BP~627

TAMPINES MERIDIAN JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME	
CIVICS GROUP	21S

H2 CHEMISTRY **9729/02**

Paper 2 Structured Questions

15 September 2022

2 hours

Candidates answer on the Question Paper.

Additional materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and civics group in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams and graphs.
Do not use 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.

A Data Booklet is provided.

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

Examiner's Use		
Paper 1	**MCQ**	**/ 30**
Paper 2	**Q1**	**/ 15**
	Q2	**/ 14**
	Q3	**/ 16**
	Q4	**/ 15**
	Q5	**/ 15**
		/ 75
Paper 3		**/ 80**
Paper 4		**/ 55**
Total		**/ 100**
Grade		

This document consists of **25** printed pages and **1** blank page.

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

1 **(a)** The elements of Period 3 form different oxides when reacted with oxygen.

(i) State and explain the variation in bonding within the oxides across Period 3.

....

....

....

....

.... [2]

Compounds **A** and **B** are oxides of Period 3 elements which exist in the solid state at room temperature.

When excess water is added to a sample of **A**, the solid dissolves completely and an acidic solution is obtained.

However, when excess water is added to **B**, the solid remains insoluble and a neutral solution is obtained.

(ii) Identify compound **A**.

.... [1]

(iii) Suggest **two** possible identities of compound **B** and describe how the identity of compound **B** can be confirmed using the acid-base behaviour of Period 3 oxides.

Include all relevant observations and an equation in your answer.

....

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....

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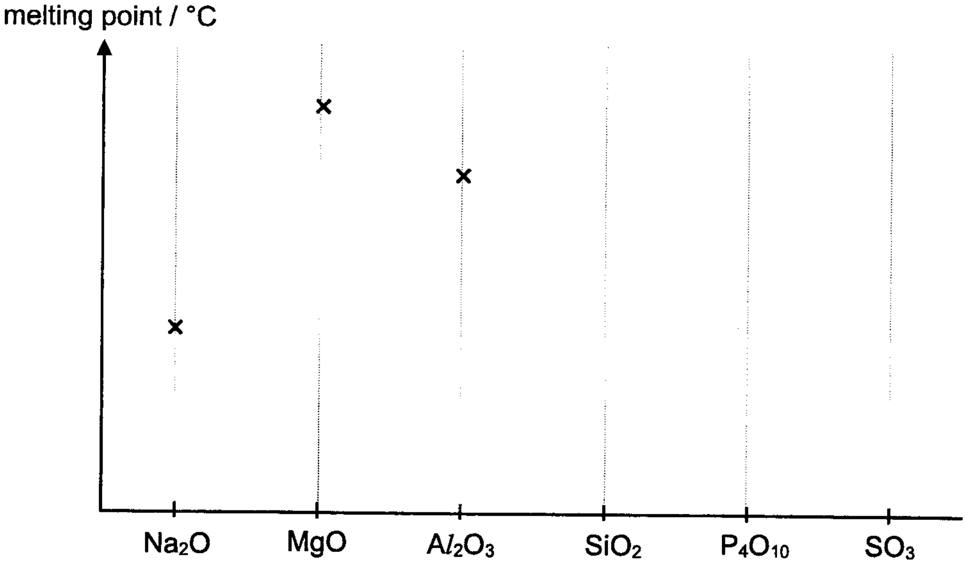
....

....

.... [3]

(b) **(i)** Complete the variation in the melting points of Period 3 oxides.



[1]

(ii) Explain the variation in melting points from Na_2O to Al_2O_3.

....

....

....

....

.... [2]

[Turn over

(c) Sodium azide, NaN_3, is commonly used in car airbags to produce nitrogen gas upon collisions.

(i) Draw a 'dot-and-cross' diagram for the azide ion, N_3^-, showing all of the outer shell electrons.

[1]

(ii) State and explain, with reference to the Valence Shell Electron Pair Repulsion theory, the shape and bond angle around the central atom of N_3^-.

....

....

....

.... [2]

When a car is involved in a collision, sensors send an electric signal to the container inside the airbag where the sodium azide is stored. This triggers the decomposition of sodium azide and inflates the airbag with nitrogen gas to nearly its full volume in a very short period to protect the driver, after which the airbag slowly deflates. The typical volume of a fully inflated airbag is 60 dm^3.

The decomposition of sodium azide is shown in reaction 1.

reaction 1 $2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$

As the sodium metal by-product of reaction 1 is highly reactive, airbag manufacturers mix sodium azide with potassium nitrate to remove the sodium by-product as shown in reaction 2.

reaction 2 $2KNO_3(s) + 10Na(s) \rightarrow 5Na_2O(s) + K_2O(s) + N_2(g)$

This also produces additional nitrogen gas which contributes to the airbag.

(iii) Given that an airbag contains 100 g of sodium azide, calculate the volume of nitrogen gas that can be produced at room temperature and pressure.

[3]

[Total: 15]

[Turn over

2 Wastewater comprises of various organic matter and is treated to remove all harmful contaminants before being discharged into water bodies.

(a) Tonalide is an organic compound commonly found in sewage sludge produced by wastewater treatment plants.

In an experiment, a sample of tonalide was combusted underneath a container containing 170 g of water. It was found that the temperature of the water increased by 55 °C after 0.050 mol of tonalide had been combusted.

(i) Calculate the enthalpy change of combustion of tonalide, ΔH_c, in kJ mol^{-1}. Assume the container absorbed negligible heat from the combustion.

[2]

(ii) The literature value for enthalpy change of combustion of tonalide is −865 kJ mol^{-1}. Compare this value to the one you have calculated in **(a)(i)** and suggest a reason for the discrepancy.

....

.... [1]

(b) Tonalide has molecular formula C_xH_yO.

0.3 dm^3 of gaseous tonalide was combusted in excess oxygen in an enclosed vessel at 400 °C. The gas mixture obtained at the end of combustion was then treated by:

- passing it through a dehydrating agent, resulting in a volume contraction of 3.9 dm^3; followed by
- bubbling the remaining gas mixture through aqueous sodium hydroxide, with a further contraction of 5.4 dm^3.

Determine the values of x and y in the molecular formula of tonalide. Show your working clearly.

[2]

[Turn over

(c) Ammonia is also another contaminant commonly found in agricultural wastewater. It is harmful to the aquatic ecosystems if present in significant quantity.

When ammonia is completely combusted, it produces nitrogen gas and water only.

(i) Define, with aid of an equation, the *standard enthalpy change of combustion of ammonia,* $NH_3(g)$.

....

....

.... [2]

(ii) Using appropriate data from the *Data Booklet*, calculate the enthalpy change of combustion of ammonia.

[2]

(iii) With the advancement in combustion technology, ammonia has been studied as a potential source for clean energy. Presently however, oxides of nitrogen are often produced as by-products of the reaction.

Suggest **one** advantage and **one** disadvantage of using ammonia as a fuel.

Advantage ....

....

....

Disadvantage ....

....

.... [2]

(iv) The process of nitrification is often used to convert ammonia into a less toxic nitrate.

$$NH_3(aq) + 2O_2(g) \rightarrow NO_3^-(aq) + H^+(aq) + H_2O(l) \qquad \Delta H_r$$

Using the information below, construct a suitable energy cycle to determine the enthalpy change of nitrification reaction, ΔH_r.

$NH_3(aq) + O_2(g) + H_2(g) \rightarrow NH_2OH(aq) + H_2O(l)$ $\quad \Delta H_1 = -284$ kJ mol^{-1}

$NH_2OH(aq) + H_2O(l) + \frac{1}{2}O_2(g) \rightarrow NO_3^-(aq) + 2H_2(g) + H^+(aq)$ $\quad \Delta H_2 = +1653$ kJ mol^{-1}

$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$ $\quad \Delta H_3 = +572$ kJ mol^{-1}

[3]

[Total: 14]

[Turn over

3 (a) Halogenoalkanes are important intermediates in organic chemistry. Fig. 3.1 shows the conversion of an alcohol to nitrogen-containing compounds, **F** and **G**, involving a halogenoalkane.

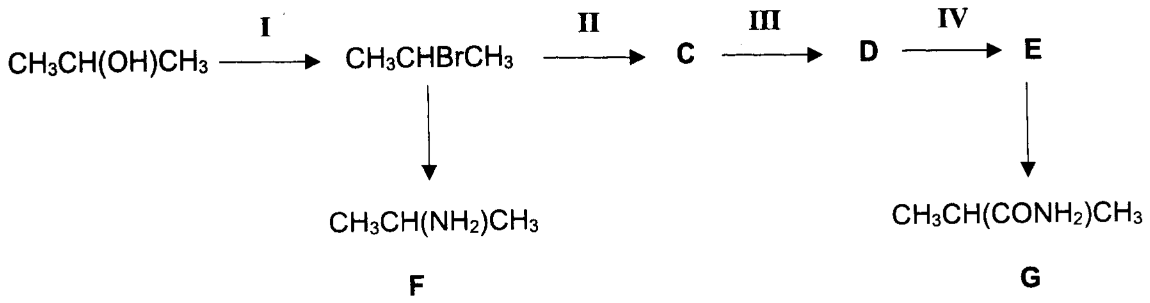


Fig. 3.1

(i) Draw the **displayed** formula of **C**.

C

[1]

(ii) Draw the structures of **D** and **E**.

D **E**

[2]

(iii) State the reagents and conditions for steps **II** and **III**.

step **II** ....

step **III** ....

[2]

(iv) Describe and explain how the basicity of **G** would compare to that of **F**.

....

....

....

.... [2]

(b) The hydrolysis of 2-bromo-2-methylpropane takes place as follows.

$$(CH_3)_3CBr + H_2O \rightarrow (CH_3)_3COH + H^+ + Br^-$$

An experiment to investigate the kinetics of the reaction was carried out. The results were consistent with the reaction being overall first order.

(i) Suggest a suitable experimental technique for studying the rate of this reaction.

....

.... [1]

(ii) Write the rate equation for the reaction and state the units of the rate constant.

rate equation ....

units of rate constant ....

[1]

(iii) Draw the structure of the intermediate formed in the reaction.

intermediate

[1]

[Turn over

(c) Carbocations frequently undergo structural changes, called rearrangements, to form more stable ions.

(i) Explain why a tertiary carbocation is more stable than a secondary carbocation.

....

....

.... [1]

Fig. 3.2 shows two types of carbocation rearrangements: a hydride shift and a methyl shift.

