



YISHUN INNOVA JUNIOR COLLEGE  
 JC 2 PRELIMINARY EXAMINATION  
**Higher 2**

CANDIDATE  
 NAME

CG

INDEX NO

**CHEMISTRY**

**9729/02**

Paper 2 Structured Questions

**29 August 2022**

**2 hours**

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

**READ THESE INSTRUCTIONS FIRST**

Write your name and class in the spaces at the top of this page.

Write in dark blue or black pen on both sides of the paper. You may use an HB pencil for any diagrams or graphs. Do not use staples, paper clips, highlighters, glue or correction fluid/tape.

Answer **all** questions in the spaces provided on the Question Paper.

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

A Data Booklet is provided.

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

For Examiner's Use		
<b>1</b>	<b>/ 14</b>	
<b>2</b>	<b>/ 17</b>	
<b>3</b>	<b>/ 12</b>	
<b>4</b>	<b>/ 15</b>	
<b>5</b>	<b>/ 17</b>	
<b>Penalty</b>	<b>units</b>	<b>significant figures</b>
<b>Overall</b>	<b>/ 75</b>	

This document consists of **24** printed pages and **4** blank pages.

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

1 Gallium, chromium and iron are metals that are found in Period 4 of the Periodic Table.

(a) (i) Naturally occurring gallium, Ga, is a mixture of two isotopes.

Table 1.2 shows the relative percentage abundance of the two isotopes.

**Table 1.2**

relative mass	relative % abundance
68.9256	60.11
70.9247	39.89

Calculate the relative atomic mass of Ga to four significant figures.  
Show your working

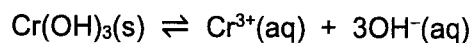
[2]

(ii) Gallium reacts with nitrogen to form gallium nitride, GaN.

Calculate the volume of nitrogen gas needed to react with 10 kg of gallium at s.t.p..

[2]

- (b) Chromium(III) hydroxide,  $\text{Cr}(\text{OH})_3$ , is sparingly soluble in water.



- (i) Write an expression for the solubility product,  $K_{\text{sp}}$ , of chromium(III) hydroxide, stating its units.

$K_{\text{sp}} =$  \_\_\_\_\_ units ..... [2]

- (ii) Calculate the concentration of  $\text{OH}^{-}(\text{aq})$  in a saturated solution of chromium(III) hydroxide, given the value of  $K_{\text{sp}}$  is  $6.7 \times 10^{-31}$ .

[2]

- (iii) Describe and explain how the solubility of chromium (III) hydroxide is affected by adding  $\text{Cr}_2(\text{SO}_4)_3(\text{aq})$ .

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 .....  
 .....  
 ..... [1]

- (c) Iron(II) oxide, FeO, is used to form Fe<sub>3</sub>O<sub>4</sub> as shown.



Each formula unit of Fe<sub>3</sub>O<sub>4</sub> contains one Fe<sup>2+</sup> and two Fe<sup>3+</sup> ions.

- (i) Using oxidation number, show how the reaction can be described as a *disproportionation* reaction.

.....  
 .....  
 ..... [1]

Fe<sub>3</sub>O<sub>4</sub>(l) can be electrolysed using inert electrodes to form Fe.

- (ii) Write the half-equation for the reaction that occurs at the anode during the electrolysis of Fe<sub>3</sub>O<sub>4</sub>(l).

..... [1]

- (iii) Calculate the maximum mass of iron metal formed when Fe<sub>3</sub>O<sub>4</sub>(l) is electrolysed for 6 hours using a current of 50 A.

Assume that one Fe<sup>2+</sup> and two Fe<sup>3+</sup> ions are discharged at the same rate.

[3]

[Total: 14]

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- 2 (a) An organic compound **A**,  $C_5H_yO$ , undergoes complete combustion to produce  $CO_2$  and  $H_2O$ .

The value of  $y$  in the molecular formula of **A** can be determined by exploding it with an excess oxygen and analysing the products of the combustion.

- (i) Balance the following equation, in terms of  $y$ , for the complete combustion of one mole of compound **A** at  $300\text{ }^\circ\text{C}$  and  $1\text{ atm}$ .



- (ii) When  $10\text{ cm}^3$  of gaseous compound **A** was mixed with an excess oxygen at  $300\text{ }^\circ\text{C}$  and  $1\text{ atm}$ , there is an expansion of volume by  $25\text{ cm}^3$ .

Determine the value of  $y$ .

[2]

- (iii) Draw the arrangement of the hybridised orbitals of one of the carbon atoms in Compound **A**.

[1]

- (b) Draw the displayed formula of all the constitutional (structural) isomers with the formula  $C_5H_{12}$ .

[1]

- (c) Cyanamide,  $NH_2CN$ , is an organic compound used in agriculture and in the synthesis of pharmaceuticals.

The carbon atom is bonded to both nitrogen atoms in the cyanamide molecule.

- (i) Draw a 'dot-and-cross' diagram of the cyanamide molecule.  
You should distinguish carefully between electrons originating from the central atom and those from the other atoms.

[1]

- (ii) Cyanamide can be produced by the hydrolysis of calcium cyanamide in the presence of carbon dioxide.

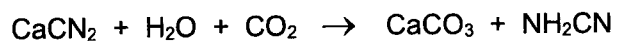


Table 2.1 gives the melting points of  $\text{CaCN}_2$  and  $\text{NH}_2\text{CN}$ .

**Table 2.1**

compound	melting point / °C
$\text{CaCN}_2$	1340
$\text{NH}_2\text{CN}$	44

Explain, in terms of structure and bonding, the difference in melting point between  $\text{CaCN}_2$  and  $\text{NH}_2\text{CN}$

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[2]



- (d) When  $\text{CO}_2$  reacts with  $\text{H}_2$ , methanol,  $\text{CH}_3\text{OH}$ , is produced according to equation.

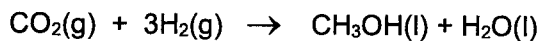


Table 2.2 shows the standard enthalpy and entropy changes of reaction for this process at 298K.

**Table 2.2**

$\Delta H^\ominus$ at 298 K	$-131 \text{ kJ mol}^{-1}$
$\Delta S^\ominus$ at 298 K	$-410 \text{ J K}^{-1} \text{ mol}^{-1}$

- (i) Explain why the process shows an overall negative value for  $\Delta S^\ominus$ .

.....

.....

..... [1]

- (ii) Calculate the standard Gibbs free energy change,  $\Delta G^\ominus$ , for this reaction at 298 K.

[1]

- (iii) Predict the effect of increasing the temperature on the spontaneity of this reaction. Explain your answer.

.....

.....

..... [2]

- (e) (i) Define the term *standard enthalpy change of combustion*.

.....  
..... [1]

- (ii) Use of the *Data Booklet* is relevant to this question.

In an experiment to determine the standard enthalpy change of combustion of ethanol,  $\text{CH}_3\text{CH}_2\text{OH}$ , 0.230 g of ethanol was burned, and the heat given off raised the temperature of 100 g of water by 16.3 °C.

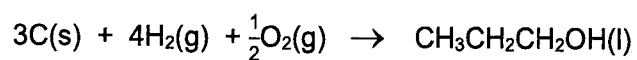
Calculate the enthalpy change of combustion,  $\Delta H_c^\ominus$ , of ethanol.

[2]

- (iii) Suggest one reason why the value for the enthalpy change of combustion of ethanol determined by a simple laboratory calorimetry experiment is likely to be lower than the true value.

.....  
..... [1]

- (f) The equation below represents the standard enthalpy change of formation of propan-1-ol.



Calculate the standard enthalpy change of formation,  $\Delta H_f^\ominus$ , of liquid propan-1-ol using the data given in Table 2.3.

**Table 2.3**

standard enthalpy change of combustion of $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH(l)}$	$-2021 \text{ kJ mol}^{-1}$
standard enthalpy change of combustion of $\text{C(s)}$	$-393.5 \text{ kJ mol}^{-1}$
standard enthalpy change of formation of $\text{H}_2\text{O(l)}$	$-285.8 \text{ kJ mol}^{-1}$

[1]

[Total: 17]



- (b) The order of reaction with respect to [KI] is one.

Use this information and the procedure given in (a) to sketch a graph on Fig. 3.1 showing the relationship between the time taken to draw out the reaction mixture and the volume of sodium thiosulfate added.

No calculations for volume of sodium thiosulfate are required.

