



Cambridge International AS & A Level

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CHEMISTRY

9701/31

Paper 3 Advanced Practical Skills 1

May/June 2025

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 **16** pages. Any blank pages are indicated.



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 answer to **each** step of your calculations.

- 1 You will determine the percentage purity of a sample of calcium carbonate by reacting it with excess hydrochloric acid and measuring the volume of carbon dioxide produced.



FA 1 is impure calcium carbonate, CaCO_3 .

FA 2 is $0.500 \text{ mol dm}^{-3}$ hydrochloric acid, HCl .

(a) Method

- Weigh the container with **FA 1**. Record the mass in the space for results.
- Fill the tub with water to a depth of approximately 5 cm.
- Fill the 250 cm^3 measuring cylinder completely with water. Holding a piece of paper towel firmly over the top, invert the measuring cylinder and place it in the water in the tub.
- Remove the paper towel and clamp the inverted measuring cylinder so the open end is in the water just above the base of the tub.
- Using the 50 cm^3 measuring cylinder, transfer 50.0 cm^3 of **FA 2** into the flask labelled **X**. Check that the bung fits tightly into the neck of flask **X**, clamp flask **X** and place the end of the delivery tube into the inverted 250 cm^3 measuring cylinder.
- Remove the bung from the neck of the flask. Tip all of the **FA 1** into the acid in the flask and replace the bung **immediately**. Remove the flask from the clamp and swirl it to mix the contents.
- Replace the flask in the clamp and leave until the fizzing stops. Swirl the flask occasionally.
- Weigh the container with any residual **FA 1**. Record the mass.
- Calculate and record the mass of **FA 1** that is added to the acid.
- When no more gas is collected, record the final volume of gas.

You may wish to start Question 2 or Question 3 while the gas is being collected.

Results

I	
II	
III	

[3]





(b) Calculations

- (i) Calculate the amount, in mol, of carbon dioxide collected in the measuring cylinder (at room conditions).

amount of CO_2 = ... mol

Hence, deduce the amount, in mol, of calcium carbonate present in the **FA 1** used.

amount of CaCO_3 = ... mol
[1]

- (ii) Use your answer to **(b)(i)** and the mass of **FA 1** used to calculate the percentage purity of calcium carbonate. Show your working.

purity of calcium carbonate = ... % [1]

- (c) A student carries out the experiment described in **(a)** using 25.0cm^3 of 1.00mol dm^{-3} hydrochloric acid. The mass of **FA 1** is **not** changed.

Suggest the consequence of this change on the percentage purity of calcium carbonate calculated by placing **one** tick (✓) in Table 1.1.

Table 1.1

The percentage purity calculated would increase.	
The percentage purity calculated would stay the same.	
The percentage purity calculated would decrease.	

Explain your answer.

.....

.....

.....

.....

[2]





(d) The student repeats the method in (a) but the hydrochloric acid is **not** used in excess.

(i) State an observation that shows that the acid is **not** used in excess.

..... [1]

(ii) Explain what effect, if any, this would have on the percentage purity of calcium carbonate calculated in (b)(ii).

.....

.....

..... [2]

[Total: 10]



- 2 You will determine the percentage purity of another sample of calcium carbonate, CaCO_3 , by titration.

The experiment involves three steps.

- step 1 A known mass of the same impure calcium carbonate, **FA 1**, is reacted with an excess of hydrochloric acid to form **FA 3**. This step has been done for you.
- step 2 You will dilute the products of step 1 to a known volume.
- step 3 You will carry out a titration to find out how much acid remains after the reaction in step 1.

FA 3 has been prepared by reacting 19.0 g of **FA 1** with 250 cm³ of 2.00 mol dm⁻³ hydrochloric acid, HCl.

FA 5 is 0.0900 mol dm⁻³ sodium hydroxide, NaOH.

FA 6 is bromophenol blue indicator.

(a) Method

step 2

- Pipette 25.0 cm³ of **FA 3** into the 250 cm³ volumetric flask.
- Make the solution up to 250 cm³ with distilled water.
- Thoroughly mix the contents of the volumetric flask. This solution is **FA 4**.

step 3

- Fill the burette with **FA 5**.
- Rinse the pipette with distilled water and then with **FA 4**.
- Pipette 25.0 cm³ of **FA 4** into a conical flask.
- Add several drops of **FA 6**.
- 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 **FA 5** 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 4** required cm³ of **FA 5**. [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 hydroxide in the volume of **FA 5** in (b).

amount of NaOH = ... mol [1]

- (iii) Use your answer to (c)(ii) to calculate the amount, in mol, of hydrochloric acid in 250 cm³ of **FA 4**.

amount of HCl in 250 cm³ of **FA 4** = ... mol

Hence, calculate the amount, in mol, of hydrochloric acid present in 250 cm³ of **FA 3**.

amount of HCl in 250 cm³ of **FA 3** = ... mol [1]

- (iv) Calculate the amount, in mol, of hydrochloric acid used to prepare **FA 3**.

amount of HCl = ... mol [1]





- (v) Use your answers to (c)(iii) and (c)(iv) to calculate the amount, in mol, of hydrochloric acid that reacted with the **FA 1** in step 1.

amount of HCl that reacted with **FA 1** = ... mol [1]

- (vi) Use your answer to (c)(v) to calculate the amount, in mol, of calcium carbonate present in **FA 1**.



amount of CaCO_3 in **FA 1** = ... mol [1]

- (vii) Use your answer to (c)(vi) and the mass of **FA 1** used to calculate the percentage purity of calcium carbonate. Show your working.

purity of calcium carbonate = ... % [1]

- (d) The percentage purity of calcium carbonate in **FA 1** has been determined by two different methods, gas collection and titration. The gas collection method used in Question 1 is **less** accurate.

- (i) Suggest **two** reasons why the gas collection method is less accurate.

1

.....

2

.....

[2]

- (ii) Describe a change to the gas collection method that would improve the accuracy of the percentage purity determined in Question 1.

.....

.....

..... [1]

[Total: 18]





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 is a solution containing two cations and one anion. All of the ions are listed in the Qualitative analysis notes.

- (i) Carry out the following tests and record your observations in Tables 3.1 and 3.2. For each test use a 1 cm depth of **FA 7** in a test-tube unless the solution requires heating.

Table 3.1

<i>test</i>	<i>observations</i>
Test 1 Add aqueous ammonia.	
Test 2 To a 1 cm depth of FA 7 in a boiling tube, add aqueous sodium hydroxide, then warm the mixture carefully.	
Test 3 Add a few drops of silver nitrate.	





Table 3.2

<i>test</i>	<i>observations</i>
Test 4 Add a 1 cm depth of aqueous barium chloride or aqueous barium nitrate.	
Test 5 Add a 1 cm depth of dilute nitric acid, then ----- leave to stand for a few minutes.	
Test 6 Add a 1 cm depth of aqueous potassium iodide, then ----- add a few drops of starch solution.	

[5]

- (ii) Write an ionic equation for a reaction in **(a)(i)** that resulted in the formation of a precipitate. Include state symbols.

..... [1]

- (iii) Give the formula of each ion present in **FA 7**. If you cannot identify an ion, write 'unknown.'

cations and

anion

[2]





(b) **FA 8** is an anhydrous sodium compound.

- (i) Transfer a spatula measure of **FA 8** to a hard-glass test-tube. Heat the test-tube gently at first, then more strongly until no further change occurs. Record your observations.

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

- (ii) The **FA 9** provided is a sample of the residue obtained from heating **FA 8**. To a 2 cm depth of nitric acid in a test-tube, slowly add a small spatula measure of **FA 9**. Record your observations.

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

- (iii) Deduce the formula of **FA 8**.

FA 8 is [1]

[Total: 12]











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	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
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													13	14	15	16	17	18		
														1 H hydrogen 1.0							

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	europlum	gadolinium	terbium	dysprosium	holmium	erbium	thulium	ytterbium	lutetium
138.9	140.1	140.9	144.2	—	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	—	—	—	—	—	—	—	—	—	—	—





Cambridge International AS & A Level

CANDIDATE
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CANDIDATE
NUMBER

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CHEMISTRY

9701/32

Paper 3 Advanced Practical Skills 2

May/June 2025

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.
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- 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. Any blank pages are indicated.



