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
The following steps show how to use a type of glue.

**Step 1** Measure out equal amounts of the liquids from tubes A and B.

![Image of measuring tubes](image)

**Step 2** Mix the liquids to make the glue. Put a thin layer of the glue onto each of the surfaces to be joined.

![Image of mixing glue](image)

**Step 3** Put the pieces together and hold them with tape.

![Image of putting pieces together](image)

**Step 4** Leave the glue to set.

(a) When liquids A and B are mixed a chemical reaction takes place. This reaction is *exothermic*.

What does *exothermic* mean?

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

(2)
(b) The time taken for the glue to set at different temperatures is given in the table below.

<table>
<thead>
<tr>
<th>Temperature in°C</th>
<th>Time taken for the glue to set</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>3 days</td>
</tr>
<tr>
<td>60</td>
<td>6 hours</td>
</tr>
<tr>
<td>90</td>
<td>1 hour</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>decreases</th>
<th>increases</th>
<th>stays the same</th>
</tr>
</thead>
</table>

When the temperature is increased the time taken for the glue to set

________________________________________________________________________

When the temperature is increased the rate of the setting reaction

________________________________________________________________________

(2)

(ii) Tick (✓) two reasons why an increase in temperature affects the rate of reaction.

<table>
<thead>
<tr>
<th>Reason</th>
<th>Tick (✓)</th>
</tr>
</thead>
<tbody>
<tr>
<td>It gives the particles more energy</td>
<td></td>
</tr>
<tr>
<td>It increases the concentration of the particles</td>
<td></td>
</tr>
<tr>
<td>It increases the surface area of the particles</td>
<td></td>
</tr>
<tr>
<td>It makes the particles move faster</td>
<td></td>
</tr>
</tbody>
</table>

(2)

(Total 6 marks)

This question is about energy changes in chemical reactions.

(a) Complete the word equation for the combustion of hydrogen.

hydrogen + oxygen → ____________________

(1)
(b) **Figure 1** shows a simple energy level diagram.

![Energy Level Diagram](image_url)

(i) Which arrow, A, B or C, shows the activation energy?

Tick (✓) one box.

- A
- B
- C

(ii) What type of reaction is shown by the energy level diagram in **Figure 1**?

Give a reason for your answer.

Type of reaction _______________________________________________

Reason _______________________________________________________

______________________________________________________________

(iii) For a reaction, the value of A is 1370 kJ and C is 3230 kJ. Calculate the value of B.

B = _____________________________ kJ

(1)
Alcohols are used as fuels.

A group of students investigated the amount of energy released when different alcohols are burned.

The students used the apparatus shown in Figure 2.

Figure 2

![Diagram of apparatus](image)

(i) Figure 3 shows the start temperature and the final temperature of the water.

Figure 3

![Temperature readings](image)

Write the start temperature and the final temperature of the water in Table 1. Work out the increase in temperature to complete Table 1.

<table>
<thead>
<tr>
<th>Start temperature of the water in °C</th>
<th>Final temperature of the water in °C</th>
<th>Increase in temperature in °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(3)
(ii) The students worked out the heat energy released by burning 1 g of each alcohol. The students used the equation:

\[ \text{Heat energy released} = m \times 4.2 \times \text{increase in temperature} \]

Look at Figure 2. What is the value of \( m \)?

\[ m = \underline{\hspace{2cm}} \text{g} \]  

(1)

(iii) Table 2 shows the students’ results.

<table>
<thead>
<tr>
<th>Name of alcohol</th>
<th>Number of carbon atoms in one molecule of alcohol</th>
<th>Heat energy released when 1 g of alcohol is burned in kJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methanol</td>
<td>1</td>
<td>11.4</td>
</tr>
<tr>
<td>Ethanol</td>
<td>2</td>
<td>13.5</td>
</tr>
<tr>
<td>Propanol</td>
<td>3</td>
<td>20.1</td>
</tr>
<tr>
<td>Butanol</td>
<td>4</td>
<td>16.8</td>
</tr>
<tr>
<td>Pentanol</td>
<td>5</td>
<td>17.2</td>
</tr>
</tbody>
</table>

Which value of heat energy released is anomalous?

\[ \underline{\hspace{2cm}} \]  

(1)

(iv) Look at Table 2. What is the relationship between the number of carbon atoms in one molecule of alcohol and the heat energy released when 1 g of the alcohol is burned?

\[ \underline{\hspace{2cm}} \]  

\[ \underline{\hspace{2cm}} \]  

\[ \underline{\hspace{2cm}} \]  

(1)
(v) The value in a data book for the amount of heat energy released when 1 g of butanol is burned completely is 36.2 kJ.

