

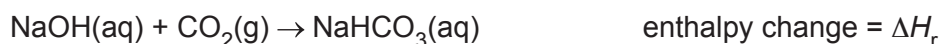
Quantitative analysis

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

Show the precision of the apparatus you used in the data you record.

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 enthalpy change, ΔH_r , for the reaction shown.



You will react each of sodium hydroxide and sodium hydrogencarbonate with excess dilute sulfuric acid. You will determine the enthalpy change for each reaction, then use Hess's law to calculate ΔH_r .

(a) Reaction of sodium hydroxide with sulfuric acid



FA 1 is 2.00 mol dm⁻³ sodium hydroxide, NaOH.

FA 2 is 2.00 mol dm⁻³ sulfuric acid, H₂SO₄.

Method

- Support a cup in the 250 cm³ beaker.
- Use the 50 cm³ measuring cylinder to transfer 30.0 cm³ of **FA 1** into the cup.
- Place the thermometer in **FA 1** and tilt the cup, if necessary, so that the bulb of the thermometer is fully covered. Record the temperature of **FA 1**.
- Use the 25 cm³ measuring cylinder to add 20.0 cm³ of **FA 2** to the **FA 1** in the cup.
- Stir the mixture.
- Measure and record the maximum temperature reached.
- Calculate and record the change in temperature.

Results

I	
II	

[2]

(b) Calculations

(i) Calculate the energy change, in J, in your experiment.

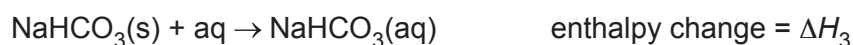
energy change = ... J [1]

(d) Calculations

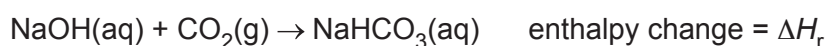
Use your data to calculate the enthalpy change, ΔH_2 , in kJ mol^{-1} of sulfuric acid, for the reaction of $\text{NaHCO}_3(\text{s})$ with $\text{H}_2\text{SO}_4(\text{aq})$.
Show your working.

$$\Delta H_2 = \underset{\text{sign}}{\dots\dots\dots} \underset{\text{value}}{\dots\dots\dots} \text{ kJ mol}^{-1} \text{ of } \text{H}_2\text{SO}_4 \text{ [3]}$$

(e) The enthalpy change when one mole of sodium hydrogencarbonate dissolves in water is ΔH_3 .



Using the symbols ΔH_1 , ΔH_2 and ΔH_3 in your answer, use Hess's law to deduce an expression for ΔH_r .



$$\Delta H_r = \dots\dots\dots \text{ kJ mol}^{-1} \text{ [1]}$$

(f) A student suggested that the experiment in **(c)** would be more accurate if 25.0 cm^3 of 3.00 mol dm^{-3} sulfuric acid was used instead of 25.0 cm^3 of 2.00 mol dm^{-3} sulfuric acid.

State whether the student's suggestion is correct.

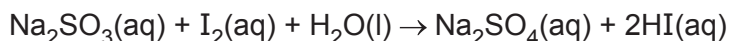
Explain your answer.

.....

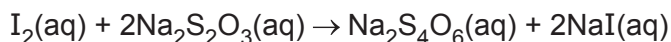
 [1]

[Total: 13]

- 2 Sodium sulfite is oxidised when it reacts with excess iodine.



The remaining iodine is then titrated using aqueous sodium thiosulfate.



You will determine the integer value of x in the formula of hydrated sodium sulfite, $\text{Na}_2\text{SO}_3 \cdot x\text{H}_2\text{O}$, by titration.

FA 4 is aqueous sodium thiosulfate containing 14.24 g of $\text{Na}_2\text{S}_2\text{O}_3$ in 1.00 dm^3 .

FA 5 is aqueous iodine, prepared as shown.

- 5.00 g of hydrated sodium sulfite is added to 600 cm^3 of $0.100 \text{ mol dm}^{-3}$ aqueous iodine.
- The mixture is allowed to stand to ensure that all the sodium sulfite has been oxidised.
- The mixture containing the remaining iodine is made up to 1.00 dm^3 with distilled water.

FA 6 is starch indicator.

(a) Method

- Fill the burette with **FA 4**.
- Pipette 25.0 cm^3 of **FA 5** into a conical flask.
- Add **FA 4** from the burette into the conical flask until the colour of the solution changes to yellow.
- Add 10 drops of **FA 6** to the conical flask. Continue titrating until the blue-black colour just disappears.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

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

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your accurate titration results, calculate a suitable mean value to use in your calculations. Show clearly how you obtain the mean value.

25.0 cm³ of **FA 5** required cm³ of **FA 4**. [1]

(c) Calculations

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

- (ii) Calculate the amount, in mol, of sodium thiosulfate present in the volume of **FA 4** in (b).

amount of Na₂S₂O₃ = ... mol [1]

- (iii) Calculate the amount, in mol, of iodine in 1.00 dm³ of **FA 5**.

amount of I₂ in 1.00 dm³ = ... mol [1]

- (iv) Use the information given and your answer to (c)(iii) to calculate the amount, in mol, of iodine that reacted with sodium sulfite when solution **FA 5** was prepared.

amount of I₂ reacted with sodium sulfite = ... mol [1]

- (v) Use your answer to (c)(iv) to calculate the relative formula mass, M_r , of hydrated sodium sulfite.

M_r of Na₂SO₃·xH₂O = ... [1]

- (vi) Calculate the value of x.

Show your working.

x = ... [1]

[Total: 14]

Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

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

You should record clearly at what stage in a test an observation is made.

Where no change is observed, you should write 'no change'.

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

If any solution is warmed, a boiling tube must be used. If a solid is heated, a hard-glass test-tube must be used.

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

No additional tests should be attempted.

3 (a) FA 7, FA 8 and FA 9 are dilute ethanoic acid, dilute hydrochloric acid and aqueous silver nitrate but **not** necessarily in that order. The solutions of acids have equal concentrations.

- (i) You are supplied with strips of magnesium ribbon.
You must **not** use any other reagents in this part of the question.

Carry out tests to identify each of the three solutions, **FA 7**, **FA 8** and **FA 9**.
Obtain as much evidence as you can for your identifications.
Use a 1 cm depth of solution in a test-tube for each test you carry out.

Record all your observations.

FA 7 is **FA 8** is **FA 9** is [5]

- (ii) Give the ionic equation for the reaction of magnesium with **FA 8**. Include state symbols.

..... [1]

(b) **FA 10** and **FA 11** are both aqueous solutions of salts, each of which contains one cation and one anion listed in the Qualitative analysis notes.

(i) Carry out the following tests and record your observations in Table 3.1.

For Tests 1 and 2, use a 1 cm depth of **FA 10** or **FA 11** in a test-tube.

For Test 3, use a 1 cm depth of **FA 10** or **FA 11** in a boiling tube.

Table 3.1

<i>test</i>	<i>observations</i>	
	FA 10	FA 11
Test 1 Add aqueous ammonia.		
Test 2 Add a few drops of aqueous barium chloride or aqueous barium nitrate, then		
add dilute hydrochloric acid.		
Test 3 Add aqueous sodium hydroxide, then		
warm the mixture carefully, then		
add one piece of aluminium foil.		