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 Acids donate H^+ in aqueous solution. The number of moles of H^+ donated per mole of acid is the **proticity** of the acid. For example, sulfuric acid is diprotic as it donates two moles of H^+ per mole of acid.

In this experiment you will carry out a titration to determine the proticity of citric acid, $\text{C}_6\text{H}_8\text{O}_7$.

FB 1 is aqueous citric acid containing $7.50 \text{ g dm}^{-3} \text{ C}_6\text{H}_8\text{O}_7$.

FB 2 is aqueous sodium hydroxide containing $4.50 \text{ g dm}^{-3} \text{ NaOH}$.

FB 3 is thymolphthalein indicator.

(a) Method

- Fill the burette with **FB 2**.
- Pipette 25.0 cm^3 of **FB 1** into a conical flask.
- Add a few drops of **FB 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 **FB 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 cm^3 of **FB 1** required cm^3 of **FB 2**. [1]



**(c) Calculations**

- (i) Calculate the amount, in mol, of citric acid in 25.0 cm^3 of **FB 1**.
Show your working.

amount of $\text{C}_6\text{H}_8\text{O}_7 = \dots\dots\dots \text{ mol}$ [2]

- (ii) Calculate the amount, in mol, of sodium hydroxide in the volume of **FB 2** in (b).

amount of $\text{NaOH} = \dots\dots\dots \text{ mol}$ [1]

- (iii) Citric acid is triprotic.
Show whether your results in this experiment support this statement.

[1]

- (iv) Complete the equation for the reaction of citric acid, $\text{C}_6\text{H}_8\text{O}_7$, with sodium hydroxide.

$\text{C}_6\text{H}_8\text{O}_7 + \dots\dots \text{NaOH} \rightarrow \dots\dots\dots + \dots\dots\dots$ [1]

- (v) Citric acid does **not** contain a chiral carbon atom.
Draw a possible structural formula of a molecule of citric acid.

[1]

- (d) A student uses a pipette labelled $25.0 \pm 0.06\text{ cm}^3$ to measure **FB 1**.
The student suggests that it is more accurate to measure the volume of **FB 1** with a burette instead of the pipette.

State whether the student's suggestion is correct. Explain your answer.

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



- (c) **Experiment 2** is the determination of the enthalpy change, ΔH_2 , for the reaction of one mole of solid citric acid with aqueous sodium hydroxide. In this experiment, aqueous sodium hydroxide, **FB 6**, is used in excess.

Method

- Support the second cup in the beaker.
- Add 4.80–5.00 g of **FB 5** to the cup. Record your weighings.
- Measure and record the temperature of **FB 6** in its container.
- Use the 50 cm³ measuring cylinder to transfer 50.0 cm³ of **FB 6** into the cup with **FB 5**.
- Stir the mixture until the maximum temperature is obtained. Record the maximum temperature.
- Calculate and record the mass of **FB 5** used.
- Calculate and record the temperature change.

Results

I	
II	
III	

[3]

(d) Calculations

Calculate the enthalpy change of reaction, ΔH_2 , in kJ mol⁻¹, for the reaction of 1.00 mol of solid citric acid, C₆H₈O₇, with aqueous sodium hydroxide.
Show your working.

$$\Delta H_2 = \begin{array}{c} \text{.....} \\ \text{sign} \end{array} \begin{array}{c} \text{.....} \\ \text{value} \end{array} \text{ kJ mol}^{-1} \quad [2]$$

- (e) Use your values for ΔH_1 and ΔH_2 to calculate the enthalpy change, ΔH_r , in kJ mol⁻¹, for the reaction of 1.00 mol of aqueous citric acid with aqueous sodium hydroxide.

$$\Delta H_r = \begin{array}{c} \text{.....} \\ \text{sign} \end{array} \begin{array}{c} \text{.....} \\ \text{value} \end{array} \text{ kJ mol}^{-1} \quad [1]$$

[Total: 12]

[Turn over]





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) Solutions **FB 7** and **FB 8** each contain one cation and one anion. All of the ions are listed in the Qualitative analysis notes.

(i) Carry out the following tests and record your observations in Table 3.1. Use a 1 cm depth of **FB 7** or **FB 8** in a test-tube for each test.

Table 3.1

<i>test</i>	<i>observations</i>	
	FB 7	FB 8
Test 1 Add an equal volume of aqueous potassium iodide, then		
add excess aqueous sodium thiosulfate.		
Test 2 Add a small spatula measure of zinc powder. Leave the mixture to stand.		
Test 3 Add a few drops of aqueous silver nitrate.		
Test 4 Add aqueous ammonia.		

[6]

(ii) Deduce the formula of **FB 8**.

FB 8 is

[1]

(iii) For **FB 8**, state the numbers of **all** the tests from Table 3.1 that involve a redox reaction.

..... [1]

(iv) Give the ionic equation for **one** of the reactions in **Test 4**. Include state symbols.

..... [1]





- (b) (i) Carry out tests to identify the anion in **FB 7**. The anion does **not** contain sulfur. Record your tests and observations in a suitable form in the space below.

You **must** use a boiling tube if any liquid is heated.

[3]

- (ii) Deduce the formula of **FB 7**.

FB 7 is

[1]

[Total: 13]



* 0000800000009 *





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	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
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													13	14	15	16	17	18
		Key																	
		1 H hydrogen 1.0																	

lanthanoids

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	138.9	cerium	140.1	praseodymium	140.9	neodymium	144.2	promethium	—	samarium	150.4	europlum	152.0	gadolinium	157.3	terbium	158.9	dysprosium	162.5	holmium	164.9	erbium	167.3	thulium	168.9	yterbium	173.1	lutetium	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	232.0	protactinium	231.0	uranium	238.0	neptunium	—	plutonium	—	americium	—	curium	—	berkelium	—	californium	—	einsteinium	—	fermium	—	mendeleevium	—	nobelium	—	lawrencium	—

actinoids





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NUMBER

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CHEMISTRY**9701/33**

Paper 3 Advanced Practical Skills 1

May/June 2025**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 **16** pages. Any blank pages are indicated.



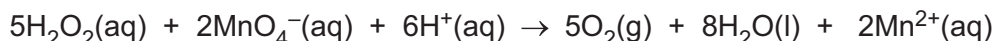
Quantitative analysis

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 answer to **each** step of your calculations.

- 1 Hydrogen peroxide, H_2O_2 , reacts rapidly with acidified potassium manganate(VII), KMnO_4 .



You will determine the concentration of a solution of hydrogen peroxide. You will first dilute the solution and then carry out a titration with acidified potassium manganate(VII).

FA 1 is aqueous hydrogen peroxide, H_2O_2 .

FA 2 is $0.0300 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .

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

(a) Method

Dilution of **FA 1**

- Pipette 25.0 cm^3 of **FA 1** into the 250 cm^3 volumetric flask.
- Add distilled water to make 250 cm^3 of solution.
- Shake the flask thoroughly.
- Label this diluted solution of hydrogen peroxide **FA 4**.

Titration

- Fill the burette with **FA 2**.
- Rinse the 25.0 cm^3 pipette with distilled water and then with **FA 4**.
- Pipette 25.0 cm^3 of **FA 4** into a conical flask.
- Use the 25 cm^3 measuring cylinder to add 10 cm^3 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 your recorded results show the precision of your practical work.
- Record, in a suitable form in the space for results, all your burette readings and the volume of **FA 2** added in each accurate titration.

Keep FA 1 for use in Questions 2 and 3.

Keep FA 2 for use in Question 3.





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 4** required cm³ of **FA 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 manganate(VII) ions in the volume of **FA 2** in (b).

amount of MnO₄⁻ = ... mol [1]

- (iii) Calculate the amount, in mol, of hydrogen peroxide in 25.0 cm³ of **FA 4**.

amount of H₂O₂ = ... mol [1]

- (iv) Calculate the concentration, in mol dm⁻³, of hydrogen peroxide in **FA 1**.

concentration of H₂O₂ in **FA 1** = ... mol dm⁻³ [1]





- (d) A student suggests that the experiment would be more accurate if a 10 cm^3 pipette is used to measure **FA 3** in place of the measuring cylinder.

