



# Cambridge International AS & A Level

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**CHEMISTRY**

**9701/31**

Paper 3 Advanced Practical Skills 1

**October/November 2021**

**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, use appropriate units and use an appropriate number of significant figures.
- Give details of the practical session and laboratory, where appropriate, in the boxes provided.

## 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.
- Notes for use in qualitative analysis are provided in the question paper.

| Session    |  |
|------------|--|
|            |  |
| Laboratory |  |
|            |  |

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| 1                  |  |
| 2                  |  |
| 3                  |  |
| <b>Total</b>       |  |

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

- 1 You will investigate a compound of a Group 1 element to determine which element is present. Group 1 carbonates decompose to give carbon dioxide when heated to high temperatures.



**FA 1** is the carbonate of the element,  $\text{X}_2\text{CO}_3$ .

### (a) Method

- Weigh a crucible with its lid and record the mass.
- Add 1.40–1.60 g of **FA 1** to the crucible.
- Weigh the crucible and its lid with **FA 1** and record the mass.
- Place the crucible on the pipe-clay triangle. Heat the crucible, with its lid on, gently for approximately 1 minute. Then heat strongly for another minute.
- Carefully remove the lid. Heat the crucible strongly for 4 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.

**While the crucible is cooling you may wish to begin work on Question 2.**

- Reweigh the crucible and contents with its lid. Record the mass.
- Remove the lid. Heat the crucible and contents strongly for a further 2 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes. Reweigh the crucible and residue with its lid. Record the mass.
- Calculate and record the mass of **FA 1** added to the crucible. Calculate the mass of residue obtained.

### Results

|     |  |
|-----|--|
| I   |  |
| II  |  |
| III |  |
| IV  |  |
| V   |  |

[5]

**(b) Calculations**

- (i) Calculate the mass of carbon dioxide produced when the sample of  $\text{X}_2\text{CO}_3$  was heated.

mass of  $\text{CO}_2$  produced = ..... g [1]

- (ii) Calculate the number of moles of  $\text{X}_2\text{CO}_3$  needed to produce the mass of carbon dioxide calculated in (b)(i).

moles of  $\text{X}_2\text{CO}_3$  needed = ..... mol [1]

- (iii) Use your answer to (b)(ii) and the information on page 2 to calculate the relative formula mass,  $M_r$ , of  $\text{X}_2\text{CO}_3$ .

$M_r$  of  $\text{X}_2\text{CO}_3$  = ..... [1]

- (iv) Use your answer to (b)(iii) to calculate the relative atomic mass,  $A_r$ , of **X**. Hence identify **X**. Explain how you reached your conclusion.

**X** is .....

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

- (c) In this experiment you heated the sample of  $\text{X}_2\text{CO}_3$  for approximately 8 minutes.

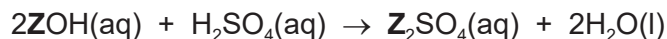
Explain, using evidence from your results in (a), whether your sample of  $\text{X}_2\text{CO}_3$  had decomposed completely.

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

[Total: 11]

- 2 In this experiment you will titrate a solution of the hydroxide of a Group 1 element, **Z**, with sulfuric acid. The equation for the reaction is shown.

**Z** may or may not be the same as **X**.



**FA 2** is  $26.3 \text{ g dm}^{-3}$  aqueous hydroxide of metal **Z**, **ZOH**.

**FA 3** is  $0.0500 \text{ mol dm}^{-3}$  sulfuric acid,  $\text{H}_2\text{SO}_4$ .  
bromophenol blue indicator

**(a) Method**

- Pipette  $25.0 \text{ cm}^3$  of **FA 2** into the  $250 \text{ cm}^3$  volumetric flask.
- Add distilled water to the flask to make  $250 \text{ cm}^3$  of solution. Shake the flask thoroughly to ensure complete mixing. Label this solution **FA 4**.
- Rinse the pipette with a little distilled water and then a little **FA 4**.
- Fill the burette with **FA 3**.
- Pipette  $25.0 \text{ cm}^3$  of **FA 4** into a conical flask.
- Add a few drops of bromophenol blue indicator.
- Carry out a rough titration and record your burette readings in the space below.

The rough titre is .....  $\text{cm}^3$ .

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure your recorded results show the accuracy of your practical work.
- Record in a suitable form in the space below all of your burette readings and the volume of **FA 3** added in each accurate titration.

|     |  |
|-----|--|
| I   |  |
| II  |  |
| III |  |
| IV  |  |
| V   |  |
| VI  |  |
| VII |  |

[7]

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

$25.0 \text{ cm}^3$  of **FA 4** required .....  $\text{cm}^3$  of **FA 3**. [1]

**(c) Calculations**

- (i) Give your answers to **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to the appropriate number of significant figures. [1]
- (ii) Calculate the number of moles of sulfuric acid present in the volume of **FA 3** you calculated in **(b)**.

moles of  $\text{H}_2\text{SO}_4$  = ..... mol [1]

- (iii) Use your answer to **(c)(ii)** and the information on page 4 to calculate the concentration, in  $\text{mol dm}^{-3}$ , of **ZOH** present in **FA 4**.

concentration of **FA 4** = .....  $\text{mol dm}^{-3}$  [1]

- (iv) Calculate the concentration, in  $\text{mol dm}^{-3}$ , of **ZOH** in **FA 2**.

concentration of **FA 2** = .....  $\text{mol dm}^{-3}$  [1]

- (v) Use your answer to **(c)(iv)** and the information on page 4 to calculate the relative atomic mass,  $A_r$ , of **Z**. Hence identify **Z**.  
Show your working.

**Z** is ..... [2]

- (d) Using the value for the relative atomic mass of **Z** that you calculated in **(c)(v)**, calculate the percentage difference of your value from that shown in the Periodic Table.

(If you did not obtain a value for the  $A_r$  of **Z**, assume it is 32.0. Note, this is **not** the correct value.)

percentage difference = ..... % [1]

[Total: 15]

## Qualitative analysis

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

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

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

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

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

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

**No additional tests for ions present should be attempted.**

- 3** Half-fill the 250 cm<sup>3</sup> beaker with water and place it on a tripod and gauze above a heatproof mat. Heat the water until boiling and then turn off the Bunsen burner. You will use this as a hot water-bath in **3(b)(i)**.

- (a) FA 5, FA 6 and FA 7** are solutions. Each solution contains one cation and one anion. Carbonate, CO<sub>3</sub><sup>2-</sup>, is **not** present in any of the solutions.

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

| test                                                               | observations |      |      |
|--------------------------------------------------------------------|--------------|------|------|
|                                                                    | FA 5         | FA 6 | FA 7 |
| <b>Test 1</b><br>Add an equal depth of dilute sulfuric acid.       |              |      |      |
| <b>Test 2</b><br>Add an equal depth of aqueous sodium carbonate.   |              |      |      |
| <b>Test 3</b><br>Add an equal depth of aqueous magnesium chloride. |              |      |      |

[5]

- (ii) Use your observations in (a)(i) to suggest a **possible** formula for each of the following:

The cation in **FA 5** is .....

The cation in **FA 6** is .....

The anion in **FA 7** is .....

[3]

- (iii) Apart from using an indicator, suggest a further test that would confirm the identity of the anion in **FA 7**.

Carry out this test and record the result.

.....

.....

..... [1]

- (iv) Did the result of your test in (a)(iii) confirm the identity of the anion in **FA 7**?  
Explain your answer.

.....

.....

..... [1]

(b) **FA 8** is an aqueous solution.

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

| <i>test</i>                                                                                                                                                  | <i>observations</i> |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| <b>Test 1</b><br>To a 1 cm depth of <b>FA 8</b> in a test-tube, add a few drops of acidified potassium manganate(VII). Place the tube in the hot water-bath. |                     |
| <b>Test 2</b><br>To a 1 cm depth of <b>FA 8</b> in a test-tube, add a 1 cm length of magnesium ribbon.                                                       |                     |

[2]

(ii) For each observation, state what you can conclude about the chemical properties of **FA 8**.

Test 1 .....

Test 2 .....

[2]

[Total: 14]

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## Qualitative Analysis Notes

## 1 Reactions of aqueous cations

| ion                                            | reaction with                                                                      |                                                                                    |
|------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
|                                                | NaOH(aq)                                                                           | NH <sub>3</sub> (aq)                                                               |
| aluminium,<br>Al <sup>3+</sup> (aq)            | white ppt.<br>soluble in excess                                                    | white ppt.<br>insoluble in excess                                                  |
| ammonium,<br>NH <sub>4</sub> <sup>+</sup> (aq) | no ppt.<br>ammonia produced on heating                                             | —                                                                                  |
| barium,<br>Ba <sup>2+</sup> (aq)               | faint white ppt. is nearly always<br>observed unless reagents are pure             | no ppt.                                                                            |
| calcium,<br>Ca <sup>2+</sup> (aq)              | white ppt. with high [Ca <sup>2+</sup> (aq)]                                       | no ppt.                                                                            |
| chromium(III),<br>Cr <sup>3+</sup> (aq)        | grey-green ppt.<br>soluble in excess                                               | grey-green ppt.<br>insoluble in excess                                             |
| copper(II),<br>Cu <sup>2+</sup> (aq)           | pale blue ppt.<br>insoluble in excess                                              | pale blue ppt. soluble in excess<br>giving dark blue solution                      |
| iron(II),<br>Fe <sup>2+</sup> (aq)             | green ppt. turning brown on contact<br>with air<br>insoluble in excess             | green ppt. turning brown on contact<br>with air<br>insoluble in excess             |
| iron(III),<br>Fe <sup>3+</sup> (aq)            | red-brown ppt.<br>insoluble in excess                                              | red-brown ppt.<br>insoluble in excess                                              |
| magnesium,<br>Mg <sup>2+</sup> (aq)            | white ppt.<br>insoluble in excess                                                  | white ppt.<br>insoluble in excess                                                  |
| manganese(II),<br>Mn <sup>2+</sup> (aq)        | off-white ppt. rapidly turning brown<br>on contact with air<br>insoluble in excess | off-white ppt. rapidly turning brown<br>on contact with air<br>insoluble in excess |
| zinc,<br>Zn <sup>2+</sup> (aq)                 | white ppt.<br>soluble in excess                                                    | white ppt.<br>soluble in excess                                                    |

