = \underline{12540 \text{ J}} \text{ [1]}$$

- (ii) Given that the **total** heat energy gain is 13.5 kJ, calculate the specific heat capacity of the copper can used in this experiment. [2]

$$\text{Heat energy gained by copper can} = 13500 - 12540 \\ = \underline{960 \text{ J}} \text{ [1]}$$

$$\text{Specific heat capacity of copper can} = \frac{960}{(250)(10)} = \underline{0.384 \text{ J g}^{-1} \text{ K}^{-1}} \text{ [1]}$$

- (iii) Using the  $\Delta H_c^\circ$  of methyl ethanoate given in the table of part (a), calculate the total theoretical heat energy in kJ released by the mass of methyl ethanoate burnt in this experiment. [2]

$$n(\text{methyl ethanoate}) = \frac{0.98}{74.0} = \underline{0.01324 \text{ mol}} \text{ [1]}$$

$$\text{Heat energy released} = 0.01324 \times 1592.1 = \underline{21.1 \text{ kJ}} \text{ [1]}$$

- (iv) Calculate the percentage efficiency of heat transfer in this experiment and suggest a reason for this value. [2]

$$\text{Percentage efficiency of heat transfer} = \frac{13500}{21100} \times 100 \% = \underline{64.0 \%} \text{ [1]}$$

Heat loss to surroundings/ Room temperature was not constant. [1]

- (c) Methane is used to produce synthesis gas (syngas), a mixture that includes carbon monoxide and hydrogen, by reacting with steam on a nickel catalyst in a  $2 \text{ dm}^3$  vessel. Syngas is then used to produce liquid hydrocarbons and methanol.



The equilibrium mixture was found to contain 1 mole of methane, 1 mole of steam, 1.5 moles of carbon monoxide and 4.5 moles of hydrogen gas.

- (i) State Le Chatelier's Principle. [1]

**Le Chatelier's Principle** states that when a system in equilibrium is disturbed, the system will react to counteract the change imposed so as to re-establish the equilibrium. [1]

- (ii) Write an expression for the equilibrium constant,  $K_c$  and determine its value, including units. [2]

$$K_c = \frac{[\text{CO}][\text{H}_2]^3}{[\text{CH}_4][\text{H}_2\text{O}]} = \frac{\left(\frac{1.5}{2}\right)\left(\frac{4.5}{2}\right)^3}{\frac{1}{2}\left(\frac{1}{2}\right)} = \underline{34.2 \text{ mol}^2 \text{ dm}^{-6}} \text{ [1]}$$

- (iii) Define the term *endothermic reaction*. [1]

Endothermic means that heat/energy is absorbed [1] from the surrounding / required to take place.

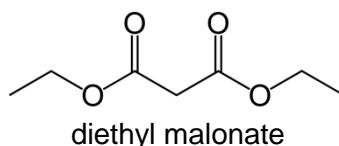
- (iv) With reference to the above equilibrium, predict and explain the effect of **separately** increasing pressure and decreasing temperature on the position of equilibrium, yield and  $K_c$ . [6]

On increasing the pressure, by Le Chatelier's Principle, the position of equilibrium will shift to the left to reduce the total number of moles of gas. [1] Yield decreases. [1]  $K_c$  remained unchanged as it is temperature dependent. [1]

On decreasing the temperature, by Le Chatelier's Principle, the position of equilibrium will shift to the left towards the exothermic reaction to release heat. [1] Yield decreased. [1]  $K_c$  decreased. [1]

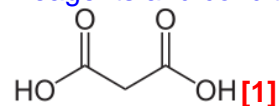
[Total : 20]

- 2 Diethyl malonate, also known as DEM exist as a colourless liquid, commonly used in the manufacture of perfumes, artificial flavourings and vitamins. The structure of diethyl malonate is shown below.

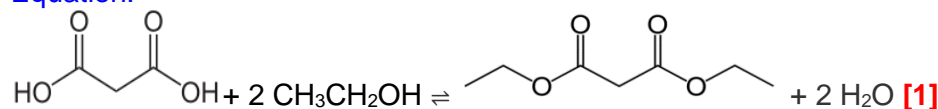


- (a) (i) Diethyl malonate is synthesised from the esterification of malonic acid and an alcohol. Draw the structure of malonic acid and state the reagents and conditions required for this process. Write a balanced chemical equation for this synthesis. [3]

Reagents and conditions: conc  $H_2SO_4$ , heat. [1]