[2]

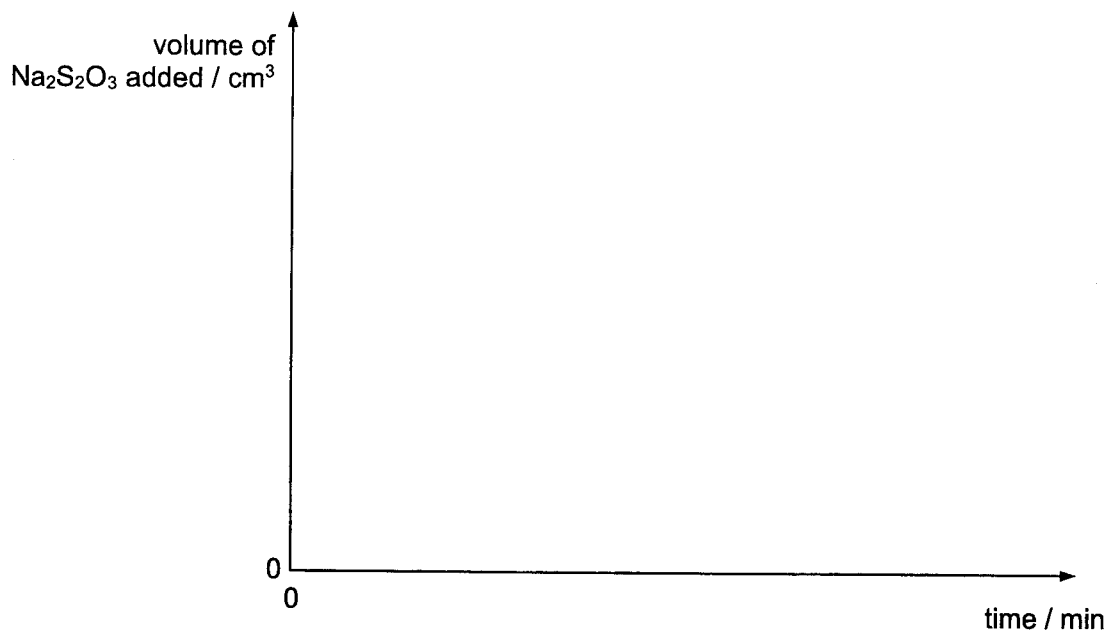


Fig. 3.1

- (c) The concentration of peroxydisulfate ions was halved and a new series of experiments carried out at the same temperature. When a similar graph was plotted, the gradient at each point was half that obtained from (b).

What is the order of reaction with respect to peroxydisulfate ions? Explain your answer.

.....

..... [2]

(d) The reaction between iodide and peroxodisulfate ions is very slow. If a small amount of aqueous iron(II) ions is added to the mixture, the rate of reaction increases.

(i) Explain why the iron(II) ions can be described as a *homogeneous catalyst*.

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..... [2]

(ii) State the property, typical of transition metals, which allows iron(II) ions to behave as a catalyst in this reaction.

Include relevant chemical equations to support your answer.

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..... [3]

[Total: 12]

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- 4 (a) Amphetamine is a synthetic stimulant drug that stimulates the nervous system. It is used for treatment of attention-deficit hyperactivity disorder (ADHD).

Amphetamine can be synthesised from phenylpropanone as shown in Fig. 4.1.

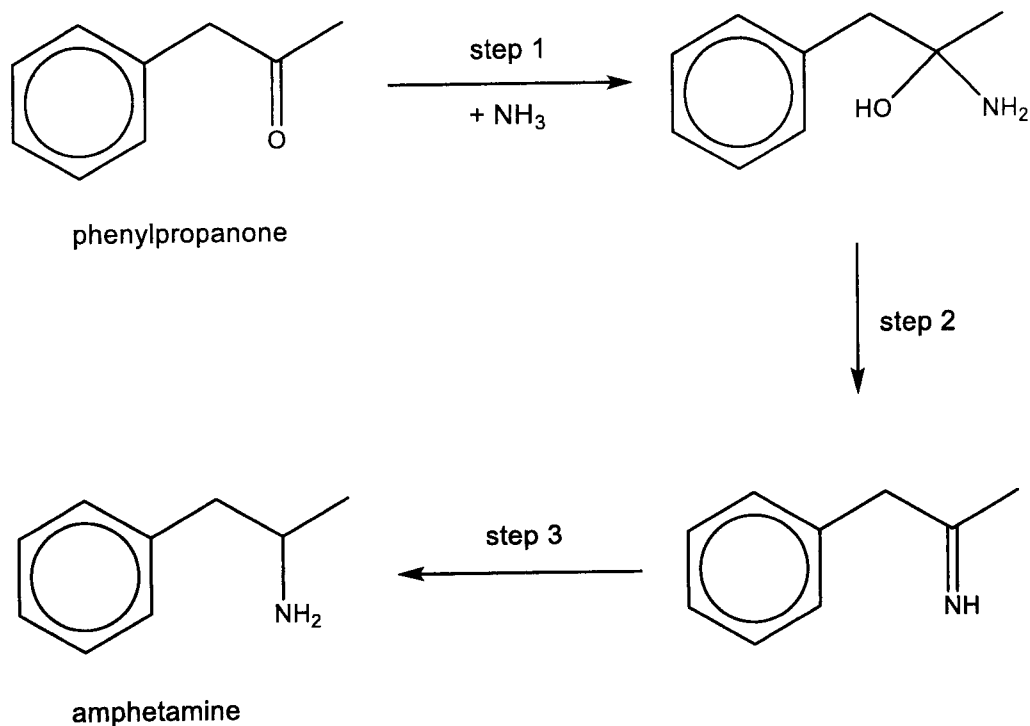


Fig. 4.1

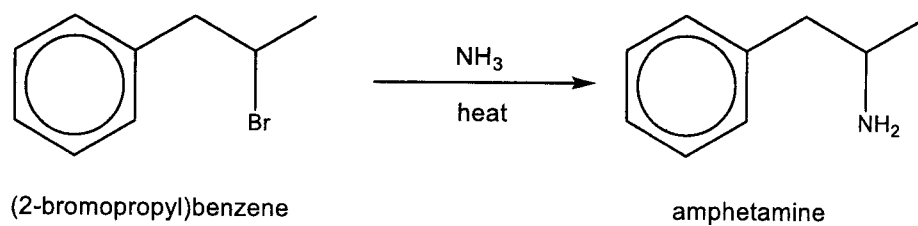
- (i) State the *type of reactions* that occur during each of the steps 1, 2 and 3.

step	type of reaction
1	
2	
3	

[3]



- (ii) Amphetamine can be also synthesised from (2-bromopropyl)benzene with ammonia as shown in Fig. 4.2.



**Fig. 4.2**

When plane-polarised light is passed through the amphetamine that is synthesised using this reaction, there is no effect.

Draw a mechanism that can explain the above observation. Show relevant lone pairs and dipole, and use curly arrows to indicate the movement of electrons pairs. Use R to represent -CH<sub>2</sub>C<sub>6</sub>H<sub>5</sub>.

[3]

The building blocks of proteins are  $\alpha$ -amino acids that have the general structure as shown.

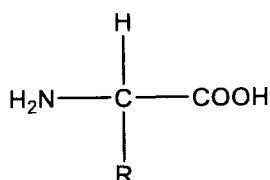


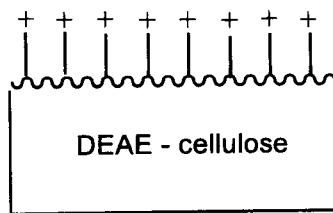
Table 4.1 shows the  $pK_a$  values of the different functional groups present in three  $\alpha$ -amino acids.

**Table 4.1**

amino acid	R group	$pK_a$ of $\alpha$ -carboxyl group	$pK_a$ of $\alpha$ -amino group	$pK_a$ of side chain
aspartic acid	$-\text{CH}_2\text{CO}_2\text{H}$	2.09	9.82	3.86
lysine	$-(\text{CH}_2)_4\text{NH}_2$	2.15	9.16	10.67
glutamine	$-(\text{CH}_2)_2\text{CONH}_2$	2.20	9.10	—

- (b) Mixtures of  $\alpha$ -amino acids can be separated by ion-exchange chromatography. This technique involves pouring the mixture of  $\alpha$ -amino acids dissolved in water at pH 7 down a column containing an ion-exchange resin called DEAE-cellulose.

The structure of the DEAE-cellulose can be presented as shown below.



The '+' signs on the diagram show that the DEAE-cellulose is positively charged at pH 7.

The separation of the  $\alpha$ -amino acids from the mixture is based on the net charge of their predominant species at pH 7.0.

- (i) A mixture of aspartic acid, lysine, and glutamine are dissolved in water and poured down the ion-exchange column as shown in Fig. 4.1.

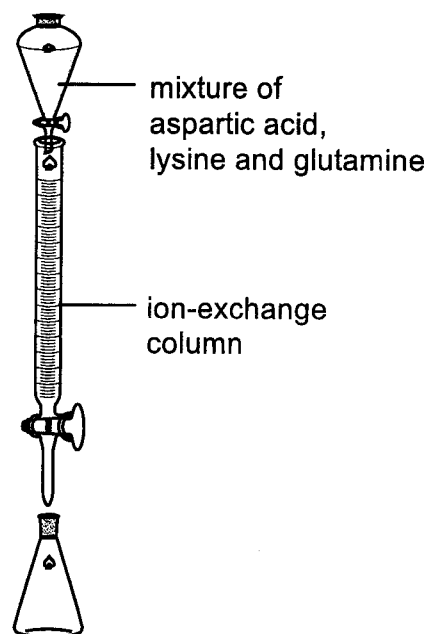
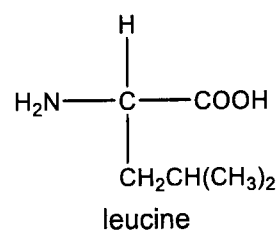
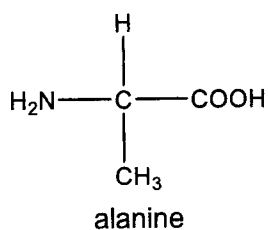


Fig. 4.1

Draw the structure of the predominant species of the three  $\alpha$ -amino acids at pH 7.0 and suggest the order in which the  $\alpha$ -amino acids will be collected. Explain your answer.

order of $\alpha$ -amino acids collected	structure of predominant species of $\alpha$ -amino acid at pH 7.0	explanation
first		
second		
last		

- (ii) Alanine and leucine are also
- $\alpha$
- amino acids.