## 2 Reactions of anions

| <i>ion</i>                                | <i>reaction</i>                                                                                 |
|-------------------------------------------|-------------------------------------------------------------------------------------------------|
| carbonate,<br>$\text{CO}_3^{2-}$          | $\text{CO}_2$ liberated by dilute acids                                                         |
| chloride,<br>$\text{Cl}^-(\text{aq})$     | gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$ )           |
| bromide,<br>$\text{Br}^-(\text{aq})$      | gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$ ) |
| iodide,<br>$\text{I}^-(\text{aq})$        | gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$ )        |
| nitrate,<br>$\text{NO}_3^-(\text{aq})$    | $\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil           |
| nitrite,<br>$\text{NO}_2^-(\text{aq})$    | $\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil           |
| sulfate,<br>$\text{SO}_4^{2-}(\text{aq})$ | gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)     |
| sulfite,<br>$\text{SO}_3^{2-}(\text{aq})$ | gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)       |

## 3 Tests for gases

| <i>gas</i>                    | <i>test and test result</i>                                                   |
|-------------------------------|-------------------------------------------------------------------------------|
| ammonia, $\text{NH}_3$        | turns damp red litmus paper blue                                              |
| carbon dioxide, $\text{CO}_2$ | gives a white ppt. with limewater (ppt. dissolves with excess $\text{CO}_2$ ) |
| chlorine, $\text{Cl}_2$       | bleaches damp litmus paper                                                    |
| hydrogen, $\text{H}_2$        | 'pops' with a lighted splint                                                  |
| oxygen, $\text{O}_2$          | relights a glowing splint                                                     |



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9701/33

October/November 2021

**2 hours**

You must answer on the question paper.

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

- Answer **all** questions.
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- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working, use appropriate units and use an appropriate number of significant figures.
- Give details of the practical session and laboratory, where appropriate, in the boxes provided.

|  |                |
|--|----------------|
|  | <b>Session</b> |
|--|----------------|

- 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.
- Notes for use in qualitative analysis are provided in the question paper.

|                   |
|-------------------|
| <b>Session</b>    |
|                   |
| <b>Laboratory</b> |
|                   |

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| <b>1</b>           |  |
| <b>2</b>           |  |
| <b>3</b>           |  |
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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 your working and appropriate significant figures in the final answer to **each** step of your calculations.

- 1 Group 1 metal carbonates have the formula  $M_2CO_3$ . The identity of the metal ion,  $M^+$ , may be determined by a gravimetric method. The metal carbonate is reacted with excess acid and the mass of carbon dioxide given off is measured.



**FA 1** is a Group 1 metal carbonate,  $M_2CO_3$ .

**FA 2** is  $2.0 \text{ mol dm}^{-3}$  hydrochloric acid,  $HCl$ .

### (a) Method

- Use the  $25 \text{ cm}^3$  measuring cylinder to transfer  $25.0 \text{ cm}^3$  of **FA 2** into a conical flask. Weigh the flask with the acid and record the mass.
- Weigh the container with **FA 1** and record the mass.
- **Carefully** tip all of **FA 1** into the acid in the conical flask. Swirl the contents of the flask and leave the flask to stand.
- Weigh the container with any residual **FA 1**. Record the mass.
- Calculate and record the mass of **FA 1** added to the conical flask.
- Calculate and record the theoretical initial mass of flask + acid + **FA 1**.
- Swirl the flask occasionally while leaving it to stand for approximately 5 minutes.

**During this step you may wish to start Question 2 or Question 3.**

- Weigh the flask and contents and record this mass.
- Calculate and record the mass of carbon dioxide given off during the experiment.

### Results

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

[4]

**(b) Calculations**

- (i) Calculate the number of moles of carbon dioxide given off in the experiment.

moles of  $\text{CO}_2$  = ..... mol [1]

- (ii) Calculate the relative formula mass,  $M_r$ , of  $\text{M}_2\text{CO}_3$ .

$M_r$  of  $\text{M}_2\text{CO}_3$  = ..... [1]

- (iii) Identify the Group 1 cation,  $\text{M}^+$ , in **FA 1**.  
Show your working.

$\text{M}^+$  is ..... [1]

- (c) One source of error in this experiment is the solubility of carbon dioxide in water.

- (i) Suggest **one** modification, to the method in (a), to reduce the solubility of carbon dioxide in the solution in the flask.

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

- (ii) An assumption made in the method in (a) is that the acid is in excess.

Show by calculation that this assumption is true.

[2]

[Total: 10]

- 2 The identity of a Group 1 metal carbonate may also be found by a titration method.

$M^+$  in this question may or may not be the same cation as that in **Question 1**.



**FA 3** is an aqueous solution containing  $7.46 \text{ g dm}^{-3}$  of a Group 1 metal carbonate,  $M_2CO_3$ .

**FA 4** is  $0.110 \text{ mol dm}^{-3}$  hydrochloric acid,  $HCl$ .

bromophenol blue indicator

**(a) Method**

- Fill the burette with **FA 4**.
- Pipette  $25.0 \text{ cm}^3$  of **FA 3** into a conical flask.
- Add a few drops of bromophenol blue indicator.
- Carry out a rough titration and record your burette readings in the space below.

The rough titre is .....  $\text{cm}^3$ .

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

|     |  |
|-----|--|
| I   |  |
| II  |  |
| III |  |
| IV  |  |
| V   |  |
| VI  |  |
| VII |  |

[7]

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

$25.0 \text{ cm}^3$  of **FA 3** required .....  $\text{cm}^3$  of **FA 4**. [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 number of moles of hydrochloric acid present in the volume of **FA 4** calculated in **(b)**.

moles of  $\text{HCl}$  = ..... mol [1]

- (iii) Calculate the number of moles of Group 1 metal carbonate,  $\text{M}_2\text{CO}_3$ , present in  $25.0\text{ cm}^3$  of **FA 3**.

moles of  $\text{M}_2\text{CO}_3$  in  $25.0\text{ cm}^3$  = ..... mol [1]

- (iv) Calculate the relative formula mass,  $M_r$ , of  $\text{M}_2\text{CO}_3$ .

$M_r$  of  $\text{M}_2\text{CO}_3$  = ..... [1]

- (v) Identify the cation,  $\text{M}^+$ .  
Show your working.

$\text{M}^+$  is ..... [1]

- (d) A student carrying out a similar experiment, using the same method, found the cation in **Question 2** to be  $\text{Rb}^+$ . The student is told that the acid provided, **FA 4**, was incorrectly prepared. The cation in the student's experiment should have been identified as  $\text{K}^+$ .

State whether the acid supplied is more, or less, concentrated than  $0.110\text{ mol dm}^{-3}$ .  
Explain your answer.

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

[Total: 14]

## Qualitative analysis

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

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

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

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

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

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

**No additional tests for ions present should be attempted.**

**3 (a) FA 5** is a salt containing one cation and one anion, both of which are listed in the Qualitative Analysis Notes.

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

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

- (ii) Place the remaining **FA 5** into a 100cm<sup>3</sup> beaker and add approximately 15cm<sup>3</sup> of distilled water. Stir to make a solution. This solution is **FA 6**.  
You will use portions of **FA 6** for the following test and tests in (b).

To a 1 cm depth of **FA 6** in a test-tube add a 1 cm depth of dilute hydrochloric acid.  
Record your observations.

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

- (b) (i) **FA 7** and **FA 8** are solutions each containing one cation and one anion, all of which are listed in the Qualitative Analysis Notes.

Carry out the following tests in separate test-tubes. Use a 1 cm depth of each solution unless otherwise specified.

|                                            | <i>observations</i> |             |             |
|--------------------------------------------|---------------------|-------------|-------------|
| <i>solution</i>                            | <b>FA 6</b>         | <b>FA 7</b> | <b>FA 8</b> |
| Add a few drops of aqueous silver nitrate. |                     |             |             |
| <b>FA 6</b>                                |                     |             |             |
| <b>FA 7</b>                                |                     |             |             |

[4]

- (ii) Carry out tests using aqueous sodium hydroxide and dilute sulfuric acid to identify or confirm the identity of the ions in **FA 6**, **FA 7** and **FA 8**.  
Record your tests and observations in a table in the space below.

[5]

- (c) (i) From your observations in (a) and (b) identify the cation and the anion present in each of **FA 6**, **FA 7** and **FA 8** by giving their formulae.

|             | <i>cation</i> | <i>anion</i> |
|-------------|---------------|--------------|
| <b>FA 6</b> |               |              |
| <b>FA 7</b> |               |              |
| <b>FA 8</b> |               |              |

[3]

- (ii) Give an ionic equation for a precipitation reaction observed in (b)(i). Include state symbols.

