

TEMASEK JUNIOR COLLEGE
2022 JC2 PRELIMINARY EXAMINATION
Higher 2



CANDIDATE
NAME

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CIVICS GROUP

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Chemistry

9729/04

Paper 4 Practical

29 August 2022

2 hours 30 minutes

Candidates answer on the Question Paper.

READ THESE INSTRUCTIONS FIRST

Write your Civics Group and name on all the work you hand in.

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.

Shift
Laboratory

For Examiner's Use	
1	/ 12
2	/ 19
3	/ 14
4	/ 10
Total	/ 55

This document consists of **23** printed pages and **1** blank page.

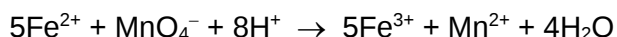
Answer **all** the questions in the spaces provided.

1 Determination of the percentage by mass of water of crystallisation in $\text{FeSO}_4 \cdot n\text{H}_2\text{O}$

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

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



In this experiment, you will determine the percentage by mass of water of crystallisation in $\text{FeSO}_4 \cdot n\text{H}_2\text{O}$. You will titrate a solution of **FA 1** against **FA 3**.

You are provided with

FA 1, contains 26.07 g dm^{-3} of hydrated iron(II) sulfate, $\text{FeSO}_4 \cdot n\text{H}_2\text{O}$, where n is an integer.

FA 2, 1.0 mol dm^{-3} dilute sulfuric acid, H_2SO_4

FA 3, $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4

You are to keep **FA 2** and **FA 3** for questions 2 and 3.

(a) (i) Titration of FA 1 against FA 3

1. Fill a burette, labelled **FA 3**, with **FA 3**.
2. Use a pipette to transfer 10.0 cm^3 of **FA 1** into a 250 cm^3 conical flask.
3. Use a measuring cylinder to add about 10 cm^3 of **FA 2** to this flask.
4. Titrate **FA 1** with **FA 3** from the burette until the appearance of the first permanent pale-pink colour.
5. Record your titration results, to an appropriate level of precision, in the space on **Page 3**.
6. Repeat steps 1 to 4 until consistent results are obtained.

Titration Results

[2]

- (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** =[3]

- (b) (i) Calculate the amount of Fe^{2+} in 10.0 cm^3 of **FA 1**.

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

- (ii) Calculate the amount of Fe^{2+} in 1 dm^3 of **FA 1**.

amount of Fe^{2+} in 1 dm^3 of **FA 1** = [1]

- (iii) Calculate the M_r of the hydrated iron(II) sulfate, $\text{FeSO}_4 \cdot n\text{H}_2\text{O}$, in **FA 1**.

M_r of the hydrated iron(II) sulfate =

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

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

n =

[2]

- (iv) Hence, determine the percentage by mass of water of crystallisation in $\text{FeSO}_4 \cdot n\text{H}_2\text{O}$.
Show your working.

Percentage by mass of water of crystallisation =

[1]

- (v) Iron(II) sulfate in solution is readily oxidised by air to form iron(III) sulfate.
State the effect, on the value of n calculated in (b)(iii), if some of your sample of **FA 1** had oxidised before you carried out the titration. Explain your answer.

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[2]

[Total: 12]

2 To investigate the reaction between manganate(VII) ions and $\text{C}_2\text{O}_4^{2-}$ ions

In this experiment, you will investigate the kinetics of the reaction between MnO_4^- and $\text{C}_2\text{O}_4^{2-}$.

FA 4 is $0.0100 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$

FA 5 is $0.200 \text{ mol dm}^{-3}$ sodium ethanedioate, $\text{Na}_2\text{C}_2\text{O}_4$

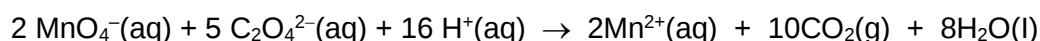
FA 6 is $0.100 \text{ mol dm}^{-3}$ potassium iodide, KI

FA 2 and **FA 3** are solutions from question 1.