[5]

- (ii) Use your observations in (b)(i) to complete Table 3.2 by identifying the formulae of the ions present in **FA 10** and **FA 11**.
If you cannot identify an ion write 'unknown'.

Table 3.2

	cation	anion
FA 10		
FA 11		

[2]

[Total: 13]

Qualitative analysis notes

1 Reactions of cations

cation	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 warming	–
barium, Ba ²⁺ (aq)	faint white ppt. is observed unless [Ba ²⁺ (aq)] is very low	no ppt.
calcium, Ca ²⁺ (aq)	white ppt. unless [Ca ²⁺ (aq)] is very low	no ppt.
chromium(III), Cr ³⁺ (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu ²⁺ (aq)	pale blue ppt. insoluble in excess	pale 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

anion	reaction
carbonate, CO ₃ ²⁻	CO ₂ liberated by dilute acids
chloride, Cl ⁻ (aq)	gives white ppt. with Ag ⁺ (aq) (soluble in NH ₃ (aq))
bromide, Br ⁻ (aq)	gives cream / off-white ppt. with Ag ⁺ (aq) (partially soluble in NH ₃ (aq))
iodide, I ⁻ (aq)	gives pale yellow ppt. with Ag ⁺ (aq) (insoluble in NH ₃ (aq))
nitrate, NO ₃ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil
nitrite, NO ₂ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil; decolourises acidified aqueous KMnO ₄
sulfate, SO ₄ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (insoluble in excess dilute strong acids); gives white ppt. with high [Ca ²⁺ (aq)]
sulfite, SO ₃ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (soluble in excess dilute strong acids); decolourises acidified aqueous KMnO ₄
thiosulfate, S ₂ O ₃ ²⁻ (aq)	gives off-white / pale yellow ppt. slowly with H ⁺

3 Tests for gases

gas	test and test result
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

4 Tests for elements

element	test and test result
iodine, I_2	gives blue-black colour on addition of starch solution

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 $\text{J g}^{-1} \text{ K}^{-1}$)

The Periodic Table of Elements

Group																							
1	2	Key										13	14	15	16	17	18						
		atomic number atomic symbol name relative atomic mass										1 H hydrogen 1.0											
3 Li lithium 6.9	4 Be beryllium 9.0																						
11 Na sodium 23.0	12 Mg magnesium 24.3																						
19 K potassium 39.1	20 Ca calcium 40.1	3 Sc scandium 45.0	4 Ti titanium 47.9	5 V vanadium 50.9	6 Cr chromium 52.0	7 Mn manganese 54.9	8 Fe iron 55.8	9 Co cobalt 58.9	10 Ni nickel 58.7	11 Cu copper 63.5	12 Zn zinc 65.4	5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2						
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 —	113 Nh nihonium —	114 Fl flerovium —	115 Mc moscovium —	116 Lv livermorium —	117 Ts tennessine —	118 Og oganeson —						

Lanthanoids

actinoids

57	La	lanthanum	138.9	58	Ce	cerium	140.1	59	Pr	praseodymium	140.9	60	Nd	neodymium	144.2	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	167.3	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	—

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9701/32

May/June 2024

2 hours

You must answer on the question paper.

You will need: The materials and apparatus listed in the confidential instructions

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

- The total mark for this paper is 40.
- The number of marks for each question or part question is shown in brackets [].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.
- Notes for use in qualitative analysis are provided in the question paper.

Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

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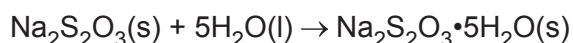
Quantitative analysis

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

Show the precision of the apparatus you used in the data you record.

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

- 1 Students are told to plan and carry out an experiment to determine the enthalpy change, ΔH_1 , when one mole of anhydrous sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$, is hydrated.



One student suggested adding five moles of water to one mole of anhydrous sodium thiosulfate and measuring the temperature change.

Their teacher said that method would **not** work and suggested another method using Hess's law.

You will carry out the teacher's method to determine the enthalpy change, ΔH_2 , when one mole of hydrated sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$, is dissolved in water.



You will do this by adding a known mass of hydrated sodium thiosulfate to a known volume of water and measuring the temperature change when the solid dissolves.

- (a) Explain why the student's suggestion to add five moles of water to one mole of anhydrous sodium thiosulfate would **not** be a suitable method to determine ΔH_1 .

.....
 [1]

(b) Teacher's method

FB 1 is hydrated sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$.

- Support the cup in the 250 cm³ beaker.
- Use the 25 cm³ measuring cylinder to transfer 25.0 cm³ of distilled water into the cup.
- Place the thermometer in the water and tilt the cup, if necessary, so that the bulb of the thermometer is fully covered. Record the temperature of the water in the space for results.
- Weigh the container with **FB 1**. Record the mass.
- Add all of the **FB 1** to the water in the cup.
- Stir the mixture. Measure and record the minimum temperature reached.
- Reweigh the container and any residual **FB 1**. Record the mass.
- Calculate and record the mass of **FB 1** added.
- Calculate and record the change in temperature.

Results

I	
II	
III	
IV	

[4]

(c) Calculations

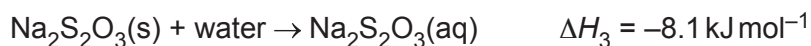
- (i) Calculate the energy change, in J, when **FB 1** is added to water.

energy change = ... J [1]

- (ii) Calculate the enthalpy change, ΔH_2 , in kJ mol^{-1} , when one mole of hydrated sodium thiosulfate, **FB 1**, dissolves in water.

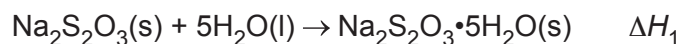
$\Delta H_2 = \underset{\text{sign}}{\text{.....}} \underset{\text{value}}{\text{.....}} \text{ kJ mol}^{-1}$ [2]

- (iii) The enthalpy change, ΔH_3 , when one mole of anhydrous sodium thiosulfate is dissolved in water is -8.1 kJ mol^{-1} .



Use your answer to **(c)(ii)** and the information given to construct a Hess's cycle to calculate ΔH_1 in kJ mol^{-1} . Show clearly how you used the data.

(If you were unable to calculate an answer in **(c)(ii)**, assume a value of 31.6 kJ mol^{-1} . Note this may **not** be the correct value and the sign has been omitted.)



$$\Delta H_1 = \underset{\text{sign}}{\text{.....}} \underset{\text{value}}{\text{.....}} \text{ kJ mol}^{-1} \quad [2]$$

- (d) A sample of **FB 1** was contaminated with anhydrous sodium thiosulfate. State what effect this would have on the temperature change in **(b)**. Explain your answer.

.....

 [1]

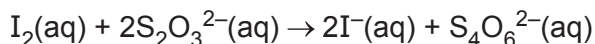
[Total: 11]

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- 2 Iodate ions contain iodine and oxygen. They have the formula IO_x^- where x is an integer.

In this experiment you will determine the value of x in an iodate. You will first react IO_x^- with an excess of iodide ions, I^- , to form iodine, I_2 .

The amount of iodine produced is then determined by titration with thiosulfate ions, $\text{S}_2\text{O}_3^{2-}$.



FB 2 is $0.100 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

FB 3 is a solution containing $0.0140 \text{ mol dm}^{-3}$ IO_x^- ions.

