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CHEMISTRY

9701/31

Paper 3 Advanced Practical Skills 1

May/June 2019

2 hours

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

Write your centre number, candidate number and name on all the work you hand in.
Give details of the practical session 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.
DO NOT WRITE IN ANY BARCODES.

Answer **all** questions.
Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.
Use of a Data Booklet is unnecessary.

Qualitative Analysis Notes are printed on pages 10 and 11.
A copy of the Periodic Table is printed on page 12.

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.

Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

This document consists of **12** printed pages.

Quantitative Analysis

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.

- 1 Metal carbonates react with acid to produce carbon dioxide. You will determine the identity of a Group 2 metal **M** in a carbonate of formula MCO_3 by reacting the carbonate with excess dilute hydrochloric acid and measuring the volume of carbon dioxide produced.



FA 1 is 50 cm³ of 4.00 mol dm⁻³ hydrochloric acid, HCl.

FA 2 is the metal carbonate, MCO_3 .

(a) Method

- Fill the tub with water to a depth of approximately 5 cm.
- Fill the 250 cm³ measuring cylinder **completely** with water. Hold a piece of paper towel firmly over the top, invert the measuring cylinder and place it in the water in the tub.
- Remove the paper towel and clamp the inverted measuring cylinder so the open end is in the water just above the base of the tub.
- Add all the **FA 1** into the flask labelled **X**.
- Check that the bung fits tightly into the neck of flask **X**, clamp flask **X** and place the end of the delivery tube into the inverted 250 cm³ measuring cylinder.
- Weigh the container with **FA 2** and record the mass.
- Remove the bung from the neck of the flask. Tip the **FA 2**, from the container, into the acid in the flask and replace the bung **immediately**. Remove the flask from the clamp and swirl it to mix the contents.
- Replace the flask in the clamp. Leave for several minutes, swirling the flask occasionally.

You may wish to start Question 2 while the gas is being evolved.

- When no more gas is collected, measure and record the final volume of gas in the measuring cylinder.
- Weigh the container, with any residual **FA 2**, and record the mass.
- Calculate and record the mass of **FA 2** added to flask **X**.

Results

[3]

(b) Calculations

- (i) Calculate the number of moles of carbon dioxide collected in the measuring cylinder.
[Assume that 1 mol of gas occupies 24.0 dm^3 under these conditions.]

moles of $\text{CO}_2 = \dots\dots\dots \text{ mol}$ [1]

- (ii) Use your answer to **(b)(i)** and the information on page 2 to calculate the relative atomic mass, A_r , of **M**.

A_r of **M** = $\dots\dots\dots$ [3]

- (iii) Use your answer to **(b)(ii)** to identify **M**.

M is $\dots\dots\dots$ [1]

- (c) (i) A student suggested that, using the same apparatus, the accuracy of the experiment would be increased if approximately 2g of MCO_3 were used to react with the excess hydrochloric acid.

State and explain whether the student was correct.

$\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$ [1]

- (ii) Another student suggested that the experiment would be more accurate if the carbon dioxide was collected in a gas syringe rather than over water.

State and explain whether the student was correct.

$\dots\dots\dots$
 $\dots\dots\dots$
 $\dots\dots\dots$ [1]

[Total: 10]

- 2 In **Question 1** you measured the volume of carbon dioxide produced by a metal carbonate, MCO_3 , in order to identify **M**. In **Question 2** you will identify another Group 2 metal, **Q**, by using a gravimetric method.

When Group 2 carbonates are heated they decompose.



FA 3 is the metal carbonate, QCO_3 .

(a) Method

- Weigh the crucible with its lid and record the mass.
- Add between 1.30 g and 1.50 g of **FA 3** into the crucible. Record the mass of crucible, lid and **FA 3**.
- Place the crucible on the pipe-clay triangle on the tripod. Put the lid on the crucible and heat gently for approximately 1 minute.
- Use tongs to remove the lid and heat the crucible strongly for approximately 5 minutes. Replace the lid and then leave to cool.
- While the crucible is cooling, begin work on **Question 3**.
- When cool, reweigh the crucible with its lid and contents. Record the mass.
- Calculate and record the mass of **FA 3** placed in the crucible.
- Calculate and record the mass of residue left after heating.

Keep the crucible and its contents for use in Question 3(b).

Results

I	
II	
III	
IV	

[4]

(b) Calculations

- (i) Calculate the number of moles of carbon dioxide produced during heating of **FA 3**.

moles CO_2 = ... mol [1]

- (ii) Use the mass of **FA 3** in (a) and your answer to (b)(i) to calculate the relative atomic mass, A_r , of **Q** and hence identify **Q**. You should assume complete decomposition of QCO_3 .

A_r of **Q** is

Q is

[4]

- (c) Explain why the lid was placed on the crucible when the residue was left to cool.

.....

..... [1]

(d) In order to decompose Group 2 carbonates, the solid must be heated strongly. In this experiment QCO_3 was heated for a few minutes.

- (i) Suggest an improvement to the method used that would ensure that decomposition was complete.

.....
 [1]

- (ii) Suggest a chemical test to determine whether the decomposition of QCO_3 was complete. State the expected observation if the decomposition was incomplete.

Do not carry out this test.

.....
 [1]

- (e) (i) In your calculation in (b) you used the mass of QCO_3 and assumed that it was all decomposed during the heating.

Explain what effect incomplete decomposition would have on the calculated value of the A_r of **Q**.

.....

 [1]

- (ii) A student suggested that you could use the mass of the residue, **QO**, rather than the mass of QCO_3 in a calculation to identify **Q**.

Explain why this method of calculating the A_r of **Q** is valid.

.....
 [1]

[Total: 14]

Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

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

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 (a) FA 4 and FA 5 are aqueous solutions each containing one anion and one cation.

- (i) Carry out the following tests and record your observations. For each test use a 1 cm depth of **FA 4** or **FA 5** in a test-tube.

test	observations	
	FA 4	FA 5
Add a 1 cm depth of dilute hydrochloric acid. Leave to stand.		
Add a 1 cm depth of aqueous copper(II) sulfate. Leave to stand.		
Add a few drops of aqueous silver nitrate, then		
add aqueous ammonia.		
Add a 1 cm depth of aqueous chlorine, then		
add a 1 cm depth of FA 5 .		

[5]

- (ii) From your observations in (a)(i) identify one of the ions present in either **FA 4** or **FA 5**.

Ion present in is [1]

- (iii) Apart from the reaction with **FA 5** suggest a test that could be used to identify the coloured product formed in the reaction between aqueous chlorine and **FA 4**. You should include the reagent used and the expected observation.

Do not carry out this test.

reagent

expected observation [1]

- (b) (i) Place the cooled crucible and residue from **Question 2** onto a heatproof mat and add approximately 5 cm³ of water.

Test the solution with litmus papers.
Record your observations.

.....

..... [1]

- (ii) Using **QO** as the formula of the residue, write the equation for the reaction with water that occurs in (b)(i). Include state symbols.

..... [1]

(c) In **Questions 1** and **2** you identified the Group 2 metals present in MCO_3 and QCO_3 .

