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9701/31

May/June 2018

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 **14** printed pages and **2** blank 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 In this experiment you will use a solution of sodium carbonate, Na_2CO_3 , to determine the concentration of a solution of hydrochloric acid, HCl , by carrying out a titration.



FA 1 is a solution of sodium carbonate containing 1.30 g Na_2CO_3 in each 250 cm^3 .

FA 2 is hydrochloric acid, HCl .

methyl orange indicator

(a) Method

- Fill a burette with **FA 2**.
- Use the pipette to transfer 25.0 cm^3 of **FA 1** into a conical flask.
- Add a few drops of methyl orange indicator.
- 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 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 2** 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 2** to be used in your calculations. Show clearly how you obtained this value.

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

(c) Calculations

(i) Give your answer to (ii), (iii) and (iv) to an appropriate number of significant figures. [1]

(ii) Calculate the number of moles of sodium carbonate present in 25.0 cm³ of **FA 1**.

moles of Na₂CO₃ = ... mol [1]

(iii) Calculate the number of moles of hydrochloric acid that reacted with the number of moles of sodium carbonate you calculated in (ii).

moles of HCl = ... mol [1]

(iv) Use your answers to (b) and (c)(iii) to calculate the concentration of hydrochloric acid in **FA 2**.

concentration of HCl in **FA 2** = ... mol dm⁻³ [1]

[Total: 12]

- 2 In this question you will determine the identity of the halogen in compound **W**. Compound **W** is the halogenoethanoic acid $\text{CH}_2\text{XCO}_2\text{H}$, where X is a halogen.

4 g of **W** were heated with 250 cm^3 of 0.400 mol dm^{-3} aqueous sodium hydroxide. Some of the sodium hydroxide reacted with compound **W**. The solution that remained after this reaction is **FA 3**.

By titrating **FA 3** with hydrochloric acid, you will determine how much of the sodium hydroxide remained after reaction with **W**. You will then calculate how much sodium hydroxide had reacted and use this to determine the identity of X in $\text{CH}_2\text{XCO}_2\text{H}$.

FA 3 is aqueous sodium hydroxide after reaction with **W**.

FA 4 is 0.100 mol dm^{-3} hydrochloric acid, HCl .

bromophenol blue indicator

(a) Method

- Fill the second burette with **FA 4**.
- Rinse the pipette with distilled water followed by a little **FA 3**.
- Use the pipette to transfer 25.0 cm^3 of **FA 3** into a conical flask.
- Add a few drops of bromophenol blue indicator.
- 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 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	

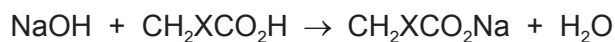
- From your accurate titration results, obtain a suitable value for the volume of **FA 4** to be used in your calculations. Show clearly how you obtained this value.

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

(b) Calculations

A halogenoethanoic acid reacts with aqueous sodium hydroxide in two reactions.

The alkali neutralises the carboxylic acid.



The halogenoalkyl group then undergoes a substitution reaction.



- (i) Calculate the number of moles of hydrochloric acid, **FA 4**, present in the volume calculated in (a).

moles of HCl = ... mol

Hence deduce the number of moles of sodium hydroxide present in 25.0 cm^3 of **FA 3**.

moles of NaOH in 25.0 cm^3 **FA 3** = ... mol
[1]

- (ii) Calculate the number of moles of sodium hydroxide added to the 4 g of **W**.

moles of NaOH added to 4 g **W** = ... mol

Calculate the number of moles of sodium hydroxide that **remain after** the reaction with compound **W**.

moles of NaOH remaining after reaction with **W** = ... mol
[1]

- (iii) Calculate the number of moles of sodium hydroxide that reacted with **W**.

moles of NaOH that reacted with **W** = ... mol

Hence calculate the number of moles of **W** that reacted with this number of moles of sodium hydroxide.

moles of **W** that reacted = ... mol
[1]

- (iv) Use your answer to (iii), and the mass of **W** used to make **FA 3**, to calculate the M_r of **W**.

M_r of **W** = ... [1]

- (v) **W** is a halogenoethanoic acid, $\text{CH}_2\text{XCO}_2\text{H}$. Use your answer to (iv) to determine the identity of X. Explain how you reached your conclusion.

.....

 [2]

- (c) Apart from any inaccuracies in reading the volumes of solutions, suggest a significant source of error in this practical exercise.
Explain how you could minimise this error.

.....

.....

..... [1]

- (d) State at what M_r value of **W**, closest to the one calculated in (b)(iv), you would have concluded that X was a different halogen.

M_r value = ... [1]

[Total: 11]

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) Half fill the 250 cm³ beaker with water. Heat to approximately 70 °C, then turn off the Bunsen burner. This will be used as a water bath.

- (i) **FA 5** is an aqueous solution of an organic compound. Carry out the following tests on **FA 5** and record your observations in the table.

<i>test</i>	<i>observations</i>
To a 1 cm depth of FA 5 in a test-tube add a small spatula measure of sodium carbonate.	
To a 1 cm depth of FA 5 in a test-tube add two drops of acidified potassium manganate(VII). Leave to stand in the water bath.	
To a 1 cm depth of FA 5 in a test-tube add a few drops of aqueous silver nitrate.	
To a 1 cm depth of aqueous silver nitrate in a test-tube add a few drops of aqueous sodium hydroxide and then add aqueous ammonia slowly until the grey precipitate that forms just dissolves. This is Tollens' reagent. To this solution add a 1 cm depth of FA 5 and leave to stand in the water bath. Care: rinse the tube as soon as you have completed this test.	