Explain why DEAE-cellulose cannot be used to separate a mixture of these two  $\alpha$ -amino acids.

.....  
 .....  
 ..... [1]

- (c) A tripeptide can be made by reacting aspartic acid, lysine and glutamine.

amino acid	R group
aspartic acid	$-\text{CH}_2\text{CO}_2\text{H}$
lysine	$-(\text{CH}_2)_4\text{NH}_2$
glutamine	$-(\text{CH}_2)_2\text{CONH}_2$

- (i) Name the type of reaction occurring when a tripeptide is formed from the three amino acids.

..... [1]

- (ii) State the maximum number of different tripeptides that can be formed from the three amino acids.

..... [1]

- (iii) Draw the skeletal formula of one of the possible tripeptides that can be formed from the three amino acids.

[2]

[Total: 15]

[Turn over]

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- 5 The alcoholic drinks industry produces a vast range of products every year. Alcohol in the body depressed the activity of the central nervous system and so drinking alcohol reduces vigilance, slows reaction times and impair judgement. Most countries in the world have introduced laws to control the use of alcohol, particularly in relation to operating machines and driving.

Blood alcohol concentration (BAC) is a good measure of the extent to which the activity of the central nervous system is depressed. It is usually defined as follows.

$$\text{BAC} = \text{mg of ethanol per } 100 \text{ cm}^3 \text{ of blood}$$

After the consumption of too much alcoholic beverage, people sometimes experience a hangover the following day. There are a variety of causes of a hangover, one of these is the accumulation of the toxic metabolites of ethanol in the body.

Ethanol is removed from the blood by enzymes in a two-step process as shown in Fig. 5.1. Ethanol first converted to ethanal by a group of enzymes known as alcohol dehydrogenase, and the ethanal formed is then converted to ethanoic acid by another enzyme, acetaldehyde dehydrogenase.

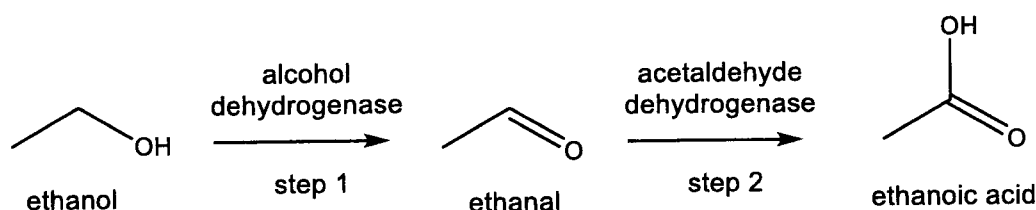


Fig. 5.1

Ethanal is relatively toxic and it is responsible for alcohol-related facial flushing, headaches, nausea and increased heart rate.

- (a) In step 1 of Fig. 5.1, ethanol reacts with nicotinamide adenine dinucleotide,  $\text{NAD}^+$ , a coenzyme, to form ethanal,  $\text{H}^+$  and a compound called NADH.

- (i) State the type of reaction that has occurred for  $\text{NAD}^+$  in this reaction.

..... [1]

- (ii) Both ethanal and ethanoic acid can be obtained from ethanol in the laboratory. State the reagents you could use to carry out these reactions. How would you ensure that the main product was ethanal rather than ethanoic acid.

..... [1]

- (iii) State a reagent you could use to convert ethanoic acid into ethanol.

..... [1]

- (b) Alcohol dehydrogenase enzyme combines with ethanol to form an enzyme-substrate complex which will then be converted into ethanal.

Fig. 5.2 shows the relationship between the [ethanol] and the rate of reaction, using a fixed amount of the alcohol dehydrogenase enzyme.

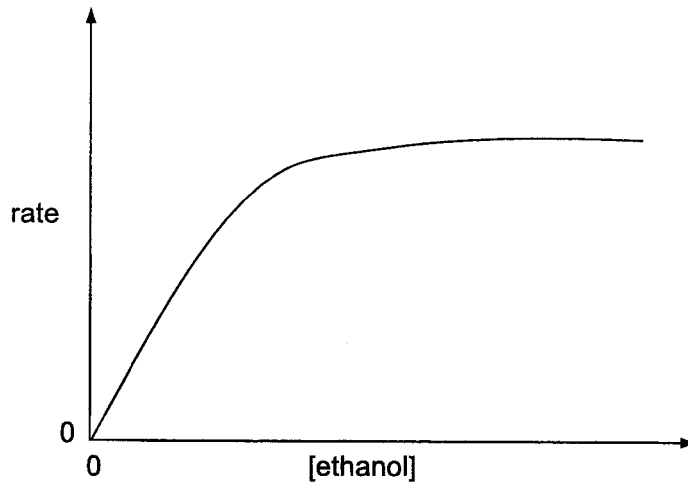


Fig. 5.2

Explain the relationship between [ethanol] and the rate of the enzyme catalysed reaction.

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[2]

- (c) The rate equation for the conversion of ethanol to ethanal by the alcohol dehydrogenase enzyme is

$$\text{rate} = \frac{k_{\text{cat}}[\text{AD}][\text{S}]}{K_{\text{M}} + [\text{S}]}$$

Where: [AD] is the concentration of the alcohol dehydrogenase enzyme,  
 [S] is the concentration of the substrate, ethanol,  
 $k_{\text{cat}}$  is the rate constant,  
 $K_{\text{M}}$  is a constant that measures the ease of dissociation of the enzyme-substrate complex back to the reactants.

Table 5.1 gives the values of  $k_{\text{cat}}$  and  $K_{\text{M}}$  for ethanol.

**Table 5.1**

$k_{\text{cat}} / \text{s}^{-1}$	$K_{\text{M}} / \text{mol dm}^{-3}$
1.33	$1.00 \times 10^{-3}$

At present in Singapore the legal limit to drive a car is 80 mg of ethanol per 100 cm<sup>3</sup> of blood.

- (i) The concentration of ethanol at the Singapore legal limit to drive a car, when expressed in mol dm<sup>-3</sup>, is  $1.74 \times 10^{-2}$  mol dm<sup>-3</sup>.

Using the information given above, show that the rate equation of this reaction is

$$\text{rate} = k_{\text{cat}}[\text{AD}]$$

when [ethanol] is at the Singapore's legal limit to drive a car.

[1]



Drivers who consume too much alcoholic beverages will need to wait for the BAC in their blood to fall below the legal limit. This process of waiting is known as sobering up.

The rate of loss of ethanol per 100 cm<sup>3</sup> of blood is 18.33 mg hr<sup>-1</sup> and is a constant value.

(ii) Calculate the rate loss of ethanol, in mol dm<sup>-3</sup> s<sup>-1</sup>, when a person is sobering up.

[3]

(iii) Use your answer to (c)(i) and (c)(ii) to calculate the concentration of alcohol dehydrogenase enzyme in this person.

[1]

(iv) Calculate the time, in hours, required for the person with a BAC of 345 mg of ethanol per 100 cm<sup>3</sup> of blood to fall to the Singapore's legal limit to drive a car immediately after he has stopped consuming any more alcoholic beverages.

[1]

(d) Methanol and ethane-1,2-diol are poisonous chemicals. When ingested, alcohol dehydrogenase metabolises these alcohols to form acidic metabolites that are highly toxic.

- (i) Write an equation of the oxidation of ethane-1,2-diol to its corresponding acid. Use [O] to present the formula of the oxidising agent.

[1]

- (ii) Ethanol is used to treat victims of methanol or ethane-1,2-diol poisoning. This is because ethanol is a better substrate for alcohol dehydrogenase, and it will be metabolised preferentially by the enzyme.

Describe a simple chemical test that could be used to distinguish ethanol from methanol and state your observations clearly

[2]

- (iii) Ethane-1,2-diol dissolves in water readily.

Draw a diagram to show how water molecules interact with the ethane-1,2-diol molecule. Label the diagram to show the interaction involved.

[1]

- (e) The first four members of the series of carboxylic acids represented by the general formula  $H-(CH_2)_n-CO_2H$  ( $n = 0, 1, 2, 3\dots$ ) are fully soluble in water, but as the value of  $n$  increases from 4 upwards, the acids become increasingly insoluble.

By considering the relevant interactions between the molecules of the carboxylic acids with each other, and also with the solvent, suggest reason for this decreasing solubility.

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[2]

[Total: 17]

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YISHUN INNOVA JUNIOR COLLEGE  
JC 2 PRELIMINARY EXAMINATION  
**Higher 2**

CANDIDATE  
NAME

CG

INDEX NO

**CHEMISTRY**

**9729/03**

Paper 3 Free Response

**12 September 2022**

Candidates answer on the Question Paper.  
Additional Materials: Data Booklet

**2 hours**

**READ THESE INSTRUCTIONS FIRST**

Write your name, class and index number on all the work you hand in.  
Write in dark blue or black pen on both sides of the paper.  
You may use an HB pencil for any diagrams or graphs.  
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper. If additional space is required, you should use the pages at the end of this booklet. The question number must be clearly shown.

**Section A**

Answer **all** the questions.

**Section B**

Answer **one** question.

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

A Data Booklet is provided.

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		
Section A		
<b>1</b>	<b>/ 17</b>	
<b>2</b>	<b>/ 18</b>	
<b>3</b>	<b>/ 25</b>	
Section B		
<b>4 or 5</b>	<b>/ 20</b>	
Penalty	units	significant figures
<b>Overall</b>	<b>/ 80</b>	

This document consists of **31** printed pages and **1** blank page

## Section A

Answer all the questions in this section.

