

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

1 Identification of two cations and one anion

(a) **FA 1** and **FA 2** contain a different cation and the same anion.

The volumes given in Table 1.1 are approximate and should be estimated rather than measured.

Test any gas evolved during the tests.

If there is no observable change, write **no observable change**.

(i) Carry out the tests described in Table 1.1.

Carefully record your observations in Table 1.1.

Table 1.1

	test	observations with FA 1	observations with FA 2
1	Add 1 cm depth of the FA solution into a clean test-tube. Test the FA solution using Universal Indicator paper.		UI paper turns orange. pH is 2 / 3 / 4. ✓
2	Add 1 cm depth of the FA solution into a clean boiling tube. Add 1 cm depth of aqueous sodium hydroxide slowly, with shaking, until the aqueous sodium hydroxide is in excess.	Blue ppt $\text{Cu}(\text{OH})_2$ ✓ Insoluble in excess NaOH ✓	White ppt $\text{Al}(\text{OH})_3$ ✓ Soluble (dissolve) in excess NaOH to form a colourless solution $[\text{Al}(\text{OH})_3]^-$ ✓
	Gently warm the boiling tube.	Black / dark brown ppt CuO seen ✓	No observable change ✓
3	Add 1 cm depth of the FA solution into a clean test-tube. Add 1 cm depth of aqueous ammonia slowly, with shaking, until the aqueous ammonia is in excess.	Blue ppt $\text{Cu}(\text{OH})_2$ ✓ Soluble (dissolve) in excess NH_3 to form a dark blue solution $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ ✓	White ppt $\text{Al}(\text{OH})_3$ ✓ Insoluble in excess NH_3 ✓

4	Add 1 cm depth of the FA solution into a clean test-tube. Add a few drops of aqueous silver nitrate, then	White ppt AgCl formed ✓	White ppt AgCl formed ✓
	add aqueous ammonia to the mixture, with shaking, until the aqueous ammonia is in excess.	- Pale blue ppt formed Cu(OH)₂ - Completely soluble in excess to form a dark blue solution ✓ Cu(OH)₂(s) forms [Cu(NH₃)₄(H₂O)₂]²⁺(aq) and AgCl(s) forms [Ag(NH₃)₂]⁺(aq)	Ppt is partially soluble in excess. ✓ AgCl(s) forms [Ag(NH₃)₂]⁺(aq) and Al³⁺(aq) forms Al(OH)₃(s)

[7]

(b) (i) Complete Table 1.2 to identify the cations and anion in **FA 1** and **FA 2**.

Table 1.2

	FA 1	FA 2
cation present	Cu²⁺	Al³⁺
anion present	Cl⁻	

[3]

(ii) Explain which test was used to identify the anion.

Test⁴ of FA¹ was used to identify the anion.

In test 4, **AgCl** was formed which dissolved (completely soluble) in excess aq. **NH₃** to form **[Ag(NH₃)₂]⁺**

Evidence: [1]

(iii) Write an equation and explain the observation of **FA 2** in test 1.



[Al(H₂O)₆]³⁺(aq) undergoes partial / substantial hydrolysis to form **H⁺** ions, due to the high charge density / polarising power of the cation.

..... [2]

[Total: 13]

2 Determination of the kinetics of a clock reaction

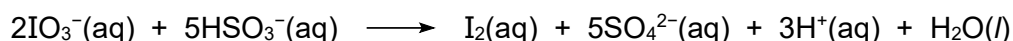
FA 3 is $0.100 \text{ mol dm}^{-3}$ potassium iodate(V), KIO_3 .

FA 4 is $0.0500 \text{ mol dm}^{-3}$ sodium hydrogensulfite, NaHSO_3 .

You are also provided with:

- **starch solution**
- deionised water.

Iodate(V) ions react with hydrogensulfite ions in aqueous solution according to the equation shown.



