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Monday 20 June 2022 – 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

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 **28** pages.

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

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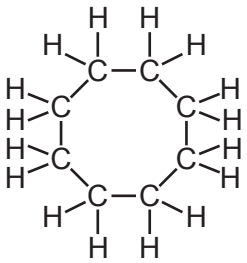
Answer **all** the questions.

1 **Fig. 1.1** shows the uses, properties and structure of some substances which contain carbon atoms.

Cyclo-octane

Added to petrol

Very flammable

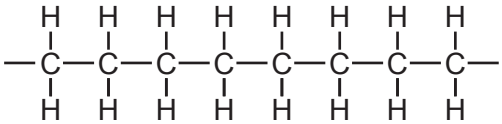


Carbon atoms bonded to other carbon atoms in rings and to hydrogen atoms

Polyethene

Used to make carrier bags

Flexible, softens at 1200 °C, stretches and breaks easily

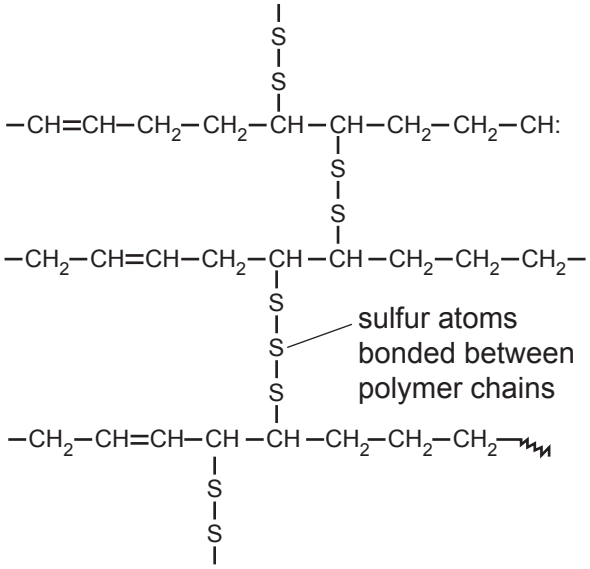


Carbon atoms bonded to other carbon atoms in long chains and to hydrogen atoms

Synthetic rubber

Used to make car tyres

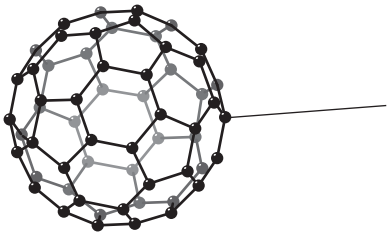
Stronger and harder than most polymers and has a higher melting point

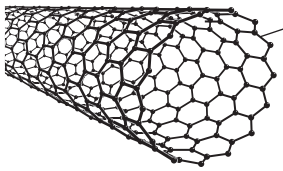


Carbon atoms bonded to other carbon atoms in long chains with sulfur atoms bonded between the polymer chains

Nanoparticles

Used to carry medicine molecules into the body





Carbon atoms bonded to other carbon atoms to form balls and tubes

Fig. 1.1

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(a) Petrol contains cyclo-octane.

(i) Which symbol should be used to warn people of the main hazard when handling cyclo-octane?

Tick (✓) **one** box.

☐

☐

☐

☐

[1]

(ii) Write down **two** safety precautions people should take when filling their cars with petrol.

1 .....

.....

2 .....

.....

[2]

(b) Carbon makes a much bigger range of different types of molecules than any other element.

Give **one** reason why carbon atoms can form so many different types of molecules.

Use **Fig. 1.1** to help you to answer.

.....

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

(c) Explain why polyethene and synthetic rubber have different properties.

Use ideas about structure from **Fig. 1.1** to help you to answer.

.....

.....

.....

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

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(d) **(i)** How are nanoparticles different to the other substances in **Fig. 1.1**?

.....

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

(ii) Explain why the structure of carbon nanoparticles helps them to carry medicine molecules into the body.

.....

