Oxford Cambridge and RSA

Tuesday 11 June 2024 – Morning

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

J258/04 Depth 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:
- a scientific or graphical calculator
- an HB pencil

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 **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **32** pages.

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

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1 Millions of tonnes of carbon dioxide (CO_2) are added to the air in the UK every year.

Carbon dioxide is produced when fossil fuels are burned in power stations to generate electricity.

(a) Schemes are being developed to remove carbon dioxide from power station waste gases. These schemes add to the cost of electricity.

Explain why it is important to remove carbon dioxide, despite the cost.

Use ideas of risk and benefit.

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

(b) The UK government says that the mass of carbon dioxide added to the air during the year 2020 decreased by 400 million tonnes compared to 1990. This is a decrease of 49%.

Calculate the mass of carbon dioxide added to the air during 1990.

Use the formula: $\text{percentage decrease} = \dfrac{\text{decrease in mass}}{\text{mass added to the air during 1990}} \times 100$

Mass added to the air during 1990 = ... million tonnes **[3]**

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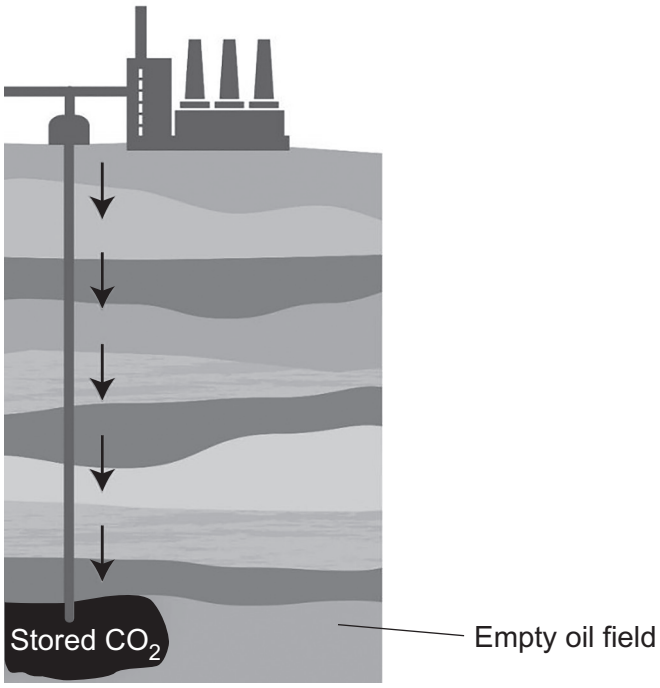
(c) Scientists are developing a new scheme to remove carbon dioxide from the air and store it in empty oil fields.



Scientists make two predictions:

1. Burning fossil fuels in the UK will add 230 million tonnes of carbon dioxide to the air each year.

2. There is enough space in UK oil fields to store all this carbon dioxide for at least the next 100 years.

(i) Which is the best estimate of the amount of carbon dioxide that can be stored in UK oil fields?

Tick (✓) **one** box.

$< 2.3 \times 10^3$ million tonnes ☐

$> 2.3 \times 10^4$ million tonnes ☐

$< 2.3 \times 10^6$ million tonnes ☐

$> 2.3 \times 10^6$ million tonnes ☐

[1]

(ii) The demand for energy for electricity is one factor that affects the amount of fossil fuels we burn.

State **one other** factor that affects the amount of fossil fuels we burn.

.....

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

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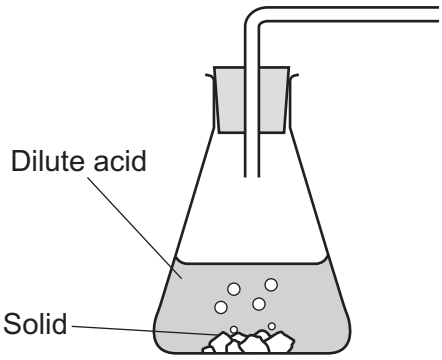
2 A student investigates the rate of reaction when a solid reacts with a dilute acid.

(a) The reaction makes a gas.

The student collects the gas in a measuring cylinder over water.

(i) **Complete** the diagram to show how the student sets up their measuring cylinder to collect the gas over water.

Include labels on your diagram.



[3]

(ii) The student finds it difficult to measure the volume accurately in the measuring cylinder.

Suggest another method they could use to get more accurate readings.