[4]

- (ii) Suggest **two** functional groups that could be present in **FA 5**.

..... and [2]

- (b) **FA 6** is a mixture that contains two cations and two anions from the Qualitative Analysis Notes. Distilled water was added to **FA 6**, the mixture was stirred and then filtered. You are provided with the dried residue, **FA 7**, and the filtrate, **FA 8**, from this process.

(i) **Tests on the residue, FA 7**

Carry out the following tests and record your observations in the table.

<i>test</i>	<i>observations</i>
Place a spatula measure of FA 7 in a boiling tube. Add dilute hydrochloric acid until no further reaction occurs, then	
transfer a 1 cm depth of the solution into a test-tube. To this add aqueous sodium hydroxide.	

[3]

(ii) **Tests on the filtrate, FA 8**

Carry out the following tests and record your observations in the table.

<i>test</i>	<i>observations</i>
To a 1 cm depth of FA 8 in a boiling tube add a 1 cm depth of aqueous sodium hydroxide, then	
warm gently.	
To a 1 cm depth of FA 8 in a boiling tube add a piece of aluminium foil and a 1 cm depth of aqueous sodium hydroxide. Warm gently.	

[3]

(iii) Conclusions about cations

State **one** cation that is **definitely** present in **FA 6**.

.....

State **two** possible identities for the other cation present in **FA 6**.

..... or

Suggest how you could determine which of these two possible cations is present.
Do not carry out this test.

.....

.....

.....

[3]

(iv) Conclusions about anions

State **one** anion that is **definitely** present in **FA 6**.

.....

State **two** possible identities for the other anion present in **FA 6**.

..... or

[2]

[Total: 17]

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	
		1 H hydrogen 1.0																
		atomic number atomic symbol name relative atomic mass																
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 —	
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 —	118 Og oganesson —	119 Uue unbinilium —	120 Uuh ununilium —	

lanthanoids

actinoids

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

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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 Many metal hydroxides decompose when heated to produce water vapour and the metal oxide as residue.

In this experiment, you will heat a metal hydroxide $M(OH)_2$. You will then identify the metal **M**.



FB 1 is the hydroxide of a metal in Group 2 of the Periodic Table, $M(OH)_2$.
You are supplied with approximately 2 g of **FB 1**.

(a) Method

Experiment 1

- Weigh a crucible with its lid and record the mass.
- Add between 0.5 and 0.7 g of **FB 1** to the crucible. Weigh the crucible with **FB 1** and lid and record the mass.
- Place the crucible on the pipe-clay triangle and remove the lid.
- Heat the crucible and contents strongly for about four minutes.
- Replace the lid and leave the crucible and residue to cool.
- While the crucible is cooling, begin work on a different question.
- Once the crucible is cool, reweigh the crucible and contents with the lid on. Record the mass.
- Calculate and record the mass of **FB 1** used and the mass of residue obtained.

Experiment 2

- Repeat the method used in **Experiment 1**, using between 0.8 and 1.0 g of **FB 1** in the second crucible.
- Calculate and record the mass of **FB 1** used and the mass of residue obtained.

Results

I	
II	
III	
IV	
V	

[5]

(b) Calculations

- (i) Calculate the mean mass of **FB 1** used in your experiments and calculate the mean mass of residue obtained.
Express both answers to **two** decimal places.

mean mass of **FB 1** = ... g

mean mass of residue = ... g
[1]

- (ii) Calculate the mean number of moles of water lost during your experiments.

mean moles of H_2O = ... mol [1]

- (iii) Using your answer to (ii) and the equation for the decomposition of $\text{M}(\text{OH})_2$, calculate the relative formula mass of the metal oxide, **MO**.

M_r of **MO** = ... [1]

- (iv) Calculate the relative atomic mass of **M**.
M is in Group 2 of the Periodic Table. Suggest the identity of **M**.

A_r of **M** = ...

M is
[1]

- (c) (i) State how you could ensure that the decomposition of $\text{M}(\text{OH})_2$ in your experiments was complete.

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

- (ii) A student repeated the experiment using **FB 1** contaminated with MCO_3 .

State and explain what effect this impurity would have on the value of the relative atomic mass of **M** that this student would calculate.

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

[Total: 12]

- 2 In this experiment you will determine the enthalpy change, ΔH_r , for the decomposition of calcium hydroxide to calcium oxide.



To do this, you will determine the enthalpy changes for the reactions of calcium hydroxide and calcium oxide with hydrochloric acid. Excess acid will be used for both experiments.

You will then use Hess' Law to calculate the enthalpy change for the reaction above.

FB 2 is 3.0 mol dm⁻³ hydrochloric acid, HCl.

FB 3 is calcium hydroxide, Ca(OH)₂.

FB 4 is calcium oxide, CaO.

- (a) Determination of the enthalpy change for the reaction of calcium hydroxide, **FB 3**, with hydrochloric acid, **FB 2**.

(i) **Method**

- Support a plastic cup in the 250 cm³ beaker.
- Weigh the container with **FB 3**. Record the mass.
- Use the measuring cylinder to transfer 30 cm³ of **FB 2** into the 100 cm³ beaker.
- Place the beaker on the tripod and gauze and heat **FB 2** gently until its temperature is between 35 °C and 40 °C. Turn off the Bunsen burner.
- Carefully transfer all **FB 2** from the 100 cm³ beaker into the plastic cup.
- Measure and record the temperature of **FB 2** in the plastic cup in the space below.
- Immediately add all the **FB 3** from the container to the **FB 2** in the plastic cup.
- Stir constantly until the maximum temperature is reached.
- Measure and record the maximum temperature.
- Weigh and record the mass of the container with any residual solid.
- Calculate and record the mass of **FB 3** used.
- Calculate and record the temperature rise.