..... [1]

[Total: 16]

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## Qualitative Analysis Notes

## 1 Reactions of aqueous cations

| ion                                            | reaction with                                                                      |                                                                                    |
|------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
|                                                | NaOH(aq)                                                                           | NH <sub>3</sub> (aq)                                                               |
| aluminium,<br>Al <sup>3+</sup> (aq)            | white ppt.<br>soluble in excess                                                    | white ppt.<br>insoluble in excess                                                  |
| ammonium,<br>NH <sub>4</sub> <sup>+</sup> (aq) | no ppt.<br>ammonia produced on heating                                             | –                                                                                  |
| barium,<br>Ba <sup>2+</sup> (aq)               | faint white ppt. is nearly always<br>observed unless reagents are pure             | no ppt.                                                                            |
| calcium,<br>Ca <sup>2+</sup> (aq)              | white ppt. with high [Ca <sup>2+</sup> (aq)]                                       | no ppt.                                                                            |
| chromium(III),<br>Cr <sup>3+</sup> (aq)        | grey-green ppt.<br>soluble in excess                                               | grey-green ppt.<br>insoluble in excess                                             |
| copper(II),<br>Cu <sup>2+</sup> (aq)           | pale blue ppt.<br>insoluble in excess                                              | pale blue ppt. soluble in excess<br>giving dark blue solution                      |
| iron(II),<br>Fe <sup>2+</sup> (aq)             | green ppt. turning brown on contact<br>with air<br>insoluble in excess             | green ppt. turning brown on contact<br>with air<br>insoluble in excess             |
| iron(III),<br>Fe <sup>3+</sup> (aq)            | red-brown ppt.<br>insoluble in excess                                              | red-brown ppt.<br>insoluble in excess                                              |
| magnesium,<br>Mg <sup>2+</sup> (aq)            | white ppt.<br>insoluble in excess                                                  | white ppt.<br>insoluble in excess                                                  |
| manganese(II),<br>Mn <sup>2+</sup> (aq)        | off-white ppt. rapidly turning brown<br>on contact with air<br>insoluble in excess | off-white ppt. rapidly turning brown<br>on contact with air<br>insoluble in excess |
| zinc,<br>Zn <sup>2+</sup> (aq)                 | white ppt.<br>soluble in excess                                                    | white ppt.<br>soluble in excess                                                    |

## 2 Reactions of anions

| <i>ion</i>                                | <i>reaction</i>                                                                                 |
|-------------------------------------------|-------------------------------------------------------------------------------------------------|
| carbonate,<br>$\text{CO}_3^{2-}$          | $\text{CO}_2$ liberated by dilute acids                                                         |
| chloride,<br>$\text{Cl}^-(\text{aq})$     | gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$ )           |
| bromide,<br>$\text{Br}^-(\text{aq})$      | gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$ ) |
| iodide,<br>$\text{I}^-(\text{aq})$        | gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$ )        |
| nitrate,<br>$\text{NO}_3^-(\text{aq})$    | $\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil           |
| nitrite,<br>$\text{NO}_2^-(\text{aq})$    | $\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil           |
| sulfate,<br>$\text{SO}_4^{2-}(\text{aq})$ | gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)     |
| sulfite,<br>$\text{SO}_3^{2-}(\text{aq})$ | gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)       |

## 3 Tests for gases

| <i>gas</i>                    | <i>test and test result</i>                                                   |
|-------------------------------|-------------------------------------------------------------------------------|
| ammonia, $\text{NH}_3$        | turns damp red litmus paper blue                                              |
| carbon dioxide, $\text{CO}_2$ | gives a white ppt. with limewater (ppt. dissolves with excess $\text{CO}_2$ ) |
| chlorine, $\text{Cl}_2$       | bleaches damp litmus paper                                                    |
| hydrogen, $\text{H}_2$        | 'pops' with a lighted splint                                                  |
| oxygen, $\text{O}_2$          | relights a glowing splint                                                     |





# Cambridge International AS & A Level

CANDIDATE  
NAME

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CENTRE  
NUMBER

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## CHEMISTRY

9701/34

Paper 3 Advanced Practical Skills 2

October/November 2021

2 hours

You must answer on the question paper.

You will need: The materials and apparatus listed in the confidential instructions  
Insert (enclosed)

## 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, use appropriate units and use an appropriate number of significant figures.
- Give details of the practical session and laboratory, where appropriate, in the boxes provided.

## 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.
- Notes for use in qualitative analysis are provided in the question paper.
- The insert contains additional resources referred to in the questions.

Session

Laboratory

For Examiner's Use

1

2

3

Total

This document has **16** pages. Any blank pages are indicated.

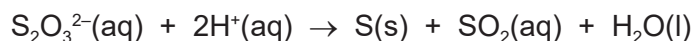


## Quantitative analysis

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

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

- 1 The thiosulfate ion,  $\text{S}_2\text{O}_3^{2-}$ , is unstable in the presence of acid. The following reaction occurs.



The rate of this reaction can be measured by timing how long it takes for the solid sulfur that is formed to make the mixture too cloudy to see through.

You will investigate how the concentration of the thiosulfate ions affects the rate of this reaction.

**Throughout these experiments care must be taken to avoid inhaling any  $\text{SO}_2$  that is produced. It is very important that as soon as each experiment is complete, the contents of the beaker are emptied into the quenching bath and the beaker is rinsed thoroughly.**

**FB 1** is  $0.100 \text{ mol dm}^{-3}$  sodium thiosulfate,  $\text{Na}_2\text{S}_2\text{O}_3$ .

**FB 2** is  $2.00 \text{ mol dm}^{-3}$  hydrochloric acid,  $\text{HCl}$ .

distilled water

### (a) Method

#### Experiment 1

- Label one burette **FB 1** and fill it with **FB 1**.
- Run  $45.00 \text{ cm}^3$  of **FB 1** from the burette into the  $100 \text{ cm}^3$  beaker.
- Use the  $25 \text{ cm}^3$  measuring cylinder to measure  $10.0 \text{ cm}^3$  of **FB 2**.
- Add **FB 2** to **FB 1** and start timing **immediately**.
- Stir the mixture once and place the beaker on the printed insert.
- View the print on the insert from above the mixture.
- Stop timing when the print on the insert is no longer visible.
- Record this reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker so it is ready for use in **Experiment 2**.

#### Experiment 2

- Fill the second burette with distilled water.
- Refill the burette labelled **FB 1** with **FB 1**.
- Run  $20.00 \text{ cm}^3$  of **FB 1** into the  $100 \text{ cm}^3$  beaker.
- Run  $25.00 \text{ cm}^3$  of distilled water into the same beaker.
- Use the  $25 \text{ cm}^3$  measuring cylinder to measure  $10.0 \text{ cm}^3$  of **FB 2**.
- Add **FB 2** to the beaker and start timing **immediately**.
- Stir the mixture once and place the beaker on the printed insert.
- View the print on the insert from above the mixture.
- Stop timing when the print on the insert is no longer visible.
- Record this reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker so it is ready for use in the next experiment.

### Experiments 3–5

- Carry out three further experiments to investigate how the reaction time changes with different volumes of **FB 1**.

The combined volume of **FB 1** and distilled water must always be 45.00 cm<sup>3</sup>.  
Do not use a volume of **FB 1** that is less than 20.00 cm<sup>3</sup>.

Record all your results in a table.

You should include the volume of **FB 1**, the volume of distilled water, the reaction time and the reaction rate for each of your five experiments.

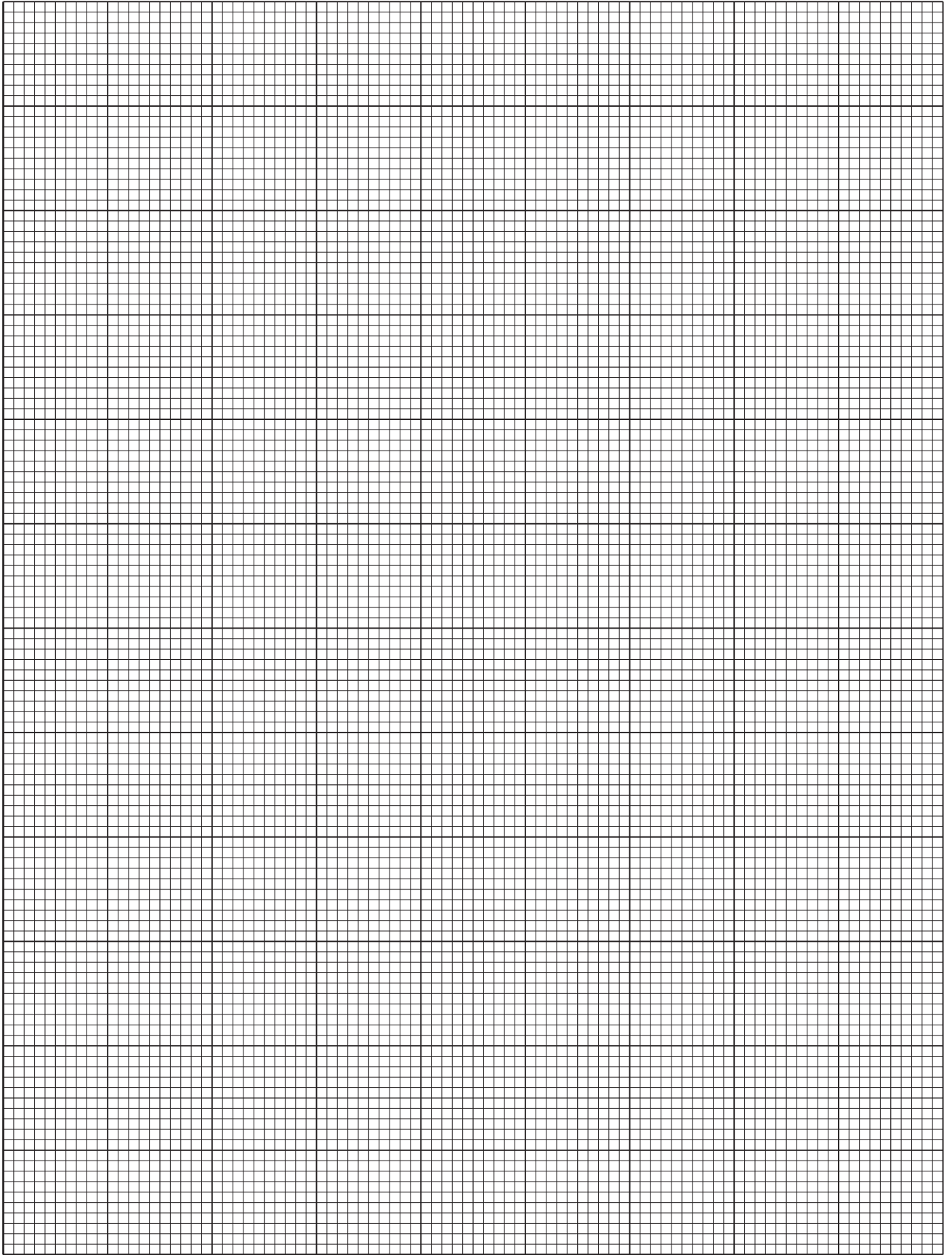
Calculate the rate of reaction using the following formula.

