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9701/31

October/November 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	
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 the percentage purity of a sample of impure anhydrous sodium carbonate. You will use two different methods to measure the enthalpy change of reaction when a sample of impure anhydrous sodium carbonate reacts with excess dilute hydrochloric acid.

FA 1 is a sample of the impure anhydrous sodium carbonate.

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

FA 3 is a second sample of the impure anhydrous sodium carbonate used in **FA 1**.

(a) Method 1

- Weigh the container with **FA 1**. Record this mass.

mass of container with **FA 1** = ... g

- Support one of the plastic cups in the 250 cm^3 beaker.
- Use the measuring cylinder to place 25 cm^3 of **FA 2** into the cup.
- Measure the temperature of the **FA 2** in the cup. Tilt the cup if necessary so that the bulb of the thermometer is fully covered. Record this temperature at time $t = 0$.
- Start the stopclock and leave it running for the whole experiment.
- Measure and record the temperature of **FA 2** in the cup every half minute for 2 minutes.
- At $t = 2\frac{1}{2}$ minutes tip all the **FA 1** into the cup. Stir the contents of the cup.
- Measure and record the temperature of the contents of the cup at $t = 3$ minutes and then every half minute up to $t = 9$ minutes.
- Weigh the container with any residual **FA 1**. Record this mass.

I	
II	
III	
IV	
V	

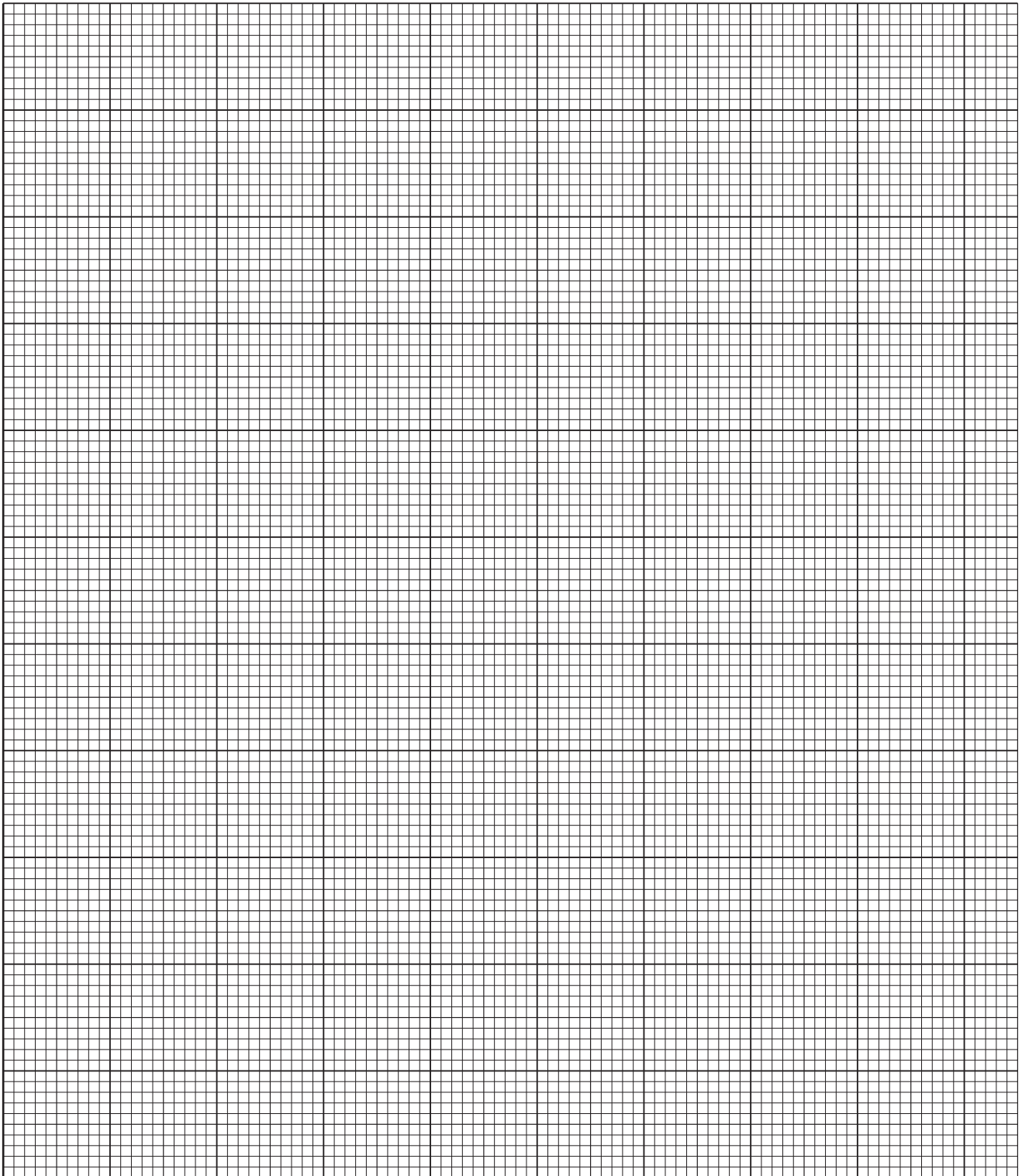
mass of container with residual **FA 1** = ... g
[5]

- (b) (i) On the grid on page 3, plot a graph of temperature (y-axis) against time (x-axis). You should choose a scale that allows you to plot 2°C above the maximum temperature reached.

I	
II	
III	
IV	

On your graph, draw two straight lines of best fit. One line is for the temperature before adding **FA 1** and the other line for the cooling of the solution once reaction is complete.

Extrapolate these two lines to $t = 2\frac{1}{2}$ minutes. [4]



(ii) From your graph, find the theoretical temperature rise at $t = 2\frac{1}{2}$ minutes.

theoretical temperature rise = ... °C [1]

- (c) (i) Calculate the energy released in the reaction.

(Assume 4.2 J of heat energy changes the temperature of 1.0 cm³ of solution by 1.0 °C.)

energy released = ... J [1]

- (ii) The equation for the reaction between anhydrous sodium carbonate and hydrochloric acid is shown.



The literature value for the enthalpy change of this reaction is $-27.0 \text{ kJ mol}^{-1}$.

Use this figure, and the value that you found in (i), to find the mass of anhydrous sodium carbonate you used in (a). You should assume that no energy was lost to the surroundings in your experiment.

mass Na_2CO_3 = ... g [2]

- (iii) Calculate the percentage of anhydrous sodium carbonate present in **FA 1**.

percentage Na_2CO_3 in **FA 1** = ... % [1]

- (d) In your calculation in (c), what assumption have you made about the impurity present in **FA 1**?