You will now plan and carry out tests to confirm, or not confirm, the identities of **M** and **Q**. Both **M** and **Q** are listed in the Qualitative Analysis Notes.

- (i) Group 2 carbonates are insoluble in water. In order to test for the cations present (M^{2+} and Q^{2+}) they must be in solution.

Name a reagent you could use to prepare solutions of the cations from solid samples of MCO_3 and QCO_3 .

..... [1]

- (ii) You are provided with the following solutions.

FA 6 contains $\text{M}^{2+}(\text{aq})$.

FA 7 contains $\text{Q}^{2+}(\text{aq})$.

Choose reagents that could be used to confirm the identity of **M** and **Q**.
Carry out the tests. Record the tests, observations and conclusions.

[5]

- (iii) Do your conclusions confirm your identification of **M** and **Q** in **Questions 1** and **2**?
Explain your answer.

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

[Total: 16]

Qualitative Analysis Notes

1 Reactions of aqueous cations

<i>ion</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)	no ppt. ammonia produced on heating	—
barium, Ba ²⁺ (aq)	faint white ppt. is nearly always observed unless 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	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

2 Reactions of anions

<i>ion</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 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
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)

3 Tests 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

The Periodic Table of Elements

Group																																			
1	2	Key												13	14	15	16	17	18																
		atomic number atomic symbol name relative atomic mass												1 H hydrogen 1.0																					
3	Li lithium 6.9	4	Be beryllium 9.0																																
11	Na sodium 23.0	12	Mg magnesium 24.3																																
19	K potassium 39.1	20	Ca calcium 40.1	21	Sc scandium 45.0	22	Ti titanium 47.9	23	V vanadium 50.9	24	Cr chromium 52.0	25	Mn manganese 54.9	26	Fe iron 55.8	27	Co cobalt 58.9	28	Ni nickel 58.7	29	Cu copper 63.5	30	Zn zinc 65.4	31	Ga gallium 69.7	32	Ge germanium 72.6	33	As arsenic 74.9	34	Se selenium 79.0	35	Br bromine 79.9	36	Kr krypton 83.8
37	Rb rubidium 85.5	38	Sr strontium 87.6	39	Y yttrium 88.9	40	Zr zirconium 91.2	41	Nb niobium 92.9	42	Mo molybdenum 95.9	43	Tc technetium —	44	Ru ruthenium 101.1	45	Rh rhodium 102.9	46	Pd palladium 106.4	47	Ag silver 107.9	48	Cd cadmium 112.4	49	In indium 114.8	50	Sn tin 118.7	51	Sb antimony 121.8	52	Te tellurium 127.6	53	I iodine 126.9	54	Xe xenon 131.3
55	Cs caesium 132.9	56	Ba barium 137.3	57–71 lanthanoids		72	Hf hafnium 178.5	73	Ta tantalum 180.9	74	W tungsten 183.8	75	Re rhenium 186.2	76	Os osmium 190.2	77	Ir iridium 192.2	78	Pt platinum 195.1	79	Au gold 197.0	80	Hg mercury 200.6	81	Tl thallium 204.4	82	Pb lead 207.2	83	Bi bismuth 209.0	84	Po polonium —	85	At astatine —	86	Rn radon —
87	Fr francium —	88	Ra radium —	89–103 actinoids		104	Rf rutherfordium —	105	Db dubnium —	106	Sg seaborgium —	107	Bh bohrium —	108	Hs hassium —	109	Mt meitnerium —	110	Ds darmstadtium —	111	Rg roentgenium —	112	Cn copernicium —	114	Fl flerovium —	116	Lv livermorium —								

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9701/32

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1	
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Total	

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Quantitative Analysis

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- 1 Amidosulfonic acid is a monoprotic acid with the formula HSO_xNH_2 . In this experiment you will determine the value of x in the formula by titration with an alkali.

FB 1 is amidosulfonic acid, HSO_xNH_2 . You are supplied with approximately 3.0 g.

FB 2 is $0.110 \text{ mol dm}^{-3}$ sodium hydroxide, NaOH.

thymolphthalein indicator

(a) Method

Preparing a solution of amidosulfonic acid

- Weigh the empty beaker. Record the mass.
- Add 2.50–2.70 g of **FB 1** to the beaker. Weigh the beaker and its contents. Record the mass.
- Calculate and record the mass of **FB 1** used.
- Add approximately 100 cm^3 of distilled water to the beaker and stir to dissolve **FB 1**.
- Transfer the solution to the 250 cm^3 volumetric flask.
- Rinse the beaker twice with approximately 20 cm^3 of distilled water each time and add to the volumetric flask.
- Add distilled water to the volumetric flask to make 250 cm^3 of solution.
- Shake the volumetric flask to mix the solution thoroughly and label it **FB 3**.

Titration of **FB 3**

- Fill the burette with **FB 2**.
- Pipette 25.0 cm^3 of **FB 3** into a conical flask.
- Add a few drops of thymolphthalein to the conical flask.
- Carry out a **rough** titration.
- Record your burette readings and the rough titre in the space below.

The rough titre is cm^3 .

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record all of your burette readings and the volume of **FB 2** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

- (b) From your accurate titration results, obtain a suitable value for the volume of **FB 2** to be used in your calculations.
Show clearly how you obtained this value.

25.0 cm³ of **FB 3** required cm³ of **FB 2**. [1]

(c) **Calculations**

- (i) Give your answers to (ii), (iii), (iv) and (v) to the appropriate number of significant figures. [1]

- (ii) Calculate the number of moles of sodium hydroxide, NaOH, in the volume of **FB 2** calculated in (b).

moles of NaOH = ... mol [1]

- (iii) One mole of sodium hydroxide neutralises one mole of amidosulfonic acid.

Complete the equation for the reaction of amidosulfonic acid with sodium hydroxide.
Include state symbols.



State the number of moles of amidosulfonic acid that reacted with the number of moles of NaOH calculated in (ii).

moles of HSO_xNH₂ = ... mol [1]

- (iv) Use your results on page 2 and your answer to (iii) to calculate the relative formula mass, M_r , of amidosulfonic acid.

M_r of amidosulfonic acid = ... [1]

- (v) Calculate the value of x in the formula of amidosulfonic acid, HSO_xNH_2 .

x = ... [1]

- (d) The salts produced from amidosulfonic acid are called amidosulfonates.

You are to carry out an experiment using **FB 1** to find out if barium amidosulfonate is soluble in water.

- Describe your experiment.
- Record your observation(s) **and** conclusion.

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

[Total: 16]

Question 2 starts on the next page.

- 2 When hydrated copper hydroxycarbonate, $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2 \cdot y\text{H}_2\text{O}$ is heated, it decomposes as shown.



In this experiment, you will heat hydrated copper hydroxycarbonate to decompose it. You will use your results to investigate the value of y .

FB 4 is hydrated copper hydroxycarbonate, $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2 \cdot y\text{H}_2\text{O}$.

(a) Method

- Weigh the crucible with its lid and record the mass.
- Add all the **FB 4** from the container into the crucible.
- Weigh the crucible and lid with **FB 4** and record the mass.
- Place the crucible and contents on the pipe-clay triangle.
- Heat the crucible and contents gently for approximately two minutes with the lid on.
- Use tongs to remove the lid and heat strongly for approximately three minutes.
- Replace the lid and leave the crucible and residue to cool for several minutes.