State whether the student's suggestion is correct. Explain your answer.
Include a calculation as part of your explanation.

.....

.....

.....

[2]

[Total: 14]



* 0000800000005 *



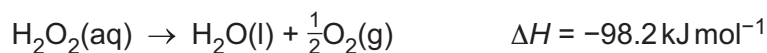
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- 2 You will now determine the concentration of a solution of hydrogen peroxide by a different method.

Hydrogen peroxide decomposes slowly into water and oxygen at room temperature. This reaction is exothermic. When a catalyst is added, the decomposition is fast and there is a measurable temperature rise.



FA 1 is aqueous hydrogen peroxide, H_2O_2 .

FA 5 is manganese(IV) oxide, MnO_2 .

(a) Method

Experiment 1

- Support one of the cups in the 250 cm^3 beaker.
- Use the 50 cm^3 measuring cylinder to add 25.0 cm^3 of **FA 1** to the cup.
- Place the thermometer in the **FA 1** and tilt the cup, if necessary, so that the bulb of the thermometer is fully covered. Record the temperature in the space for results.
- Add a heaped spatula measure of **FA 5** to the solution in the cup.
- Stir constantly until the maximum temperature is reached. Record this temperature.
- Calculate and record the temperature rise.
- Rinse and dry the thermometer.

Experiment 2

- Support the second cup in the 250 cm^3 beaker.
- Use the 50 cm^3 measuring cylinder to add 40.0 cm^3 of **FA 1** to the second cup.
- Measure and record the initial temperature of the solution.
- Add a heaped spatula measure of **FA 5** to the solution in the second cup.
- Stir constantly until the maximum temperature is reached. Record this temperature.
- Calculate and record the temperature rise.

Keep FA 5 for use in Question 3.

Results

I	
II	
III	
IV	
V	

[5]



(b) Calculations

- (i) Calculate the energy change, in J, in **Experiment 2**.

energy change = ... J [1]

- (ii) Use the information given and your answer to **(b)(i)** to calculate the concentration, in mol dm^{-3} , of hydrogen peroxide in **FA 1**.

concentration of H_2O_2 in **FA 1** = ... mol dm^{-3} [2]

- (c) The concentration of hydrogen peroxide in **FA 1** calculated using the method given for Question 1 is more accurate than that using the method given for Question 2.

- (i) Heat loss is a large source of error when carrying out the method for Question 2. Describe and explain the effect of heat loss on the value of the concentration of hydrogen peroxide calculated.

.....

 [1]

- (ii) A student suggests that calculating the concentration of hydrogen peroxide using the method in Question 2 would be less accurate when the concentration is lower. Suggest whether the student is correct. Explain your answer.

.....
 [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) (i)** Transfer a 2 cm depth of **FA 2**, KMnO_4 , into a test-tube. Add the same volume of aqueous sodium hydroxide followed by a small spatula measure of **FA 5**, MnO_2 . Stir for approximately 30 seconds then filter the mixture into a second test-tube.

observations

.....

Add dilute sulfuric acid to the filtrate until no further change.

observations

.....

[2]

- (ii)** Transfer a 1 cm depth of aqueous iron(II) sulfate into a boiling tube. Add the same depth of dilute sulfuric acid followed by a very small spatula measure of **FA 5**, MnO_2 . Carefully warm the mixture using a Bunsen burner for about 20 seconds. Filter the warm mixture into a test-tube.

observations

.....

Add aqueous sodium hydroxide dropwise to the filtrate until no further change.

observations

.....

[2]



- (iii) Suggest a conclusion about the chemical behaviour of **FA 5** using your observations in (a)(ii).

FA 5 is acting as [1]

- (iv) Write an ionic equation for the reaction between aqueous sodium hydroxide and the filtrate in (a)(ii). Include state symbols.

..... [1]

Question 3 continues on page 10.





- (b) **FA 6** and **FA 7** are both aqueous solutions of salts. Neither solution includes an ion that contains sulfur.

FA 6 contains two cations and one anion. Two of the ions are listed in the Qualitative analysis notes.

FA 7 contains one cation and one anion. One of the ions is listed in the Qualitative analysis notes.

- (i) Carry out the following tests and record your observations in Table 3.1.
Use a 1 cm depth of **FA 6** or **FA 7** in a boiling tube for Test 1. Use a 1 cm depth of **FA 6** or **FA 7** in a test-tube for Tests 2, 3 and 4.

Table 3.1

<i>test</i>	<i>observations</i>	
	FA 6	FA 7
Test 1 Add aqueous sodium hydroxide, then		
warm gently.		
Test 2 Add acidified aqueous KMnO_4 dropwise until no further change.		
Test 3 Add an equal volume of FA 1 , H_2O_2 , then	X	
add a few drops of starch solution.		
Test 4 Add aqueous sodium carbonate.		

[6]



- (ii) The anion in **FA 6** does **not** contain nitrogen. Select **one** further reagent to identify the anion present in **FA 6**.

Carry out a test with this reagent and record your observations in Table 3.2.

Table 3.2

<i>reagent</i>	<i>observations</i>

[1]

- (iii) Give the formulae of the ions present in **FA 6** and **FA 7**. If you are unable to identify an ion from your tests, write 'unknown.'

The ions present in **FA 6** are and and

The ions present in **FA 7** are and

[3]

[Total: 16]









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	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
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 $\text{J g}^{-1} \text{ K}^{-1}$)



Group																		
1	2		Group															18
3 Li lithium 6.9	4 Be beryllium 9.0	Key 1 H hydrogen 1.0																2 He helium 4.0
		atomic number atomic symbol name relative atomic mass																
11 Na sodium 23.0	12 Mg magnesium 24.3	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	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	
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 —	

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	euroium	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
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	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	—

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	euroium	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
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	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	—



Cambridge International AS & A Level

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NUMBER

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CHEMISTRY

9701/34

Paper 3 Advanced Practical Skills 2

May/June 2025

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 Iron is an element that is essential in the human diet. Some people need to take iron supplement tablets to ensure an adequate intake of iron.

You will investigate the mass of iron in an iron supplement tablet by titrating a solution with potassium manganate(VII).



FB 1 is an aqueous solution of iron supplement tablets made by dissolving 14 tablets in 1.00 dm^3 of solution. The iron in each tablet is iron(II) sulfate, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$.

FB 2 is $0.0100 \text{ mol dm}^{-3}$ acidified aqueous potassium manganate(VII), KMnO_4 .

FB 3 is dilute sulfuric acid, H_2SO_4 .

(a) Method

- Fill a burette with **FB 2**.
- Pipette 25.0 cm^3 of **FB 1** into a conical flask.
- Use the 25 cm^3 measuring cylinder to add 10.0 cm^3 of **FB 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 **FB 2** added in each accurate titration.

Rinse the burette with distilled water and leave to drain while you continue Question 1.

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 **FB 1** 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 manganate(VII) ions in the volume of **FB 2** in (b).

amount of MnO_4^- = ... mol [1]

- (iii) Use your answer to (c)(ii) and the equations at the start of the question to calculate the concentration, in mol dm⁻³, of iron(II) ions in **FB 1**.

concentration of Fe^{2+} = ... mol dm⁻³ [1]

- (iv) Use your answer to (c)(iii) to calculate the concentration, in g dm⁻³, of iron(II) ions in **FB 1**.

concentration of Fe^{2+} = ... g dm⁻³ [1]

- (v) The manufacturer of the iron supplement tablets used to make **FB 1** claims that each tablet contains a minimum of 150 mg of Fe^{2+} .

Use your answer to (c)(iv) and the information given about **FB 1** to determine whether this claim is correct. Show your working.

[1]

- (d) A student used all the **FB 3** and suggests that dilute hydrochloric acid would be a suitable replacement. Suggest whether the student is correct or not. Explain your answer.

.....

.....

..... [1]

[Total:14]



- 2 The reaction between an acid and an alkali is exothermic. You will carry out a neutralisation experiment to determine the enthalpy change involved.

