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9701/31

May/June 2017

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.



- 1 In this experiment you will determine the relative formula mass of a copper salt by titration.

A solution of the copper salt reacts with excess acidified potassium iodide, producing iodine. This iodine is then titrated with aqueous sodium thiosulfate, using starch indicator.

FA 1 is an aqueous solution of the copper salt prepared by dissolving 26.0 g of the salt to make 1.00 dm³ of solution.

FA 2 is dilute sulfuric acid, H₂SO₄.

FA 3 is aqueous potassium iodide, KI.

FA 4 is 0.110 mol dm⁻³ sodium thiosulfate, Na₂S₂O₃.
starch indicator

(a) Method

- Fill the burette with **FA 4**.
- Pipette 25.0 cm³ of **FA 1** into a conical flask.
- Use the measuring cylinder to add approximately 10 cm³ of **FA 2** to the same conical flask.
- Use the measuring cylinder to add approximately 20 cm³ of **FA 3** to the mixture in the conical flask. The mixture will now be a brown colour, due to iodine produced in the reaction.
- Begin your rough titration by adding **FA 4** from the burette until the mixture becomes light brown.
- Add 10 drops of starch indicator. The mixture will become darker.
- Continue titrating until the mixture becomes an off-white colour. This is the end-point.
- Add **one** drop of starch indicator to check that no traces of dark colour are produced. If the mixture stays off-white, the titration is finished. If some dark colour is produced, because iodine is still present, continue the titration.
- Record your burette readings and the rough titre in the space below.

The rough titre is cm³.

- 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 in a suitable form below all of your burette readings and the volume of **FA 4** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

Keep FA 3 and starch indicator for use in Question 3.

[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.

The iodine produced required cm³ of **FA 4**. [1]

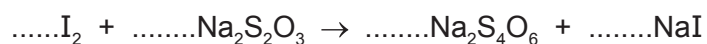
(c) Calculations

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

- (i) Calculate the number of moles of sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$, in the volume of **FA 4** calculated in **(b)**.

moles of $\text{Na}_2\text{S}_2\text{O}_3$ = ... mol

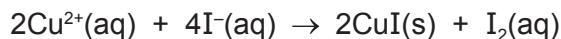
- (ii) Balance the equation for the reaction of iodine with sodium thiosulfate. State symbols are not required.



- (iii) Using your answer to **(ii)**, calculate the number of moles of iodine that reacted with the number of moles of $\text{Na}_2\text{S}_2\text{O}_3$ calculated in **(i)**.

moles of I_2 = ... mol

- (iv) Iodine, I_2 , is produced in the reaction between **FA 1** and **FA 3**. **FA 3** is in excess.



Using your answer to **(iii)**, calculate the number of moles of copper(II) ions in 25.0 cm^3 of **FA 1**.

moles of Cu^{2+} ions = ... mol

- (v) Using your answer to **(iv)** and the information on page 2, calculate the relative formula mass of the copper compound in **FA 1**.

M_r of copper compound = ...
[4]

[Total: 12]

- 2 Malachite is a basic form of copper carbonate in which copper hydroxide is also present. The accepted chemical formula of malachite is $\text{CuCO}_3 \cdot \text{Cu(OH)}_2 \cdot \text{H}_2\text{O}$.

When malachite is heated, it decomposes as shown.



In this experiment, you will heat malachite to decompose it and use your results to obtain evidence about the accepted formula of malachite.

FA 5 is malachite, $\text{CuCO}_3 \cdot \text{Cu(OH)}_2 \cdot \text{H}_2\text{O}$.

(a) Method

Read through the method before starting any practical work.

In the space below prepare a **single** table for your results of **Experiments 1** and **2**.

Experiment 1

- Weigh a crucible with its lid and record the mass.
- Add between 2.5 g and 3.0 g of **FA 5** to the crucible. Weigh the crucible with **FA 5** and lid and record the mass.
- Place the crucible on the pipe-clay triangle.
- Heat the crucible and contents gently for about two minutes, with the lid on.
- Remove the lid and continue heating gently for about three minutes.
- Replace the lid and leave the crucible and residue to cool for at least five minutes. Then reweigh the crucible and contents with the lid on. Record the mass.
- **While the crucible is cooling, you may wish to begin work on Question 3.**
- Calculate and record the mass of **FA 5** used and the mass of residue obtained.
- State the observation(s) you made while the reaction was taking place.

.....

Experiment 2

Repeat the method used in **Experiment 1**, using between 1.5 g and 2.0 g of **FA 5** in the second crucible.

Results

I	
II	
III	
IV	
V	
VI	

[6]

(b) Calculations

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

- (i) Use your results from **Experiment 1** to calculate the number of moles of copper oxide, CuO, obtained as residue.
Use the Periodic Table on page 12 for any data you may require.

moles of CuO obtained in **Experiment 1** = ... mol

- (ii) Use your answer to (i), the equation on page 4 and the mass of **FA 5** you used in **Experiment 1**, to calculate the relative formula mass, M_r , of malachite.

M_r of malachite (from **Experiment 1**) = ...

- (iii) Use your results from **Experiment 2** to calculate another value for the relative formula mass, M_r , of malachite.

M_r of malachite (from **Experiment 2**) = ...

- (iv) Use data from the Periodic Table to calculate the relative formula mass, M_r , of malachite from its accepted formula, $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2 \cdot \text{H}_2\text{O}$.

M_r of malachite (from formula) = ...

- (v) If the relative formula mass of malachite obtained from **either** of your experiments is within 2.5% of the answer in (iv), this is good evidence that the accepted formula, $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2 \cdot \text{H}_2\text{O}$, is correct.

Show by calculation whether either of your experiments supports the accepted formula.

- (c) (i) State **one** way of improving the accuracy of the experimental method, using the same masses of **FA 5**.

Explain the benefit of your improvement.

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- (ii) Explain why you would expect **Experiment 1** to be more accurate than **Experiment 2**.

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[3]

[Total: 14]

3 Qualitative Analysis

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

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

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

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

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

No additional tests for ions present should be attempted.

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

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

(a) **FA 6** is another salt of copper. The anion present is one of those listed in the Qualitative Analysis Notes.

- (i) Transfer a **small** spatula measure of **FA 6** into a hard-glass test-tube. Heat gently at first, then heat strongly, until no further change occurs.

Record **all** your observations below.

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- (ii) Suggest the chemical formula of **FA 6**.

.....

[3]

- (b) (i)** Dissolve the remainder of **FA 6** in an approximately 10 cm depth of distilled water in a boiling tube.