Results

- energy produced = ... J [1]

- moles of $\text{Ca(OH)}_2 = \dots\dots\dots \text{mol}$ [1]

- $$\text{Ca(OH)}_2(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{CaCl}_2(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$$

$$\Delta H_1 = \text{.....} \text{ kJ mol}^{-1}$$

(sign) (value)

[1]

- (c) Use your values for ΔH_1 and ΔH_2 to calculate the enthalpy change for the decomposition of calcium hydroxide, ΔH_r .

Show clearly how you obtained your answer by drawing a Hess' Law energy cycle.

(If you were unable to calculate the enthalpy changes, assume that ΔH_1 is -129 kJ mol^{-1} and ΔH_2 is -150 kJ mol^{-1} . Note: these are not the correct values.)



$$\Delta H_r = \begin{array}{cc} \text{.....} & \text{.....} \end{array} \text{ kJ mol}^{-1}$$

(sign) (value)

[2]

- (d) (i) Give a reason why **FB 2** was heated before **FB 3** or **FB 4** were added to it.

.....
 [1]

- (ii) The procedure in (b) was repeated using the same mass of calcium oxide, **FB 4**. However, 30 cm^3 of $4.0 \text{ mol dm}^{-3} \text{ HCl}$ was used instead of 30 cm^3 of $3.0 \text{ mol dm}^{-3} \text{ HCl}$.

How would the temperature rise compare with the one you obtained in the experiment in (b)?

Explain your answer.

.....

 [1]

[Total: 15]

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, FB 6 and FB 7 are all aqueous solutions.

Each solution contains one cation and one anion.

The cation in **FB 6** is listed in the Qualitative Analysis Notes, but the other cations are not.

The anions present are chloride, nitrate and sulfate (but not necessarily in that order).

Use a 1 cm depth of each solution in a test-tube for the following tests.

Record all your observations in the table.

<i>test</i>	<i>observations</i>		
	FB 5	FB 6	FB 7
Add a 2 cm strip of magnesium ribbon.			
Add several drops of aqueous sodium carbonate.			
Add aqueous sodium hydroxide.			
Add several drops of aqueous barium chloride or aqueous barium nitrate.			

<i>test</i>	<i>observations</i>		
	FB 5	FB 6	FB 7
Add a 1 cm depth of FB 5 .			
Add a 1 cm depth of FB 6 .			
Add a 1 cm depth of aqueous potassium iodide.			

[9]

- (b) (i) From your observation of the reaction of **FB 7** with aqueous potassium iodide, suggest the identity of the cation in **FB 7**.

..... [1]

- (ii) Give the ionic equation for the reaction of magnesium with **FB 5**.
Include state symbols.

..... [1]

- (iii) What **type** of reaction takes place when **FB 6** reacts with sodium carbonate?

..... [1]

- (iv) Give the ionic equation for the reaction between **FB 6** and **FB 7**.
Include state symbols.

..... [1]

[Total: 13]

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 —																								

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9701/33

May/June 2018

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 **11** printed pages and **1** blank page.



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 Acids are defined as substances that can donate hydrogen ions, H^+ , to bases. Monoprotic acids contain one H^+ that can be donated per molecule. Diprotic acids contain two H^+ that can be donated per molecule.

You will determine by a titration method whether acid **Z** is monoprotic or diprotic.

FA 1 is a solution containing 6.10 g dm^{-3} of acid **Z**.

FA 2 is $0.105 \text{ mol dm}^{-3}$ aqueous sodium hydroxide, NaOH .
bromophenol blue indicator

(a) Method

- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Fill a burette with **FA 2**.
- Add several drops of bromophenol blue indicator to the conical flask.
- Carry out 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 accuracy of your practical work.
- Record, in a suitable form below, all of your burette readings and the volume of **FA 2** added in each accurate titration.

I	
II	
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V	
VI	
VII	

[7]

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

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

(c) Calculations

- (i) Calculate the number of moles of sodium hydroxide present in the volume of **FA 2** calculated in (b).

moles of NaOH = ... mol

Then deduce the number of moles of H⁺ present in 25.0 cm³ of **FA 1**.

moles of H⁺ in 25.0 cm³ of **FA 1** = ... mol [1]

- (ii) Calculate the number of moles of H⁺ present in 1 dm³ of **FA 1**.

moles of H⁺ in 1 dm³ of **FA 1** = ... mol [1]

- (iii) **FA 1** contains 6.10 g dm⁻³ of acid **Z**. The relative molecular mass of **Z** is 126.

Calculate the number of moles of **Z** in 1 dm³ of **FA 1**.

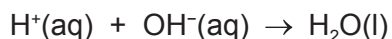
moles of **Z** in 1 dm³ of **FA 1** = ... mol [1]

- (iv) Use your answers to (ii) and (iii) to determine whether **Z** is a monoprotic or a diprotic acid. Explain your answer.

.....
 [1]

[Total: 12]

- 2 When an acid reacts with an alkali the neutralisation reaction is always exothermic.



You will determine the enthalpy change of neutralisation, ΔH , for a monoprotic acid **X**.

FA 3 is aqueous sodium hydroxide, NaOH.

FA 4 is a 2.00 mol dm^{-3} solution of monoprotic acid **X**.

