



# Cambridge International AS & A Level

CANDIDATE  
NAME

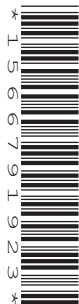
|  |
|--|
|  |
|--|

CENTRE  
NUMBER

|  |  |  |  |  |
|--|--|--|--|--|
|  |  |  |  |  |
|--|--|--|--|--|

CANDIDATE  
NUMBER

|  |  |  |  |
|--|--|--|--|
|  |  |  |  |
|--|--|--|--|



## CHEMISTRY

9701/32

Paper 3 Advanced Practical Skills 2

May/June 2023

2 hours

You must answer on the question paper.

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

## INSTRUCTIONS

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

## INFORMATION

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

Session

Laboratory

For Examiner's Use

1

2

3

Total

This document has **12** pages.

## Quantitative Analysis

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

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

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

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

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

### (a) Method

- Weigh the empty crucible with its lid. Record the mass.
- Transfer all of the **FB 1** from the container into the crucible.
- Weigh the crucible, lid and **FB 1**. Record the mass.
- Calculate and record the mass of **FB 1** 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 off, for a further 4 minutes.
- Replace the lid and leave the crucible to cool for at least 5 minutes.

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

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

### Results

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

[5]

### (b) Calculations

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

..... [1]

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

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

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

amount of CO<sub>2</sub> = ..... mol [1]

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

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

- (iv) Calculate the relative atomic mass of metal **M**.

$A_r$  of **M** = ..... [1]

- (c) A student accidentally spilt a little of the residue before carrying out the final weighing.  
Predict whether the calculated value of the relative atomic mass of **M** will be higher or lower  
as a result of this mistake.  
Explain your answer.

The  $A_r$  of **M** will be .....

explanation .....

.....

..... [1]

- (d) A student suggested that addition of sulfuric acid to the residue from (a) would show whether  
the basic metal carbonate had decomposed fully.  
State whether the student is correct.  
Explain your answer.

.....

.....

..... [1]

[Total: 11]

- 2 In this experiment you will determine the relative atomic mass,  $A_r$ , of another metal, **X**, by a titration method using the metal carbonate,  $\text{X}_2\text{CO}_3$ .

**FB 2** is  $0.0460 \text{ mol dm}^{-3}$  hydrochloric acid,  $\text{HCl}$ .

**FB 3** is the metal carbonate,  $\text{X}_2\text{CO}_3$ .

**FB 4** is methyl orange indicator.

(a) **Method**

**Preparing a solution of FB 3**

- Weigh the stoppered container of **FB 3**. Record the mass in the space below.
- Tip all of the **FB 3** into the  $250 \text{ cm}^3$  beaker.
- Reweigh the container with its stopper. Record the mass.
- Calculate and record the mass of **FB 3** used.
- Add approximately  $100 \text{ cm}^3$  of distilled water to **FB 3** in the beaker.
- Stir the mixture with a glass rod until all the **FB 3** has dissolved.
- Transfer this solution into the  $250 \text{ cm}^3$  volumetric flask.
- Wash the beaker with distilled water and transfer the washings to the volumetric flask.
- Rinse the glass rod with distilled water and transfer the washings to the volumetric flask.
- Make up the solution in the volumetric flask to the mark using distilled water.
- Shake the flask thoroughly.
- This solution of  $\text{X}_2\text{CO}_3$  is **FB 5**. Label the flask **FB 5**.

**Titration**

- Fill the burette with **FB 2**.
- Pipette  $25.0 \text{ cm}^3$  of **FB 5** into a conical flask.
- Add several drops of **FB 4** to the conical flask.
- Perform a rough titration and record your burette readings in the space below.

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

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

|      |  |
|------|--|
| I    |  |
| 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 obtain the mean value.

25.0 cm<sup>3</sup> of **FB 5** required ..... cm<sup>3</sup> of **FB 2**. [1]

(c) **Calculations**

- (i) Give your answers to (c)(ii), (c)(iv), (c)(v) and (c)(vi) to an appropriate number of significant figures. [1]
- (ii) Calculate the amount, in mol, of hydrochloric acid present in the volume of **FB 2** in (b).

amount of HCl = ..... mol [1]

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

.....CO<sub>3</sub><sup>2-</sup>..... + ..... → ..... + ..... [1]

- (iv) Calculate the concentration of **X<sub>2</sub>CO<sub>3</sub>**, in mol dm<sup>-3</sup>, in **FB 5**.

concentration of **X<sub>2</sub>CO<sub>3</sub>** in **FB 5** = ..... mol dm<sup>-3</sup> [1]

(v) Calculate the relative formula mass,  $M_r$ , of  $\text{X}_2\text{CO}_3$ .

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

(vi) Calculate the relative atomic mass of **X**.

$A_r$  of **X** = ..... [1]

(vii) Identify **X**.

**X** is ..... [1]

[Total: 16]

## Qualitative Analysis

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

Examples of observations include:

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

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

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

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

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

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

No additional tests should be attempted.

