OCR
Oxford Cambridge and RSA

Monday 22 May 2023 – Morning

GCSE (9−1) Chemistry B (Twenty First Century Science)

J258/03 Breadth in Chemistry (Higher Tier)

Time allowed: 1 hour 45 minutes

You must have:
- a ruler (cm/mm)
- the Data Sheet for GCSE (9–1) Chemistry B (inside this document)

You can use:
- an HB pencil
- a scientific or graphical calculator

H

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **90**.
- The marks for each question are shown in brackets **[ ]**.
- This document has **20** pages.

ADVICE
- Read each question carefully before you start your answer.

1 Argon forms 1% of the air and is unreactive.

Argon is used as a replacement for nitrogen when nitrogen is too reactive.

(a) Argon is unreactive because it is in Group 0 of the Periodic Table.

State **one** other property of argon.

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

(b) Chlorine is very reactive. Argon is unreactive.

Explain how the reactivity of these two elements are related to the arrangement of electrons in their atoms.

.....

.....

.....

..... **[2]**

(c) An element **X** has two electron shells with one electron in its outer shell.

(i) Which statements about **X** are **true**, and which are **false**?

Tick (✓) **one** box in each row.

	True	**False**
X is a metal.		
X is in the first period of the Periodic Table.		
X forms X^- ions.		
X loses one electron when it reacts.		

[2]

(ii) Name **one** element that is more reactive than element **X**.

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

(d) An argon atom has a mass number of 40.

Calculate the number of neutrons in its nucleus.

Use the Periodic Table.

Number of neutrons = ... **[1]**

2 Formic acid is used to remove limescale from kettles.

(a) Formic acid is a carboxylic acid with the formula HCOOH.

(i) Draw the displayed formula of formic acid.

Show all the bonds.

[1]

(ii) The name of the carboxylic acid with the formula CH_3COOH is ethanoic acid.

What is the name of formic acid?

Tick (✓) **one** box.

Butanoic acid ☐

Methanoic acid ☐

Propanoic acid ☐

[1]

(b) Ling and Taylor dip a piece of universal indicator paper into a solution of formic acid.

What pH value could the solution of formic acid be?

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

(c) Limescale contains calcium carbonate.

A solution of formic acid fizzes when it reacts with calcium carbonate.

(i) Name the gas that causes the fizzing.

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

(ii) A salt called calcium formate is also formed when formic acid reacts with calcium carbonate.

The formula of the calcium ion is Ca^{2+}. The formula of the formate ion is $HCOO^-$.

Write the formula of calcium formate.

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

(d) Calcium carbonate is insoluble in water. Calcium formate is soluble in water.

Sam wants to make some calcium formate crystals.

This is the method:
- stir calcium carbonate with a solution of formic acid
- stop adding calcium carbonate when no more reacts
- leave the mixture to crystallise.

An extra step is needed to make pure calcium formate crystals.

Name the extra step **and** explain why it is needed.

Extra step .....

.....

Explanation .....

.....

[2]

(e) **(i)** Umi and Zayn have a dilute solution of calcium formate.

They want to make **dry** crystals of calcium formate.

Name **one** separation technique they must use.

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

(ii) They use 20.0 g of calcium carbonate and get 7.8 g of pure calcium formate.

Chemists calculate that 10.0 g of calcium carbonate should make 13.0 g of calcium formate.

Calculate the percentage yield of calcium formate.

Use the formula: percentage yield = $\frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$

Percentage yield of calcium formate = ... % **[3]**

3 There are links between our increased use of energy from fossil fuels and the concentration of carbon dioxide in the atmosphere.

Fig. 3.1 shows the world's usage of energy from fossil fuels from 1800 to 2019 in watt-hours (Wh).

