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.
Borax is an alkali which has many uses. In this experiment you will determine $x$ in the chemical formula of borax, $\text{Na}_2\text{B}_x\text{O}_7.10\text{H}_2\text{O}$, by titration with hydrochloric acid.

$\text{FB 1}$ is a solution containing 15.5 g dm$^{-3}$ of borax, $\text{Na}_2\text{B}_x\text{O}_7.10\text{H}_2\text{O}$.  
$\text{FB 2}$ is 2.00 mol dm$^{-3}$ hydrochloric acid, $\text{HCl}$.

(a) Method

Dilution of $\text{FB 2}$

- Pipette $10.0 \text{ cm}^3$ of $\text{FB 2}$ into the 250 cm$^3$ volumetric flask.
- Make the solution up to 250 cm$^3$ using distilled water.
- Shake the solution in the volumetric flask thoroughly.
- This diluted solution of hydrochloric acid is $\text{FB 3}$. Label the volumetric flask $\text{FB 3}$.

Titration

- Fill the burette with $\text{FB 3}$.
- Pipette $25.0 \text{ cm}^3$ of $\text{FB 1}$ into a conical flask.
- Add several drops of methyl orange.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is ..................... cm$^3$.

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

(b) From your accurate titration results, obtain a suitable value for the volume of $\text{FB 3}$ to be used in your calculations.

Show clearly how you obtained this value.

25.0 cm$^3$ of $\text{FB 1}$ required ..................... cm$^3$ of $\text{FB 3}$. [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 hydrochloric acid present in the volume of FB 3 calculated in (b).

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

(ii) 1 mole of borax is neutralised by 2 moles of hydrochloric acid.
Calculate the number of moles of borax that react with the hydrochloric acid in (i).

\[
\text{moles of borax} = \text{.................. mol}
\]

(iii) Use your answer to (ii) to calculate the number of moles of borax in 1.00 dm\(^3\) of FB 1.

\[
\text{moles of borax in } 1.00 \text{ dm}^3 \text{ FB 1} = \text{.................. mol}
\]

(iv) Use your answer to (iii) and the information on page 2 to calculate the relative formula mass, \(M_r\), of borax.

\[
M_r \text{ of borax} = \text{..................}
\]

(v) Calculate \(x\) in the formula of borax, \(\text{Na}_2\text{B}_x\text{O}_7\cdot10\text{H}_2\text{O}\).
Use data from the Periodic Table on page 12.

\[
\text{x} = \text{..................} \quad [5]
\]

[Total: 13]
Some metal carbonates cannot be obtained in a pure state. For example magnesium carbonate exists in a ‘basic’ form, in which magnesium hydroxide is also present.

One possible chemical formula of basic magnesium carbonate is \( \text{MgCO}_3 \cdot \text{Mg(OH)}_2 \cdot 2\text{H}_2\text{O} \).

When basic magnesium carbonate is heated, if the possible formula were correct, it would decompose as shown below.

\[
\text{MgCO}_3 \cdot \text{Mg(OH)}_2 \cdot 2\text{H}_2\text{O} \rightarrow 2\text{MgO} + \text{CO}_2 + 3\text{H}_2\text{O}
\]

In this experiment, you will decompose basic magnesium carbonate by heating it, and you will use your results to determine whether this possible formula is correct.

**FB 4** is basic magnesium carbonate.

(a) **Method**

Read through the method before starting any practical work and prepare a table for your results in the space below.

- Weigh a crucible with its lid and record the mass.
- Add 1.1-1.3 g of **FB 4** to the crucible. Weigh the crucible and lid with **FB 4** and record the mass.
- Place the crucible on the pipe-clay triangle and remove the lid.
- Heat the crucible and contents **gently** for about one minute.
- Then heat the crucible and contents strongly for about four minutes.
- Replace the lid and allow the crucible to cool for at least five minutes.
- **While the crucible is cooling, you may wish to begin work on Question 3.**
- Re-weigh the crucible and contents with lid. Record the mass.
- Calculate, and record, the mass of **FB 4** used and the mass of residue obtained.
(b) Calculations