- 3 (a) FB 6** is a solution containing one cation listed in the Qualitative analysis notes.  
The anion contains sulfur.

- (i) State the reagents you would use to identify the cation in **FB 6**.

reagents .....

Use your selected reagents to test **FB 6**.

Use 1 cm depth of **FB 6** in a test-tube for each test.

Record your observations in the space below.

[2]

- (ii) Identify the anion in **FB 6**.  
Include a description of your procedure and the observations you make.

anion in **FB 6** ..... [2]

- (iii) Deduce the formula of **FB 6**.

formula of **FB 6** ..... [1]

- (b) You will devise chemical tests to distinguish between the two possible identities given for each of compounds **FB 7**, **FB 8**, **FB 9** and **FB 10**.

In each case, you should:

- name the reagent or reagents you will use to identify the compound
- state any necessary conditions for your test
- use a 1 cm depth of the solution of the unknown compound and use a boiling tube if you need to warm a mixture
- carry out your test and record the observations you make (if any)
- state your conclusion about the identity of the compound.

- (i) **FB 7** is either aqueous sodium nitrate or aqueous sodium nitrite.

**FB 7** is ..... [2]

- (ii) **FB 8** is either aqueous sodium nitrate or aqueous silver nitrate.

**FB 8** is ..... [2]

- (iii) **FB 9** is either aqueous ethanol or aqueous propan-1-ol.  
(In your test, do **not** heat but you may need to leave your reaction mixture to stand.)

**FB 9** is ..... [2]

- (iv) **FB 10** is either aqueous methanol or aqueous ethanoic acid.

**FB 10** is ..... [2]

[Total: 13]

## Qualitative analysis notes

## 1 Reactions of cations

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

## 2 Reactions of anions

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

### 3 Tests for gases

| gas                           | test and test result              |
|-------------------------------|-----------------------------------|
| ammonia, $\text{NH}_3$        | turns damp red litmus paper blue  |
| carbon dioxide, $\text{CO}_2$ | gives a white ppt. with limewater |
| hydrogen, $\text{H}_2$        | 'pops' with a lighted splint      |
| oxygen, $\text{O}_2$          | relights a glowing splint         |

### 4 Tests for elements

| element              | test and test result                                   |
|----------------------|--------------------------------------------------------|
| iodine, $\text{I}_2$ | gives blue-black colour on addition of starch solution |