You will mix different volumes of an acid with a fixed volume of an alkali and measure the temperature rises that occur.

FB 4 is aqueous sodium hydroxide, NaOH.

FB 5 is 2.00 mol dm^{-3} hydrochloric acid, HCl.

(a) Method

- Use the thermometer to measure the initial temperature of **FB 4**. Record this initial temperature in the space for results.
- Support the cup in the 250 cm^3 beaker.
- Fill one burette with **FB 5**. Label the burette **FB 5**.
- Fill the other burette with distilled water.

Experiment 1

- Use the 10 cm^3 pipette to transfer 10.0 cm^3 of **FB 4** into the cup.
- Add 9.00 cm^3 of distilled water from the burette to the same cup.
- Add 1.00 cm^3 of **FB 5** from the other burette to the same cup.
- Stir the mixture and use the thermometer to measure the maximum temperature. If necessary, tilt the cup so that the solution covers the bulb of the thermometer.
- Record the maximum temperature in Table 2.1.
- Empty, rinse and dry the cup ready for use in further experiments.

Further experiments

Repeat this method for Experiments 2–5, using 10.0 cm^3 of **FB 4** and the volumes of water and **FB 5** shown in Table 2.1. In each case, measure and record the maximum temperature.

Carry out **two** further experiments, Experiments 6 and 7, which will enable you to determine more precisely the volume of **FB 5** that gives the largest maximum temperature. Record your measurements in Table 2.1.

Results

initial temperature of **FB 4** = ... °C

Table 2.1

experiment	volume of water / cm^3	volume of FB 5 / cm^3	maximum temperature / °C
1	9.00	1.00	
2	7.00	3.00	
3	5.00	5.00	
4	3.00	7.00	
5	1.00	9.00	
6			
7			

I	
II	
III	
IV	

[4]

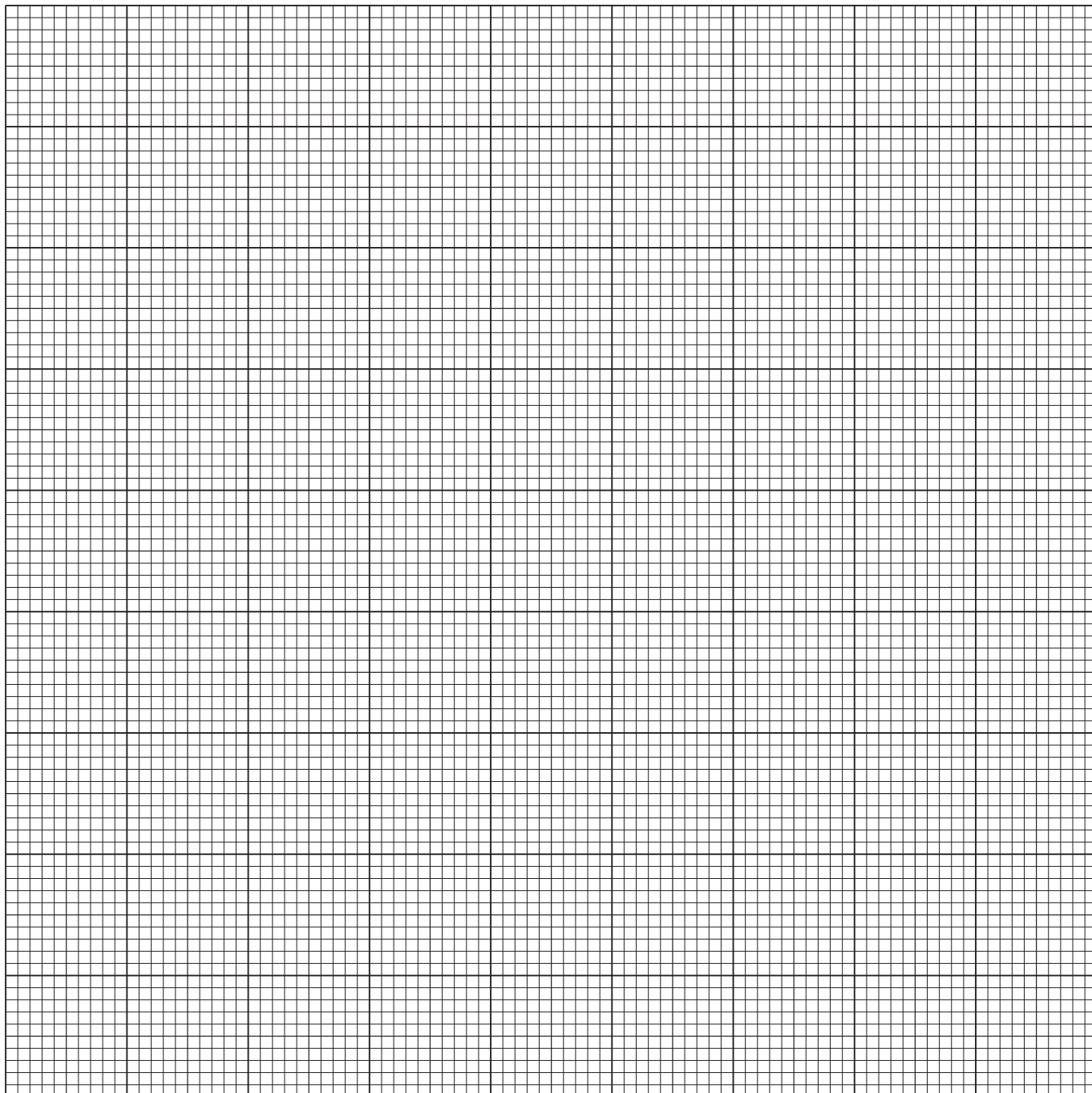




- (b) (i) Plot a graph of the maximum temperature (y -axis) against the volume of **FB 5** (x -axis) on the grid. The scale on the y -axis should be suitable for temperature readings to be 2°C above the largest maximum temperature.

Label any points you consider to be anomalous.

Draw **two** lines of best fit, the first for the increase in maximum temperature and the second for after the largest maximum temperature has been reached. Extrapolate both lines so that they intersect.



[4]

I		II		III		IV	
---	--	----	--	-----	--	----	--



- volume of **FB 5** = ... cm³ [1]

DO NOT WRITE IN THIS MARGIN

- (If you were unable to determine an answer to **(b)(ii)**, use 5.10 cm^3 as the volume of **FB 5**. This may **not** be the correct answer.)

amount of HCl = ... mol

Deduce the amount, in mol, of sodium hydroxide in 10.0 cm³ of **FB 4**.

amount of NaOH = ... mol
[1]

- DO NOT WRITE IN THIS MARGIN

energy change = ... J [1]

- DO NOT WRITE IN THIS MARGIN

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

DO NOT WRITE IN THIS MARGIN



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) (i) FB 6, FB 7 and FB 8** are aqueous solutions of different compounds that each contain at least one oxygen atom.

Carry out the following tests and record your observations in Table 3.1. Three of the tests have been done for you. Use a 1 cm depth of solution in a test-tube for each test.

Table 3.1

<i>test</i>	<i>observations</i>		
	FB 6	FB 7	FB 8
Test 1 Add a small spatula measure of manganese(IV) oxide.	No change.	No change.	
Test 2 Add a 1 cm length of magnesium.			No change.
Test 3 Add a few drops of aqueous iron(II) sulfate.			

[4]





- (ii) Use your observations in Table 3.1 to suggest a possible formula for each of **FB 6**, **FB 7** and **FB 8**.

FB 6

FB 7

FB 8

[2]

- (b) **FB 9** contains two anions and two cations, three of which are listed in the Qualitative analysis notes.

- (i) To a small spatula measure of **FB 9** in a test-tube, add a 2 cm depth of dilute nitric acid. Record your observations.

Keep the resulting solution for the test in (b)(ii).

.....

 [2]

- (ii) To the solution from **(b)(i)**, add a few drops of aqueous silver nitrate. Then add excess aqueous ammonia. Record your observations.

.....