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

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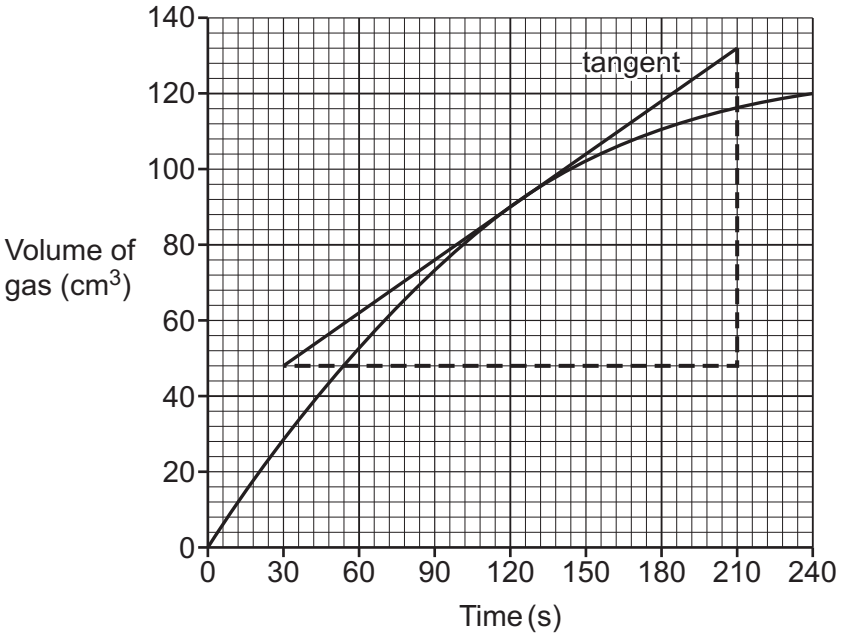
(b) The student plots a graph of their results.

The student draws a tangent to the curve at the point where time = 120 s.



(i) Calculate the gradient of the tangent shown on the graph.

Gradient = ... cm^3/s **[3]**

(ii) What information does your answer to **(i)** give about the reaction?

Tick (✓) **one** box.

The increase in volume and time at 180 s. ☐

The rate of reaction at 120 s. ☐

The time taken to make 90 cm^3 gas. ☐

The volume of gas made in the first minute of the reaction. ☐

[1]

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(c) The student repeats their experiment using different conditions.

The rate of the reaction increases each time.

Draw lines to connect each **change in condition** with its correct **explanation** for the increase in rate.

Change in condition	**Explanation**
Increased concentration of acid	Frequency of particle collision increases because surface area increases.
Increased temperature	Frequency of particle collision increases because particles are closer together.
Smaller pieces of solid	More particle collisions are successful because the energy of the particles increases.

[2]

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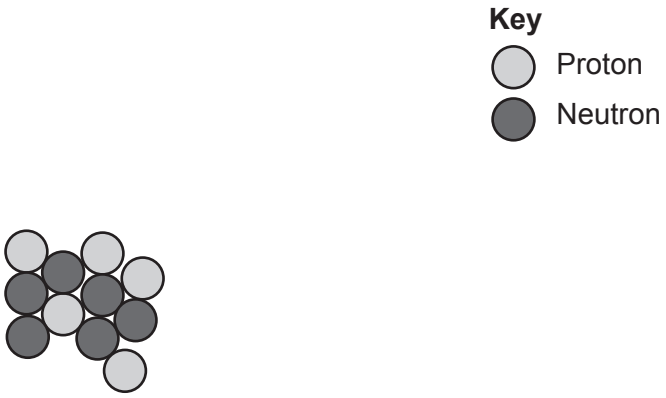
3 A student makes a model of an atom.

(a) They use small, coloured beads to represent the protons and neutrons in the nucleus of the model, as shown in the diagram.



The student shows the arrangement of electrons by using more beads to add shells of electrons to their model.

(i) **Complete the diagram** to show the arrangement of electrons in the atom.

Use **X** to represent each electron. **[2]**

(ii) Write a description for each of the particles in the atom.

Your description should include the relative charges, relative masses and position of each particle.

Proton .....

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Neutron .....

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Electron .....

