Materials
For this paper you must have:
- a ruler
- a calculator
- the periodic table (enclosed).

Instructions
- Answer all questions in the spaces provided.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- There are 100 marks available on this paper.
- The marks for questions are shown in brackets.
- You are expected to use a calculator where appropriate.
- You are reminded of the need for good English and clear presentation in your answers.
- When answering questions 06.3 and 08.3 you need to make sure that your answer:
  - is clear, logical, sensibly structured
  - fully meets the requirements of the question
  - shows that each separate point or step supports the overall answer.

Advice
In all calculations, show clearly how you work out your answer.

Please write clearly, in block capitals.

Centre number   Candidate number
Surname
Forename(s)
Candidate signature
This question is about different substances and their structures.

Draw **one** line from each statement to the diagram which shows the structure.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>The substance is a gas</td>
<td></td>
</tr>
<tr>
<td>The substance is a liquid</td>
<td></td>
</tr>
<tr>
<td>The substance is ionic</td>
<td></td>
</tr>
<tr>
<td>The substance is a solid metal</td>
<td></td>
</tr>
</tbody>
</table>

[4 marks]
Figure 1 shows the structure of an element.

Figure 1

What is the name of this element?

Tick one box.

- Carbon
- Chloride
- Nitrogen
- Xenon

Why does this element conduct electricity?

Tick one box.

- It has delocalised electrons
- It contains hexagonal rings
- It has weak forces between the layers
- It has ionic bonds

Question 1 continues on the next page
**Figure 2** shows the structure of an alloy.

**Figure 2**

Explain why this alloy is harder than the pure metal Y. [2 marks]

What percentage of the atoms in the alloys are atoms of X? [2 marks]
What type of substance is an alloy?

Tick one box.

- Compound
- Element
- Mixture

[1 mark]

Turn over for the next question
A student investigated the reactivity of three different metals.

This is the method used.

1. Place 1 g of metal powder in a test tube.
2. Add 10 cm$^3$ of metal sulfate.
3. Wait 1 minute and observe.
4. Repeat using the other metals and metal sulfates.

The student placed a tick in Table 1 if there was a reaction and a cross if there was no reaction.

<table>
<thead>
<tr>
<th></th>
<th>Zinc</th>
<th>Copper</th>
<th>Magnesium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper sulfate</td>
<td>✓</td>
<td>x</td>
<td>✓</td>
</tr>
<tr>
<td>Magnesium sulfate</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Zinc sulfate</td>
<td>x</td>
<td>x</td>
<td>✓</td>
</tr>
</tbody>
</table>

What is the dependent variable in the investigation?

Tick one box.

- Time taken
- Type of metal
- Volume of metal sulfate
- Whether there was a reaction or not

Give one observation the student could make that shows there is a reaction between zinc and copper sulfate.
The student used measuring instruments to measure some of the variables.

Draw one line from each variable to the measuring instrument used to measure the variable.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Measuring instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of metal powder</td>
<td>Balance</td>
</tr>
<tr>
<td>Volume of metal sulfate</td>
<td>Measuring cylinder</td>
</tr>
<tr>
<td></td>
<td>Ruler</td>
</tr>
<tr>
<td></td>
<td>Burette</td>
</tr>
<tr>
<td></td>
<td>Thermometer</td>
</tr>
<tr>
<td></td>
<td>Test tube</td>
</tr>
</tbody>
</table>

Use the results shown in Table 1 to place zinc, copper and magnesium in order of reactivity.

Most reactive

Least reactive

Suggest one reason why the student should not use sodium in this investigation.
Which metal is found in the Earth as the metal itself? [1 mark]

Tick one box.

- Calcium
- Gold
- Lithium
- Potassium

Iron is found in the Earth as iron oxide ($\text{Fe}_2\text{O}_3$).

Iron oxide is reduced to produce iron.

Balance the equation for the reaction. [1 mark]

$$\_\_\text{Fe}_2\text{O}_3 \ + \ _\_\text{C} \ \rightarrow \ _\_\text{Fe} \ + \ _\_\text{CO}_2$$
02.8 Name the element used to reduce iron oxide. [1 mark]

02.9 What is meant by reduction? [1 mark]
Tick one box.

- Gain of iron
- Gain of oxide
- Loss of iron
- Loss of oxygen

Turn over for the next question
Lithium carbonate reacts with dilute hydrochloric acid.

