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.
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 determine the percentage purity of a sample of impure anhydrous sodium carbonate. You will use two different methods to measure the enthalpy change of reaction when a sample of impure anhydrous sodium carbonate reacts with excess dilute hydrochloric acid.

FA 1 is a sample of the impure anhydrous sodium carbonate.
FA 2 is 2.00 mol dm⁻³ hydrochloric acid, HCl.
FA 3 is a second sample of the impure anhydrous sodium carbonate used in FA 1.

(a) Method 1

- Weigh the container with FA 1. Record this mass.

\[
\text{mass of container with FA 1} = \text{......................... g}
\]

- Support one of the plastic cups in the 250 cm³ beaker.
- Use the measuring cylinder to place 25 cm³ of FA 2 into the cup.
- Measure the temperature of the FA 2 in the cup. Tilt the cup if necessary so that the bulb of the thermometer is fully covered. Record this temperature at time \( t = 0 \).
- Start the stopwatch and leave it running for the whole experiment.
- Measure and record the temperature of FA 2 in the cup every half minute for 2 minutes.
- At \( t = 2\frac{1}{2} \) minutes tip all the FA 1 into the cup. Stir the contents of the cup.
- Measure and record the temperature of the contents of the cup at \( t = 3 \) minutes and then every half minute up to \( t = 9 \) minutes.
- Weigh the container with any residual FA 1. Record this mass.

\[
\text{mass of container with residual FA 1} = \text{......................... g}
\]

(b) (i) On the grid on page 3, plot a graph of temperature (y-axis) against time (x-axis). You should choose a scale that allows you to plot \( 2^\circ \text{C} \) above the maximum temperature reached.

On your graph, draw two straight lines of best fit. One line is for the temperature before adding FA 1 and the other line for the cooling of the solution once reaction is complete.

Extrapolate these two lines to \( t = 2\frac{1}{2} \) minutes.

\[\text{[4]}\]
(ii) From your graph, find the theoretical temperature rise at $t = 2\frac{1}{2}$ minutes.

theoretical temperature rise = ......................... °C [1]
(c) (i) Calculate the energy released in the reaction.

(Assume 4.2 J of heat energy changes the temperature of 1.0 cm$^3$ of solution by 1.0 $^\circ$C.)

energy released = ........................................ J [1]

(ii) The equation for the reaction between anhydrous sodium carbonate and hydrochloric acid is shown.

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

The literature value for the enthalpy change of this reaction is $-27.0 \text{kJ mol}^{-1}$.

Use this figure, and the value that you found in (i), to find the mass of anhydrous sodium carbonate you used in (a). You should assume that no energy was lost to the surroundings in your experiment.

mass Na$_2$CO$_3$ = ........................................ g [2]

(iii) Calculate the percentage of anhydrous sodium carbonate present in FA 1.

percentage Na$_2$CO$_3$ in FA 1 = ........................................ % [1]

(d) In your calculation in (c), what assumption have you made about the impurity present in FA 1?

....................................................................................................................................................
........................................................................................................................................................ [1]
(e) Method 2

- Weigh a clean, dry plastic cup and record the mass.
- Add between 1.70 g and 1.90 g of FA 3 to the plastic cup and record the mass.
- Support the plastic cup in the 250 cm³ beaker.
- Pour 25 cm³ of FA 2 into the measuring cylinder.
- Measure and record the initial temperature of FA 2 in the measuring cylinder.
- Pour the 25 cm³ of FA 2 into the plastic cup.
- Stir the contents of the cup and record the maximum temperature. Tilt the cup if necessary so that the bulb of the thermometer is fully covered.
- Calculate and record the mass of FA 3 used and the change in temperature.

(f) Use the temperature rise in (e), and the fact that the enthalpy change for the reaction between anhydrous sodium carbonate and hydrochloric acid is –27.0 kJ mol⁻¹, to calculate the percentage of anhydrous sodium carbonate in FA 3.

\[
\text{percentage } \text{Na}_2\text{CO}_3 \text{ in FA 3} = \ldots \ldots \ldots \ldots \ldots \% \quad [2]
\]
(g) **FA 1** and **FA 3** are both samples of the same impure anhydrous sodium carbonate and so the percentage of anhydrous sodium carbonate found using **Method 1** and **Method 2** should be the same. In practice the percentages are sometimes different from each other.