- 1 (a) Describe and explain the trend in the thermal stability of the hydrogen halides, HCl, HBr and HI. Include an equation for the thermal decomposition reaction in your answer. [3]

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- (b) Alkanes are generally considered to be unreactive compounds, showing an inertness to common reagents such as NaOH, H<sub>2</sub>SO<sub>4</sub>, and K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>.

- (i) Suggest a reason why these reagents do not react with an alkane such as propane. [1]

Propane can be converted into 2-chloropropane when it reacts with chlorine in ultraviolet (UV) light.

- (ii) Describe the mechanism of the reaction between propane and chlorine in UV light. [3]

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- (c) (i) Define the term *lattice energy*. [1]
- (ii) Use the data in Table 1.1, together with data from the *Data Booklet*, to calculate a value for the lattice energy of silver iodide, AgI(s). Show your working.

Table 1.1

	value / kJ mol <sup>-1</sup>
electron affinity of iodine, $I(g) + e^- \rightarrow I^-(g)$	-295
enthalpy change of sublimation of iodine molecules, $I_2(s) \rightarrow I_2(g)$	+62
standard enthalpy change of atomisation of Ag(s)	+285
standard enthalpy change of formation of AgI(s)	-62

[3]

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- (d) Air bags in car inflate rapidly during an accident to protect the front passengers. The air bag contains sodium azide,  $\text{NaN}_3$ , silicon dioxide,  $\text{SiO}_2$ , and potassium nitrate,  $\text{KNO}_3$ .

On impact, three reactions take place.

The sodium azide first decomposes to sodium and nitrogen.

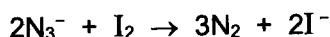


The nitrogen formed inflates the air bag while the sodium formed reacts with potassium nitrate to form sodium oxide, potassium oxide and additional nitrogen gas, which may be used to fill the air bag.

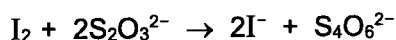
Potassium oxide and sodium oxide then react with silicon dioxide to form harmless metal silicates.



- (i) Write an equation, with state symbols, for the reaction between sodium and potassium nitrate. [1]
- (ii) Calculate the mass of sodium azide needed to inflate an air bag of capacity  $60 \text{ dm}^3$  at room temperature and pressure. [2]
- (iii) To determine the amount of sodium azide in an impure sample, the azide present is first reacted with excess iodine.



The amount of unreacted iodine is then titrated with a standard solution of sodium thiosulfate.



0.120 g of an impure sample of sodium azide was dissolved in water. The mixture was reacted with  $25.0 \text{ cm}^3$  of  $0.050 \text{ mol dm}^{-3}$  of aqueous iodine. The excess iodine was found to require  $23.10 \text{ cm}^3$  of  $0.040 \text{ mol dm}^{-3}$  aqueous sodium thiosulfate for reaction. Calculate the percentage purity of sodium azide in the sample. [3]

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[Total: 17]

- 2 (a) Ammonia is manufactured by the following reaction.



The value of the equilibrium constant,  $K_p$ , measured at two different temperatures is shown in Table 2.1.

**Table 2.1**

temperature / K	$K_p / \text{atm}^{-2}$
600	$1.33 \times 10^{-2}$
750	$1.33 \times 10^{-4}$

- (i) Write the expression for the equilibrium constant,  $K_p$ , for this reaction. [1]
- (ii) A plant is designed to convert, at equilibrium, 50% of the reactants into ammonia. Assuming that the reactants are a mixture of  $\text{N}_2$  and  $\text{H}_2$  in a 1 : 3 ratio by volume, calculate the total equilibrium pressure necessary to bring about a 50% conversion at
- 600 K, and
  - 750 K. [2]
- (iii) Discuss the relative advantage and disadvantage of using plants designed to run at 600 K instead of 750 K. [2]

Theory shows that  $K_p$  varies with temperature according to the equation below.

$$\log_{10} \frac{K_p \text{ (at temperature } T_1\text{)}}{K_p \text{ (at temperature } T_2\text{)}} = \frac{-\Delta H}{2.30R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$$

where:  $T_1$  and  $T_2$  are the temperatures in Kelvins,  
 $\Delta H$  is the enthalpy change of the reaction,  
 $R$  is the molar gas constant.

- (iv) Use the data in Table 2.1, together with data from the *Data Booklet*, and to calculate the enthalpy change,  $\Delta H$ , in  $\text{kJ mol}^{-1}$ , for the reaction in equation 2.1. [1]
- (v) The standard enthalpy change of formation of ammonia is  $-46 \text{ kJ mol}^{-1}$ , given that  $\Delta H$  for the reaction in equation 2.1 to be  $-92 \text{ kJ mol}^{-1}$ .

Suggest one reason why this differs from the value calculated in (iv). [1]

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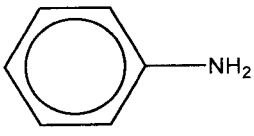
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(b) The  $K_b$  values of three bases, at 25 °C, are shown in Table 2.2.

Table 2.2

base	formula	$K_b / \text{mol dm}^{-3}$
ammonia	$\text{NH}_3$	$1.8 \times 10^{-5}$
ethylamine	$\text{CH}_3\text{CH}_2\text{NH}_2$	$4.5 \times 10^{-4}$
phenylamine		$7.4 \times 10^{-10}$

- (i) Calculate the pH of 0.25 mol dm<sup>-3</sup> solution of ethylamine. [2]
- (ii) Explain the relative magnitudes of the  $K_b$  values in Table 2.2. [2]
- (iii) Explain why amides, RCONH<sub>2</sub>, are neutral, rather than basic. [1]

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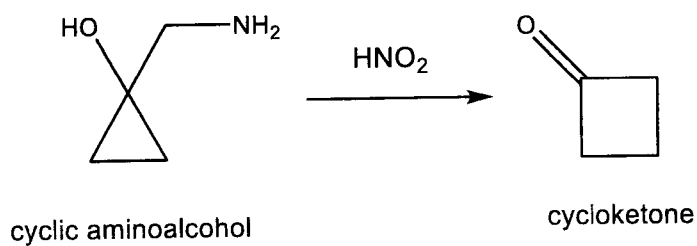
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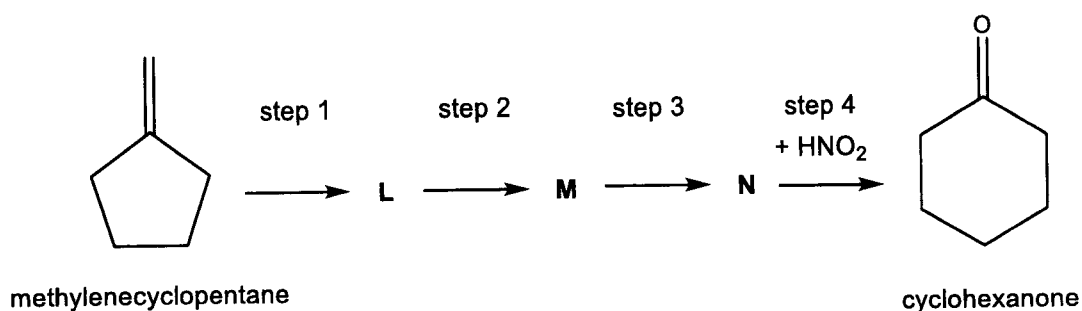
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- (c) Nitrous acid,  $\text{HNO}_2$ , can be used to react with aminoalcohol to form an enlarged cycloketone via the Tiffeneau-Demjanov Rearrangement, as shown below.



Methylenecyclopentane can be used to synthesise cyclohexanone by the four-step route shown in Fig. 2.1.



**Fig. 2.1**

State the reagents and conditions required for step 1, 2 and 3 and suggest structures for the organic compounds **L**, **M** and **N**. [6]

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[Total: 18]

[Turn over

- 3 (a) (i) Explain what is meant by the term *transition element*. [1]
- (ii) State the electronic configuration of the Cu atom and Ni<sup>2+</sup> ion. [2]
- (iii) Explain why transition element complexes are usually coloured. [3]

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- (b) (i) Draw a fully labelled diagram of the experimental set-up used to measure the standard electrode potential of the  $\text{Ni}^{2+}(\text{aq})/\text{Ni}(\text{s})$  half-cell. Indicate clearly the positive and negative electrodes. [3]

Another cell composing of a standard  $\text{Ni}^{2+}(\text{aq})/\text{Ni}$  half-cell and a standard  $\text{Cr}_2\text{O}_7^{2-}(\text{aq})/\text{Cr}^{3+}(\text{aq})$  half-cell was set up.

- (ii) Calculate  $\Delta G^\ominus$ , in  $\text{kJ mol}^{-1}$ , for the reaction that occurs [2]
- (iii) Predict how the voltage of this cell would change, if at all, if the pH of the  $\text{Cr}_2\text{O}_7^{2-}(\text{aq})/\text{Cr}^{3+}(\text{aq})$  half-cell was increased. Explain your answer. [1]

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- (c) Table 3.1 give data about some physical properties of the elements calcium, iron and copper.

Table 3.1

property	calcium	iron	copper
relative atomic mass	40.1	55.8	63.5
atomic radius (metallic) / nm	0.197	0.126	0.128
ionic radius (2+) / nm	0.099	0.076	0.069
melting point / K	1112	1808	1358
density / g cm <sup>-3</sup>	1.54	7.86	8.92
electrical conductivity / × 10 <sup>6</sup> S cm <sup>-1</sup>	0.298	0.100	0.596

- (i) Explain why the atomic radii of iron and copper are similar to each other. [2]
- (ii) Explain why the densities of iron and copper are significantly greater than that of calcium using relevant data from Table 3.1. (No calculations are required.) [2]

When solid copper(II) carbonate is heated, it behaves in a similar way to the Group 2 carbonates.

