GCSE
CHEMISTRY
AQA - COMBINED SCIENCE

Materials
For this paper you must have:
• Ruler
• Pencil, Rubber, Protractor and Compass
• Scientific calculator, which you are expected to use when appropriate

Instructions
• Answer all questions
• Answer questions in the space provided
• All working must be shown
• Do all rough work in this book. Cross out any rough work you don't want to be marked

Information
• The marks for the questions are shown in brackets
A student investigated the effect of temperature on the rate of a reaction.

**Figure 1** shows an experiment.

The student:

- put 50 cm$^3$ sodium thiosulfate solution into a conical flask
- heated the sodium thiosulfate solution to the required temperature
- put the flask on a cross drawn on a piece of paper
- added 5 cm$^3$ dilute hydrochloric acid and started a stopclock
- stopped the stopclock when the cross could no longer be seen
- repeated the experiment at different temperatures.

The equation for the reaction is:

$$\text{Na}_2\text{S}_2\text{O}_3(aq) + 2\text{HCl}(aq) \rightarrow 2\text{NaCl}(aq) + \text{H}_2\text{O}(l) + \text{SO}_2(g) + \text{S(s)}$$

(sodium thiosulfate + hydrochloric acid $\rightarrow$ sodium chloride + water + sulfur + sulfur dioxide)

(a) Which product is a gas?

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(1)
(b) Figure 2 shows the results of this experiment at five different temperatures.

The circled result point is anomalous.

Figure 2

(i) Draw a line of best fit on Figure 2 to show how the reaction time varied with reaction temperature.

(ii) Give a possible reason for the anomalous result at 40 °C.

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(iii) The reaction at 20 °C produced 0.32 g of sulfur in 64 seconds.

Calculate the rate of the reaction at 20 °C using the equation:

\[
\text{Rate of reaction} = \frac{\text{mass of sulfur}}{\text{time}}
\]

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Rate of reaction = _________________ grams per second

(2)
(iv) Give two reasons why the rate of the reaction increases as the temperature increases.

Tick (✔) two boxes.

- The particles move faster. [ ]
- The particles collide less often. [ ]
- All the particles have the same energy. [ ]
- The particles collide with more energy. [ ]
- The number of particles increases. [ ]

(v) Use the correct answer from the box to complete the sentence.

The minimum amount of energy particles must have to react is called the __________________________ energy.

(Total 8 marks)
A student investigated the rate of the reaction between magnesium and dilute hydrochloric acid. The student used the apparatus shown in Figure 1 to collect the gas produced.

Figure 1

(a) Outline a plan to investigate how the rate of this reaction changed when the concentration of the hydrochloric acid was changed.

• Describe how you would do the investigation and the measurements you would make.
• Describe how you would make it a fair test.

You do not need to write about safety precautions.

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(6)
(b) **Figure 2** shows the gas syringe during one of the experiments.

![Figure 2](image)

What is the volume of gas collected?

Tick one box.

- 5.3 cm³
- 6.0 cm³
- 6.5 cm³
- 7.0 cm³
(c) **Figure 3** shows the student’s results for one concentration of hydrochloric acid.

![Figure 3](image)

The table below shows the student’s results when the concentration was two times greater than the results on **Figure 3**.

<table>
<thead>
<tr>
<th>Time in seconds</th>
<th>Volume of gas produced in cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>35</td>
</tr>
<tr>
<td>15</td>
<td>52</td>
</tr>
<tr>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>30</td>
<td>87</td>
</tr>
</tbody>
</table>

Plot the results in the table above on the grid in **Figure 3**.
Draw a line of best fit.
(d) Give one conclusion about how the rate of reaction changed when the concentration of hydrochloric acid was changed.

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(Total 11 marks)

A student investigated the rate of reaction between calcium carbonate (marble chips) and hydrochloric acid.

The student used the apparatus shown in Figure 1.

The student:
• recorded the volume of gas collected every 5 seconds
• repeated the experiment using hydrochloric acid at different temperatures.

The equation for the reaction is:

\[ \text{CaCO}_3(s) + 2 \text{HCl(aq)} \rightarrow \text{CaCl}_2(aq) + \text{H}_2\text{O(l)} + \text{CO}_2(g) \]
(a) The student plotted results for the hydrochloric acid at 20 °C and 40 °C on a graph.