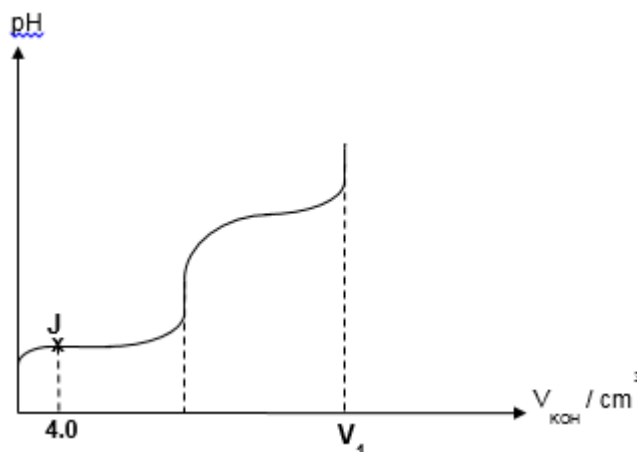
Equation:



- (ii) State the number of moles of  $H_2$  gas produced per mole of malonic acid with Mg. [1]

1 [1]

- (b) 7.0 grams of malonic acid was dissolved in  $250\text{ cm}^3$  of distilled water. The following titration curve was obtained when  $25\text{ cm}^3$  of this solution was titrated against  $0.40\text{ mol dm}^{-3}$  potassium hydroxide.



The dissociation of malonic acid ( $\text{H}_2\text{A}$ ) can be regarded as follows.



- (i) Suggest why  $K_{a2}$  is much smaller than  $K_{a1}$ . [1]

It is more difficult to remove a second positively charged proton from a negatively charged anion in the second dissociation as compared to the first dissociation from a neutral molecule. [1]

OR

The 'second' acidic proton in the  $\text{COOH}$  group is held more tightly by the monoanion via intramolecular hydrogen bonding, resulting in a very stable monoanion. This stabilisation effect also explains why the second  $K_a$  of these 2 acids is significantly smaller as the second acid proton will not be dissociated easily.

- (ii) Write an expression for  $K_{a1}$  stating its units. [2]

$$K_{a1} = \frac{[\text{HA}^-][\text{H}^+]}{[\text{H}_2\text{A}]} \quad [1]$$

$\text{mol dm}^{-3}$  [1]

- (iii) Ignoring the effects of  $K_{a2}$ , hence, or otherwise, calculate the initial pH of the solution. [2]

$$n_{\text{H}_2\text{A}} \text{ in } 250 \text{ cm}^3 = \frac{7.0}{104} = 0.06731 \text{ mol}$$

$$[\text{H}_2\text{A}] = \frac{0.06731}{\frac{250}{1000}} = \underline{0.2692 \text{ mol dm}^{-3}} \quad [1]$$

$$[\text{H}^+] = \sqrt{K_a \times [\text{H}_2\text{A}]} = \sqrt{1.479 \times 10^{-3} \times 0.2692} = 0.01996 \text{ mol dm}^{-3}$$

$$\text{pH} = -\lg [\text{H}^+] = \underline{1.70} \quad [\text{A1}]$$

- (iv) Calculate the volume of KOH,  $V_1$ , required to completely neutralise malonic acid in  $25 \text{ cm}^3$  of solution. [1]

$$n_{\text{malonic acid}} \text{ in } 25 \text{ cm}^3 = \frac{0.06731}{10} = 0.006731 \text{ mol}$$

$V_{\text{KOH}}$  required for **complete neutralisation**,  $V_1$

$$= \frac{0.006731}{0.40} \times 2 = 0.033653 \text{ dm}^3 = \underline{33.7 \text{ cm}^3} \quad [1] \text{ with ecf}$$

- (v) Explain what it means to be a buffer solution. [1]

It is the buffer which is able to resist pH change/maintain a fairly constant pH when a small amount of acid or base is added to. [1]

- (vi) The pH of a buffer solution can be determined by the following equation.

$$\text{pH} = -\lg K_a + \lg \frac{[\text{conjugate base}]}{[\text{acid}]}$$

Identify the species present at point J. Calculate the amount of malonic acid remaining, and use the above equation to calculate the pH. [3]

Species present: H<sub>2</sub>A and HA<sup>-</sup> [1] ignore H<sub>2</sub>O

$$n_{\text{NaOH}} = 4.0/1000 \times 0.4 = 1.60 \times 10^{-3}$$

$$n_{\text{H}_2\text{A}} = (0.006731 - 1.60 \times 10^{-3}) = \underline{0.005131 \text{ mol}} \text{ [1]}$$

$$n_{\text{HA}^-} = (1.60 \times 10^{-3})$$

$$\text{pH} = -\lg 1.479 \times 10^{-3} + \lg \frac{\frac{[0.00160]}{V}}{\frac{[0.005131]}{V}} = \underline{2.32} \text{ [1] ecf}$$

- (vii) The pH at the second end point is more than 7. Explain this observation with the aid of relevant equations. [2]

Only A<sup>2-</sup> and water is present at the second end-point.