While the crucible is cooling, you may wish to begin work on Question 3.

- When the crucible is cool, reweigh it with its lid and contents. Record the mass.
- Calculate and record the mass of **FB 4** and the mass of residue obtained.

Results

I	
II	
III	
IV	

State the observations made while the decomposition of **FB 4** was taking place.

.....

.....

[4]

(b) Calculations

- (i) Calculate the number of moles of copper oxide, CuO, obtained as residue.

moles of CuO obtained = ... mol [1]

- (ii) Use your results to calculate the relative formula mass, M_r , of hydrated copper hydroxycarbonate, $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2 \cdot y\text{H}_2\text{O}$.

M_r of $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2 \cdot y\text{H}_2\text{O}$ = ... [2]

- (iii) Use the Periodic Table to calculate the relative formula mass of $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$.

M_r of $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$ = ...

Use your answer to (ii) and this M_r to comment on the value of y in the formula of hydrated copper hydroxycarbonate.

.....
 [2]

- (c) State **one** way to improve the accuracy of the experiment, using the same mass of **FB 4**.

.....
 [1]

[Total: 10]

Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

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

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 (a) FB 5 contains one cation and one anion from those listed in the Qualitative Analysis Notes.

- (i) Transfer a **small** spatula measure of **FB 5** into a hard-glass test-tube. Heat gently at first and then heat strongly, until no further change occurs.

Record **all** your observations.

.....

.....

.....

.....

.....

..... [3]

- (ii) To a 1 cm depth of dilute hydrochloric acid in a test-tube, add a **small** spatula measure of **FB 5**.

Record your observations.

.....

.....

.....

..... [2]

- (iii) Deduce the formula of **FB 5**.

..... [1]

(b) **FB 6** is a solution of a compound containing one cation from those listed in the Qualitative Analysis Notes.

(i) Carry out the following tests using a 1 cm depth of **FB 6** in a test-tube for each test.

<i>test</i>	<i>observations</i>
Add two drops of Universal Indicator solution.	
Add an equal volume of aqueous manganese(II) chloride.	
Add an equal volume of dilute sulfuric acid.	
Add a few drops of aqueous silver nitrate, then	
add aqueous ammonia.	
Add a few drops of aqueous copper(II) sulfate, then	
add excess dilute hydrochloric acid.	

[4]

(ii) What can be determined about **FB 6** from its reaction with manganese(II) chloride?

..... [1]

(iii) Give the ionic equation for the reaction between **FB 6** and sulfuric acid. Include state symbols.

..... [1]

(iv) When aqueous copper(II) sulfate was added to **FB 6**, **two** precipitates were formed.

Deduce the identity of the two precipitates.

..... and

Explain the observation you made when you added excess dilute hydrochloric acid in the final test of (b)(i).

.....

[2]

[Total: 14]

Qualitative Analysis Notes

1 Reactions of aqueous cations

ion	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)	no ppt. ammonia produced on heating	—
barium, Ba ²⁺ (aq)	faint white ppt. is nearly always observed unless 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	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

2 Reactions of anions

<i>ion</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 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
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)

3 Tests 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

The Periodic Table of Elements

Group																									
1	2	Key												13	14	15	16	17	18						
		atomic number atomic symbol name relative atomic mass												1 H hydrogen 1.0											
3	4																								
Li lithium 6.9	Be beryllium 9.0																								
11	12																								
Na sodium 23.0	Mg magnesium 24.3																								
19	20																								
K potassium 39.1	Ca calcium 40.1																								
37	38																								
Rb rubidium 85.5	Sr strontium 87.6																								
55	56																								
Cs caesium 132.9	Ba barium 137.3																								
87	88																								
Fr francium —	Ra radium —																								

CANDIDATE
NAME

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CENTRE
NUMBER

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CANDIDATE
NUMBER

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CHEMISTRY

9701/33

Paper 3 Advanced Practical Skills 1

May/June 2019

2 hours

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

Write your centre number, candidate number and name on all the work you hand in.
Give details of the practical session 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.
DO NOT WRITE IN ANY BARCODES.

Answer **all** questions.
Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.
Use of a Data Booklet is unnecessary.

Qualitative Analysis Notes are printed on pages 14 and 15.
A copy of the Periodic Table is printed on page 16.

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.

Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

This document consists of **12** printed pages, **4** blank pages and **1** Insert.

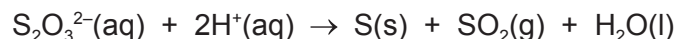


Quantitative Analysis

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.

- 1 The thiosulfate ion, $\text{S}_2\text{O}_3^{2-}$, reacts in acidic conditions as shown.



You will investigate how the concentration of the thiosulfate ions affects the rate of this reaction. The rate can be measured by timing how long it takes for the solid sulfur that is formed to make the solution too cloudy to see through.

Small amounts of SO_2 gas may be produced during this reaction. Care must be taken to avoid inhaling this SO_2 gas.

It is very important that as soon as each experiment is complete the beaker containing the reaction mixture is emptied into the quenching bath.

FA 1 is $0.100 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

FA 2 is 2.00 mol dm^{-3} hydrochloric acid, HCl .
distilled water

(a) Method

Experiment 1

- Fill the burette labelled **FA 1** with **FA 1**.
- Run 45.00 cm^3 of **FA 1** from the burette into the 100 cm^3 beaker.
- Use the measuring cylinder to measure 10.0 cm^3 of **FA 2**.
- Add the **FA 2** to the **FA 1** in the beaker and start timing immediately.
- Stir the mixture once and place the beaker on the printed insert.
- Look down through the solution in the beaker at the print on the insert.
- Stop timing as soon as the precipitate of sulfur makes the print on the insert **just** invisible.
- Record this reaction time to the nearest second in your results table.
- Empty the contents of the beaker into the quenching bath.
- Wash out the beaker thoroughly.
- Shake the beaker to remove any excess water.

Experiment 2

- Fill a second burette with distilled water.
- Refill the burette labelled **FA 1** with **FA 1**.
- Run 20.00 cm³ of **FA 1** into the 100 cm³ beaker.
- Run 25.00 cm³ of distilled water into the same beaker.
- Use the measuring cylinder to measure 10.0 cm³ of **FA 2**.
- Add the **FA 2** to the **FA 1** in the beaker and start timing immediately.
- Stir the mixture once and place the beaker on the printed insert.
- Look down through the solution in the beaker at the print on the insert.
- Stop timing as soon as the precipitate of sulfur makes the print on the insert **just** invisible.
- Record this reaction time to the nearest second in your results table.
- Empty the contents of the beaker into the quenching bath.
- Wash out the beaker thoroughly.
- Shake the beaker to remove any excess water.

Experiments 3–5

Carry out three further experiments to investigate how the reaction time changes with different volumes of **FA 1**.

Note that the combined volume of **FA 1** and distilled water must always be 45.00 cm³.

Do not use a volume of **FA 1** that is less than 20.00 cm³.