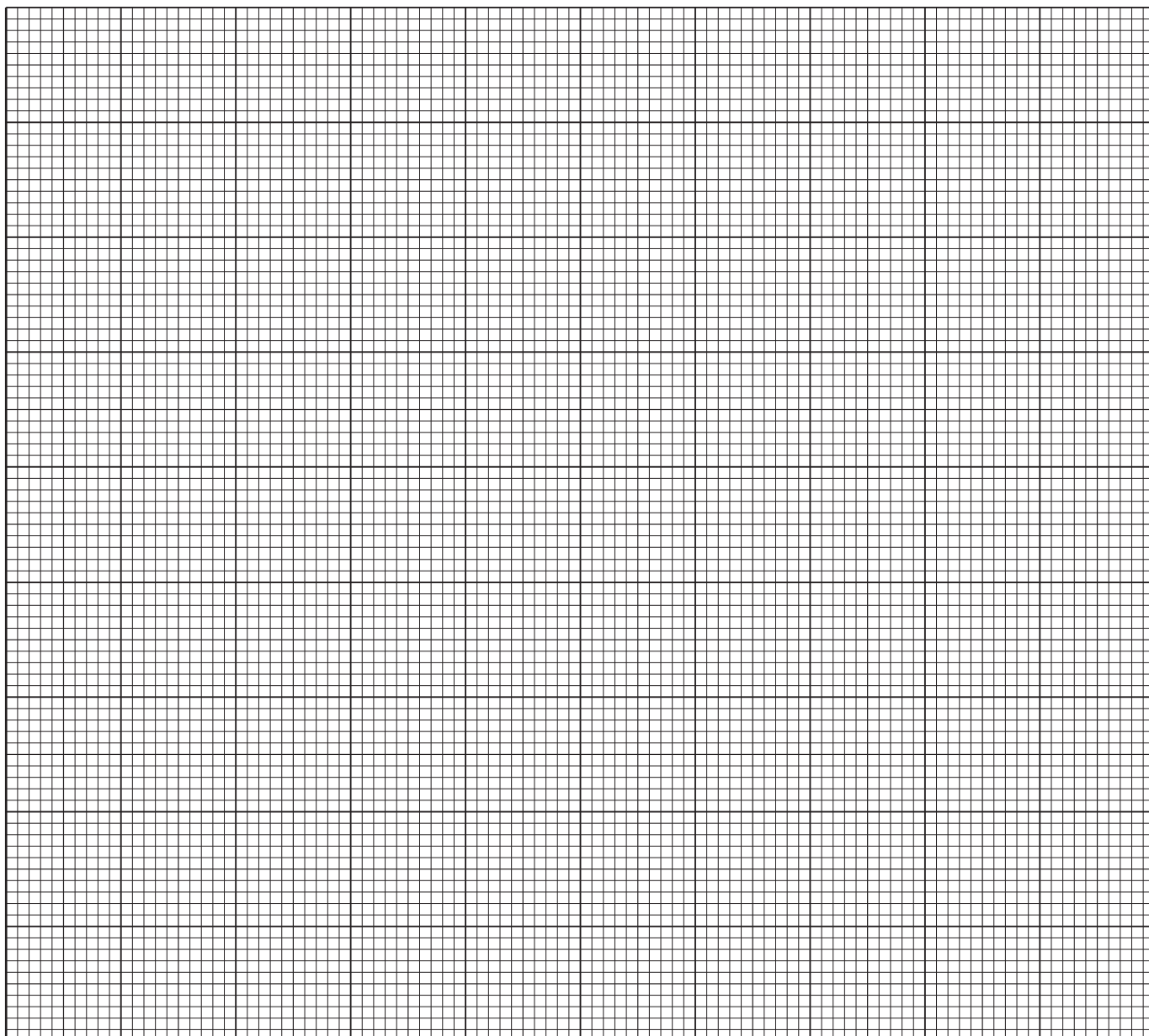
(a) Method

- Support the plastic cup in the 250 cm^3 beaker.
- Fill the second burette with **FA 3**.
- Use the measuring cylinder to transfer 25.0 cm^3 of **FA 4** into the plastic cup.
- Measure and record the temperature of **FA 4** in the plastic cup.
- Add 5.00 cm^3 of **FA 3** from the burette into the plastic cup. Stir the contents of the cup. Read and record the maximum temperature of the solution.
- Add a further 5.00 cm^3 of **FA 3** from the burette into the cup. Stir the contents of the cup. Read and record the maximum temperature of the solution.
- Repeat the addition of **FA 3**, in 5.00 cm^3 portions, until 50.00 cm^3 have been added. Read and record the maximum temperature of the solution after each addition.

I	
II	
III	
IV	

[4]

- (b) On the grid plot a graph of temperature, (y-axis), against volume of **FA 3** added, (x-axis).
Your scale should allow a temperature of 2°C above the maximum measured to be plotted.



On your graph draw two lines of best fit. One line should be for when the temperature was rising and the other for after the maximum temperature had been reached. You should indicate clearly any points you consider to be anomalous.

Extrapolate the lines so that they intersect.

[4]

- (c) From your graph, determine the maximum temperature reached in the experiment and the volume of **FA 3** added to produce this maximum temperature.

maximum temperature reached = ... °C

volume of **FA 3** added to reach maximum temperature = ... cm³

[1]

- (d) (i) Calculate the energy released during this experiment.

[Assume that 4.2 J of heat energy changes the temperature of 1.0 cm³ of solution by 1.0 °C.]

energy released = ... J [1]

- (ii) Calculate the number of moles of acid **X** in 25.0 cm³ of **FA 4**.

moles of **X** = ... mol [1]

- (iii) Calculate, in kJ mol⁻¹, the enthalpy change of neutralisation for acid **X**.