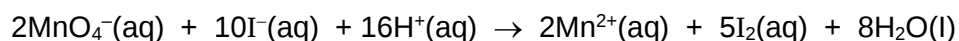
You are to keep **FA 5** for question 3.

You are also provided with a starch indicator.

Acidified potassium manganate(VII) ions oxidises $\text{C}_2\text{O}_4^{2-}$ ions to produce Mn^{2+} ions which act as an autocatalyst for the reaction.

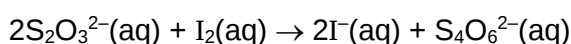


Acidified potassium manganate(VII) ions also oxidises I^- ions according to the following reaction:



You will add a solution of acidified potassium manganate(VII) to a mixture containing **FA 2** and **FA 5**. At timed intervals, you will draw 10 cm^3 aliquots of the reaction mixture. The concentration of MnO_4^- ions in each aliquot will be determined after adding the aliquot to an excess of I^- solution and titrating the iodine produced against $\text{S}_2\text{O}_3^{2-}$ solution.

The reaction between iodine from the reaction mixture and $\text{S}_2\text{O}_3^{2-}$ solution is given below.



Note: $\text{C}_2\text{O}_4^{2-}$ does not react with I^- in the reaction mixture.

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Question 2 continues on the next page.

Note: Read all instructions in the procedure before you start performing the experiment.

Recording your results

In an appropriate format in the space provided on **page 9**, draw a table to record your

- transfer time (in minutes and seconds, to the nearest second) when half of the reaction mixture has emptied from the pipette,
- the decimal time, t_d , in minutes, to 0.1 min, for example, if $t = 3 \text{ min } 20 \text{ s}$ then $t_d = 3 \text{ min} + 20/60 = 3.3 \text{ min}$,
- titration results for each of your aliquots. Make certain that your recorded results show the precision of your working.

Procedure

1. Label each of the large test-tubes **1** to **6**. Using a measuring cylinder, add approximately 10 cm^3 of **FA 6** to each of these test-tubes.
2. Using appropriate measuring cylinders, transfer 50.0 cm^3 of **FA 5**, 5.0 cm^3 of **FA 2** and 45.0 cm^3 of deionised water into a conical flask labelled **reaction mixture**.
3. Using an appropriate measuring cylinder, transfer 25.0 cm^3 of **FA 3** to the conical flask labelled **reaction mixture**. Start the stopwatch and swirl the mixture thoroughly to mix its contents.
4. At approximately 1 minute, use a 10 cm^3 pipette to remove a 10.0 cm^3 aliquot of the reaction mixture. **Immediately** transfer this aliquot into the test-tube labelled **1** and swirl the mixture. Note and record the transfer time (in minutes and seconds, to the nearest second) when half of the reaction mixture has emptied from the pipette.
5. At approximately 2 minutes, repeat step 4. Transfer this aliquot into the large test-tube labelled **2**.
6. Repeat step 4 four more times at about three minute intervals, transferring the aliquots into test-tubes labelled **3** to **6**.