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[3]

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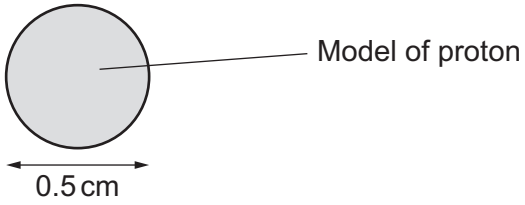
(b) In the model, the protons have a diameter of 0.5 cm.



An atom is 1×10^5 times larger than a proton.

If they make their model to scale, what is the diameter of the model atom?

Give your answer in metres.

Diameter of the model atom = ... m **[2]**

(c) The student makes a model of some atoms of other elements.

Table 3.1 shows the particles in each atom.

Table 3.1

Element	Number of protons	Number of neutrons	Electron arrangement
A	3	4	2.1
B	8	8	2.6
C	12	12	2.8.2

(i) Identify whether each element is a metal or a non-metal.

Put **one** tick (✓) in each row.

Element	Metal	Non-metal
A		
B		
C		

[2]

(ii) Use ideas about electron arrangement to explain how you decided if each element was a metal or a non-metal.

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

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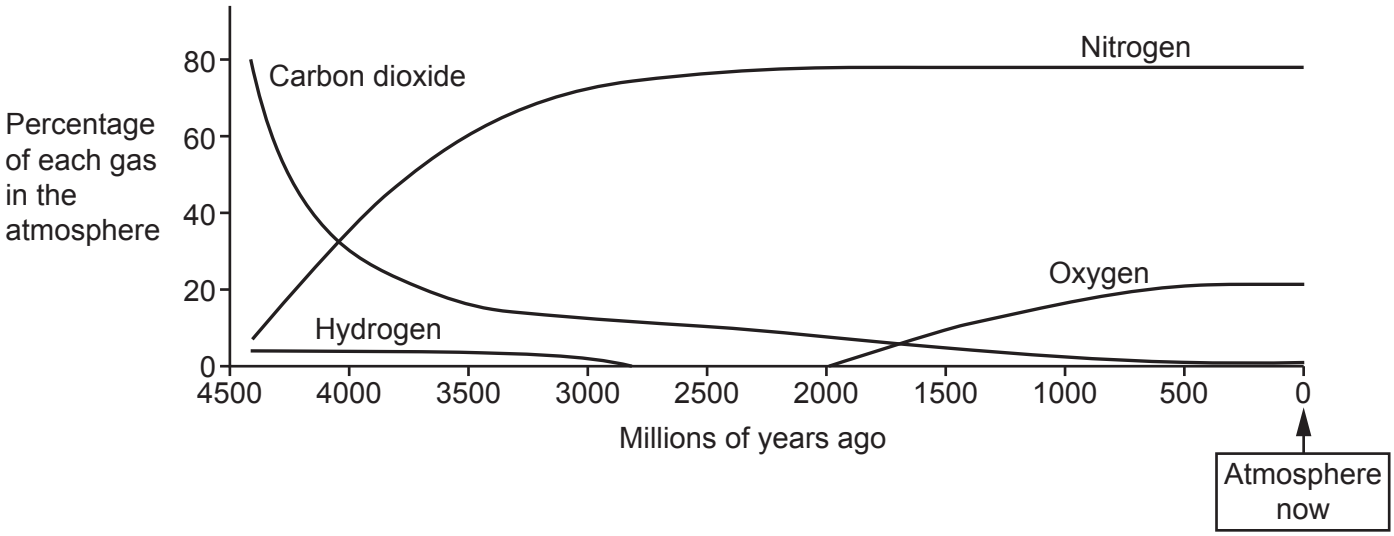
4 Scientists collect data to explain how the Earth's atmosphere formed.

The graph shows how the percentages of some gases in the atmosphere have changed since 4400 million years ago.



Scientists also study the composition of gases that come out of active volcanoes today.

The table shows the composition of gases from an active volcano.

Gas	Percentage composition
Water vapour	92
Carbon dioxide	4.6
Hydrogen	0.5
Nitrogen	0.7

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(a) Scientists have ideas about where the Earth's atmosphere and oceans came from. They think that:

1. The atmosphere formed from gases that came out of volcanoes.

2. More than 4400 million years ago, water vapour from volcanoes condensed to form the oceans, leaving other gases in the air.

How does the data in the table and the graph support these ideas?

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

(b)
(i) Explain the changes to the percentages of oxygen and carbon dioxide in the atmosphere shown on the graph.