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

(i) Use your results to calculate the number of moles of magnesium oxide, MgO, obtained as residue.

moles of MgO obtained = ......................... mol

(ii) Use your answer to (i), with the equation on page 4 and the mass of FB 4 you used, to calculate the relative formula mass, \( M_r \), of basic magnesium carbonate.

\[ M_r \text{ of basic magnesium carbonate (from experiment)} = \ldots \]

(iii) Use data from the Periodic Table to calculate the relative formula mass, \( M_r \), of basic magnesium carbonate from its possible formula, MgCO\(_3\).Mg(OH)\(_2\).2H\(_2\)O.

\[ M_r \text{ of basic magnesium carbonate (from formula)} = \ldots \]

(iv) If the relative formula mass of basic magnesium carbonate obtained from your experiment is within 2.5% of the answer in (iii), this is good evidence that the possible formula, MgCO\(_3\).Mg(OH)\(_2\).2H\(_2\)O, is correct. Does your experiment support the possible formula? Give a reason for your answer.

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

[5]
(c) **Evaluation**

(i) **State one way in which the accuracy of the experimental procedure could have been improved using the same mass of FB 4.**

Explain your answer.

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

(ii) A student carried out the experiment twice using different masses of FB 4. He used the mean mass of FB 4 and the mean mass of magnesium oxide obtained to calculate the relative formula mass of basic magnesium carbonate.

Instead of doing this, he could have calculated the relative formula mass of basic magnesium carbonate from his two experiments separately.

Suggest **one** advantage of carrying out separate calculations for each experiment.

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

(iii) **State the error when making one reading on your balance.**

\[
\text{error} = .................. \text{ g}
\]

Calculate the maximum percentage error in the mass of FB 4 used.

\[
\text{percentage error} = .................. \% \quad [4]
\]

[Total: 14]
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) FB 5, FB 6 and FB 7 are solutions, each of which contain one cation and one anion. The anions present are all listed on page 11. Use a 1 cm depth of these solutions in a test-tube for each of the following tests. Complete the table below.

<table>
<thead>
<tr>
<th>test</th>
<th>observations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FB 5</td>
</tr>
<tr>
<td>Add a 2 cm strip of magnesium ribbon.</td>
<td></td>
</tr>
<tr>
<td>Add aqueous sodium hydroxide.</td>
<td></td>
</tr>
<tr>
<td>Add an equal depth of aqueous potassium iodide.</td>
<td></td>
</tr>
<tr>
<td>Add a few drops of FB 5.</td>
<td>X</td>
</tr>
</tbody>
</table>
(b) (i) From the observation made when potassium iodide was added to FB 6, suggest the identity of the cation in FB 6. Explain your conclusion.

cation in FB 6 ....................................................................................................................

explanation ..........................................................................................................................

(ii) FB 5 gives no precipitate when aqueous ammonia is added. Suggest the identities of both ions in FB 5.

cation in FB 5 ........................................
anion in FB 5 .................................

(iii) Identify FB 7.

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

(iv) Give the ionic equation for the reaction between magnesium and FB 7.

.............................................................................................................................................[4]

(c) FB 8 is a solid. Carry out the following tests on FB 8. Record your observations in each test.

(i) Heat a small spatula measure of FB 8 gently in a hard-glass test-tube.

observations .......................................................................................................................[4]

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

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

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

(ii) To a 1 cm depth of hydrochloric acid in a test-tube, add a small spatula measure of FB 8.

observations .......................................................................................................................[4]

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

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

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

(iii) What conclusions, if any, can you make about the identities of the ions in FB 8?

cation in FB 8 .................................
anion in FB 8 ................................. [4]