FA 7 is a solution of a salt containing one anion from those listed in the Qualitative Analysis Notes.

Two cations are also present.

Carry out the tests described below using separate portions of solutions **FA 6** and **FA 7**. Record your observations in the table.

<i>test</i>	<i>observations</i>	
	FA 6	FA 7
To a 1 cm depth of solution in a test-tube, add an equal volume of FA 3 , aqueous potassium iodide, followed by a few drops of starch indicator.		
To a 1 cm depth of solution in a boiling tube, add aqueous sodium hydroxide, then		
heat gently and carefully .		
To a 1 cm depth of solution in a test-tube, add a few drops of aqueous silver nitrate.		
To a 1 cm depth of solution in a test-tube, add aqueous ammonia.		
To a 1 cm depth of solution in a test-tube, add a folded 3 cm length of magnesium ribbon.		

- (ii)** What can you deduce about solution **FA 7** from its reaction with magnesium? Explain your answer.

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- (iii) Give the ionic equation for the reaction of the metal cation in **FA 7** with aqueous sodium hydroxide. Include state symbols.

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- (iv) What **type** of reaction took place when aqueous potassium iodide was added to **FA 7**? Use your observations to help you explain your answer.

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- (v) The observation you made when aqueous silver nitrate was added to **FA 7** does not allow the anion in **FA 7** to be identified with certainty.

Explain why you cannot be certain about the identity of the anion.

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- (vi) A student suggested that the anion in **FA 7** could be identified with more certainty if excess ammonia solution was added after the aqueous silver nitrate.

Explain why this suggestion is **not** correct.

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[11]

[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; NO liberated by dilute acids (colourless $\text{NO} \rightarrow$ (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, $\text{SO}_3^{2-}(\text{aq})$	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	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																					
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 —																					

lanthanoids

actinoids

57	La	58	Ce	59	Pr	60	Nd	61	Pm	62	Sm	63	Eu	64	Gd	65	Tb	66	Dy	67	Ho	68	Er	69	Tm	70	Yb	71	Lu
	lanthanum		cerium		praseodymium		neodymium		promethium		samarium		eurogium		gadolinium		terbium		dysprosium		holmium		erbium		thulium		ytterbium		lutetium
	138.9		140.1		140.9		144.4		—		150.4		152.0		157.3		158.9		162.5		164.9		167.3		168.9		173.1		175.0
89	Ac	90	Th	91	Pa	92	U	93	Np	94	Pu	95	Am	96	Cm	97	Bk	98	Cf	99	Es	100	Fm	101	Md	102	No	103	Lr
	actinium		thorium		protactinium		uranium		neptunium		plutonium		americium		curium		berkelium		californium		einsteinium		fermium		mendeleevium		nobelium		lawrencium
	—		232.0		231.0		238.0		—		—		—		—		—		—		—		—		—		—		—

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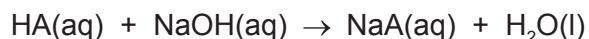
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Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

This document consists of **14** printed pages and **2** blank pages.

- 1 HA is an organic acid where A^- is the anion. You will determine the relative formula mass, M_r , of HA by titration with sodium hydroxide of known concentration and so identify the anion, A^- . The equation for the reaction is shown.



FB 1 is a solution of organic acid, HA, containing 12.60 g dm^{-3} .

FB 2 is $0.100 \text{ mol dm}^{-3}$ sodium hydroxide, NaOH.

thymol blue indicator

(a) Method

- Fill the burette with **FB 1**.
- Pipette 25.0 cm^3 of **FB 2** into a conical flask.
- Add approximately 10 drops of thymol blue indicator. This indicator is blue in alkaline solutions and yellow in acidic solutions.
- 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, in a suitable form below, all of your burette readings and the volume of **FB 1** 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 **FB 1** to be used in your calculations. Show clearly how you obtained this value.

25.0 cm^3 of **FB 2** required cm^3 of **FB 1**.
[1]

(c) Calculations

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

- (i) Calculate the number of moles of sodium hydroxide present in 25.0 cm³ of **FB 2** pipetted into the conical flask.

moles of NaOH = ... mol

- (ii) Use your answers to (b) and (c)(i) to determine the concentration of the organic acid HA, in **FB 1**, in mol dm⁻³.

concentration of HA in **FB 1** = ... mol dm⁻³

- (iii) Use your answer to (ii) and the information given on page 2 to determine the relative formula mass, M_r , of the organic acid, HA.

M_r of HA = ...

- (iv) The organic acid was known to have one of the following structural formulae.



Use your answer to (iii) and the Periodic Table on page 16 to identify the anion, A⁻.

anion, A⁻ = ...
[4]

(d) A student carried out the same procedure accurately but was supplied with a solution of less concentrated sodium hydroxide by mistake.

- (i) What effect would this have on the calculated value of the relative formula mass, M_r ? Explain your answer.

.....

.....

- (ii) Explain how this would affect the identification of the acid.

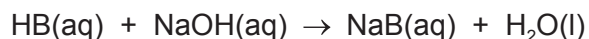
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[2]

[Total: 14]

- 2 You are to determine the enthalpy change of neutralisation for a different acid from that used in **Question 1**. The acid is represented by HB where B⁻ represents the anion.



FB 3 is 2.00 mol dm⁻³ acid, HB.

FB 4 is 72.00 g dm⁻³ sodium hydroxide, NaOH.

(a) Method

Read through the method before starting your practical work and prepare a table below for recording your results.

Experiment 1

- Place the plastic cup in the 250 cm³ beaker.
- Pour 25 cm³ of **FB 3** into the larger measuring cylinder.
- Measure and record the temperature of **FB 3**.
- Rinse and dry the thermometer.
- Use the smaller measuring cylinder to transfer 25 cm³ of **FB 4** into the plastic cup.
- Measure and record the temperature of **FB 4**.
- Add the 25 cm³ of **FB 3** to **FB 4** in the plastic cup and stir the mixture. Measure and record the highest temperature reached.
- Calculate and record the average initial temperature of the solutions.
- Calculate and record the temperature rise.
- Empty the plastic cup, rinse it with water and shake it to remove excess water.

Experiment 2

- Repeat the method given for **Experiment 1** using 50 cm³ of each solution.
- Use the larger measuring cylinder for **FB 3** and the smaller measuring cylinder for **FB 4**.

Results

I	
II	
III	
IV	

[4]

(b) Calculations

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

- (i) Show by calculation that in **Experiment 1**, the number of moles of acid was in excess of the number of moles of sodium hydroxide.

