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.
Sulfur forms the peroxodisulfate anion, $S_2O_8^{2-}$. This ion can oxidise iodide ions, $I^-$, to iodine, $I_2$, as shown in the equation.

$$2I^-(aq) + S_2O_8^{2-}(aq) \rightarrow I_2(aq) + 2SO_4^{2-}(aq)$$

You will carry out a series of experiments to investigate how the rate of this reaction is affected by changing the concentration of the solutions.

The rate can be measured by adding thiosulfate ions, $S_2O_3^{2-}$, and starch indicator. As the reaction between $S_2O_8^{2-}$ and $I^-$ occurs iodine is produced, but it reacts immediately with the thiosulfate.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

When all the thiosulfate has reacted, the iodine will remain in the mixture and cause the starch indicator to turn blue-black. The rate of reaction may be determined by timing how long it takes the reaction mixture to turn blue-black.

**FA 1** is 0.0200 mol dm$^{-3}$ potassium peroxodisulfate, $K_2S_2O_8$.
**FA 2** is 1.00 mol dm$^{-3}$ potassium iodide, $KI$.
**FA 3** is 0.00500 mol dm$^{-3}$ sodium thiosulfate, $Na_2S_2O_3$.

**Starch indicator**

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

(a) **Method**

**Experiment 1**
- Fill the burette labelled **FA 1** with **FA 1**.
- Use the pen to label one of the 100 cm$^3$ beakers ‘A’ and the other 100 cm$^3$ beaker ‘B’.
- Run 20.00 cm$^3$ of **FA 1** from the burette into beaker A.
- Use the measuring cylinder to add 20.0 cm$^3$ of **FA 2** into beaker B.
- Use the measuring cylinder to add 10.0 cm$^3$ of **FA 3** to beaker B.
- Add 10 drops of starch indicator to beaker B.
- Add the contents of beaker A to beaker B 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.
- Record this reaction time to the nearest second in your results table.
- Wash out both beakers and shake to remove excess water.

**Experiment 2**
- Fill a second burette with distilled water.
- Run 10.00 cm$^3$ of **FA 1** into beaker A.
- Run 10.00 cm$^3$ of distilled water into beaker A.
- Use the measuring cylinder to add 20.0 cm$^3$ of **FA 2** into beaker B.
- Use the measuring cylinder to add 10.0 cm$^3$ of **FA 3** to beaker B.
- Add 10 drops of starch indicator to beaker B.
- Add the contents of beaker A to beaker B 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.
- Record this reaction time to the nearest second in your results table.
- Wash out both beakers and shake to remove excess water.
Experiments 3-5

- Carry out three further experiments to investigate how the reaction time changes with different volumes of potassium peroxodisulfate, FA 1. Note that the combined volume of FA 1 and distilled water must always be 20.00 cm³. Do not use a volume of FA 1 that is less than 6.00 cm³.

Keep FA 1, FA 2, FA 3 and the starch indicator for use in (e).

Calculating the rate of the reaction

The rate of the reaction can be represented by the formula shown.

\[
\text{rate} = \frac{500}{\text{reaction time in seconds}}
\]

Use this formula to calculate the rate for each of your five experiments.

Record all your results in a single table. You should include the volume of FA 1, the volume of distilled water, the reaction time and the reaction rate for each of your five experiments.

(b) On the grid on page 5, plot the rate (y-axis) against the volume of FA 1 (x-axis). Include the origin in your plot. Draw a straight line of best fit and circle any clearly anomalous points.
(c) The volume of FA 1 is directly related to the concentration of potassium peroxodisulfate.

From your results, what can be stated about the relationship between the rate of reaction and the concentration of potassium peroxodisulfate? 

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

(d) (i) **Use your graph** to calculate the reaction time you would expect to measure if you carried out an experiment using 5.00 cm$^3$ of FA 1. Show your working.

reaction time = ....................... s

(ii) Assume that the error in the time measured for each reaction was ±0.5 s in total. Calculate the maximum percentage error in the reaction time you measured in **Experiment 1**. Show your working.

maximum percentage error = ....................... %

(iii) A student suggested that this error could be reduced if 0.0100 mol dm$^{-3}$ sodium thiosulfate were used in place of FA 3.