Titration

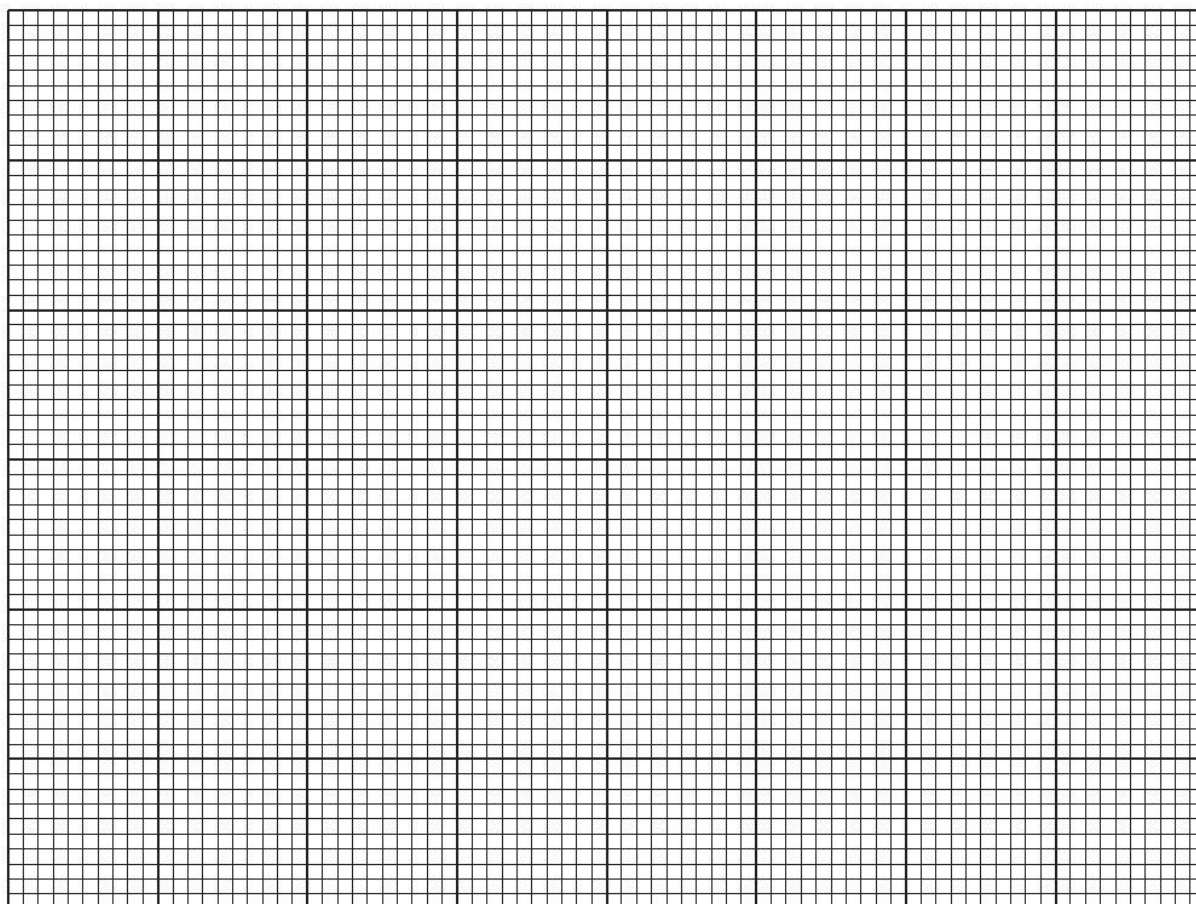
Note: You will only be able to perform each titration **once**. Be careful not to overshoot the end-point. Performing all of the titrations only after all the aliquots have been collected may affect time management.

7. Pour the contents of test-tube labelled **1** into a clean 250 cm^3 conical flask. Rinse the test-tube and add the washings to the conical flask.
8. Titrate the iodine in this solution with **FA 4**. When the colour of the solution turns pale yellow, add about 1 cm^3 of starch indicator. The solution will turn dark blue/black. The end-point is reached when the dark blue/black colour just disappears. Record your results.
9. Repeat steps **8** to **9** for each of the remaining test-tubes labelled **2** to **6**.

(a) Experimental results

[3]

- (b) (i)** On the grid in **Fig. 2.1**, plot a graph of **volume of sodium thiosulfate, FA 4**, on the y-axis, against time, t_d , on the x-axis. You should draw the most suitable line that takes into account all of your plotted points.

Fig. 2.1

[3]

- (ii) Consider the **shape** of the graph in **Fig. 2.1**.

Describe the shape and explain how it relates to the rate of reaction between MnO_4^- and $\text{C}_2\text{O}_4^{2-}$.