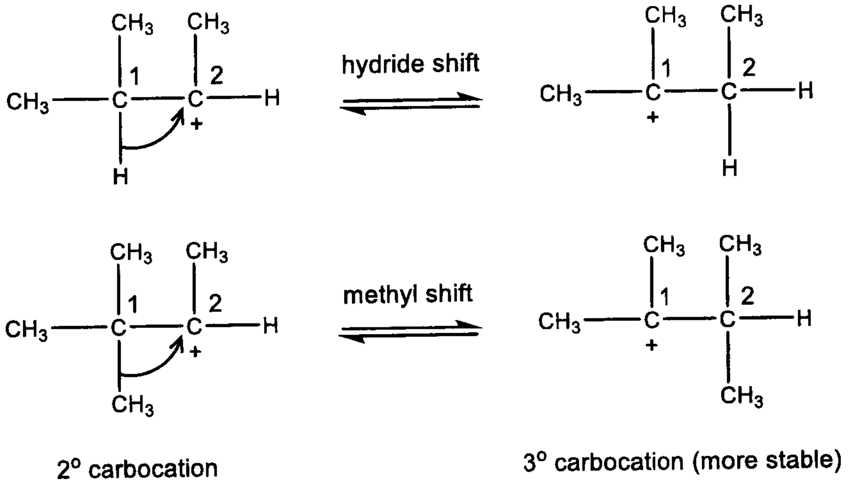


Fig. 3.2

Once rearranged, the resultant carbocation will react further to form a final product (rearranged substitution product) which has a different alkyl skeleton from the starting compound.

An example of a reaction with rearrangement is the S_N1 reaction of 2-bromo-3-methylbutane in boiling ethanol as shown in Fig. 3.3.

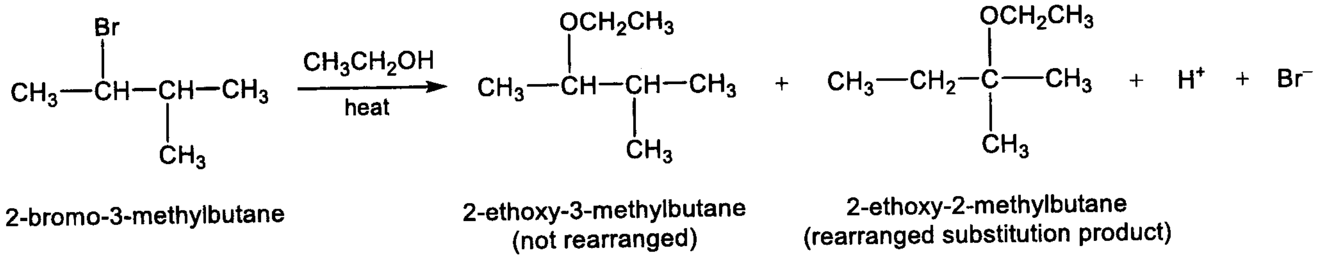
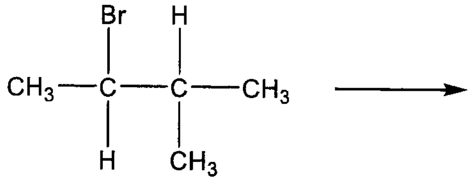


Fig. 3.3

(ii) Complete the four-step mechanism involving a hydride shift for the formation of 2-ethoxy-2-methylbutane (rearranged substitution product) as shown in Fig. 3.3.

Include all the necessary charges, dipoles, lone pairs and curly arrows.

Step 1: Ionisation of 2-bromo-3-methylbutane gives a carbocation.



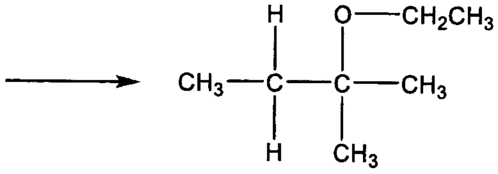
$CH_3CHBrCH(CH_3)CH_3 \longrightarrow$

2-bromo-3-methylbutane

Step 2: Carbocation undergoes rearrangement to form a more stable ion.

Step 3: CH_3CH_2OH attacks the rearranged carbocation.

Step 4: Deprotonation gives 2-ethoxy-2-methylbutane.



$\longrightarrow CH_3CH_2C(CH_3)_2OCH_2CH_3$

2-ethoxy-2-methylbutane

[3]

[Turn over

(d) When 1-bromo-2,2-dimethylpropane is boiled in ethanol, it gives only a rearranged substitution product, **H**, as shown in Fig. 3.4.

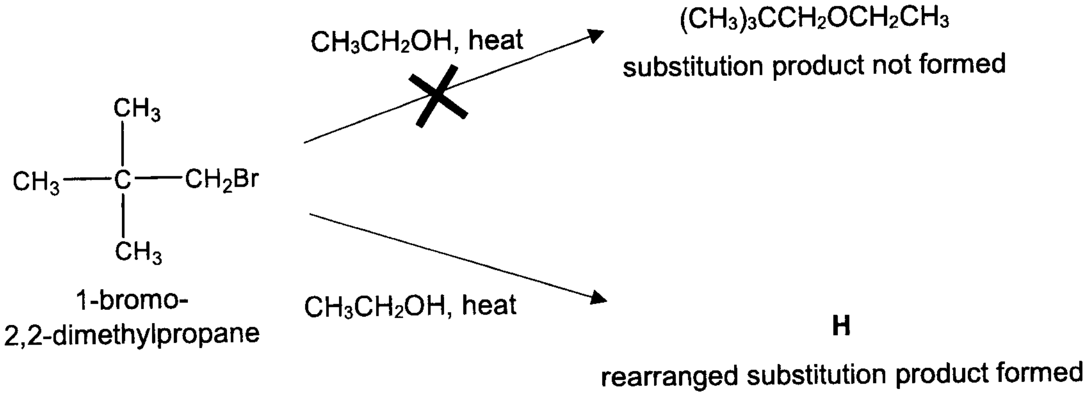


Fig. 3.4

(i) Suggest why $(CH_3)_3CCH_2OCH_2CH_3$ is not formed.

....

.... [1]

(ii) Suggest the structure of the rearranged substitution product **H**.

H

[1]

[Total: 16]

4 Methanoic acid, HCOOH, is the simplest carboxylic acid. It occurs naturally in the stings of certain ants.

(a) When an ant bites, it injects a solution containing 58% by volume of methanoic acid. A typical ant may inject around 6.0×10^{-3} cm^3 of this solution.

(i) When an ant bites a person, it typically injects 80% of its methanoic acid and keeps the rest as reserve.

Calculate the volume of pure methanoic acid found in an ant.

[1]

(ii) Suggest a method whereby ant stings can be treated. Explain your answer.

....

.... [1]

(b) One industrial method of producing methanoic acid is a 2-step reaction, via the carbonylation of ethanol, as shown below.

step 1: $CH_3CH_2OH + CO \xrightarrow[\text{high pressure}]{CH_3CH_2O^-Na^+} \underset{\textbf{J}}{HCOOCH_2CH_3}$

step 2: $\underset{\textbf{J}}{HCOOCH_2CH_3} + H_2O \xrightarrow[\text{heat}]{} HCOOH + CH_3CH_2OH$

(i) Name the ester **J**, $HCOOCH_2CH_3$.

.... [1]

(ii) Suggest the type of reaction for step 2.

step 2: .... [1]

(iii) **K** and **L** are constitutional isomers of **J** ($HCOOCH_2CH_3$). Table 4.1 shows some information about the isomers.

Table 4.1

isomer	boiling point / ° C	reaction with $Na_2CO_3(s)$ at r.t.p.
J	54.0	no effervescence
K	57.1	no effervescence
L	141.2	gas evolved gave white ppt with limewater

Use the information in Table 4.1 to suggest the structural formulae of **K** and **L** and explain why **L** has a higher boiling point than **J** or **K**.

K : ....

L : ....

....

.... [2]

(c) In the presence of hydroxyl radicals (•OH), methanoic acid can decompose into carbon dioxide and water. The mechanism of this reaction is thought to involve three steps:

step I: Hydroxyl radical radicals are generated from H_2O_2 through photocatalysis via homolytic fission.

step II: The hydroxyl radical abstracts a hydrogen from methanoic acid to form an intermediate and water.

step III: Another hydroxyl radical abstracts a hydrogen from the intermediate and forms carbon dioxide gas and water.

(i) Explain what is meant by the term *homolytic fission.*

....

.... [1]

(ii) Complete Fig. 4.1 to suggest the mechanism for steps I to III.

Show the structural formulae of the intermediates, the movement of unpaired electron by using curly arrow (⌒) and indicate any unpaired electron with a dot (•).

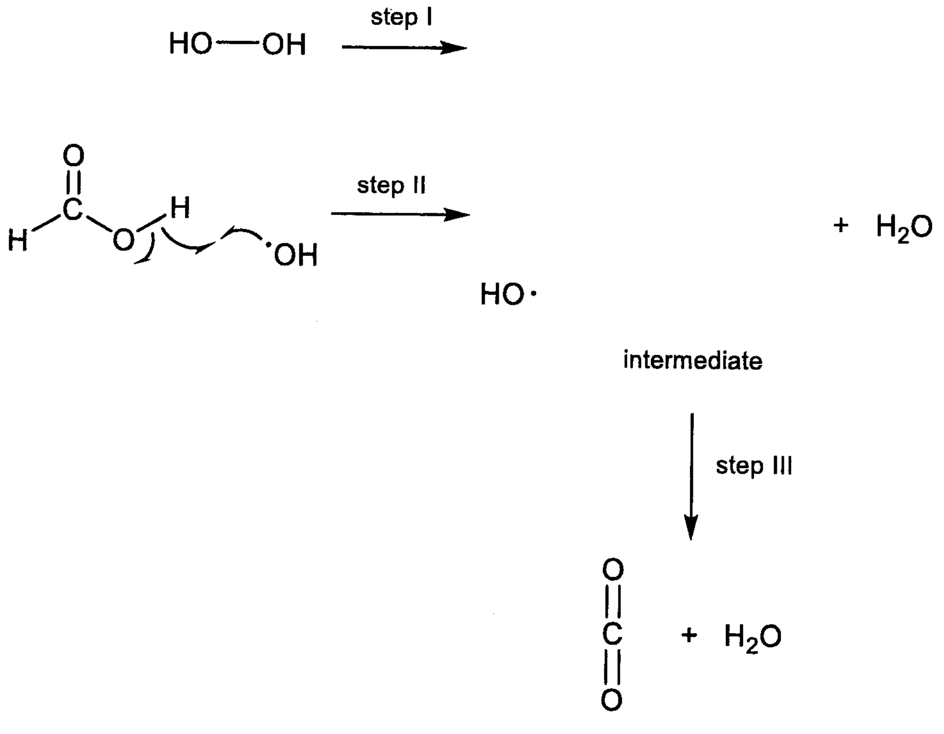


Fig. 4.1

[2]

(d) Methanoic acid has, in recent years, gained attention as a potential fuel for generating electricity. The Direct Formic Acid Fuel Cell (DFAFC) has been developed and is used to power vehicles, including buses. Fig. 4.2 shows the setup of a DFAFC.