A group of students investigated the volume of gas produced.

This is the method used.

1. Place a known mass of lithium carbonate in a conical flask.
2. Measure 10 cm$^3$ of dilute hydrochloric acid using a measuring cylinder.
3. Pour the acid into the conical flask.
4. Place a bung in the flask and collect the gas as shown in Figure 3.

Figure 3
Figure 4 shows the measuring cylinder.

Figure 4

What volume of gas has been collected?

[1 mark]

Volume = __________________________ cm³

Question 3 continues on the next page
Table 2 shows the students’ results.

**Table 2**

<table>
<thead>
<tr>
<th>Mass of lithium carbonate in g</th>
<th>Volume of gas in cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>0.1</td>
<td>22</td>
</tr>
<tr>
<td>0.2</td>
<td>44</td>
</tr>
<tr>
<td>0.3</td>
<td>50</td>
</tr>
<tr>
<td>0.4</td>
<td>88</td>
</tr>
<tr>
<td>0.5</td>
<td>96</td>
</tr>
<tr>
<td>0.6</td>
<td>96</td>
</tr>
<tr>
<td>0.7</td>
<td>96</td>
</tr>
</tbody>
</table>
On **Figure 5**:
- Plot these results on the grid.
- Complete the graph by drawing **two** straight lines of best fit.

![Figure 5](image)

**Figure 5**

What are two possible reasons for the anomalous result?

Tick **two** boxes.

- Too much lithium carbonate was added.
- The bung was not pushed in firmly enough.
- There was too much water in the trough.
- The measuring cylinder was not completely over the delivery.
- The conical flask was too small.
Describe the pattern the graph shows up to 0.4 g of lithium carbonate added.

Lithium carbonate decomposes when heated.

The equation shows the decomposition of lithium carbonate.

\[ \text{Li}_2\text{CO}_3 (s) \rightarrow \text{Li}_2\text{O} (s) + \text{CO}_2 (g) \]

**Figure 6** shows the apparatus a student used to decompose lithium carbonate.
03.5 Why does the limewater bubble? [1 mark]

03.6 The student repeated the experiment with potassium carbonate. The limewater did not bubble.

Suggest why there were no bubbles in the limewater. [1 mark]

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Turn over for the next question
A student investigated the reactivity of different metals.

The student used the apparatus shown in Figure 7.

Figure 7

The student used four different metals.

The student measured the temperature rise for each metal three times.

The student’s results are shown in Table 3.

Table 3

<table>
<thead>
<tr>
<th>Metal</th>
<th>Temperature rise in °C</th>
<th>Mean temperature rise in °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test 1</td>
<td>Test 2</td>
</tr>
<tr>
<td>Calcium</td>
<td>17.8</td>
<td>16.9</td>
</tr>
<tr>
<td>Iron</td>
<td>6.2</td>
<td>6.0</td>
</tr>
<tr>
<td>Magnesium</td>
<td>12.5</td>
<td>4.2</td>
</tr>
<tr>
<td>Zinc</td>
<td>7.8</td>
<td>8.0</td>
</tr>
</tbody>
</table>
Give two variables the student should control so that the investigation is a fair test. [2 marks]

1

2

One of the results for magnesium is anomalous.

Which result is anomalous?

Suggest one reason why this anomalous result was obtained. [2 marks]

Result

Reason

Calculate the mean temperature rise for calcium. [1 mark]

Mean temperature rise = °C

Question 4 continues on the next page
The temperature rose when the metals were added to sulfuric acid.

Give one other observation that might be made when the metal was added to sulfuric acid. How would this observation be different for the different metals? [2 marks]

Aluminium is more reactive than iron and zinc but less reactive than calcium and magnesium.

Predict the temperature rise when aluminium is reacted with dilute hydrochloric acid. [1 mark]

Temperature rise = °C
Turn over for the next question
0 5 | Figure 8 shows magnesium burning in air.

Figure 8

0 5 . 1 Look at Figure 8.

How can you tell that a chemical reaction is taking place?

[1 mark]

0 5 . 2 Name the product from the reaction of magnesium in Figure 8.

[1 mark]
05.3 The magnesium needed heating before it would react.

What conclusion can you draw from this? [1 mark]
Tick one box.