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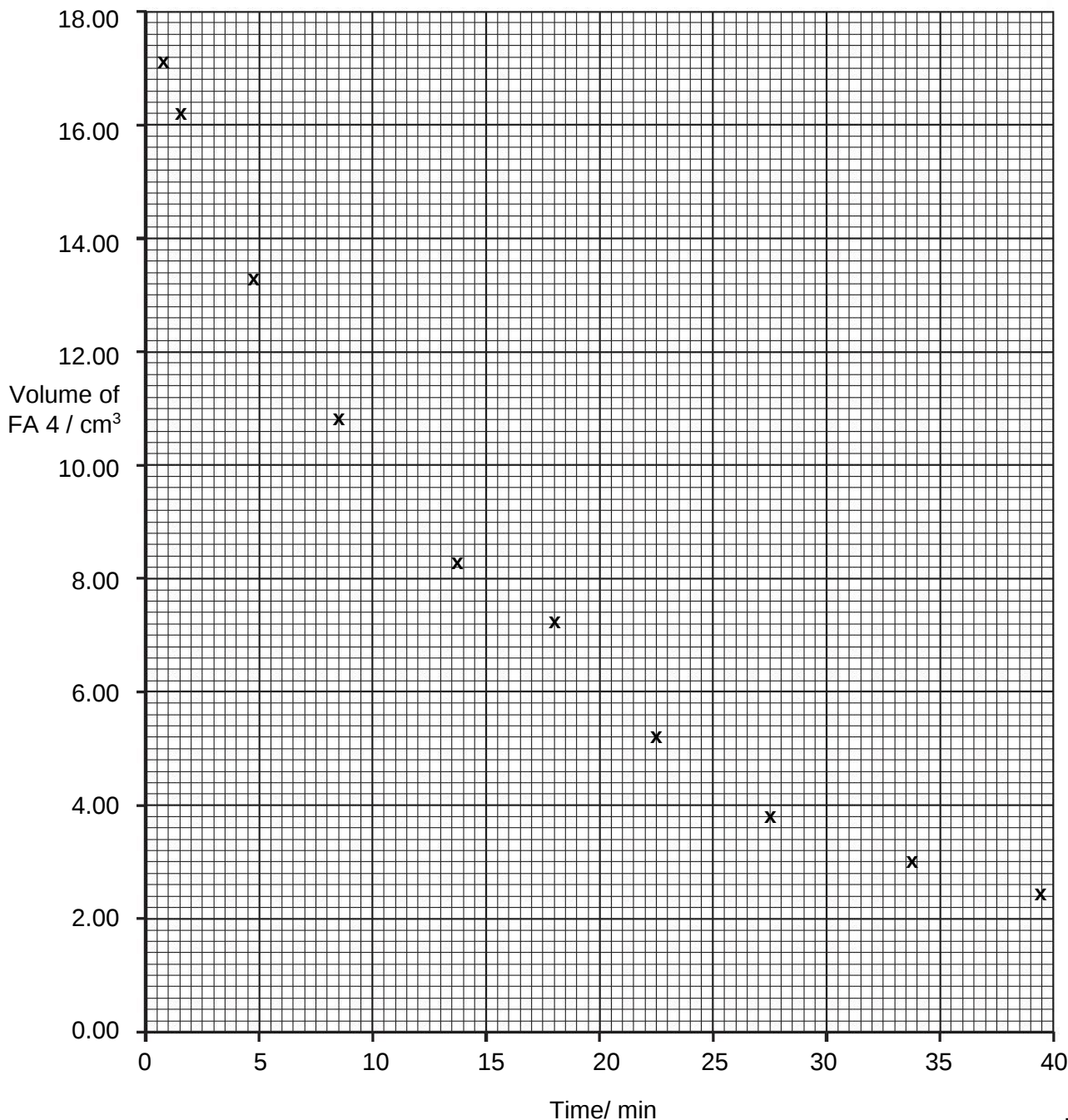
[1]

- (c) A student performed a similar experiment under a different temperature. In step 2 of the procedure on **page 8**, she used the same volumes of **FA 2** and **FA 5** that you used but she also added 5.0 cm³ of 1.00 mol dm⁻³ manganese(II) sulfate. To keep the total volume of the same as your experiment, she added 40.0 cm³ of deionised water.