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

|      |  |
|------|--|
| I    |  |
| II   |  |
| III  |  |
| IV   |  |
| V    |  |
| VI   |  |
| VII  |  |
| VIII |  |

[8]

- (b) On the grid opposite, plot the rate on the y-axis against the volume of **FB 1** on the x-axis. Identify any anomalous points. Draw a line of best fit.



[4]

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

- (c) In these experiments, the volume of **FB 1** is related to the concentration of the thiosulfate ions.

Use your graph to suggest the relationship between the rate of reaction and the concentration of the thiosulfate ions.

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

- (d) The quenching bath contains an aqueous mixture of sodium carbonate and universal indicator.

- (i) How does the quenching bath prevent the further production of  $\text{SO}_2$  from the reaction?

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

- (ii) Suggest why the mixture contains universal indicator.

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

- (e) (i) In each experiment the acid is in large excess.

Show, by calculation, that the acid is in large excess in **Experiment 1**.

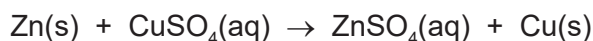
[2]

- (ii) Suggest a reason why the acid used should be in large excess.

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

[Total: 18]

- 2 In this experiment you will determine the concentration of a solution of copper(II) sulfate. You will react an excess of zinc with copper(II) sulfate as shown.



**FB 3** is zinc powder.

**FB 4** is aqueous copper(II) sulfate,  $\text{CuSO}_4$ .

**(a) Method**

- Support the cup in the 250 cm<sup>3</sup> beaker.
- Using the 50 cm<sup>3</sup> measuring cylinder, transfer 40 cm<sup>3</sup> of **FB 4** into the cup.
- Measure and record the temperature of the solution in the cup.
- Add all of **FB 3** to the cup.
- Use the thermometer to stir the mixture gently.
- Measure and record the maximum temperature reached.
- Calculate and record the change in temperature.

[3]

**(b) Calculations**

- (i) Use your results from **(a)** to calculate the heat energy produced in the reaction.  
(Assume that 4.2 J are required to change the temperature of 1.0 cm<sup>3</sup> of solution by 1.0 °C.)

heat energy produced = ..... J [1]

- (ii) You can assume that under the conditions of your experiment the molar enthalpy change for the reaction is  $-218.7 \text{ kJ mol}^{-1}$ .

Use this value to calculate the concentration, in mol dm<sup>-3</sup>, of **FB 4**.

concentration of **FB 4** = ..... mol dm<sup>-3</sup>  
[2]

- (c) (i) Calculate the maximum percentage error in the temperature rise that you recorded in (a).

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

maximum percentage error = ..... % [1]

- (ii) The maximum percentage error becomes smaller if the temperature rise is increased.  
A student suggests that using a greater volume of **FB 4** would increase the temperature rise as long as the zinc remains in excess.

Explain whether the student is correct.

.....

.....

.....

..... [2]

[Total: 9]

## Qualitative analysis

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

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

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

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

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

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

**No additional tests for ions present should be attempted.**

- 3 (a) FB 5** is an aqueous solution containing three cations and a single anion.  
Two of the cations are listed in the Qualitative Analysis Notes.  
The anion is either the sulfate ion,  $\text{SO}_4^{2-}$ , or the sulfite ion,  $\text{SO}_3^{2-}$ .

- (i)** Carry out tests to identify the **three cations**.  
Record your tests and observations.

|     |  |
|-----|--|
| I   |  |
| II  |  |
| III |  |
| IV  |  |
| V   |  |
| VI  |  |
| VII |  |

The formulae for the cations present in **FB 5** are ..... , ..... and .....

[7]

- (ii) Carry out tests to identify whether **FB 5** contains the sulfate ion,  $\text{SO}_4^{2-}$ , or the sulfite ion,  $\text{SO}_3^{2-}$ .  
Record your observations.

The anion present in **FB 5** is .....

[2]

- (b) (i) Carry out the following tests on **FB 6** and **FB 7** and record your observations.

| <i>test</i>                                                                                                                                           | <i>observations</i> |
|-------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| <b>Test 1</b><br>Add a small spatula measure of <b>FB 6</b> to a hard-glass test-tube.<br><br>Heat the sample gently at first and then more strongly. |                     |
| <b>Test 2</b><br>Add a small spatula measure of <b>FB 7</b> to a hard-glass test-tube.<br><br>Heat the sample strongly.                               |                     |

[3]

- (ii) State the type of reaction observed with **FB 6** in (b)(i).

..... [1]

[Total: 13]







## Qualitative Analysis Notes

## 1 Reactions of aqueous cations

| ion                                            | reaction with                                                                      |                                                                                    |
|------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
|                                                | NaOH(aq)                                                                           | NH <sub>3</sub> (aq)                                                               |
| aluminium,<br>Al <sup>3+</sup> (aq)            | white ppt.<br>soluble in excess                                                    | white ppt.<br>insoluble in excess                                                  |
| ammonium,<br>NH <sub>4</sub> <sup>+</sup> (aq) | no ppt.<br>ammonia produced on heating                                             | –                                                                                  |
| barium,<br>Ba <sup>2+</sup> (aq)               | faint white ppt. is nearly always<br>observed unless reagents are pure             | no ppt.                                                                            |
| calcium,<br>Ca <sup>2+</sup> (aq)              | white ppt. with high [Ca <sup>2+</sup> (aq)]                                       | no ppt.                                                                            |
| chromium(III),<br>Cr <sup>3+</sup> (aq)        | grey-green ppt.<br>soluble in excess                                               | grey-green ppt.<br>insoluble in excess                                             |
| copper(II),<br>Cu <sup>2+</sup> (aq)           | pale blue ppt.<br>insoluble in excess                                              | pale blue ppt. soluble in excess<br>giving dark blue solution                      |
| iron(II),<br>Fe <sup>2+</sup> (aq)             | green ppt. turning brown on contact<br>with air<br>insoluble in excess             | green ppt. turning brown on contact<br>with air<br>insoluble in excess             |
| iron(III),<br>Fe <sup>3+</sup> (aq)            | red-brown ppt.<br>insoluble in excess                                              | red-brown ppt.<br>insoluble in excess                                              |
| magnesium,<br>Mg <sup>2+</sup> (aq)            | white ppt.<br>insoluble in excess                                                  | white ppt.<br>insoluble in excess                                                  |
| manganese(II),<br>Mn <sup>2+</sup> (aq)        | off-white ppt. rapidly turning brown<br>on contact with air<br>insoluble in excess | off-white ppt. rapidly turning brown<br>on contact with air<br>insoluble in excess |
| zinc,<br>Zn <sup>2+</sup> (aq)                 | white ppt.<br>soluble in excess                                                    | white ppt.<br>soluble in excess                                                    |

## 2 Reactions of anions

| <i>ion</i>                                | <i>reaction</i>                                                                                 |
|-------------------------------------------|-------------------------------------------------------------------------------------------------|
| carbonate,<br>$\text{CO}_3^{2-}$          | $\text{CO}_2$ liberated by dilute acids                                                         |
| chloride,<br>$\text{Cl}^-(\text{aq})$     | gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$ )           |
| bromide,<br>$\text{Br}^-(\text{aq})$      | gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$ ) |
| iodide,<br>$\text{I}^-(\text{aq})$        | gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$ )        |
| nitrate,<br>$\text{NO}_3^-(\text{aq})$    | $\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil           |
| nitrite,<br>$\text{NO}_2^-(\text{aq})$    | $\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil           |
| sulfate,<br>$\text{SO}_4^{2-}(\text{aq})$ | gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)     |
| sulfite,<br>$\text{SO}_3^{2-}(\text{aq})$ | gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)       |

## 3 Tests for gases

| <i>gas</i>                    | <i>test and test result</i>                                                   |
|-------------------------------|-------------------------------------------------------------------------------|
| ammonia, $\text{NH}_3$        | turns damp red litmus paper blue                                              |
| carbon dioxide, $\text{CO}_2$ | gives a white ppt. with limewater (ppt. dissolves with excess $\text{CO}_2$ ) |
| chlorine, $\text{Cl}_2$       | bleaches damp litmus paper                                                    |
| hydrogen, $\text{H}_2$        | 'pops' with a lighted splint                                                  |
| oxygen, $\text{O}_2$          | relights a glowing splint                                                     |