Fig. 3.1

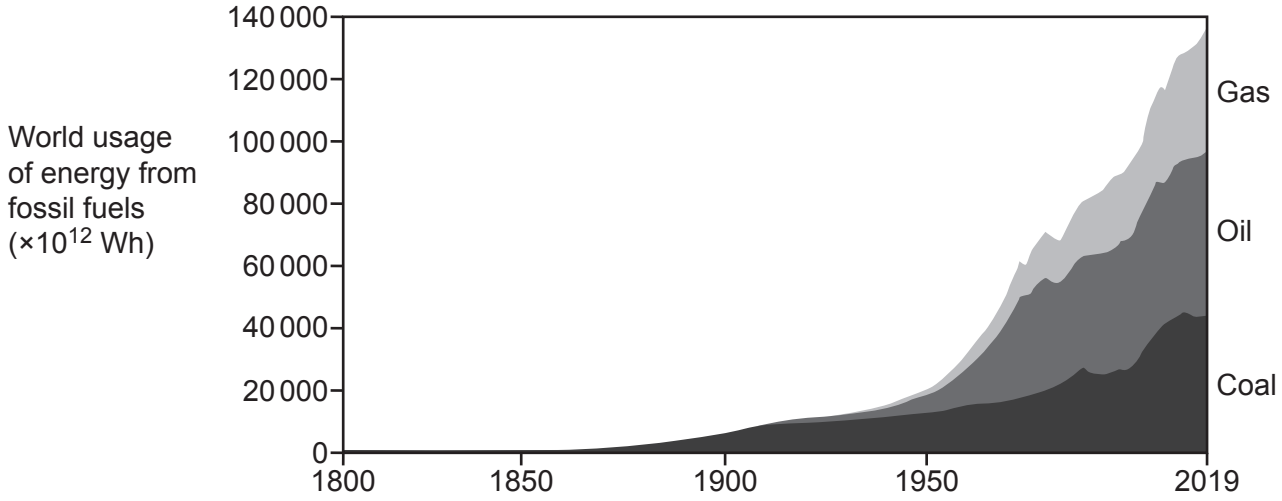
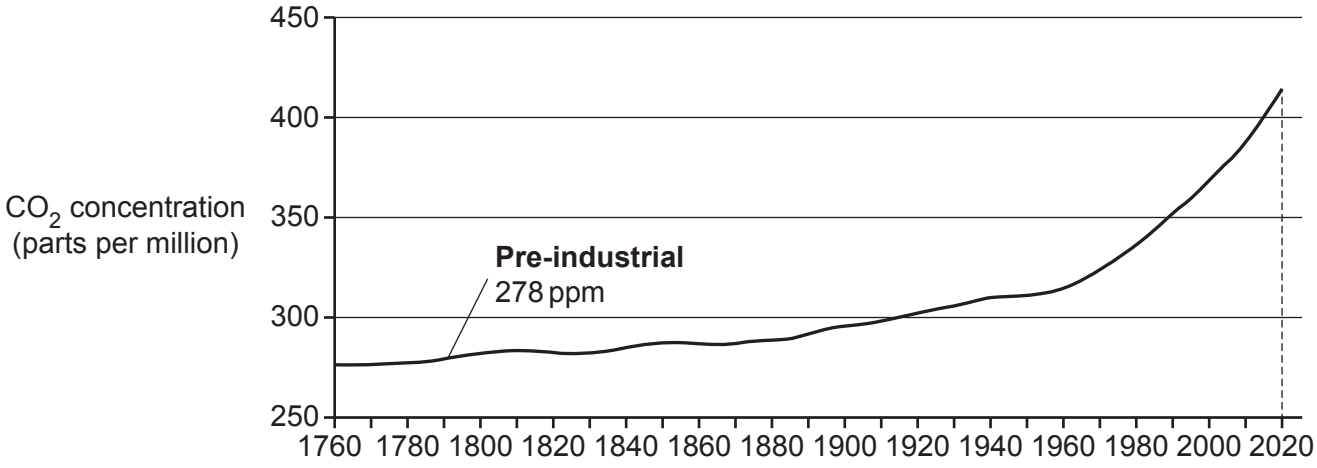


Fig. 3.2 shows the carbon dioxide (CO_2) concentration in the atmosphere from 1760 to 2020.

Fig. 3.2



(a) Casey thinks that the change in carbon dioxide concentration in the last **20 years** is due to burning coal.

Explain why Casey is **wrong**. Use evidence from both graphs in your answer.

.....

.....

.....

.....

..... **[3]**

(b) The world's usage of energy from fossil fuels in 2019 was approximately $135\,000 \times 10^{12}$ Wh.

A solar panel generates 1350 kWh per year.

