READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Give details of the practical session and laboratory where appropriate, in the boxes provided.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO NOT WRITE IN ANY BARCODES.

Answer all questions.
Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.
Use of a Data Booklet is unnecessary.

Qualitative Analysis Notes are printed on pages 10 and 11.
A copy of the Periodic Table is printed on page 12.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.
In Questions 1 and 2 you will determine the percentage purity of industrial grade calcium carbonate, CaCO₃, by two different methods.

In the first method you will collect and measure the volume of gas given off in the reaction between a known mass of industrial grade calcium carbonate, in the form of small marble chips, and a known amount of dilute hydrochloric acid. The acid will be in excess. The impurities in the calcium carbonate will not react with the acid.

\[
\text{CaCO}_3(s) + 2\text{HCl(aq)} \rightarrow \text{CaCl}_2(aq) + \text{H}_2\text{O(l)} + \text{CO}_2(g)
\]

FA 1 is industrial grade calcium carbonate, CaCO₃, in the form of small marble chips. FA 2 is 2.00 mol dm⁻³ hydrochloric acid, HCl.

(a) Method

Read through the whole method before starting any practical work.

The diagram below may help you in setting up your apparatus.

- Fill the tub with water to a depth of about 5 cm.
- Fill the 250 cm³ measuring cylinder **completely** with water. Hold a piece of paper towel firmly over the top, invert the measuring cylinder and place it in the water in the tub.
- Remove the paper towel and clamp the inverted measuring cylinder so the open end is in the water just above the base of the tub.
- Pipette 25.0 cm³ of FA 2 into the reaction flask labelled X.
- Check that the bung fits tightly in the neck of flask X, clamp flask X and place the end of the delivery tube into the inverted 250 cm³ measuring cylinder.
- Weigh the container with FA 1 and record the mass in the space on page 3.
- Remove the bung from the neck of the flask. Tip FA 1 into the acid and replace the bung **immediately**. Remove the flask from the clamp and swirl it to mix the contents. Swirl the flask occasionally until no more gas is evolved. Replace the flask in the clamp.
- Reweigh the container and any residue of FA 1 and record the mass in the space on page 3.
- Calculate and record in the space on page 3 the mass of FA 1 used.
- When no more gas is given off, measure and record the final volume of gas in the measuring cylinder in the space on page 3.

**Keep the contents of flask X for use in Question 2.**
Results

(b) Calculations

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

(i) Calculate the number of moles of carbon dioxide gas collected in the measuring cylinder. (Assume that 1 mole of gas occupies 24.0 dm$^3$ under these conditions.)

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

(ii) Use your answer to (i) and the Periodic Table on page 12 to calculate the mass of pure calcium carbonate in the sample of industrial grade calcium carbonate, FA 1.

$$\text{mass of CaCO}_3 = \text{.......... g}$$

(iii) Use your answer to (ii) and the mass of marble chips used in (a) to calculate a value for the percentage purity of the sample of industrial grade calcium carbonate, FA 1.

$$\text{percentage purity of FA 1} = \text{.......... %}$$

(c) Not all the carbon dioxide given off in the reaction is collected in the measuring cylinder.

Suggest a change to the method which would lead to an increase in the volume of carbon dioxide collected.

....................................................................................................................................................
...............................................................................................................................................  [1]
2 You will determine the amount of hydrochloric acid remaining in flask X after the reaction with the marble chips in Question 1. You will do this by titration with sodium hydroxide of known concentration.

\[ \text{NaOH(aq)} + \text{HCl(aq)} \rightarrow \text{NaCl(aq)} + \text{H}_2\text{O(l)} \]

The impurities in the calcium carbonate will not react with the alkali.

**FA 3** is 0.140 mol dm\(^{-3}\) sodium hydroxide, NaOH.

bromophenol blue indicator

(a) Method

- Transfer all the contents of flask X into the 250 cm\(^3\) volumetric flask.
- Rinse flask X with distilled water and add the washings to the volumetric flask. Add distilled water up to the mark.
- Stopper the volumetric flask and mix the contents thoroughly. Label this solution FA 4.
- Rinse the pipette then use it to transfer 25.0 cm\(^3\) of FA 4 into a conical flask.
- Add about 10 drops of bromophenol blue indicator.
- Fill the burette with FA 3.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is ......................... cm\(^3\).

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

(b) From your accurate titration results, obtain a suitable value for the volume of FA 3 to be used in your calculations. Show clearly how you obtained this value.