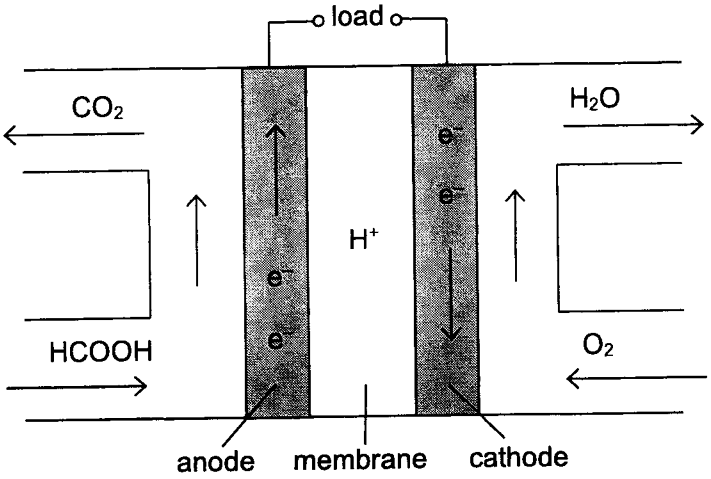


Fig. 4.2

In the DFAFC, methanoic acid is oxidised at the anode while oxygen is reduced at the cathode. The $E^{\ominus}_{\text{cell}}$ value for the cell is +1.47 V.

(i) Write an equation for the reaction occurring at the anode.

Anode: .... [1]

(ii) Hence or otherwise, construct a balanced equation for the reduction of oxygen by one mole of methanoic acid.

.... [1]

(iii) Using appropriate data from the *Data Booklet*, determine a value for the standard electrode potential, $E^{\ominus}$, of the $CO_2(g)/HCOOH(aq)$ half-cell.

[1]

(iv) Show that $\Delta G^{\ominus}$ at 298 K for the equation you have written in **(d)(ii)** is -284 kJ mol^{-1}.

[1]

(v) Based on the setup in Fig. 4.2, suggest a reason to explain why the actual $E^{\ominus}_{\text{cell}}$ value measured in a DFAFC may be lower than +1.47 V.

....

....

....

.... [2]

[Total: 15]

[Turn over

5 **(a)** Ethylenediamine has the structural formula $NH_2CH_2CH_2NH_2$.

When an aqueous solution of ethylenediamine is titrated with HC*l*(aq), two successive acid-base reactions take place.

A 0.10 mol dm^{-3} solution of ethylenediamine has a pH of 11.5. When 30 cm^3 of 0.10 mol dm^{-3} HC*l*(aq) is added to 10 cm^3 of a 0.10 mol dm^{-3} solution of ethylenediamine, the final pH is 1.6.

Fig. 5.1 shows the pH changes that occur during this addition of HC*l*(aq).

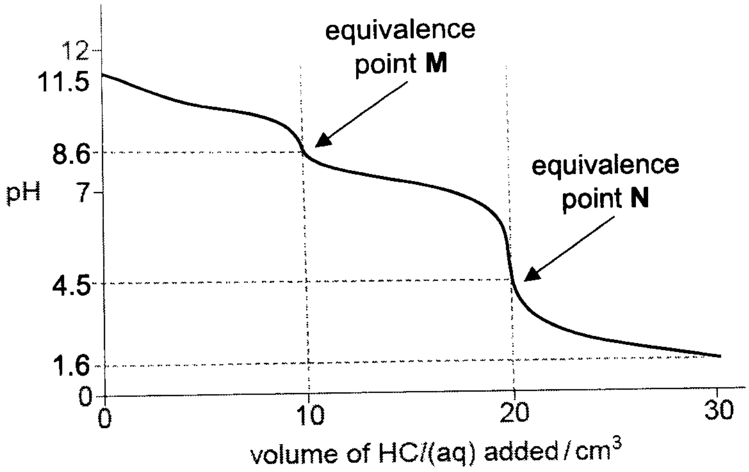


Fig. 5.1

Table 5.1 shows some indicators used in acid-base titrations.

Table 5.1

indicator	pH range	colour in		
		acid	end-point	base
malachite green	0.2 – 1.8	yellow	green	blue-green
methyl orange	3.2 – 4.4	red	orange	yellow
bromocresol green	3.8 – 5.4	yellow	green	blue
bromothymol blue	6.0 – 7.6	yellow	green	blue
phenol red	6.4 – 8.0	yellow	orange	red
phenolphthalein	8.2 – 10.0	colourless	pale pink	pink
alizarin yellow	10.1 – 13.0	yellow	orange	red

(i) Write equations for the two acid-base reactions when ethylenediamine is titrated with HC*l*.

....

.... [1]

(ii) Using the information in Fig. 5.1 and Table 5.1, suggest which indicators could best be used to determine the end-points of the successive titrations for **M** and **N**.

Indicator for **M** ....

Indicator for **N** ....

[1]

(iii) Give a reason for your choice of indicators in **(a)(ii)**.

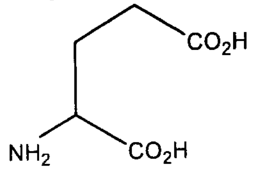
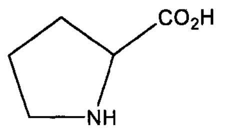
....

.... [1]

[Turn over

(b) Glutamic acid and proline are naturally occurring amino acids shown in Table 5.2.

Table 5.2

amino acid	glutamic acid  	proline 
isoelectric point	3.1	6.5

The isoelectric point of an amino acid is the pH at which it exists as a zwitterion.

(i) Explain what is meant by the term *zwitterion*.

....

.... [1]

(ii) A mixture of amino acids may be separated using electrophoresis. A typical practical set up is shown in Fig. 5.2.

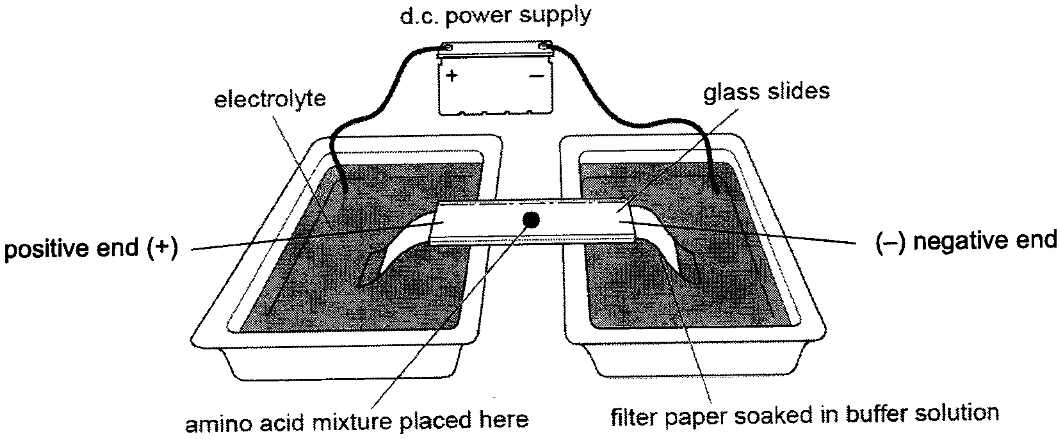


Fig. 5.2

A mixture containing glutamic acid and proline was analysed by electrophoresis using a buffer solution at pH 4.0.

Suggest the structures of the amino acid species at the positive and negative ends of the filter paper strip after the electrophoresis was carried out for a period of time.

positive end	negative end

[2]

(c) The weak acid ACES, $C_4H_{10}N_2O_4S$, together with its sodium salt, $C_4H_9N_2O_4SNa$, can be used to make a buffer solution for electrophoresis experiments.

You may use HA and Na^+A^- to represent ACES and its sodium salt.

(i) Write an ionic equation to show how the buffer solution maintains a fairly constant pH when a small amount of acid is added to it.

....

.... [1]

A buffer solution is prepared by the following steps.

- 3.50 g of Na^+A^- is dissolved in 100 cm^3 of distilled water.
- 50.0 cm^3 of 0.200 mol dm^{-3} dilute HC*l* is added to the solution.
- The resulting mixture is transferred to a 250.0 cm^3 volumetric flask, and the solution made up to the mark.

The pK_a of HA is 6.88 at 298 K.

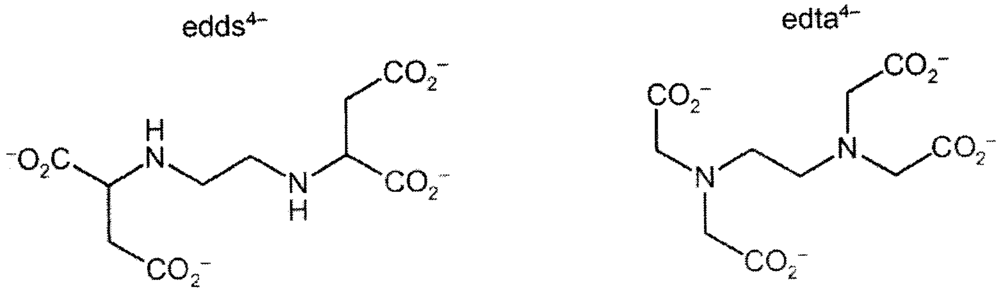
(ii) Calculate the pH of the buffer solution formed at 298 K. Show your working.

[M_r of Na^+A^- is 204.1]

[3]

[Turn over

(d) Edds^{4-} and edta^{4-} are polydentate ligands which can be derived from ethylenediamine. These ligands form octahedral complexes with Fe^{3+}(aq).



The formulae of the complexes are [Fe(edds)]$^-$ and [Fe(edta)]$^-$ respectively.

(i) On the diagram of **edds^{4-}**, circle each atom that forms a bond to the Fe^{3+} ion in [Fe(edds)]$^-$. [1]

(ii) [Fe(edds)]$^-$ and [Fe(edta)]$^-$ have different colours.

Explain why the two complexes differ in colour.

....

....

....

....