The Periodic Table of Elements

| Group                  |                         |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        |  |  |   |  |                       |                         |                          |                          |                        |                       |                       |                         |                        |                        |                        |   |
|------------------------|-------------------------|----------------------------------------------------------------|-------------------------|-----------------------|--------------------------|-------------------------|--------------------------|------------------------|--------------------------|-----------------------|------------------------|--|--|---|--|-----------------------|-------------------------|--------------------------|--------------------------|------------------------|-----------------------|-----------------------|-------------------------|------------------------|------------------------|------------------------|---|
| 1                      | 2                       | Key                                                            |                         |                       |                          |                         |                          |                        |                          |                       |                        |  |  |   |  | 17                    | 18                      |                          |                          |                        |                       |                       |                         |                        |                        |                        |   |
|                        |                         | atomic number<br>atomic symbol<br>name<br>relative atomic mass |                         |                       |                          |                         |                          |                        |                          |                       |                        |  |  | 1 |  |                       |                         | 2                        |                          |                        |                       |                       |                         |                        |                        |                        |   |
| 3                      | 4                       |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        |  |  |   |  |                       |                         |                          |                          |                        |                       |                       |                         |                        |                        |                        |   |
| Li<br>lithium<br>6.9   | Be<br>beryllium<br>9.0  |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        |  |  |   |  |                       |                         | H<br>hydrogen<br>1.0     |                          |                        |                       |                       |                         |                        |                        |                        |   |
| 11                     | 12                      |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        |  |  |   |  |                       |                         |                          |                          |                        |                       |                       |                         |                        |                        |                        |   |
| Na<br>sodium<br>23.0   | Mg<br>magnesium<br>24.3 |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        |  |  |   |  |                       |                         |                          |                          |                        |                       |                       |                         |                        |                        |                        |   |
| 19                     | 20                      |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        |  |  |   |  |                       |                         |                          |                          |                        |                       |                       |                         |                        |                        |                        |   |
| K<br>potassium<br>39.1 | Ca<br>calcium<br>40.1   |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        |  |  |   |  |                       |                         |                          |                          |                        |                       |                       |                         |                        |                        |                        |   |
| 37                     | 38                      |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        |  |  |   |  |                       |                         |                          |                          |                        |                       |                       |                         |                        |                        |                        |   |
| Rb<br>rubidium<br>85.5 | Sr<br>strontium<br>87.6 |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        |  |  |   |  |                       |                         |                          |                          |                        |                       |                       |                         |                        |                        |                        |   |
| 55                     | 56                      |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        |  |  |   |  |                       |                         |                          |                          |                        |                       |                       |                         |                        |                        |                        |   |
| Cs<br>caesium<br>132.9 | Ba<br>barium<br>137.3   |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        |  |  |   |  |                       |                         |                          |                          |                        |                       |                       |                         |                        |                        |                        |   |
| 87                     | 88                      |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        |  |  |   |  |                       |                         |                          |                          |                        |                       |                       |                         |                        |                        |                        |   |
| Fr<br>francium<br>—    | Ra<br>radium<br>—       |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        |  |  |   |  |                       |                         |                          |                          |                        |                       |                       |                         |                        |                        |                        |   |
|                        |                         | 3                                                              | 4                       | 5                     | 6                        | 7                       | 8                        | 9                      | 10                       | 11                    | 12                     |  |  |   |  | 13                    | 14                      | 15                       | 16                       | 17                     | 18                    |                       |                         |                        |                        |                        |   |
|                        |                         | 21                                                             | 22                      | 23                    | 24                       | 25                      | 26                       | 27                     | 28                       | 29                    | 30                     |  |  |   |  | 31                    | 32                      | 33                       | 34                       | 35                     | 36                    |                       |                         |                        |                        |                        |   |
|                        |                         | Sc<br>scandium<br>45.0                                         | Ti<br>titanium<br>47.9  | V<br>vanadium<br>50.9 | Cr<br>chromium<br>52.0   | Mn<br>manganese<br>54.9 | Fe<br>iron<br>55.8       | Co<br>cobalt<br>58.9   | Ni<br>nickel<br>58.7     | Cu<br>copper<br>63.5  | Zn<br>zinc<br>65.4     |  |  |   |  | Ga<br>gallium<br>69.7 | Ge<br>germanium<br>72.6 | As<br>arsenic<br>74.9    | Se<br>selenium<br>79.0   | Br<br>bromine<br>79.9  | Kr<br>krypton<br>83.8 |                       |                         |                        |                        |                        |   |
|                        |                         | 39                                                             | 40                      | 41                    | 42                       | 43                      | 44                       | 45                     | 46                       | 47                    | 48                     |  |  |   |  | 49                    | 50                      | 51                       | 52                       | 53                     | 54                    |                       |                         |                        |                        |                        |   |
|                        |                         | Y<br>yttrium<br>88.9                                           | Zr<br>zirconium<br>91.2 | Nb<br>niobium<br>92.9 | Mo<br>molybdenum<br>95.9 | Tc<br>technetium<br>—   | Ru<br>ruthenium<br>101.1 | Rh<br>rhodium<br>102.9 | Pd<br>palladium<br>106.4 | Ag<br>silver<br>107.9 | Cd<br>cadmium<br>112.4 |  |  |   |  | In<br>indium<br>114.8 | Sn<br>tin<br>118.7      | Sb<br>antimony<br>121.8  | Te<br>tellurium<br>127.6 | I<br>iodine<br>126.9   | Xe<br>xenon<br>131.3  |                       |                         |                        |                        |                        |   |
|                        |                         | 57–71<br>lanthanoids                                           | 72                      | 73                    | 74                       | 75                      | 76                       | 77                     | 78                       | 79                    | 80                     |  |  |   |  | 81                    | 82                      | 83                       | 84                       | 85                     | 86                    |                       |                         |                        |                        |                        |   |
|                        |                         |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        |  |  |   |  |                       |                         | Tl<br>thallium<br>204.4  | Pb<br>lead<br>207.2      | Bi<br>bismuth<br>209.0 | Po<br>polonium<br>—   | At<br>astatine<br>—   | Rn<br>radon<br>—        |                        |                        |                        |   |
|                        |                         | 89–103<br>actinoids                                            | 104                     | 105                   | 106                      | 107                     | 108                      | 109                    | 110                      | 111                   | 112                    |  |  |   |  | 113                   | 114                     | 115                      | 116                      | 117                    | 118                   |                       |                         |                        |                        |                        |   |
|                        |                         |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        |  |  |   |  |                       |                         | Rf<br>rutherfordium<br>— | Db<br>dubnium<br>—       | Bh<br>bohrium<br>—     | Hs<br>hassium<br>—    | Mt<br>meitnerium<br>— | Ds<br>darmstadtium<br>— | Rg<br>roentgenium<br>— | Cn<br>copernicium<br>— | Lv<br>livermorium<br>— | — |



# Cambridge International AS & A Level

CANDIDATE  
NAME

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## CHEMISTRY

9701/35

Paper 3 Advanced Practical Skills 1

October/November 2021

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, use appropriate units and use an appropriate number of significant figures.
- Give details of the practical session and laboratory, where appropriate, in the boxes provided.

| Session    |  |
|------------|--|
|            |  |
| Laboratory |  |
|            |  |

### 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.
- Notes for use in qualitative analysis are provided in the question paper.

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

- 1 You will investigate a compound of a Group 1 element to determine which element is present. Group 1 carbonates decompose to give carbon dioxide when heated to high temperatures.



**FA 1** is the carbonate of the element,  $\text{X}_2\text{CO}_3$ .

### (a) Method

- Weigh a crucible with its lid and record the mass.
- Add 1.40–1.60 g of **FA 1** to the crucible.
- Weigh the crucible and its lid with **FA 1** and record the mass.
- Place the crucible on the pipe-clay triangle. Heat the crucible, with its lid on, gently for approximately 1 minute. Then heat strongly for another minute.
- Carefully remove the lid. Heat the crucible strongly for 4 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.

**While the crucible is cooling you may wish to begin work on Question 2.**

- Reweigh the crucible and contents with its lid. Record the mass.
- Remove the lid. Heat the crucible and contents strongly for a further 2 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes. Reweigh the crucible and residue with its lid. Record the mass.
- Calculate and record the mass of **FA 1** added to the crucible. Calculate the mass of residue obtained.

### Results

|     |  |
|-----|--|
| I   |  |
| II  |  |
| III |  |
| IV  |  |
| V   |  |

[5]

**(b) Calculations**

- (i) Calculate the mass of carbon dioxide produced when the sample of  $\text{X}_2\text{CO}_3$  was heated.

mass of  $\text{CO}_2$  produced = ..... g [1]

- (ii) Calculate the number of moles of  $\text{X}_2\text{CO}_3$  needed to produce the mass of carbon dioxide calculated in **(b)(i)**.

moles of  $\text{X}_2\text{CO}_3$  needed = ..... mol [1]

- (iii) Use your answer to **(b)(ii)** and the information on page 2 to calculate the relative formula mass,  $M_r$ , of  $\text{X}_2\text{CO}_3$ .

$M_r$  of  $\text{X}_2\text{CO}_3$  = ..... [1]

- (iv) Use your answer to **(b)(iii)** to calculate the relative atomic mass,  $A_r$ , of **X**. Hence identify **X**. Explain how you reached your conclusion.

**X** is .....

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

- (c) In this experiment you heated the sample of  $\text{X}_2\text{CO}_3$  for approximately 8 minutes.

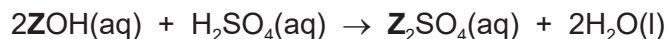
Explain, using evidence from your results in **(a)**, whether your sample of  $\text{X}_2\text{CO}_3$  had decomposed completely.

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

[Total: 11]

- 2 In this experiment you will titrate a solution of the hydroxide of a Group 1 element, **Z**, with sulfuric acid. The equation for the reaction is shown.

**Z** may or may not be the same as **X**.



**FA 2** is  $26.3 \text{ g dm}^{-3}$  aqueous hydroxide of metal **Z**, **ZOH**.

**FA 3** is  $0.0500 \text{ mol dm}^{-3}$  sulfuric acid,  $\text{H}_2\text{SO}_4$ .  
bromophenol blue indicator

**(a) Method**

- Pipette  $25.0 \text{ cm}^3$  of **FA 2** into the  $250 \text{ cm}^3$  volumetric flask.
- Add distilled water to the flask to make  $250 \text{ cm}^3$  of solution. Shake the flask thoroughly to ensure complete mixing. Label this solution **FA 4**.
- Rinse the pipette with a little distilled water and then a little **FA 4**.
- Fill the burette with **FA 3**.
- Pipette  $25.0 \text{ cm}^3$  of **FA 4** into a conical flask.
- Add a few drops of bromophenol blue indicator.
- Carry out a rough titration and record your burette readings in the space below.

The rough titre is .....  $\text{cm}^3$ .

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure your recorded results show the accuracy of your practical work.
- Record in a suitable form in the space below all of your burette readings and the volume of **FA 3** added in each accurate titration.

|     |  |
|-----|--|
| I   |  |
| II  |  |
| III |  |
| IV  |  |
| V   |  |
| VI  |  |
| VII |  |

[7]

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

$25.0 \text{ cm}^3$  of **FA 4** required .....  $\text{cm}^3$  of **FA 3**. [1]

**(c) Calculations**

- (i) Give your answers to **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to the appropriate number of significant figures. [1]
- (ii) Calculate the number of moles of sulfuric acid present in the volume of **FA 3** you calculated in **(b)**.

moles of  $\text{H}_2\text{SO}_4$  = ..... mol [1]

- (iii) Use your answer to **(c)(ii)** and the information on page 4 to calculate the concentration, in  $\text{mol dm}^{-3}$ , of **ZOH** present in **FA 4**.

concentration of **FA 4** = .....  $\text{mol dm}^{-3}$  [1]

- (iv) Calculate the concentration, in  $\text{mol dm}^{-3}$ , of **ZOH** in **FA 2**.

concentration of **FA 2** = .....  $\text{mol dm}^{-3}$  [1]

- (v) Use your answer to **(c)(iv)** and the information on page 4 to calculate the relative atomic mass,  $A_r$ , of **Z**. Hence identify **Z**.  
Show your working.