- (ii) Calculate the heat energy evolved in **Experiment 1**.
[Assume that 4.2J of heat energy changes the temperature of 1.0cm³ of solution by 1.0 °C.]

heat energy evolved = ... J

- (iii) Calculate the enthalpy change, in kJ mol⁻¹, for **Experiment 1**.

enthalpy change = ... kJ mol⁻¹
(sign) (value)

- (iv) Calculate the number of moles of sodium hydroxide neutralised in **Experiment 2**.

moles of NaOH = ... mol

- (v) Calculate the enthalpy change, in kJ mol⁻¹, for **Experiment 2**.

enthalpy change = ... kJ mol⁻¹
(sign) (value)

[5]

- (c) (i) The accuracy of the larger measuring cylinder is $\pm 0.5 \text{ cm}^3$.
The accuracy of the smaller measuring cylinder is $\pm 0.25 \text{ cm}^3$.

Calculate the maximum percentage error in the measurement of the volume of **FB 3** used in **Experiment 2** and the measurement of the volume of **FB 4** used in **Experiment 2**.

Show your working.

maximum % error in volume of **FB 3**

maximum % error in volume of **FB 4**

- (ii) Suggest a change to the method used in (a) that would improve the accuracy of your results.

.....

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[3]

[Total: 12]

3 Qualitative Analysis

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

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

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

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

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

No additional tests for ions present should be attempted.

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

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

(a) **FB 5** and **FB 6** are solutions of acids of equal concentration in mol dm^{-3} . One solution is a weak acid and the other is a strong acid.

- (i) Devise and carry out a chemical test to find out which of **FB 5** and **FB 6** is the weak acid. Record your test, observations and conclusion in the space below.

- (ii) Another acid, **FB 7**, is a dilute solution of one of hydrochloric, nitric or sulfuric acids.

Carry out the tests in the order given in the table below until you are able to identify **FB 7**. Record your observations. If any test is unnecessary write 'not needed'.

<i>test</i>	<i>observations</i>
To a 1 cm depth of FB 7 in a test-tube add aqueous silver nitrate.	
To a 0.5 cm depth of FB 7 in a boiling tube add a 1 cm depth of aqueous sodium hydroxide and a small piece of aluminium foil and warm.	
To a 1 cm depth of FB 7 in a test-tube add aqueous barium chloride or aqueous barium nitrate.	

FB 7 is acid.

[6]

- (b) **FB 8** contains a cation listed in the Qualitative Analysis Notes. **FB 9** is a solution of an organic salt. Carry out the following tests and record your observations.

<i>test</i>	<i>observations</i>
(i) To a 1 cm depth of FB 8 in a test-tube add aqueous sodium carbonate.	
(ii) To a 1 cm depth of FB 8 in a test-tube add a 1 cm depth of aqueous potassium iodide, then	
add aqueous sodium thiosulfate until in excess.	
(iii) To a 2 cm depth of FB 8 in a test-tube add a 1 cm depth of concentrated hydrochloric acid (CARE). Keep this solution for test (iv).	
(iv) To a 2 cm depth of distilled water in a boiling tube add all the contents of the test-tube from test (iii). Keep this solution for tests (v) and (vi).	
Pour a 1 cm depth of the contents of the boiling tube into three separate test-tubes for use in tests (v) and (vi). One tube is to be used for comparing colours in your observations.	
(v) To one of the test-tubes add aqueous ammonia until in excess.	
(vi) To a second test-tube add FB 9 until in excess.	

(vii) Identify the cation in **FB 8**.

cation

(viii) Write an **ionic** equation for a precipitation reaction you observed during your experiments with this cation.
Include state symbols.

..... [8]

[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; NO liberated by dilute acids (colourless $\text{NO} \rightarrow$ (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, $\text{SO}_3^{2-}(\text{aq})$	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													13	14	15	16	17	18						
														1 H hydrogen 1.0								2 He helium 4.0			

lanthanoids														
57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
lanthanum	cerium	praseodymium	neodymium	promethium	samarium	europtium	gadolinium	terbium	dysprosium	holmium	erbium	thulium	ytterbium	lutetium
138.9	140.1	140.9	144.4	—	150.4	152.0	157.3	158.9	162.5	164.9	167.3	168.9	173.1	175.0
actinoids														
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendelevium	nobelium	lawrencium
—	232.0	231.0	238.0	—	—	—	—	—	—	—	—	—	—	—

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CHEMISTRY

9701/33

Paper 3 Advanced Practical Skills 1

May/June 2017

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.

- 1 Sodium hydrogencarbonate, NaHCO_3 , is used as baking soda in cooking. Baking soda may also contain small amounts of other chemicals.
In this experiment, you will determine the percentage purity by mass of an impure sample of NaHCO_3 by titration with sulfuric acid.

FA 1 is $0.0500 \text{ mol dm}^{-3}$ sulfuric acid, H_2SO_4 .

FA 2 is impure NaHCO_3 .
methyl orange

(a) Method

Preparing a solution of FA 2

- Weigh the stoppered container of **FA 2**. Record the mass in the space below.
- Tip all the **FA 2** into the beaker.
- Reweigh the container with its stopper. Record the mass.
- Calculate and record the mass of **FA 2** used.
- Add approximately 100 cm^3 of distilled water to the **FA 2** in the beaker.
- Stir the mixture with a glass rod until all the **FA 2** has dissolved.
- Transfer this solution into the 250 cm^3 volumetric flask.
- Wash the beaker with distilled water and transfer the washings to the volumetric flask.
- Rinse the glass rod with distilled water and transfer the washings to the volumetric flask.
- Make up the solution in the volumetric flask to the mark using distilled water.
- Shake the flask thoroughly.
- This solution of impure NaHCO_3 is **FA 3**. Label the flask **FA 3**.

Results

Titration

- Fill the burette with **FA 1**.
- Pipette 25.0 cm^3 of **FA 3** into a conical flask.
- Add several 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 sure any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 1** added in each accurate titration.

Keep **FA 1** for use in Question 2.

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

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

25.0 cm³ of **FA 3** required cm³ of **FA 1**. [1]

(c) **Calculations**

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

- (i) Calculate the number of moles of sulfuric acid present in the volume of **FA 1** calculated in (b).

moles of H₂SO₄ = ... mol

- (ii) Balance the equation for the reaction of sulfuric acid and sodium hydrogencarbonate. State symbols are not required.