.... [2]

(iii) Table 5.3 shows the values for the stability constants, K_{stab}, of both complexes for the equilibrium below when L(aq) representing the ligand edds^{4-}(aq) or edta^{4-}(aq) is added to Fe^{3+}(aq).

equilibrium 1 $[Fe(H_2O)_6]^{3+}(aq) + L(aq) \rightleftharpoons [Fe(L)]^-(aq) + 6H_2O(l)$

Table 5.3

complex	K_{stab} / $mol^{-1}\ dm^3$
[Fe(edds)]$^-$	3.98×10^{20}
[Fe(edta)]$^-$	1.26×10^{25}

Predict which of the [Fe(edds)]$^-$ and [Fe(edta)]$^-$ complexes is more stable.

Explain your answer with reference to the K_{stab} value for each complex.

....

.... [1]

(iv) When an excess of edta^{4-}(aq) is added to [Fe(edds)]$^-$, the following equilibrium is established.

equilibrium 2 $\quad [Fe(edds)]^-(aq) + edta^{4-}(aq) \rightleftharpoons [Fe(edta)]^-(aq) + edds^{4-}(aq)$

Using the K_{stab} values given in Table 5.3 in **(d)(iii)**, calculate the equilibrium constant, K_c, for equilibrium 2.

[1]

[Total: 15]

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TAMPINES MERIDIAN JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME	
CIVICS GROUP	21S

H2 CHEMISTRY
Paper 3 Free Response

9729/03
20 September 2022
2 hours

Candidates answer on Question Paper.

Additional Materials: *Data Booklet*

READ THESE INSTRUCTIONS FIRST

Write your name and Civics Group in the spaces at the top of the page.

Write in dark blue or black pen on the answer booklet.

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

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

Section A
Answer **all** questions.

Section B
Answer **one** question.

A *Data Booklet* is provided.

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

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

For Examiners' Use		
Section A	Q1	/ 17
	Q2	/ 21
	Q3	/ 22
Section B	Q4	/ 20
	Q5	/ 20
Total		/ 80
Grade		

This document consists of **30** printed pages and **2** blank pages.

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Section A

Answer **all** the questions from this section.

1(a) Samples of three different oxides were added to water separately.

(i) State the Arrhenius theory of acids and bases. [1]

(ii) The pH value of the solution formed when sodium oxide is shaken with water is greater than the pH value of the solution formed when magnesium oxide is shaken with water. The pH of the solution formed when sulfur trioxide is shaken with water is less than both of these solutions.

Explain these observations using the Arrhenius theory. Write equations for all the reactions described. [3]

[Turn over

(b) Diazomethane, CH_2N_2, reacts with water to give methanol and nitrogen gas.

$$CH_2N_2 + H_2O \rightarrow CH_3OH + N_2$$

When 2.50×10^{-3} mol of CH_2N_2 was added into water, the volume of nitrogen gas evolved at various time intervals after the start of the reaction were measured. At the end of the reaction, 60 cm^3 of nitrogen gas was collected. The experiment results are plotted in Fig. 1.1 below.

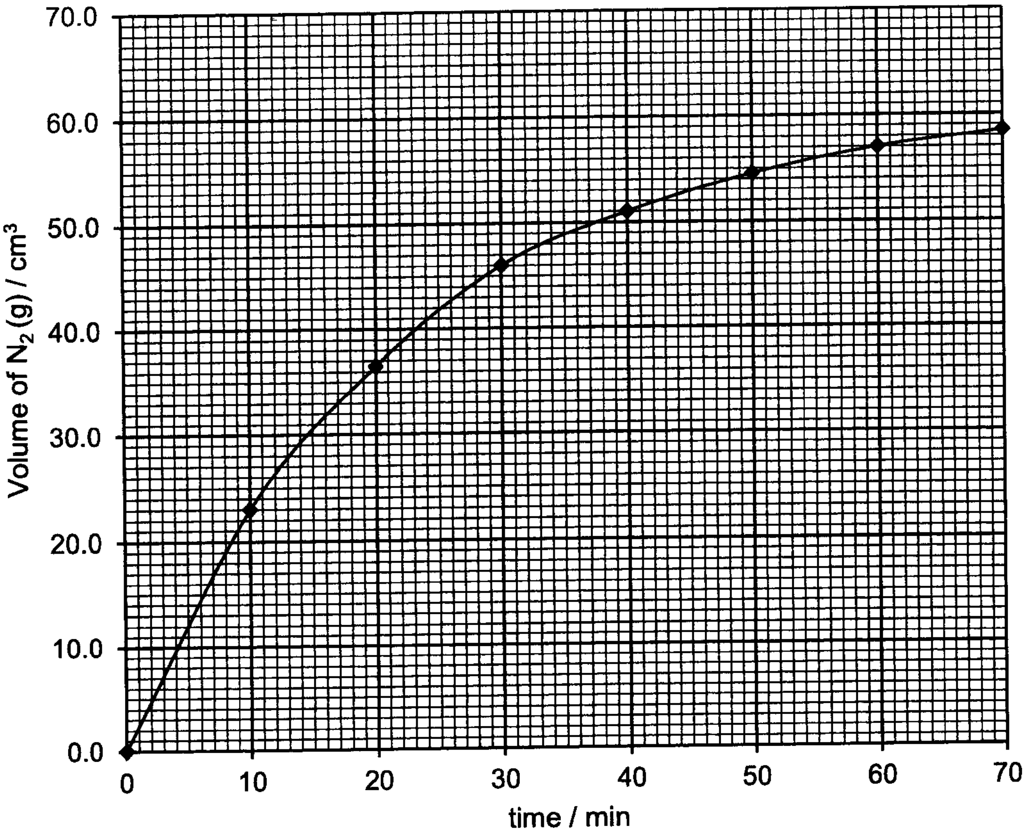


Fig. 1.1

(i) Use Fig. 1.1 and the information given to show that the order of reaction with respect to $[CH_2N_2]$ is 1. [2]

The reaction of CH_2N_2 with water takes place in the presence of an acid. Two experiments were conducted at different pH values to investigate the kinetics of this reaction. The results are shown in Table 1.1.

Table 1.1

Experiment	$[CH_2N_2]$ / mol dm^{-3}	pH	Relative rate
1	1.00×10^{-3}	1.00	1
2	4.00×10^{-3}	1.30	2

(ii) Calculate the concentration of H^+(aq) in experiment 1 and 2. [1]

(iii) Use the answer in **(b)(ii)** and data provided to determine the order of reaction with respect to $[H^+]$, and hence write the rate equation for the reaction. [2]

[Turn over

(c) Pure magnesium needed for making alloys can be obtained by the electrolysis of molten magnesium chloride as shown in Fig. 1.2.

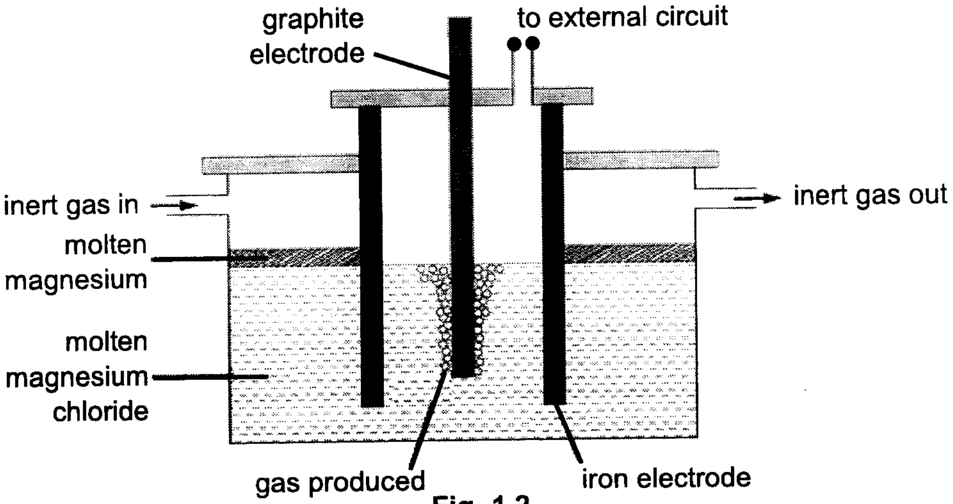


Fig. 1.2

(i) Write the half-equations, including state symbols, for the reactions occurring at the graphite and iron electrodes. Label your equations clearly to indicate the reaction occurring at the graphite and iron electrode respectively. [2]

(ii) Draw and label the direction of electron flow in the cell on Fig. 1.2. [1]

(iii) Calculate the mass of magnesium obtained if a current of 3.00 A is supplied for 10.0 h. [2]

(iv) A gas is continuously passed over the molten magnesium in the electrolytic cell to provide an inert environment. Suggest a gas that can be used for this. [1]

(v) Molten magnesium chloride in the cell is being replaced with aqueous magnesium chloride. Using relevant data from the *Data Booklet*, state and explain the reactions taking place at both electrodes when this change is made. [2]

[Total: 17]

2 Chromium is a steely-grey, hard and dense transition element. Its name came from the Greek word 'chrōma', which means colour, because many of its compounds are coloured.

(a) Define *transition element*. [1]

(b) Transition elements have significantly higher density and melting point compared to main group metals.

(i) Briefly explain why transition elements exhibit higher density. [1]

(ii) Explain why the melting point of chromium is significantly higher than the melting point of calcium. [1]

(c) Anhydrous chromium(III) chloride may be prepared by the chlorination of chromium metal.

$$Cr(s) + \frac{3}{2}Cl_2(g) \rightarrow CrCl_3(s)$$

The thermodynamic data at 298 K are given in the table below.

Substance	$\Delta S_f^\ominus$ / J mol^{-1} K^{-1}	$\Delta H_f^\ominus$ / kJ mol^{-1}
$CrCl_3$	–236.0	–556.6

(i) Explain the significance of the sign of $\Delta S_f^\ominus$. [1]

(ii) Using the information above, calculate $\Delta G^\ominus$ for the formation of $CrCl_3$ (s). [1]

(iii) Using your answer from **(c)(ii),** suggest whether the ratio of [product] / [reactants] at equilibrium for the formation of $CrCl_3$ at 298 K will be less than, equal to or greater than 1. Give a reason for your answer. [1]

(iv) Comment on the effect of increasing temperature on the spontaneity of the reaction. [2]

[Turn over

(d) The following sequence of reactions in Fig. 2.1 involves chromium.