The data from the student's experiment has been plotted in **Fig. 2.2**.

- (i) Draw the most appropriate line taking into account all of the plotted points.

Fig. 2.2



[1]

- (ii) Using the graph in (c)(i), calculate the $[\text{MnO}_4^-]$ in the reaction mixture at $t = 15$ min.

[2]

- (iii) Draw a tangent to your graph line in (c)(i) at $t = 15$ min. Calculate the gradient of this line, and hence determine the rate of change of the amount of $\text{S}_2\text{O}_3^{2-}$ ions required in mol min^{-1} .

[3]

- (iv) Using your answer in (c)(iii), calculate the rate of change of MnO_4^- in mol min^{-1} .

[1]

- (v) Hence, calculate the rate of disappearance of $[\text{MnO}_4^-]$ in the reaction mixture, at time $t = 15$ min.

[3]

- (d) Using the graph in (c)(i), show that the reaction between MnO_4^- and $\text{C}_2\text{O}_4^{2-}$ is first order with respect to $[\text{MnO}_4^-]$.

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[2]

[Total: 19]

3 To explore the chemistry of some compounds of unknown transition elements X and a hydrocarbon

FA 7 is a solid sample of a common dioxide of the unknown transition element **X**

FA 8 is a pure solution of compound **Y**, which is the product formed in **3(a)**

FA 9 is a hydrocarbon

You will need **FA 2**, **FA 3** and **FA 5** from question 1 and 2.

Perform the tests described in Table 3.1 and record your observations in the table. Test and identify any gases evolved. The observation in **(c)(iii)** has been completed for you, there is no need to carry out this test.

Table 3.1

tests		observations
(a)	Add 2 cm depth of FA 2 and 2 cm depth of FA 5 to a test-tube. Using a spatula, add FA 7 to the mixture in small portion with swirling until no further change. Filter the mixture into a test-tube. The filtrate contains compound Y. Divide the filtrate into two portions. To one portion, add aqueous sodium hydroxide until no further change. To the other portion, add aqueous ammonia until no further change.	
(b)(i)	Place 1 cm depth of FA 8 in a test-tube, add aqueous sodium hydroxide.	
(b)(ii)	Place 1 cm depth of FA 8 in a test-tube, add aqueous ammonia solution.	

(c)(i)	Place 5 cm depth of aqueous sodium hydroxide in a test-tube. Add 5 drops of FA 9 to this test-tube. Add FA 3, dropwise with shaking, until no further change is seen. Allow to stand for 5 minutes, with occasional shaking. Continue with the remaining parts of Question 3.	
(c)(ii)	Place 5 cm depth of FA 2 in a test-tube. Add 5 drops of FA 9 to this test-tube. Add FA 3, dropwise with shaking, until no further change is seen. Allow to stand for 5 minutes, with occasional shaking. Continue with the remaining parts of Question 3.	
(c)(iii)	Place 5 cm depth of water in a test-tube. Add 1 drop of FA 9 to this test-tube. Add bromine water, dropwise with shaking.	Bromine water decolourised.

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[6]

- (d) Consider your observations in (a) and (b), identify the transition ion formed in (a). Justify your choice by referring to the observations in (b).

Ion present is

Justification.....

.....

[1]

- (e) The anion in **FA 8** is not a nitrate, nitrite or carbonate ion.

You will devise and perform a series of simple tests to identify the anion present in **FA 8**.

Use the Qualitative Analysis Notes on pages 23-24 to deduce the possible anions in **FA 8** and describe **two different** tests, that will allow you to distinguish between the possible anions. You can only use the bench reagents provided.

Perform the tests described and record your observations in the space below. Hence, deduce the identity of the anion in **FA 8**.

Possible anions:

Identity of anion:

[3]

- (f) Compound **Z** is the main organic product in (c)(i) when **FA 9** reacts with **FA 3** under alkaline conditions. The molecular formula of **Z** is $C_6H_{12}O_2$.