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

(ii) The percentages of oxygen and carbon dioxide have stayed approximately the same since 500 million years ago.

Explain why.

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

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5 Steel is an alloy that contains iron and other elements.

(a) State **one** reason why steel is more useful than pure iron.

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

(b) One type of steel alloy contains 97.8% iron and 0.12% carbon by mass.

The ratio by mass of iron : carbon in this steel is greater than 800 : 1.

(i) Show by calculation that this statement is **true**.

[1]

(ii) The ratio by number of moles of iron : carbon in this steel is approximately 175 : 1.

Explain why the ratio by mass is different to the ratio by number of moles.

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

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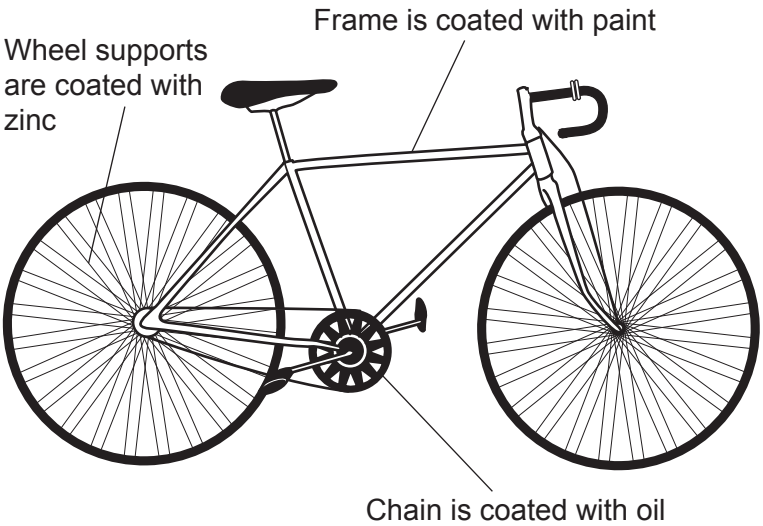
(c)* Different parts of a bike are each made from different steel alloys. Each of the alloys contains mainly iron.

The diagram shows the different methods to prevent corrosion that are used on each part of the bike.



Explain how each of the coatings used on the bike prevent corrosion and discuss how effective the coatings are if they become damaged.

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..... **[6]**

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6 A scientist works in a laboratory that tests medicines.

They make up different formulations of medicines for testing.

(a) Which statement is the definition of a formulation?

Tick (✓) **one** box.

A mixture that contains definite proportions of substances. ☐

A solid substance that is soluble in water. ☐

A useful product made under controlled conditions. ☐

Several elements bonded together to make a molecule. ☐

[1]

(b) The scientist uses water to make up their medicines.

In their laboratory they have distilled water and tap water.

Explain why distilled water is pure and tap water is impure.

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

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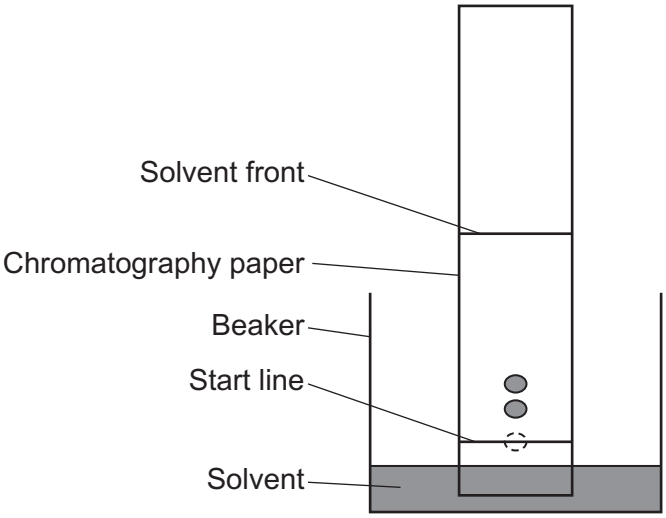
(c) The scientist uses paper chromatography to separate the substances in one of their medicines.

They use water as a solvent.

The diagram shows their results.



(i) Identify the stationary phase and the mobile phase in their experiment.

Stationary phase .....

Mobile phase .....

[2]

(ii) Use ideas about solubility to explain why the substances separate.

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

(iii) The scientist wants to improve the chromatography experiment.

