

EUNOIA JUNIOR COLLEGE JC2 Preliminary Examination 2024 General Certificate of Education Advanced Level Higher 1

CANDIDATE NAME					
CIVICS GROUP	2	3	-	INDEX NUMBER	

CHEMISTRY

Paper 2 Structured Questions

8873/02 10 September 2024 2 hours

Candidates answer on the Question Paper

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not use paper clips, highlighters, glue or correction fluid. Write your name, civics group, registration number on all the work you hand in.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Section A Answer all questions.

Section B Answer one question.

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

A Data Booklet is provided. The use of an approved scientific calculator is expected, where appropriate.

For Examiner's Use				
Section A				
1	/ 11			
2	/ 15			
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5	/ 12			
Secti	ion B			
6 / 7	/ 20			
Total	/ 80			

This document consists of 24 printed pages.

Section A

For Examiner's Use

Answer all questions in this section.

- 1 This question is regarding Period 3 elements.
 - (a) The second ionisation energy shows a general increase across Period 3 of the Periodic Table, from Mg to Ar.
 - (i) Define the term second ionisation energy.

The second ionisation energy is the **energy required** to remove **1 mole of**

electrons from 1 mole of singly charged gaseous cations to form 1 mole of

doubly charged gaseous cations. [1]

(ii) Write an equation to represent the second ionisation energy of silicon.

- $Si^{+}(g) \rightarrow Si^{2+}(g) + e^{-}$ [1]
- (iii) State the electronic configurations of Si⁺ and Al⁺.
 Hence, explain why the second ionisation energy of silicon is found to be lower than that of aluminium.

Si⁺: $1s^2 2s^2 2p^6 3s^2 3p^1$ A l^+ : $1s^2 2s^2 2p^6 3s^2$

The <u>3p</u> electron to be removed from Si⁺ is at a higher energy level than the <u>3s</u>

electron to be removed from Att. Hence, less energy is required to remove the

3p electron from Si⁺. [2]

(b) The second ionisation energies of 8 successive elements **F** to **M** from both Periods 2 and 3 of the Periodic Table are shown in Fig. 1.1.





	(i)	Explain why there is a sudden drop in the second ionisation energy from element H to I .	For Examiner's Use
		The second electron to be removed from I is from a Principal Quantum Shell/	
		electronic shell which is further away from the nucleus, as compared to that	
		from H. Hence, the 2 nd I.E. of I is much smaller as the second electron removed	
		from I is less strongly attracted to the nucleus. Hence, lesser amount energy	
		is needed to remove the second electron. [2]	
	(ii)	Identify the element which represents silicon.	
		K[1]	
	(iii)	Element E has one proton less than element F . Using a cross ' \mathbf{x} ', plot the relative position of the second ionisation energy of element E on Fig. 1.1. [1]	
(c)	(i)	State the formulae of the chlorides of the elements Na to P where the element is in its highest oxidation state.	
		NaC <i>l</i> , MgC <i>l</i> ₂ , A <i>l</i> C <i>l</i> ₃ , SiC <i>L</i> , PC <i>l</i> ₅	
		[1]	
	(ii)	The chlorides of Si and P in (c)(i) react with water.	
		Write an equation for each reaction and state the expected pH of the products.	
		SiC $l_4(l) + 2H_2O(l) \rightarrow SiO_2(s) + 4HCl (aq)$; pH of solution is 2	
		PC $l_5(s)$ + 4H ₂ O(l) → H ₃ PO ₄ (aq) + 5HC l (aq) ; pH of solution is 2 [2]	
		[Total: 11]	

2 Phosgene, Cl₂C=O, is a colourless, toxic gas. It is used in the production of pesticides, rubbers and adhesives.

4

- (a) In phosgene, the carbon atom is in the centre of the molecule and is attached to both chlorine atoms and oxygen atom.
 - (i) Draw the dot-and-cross diagram of the phosgene molecule.

(ii) State and explain, with reference to the Valence Shell Electron Pair Repulsion theory, the shape of a phosgene molecule.

Electron pairs such as lone pairs and bond pairs around the central atom arrange

themselves to be as far away from each other as possible to minimise inter-

<u>electronic repulsion</u>.

There are **3 bond pairs and no lone pairs around the central atom** in COCl₂,

hence giving a trigonal planar shape. [2]

(iii) Suggest the Cl-C-Cl bond angle in the $COCl_2$ molecule.

120° [1]



[1]

(b) Table 2.1 shows the electronegativity values of the atoms in phosgene.