A<sup>2-</sup> undergoes salt hydrolysis to produce OH<sup>-</sup> [1] ions. Hence pH > 7.

- (c) Account for the relative acidities of ethanoic acid, ethanol and fluoroethanoic acid. [4]

Acid strength: ethanol < ethanoic acid < fluoroethanoic acid [1]

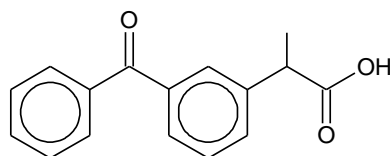
The electron-donating R group on ethanol intensifies the negative charge on the carboxylate anion hence destabilising the ethoxide anion relative to the acid. Hence, ethanol is the weakest acid. [1]

The carboxylate anion (RCOO<sup>-</sup>) is resonance stabilised by the delocalisation of the negative charge over the C atom and both oxygen atoms in ethanoic and fluoroethanoic anion, hence stabilising the carboxylate anion relative to acid. Hence, both carboxylic acids are stronger acids than ethanol. [1]

The electron-withdrawing fluoro group disperses the negative charge on the fluoroethanoic anion hence stabilises the carboxylate anion relative to the acid. Fluoroethanoic acid is a stronger acid than ethanoic acid. [1]

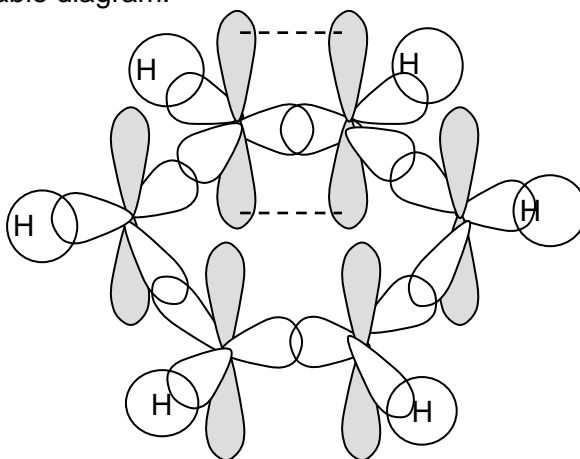
[Total: 20]

- 3 Ketoprofen, is one of the propionic acid class of nonsteroidal anti-inflammatory drugs (NSAID) with analgesic and antipyretic effects. It is generally prescribed for arthritis-related inflammatory pains or severe toothaches that result in the inflammation of the gums.



Ketoprofen

- (a) Describe the bonding in benzene in terms of orbital overlap, illustrating your answer with a suitable diagram. [3]

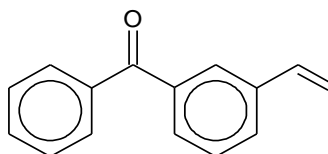


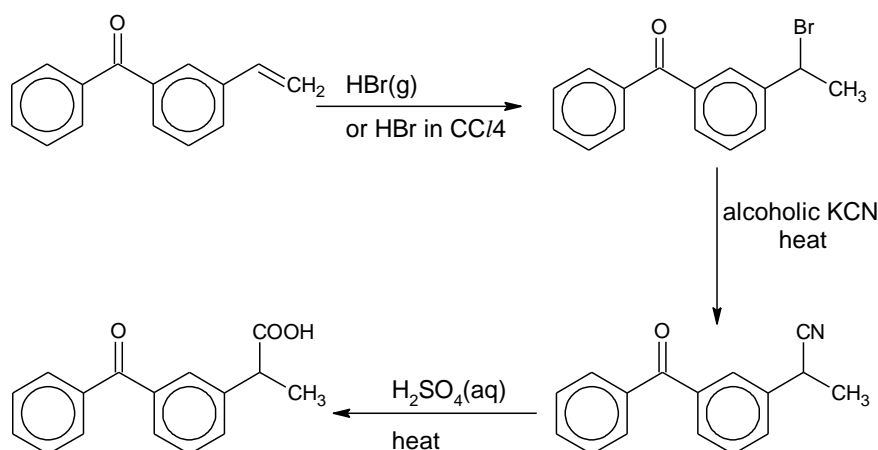
[1] for correct diagram

The carbon atoms in benzene are sp<sup>2</sup> hybridised forms 3  $\sigma$  bonds with 2 adjacent C and 1 H via head on overlap. making the molecule planar in shape. [1]

The p-orbitals overlaps with its adjacent p-orbitals via side on overlap, forming  $\pi$  bonds. [1]

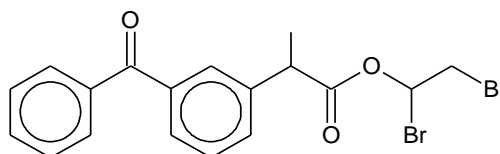
- (b) Propose a synthetic pathway for the formation of ketoprofen from the structure [3]  
below.