Calculate the number of solar panels that would have been needed to meet the world's usage of energy from fossil fuels in 2019.

Give your answer in **standard form**.

Number of solar panels = ... **[3]**

(c) Gabi says that the concentration of carbon dioxide in 2020 has increased by approximately 50% since pre-industrial times.

Explain why Gabi is correct.

Use data from **Fig. 3.2** and a calculation in your answer.

.....

..... **[3]**

(d) The greenhouse effect is caused by carbon dioxide in the atmosphere.

(i) Describe the greenhouse effect.

.....

.....

.....

.....

..... **[3]**

(ii) Describe **three** potential effects of an increase in the greenhouse effect on the Earth's climate.

1. .....

2. .....

3. .....

[3]

4 **(a)** There are two main isotopes of oxygen, ^{16}O and ^{18}O. The table shows information about the atomic structure of ^{16}O.

	^{16}O
Number of protons	8
Number of neutrons	8
Number of electrons	8

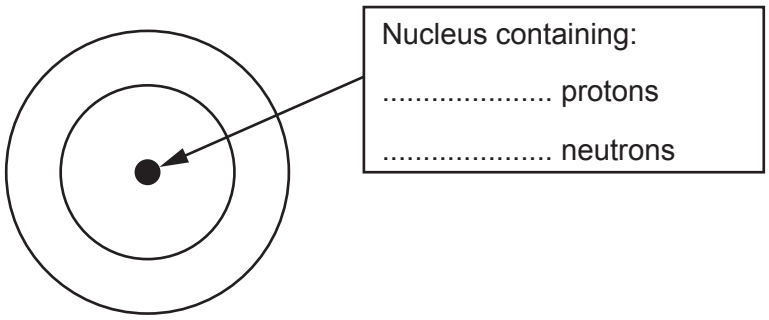
(i) Why do atoms of each isotope have the same number of electrons?

.....

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

(ii) Complete the diagram for an ^{18}O atom.

Use crosses (x) to represent electrons.

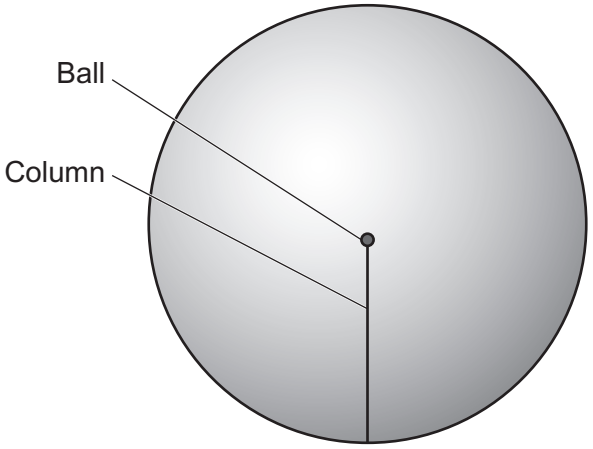


[2]

(b) The radius of an atom is approximately 1×10^4 times the radius of its nucleus.

A student imagines a ball with a radius of 0.5 cm on top of a column, as shown.

- The ball represents the nucleus.
- The height of the column represents the radius of the atom.



Calculate the height of the column.

Give your answer in **metres**.

Height = ... m **[3]**

5 Alex has a bottle of mineral water.

The label says:

Concentration of ions (mg/dm^3)	
Bicarbonate 150	
Calcium 40.5	Nitrate 3.1
Chloride 6.1	Sodium 5.6
Magnesium 10.7	Sulfate 5.3

(a) Alex increases the concentration of the mineral water by decreasing its volume.

(i) Draw a labelled diagram of the equipment that Alex uses.

[2]

(ii) Alex adds sodium hydroxide solution to some of the concentrated mineral water.

The calcium ions form a white precipitate.

Complete the **balanced symbol** equation for the reaction.

$Ca^{2+}(aq) + 2OH^{-}(aq) \rightarrow$ .....

[2]

(b) Alex tests the concentrated mineral water for calcium by doing a flame test.

Suggest why the flame they see is yellow and **not** red.

.....