**Figure 2** shows the student’s graph.

![Graph showing the volume of gas over time at 20 °C and 40 °C](image)

Use information from **Figure 2** to answer these questions.

(i) State one conclusion the student could make about the effect of temperature on the rate of the reaction.

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(1)

(ii) Give one reason why the student could make this conclusion.

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(1)

(iii) For the hydrochloric acid at 60 °C the student had collected 30 cm³ after 15 seconds.

Calculate the average rate of reaction from 0 to 15 seconds.

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Rate of reaction = ____________________ cm³ per second

(1)
(b) The student then investigated how the surface area of marble chips affected the rate of reaction.

(i) Which two variables should the student keep constant?

Tick (✓) two boxes.

- Amount of water in the trough
- Concentration of acid
- Mass of marble chips
- Size of marble chips
- Volume of measuring cylinder

(ii) Explain, in terms of particles and collisions, the effect that increasing the surface area of the marble chips has on the rate of reaction.

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(c) Calcium carbonate is a catalyst for the industrial production of biodiesel.

Give one reason why using a catalyst reduces costs.

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(Total 8 marks)
A student investigated the rate of reaction between sodium thiosulfate solution and dilute hydrochloric acid, as shown in Figure 1.

Figure 1

The reaction produced a precipitate, which made the mixture turn cloudy.

The student timed how long it took until she could no longer see the cross.

She calculated the rate of the reaction.

(a) The equation for the reaction is:

\[
Na_2S_2O_3(aq) + 2 \text{HCl}(aq) \rightarrow 2 \text{NaCl}(aq) + S(s) + \text{SO}_2(g) + \text{H}_2\text{O}(l)
\]

Name the product that made the mixture go cloudy.

___________________________________________________________________

(1)
The student investigated the effect of changing the temperature of the sodium thiosulfate solution on the rate of reaction.

She plotted her results on a graph, as shown in Figure 2.

![Figure 2](image)

Describe the trends shown in the student’s results.

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(2)
(c) The student then investigated the effect of changing the concentration of sodium thiosulfate solution on the rate of the reaction.

(i) Suggest **two** variables the student would need to control to make sure that her results were valid.

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(ii) From this investigation the student correctly concluded:

‘As the concentration of sodium thiosulfate solution doubles, the rate of reaction doubles.’

Explain the student’s conclusion in terms of particles.

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(3)

(Total 8 marks)
A student investigated the rate of reaction between sodium thiosulfate and dilute hydrochloric acid.

The student placed a conical flask over a cross on a piece of paper.

The student mixed the solutions in the flask.

The solution slowly went cloudy.

The student timed how long it took until the cross could not be seen.

The equation for the reaction is:

\[
Na_2S_2O_3(aq) + 2 \text{HCl(aq)} \rightarrow 2 \text{NaCl(aq)} + \text{H}_2\text{O(l)} + \text{SO}_2(g) + \text{S(s)}
\]

(a) Explain why the solution goes cloudy.
(b) The student repeated the experiment with different concentrations of sodium thiosulfate.

<table>
<thead>
<tr>
<th>Concentration of sodium thiosulfate in moles per dm³</th>
<th>Time taken until the cross could not be seen in seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trial 1</td>
</tr>
<tr>
<td>0.040</td>
<td>71</td>
</tr>
<tr>
<td>0.060</td>
<td>42</td>
</tr>
<tr>
<td>0.080</td>
<td>31</td>
</tr>
</tbody>
</table>

(i) Calculate the mean time for 0.080 moles per dm³ of sodium thiosulfate.

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Mean = ____________________ seconds

(ii) Describe and explain, in terms of particles and collisions, the effect that increasing the concentration of sodium thiosulfate has on the rate of the reaction.

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(Total 7 marks)

A student investigated how rate of reaction changes with concentration.

The student reacted dilute hydrochloric acid with sodium thiosulfate solution.

The reaction forms a cloudy solution.

The equation for the reaction is:

\[ 2\text{HCl(aq)} + \text{Na}_2\text{S}_2\text{O}_3(aq) \rightarrow 2\text{NaCl(aq)} + \text{S(s)} + \text{SO}_2(g) + \text{H}_2\text{O(l)} \]
(a) Explain why the solution turns cloudy.

Use the equation to help you.