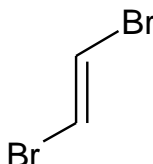
[1] for logical sequence of steps  
 [1] for all reagents and conditions correct  
 [1] for all correct intermediates drawn

(c) Ketoprofen is reacted with an alcohol and forms an ester as shown.

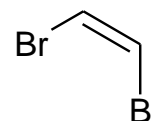


(i) Name the alcohol used in forming the ester. [1]  
1,2-dibromoethanol [1]

(ii) The alcohol was heated in the presence of aluminum oxide. Draw the structures of the two isomeric products formed and name them accordingly. [2]



trans-1,2-dibromoethene



cis-1,2-dibromoethene

[1] for each correct structure + name

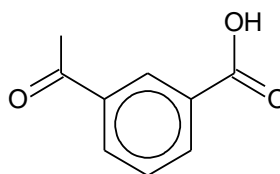
(iii) Predict the relative boiling points of the products formed, giving reasons for your answer. [1]

Both are simple molecular structures, but cis-1,2-dibromoethene is polar with stronger intermolecular permanent dipole permanent dipole interactions which requires more energy to overcome than the weaker intermolecular instantaneous dipole induced dipole interactions in the non polar trans-1,2-dibromoethene.

Hence trans-1,2-dibromoethene has a lower boiling point than cis-1,2-dibromoethene. [1]

(d) Compound **K**, a sweet smelling liquid, is an isomer of ketoprofen. Upon heating **K** with dilute sulfuric acid, compound **L** and benzoic acid are produced. Compound **L** is an alcohol which also produces a silver mirror with Tollens' reagent and a blue solution with Fehling's solution. It also reacts with hot acidified potassium dichromate(VI) to form compound **M** as shown below.

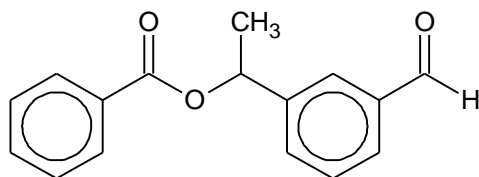
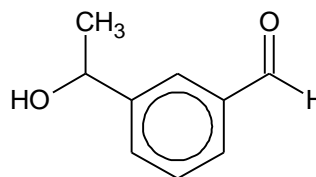
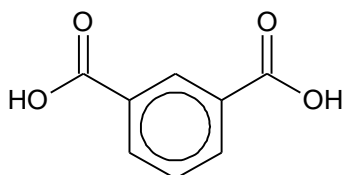
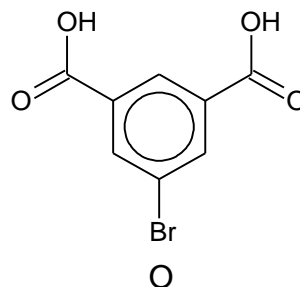


Compound **M**

Compound **L** reacts with hot acidified potassium manganate(VII) to form carbon dioxide and compound **N** which will subsequently react with liquid bromine and anhydrous aluminium bromide solid to form compound **O**.

Deduce, with reasoning, the structures for compounds **K**, **L**, **N** and **O**.

[10]

**K****L****N****O**

**[1] each for each structure**

Compound **K** undergoes acidic hydrolysis to form **L** and benzoic acid

⇒ **K** is an ester **[1]**

Compound **L** is oxidised by Tollens' reagent but not Fehling's solution

⇒ **L** contains aromatic aldehyde **[1]**

Compound **L** reacted with  $K_2Cr_2O_7$  to form **M**

⇒ aldehyde oxidised to carboxylic acid **[1]**

⇒ secondary alcohol oxidised to ketone **[1]**

Compound **L** reacted with  $KMnO_4$  to form **N**

⇒ aldehyde oxidised to carboxylic acid **[1]**

⇒ sidechain oxidised to carboxylic acid **[1]**

Compound **N** undergoes electrophilic substitution with  $Br_2$  to form **O**

⇒ **O** is a bromoarene **[1]**

**Statements max 6 out of 7 marks**

[Total: 20]

**END OF PAPER**