Suggest **one** way they can increase the separation of the substances.

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

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(d) The scientist measures the melting point of some of the substances they use to make medicines.

The table shows their results.

Substance	Melting point (°C)
A	102
B	151–156
C	2032
D	1040–1056
E	325–333

Which substances are impure?

Explain your reasoning.

Impure substances .....

Explanation .....

.....

[2]

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Turn over for the next question

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7

(a) **Table 7.1** shows the formulae and boiling points of some alkanes.

Table 7.1

Alkane	Formula	Boiling point (°C)
Ethane	C_2H_6	–89
Butane	C_4H_{10}	–0.5
Pentane	C_5H_{12}	36
Hexane	C_6H_{14}	69

(i) Use the data in **Table 7.1** to complete the graph.

You need to:
- complete the scale on the vertical axis
- plot the boiling point of each alkane
- draw a line of best fit.

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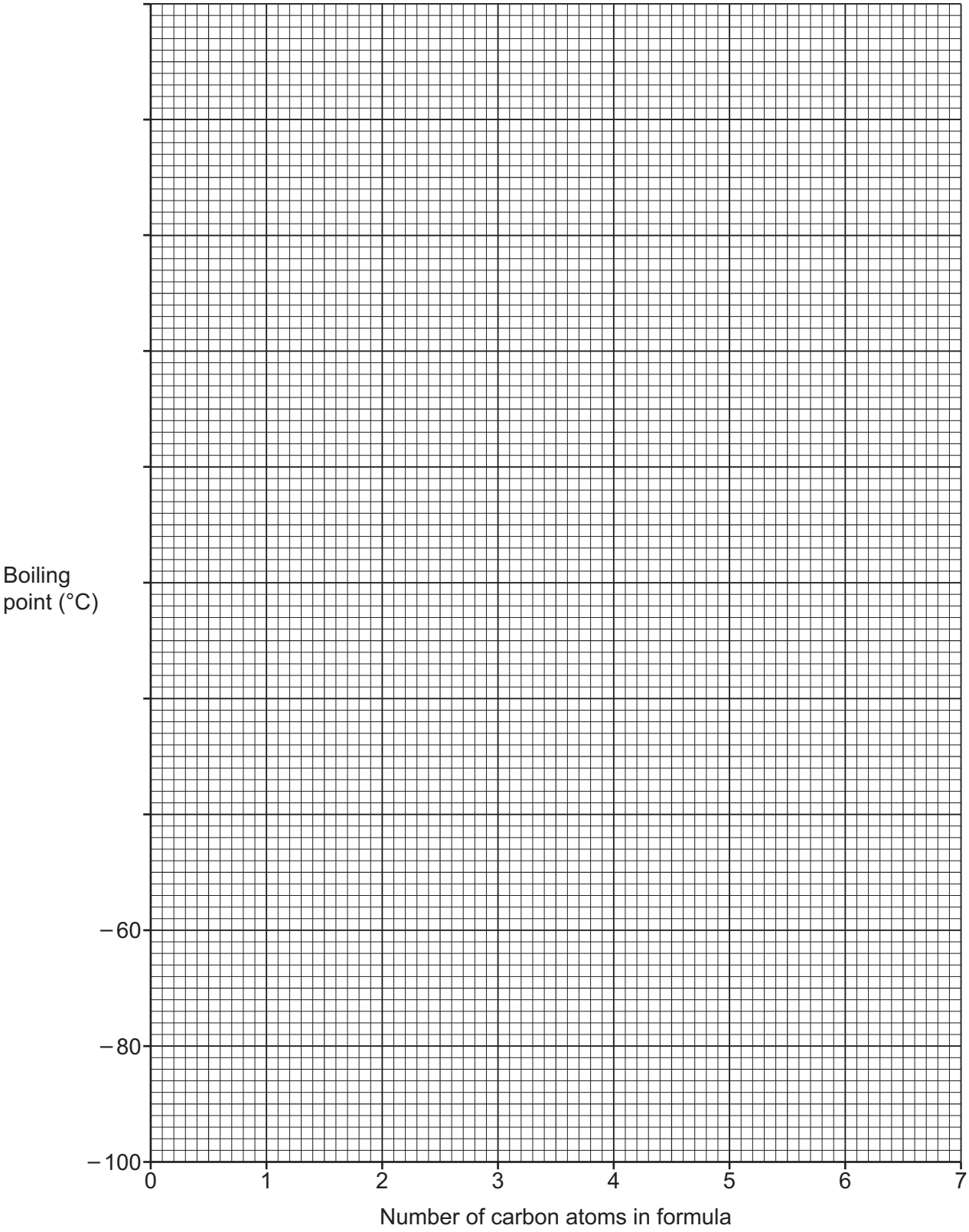

[3]

(ii) Use your graph to estimate the boiling point of propane, C_3H_8.