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

- (e) Without changing the apparatus or solutions used, suggest **one** way in which the experiment could be modified to make the values obtained in (c) more accurate.

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

- (f) The enthalpy change of neutralisation of hydrochloric acid with aqueous sodium hydroxide is more exothermic than the enthalpy change of neutralisation of acid **X**.

Explain what this tells you about acid **X**.

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

[Total: 15]

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 1.0 mol dm^{-3} sulfuric acid, 0.1 mol dm^{-3} sulfuric acid and 1.0 mol dm^{-3} hydrochloric acid but not necessarily in that order.

You are to plan and carry out tests to determine the identities of **FA 5**, **FA 6** and **FA 7**. You should record, in a suitable form in the space below, your tests and observations. You should show clearly the observations for each of **FA 5**, **FA 6** and **FA 7** with all test reagents.

FA 5 is

FA 6 is

FA 7 is

[4]

(b) FA 8 and FA 9 each contain one anion and one cation.

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

For each test you should use a **small** spatula measure of **FA 8** or **FA 9**.

test	observations	
	FA 8	FA 9
Add a small spatula measure to a 1 cm depth of distilled water in a test-tube and shake. Add a few drops of universal indicator. Record the pH of the mixture.		
Heat a small spatula measure in a hard-glass test-tube.		
Dissolve a small spatula measure in a 2 cm depth of dilute hydrochloric acid in a boiling tube (heat gently if necessary). Place a 1 cm depth of this solution into two test-tubes.		
To one test-tube, add aqueous sodium hydroxide.		
To the second test-tube, add aqueous ammonia.		

[6]

(ii) Mix a spatula measure of **FA 8** with a spatula measure of **FA 9**. Heat the mixture in a hard-glass test-tube. Record your observations.

.....

 [1]

(iii) From your observations in **(b)(i)** and **(b)(ii)** identify the ions present in **FA 8** and **FA 9**. If you are unable to identify an ion, write 'unknown'.

FA 8 cation anion

FA 9 cation anion

[2]

[Total: 13]

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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

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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
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CANDIDATE
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CHEMISTRY

9701/34

Paper 3 Advanced Practical Skills 2

May/June 2018

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.
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Session
Laboratory

For Examiner's Use	
1	
2	
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 Glucose, $\text{C}_6\text{H}_{12}\text{O}_6$, is a sugar that can act as a reducing agent. You will investigate how an increase in temperature affects the rate of the redox reaction between glucose and acidified potassium manganate(VII).

FB 1 is $0.010 \text{ mol dm}^{-3}$ acidified potassium manganate(VII), KMnO_4 .

FB 2 is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4 .

FB 3 is an aqueous solution containing 32.8 g dm^{-3} glucose, $\text{C}_6\text{H}_{12}\text{O}_6$.
distilled water

You will measure the time it takes for the purple colour to disappear. Your table of results on page 4 should include the rate of reaction for each experiment.

(a) Method

Experiment 1

- Fill the burette with **FB 1**.
- Add 10.00 cm^3 of **FB 1** into the 250 cm^3 beaker.
- Use the 50 cm^3 measuring cylinder to transfer 50.0 cm^3 of **FB 2** into the beaker containing **FB 1**.
- Use the same measuring cylinder to transfer 50.0 cm^3 of distilled water into the same beaker.
- Place the beaker on the tripod and heat its contents to between 65°C and 70°C .
- While the solution in the beaker is heating pour 25.0 cm^3 of **FB 3** into the 25 cm^3 measuring cylinder.
- When the temperature of the contents of the beaker has reached between 65°C and 70°C , remove the Bunsen burner and **carefully** place the hot beaker onto the white tile.
- Record the temperature of the solution in the beaker.
- Add the 25.0 cm^3 of **FB 3** and **immediately** start timing.
- Stir the contents of the beaker once and stop timing as soon as the solution turns colourless. Record the time to the nearest second.
- Record the temperature of the solution as soon as it is colourless.
- Calculate and record the average temperature of the reaction mixture to one decimal place.
- Empty, rinse and dry the beaker so it is ready for use in **Experiment 2**.

Experiment 2

- Add 10.00 cm³ of **FB 1** into the 250 cm³ beaker.
- Use the 50 cm³ measuring cylinder to transfer 50.0 cm³ of **FB 2** into the beaker containing **FB 1**.
- Use the same measuring cylinder to transfer 50.0 cm³ of distilled water into the same beaker.
- Place the beaker on the tripod and heat its contents to between 30 °C and 35 °C.
- While the solution in the beaker is heating pour 25.0 cm³ of **FB 3** into the 25 cm³ measuring cylinder.
- When the temperature of the contents of the beaker has reached between 30 °C and 35 °C, remove the Bunsen burner and **carefully** place the hot beaker onto the white tile.
- Record the temperature of the solution in the beaker.
- Add the 25.0 cm³ of **FB 3** and **immediately** start timing.
- Stir the contents of the beaker once and stop timing as soon as the solution turns colourless. Record the time to the nearest second.
- Record the temperature of the solution as soon as it is colourless.
- Calculate and record the average temperature of the reaction mixture to one decimal place.
- Empty, rinse and dry the beaker so it is ready for use in **Experiment 3**.

Experiments 3, 4 and 5

- Repeat the method for **Experiment 2** at three different temperatures.
- Keep the temperature of the contents of the beaker between room temperature and 70 °C.
- Record all your results in your table.

Results

The rate of reaction can be calculated as shown.

$$\text{rate} = \frac{1000}{\text{reaction time}}$$

Calculate the rate of reaction for each experiment and include this in your table.