FB 4 is dilute sulfuric acid, H_2SO_4 .

FB 5 is $0.500 \text{ mol dm}^{-3}$ potassium iodide, KI .

FB 6 is starch indicator.

(a) Method

- Fill the burette with **FB 2**.
- Pipette 25.0 cm^3 of **FB 3** into a conical flask.
- Use the 25 cm^3 measuring cylinder to add 10 cm^3 of **FB 4** to the conical flask.
- Use the same measuring cylinder to add 10 cm^3 of **FB 5** to the conical flask.
- Add **FB 2** from the burette until the solution turns yellow.
- Add 10–15 drops of **FB 6** to the solution in the conical flask.
- Continue to add more **FB 2** from the burette until the blue-black colour just disappears.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

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

Keep the remaining FB 2 for use in Question 3.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your accurate titration results, calculate a suitable mean value to use in your calculations. Show clearly how you obtain the mean value.

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

(c) Calculations

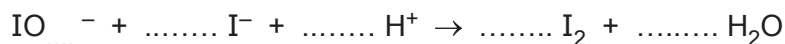
- (i) Give your answers to (c)(ii), (c)(iii) and (c)(iv) to an appropriate number of significant figures. [1]
- (ii) Use your answer to (b) and the information given to calculate the amount, in mol, of iodine formed when 25.0 cm³ of **FB 3** reacts with 10 cm³ of **FB 5**.

amount of I₂ = ... mol [1]

- (iii) Calculate the amount, in mol, of IO_x⁻ ions in 25.0 cm³ of **FB 3**.

amount of IO_x⁻ ions = ... mol [1]

- (iv) An unbalanced equation for the reaction of IO_x⁻ ions with iodide ions, I⁻, and hydrogen ions, H⁺, is shown.



Use the ratio of your answers to (c)(ii) and (c)(iii) to balance this equation and determine the value of *x*.
Show your working.

ratio IO_x⁻ : I₂ = 1 :

x = ... [2]

- (d) A student carries out the same experiment as in (a) but uses $0.0140 \text{ mol dm}^{-3} \text{ IO}_2^-$ ions in place of **FB 3**.

Tick the correct box in Table 2.1. Explain your answer.

(If you were unable to determine the value of x in (c)(iv) or you determined the value of x to be 2, assume $x = 4$. Note that this may **not** be the correct value).

Table 2.1

Volume of FB 2 will be smaller.	
Volume of FB 2 will be unchanged.	
Volume of FB 2 will be larger.	

.....

.....

.....

[2]

[Total: 15]

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Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

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

You should record clearly at what stage in a test an observation is made.

Where no change is observed, you should write 'no change'.

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

If any solution is warmed, a boiling tube must be used. If a solid is heated, a hard-glass test-tube must be used.

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

No additional tests should be attempted.

3 **FB 7** is an aqueous solution of a salt containing one cation and one anion, both of which are listed in the Qualitative analysis notes.

- (a) (i) Carry out the following tests using a 1 cm depth of **FB 7** in a test-tube for each test. Record your observations in Table 3.1.

Table 3.1

<i>test</i>	<i>observations</i>
Test 1 Add aqueous barium chloride or aqueous barium nitrate.	
Test 2 Add aqueous sodium hydroxide, then	
transfer the mixture to a boiling tube and warm gently, then	
add a small piece of aluminium foil.	
Test 3 Add aqueous ammonia.	

[4]

- (ii) The results of the tests in Table 3.1 allow you to deduce **one** cation and **two** possible anions in **FB 7**.

Deduce which ions may be present in **FB 7**. Give the formulae of the ions.

cation

anion or

[2]

- (iii) Describe a test to identify which of the possible anions is present in **FB 7**.

Carry out your test. Record your observations and conclusion.

test

.....

observations

conclusion

[2]

Question 3 continues on page 12.

- (b) (i) **FB 8** and **FB 9** are solutions of Group 1 salts. Each contains one anion, both of which are listed in the Qualitative analysis notes. One of the anions contains oxygen but **not** nitrogen. The other anion is a halide.

Carry out tests to identify the **two** anions. Record your tests and observations in a suitable form in the space below.

[4]

- (ii) Use your observations in (b)(i) to complete Table 3.2 by identifying the formulae of the anions in **FB 8** and **FB 9**.

Table 3.2

	FB 8	FB 9
anion		

[1]

- (iii) Write an ionic equation for a reaction observed in (b)(i) for **one** of the anions tested. Include state symbols.

..... [1]

[Total: 14]

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Qualitative analysis notes

1 Reactions of cations

cation	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 warming	–
barium, Ba ²⁺ (aq)	faint white ppt. is observed unless [Ba ²⁺ (aq)] is very low	no ppt.
calcium, Ca ²⁺ (aq)	white ppt. unless [Ca ²⁺ (aq)] is very low	no ppt.
chromium(III), Cr ³⁺ (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu ²⁺ (aq)	pale blue ppt. insoluble in excess	pale 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

anion	reaction
carbonate, CO ₃ ²⁻	CO ₂ liberated by dilute acids
chloride, Cl ⁻ (aq)	gives white ppt. with Ag ⁺ (aq) (soluble in NH ₃ (aq))
bromide, Br ⁻ (aq)	gives cream/off-white ppt. with Ag ⁺ (aq) (partially soluble in NH ₃ (aq))
iodide, I ⁻ (aq)	gives pale yellow ppt. with Ag ⁺ (aq) (insoluble in NH ₃ (aq))
nitrate, NO ₃ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil
nitrite, NO ₂ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil; decolourises acidified aqueous KMnO ₄
sulfate, SO ₄ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (insoluble in excess dilute strong acids); gives white ppt. with high [Ca ²⁺ (aq)]
sulfite, SO ₃ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (soluble in excess dilute strong acids); decolourises acidified aqueous KMnO ₄
thiosulfate, S ₂ O ₃ ²⁻ (aq)	gives off-white/pale yellow ppt. slowly with H ⁺

3 Tests for gases

gas	test and test result
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

4 Tests for elements

element	test and test result
iodine, I_2	gives blue-black colour on addition of starch solution

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 $\text{J g}^{-1} \text{ K}^{-1}$)

The Periodic Table of Elements

Group																			
1	2	Key										13	14	15	16	17	18		
		atomic number atomic symbol name relative atomic mass										1 H hydrogen 1.0							
3 Li lithium 6.9	4 Be beryllium 9.0																		
11 Na sodium 23.0	12 Mg magnesium 24.3	3	4	5	6	7	8	9	10	11	12	5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2		
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	13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9		
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 —	113 Nh nihonium —	114 Fl flerovium —	115 Mc moscovium —	116 Lv livermorium —	117 Ts tennessine —	118 Og oganeson —	
lanthanoids		57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	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			
actinoids		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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CHEMISTRY

9701/33

Paper 3 Advanced Practical Skills 1

May/June 2024

2 hours

You must answer on the question paper.

You will need: The materials and apparatus listed in the confidential instructions

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 40.
- The number of marks for each question or part question is shown in brackets [].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.
- Notes for use in qualitative analysis are provided in the question paper.

Session

Laboratory

For Examiner's Use	
1	
2	
3	
Total	

This document has **12** pages.