 [1]





- (iii) Make an aqueous solution of **FB 9** by adding a 5 cm depth of distilled water to a spatula measure of **FB 9** in a test-tube. Carry out the following tests on the aqueous solution of **FB 9** and record your observations in Table 3.2.

Table 3.2

<i>test</i>	<i>observations</i>
Test 1 To a 1 cm depth in a boiling tube, add aqueous sodium hydroxide, then ----- warm.	
Test 2 To a 1 cm depth in a test-tube, add a few drops of dilute hydrochloric acid, then add a few drops of aqueous chlorine. Empty and rinse the test-tube with water immediately after use.	

[2]

- (iv) Use your observations in (b)(i), (b)(ii) and Table 3.2 to deduce the formulae of the cations and anions in **FB 9**. If you are unable to identify an ion, write 'unknown'.

cations and

anions and

[2]

- (v) Write an ionic equation for the reaction in (b)(ii). Include state symbols.

..... [1]

[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	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
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 Hhydrogen1.0										13	14	15	16	17	18								
		Key atomic number atomic symbol name relative atomic mass																							
3	4																	5	6	7	8	9	10	11	12
Li lithium 6.9	Be beryllium 9.0																	B boron 10.8	C carbon 12.0	N nitrogen 14.0	O oxygen 16.0	F fluorine 19.0	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								
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

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	europlum	gadolinium	terbium	dysprosium	holmium	erbium	thulium	ytterbium	lutetium
138.9	140.1	140.9	144.2	—	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	—	—	—	—	—	—	—	—	—	—	—





Cambridge International AS & A Level

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CHEMISTRY

9701/35

Paper 3 Advanced Practical Skills 1

May/June 2025

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 answer to **each** step of your calculations.

- 1 Group 1 metal carbonates react with dilute acids to form a salt, water and carbon dioxide. The identity of the metal, **M**, can be determined by measuring the volume of carbon dioxide produced when excess acid is added to a known mass of the carbonate, M_2CO_3 .

FA 1 is the metal carbonate, M_2CO_3 .

FA 2 is $0.250 \text{ mol dm}^{-3}$ sulfuric acid, H_2SO_4 .

(a) Method

- Weigh the container with **FA 1**. Record the mass in the space for results.
- Fill the tub with water to a depth of approximately 5 cm.
- Fill the 250 cm^3 measuring cylinder completely with water. Holding a piece of paper towel firmly over the top, invert the measuring cylinder and place it in the water in the tub.
- Remove the paper towel and clamp the inverted measuring cylinder so the open end is in the water just above the base of the tub.
- Use the 50 cm^3 measuring cylinder to transfer 50.0 cm^3 of **FA 2** into the flask labelled **X**. Check that the bung fits tightly into the neck of flask **X**, clamp flask **X** and place the delivery tube into the inverted 250 cm^3 measuring cylinder.
- Remove the bung from the neck of the flask. Add all of the **FA 1** into the acid in the flask and replace the bung **immediately**. Remove the flask from the clamp and swirl it to mix the contents.
- Replace the flask in the clamp and leave until the fizzing stops. Swirl the flask occasionally.
- Weigh the container with any residual **FA 1**. Record the mass.
- Calculate and record the mass of **FA 1** that is added to the acid.
- When no more gas is collected, record the final volume of gas.

You may wish to start Question 2 or Question 3 while the gas is being collected.

Results

I	
II	
III	

[3]



(b) Calculations

- (i) Calculate the amount, in mol, of carbon dioxide collected in the measuring cylinder (at room conditions).

amount of CO_2 = ... mol [1]

- (ii) Write an equation for the reaction between sulfuric acid and the metal carbonate, M_2CO_3 . Include state symbols.

..... [1]

- (iii) Use your answers to **(b)(i)** and **(b)(ii)** to deduce the amount, in mol, of the metal carbonate in the mass of **FA 1** you used in your experiment.

amount of M_2CO_3 = ... mol

Hence, calculate the relative formula mass, M_r , of the metal carbonate.

M_r of M_2CO_3 = ... [1]

- (iv) Use your answer to **(b)(iii)** to calculate the relative atomic mass, A_r , of metal **M**. Hence, identify metal **M** in **FA 1**.

A_r of **M** = ...

M is [2]

- (c) A student carries out a similar experiment on a powdered Group 2 carbonate. The student determines the relative atomic mass, A_r , to be 49.3 and concludes that the metal in the carbonate is calcium.

Calculate the percentage error in the student's result. Show your working.

percentage error in A_r of Ca = ... % [1]

- (d) Suggest why the method you used in **(a)** would be unsuitable for use with small lumps of calcium carbonate.

..... [1]

[Total: 10]

[Turn over]





- 2 The identity of a Group 1 metal in a metal carbonate may also be determined by titration with acid. Z_2CO_3 is a Group 1 metal carbonate. The metal may or may not be the same as that in **FA 1**. You will determine which metal is present in Z_2CO_3 .

FA 3 is $7.26 \text{ g dm}^{-3} Z_2CO_3$.

FA 4 is $0.0500 \text{ mol dm}^{-3}$ sulfuric acid, H_2SO_4 .

FA 5 is bromophenol blue indicator.

(a) Method

- Fill the burette with **FA 4**.
- Pipette 25.0 cm^3 of **FA 3** into a conical flask.
- Add a few drops of **FA 5** to the same 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 4** 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 cm^3 of **FA 3** required cm^3 of **FA 4**. [1]



(c) Calculations

- (i) Calculate the amount, in mol, of sulfuric acid present in the volume of **FA 4** in (b).

amount of H_2SO_4 = ... mol [1]

- (ii) Use your answer to (c)(i) to calculate the amount, in mol, of Z_2CO_3 in 1.0 dm^3 of **FA 3**.

amount of Z_2CO_3 = ... mol [1]

- (iii) Use your answer to (c)(ii) to determine the identity of metal **Z**.

Metal **Z** is [2]

- (d) Z_2CO_3 also exists as the hydrated salt.

State whether your titre will increase or decrease if 7.26 g of hydrated Z_2CO_3 is dissolved to prepare 1 dm^3 of **FA 3**. Explain your answer.

.....

 [1]

- (e) A titration is a more accurate method of determining the relative atomic mass of the metal in a metal carbonate than gas collection.

Give **two** reasons why titration is a more accurate method.

1

 2
 [2]

[Total: 15]





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 any 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 Half-fill the 250 cm³ beaker with water and place it on a tripod and gauze. Heat the water until boiling then switch off your Bunsen burner. This is your hot water bath for use in (b).
- (a) **FA 6** and **FA 7** are aqueous solutions that each contain one cation and one anion. All the ions are listed in the Qualitative analysis notes. None of the ions contains nitrogen.
- (i) Carry out the following tests using a 1 cm depth of **FA 6** or **FA 7** in a test-tube for each test. Record your observations in Table 3.1.

Table 3.1

test	observations	
	FA 6	FA 7
Test 1 Add aqueous sodium hydroxide.		
Test 2 Add aqueous ammonia, then		
let the mixture stand for 5 minutes.		
Test 3 Add hydrogen peroxide, mix well, then		
add aqueous sodium hydroxide.		

[4]





- (ii) Carry out tests to identify the anions in **FA 6** and **FA 7**.

Record your tests and observations in a suitable form in the space below.

[4]

- (iii) Use your observations from (a)(i) and (a)(ii) to deduce the formulae of **FA 6** and **FA 7**.

FA 6 is

FA 7 is

[2]



Ensure your water bath is hot and the Bunsen burner is turned off before you start **(b)**.

- (b) FA 8** is an organic liquid containing **one** functional group and **only** the elements C, H and O. You will carry out two tests to investigate **FA 8**.

For each test you will record your observations and then conclude one of the following:

- at least two types of compound that **FA 8** could be
- or
- one type of compound that **FA 8 cannot** be.

- (i)** To a 1 cm depth of **FA 8** in a test-tube, add a few drops of acidified aqueous potassium manganate(VII), then place the test-tube in the hot water bath.

observation

.....

conclusion

[2]

- (ii)** To a 1 cm depth of **FA 8** in a test-tube, add a small spatula measure of sodium carbonate.

observation

.....

conclusion

[2]

- (iii)** Suggest a further test you could carry out to identify one of the types of compound that you have concluded could be **FA 8**.