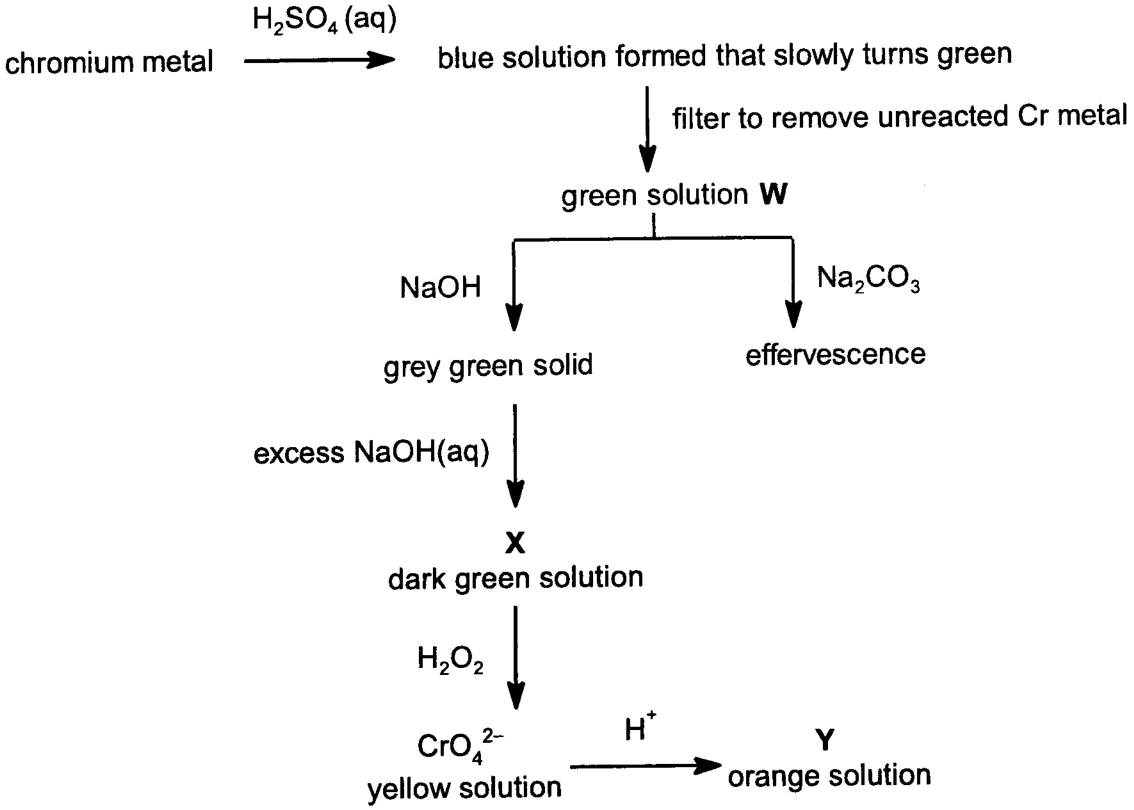


Fig. 2.1

(i) Using relevant $E^\ominus$ values from the *Data Booklet*, explain why the blue solution slowly turns green in air. [2]

(ii) State the type of reaction and write a balanced equation to account for the observation when a small amount of aqueous sodium hydroxide was added to a solution **W**. [2]

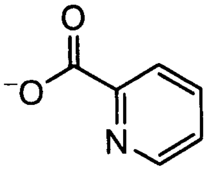
(iii) Suggest the formula of the chromium containing species in **X** and **Y**. [2]

(iv) State, with reasoning, the role of hydrogen peroxide in Fig. 2.1. [1]

[Turn over

(e) Chromium(III) picolinate is a chemical compound with the formula $Cr(C_5H_4N(CO_2))_3$, commonly abbreviated as $CrPic_3$. It is sold as a nutritional supplement to treat type-2 diabetes and promote weight loss.

The structure of the bidentate ligand picolinate is shown below.



Pic

Draw the structure of chromium(III) picolinate. [1]

(f) Aluminium hydroxide, $Al(OH)_3$, was used as white pigment for paints. $Al(OH)_3$ has a solubility of 2.90×10^{-9} mol dm^{-3} in pure water.

(i) Write the expression for the solubility product, K_{sp}, of $Al(OH)_3$ and calculate its solubility product in pure water. [3]

(ii) How would you expect the solubility of $Al(OH)_3$ in excess NaOH(aq) to compare with that in pure water? Briefly explain your answer with an equation with state symbols. [2]

[Total: 21]

[Turn over

3(a) Outline the mechanism of the reaction between hydrogen cyanide, HCN and propanal, CH_3CH_2CHO, to form 2-hydroxybutanenitrile, $CH_3CH_2CH(OH)CN$.

Include all the necessary charges, dipoles, lone pairs and curly arrows. [3]

(b) Compound **P** is an isomer of propanal and it forms a yellow precipitate when reacted with alkaline aqueous iodine.

P can be converted to compound **S** as shown in Fig. 3.1.

$$\mathbf{P} \xrightarrow{\text{I}} \mathbf{Q} \xrightarrow{\text{II}} \mathbf{R} \xrightarrow{\text{III}} (CH_3)_2C(OH)CO_2CH_2CH_3$$

compound **S**

Fig. 3.1

(i) Suggest structures for the compounds **P**, **Q** and **R**. [3]

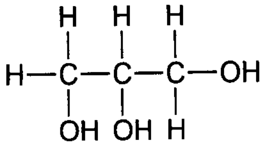
(ii) Suggest reagents and conditions for each of the steps **I**, **II** and **III**. [3]

(iii) Suggest a suitable carbonyl compound which can be used to form $CH_3CH_2CH_2CH(OH)CO_2CH_2CH_3$ using the three-step synthesis shown in Fig. 3.1. [1]

[Turn over

(c) Compound **T** is another isomer of propanal and it contains two different functional groups.

T reacts with cold alkaline $KMnO_4$ to form propane-1,2,3-triol.



$\text{H}-\underset{\text{OH}}{\overset{\text{H}}{\text{C}}}-\underset{\text{OH}}{\overset{\text{H}}{\text{C}}}-\underset{\text{H}}{\overset{\text{H}}{\text{C}}}-\text{OH}$

propane-1,2,3-triol

(i) Give the **displayed** formula of **T**. [1]

(ii) Draw the structure of the compound **U** formed when propane-1,2,3-triol reacts with hot acidified $K_2Cr_2O_7$. [1]

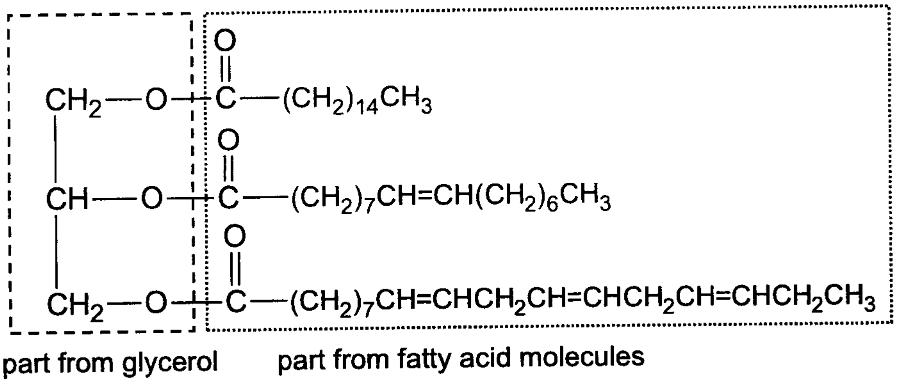
(iii) How would you expect the acidity of compound **U** to compare with that of propane-1,2,3-triol? Briefly explain your answer. [2]

[BLANK PAGE]

[Turn over

(d) Triglycerides are triesters formed from a glycerol (propane-1,2,3-triol) and three fatty acid (carboxylic acid) molecules.

A natural triglyceride with three different fatty acid chains is shown below.



A particular triglyceride, **J**, in castor oil produces glycerol (1 mol) and compound **K**, $C_{18}H_{34}O_3$ (3 mol) when heated with dilute sulfuric acid.

K decolourises bromine in an organic solvent. On gentle oxidation, **K** gives **L**, $C_{18}H_{32}O_3$, which gives an orange precipitate with 2,4-dinitrophenylhydrazine.

Warming **K** with concentrated sulfuric acid gives a compound **M**, $C_{18}H_{32}O_2$. On treating **M** with hot concentrated $KMnO_4$, $CH_3(CH_2)_5COOH$, $HO_2C(CH_2)_7CO_2H$ and CO_2 are produced.

Suggest structures for **K, M** and **J**. For each reaction, state the type of reaction described and the functional group present in each compound.. [8]

[Total: 22]

[Turn over

Section B

Answer **one** question from this section.

4(a) Carbon dioxide is the most significant greenhouse gas in Earth's atmosphere. The volume of 0.30 mol of carbon dioxide gas was measured at a temperature of 25 °C when various pressures were applied. The following results were obtained.

Table 4.1

pressure, p / atm	volume, V / dm^3	pressure x volume, pV / atm dm^3
5.00	1.436	7.18
10.0	0.7015	7.02
15.0	0.4566	6.85

(i) Calculate the volume, in dm^3, of 0.30 mol of an ideal gas at a temperature of 25 °C and at a pressure of 12.0 atm. [1]

(ii) Based on the data given in Table 4.1, estimate the value of pV when p = 12.0 atm. Hence, calculate the value of V when p = 12.0 atm. [1]

(iii) Compare the values of V you have obtained in **(a)(i)** and **(a)(ii)**. Account for the difference in the values by taking into consideration the properties of CO_2 molecules. [1]

(b) Dry ice is the solid form of carbon dioxide. Dry ice sublimes readily and is commonly used to preserve ice cream where mechanical cooling is unavailable.

Table 4.2 shows the standard enthalpy changes of sublimation for several substances. Enthalpy change of sublimation is the energy required to change one mole of a substance from solid state to gaseous state.

Table 4.2

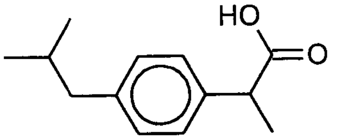
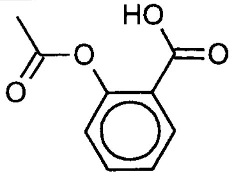
	$\Delta H^\ominus_{sub}$ / kJ mol^{-1}
standard enthalpy change of sublimation of C(s)	+715
standard enthalpy change of sublimation of Si(s)	+456
standard enthalpy change of sublimation of CO_2(s)	+25.0

Explain the relative standard enthalpy change of sublimation for these three substances. [2]

[Turn over

(c) Ibuprofen and aspirin are nonsteroidal anti-inflammatory drugs that are commonly used as painkiller and for fever reduction. Some data of ibuprofen and aspirin are shown below in Table 4.3.