Table 2.1			
atom	electronegativity/Pauling units		
carbon	2.5		
chlorine	3.0		
oxygen	3.5		

·-----

(i) Explain what is meant by electronegativity.

Electronegativity refers to the tendency of an atom to attract a shared (bonding)

pair of electrons (or electron density) towards itself.

.....[1]

 (ii) With reference to Table 2.1, explain why COC l₂ is a polar molecule. Hence, state all the possible intermolecular forces which could exist between phosgene molecules.

The C=O and C–Cl **bonds are polar** due to electronegativity difference between

the atoms. COC12 is trigonal planar in shape. Since the dipole moment cannot

cancel out each other, there will be a net dipole moment in COC12. Thus,

 $COC l_2$ is a polar molecule, with **<u>permanent dipole-permanent dipole</u>**

interactions and instantaneous dipole-induced dipole interactions between

molecules. [2]

(c) Phosgene can be formed readily from carbon monoxide and chlorine.

$$CO(g) + Cl_2(g) \square COCl_2(g) \qquad \Delta H < 0$$

An experiment was carried out with 1:1 molar ratio of carbon monoxide and chlorine in a 2 dm³ vessel at 25 °C. Graph **A** in Fig 2.1 shows how the amount of $COCl_2$ changes with time.



Fig. 2.1

- (i) On Fig. 2.1, mark using a cross 'x', the point on graph A that represents the time at which equilibrium is first reached.
- (ii) Write an expression for the equilibrium constant, K_c , for the reaction above.

 $K_{c} = \frac{[COCl_{2}]}{[CO][Cl_{2}]}$

(iii) The value of K_c for the reaction at 25 °C is 1.20×10^{12} .

Using Fig. 2.1 and the information given, calculate the equilibrium concentration of $COC l_2$.

.....[1]

Hence, determine the amount of carbon monoxide present in the mixture when equilibrium is reached.

Let x be the amount of carbon monoxide present in the equilibrium mixture. Since amt. of carbon monoxide = amt. of chlorine,

$$K_{c} = \frac{[COCl_{2}]}{[CO][Cl_{2}]}$$
$$= \frac{\left(\frac{5}{2}\right)}{\left(\frac{x}{2}\right)\left(\frac{x}{2}\right)} = 1.20 \times 10^{12}$$
$$x = 2.89 \times 10^{-6} \text{ mol}$$

[2]

For Examiner's Use (iv) A similar experiment was carried out with 1:1 molar ratio of carbon monoxide and chlorine at the same temperature, but in a 5 dm³ vessel.

State and explain how the change affects the amount of phosgene present in the equilibrium mixture.

 When the volume increases, pressure of the system decreases (concentration

 of CO and Cl₂ decreases). Position of equilibrium lies to the left to favour

 the side with a larger number of gaseous particles. Thus amount of phosgene

 present at equilibrium would be smaller.

 [2]

 (v) On Fig 2.1, sketch how the graph would look like if the the same experiment was carried out in a 2 dm³ vessel,

 • At a higher temperature. Label this line as "B"
 [1]

 • In the presence of a catalyst. Label this line as "C".
 [1]

[Total: 15]

3 (a) Nitric acid, HNO₃, is a strong acid. It is a useful chemical used in the production of fertilisers and nitrogen containing organic compounds.

For Examiner's Use

Nitric acid can be produced industrially through the Ostwald process using ammonia and oxygen as raw materials.

$$\mathsf{NH}_3 + 2\mathsf{O}_2 \to \mathsf{HNO}_3 + \mathsf{H}_2\mathsf{O}$$

(i) State and explain in terms of oxidation numbers, which element is being oxidised and which element is being reduced in the Ostwald process.

Nitrogen is being oxidised as the oxidation number of N increases from -3

in NH₃ to +5 in HNO₃. Oxygen is being reduced as the oxidation number of

O decrease from 0 in O₂ to -2 in H₂O.

-[2]
- (ii) Hence, suggest why nitric acid can only act as an oxidising agent.

HNO3 can only act as an oxidising agent as the nitrogen has the highest

oxidation state of +5, so it can only be reduced and oxidises other

compounds. [1]

(iii) Calculate the pH of 0.0264 mol dm⁻³ nitric acid. Give your answer to three significant figures.