State the reagent you would use. State what a positive result would indicate about the identity of **FA 8**.

Do **not** carry out your test.

reagent

conclusion from a positive result

.....

[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	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
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													13	14	15	16	17	18		
		1 Hhydrogen1.0																			
		Key atomic number atomic symbol name relative atomic mass																			
3	4													5	6	7	8	9	10	11	12
Li	Be													B	C	N	O	F	Ne		
lithium	beryllium													boron	carbon	nitrogen	oxygen	fluorine	neon		
6.9	9.0													10.8	12.0	14.0	16.0	19.0	20.2		
11	12													13	14	15	16	17	18		
Na	Mg													Al	Si	P	S	Cl	Ar		
sodium	magnesium													aluminium	silicon	phosphorus	sulfur	chlorine	argon		
23.0	24.3													27.0	28.1	31.0	32.1	35.5	39.9		
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36				
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr				
potassium	calcium	scandium	titanium	vanadium	chromium	manganese	iron	cobalt	nickel	copper	zinc	gallium	germanium	arsenic	selenium	bromine	krypton				
39.1	40.1	45.0	47.9	50.9	52.0	54.9	55.8	58.9	58.7	63.5	65.4	69.7	72.6	74.9	79.0	79.9	83.8				
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54				
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe				
rubidium	strontium	yttrium	zirconium	niobium	molybdenum	technetium	ruthenium	rhodium	palladium	silver	cadmium	indium	tin	antimony	tellurium	iodine	xenon				
85.5	87.6	88.9	91.2	92.9	95.9	—	101.1	102.9	106.4	107.9	112.4	114.8	118.7	121.8	127.6	126.9	131.3				
55	56	57–71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86				
Cs	Ba	lanthanoids	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn				
caesium	barium		hafnium	tantalum	tungsten	rhenium	osmium	iridium	platinum	gold	mercury	thallium	lead	bismuth	polonium	astatine	radon				
132.9	137.3		178.5	180.9	183.8	186.2	190.2	192.2	195.1	197.0	200.6	204.4	207.2	209.0	—	—	—				
87	88	89–103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118				
Fr	Ra	actinoids	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og				
francium	radium		rutherfordium	dubnium	seaborgium	bohrium	hassium	meitnerium	darmstadtium	roentgenium	copernicium	nihonium	flerovium	moscovium	livermorium	tennessine	oganesson				
—	—		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—				

lanthanoids

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	europlum	gadolinium	terbium	dysprosium	holmium	erbium	thulium	ytterbium	lutetium	lanthanum	cerium	praseodymium	neodymium	promethium	samarium	europlum	gadolinium	terbium	dysprosium	holmium	erbium	thulium	ytterbium	lutetium
138.9	140.1	140.9	144.2	—	150.4	152.0	157.3	158.9	162.5	164.9	167.3	168.9	173.1	175.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

actinoids

89	Ac	90	Th	91	Pa	92	U	93	Np	94	Pu	95	Am	96	Cm	97	Bk	98	Cf	99	Es	100	Fm	101	Md	102	No	103	Lr
actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendeleevium	nobelium	lawrencium	actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendeleevium	nobelium	lawrencium
—	—	231.0	238.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—





Cambridge International AS & A Level

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NUMBER

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CHEMISTRY

9701/37

Paper 3 Advanced Practical Skills 1

May/June 2025

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 **16** pages. Any blank pages are indicated.



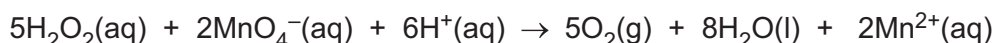
Quantitative analysis

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 answer to **each** step of your calculations.

- 1 Hydrogen peroxide, H_2O_2 , reacts rapidly with acidified potassium manganate(VII), KMnO_4 .



You will determine the concentration of a solution of hydrogen peroxide. You will first dilute the solution and then carry out a titration with acidified potassium manganate(VII).

FA 1 is aqueous hydrogen peroxide, H_2O_2 .

FA 2 is $0.0300 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .

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

(a) Method

Dilution of **FA 1**

- Pipette 25.0 cm^3 of **FA 1** into the 250 cm^3 volumetric flask.
- Add distilled water to make 250 cm^3 of solution.
- Shake the flask thoroughly.
- Label this diluted solution of hydrogen peroxide **FA 4**.

Titration

- Fill the burette with **FA 2**.
- Rinse the 25.0 cm^3 pipette with distilled water and then with **FA 4**.
- Pipette 25.0 cm^3 of **FA 4** into a conical flask.
- Use the 25 cm^3 measuring cylinder to add 10 cm^3 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 your recorded results show the precision of your practical work.
- Record, in a suitable form in the space for results, all your burette readings and the volume of **FA 2** added in each accurate titration.

Keep FA 1 for use in Questions 2 and 3.

Keep FA 2 for use in Question 3.





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 4** required cm³ of **FA 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 manganate(VII) ions in the volume of **FA 2** in (b).

amount of MnO₄⁻ = ... mol [1]

- (iii) Calculate the amount, in mol, of hydrogen peroxide in 25.0 cm³ of **FA 4**.

amount of H₂O₂ = ... mol [1]

- (iv) Calculate the concentration, in mol dm⁻³, of hydrogen peroxide in **FA 1**.

concentration of H₂O₂ in **FA 1** = ... mol dm⁻³ [1]





- (d) A student suggests that the experiment would be more accurate if a 10 cm^3 pipette is used to measure **FA 3** in place of the measuring cylinder.

State whether the student's suggestion is correct. Explain your answer.
Include a calculation as part of your explanation.

.....

.....

.....

[2]

[Total: 14]



* 0000800000005 *



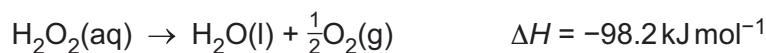
5

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- 2 You will now determine the concentration of a solution of hydrogen peroxide by a different method.

Hydrogen peroxide decomposes slowly into water and oxygen at room temperature. This reaction is exothermic. When a catalyst is added, the decomposition is fast and there is a measurable temperature rise.



FA 1 is aqueous hydrogen peroxide, H_2O_2 .

FA 5 is manganese(IV) oxide, MnO_2 .

(a) Method

Experiment 1

- Support one of the cups in the 250 cm^3 beaker.
- Use the 50 cm^3 measuring cylinder to add 25.0 cm^3 of **FA 1** to the cup.
- Place the thermometer in the **FA 1** and tilt the cup, if necessary, so that the bulb of the thermometer is fully covered. Record the temperature in the space for results.
- Add a heaped spatula measure of **FA 5** to the solution in the cup.
- Stir constantly until the maximum temperature is reached. Record this temperature.
- Calculate and record the temperature rise.
- Rinse and dry the thermometer.

Experiment 2

- Support the second cup in the 250 cm^3 beaker.
- Use the 50 cm^3 measuring cylinder to add 40.0 cm^3 of **FA 1** to the second cup.
- Measure and record the initial temperature of the solution.
- Add a heaped spatula measure of **FA 5** to the solution in the second cup.
- Stir constantly until the maximum temperature is reached. Record this temperature.
- Calculate and record the temperature rise.

Keep FA 5 for use in Question 3.

Results

I	
II	
III	
IV	
V	

[5]



(b) Calculations

- (i) Calculate the energy change, in J, in **Experiment 2**.

energy change = ... J [1]

- (ii) Use the information given and your answer to **(b)(i)** to calculate the concentration, in mol dm^{-3} , of hydrogen peroxide in **FA 1**.

concentration of H_2O_2 in **FA 1** = ... mol dm^{-3} [2]

- (c) The concentration of hydrogen peroxide in **FA 1** calculated using the method given for Question 1 is more accurate than that using the method given for Question 2.

- (i) Heat loss is a large source of error when carrying out the method for Question 2. Describe and explain the effect of heat loss on the value of the concentration of hydrogen peroxide calculated.

.....

 [1]

- (ii) A student suggests that calculating the concentration of hydrogen peroxide using the method in Question 2 would be less accurate when the concentration is lower. Suggest whether the student is correct. Explain your answer.