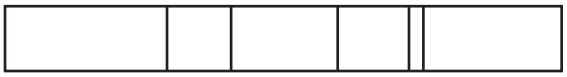
..... **[1]**

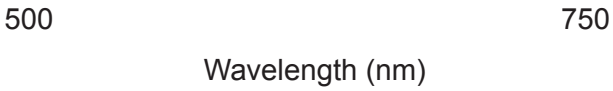
(c) An industrial laboratory uses an instrumental method of analysis to test some mineral water.

Some results are shown:

Mineral water

Solution of calcium chloride





(i) What instrumental method of analysis is the laboratory using?

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

(ii) Give **two** conclusions that you can make about the presence of minerals in **this** mineral water.

1 .....

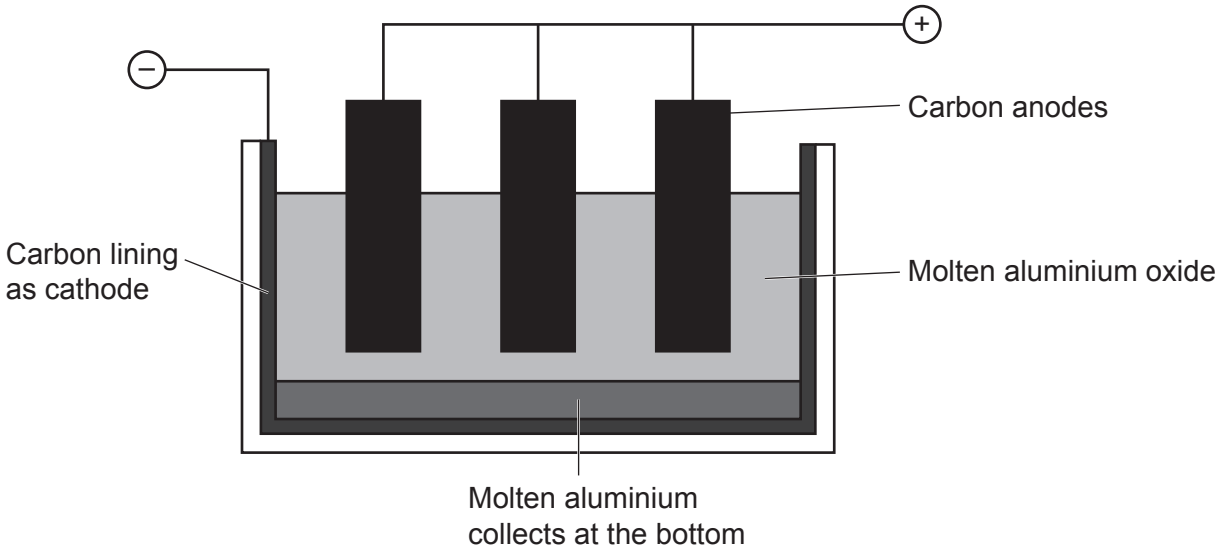
.....

2 .....

.....

[2]

6 Aluminium is made by the electrolysis of molten aluminium oxide, Al_2O_3.



(a) Why is the aluminium oxide molten?

.....

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

(b) The half-equation for the reaction at the anode is

$2O^{2-} \longrightarrow O_2 + 4e^-$

(i) Explain why the reaction is described as oxidation.

.....

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

(ii) **Name** the species which is oxidised in the equation.

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

(iii) Explain why carbon dioxide is also produced at the anode.

.....

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

(c) Write the **balanced half** equation for the production of aluminium at the cathode.

..... **[2]**

(d) The overall equation for the electrolysis is

$Al_2O_3 \rightarrow 2Al + 1.5O_2$

(i) The relative formula mass of Al_2O_3 is 102.

Show how this is calculated.

Relative atomic mass (A_r): O = 16 Al = 27

[1]

(ii) Calculate the mass of aluminium, Al, that is made from 1.0 g of aluminium oxide, Al_2O_3.

Use the overall equation and the formula:

$$\text{number of moles} = \frac{\text{mass of substance (g)}}{\text{relative formula mass (g)}}$$

Give your answer to **2** significant figures.

Mass of aluminium = ... g **[4]**

(e) A solution of aluminium sulfate contains aluminium ions.

Amit says it should give aluminium at the cathode when it is electrolysed.

Explain why Amit is **wrong**.

.....

.....

.....