- The reaction is reversible
- The reaction has a high activation energy
- The reaction is exothermic
- Magnesium has a high melting point

05.4 A sample of the product from the reaction in Figure 8 was added to water and shaken.

Universal indicator was added.

The universal indicator turned blue.

What is the pH value of the solution? [1 mark]
Tick one box.

1  
4  
7  
9  

Question 5 continues on the next page
0.5  1

Why are nanoparticles effective in very small quantities?

Tick one box.

- They are elements
- They are highly reactive
- They have a low melting point
- They have a high surface area to volume ratio

0.5  1

Give one advantage of using nanoparticles in sun creams.

0.5  1

Give one disadvantage of using nanoparticles in sun creams.
A coarse particle has a diameter of $1 \times 10^{-6}$ m.
A nanoparticle has a diameter of $1.6 \times 10^{-9}$ m.

Calculate how many times bigger the diameter of the coarse particle is than the diameter of the nanoparticle.

[2 marks]
A student investigated the reaction of copper carbonate with dilute sulfuric acid.

The student used the apparatus shown in Figure 9.

Figure 9

[Copper carbonate][Dilute sulfuric acid][Balance]

Complete the state symbols in the equation. [2 marks]

\[
\text{CuCO}_3 \text{(s)} + \text{H}_2\text{SO}_4 \text{(aq)} \rightarrow \text{CuSO}_4 \text{(aq)} + \text{H}_2\text{O} \text{(aq)} + \text{CO}_2 \text{(g)}
\]

Why did the balance reading decrease during the reaction? [1 mark]

Tick one box.

- The copper carbonate broke down.
- A salt was produced in the reaction.
- A gas was lost from the flask.
- Water was produced in the reaction.
Describe a safe method for making pure crystals of copper sulfate from copper carbonate and dilute sulfuric acid. Use the information in Figure 9 to help you.

In your method you should name all of the apparatus you will use.

[6 marks]

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Question 6 continues on the next page
The percentage atom economy for a reaction is calculated using:

\[
\text{Atom economy} = \left( \frac{\text{Relative formula mass of desired product from equation}}{\text{Sum of relative formula masses of all reactants from equation}} \right) \times 100
\]

The equation for the reaction of copper carbonate and sulfuric acid is:

\[
\text{CuCO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{H}_2\text{O} + \text{CO}_2
\]

Relative formula masses: \(\text{CuCO}_3 = 123.5\); \(\text{H}_2\text{SO}_4 = 98.0\); \(\text{CuSO}_4 = 159.5\)

Calculate the percentage atom economy for making copper sulfate from copper carbonate.

[3 marks]

\[
\text{Atom economy} = \text{percentage atom economy}
\]

SPECIMEN MATERIAL
Give one reason why it is important for the percentage atom economy of a reaction to be as high as possible. [1 mark]

Turn over for the next question
The electronic structure of the atoms of five elements are shown in Figure 10.

The letters are not the symbols of the elements.

Choose the element to answer questions 07.1 to 07.5. Each element can be used once, more than once or not at all.

Use the periodic table to help you.

Which element is hydrogen?  
Tick one box.  

Which element is a halogen?  
Tick one box.
Which element is a metal in the same group of the periodic table as element A? [1 mark]

Tick one box.

B  C  D  E

Which element exists as single atoms? [1 mark]

Tick one box.

A  B  C  D  E

There are two isotopes of element A. Information about the two isotopes is shown in Table 4.

<table>
<thead>
<tr>
<th>Mass number of the isotope</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage abundance</td>
<td>92.5</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Use the information in Table 4 to calculate the relative atomic mass of element A. Give your answer to 2 decimal places. [4 marks]

Relative atomic mass =
An atom of aluminium has the symbol $^{27}_{13}\text{Al}$.

Give the number of protons, neutrons and electrons in this atom of aluminium. [3 marks]

Number of protons _____________________
Number of neutrons _____________________
Number of electrons _____________________

Why is aluminium positioned in Group 3 of the periodic table? [1 mark]
In the periodic table, the transition elements and Group 1 elements are metals.

Some of the properties of two transition elements and two Group 1 elements are shown in Table 5.