.....
 [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) (i)** Transfer a 2 cm depth of **FA 2**, KMnO_4 , into a test-tube. Add the same volume of aqueous sodium hydroxide followed by a small spatula measure of **FA 5**, MnO_2 . Stir for approximately 30 seconds then filter the mixture into a second test-tube.

observations

.....

Add dilute sulfuric acid to the filtrate until no further change.

observations

.....

[2]

- (ii)** Transfer a 1 cm depth of aqueous iron(II) sulfate into a boiling tube. Add the same depth of dilute sulfuric acid followed by a very small spatula measure of **FA 5**, MnO_2 . Carefully warm the mixture using a Bunsen burner for about 20 seconds. Filter the warm mixture into a test-tube.

observations

.....

Add aqueous sodium hydroxide dropwise to the filtrate until no further change.

observations

.....

[2]



- (iii) Suggest a conclusion about the chemical behaviour of **FA 5** using your observations in (a)(ii).

FA 5 is acting as [1]

- (iv) Write an ionic equation for the reaction between aqueous sodium hydroxide and the filtrate in (a)(ii). Include state symbols.

..... [1]

Question 3 continues on page 10.





- (b) **FA 6** and **FA 7** are both aqueous solutions of salts. Neither solution includes an ion that contains sulfur.

FA 6 contains two cations and one anion. Two of the ions are listed in the Qualitative analysis notes.

FA 7 contains one cation and one anion. One of the ions is listed in the Qualitative analysis notes.

- (i) Carry out the following tests and record your observations in Table 3.1.
Use a 1 cm depth of **FA 6** or **FA 7** in a boiling tube for Test 1. Use a 1 cm depth of **FA 6** or **FA 7** in a test-tube for Tests 2, 3 and 4.

Table 3.1

<i>test</i>	<i>observations</i>	
	FA 6	FA 7
Test 1 Add aqueous sodium hydroxide, then		
warm gently.		
Test 2 Add acidified aqueous KMnO_4 dropwise until no further change.		
Test 3 Add an equal volume of FA 1 , H_2O_2 , then	X	
add a few drops of starch solution.		
Test 4 Add aqueous sodium carbonate.		

[6]



- (ii) The anion in **FA 6** does **not** contain nitrogen. Select **one** further reagent to identify the anion present in **FA 6**.

Carry out a test with this reagent and record your observations in Table 3.2.

Table 3.2

<i>reagent</i>	<i>observations</i>

[1]

- (iii) Give the formulae of the ions present in **FA 6** and **FA 7**. If you are unable to identify an ion from your tests, write 'unknown.'

The ions present in **FA 6** are and and

The ions present in **FA 7** are and

[3]

[Total: 16]









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	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
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 $\text{J g}^{-1} \text{ K}^{-1}$)



Group																	
1	2	Key										13	14	15	16	17	18
		atomic number atomic symbol name relative atomic mass															
3	4																
Li lithium 6.9	Be beryllium 9.0	21	20	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Na sodium 23.0	Mg magnesium 24.3	Sc scandium 45.0	Ca calcium 40.1	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
11	12	39	38	40	41	42	44	45	46	47	48	49	50	51	52	53	54
Y yttrium 88.9	La lanthanoids 57-71	Zr zirconium 91.2	Nb niobium 92.9	Ta tantalum 180.9	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	73	72	74	75	76	77	78	79	80	81	82	83	84	85	86	87
Rb rubidium 85.5	Sr strontium 87.6	Y yttrium 88.9	Hf hafnium 178.5	Ta tantalum 180.9	W tungsten 183.8	Re rhenium 186.2	Os osmium 190.2	Ir iridium 192.2	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 -	Fr francium -
87	88	89-103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
Ac actinoids	Ra radium	103-118	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 oganeson

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	euroium	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
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	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	mendeleevium	—
102	No	nobelium	—
103	Lr	lawrencium	—

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	euroium	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
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	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	mendeleevium	—
102	No	nobelium	—
103	Lr	lawrencium	—



Cambridge International AS & A Level

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NAME
CENTRE
NUMBER

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CANDIDATE
NUMBER

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CHEMISTRY

9701/38

Paper 3 Advanced Practical Skills 2

May/June 2025

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.
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- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

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- The number of marks for each question or part question is shown in brackets [].
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- 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 Iron is an element that is essential in the human diet. Some people need to take iron supplement tablets to ensure an adequate intake of iron.

You will investigate the mass of iron in an iron supplement tablet by titrating a solution with potassium manganate(VII).



FB 1 is an aqueous solution of iron supplement tablets made by dissolving 14 tablets in 1.00 dm^3 of solution. The iron in each tablet is iron(II) sulfate, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$.

FB 2 is $0.0100 \text{ mol dm}^{-3}$ acidified aqueous potassium manganate(VII), KMnO_4 .

FB 3 is dilute sulfuric acid, H_2SO_4 .

(a) Method

- Fill a burette with **FB 2**.
- Pipette 25.0 cm^3 of **FB 1** into a conical flask.
- Use the 25 cm^3 measuring cylinder to add 10.0 cm^3 of **FB 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 **FB 2** added in each accurate titration.

Rinse the burette with distilled water and leave to drain while you continue Question 1.

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 **FB 1** 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 manganate(VII) ions in the volume of **FB 2** in (b).

amount of MnO_4^- = ... mol [1]

- (iii) Use your answer to (c)(ii) and the equations at the start of the question to calculate the concentration, in mol dm⁻³, of iron(II) ions in **FB 1**.

concentration of Fe^{2+} = ... mol dm⁻³ [1]

- (iv) Use your answer to (c)(iii) to calculate the concentration, in g dm⁻³, of iron(II) ions in **FB 1**.

concentration of Fe^{2+} = ... g dm⁻³ [1]

- (v) The manufacturer of the iron supplement tablets used to make **FB 1** claims that each tablet contains a minimum of 150 mg of Fe^{2+} .

Use your answer to (c)(iv) and the information given about **FB 1** to determine whether this claim is correct. Show your working.

[1]

- (d) A student used all the **FB 3** and suggests that dilute hydrochloric acid would be a suitable replacement. Suggest whether the student is correct or not. Explain your answer.

.....

.....

..... [1]

[Total:14]



- 2 The reaction between an acid and an alkali is exothermic. You will carry out a neutralisation experiment to determine the enthalpy change involved.

You will mix different volumes of an acid with a fixed volume of an alkali and measure the temperature rises that occur.

FB 4 is aqueous sodium hydroxide, NaOH.

FB 5 is 2.00 mol dm^{-3} hydrochloric acid, HCl.

(a) Method

- Use the thermometer to measure the initial temperature of **FB 4**. Record this initial temperature in the space for results.
- Support the cup in the 250 cm^3 beaker.
- Fill one burette with **FB 5**. Label the burette **FB 5**.
- Fill the other burette with distilled water.

Experiment 1

- Use the 10 cm^3 pipette to transfer 10.0 cm^3 of **FB 4** into the cup.
- Add 9.00 cm^3 of distilled water from the burette to the same cup.
- Add 1.00 cm^3 of **FB 5** from the other burette to the same cup.
- Stir the mixture and use the thermometer to measure the maximum temperature. If necessary, tilt the cup so that the solution covers the bulb of the thermometer.
- Record the maximum temperature in Table 2.1.
- Empty, rinse and dry the cup ready for use in further experiments.

Further experiments

Repeat this method for Experiments 2–5, using 10.0 cm^3 of **FB 4** and the volumes of water and **FB 5** shown in Table 2.1. In each case, measure and record the maximum temperature.

Carry out **two** further experiments, Experiments 6 and 7, which will enable you to determine more precisely the volume of **FB 5** that gives the largest maximum temperature. Record your measurements in Table 2.1.