I	
II	
III	
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VI	
VII	
VIII	

[8]

- (b) Plot a graph of rate (y-axis) against average temperature (x-axis) on the grid opposite. Select a scale on the x-axis to include an average temperature of 15.0 °C. Label any points you consider anomalous.

Draw a line of best fit and extrapolate it to 15.0 °C.

[4]

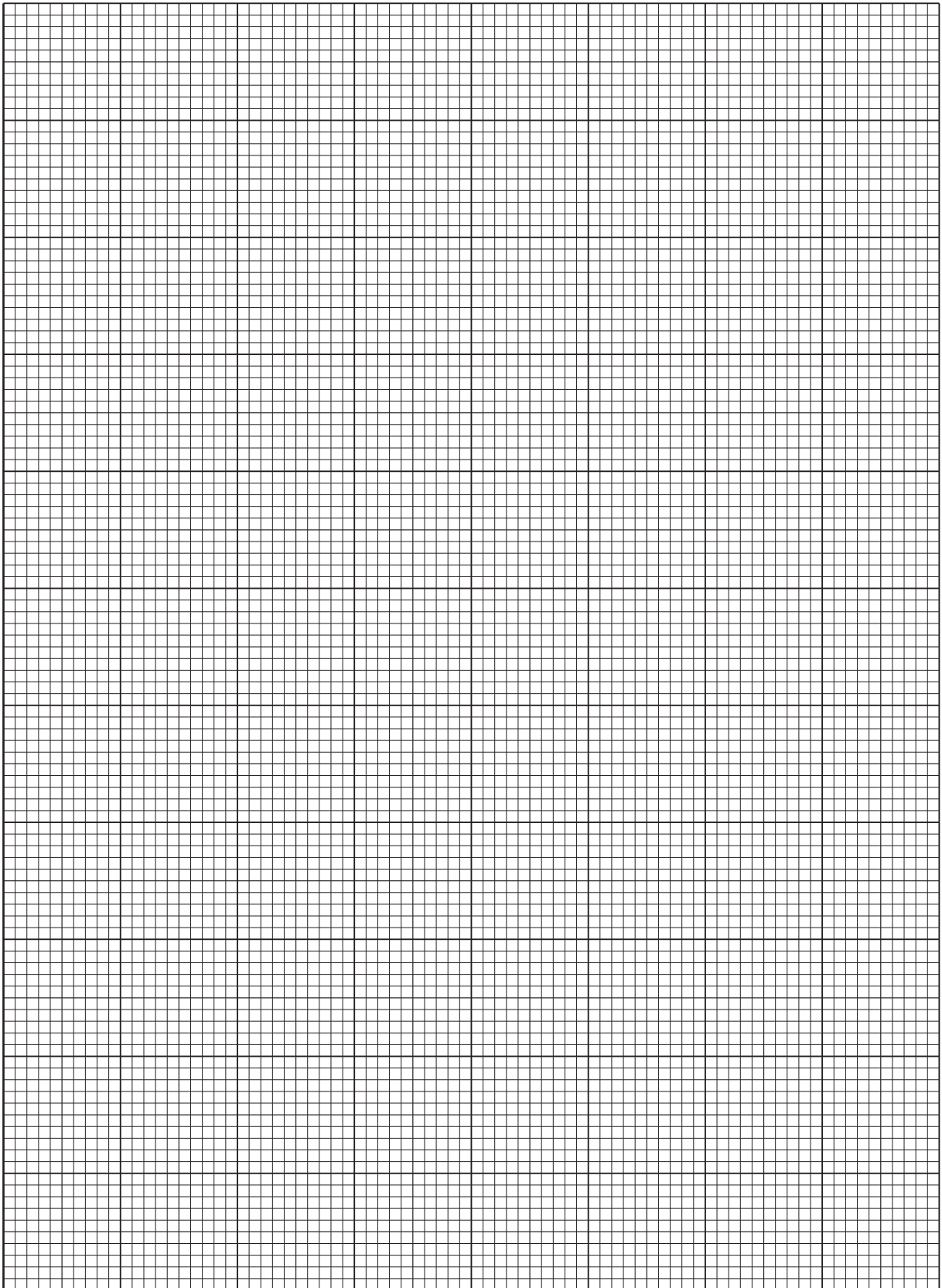
- (c) **Use your graph** to calculate the **time** to the nearest second that the reaction would have taken if the average temperature had been 52.5 °C.
Show **on the grid** how you obtained your answer.

time = ... s [2]

- (d) Explain, by referring to your graph or your table of results, how the rate of reaction is affected by an increase in temperature.

.....

 [2]



I	
II	
III	
IV	

- (e) (i) Calculate the concentration of glucose in **FB 3** in mol dm^{-3} .

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

- (ii) Under certain conditions, 1.0 mole of acidified potassium manganate(VII), KMnO_4 , can oxidise 2.5 moles of glucose.

Calculate the volume of $0.010 \text{ mol dm}^{-3}$ acidified KMnO_4 that would react with **all** the glucose present in 25.0 cm^3 of **FB 3**.

[3]

- (iii) The formula of glucose can be written as $\text{CHO}(\text{CHOH})_4\text{CH}_2\text{OH}$.

Suggest the formula of an organic product of the oxidation of glucose.

..... [1]

- (f) (i) Calculate the maximum percentage error in the reaction time recorded for **Experiment 1**. Assume the error of the timer is $\pm 1 \text{ s}$.

maximum percentage error in **Experiment 1** = ... % [1]

- (ii) You have carried out experiments at five different temperatures.