- (iii) Using your answers to (i) and (ii), calculate the number of moles of sodium hydrogencarbonate used in each titration.

moles of NaHCO₃ = ... mol

- (iv) Using your answer to (iii), calculate the mass of sodium hydrogencarbonate present in the mass of **FA 2** used to prepare **FA 3**.

mass of NaHCO_3 = ... g

- (v) Calculate the percentage purity by mass of the impure sodium hydrogencarbonate sample, **FA 2**.

percentage purity by mass of impure NaHCO_3 , **FA 2** = ... %

- (vi) What did you assume about the impurities in **FA 2** when you calculated the percentage purity?

.....

- (vii) A volumetric flask was labelled $250.0 \pm 0.10 \text{ cm}^3$.

Calculate the maximum percentage error when using this volumetric flask.

maximum percentage error = ... %
 [7]

[Total: 16]

- 2 When baking soda is heated, carbon dioxide is produced. In this experiment you will investigate the reaction taking place when the sodium hydrogencarbonate in baking soda is thermally decomposed.

FA 4 is baking soda (impure NaHCO_3). Its composition is the same as that of **FA 2**.

(a) Method

Record all your readings in the space below.

- Weigh the crucible with its lid.
- Transfer all the **FA 4** from the container into the crucible.
- Weigh the crucible, lid and **FA 4**.
- Calculate and record the mass of **FA 4** used.
- Place the crucible and contents on a pipe-clay triangle.
- Heat gently, with the lid on, for approximately one minute.
- Heat strongly, with the lid off, for a further three minutes.
- Replace the lid and leave the crucible to cool for at least five minutes.

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

- When it is cool, weigh the crucible with its lid and contents.
- Heat strongly, with the lid off, for a further two minutes.
- Replace the lid and leave the crucible to cool for at least five minutes.
- When it is cool, weigh the crucible with its lid and contents.
- Calculate and record the mass of residue obtained.
- This residue is **FA 5**. Keep this for use in **2(d)**.

Results

I	
II	
III	
IV	

[4]

(b) Calculations

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

- (i) Use the percentage purity by mass of **FA 2** you calculated in **1(c)(v)**, to calculate the mass of sodium hydrogencarbonate in the sample of **FA 4** that you weighed out.

(If you were unable to carry out the calculation in **1(c)(v)**, assume that the percentage purity by mass of **FA 2** is 95.8%.)

mass of NaHCO_3 in **FA 4** weighed out = ... g

- (ii) Calculate the mass of impurity present in your sample of **FA 4**.

mass of impurity = ... g

- (iii) The impurity in **FA 4** does not decompose when it is heated.
This means that the residue, **FA 5**, contains the mass of impurity calculated in (ii) together with the solid decomposition product of sodium hydrogencarbonate.

Calculate the mass of the solid decomposition product.

mass of solid decomposition product = ... g

- (iv) Use your answers to (i) and (iii) to calculate the mass of solid decomposition product that would be obtained if 84.0 g of **pure** sodium hydrogencarbonate were heated.

mass of solid decomposition product = ... g

- (v) A student carried out the experiment by heating to constant mass and calculated that heating 84.0 g of pure NaHCO_3 would produce 52.3 g of the solid decomposition product. The student then suggested the following equation for the thermal decomposition of sodium hydrogencarbonate.



Use data from the Periodic Table on page 12 to explain why the student's suggestion cannot be correct.

.....
.....

[4]

- (c) (i) Why was the lid put on while the crucible and its contents cooled?

.....

- (ii) The experiment could be made more accurate by heating to constant mass or using a more accurate balance. Suggest a further improvement to make the experiment more accurate.

.....

[2]

- (d) (i) Pour a 1 cm depth of sulfuric acid, **FA 1**, into a test-tube.
 Add some **FA 5** from the crucible to the acid in the test-tube.
 Record all your observations.

.....

- (ii) Use your observation(s) in (i) to identify an anion present in **FA 5**.
 Explain your answer.

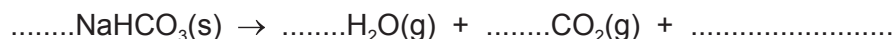
identity

explanation

.....

- (iii) Steam is one of **three** products obtained when sodium hydrogencarbonate is thermally decomposed.

Use your answer in (ii) to complete and balance the equation for the thermal decomposition of sodium hydrogencarbonate. Include state symbols.



- (iv) State whether the balanced equation in (iii) agrees with the student's results given in **2(b)(v)**.
 Show working in order to explain your answer.

.....

[4]

[Total: 14]

3 Qualitative Analysis

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

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

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

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

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

No additional tests for ions present should be attempted.

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

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

(a) (i) **FA 6** and **FA 7** are aqueous solutions.

Each solution contains one cation and one anion from those listed in the Qualitative Analysis Notes.

Use 1 cm depths of **FA 6** or **FA 7** in test-tubes for the following tests.

Complete the table by recording your observations.

<i>test</i>	<i>observations</i>	
	FA 6	FA 7
Add a few drops of aqueous barium chloride or aqueous barium nitrate, then		
add dilute nitric acid.		
Add a few drops of aqueous silver nitrate.		
Add a small spatula measure of sodium carbonate. Shake the mixture.		

(ii) From your observations, deduce which solution, **FA 6** or **FA 7**, has the lower pH.
Give your evidence.

solution with lower pH

evidence

.....

[4]

(b) Choose **two** reagents that would allow you to identify the cations in **FA 6** and **FA 7**.

reagents and

Use these reagents to test solutions **FA 6** and **FA 7**.

Record all your observations in the space below.

[4]

(c) Deduce the chemical **formulae** of **FA 6** and **FA 7**.

FA 6

FA 7

[2]

[Total: 10]

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; NO liberated by dilute acids (colourless $\text{NO} \rightarrow$ (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, $\text{SO}_3^{2-}(\text{aq})$	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 2017

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	
Total	

This document consists of **14** printed pages and **2** blank pages.



- 1 Strong acids, such as hydrochloric acid, HCl , are completely ionised in aqueous solution. Weak acids, such as ethanoic acid, CH_3COOH , are partially ionised in aqueous solution.

You will investigate the enthalpy change for the reaction of an excess of each of these acids with magnesium and hence determine the energy needed to cause the weak acid to ionise completely.

(a) Reaction 1 Enthalpy change of a weak acid

FB 1 is ethanoic acid, CH_3COOH .

FB 2 is magnesium, Mg .