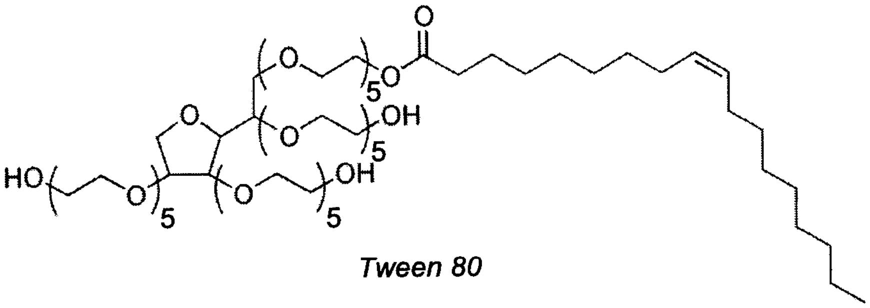
Table 4.3

	ibuprofen	aspirin
Structural formula		
Molecular formula	$C_{13}H_{18}O_2$	$C_9H_8O_4$
pK_a value	4.45	3.49

(i) Ibuprofen exhibits stereoisomerism. Explain how this stereoisomerism arises. Draw the structures of these stereoisomers. [2]

(ii) Compare and explain the relative acidity of ibuprofen and aspirin. [1]

(iii) Young children often find it difficult to swallow tablets. Thus, ibuprofen can also be supplied in the form of an emulsion. Given that ibuprofen is insoluble in water, an emulsifier such as *Tween 80* is used to create a homogenous mixture.



Tween 80

Using your knowledge from chemical bonding and the above information on the role of an emulsifier, explain clearly in terms of intermolecular forces, how *Tween 80* can create a homogenous mixture of ibuprofen in water. [2]

[Turn over

(d) A student proposed using 2-methylpropylbenzene to synthesise ibuprofen. The reaction scheme is shown in Fig. 4.1 below.

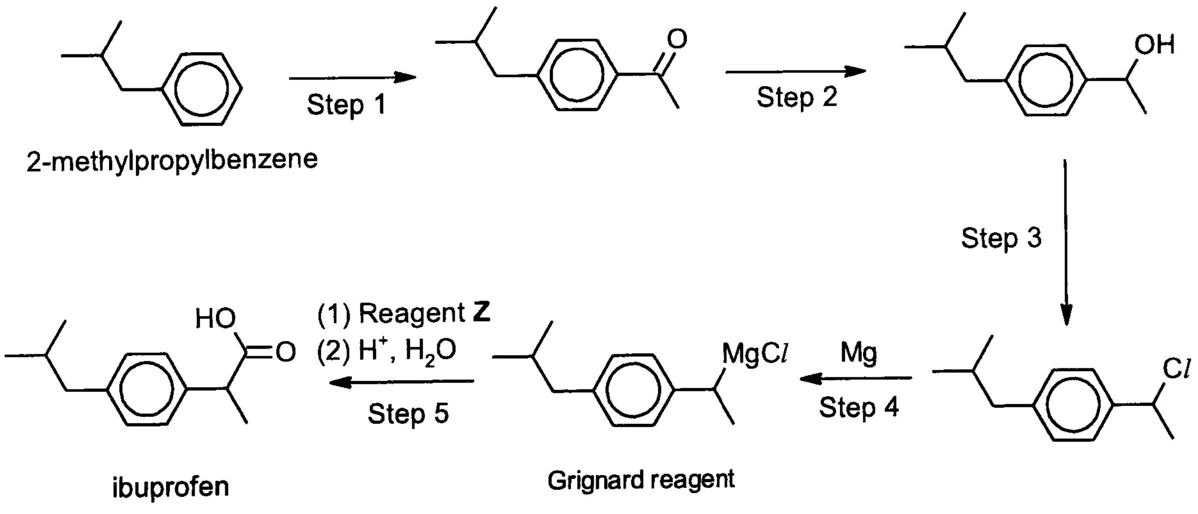


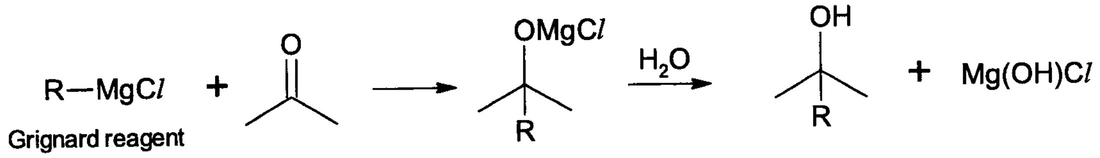
Fig. 4.1

(i) Name the type of reaction that occurs in steps 1 and 3. [2]

(ii) Suggest the reagents and conditions for steps 1 and 2. [2]

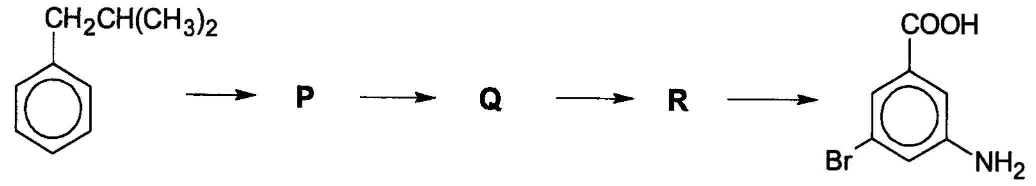
(iii) Describe a simple chemical test that can be carried out to indicate that Step 3 of the reaction scheme is complete. [2]

Step 4 in the reaction scheme involves the formation of a Grignard reagent. A Grignard reagent is useful to form new carbon-carbon bonds. The alkyl group in R–MgC*l* behaves like an anion, R^-. The Grignard reagent adds to a reagent via a nucleophilic addition reaction as shown below.



(iv) Suggest the identity for Reagent **Z** in Step 5. [1]

(e) 2-methylpropylbenzene undergoes a four-step reaction as shown below.



Suggest the structures of intermediates **P**, **Q** and **R** [3]

[Total: 20]

[Turn over

5(a) The halogens (chlorine, bromine and iodine) are found in Group 17 of the Periodic Table.

(i) Copy and complete the electronic configuration for a bromine atom, Br. [1]

$1s^2$ ……………………………….

(ii) Hence, sketch and label all occupied valence orbitals of the bromine atom. [2]

(iii) State and explain the trend in first ionisation energy down Group 17. [2]

(iv) By considering the relative positions of iodine, $_{53}I$, and lead, $_{82}Pb$, in the Periodic Table, and their first ionisation energies given in the *Data Booklet*, suggest a value for the first ionisation energy of astatine, $_{85}At$. Explain your answer. [2]

(b) The Period 3 elements sodium, aluminium and silicon, react with chlorine gas to produce chlorides with varying chemical properties.

Describe what would be observed when water is added to separate samples of $NaCl$, $AlCl_3$ and $SiCl_4$. Suggest the pH of the resulting solutions and write equations where appropriate. [3]

[Turn over

(c) At 450 K, phosphorus pentachloride, $PCl_5(g)$, decomposes to form phosphorus trichloride, $PCl_3(g)$, and chlorine, $Cl_2(g)$. A *dynamic equilibrium* is established as shown.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g) \qquad \Delta H = +124 \text{ kJ mol}^{-1}$$

(i) Explain what is meant by the term *dynamic equilibrium*. [1]

(ii) Suggest, with reasoning, the effect of increasing temperature on the percentage of $PCl_5(g)$ that decomposes. [1]

When 2.00 mol of $PCl_5(g)$ are decomposed at 450 K and 1.00×10^5 Pa, the resulting equilibrium mixture contains 0.900 mol of $Cl_2(g)$.

(iii) Write the expression for the equilibrium constant, K_p, for the decomposition of $PCl_5(g)$.[1]

(iv) Determine the partial pressures of each of the gases at equilibrium. Hence, calculate the value of K_p and state its units. [3]

[Turn over

(d) Nitrogen mustard gas was stockpiled as a chemical warfare agent in World War II. However, it was not deployed in combat.

It was proposed that the synthesis of nitrogen mustard can be carried out via the following synthetic pathway as shown in Fig. 5.1.

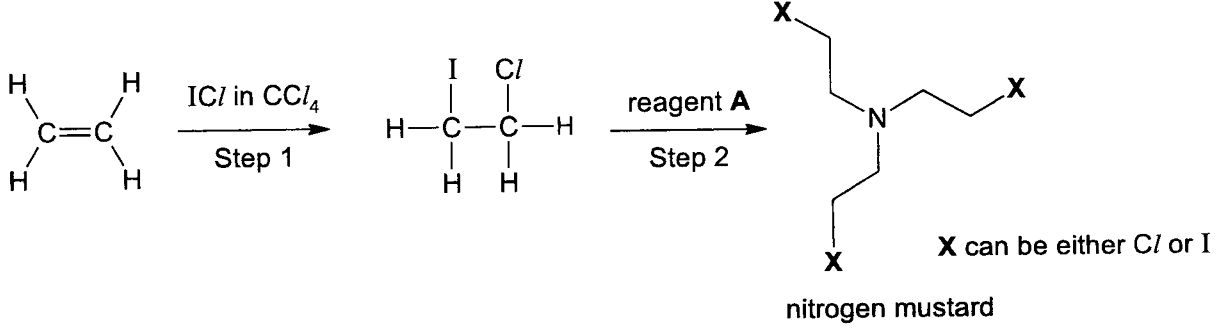


Fig. 5.1

(i) Suggest the reagents and conditions necessary for an optimal yield in Step 2 in Fig. 5.1. [1]

(ii) Is **X** in nitrogen mustard more likely to be C*l* or I? Explain your answer. [1]

Another reaction pathway was suggested for the synthesis of nitrogen mustard, with reagent **A** used in the first step as shown in Fig. 5.2.

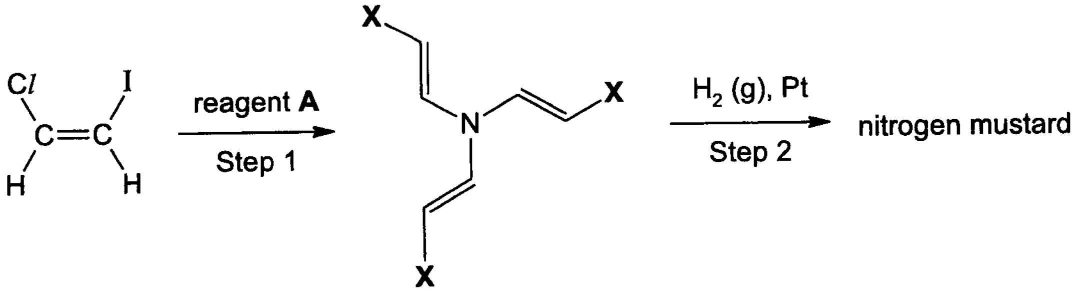


Fig. 5.2

(iii) By considering Step **1** of the reaction pathway in Fig. 5.2, explain why this method of synthesis is not likely to be feasible. [2]

[Total: 20]

[Turn over

Additional answer space

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

TAMPINES MERIDIAN JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME

CIVICS GROUP 21S

H2 CHEMISTRY
Paper 4 Practical

9729 / 04
30 August 2022
2 hours 30 minutes

Candidates answer on the Question Paper.