25.0 cm\(^3\) of FA 4 required ......................... cm\(^3\) of FA 3. [1]
(c) Calculations

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

(i)  Calculate the number of moles of sodium hydroxide, NaOH, present in the volume of FA 3 you calculated in (b).

moles of NaOH = ......................... mol

(ii) Use your answer to (i) and the equation on page 4 to determine the number of moles of hydrochloric acid, HCl, present in the 25.0 cm$^3$ of FA 4 pipetted in (a).

moles of HCl = ......................... mol

(iii) Use your answer to (ii) to calculate the number of moles of hydrochloric acid, HCl, remaining in flask X after the reaction in 1(a).

moles of HCl remaining = ......................... mol

(iv) Use the relevant information on page 2 to calculate the number of moles of hydrochloric acid, HCl, pipetted into flask X in 1(a).

moles of HCl pipetted into flask X = ......................... mol

(v) Use your answers to (iii) and (iv) to calculate the number of moles of hydrochloric acid, HCl, which reacted with the marble chips in flask X.

moles of HCl which reacted in flask X = ......................... mol
(vi) Use your answer to (v), the equation in **Question 1** and the Periodic Table on page 12 to calculate the mass of pure calcium carbonate, CaCO₃, in the sample of industrial grade calcium carbonate, FA 1.

mass of CaCO₃ = ......................... g

(vii) Use your answer to (vi) and the mass of marble chips recorded in 1(a) to calculate the percentage purity of FA 1.

percentage purity of FA 1 = ......................... %

[d] You have carried out two different methods to find the percentage purity of industrial grade calcium carbonate.

A source of error in **Question 1** is that some carbon dioxide escapes before the bung can be inserted.

How would this affect the percentage purity of FA 1 calculated in the two questions? Explain your answers.

**Question 1**

....................................................................................................................................................
....................................................................................................................................................
....................................................................................................................................................

**Question 2**

....................................................................................................................................................
....................................................................................................................................................
....................................................................................................................................................

[3]

[Total: 16]
3 Qualitative Analysis

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

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs. **No additional tests for ions present should be attempted.**

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

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

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

(a) **FA 5** and **FA 6** are solids each containing one cation and one anion. Carry out the following tests and record your observations in the table below.

<table>
<thead>
<tr>
<th>test</th>
<th>observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i)</td>
<td></td>
</tr>
</tbody>
</table>

Place a spatula measure of solid in a hard-glass test-tube and heat gently at first, then heat strongly until no further change takes place.

Leave the tube to cool completely then add a 2 cm depth of dilute sulfuric acid to the solid residue. Shake the contents of the tube then leave it to stand.
<table>
<thead>
<tr>
<th>test</th>
<th>observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>(ii) Place a spatula measure of solid in a boiling tube and add a 2 cm depth of dilute sulfuric acid.</td>
<td></td>
</tr>
<tr>
<td>(iii) To a 1 cm depth of solution from (ii) in a test-tube, add aqueous sodium hydroxide.</td>
<td></td>
</tr>
<tr>
<td>(iv) To a 1 cm depth of solution from (ii) in a test-tube, add aqueous ammonia.</td>
<td></td>
</tr>
</tbody>
</table>

Keep the solutions formed in (ii) for tests (iii) and (iv).

(v) Identify as many ions as you can from your observations. Write ‘unknown’ where you have not been able to identify an ion.

**FA 5:** cation ...................................................... anion ......................................................

**FA 6:** cation ...................................................... anion ......................................................

(vi) Write an equation, including state symbols, for the reaction between **FA 6** and dilute sulfuric acid.

.............................................................................................................................................
(b) **FA 7** is a solution containing one anion from those listed on page 11. The anion is either a halide or contains nitrogen.

(i) You are to select suitable reagents to determine the identity of this anion. Record these in a suitable form below.

(ii) Use these reagents to carry out tests to identify the anion in **FA 7**.

Record your observations and conclusions in the space below.
**Qualitative Analysis Notes**

**Key:** \( [ppt. = precipitate] \)

### 1 REACTIONS OF AQUEOUS CATIONS

<table>
<thead>
<tr>
<th>ion ( \text{ion} )</th>
<th>( \text{reaction with} ) ( \text{NaOH(aq)} )</th>
<th>( \text{NH}_3\text{(aq)} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>aluminium, ( \text{Al}^{3+}\text{(aq)} )</td>
<td>white ppt. soluble in excess</td>
<td>white ppt. insoluble in excess</td>
</tr>
<tr>
<td>ammonium, ( \text{NH}_4^+\text{(aq)} )</td>
<td>no ppt. ammonia produced on heating</td>
<td>–</td>
</tr>
<tr>
<td>barium, ( \text{Ba}^{2+}\text{(aq)} )</td>
<td>no ppt. (if reagents are pure)</td>
<td>no ppt.</td>
</tr>
<tr>
<td>calcium, ( \text{Ca}^{2+}\text{(aq)} )</td>
<td>white ppt. with high [( \text{Ca}^{2+}\text{(aq)} )]</td>
<td>no ppt.</td>
</tr>
<tr>
<td>chromium(III), ( \text{Cr}^{3+}\text{(aq)} )</td>
<td>grey-green ppt. soluble in excess</td>
<td>grey-green ppt. insoluble in excess</td>
</tr>
<tr>
<td>copper(II), ( \text{Cu}^{2+}\text{(aq)} )</td>
<td>pale blue ppt. insoluble in excess</td>
<td>blue ppt. soluble in excess giving dark blue solution</td>
</tr>
<tr>
<td>iron(II), ( \text{Fe}^{2+}\text{(aq)} )</td>
<td>green ppt. turning brown on contact with air insoluble in excess</td>
<td>green ppt. turning brown on contact with air insoluble in excess</td>
</tr>
<tr>
<td>iron(III), ( \text{Fe}^{3+}\text{(aq)} )</td>
<td>red-brown ppt. insoluble in excess</td>
<td>red-brown ppt. insoluble in excess</td>
</tr>
<tr>
<td>magnesium, ( \text{Mg}^{2+}\text{(aq)} )</td>
<td>white ppt. insoluble in excess</td>
<td>white ppt. insoluble in excess</td>
</tr>
<tr>
<td>manganese(II), ( \text{Mn}^{2+}\text{(aq)} )</td>
<td>off-white ppt. rapidly turning brown on contact with air insoluble in excess</td>
<td>off-white ppt. rapidly turning brown on contact with air insoluble in excess</td>
</tr>
<tr>
<td>zinc, ( \text{Zn}^{2+}\text{(aq)} )</td>
<td>white ppt. soluble in excess</td>
<td>white ppt. soluble in excess</td>
</tr>
</tbody>
</table>
2 Reactions of anions