Do you agree with this student? Explain your answer.

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

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

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

(iv) A student repeated **Experiment 1** but used 0.100 mol dm$^{-3}$ sodium thiosulfate in place of FA 3. The student found that the reaction mixture never turned blue-black.

Explain why.

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

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

................................................................................................................................................................................ [5]
(e) (i) Using the same method as in (a), carry out an additional experiment to record the reaction time to the nearest second when the following solutions are mixed together.

- 10.00 cm$^3$ of FA 1
- 20.0 cm$^3$ of FA 2
- 5.0 cm$^3$ of FA 3
- 15.00 cm$^3$ of distilled water
- 10 drops of starch indicator

reaction time = ..................................

(ii) Use your answer to (i) to estimate the reaction time that would be measured if the following solutions were mixed together.

**DO NOT CARRY OUT THIS EXPERIMENT**

- 10.00 cm$^3$ of FA 1
- 20.0 cm$^3$ of FA 2
- 20.0 cm$^3$ of FA 3
- 10 drops of starch indicator

Explain your answer.

estimated reaction time = ..................................

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

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

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

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

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

[Total: 24]
2 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 reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

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.

(a) FA 4 and FA 5 are aqueous solutions. Each solution contains two different cations and the sulfate anion.

(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 solution in a boiling tube, add aqueous sodium hydroxide, then warm the tube carefully.</td>
<td></td>
</tr>
<tr>
<td>To a 1 cm depth of solution in a test-tube, add aqueous ammonia.</td>
<td></td>
</tr>
</tbody>
</table>

(ii) Identify as many as possible of the cations in FA 4 and FA 5.

FA 4 contains the cation(s) ...................................................... .

FA 5 contains the cation(s) ...................................................... .
(b) **FA 6** is a salt containing either the sulfate anion or sulfite anion. You will first make a solution of FA 6.

- Rinse one of the 100 cm³ beakers with distilled water.
- Place all the sample of FA 6 into the beaker and add approximately 40 cm³ of distilled water.
- Stir the mixture until the solid has dissolved.

Select reagent(s) and carry out tests to identify the anion in FA 6. Record your results in the space below.

The formula of the anion in FA 6 is ......................... . [3]

(c) **FA 7** is a solution containing one cation and the sulfate anion. **FA 8** is a solution containing the sodium cation and one of the anions from those listed in the Qualitative Analysis Notes.

(i) Carry out the following tests to determine the formulae of **FA 7** and **FA 8**.

<table>
<thead>
<tr>
<th>test</th>
<th>observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>To a 2 cm depth of <strong>FA 7</strong> in a test-tube, add a 2 cm strip of magnesium.</td>
<td></td>
</tr>
<tr>
<td>To a 1 cm depth of <strong>FA 7</strong> in a test-tube add a 1 cm depth of <strong>FA 8</strong> and shake the tube.</td>
<td></td>
</tr>
</tbody>
</table>

(ii) The formula of **FA 7** is ................................................... .

The formula of **FA 8** is ................................................... .

(iii) Give the ionic equation for the reaction that takes place when magnesium is added to **FA 7**. Include state symbols.

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

[6]

[Total: 16]
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. soluable 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. soluable 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. soluable 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. soluable in excess</td>
<td>white ppt. soluable 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; $\text{NO}$ liberated by dilute acids (colourless $\text{NO}$ $\to$ (pale) brown $\text{NO}_2$ in air)</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

| Group | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|-------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|       | H | He | Li | Be | B | C | N | O | F | Ne | Na | Mg | K | Ca | Sc | Ti | V | Cr | Mn |
| Key   |    |    |    |    |   |   |   |   |   |    |    |    |   |    |   |    |   |   | 1  |
| atomic number | 1.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 | 10.0 | 11.0 | 12.0 | 13.0 | 14.0 | 15.0 | 16.0 | 17.0 | 18.0 | 19.0 |
| atomic symbol | H | He | Li | Be | B | C | N | O | F | Ne | Na | Mg | K | Ca | Sc | Ti | V | Cr | Mn |
| name | hydrogen |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

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