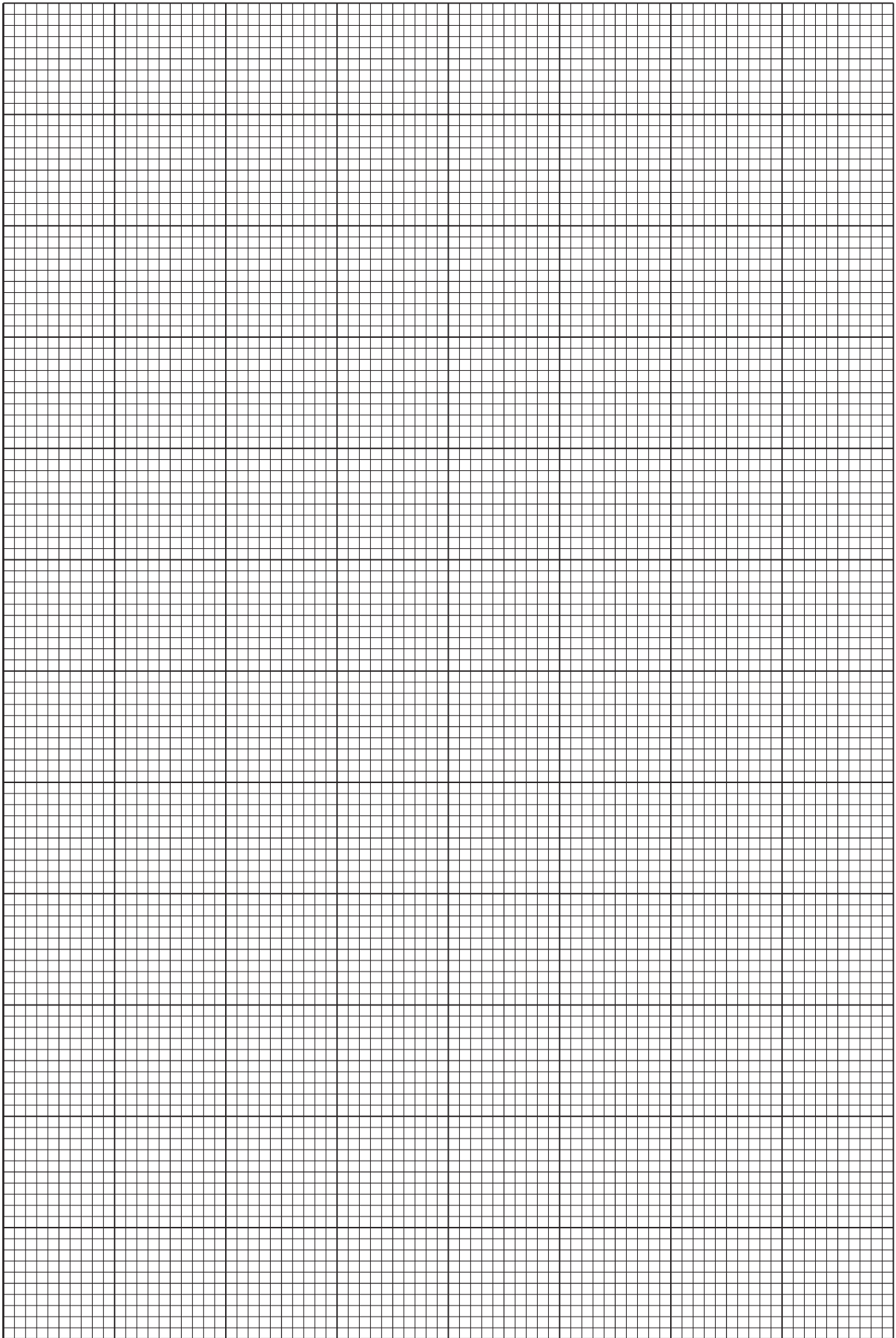
Record all your results in a table. You should include the volume of **FA 1**, the volume of distilled water, the reaction time and the reaction rate for each of your five experiments. The rate of reaction can be calculated using the following expression.

$$\text{rate} = \frac{500}{\text{reaction time}}$$

I	
II	
III	
IV	
V	
VI	
VII	
VIII	
IX	

[9]

- (b) On the grid, plot a graph of the rate (y-axis) against the volume of **FA 1** (x-axis). Label any anomalous points. Draw a line of best fit.



I	
II	
III	
IV	

[4]

- (c) In these experiments, the volume of **FA 1** is related to the concentration of the thiosulfate ions. From your graph state the relationship between the rate of reaction and the concentration of the thiosulfate ions.

.....
 [1]

- (d) Assume that the error in the time measured for each experiment was ± 2 s.

Calculate the minimum value for the reaction rate you observed in **Experiment 2**.
 Show your working.

minimum rate for **Experiment 2** = ... [2]

- (e) (i) A student suggested that, using a 250 cm³ beaker, the time recorded for **Experiment 1** would be the same.

Discuss whether the student is correct.

.....
 [1]

- (ii) A student carried out a further experiment using the same procedure as in (a). The student used 5.00 cm³ of **FA 1**, 40.00 cm³ of distilled water and 10.0 cm³ of **FA 2**.
 The print on the insert never became invisible.

Explain why.

.....
 [1]

[Total: 18]

- 2 In this experiment you will determine the enthalpy change of solution for hydrated sodium thiosulfate.

FA 3 is hydrated sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$.

(a) Method

- Support the plastic cup in the 250 cm^3 beaker.
- Rinse the measuring cylinder.
- Using the measuring cylinder, pour 25.0 cm^3 of distilled water into the plastic cup.
- Measure the temperature of the water in the cup.
- Weigh the container with **FA 3**.
- Add all the **FA 3** to the distilled water in the cup.
- Use the thermometer to stir the mixture gently until all the solid has dissolved.
- Measure the lowest temperature that is reached.
- Reweigh the container with any remaining **FA 3**.
- Record all your measurements.
- Calculate and record the mass of **FA 3** added and the change in temperature.

I	
II	
III	
IV	

[4]

- (b)** The enthalpy change of solution for **FA 3** is the enthalpy change when 1 mole of **FA 3** is dissolved in 1 dm^3 of solution.

- (i)** Calculate how many moles of **FA 3** were added to the water.

moles of **FA 3** = ... mol [1]

(iii) Calculate the enthalpy change of solution of **FA 3**.

enthalpy change of solution = ...
sign *value* *units*
[1]

- Suggest two other ways in which this experiment could be altered to give a more accurate value for the enthalpy change. Explain how each would improve the accuracy.

.....

.....

.....

.....

[2]

- Explain why the time was greater.

..... [1]

9701/33/M/J/19

Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

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

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

3 (a) FA 4 is an aqueous solution containing a single cation and a single anion.

The anion is either the sulfate ion, SO_4^{2-} , or the sulfite ion, SO_3^{2-} .

- (i) To an approximately 1 cm depth of **FA 4** in a test-tube, add aqueous sodium carbonate. Record your observations.

.....

 [2]

- (ii) Select reagents to identify the anion present in **FA 4**.
 Carry out a test with these reagents and record your observations.

reagents
 observations

 [2]

- (iii) Identify **FA 4**.

