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 14 and 15.
A copy of the Periodic Table is printed on page 16.

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 Iron(III) ions oxidise iodide ions, I\(^-\), to iodine, I\(_2\).

\[ 2\text{Fe}^{3+}(aq) + 2\text{I}^-(aq) \rightarrow 2\text{Fe}^{2+}(aq) + \text{I}_2(aq) \]

In this experiment you will investigate how the rate of this reaction is affected by the concentration of Fe\(^{3+}\) ions. To do this you will add thiosulfate ions, S\(_2\)O\(_3\)^{2-}\), and starch indicator to a mixture of Fe\(^{3+}\)(aq) and I\(^-\)(aq). The iodine produced by the reaction reacts immediately with the thiosulfate ions and is reduced back to iodide.

\[ \text{I}_2(aq) + 2\text{S}_2\text{O}_3^{2-}(aq) \rightarrow 2\text{I}^-(aq) + \text{S}_4\text{O}_6^{2-}(aq) \]

When all the thiosulfate has reacted, the iodine remaining in solution turns the starch indicator blue-black. The rate of reaction can be determined by timing how long it takes for the reaction mixture to turn blue-black.

**FB 1** is 0.0500 mol dm\(^{-3}\) acidified iron(III) chloride, FeCl\(_3\).
**FB 2** is 0.0500 mol dm\(^{-3}\) potassium iodide, KI.
**FB 3** is 0.00500 mol dm\(^{-3}\) sodium thiosulfate, Na\(_2\)S\(_2\)O\(_3\).
**FB 4** is starch indicator.
(a) **Method**

**Experiment 1**

- Fill the burette labelled **FB 1** with **FB 1**.
- Run 20.00 cm³ of **FB 1** into a 100 cm³ beaker.
- Using the measuring cylinder add the following to the second 100 cm³ beaker:
  - 10 cm³ of **FB 2**
  - 20 cm³ of **FB 3**
  - 10 cm³ of **FB 4**
- Add the contents of the first beaker to the second beaker and start timing immediately.
- Stir the mixture once and place the beaker on a white tile.
- Stop timing as soon as the solution turns blue-black. Ignore any colour changes that occur before the intense blue-black colouration.
- Record this reaction time to the nearest second in the space provided on page 4.
- Rinse both beakers and shake dry. Rinse and dry the glass rod.

**Experiment 2**

- Fill a second burette with distilled water.
- Run 10.00 cm³ of **FB 1** into a 100 cm³ beaker.
- Run 10.00 cm³ of distilled water into the same beaker containing **FB 1**.
- Using the measuring cylinder add the following to the second 100 cm³ beaker:
  - 10 cm³ of **FB 2**
  - 20 cm³ of **FB 3**
  - 10 cm³ of **FB 4**
- Add the contents of the first beaker to the second beaker and start timing immediately.
- Stir the mixture once and place the beaker on a white tile.
- Stop timing as soon as the solution turns blue-black. Ignore any colour changes that occur before the intense blue-black colouration.
- Record this reaction time to the nearest second in the space provided on page 4.
- Rinse both beakers and shake dry. Rinse and dry the glass rod.
Experiments 3–5

- Carry out three further experiments to investigate how the reaction time changes with different volumes of FB 1.
  Remember that the combined volume of FB 1 and distilled water must always be 20.00 cm³.
  Do not carry out an experiment using 15.00 cm³ of FB 1.
  Do not use a volume of FB 1 that is less than 5.00 cm³.

Keep all FB labelled solutions for use in (e) and in Question 2.

Record all your results in a single table. You should include the volume of FB 1, the volume of distilled water and the reaction time.

The relative rate for the reaction is given by the following expression.

\[
\text{relative rate} = \frac{1000}{\text{reaction time in seconds}}
\]

Use this expression to calculate the relative rate for each of your experiments and record the values in your results table.

(b) On the grid opposite, plot the relative rate against the volume of FB 1. Include the origin in your plot. Label any points you consider anomalous. Draw a line of best fit.
(c) From your graph, what conclusion can you make about the relationship between the relative rate for the reaction and the volume of FB 1 used? Explain your answer.
....................................................................................................................................................
....................................................................................................................................................
....................................................................................................................................................  [2]

(d) A student carried out the same experiment but used 15.00 cm$^3$ of FB 1. The student recorded a value for the reaction time of 28 s.