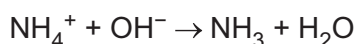
Quantitative analysis

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

Show the precision of the apparatus you used in the data you record.

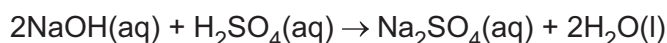
Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

- 1 When ammonium compounds are heated with sodium hydroxide or calcium hydroxide, ammonia is liberated. The ionic equation for the reaction is shown.



FA 1 is prepared by heating 10.0 cm^3 of aqueous ammonium chloride, $\text{NH}_4\text{Cl}(\text{aq})$, with 25.0 cm^3 of 2.00 mol dm^{-3} sodium hydroxide, NaOH . The sodium hydroxide is in excess. The reaction mixture is cooled and diluted to 250 cm^3 with distilled water.

You will determine the concentration of the aqueous solution of ammonium chloride by titrating the remaining sodium hydroxide from the preparation of **FA 1** with a known concentration of sulfuric acid.



FA 2 is $0.0520\text{ mol dm}^{-3}$ sulfuric acid, H_2SO_4 .

FA 3 is bromophenol blue indicator.

(a) Method

- Fill the burette with **FA 2**.
- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Add a few drops of **FA 3** to the conical flask.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

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

Results

I	
II	
III	
IV	
V	
VI	
VII	

[7]





- (b) From your accurate titration results, calculate a suitable mean value to use in your calculations. Show clearly how you obtain the mean value.

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

(c) **Calculations**

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

- (ii) Calculate the amount, in mol, of sulfuric acid present in the volume of **FA 2** in (b).

amount of H₂SO₄ = ... mol [1]

- (iii) Use your answer to (c)(ii) to calculate the amount, in mol, of sodium hydroxide in 25.0 cm³ of **FA 1**.

amount of NaOH = ... mol [1]

- (iv) Use your answer to (c)(iii) and the information given to calculate the amount, in mol, of sodium hydroxide that reacted with the ammonium chloride when **FA 1** was prepared.

amount of NaOH that reacted with NH₄Cl = ... mol [2]

- (v) Use your answer to (c)(iv) and the information given to calculate the concentration, in mol dm⁻³, of the ammonium chloride solution used to prepare **FA 1**.

concentration of NH₄Cl = ... mol dm⁻³ [1]

- (d) When ammonia gas is prepared by heating one of its salts with calcium hydroxide, it can be dried by passing it through a drying agent.

Drying agents for gases include calcium oxide, calcium sulfate, concentrated sulfuric acid and phosphorus(V) oxide.

Select **one** of these drying agents and suggest why it is **not** suitable for drying ammonia gas.

..... is **not** suitable because

..... [1]





- 2 A sample of ammonium bromide has been accidentally mixed with another salt.

A student suggests that the percentage purity of the ammonium bromide can be determined by measuring the change in temperature when a solution is prepared. The enthalpy change when the sample dissolves in water, ΔH , can then be calculated and compared with the literature value for ammonium bromide. You will carry out the student's experiment.

FA 4 is ammonium bromide, NH_4Br , mixed with another salt.

(a) Method

- Support the cup in the 250 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to transfer 25.0 cm^3 of distilled water into the cup.
- Place the thermometer in the water and tilt the cup, if necessary, so that the bulb of the thermometer is fully covered. Record the temperature of the water in the space for results.
- Weigh the container with **FA 4**. Record the mass.
- Add all of **FA 4** to the water in the cup.
- Stir the mixture gently so that **FA 4** dissolves.
- Measure and record the minimum temperature reached.
- Calculate and record the change in temperature.
- Weigh the container with any residual **FA 4**. Record the mass.
- Calculate and record the mass of **FA 4** added to the cup.

Results

I	
II	
III	
IV	

[4]

- (b) (i)** Calculate the energy change, in J, for the reaction.

energy change = ... J [1]

- (ii)** When one mole of ammonium bromide dissolves in water the enthalpy change, ΔH , is $+16.8\text{ kJ mol}^{-1}$.

Use this value to calculate the amount, in mol, of ammonium bromide in the 25.0 cm^3 of solution **FA 4** used in your experiment.

Assume that the enthalpy change when the other salt dissolves in water is 0 kJ mol^{-1} .

amount of NH_4Br in 25.0 cm^3 = ... mol [1]





- (iii) Calculate the mass, in g, of ammonium bromide in your sample.

(If you were unable to calculate the amount of ammonium bromide in (b)(ii), then assume it is 2.06×10^{-2} mol. This may **not** be the correct answer.)

mass of NH_4Br in sample = ... g [1]

- (iv) Hence calculate the percentage by mass of ammonium bromide in your sample.

% by mass of NH_4Br = ... % [1]

- (c) Another student states that this method is **not** accurate as the enthalpy change when the other salt dissolves in water could be exothermic.

Suggest how the calculated value in (b)(iv) would change if the other salt dissolves in water exothermically. Explain your answer.

.....

 [1]

- (d) The maximum uncertainty in a single thermometer reading is $\pm 0.5^\circ\text{C}$.

Calculate the maximum percentage error in your temperature change recorded in (a).
 Show your working.

maximum percentage error = ... % [1]

[Total: 10]





Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

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

You should record clearly at what stage in a test an observation is made.

Where no change is observed, you should write 'no change'.

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

If any solution is warmed, a boiling tube must be used. If a solid is heated, a hard-glass test-tube must be used.

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

No additional tests should be attempted.

3 (a) **FA 5** is a mixture containing two cations and two anions. Three of the ions are listed in the Qualitative analysis notes.

(i) Carry out the following tests and record your observations in Table 3.1.

Table 3.1

<i>test</i>	<i>observations</i>
Test 1 Heat a spatula measure of FA 5 in a hard-glass test-tube.	
Test 2 Put a 2 cm depth of dilute nitric acid in a boiling tube. Add a spatula measure of FA 5 .	
Dilute the solution from Test 2 with an equal volume of distilled water. Keep the resulting solution for use in (a)(ii). This solution is FA 6.	

[3]



- (ii) Carry out the following tests using a 1 cm depth of **FA 6** in a test-tube for each test. Record your observations in Table 3.2.

Table 3.2

<i>test</i>	<i>observations</i>
Test 1 Add a 1 cm depth of sodium chlorate(I), then	
add aqueous sodium thiosulfate dropwise.	
Test 2 Add aqueous sodium hydroxide.	
Test 3 Add aqueous ammonia.	
Test 4 Add a 1 cm depth of aqueous copper(II) sulfate, then	
add aqueous sodium thiosulfate dropwise until no further change occurs.	
Test 5 Add a few drops of aqueous silver nitrate, then	
add aqueous ammonia until no further change occurs.	

[4]





- (iii) **FA 5** reacts with nitric acid to make **FA 6** in Test 2 in Table 3.1.

State a change you would see in one of the observations in Table 3.2 if hydrochloric acid had been used to prepare **FA 6**.

.....
 [1]

- (iv) Use your observations in (a)(i) and (a)(ii) to identify the formulae of three of the ions present in **FA 5**.

Formulae of ions present are and and [2]

- (b) **FA 7**, **FA 8** and **FA 9** are each known to be propan-1-ol, propanal, propanoic acid or propanone. No two liquids are identical.