.....
 [1]

(e) Method 2

- Weigh a clean, dry plastic cup and record the mass.
- Add between 1.70 g and 1.90 g of **FA 3** to the plastic cup and record the mass.
- Support the plastic cup in the 250 cm³ beaker.
- Pour 25 cm³ of **FA 2** into the measuring cylinder.
- Measure and record the initial temperature of **FA 2** in the measuring cylinder.
- Pour the 25 cm³ of **FA 2** into the plastic cup.
- Stir the contents of the cup and record the maximum temperature. Tilt the cup if necessary so that the bulb of the thermometer is fully covered.
- Calculate and record the mass of **FA 3** used and the change in temperature.

[2]

- (f)** Use the temperature rise in **(e)**, and the fact that the enthalpy change for the reaction between anhydrous sodium carbonate and hydrochloric acid is $-27.0 \text{ kJ mol}^{-1}$, to calculate the percentage of anhydrous sodium carbonate in **FA 3**.

percentage Na₂CO₃ in **FA 3** = ... % [2]

- (g) **FA 1** and **FA 3** are both samples of the same impure anhydrous sodium carbonate and so the percentage of anhydrous sodium carbonate found using **Method 1** and **Method 2** should be the same. In practice the percentages are sometimes different from each other.

In both methods, percentage errors occur due to measuring the mass of solid and the temperature rise.

Ignoring these errors, which method is more accurate?

Tick the correct box and explain your answer.

Method 1 more accurate

☐

Method 2 more accurate

☐

Method 1 and Method 2 equally accurate

☐

.....

 [1]

- (h) A student decided to confirm by experiment the literature value for the enthalpy change of the reaction between anhydrous sodium carbonate and hydrochloric acid. By mistake the student weighed a sample of hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$, instead of anhydrous sodium carbonate, Na_2CO_3 .

State what effect this would have on the calculated value of the enthalpy change for the reaction. Explain your answer.

.....

 [2]

- (i) A student used 3.00 g of anhydrous sodium carbonate that was 80.0% pure by mass.

Calculate the minimum volume of 2.00 mol dm^{-3} hydrochloric acid that would be needed to react completely with this sample of impure anhydrous sodium carbonate.

volume of HCl = ... cm^3 [3]

[Total: 25]

Qualitative Analysis

Where reagents are selected for use in a test, the **full 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 (a) (i) **FA 4** is a sodium compound that was the impurity in the **FA 1** and **FA 3** that you used in **Question 1**. The anion in **FA 4** is one of those listed in the Qualitative Analysis Notes.

Carry out appropriate tests to allow you to positively identify the anion in **FA 4**.

For the test that gives a positive result, record the test and the results of it.
State the name of the anion in **FA 4**.

anion in **FA 4** = ...

[2]

- (ii) Write the ionic equation for the reaction that you have used to identify the anion in **FA 4**.
Include state symbols.

..... [1]

- (b) **FA 5** is a mixture that contains two cations and three anions from those listed in the Qualitative Analysis Notes.

A sample of **FA 5** was added to water and the water stirred. The mixture produced was filtered to give a solid residue, **FA 6**, and a filtrate, **FA 7**.

- (i) Carry out the following tests on **FA 6** and record your observations.

<i>test</i>	<i>observations</i>
To a small spatula measure of FA 6 in a test-tube add dilute hydrochloric acid, then	
add aqueous ammonia.	
Place a small spatula measure of FA 6 in a hard-glass test-tube and heat gently.	

[4]

- (ii) Carry out the following tests on **FA 7** and record your observations.

<i>test</i>	<i>observations</i>
To a 1 cm depth of FA 7 in a test-tube add aqueous sodium hydroxide.	
To a 1 cm depth of FA 7 in a test-tube add aqueous ammonia.	
To a 1 cm depth of FA 7 in a test-tube add a few drops of aqueous silver nitrate.	
To a 1 cm depth of FA 7 in a test-tube add a few drops of aqueous barium nitrate or aqueous barium chloride, then	
add dilute nitric acid.	
To a 0.5 cm depth of FA 7 in a boiling tube add a 2 cm depth of aqueous sodium hydroxide and warm, then	
add a small piece of aluminium foil.	

[5]

(iii) From your observations, identify the two cations present in **FA 5**.

cations and [1]

(iv) From your observations, identify two anions present in **FA 5**.

..... [1]

(v) From your observations, identify two anions that could be present in **FA 5**.

..... [1]

[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	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	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	europium	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	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	—	238.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	

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CANDIDATE
NUMBER

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CHEMISTRY

9701/33

Paper 3 Advanced Practical Skills 1

October/November 2018

2 hours

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

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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	

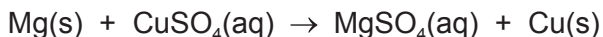
This document consists of **14** printed pages and **2** blank pages.

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 You will determine the enthalpy change, ΔH , for the reaction between magnesium and aqueous copper(II) sulfate. To do this you will measure the change in temperature when magnesium powder reacts with aqueous copper(II) sulfate. The magnesium is in excess.



FA 1 is a solution containing 151.9 g dm^{-3} copper(II) sulfate, CuSO_4 .

FA 2 is magnesium powder, Mg .

(a) Method

- Weigh the container with **FA 2** and record the mass in the space below.
- Support the plastic cup in the 250 cm^3 beaker.
- Use the measuring cylinder to transfer 25 cm^3 of **FA 1** into the plastic cup.
- Place the thermometer in the solution and tilt the cup if necessary so that the bulb of the thermometer is fully covered. Record the temperature at time zero in the table of results.
- Start timing and do not stop the clock until the whole experiment has been completed.
- Record the temperature of the solution every half minute for 2 minutes.
- At $2\frac{1}{2}$ minutes carefully transfer **all** of **FA 2** into the solution in the cup and stir the mixture.
- Record the temperature of the mixture at 3 minutes and complete the table by recording the temperature every half minute. Stir the mixture continuously between thermometer readings.
- Weigh the container with any residual **FA 2** and record the mass below.
- Calculate and record the mass of **FA 2** used.

Keep FA 1 for use in Question 2.