Suggest two reasons why the students’ result for butanol is lower than the data book value.

1. __________________________________________________________
   __________________________________________________________

2. __________________________________________________________
   __________________________________________________________

(vi) The displayed structure of butanol is:

What is the functional group of the alcohol?

Tick (✔) one box.

--- C --- C
--- C --- H
--- O --- H

(Total 14 marks)
A student investigates the energy released when zinc powder reacts with copper sulfate solution. The student uses the apparatus shown in Figure 1.

**Figure 1**

1 g zinc powder

Thermometer

Glass beaker

100 cm$^3$ copper sulfate solution

The student:

• measures 100 cm$^3$ copper sulfate solution into a beaker
• measures the temperature of the copper sulfate solution
• puts 1 g zinc powder into the beaker
• stirs the mixture with a thermometer
• measures the highest temperature.

The student’s results were:

Starting temperature = 21 °C
Highest temperature = 32 °C

(a) (i) Calculate the change in temperature.

\[
\text{Change in temperature} = \text{Highest temperature} - \text{Starting temperature}
\]

\[
\text{Change in temperature} = 32 °C - 21 °C = 11 °C
\]

(1)

(ii) Calculate the energy released in the reaction.

Use the equation

\[
\text{energy released} = \text{volume of solution} \times \frac{\text{temperature change}}{4.2}\text{in }\text{J}
\]

\[
\text{energy released} = 100 \text{cm}^3 \times \frac{11 °C}{4.2} \text{J}
\]

\[
\text{energy released} = \frac{1100}{4.2} \text{J} = 261.905 \text{J}
\]

(2)
(b) The reaction of zinc with copper sulfate is exothermic.

How can you tell from the student’s results that the reaction is exothermic?

___________________________________________________________________

___________________________________________________________________

(1)

(c) The energy diagram for the reaction is shown in Figure 2.

\[ \text{Figure 2} \]

(i) How can you tell from the energy diagram that the reaction is exothermic?

___________________________________________________________________

___________________________________________________________________

(1)

(ii) Which arrow shows the activation energy in Figure 2?

Tick (✓) one box.

\[ \text{A} \]

\[ \text{B} \]

\[ \text{C} \]

(1)

(Total 6 marks)
A student did an experiment to find the energy change when hydrochloric acid reacts with sodium hydroxide.

The equation which represents the reaction is:

\[
\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}
\]

The student used the apparatus shown in the diagram.

![Diagram of apparatus](image)

The student placed 50 cm³ of hydrochloric acid in a glass beaker and measured the initial temperature.

The student then quickly added 50 cm³ of sodium hydroxide solution and stirred the mixture with the thermometer. The highest temperature was recorded.

The student repeated the experiment, and calculated the temperature change each time.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Initial temperature in °C</th>
<th>Highest temperature in °C</th>
<th>Temperature change in °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19.0</td>
<td>26.2</td>
<td>7.2</td>
</tr>
<tr>
<td>2</td>
<td>22.0</td>
<td>29.0</td>
<td>7.0</td>
</tr>
<tr>
<td>3</td>
<td>19.2</td>
<td>26.0</td>
<td>6.8</td>
</tr>
<tr>
<td>4</td>
<td>19.0</td>
<td>23.5</td>
<td>4.5</td>
</tr>
</tbody>
</table>

(a) The biggest error in this experiment is heat loss.

Suggest how the apparatus could be modified to reduce heat loss.

___________________________________________________________________
___________________________________________________________________
(1)

(b) Suggest why it is important to mix the chemicals thoroughly.