The formula of **FA 4** is [1]

- (b) (i) **FA 5** contains one cation and two anions. Two of these ions are listed in the Qualitative Analysis Notes.
Carry out the following tests and record your observations.

<i>test</i>	<i>observations</i>
Add a small spatula measure of FA 5 to a hard-glass test-tube. Heat the sample gently at first and then more strongly.	
Pour a 4 cm depth of dilute sulfuric acid into a boiling tube. Carefully add the remaining FA 5 . Leave to stand until the reaction is complete. The solution produced is FA 6 . Keep FA 6 for use in the following tests.	
To a 1 cm depth of FA 6 in a test-tube add aqueous sodium hydroxide.	
To a 1 cm depth of FA 6 in a test-tube add aqueous ammonia.	

[5]

- (ii) State the type of reaction observed when **FA 5** was heated.

..... [1]

- (iii) Give the formula of the cation and one of the anions present in **FA 5**.

cation: anion: [1]

[Total: 12]

Qualitative Analysis Notes

1 Reactions of aqueous cations

ion	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)	no ppt. ammonia produced on heating	—
barium, Ba ²⁺ (aq)	faint white ppt. is nearly always observed unless 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	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

2 Reactions of anions

<i>ion</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 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
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)

3 Tests 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

The Periodic Table of Elements

Group																											
1	2	Key												13	14	15	16	17	18								
		atomic number atomic symbol name relative atomic mass												1 H hydrogen 1.0													
3	4																										
Li lithium 6.9	Be beryllium 9.0																										
11	12																										
Na sodium 23.0	Mg magnesium 24.3																										
19	20																										
K potassium 39.1	Ca calcium 40.1																										
37	38																										
Rb rubidium 85.5	Sr strontium 87.6																										
55	56																										
Cs caesium 132.9	Ba barium 137.3																										
87	88																										
Fr francium —	Ra radium —																										

CANDIDATE
NAME

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CHEMISTRY

9701/34

Paper 3 Advanced Practical Skills 2

May/June 2019

2 hours

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

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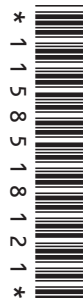
Qualitative Analysis Notes are printed on pages 10 and 11.
A copy of the Periodic Table is printed on page 12.

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.

Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

This document consists of **12** printed pages.



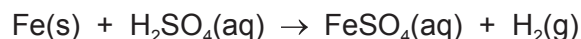
Quantitative Analysis

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

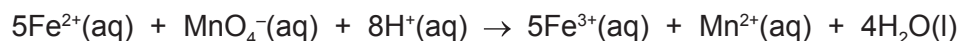
Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

- 1** Iron wire contains impurities. You will investigate the percentage by mass of iron in a sample of iron wire.

A sample of iron wire is reacted with an excess of sulfuric acid to produce a solution of iron(II) sulfate.



You will titrate the solution of iron(II) sulfate with potassium manganate(VII) of known concentration to determine the amount of iron(II) ions present and hence the percentage by mass of iron in the wire. You may assume the impurities do not form any products that react with potassium manganate(VII).



FB 1 is 0.0200 mol dm⁻³ potassium manganate(VII), KMnO₄.

FB 2 is a solution of FeSO₄ prepared by reacting 6.02 g of iron wire with sulfuric acid to make 1 dm³ of solution.

FB 3 is dilute sulfuric acid, H₂SO₄.

(a) Method

- Fill a burette with **FB 1**.
- Pipette 25.0 cm³ of **FB 2** into a conical flask.
- Use the measuring cylinder to transfer 25 cm³ of **FB 3** into the conical flask.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm³.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make certain that any recorded results show the precision of your practical work.
- Record all of your burette readings and the volume of **FB 1** added in each accurate titration.

Keep **FB 3** for use in Question 2.

Results

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your accurate titration results, obtain a suitable value for the volume of **FB 1** to be used in your calculations. Show clearly how you obtained this value.

25.0 cm³ of **FB 2** required cm³ of **FB 1**. [1]

- (c) (i) Give your answers to (ii), (iii), (iv) and (v) to the appropriate number of significant figures. [1]

- (ii) Use your answer to (b) to calculate the number of moles of potassium manganate(VII), **FB 1**, which reacted with 25.0 cm³ of **FB 2**.

moles of MnO₄⁻ = ... mol [1]

- (iii) Use the information on page 2 to calculate the number of moles of iron(II) ions present in 25.0 cm³ of **FB 2**.

moles of Fe²⁺ = ... mol [1]

- (iv) Calculate the mass of iron present in 25.0 cm³ of **FB 2**.

mass of Fe = ... g [1]

- (v) Calculate the percentage by mass of iron in the sample of iron wire.

percentage by mass of iron in iron wire = ... % [1]

- (d) A student suggested that when a piece of iron wire was dissolved in a known volume and concentration of sulfuric acid, the number of moles of iron that reacted with the acid could be determined by working out how much acid was left after the reaction. The amount of excess acid could be determined by titrating the mixture with a known concentration of sodium hydroxide.

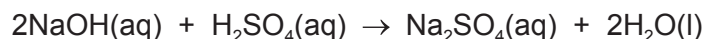
Explain whether the student was correct.

.....

 [1]

[Total: 14]

- 2 In **Question 1** you used dilute sulfuric acid, **FB 3**. You will now determine the concentration of **FB 3** by measuring the temperature of its reaction with sodium hydroxide.



FB 4 is 0.90 mol dm^{-3} sodium hydroxide, NaOH.