READ THESE INSTRUCTIONS FIRST

Write your name and Civics Group in the spaces at the top of the 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 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 21 and 22.

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

Shift
1 / 2 / 3
Laboratory

For Examiner's Use	
1	/ 11
2	/ 20
3	/ 10
4	/ 14
Total	**/ 55**

This document consists of **22** printed pages.

1 Determination of water of crystallisation in a hydrated iron(III) salt

A variety of hydrated iron(III) sulfates are known. Solutions of iron(III) sulfate are used in dyeing, and as coagulant for industrial waste.

FA 1 is a solution containing 26.0 g dm^{-3} of hydrated iron(III) sulfate, $Fe_2(SO_4)_3.nH_2O$.
The addition of excess zinc to a solution of **FA 1** reduces the Fe^{3+} ions to Fe^{2+} ions.

The amount of Fe^{2+} ions can be determined quantitatively by titration against a standard solution of potassium manganate(VII), $KMnO_4$. The reaction is shown below.

$$5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$$

In this experiment, you are to perform titrations to determine the value of n, the water of crystallisation in **FA 1**.

You are provided with
FA 1, solution containing 26.0 g dm^{-3} of hydrated iron(III) sulfate, $Fe_2(SO_4)_3.nH_2O$.
FA 2, dilute sulfuric acid,
FA 3, 0.0200 mol dm^{-3} potassium manganate(VII), $KMnO_4$,
zinc powder

(a) Preparation of Fe^{2+} solution from FA 1

1. Use a measuring cylinder to transfer 80 cm^3 of **FA 1** into a 250 cm^3 beaker.
2. Add all the zinc powder into the beaker. Cover the beaker with a white tile.
3. Allow the reaction to take place for about 5 minutes, stirring the reaction mixture from time to time.
4. Filter the mixture into the **dry** beaker provided using a **dry** filter paper and filter funnel. Ignore any reaction that may still be taking place.
5. Label the filtrate as **FA 4**. Proceed to **1(b)** once you have collected sufficient filtrate.

(b) Titration of FA 4 against FA 3

6. Fill the burette labelled **FA 3** with **FA 3**.
7. Use a pipette to transfer 10.0 cm^3 of **FA 4** into a 100 cm^3 conical flask.
8. Use a measuring cylinder to add 10 cm^3 of **FA 2** to this flask.
9. Titrate **FA 4** with **FA 3** from the burette until the appearance of the first permanent pale pink colour.
10. Record your titration results, to an appropriate level of precision, in the space provided on page 3.
11. Repeat steps 7 to 10 until consistent results are obtained.

Wash out the conical flasks and stand it upside down to drain for use in **Question 2**.

(i) **Results**

[3]

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

$V_{FA\ 3}$ = ... [3]

M1	M2	M3	M4	M5	M6

(c) **(i)** Calculate the amount of Fe^{2+} in 10.0 cm^3 of **FA 4**.

amount of Fe^{2+} in 10.0 cm^3 of **FA 4** = ... [1]

M7	

(ii) In step 2, an excess of zinc was added to convert the Fe^{3+} to Fe^{2+}.

Calculate the amount of Fe^{3+} in 1 dm^3 of **FA 1**.

amount of Fe^{3+} in 1 dm^3 of **FA 1** = ... [1]

M8	

[Turn Over

(iii) Use your answer from **(c)(ii)** to calculate the M_r of the hydrated iron(III) sulfate, $Fe_2(SO_4)_3.nH_2O$, in **FA 1**.

M_r of the hydrated iron(III) sulfate = ...

Hence, deduce the value of n, the water of crystallisation in the hydrated iron(III) sulfate.

[A_r: Fe, 55.8; S, 32.1; O, 16.0; H, 1.0]

n = ... [2]

M9	M10

(d) In step 4, excess zinc was filtered off before titration of **FA 4** against **FA 3**.

Suggest why it was necessary to filter off the excess zinc metal, and what effect it would have on the titre values if this filtration was not carried out.

....

....

.... [1]

M11	

[Total: 11]

2 Determination of the kinetics of the reaction between M^{3+} ions and iodide ions, I^-.

You are provided with the following reagents.

FA 5 contains 0.0200 mol dm^{-3} metal ions, M^{3+}, also present in **FA 9**.
FA 6 is 0.0080 mol dm^{-3} aqueous potassium iodide, KI
FA 7 is 0.0060 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$
starch solution

M^{3+} ions oxidise iodide ions, I^-, to iodine, I_2 as shown in equation 1. In this experiment, you will investigate how the rate of this reaction is affected by the concentration of M^{3+} ions.

equation 1 $2M^{3+}(aq) + 2I^-(aq) \rightarrow 2M^{2+}(aq) + I_2(aq)$

A fixed and small amount of thiosulfate ions, $S_2O_3^{2-}$, and starch indicator will be added to a mixture of $M^{3+}(aq)$ and $I^-(aq)$. The iodine, I_2, produced reacts immediately with thiosulfate ions, $S_2O_3^{2-}$ as shown in equation 2.

equation 2 $I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$

When all the thiosulfate has been used, the iodine produced will turn starch indicator blue-black. The rate of the reaction can therefore be measured by finding the time it takes for the reaction mixture to turn blue–black.

You will perform a series of **four** experiments. Then, you will graphically analyse your results to determine the order with respect to the concentration of M^{3+} ions, $[M^{3+}]$.

For each experiment, you will note the volume of **FA 5** added, $V_{FA\,5}$, and the time taken, t, for the reaction mixture to become blue-black. In each experiment, you will need to ensure that the same total volume of reaction mixture is used by adding deionised water as required.

You will then calculate values for

- $\frac{1}{t}$,
- $\lg\left(\frac{1}{t}\right)$,
- $\lg(V_{FA\,5})$.

(a) Prepare a table in the space provided on page 7 in which to record, to an appropriate level of precision:

- volumes of **FA 5** and deionised water,
- all values of t,
- all calculated values of $\frac{1}{t}$, $\lg\left(\frac{1}{t}\right)$ and $\lg(V_{FA\,5})$.

[Turn Over

(i) **Experiment 1**

1. Fill a burette with **FA 5**.
2. Transfer 20.00 cm^3 of **FA 5** into a 100 cm^3 conical flask.
3. Use the measuring cylinders to place the following in a 100 cm^3 beaker.
    - 10 cm^3 of **FA 6**
    - 15 cm^3 of **FA 7**
    - 10 cm^3 of starch solution
4. Add the contents of the beaker rapidly to the conical flask and start the stopwatch.
5. Swirl the mixture and place the conical flask on the white tile.
6. The mixture turns purple and then yellow before turning a blue-black colour. Stop timing when this **blue-black colour first** appears.
7. Record the time taken, *t*, to 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.

(ii) **Experiment 2**

1. Run 8.00 cm^3 of **FA 5** into a 100 cm^3 conical flask.
2. Using another measuring cylinder, add 12.0 cm^3 of deionised water into the conical flask containing **FA5**.
3. Use the measuring cylinders from Experiment 1 to place the following in a 100 cm^3 beaker.
    - 10 cm^3 of **FA 6**
    - 15 cm^3 of **FA 7**
    - 10 cm^3 of starch solution
4. Add the contents of the beaker rapidly to the conical flask and start the stopwatch.
5. Swirl the mixture and place the conical flask on the white tile.
6. The mixture turns purple and then yellow before turning a blue-black colour. Stop timing when this **blue-black colour first** appears.
7. Record the time taken, *t*, to 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.

In Experiment 1 you will have obtained the time taken for a 'fast' reaction and in Experiment 2 the time taken for a 'slow' reaction.

Carry out **two** further experiments to investigate the effect of changing the concentration of M^{3+}(aq) by altering the volume of M^{3+}, **FA 5**, used. In each case, you will need to ensure that the **same total volume** of reaction mixture is used by adding deionised water as required.

Do not use a volume of **FA 5** that is less than 8.00 cm^3.

You should alternate the use of the two 100 cm^3 conical flasks.

Record all required volumes, time taken and calculated values in your table.

(iii) Results

[5]

M12	M13	M14	M15	M16

(b) **(i)** Plot a graph of $\lg\left(\frac{1}{t}\right)$ on the y–axis against $\lg(V_{FA\,5})$ on the x–axis.

Draw the best–fit straight line taking into account all of your plotted points

[3]

M17	M18	M19

(ii) Calculate the gradient of the line to three significant figures, showing clearly how you did this. Hence, deduce the order of the reaction with respect to [M^{3+}].

gradient = ...

order = ...

[3]

M20	M21	M22

(c) When you performed this experiment, you were instructed to wash **and** drain a 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]

M23	

(d) Explain why a small and fixed amount of sodium thiosulfate was added in each reaction mixture.

....

....

....

.... [1]

M24	

(e) The rate of this reaction relative to [M^{3+}] can be determined using the following expression. The change in the concentration of M^{3+}(aq) can be determined at the point when sufficient iodine was produced for the appearance of the blue-black colour.

$$rate = \left| \frac{\Delta\,[M^{3+}]}{\Delta t} \right|$$

(i) Calculate the amount of iodine that reacted with the thiosulfate ions used in each experiment in **(a)**.

amount of I_2 = ... [1]

M25	

(ii) Calculate the amount of M^{3+} ions that was required to produce the amount of iodine in **(e)(i)**. Hence, calculate the rate of this reaction relative to [M^{3+}] for **Experiment 1** in **2(a)** when the blue-black colour first appears.

Amount of M^{3+} ions required = ...

rate of reaction = ... mol dm^{-3} s^{-1}

[4]

M26	M27	M28	M29

(f) The following steps represent a possible mechanism for the reaction shown in equation 1

step 1	$M^{3+} + I^-$	$\rightleftharpoons$	$[MI]^{2+}$	
step 2	$[MI]^{2+} + I^-$	$\rightarrow$	$M^{2+} + I_2^-$	(slow)
step 3	$M^{3+} + I_2^-$	$\rightarrow$	$M^{2+} + I_2$	

State which step is the rate–determining step. Hence, derive the rate law for this reaction.

