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 a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, 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 12 and 13.

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.
1 When aqueous hydrochloric acid is mixed with aqueous sodium hydroxide, the neutralisation reaction releases heat causing a rise in the temperature of the solution.

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

In this experiment you will mix different volumes of hydrochloric acid and sodium hydroxide but the total volume will be kept constant. For each mixture you will record the temperature rise. Since the combined volume remains the same, the temperature rise is a direct measure of the heat given out by the reaction. The maximum heat given out occurs when all the acid present is exactly neutralised by all the alkali present. By determining the volumes when this occurs you can work out the concentration of the sodium hydroxide.

FB 1 is 2.00 mol dm\(^{-3}\) hydrochloric acid, HCl.
FB 2 is aqueous sodium hydroxide, NaOH.

Read through the instructions carefully and prepare a table for your results in the space on page 4 before starting any practical work.

(a) Method

Experiment 1
- Support the plastic cup in the 250 cm\(^3\) beaker.
- Fill the unlabelled burette with FB 1.
- Run 26.00 cm\(^3\) of FB 1 from the burette into the plastic cup.
- Record the temperature of FB 1, \(T_1\), in the space below.

\[ T_1 = \ldots \ldots \ldots \, ^\circ\text{C} \]

- Fill the burette labelled FB 2 with FB 2.
- Run 4.00 cm\(^3\) of FB 2 from the burette into the plastic cup.
- Stir the mixture thoroughly and record in your table the maximum temperature of the solution.
- Empty the plastic cup, rinse thoroughly with water and shake dry.

Experiment 2
- Support the plastic cup in the 250 cm\(^3\) beaker.
- Run 22.00 cm\(^3\) of FB 1 from the burette into the plastic cup.
- Run 8.00 cm\(^3\) of FB 2 from the burette into the plastic cup.
- Stir the mixture thoroughly and record in your table the maximum temperature of the solution.
- Empty the plastic cup, rinse thoroughly with water and shake dry.
Experiments 3 – 7

- Repeat the experiment using 18.00, 14.00, 10.00, 6.00 and 2.00 cm³ of FB 1 respectively. Add sufficient FB 2 each time to make sure that the total volume remains 30.00 cm³.

For each of your seven experiments, record in the space below

- the volume of FB 1,
- the volume of FB 2,
- the maximum temperature of the solution,
- the temperature rise, \( \Delta T \), where \( \Delta T = \text{maximum temperature recorded} - T_1 \).

(b) (i) On the grid opposite, plot the temperature rise, \( \Delta T \), on the y-axis against the volume of FB 1 on the x-axis.

The scale for \( \Delta T \) should extend at least 2 °C above your greatest temperature rise.

(ii) Draw a straight line of best fit through the points where the values of \( \Delta T \) are increasing.

Draw a second straight line of best fit through the points where the values of \( \Delta T \) are decreasing.

(iii) From your graph, determine the value of the volume of FB 1 where the two lines of best fit intersect.

\[
\text{volume of FB 1} = \text{................................................ cm}^3
\]
(c) Calculations

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

(i) Calculate how many moles of hydrochloric acid are contained in the volume recorded in (b)(iii).

moles of HCl = ………………… mol

(ii) Calculate how many moles of sodium hydroxide would react completely with the number of moles of hydrochloric acid in (c)(i).

moles of NaOH = ………………… mol

(iii) Calculate the concentration of FB 2. Remember that the combined volume of FB 1 and FB 2 in each experiment was 30.00 cm³.

concentration of FB 2 = ………………… mol dm⁻³ [3]

(d) A student decided to modify the experiment. The total volume of the solution was increased to 50 cm³ and temperature rises were recorded for 5, 10, 15, 20, 25, 30, 35, 40 and 45 cm³ of FB 2. The volumes were measured using a 50 cm³ measuring cylinder. Discuss how these changes would affect the accuracy with which the concentration of FB 2 could be determined.

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

[Total: 16]
A second way to determine the concentration of an alkali is by volumetric titration. In this experiment you will first dilute the sample of FB 2 that you used in Question 1 and then titrate the diluted solution using hydrochloric acid.

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

FB 2 is aqueous sodium hydroxide, NaOH.
FB 3 is 0.200 mol dm\(^{-3}\) hydrochloric acid, HCl.

(a) Method

Dilution of FB 2
- Use the burette labelled FB 2 to transfer 25.00 cm\(^3\) of FB 2 into the 250 cm\(^3\) graduated (volumetric) flask, labelled FB 4.
- Make up the contents of the flask to the 250 cm\(^3\) mark with distilled water.
- Stopper the flask and mix the contents thoroughly. This solution FB 4.

Titration
- Rinse the unlabelled burette thoroughly with distilled water and then with a little FB 3. Fill this burette with FB 3.
- Use a pipette to transfer 25.0 cm\(^3\) of FB 4 into a conical flask.
- Add to the flask a few drops of the acid-base indicator provided.
- Titrate the alkali in the flask with the acid, FB 3.

You should perform a rough titration.
In the space below record your burette readings for this rough titration.

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 FB 3 added in each accurate titration. Make certain that any recorded results show the precision of your practical work.
(b) From your titration results obtain a suitable value to be used in your calculation. Show clearly how you have obtained this value.

25.0 cm$^3$ of FB 4 required .......... cm$^3$ of FB 3.  \[1\]

(c) (i) Calculate how many moles of HCl are contained in the volume recorded in (b).

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

(ii) Hence, calculate how many moles of NaOH are contained in 25.0 cm$^3$ of FB 4.