(i) Use your graph to calculate the time you would have expected to record if you had carried out an experiment using 15.00 cm$^3$ of FB 1.
Show the construction lines on your graph and show your working in the calculation.

reaction time = .............................. s  [2]

(ii) Calculate the percentage difference between your value and that of the student.
Show your working.

percentage difference = .............................. %  [1]

(e) You are to carry out a sixth experiment. The concentrations of iron(III) chloride, sodium thiosulfate and starch indicator should all be the same as in Experiment 2 but the concentration of iodide ions should be twice the value that it is in Experiment 2.
State the volume of each solution used and record the reaction time to the nearest second.
(f) (i) 20.00 cm$^3$ of 0.0500 mol dm$^{-3}$ FeCl$_3$, FB 1, were reacted with excess KI, FB 2.

Using the information on page 2, calculate the number of moles of I$_2$ produced.

moles I$_2$ = .................................... mol [2]

(ii) The iodine produced in (i) required 35.00 cm$^3$ of a different solution of sodium thiosulfate for complete reaction.

Calculate the concentration of the solution of sodium thiosulfate used.

concentration of Na$_2$S$_2$O$_3$ = .................................... mol dm$^{-3}$ [1]

[Total: 24]
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) **FB 1** is aqueous acidified iron(III) chloride, FeCl₃.

**FB 5** is 0.150 mol dm⁻³ sodium thiosulfate, Na₂S₂O₃.

(i) Carry out the following tests 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>FB 1</strong> in a test-tube add a 1 cm depth of <strong>FB 5</strong>. Leave to stand until there is no further change, then</td>
<td></td>
</tr>
<tr>
<td>add aqueous sodium hydroxide.</td>
<td></td>
</tr>
<tr>
<td>To a 1 cm depth of <strong>FB 5</strong> in a test-tube add a few drops of dilute hydrochloric acid. Leave to stand. Rinse the tube thoroughly.</td>
<td></td>
</tr>
</tbody>
</table>
(ii) In (i) you should have observed a reaction between Fe$^{3+}$(aq) and S$_2$O$_3^{2-}$(aq).

Do you think that this reaction affected your results in Question 1? Refer to the equations on page 2. Explain your answer.

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

(b) FB 6 is a solution containing a halide ion.

(i) Carry out the following tests and record your observations.

<table>
<thead>
<tr>
<th>test</th>
<th>observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>To a 1 cm depth of FB 6 in a test-tube add aqueous silver nitrate, then add aqueous ammonia.</td>
<td></td>
</tr>
</tbody>
</table>

To a 1 cm depth of FB 6 in a test-tube add aqueous silver nitrate, then add FB 5.

(ii) The halide in FB 6 is ......................... . [1]
(c) **FB 7** is a solution of copper(II) sulfate, CuSO₄.

(i) Carry out the following tests 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>FB 7</strong> in a test-tube add a 1 cm depth of <strong>FB 2</strong>, KI, then add <strong>FB 4</strong>, starch indicator.</td>
<td></td>
</tr>
<tr>
<td>To a 1 cm depth of <strong>FB 7</strong> in a test-tube add a 1 cm depth of <strong>FB 5</strong>, then add a 1 cm depth of <strong>FB 2</strong> followed by <strong>FB 4</strong>, starch indicator.</td>
<td></td>
</tr>
</tbody>
</table>

(ii) Give the formula of one of the products formed in the reaction of **FB 7** with **FB 2** in the first test.

............................................................. [1]
(d) **FB 8** is a solution of a salt containing one cation and one anion from those listed in the Qualitative Analysis Notes.  
The cation in **FB 8** is one of Mg$^{2+}$, Zn$^{2+}$ or Al$^{3+}$.  
The anion in **FB 8** is either SO$_3^{2-}$ or SO$_4^{2-}$.  

(i) Select reagents and carry out tests to identify which ions are present in **FB 8**.  
Give details of your tests and observations.  

(ii) The formula of **FB 8** is .............................. .  