In both methods, percentage errors occur due to measuring the mass of solid and the temperature rise.

Ignoring these errors, which method is more accurate?

Tick the correct box and explain your answer.

- Method 1 more accurate
- Method 2 more accurate
- Method 1 and Method 2 equally accurate

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

[1]

(h) A student decided to confirm by experiment the literature value for the enthalpy change of the reaction between anhydrous sodium carbonate and hydrochloric acid. By mistake the student weighed a sample of hydrated sodium carbonate, Na₂CO₃·10H₂O, instead of anhydrous sodium carbonate, Na₂CO₃.

State what effect this would have on the calculated value of the enthalpy change for the reaction. Explain your answer.

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

(i) A student used 3.00 g of anhydrous sodium carbonate that was 80.0% pure by mass.

Calculate the minimum volume of 2.00 mol dm⁻³ hydrochloric acid that would be needed to react completely with this sample of impure anhydrous sodium carbonate.

\[
\text{volume of HCl} = \text{... cm}^3
\]

[Total: 25]
Qualitative Analysis

Where reagents are selected for use in a test, the full 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.

2 (a) (i) FA 4 is a sodium compound that was the impurity in the FA 1 and FA 3 that you used in Question 1. The anion in FA 4 is one of those listed in the Qualitative Analysis Notes.

Carry out appropriate tests to allow you to positively identify the anion in FA 4.

For the test that gives a positive result, record the test and the results of it.

State the name of the anion in FA 4.

\[
\text{anion in } \text{FA 4} = \text{..........................................................} \quad [2]
\]

(ii) Write the ionic equation for the reaction that you have used to identify the anion in FA 4. Include state symbols.

\[
\text{........................................................................................................} \quad [1]
\]
(b) **FA 5** is a mixture that contains two cations and three anions from those listed in the Qualitative Analysis Notes.

A sample of **FA 5** was added to water and the water stirred. The mixture produced was filtered to give a solid residue, **FA 6**, and a filtrate, **FA 7**.

(i) Carry out the following tests on **FA 6** and record your observations.

<table>
<thead>
<tr>
<th>test</th>
<th>observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>To a small spatula measure of <strong>FA 6</strong> in a test-tube add dilute hydrochloric acid, then add aqueous ammonia.</td>
<td></td>
</tr>
<tr>
<td>Place a small spatula measure of <strong>FA 6</strong> in a hard-glass test-tube and heat gently.</td>
<td></td>
</tr>
</tbody>
</table>

(ii) Carry out the following tests on **FA 7** and record your observations.

<table>
<thead>
<tr>
<th>test</th>
<th>observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>To a 1 cm depth of <strong>FA 7</strong> in a test-tube add aqueous sodium hydroxide.</td>
<td></td>
</tr>
<tr>
<td>To a 1 cm depth of <strong>FA 7</strong> in a test-tube add aqueous ammonia.</td>
<td></td>
</tr>
<tr>
<td>To a 1 cm depth of <strong>FA 7</strong> in a test-tube add a few drops of aqueous silver nitrate.</td>
<td></td>
</tr>
<tr>
<td>To a 1 cm depth of <strong>FA 7</strong> in a test-tube add a few drops of aqueous barium nitrate or aqueous barium chloride, then add dilute nitric acid.</td>
<td></td>
</tr>
<tr>
<td>To a 0.5 cm depth of <strong>FA 7</strong> in a boiling tube add a 2 cm depth of aqueous sodium hydroxide and warm, then add a small piece of aluminium foil.</td>
<td></td>
</tr>
</tbody>
</table>
(iii) From your observations, identify the two cations present in FA 5.

Cations ............................................................. and ........................................................... [1]

(iv) From your observations, identify two anions present in FA 5.

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

(v) From your observations, identify two anions that could be present in FA 5.