- (i) You will carry out tests to identify samples of **FA 7**, **FA 8** and **FA 9**.

Test 1 has been carried out for you.

Carry out Test 2 and record your observations in Table 3.3.

Table 3.3

<i>test</i>	<i>observations</i>		
	FA 7	FA 8	FA 9
Test 1 Put a 1 cm depth in a test-tube. Add a few drops of 2,4-dinitrophenylhydrazine (2,4-DNPH reagent).	orange precipitate	orange precipitate	no change
Test 2 Put a 1 cm depth in a test-tube. Add a small spatula measure of solid sodium carbonate.			

[1]

- (ii) State what you can deduce from Tests 1 and 2 in Table 3.3 about the functional group present in each of **FA 7**, **FA 8** and **FA 9**.

.....

 [2]





(iii) Describe a test to identify **FA 7** and **FA 8** using the reagents provided.

Carry out your test. Record your observations and conclusions.

test

.....

observations

.....

FA 7 is

FA 8 is

[2]

[Total: 15]





Qualitative analysis notes

1 Reactions of cations

cation	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 warming	–
barium, Ba ²⁺ (aq)	faint white ppt. is observed unless [Ba ²⁺ (aq)] is very low	no ppt.
calcium, Ca ²⁺ (aq)	white ppt. unless [Ca ²⁺ (aq)] is very low	no ppt.
chromium(III), Cr ³⁺ (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu ²⁺ (aq)	pale blue ppt. insoluble in excess	pale blue ppt. soluble in excess giving dark blue solution
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zinc, Zn ²⁺ (aq)	white ppt. soluble in excess	white ppt. soluble in excess

2 Reactions of anions

anion	reaction
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sulfate, SO ₄ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (insoluble in excess dilute strong acids); gives white ppt. with high [Ca ²⁺ (aq)]
sulfite, SO ₃ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (soluble in excess dilute strong acids); decolourises acidified aqueous KMnO ₄
thiosulfate, S ₂ O ₃ ²⁻ (aq)	gives off-white/pale yellow ppt. slowly with H ⁺



3 Tests for gases

gas	test and test result
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hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

4 Tests for elements

element	test and test result
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Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
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specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ ($4.18 \text{ J g}^{-1} \text{ K}^{-1}$)



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	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					
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										
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										
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54										
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										
55	56	57–71 lanthanoids		72	73	74	75	76	77	78	79	80	81	82	83	84	85	86									
Cs caesium 132.9	Ba barium 137.3			Hf hafnium 178.5	Ta tantalum 180.9	W tungsten 183.8	Re rhenium 186.2	Os osmium 190.2	Ir iridium 192.2	Pt platinum 195.1	Au gold 197.0	Hg mercury 200.6	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	113	114	115	116	117	118									
Fr francium —	Ra radium —			Rf rutherfordium —	Db dubnium —	Sg seaborgium —	Bh bohrium —	Hs hassium —	Mt meitnerium —	Ds darmstadtium —	Rg roentgenium —	Cn copernicium —	Nh nihonium —	Fl flerovium —	Mc moscovium —	Lv livermorium —	Ts tennessine —	Og oganesson —									

lanthanoids		57	La lanthanum 138.9	58	Ce cerium 140.1	59	Pr praseodymium 140.9	60	Nd neodymium 144.2	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
actinoids		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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CHEMISTRY

9701/34

Paper 3 Advanced Practical Skills 2

May/June 2024

2 hours

You must answer on the question paper.

You will need: The materials and apparatus listed in the confidential instructions

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
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- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 40.
- The number of marks for each question or part question is shown in brackets [].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.
- Notes for use in qualitative analysis are provided in the question paper.

Session

Laboratory

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For Examiner's Use

1	
2	
3	
Total	

This document has **12** 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 the precision of the apparatus you used in the data you record.

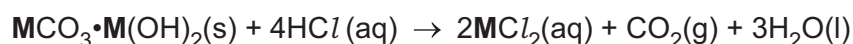
Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

- 1 In this experiment you will determine the relative formula mass, M_r , of a basic metal carbonate, $\text{MCO}_3 \cdot \text{M}(\text{OH})_2$, by a titration method.

FB 1 is the basic metal carbonate $\text{MCO}_3 \cdot \text{M}(\text{OH})_2$.

FB 2 is a solution containing hydrochloric acid, HCl , and MCl_2 , prepared using **FB 1** as follows.

- 22.50 g of **FB 1**, $\text{MCO}_3 \cdot \text{M}(\text{OH})_2$, is weighed out.
- 100.0 cm³ of 5.00 mol dm⁻³ hydrochloric acid (a small excess) is added to **FB 1**.
- The mixture is left to allow **FB 1** to react completely.



- The resulting solution is made up to 1.00 dm³ with distilled water.
- This solution is **FB 2**.

FB 3 is potassium hydroxide, KOH , of concentration 5.05 g dm⁻³.

FB 4 is thymolphthalein indicator.

(a) Method

- Fill the burette with **FB 2**.
- Pipette 25.0 cm³ of **FB 3** into a conical flask.
- Add a few drops of **FB 4** to the conical flask.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm³.

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

I	
II	
III	
IV	
V	
VI	
VII	

[7]





- (b) From your accurate titration results, calculate a suitable mean value to use in your calculations. Show clearly how you obtain the mean value.

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

(c) **Calculations**

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

- (ii) Calculate the amount, in mol, of potassium hydroxide present in 25.0 cm³ of **FB 3**.

amount of KOH = ... mol [1]

- (iii) Give the ionic equation for the reaction of hydrochloric acid with potassium hydroxide during the titration. Include state symbols.

.....

Hence calculate the concentration, in mol dm⁻³, of hydrochloric acid in **FB 2**.

concentration of HCl = ... mol dm⁻³ [2]

- (iv) Use the information about **FB 2** and your answer to (c)(iii) to calculate the relative formula mass, M_r , of $\text{MCO}_3 \cdot \text{M(OH)}_2$.

M_r of $\text{MCO}_3 \cdot \text{M(OH)}_2$ = ... [2]

- (d) A student suggested that the procedure used in (a) would be more accurate if the mass of **FB 1** used to prepare solution **FB 2** is doubled. No other change to the procedure is made.

Explain why the student is **not** correct.

.....

.....

..... [1]





- 2 In this experiment you will determine the relative atomic mass, A_r , of metal **M** by thermal decomposition of the same basic metal carbonate, $\text{MCO}_3 \cdot \text{M}(\text{OH})_2$, **FB 1**.

(a) Method

- Weigh the empty crucible with its lid. Record the mass in the results section.
- Transfer all of the **FB 1** from the container into the crucible.
- Weigh the crucible, lid and **FB 1**. Record the mass.
- Calculate the mass of **FB 1** used. Record this mass in the space for other results.
- Place the crucible and contents on a pipe-clay triangle.
- Heat the crucible gently, with the lid on, for approximately 1 minute.
- Heat strongly, with the lid off, for a further 5 minutes.
- Replace the lid and leave the crucible to cool for at least 5 minutes.

During the cooling period, you may wish to begin work on Question 3.