[Total: 16]
## Qualitative Analysis Notes

### 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.</td>
<td>white ppt.</td>
</tr>
<tr>
<td></td>
<td>soluble in excess</td>
<td>insoluble in excess</td>
</tr>
<tr>
<td>ammonium, NH₄⁺(aq)</td>
<td>no ppt.</td>
<td>ammonia produced on heating</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.</td>
<td>grey-green ppt.</td>
</tr>
<tr>
<td></td>
<td>soluble in excess</td>
<td>insoluble in excess</td>
</tr>
<tr>
<td>copper(II), Cu²⁺(aq)</td>
<td>pale blue ppt.</td>
<td>blue ppt. soluble in excess</td>
</tr>
<tr>
<td></td>
<td>insoluble in excess</td>
<td>giving dark blue solution</td>
</tr>
<tr>
<td>iron(II), Fe²⁺(aq)</td>
<td>green ppt. turning brown on contact with air</td>
<td>green ppt. turning brown on contact with air</td>
</tr>
<tr>
<td></td>
<td>insoluble in excess</td>
<td>insoluble in excess</td>
</tr>
<tr>
<td>iron(III), Fe³⁺(aq)</td>
<td>red-brown ppt.</td>
<td>red-brown ppt.</td>
</tr>
<tr>
<td></td>
<td>insoluble in excess</td>
<td>insoluble in excess</td>
</tr>
<tr>
<td>magnesium, Mg²⁺(aq)</td>
<td>white ppt.</td>
<td>white ppt.</td>
</tr>
<tr>
<td></td>
<td>insoluble in excess</td>
<td>insoluble in excess</td>
</tr>
<tr>
<td>manganese(II), Mn²⁺(aq)</td>
<td>off-white ppt. rapidly turning brown on contact with air</td>
<td>off-white ppt. rapidly turning brown on contact with air</td>
</tr>
<tr>
<td></td>
<td>insoluble in excess</td>
<td>insoluble in excess</td>
</tr>
<tr>
<td>zinc, Zn²⁺(aq)</td>
<td>white ppt.</td>
<td>white ppt.</td>
</tr>
<tr>
<td></td>
<td>soluble in excess</td>
<td>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 $\text{Ag}^+(aq)$ (soluble in $\text{NH}_3(aq)$)</td>
</tr>
<tr>
<td>bromide, $\text{Br}^-$ (aq)</td>
<td>gives cream ppt. with $\text{Ag}^+(aq)$ (partially soluble in $\text{NH}_3(aq)$)</td>
</tr>
<tr>
<td>iodide, $\text{I}^-$ (aq)</td>
<td>gives yellow ppt. with $\text{Ag}^+(aq)$ (insoluble in $\text{NH}_3(aq)$)</td>
</tr>
<tr>
<td>nitrate, $\text{NO}_3^-$ (aq)</td>
<td>$\text{NH}_3$ liberated on heating with $\text{OH}^-(aq)$ and $\text{Al}$ foil</td>
</tr>
<tr>
<td>nitrite, $\text{NO}_2^-$ (aq)</td>
<td>$\text{NH}_3$ liberated on heating with $\text{OH}^-(aq)$ and $\text{Al}$ foil</td>
</tr>
<tr>
<td>sulfate, $\text{SO}_4^{2-}$ (aq)</td>
<td>gives white ppt. with $\text{Ba}^{2+}(aq)$ (insoluble in excess dilute strong acids)</td>
</tr>
<tr>
<td>sulfite, $\text{SO}_3^{2-}$ (aq)</td>
<td>gives white ppt. with $\text{Ba}^{2+}(aq)$ (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, $\text{NH}_3$</td>
<td>turns damp red litmus paper blue</td>
</tr>
<tr>
<td>carbon dioxide, $\text{CO}_2$</td>
<td>gives a white ppt. with limewater (ppt. dissolves with excess $\text{CO}_2$)</td>
</tr>
<tr>
<td>chlorine, $\text{Cl}_2$</td>
<td>bleaches damp litmus paper</td>
</tr>
<tr>
<td>hydrogen, $\text{H}_2$</td>
<td>'pops' with a lighted splint</td>
</tr>
<tr>
<td>oxygen, $\text{O}_2$</td>
<td>relights a glowing splint</td>
</tr>
</tbody>
</table>
The Periodic Table of Elements

<table>
<thead>
<tr>
<th>Group</th>
<th>Period</th>
<th>Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>H, He</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>Li, Be, B, C, N, O, F, Ne</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>Na, Mg, Al, Si, P, S, Cl, Ar</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, Kr</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>Rb, Sr, Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb, Te, I, Xe</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>Cs, Ba, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>Fr, Ra, Actinoids</td>
</tr>
</tbody>
</table>

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

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