### Important values, constants and standards

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

The Periodic Table of Elements

| Group                        |                               |                                                                |                                 |                               |                                |                               |                                |                              |                                |                               |                               |                               |                               |                               |                                |                              |                             |                               |                             |                               |                           |                              |                           |
|------------------------------|-------------------------------|----------------------------------------------------------------|---------------------------------|-------------------------------|--------------------------------|-------------------------------|--------------------------------|------------------------------|--------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|------------------------------|-----------------------------|-------------------------------|-----------------------------|-------------------------------|---------------------------|------------------------------|---------------------------|
| 1                            | 2                             |                                                                |                                 |                               |                                |                               |                                |                              |                                |                               |                               |                               |                               | 13                            | 14                             | 15                           | 16                          | 17                            | 18                          |                               |                           |                              |                           |
|                              |                               |                                                                |                                 |                               |                                |                               |                                |                              |                                |                               |                               |                               |                               | 1<br>H<br>hydrogen<br>1.0     |                                |                              |                             |                               |                             |                               |                           | 2<br>He<br>helium<br>4.0     |                           |
|                              |                               | Key                                                            |                                 |                               |                                |                               |                                |                              |                                |                               |                               |                               |                               |                               |                                |                              |                             |                               |                             |                               |                           |                              |                           |
|                              |                               | atomic number<br>atomic symbol<br>name<br>relative atomic mass |                                 |                               |                                |                               |                                |                              |                                |                               |                               |                               |                               |                               |                                |                              |                             |                               |                             |                               |                           |                              |                           |
| 3<br>Li<br>lithium<br>6.9    | 4<br>Be<br>beryllium<br>9.0   |                                                                |                                 |                               |                                |                               |                                |                              |                                |                               |                               |                               |                               |                               |                                |                              |                             | 5<br>B<br>boron<br>10.8       | 6<br>C<br>carbon<br>12.0    | 7<br>N<br>nitrogen<br>14.0    | 8<br>O<br>oxygen<br>16.0  | 9<br>F<br>fluorine<br>19.0   | 10<br>Ne<br>neon<br>20.2  |
| 11<br>Na<br>sodium<br>23.0   | 12<br>Mg<br>magnesium<br>24.3 |                                                                |                                 |                               |                                |                               |                                |                              |                                |                               |                               |                               |                               |                               |                                |                              |                             | 13<br>Al<br>aluminium<br>27.0 | 14<br>Si<br>silicon<br>28.1 | 15<br>P<br>phosphorus<br>31.0 | 16<br>S<br>sulfur<br>32.1 | 17<br>Cl<br>chlorine<br>35.5 | 18<br>Ar<br>argon<br>39.9 |
| 19<br>K<br>potassium<br>39.1 | 20<br>Ca<br>calcium<br>40.1   | 21<br>Sc<br>scandium<br>45.0                                   | 22<br>Ti<br>titanium<br>47.9    | 23<br>V<br>vanadium<br>50.9   | 24<br>Cr<br>chromium<br>52.0   | 25<br>Mn<br>manganese<br>54.9 | 26<br>Fe<br>iron<br>55.8       | 27<br>Co<br>cobalt<br>58.9   | 28<br>Ni<br>nickel<br>58.7     | 29<br>Cu<br>copper<br>63.5    | 30<br>Zn<br>zinc<br>65.4      | 31<br>Ga<br>gallium<br>69.7   | 32<br>Ge<br>germanium<br>72.6 | 33<br>As<br>arsenic<br>74.9   | 34<br>Se<br>selenium<br>79.0   | 35<br>Br<br>bromine<br>79.9  | 36<br>Kr<br>krypton<br>83.8 |                               |                             |                               |                           |                              |                           |
| 37<br>Rb<br>rubidium<br>85.5 | 38<br>Sr<br>strontium<br>87.6 | 39<br>Y<br>yttrium<br>88.9                                     | 40<br>Zr<br>zirconium<br>91.2   | 41<br>Nb<br>niobium<br>92.9   | 42<br>Mo<br>molybdenum<br>95.9 | 43<br>Tc<br>technetium<br>—   | 44<br>Ru<br>ruthenium<br>101.1 | 45<br>Rh<br>rhodium<br>102.9 | 46<br>Pd<br>palladium<br>106.4 | 47<br>Ag<br>silver<br>107.9   | 48<br>Cd<br>cadmium<br>112.4  | 49<br>In<br>indium<br>114.8   | 50<br>Sn<br>tin<br>118.7      | 51<br>Sb<br>antimony<br>121.8 | 52<br>Te<br>tellurium<br>127.6 | 53<br>I<br>iodine<br>126.9   | 54<br>Xe<br>xenon<br>131.3  |                               |                             |                               |                           |                              |                           |
| 55<br>Cs<br>caesium<br>132.9 | 56<br>Ba<br>barium<br>137.3   | 57–71<br>lanthanoids                                           | 72<br>Hf<br>hafnium<br>178.5    | 73<br>Ta<br>tantalum<br>180.9 | 74<br>W<br>tungsten<br>183.8   | 75<br>Re<br>rhenium<br>186.2  | 76<br>Os<br>osmium<br>190.2    | 77<br>Ir<br>iridium<br>192.2 | 78<br>Pt<br>platinum<br>195.1  | 79<br>Au<br>gold<br>197.0     | 80<br>Hg<br>mercury<br>200.6  | 81<br>Tl<br>thallium<br>204.4 | 82<br>Pb<br>lead<br>207.2     | 83<br>Bi<br>bismuth<br>209.0  | 84<br>Po<br>polonium<br>—      | 85<br>At<br>astatine<br>—    | 86<br>Rn<br>radon<br>—      |                               |                             |                               |                           |                              |                           |
| 87<br>Fr<br>francium<br>—    | 88<br>Ra<br>radium<br>—       | 89–103<br>actinoids                                            | 104<br>Rf<br>rutherfordium<br>— | 105<br>Db<br>dubnium<br>—     | 106<br>Sg<br>seaborgium<br>—   | 107<br>Bh<br>bohrium<br>—     | 108<br>Hs<br>hassium<br>—      | 109<br>Mt<br>meitnerium<br>— | 110<br>Ds<br>darmstadtium<br>— | 111<br>Rg<br>roentgenium<br>— | 112<br>Cn<br>copernicium<br>— | 113<br>Nh<br>nihonium<br>—    | 114<br>Fl<br>flerovium<br>—   | 115<br>Mc<br>moscovium<br>—   | 116<br>Lv<br>livermorium<br>—  | 117<br>Ts<br>tennessine<br>— | 118<br>Og<br>oganesson<br>— |                               |                             |                               |                           |                              |                           |

|             |           |         |              |           |            |           |           |            |           |             |             |         |             |           |            |  |  |
|-------------|-----------|---------|--------------|-----------|------------|-----------|-----------|------------|-----------|-------------|-------------|---------|-------------|-----------|------------|--|--|
| lanthanoids |           |         |              |           |            |           |           |            |           |             |             |         |             |           |            |  |  |
| 57          | La        | Ce      | Pr           | Nd        | Pm         | Sm        | Eu        | Gd         | Tb        | Dy          | Ho          | Er      | Tm          | Yb        | Lu         |  |  |
|             | lanthanum | cerium  | praseodymium | neodymium | promethium | samarium  | euroium   | 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      |  |  |
| actinoids   |           |         |              |           |            |           |           |            |           |             |             |         |             |           |            |  |  |
| 89          | 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     |            |           |           |            |           |             |             |         |             |           |            |  |  |