In this experiment, the rate of reaction is studied by measuring the time taken to form a fixed amount of iodine using a 'clock' method. In the presence of starch, a blue-black colour indicates the formation of iodine.

The reaction proceeds through several steps, so the blue-black colour does not appear immediately. You will vary the concentration of iodate(V) ions and measure the time, t , taken for the blue-black complex to appear.

You will perform a series of five experiments, in which the volume of **FA 3** is varied while the volume of **FA 4** is kept constant. In each experiment, you will adjust the volume of deionised water so that the total volume of the reaction mixture is 20.0 cm^3 .

Experiment 1

1. Use a teat pipette to add 10 drops of **starch solution** to a clean 100 cm^3 conical flask.
2. Use a 10 cm^3 measuring cylinder to measure 2.0 cm^3 of **FA 3** into the conical flask.
3. Use a 25 cm^3 measuring cylinder to add 16.0 cm^3 of deionised water into the same conical flask. Swirl gently to mix.
4. Use a second 10 cm^3 measuring cylinder to measure 2.0 cm^3 of **FA 4**.
5. Pour **FA 4** into the conical flask, starting the stopwatch during this addition.
6. Swirl the mixture thoroughly. Place the flask on a white tile.
7. Stop the stopwatch at the first appearance of a blue-black colour.
8. Record the time taken, t , to the nearest second, in your table.
9. Wash the conical flask thoroughly with tap water, then with deionised water. Stand it upside down on a paper towel to drain.

Record all volumes, the time taken and the calculated values of $1/t$, $\log(1/t)$ and $\log(V_{\text{FA3}})$ in the space provided on page 6.

Experiments 2 to 5

Repeat experiment 1 four times, using 4.0 cm³, 6.0 cm³, 8.0 cm³ and 10.0 cm³ of **FA 3** respectively in step 2.

In each experiment, you should adjust the volume of deionised water in step 3 to ensure that the total volume of reaction mixture is 20.0 cm³.

You should alternate the use of two 100 cm³ conical flasks.

(a) Results

Expt	$V_{\text{FA 3}} / \text{cm}^3$	$V_{\text{FA 4}} / \text{cm}^3$	$V_{\text{H}_2\text{O}} / \text{cm}^3$	t / s	$1/t / \text{s}^{-1}$	$\log(1/t)$	$\log(V_{\text{FA 3}})$
1	2.0	2.0	16.0	57	0.0175	-1.76	0.301
2	4.0	2.0	14.0	26	0.0385	-1.41	0.602
3	6.0	2.0	12.0	16	0.0625	-1.20	0.778
4	8.0	2.0	10.0	14	0.0714	-1.15	0.903
5	10.0	2.0	8.0	11	0.0909	-1.00	1.00

Examiner's Comments:

- Good answers ensured that:
 - there are correct headers and units, correct values of $V_{\text{H}_2\text{O}}$
 - all volumes recorded to 1 decimal place,
 - t values recorded to the nearest second
 - $\log(1/t)$ (all negative values), $1/t$ and $\log(V_{\text{FA 3}})$ calculated correctly to 3 s.f.

[5]

- (b) Plot a graph of $\log(1/t)$ on the y -axis against $\log(V_{FA3})$ on the x -axis for experiments 1 to 5 on the grid in Fig. 2.1.

Draw the best-fit straight line.