___________________________________________________________________

(1)
(c) Which one of these experiments was probably done on a different day to the others? Give a reason for your answer.
___________________________________________________________________ (1)

(d) Suggest why experiment 4 should not be used to calculate the average temperature change.
___________________________________________________________________
___________________________________________________________________ (1)

(e) Calculate the average temperature change from the first three experiments.
___________________________________________________________________
Answer = _________________________ °C (1)

(f) Use the following equation to calculate the energy change for this reaction.

Energy change in joules = 100 × 4.2 × average temperature change
___________________________________________________________________
Answer = _________________________ J (1)

(g) Which one of these energy level diagrams represents the energy change for this reaction? Give a reason for your answer.

Diagram A

Diagram B

______________________________________________________________
______________________________________________________________ (1)
(Total 7 marks)
The equation for the reaction of ethene and bromine is:

\[
\text{C}_2\text{H}_4(\text{g}) + \text{Br}_2(\text{l}) \rightarrow \text{C}_2\text{H}_4\text{Br}_2(\text{l})
\]

The reaction is exothermic.

(a) Complete the energy level diagram.

You should label:
- the activation energy
- the enthalpy change \(\Delta H\).

(b) (i) The equation for the reaction can be represented as:

\[
\begin{align*}
\text{C} & \equiv \text{C} + \text{Br} & \equiv \text{Br} \\
\text{H} & \equiv \text{H} & \equiv \text{H}
\end{align*}
\]

<table>
<thead>
<tr>
<th>Bond</th>
<th>Bond dissociation energy in kJ per mole</th>
</tr>
</thead>
<tbody>
<tr>
<td>C — H</td>
<td>413</td>
</tr>
<tr>
<td>C = C</td>
<td>614</td>
</tr>
<tr>
<td>Br—Br</td>
<td>193</td>
</tr>
<tr>
<td>C — C</td>
<td>348</td>
</tr>
<tr>
<td>C—Br</td>
<td>276</td>
</tr>
</tbody>
</table>
Use the bond dissociation energies in the table to calculate the enthalpy change ($\Delta H$) for this reaction.

Enthalpy change ($\Delta H$) = ______ kJ per mole

(ii) The reaction is exothermic.

Explain why, in terms of bonds broken and bonds formed.

(Total 8 marks)
When ammonium chloride is dissolved in water, there is a temperature change.

A student investigated how the temperature of water changed when different masses of ammonium chloride were added to the same volume of water.

The water used was at room temperature.

The student’s results are shown in the table.

<table>
<thead>
<tr>
<th>Mass of ammonium chloride in g</th>
<th>Final temperature of solution in ºC</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>14.5</td>
</tr>
<tr>
<td>20</td>
<td>8.5</td>
</tr>
<tr>
<td>25</td>
<td>5.5</td>
</tr>
<tr>
<td>30</td>
<td>2.5</td>
</tr>
<tr>
<td>35</td>
<td>1.0</td>
</tr>
<tr>
<td>40</td>
<td>1.0</td>
</tr>
<tr>
<td>45</td>
<td>1.0</td>
</tr>
</tbody>
</table>

(a) (i) Use the correct word from the box to complete the sentence.

| endothermic | exothermic | reduction |

When ammonium chloride dissolves in water, the change can be described as ___________________________.

(ii) Give a reason for your answer to part (a) (i). Refer to the table of results in your answer.

________________________________________________________________________________________
________________________________________________________________________________________

(1)
(b) The student added the ammonium chloride to water and stirred the mixture.

The water was in a glass beaker.

His teacher said that using a glass beaker could cause inaccurate results.

What could the student have used instead of a glass beaker to improve the accuracy?

Give a reason why this would improve the accuracy of his results.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

(2)

(c) The student made sure his investigation was a fair test.

State **two** control variables the student should keep the same.

Give a reason why changing each of these two control variables would affect the temperature change.

Control variable 1 ____________________________________________________

Reason ____________________________________________________________
___________________________________________________________________
___________________________________________________________________

Control variable 2 ____________________________________________________

Reason ____________________________________________________________
___________________________________________________________________
___________________________________________________________________
(d) (i) The student’s results table has been repeated below.