- (i) Deduce the molecular formula of **FA 9**.

Explain your deduction. Your explanation should be supported by evidence from your observations in (c).

Molecular formula of **FA 9** is

Explanation:.....

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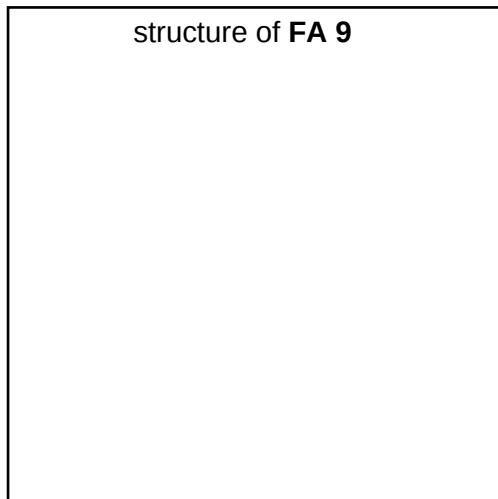
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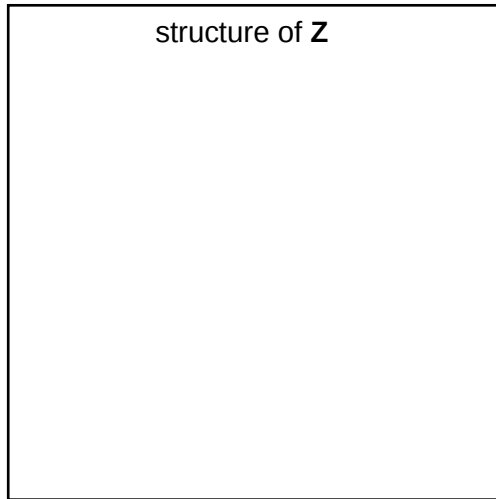
[2]

- (ii) Draw the structural formulae for **FA 9** and compound **Z**.

structure of **FA 9**



structure of **Z**

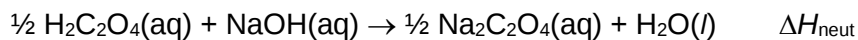


[2]

[Total:14]

4 Planning

You are to plan an experiment to determine the concentration of a solution of $\text{H}_2\text{C}_2\text{O}_4$ and the ΔH_{neut} between ethanedioic acid and sodium hydroxide.



You are provided with 2.00 mol dm^{-3} NaOH and a solution of $\text{H}_2\text{C}_2\text{O}_4$ of approximately the same concentration. A series of experiments can be carried out using different volumes of the two solutions. In each experiment, the total volume of the two solutions is to be kept at 50 cm^3 and the increase in temperature, ΔT , is determined.

A graph of ΔT against *volume of $\text{H}_2\text{C}_2\text{O}_4$* can then be used to determine the exact concentration of the $\text{H}_2\text{C}_2\text{O}_4$ solution and ΔH_{neut} .

- (a) Determine the volume of $\text{H}_2\text{C}_2\text{O}_4$ and of NaOH to be used such that both solutions will react completely. Show your working clearly and give your answers to the **nearest whole number**.

[1]

- (b) Plan a procedure to collect sufficient data to allow a graph of ΔT against *volume of $H_2C_2O_4$* to be drawn.

You are provided with:

- $2.00 \text{ mol dm}^{-3} \text{ NaOH}$,
- $H_2C_2O_4$ solution of approximately the same concentration,
- the equipment normally found in a school laboratory.

In your plan, you should include the following:

- the procedure, including the apparatus you would use
- a tabulation of the experimental data to be collected, including the volumes of $H_2C_2O_4$ and NaOH

You may assume that the $H_2C_2O_4$ and NaOH solutions have the same initial temperature.

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[4]

- (c) Using your answer in (a), sketch, on **Fig. 4.1**, the graph you would expect to obtain from the results.