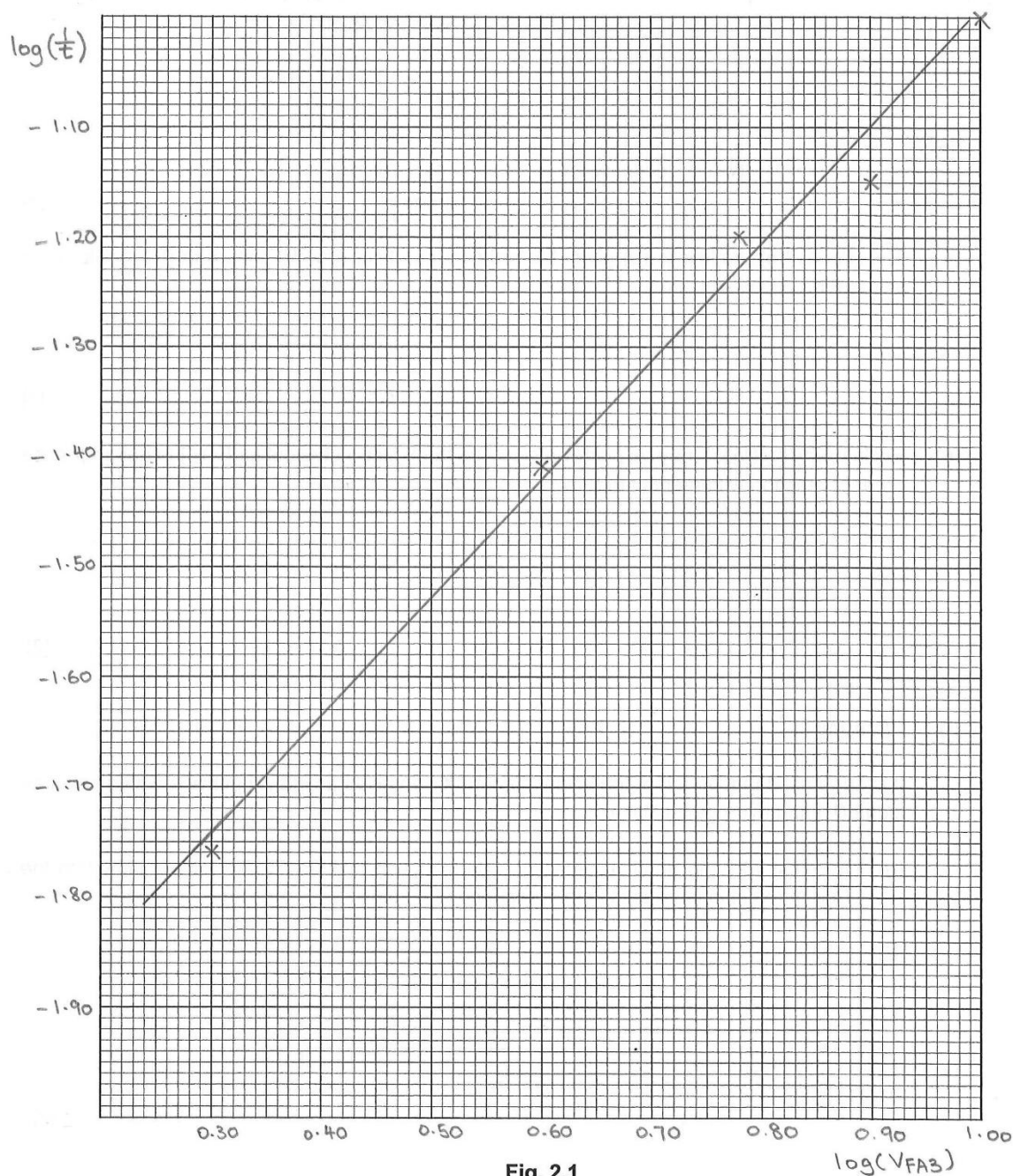


Fig. 2.1

[3]

- Good answers ensured that
 - There were correct axes + axes labels + units + appropriate scale
 - Scale is chosen so that plotted points occupy more than half the graph grid in both x and y directions.
 - All 5 points plotted correctly to within $\pm 1/2$ small square
- A best-fit straight line is drawn (with all points no more than 5 small squares away from the line)

- (c) Calculate the gradient of your best-fit line to three significant figures, showing clearly how you did this.

gradient =[1]

$$\text{Gradient} = \frac{-1.10 - (-1.70)}{0.9 - 0.34} = 1.07$$

- (d) The gradient of the line in (b) gives the order of reaction, n , with respect to $[\text{IO}_3^-]$. State the value of n .