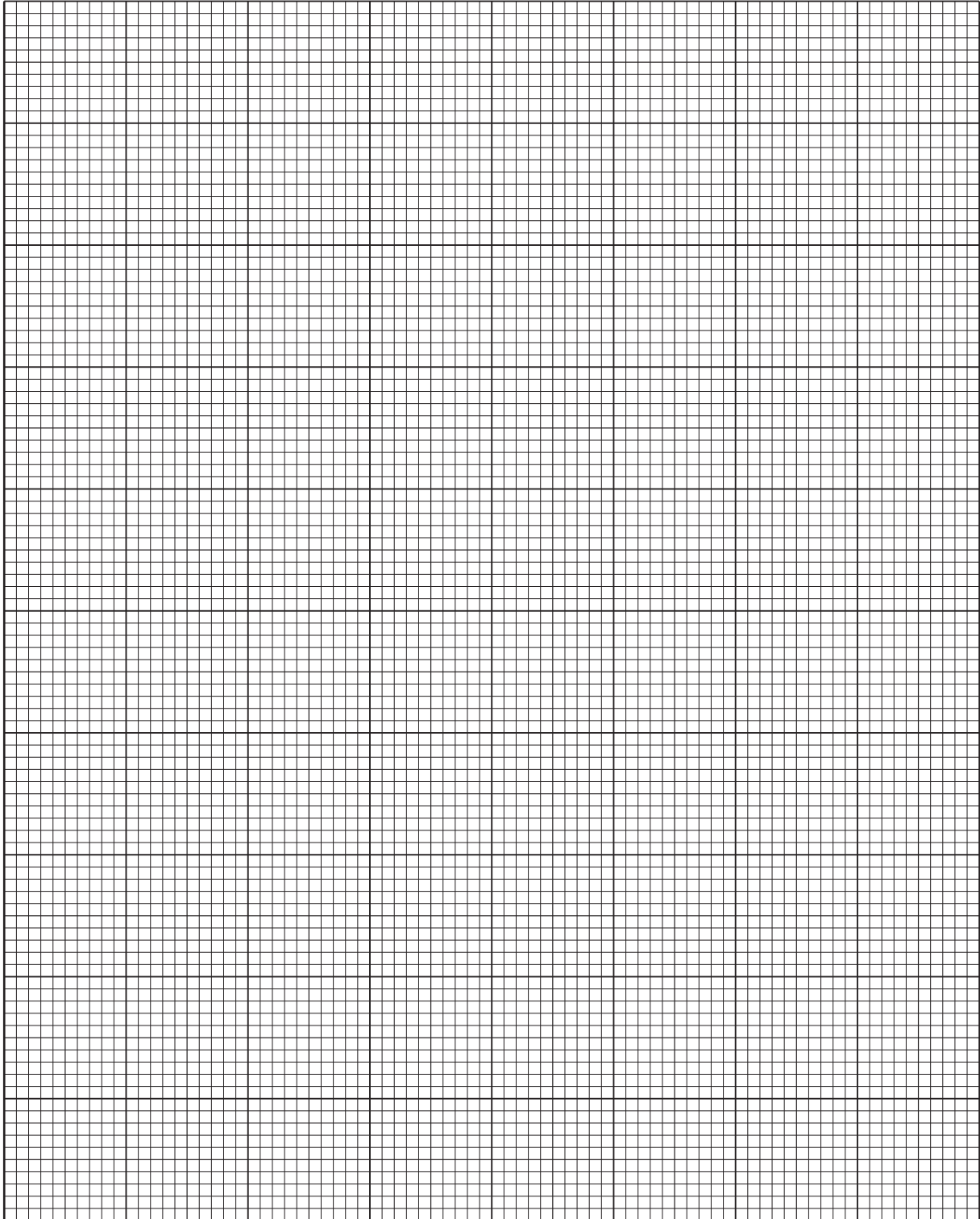
Results

time / minutes	0	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4
temperature / °C									

time / minutes	$4\frac{1}{2}$	5	$5\frac{1}{2}$	6	$6\frac{1}{2}$	7	$7\frac{1}{2}$	8
temperature / °C								

[4]

- (b) (i) 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 at least 10°C above your highest recorded temperature. You will use the graph to determine the theoretical maximum temperature rise at $2\frac{1}{2}$ minutes. Draw two lines of best fit through the points on your graph, the first for the temperature before adding **FA 2** and the second for the cooling of the mixture. Label any points you consider anomalous.



I	
II	
III	

[3]

- (ii) Extrapolate the two lines to $2\frac{1}{2}$ minutes, draw a vertical line between the two lines of best fit and so determine the theoretical rise in temperature, ΔT , at this time.

$\Delta T = \dots\dots\dots$ °C
[2]

(c) Calculations

- (i) Use the information given to calculate the concentration of copper(II) sulfate in **FA 1** in mol dm^{-3} .

concentration of **FA 1** = $\dots\dots\dots$ mol dm^{-3} [1]

- (ii) Hence calculate the number of moles of copper(II) sulfate you used in **(a)**.

moles of $\text{CuSO}_4 = \dots\dots\dots$ mol [1]

- (iii) Use your answer to **(b)(ii)** to calculate the heat energy evolved when **FA 2** is added to **FA 1**. (Assume 4.2 J of heat energy changes the temperature of 1.0 cm^3 of the mixture by 1.0°C .)

heat energy evolved = $\dots\dots\dots$ J [1]

- (iv) Calculate the enthalpy change, in kJ mol^{-1} , when 1 mole of CuSO_4 reacts with magnesium.

enthalpy change = $\dots\dots\dots$ kJ mol^{-1} [1]
(sign) (value)

- (v) Show by calculation that the magnesium was in excess.

[1]

- (d) (i) A student suggested that the calculated enthalpy change would be more accurate if magnesium turnings were used instead of magnesium powder.

State whether you agree with the student and give a reason for your answer.

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

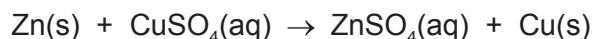
- (ii) The enthalpy change determined in (c)(iv) is only an approximation of the actual value.

Suggest and explain **one** improvement to the **method** in (a) you would make to increase the accuracy of the experiment.

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

[Total: 16]

- 2 In this experiment you will determine the enthalpy change, ΔH , for the reaction between aqueous copper(II) sulfate and zinc. The zinc is in excess. The method used in this question is slightly different from that used in **Question 1**.



FA 3 is zinc powder, Zn.