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

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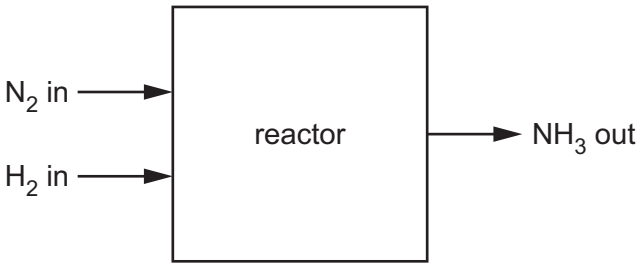
2 Ammonia is used to make fertilisers. It is produced in a large-scale process.

The equation shows the reaction that happens in the process:

$$N_2 + 3H_2 \rightleftharpoons \underset{\text{ammonia}}{2NH_3}$$

The process happens in a reactor.



(a) The percentage yield of ammonia is usually between 10% and 20%.

(i) Use the equation to explain why it is not possible to get 100% yield of ammonia.

.....

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

(ii) The gas that leaves the reactor contains ammonia mixed with two other gases.

Use the equation to help you to give the names of the other **two** gases.

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

(b) An ammonia factory tests a new reactor.

The table shows the theoretical yield and actual yield for a process in the new reactor.

Theoretical yield (tonnes)	150
Actual yield (tonnes)	19.5

Calculate the percentage yield for the process in the new reactor.

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

percentage yield = ... % **[2]**

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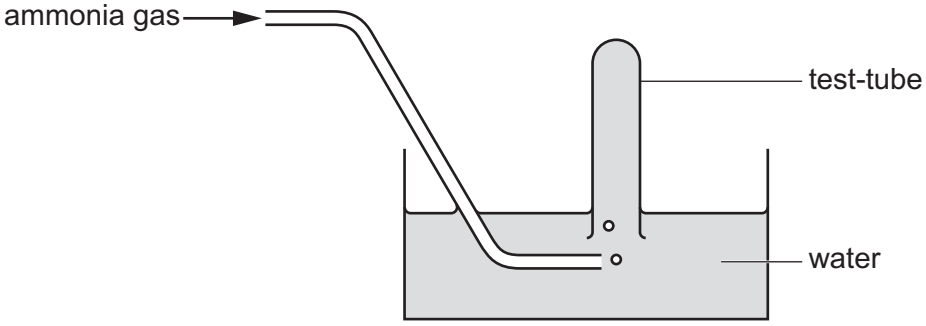
(c) Ammonia is very soluble in water.

Kofi does an experiment to make some ammonia.

He tries to collect it using the apparatus shown.



(i) Bubbles of ammonia gas enter the water but no gas collects in the test-tube.

What happens to the ammonia gas when it enters the water?

.....

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

(ii) Which apparatus should Kofi use to collect ammonia?

Tick (✓) **one** box.

burette ☐

gas syringe ☐

measuring cylinder ☐

volumetric flask ☐

[1]

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(d) Ammonia is an alkaline gas.

The pH of ammonia solution can be measured using a pH meter.

(i) Predict the pH of ammonia.

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

(ii) Describe another method you could use to measure the pH of ammonia solution.

.....

.....