<table>
<thead>
<tr>
<th>Mass of ammonium chloride in g</th>
<th>Final temperature of solution in °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>14.5</td>
</tr>
<tr>
<td>20</td>
<td>8.5</td>
</tr>
<tr>
<td>25</td>
<td>5.5</td>
</tr>
<tr>
<td>30</td>
<td>2.5</td>
</tr>
<tr>
<td>35</td>
<td>1.0</td>
</tr>
<tr>
<td>40</td>
<td>1.0</td>
</tr>
<tr>
<td>45</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Plot the results on the grid.

(ii) Complete the graph by drawing two straight lines of best fit through the points.
(iii) Use the graph to estimate the temperature of the room.

Show your working on the graph.

Temperature of room = __________________ °C

(2)

(e) Explain why the final temperature was the same for all masses of 35 g and greater.
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

(2)

(f) A second student also did one of the experiments.

This student recorded a final temperature of 14.5 °C.

Both students dissolved 20 g of ammonium chloride in water.

Use the graph to explain the difference in the two final temperatures.
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

(2)

(Total 18 marks)
A student investigates the energy released when hydrochloric acid completely neutralises sodium hydroxide solution. The student uses the apparatus shown in Figure 1.

The student:

• measures 25 cm$^3$ sodium hydroxide solution into a polystyrene cup
• fills a burette with hydrochloric acid
• measures the temperature of the sodium hydroxide solution
• adds 5 cm$^3$ hydrochloric acid to the sodium hydroxide solution in the polystyrene cup
• stirs the mixture and measures the highest temperature of the mixture
• continues to add 5 cm$^3$ portions of hydrochloric acid, stirring and measuring the highest temperature of the mixture after each addition.
(a) The student has plotted a graph of the results.

The graph line has been incorrectly drawn by including an anomalous result.

The graph is shown in Figure 2.

![Figure 2](image)

(i) Suggest a cause for the anomalous result when 20 cm³ of hydrochloric acid is added.

______________________________________________________________

______________________________________________________________

(1)

(ii) Suggest the true value of the temperature of the anomalous point.

Temperature = _______________ °C

(1)

(iii) What was the total volume of the mixture when the maximum temperature was reached?

______________________________________________________________

Total volume of the mixture = _______________ cm³

(1)

(iv) Calculate the overall temperature increase in this experiment.

______________________________________________________________

Overall temperature increase = _______________ °C

(1)
(v) Use your answers to (iii) and (iv) and the equation to calculate the energy released in the reaction. Give the unit.

Assume the volume in cm$^3$ is equivalent to the mass of solution in grams.

Equation: $Q = mc\Delta T$

where:
$Q =$ energy released
$m =$ mass of solution (g)
$c =$ 4.2 (J per g per °C)
$\Delta T =$ change in temperature (°C)

Energy released = _______________ Unit = __________

(b) The student did the experiment again, starting with 50 cm$^3$ of sodium hydroxide solution instead of 25 cm$^3$.

Explain why this would make no difference to the overall temperature increase.

______________________________________________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

(2)

(Total 8 marks)
Methanol (CH$_3$OH) can be made by reacting methane (CH$_4$) and oxygen (O$_2$). The reaction is exothermic.

The equation for the reaction is:

$$2\text{CH}_4 + \text{O}_2 \rightarrow 2\text{CH}_3\text{OH}$$

(a) The energy level diagram for this reaction is given below.

(i) How does the diagram show that this reaction is exothermic?

(ii) A platinum catalyst can be used to increase the rate of this reaction. What effect does adding a catalyst have on the energy level diagram?
(b) The equation can also be written showing the structural formulae of the reactants and the product.

\[
\begin{align*}
2 \text{H-C-H} + \text{O=O} & \rightarrow 2 \text{H-C-O-H} \\
\end{align*}
\]

(i) Use the bond energies given in the table to help you to calculate the energy change for this reaction.

<table>
<thead>
<tr>
<th>Bond</th>
<th>Bond energy in kJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-H</td>
<td>435</td>
</tr>
<tr>
<td>O=O</td>
<td>497</td>
</tr>
<tr>
<td>C-O</td>
<td>336</td>
</tr>
<tr>
<td>O-H</td>
<td>464</td>
</tr>
</tbody>
</table>

Energy change = ________________ kJ

(3)

(iii) In terms of the bond energies, why is this an exothermic reaction?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

(1)

(Total 6 marks)