$n = \dots\dots\dots$ [1]

$$n = 1$$

- (e) Explain why $\log(V_{\text{FA3}})$ may be plotted directly on the x -axis instead of $\log[\text{IO}_3^-]$ to determine the order of reaction with respect to $[\text{IO}_3^-]$. [2]

Since the total volume of the reaction mixture is kept constant in every experiment, $[\text{IO}_3^-]$ is directly proportional to V_{FA3} . Therefore the graph of $\log(1/t)$ against $\log(V_{\text{FA3}})$ has the same gradient as a graph of $\log(1/t)$ against $\log[\text{IO}_3^-]$.

(f) **Planning**

It is suggested that an ion of transition element **X** serves as a catalyst in the reaction between iodate(V) and hydrogensulfite ions.

- (i) Suggest why the reaction between iodate(V) and hydrogensulfite ions is slow and the rate of reaction increases in the presence of a catalyst. [2]

IO_3^- and HSO_3^- are both negatively charged ions and will experience repulsion, leading to a high activation energy for the reaction.

A catalyst will provide an alternative reaction pathway with lower activation energy, and increase the frequency of effective collisions.

- (ii) Plan an extension to the investigation in question 2 to determine if aqueous X^{n+} act as a catalyst. You should **not** carry out your plan.

You may assume you are provided with the following solution:

- $0.10 \text{ mol dm}^{-3} X^{n+}(\text{aq})$
- the solutions provided in question 2.

Your plan should include:

- one further experiment
- a table of volumes of solutions used
- how you would know if aqueous X^{n+} act as a catalyst in the clock reaction

You do **not** need to rewrite the method given.

..... [3]

Perform steps 1 to 9 in experiment 1, with the following change:

- For step 3, measure 14.0 cm^3 of deionised water and then 2.0 cm^3 of $X^{n+}(\text{aq})$ using a 25.0 cm^3 measuring cylinder, making sure that the **total volume of the reaction mixture is 20.0 cm^3** .

expt	$V_{\text{FA3}} / \text{cm}^3$	$V_{\text{FA4}} / \text{cm}^3$	$V_{\text{H}_2\text{O}} / \text{cm}^3$	$X^{n+}(\text{aq}) / \text{cm}^3$	t / s
1	2.0	2.0	16.0	0.0	57
1a	2.0	2.0	14.0	2.0	To be determined

To determine if X^{n+} catalyses the reaction, compare the time taken for the blue-black colour to form between expt 1 and 1a. **If expt 1a takes a shorter time for the blue black colour to form, X^{n+} is a catalyst**, if the time taken is similar, X^{n+} is not a catalyst.

[Total: 17]

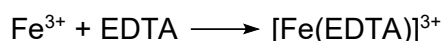
3 Analysis of the mass of iron in an iron tablet

Iron is an essential element in the human diet. Some people need to take iron supplement tablets to ensure an adequate intake of iron.

FA 5 is a solution prepared by dissolving 5 tablets in 1.00 dm³ of acidified hydrogen peroxide solution. The iron in each iron supplement tablet has the formula FeSO₄•7H₂O. As hydrogen peroxide is present in excess, Fe²⁺ is oxidised completely to Fe³⁺.

You will investigate the mass of iron in an iron supplement tablet by titrating **FA 5** with ethylenediaminetetraacetic acid (EDTA).

When titrated with EDTA, Fe³⁺ binds strongly to form a yellow – coloured complex.



There is no reaction between EDTA and hydrogen peroxide.

FA 6 is 0.010 mol dm⁻³ EDTA solution.

Solution S is salicylic acid indicator.

(a) (i) Procedure

1. Fill the burette with **FA 6**.
2. Pipette 10.0 cm³ of **FA 5** into a 100 cm³ conical flask.
3. Add 5 drops of **Solution S**.
4. Titrate the solution in the conical flask with **FA 6**. The end-point is reached when the solution turns from dark purple to pale yellow.
5. Record your titration results to an appropriate level of precision in the space on page 10.
6. Repeat steps 2 to 5 until consistent results are obtained.