Method 1

- Weigh the strip of magnesium and record the balance reading in the space below.
- Support the plastic cup in the 250 cm^3 beaker.
- Coil the magnesium ribbon loosely so that it fits into the bottom of the plastic cup and then remove the ribbon.
- Use the measuring cylinder to transfer 25 cm^3 of the acid, **FB 1**, into the plastic cup.
- Place the thermometer in the acid and read the initial temperature. This is the temperature at time zero ($t = 0$).
- Start timing and do not stop the clock until the whole experiment has been completed.
- Read the temperature of the acid every half minute for two minutes.
- At time $t = 2\frac{1}{2}$ minutes drop the magnesium, **FB 2**, into the acid and stir the mixture.
- Measure and record, in the table below, the temperature of the mixture at $t = 3$ minutes and then every half minute until $t = 10$ minutes. Stir the mixture continuously between thermometer readings.
- Rinse the plastic cup for use in **Method 2**. Shake to remove excess water.

Results

Mass of magnesium

Temperature

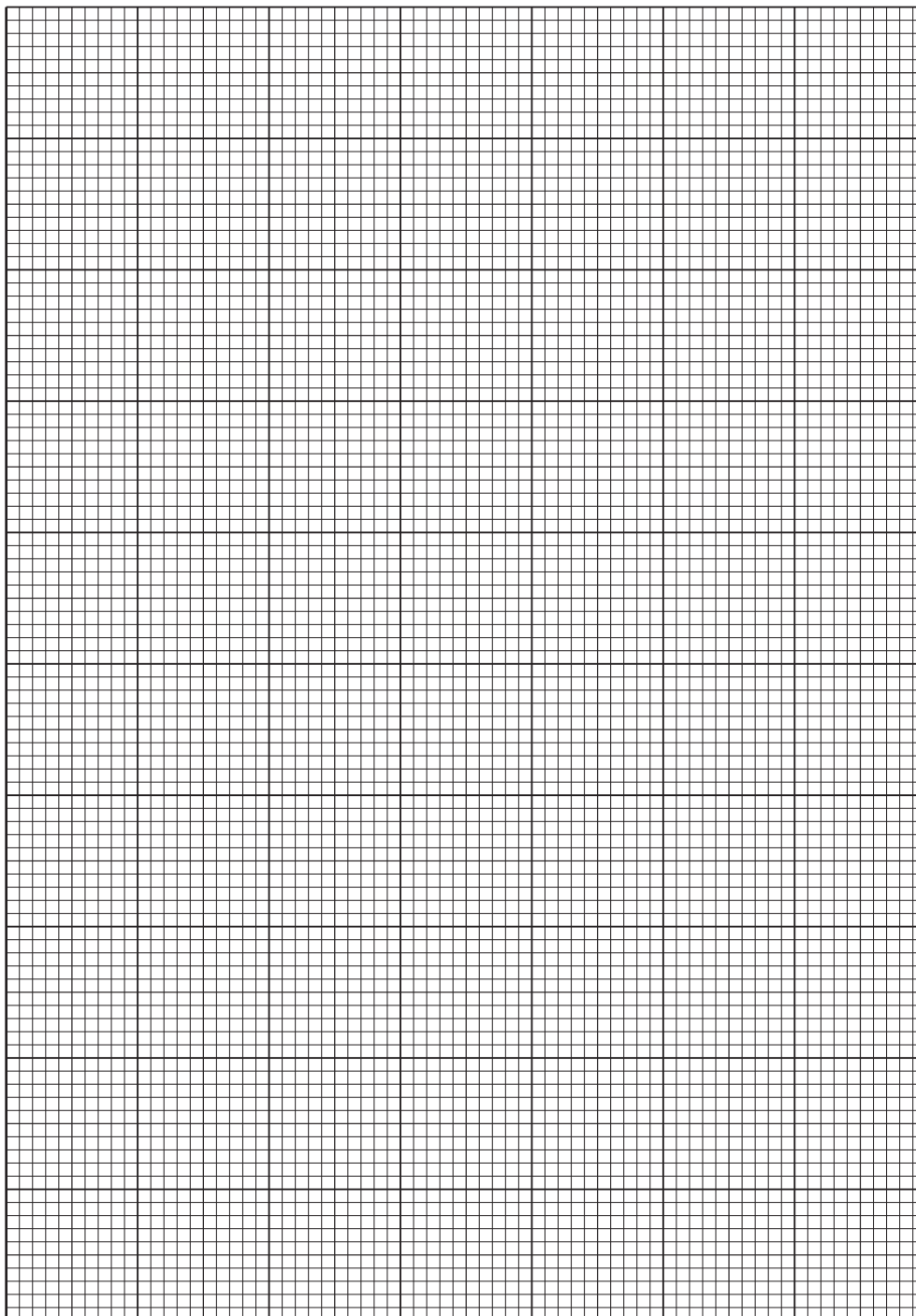
time/minutes	0	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$	5
temperature/ $^{\circ}\text{C}$											

time/minutes	$5\frac{1}{2}$	6	$6\frac{1}{2}$	7	$7\frac{1}{2}$	8	$8\frac{1}{2}$	9	$9\frac{1}{2}$	10
temperature/ $^{\circ}\text{C}$										

[4]

I	
II	
III	
IV	

- (b) Plot a graph of temperature on the y-axis against time on the x-axis on the grid below. The scale for temperature should extend 10°C above your highest recorded temperature. You will use this graph to determine the theoretical maximum temperature rise at $2\frac{1}{2}$ minutes.



I	
II	
III	
IV	
V	

Draw two lines of best fit through the points on your graph. The first line should be for the temperature before adding **FB 2** and the second for the cooling of the mixture once the reaction is complete.

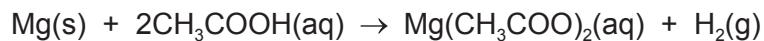
Extrapolate the two lines to $2\frac{1}{2}$ minutes, draw a vertical line between the two and determine the theoretical rise in temperature at this time.

theoretical rise in temperature at $2\frac{1}{2}$ minutes = ... $^{\circ}\text{C}$ [5]

(c) Calculations

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

Magnesium reacts with ethanoic acid according to the equation shown.



- (i) Use your answer to (b) to calculate the heat energy, in joules, given out when **FB 2** is added to the acid.
[Assume 4.2 J of heat energy raises the temperature of 1.0 cm³ of the mixture by 1.0 °C.]

heat energy evolved = ... J

- (ii) Use the Periodic Table on page 16 and your answer to (i) to calculate the enthalpy change, in kJ mol⁻¹, when 1 mole of **FB 2**, Mg, reacts with ethanoic acid.

enthalpy change, ΔH = ... kJ mol⁻¹
(sign) (value)

[3]

(d) Reaction 2 Enthalpy change of a strong acid.