Boiling point of propane = ... °C **[1]**

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(b) **Table 7.2** shows the molecular formula and empirical formula of some of the alkanes.

Table 7.2

Alkane	Molecular formula	Empirical formula
Ethane	C_2H_6	CH_3
Propane	C_3H_8	C_3H_8
Butane	C_4H_{10}	.....

(i) Complete **Table 7.2** by filling in the empirical formula for butane. **[1]**

(ii) Explain why the molecular formula and empirical formula for propane are the same.

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

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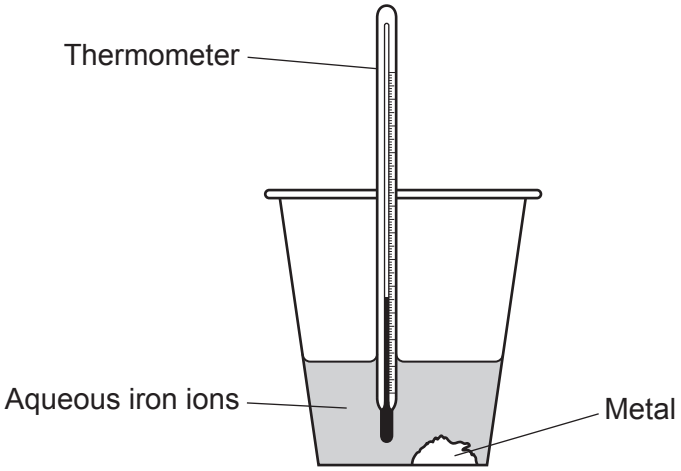
8* Metals react with other metal ions in displacement reactions.

The greater the difference in reactivity between the metal and the metal ion, the greater the energy given out when they react together.

A student does an experiment to find out the order of reactivity of some metals.

They measure the maximum temperature change when each metal is added to a solution that contains aqueous iron ions.



The student repeats their experiment.

This time they add each metal to a solution that contains aqueous copper ions.

The table shows their results.

	Maximum temperature change (°C)	
	When added to aqueous iron ions	**When added to aqueous copper ions**
Calcium	12	15
Lead	0	2
Iron	0	4
Zinc	8	11
Magnesium	10	12

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What conclusions can be made about the order of reactivity of the metals, including copper, from the information in the table?

Use ideas about temperature changes and reactivity in your answer.

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..... **[6]**

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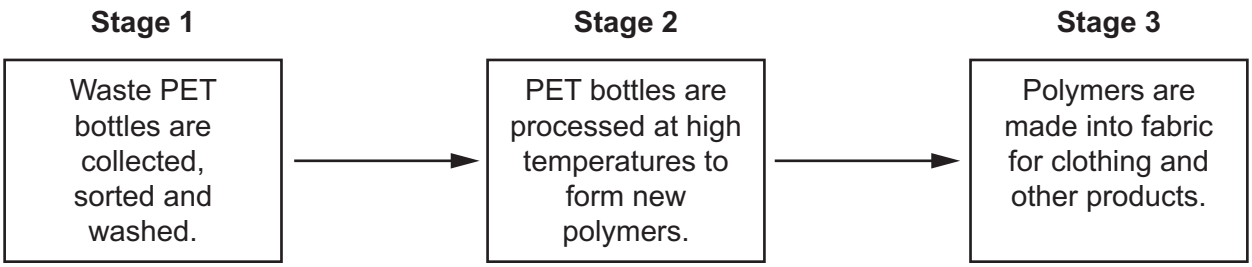
9 PET is a polymer made from crude oil. Most plastic water bottles are made from PET.

A recycling process uses PET from waste bottles to make new polymers.

These new polymers can be used to make fabric for clothing and other products.

The diagram below shows the three stages involved in the recycling process.



(a) A scientist carries out a life cycle assessment for this recycling process.

They find that the recycling process uses large amounts of energy.