(a) Method

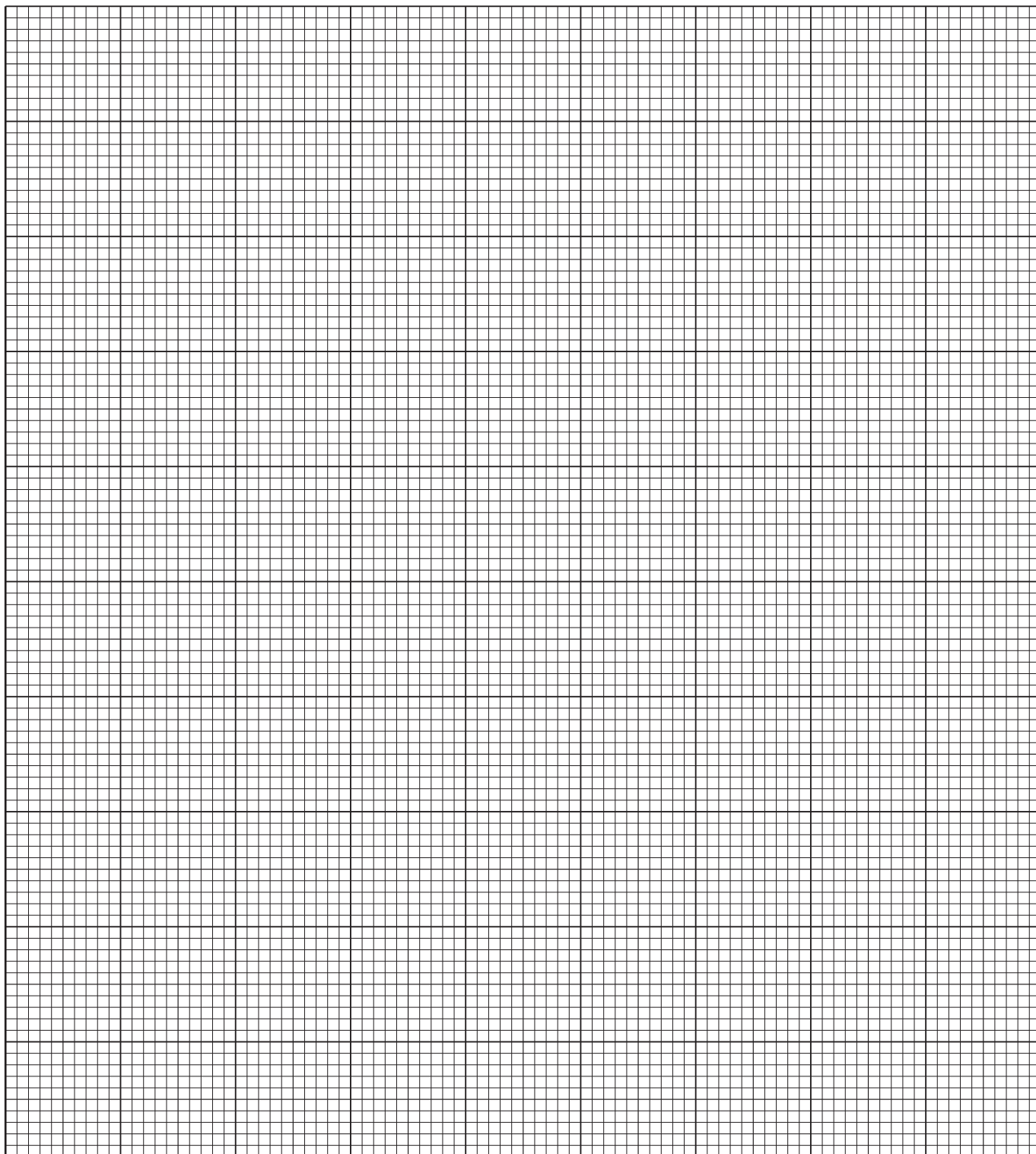
- Fill the second burette with **FB 4**.
- Support the plastic cup in the 250 cm^3 beaker.
- Pipette 10.0 cm^3 of **FB 3** into the plastic cup.
- Place the thermometer into the **FB 3**. Tilt the cup so that the bulb of the thermometer is surrounded by solution. Record the temperature in the table below. This is the temperature of the solution before any **FB 4** has been added.
- Add 5.00 cm^3 of **FB 4** from the burette to the **FB 3** in the plastic cup. Stir the mixture and record the temperature reached. Record the volume of **FB 4** added.
- Add a second 5.00 cm^3 portion of **FB 4** to the plastic cup, stir the mixture and record the temperature reached. Record the total volume of **FB 4** added.
- Continue adding 5.00 cm^3 portions of **FB 4** until 40.00 cm^3 have been added. After each addition, stir and record the temperature reached and total volume of **FB 4** added.

Results

total volume of FB 4 added / cm^3	temperature of solution / $^{\circ}\text{C}$

[3]

- (b)** Plot a graph of temperature of solution on the y-axis against total volume of **FB 4** added on the x-axis. Select a scale on the y-axis to include a temperature of 2.0°C above your maximum thermometer reading. Label any points you consider to be anomalous. You will use the graph to find the volume of **FB 4** needed to neutralise 10.0 cm^3 of **FB 3**.



I	
II	
III	
IV	

Draw two lines of best fit through the points on your graph, the first for the increase in temperature and the second for the decrease in temperature of the mixtures. Extrapolate the two lines so they intersect and hence determine the volume of **FB 4** required to neutralise 10.0 cm³ of **FB 3**.

volume of **FB 4** = ... cm³
[4]

- (c) (i) Use your answer to (b) to calculate the number of moles of sodium hydroxide required to neutralise 10.0 cm^3 of **FB 3**.

moles of NaOH = ... mol [1]

- (ii) Calculate the number of moles of sulfuric acid present in 10.0 cm^3 of **FB 3**.

moles of H_2SO_4 = ... mol

Hence calculate the concentration, in mol dm^{-3} , of sulfuric acid in **FB 3**.

concentration of H_2SO_4 in **FB 3** = ... mol dm^{-3}
[1]

- (d) Explain how you would use the data obtained in **Question 2** to calculate the enthalpy change of neutralisation of the sulfuric acid. You do not need to carry out the calculation.

.....
.....
.....
..... [3]

[Total: 12]

Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

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

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

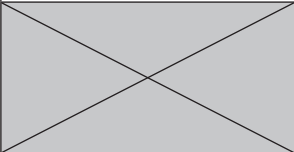
No additional tests for ions present should be attempted.

3 (a) **FB 5** is a solution of a sodium salt of an organic acid.

FB 6 and **FB 7** each contain one cation and one anion from those listed in the Qualitative Analysis Notes.

Carry out the following tests and record your observations.

Use a separate 1 cm depth of each solution in a test-tube for each test.

<i>test</i>	<i>observations</i>		
	FB 5	FB 6	FB 7
Add 2 or 3 drops of acidified potassium manganate(VII).			
If there is no visible change, pour into a boiling tube and warm gently.			
Add a 1 cm depth of dilute nitric acid, then			
add 2 or 3 drops of aqueous silver nitrate.			
Add a 1 cm depth of dilute hydrochloric acid, then			
add a 1 cm depth of aqueous barium nitrate or aqueous barium chloride.			
Add a 1 cm depth of FB 5 and leave to stand for a few minutes.			

[7]

- (b) (i)** Select reagents for two further tests to help identify the cations present in **FB 6** and **FB 7**.

Record in a suitable form below the reagents you use and your observations.

[4]

- (ii)** Use your observations to identify as many ions as possible. Give the formula of the ion present. Write 'unknown' if you were unable to identify an ion.

	FB 6	FB 7
cation		
anion		

[2]

- (iii)** Write an ionic equation for any precipitation reaction observed involving **FB 7**. Include state symbols.

..... [1]

[Total: 14]

Qualitative Analysis Notes

1 Reactions of aqueous cations

ion	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)	no ppt. ammonia produced on heating	—
barium, Ba ²⁺ (aq)	faint white ppt. is nearly always observed unless 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	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

2 Reactions of anions

<i>ion</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 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
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)

3 Tests 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

The Periodic Table of Elements

Group																	
1	2	Key														17	18
		atomic number atomic symbol name relative atomic mass												1 H hydrogen 1.0			
3	4	5	6	7	8	9	10	11	12								
Li lithium 6.9	Be beryllium 9.0																
11	12																
Na sodium 23.0	Mg magnesium 24.3														6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0
																	9 F fluorine 19.0
																	10 Ne neon 20.2
						</											

CANDIDATE
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CANDIDATE
NUMBER

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CHEMISTRY

9701/35

Paper 3 Advanced Practical Skills 1

May/June 2019

2 hours

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

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DO NOT WRITE IN ANY BARCODES.