### Table 5

<table>
<thead>
<tr>
<th></th>
<th>Transition elements</th>
<th>Group 1 elements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chromium</td>
<td>Iron</td>
</tr>
<tr>
<td>Melting point in°C</td>
<td>1857</td>
<td>1535</td>
</tr>
<tr>
<td>Formula of oxides</td>
<td>CrO</td>
<td>FeO</td>
</tr>
<tr>
<td></td>
<td>Cr₂O₃</td>
<td>Fe₂O₃</td>
</tr>
<tr>
<td></td>
<td>CrO₂</td>
<td>Fe₃O₄</td>
</tr>
<tr>
<td></td>
<td>CrO₃</td>
<td></td>
</tr>
</tbody>
</table>

Use your own knowledge and the data in Table 5 to compare the chemical and physical properties of transition elements and Group 1 elements.

[6 marks]
Figure 11 shows the outer electrons in an atom of the Group 1 element potassium and in an atom of the Group 6 element sulfur.

Potassium forms an ionic compound with sulfur.

Describe what happens when two atoms of potassium react with one atom of sulfur.

Give your answer in terms of electron transfer.

Give the formulae of the ions formed.

[5 marks]
The structure of potassium sulfide can be represented using the ball and stick model in Figure 12.

**Figure 12**

The ball and stick model is **not** a true representation of the structure of potassium sulfide.

Give one reason why.

[1 mark]

---

Question 9 continues on the next page
Sulfur can also form covalent bonds.

Complete the dot and cross diagram to show the covalent bonding in a molecule of hydrogen sulfide.

Show the outer shell electrons only.

[2 marks]

![Hydrogen sulfide dot and cross diagram]

Calculate the relative formula mass \((M_r)\) of aluminium sulfate \(\text{Al}_2(\text{SO}_4)_3\)

Relative atomic masses \((A_i)\): oxygen = 16; aluminium = 27; sulfur = 32

[2 marks]

\[\text{Relative formula mass} = \]
Covalent compounds such as hydrogen sulfide have low melting points and do **not** conduct electricity when molten.

Draw **one** line from each property to the explanation of the property.

<table>
<thead>
<tr>
<th>Property</th>
<th>Explanation of property</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low melting point</td>
<td>Electrons are free to move</td>
</tr>
<tr>
<td>Does not conduct electricity when molten</td>
<td>There are no charged particles free to move</td>
</tr>
<tr>
<td></td>
<td>Ions are free to move</td>
</tr>
<tr>
<td></td>
<td>Weak intermolecular forces of attraction</td>
</tr>
<tr>
<td></td>
<td>Bonds are weak</td>
</tr>
<tr>
<td></td>
<td>Bonds are strong</td>
</tr>
</tbody>
</table>
Ionic compounds such as potassium sulfide have high boiling points and conduct electricity when dissolved in water.

Draw one line from each property to the explanation of the property.

<table>
<thead>
<tr>
<th>Property</th>
<th>Explanation of property</th>
</tr>
</thead>
<tbody>
<tr>
<td>High boiling point</td>
<td>Electrons are free to move</td>
</tr>
<tr>
<td>Conduct electricity when molten</td>
<td>There are no charged particles free to move</td>
</tr>
<tr>
<td></td>
<td>Ions are free to move</td>
</tr>
<tr>
<td></td>
<td>Weak intermolecular forces of attraction</td>
</tr>
<tr>
<td></td>
<td>Bonds are weak</td>
</tr>
<tr>
<td></td>
<td>Bonds are strong</td>
</tr>
</tbody>
</table>
10

Rock salt is a mixture of sand and salt.

Salt dissolves in water. Sand does not dissolve in water.

Some students separated rock salt.

This is the method used.

1. Place the rock salt in a beaker.
2. Add 100 cm$^3$ of cold water.
3. Allow the sand to settle to the bottom of the beaker.
4. Carefully pour the salty water into an evaporating dish.
5. Heat the contents of the evaporating dish with a Bunsen burner until salt crystals start to form.

10.1 Suggest one improvement to step 2 to make sure all the salt is dissolved in the water.

[1 mark]

10.2 The salty water in step 4 still contained very small grains of sand.

Suggest one improvement to step 4 to remove all the sand.

[1 mark]

10.3 Suggest one safety precaution the students should take in step 5.

[1 mark]

Question 10 continues on the next page
Another student removed water from salty water using the apparatus in Figure 13.

**Figure 13**

10.4 Describe how this technique works by referring to the processes at A and B.

[2 marks]

10.5 What is the reading on the thermometer during this process?

[1 mark]

_____________ °C

END OF QUESTIONS