(a) Method

- Weigh a clean, dry plastic cup and record the mass.
- Add between 1.8 g and 2.0 g of zinc powder, **FA 3**, and record the mass.
- Place the plastic cup in the 250 cm³ beaker.
- Pour 25 cm³ of **FA 1** into the 25 cm³ measuring cylinder.
- Place the thermometer in the solution in the measuring cylinder and record the initial temperature.
- Pour the 25 cm³ of **FA 1** into the plastic cup.
- Stir the contents of the cup and record the highest temperature of the mixture. Tilt the cup if necessary to ensure the thermometer bulb is fully covered.
- Calculate and record the mass of **FA 3** used and the change in temperature.

Keep the remainder of FA 3 for use in Question 3.

Results

[3]

- (d) Use the information given in **Question 1** and **Question 2** and your answers to **1(c)(iv)** and **2(b)(i)** to construct a Hess' cycle diagram for the reaction between magnesium and zinc sulfate to form magnesium sulfate and zinc.

Calculate the enthalpy change for this reaction.

(If you were unable to complete the calculations then assume the enthalpy change for **1(c)(iv)** is -320 kJ mol^{-1} and the enthalpy change for **2(b)(i)** is -201 kJ mol^{-1} . These are not the correct values.)

enthalpy change = ... kJ mol^{-1} [2]
(sign) (value)

[Total: 9]

Qualitative Analysis

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

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

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

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

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

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

No additional tests for ions present should be attempted.

3 (a) FA 4 is a solution of a transition metal compound dissolved in acid.

Carry out the following tests on **FA 4** and record your observations.

<i>test</i>	<i>observations</i>
To a 1 cm depth of FA 4 in a test-tube, add a 1 cm depth of potassium iodide, then	
add aqueous sodium thiosulfate.	
To a 3 cm depth of FA 4 in a boiling tube, add a spatula measure of zinc powder, FA 3 . If no reaction occurs, carefully warm the mixture. Leave the mixture for 5–15 minutes, observing the mixture occasionally.	
Keep the mixture of FA 4 and FA 3 for use in (c). The solution formed from the mixture is FA 6. Complete part (b) while FA 4 and FA 3 continue reacting.	

[5]

- (b) (i) **FA 5** is the acid used to make **FA 4**. The anion in **FA 5** is listed in the Qualitative Analysis Notes.

List the reagents you would use to identify this anion and state which acid the reagents are testing for.

[2]

- (ii) Carry out **one** of your tests in (i) and record your observations.

Give the formula of the anion present in **FA 5**. Write 'unknown' if your test could not positively identify this anion.

.....

[2]

- (c) Carry out the following tests on **FA 6** (the solution formed in (a)).

<i>test</i>	<i>observations</i>
To a 1 cm depth of FA 6 in a test-tube, add acidified potassium manganate(VII) a few drops at a time until in excess. At this stage the solution will be pink.	
To a 1 cm depth of FA 6 in a test-tube, add a 1 cm depth of FA 4 .	

[3]

- (d) (i) State the type of reaction occurring in (c) when acidified potassium manganate(VII) was added to **FA 6**.

Give a reason for your answer.

.....

..... [2]

- (ii) The ion present in **FA 4** when in acidic solution is usually written as MO_2^+ where **M** represents the transition metal.

Calculate the oxidation state of **M** in MO_2^+ .

oxidation state of **M** = ... [1]

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

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9701/34

October/November 2018

2 hours

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

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DO NOT WRITE IN ANY BARCODES.

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

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

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

Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

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



Quantitative Analysis

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

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

- 1** In this experiment you will determine the percentage by mass of an impure sample of sodium hydrogencarbonate, NaHCO_3 .
You will do this by titration with hydrochloric acid, HCl . The impurity in the sample is **X**. **X** is a sodium compound which does not react with HCl .

FB 1 is a mixture containing sodium hydrogencarbonate and **X**.

You are supplied with approximately 6.5 g of **FB 1**. You will also use **FB 1** in **Question 2**.

FB 2 is $0.105 \text{ mol dm}^{-3}$ hydrochloric acid, HCl .

methyl orange indicator

(a) Method

Preparing a solution of **FB 1**

- Weigh the 100 cm^3 beaker. Record the mass.
- Add between 2.8 g and 3.0 g of **FB 1** to the beaker.
- Reweigh the beaker with **FB 1**. Record the mass.
- Calculate and record the mass of **FB 1** used.
- Add approximately 50 cm^3 of distilled water to **FB 1** in the beaker.
- Stir the mixture with a glass rod until all the **FB 1** 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.
- Add distilled water to the volumetric flask up to the mark.
- Shake the flask thoroughly.
- This solution of impure sodium hydrogencarbonate is **FB 3**. Label the flask **FB 3**.

Titration of **FB 3**

- Fill the burette with **FB 2**.
- Pipette 25.0 cm^3 of **FB 3** into a conical flask.
- Add approximately 10 drops of methyl orange indicator.
- Carry out a rough titration.
- Record your burette readings and the rough titre in the space below.

The rough titre is cm^3 .

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

I	
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VIII	

[8]

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

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

(c) Calculations

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

(ii) Calculate the number of moles of hydrochloric acid, HCl , in the volume of **FB 2** calculated in (b).

moles of HCl = ... mol [1]

(iii) Complete and balance the equation for the reaction of sodium hydrogencarbonate with hydrochloric acid. Include state symbols.



Deduce the number of moles of sodium hydrogencarbonate that reacted with the number of moles of HCl calculated in (ii).

moles of NaHCO_3 = ... mol [1]

(iv) Use your answer to (iii) to calculate the number of moles of sodium hydrogencarbonate in the **FB 1** that you weighed out.

moles of NaHCO_3 in **FB 1** used = ... mol [1]

(v) Calculate the percentage by mass of NaHCO_3 in **FB 1**.

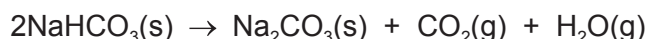
percentage by mass of NaHCO_3 in **FB 1** = ... % [1]

[Total: 14]

Question 2 starts on the next page.

- 2 You will determine the percentage by mass of NaHCO_3 in **FB 1** again, this time by thermal decomposition.

The equation for the thermal decomposition of sodium hydrogencarbonate is shown.



FB 1 is a mixture containing sodium hydrogencarbonate and an impurity, **X**.

(a) Method

- Weigh a crucible with its lid and record the mass.
- Add between 2.8g and 3.0g of **FB 1** to the crucible. Weigh the crucible and lid with **FB 1** and record the mass.
- Place the crucible on the pipe-clay triangle. Heat the crucible and contents gently for approximately two minutes, with the lid off.
- Then heat strongly for approximately three minutes.
- Replace the lid and leave the crucible and residue to cool for at least five minutes.

