



Cambridge International AS & A Level

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CHEMISTRY

9701/33

Paper 3 Advanced Practical Skills 1

February/March 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 In this experiment you will carry out a titration to identify the Group 1 metal, **M**, present in a metal hydrogencarbonate, **MHCO₃**.

FA 1 is 0.0550 mol dm⁻³ sulfuric acid, H₂SO₄.

FA 2 is the metal hydrogencarbonate, **MHCO₃**.
bromophenol blue indicator

(a) Method

Preparing a solution of **FA 2**

- Weigh the stoppered container of **FA 2**. Record the mass in the space below.
- Tip all the **FA 2** into the beaker.
- Reweigh the container with its stopper. Record the mass.
- Calculate and record the mass of **FA 2** used.
- Add approximately 100 cm³ of distilled water to **FA 2** in the beaker.
- Stir the mixture with a glass rod until all the **FA 2** has dissolved.
- Transfer this solution into the 250 cm³ 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 **MHCO₃** is **FA 3**. Label the flask **FA 3**.

Titration

- Fill the burette with **FA 1**.
- Pipette 25.0 cm³ of **FA 3** into a conical flask.
- Add a few drops of bromophenol blue indicator to the conical flask.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm³.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 1** added in each accurate titration.

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

[8]

- (b) From your accurate titration results, obtain a suitable value for the volume of **FA 1** to be used in your calculations.
Show clearly how you obtained this value.

25.0 cm³ of **FA 3** required cm³ of **FA 1**. [1]

(c) Calculations

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

moles of H₂SO₄ = mol [1]

- (iii) Complete the equation for the reaction of sulfuric acid and **MHCO₃**.
State symbols are not required.



Use your answer to (c)(ii) to deduce the number of moles of **MHCO₃** used in each titration.

moles of **MHCO₃** = mol [1]

- (iv) Use your answer to (c)(iii) and your data on page 2 to calculate the relative formula mass, M_r , of MHCO_3 .

M_r of $\text{MHCO}_3 = \dots\dots\dots$ [1]

- (v) Calculate the relative atomic mass, A_r , of **M**.

A_r of **M** = $\dots\dots\dots$

Suggest the identity of **M**.

M is $\dots\dots\dots$.
[1]

- (d) (i) A student used a pipette that was labelled $25.0 \pm 0.06 \text{ cm}^3$ to measure **FA 3**.

Show how you calculate the maximum percentage error in the volume of **FA 3**.

[1]

- (ii) The student suggested that it would have been more accurate to measure the volume of **FA 3** with a burette instead of the pipette.

State and explain whether you agree with the student.

$\dots\dots\dots$
 $\dots\dots\dots$ [1]

[Total: 16]

- 2 In this experiment you will determine the relative formula mass of the same metal hydrogencarbonate, MHCO_3 , by thermal decomposition. Then you will compare the result obtained with your answer from 1(c)(iv).

FA 4 is another sample of the metal hydrogencarbonate, MHCO_3 .

(a) Method

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

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

- When the crucible has cooled, weigh the crucible with its lid and contents. Record the mass.
- Heat strongly, with the lid off, for a further two minutes.
- Replace the lid and leave the crucible to cool for at least five minutes.
- When the crucible has cooled, reweigh the crucible with its lid and contents. Record the mass.
- Calculate and record the mass of residue obtained.
- This residue is **FA 5**.

Keep FA 5 for use in 2(b)(i).

Results

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

[5]

- (b) (i)** Pour a 1 cm depth of dilute hydrochloric acid into a test-tube. Add a spatula measure of residue **FA 5** to the acid.

Record **all** your observations and identify any gas formed.

.....

 [2]

- (ii) Use your observations in **(b)(i)** to identify the anion in **FA 5**. Assume all the MHCO_3 has decomposed.

Anion in **FA 5** is [1]

- (iii) Steam is produced when the metal hydrogencarbonate, **FA 4**, is thermally decomposed.

Use your answer in **(b)(ii)** to complete the equation for the thermal decomposition of MHCO_3 . Include state symbols.



- (iv) The number of moles of carbon dioxide given off during the thermal decomposition is given by the formula below.

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

Calculate the number of moles of carbon dioxide given off.

moles CO_2 = mol [1]

- (v) Calculate the relative formula mass, M_r , of MHCO_3 .

Show how you obtained your answer using your data from **Question 2**.

M_r of MHCO_3 = [1]

- (vi) You have obtained two values for the M_r of MHCO_3 ; one in **1(c)(iv)** and another in **2(b)(v)**.

State which value is likely to be more accurate. Explain your answer in terms of the practical procedures used.

The M_r obtained in Question is more accurate.

reason

.....

..... [1]

[Total: 12]

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 6** contains one cation and one anion both of which are listed in the Qualitative analysis notes.

- (i) Heat **FA 6** gently for one minute in the hard-glass test-tube in which it is supplied. Then heat strongly until no further change occurs.

Record **all** of your observations.

.....

.....

.....

.....

.....

..... [2]

- (ii) Identify the ion that **must** be present in **FA 6**.

..... [1]

- (b) (i) **FA 7** and **FA 8** are aqueous solutions. Each solution contains one cation and one anion both of which are listed in the Qualitative analysis notes. Use 1 cm depths of **FA 7** or **FA 8** in test-tubes for the following tests. Complete the table by recording your observations.

| <i>test</i> | <i>observations</i> | |
|--|---------------------|-------------|
| | FA 7 | FA 8 |
| Test 1 Add a few drops of aqueous acidified potassium manganate(VII), then ----- add a few drops of starch indicator. | | |
| Test 2 Add a few drops of aqueous silver nitrate, then ----- add aqueous ammonia. | | |
| Test 3 Add aqueous sodium hydroxide, then ----- pour the mixture into a boiling tube. Warm gently and carefully , then ----- add a piece of aluminium foil. | | |
| Test 4 Add a few drops of dilute sulfuric acid. | | |

[6]

- (ii) Deduce the chemical formulae of **FA 7** and **FA 8**.

FA 7 is and **FA 8** is [2]

- (iii) Give the ionic equation for the reaction of **FA 8** with sulfuric acid. Include state symbols.

..... [1]

[Total: 12]

Qualitative analysis notes

1 Reactions of aqueous cations

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

2 Reactions of anions

| <i>ion</i> | <i>reaction</i> |
|---|---|
| carbonate, CO_3^{2-} | CO_2 liberated by dilute acids |
| chloride, $\text{Cl}^-(\text{aq})$ | gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$) |
| bromide, $\text{Br}^-(\text{aq})$ | gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$) |
| iodide, $\text{I}^-(\text{aq})$ | gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$) |
| nitrate, $\text{NO}_3^-(\text{aq})$ | NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil |
| nitrite, $\text{NO}_2^-(\text{aq})$ | NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil |
| sulfate, $\text{SO}_4^{2-}(\text{aq})$ | gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids) |
| sulfite, $\text{SO}_3^{2-}(\text{aq})$ | gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids) |

3 Tests for gases

| <i>gas</i> | <i>test and test result</i> |
|-------------------------------|---|
| ammonia, NH_3 | turns damp red litmus paper blue |
| carbon dioxide, CO_2 | gives a white ppt. with limewater (ppt. dissolves with excess CO_2) |
| chlorine, Cl_2 | bleaches damp litmus paper |
| hydrogen, H_2 | 'pops' with a lighted splint |
| oxygen, O_2 | relights a glowing splint |