..... **[2]**

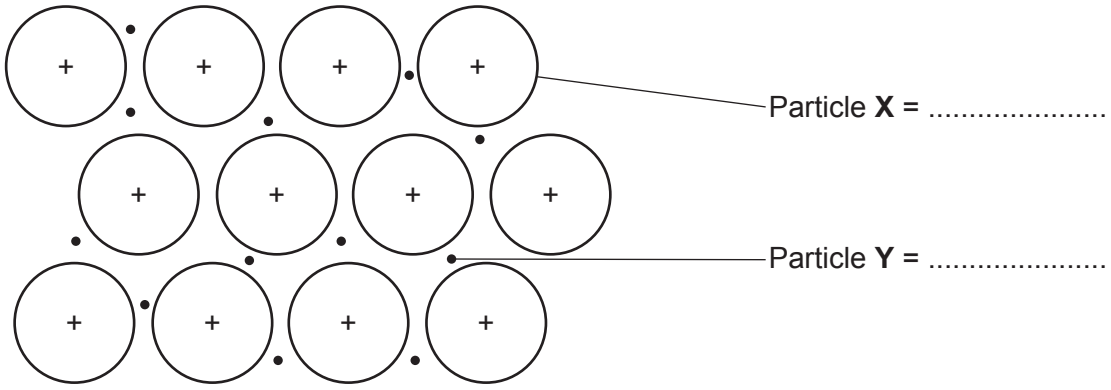
(f) Explain why aluminium is **not** made by heating its oxide with carbon.

.....

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

7 Aluminium and iron are both metals used to make everyday objects.

(a) **(i)** Complete the diagram by identifying particle **X** and particle **Y**.



[2]

(ii) Explain what happens to particle **X** and particle **Y** in the structure when a metal conducts electricity.

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.....

..... **[2]**

(b) Aluminium alloys are used as they are harder than pure aluminium.

One aluminium alloy contains 1% magnesium.

Explain why this aluminium alloy is harder than pure aluminium.

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.....

..... **[3]**

(c) A disadvantage of using iron is that it rusts.

Charlie has two pieces of iron.

Piece A has a coating of copper, and Piece B has a coating of zinc.

Charlie places both pieces in a beaker of water.

(i) Explain why neither piece will rust.

.....

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.....

..... **[2]**

(ii) Charlie scratches the two pieces deeply and puts them back in the water.

Explain why one of the pieces rusts but the other does not.

.....

.....

.....

..... **[2]**

8 Carbon monoxide and nitrogen monoxide are two polluting gases produced by petrol engines.

(a) Describe how each of these polluting gases is produced in a petrol engine.

Carbon monoxide .....

.....

Nitrogen monoxide .....

.....

.....