> pH = −lg[H⁺(aq)] = −lg(0.0264) = **1.58**

> > [1]

(b)	Anc	other nitrogen	n containing acid, ni	trous acid, HNO ₂ , is a weal	k acid.	For Fxaminer's
	(i)	Explain the meaning of the terms <i>acid</i> and <i>weak acid</i> , in terms of the Brønsted-Lowry theory of acids.				
		A Brønsted	-Lowry acid is a <u>H*</u>	donor.		
		A weak acid	d dissociates / ion	ises partially in water.	[2]	
	(ii)	Write an equ	uation to show the r	eaction of nitrous acid with	water.	
		HNO ₂ (aq) +	⊦ H₂O(<i>t</i>) □ H₃O⁺(aq)	+ NO₂(aq)	[1]	
	(iii)	Identify the (b)(ii).	two different conju	igate acid-base pairs in th	e reaction occurring in	
		acid	HNO ₂ (aq)	conjugate base	NO₂(aq)	
		base	H ₂ O(<i>1</i>)	conjugate acid	H₃O⁺(aq)	
(c)	Nitr nitro	ogen natural ogen atoms h	lly consists of two	stable isotopes, ¹⁴ N and c mass of 14.23.	¹⁵ N. A sample of pure	
	(i)	Define the te	erm relative atomic	mass of an element.		
		The relative	e atomic mass of an	element is the average ma	ass.of.one.atom.of.the	
		element, co	ompared to 1/12 the	mass of carbon-12 atom.	[1]	
	(ii)	Calculate the	e percentage abund	dances of both 14 N and 15 N	in this sample.	
		Let the % a	abundance of ¹⁴ N be	e <i>x</i> %.		
		% abundar	nce of ¹⁵ N = (100 -	x)%		
		$\frac{x}{100} \times 14 + \frac{10}{2}$	$\frac{00-x}{100}$ × 15 = 14.23			
		<i>x</i> = 77.0				
		% abundar	nce of ¹⁴ N is 77.0%;	; % abundance of ¹⁵ N is 23.	0%	
					[2]	
					[Total: 11]	

[Turn over

4 Geraniol and citral are colourless oils which are responsible for aromas in perfumes. They can be extracted from plants.

For Examiner's Use



(a) (i) Define the term molecular formula.

 Molecular formula is the formula that shows the actual number of atoms of each element in one molecule of the compound.
 [1]

 (ii) Deduce the molecular formula of citral.
 [1]

 (ii) Deduce the molecular formula of citral.
 [1]

 (b) (i) Identify the functional group common to geraniol and citral.
 [1]

 (ii) Describe a chemical test to confirm the presence of this functional group using a reagent that will not react with the other functional groups present.
 [1]

 Add Br2 in CCI4 at room temperature to separate samples. Orange-red Br2 decolourises for both.
 [2]

(c) Compound A is a constitutional isomer of citral, containing the same functional groups.
 Fig. 4.1 shows a reaction scheme involving compound A.



Fig. 4.1

(i) Compound A exists as a pair of *cis-trans* isomers.
 Explain why compound A can exhibit *cis-trans* isomerism.

There are <u>2 different substituents attached to each of the two carbon</u> <u>atoms of the C=C bond, and there is restricted rotation about the C=C</u> <u>double bond</u>. [2]

- (ii) Hence, with reference to your answer in (a)(ii), draw the structural formula of one of the isomers of compound A in Fig. 4.1. [1]
 (iii) State the reagents and conditions necessary for steps II and III. step II : ...K₂Cr₂O₇/ KMnO₄(aq), H₂SO₄(aq), heat
- step III : NH(CH₃)₂, DCC
 [2]

 (iv) State the type of reaction for step III.
 [1]

[Total: 11]

5 (a) Laundry and dishwashing detergent pods have gained popularity in the market over the past years for the convenience they offer.

For Examiner's Use

The pods are small capsules which consist of detergent and other cleaning ingredients enclosed in a water-soluble film. Upon contact with water in the washing machine, the film dissolves and releases the cleaning agents within the capsule.

The water-soluble film is made up of polyvinyl alcohol (PVA). It is made from the monomer as shown.



(i) State the type of polymerisation that produces PVA and name the type of covalent bond formed during this polymerisation.

Addition polymerisation. A C-C sigma bond is formed in the polymerisation.[1]

(ii) Draw one repeat unit of PVA.



[1]

For a material to be suitable for use as the film in the pods, it must remain intact while containing alkaline cleaning agents, but dissolve quickly and completely in water.

(iii) Explain why PVA is able to contain alkaline cleaning agents.