- (iii) Write an equation, with state symbols, for the decomposition of the carbonate ion, CO<sub>3</sub><sup>2-</sup>. [1]
- (iv) Copper(II) carbonate decomposes at 300 °C while calcium carbonate decomposes at 830 °C.

Suggest an explanation for the difference in the temperature at which the two metal carbonates will decompose. [2]

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(d) Describe and explain what you would see when  $\text{NH}_3(\text{aq})$  is added slowly to a solution containing  $\text{Cu}^{2+}(\text{aq})$  ions, until the  $\text{NH}_3(\text{aq})$  is in excess.

Write equations for any reactions that occur.

[4]

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- (e) An alkaline solution of complexed  $\text{Cu}^{2+}(\text{aq})$  is used in organic chemistry to test for a particular functional group.

Draw the displayed formulae of **one** compound with the molecular formula  $\text{C}_4\text{H}_8\text{O}$  that would show a positive result in this test, and the displayed formulae of **one** compound with the same molecular formula that would not. Label your structures clearly. [2]

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[Total: 25]

## Section B

Answer **one** question in this section.

- 4 (a) Table 4.1 shows the melting points of these four elements found in Period 3 of the Periodic Table.

Table 4.1

element	melting point / °C
sodium	97
silicon	1410
sulfur	112
chlorine	-100

These four elements differ greatly in their melting points. Explain this variation. [4]

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**(b)** Beams of charged particles are deflected by an electric field.

**(i)** State two ways in which the behaviour of electrons in an electric field differs from that of protons. [1]

**(ii)** In a particular experimental set-up, protons are deflected through an angle of +15°.

Assuming an identical set of experimental conditions, by what angles will the following particles be deflected?

- $^2\text{H}^-$
  - $^3\text{He}^{2+}$
- [2]

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- (c) (i) State three basic assumptions of the kinetic theory as applied to an ideal gas. [2]
- (ii) Diving tanks store a mixture of oxygen, nitrogen and helium gas at high pressures for deep-water diving for long periods of time.

When air bubbles are released underwater, they expand in size.  
A 10 cm<sup>3</sup> bubble was released from a diver, 120 m below the water surface at a pressure of 1300 kPa and temperature of 10 °C.  
It was estimated that pressure increases by 101 kPa with each 10 m depth.

Calculate the volume of the air bubble when it ascends towards the water surface by 60 m where the water temperature is 20 °C. [1]

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- (d) Buttercups contain a poisonous cyclic compound called *protoanemonin*,  $C_5H_4O_2$ .

On catalytic hydrogenation, *protoanemonin* gives compound **A**,  $C_5H_8O_2$ . When **A** is heated with an acid, compound **B**,  $C_5H_{10}O_3$ , is formed. On standing, **B** slowly loses water and is converted back to **A** again.

Compound **B** gives a yellow precipitation with aqueous alkaline iodine and compound **C**,  $C_4H_6O_4$ , can be isolated.

*Protoanemonin* is an unstable oil which when treated with an acid or alkali, it is converted to compound **D**,  $C_5H_6O_3$ . Unlike *protoanemonin*, **D** effervesces with aqueous sodium hydrogencarbonate and gives a precipitate with 2,4-dinitrophenylhydrazine but does not react with Tollens' reagent.

Suggest possible structures for **A**, **B**, **C**, **D**, and *protoanemonin*. For each reaction, state the *type of reaction* described and explain what the information tells you about the functional group present in each compound. [10]

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- 5 (a) (i) Describe the reactions, if any, of the chlorides  $\text{NaCl}$ ,  $\text{AlCl}_3$  and  $\text{SiCl}_4$  with water. Write equations for all reactions that occur, and suggest the pH of the resulting solutions. [3]

- (ii) Aluminium oxide is amphoteric.

Write equations to illustrate the acid-basic behaviour of aluminium oxide. [2]

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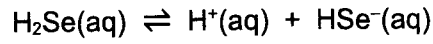
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(b) Hydrogen selenide can act as a weak acid.



NaHSe is a weak base. The pH of a solution of  $0.10 \text{ mol dm}^{-3}$  NaHSe is 8.45.

Calculate the  $pK_a$  of  $\text{H}_2\text{Se}$ .

[3]

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- (c) The Gattermann–Koch reaction is used to produce benzaldehyde as shown in Fig. 5.1.

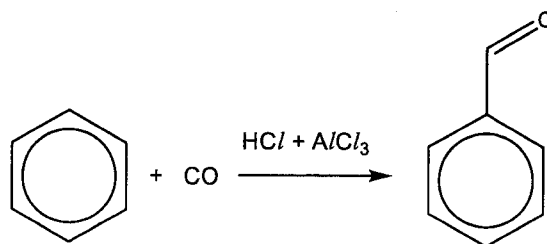


Fig. 5.1

- (i) Name the *type of reaction* in the Gattermann-Koch reaction. [1]

Fig. 5.2 shows the synthesis of compound **U**, which involves the Gattermann-Koch reaction.

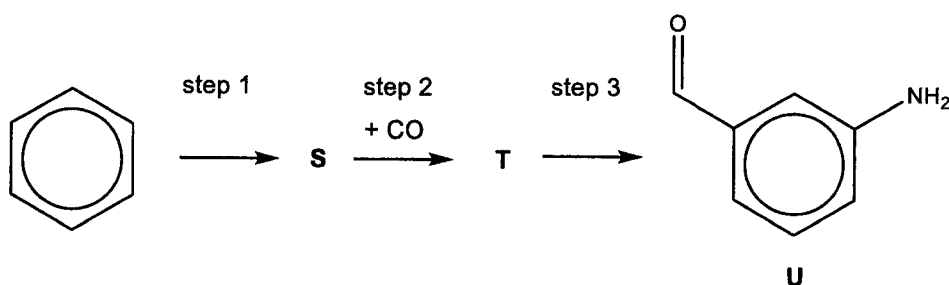


Fig. 5.2

- (ii) Suggest the structures of the intermediate organic products **S** and **T**. [2]
- (iii) Suggest the reagents and conditions for step 1 and step 3. [2]

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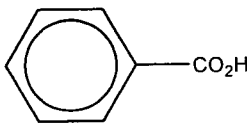
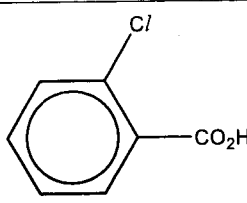
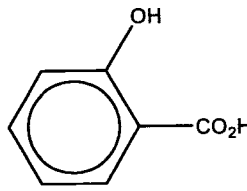
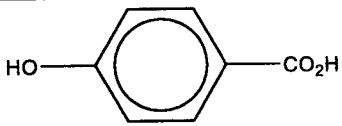
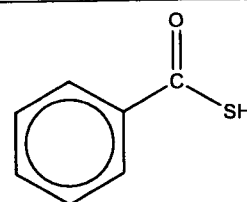
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(d) Table 5.1 lists the  $pK_a$  values for some other weak acids.

**Table 5.1**

acid	formula	$pK_a$
benzoic acid		4.20
2-chlorobenzoic acid		2.89
2-hydroxybenzoic acid		2.97
4-hydroxybenzoic acid		4.54
thiobenzoic acid		3.61

- (i) Explain the difference in the  $pK_a$  values between 2-chlorobenzoic acid and benzoic acid. [1]
- (ii) Suggest a reason why the  $pK_a$  value of 2-hydroxybenzoic acid is so much less than the  $pK_a$  of 4-hydroxybenzoic acid. [1]
- (iii) Thiobenzoic acid is related to benzoic acid by the replacement of one of the oxygen atoms with a sulfur atom.

Suggest a reason why the  $pK_a$  for thiobenzoic acid is lower than benzoic acid. [1]

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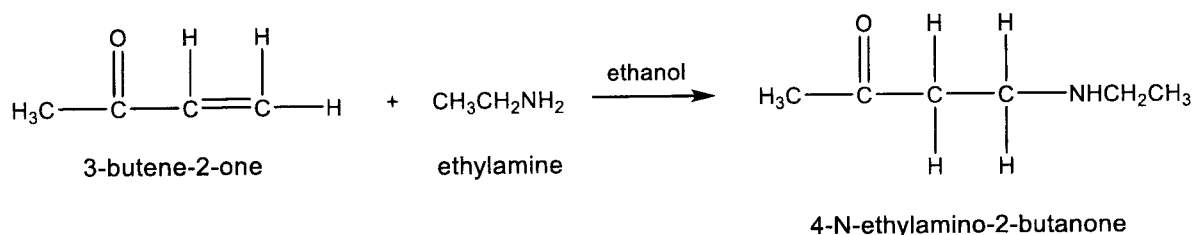
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- (e) Enones are ketones having a neighbouring C=C double. Enones undergoes a reaction called conjugate addition, a type of nucleophilic addition reaction, with a primary amine.

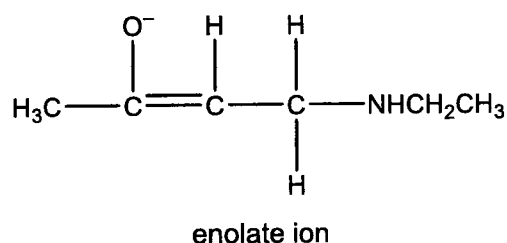
The reaction of 3-butene-2-one, an enone, with ethylamine via conjugate addition is as shown.