**Z** is ..... [2]

- (d) Using the value for the relative atomic mass of **Z** that you calculated in **(c)(v)**, calculate the percentage difference of your value from that shown in the Periodic Table.

(If you did not obtain a value for the  $A_r$  of **Z**, assume it is 32.0. Note, this is **not** the correct value.)

percentage difference = ..... % [1]

[Total: 15]

## Qualitative analysis

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

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

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

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

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

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

**No additional tests for ions present should be attempted.**

- 3** Half-fill the 250 cm<sup>3</sup> beaker with water and place it on a tripod and gauze above a heatproof mat. Heat the water until boiling and then turn off the Bunsen burner. You will use this as a hot water-bath in **3(b)(i)**.

- (a) FA 5, FA 6 and FA 7** are solutions. Each solution contains one cation and one anion. Carbonate, CO<sub>3</sub><sup>2-</sup>, is **not** present in any of the solutions.

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

| test                                                               | observations |      |      |
|--------------------------------------------------------------------|--------------|------|------|
|                                                                    | FA 5         | FA 6 | FA 7 |
| <b>Test 1</b><br>Add an equal depth of dilute sulfuric acid.       |              |      |      |
| <b>Test 2</b><br>Add an equal depth of aqueous sodium carbonate.   |              |      |      |
| <b>Test 3</b><br>Add an equal depth of aqueous magnesium chloride. |              |      |      |

[5]

- (ii) Use your observations in (a)(i) to suggest a **possible** formula for each of the following:

The cation in **FA 5** is .....

The cation in **FA 6** is .....

The anion in **FA 7** is .....

[3]

- (iii) Apart from using an indicator, suggest a further test that would confirm the identity of the anion in **FA 7**.

Carry out this test and record the result.

.....

.....

..... [1]

- (iv) Did the result of your test in (a)(iii) confirm the identity of the anion in **FA 7**?  
Explain your answer.

.....

.....

..... [1]

(b) **FA 8** is an aqueous solution.

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

| <i>test</i>                                                                                                                                                  | <i>observations</i> |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| <b>Test 1</b><br>To a 1 cm depth of <b>FA 8</b> in a test-tube, add a few drops of acidified potassium manganate(VII). Place the tube in the hot water-bath. |                     |
| <b>Test 2</b><br>To a 1 cm depth of <b>FA 8</b> in a test-tube, add a 1 cm length of magnesium ribbon.                                                       |                     |

[2]

(ii) For each observation, state what you can conclude about the chemical properties of **FA 8**.

Test 1 .....

Test 2 .....

[2]

[Total: 14]

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## Qualitative Analysis Notes

## 1 Reactions of aqueous cations

| ion                                            | reaction with                                                                      |                                                                                    |
|------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
|                                                | NaOH(aq)                                                                           | NH <sub>3</sub> (aq)                                                               |
| aluminium,<br>Al <sup>3+</sup> (aq)            | white ppt.<br>soluble in excess                                                    | white ppt.<br>insoluble in excess                                                  |
| ammonium,<br>NH <sub>4</sub> <sup>+</sup> (aq) | no ppt.<br>ammonia produced on heating                                             | —                                                                                  |
| barium,<br>Ba <sup>2+</sup> (aq)               | faint white ppt. is nearly always<br>observed unless reagents are pure             | no ppt.                                                                            |
| calcium,<br>Ca <sup>2+</sup> (aq)              | white ppt. with high [Ca <sup>2+</sup> (aq)]                                       | no ppt.                                                                            |
| chromium(III),<br>Cr <sup>3+</sup> (aq)        | grey-green ppt.<br>soluble in excess                                               | grey-green ppt.<br>insoluble in excess                                             |
| copper(II),<br>Cu <sup>2+</sup> (aq)           | pale blue ppt.<br>insoluble in excess                                              | pale blue ppt. soluble in excess<br>giving dark blue solution                      |
| iron(II),<br>Fe <sup>2+</sup> (aq)             | green ppt. turning brown on contact<br>with air<br>insoluble in excess             | green ppt. turning brown on contact<br>with air<br>insoluble in excess             |
| iron(III),<br>Fe <sup>3+</sup> (aq)            | red-brown ppt.<br>insoluble in excess                                              | red-brown ppt.<br>insoluble in excess                                              |
| magnesium,<br>Mg <sup>2+</sup> (aq)            | white ppt.<br>insoluble in excess                                                  | white ppt.<br>insoluble in excess                                                  |
| manganese(II),<br>Mn <sup>2+</sup> (aq)        | off-white ppt. rapidly turning brown<br>on contact with air<br>insoluble in excess | off-white ppt. rapidly turning brown<br>on contact with air<br>insoluble in excess |
| zinc,<br>Zn <sup>2+</sup> (aq)                 | white ppt.<br>soluble in excess                                                    | white ppt.<br>soluble in excess                                                    |

## 2 Reactions of anions

| <i>ion</i>                                | <i>reaction</i>                                                                                 |
|-------------------------------------------|-------------------------------------------------------------------------------------------------|
| carbonate,<br>$\text{CO}_3^{2-}$          | $\text{CO}_2$ liberated by dilute acids                                                         |
| chloride,<br>$\text{Cl}^-(\text{aq})$     | gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$ )           |
| bromide,<br>$\text{Br}^-(\text{aq})$      | gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$ ) |
| iodide,<br>$\text{I}^-(\text{aq})$        | gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$ )        |
| nitrate,<br>$\text{NO}_3^-(\text{aq})$    | $\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil           |
| nitrite,<br>$\text{NO}_2^-(\text{aq})$    | $\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil           |
| sulfate,<br>$\text{SO}_4^{2-}(\text{aq})$ | gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)     |
| sulfite,<br>$\text{SO}_3^{2-}(\text{aq})$ | gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)       |

## 3 Tests for gases

| <i>gas</i>                    | <i>test and test result</i>                                                   |
|-------------------------------|-------------------------------------------------------------------------------|
| ammonia, $\text{NH}_3$        | turns damp red litmus paper blue                                              |
| carbon dioxide, $\text{CO}_2$ | gives a white ppt. with limewater (ppt. dissolves with excess $\text{CO}_2$ ) |
| chlorine, $\text{Cl}_2$       | bleaches damp litmus paper                                                    |
| hydrogen, $\text{H}_2$        | 'pops' with a lighted splint                                                  |
| oxygen, $\text{O}_2$          | relights a glowing splint                                                     |

The Periodic Table of Elements

| Group                  |                         |                                                                |  |  |  |  |  |  |  |  |  |  |  |  |  |    |    |
|------------------------|-------------------------|----------------------------------------------------------------|--|--|--|--|--|--|--|--|--|--|--|--|--|----|----|
| 1                      | 2                       | 1<br>H<br>hydrogen<br>1.0                                      |  |  |  |  |  |  |  |  |  |  |  |  |  | 17 | 18 |
|                        |                         | Key                                                            |  |  |  |  |  |  |  |  |  |  |  |  |  |    |    |
|                        |                         | atomic number<br>atomic symbol<br>name<br>relative atomic mass |  |  |  |  |  |  |  |  |  |  |  |  |  |    |    |
| 3                      | 4                       |                                                                |  |  |  |  |  |  |  |  |  |  |  |  |  |    |    |
| Li<br>lithium<br>6.9   | Be<br>beryllium<br>9.0  |                                                                |  |  |  |  |  |  |  |  |  |  |  |  |  |    |    |
| 11                     | 12                      |                                                                |  |  |  |  |  |  |  |  |  |  |  |  |  |    |    |
| Na<br>sodium<br>23.0   | Mg<br>magnesium<br>24.3 |                                                                |  |  |  |  |  |  |  |  |  |  |  |  |  |    |    |
| 19                     | 20                      |                                                                |  |  |  |  |  |  |  |  |  |  |  |  |  |    |    |
| K<br>potassium<br>39.1 | Ca<br>calcium<br>40.1   |                                                                |  |  |  |  |  |  |  |  |  |  |  |  |  |    |    |
| 37                     | 38                      |                                                                |  |  |  |  |  |  |  |  |  |  |  |  |  |    |    |
| Rb<br>rubidium<br>85.5 | Sr<br>strontium<br>87.6 |                                                                |  |  |  |  |  |  |  |  |  |  |  |  |  |    |    |
| 55                     | 56                      |                                                                |  |  |  |  |  |  |  |  |  |  |  |  |  |    |    |
| Cs<br>caesium<br>132.9 | Ba<br>barium<br>137.3   |                                                                |  |  |  |  |  |  |  |  |  |  |  |  |  |    |    |
| 87                     | 88                      |                                                                |  |  |  |  |  |  |  |  |  |  |  |  |  |    |    |
| Fr<br>francium<br>—    | Ra<br>radium<br>—       |                                                                |  |  |  |  |  |  |  |  |  |  |  |  |  |    |    |
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lanthanoids

actinoids

|           |         |              |           |            |           |           |            |           |             |             |         |             |           |            |
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| 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        | 144.4     | —          | 150.4     | 152.0     | 157.3      | 158.9     | 162.5       | 164.9       | 167.3   | 168.9       | 173.1     | 175.0      |
| 89        | 90      | 91           | 92        | 93         | 94        | 95        | 96         | 97        | 98          | 99          | 100     | 101         | 102       | 103        |
| Ac        | Th      | Pa           | U         | Np         | Pu        | Am        | Cm         | Bk        | Cf          | Es          | Fm      | Md          | No        | Lr         |
| actinium  | thorium | protactinium | uranium   | neptunium  | plutonium | americium | curium     | berkelium | californium | einsteinium | fermium | mendelevium | nobelium  | lawrencium |
| —         | 232.0   | 231.0        | 238.0     | —          | —         | —         | —          | —         | —           | —           | —       | —           | —         | —          |



# Cambridge International AS & A Level

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**CHEMISTRY**

**9701/36**

Paper 3 Advanced Practical Skills 2

**October/November 2021**

**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, use appropriate units and use an appropriate number of significant figures.
- Give details of the practical session and laboratory, where appropriate, in the boxes provided.