C-C bonds are resistant to alkaline hydrolysis / do not react with alkali /

chemically inert. [1]

(iv) Explain how PVA dissolves in water. For Examiner's Use Include a labelled diagram in your answer. h**ydroge**r bonding Show lone pair on oxygen, partial charges and label The –OH group present in PVA is able to form <u>favourable</u> hydrogen bonds with water molecules, which **provide sufficient energy** to overcome the solute-solute and solvent-solvent interactions. Hence, PVA is soluble in water. [3] One pod is sufficient for one wash in the washing machine. Some users have complained that the film of the pod does not dissolve completely in one washing cycle, leaving behind some residue. (v) Suggest one possible change that the user can make to help increase the solubility of the film. Use warm water. / Use more water in each wash.[1] (vi) Poly(vinyl chloride), PVC, is a polymer that has a similar structure to PVA. It is made from the monomer chloroethene. C=C In recent years, the use of PVC has declined due to health and environmental concerns when it is burnt. Considering the atoms in the polymer, suggest a reason for such concerns. Chlorine atoms are present in the polymer. When using PVC, it might result in the release of chlorine-containing chemicals that are toxic for human health / pollutes the enviroment. [1]

(b) A car manufacturer wants to select a polymer to make the headlight lenses for his new line of cars. These lenses are transparent covers that protect the front lights of a car.

Examiner's Use

For

Table 5.1 shows properties of 4 polymers.

polymer	heat resistance	light transmission	UV resistance	impact strength
A	medium	92%	high	medium
В	high	90%	low	low
С	high	50%	low	high
D	high	90%	medium	high

Table 5.1

- The higher the light transmission value for a polymer, the more transparent the polymer is.
- Prolonged exposure to UV light can cause yellowing in polymers. UV resistance is a measure of the polymer's life span when used outdoors.
- Impact strength is a measure of the polymer's ability to resist sudden and forceful impacts.

The car manufacturer needs to consider the ability of the polymer to withstand prolonged exposure under the sun, transparency of the material and overall safety of the car.

State which polymer would the car manufacturer select for making headlight lenses.

Explain your choice by considering each of the 4 properties listed in Table 5.1.

Polymer D is the most suitable.
It has high heat resistance which allows for it to be used on the car which might heat
up when under the sun/from the car engine.
It has a high light transmission of 90% which allows light to pass through.
It also has medium UV resistance , it which allows it to be used outdoors for some
<u>time before yellowing</u> .
It has high impact strength which improves the safety of the car especially in the
case of a head on collision. [4]

[Total: 12]

Section B

Answer **<u>one</u>** question in this section.

6 At the commercial scale, methanol can be synthesised from methane and steam over $Cu/ZnO/Al_2O_3$ catalyst at a pressure of 50–100 bar and temperature of 220–300 °C.

$$CH_4(g) + H_2O(g) \rightarrow H_2(g) + CH_3OH(g)$$
 $\Delta H = +115 \text{ kJ mol}^{-1}$

(a) A chemist carries out a series of experiments to determine the rate equation for the reaction.

experiment	[CH₄] / mol dm⁻³	[H₂O] / mol dm ⁻³	initial rate / mol dm ⁻³ s ⁻¹
1	5.0×10^{-2}	$1.5 imes 10^{-1}$	1.19 × 10⁻⁵
2	5.0×10^{-2}	3.0×10^{-1}	2.38 × 10 ⁻⁵
3	1.0 × 10 ⁻¹	6.0 × 10 ⁻¹	9.52 × 10⁻⁵

(i) Determine the order of reaction with respect to CH₄ and H₂O. Hence, write the rate equation.

By comparing expt 1 and 2,
when [CH4] is kept constant and [H2O] doubles, the initial rate of reaction also
doubles. Thus reaction is first order with respect to H ₂ O.
By comparing expt 1 and 3,
when [CH ₄] doubles, and [H ₂ O] ×4, the initial rate of reaction ×8 (1.19 × 10 ⁻⁵
\times 4 \times 2 = 9.52 \times 10 ⁻⁵). Since it is first order with respect to H ₂ O, thus reaction is
first order with respect to CH4.
rate = <i>k</i> [CH ₄][H ₂ O] [3]
Using the data from experiment 1, calculate the rate constant, k , for the reaction. State the units, if any.
Using values from expt 1, $1.19 \times 10^{-5} = k(5.0 \times 10^{-2})(1.5 \times 10^{-1})$

 $k = 1.59 \times 10^{-3} \text{ mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$ [2]

(ii)

For

Examiner's Use (iii) With the aid of a suitable diagram, explain how the catalyst increases the rate of reaction. Examiner's

For

Use



- (b) Elemental copper nanoparticles are used as a heterogeneous catalyst for the synthesis of methanol in the laboratory. Copper was found to be more effective as nanoparticles than in its bulk form.
 - (i) Define the term nanoparticles.