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

- Reweigh the crucible and contents with the lid on. Record the mass.
- Heat the crucible and contents strongly for a further two minutes, without the lid.
- Replace the lid and leave the crucible and residue to cool for at least five minutes.
- Reweigh the crucible and contents with the lid on. Record the mass.
- Calculate and record the starting mass of **FB 1** and the mass of residue obtained.

I	
II	
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[5]

(b) Calculations

- (i) Calculate the number of moles of carbon dioxide produced during the thermal decomposition of **FB 1** by using the formula below.

$$\text{moles of CO}_2 \text{ produced} = \frac{\text{mass lost during heating}}{M_r\text{CO}_2 + M_r\text{H}_2\text{O}}$$

moles of CO_2 produced = ... mol [1]

- (ii) Use your answer to (i) and the equation on page 6 to calculate the mass of sodium hydrogencarbonate in the **FB 1** you used in this experiment.

mass of NaHCO_3 in **FB 1** = ... g [1]

- (iii) For this experiment calculate the percentage by mass of NaHCO_3 in **FB 1**.

percentage by mass of NaHCO_3 in **FB 1** = ... % [1]

- (c) (i) Explain why the crucible and contents were heated for a further two minutes after the first weighing of the crucible and residue.

.....

 [2]

- (ii) What assumption did you make about the behaviour of **X** when you carried out the calculation?

.....
 [1]

- (iii) A student suggested that it would have been more accurate to carry out the thermal decomposition with the lid on the crucible throughout the experiment.

State and explain whether or not you agree with this suggestion.

.....
 [1]

- (iv) Suggest which of the two procedures, titration or thermal decomposition, gives a more accurate value for the percentage by mass of NaHCO_3 in **FB 1**.
 Explain your choice.

.....

 [1]

[Total: 13]

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 4 has the same composition as the residue obtained in **Question 2**.

It contains two sodium compounds, one of which is **X**.

Both anions present in **FB 4** are listed in the Qualitative Analysis Notes.

- (i) To a small spatula measure of **FB 4** in a test-tube, add dilute nitric acid slowly. Record your observations. Keep the solution produced for use in (ii).

.....

 [2]

- (ii) To a 1 cm depth of the solution obtained in (i) in a test-tube, add a few drops of aqueous silver nitrate, followed by aqueous ammonia. Record your observations.

.....

 [1]

- (iii) Give the equation for one reaction taking place in (i). State symbols are **not** required.

..... [1]

(b) Dissolve the remaining **FB 4** in a 5 cm depth of distilled water in a boiling tube. This solution is **FB 5**.

- (i) Carry out the following tests and record your observations.
Use a 1 cm depth of **FB 5** in a test-tube for each test.

<i>test</i>	<i>observations</i>
Add several drops of aqueous copper(II) sulfate, then	
add dilute sulfuric acid.	
Add a few drops of aqueous barium chloride or aqueous barium nitrate, then	
add dilute nitric acid.	
Add a few drops of methyl orange indicator.	
Add several drops of aqueous silver nitrate, then	
add dilute nitric acid.	

[6]

- (ii) To a 1 cm depth of **FB 5** in a boiling tube, add an equal volume of aqueous sodium hydroxide and warm carefully, then add a small piece of aluminium foil to the mixture. Record your observations.

[1]

- (iii) Using your observations in (a) and (b), name **X**.

..... [1]

- (iv) What can you deduce about **FB 4** from the observation when methyl orange indicator was added to **FB 5**?

..... [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 —																							
		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 —				

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9701/35

October/November 2018

2 hours

Candidates answer on the Question Paper.

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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 **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 the percentage purity of a sample of impure anhydrous sodium carbonate. You will use two different methods to measure the enthalpy change of reaction when a sample of impure anhydrous sodium carbonate reacts with excess dilute hydrochloric acid.

FA 1 is a sample of the impure anhydrous sodium carbonate.

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

FA 3 is a second sample of the impure anhydrous sodium carbonate used in **FA 1**.

(a) Method 1

- Weigh the container with **FA 1**. Record this mass.

mass of container with **FA 1** = ... g

- Support one of the plastic cups in the 250 cm^3 beaker.
- Use the measuring cylinder to place 25 cm^3 of **FA 2** into the cup.
- Measure the temperature of the **FA 2** in the cup. Tilt the cup if necessary so that the bulb of the thermometer is fully covered. Record this temperature at time $t = 0$.
- Start the stopclock and leave it running for the whole experiment.
- Measure and record the temperature of **FA 2** in the cup every half minute for 2 minutes.
- At $t = 2\frac{1}{2}$ minutes tip all the **FA 1** into the cup. Stir the contents of the cup.
- Measure and record the temperature of the contents of the cup at $t = 3$ minutes and then every half minute up to $t = 9$ minutes.
- Weigh the container with any residual **FA 1**. Record this mass.