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

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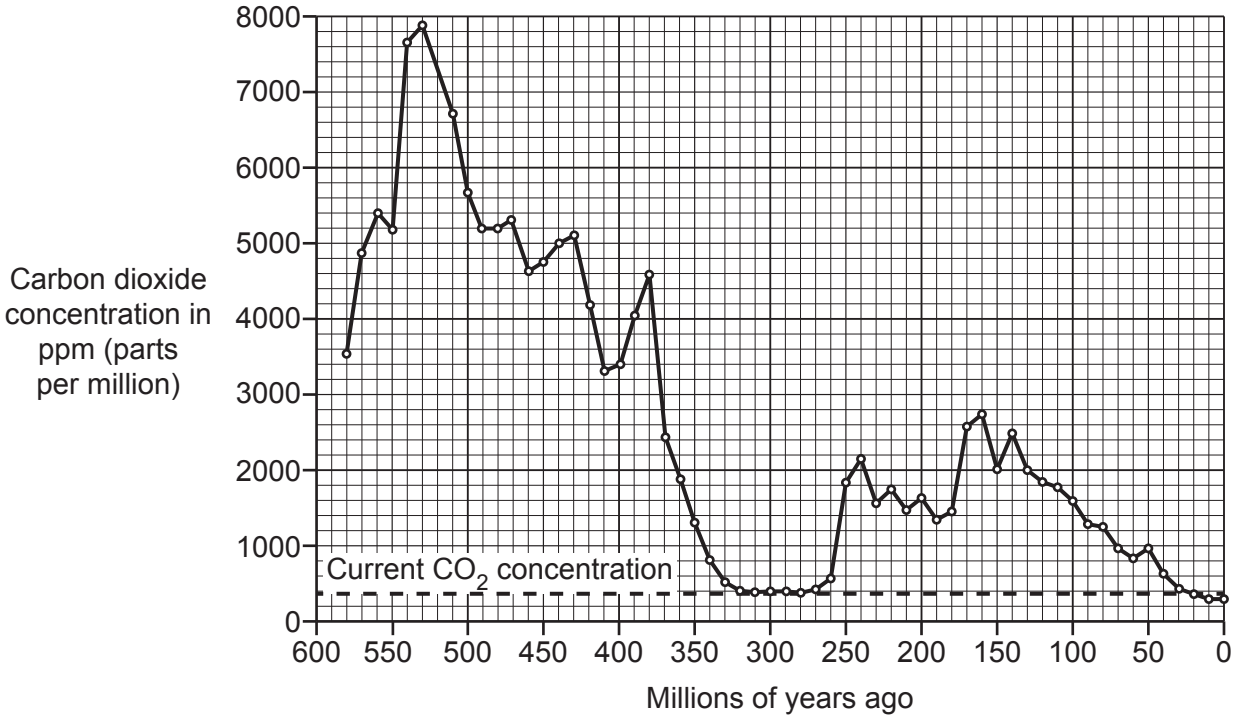
3 The graph shows the change in carbon dioxide concentration in the Earth's atmosphere over the last 575 million years.



(a) **(i)** How many millions of years ago was the concentration of carbon dioxide at its highest point?

..... million years ago **[1]**

(ii) What was the concentration of carbon dioxide at its highest point?

..... ppm (parts per million) **[1]**

(b) Ben looks at the graph and says, 'Carbon dioxide concentration was always much higher in the past than it is today.'

Does the graph support this statement?

Tick (✓) **one** box.

Yes ☐

No ☐

Use values from the graph to explain your answer.

.....

.....

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

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(c) Scientists say that the concentration of carbon dioxide is now 0.04 %.

In the year 2000 the concentration of carbon dioxide was 370 ppm (parts per million).

Do a calculation to find out the difference between these two values.

Give your answer in ppm.

Use this formula:

$$\text{concentration in ppm} = \text{concentration in \%} \times 10^4$$

difference between values ..... ppm **[2]**

(d) Some scientists fear that increased carbon dioxide in the air may lead to global food shortages.

Explain why this could happen.

.....

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

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4 The table shows information about some alkanes.

Alkane	Molecular formula	Relative formula mass	Melting point (°C)	State at room temperature (at 20 °C)
methane	CH_4	16	–182	gas
propane	C_3H_8	44	–190	gas
octane	C_8H_{18}	114	–57	liquid
pentacontane	$C_{50}H_{102}$	702	93	solid

(a) The empirical formula of octane is C_4H_9.

(i) What is the **empirical** formula of pentacontane?

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

(ii) The empirical formulae of methane and propane are the same as their molecular formulae.

Explain why.

.....

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

(b) Predict the **boiling** point of octane.

Explain your reasoning.

Boiling point ..... °C

Reason .....

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

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(c)* A text book has this description of a homologous series.

> A homologous series contains compounds with similar structures, the same general formula and similar chemical properties. The compounds show a trend in physical properties down the series.

Use your own knowledge and the information in the table to explain how the alkanes match this description of a homologous series.

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

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5 Some metals are extracted from their ores by heating with carbon.

Other metals are extracted from their ores by electrolysis.

Fig. 5.1 shows the order of reactivity of some metals, compared to carbon.