In this reaction, an amine is added directly to an alkene carbon.

The reaction takes place in 3 steps.

- step 1 The amine attacks the terminal alkene carbon to form an enolate ion intermediate.



- step 2 The intermediate will undergo rearrangement to form back the ketone and a carbanion.
- step 3 The carbanion is then protonated to form the product.

- (i) Suggest the mechanism for the conjugate addition reaction between 3-butene-2-one and ethylamine to form 4-N-ethylamino-2-butanone.

Show all charges and relevant lone pairs and show the movement of electron pairs by using curly arrows. [3]

- (ii) In the absence of the carbonyl group,  $-\text{C}=\text{O}$ , there will be no reaction between butene and ethylamine.

Suggest why this is so. [1]

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[Total: 20]

Additional Answer Space

If you use the following pages to complete the answer to any question, the question number must be clearly shown.

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**YISHUN INNOVA JUNIOR COLLEGE  
JC 2 PRELIMINARY EXAMINATION**

CANDIDATE  
NAME

CLASS

DATE

**H2 CHEMISTRY**

**9729/04**

Paper 4 Practical Paper

**23 August 2022**  
2 hours 30 minutes

Candidates answer on question paper.

Additional Materials: As listed in the Confidential Instructions  
Insert

**READ THESE INSTRUCTIONS FIRST**

Write your name and class in the spaces at the top of this page.  
Give details of the practical shift and laboratory where appropriate, in the boxes provided.

Write in dark blue or black pen.

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

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

Answer all questions in the spaces provided on the Question Paper.

The use of an approved scientific calculator is expected, where appropriate.  
You may lose marks if you do not show your working or if you do not use appropriate units.

Qualitative Analysis Notes are printed on pages 23 and 24.

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.

<b>Shift</b>	
<b>Laboratory</b>	

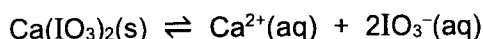
<b>For Examiner's use</b>	
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<b>Total</b>	<b>55</b>

This document consists of **24** printed pages.

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

**1 Determination of a value for the solubility product,  $K_{sp}$ , of calcium iodate(V),  $\text{Ca}(\text{IO}_3)_2$**

The solubility in water of solid calcium iodate(V),  $\text{Ca}(\text{IO}_3)_2$ , is low. When a sample of this salt is mixed with water, a small amount dissolves and an equilibrium between the solid salt and its aqueous ions is established.

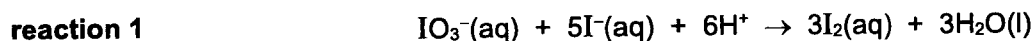


If separate aqueous solutions containing  $\text{Ca}^{2+}$  ions and  $\text{IO}_3^{-}$  ions are mixed, some of the solid salt is formed and, again an equilibrium is established.

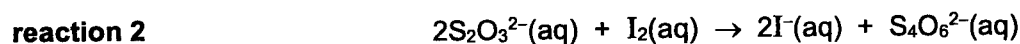
When specified volumes of potassium iodate and calcium nitrate are mixed, some calcium iodate(V) is formed as a white solid. The mixture should be left to stand for some time.

After the solid is removed by filtration, the amount of iodate(V) ions left in the filtrate is determined as described below.

When excess potassium iodide, KI, is added to an acidified solution containing iodate(V) ions, iodine is liberated as follows.



The liberated iodine is then titrated with a standard solution of sodium thiosulfate.



In this question, you will perform a titration to determine the solubility product,  $K_{sp}$ , of calcium iodate(V).

You are provided with:

- **FA 1**,  $0.200 \text{ mol dm}^{-3}$  potassium iodate,  $\text{KIO}_3$
- **FA 2**,  $1.00 \text{ mol dm}^{-3}$  calcium nitrate,  $\text{Ca}(\text{NO}_3)_2$
- **FA 3**,  $0.0400 \text{ mol dm}^{-3}$  sodium thiosulfate,  $\text{Na}_2\text{S}_2\text{O}_3$
- **FA 4**, aqueous solution of potassium iodide, KI
- **FA 5**, dilute hydrochloric acid, HCl

You are also provided with starch solution.

**(a) Preparation of the reaction mixture**

1. Use a measuring cylinder to transfer 50 cm<sup>3</sup> of **FA 1** to the beaker labelled **reaction mixture**.
2. Use a measuring cylinder to transfer 20 cm<sup>3</sup> of **FA 2** to the same beaker.
3. A precipitate will form, stir the mixture thoroughly. Leave this mixture to stand for 15 minutes to allow equilibrium to be reached.

**While you are waiting for the mixture to reach equilibrium, proceed with Question 2(a).**

**(b) (i) Analysing the filtrate**

1. Filter the reaction mixture through a **dry** filter paper into a **dry** conical flask, labelled **FA 6**. This is the filtrate, **FA 6**. Do not wash the white precipitate with water.
2. Fill a burette with **FA 3**.
3. Use a pipette to transfer 10.0 cm<sup>3</sup> of **FA 6** into a 250 cm<sup>3</sup> conical flask.
4. Use a measuring cylinder to add about 10 cm<sup>3</sup> of **FA 4** to the conical flask.
5. Use a measuring cylinder to add about 2 cm<sup>3</sup> of **FA 5** to the conical flask.
6. Run **FA 3** from the burette into the conical flask until the brown colour of the iodine fades to a pale yellow colour.
7. Add about 5 drops of starch solution to the conical flask. Continue adding **FA 3** until the blue-black colour **just** disappears.
8. Record your titration results, to an appropriate level of precision, in the space provided below.
9. Repeat points 3 to 7 until consistent results are obtained.

Rinse the conical flask thoroughly between each titration.

**Titration results**

[3]

- (ii) From your titrations, obtain a suitable volume of **FA 3** to be used in your calculations. Show clearly how you obtained this volume.

volume of **FA 3** = ..... cm<sup>3</sup> [3]

- (c) (i) Calculate the amount of  $\text{S}_2\text{O}_3^{2-}$  ions present in the volume of **FA 3** recorded in (b)(ii).

amount of  $\text{S}_2\text{O}_3^{2-}$  ions present in **FA 3** = ..... [1]

- (ii) Calculate the amount of  $\text{IO}_3^-$  ions present in 10.0 cm<sup>3</sup> of the filtrate, **FA 6**.

amount of  $\text{IO}_3^-$  ions present in 10.0 cm<sup>3</sup> of the filtrate, **FA 6** = ..... [1]

- (iii) Calculate the total amount of  $\text{IO}_3^-$  ions present in the filtrate, **FA 6**.

amount of  $\text{IO}_3^-$  ions present in the filtrate, **FA 6** = ..... [1]



- (d) (i) Using the initial amount of  $\text{IO}_3^-$  ions in the reaction mixture prepared in (a), and your answer from (c)(iii), calculate the amount of  $\text{IO}_3^-$  ions precipitated as  $\text{Ca}(\text{IO}_3)_2$ .

amount of  $\text{IO}_3^-$  ions precipitated as  $\text{Ca}(\text{IO}_3)_2$  = ..... [1]

- (ii) Deduce the amount of  $\text{Ca}^{2+}$  ions removed by precipitation in (a), point 3, and hence, calculate the amount of  $\text{Ca}^{2+}$  ions left in FA 6.

amount of  $\text{Ca}^{2+}$  ions left in FA 6 = ..... [2]

- (e) (i) Write an expression for the solubility product,  $K_{\text{sp}}$ , of calcium iodate(V).

[1]

- (ii) Use this expression, together with your answers to parts (c)(iii) and (d)(ii) to calculate a value for this solubility product. Include units in your answer.

solubility product = ..... [1]

(f) A student added solid calcium nitrate to his filtrate, **FA 6**.

Predict, qualitatively, the effect of such an addition on the filtrate, and on the magnitude of the mean titre, in part (b)(ii). Explain your answer.

predictions .....

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explanation .....

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[2]

(g) In part (b)(i), point 1, you are told to use **dry** apparatus and to avoid washing the residue with water. Suggest and explain the likely consequences on your mean titre value in part (b)(ii) if you failed to follow these instructions.

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..... [1]

- (h) A teacher performed this experiment and obtained a value for the solubility product,  $K_{sp}$ , of  $2.77 \times 10^{-5}$ . A literature value for this solubility product is  $6.71 \times 10^{-6}$  at  $20^\circ\text{C}$ .

You should assume that apparatus of the same precision was used in each case.

Give a possible explanation for the higher value of  $K_{sp}$  obtained by the teacher. Suggest an improvement which might allow a value closer to the literature value to be obtained.

explanation .....

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improvement .....

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..... [1]

[Total: 18]

## 2 Qualitative Analysis

In this question, you will perform tests to

- investigate reactions involving vanadate(V) ion,  $\text{VO}_3^-$
- deduce the functional groups present in four organic compounds.

You are provided with:

- **FA 7**, ammonium vanadate(V),  $\text{NH}_4\text{VO}_3$
- zinc, Zn

Unless otherwise stated, the volumes given below are approximate and should be estimated rather than measured.

- (a) (i)** To a 2 cm depth of **FA7** in a test-tube, add a small spatula of zinc. Leave for approximately 4 minutes with occasional shaking. Record all your observations.

Keep the reaction mixture for use in **2(a)(ii)**.