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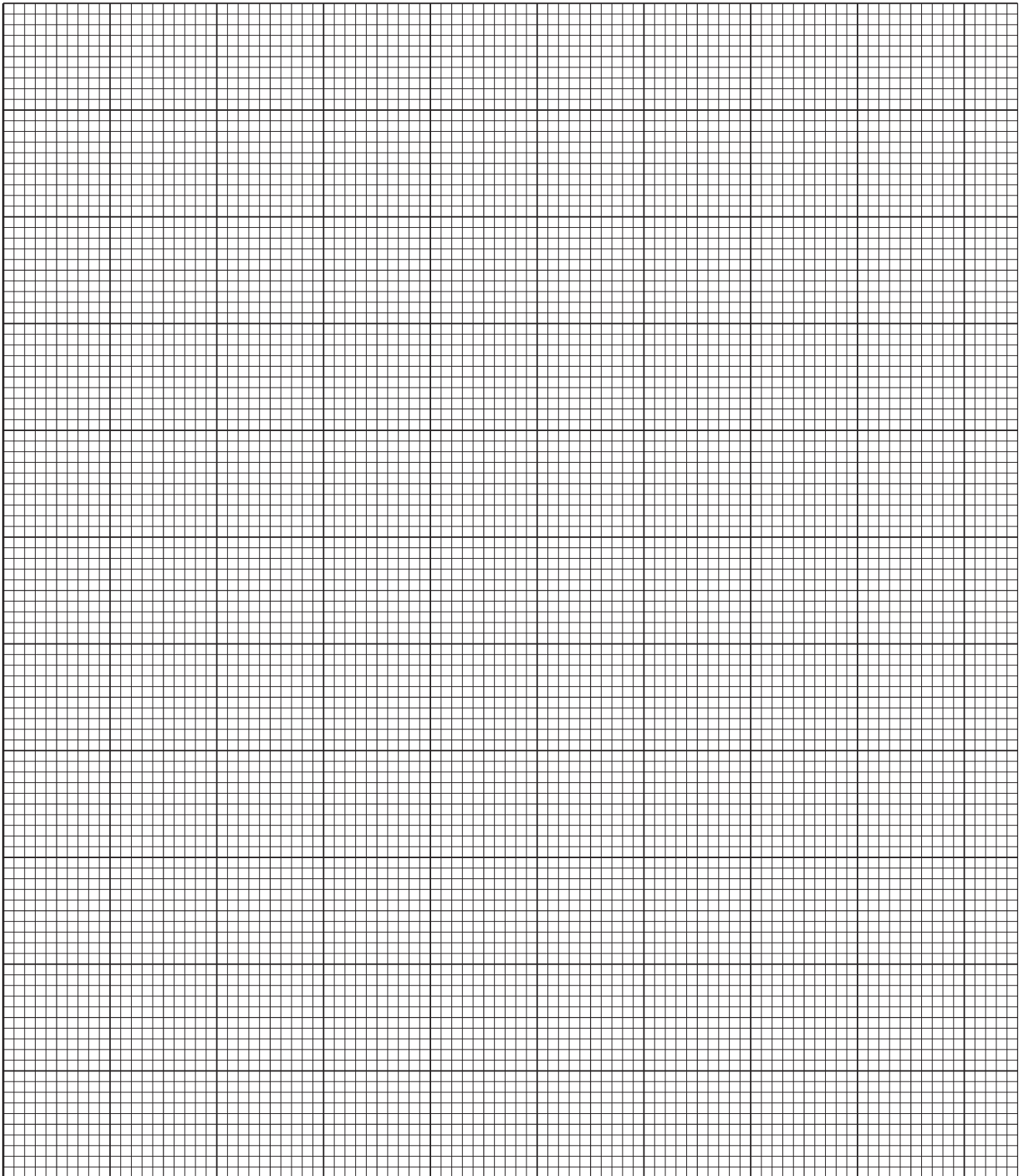
mass of container with residual **FA 1** = ... g
[5]

- (b) (i) On the grid on page 3, plot a graph of temperature (y-axis) against time (x-axis). You should choose a scale that allows you to plot 2°C above the maximum temperature reached.

I	
II	
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On your graph, draw two straight lines of best fit. One line is for the temperature before adding **FA 1** and the other line for the cooling of the solution once reaction is complete.

Extrapolate these two lines to $t = 2\frac{1}{2}$ minutes. [4]



(ii) From your graph, find the theoretical temperature rise at $t = 2\frac{1}{2}$ minutes.

theoretical temperature rise = ... °C [1]

- (c) (i) Calculate the energy released in the reaction.

(Assume 4.2 J of heat energy changes the temperature of 1.0 cm³ of solution by 1.0 °C.)

energy released = ... J [1]

- (ii) The equation for the reaction between anhydrous sodium carbonate and hydrochloric acid is shown.



The literature value for the enthalpy change of this reaction is $-27.0 \text{ kJ mol}^{-1}$.

Use this figure, and the value that you found in (i), to find the mass of anhydrous sodium carbonate you used in (a). You should assume that no energy was lost to the surroundings in your experiment.

mass Na_2CO_3 = ... g [2]

- (iii) Calculate the percentage of anhydrous sodium carbonate present in **FA 1**.

percentage Na_2CO_3 in **FA 1** = ... % [1]

- (d) In your calculation in (c), what assumption have you made about the impurity present in **FA 1**?

.....
 [1]

(e) Method 2

- Weigh a clean, dry plastic cup and record the mass.
- Add between 1.70 g and 1.90 g of **FA 3** to the plastic cup and record the mass.
- Support the plastic cup in the 250 cm³ beaker.
- Pour 25 cm³ of **FA 2** into the measuring cylinder.
- Measure and record the initial temperature of **FA 2** in the measuring cylinder.
- Pour the 25 cm³ of **FA 2** into the plastic cup.
- Stir the contents of the cup and record the maximum temperature. Tilt the cup if necessary so that the bulb of the thermometer is fully covered.
- Calculate and record the mass of **FA 3** used and the change in temperature.

[2]

- (f)** Use the temperature rise in **(e)**, and the fact that the enthalpy change for the reaction between anhydrous sodium carbonate and hydrochloric acid is $-27.0 \text{ kJ mol}^{-1}$, to calculate the percentage of anhydrous sodium carbonate in **FA 3**.

percentage Na₂CO₃ in **FA 3** = ... % [2]

- (g) **FA 1** and **FA 3** are both samples of the same impure anhydrous sodium carbonate and so the percentage of anhydrous sodium carbonate found using **Method 1** and **Method 2** should be the same. In practice the percentages are sometimes different from each other.

In both methods, percentage errors occur due to measuring the mass of solid and the temperature rise.

Ignoring these errors, which method is more accurate?

Tick the correct box and explain your answer.

Method 1 more accurate

☐

Method 2 more accurate

☐

Method 1 and Method 2 equally accurate

☐

.....

 [1]

- (h) A student decided to confirm by experiment the literature value for the enthalpy change of the reaction between anhydrous sodium carbonate and hydrochloric acid. By mistake the student weighed a sample of hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$, instead of anhydrous sodium carbonate, Na_2CO_3 .

State what effect this would have on the calculated value of the enthalpy change for the reaction. Explain your answer.

.....

 [2]

- (i) A student used 3.00 g of anhydrous sodium carbonate that was 80.0% pure by mass.

Calculate the minimum volume of 2.00 mol dm^{-3} hydrochloric acid that would be needed to react completely with this sample of impure anhydrous sodium carbonate.

volume of HCl = ... cm^3 [3]

[Total: 25]

Qualitative Analysis

Where reagents are selected for use in a test, the **full 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 (a) (i) **FA 4** is a sodium compound that was the impurity in the **FA 1** and **FA 3** that you used in **Question 1**. The anion in **FA 4** is one of those listed in the Qualitative Analysis Notes.

Carry out appropriate tests to allow you to positively identify the anion in **FA 4**.

For the test that gives a positive result, record the test and the results of it.
State the name of the anion in **FA 4**.

anion in **FA 4** = ...

[2]

- (ii) Write the ionic equation for the reaction that you have used to identify the anion in **FA 4**.
Include state symbols.

..... [1]

- (b) **FA 5** is a mixture that contains two cations and three anions from those listed in the Qualitative Analysis Notes.