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

3 Tests for gases

<table>
<thead>
<tr>
<th>gas</th>
<th>test and test result</th>
</tr>
</thead>
<tbody>
<tr>
<td>ammonia, NH$_3$</td>
<td>turns damp red litmus paper blue</td>
</tr>
<tr>
<td>carbon dioxide,</td>
<td>gives a white ppt. with limewater (ppt. dissolves with excess CO$_2$)</td>
</tr>
<tr>
<td>CO$_2$</td>
<td></td>
</tr>
<tr>
<td>chlorine, Cl$_2$</td>
<td>bleaches damp litmus paper</td>
</tr>
<tr>
<td>hydrogen, H$_2$</td>
<td>“pops” with a lighted splint</td>
</tr>
<tr>
<td>oxygen, O$_2$</td>
<td>relights a glowing splint</td>
</tr>
</tbody>
</table>
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The Periodic Table of Elements

<table>
<thead>
<tr>
<th>Group</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H</td>
<td>He</td>
<td>Li</td>
<td>Be</td>
<td>B</td>
<td>C</td>
<td>N</td>
<td>O</td>
<td>F</td>
<td>Ne</td>
<td>Na</td>
<td>Mg</td>
<td>Al</td>
<td>Si</td>
<td>P</td>
<td>S</td>
<td>Cl</td>
<td>Ar</td>
</tr>
<tr>
<td>atomic number</td>
<td>1.0</td>
<td>4.0</td>
<td>6.9</td>
<td>9.0</td>
<td>10.8</td>
<td>12.0</td>
<td>14.0</td>
<td>16.0</td>
<td>19.0</td>
<td>20.2</td>
<td>23.0</td>
<td>24.3</td>
<td>27.0</td>
<td>28.1</td>
<td>31.0</td>
<td>32.1</td>
<td>35.5</td>
<td>39.9</td>
</tr>
<tr>
<td>name</td>
<td>hydrogen</td>
<td>helium</td>
<td>lithium</td>
<td>beryllium</td>
<td>boron</td>
<td>carbon</td>
<td>nitrogen</td>
<td>oxygen</td>
<td>fluorine</td>
<td>neon</td>
<td>sodium</td>
<td>magnesium</td>
<td>aluminium</td>
<td>silicon</td>
<td>phosphorus</td>
<td>sulphur</td>
<td>chlorine</td>
<td>argon</td>
</tr>
<tr>
<td>atomic symbol</td>
<td>H</td>
<td>He</td>
<td>Li</td>
<td>Be</td>
<td>B</td>
<td>C</td>
<td>N</td>
<td>O</td>
<td>F</td>
<td>Ne</td>
<td>Na</td>
<td>Mg</td>
<td>Al</td>
<td>Si</td>
<td>P</td>
<td>S</td>
<td>Cl</td>
<td>Ar</td>
</tr>
<tr>
<td>relative atomic mass</td>
<td>1.0</td>
<td>4.0</td>
<td>6.9</td>
<td>9.0</td>
<td>10.8</td>
<td>12.0</td>
<td>14.0</td>
<td>16.0</td>
<td>19.0</td>
<td>20.2</td>
<td>23.0</td>
<td>24.3</td>
<td>27.0</td>
<td>28.1</td>
<td>31.0</td>
<td>32.1</td>
<td>35.5</td>
<td>39.9</td>
</tr>
</tbody>
</table>

Key

- **Group 1**: Hydrogen (H) and Helium (He)
- **Group 2**: Lithium (Li) to Argon (Ar)
- **Group 3**: Boron (B) to Copper (Cu)
- **Group 4**: Nitrogen (N) to Zinc (Zn)
- **Group 5**: Oxygen (O) to Mercury (Hg)
- **Group 6**: Fluorine (F) to Barium (Ba)
- **Group 7**: Neon (Ne) to Actinium (Ac)

**Periodic Table Elements**

- **Lanthanoids (La to Lu)**: Elements 57 to 71
- **Actinoids (Ac to Lr)**: Elements 89 to 103

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