.....  
 .....  
 .....  
 ..... [2]

- (ii)** To 1 cm depth of the **solution** from **(a)(i)** in a test-tube, add 1 cm depth of sulfuric acid. Then add potassium manganate(VII) a few drops at a time until no further reaction occurs. At this stage, the solution is pink because unreacted  $\text{KMnO}_4$  is present.

Record all the changes you observe.

.....  
 .....  
 .....  
 ..... [2]

- (iii)** State the type of reaction occurring in the test in **(a)(ii)**.

..... [1]

(b) You are provided with samples of **FA 8**, **FA 9**, **FA 10** and **FA 11**, each of which is an aqueous solution containing a different one of the following:

- a carboxylic acid
- a ketone
- an alcohol
- an aldehyde

You will perform the tests described in Table 2.1.

In addition to having access to the usual bench reagents, you are also provided with the following:

- iodine solution,
- solid sodium carbonate.

Perform the tests described in Table 2.1. Some of the observations have been completed for you. There is no need to carry those tests. Record your observations in Table 2.1.

Test and identify any gases evolved. If there is no observable change write **no observation change**.

**Use a fresh sample of each solution in each test.**

Table 2.1

	observations with FA 8	observations with FA 9	observations with FA 10	observations with FA 11
<p>1. Add about 1 cm depth of <b>FA 8</b> in a test-tube.</p> <p>To this test-tube, add 6 drops of sodium hydroxide solution, followed by iodine solution, dropwise, until a permanent orange/red colour is present.</p> <p>Warm the mixture in a beaker of hot water for two minutes.</p> <p>Add sodium hydroxide solution using a teat pipette until no further change is seen.</p> <p><b>Repeat using FA 10 instead of FA 8.</b></p>		no observable change		pale yellow precipitate formed
<p>Place about 2 cm depth of aqueous silver nitrate in a boiling tube. Then slowly add 1 cm depth of aqueous sodium hydroxide. Add aqueous ammonia slowly, with shaking, until the precipitate just dissolves. You can use a clean glass rod to stir the mixture and help dissolve the precipitate. Use this solution for test 2.</p>				
<p>2. Add about 1 cm depth of the solution prepared in a test-tube.</p> <p>Add 1 cm depth of <b>FA 8</b> to the test-tube, shake the tube and place it in the test-tube rack to stand.</p> <p><b>Repeat using FA 9, instead of FA 8.</b></p>			no observable change	no observable change

[2]

(ii) The observations in Table 2.1 are sufficient to identify the functional group present in **FA 9**.

State the functional group present in **FA 9** and give evidence to support your answer.

functional group in **FA 9** .....

evidence .....

[1]

- (iii) Devise and perform simple tests to identify the functional groups in **FA 8**, **FA 10** and **FA 11**. Your test should use only the reagents provided. Record your test and observations in the space below.

**Any test requiring heating MUST be performed using a beaker of hot water.**

[4]

(iv) Complete Table 2.2 with the functional groups present in **FA 8**, **FA 10** and **FA 11**.

Give evidence from the observations in Table 2.1 and (b)(ii) to support your conclusions.

**Table 2.2**

	functional group present	evidence
<b>FA 8</b>		
<b>FA 10</b>		
<b>FA 11</b>		

[3]

[Total: 15]

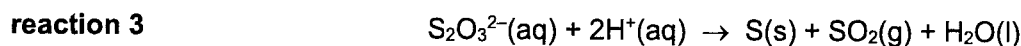


### 3 Determination of a value for the activation energy of a reaction

**FA 12** is 0.1 mol dm<sup>-3</sup> solution of hydrated sodium thiosulfate, Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>·5H<sub>2</sub>O.

**FA 13** is 2.0 mol dm<sup>-3</sup> hydrochloric acid.

Solid sulfur is one of the products formed in the reaction between sodium thiosulfate and a strong acid, as shown in equation below. The presence of sulfur causes the solution to be opaque.



In order to determine the activation energy for this experiment, you will need to investigate the effect of temperature on its rate. The rate of this reaction is studied by measuring the time taken for the reaction to become opaque.

The activation energy,  $E_a$ , can be determined from the Arrhenius Equation, where  $T$  is the reaction temperature in Kelvin and  $k$  is the rate constant at temperature  $T$ . The frequency factor,  $A$ , can be regarded as a constant under the conditions of this experiment.

$$k = Ae^{\frac{E_a}{RT}}$$

In this question, you will perform a series of five experiments, at different temperatures,  $T_K$ , each using the same volumes of **FA 12** and **FA 13**. Then, you will determine the value for the activation energy of the reaction graphically by plotting values of  $\ln(1/t)$  on the  $y$ -axis against  $1/T_K$  on the  $x$ -axis, a straight line of best fit may be drawn. The gradient of this line is  $-E_a/R$ , where  $R$  is the ideal gas constant.

For each experiment, you will note the temperature of the reaction,  $T$ , and the time taken,  $t$ , for the reaction mixture to become opaque.

You will then calculate values, to 3 significant figures, for

- $1/t$ ,
- $\ln(1/t)$ ,
- $T$  in Kelvin,  $T_K$  ( $0.0\text{ }^\circ\text{C} = 273.0\text{ K}$ )
- $1/T_K$

(a) Prepare a table in the space provided on page 16 in which to record, to an appropriate level of precision:

- all temperatures,
- all values of  $t$ ,
- all calculated values of  $1/t$ ,  $\ln(1/t)$ ,  $T_K$  and  $1/T_K$ .

Notes: In each of these experiments, you will need to place the conical flask containing the reaction mixture on the printed page on page 2 of the insert. You will view the page by looking vertically down through the mixture. You will stop the stopwatch when the mixture **first** becomes opaque. This will be the first instant when you can no longer see the printed numbers on the page.

Under no circumstances should the equipment used to measure one solution be used to measure another solution.

Before you prepare your experimental solutions,

- rinse the inside of the two boiling tubes labelled '1' with about 2 cm<sup>3</sup> of **FA 12**. Pour this **FA 12** into the waste bottle and place the boiling tubes in the test-tube rack until you need them.
- rinse the inside of the two boiling tubes labelled '2' with about 2 cm<sup>3</sup> of **FA 13**. Pour this **FA 13** into the waste bottle and place the boiling tubes in the test-tube rack until you need them.

Experiment 1 is performed at room temperature. This is the lowest temperature you will carry out. Experiment 2 is performed at 70 °C. This is the highest temperature you will carry out. The other three experiments are performed at different temperatures. You will use water baths to change the temperature of these reaction mixtures.

To prepare a hot water bath, you will mix tap water with the hot water provided until an appropriate temperature is reached.

1. Use a measuring cylinder to transfer 10 cm<sup>3</sup> of **FA 12** into the boiling tube labelled '1'. Place the boiling tube into a 250 cm<sup>3</sup> beaker containing hot water. This is the hot water bath.
2. Use another measuring cylinder to transfer 20 cm<sup>3</sup> of **FA 13** into the boiling tube labelled '2'. Place the boiling tube into the hot water bath.
3. Leave the boiling tubes in the hot water bath for use in **Experiment 2** and start **Experiment 1**.

**Experiment 1**

1. Use a measuring cylinder to transfer 20 cm<sup>3</sup> of **FA 13** into a 100 cm<sup>3</sup> conical flask.
2. Measure and record the temperature of **FA 13**.
3. Use another measuring cylinder to measure 10 cm<sup>3</sup> of **FA 12**.

Note: Small amounts of SO<sub>2</sub> will be produced during the reaction.  
Minimise inhalation of SO<sub>2</sub>.

4. Pour **FA 12** rapidly into the same conical flask. Start the stopwatch when about half of the **FA 12** solution has been added.
5. Swirl the conical flask once to mix the solutions. Then place the flask on the printed page of page 2 of the insert.
6. Stop the stopwatch when the solution **first** becomes opaque.
7. Record the time taken, *t*, to the nearest second in your table.
8. Discard the reaction mixture **immediately** down the sink. Wash out the conical flask and stand it upside down on a paper towel to drain.

**Experiment 2**

1. Measure and record the temperature of **FA 13** in boiling tube 2.
2. Remove the thermometer and carefully transfer the hot content of boiling tube 2 into a 100 cm<sup>3</sup> conical flask.
3. Pour rapidly the hot content of boiling tube 1 into the same conical flask. Start the stopwatch when about half of the **FA 12** solution has been added.
4. Swirl the conical flask once to mix the solutions. Then place the flask on the printed page of page 2 of the insert.
5. Stop the stopwatch when the solution **first** becomes opaque.
6. Record the time taken, *t*, to the nearest second in your table.
7. Discard the reaction mixture **immediately** down the sink. Wash out the conical flask and stand it upside down on a paper towel to drain.