A sample of **FA 5** was added to water and the water stirred. The mixture produced was filtered to give a solid residue, **FA 6**, and a filtrate, **FA 7**.

- (i) Carry out the following tests on **FA 6** and record your observations.

<i>test</i>	<i>observations</i>
To a small spatula measure of FA 6 in a test-tube add dilute hydrochloric acid, then	
add aqueous ammonia.	
Place a small spatula measure of FA 6 in a hard-glass test-tube and heat gently.	

[4]

- (ii) Carry out the following tests on **FA 7** and record your observations.

<i>test</i>	<i>observations</i>
To a 1 cm depth of FA 7 in a test-tube add aqueous sodium hydroxide.	
To a 1 cm depth of FA 7 in a test-tube add aqueous ammonia.	
To a 1 cm depth of FA 7 in a test-tube add a few drops of aqueous silver nitrate.	
To a 1 cm depth of FA 7 in a test-tube add a few drops of aqueous barium nitrate or aqueous barium chloride, then	
add dilute nitric acid.	
To a 0.5 cm depth of FA 7 in a boiling tube add a 2 cm depth of aqueous sodium hydroxide and warm, then	
add a small piece of aluminium foil.	

[5]

(iii) From your observations, identify the two cations present in **FA 5**.

cations and [1]

(iv) From your observations, identify two anions present in **FA 5**.

..... [1]

(v) From your observations, identify two anions that could be present in **FA 5**.

..... [1]

[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								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	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
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	—	—	—	—	—	—	—	—	—	—	—

CANDIDATE
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CANDIDATE
NUMBER

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CHEMISTRY

9701/36

Paper 3 Advanced Practical Skills 2

October/November 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	
Total	

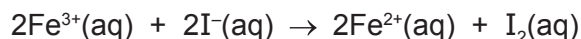
This document consists of **14** printed pages and **2** blank pages.

Quantitative Analysis

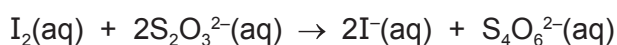
Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

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

- 1** Iron(III) ions oxidise iodide ions, I^- , to iodine, I_2 .



In this experiment you will investigate how the rate of this reaction is affected by the concentration of Fe^{3+} ions. To do this you will add thiosulfate ions, $\text{S}_2\text{O}_3^{2-}$, and starch indicator to a mixture of $\text{Fe}^{3+}(\text{aq})$ and $\text{I}^-(\text{aq})$. The iodine produced by the reaction reacts immediately with the thiosulfate ions and is reduced back to iodide.



When all the thiosulfate has reacted, the iodine remaining in solution turns the starch indicator blue-black. The rate of reaction can be determined by timing how long it takes for the reaction mixture to turn blue-black.

FB 1 is $0.0500 \text{ mol dm}^{-3}$ acidified iron(III) chloride, FeCl_3 .

FB 2 is $0.0500 \text{ mol dm}^{-3}$ potassium iodide, KI .

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

FB 4 is starch indicator.

(a) Method*Experiment 1*

- Fill the burette labelled **FB 1** with **FB 1**.
- Run 20.00 cm³ of **FB 1** into a 100 cm³ beaker.
- Using the measuring cylinder add the following to the second 100 cm³ beaker:
 - 10 cm³ of **FB 2**
 - 20 cm³ of **FB 3**
 - 10 cm³ of **FB 4**
- Add the contents of the first beaker to the second beaker 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. Ignore any colour changes that occur before the intense blue-black colouration.
- Record this reaction time to the nearest second in the space provided on page 4.
- Rinse both beakers and shake dry. Rinse and dry the glass rod.

Experiment 2

- Fill a second burette with distilled water.
- Run 10.00 cm³ of **FB 1** into a 100 cm³ beaker.
- Run 10.00 cm³ of distilled water into the same beaker containing **FB 1**.
- Using the measuring cylinder add the following to the second 100 cm³ beaker:
 - 10 cm³ of **FB 2**
 - 20 cm³ of **FB 3**
 - 10 cm³ of **FB 4**
- Add the contents of the first beaker to the second beaker 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. Ignore any colour changes that occur before the intense blue-black colouration.
- Record this reaction time to the nearest second in the space provided on page 4.
- Rinse both beakers and shake dry. Rinse and dry the glass rod.

Experiments 3–5

- Carry out three further experiments to investigate how the reaction time changes with different volumes of **FB 1**.
Remember that the combined volume of **FB 1** and distilled water must always be 20.00 cm³.
Do **not** carry out an experiment using 15.00 cm³ of **FB 1**.
Do **not** use a volume of **FB 1** that is less than 5.00 cm³.

Keep all FB labelled solutions for use in (e) and in Question 2.

Record all your results in a single table. You should include the volume of **FB 1**, the volume of distilled water and the reaction time.

The relative rate for the reaction is given by the following expression.