Answer **all** questions.
Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.
Use of a Data Booklet is unnecessary.

Qualitative Analysis Notes are printed on pages 10 and 11.
A copy of the Periodic Table is printed on page 12.

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.

Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

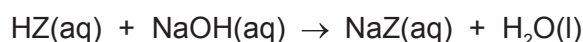
This document consists of **12** printed pages.

Quantitative Analysis

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.

- 1 The reaction between acids and alkalis is exothermic. You will find the concentration of a monoprotic acid, HZ, by a thermometric method using a solution of sodium hydroxide of known concentration.



FA 1 is a solution of acid HZ.

FA 2 is 2.00 mol dm^{-3} sodium hydroxide, NaOH.

(a) Method

- Place the thermometer into **FA 1**. Record the temperature of **FA 1** in the table. This is the temperature when the volume of **FA 2** is 0.0.
- Rinse and dry the thermometer.
- Place the thermometer into **FA 2**. Record the temperature of **FA 2** in the table. This is the temperature when the volume of **FA 1** is 0.0.
- Fill a burette with **FA 1**.
- Support the plastic cup in the 250 cm^3 beaker.
- From the burette transfer 35.0 cm^3 of **FA 1** into the plastic cup.
- Use the 50 cm^3 measuring cylinder to measure 5.0 cm^3 of **FA 2**.
- Transfer the 5.0 cm^3 of **FA 2** into the plastic cup. Stir the mixture and record the highest temperature.
- Tip out the solution, rinse the plastic cup with water, shake it to remove excess water and replace the cup in the beaker.
- Rinse and dry the thermometer.
- Use the burette to transfer 30.0 cm^3 of **FA 1** into the plastic cup.
- Use the measuring cylinder to transfer 10.0 cm^3 of **FA 2** into the plastic cup.
- Stir the mixture and record the highest temperature.
- Tip out the solution, rinse the plastic cup with water, shake it to remove excess water and replace the cup in the beaker.
- Rinse and dry the thermometer.
- Continue the experiment using the volumes of **FA 1** and **FA 2** given in the table and record the maximum temperature of each mixture.

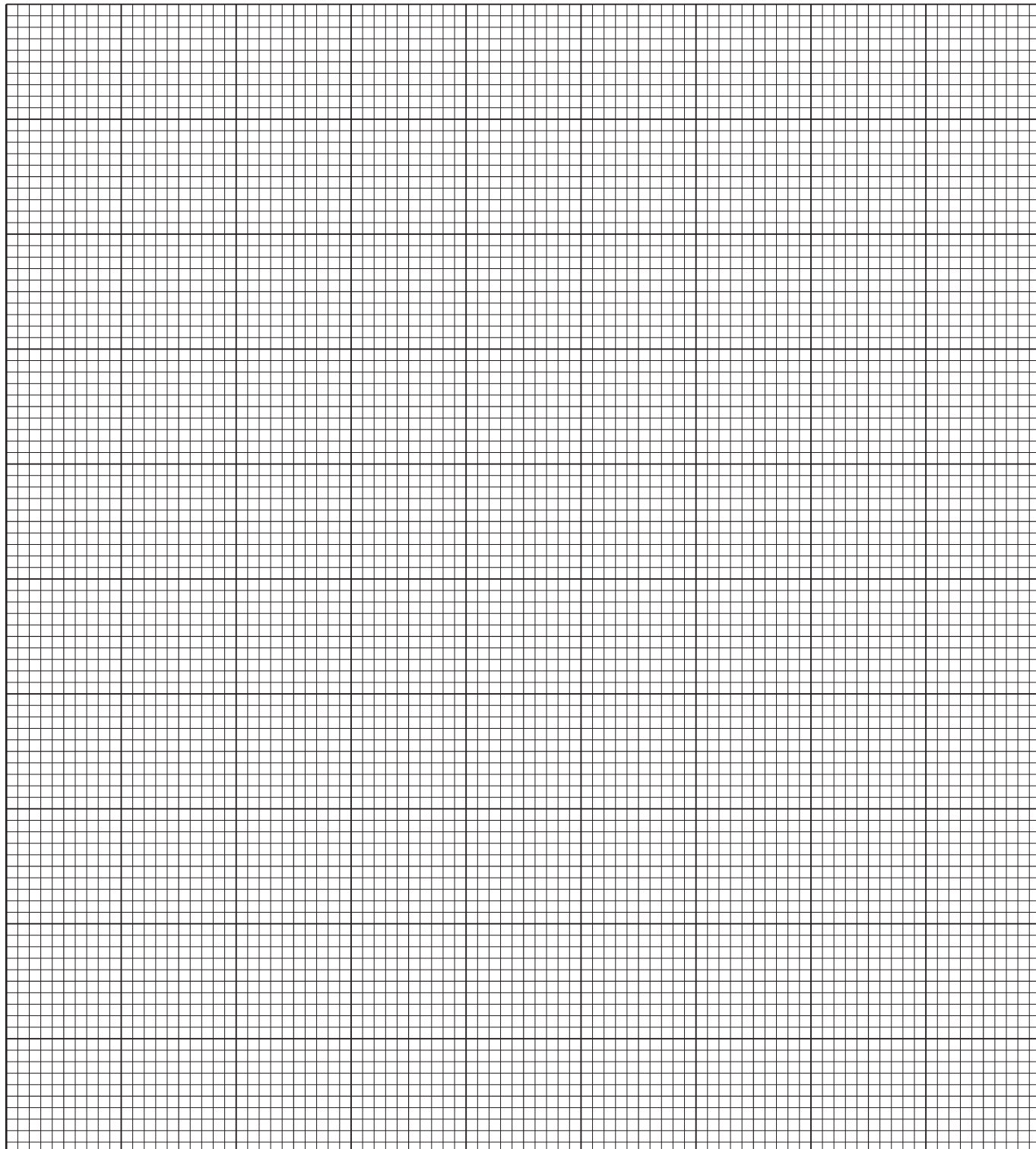
volume FA 1 / cm^3	40.0	35.0	30.0	25.0	20.0	15.0	10.0	5.0	0.0
volume FA 2 / cm^3	0.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0
temperature / $^{\circ}\text{C}$									

[3]

Keep FA 1 for use in Question 2.

- (b) (i) Plot a graph of temperature of solution (y -axis) against volume of **FA 2** added (x -axis) on the grid. Select a scale on the y -axis to include a temperature of 2°C above your maximum thermometer reading. Label any points you consider anomalous.

Draw two lines of best fit through the points on your graph, the first for the increase in temperature and the second for the decrease in temperature of the mixtures. Extrapolate the two lines so they intersect. [3]



I	
II	
III	

- (ii) The intersection on your graph occurs at the volume of **FA 2** that reacted to form a neutral solution.

Determine the volumes of **FA 1** and **FA 2** required to form a neutral solution.

..... cm³ of **FA 1** neutralises cm³ of **FA 2**.
[1]

- (c) (i) Calculate the number of moles of sodium hydroxide, **FA 2**, required to obtain a neutral solution in this experiment.

moles of NaOH = ... mol [1]

- (ii) Hence calculate the concentration of HZ in **FA 1**.

concentration of HZ = ... mol dm⁻³ [1]

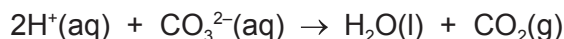
- (d) Explain how you would use the data obtained to calculate the enthalpy change of neutralisation of HZ. You do not need to carry out the calculation.