Identify an experiment, if any, you should have repeated. Give a reason for your answer.

.....

 [1]

- (g) Suggest **two** ways to improve the accuracy of the results for this investigation.

1

 2
 [2]

[Total: 25]

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.

- 2 Sandell's solution reacts in a similar way to Fehling's reagent.
You will need to heat Sandell's solution in a hot water bath when using it in tests.

Half fill the 250 cm³ beaker with water and place it on the tripod and gauze. Heat the water until it is boiling then turn off the Bunsen burner. This will be your hot water bath.

(a) **FB 4**, **FB 5** and **FB 6** are all solutions of carbohydrates.

- Sugars and starch are carbohydrates.
- Some sugars contain an aldehyde group so act as reducing agents.
- Other sugars do not contain an aldehyde group.

- (i) For each test use a 1 cm depth of the solution in a test-tube. Record all your observations in the table.

test	observations		
	FB 4	FB 5	FB 6
Add 2 or 3 drops of aqueous iodine.			
Add 2 or 3 drops of acidified potassium manganate(VII) and allow to stand for two minutes.			
Add a 3 cm depth of Sandell's solution and place the tube in the hot water bath for two minutes.			

[3]

- (ii) Circle the carbohydrate that could be starch.

FB 4

FB 5

FB 6

Circle the carbohydrate that contains an aldehyde group.

FB 4

FB 5

FB 6

[1]

- (iii) Suggest a different test, other than using Fehling's reagent, that could be carried out to identify the presence of an aldehyde group. State the reagent(s) you would use and the expected observation if the result were positive.

Do not carry out your test.

reagent(s)

observation

[1]

- (b) (i) **FB 7** and **FB 8** are two of the components of Sandell's solution. Each contains one cation and one anion. Two of the ions are listed in the Qualitative Analysis Notes.

For each test use a 1 cm depth of solution in a test-tube. Record all your observations in the table.

<i>test</i>	<i>observations</i>	
	FB 7	FB 8
Add a few drops of aqueous silver nitrate.		
Add a few drops of aqueous barium nitrate or aqueous barium chloride, then		
add dilute nitric acid.		
Add a few drops of aqueous iodine.		
Add a 1 cm depth of aqueous iron(II) sulfate.		
Add a 1 cm depth of FB 8 .		

[6]

- (ii) Identify the ions in **FB 7** and **FB 8**. If you are unable to identify any of the ions, write 'unknown'.

FB 7 cation anion

FB 8 cation anion

[2]

- (iii) Write an ionic equation for any reaction in (i) that produced a precipitate. Include state symbols.

..... [2]

[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
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																		
		Key atomic number atomic symbol name relative atomic mass																		
3	4											5	6	7	8	9	10	11	12	
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				
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			
K potassium 39.1	Ca calcium 40.1											Ga gallium 69.7	Ge germanium 72.6	As arsenic 74.9	Se selenium 79.0	Br bromine 79.9	Kr krypton 83.8			
Rb rubidium 85.5	Sr strontium 87.6											In indium 114.8	Sn tin 118.7	Sb antimony 121.8	Te tellurium 127.6	I iodine 126.9	Xe xenon 131.3			
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 —			
Fr francium —	Ra radium —												Fl flerovium —		Lv liveonium —					

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

lanthanoids

actinoids

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9701/35

May/June 2018

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 In this experiment you will determine **x** in the formula of hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$, by titration.

FA 1 is hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.

FA 2 is $0.110 \text{ mol dm}^{-3}$ hydrochloric acid, HCl .
methyl orange indicator

(a) Method

Making a solution of FA 1

- Record all masses in the space below.
- Weigh the container with **FA 1**.
- Tip all the solid **FA 1** into the 250 cm^3 beaker.
- Weigh the container with any residual **FA 1**.
- Add approximately 100 cm^3 of distilled water to the beaker and stir to dissolve **FA 1**.
- Transfer the solution to the 250 cm^3 volumetric flask.
- Rinse the beaker twice, each time with about 20 cm^3 of distilled water, and add this to the volumetric flask.
- Add distilled water to the volumetric flask to make 250 cm^3 of solution and shake thoroughly. Label this solution **FA 3**.
- Calculate and record the mass of **FA 1** used to make this solution.

Titration

- Pipette 25.0 cm^3 of **FA 3** into a conical flask.
- Fill the burette with **FA 2**.
- Add several drops of methyl orange indicator to the conical flask.
- Carry out a **rough** titration and record your burette readings in the space below.

The rough titre is cm^3 .

I	
II	
III	
IV	
V	
VI	
VII	

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

[7]

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

25.0 cm³ of **FA 3** required cm³ of **FA 2** [1]

(c) Calculations

- (i) Give your answers to (ii), (iii) and (iv) to the appropriate number of significant figures. [1]
- (ii) Calculate the number of moles of hydrochloric acid in the volume of **FA 2** calculated in (b).

moles of HCl = ... mol [1]

- (iii) Complete the equation below and include the missing state symbols.



Calculate the number of moles of sodium carbonate in 25.0 cm³ of **FA 3**.

moles of Na₂CO₃ in 25.0 cm³ of **FA 3** = ... mol [1]

- (iv) Calculate the number of moles of sodium carbonate in 250.0 cm^3 of **FA 3**.

moles of Na_2CO_3 in 250.0 cm^3 of **FA 3** = ... mol

Use this answer and your data on page 2 to calculate the relative formula mass, M_r , of hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.