## 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.
- Notes for use in qualitative analysis are provided in the question paper.

|                   |  |
|-------------------|--|
| <b>Session</b>    |  |
|                   |  |
| <b>Laboratory</b> |  |
|                   |  |

| <b>For Examiner's Use</b> |  |
|---------------------------|--|
| <b>1</b>                  |  |
| <b>2</b>                  |  |
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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 your working and appropriate significant figures in the final answer to **each** step of your calculations.

- 1 Solid **FB 1** is hydrated sodium carbonate,  $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ . You will determine the value of **x** in a sample of **FB 1**.

The experiment involves three steps:

- Step 1** React a known mass of sodium carbonate, **FB 1**, with an excess of acid.  
**Step 2** Dilute the products of **Step 1** to a known volume.  
**Step 3** Carry out a titration to find out how much acid remained after the reaction in **Step 1**.

You will use the results of these three steps to find **x**.

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

**FB 2** is  $0.800 \text{ mol dm}^{-3}$  hydrochloric acid,  $\text{HCl}$ .

**FB 4** is  $0.100 \text{ mol dm}^{-3}$  sodium hydroxide,  $\text{NaOH}$ .  
 bromophenol blue indicator

### (a) Method

#### Step 1

- Label a burette **FB 2** and fill this burette with **FB 2**.
- Run  $50.00 \text{ cm}^3$  of **FB 2** into the  $250 \text{ cm}^3$  beaker.
- Weigh the container with **FB 1**. Record the mass.
- Slowly, and in small portions, add **FB 1** to the acid.
- Stir the mixture until the fizzing has stopped. Leave the stirring rod in the beaker.
- Reweigh the container with any residue. Record the mass.
- Calculate and record the mass of **FB 1** added to the acid.

**Step 2**

- Stir the mixture from **Step 1** and ensure that all the solid has dissolved. Transfer this solution to the graduated flask.
- Rinse the beaker and stirring rod twice with distilled water, then add the washings into the graduated flask.
- Make the solution up to 250 cm<sup>3</sup> with distilled water. Thoroughly mix the contents of the flask. This solution is **FB 3**.

**Step 3**

- Label the other burette **FB 4**. Fill this burette with **FB 4**.
- Pipette 25.0 cm<sup>3</sup> of **FB 3** into a conical flask.
- Add several drops of bromophenol blue indicator.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is ..... cm<sup>3</sup>.

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

|      |  |
|------|--|
| I    |  |
| II   |  |
| III  |  |
| IV   |  |
| V    |  |
| VI   |  |
| VII  |  |
| VIII |  |

[8]

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

25.0 cm<sup>3</sup> of **FB 3** required ..... cm<sup>3</sup> of **FB 4**. [1]

**Calculations**

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

- (ii) Calculate the number of moles of hydrochloric acid in the **FB 2** used in **Step 1**.

moles of HCl in **FB 2** used in **Step 1** = ..... mol [1]

- (iii) Use your answer to (b) to calculate the number of moles of sodium hydroxide, **FB 4**, required to react with 25.0 cm<sup>3</sup> of **FB 3** in **Step 3**.

moles of NaOH required = ..... mol

Use this answer to deduce the number of moles of hydrochloric acid in 250 cm<sup>3</sup> of **FB 3**. This is the number of moles remaining after the reaction in **Step 1**.

moles of HCl in 250 cm<sup>3</sup> of **FB 3** = ..... mol [1]

- (iv) Use your answers to (c)(ii) and (c)(iii) to calculate the number of moles of hydrochloric acid that reacted with sodium carbonate in **FB 1**.

moles of HCl that reacted with **FB 1** = ..... mol [1]

- (v) Write an equation for the reaction of sodium carbonate with hydrochloric acid in **Step 1**. Include state symbols.

..... [1]

- (vi) Use the equation and your answer to (c)(iv) to determine the moles of sodium carbonate present in **FB 1**.

moles of Na<sub>2</sub>CO<sub>3</sub> = ..... mol [1]

- (vii) Use your answer to (c)(vi) and your mass of **FB 1** to calculate the formula mass of hydrated sodium carbonate.  
Hence find the value for **x**.

(If you were unable to calculate the number of moles of  $\text{Na}_2\text{CO}_3$  in (c)(vi) assume that it is  $5.55 \times 10^{-3} \text{ mol}$ . This is **not** the correct value.)

**x** = ..... [2]

- (d) State the maximum error in a single balance reading.

maximum error in a balance reading = ..... g

Calculate the maximum percentage error in the mass of **FB 1** you used.  
Show your working.

maximum percentage error = ..... %  
[1]

- (e) A student decided to use a larger mass of **FB 1** when carrying out the same method.

What effect would this have on the titre volume in **Step 3**?  
Explain your answer.

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

[Total: 19]

- 2 In this question you will determine the value of **y** in another sample of hydrated sodium carbonate by thermal decomposition.

The equation for the reaction which occurs is given below.



Solid **FB 5** is another sample of hydrated sodium carbonate,  $\text{Na}_2\text{CO}_3 \cdot y\text{H}_2\text{O}$ .

**(a) Method**

- Weigh the empty crucible with its lid. Record the mass.
- Transfer all the **FB 5** from its container into the crucible.
- Weigh the crucible, lid and **FB 5**. Record the mass.
- Calculate and record the mass of **FB 5** used.
- Place the crucible and contents on a pipe-clay triangle.
- Heat the crucible gently, with the lid on, for approximately 1 minute.
- Heat strongly, with the lid on, for a further 1 minute.
- Heat strongly, with the lid off, for a further 4 minutes.
- Allow the crucible to cool, with the lid on, for at least 5 minutes.

**During the cooling period you may wish to start work on Question 3.**

- When the crucible is cool, weigh the crucible with its lid and contents.
- Calculate and record the mass of the residue obtained and the mass lost during heating.

|     |  |
|-----|--|
| I   |  |
| II  |  |
| III |  |

[3]

(b) Use your results to calculate a value for  $y$ .

$y = \dots\dots\dots$  [2]

(c) Suggest **one** improvement to the method used in **Question 2** which would lead to a more accurate value for  $y$ .

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

[Total: 6]

## Qualitative analysis

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

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

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

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

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

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

**No additional tests for ions present should be attempted.**

- 3 (a) FB 6, FB 7 and FB 8** each contain one cation and one anion. All the cations and anions are different. All the cations and two of the anions are listed in the Qualitative Analysis Notes. **FB 7** is an aqueous solution.

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

| <i>test</i>                                                                                                                                                                                                                                                                                                            | <i>observations</i> |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| <b>Test 1</b><br>To a 1 cm depth of hydrogen peroxide in a test-tube, add a small spatula measure of <b>FB 6</b> .                                                                                                                                                                                                     |                     |
| <b>Test 2</b><br>To a 2 cm depth of aqueous potassium manganate(VII) in a test-tube, add the same depth of aqueous sodium hydroxide. Then add a small spatula measure of <b>FB 6</b> . Stir for about 30 seconds. Filter the mixture and collect the filtrate, then<br><hr/> add dilute sulfuric acid to the filtrate. |                     |

| <i>test</i>                                                                                                                                                                                                          | <i>observations</i> |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| <b>Test 3</b><br>To a 1 cm depth of <b>FB 7</b> in a test-tube, add an equal volume of hydrogen peroxide. Shake the tube, then<br>-----<br>add aqueous sodium hydroxide.                                             |                     |
| <b>Test 4</b><br>To a 1 cm depth of <b>FB 7</b> in a test-tube, add a few drops of aqueous barium chloride or aqueous barium nitrate, then<br>-----<br>add dilute hydrochloric acid.                                 |                     |
| <b>Test 5</b><br>Place a small spatula measure of <b>FB 8</b> into a hard-glass test-tube. Heat the contents.                                                                                                        |                     |
| <b>Test 6</b><br>Dissolve a small spatula measure of <b>FB 8</b> in a 2 cm depth of distilled water in a test-tube. To the solution add a few drops of aqueous silver nitrate, then<br>-----<br>add aqueous ammonia. |                     |

[7]

- (ii) From your test results, identify the anions in **FB 6**, **FB 7** and **FB 8**. If the tests do not allow you to positively identify an anion, write 'unknown'.

|                  | <b>FB 6</b> | <b>FB 7</b> | <b>FB 8</b> |
|------------------|-------------|-------------|-------------|
| formula of anion |             |             |             |

[2]

- (b) Aqueous sodium hydroxide may be used to help identify cations. You will use this reagent to carry out tests on **FB 7** and **FB 8**.

Record your method, observations and conclusions in the space below.

You are reminded that if any solution is warmed, a boiling tube **must** be used.

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

[4]

- (c) (i) From your observations, suggest a conclusion that could be made about the chemical behaviour of **FB 7** in **Test 3** of (a)(i).  
Explain your answer.

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

- (ii) Write an ionic equation for any precipitation reaction you observed in (a)(i).  
Include state symbols.