.....

 [3]

[Total: 12]

- 2 You will now determine the concentration of HZ in **FA 1** by titration using aqueous sodium carbonate of known concentration.



FA 3 is $0.0353 \text{ mol dm}^{-3}$ aqueous sodium carbonate, Na_2CO_3 .
methyl orange indicator

(a) Dilution of FA 1

- Use the 10.0 cm^3 pipette to transfer 10.0 cm^3 of **FA 1** into the 250 cm^3 volumetric flask.
- Add distilled water to the mark.
- Shake the flask to mix the solution thoroughly and label it **FA 4**.

Titration

- Fill the second burette with **FA 4**.
- Pipette 25.0 cm^3 of **FA 3** into a conical flask.
- Add approximately 10 drops of methyl orange.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make certain that any recorded results show the precision of your practical work.
- Record all of your burette readings and the volume of **FA 4** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b)** From your accurate titration results, obtain a suitable value for the volume of **FA 4** to be used in your calculations. Show clearly how you obtained this value.

25.0 cm^3 of **FA 3** required cm^3 of **FA 4**. [1]

- (c) (i) Give your answers to (ii), (iii) and (iv) to an appropriate number of significant figures. [1]
- (ii) Calculate the number of moles of sodium carbonate in the **FA 3** pipetted into the conical flask.

moles of Na_2CO_3 = ... mol [1]

- (iii) Deduce the number of moles of HZ present in the volume of **FA 4** recorded in (b).

moles of HZ = ... mol [1]

- (iv) Calculate the concentration of HZ present in **FA 1**.

concentration of HZ in **FA 1** = ... mol dm^{-3} [1]

- (d) In **Question 1** you determined the concentration of HZ in **FA 1** by a thermometric method. In **Question 2** you determined the concentration of HZ in **FA 1** by titration. Tick which one of the following statements you believe to be true.

The method in Question 1 is more accurate than the method in Question 2 .	
The method in Question 2 is more accurate than the method in Question 1 .	
The two methods are of equal accuracy.	

Explain your answer.

.....

.....

.....

[1]

- (e) A teacher informed a class that 112.3g of pure HZ had been dissolved in distilled water to make 1 dm³ of **FA 1**. A student in the class suggested that HZ could be ethanoic acid.

Using your answer to (c)(iv) show, by calculation, whether the student was correct.
(If you were unable to complete the calculation in (c)(iv) you may assume the concentration was 2.08 mol dm⁻³. This is not the correct value.)

The student was correct/incorrect because

..... [1]

[Total: 14]

Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

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

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

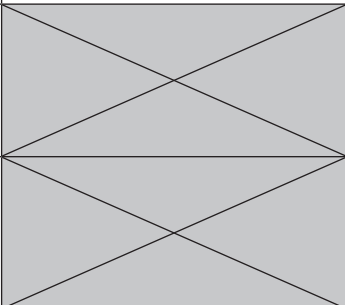
You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

- 3 (a) FA 5, FA 6 and FA 7** are solutions each containing one cation and one anion. One of the cations and all of the anions are listed in the Qualitative Analysis Notes. You will carry out a series of tests on **FA 5**, **FA 6** and **FA 7** and draw conclusions from your observations. Use a separate 1 cm depth of each solution in a test-tube for the following tests.

<i>test</i>	<i>observations</i>		
	FA 5	FA 6	FA 7
Add a 1 cm depth of aqueous sodium carbonate.			
Add a 1 cm length of magnesium ribbon.			
Add 2 or 3 drops of aqueous silver nitrate, then			
add aqueous ammonia.			
Add a 1 cm depth of aqueous barium nitrate, then			
add a 1 cm depth of dilute hydrochloric acid.			

<i>test</i>	<i>observations</i>		
	FA 5	FA 6	FA 7
Add aqueous sodium hydroxide.			
Add a 1 cm depth of FA 7 .			

[10]

- (b) Use your observations from (a) to identify as many ions as possible. Give the formula of each ion present. Write 'unknown' if you were unable to make a positive identification of an ion.

	FA 5	FA 6	FA 7
cation			
anion			

[3]

- (c) Give the ionic equation for any precipitation reaction involving **FA 5** that you observed in (a). Include state symbols.

..... [1]

[Total: 14]

Qualitative Analysis Notes

1 Reactions of aqueous cations

<i>ion</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)	no ppt. ammonia produced on heating	—
barium, Ba ²⁺ (aq)	faint white ppt. is nearly always observed unless 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	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

2 Reactions of anions

<i>ion</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 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
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)

3 Tests 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

The Periodic Table of Elements

Group																																			
1	2	Key												13	14	15	16	17	18																
		atomic number atomic symbol name relative atomic mass												1 H hydrogen 1.0																					
3	Li lithium 6.9	4	Be beryllium 9.0																																
11	Na sodium 23.0	12	Mg magnesium 24.3																																
19	K potassium 39.1	20	Ca calcium 40.1	21	Sc scandium 45.0	22	Ti titanium 47.9	23	V vanadium 50.9	24	Cr chromium 52.0	25	Mn manganese 54.9	26	Fe iron 55.8	27	Co cobalt 58.9	28	Ni nickel 58.7	29	Cu copper 63.5	30	Zn zinc 65.4	31	Ga gallium 69.7	32	Ge germanium 72.6	33	As arsenic 74.9	34	Se selenium 79.0	35	Br bromine 79.9	36	Kr krypton 83.8
37	Rb rubidium 85.5	38	Sr strontium 87.6	39	Y yttrium 88.9	40	Zr zirconium 91.2	41	Nb niobium 92.9	42	Mo molybdenum 95.9	43	Tc technetium —	44	Ru ruthenium 101.1	45	Rh rhodium 102.9	46	Pd palladium 106.4	47	Ag silver 107.9	48	Cd cadmium 112.4	49	In indium 114.8	50	Sn tin 118.7	51	Sb antimony 121.8	52	Te tellurium 127.6	53	I iodine 126.9	54	Xe xenon 131.3
55	Cs caesium 132.9	56	Ba barium 137.3	57–71 lanthanoids		72	Hf hafnium 178.5	73	Ta tantalum 180.9	74	W tungsten 183.8	75	Re rhenium 186.2	76	Os osmium 190.2	77	Ir iridium 192.2	78	Pt platinum 195.1	79	Au gold 197.0	80	Hg mercury 200.6	81	Tl thallium 204.4	82	Pb lead 207.2	83	Bi bismuth 209.0	84	Po polonium —	85	At astatine —	86	Rn radon —
87	Fr francium —	88	Ra radium —	89–103 actinoids		104	Rf rutherfordium —	105	Db dubnium —	106	Sg seaborgium —	107	Bh bohrium —	108	Hs hassium —	109	Mt meitnerium —	110	Ds darmstadtium —	111	Rg roentgenium —	112	Cn copernicium —	114	Fl flerovium —	116	Lv livermorium —								