M_r of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ = ... [1]

- (v) Calculate the value of x in $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$. Give your answer to the nearest whole number.

x = ... [1]

- (d) A student suggested using 0.110 mol dm^{-3} sulfuric acid in place of the 0.110 mol dm^{-3} hydrochloric acid used in the experiment above. The mass of **FA 1** used was unchanged.

Explain what effect this change would have on the accuracy of the experiment.

.....

 [2]

[Total: 15]

- 2 In **Question 1** you used a titration method to investigate a hydrated compound. In **Question 2** you will use a method involving measuring masses. You will find the identity of a Group 2 element, **Y**, whose hydrated sulfate has the formula $\text{YSO}_4 \cdot 7\text{H}_2\text{O}$.

When heated, the hydrated sulfate loses its water of crystallisation to form anhydrous sulfate. The anhydrous sulfate does not decompose at the temperature of the Bunsen flame.



FA 4 is the hydrated sulfate of **Y**, $\text{YSO}_4 \cdot 7\text{H}_2\text{O}$.

(a) Method

- Weigh the crucible with its lid and record the mass.
- Tip between 1.80g and 2.00g of **FA 4** into the crucible. **Keep the remaining FA 4 for Question 3.**
- Weigh and record the mass of crucible, lid and **FA 4**.
- Place the crucible on the pipe-clay triangle on the tripod. Put the lid on the crucible and heat gently for about 1 minute.
- Use tongs to remove the lid and heat the crucible strongly for about 4 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 and record the mass.
- Calculate and record the mass of **FA 4** before heating, the mass of residue after heating and the mass of water lost.

[4]

(b) Calculations

- (i) Calculate the number of moles of water lost on heating **FA 4**.

moles of H_2O lost = ... mol [1]

- (ii) Deduce the number of moles of anhydrous YSO_4 that are formed when this water is lost.

moles of YSO_4 = ... mol [1]

- (iii) Use your answer to (ii) and the mass of residue left after heating **FA 4** to determine the relative atomic mass, A_r , of **Y**.

A_r of **Y** = ... [2]

- (iv) Identify **Y**.

Y is [1]

- (c) A student did not heat the sample of **FA 4** for long enough to remove all the water.

What would be the effect of this on the calculated value of the relative atomic mass of **Y**?

Explain your answer.

.....

 [2]

[Total: 11]

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) In **Question 2** you used a gravimetric method to identify the cation, **Y**, present in **FA 4**. You will now use a qualitative analysis method to confirm whether your identification of **Y** was correct.

Transfer a spatula measure of **FA 4** into a boiling tube. Add a 5 cm depth of distilled water and shake the tube to dissolve the solid.

- (i) Use 1 cm depths of this solution in test-tubes to carry out tests to identify the cation, **Y**, present in **FA 4**. Record your tests and observations in a suitable form in the space below.

[3]

- (ii) Do your qualitative analysis tests in (i) confirm your identity of **Y** in **Question 2**? Explain your answer.

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

- (b) **FA 5** contains **two** of the ions listed in the Qualitative Analysis Notes.

- (i) Place a small spatula measure of **FA 5** into a hard-glass test-tube and heat, gently at first and then strongly. Record your observations.

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

- (ii) Transfer the remaining **FA 5** into the 100 cm³ beaker. Add approximately 20 cm³ of distilled water and stir to form a solution.

For each of the tests below use a separate 1 cm depth of this solution in a test-tube. Record your observations.

<i>test</i>	<i>observations</i>
Add aqueous sodium hydroxide.	
Add a few drops of acidified potassium manganate(VII), then	
add a few drops of ammonium thiocyanate. Tip the contents of the tube down the sink and rinse the tube and sink with tap water.	
Add a 1 cm depth of hydrogen peroxide, then	
add aqueous sodium hydroxide.	
Add a 1 cm depth of dilute nitric acid and then a few drops of aqueous silver nitrate.	
Add a few drops of aqueous barium nitrate or aqueous barium chloride, then	
add dilute hydrochloric acid.	

[6]

- (iii) Identify the ions present in **FA 5**.

ions present and [1]

- (iv) What **type** of reaction is occurring when **FA 5** reacts with acidified potassium manganate(VII)?

..... [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												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 —																							
		21	22	23	24	25	26	27	28	29	30					31	32	33	34	35				
		Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn					Ga	Ge	As	Se	Br				
		scandium 45.0	titanium 47.9	vanadium 50.9	chromium 52.0	manganese 54.9	iron 55.8	cobalt 58.9	nickel 58.7	copper 63.5	zinc 65.4					gallium 69.7	germanium 72.6	arsenic 74.9	selenium 79.0	bromine 79.9				
		39	40	41	42	43	44	45	46	47	48					49	50	51	52	53				
		Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd					In	Sn	Sb	Te	I				
		yttrium 88.9	zirconium 91.2	niobium 92.9	molybdenum 95.9	technetium —	ruthenium 101.1	rhodium 102.9	palladium 106.4	silver 107.9	cadmium 112.4					indium 114.8	tin 118.7	antimony 121.8	tellurium 127.6	iodine 126.9				
		57–71 lanthanoids	72	73	74	75	76	77	78	79	80					81	82	83	84	85				
		lanthanoids	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg					Tl	Pb	Bi	Po	At				
		hafnium 178.5	tantalum 180.9	tungsten 183.8	rhenium 186.2	osmium 190.2	iridium 192.2	platinum 195.1	gold 197.0	mercury 200.6	thallium 204.4					lead 207.2	bismuth 209.0	polonium —	astatine —					
		89–103 actinoids	104	105	106	107	108	109	110	111	112					113	114	115	116	117				
		actinoids	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn					flerovium —	livermorium —	tennessine —	oganesson —					