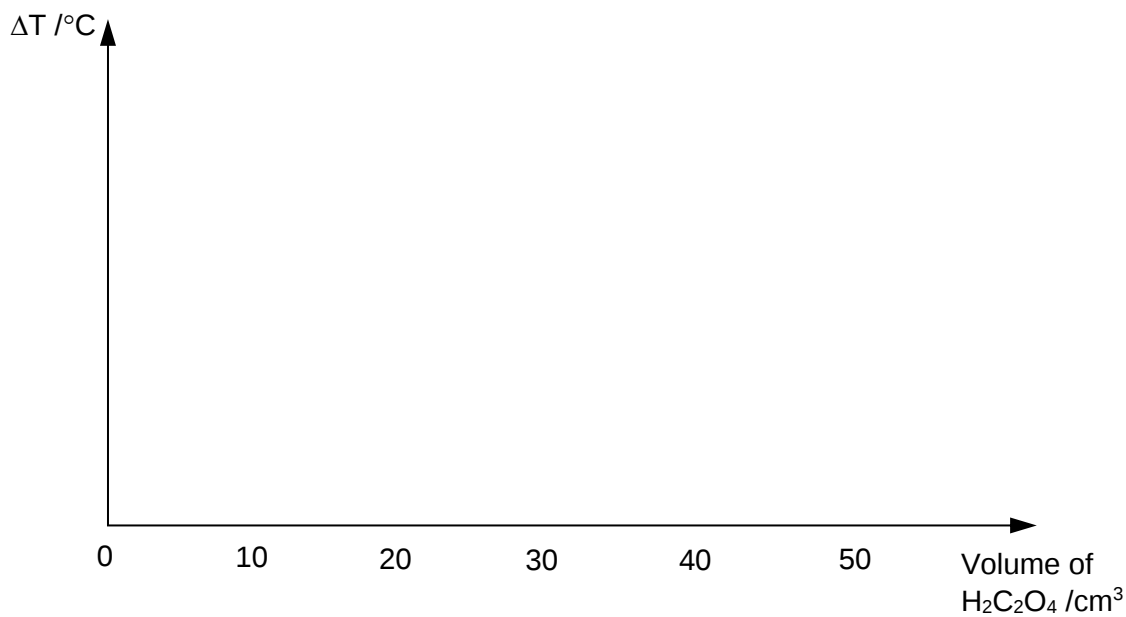


Fig. 4.1

[2]

- (d) Suggest a method to minimise heat lost to the surroundings to ensure the results obtained are accurate.

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[1]

(e) Another student conducted a similar experiment but used 1.00 mol dm^{-3} of NaOH instead. He obtained the following results:

- Volume of ethanedioic acid needed for complete neutralisation = 15 cm^3
- Maximum temperature change = 9.0°C

Calculate the concentration of the $\text{H}_2\text{C}_2\text{O}_4$ solution, in mol dm^{-3} and the ΔH_{neut} in kJ mol^{-1} .

You may assume the following:

- specific heat capacity of all solutions is $4.18 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1}$,
- density of all solutions is 1.00 g cm^{-3} .

[2]

[Total: 10]

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Qualitative Analysis Notes

[ppt. = precipitate]

(a) Reactions of aqueous cations

<i>cation</i>	<i>reaction with</i>	
	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

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(b) Reactions of aqueous anions

<i>anion</i>	<i>reaction</i>
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$)
bromide, $\text{Br}^-(\text{aq})$	gives pale cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$)
iodide, $\text{I}^-(\text{aq})$	gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$)
nitrate, $\text{NO}_3^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil; NO liberated by dilute acids (colourless NO $\rightarrow$ (pale) brown NO_2 in air)
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	SO_2 liberated with dilute acids; gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in dilute strong acids)

(c) Test for gases

<i>gas</i>	<i>test and test result</i>
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

<i>halogen</i>	<i>colour of element</i>	<i>colour in aqueous solution</i>	<i>colour in hexane</i>
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