A nanoparticle has all dimensions in the range of 1 nm to 100 nm. [1]

(ii) Briefly explain why copper in its nanoparticle form works as a better catalyst than in its bulk form.

A nanoparticle has greater surface area to volume ratio, hence, there are

more active sites available for catalytic reaction to take place. [1]

(iii) Explain why protective gloves must be worn when handling the copper nanoparticles.

Nanoparticles might go through skin pores such that it gets into the blood

and damage cells and organs. [1]

(c) The hydrogen gas produced during the synthesis of methanol is stored in gas tanks packed with graphene nanotubes. Graphene oxide can be reduced to graphene to get large sheets of graphene which is then converted to the tubular form.

For Examiner's Use



(i) Explain why the electrical conductivity of graphene oxide is low.

Graphene oxide has low electrical conductivity because there are lesser p-

orbitals that can overlap sideways to form a continuous π -electron cloud

which allows delocalisation of electrons acting as mobile charge carriers. [1]

(ii) Other than safety considerations, suggest and describe clearly **two** advantages of using a fuel tank packed with carbon nanotubes over the use of liquid hydrogen.

Economically cheaper as high cost is required to maintain high pressure and

low temperature in that of a conventional tank.

More hydrogen can be packed into the same space / volume due to the high

surface area to volume ratio of carbon nanotubes. [2]

- (d) The energy cycle shown in Fig. 6.1 on page 18 can be used to calculate the standard enthalpy change of combustion of methanol, using standard enthalpy change of formation data.
 - (i) Define the term standard enthalpy change of formation of a compound.

The standard enthalpy change of formation is the <u>energy change</u> when <u>1 mole</u> of a substance in its standard state is formed from its constituent elements in their standard states, under standard conditions.

......[1]



Fig.	6.	1
------	----	---

- (ii) Complete the energy cycle in Fig. 6.1.
- (iii) Use Fig. 6.1 and the data in Table 6.1 to calculate the standard enthalpy change of combustion of methanol, ΔH_c^{Θ} .

	$\Delta H_{\rm f}^{\Theta}$ / kJ mol ⁻¹
CO ₂ (g)	-393.5
H ₂ O(<i>l</i>)	-285.8
CH ₃ OH(<i>l</i>)	-239.1

		_		
т	'ah	P	6	1

 $\Delta H_{c}^{\Theta} = \Sigma \Delta H_{f}^{\Theta} \text{ (products)} - \Sigma \Delta H_{f}^{\Theta} \text{ (reactants)}$

= (-393.5 + 2(-285.8)) - (-239.1 + 1.5(0)) = -726 kJ mol⁻¹

[2]

[1]

(iv) Using bond energy data, the standard enthalpy change of combustion of methanol can also be determined. However, the value obtained is found to be different from that calculated in (d)(iii).

With reference to the energy cycle in Fig. 6.1, suggest **two** reasons for the difference in the two calculated values.

The bond energy values are average values. In the calculation using bond

energy data, the particles are assumed in the gaseous state. Hence, the physical

state of liquid methanol and water is not taken into consideration. [2]

[Total: 20]

7 (a) The standard enthalpy change of neutralisation reaction is commonly determined experimentally using a coffee-cup calorimeter, which comprises styrofoam cups and a thermometer. The cross-section of such a calorimeter is shown in Fig. 7.1.

For Examiner's Use



Fig. 7.1

(i) With the aid of an equation, define the term standard enthalpy change of neutralisation between ethanoic acid and potassium hydroxide.

 $CH_3CO_2H(aq) + KOH(aq) \rightarrow CH_3CO_2K(aq) + H_2O(I)$

Standard enthalpy change of neutralisation is the **energy released** when **1 mol**

of water is formed from the reaction between ethanoic acid and potassium

hydroxide all in their standard states, at a specified temperature, usually 298

<u>K</u>......[2]

hydroxide were mixed in the calorimeter at 4 min and the temperature of the solution was recorded at regular time intervals. The results are shown in Fig. 7.2.

(ii) To account for heat loss to the surroundings, two straight lines of best fit can be drawn to obtain the theoretical maximum temperature rise, ΔT_{max} .