Results

Final burette reading / cm ³	9.55	9.55
Initial burette reading / cm ³	0.00	0.00
Volume of FA6 / cm ³	9.55	9.55

[4]

- (ii) From your titrations, obtain a suitable volume of **FA 6** to be used in your calculations. Show clearly how you obtained this volume.

Volume of **FA 6** = [1]

$$\text{Average volume} = \frac{9.55 + 9.55}{2} = 9.55 \text{ cm}^3$$

- (b) (i) Calculate the amount of Fe^{3+} in 10.0 cm^3 of **FA 5**.

amount of Fe^{3+} in 10.0 cm^3 of **FA 5** = [1]

$$n(\text{EDTA}) = \frac{0.01}{1000} \times 9.55$$

$$\text{Fe}^{3+} \equiv \text{EDTA}$$

$$n(\text{Fe}^{3+}) = n(\text{EDTA})$$

$$= 9.55 \times 10^{-5} \text{ mol}$$

- (ii) Calculate the concentration of Fe^{3+} in **FA 5**.

concentration of **FA 5** = [1]

$$[\text{Fe}^{3+}] = \frac{9.55 \times 10^{-5}}{0.01} = 9.55 \times 10^{-3} \text{ mol dm}^{-3}$$

The manufacturer of the iron supplement tablets used to make **FA 5** claims that one tablet contains 100 mg of iron. Health authorities allow manufacturers to have a 20.0 % error in the percentage mass of iron in each tablet. [1 g = 1000 mg]

- (iii) Use your answer to (b)(ii) and the information given about **FA 5** to determine whether the mass of iron in one tablet falls within the acceptable margin of error. Show your working.

[Ar: Fe, 55.8]

..... [4]

Mass of Fe^{3+} = mass of Fe^{2+}

Mass of Fe^{2+} in one tablet = $55.8 \times 9.55 \times 10^{-3} \div 5 \times 10^3 = 106.58 \text{ mg}$

$$\% \text{ error} = \left| \frac{106.58 - 100}{100} \right| \times 100\% = 6.58 \%$$

Yes, it falls within acceptable margin.

- (c) Table 3.1 gives the colours of some manganese-containing ions and some of the substances you have used in (a)(i).

Table 3.1

species	colour
MnO_4^-	deep purple
Mn^{2+}	pale pink
H_2O_2	colourless

A student suggested that potassium manganate KMnO_4 can be used to replace hydrogen peroxide H_2O_2 in the preparation of **FA5**.

Use information from Table 3.1 to explain if KMnO_4 is a suitable replacement.

..... [1]

It is not suitable because deep purple colour of MnO_4^- that remains in excess will mask the pale yellow colour at end-point.

[Total: 12]

4 Planning

The basicity of an acid can be determined by the following procedure.

Solutions of two acids of unknown basicity are provided, one acid being monobasic and the other being dibasic. 40.0 cm³ of the acid solution, with a concentration of 0.035 mol dm⁻³ is reacted with excess solid magnesium carbonate and the gaseous carbon dioxide produced is collected. Comparing the relative volumes of carbon dioxide collected in the reaction with each acid allows the basicity of the acid to be determined.

- (a) (i) Determine the volume of carbon dioxide produced, when 40.0 cm³ solution of the dibasic acid of 0.035 mol dm⁻³ reacted with an excess of magnesium carbonate. Assume all measurements are made at room temperature and pressure.

[1]

$$n(\text{H}_2\text{A}) = \frac{3.5 \times 10^{-2}}{1000} \times 40 = 1.40 \times 10^{-3} \text{ mol}$$



$$n(\text{CO}_2) = 1.40 \times 10^{-3} \text{ mol}$$

$$V(\text{CO}_2) = 1.40 \times 10^{-3} \times 24000 = 33.6 \text{ cm}^3$$

- (ii) State how the volume of carbon dioxide collected would compare with that in (a)(i), if a monobasic acid of the same concentration and volume, were used.