(i) Explain why the process shown in the diagram uses large amounts of energy.

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

(ii) Explain why the use of energy is an important factor to consider when carrying out a life cycle assessment.

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

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(b) The scientist concludes that recycling PET bottles reduces harm to the environment despite its use of energy.

Suggest **two** reasons why recycling PET bottles reduces harm to the environment.

1 .....

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2 .....

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

(c) The fabric at the end of the process is used for different products.

Two of the products made from the fabric are padded jackets and insulation for houses.

Suggest why the life cycle assessments of these two products are different.

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

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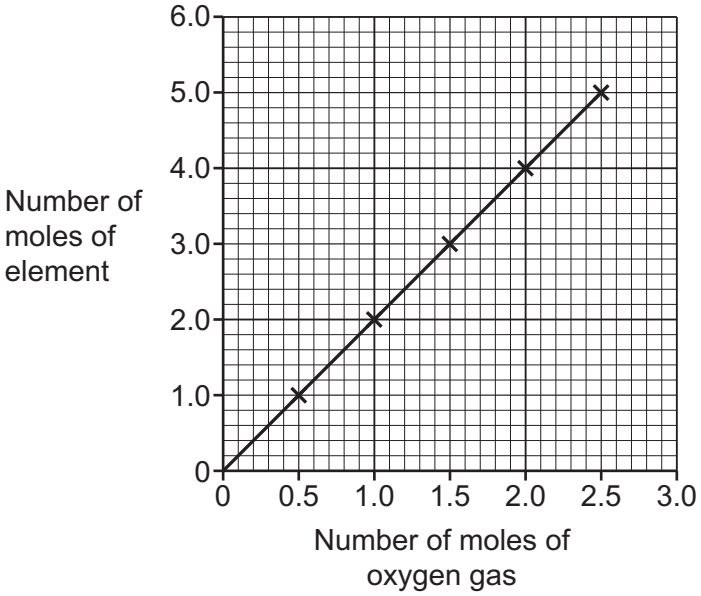
10 A student investigates the reaction of an element with oxygen gas, O_2, to make an oxide.

They calculate the number of moles of the element that react with different numbers of moles of oxygen gas.

The graph shows their results.



(a) The student concludes that the graph shows this relationship:

number of moles of element ∝ number of moles of oxygen

The student is correct.

Explain why.

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

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(b) Calculate the mass of oxygen gas that reacts with 1.5 moles of the element.

Use:
- data from the graph
- the Periodic Table.

Mass of oxygen gas = ... g **[3]**

(c) The student suggests an equation for the reaction. They use X to represent the symbol of the element.

(i) Which equation for the reaction is correct?

Use information from the graph.

Tick (✓) **one** box.

$X + O_2 \rightarrow XO_2$ ☐

$2X + O_2 \rightarrow 2XO$ ☐

$4X + O_2 \rightarrow 2X_2O$ ☐

$4X + 3O_2 \rightarrow X_2O_3$ ☐

[1]

(ii) Explain how you worked out your answer to **(c)(i)**.

.....

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

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11

(a) Ammonium sulfate, $(NH_4)_2SO_4$, is made in an industrial process for use as a fertiliser.

Aqueous ammonium carbonate reacts with **excess** solid calcium sulfate.

$(NH_4)_2CO_3(aq) + CaSO_4(s) \rightarrow (NH_4)_2SO_4(aq) + CaCO_3(s)$

Suggest the method used to separate aqueous ammonium sulfate from the mixture of products at the end of the reaction.

Explain your reasoning.

Method .....

Explanation .....

.....

[2]

(b) Ammonium sulfate can also be made on a small scale in a laboratory.

Aqueous ammonia, $NH_3(aq)$, reacts with dilute sulfuric acid to make aqueous ammonium sulfate.

Write a **balanced symbol** equation, with state symbols, for this reaction.

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

(c) Which statements about industrial processes and laboratory reactions are **true** and which are **false**?

Tick (✓) **one** box in each row.

	True	**False**
Industrial processes are usually continuous, laboratory reactions prepare chemicals in batches.		
By-products of industrial processes are disposed of as waste.		
In industry, more than one process is often used to make the same product.		

[2]

END OF QUESTION PAPER

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EXTRA ANSWER SPACE

If you need extra space use these lined pages. You must write the question numbers clearly in the margin.

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