[Total: 13]
## Qualitative Analysis Notes

### Key: \([\text{ppt.} = \text{precipitate}]\)

### 1 Reactions of aqueous cations

<table>
<thead>
<tr>
<th>ion</th>
<th>reaction with NaOH(aq)</th>
<th>reaction with NH₃(aq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>aluminium, Al³⁺(aq)</td>
<td>white ppt. soluble in excess</td>
<td>white ppt. insoluble in excess</td>
</tr>
<tr>
<td>ammonium, NH₄⁺(aq)</td>
<td>no ppt. ammonia produced on heating</td>
<td>–</td>
</tr>
<tr>
<td>barium, Ba²⁺(aq)</td>
<td>faint white ppt. is nearly always observed unless reagents are pure</td>
<td>no ppt.</td>
</tr>
<tr>
<td>calcium, Ca²⁺(aq)</td>
<td>white ppt. with high [Ca²⁺(aq)]</td>
<td>no ppt.</td>
</tr>
<tr>
<td>chromium(III), Cr³⁺(aq)</td>
<td>grey-green ppt. soluble in excess giving dark green solution</td>
<td>grey-green ppt. insoluble in excess</td>
</tr>
<tr>
<td>copper(II), Cu²⁺(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), Fe²⁺(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), Fe³⁺(aq)</td>
<td>red-brown ppt. insoluble in excess</td>
<td>red-brown ppt. insoluble in excess</td>
</tr>
<tr>
<td>magnesium, Mg²⁺(aq)</td>
<td>white ppt. insoluble in excess</td>
<td>white ppt. insoluble in excess</td>
</tr>
<tr>
<td>manganese(II), Mn²⁺(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, Zn²⁺(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, $\text{CO}_3^{2-}$</td>
<td>$\text{CO}_2$ liberated by dilute acids</td>
</tr>
<tr>
<td>chloride, $\text{Cl}^-$ (aq)</td>
<td>gives white ppt. with Ag⁺(aq) (soluble in NH₃(aq))</td>
</tr>
<tr>
<td>bromide, $\text{Br}^-$ (aq)</td>
<td>gives cream ppt. with Ag⁺(aq) (partially soluble in NH₃(aq))</td>
</tr>
<tr>
<td>iodide, $\text{I}^-$ (aq)</td>
<td>gives yellow ppt. with Ag⁺(aq) (insoluble in NH₃(aq))</td>
</tr>
<tr>
<td>nitrate, $\text{NO}_3^-$ (aq)</td>
<td>NH₃ liberated on heating with OH⁻(aq) and Al foil</td>
</tr>
<tr>
<td>nitrite, $\text{NO}_2^-$ (aq)</td>
<td>NH₃ liberated on heating with OH⁻(aq) and Al foil; NO liberated by dilute acids (colourless NO → (pale) brown NO₂ in air)</td>
</tr>
<tr>
<td>sulfate, $\text{SO}_4^{2-}$ (aq)</td>
<td>gives white ppt. with Ba²⁺(aq) (insoluble in excess dilute strong acids)</td>
</tr>
<tr>
<td>sulfite, $\text{SO}_3^{2-}$ (aq)</td>
<td>gives white ppt. with Ba²⁺(aq) (soluble in excess dilute strong acids)</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, NH₃</td>
<td>turns damp red litmus paper blue</td>
</tr>
<tr>
<td>carbon dioxide, CO₂</td>
<td>gives a white ppt. with limewater (ppt. dissolves with excess CO₂)</td>
</tr>
<tr>
<td>chlorine, Cl₂</td>
<td>bleaches damp litmus paper</td>
</tr>
<tr>
<td>hydrogen, H₂</td>
<td>“pops” with a lighted splint</td>
</tr>
<tr>
<td>oxygen, O₂</td>
<td>relights a glowing splint</td>
</tr>
</tbody>
</table>
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>
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<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
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<tbody>
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<tr>
<td>3</td>
<td>Li</td>
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<td>B</td>
<td>C</td>
<td>N</td>
<td>O</td>
<td>F</td>
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<td>Kr</td>
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<td>Zr</td>
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</tr>
</tbody>
</table>

**Key**
- Atomic number
- Atomic symbol
- Name
- Relative atomic mass

**Table Notes**
- The table includes elements from groups 1 to 18.
- Each element is listed with its atomic number, atomic symbol, name, and relative atomic mass.
- The table is color-coded for easy identification.

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