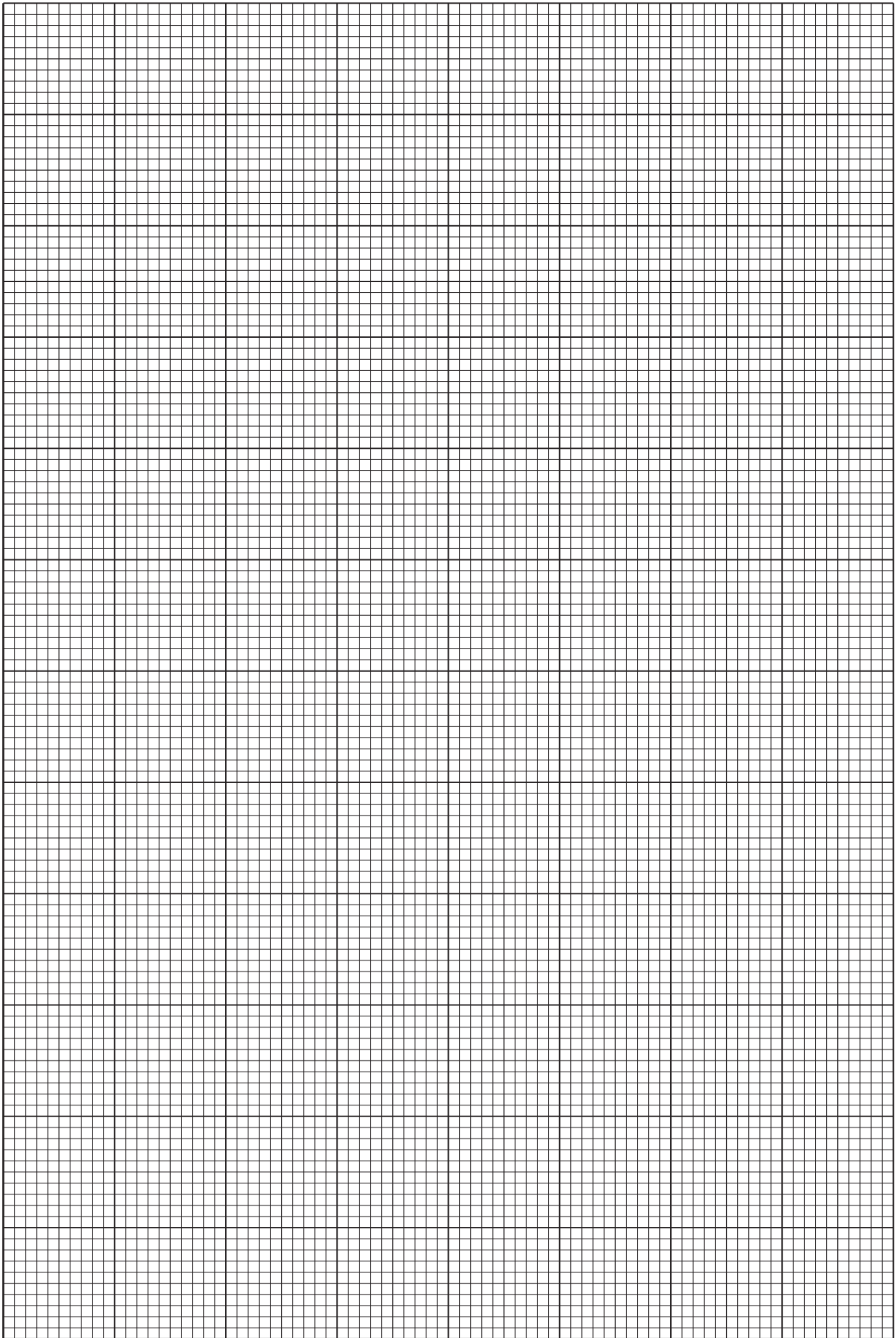
$$\text{relative rate} = \frac{1000}{\text{reaction time in seconds}}$$

Use this expression to calculate the relative rate for each of your experiments and record the values in your results table.

I	
II	
III	
IV	
V	
VI	
VII	
VIII	
IX	
X	

[10]

- (b) On the grid opposite, plot the relative rate against the volume of **FB 1**. Include the origin in your plot. Label any points you consider anomalous. Draw a line of best fit.



I	
II	
III	
IV	

[4]

- (c) From your graph, what conclusion can you make about the relationship between the relative rate for the reaction and the volume of **FB 1** used? Explain your answer.

.....

 [2]

- (d) A student carried out the same experiment but used 15.00 cm^3 of **FB 1**. The student recorded a value for the reaction time of 28 s.

- (i) Use your graph to calculate the time you would have expected to record if you had carried out an experiment using 15.00 cm^3 of **FB 1**.
Show the construction lines on your graph and show your working in the calculation.

reaction time = ... s [2]

- (ii) Calculate the percentage difference between your value and that of the student.
Show your working.

percentage difference = ... % [1]

- (e) You are to carry out a sixth experiment. The concentrations of iron(III) chloride, sodium thiosulfate and starch indicator should all be the same as in *Experiment 2* but the concentration of **iodide ions** should be **twice** the value that it is in *Experiment 2*.
 State the volume of each solution used and record the reaction time to the nearest second.

[2]

- (f) (i) 20.00 cm^3 of $0.0500\text{ mol dm}^{-3}$ FeCl_3 , **FB 1**, were reacted with excess KI, **FB 2**.

Using the information on page 2, calculate the number of moles of I_2 produced.

moles I_2 = ... mol [2]

- (ii) The iodine produced in (i) required 35.00 cm^3 of a different solution of sodium thiosulfate for complete reaction.

Calculate the concentration of the solution of sodium thiosulfate used.

concentration of $\text{Na}_2\text{S}_2\text{O}_3$ = ... mol dm^{-3} [1]

[Total: 24]

Qualitative Analysis

Where reagents are selected for use in a test, the **full 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 (a) **FB 1** is aqueous acidified iron(III) chloride, FeCl_3 .
FB 5 is $0.150 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

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

<i>test</i>	<i>observations</i>
To a 1 cm depth of FB 1 in a test-tube add a 1 cm depth of FB 5 . Leave to stand until there is no further change, then	
add aqueous sodium hydroxide.	
To a 1 cm depth of FB 5 in a test-tube add a few drops of dilute hydrochloric acid. Leave to stand. Rinse the tube thoroughly.	

[3]

- (ii) In (i) you should have observed a reaction between $\text{Fe}^{3+}(\text{aq})$ and $\text{S}_2\text{O}_3^{2-}(\text{aq})$.

Do you think that this reaction affected your results in **Question 1**? Refer to the equations on page 2. Explain your answer.

.....
 [1]

- (b) **FB 6** is a solution containing a halide ion.

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

<i>test</i>	<i>observations</i>
To a 1 cm depth of FB 6 in a test-tube add aqueous silver nitrate, then	
add aqueous ammonia.	
To a 1 cm depth of FB 6 in a test-tube add aqueous silver nitrate, then	
add FB 5 .	

[2]

- (ii) The halide in **FB 6** is

[1]

(c) **FB 7** is a solution of copper(II) sulfate, CuSO_4 .

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

<i>test</i>	<i>observations</i>
To a 1 cm depth of FB 7 in a test-tube add a 1 cm depth of FB 2 , KI, then	
add FB 4 , starch indicator.	
To a 1 cm depth of FB 7 in a test-tube add a 1 cm depth of FB 5 , then	
add a 1 cm depth of FB 2 followed by FB 4 , starch indicator.	

[3]

(ii) Give the formula of one of the products formed in the reaction of **FB 7** with **FB 2** in the first test.

.....

[1]

- (d) **FB 8** is a solution of a salt containing one cation and one anion from those listed in the Qualitative Analysis Notes.

The cation in **FB 8** is one of Mg^{2+} , Zn^{2+} or Al^{3+} .

The anion in **FB 8** is either SO_3^{2-} or SO_4^{2-} .

- (i) Select reagents and carry out tests to identify which ions are present in **FB 8**.
Give details of your tests and observations.

[4]

- (ii) The formula of **FB 8** is

[1]

[Total: 16]

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 —																								