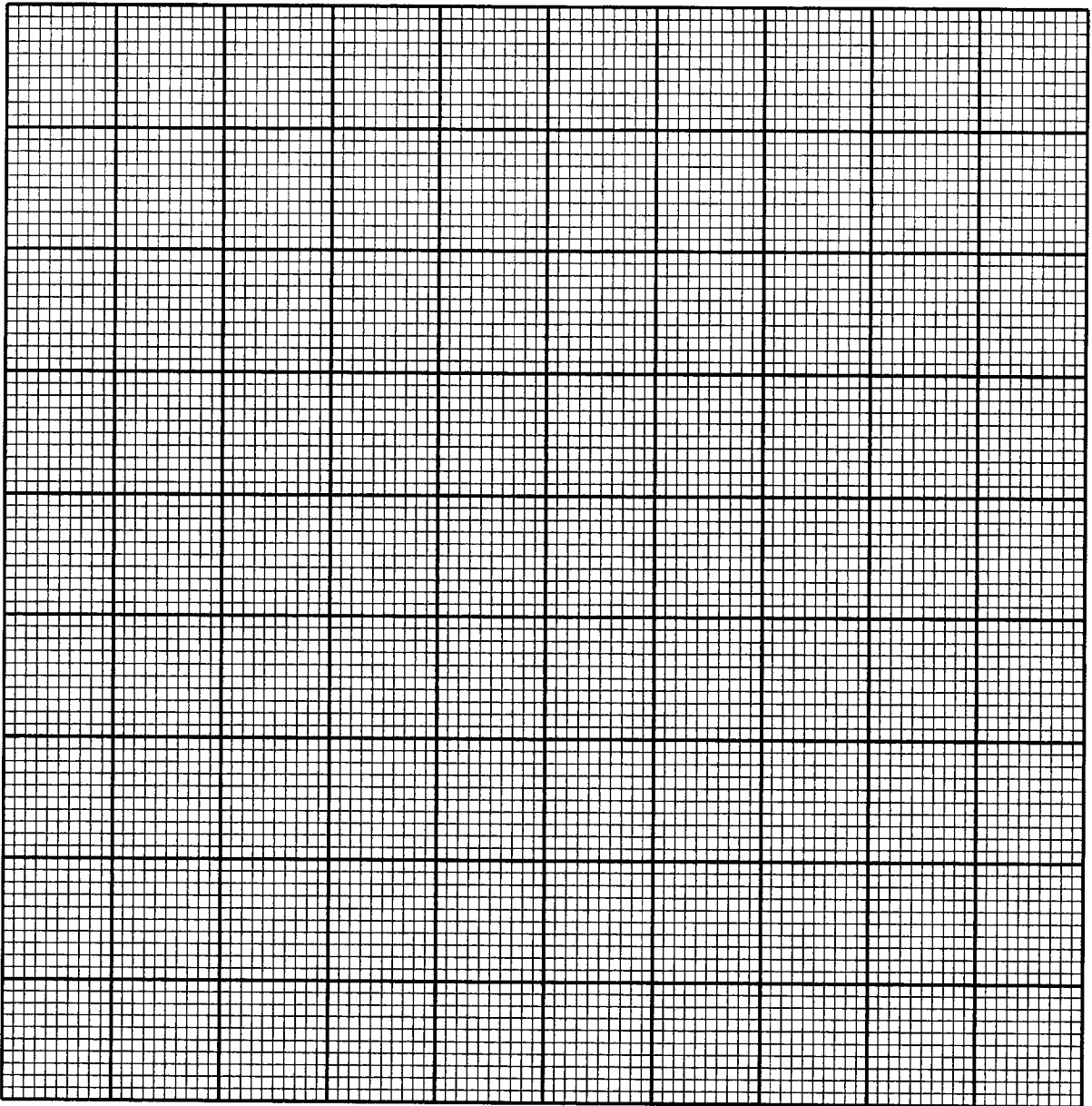
**Experiment 3, 4 and 5**

Repeat **Experiment 2** but at three different temperatures. Keep the temperature of **FA 13** between room temperature and 70 °C. Do not exceed 70 °C. You will use water baths to change the temperature of these reaction mixtures.

**Results**

[4]

(b) (i) Plot a graph of  $\ln(1/f)$  on the  $y$ -axis against  $1/T_K$  on the  $x$ -axis. Draw the best-fit straight line taking into account all of your plotted points.



[3]

(ii) Calculate the value of the gradient of the line to three significant figures, showing clear how you did this.

gradient = ..... [1]

- (iii) Calculate the activation energy,  $E_a$ , for reaction 3.  
 [ $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$ ]

activation energy,  $E_a =$  ..... [4]

- (c) In **Experiment 1**, you are told to start the stopwatch when about half of the **FA 12** solution has been added.

Suggest why this method is likely to be more accurate than starting the stopwatch after all the **FA 12** has been added.

.....  
 .....  
 ..... [1]

- (d) When you performed this experiment, you were instructed to wash and drain the conical flask before using it again.

State and explain the likely effect on  $t$  of not draining a flask before it is reused.

effect on  $t$  .....  
 .....

explanation .....  
 .....  
 ..... [1]

- (e) A student repeated the experiment but chose to use burettes to measure the volumes of **FA 12** and **FA 13**.

State and explain, in terms of percentage error, whether the student was wise to use a burette, rather than a 100 cm<sup>3</sup> measuring cylinder, to measure the volume of **FA 12**.

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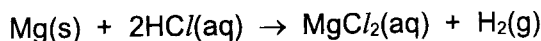
..... [1]

[Total: 15]

#### 4 Planning

- (a) Relative atomic mass of an element is the average mass of one atom of that element as compared to  $\frac{1}{12}$  of the mass of a  $^{12}\text{C}$  atom.

Magnesium is a reactive metal and appears dull because the metal on the surface is oxidised by air. The metal reacts with hydrochloric acid according to the following equation.



Plan an investigation to determine the relative atomic mass of magnesium.

You should make use of the water displacement method for collection of gas in your plan. In addition, you should plan to prepare a solution of hydrochloric acid of a suitable concentration and to collect a suitable volume of gas in your investigation.

You may assume that you are provided with:

- one piece of magnesium strip
- $0.50 \text{ mol dm}^{-3}$  hydrochloric acid
- a piece of sandpaper
- the equipment normally found in a school or college laboratory

Your plan should include brief details of:

- the apparatus you would use
- the quantities of the reactants and conditions that you would use
- the procedure that you would follow
- the measurements you would make (you may find it useful to label measurements in your plan as M1, M2 etc)
- an outline of how you would use your results to determine the *relative atomic mass* of magnesium.

[Ar: H, 1.0; Cl: 35.5]

You may assume that 1 mole of a gas has a volume of approximately  $24 \text{ dm}^3$  at 293 K and 1 atm.

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[6]

- (b) Identify one safety issue, relating to the properties of chemicals used or produced, in this procedure. Explain the precaution you would take to minimise the issue.

safety issue .....

.....

precaution .....

..... [1]

[Total: 7]

## Qualitative Analysis Notes

[ppt. = precipitate]

## (a) Reactions of aqueous cations

cation	reaction with	
	NaOH(aq)	NH <sub>3</sub> (aq)
aluminium, Al <sup>3+</sup> (aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH <sub>4</sub> <sup>+</sup> (aq)	ammonia produced on heating	–
barium, Ba <sup>2+</sup> (aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca <sup>2+</sup> (aq)	white ppt. with high [Ca <sup>2+</sup> (aq)]	no ppt.
chromium(III), Cr <sup>3+</sup> (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu <sup>2+</sup> (aq),	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe <sup>2+</sup> (aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe <sup>3+</sup> (aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg <sup>2+</sup> (aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn <sup>2+</sup> (aq)	off-white ppt., rapidly turning brown on contact with air insoluble in excess	off-white ppt., rapidly turning brown on contact with air insoluble in excess
zinc, Zn <sup>2+</sup> (aq)	white ppt. soluble in excess	white ppt. soluble in excess

**(b) Reactions of anions**

<i>ions</i>	<i>reaction</i>
carbonate, $\text{CO}_3^{2-}$	$\text{CO}_2$ liberated by dilute acids
chloride, $\text{Cl}^-$ (aq)	gives white ppt. with $\text{Ag}^+$ (aq) (soluble in $\text{NH}_3$ (aq))
bromide, $\text{Br}^-$ (aq)	gives pale cream ppt. with $\text{Ag}^+$ (aq) (partially soluble in $\text{NH}_3$ (aq))
iodide, $\text{I}^-$ (aq)	gives yellow ppt. with $\text{Ag}^+$ (aq) (insoluble in $\text{NH}_3$ (aq))
nitrate, $\text{NO}_3^-$ (aq)	$\text{NH}_3$ liberated on heating with $\text{OH}^-$ (aq) and Al foil
nitrite, $\text{NO}_2^-$ (aq)	$\text{NH}_3$ liberated on heating with $\text{OH}^-$ (aq) and Al foil; $\text{NO}$ liberated by dilute acids (colourless $\text{NO} \rightarrow$ (pale) brown $\text{NO}_2$ in air)
sulfate, $\text{SO}_4^{2-}$ (aq)	gives white ppt. with $\text{Ba}^{2+}$ (aq) (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}$ (aq)	$\text{SO}_2$ liberated with dilute acids; gives white ppt. with $\text{Ba}^{2+}$ (aq) (soluble in dilute strong acids)

**(c) Test for gases**

<i>ions</i>	<i>reaction</i>
ammonia, $\text{NH}_3$	turns damp red litmus paper blue
carbon dioxide, $\text{CO}_2$	gives a white ppt. with limewater (ppt. dissolves with excess $\text{CO}_2$ )
chlorine, $\text{Cl}_2$	bleaches damp litmus paper
hydrogen, $\text{H}_2$	"pops" with a lighted splint
oxygen, $\text{O}_2$	relights a glowing splint
sulfur dioxide, $\text{SO}_2$	turns aqueous acidified potassium manganate(VII) from purple to colourless

**(d) Colour of halogens**

<i>halogen</i>	<i>colour of element</i>	<i>colour in aqueous solution</i>	<i>colour in hexane</i>
chlorine, $\text{Cl}_2$	greenish yellow gas	pale yellow	pale yellow
bromine, $\text{Br}_2$	reddish brown gas / liquid	orange	orange-red
iodine, $\text{I}_2$	black solid / purple gas	brown	purple