- When the crucible is cool, weigh the crucible with its lid and contents. Record the mass.
- Place the crucible and contents on the pipe-clay triangle. Remove the lid.
- Heat strongly for a further 2 minutes.
- Replace the lid and leave the crucible to cool for at least 5 minutes.
- When the crucible is cool, reweigh the crucible with its lid and contents. Record the mass.
- Calculate the mass of residue obtained. Record this mass in the space for other results.

Results

mass of empty crucible and lid = ...

mass of crucible, lid and **FB 1** (before heating) = ...

mass of crucible, lid and **FB 1** (after first heating) = ...

mass of crucible, lid and **FB 1** (after second heating) = ...

Other results

I	
II	
III	
IV	

[4]

(b) Calculations

- (i) When **FB 1** undergoes thermal decomposition, the products are the metal oxide, **MO**, carbon dioxide and water vapour.
Give the equation for the thermal decomposition of **FB 1**. Include state symbols.

..... [1]



- (ii) The amount, in mol, of carbon dioxide produced is given by the following formula.

$$\text{amount of CO}_2 = \frac{\text{mass loss during heating}}{(M_r \text{ of CO}_2 + M_r \text{ of H}_2\text{O})}$$

Calculate the amount, in mol, of carbon dioxide produced in (a).

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

- (iii) Calculate the relative formula mass, M_r , of the basic metal carbonate.

$$M_r \text{ of } \text{MCO}_3 \cdot \text{M(OH)}_2 = \dots\dots\dots [1]$$

- (iv) Use your answer to (b)(iii) to calculate the relative atomic mass, A_r , of metal **M**.
Show your working.

$$A_r \text{ of } \text{M} = \dots\dots\dots [1]$$

- (c) (i) Explain why the headings for the third and fourth readings in the results section in (a) are **not** suitable.

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

- (ii) State whether or not your experiment would be more accurate if the crucible and its contents were heated for a third time. Explain your answer by referring to your results in (a).

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

- (iii) A student carries out the experiments in **Questions 1** and **2**. The student expects the value of the M_r of $\text{MCO}_3 \cdot \text{M(OH)}_2$ obtained by thermal decomposition in **Question 2** to be more accurate than the value of the M_r obtained by titration in **Question 1**.

State **one** reason why the student expects the experiment in **Question 2** to be more accurate.

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

[Total: 11]





Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

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

You should record clearly at what stage in a test an observation is made.

Where no change is observed, you should write 'no change'.

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

If any solution is warmed, a boiling tube must be used. If a solid is heated, a hard-glass test-tube must be used.

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

No additional tests should be attempted.

3 (a) **FB 5** is a compound containing one cation and one anion, both of which are listed in the Qualitative analysis notes.

- (i) Heat a **small** spatula measure of **FB 5** in a hard-glass test-tube until no further change occurs.
Record your observations.

.....

 [2]

- (ii) Describe another test to positively identify the cation in **FB 5**.
Carry out your test and record your observations.

test
 observations [1]





- (iii) Put a 1 cm depth of dilute hydrochloric acid in a test-tube. Add a **small** spatula measure of **FB 5**.

Record your observations.

.....

.....

.....

..... [2]

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

FB 5 is [1]

Question 3 continues on page 8.





- (b) You will devise chemical tests to distinguish between the two possible identities given for each of compounds **FB 6**, **FB 7**, **FB 8** and **FB 9**.

In each case you should:

- use a 1 cm depth of the solution of the unknown compound in a test-tube
- use a boiling tube if you need to warm a mixture
- use a spatula measure of the unknown solid
- record details of your test(s) and your observations
- state your conclusion about the identity of the compound.

- (i) **FB 6** is either aqueous chromium(III) sulfate or aqueous iron(II) sulfate.

FB 6 is [2]

- (ii) **FB 7** is either dilute hydrobromic acid or dilute nitric acid.

If you select a test that gives a negative result, then you must carry out a further test that gives a **positive** result.

FB 7 is [2]

- (iii) **FB 8** is either magnesium carbonate or zinc carbonate.

FB 8 is [2]





(iv) **FB 9** is either aqueous methanol or aqueous ethanol.

Note: **FB 9** is flammable and should **not** be heated with a flame.

(When carrying out your test you may need to leave the reaction mixture to stand.)

FB 9 is [2]

[Total: 14]





Qualitative analysis notes

1 Reactions of cations

cation	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 warming	–
barium, Ba ²⁺ (aq)	faint white ppt. is observed unless [Ba ²⁺ (aq)] is very low	no ppt.
calcium, Ca ²⁺ (aq)	white ppt. unless [Ca ²⁺ (aq)] is very low	no ppt.
chromium(III), Cr ³⁺ (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu ²⁺ (aq)	pale blue ppt. insoluble in excess	pale 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

anion	reaction
carbonate, CO ₃ ²⁻	CO ₂ liberated by dilute acids
chloride, Cl ⁻ (aq)	gives white ppt. with Ag ⁺ (aq) (soluble in NH ₃ (aq))
bromide, Br ⁻ (aq)	gives cream/off-white ppt. with Ag ⁺ (aq) (partially soluble in NH ₃ (aq))
iodide, I ⁻ (aq)	gives pale yellow ppt. with Ag ⁺ (aq) (insoluble in NH ₃ (aq))
nitrate, NO ₃ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil
nitrite, NO ₂ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil; decolourises acidified aqueous KMnO ₄
sulfate, SO ₄ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (insoluble in excess dilute strong acids); gives white ppt. with high [Ca ²⁺ (aq)]
sulfite, SO ₃ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (soluble in excess dilute strong acids); decolourises acidified aqueous KMnO ₄
thiosulfate, S ₂ O ₃ ²⁻ (aq)	gives off-white/pale yellow ppt. slowly with H ⁺



3 Tests for gases

gas	test and test result
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

4 Tests for elements

element	test and test result
iodine, I_2	gives blue-black colour on addition of starch solution

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 $\text{J g}^{-1} \text{ K}^{-1}$)



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	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	
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	
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	
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	
55	56	57–71 lanthanoids		72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs caesium 132.9	Ba barium 137.3			Hf hafnium 178.5	Ta tantalum 180.9	W tungsten 183.8	Re rhenium 186.2	Os osmium 190.2	Ir iridium 192.2	Pt platinum 195.1	Au gold 197.0	Hg mercury 200.6	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	113	114	115	116	117	118
Fr francium —	Ra radium —			Rf rutherfordium —	Db dubnium —	Sg seaborgium —	Bh bohrium —	Hs hassium —	Mt meitnerium —	Ds darmstadtium —	Rg roentgenium —	Cn copernicium —	Nh nihonium —	Fl flerovium —	Mc moscovium —	Lv livermorium —	Ts tennessine —	Og oganesson —

lanthanoids		57	La lanthanum 138.9	58	Ce cerium 140.1	59	Pr praseodymium 140.9	60	Nd neodymium 144.2	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
actinoids		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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9701/35

May/June 2024

2 hours

You will need: The materials and apparatus listed in the confidential instructions

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

- The total mark for this paper is 40.
- The number of marks for each question or part question is shown in brackets [].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.
- Notes for use in qualitative analysis are provided in the question paper.

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[Turn over

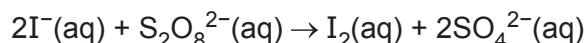
Quantitative analysis

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

Show the precision of the apparatus you used in the data you record.