FB 3 is hydrochloric acid, HCl .

The tube labelled **FB 4** contains two strips of magnesium, Mg . One strip is longer than the other strip.

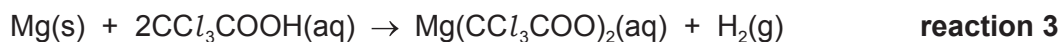
Method 2

Read the whole method before starting any practical work and prepare a table for your results in the space below.

- Weigh the longer strip of magnesium and record the balance reading.
- Support the plastic cup in the 250 cm^3 beaker.
- Coil the magnesium ribbon loosely so that it fits into the bottom of the plastic cup and then remove the ribbon.
- Use the measuring cylinder to transfer 25 cm^3 of the acid, **FB 3**, into the plastic cup.
- Place the thermometer in the acid and measure and record the initial temperature of the acid.
- Add the piece of magnesium into the acid in the cup.
- Stir constantly until the maximum temperature is reached.
- Measure and record the maximum temperature.
- Rinse the plastic cup for use in the next experiment.
- Calculate and record the temperature rise.
- Repeat this experiment using the shorter strip of magnesium and record all results.

[3]

(h) The experiment in (a) was repeated using trichloroethanoic acid instead of ethanoic acid.



Trichloroethanoic acid, CCl_3COOH , is a weak acid that is however stronger than ethanoic acid.

The enthalpy change for reaction 3 is between the two values given in Table 1.

Table 1

reaction	equation	$\Delta H/\text{kJ mol}^{-1}$
1	$\text{Mg(s)} + 2\text{CH}_3\text{COOH(aq)} \rightarrow \text{Mg}(\text{CH}_3\text{COO})_2\text{(aq)} + \text{H}_2\text{(g)}$	-460.3
2	$\text{Mg(s)} + 2\text{HCl(aq)} \rightarrow \text{MgCl}_2\text{(aq)} + \text{H}_2\text{(g)}$	-464.1

(i) Explain why the enthalpy change for reaction 3 is more exothermic than the enthalpy change for reaction 1.

.....

.....

(ii) Explain why the enthalpy change for reaction 3 is less exothermic than the enthalpy change for reaction 2.

.....

.....

[2]

[Total: 25]

2 Qualitative Analysis

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

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

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

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

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

No additional tests for ions present should be attempted.

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

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

(a) (i) FB 5, FB 6 and FB 7 each contain one anion and one cation.

Carry out the following tests and record your observations.

<i>test</i>	<i>observations</i>		
	FB 5	FB 6	FB 7
To a 1 cm depth of solution in a test-tube, add a few drops of aqueous silver nitrate, then			
add aqueous ammonia.			
To a 1 cm depth of solution in a test-tube, add a few drops of aqueous barium nitrate, or barium chloride, then			
add dilute nitric acid.			
To a 1 cm depth of solution in a test-tube, add a spatula measure of solid sodium carbonate.			

- (ii) What cation is present in **FB 5**, **FB 6** and **FB 7**?

.....

- (iii) Suggest another test that you could carry out to confirm the presence of the cation you identified in (ii).

Carry out this test on one of **FB 5**, **FB 6** or **FB 7** and record your observation.

test

observation

- (iv) Complete the table to identify, as far as possible, the anions present in **FB 5**, **FB 6** and **FB 7**. If you are not able to identify the anion from the tests you carried out in (i), write 'unknown'.

	FB 5	FB 6	FB 7
ion present			

- (v) For any **one** anion that you were unable to identify in (iv) you are to devise a test or tests that will enable you to identify it. You can assume that it is one of the anions listed in the Qualitative Analysis Notes.

Carry out the test(s), record the observation(s) you obtained and identify the unknown anion.

test(s)

.....

.....

observation(s)

.....

.....

Anion present in is

[10]

(b) **FB 8** is an aqueous solution of a mixture containing two anions and two cations.

Carry out the following tests and record your observations.

<i>test</i>	<i>observations</i>
To a 1 cm depth of FB 8 in a test-tube, add a 1 cm depth of dilute hydrochloric acid, then	
add a few drops of hydrogen peroxide, then	
add a few drops of starch.	
To a 1 cm depth of FB 8 in a test-tube, add aqueous sodium hydroxide.	
To a 1 cm depth of FB 8 in a test-tube, add a 3 cm depth of aqueous copper(II) sulfate, then	
add a 1 cm depth of dilute hydrochloric acid, then	
add aqueous sodium thiosulfate.	

From these observations, identify two ions present in **FB 8**.

ions present in **FB 8** and [5]

[Total: 15]

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; NO liberated by dilute acids (colourless $\text{NO} \rightarrow$ (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, $\text{SO}_3^{2-}(\text{aq})$	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													13	14	15	16	17	18						
														1 H hydrogen 1.0						2 He helium 4.0					

lanthanoids

actinoids

57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
lanthanum	cerium	praseodymium	neodymium	promethium	samarium	euroium	gadolinium	terbium	dysprosium	holmium	erbium	thulium	ytterbium	lutetium
138.9	140.1	140.9	144.4	—	150.4	152.0	157.3	158.9	162.5	164.9	167.3	168.9	173.1	175.0
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendeleevium	nobelium	lawrencium
—	232.0	231.0	238.0	—	—	—	—	—	—	—	—	—	—	—

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9701/35

May/June 2017

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.

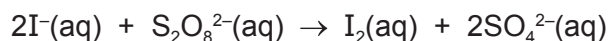
At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [] at the end of each question or part question.

Session
Laboratory

For Examiner's Use	
1	
2	
Total	

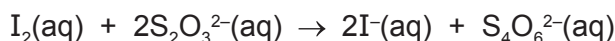
This document consists of **11** printed pages and **1** blank page.

- 1 Sulfur forms the peroxodisulfate anion, $\text{S}_2\text{O}_8^{2-}$. This ion can oxidise iodide ions, I^- , to iodine, I_2 , as shown in the equation.



You will carry out a series of experiments to investigate how the rate of this reaction is affected by changing the concentration of the solutions.

The rate can be measured by adding thiosulfate ions, $\text{S}_2\text{O}_3^{2-}$, and starch indicator. As the reaction between $\text{S}_2\text{O}_8^{2-}$ and I^- occurs iodine is produced, but it reacts immediately with the thiosulfate.



When all the thiosulfate has reacted, the iodine will remain in the mixture and cause the starch indicator to turn blue-black. The rate of reaction may be determined by timing how long it takes the reaction mixture to turn blue-black.