8.0

time / min

Fig. 7.2

10.0

Draw two separate straight lines of best fit.

6.0

- The first line should take into account the temperatures before reaction starts at *t* = 4 min.
- The second line should take into account the decreasing temperatures.

Extend both lines until t = 4 min.

4.0

Use the graph to determine ΔT_{max} of this experiment. Show your working.

 $\Delta T_{max} = 36.2 - 28.8 = +7.4 \, {}^{\circ}\text{C}$

 $\Delta T_{max} =+7.4 \, {}^{\circ}C$ [2]

12.0

14.0

16.0

27.0 ^[] 0.0

2.0

20 cm³ of 1.50 mol dm⁻³ ethanoic acid and 30 cm³ of 1.50 mol dm⁻³ potassium

For

(iii) Using your answers to (a)(ii), calculate the enthalpy change of neutralisation between ethanoic acid and potassium hydroxide.

CH₃CO₂H + KOH → CH₃CO₂K + H₂O Limiting reagent is ethanoic acid. amount of CH₃CO₂H = $\frac{20}{1000} \times 1.5 = 0.03$ mol = amount of H₂O $\Delta H = \frac{q}{\text{amount of H}_2\text{O produced}} = \frac{-mc\Delta T_{\text{max}}}{0.03}$ $= \frac{-50 \times 4.18 \times +7.4}{0.03} = \frac{-1546.6}{0.03} = -51553$ J mol⁻¹ = -51.6 kJ mol⁻¹

[2]

(iv) Hence, draw a labelled energy profile diagram for the neutralisation reaction between ethanoic acid and potassium hydroxide.



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(b) Crystal violet, $C_{25}H_{30}N_3Cl$, is a synthetic dye with a vibrant purple colour. An experiment to determine the rate equation of the reaction between crystal violet and Examiner's excess sodium hydroxide was carried out using a colourimeter.

For

Use

 $C_{25}H_{30}N_3Cl$ (aq) + NaOH(aq) $\rightarrow C_{25}H_{31}ON_3(aq)$ + NaCl(aq)

In the experiment, only crystal violet is responsible for the absorbance of light. As such, the concentration of crystal violet is proportional to the absorbance of the solution. The experimental graph generated by the colourimeter is shown in Fig. 7.3.



Fig. 7.3

The order with respect to crystal violet is one.

Explain using the shape of the graph in Fig. 7.3, why the reaction is not zero order (i) with respect to crystal violet.

The graph is a curve / not a straight line with a constant gradient. / As

concentration of crystal violet changes, the gradient of the graph changes. [1]

22

(ii) By drawing tangent at t = 0, calculate the initial rate of the experiment. For Examiner's initial rate = $\left| \frac{0 - 0.010}{107.5 - 0} \right| = 9.30 \times 10^{-5} \text{ s}^{-1}$ Use [1] (iii) When the experiment was repeated using a different concentration of NaOH, the same graph was obtained. State and explain the order of reaction with respect to NaOH. Rate is independent of concentration of NaOH, hence the reaction is a zero order with respect to NaOH. [1] (iv) Hence, write the rate equation. rate = *k*[crystal violet] [1] (v) A solid compound X, was found to be able to catalyse the reaction between crystal violet and sodium hydroxide. State the type of catalysis and outline the mode of action. Heterogeneous catalysis The reactant molecules **adsorbed** onto the active sites of the catalyst. This increases the concentration of reactants and weakens the covalent bonds within the reactant molecules, thereby reducing the activation energy for the reaction. The adsorbed product molecules breaks free from the catalyst surface and leave the surface. [3]

- (c) Compound **P** is a sweet-smelling liquid formed from methanoic acid, HCO₂H, and a tertiary alcohol, C₅H₁₂O.
 - (i) State the functional group present in compound **P**.

ester [1]

(ii) Name the tertiary alcohol.

2-methylbutan-2-ol [1]

(iii) Draw the skeletal formula of compound P.



[1]

(iv) Use the table of characteristic values for infra-red absorption in the *Data Booklet* to answer this question.

Infra-red absorptions are useful in identifying functional groups present in molecules. For example, the tertiary alcohol in **(c)(ii)** shows absorptions at $970-1260 \text{ cm}^{-1}$ and $3200-3600 \text{ cm}^{-1}$.

Use the table to identify two infra-red absorption ranges that will be shown by the functional group identified in **(c)(i)**.

[2]

[Total: 20]