....

....

....

.... [2]

M30	M31

[Total: 20]

3 Planning

A student suggested that the temperature at which Experiment 1 in **2(a)(i)** was carried out will also affect the rate of the reaction.

The activation energy, E_a, and the pre–exponential factor, A, which is a constant, can be determined from the equation.

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

T is the reaction temperature in Kelvin.
k' is the rate constant at a chosen temperature.

The procedure you followed for Experiment 1 in **2(a)(i)** can be modified and extended to investigate the effect of temperature, T, on the rate of the reaction between M^{3+} and I^-. The activation energy, E_a, and the pre–exponential factor, A, can be graphically determined.

Plotting ln k' against $\frac{1}{T}$ gives a straight line of best fit. The gradient of this line is $\frac{-E_a}{R}$, where R is the molar gas constant.

(a) Plan an investigation, based on Experiment 1 described in **2(a)(i)**, to determine the effect of temperature on the rate of reaction.

You may assume that you are provided with the same reagents as experiment in **2(a)(i)** as well as the equipment normally found in a school laboratory

In your plan, you should include brief details of

- the reactants and conditions that you would use,
- the apparatus that you would use **in addition** to that specified in Experiment 1 of **2(a)(i)**,
- the modification/ extension of procedure required in addition to the procedures spelt out in Experiment 1 of **2(a)(i)**
- the measurements that you would take and how you would determine the rate for each experiment.

....

....

....

....

....

....

....

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....

....

[4]

M32	M33	M34	M35

(b) Briefly describe how you would use results obtained from **3(a)** to determine all necessary values in order to plot a graph of ln k' against $\frac{1}{T}$.

You do not need to perform any of the calculations.

[2]

M36	M37

(c) Sketch the graph you would expect to obtain from **3(b)** on the axes in **Fig. 3.1.** Explain your answer.

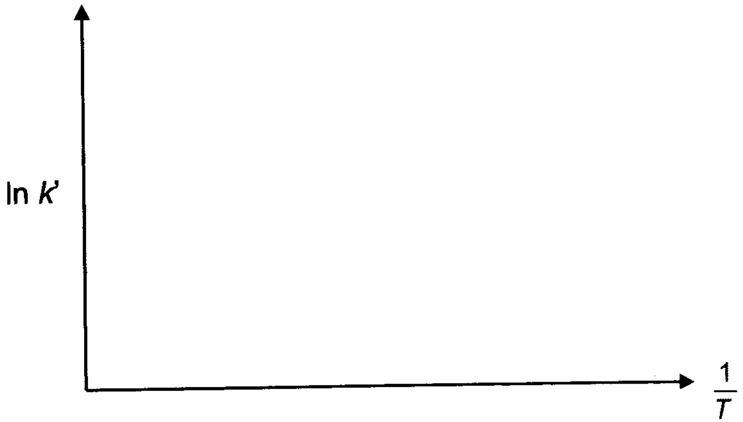

Fig. 3.1

explanation

[2]

M38	M39

(d) Describe how you would use your graph in **(c)** to determine values for E_a and A.

E_a

....

....

....

....

....

A

....

....

....

....

....

.... [2]

M40	M41

[Total: 10]

4 Investigation of some inorganic and organic reactions

In this question, you will be investigating some inorganic and organic reactions by carrying out the stipulated tests. Carefully record your observations in **Tables 4.1** and **4.2**.

Unless otherwise stated, the volumes given below are approximate and should be estimated rather than measured. Test and identify any gases evolved. If there is no observable change, write **no observable change**.

(a) Organic analysis

In this question, you will deduce the structure of an organic compound, **FA 8**.
FA 8 has the molecular formula $C_4H_8O_2$ with **two** functional groups present.

Do not carry out the tests for which observations have been recorded.

Do not use the Bunsen burner for heating in this part of the question. Instead, use the hot water provided.

Table 4.1

	tests	observations
(i)	Place about 2 cm depth of aqueous sulfuric acid in a test-tube. To this test–tube, add about 1 cm depth of **FA 8**, followed by 1 drop of aqueous potassium manganate(VII). Warm the mixture in the hot water bath for two minutes.	
(ii)	Add 1 cm depth of aqueous silver nitrate to a test-tube. Then slowly add 1 cm depth of aqueous sodium hydroxide. Add aqueous ammonia slowly, with shaking, until the precipitate just dissolves. To this mixture, add about 1 cm depth of **FA 8**. Place the test-tube containing the mixture in the hot water bath for one minute.	
(iii)	Place about 1 cm depth of **FA 8** in a test-tube. To this test-tube, add 2,4–dinitrophenylhydrazine dropwise.	Orange ppt. formed

	tests	observations
(iv)	Place about 1 cm depth of **FA 8** and add 8 drops of aqueous sodium hydroxide in a test–tube. Now add iodine solution dropwise, until a permanent yellow / orange colour is obtained. Warm the mixture in the hot water bath for two minutes.	
(v)	Place 1 cm depth of **FA 8** in a test-tube. To this test-tube, cautiously add a small piece of sodium metal.	Effervescence observed H_2 gas produced extinguishes a lighted splint with a "pop" sound.

[2]

M42	M43

(b) **(i)** Observations from **(a)(i)** to **(a)(iii)** can be used to identify one of the functional groups present in **FA 8**.

Identify the functional group and explain your answer, showing clearly your reasoning.

Functional group: ....

Explanation: ....

....

....

.... [1]

M44	

(ii) Using observations from **(a)(iv)** to **(a)(v)**, identify the other functional group present in **FA 8**.

Quote evidence from the relevant test to support your conclusion.

Functional group: ....

Evidence: ....

....

....

.... [1]

M45	

[Turn Over

(iii) Suggest a possible structure of **FA 8** that are consistent with all the observations in **Table 4.1**.

[1]

M46	

(c) **Inorganic analysis**

FA 9 is an aqueous solution that contains a mixture of salts with two cations and one anion listed in the Qualitative Analysis Notes. One of the cations is M^{3+} in **FA 5**.

You should indicate clearly at what stage in a test a change occurs. Test and identify any gases evolved. If there is no observable change, write **no observable change**.

At each stage of any test, you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

No additional tests for ions present should be attempted.

Table 4.2

	tests	observations
(i)	Test the **FA 9** solution using Universal Indicator paper.	
(ii)	To 2 cm depth of **FA 9**, add aqueous sodium hydroxide dropwise with shaking till the test-tube is half-filled. Swirl and filter the mixture, collecting the filtrate in a test-tube. The filtrate is **FA 10** which should be put to one side for use in **(iii) to (v)**.	

	tests	observations
(iii)	To 1 cm depth of **FA 10**, carefully add nitric acid dropwise until no further change is seen.	
(iv)	To 1 cm depth of **FA 10**, add 1 cm depth of nitric acid, followed by silver nitrate. Then add aqueous ammonia slowly, with shaking, until no further change is seen.	
(v)	To 1 cm depth of **FA 10**, add 1 cm depth of nitric acid, followed by barium nitrate.	

[3]

M47	M48	M49

(d) **(i)** Explain your observations in **(c)(i),** given that one of the cations present in **FA 9** is M^{3+}.

....

....

....

.... [1]

M50	

(ii) From your observations in **(c)**, suggest with evidence the identity of the anion present in **FA 10**.

Anion: ....

Evidence: ....

.... [1]

M51	

[Turn Over

(iii) Explain the observations in **(c)(iii)** when nitric acid was added to **FA 10**. Hence, suggest the identity of two possible cations that could be present in **FA 10**.

....

....

....

....

Cations: .... and .... [2]

M52	M53

(iv) Based on the cations that you have identified in **(d)(iii)**, devise a procedure to identify the cation in **FA 10**. Use a fresh sample of **FA 9** for this question and your tests should be based on the Qualitative Analysis Notes on pages 21–22 and should use only the bench reagents provided.

Record your tests and observations in the space below. Hence, state the identity of the cation in **FA 10**.

Any test requiring heating MUST be performed in a boiling tube.

[2]

M54	M55

[Total: 14]

Qualitative Analysis Notes

[ppt. = precipitate]

(a) Reactions of aqueous cations

cation	***reaction with***	
	NaOH(aq)	NH_3(aq)
aluminium, Al^{3+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH_4^+(aq)	ammonia produced on heating	
barium, Ba^{2+}(aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca^{2+}(aq)	white ppt. with high [Ca^{2+}(aq)]	no ppt.
chromium(III), Cr^{3+}(aq)	grey–green ppt. soluble in excess giving dark green solution	grey–green ppt. insoluble in excess
copper(II), Cu^{2+}(aq)	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe^{2+}(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^{3+}(aq)	red–brown ppt. insoluble in excess	red–brown ppt. insoluble in excess
magnesium, Mg^{2+}(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn^{2+}(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^{2+}(aq)	white ppt. soluble in excess	white ppt. soluble in excess

[Turn Over

(b) Reactions of anions

anion	*reaction*
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, Cl^-(aq)	gives white ppt. with Ag^+(aq) (soluble in NH_3(aq))
bromide, Br^-(aq)	gives pale cream ppt. with Ag^+(aq) (partially soluble in NH_3(aq))
iodide, I^-(aq)	gives yellow ppt. with Ag^+(aq) (insoluble in NH_3(aq))
nitrate, NO_3^-(aq)	NH_3 liberated on heating with OH^-(aq) and A*l* foil
nitrite, NO_2^-(aq)	NH_3 liberated on heating with OH^-(aq) and A*l* foil; NO liberated by dilute acids (colourless NO (pale) → brown NO_2 in air)
sulfate, SO_4^{2-}(aq)	gives white ppt. with Ba^{2+}(aq) (insoluble in excess dilute strong acid)
sulfite, SO_3^{2-}(aq)	SO_2 liberated with dilute acids; gives white ppt. with Ba^{2+}(aq) (soluble in dilute strong acid)

(c) Test for gases

gas	*tests and test result*
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	"pops" with a lighted splint
oxygen, O_2	relights a glowing splint
sulfur dioxide, SO_2	turns aqueous acidified potassium manganate(VII) from purple to colourless

(d) Colour of halogens

halogen	*colour of element*	*colour in aqueous solution*	*colour in hexane*
chlorine, Cl_2	greenish yellow gas	pale yellow	pale yellow
bromine, Br_2	reddish brown gas/liquid	orange	orange-red
iodine, I_2	black solid / purple gas	brown	purple