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The image shows the student performing the experiment.

This is the method used.

1. Put 50 cm$^3$ of sodium thiosulfate solution into a conical flask.
2. Put the flask on a cross drawn on a piece of paper.
3. Add 10 cm$^3$ of dilute hydrochloric acid.
4. Record the time taken when the cross can no longer be seen.
5. Repeat steps 1–4 with different concentrations of hydrochloric acid.
(b) The mass of the flask and its contents decreases during the reaction.

Explain why.

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The table shows the student's results.

<table>
<thead>
<tr>
<th>Concentration of hydrochloric acid in mol/dm³</th>
<th>Time taken until cross can no longer be seen in s</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>215</td>
</tr>
<tr>
<td>0.2</td>
<td>79</td>
</tr>
<tr>
<td>0.3</td>
<td>45</td>
</tr>
<tr>
<td>0.4</td>
<td>33</td>
</tr>
<tr>
<td>0.5</td>
<td>25</td>
</tr>
<tr>
<td>0.6</td>
<td>20</td>
</tr>
</tbody>
</table>

(c) Another student used the same method.

The time taken until the cross can no longer be seen was much greater.

Suggest why.

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(1)
(d) The student’s conclusion was:

‘The time is inversely proportional to the concentration of acid used.’

Explain whether the results in the table support this conclusion.

You must include calculations in your answer.

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(3)

(e) Another student investigated the effect of temperature on the rate of reaction between sodium thiosulfate and dilute hydrochloric acid.

The student used temperature values in the range 5 °C to 50 °C

Describe how the student should change the method for this investigation.

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(4)

(Total 12 marks)
Sulfur dioxide (SO\textsubscript{2}) is used to manufacture sulfuric acid.

(a) Explain why sulfur dioxide has a low boiling point.
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(b) The equation shows one stage in the manufacture of sulfuric acid from sulfur dioxide.

\[
2\text{SO}_2(g) + \text{O}_2(g) \xrightarrow{\text{catalyst}} 2\text{SO}_3(g)
\]

The reaction is exothermic in the forward direction.

Use Le Chatelier’s Principle to predict the effect of increasing the temperature on the amount of sulfur trioxide (SO\textsubscript{3}) produced at equilibrium.

Give a reason for your answer.
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(c) Use Le Chatelier’s Principle to predict the effect of increasing the pressure on the amount of sulfur trioxide (SO\textsubscript{3}) produced at equilibrium.

Give a reason for your answer.
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(Total 7 marks)
Ammonium nitrate (NH$_4$NO$_3$) is produced by reacting ammonia with nitric acid.

A student measured the mass of ammonium nitrate that dissolves in 100 cm$^3$ of water at different temperatures.

The table below shows the student's results.

<table>
<thead>
<tr>
<th>Temperature in °C</th>
<th>0</th>
<th>20</th>
<th>40</th>
<th>60</th>
<th>80</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of ammonium nitrate in g that dissolves in 100 cm$^3$ water</td>
<td>119</td>
<td>190</td>
<td>286</td>
<td>321</td>
<td>630</td>
<td>1 024</td>
</tr>
</tbody>
</table>

(a) Use the table above to plot a graph of the solubility of ammonium nitrate on the figure below.
(b) At 20 °C, 190 g of ammonium nitrate dissolves in 100 cm$^3$ of water.

Calculate the amount of ammonium nitrate (in moles) that dissolves in 1 dm$^3$ of water at 20 °C.

Relative atomic masses ($A_r$): H = 1; N = 14; O = 16

Amount of dissolved ammonium nitrate = _________ mol

(c) Farmers use ammonium nitrate as a fertiliser.

Farmers want to slow down the rate at which ammonium nitrate fertiliser dissolves in the water in the soil.

Suggest why they spread the fertiliser in the form of small beads instead of a fine powder.

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Ammonia is needed to make ammonium nitrate.

The reaction used to make ammonia is:

\[
\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \xrightarrow{\text{catalyst}} 2\text{NH}_3(\text{g})
\]

The forward reaction is exothermic.

At equilibrium, about 35% of the nitrogen and hydrogen are converted to ammonia at 450 °C and 200 atmospheres pressure.

Explain the effects of increasing the temperature, or increasing the pressure, on the amount of ammonia produced at equilibrium.

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(4)
(Total 13 marks)