..... [1]

[Total: 15]







## Qualitative Analysis Notes

## 1 Reactions of aqueous cations

| ion                                            | reaction with                                                                      |                                                                                    |
|------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
|                                                | NaOH(aq)                                                                           | NH <sub>3</sub> (aq)                                                               |
| aluminium,<br>Al <sup>3+</sup> (aq)            | white ppt.<br>soluble in excess                                                    | white ppt.<br>insoluble in excess                                                  |
| ammonium,<br>NH <sub>4</sub> <sup>+</sup> (aq) | no ppt.<br>ammonia produced on heating                                             | –                                                                                  |
| barium,<br>Ba <sup>2+</sup> (aq)               | faint white ppt. is nearly always<br>observed unless reagents are pure             | no ppt.                                                                            |
| calcium,<br>Ca <sup>2+</sup> (aq)              | white ppt. with high [Ca <sup>2+</sup> (aq)]                                       | no ppt.                                                                            |
| chromium(III),<br>Cr <sup>3+</sup> (aq)        | grey-green ppt.<br>soluble in excess                                               | grey-green ppt.<br>insoluble in excess                                             |
| copper(II),<br>Cu <sup>2+</sup> (aq)           | pale blue ppt.<br>insoluble in excess                                              | pale blue ppt. soluble in excess<br>giving dark blue solution                      |
| iron(II),<br>Fe <sup>2+</sup> (aq)             | green ppt. turning brown on contact<br>with air<br>insoluble in excess             | green ppt. turning brown on contact<br>with air<br>insoluble in excess             |
| iron(III),<br>Fe <sup>3+</sup> (aq)            | red-brown ppt.<br>insoluble in excess                                              | red-brown ppt.<br>insoluble in excess                                              |
| magnesium,<br>Mg <sup>2+</sup> (aq)            | white ppt.<br>insoluble in excess                                                  | white ppt.<br>insoluble in excess                                                  |
| manganese(II),<br>Mn <sup>2+</sup> (aq)        | off-white ppt. rapidly turning brown<br>on contact with air<br>insoluble in excess | off-white ppt. rapidly turning brown<br>on contact with air<br>insoluble in excess |
| zinc,<br>Zn <sup>2+</sup> (aq)                 | white ppt.<br>soluble in excess                                                    | white ppt.<br>soluble in excess                                                    |

## 2 Reactions of anions

| <i>ion</i>                                | <i>reaction</i>                                                                                 |
|-------------------------------------------|-------------------------------------------------------------------------------------------------|
| carbonate,<br>$\text{CO}_3^{2-}$          | $\text{CO}_2$ liberated by dilute acids                                                         |
| chloride,<br>$\text{Cl}^-(\text{aq})$     | gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$ )           |
| bromide,<br>$\text{Br}^-(\text{aq})$      | gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$ ) |
| iodide,<br>$\text{I}^-(\text{aq})$        | gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$ )        |
| nitrate,<br>$\text{NO}_3^-(\text{aq})$    | $\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil           |
| nitrite,<br>$\text{NO}_2^-(\text{aq})$    | $\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil           |
| sulfate,<br>$\text{SO}_4^{2-}(\text{aq})$ | gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)     |
| sulfite,<br>$\text{SO}_3^{2-}(\text{aq})$ | gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)       |

## 3 Tests for gases

| <i>gas</i>                    | <i>test and test result</i>                                                   |
|-------------------------------|-------------------------------------------------------------------------------|
| ammonia, $\text{NH}_3$        | turns damp red litmus paper blue                                              |
| carbon dioxide, $\text{CO}_2$ | gives a white ppt. with limewater (ppt. dissolves with excess $\text{CO}_2$ ) |
| chlorine, $\text{Cl}_2$       | bleaches damp litmus paper                                                    |
| hydrogen, $\text{H}_2$        | 'pops' with a lighted splint                                                  |
| oxygen, $\text{O}_2$          | relights a glowing splint                                                     |

The Periodic Table of Elements

| Group                  |                         |                                                                |                          |                         |                          |                         |                          |                        |                          |                        |                        |  |  |   |  |                         |                         |                         |                          |  |
|------------------------|-------------------------|----------------------------------------------------------------|--------------------------|-------------------------|--------------------------|-------------------------|--------------------------|------------------------|--------------------------|------------------------|------------------------|--|--|---|--|-------------------------|-------------------------|-------------------------|--------------------------|--|
| 1                      | 2                       | Key                                                            |                          |                         |                          |                         |                          |                        |                          |                        |                        |  |  |   |  | 17                      | 18                      |                         |                          |  |
|                        |                         | atomic number<br>atomic symbol<br>name<br>relative atomic mass |                          |                         |                          |                         |                          |                        |                          |                        |                        |  |  | 1 |  |                         |                         | 2                       |                          |  |
| 3                      | 4                       |                                                                |                          |                         |                          |                         |                          |                        |                          |                        |                        |  |  |   |  |                         |                         |                         |                          |  |
| Li<br>lithium<br>6.9   | Be<br>beryllium<br>9.0  |                                                                |                          |                         |                          |                         |                          |                        |                          |                        |                        |  |  |   |  |                         |                         | H<br>hydrogen<br>1.0    |                          |  |
| 11                     | 12                      |                                                                |                          |                         |                          |                         |                          |                        |                          |                        |                        |  |  |   |  |                         |                         |                         |                          |  |
| Na<br>sodium<br>23.0   | Mg<br>magnesium<br>24.3 |                                                                |                          |                         |                          |                         |                          |                        |                          |                        |                        |  |  |   |  |                         |                         |                         |                          |  |
| 19                     | 20                      |                                                                |                          |                         |                          |                         |                          |                        |                          |                        |                        |  |  |   |  |                         |                         |                         |                          |  |
| K<br>potassium<br>39.1 | Ca<br>calcium<br>40.1   |                                                                |                          |                         |                          |                         |                          |                        |                          |                        |                        |  |  |   |  |                         |                         |                         |                          |  |
| 37                     | 38                      |                                                                |                          |                         |                          |                         |                          |                        |                          |                        |                        |  |  |   |  |                         |                         |                         |                          |  |
| Rb<br>rubidium<br>85.5 | Sr<br>strontium<br>87.6 |                                                                |                          |                         |                          |                         |                          |                        |                          |                        |                        |  |  |   |  |                         |                         |                         |                          |  |
| 55                     | 56                      |                                                                |                          |                         |                          |                         |                          |                        |                          |                        |                        |  |  |   |  |                         |                         |                         |                          |  |
| Cs<br>caesium<br>132.9 | Ba<br>barium<br>137.3   |                                                                |                          |                         |                          |                         |                          |                        |                          |                        |                        |  |  |   |  |                         |                         |                         |                          |  |
| 87                     | 88                      |                                                                |                          |                         |                          |                         |                          |                        |                          |                        |                        |  |  |   |  |                         |                         |                         |                          |  |
| Fr<br>francium<br>—    | Ra<br>radium<br>—       |                                                                |                          |                         |                          |                         |                          |                        |                          |                        |                        |  |  |   |  |                         |                         |                         |                          |  |
|                        |                         | 3                                                              | 4                        | 5                       | 6                        | 7                       | 8                        | 9                      | 10                       | 11                     | 12                     |  |  |   |  | 13                      | 14                      | 15                      | 16                       |  |
|                        |                         | 21                                                             | 22                       | 23                      | 24                       | 25                      | 26                       | 27                     | 28                       | 29                     | 30                     |  |  |   |  | 31                      | 32                      | 33                      | 34                       |  |
|                        |                         | Sc<br>scandium<br>45.0                                         | Ti<br>titanium<br>47.9   | V<br>vanadium<br>50.9   | Cr<br>chromium<br>52.0   | Mn<br>manganese<br>54.9 | Fe<br>iron<br>55.8       | Co<br>cobalt<br>58.9   | Ni<br>nickel<br>58.7     | Cu<br>copper<br>63.5   | Zn<br>zinc<br>65.4     |  |  |   |  | Ga<br>gallium<br>69.7   | Ge<br>germanium<br>72.6 | As<br>arsenic<br>74.9   | Se<br>selenium<br>79.0   |  |
|                        |                         | 39                                                             | 40                       | 41                      | 42                       | 43                      | 44                       | 45                     | 46                       | 47                     | 48                     |  |  |   |  | 49                      | 50                      | 51                      | 52                       |  |
|                        |                         | Y<br>yttrium<br>88.9                                           | Zr<br>zirconium<br>91.2  | Nb<br>niobium<br>92.9   | Mo<br>molybdenum<br>95.9 | Tc<br>technetium<br>—   | Ru<br>ruthenium<br>101.1 | Rh<br>rhodium<br>102.9 | Pd<br>palladium<br>106.4 | Ag<br>silver<br>107.9  | Cd<br>cadmium<br>112.4 |  |  |   |  | In<br>indium<br>114.8   | Sn<br>tin<br>118.7      | Sb<br>antimony<br>121.8 | Te<br>tellurium<br>127.6 |  |
|                        |                         | 57–71<br>lanthanoids                                           | 72                       | 73                      | 74                       | 75                      | 76                       | 77                     | 78                       | 79                     | 80                     |  |  |   |  | 81                      | 82                      | 83                      | 84                       |  |
|                        |                         |                                                                | Hf<br>hafnium<br>178.5   | Ta<br>tantalum<br>180.9 | W<br>tungsten<br>183.8   | Re<br>rhenium<br>186.2  | Os<br>osmium<br>190.2    | Ir<br>iridium<br>192.2 | Pt<br>platinum<br>195.1  | Au<br>gold<br>197.0    | Hg<br>mercury<br>200.6 |  |  |   |  | Tl<br>thallium<br>204.4 | Pb<br>lead<br>207.2     | Bi<br>bismuth<br>209.0  | Po<br>polonium<br>—      |  |
|                        |                         | 89–103<br>actinoids                                            | 104                      | 105                     | 106                      | 107                     | 108                      | 109                    | 110                      | 111                    | 112                    |  |  |   |  | 113                     | 114                     | 115                     | 116                      |  |
|                        |                         |                                                                | Rf<br>rutherfordium<br>— | Db<br>dubnium<br>—      | Sg<br>seaborgium<br>—    | Bh<br>bohrium<br>—      | Hs<br>hassium<br>—       | Mt<br>meitnerium<br>—  | Ds<br>darmstadtium<br>—  | Rg<br>roentgenium<br>— | Cn<br>copernicium<br>— |  |  |   |  | Fl<br>flerovium<br>—    | Lv<br>livermorium<br>—  | At<br>astatine<br>—     | Rn<br>radon<br>—         |  |