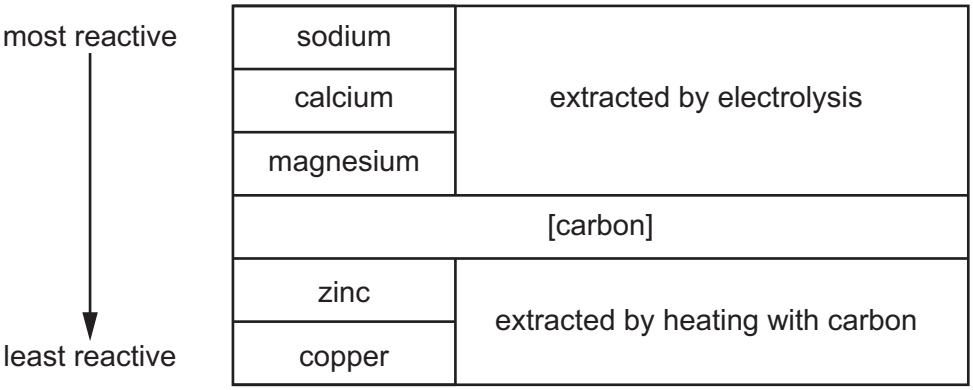

Fig. 5.1

(a) Explain why calcium and copper must be extracted by different methods.

.....

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

(b) What are the most common methods of extraction for iron, potassium, aluminium and lead from their ores?

Use ideas about the order of reactivity of the metals to help you to answer.

Put a tick (✓) in **one** box in each row.

Metal	**Extracted by heating with carbon**	**Extracted by electrolysis**
iron		
potassium		
aluminium		
lead		

[2]

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(c) Some copper ores contain copper sulfide.

Copper is extracted from copper sulfide in a two-stage process.

Stage 1: Copper sulfide reacts with oxygen:

$Cu_2S(s) + 2O_2(g) \rightarrow 2CuO(s) + SO_2(g)$

Stage 2: Copper oxide reacts with carbon:

$2CuO(s) + C(s) \rightarrow 2Cu(s) + CO_2(g)$

(i) Look at the equation for **Stage 1**.

Predict whether the mass of the solid increases, decreases or stays the same during **Stage 1**.

Use the Periodic Table and calculations of relative formula masses to help you.

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

(ii) During **Stage 2**, the total mass of the solids decreases.

Explain why **Stage 2** obeys the law of conservation of mass even though the total mass of the solids decreases.

.....

.....

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

(iii) The reaction of copper in **Stage 2** can be represented by a half equation:

$Cu^{2+} + 2e^- \rightarrow Cu$

Is copper oxidised or reduced in this half equation?

Explain your answer.

Oxidised or reduced? .....

Explanation .....

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

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6 **Fig. 6.1** shows the particle model for solids, liquids and gases.

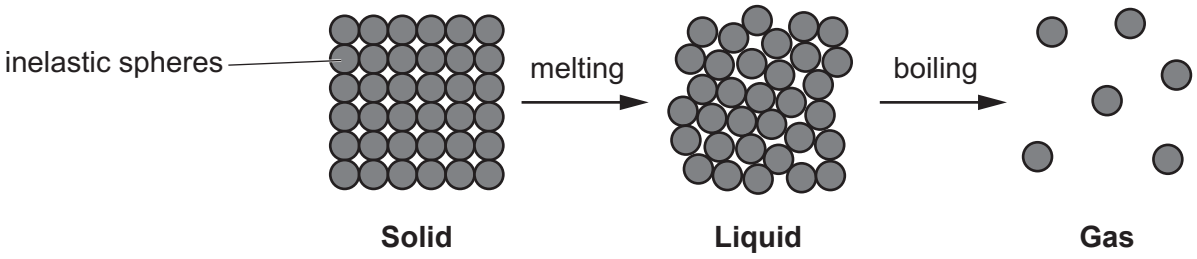

Fig. 6.1

(a) Neon is a gas in Group 18 (0) of the Periodic Table.

Use the particle model in **Fig. 6.1** to describe what happens to the arrangement and movement of the atoms when neon changes from a liquid to a gas.

.....

.....

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

(b) Sodium atoms form sodium ions with a single positive charge.

Neon atoms do not form ions.

Use ideas about electrons to explain these statements.

.....

.....

.....