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

- 1 Iodide ions in aqueous solution are oxidised to iodine by a variety of oxidising agents. One of these is the peroxodisulfate ion, $\text{S}_2\text{O}_8^{2-}$, which reacts as shown.



Sodium thiosulfate is added to the reaction mixture to react with iodine as it is produced. When all of the thiosulfate has reacted, further iodine produced reacts with starch indicator to give a dark colour.

You will carry out two experiments to investigate how the rate of this reaction is affected by changing the concentration of the peroxodisulfate ion.

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

FA 2 is $0.00500 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

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

FA 4 is starch indicator.

(a) Method

Experiment 1

- Label one of the 100 cm^3 beakers **A** and the other 100 cm^3 beaker **B**.
- Fill one burette with **FA 1**. Label this burette **FA 1**.
- Run 20.00 cm^3 of **FA 1** from the burette into beaker **A**.
- Fill the second burette with **FA 2**. Label this burette **FA 2**.
- Run 10.00 cm^3 of **FA 2** from the burette into beaker **B**.
- Use the measuring cylinder to add 20.0 cm^3 of **FA 3** to beaker **B**.
- Add 10 drops of **FA 4** to beaker **B**.
- Add the contents of beaker **A** to beaker **B** and start timing **immediately**.
- Stir the mixture once and place the beaker on the white tile.
- Stop timing as soon as the solution turns a dark colour.
- Record this time to the nearest second in the space for results.
- Wash out both beakers and dry them using paper towel.

Experiment 2

- Run 10.00 cm^3 of **FA 1** from the burette into beaker **A**.
- Run 10.00 cm^3 of **FA 2** from the burette into beaker **B**.
- Use the measuring cylinder to add 20.0 cm^3 of **FA 3** into beaker **B**.
- Use the same measuring cylinder to add 10.0 cm^3 of distilled water to beaker **B**.
- Add 10 drops of **FA 4** to beaker **B**.
- Add the contents of beaker **A** to beaker **B** and start timing **immediately**.
- Stir the mixture once and place the beaker on the white tile.
- Stop timing as soon as the solution turns a dark colour.
- Record this time to the nearest second.

Record all your data in a table. You should include the volume of **FA 1**, the volume of distilled water, the reaction time and the rate of reaction for both experiments.

Use the following formula to calculate the rate of reaction.

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

Results

I	
II	
III	
IV	
V	
VI	

[6]

- (b) (i) Explain why the concentration of potassium peroxodisulfate used in each experiment is proportional to the volume of **FA 1** used.

.....
 [1]

- (ii) A student thinks that the rate of reaction is proportional to the concentration of **FA 1**. Complete Table 1.1 to suggest volumes of reactants that could be used in a further experiment to confirm whether the student is correct. Do **not** carry out this experiment.

Table 1.1

volume / cm ³				volume
FA 1	FA 2	FA 3	distilled water	FA 4
				10 drops

[2]

- (c) A student correctly carried out the method in (a) but had been given a more concentrated solution of sodium thiosulfate. State how you would expect the student's times to differ from yours. Explain your answer.

.....
 [1]

- (d) The potassium iodide is in a large excess in Experiments 1 and 2. Suggest why a large excess of iodide ions is needed in these experiments.

.....
 [1]

[Total: 11]

- 2 You will carry out an experiment to determine the enthalpy change, ΔH , when one mole of ammonium chloride dissolves in water.

FA 5 is ammonium chloride, NH_4Cl .

(a) Method

- Weigh the container with **FA 5**. Record the mass in the space for results.
- Support the cup in the 250 cm^3 beaker.
- Use the measuring cylinder to transfer 25.0 cm^3 of distilled water into the cup.
- Place the thermometer in the water and tilt the cup, if necessary, so that the bulb of the thermometer is fully covered. Record the temperature of the water at time $t = 0$.
- Start the stop-clock and leave it running for the whole experiment.
- Measure and record the temperature of the water in the cup every half minute for 2 minutes.
- At $t = 2\frac{1}{2}$ minutes, tip all the **FA 5** 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 and including $t = 8$ minutes.
- Weigh the container with any residual **FA 5**. Record the mass.
- Calculate and record the mass of **FA 5** added.

Results

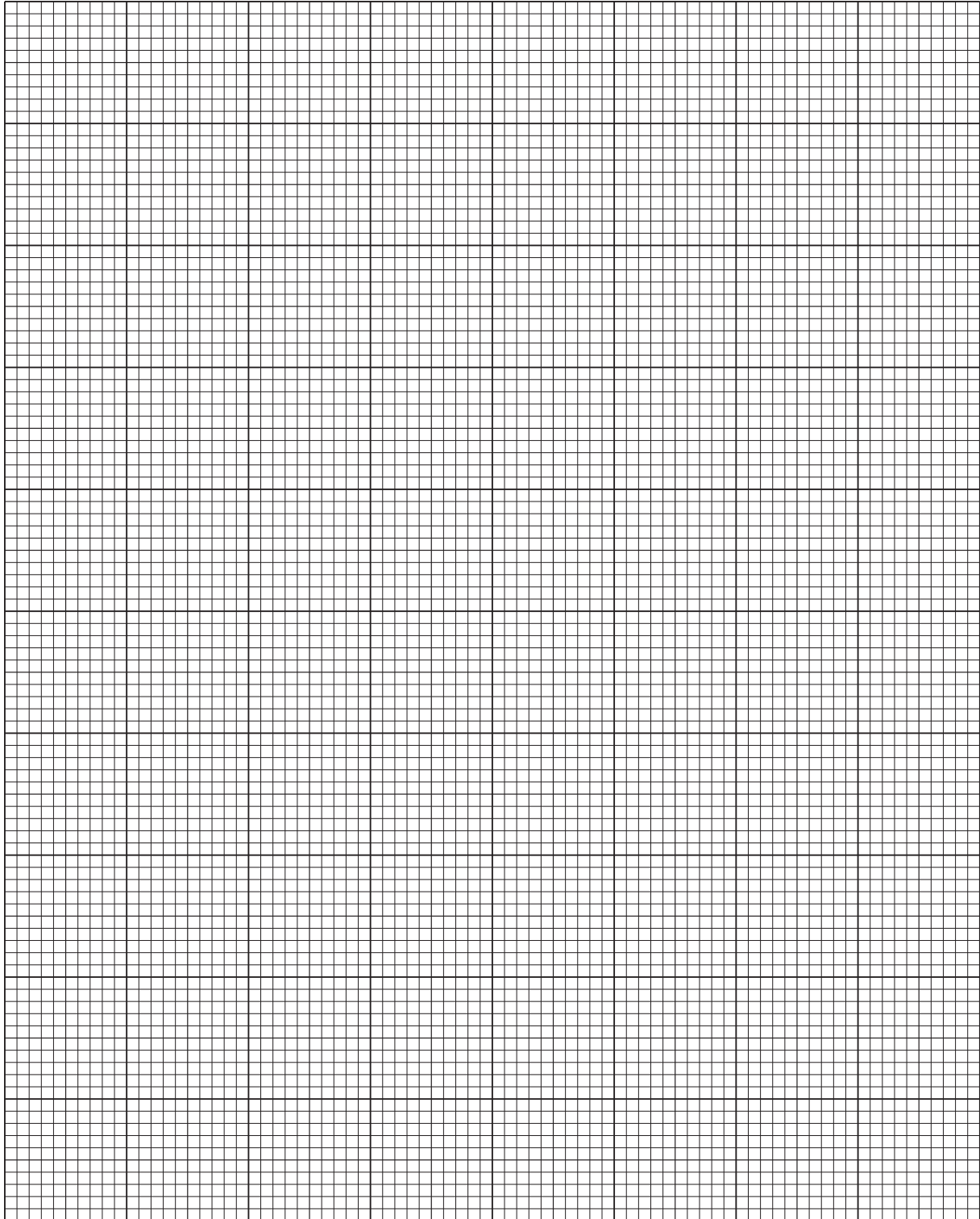
I	
II	
III	
IV	
V	

[5]

- (b)** Plot a graph of temperature (y-axis) against time (x-axis) on the grid. You should choose a scale that allows you to plot 2°C below the minimum temperature reached. Label any points you consider to be anomalous.