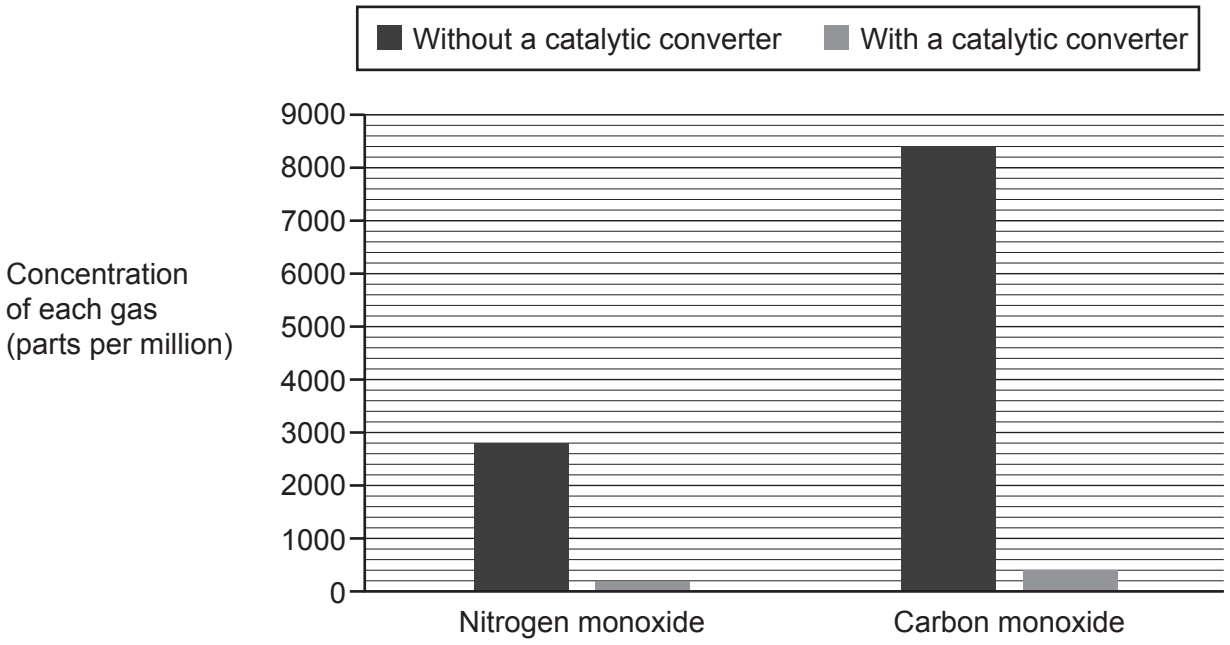
..... **[3]**

(b) In a catalytic converter, nitrogen monoxide and carbon monoxide react to form carbon dioxide and nitrogen.

Write the **balanced symbol** equation for this reaction.

..... **[2]**

(c) The bar chart shows the relative concentrations of the two polluting gases produced by a petrol engine without and with a catalytic converter.



(i) The concentrations of the two polluting gases are given in parts per million.

Convert 9000 parts per million into a percentage (parts per hundred).

Percentage = ... % **[2]**

(ii) Calculate the percentage **reduction** of nitrogen monoxide when a catalytic converter is used.

Give your answer to **1** decimal place.

Percentage reduction of nitrogen monoxide = ... % **[3]**

9 The Contact Process is used to produce sulfuric acid.

In the process, sulfur dioxide, SO_2, reacts with oxygen to make sulfur trioxide, SO_3.

$2SO_2 + O_2 \rightleftharpoons 2SO_3$

The reaction is done at 200 kPa and 450 °C with a catalyst.

(a) An industrial company reacts 2 moles of SO_2 with oxygen and makes 1.99 moles of SO_3.

Calculate the percentage yield of SO_3.

Use the formula: percentage yield = $\frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$

Percentage yield of SO_3 = ... % **[2]**

(b) Explain why a high pressure is needed to get the best yield of SO_3.

Use the symbol equation.

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.....

..... **[2]**

(c) The industrial company use a pressure of only 200 kPa.

Explain why a higher pressure is **not** used.

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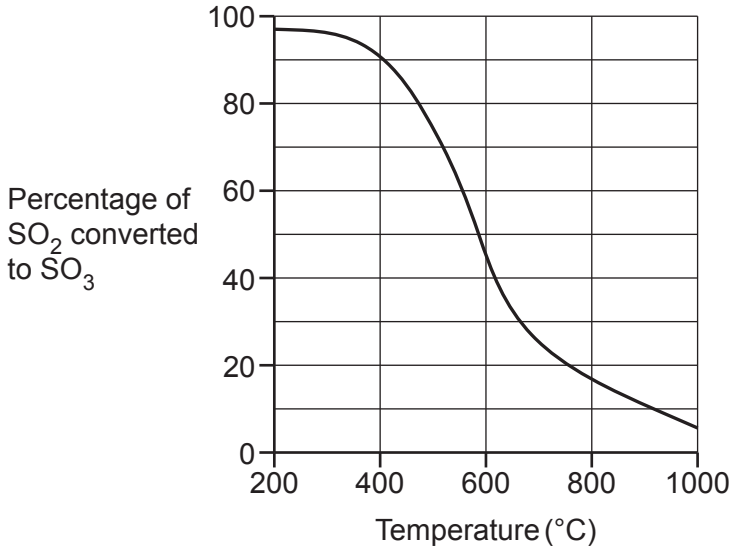
..... **[2]**

(d) The graph shows the percentage of SO_2 converted to SO_3, at different temperatures.



Describe how the percentage of SO_2 converted to SO_3 changes with temperature.

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..... **[2]**

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).