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

[Total: 15]
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</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, CO$_3^{2-}$</td>
<td>CO$_2$ liberated by dilute acids</td>
</tr>
<tr>
<td>chloride, Cl$^-$ (aq)</td>
<td>gives white ppt. with Ag$^+$ (aq) (soluble in NH$_3$(aq))</td>
</tr>
<tr>
<td>bromide, Br$^-$ (aq)</td>
<td>gives cream ppt. with Ag$^+$ (aq) (partially soluble in NH$_3$(aq))</td>
</tr>
<tr>
<td>iodide, I$^-$ (aq)</td>
<td>gives yellow ppt. with Ag$^+$ (aq) (insoluble in NH$_3$(aq))</td>
</tr>
<tr>
<td>nitrate, NO$_3^-$ (aq)</td>
<td>NH$_3$ liberated on heating with OH$^-$ (aq) and Al foil</td>
</tr>
<tr>
<td>nitrite, NO$_2^-$ (aq)</td>
<td>NH$_3$ liberated on heating with OH$^-$ (aq) and Al foil</td>
</tr>
<tr>
<td>sulfate, SO$_4^{2-}$ (aq)</td>
<td>gives white ppt. with Ba$^{2+}$ (aq) (insoluble in excess dilute strong acids)</td>
</tr>
<tr>
<td>sulfite, SO$_3^{2-}$ (aq)</td>
<td>gives white ppt. with Ba$^{2+}$ (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, NH$_3$</td>
<td>turns damp red litmus paper blue</td>
</tr>
<tr>
<td>carbon dioxide, CO$_2$</td>
<td>gives a white ppt. with limewater (ppt. dissolves with excess CO$_2$)</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>
### The Periodic Table of Elements

<table>
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</tbody>
</table>

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

### Elements
- **Group 1 (Alkali Metals):**
  - Lithium (Li)
  - Sodium (Na)
  - Potassium (K)
  - Rubidium (Rb)
  - Cesium (Cs)
  - Francium (Fr)

- **Group 2 (Alkaline Earth Metals):**
  - Beryllium (Be)
  - Magnesium (Mg)
  - Calcium (Ca)
  - Strontium (Sr)
  - Barium (Ba)
  - Lanthanum (La)

- **Group 3 (Boron):**
  - Boron (B)
  - Aluminum (Al)
  - Scandium (Sc)
  - Titanium (Ti)
  - Vanadium (V)
  - Chromium (Cr)

- **Group 4 (Carbon):**
  - Carbon (C)
  - Silicon (Si)
  - Germanium (Ge)

- **Group 5 (Nitrogen):**
  - Nitrogen (N)
  - Phosphorus (P)
  - Arsenic (As)

- **Group 6 (Oxygen):**
  - Oxygen (O)
  - Sulfur (S)
  - Selenium (Se)

- **Group 7 (Fluorine):**
  - Fluorine (F)
  - Chlorine (Cl)
  - Bromine (Br)

- **Group 8 (Neon):**
  - Neon (Ne)
  - Krypton (Kr)
  - Xenon (Xe)

- **Group 9 (Luminescent Elements):**
  - Rubidium (Rb)
  - Strontium (Sr)

- **Group 10 (Actinoids):**
  - Actinium (Ac)
  - Thorium (Th)
  - Protactinium (Pa)

- **Group 11 (Alkali Metals):**
  - Sodium (Na)
  - Potassium (K)

- **Group 12 (Transition Metals):**
  - Zinc (Zn)
  - Cadmium (Cd)

- **Group 13 (Boron):**
  - Lithium (Li)
  - Beryllium (Be)

- **Group 14 (Carbon):**
  - Carbon (C)
  - Silicon (Si)

- **Group 15 (Nitrogen):**
  - Nitrogen (N)
  - Phosphorus (P)

- **Group 16 (Oxygen):**
  - Oxygen (O)
  - Sulfur (S)

- **Group 17 (Fluorine):**
  - Fluorine (F)
  - Chlorine (Cl)

- **Group 18 (Neon):**
  - Neon (Ne)
  - Krypton (Kr)

### Notable Elements
- **Periodic Table:**
  - Lithium (Li)
  - Hydrogen (H)
  - Helium (He)
  - Neon (Ne)

- **Atomic Numbers:**
  - Hydrogen (1)
  - Helium (2)
  - Lithium (3)

- **Relative Atomic Masses:**
  - Hydrogen (1.0)
  - Helium (4.0)

- **Other Elements:**
  - Francium (87)
  - Radon (86)
  - Lanthanum (57)
  - Actinium (89)

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The Periodic Table is a fundamental tool in chemistry, providing a systematic arrangement of chemical elements. It helps in understanding the properties and interactions of elements. This table is a snapshot of the periodicity in the chemical behavior of the elements, which is crucial for various scientific applications.