Results

initial temperature of **FB 4** = ... °C

Table 2.1

experiment	volume of water / cm^3	volume of FB 5 / cm^3	maximum temperature / °C
1	9.00	1.00	
2	7.00	3.00	
3	5.00	5.00	
4	3.00	7.00	
5	1.00	9.00	
6			
7			

I	
II	
III	
IV	

[4]

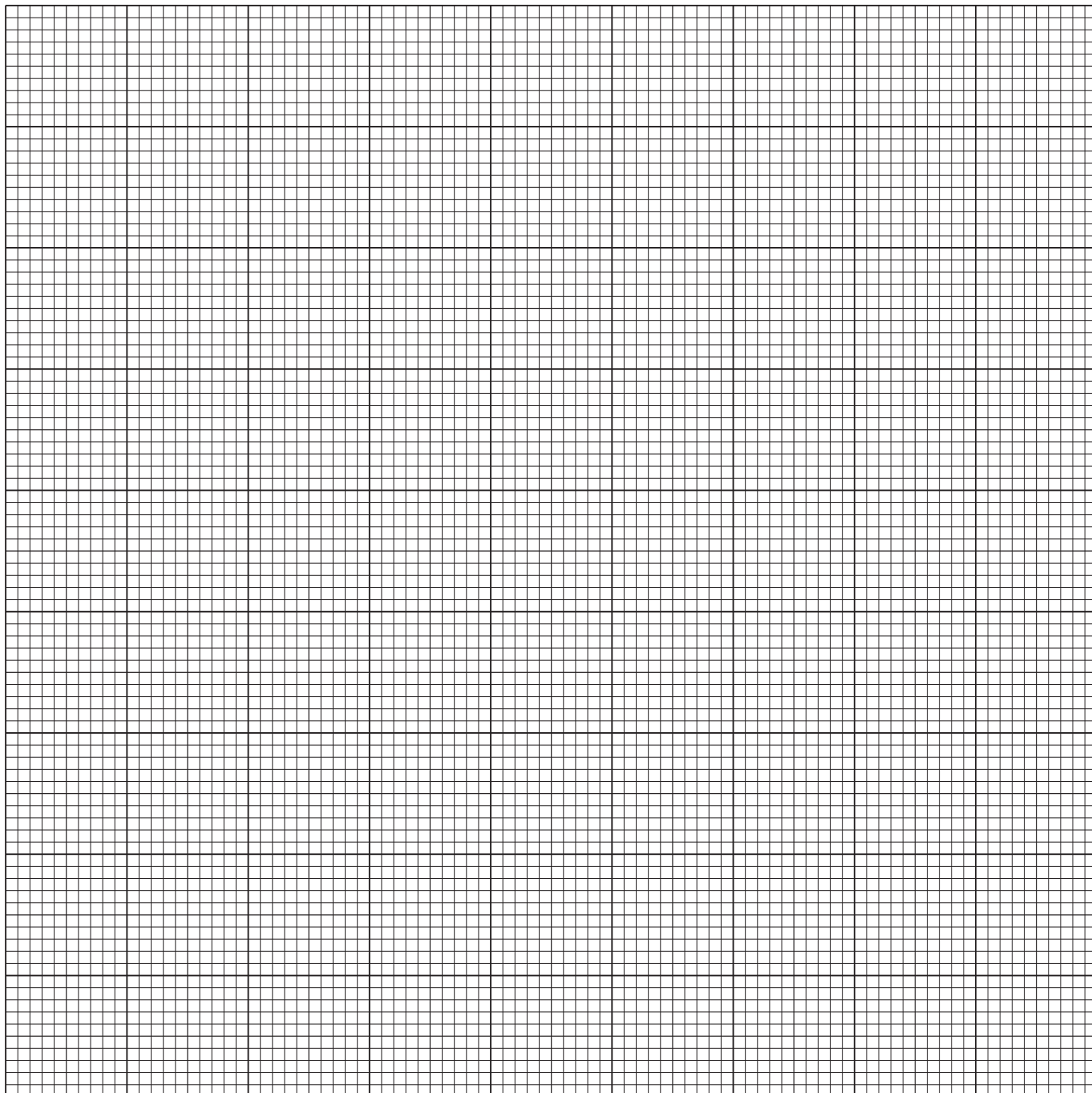




- (b) (i) Plot a graph of the maximum temperature (y -axis) against the volume of **FB 5** (x -axis) on the grid. The scale on the y -axis should be suitable for temperature readings to be 2°C above the largest maximum temperature.

Label any points you consider to be anomalous.

Draw **two** lines of best fit, the first for the increase in maximum temperature and the second for after the largest maximum temperature has been reached. Extrapolate both lines so that they intersect.



[4]

I		II		III		IV	
---	--	----	--	-----	--	----	--



- volume of **FB 5** = ... cm³ [1]

DO NOT WRITE IN THIS MARGIN

- (If you were unable to determine an answer to **(b)(ii)**, use 5.10 cm^3 as the volume of **FB 5**. This may **not** be the correct answer.)

amount of HCl = ... mol

Deduce the amount, in mol, of sodium hydroxide in 10.0 cm³ of **FB 4**.

amount of NaOH = ... mol
[1]

- DO NOT WRITE IN THIS MARGIN

energy change = ...J [1]

- DO NOT WRITE IN THIS MARGIN

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

DO NOT WRITE IN THIS MARGIN



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) (i) FB 6, FB 7 and FB 8** are aqueous solutions of different compounds that each contain at least one oxygen atom.

Carry out the following tests and record your observations in Table 3.1. Three of the tests have been done for you. Use a 1 cm depth of solution in a test-tube for each test.

Table 3.1

<i>test</i>	<i>observations</i>		
	FB 6	FB 7	FB 8
Test 1 Add a small spatula measure of manganese(IV) oxide.	No change.	No change.	
Test 2 Add a 1 cm length of magnesium.			No change.
Test 3 Add a few drops of aqueous iron(II) sulfate.			

[4]





- (ii) Use your observations in Table 3.1 to suggest a possible formula for each of **FB 6**, **FB 7** and **FB 8**.

FB 6

FB 7

FB 8

[2]

- (b) **FB 9** contains two anions and two cations, three of which are listed in the Qualitative analysis notes.

- (i) To a small spatula measure of **FB 9** in a test-tube, add a 2 cm depth of dilute nitric acid. Record your observations.

Keep the resulting solution for the test in (b)(ii).

.....

 [2]

- (ii) To the solution from **(b)(i)**, add a few drops of aqueous silver nitrate. Then add excess aqueous ammonia. Record your observations.

.....

 [1]





- (iii) Make an aqueous solution of **FB 9** by adding a 5 cm depth of distilled water to a spatula measure of **FB 9** in a test-tube. Carry out the following tests on the aqueous solution of **FB 9** and record your observations in Table 3.2.

Table 3.2

<i>test</i>	<i>observations</i>
Test 1 To a 1 cm depth in a boiling tube, add aqueous sodium hydroxide, then ----- warm.	
Test 2 To a 1 cm depth in a test-tube, add a few drops of dilute hydrochloric acid, then add a few drops of aqueous chlorine. Empty and rinse the test-tube with water immediately after use.	

[2]

- (iv) Use your observations in (b)(i), (b)(ii) and Table 3.2 to deduce the formulae of the cations and anions in **FB 9**. If you are unable to identify an ion, write 'unknown'.

cations and

anions and

[2]

- (v) Write an ionic equation for the reaction in (b)(ii). Include state symbols.

..... [1]

[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	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
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 Hhydrogen1.0												13	14	15	16	17	18				
		Key atomic number atomic symbol name relative atomic mass																					
3	4															5	6	7	8	9	10	11	12
Li lithium 6.9	Be beryllium 9.0															B boron 10.8	C carbon 12.0	N nitrogen 14.0	O oxygen 16.0	F fluorine 19.0	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						
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	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	138.9	cerium	140.1	praseodymium	140.9	neodymium	144.2	promethium	—	samarium	150.4	europlum	152.0	gadolinium	157.3	terbium	158.9	dysprosium	162.5	holmium	164.9	erbium	167.3	thulium	168.9	yterbium	173.1	lutetium	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	232.0	protactinium	231.0	uranium	238.0	neptunium	—	plutonium	—	americium	—	curium	—	berkelium	—	californium	—	einsteinium	—	fermium	—	mendeleevium	—	nobelium	—	lawrencium	—

actinoids