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

(iii) Calculate the concentration of the sodium hydroxide, FB 2.

concentration of FB 2 = ................. mol dm$^{-3}$  \[3\]

[Total: 9]
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. Marks are not given for chemical equations.

**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, FB 7 and FB 8 are aqueous solutions each of which contains a single cation and a single anion. Some of the ions present are listed below.

\[
\begin{align*}
\text{Fe}^{2+} & \quad \text{Pb}^{2+} & \quad \text{Zn}^{2+} & \quad \text{I}^- & \quad \text{OH}^- & \quad \text{SO}_4^{2-} \\
\end{align*}
\]

By observing the reactions that occur when pairs of the solutions are mixed together, you will be able to identify which solution contains which of these ions.
To a 1 cm depth of FB 6, FB 7 and FB 8 in separate test-tubes add FB 5 dropwise until in excess. Leave each test-tube to stand for a few minutes and note any changes.

- Use a 1 cm depth of each solution for the remaining tests.
- Record your observations in the following table.

<table>
<thead>
<tr>
<th></th>
<th>FB 6</th>
<th>FB 7</th>
<th>FB 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>FB 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FB 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FB 7</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(b) From your observations deduce which solution contains each of the following ions.

<table>
<thead>
<tr>
<th>ion</th>
<th>Fe^{2+}</th>
<th>Pb^{2+}</th>
<th>Zn^{2+}</th>
<th>I^-</th>
<th>OH^-</th>
<th>SO_4^{2-}</th>
</tr>
</thead>
<tbody>
<tr>
<td>solution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(c) **FB 9** is an aqueous solution containing either sulfate, \( \text{SO}_4^{2-} \), or sulfite, \( \text{SO}_3^{2-} \), ions. Describe how you would determine which ion is present.

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

Carry out this test and record your observations and conclusion.

observations ....................................................................................................................
...........................................................................................................................................

The anion in **FB 9** is ........................................... . [2]

(d) A student is given two **different** samples and told that each contains one of the following organic compounds.

- ethanol
- ethanal
- ethanoic acid

Describe two chemical tests that the student could carry out on each sample to determine which organic compound is present in each sample. For each test, give the reagent(s) to be used and explain how the different observations would allow the identity of the sample to be determined.

first reagent ..........................................................

observations ....................................................................................................................
...........................................................................................................................................

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

second reagent ..........................................................

observations ....................................................................................................................
...........................................................................................................................................

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

[4]

[Total: 15]
12
Qualitative Analysis Notes

Key: [ppt. = 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>no ppt. (if 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>lead(II), Pb²⁺(aq)</td>
<td>white ppt. soluble in excess</td>
<td>white 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>

[Lead(II) ions can be distinguished from aluminium ions by the insolubility of lead(II) chloride.]
## 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>
</tbody>
</table>
| chromate(VI), \( \text{CrO}_4^{2-}(\text{aq}) \) | yellow solution turns orange with \( \text{H}^+\)(aq);
gives yellow ppt. with \( \text{Ba}^{2+}\)(aq);
gives bright yellow ppt. with \( \text{Pb}^{2+}\)(aq) |
| chloride, \( \text{Cl}^-\)(aq) | gives white ppt. with \( \text{Ag}^+\)(aq) (soluble in \( \text{NH}_3\)(aq));
gives white ppt. with \( \text{Pb}^{2+}\)(aq) |
| bromide, \( \text{Br}^-\)(aq) | gives cream ppt. with \( \text{Ag}^+\)(aq) (partially soluble in \( \text{NH}_3\)(aq));
gives white ppt. with \( \text{Pb}^{2+}\)(aq) |
| iodide, \( \text{I}^-\)(aq) | gives yellow ppt. with \( \text{Ag}^+\)(aq) (insoluble in \( \text{NH}_3\)(aq));
gives yellow ppt. with \( \text{Pb}^{2+}\)(aq) |
| nitrate, \( \text{NO}_3^-\)(aq) | \( \text{NH}_3 \) liberated on heating with \( \text{OH}^-\)(aq) and \( \text{Al} \) foil |
| nitrite, \( \text{NO}_2^-\)(aq) | \( \text{NH}_3 \) liberated on heating with \( \text{OH}^-\)(aq) and \( \text{Al} \) foil;
NO liberated by dilute acids
(colourless NO \( \rightarrow \) (pale) brown \( \text{NO}_2 \) in air) |
| sulfate, \( \text{SO}_4^{2-}\)(aq) | gives white ppt. with \( \text{Ba}^{2+}\)(aq) or with \( \text{Pb}^{2+}\)(aq) (insoluble in excess dilute strong acids) |
| sulfite, \( \text{SO}_3^{2-}\)(aq) | \( \text{SO}_2 \) liberated with dilute acids;
gives white ppt. with \( \text{Ba}^{2+}\)(aq) (soluble in excess dilute strong acids) |

## 3 Tests for gases

<table>
<thead>
<tr>
<th>gas</th>
<th>test and test result</th>
</tr>
</thead>
<tbody>
<tr>
<td>ammonia, ( \text{NH}_3 )</td>
<td>turns damp red litmus paper blue</td>
</tr>
</tbody>
</table>
| carbon dioxide, \( \text{CO}_2 \) | gives a white ppt. with limewater
(ppt. dissolves with excess \( \text{CO}_2 \)) |
| chlorine, \( \text{Cl}_2 \) | bleaches damp litmus paper |
| hydrogen, \( \text{H}_2 \) | “pops” with a lighted splint |
| oxygen, \( \text{O}_2 \) | relights a glowing splint |
| sulfur dioxide, \( \text{SO}_2 \) | turns acidified aqueous potassium dichromate(VI) from orange to green |