FA 1 is $0.0200 \text{ mol dm}^{-3}$ potassium peroxodisulfate, $\text{K}_2\text{S}_2\text{O}_8$.

FA 2 is 1.00 mol dm^{-3} potassium iodide, KI .

FA 3 is $0.00500 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.
starch indicator

Read through the instructions carefully and prepare a table for your results on page 4 before starting any practical work.

(a) Method

Experiment 1

- Fill the burette labelled **FA 1** with **FA 1**.
- Use the pen to label one of the 100 cm^3 beakers '**A**' and the other 100 cm^3 beaker '**B**'.
- Run 20.00 cm^3 of **FA 1** from the burette into beaker **A**.
- Use the measuring cylinder to add 20.0 cm^3 of **FA 2** into beaker **B**.
- Use the measuring cylinder to add 10.0 cm^3 of **FA 3** to beaker **B**.
- Add 10 drops of starch indicator to beaker **B**.
- Add the contents of beaker **A** to beaker **B** and start timing **immediately**.
- Stir the mixture once and place the beaker on a white tile.
- Stop timing as soon as the solution turns blue-black.
- Record this reaction time to the nearest second in your results table.
- Wash out both beakers and shake to remove excess water.

Experiment 2

- Fill a second burette with distilled water.
- Run 10.00 cm^3 of **FA 1** into beaker **A**.
- Run 10.00 cm^3 of distilled water into beaker **A**.
- Use the measuring cylinder to add 20.0 cm^3 of **FA 2** into beaker **B**.
- Use the measuring cylinder to add 10.0 cm^3 of **FA 3** to beaker **B**.
- Add 10 drops of starch indicator to beaker **B**.
- Add the contents of beaker **A** to beaker **B** and start timing **immediately**.
- Stir the mixture once and place the beaker on a white tile.
- Stop timing as soon as the solution turns blue-black.
- Record this reaction time to the nearest second in your results table.
- Wash out both beakers and shake to remove excess water.

Experiments 3-5

- Carry out three further experiments to investigate how the reaction time changes with different volumes of potassium peroxodisulfate, **FA 1**.
Note that the combined volume of **FA 1** and distilled water must always be 20.00 cm³.
Do not use a volume of **FA 1** that is less than 6.00 cm³.

Keep **FA 1**, **FA 2**, **FA 3** and the starch indicator for use in (e).

Calculating the rate of the reaction

The rate of the reaction can be represented by the formula shown.

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

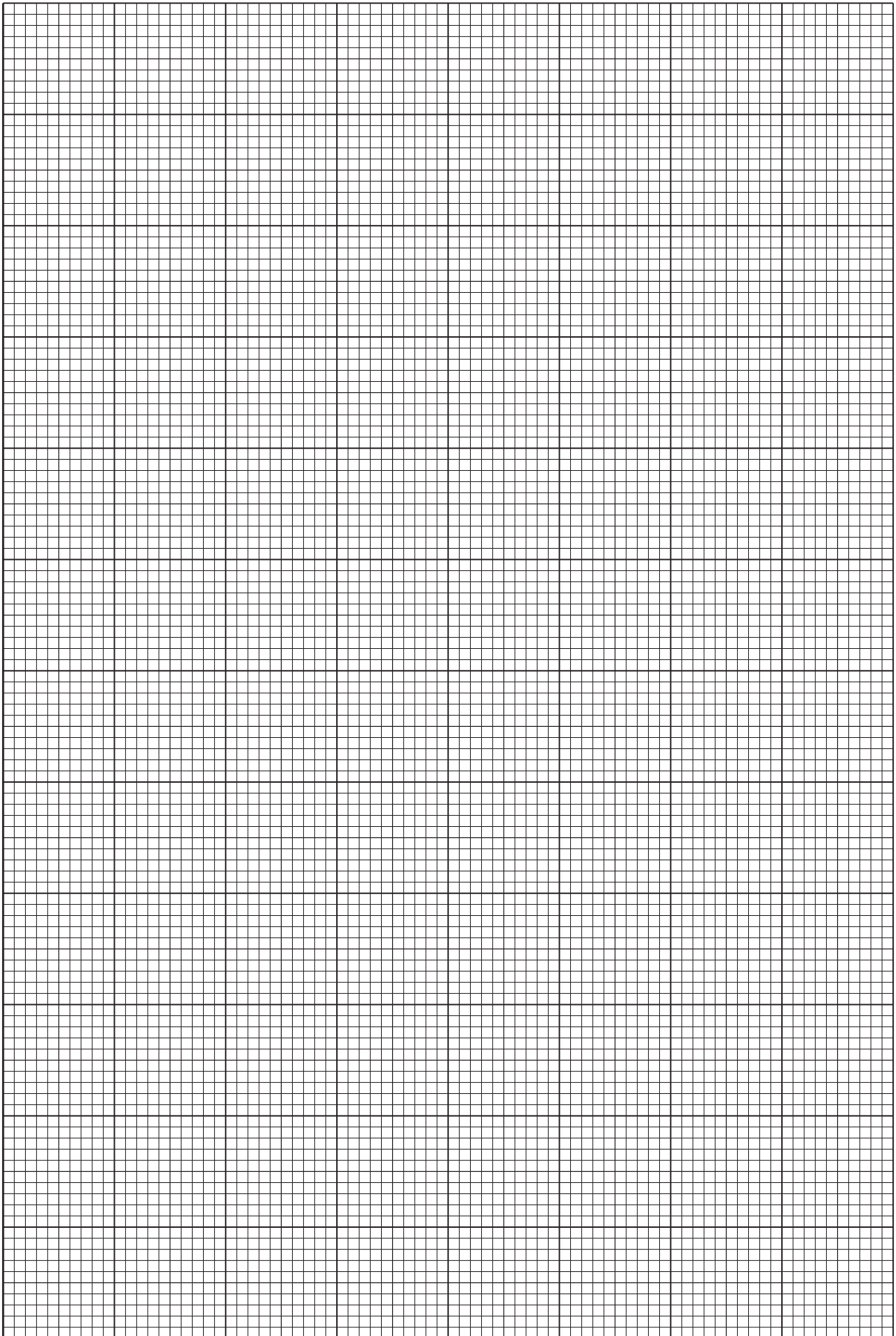
Use this formula to calculate the rate for each of your five experiments.

Record all your results in a single 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.