Explain your answer.

..... [1]

The volume would be halved as there would be half the amount of H⁺ available for reaction.

- (iii) By considering your answer to (a)(i) and (a)(ii), determine the minimum mass of magnesium carbonate to be used, which would be present in excess in the reaction with both acids.

[A_r: C, 12.0; O, 16.0; Mg, 24.3]

[1]

$$n(\text{CO}_2) = n(\text{MgCO}_3) = 1.40 \times 10^{-3} \text{ mol}$$

$$\text{mass}(\text{MgCO}_3) = 1.40 \times 10^{-3} \times 84.3 = \mathbf{0.118 \text{ g}}$$

- (b) Plan an investigation to determine the basicity of the two acids, using 40.0 cm³ solution of each acid and excess solid magnesium carbonate.

You may assume you are provided with:

- 0.035 mol dm⁻³ acid solutions **A** and **B**, each containing either the monobasic or dibasic acid
- solid magnesium carbonate
- the equipment normally found in a school or college laboratory.

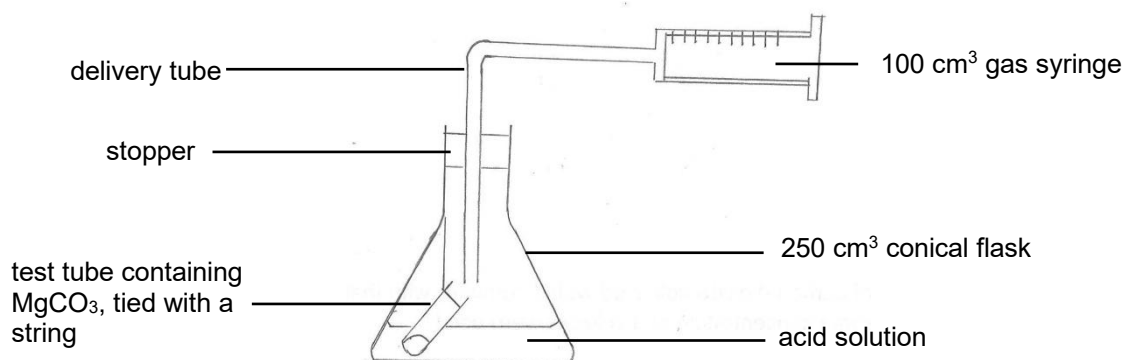
Your plan should include brief details of:

- the apparatus you would use
- the procedure you would follow
- the measurements you would take
- how you would ensure your results are accurate

You may include a suitable, labelled diagram in your plan.

..... [5]

[Total: 8]



1. Measure out 40 cm³ of acid solution using a 50 cm³ measuring cylinder.
2. Weigh the mass of MgCO₃ (as determined in (a)(iii)) in a test tube, using an electronic mass balance.
3. Set up the experiment layout as shown in the diagram above.
4. Take the initial reading of the gas syringe.
5. Swirl to mix reactants well and ensure reaction is complete.
6. Once effervescence has stopped and the volume of gas no longer changes, take the final reading on the gas syringe.

Note: an inverted burette over a water basin can be used in place of a gas syringe.

Apparatus:

- 50 cm³ measuring cylinder: for measuring acid solution
- Electronic mass balance: for measuring MgCO₃
- 100 cm³ gas syringe or burette: for collecting carbon dioxide gas

Procedure:

- Reactants are measured and introduced into the same vessel.
- Swirl to ensure good mix of reactants and that the reaction is complete

Measurements:

- Initial and final readings on measuring cylinder / burette

Accuracy:

- Ensure container is sealed and that reactants are separate before the reaction.
- Take final reading only when effervescence has stopped / the volume on the syringe is constant.