Draw **two** straight lines of best fit. One line is for the temperature before adding **FA 5** and the other line is for the warming of the solution once the minimum temperature has been reached.

Extrapolate both these lines to $t = 2\frac{1}{2}$ minutes.



I	
II	
III	
IV	

[4]

(c) (i) Use your graph to determine the temperature change, ΔT , at $t = 2\frac{1}{2}$ minutes.

ΔT at $t = 2\frac{1}{2}$ minutes = ... °C [1]

- (ii) Calculate the energy change, in J, in the reaction.

energy change = ... J [1]

- (iii) Calculate the amount, in mol, of ammonium chloride used.

amount of NH_4Cl = ... mol [1]

- (iv) Calculate the enthalpy change, ΔH , in kJ mol^{-1} , when one mole of ammonium chloride dissolves in water.

$\Delta H = \begin{matrix} \text{.....} \\ \text{sign} \end{matrix} \begin{matrix} \text{.....} \\ \text{value} \end{matrix} \text{ kJ mol}^{-1}$ [1]

- (d) Use your results in (a) to calculate the maximum percentage error for the temperature change from 0 to 4 minutes.

Assume that the maximum uncertainty in a single thermometer reading is $\pm 0.5^\circ\text{C}$.

Show your working.

maximum percentage error = ... % [1]

[Total: 14]

Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

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

You should record clearly at what stage in a test an observation is made.

Where no change is observed, you should write 'no change'.

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

If any solution is warmed, a boiling tube must be used. If a solid is heated, a hard-glass test-tube must be used.

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

No additional tests should be attempted.

- 3 (a) **FA 6** is a salt containing a Group 1 ion and an anion that consists of a transition metal and a non-metal element.

- (i) Transfer **FA 6** into a hard-glass test-tube. Heat the tube gently at first and then strongly. Record all your observations and identify the gas produced. The residue is **FA 7**. **You will use FA 7 in (a)(ii).**

observations

.....

gas produced

[3]

Allow FA 7 to cool before starting (a)(ii).

While FA 7 is cooling you may wish to continue with (b)(i).

- (ii) Put a 2 cm depth of acidified aqueous potassium manganate(VII) in a test-tube. Add the same depth of aqueous sodium hydroxide. Then add **FA 7** and stir using the glass rod for about 30 seconds. Filter the mixture and collect the filtrate. Record your observations.

.....

Put a 1 cm depth of the filtrate in a test-tube. Add sulfuric acid until in excess. Record your observations.

.....

[2]

- (b) (i) **FA 8** and **FA 9** are both aqueous solutions of salts. **FA 8** contains one cation and one anion. **FA 9** contains two cations and one anion. One of the cations and both anions are listed in the Qualitative analysis notes.

Carry out the following tests and record your observations in Table 3.1.
For each test use a 1 cm depth of **FA 8** or **FA 9** in a test-tube.

Table 3.1

<i>test</i>	<i>observations</i>	
	FA 8	FA 9
Test 1 Add sulfuric acid.		
Test 2 Add aqueous sodium hydroxide, then transfer the mixture into a boiling tube and warm.		
Test 3 Add a few drops of aqueous barium chloride or aqueous barium nitrate, then add nitric acid.		
Test 4 Add FA 8 with shaking until in excess.		

[7]

- (ii) Deduce the identity of the **three** ions listed in the Qualitative analysis notes that are present in **FA 8** and **FA 9**. Suggest the identity of **one** other cation.
Give the formula of each ion.
If you cannot identify an ion write 'unknown'.

FA 8 contains and

FA 9 contains and and

[2]

- (iii) Write an ionic equation for **one** reaction that occurred in Test 2 in Table 3.1.
Include state symbols.

..... [1]

[Total: 15]

Qualitative analysis notes

1 Reactions of cations

cation	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 warming	–
barium, Ba ²⁺ (aq)	faint white ppt. is observed unless [Ba ²⁺ (aq)] is very low	no ppt.
calcium, Ca ²⁺ (aq)	white ppt. unless [Ca ²⁺ (aq)] is very low	no ppt.
chromium(III), Cr ³⁺ (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu ²⁺ (aq)	pale blue ppt. insoluble in excess	pale 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

anion	reaction
carbonate, CO ₃ ²⁻	CO ₂ liberated by dilute acids
chloride, Cl ⁻ (aq)	gives white ppt. with Ag ⁺ (aq) (soluble in NH ₃ (aq))
bromide, Br ⁻ (aq)	gives cream/off-white ppt. with Ag ⁺ (aq) (partially soluble in NH ₃ (aq))
iodide, I ⁻ (aq)	gives pale yellow ppt. with Ag ⁺ (aq) (insoluble in NH ₃ (aq))
nitrate, NO ₃ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil
nitrite, NO ₂ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil; decolourises acidified aqueous KMnO ₄
sulfate, SO ₄ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (insoluble in excess dilute strong acids); gives white ppt. with high [Ca ²⁺ (aq)]
sulfite, SO ₃ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (soluble in excess dilute strong acids); decolourises acidified aqueous KMnO ₄
thiosulfate, S ₂ O ₃ ²⁻ (aq)	gives off-white/pale yellow ppt. slowly with H ⁺

3 Tests for gases

gas	test and test result
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

4 Tests for elements

element	test and test result
iodine, I_2	gives blue-black colour on addition of starch solution

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 $\text{J g}^{-1} \text{ K}^{-1}$)

The Periodic Table of Elements

Group																			
1	2	1														17	18		
		Key atomic number atomic symbol name relative atomic mass 1 H hydrogen 1.0																	
3 Li lithium 6.9	4 Be beryllium 9.0																		
11 Na sodium 23.0	12 Mg magnesium 24.3																		
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8		
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium —	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3		
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids		72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium —	85 At astatine —	86 Rn radon —	
87 Fr francium —	88 Ra radium —	89–103 actinoids		104 Rf rutherfordium —	105 Db dubnium —	106 Sg seaborgium —	107 Bh bohrium —	108 Hs hassium —	109 Mt meitnerium —	110 Ds darmstadtium —	111 Rg roentgenium —	112 Cn copernicium —	113 Nh nihonium —	114 Fl flerovium —	115 Mc moscovium —	116 Lv livermorium —	117 Ts tennessine —	118 Og oganeson —	