I	
II	
III	
IV	
V	
VI	
VII	
VIII	
IX	
X	

[10]

- (b) On the grid on page 5, plot the rate (y-axis) against the volume of **FA 1** (x-axis). Include the origin in your plot. Draw a straight line of best fit and circle any clearly anomalous points.



I	
II	
III	
IV	

[4]

- (c) The volume of **FA 1** is directly related to the concentration of potassium peroxodisulfate.

From your results, what can be stated about the relationship between the rate of reaction and the concentration of potassium peroxodisulfate?

.....
 [1]

- (d) (i) **Use your graph** to calculate the reaction **time** you would expect to measure if you carried out an experiment using 5.00 cm³ of **FA 1**.
 Show your working.

reaction time = ... s

- (ii) Assume that the error in the time measured for each reaction was ± 0.5 s in total.
 Calculate the maximum percentage error in the reaction time you measured in **Experiment 1**.
 Show your working.

maximum percentage error = ... %

- (iii) A student suggested that this error could be reduced if 0.0100 mol dm⁻³ sodium thiosulfate were used in place of **FA 3**.

Do you agree with this student? Explain your answer.

.....

- (iv) A student repeated **Experiment 1** but used 0.100 mol dm⁻³ sodium thiosulfate in place of **FA 3**. The student found that the reaction mixture never turned blue-black.

Explain why.

.....

[5]

- (e) (i) Using the same method as in (a), carry out an additional experiment to record the reaction time to the nearest second when the following solutions are mixed together.

- 10.00 cm³ of **FA 1**
- 20.0 cm³ of **FA 2**
- 5.0 cm³ of **FA 3**
- 15.00 cm³ of distilled water
- 10 drops of starch indicator

reaction time = ...

- (ii) Use your answer to (i) to **estimate** the reaction time that would be measured if the following solutions were mixed together.

DO NOT CARRY OUT THIS EXPERIMENT

- 10.00 cm³ of **FA 1**
- 20.0 cm³ of **FA 2**
- 20.0 cm³ of **FA 3**
- 10 drops of starch indicator

Explain your answer.

estimated reaction time = ...

.....

[4]

[Total: 24]

2 Qualitative Analysis

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

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

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

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

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

No additional tests for ions present should be attempted.

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

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

(a) **FA 4** and **FA 5** are aqueous solutions. Each solution contains two different cations and the sulfate anion.

(i) Carry out the following tests and record your observations.

<i>test</i>	<i>observations</i>	
	FA 4	FA 5
To a 1 cm depth of solution in a boiling tube, add aqueous sodium hydroxide, then		
warm the tube carefully.		
To a 1 cm depth of solution in a test-tube, add aqueous ammonia.		

(ii) Identify as many as possible of the cations in **FA 4** and **FA 5**.

FA 4 contains the cation(s)

FA 5 contains the cation(s)

[7]

(b) **FA 6** is a salt containing either the sulfate anion or sulfite anion. You will first make a solution of **FA 6**.

- Rinse one of the 100 cm³ beakers with distilled water.
- Place all the sample of **FA 6** into the beaker and add approximately 40 cm³ of distilled water.
- Stir the mixture until the solid has dissolved.

Select reagent(s) and carry out tests to identify the anion in **FA 6**. Record your results in the space below.

The formula of the anion in **FA 6** is [3]

(c) **FA 7** is a solution containing one cation and the **sulfate** anion.

FA 8 is a solution containing the **sodium** cation and one of the anions from those listed in the Qualitative Analysis Notes.

(i) Carry out the following tests to determine the formulae of **FA 7** and **FA 8**.

<i>test</i>	<i>observations</i>
To a 2 cm depth of FA 7 in a test-tube, add a 2 cm strip of magnesium.	
To a 1 cm depth of FA 7 in a test-tube add a 1 cm depth of FA 8 and shake the tube.	

(ii) The formula of **FA 7** is

The formula of **FA 8** is

(iii) Give the ionic equation for the reaction that takes place when magnesium is added to **FA 7**. Include state symbols.

..... [6]

[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; NO liberated by dilute acids (colourless $\text{NO} \rightarrow$ (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, $\text{SO}_3^{2-}(\text{aq})$	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						2 He helium 4.0					
3	4													5	6	7	8	9							
Li lithium 6.9	Be beryllium 9.0													B boron 10.8	C carbon 12.0	N nitrogen 14.0	O oxygen 16.0	F fluorine 19.0	Ne neon 20.2						
11	12													13	14	15	16	17	18						
Na sodium 23.0	Mg magnesium 24.3													Al aluminium 27.0	Si silicon 28.1	P phosphorus 31.0	S sulfur 32.1	Cl chlorine 35.5	Ar argon 39.9						
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38						
K potassium 39.1	Ca calcium 40.1	Sc scandium 45.0	Ti titanium 47.9	V vanadium 50.9	Cr chromium 52.0	Mn manganese 54.9	Fe iron 55.8	Co cobalt 58.9	Ni nickel 58.7	Cu copper 63.5	Zn zinc 65.4	Ga gallium 69.7	Ge germanium 72.6	As arsenic 74.9	Se selenium 79.0	Br bromine 79.9	Kr krypton 83.8	85	86						
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56						
Rb rubidium 85.5	Sr strontium 87.6	Y yttrium 88.9	Zr zirconium 91.2	Nb niobium 92.9	Mo molybdenum 95.9	Tc technetium —	Ru ruthenium 101.1	Rh rhodium 102.9	Pd palladium 106.4	Ag silver 107.9	Cd cadmium 112.4	In indium 114.8	Sn tin 118.7	Sb antimony 121.8	Te tellurium 127.6	I iodine 126.9	Xe xenon 131.3	87	88						
55	56	57–71 lanthanoids	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	89	90						
Cs caesium 132.9	Ba barium 137.3													Tl thallium 204.4	Pb lead 207.2	Bi bismuth 209.0	Po polonium —	At astatine —	Rn radon —						
87	88	89–103 actinoids	104	105	106	107	108	109	110	111	112				114	116	—								
Fr francium —	Ra radium —													Fl flerovium —				Lv livermorium —	—						

lanthanoids

actinoids

57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
lanthanum	cerium	praseodymium	neodymium	promethium	samarium	euroium	gadolinium	terbium	dysprosium	holmium	erbium	thulium	ytterbium	lutetium
138.9	140.1	140.9	144.4	—	150.4	152.0	157.3	158.9	162.5	164.9	167.3	168.9	173.1	175.0
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendeleevium	nobelium	lawrencium
—	232.0	231.0	238.0	—	—	—	—	—	—	—	—	—	—	—