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

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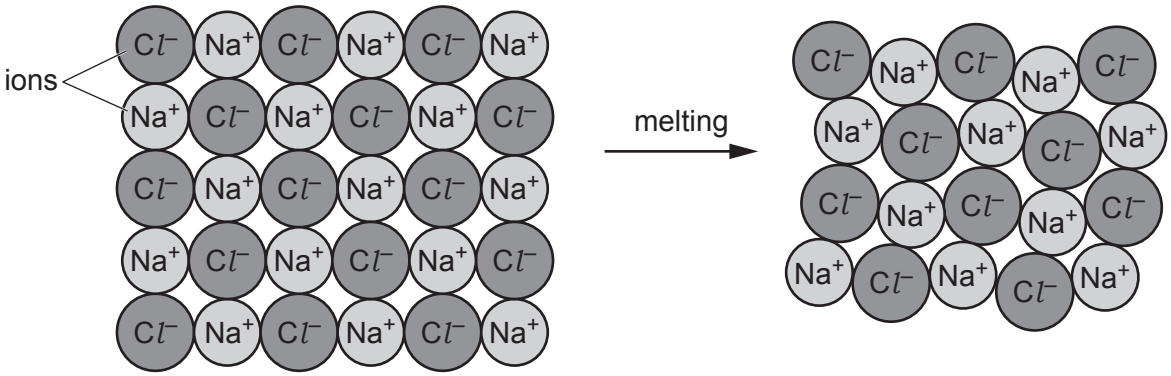
(c)* Sodium chloride contains sodium ions, Na^+, and chloride ions, Cl^-.

Fig. 6.2 shows the ionic model for solid and liquid sodium chloride.



Solid **Liquid**

Fig. 6.2

The melting points of neon and sodium chloride are shown in the table.

	Melting point (°C)
neon	–249
sodium chloride	801

Describe the similarities and differences in how melting is represented by the models in **Fig. 6.1 and Fig. 6.2** and explain why both models are needed to explain the differences in the melting points shown in the table.

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

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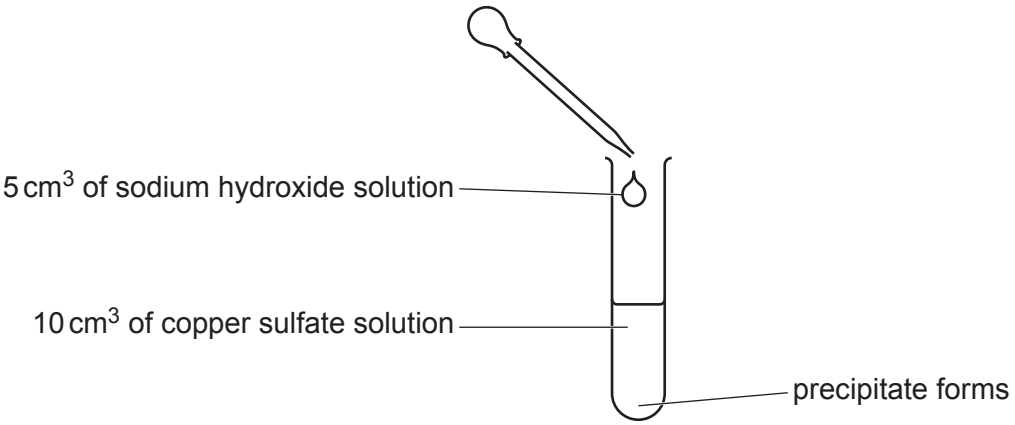
7 Jane does an experiment.

She puts 10 cm^3 of copper sulfate solution in a boiling tube. She adds 5 cm^3 of sodium hydroxide solution. A precipitate of copper hydroxide forms.



(a) Complete the **word** and **symbol** equations for the reaction in the boiling tube by filling in the name of the missing product and the state symbols for each substance.

copper sulfate + sodium hydroxide → copper hydroxide + ...
.....

$CuSO_4$(.....) + 2NaOH(.....) → $Cu(OH)_2$(.....) + Na_2SO_4(.....)

[3]

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(b) The final mixture contains a precipitate of copper hydroxide mixed with a solution of other dissolved substances.

Jane wants to separate pure copper hydroxide from this mixture. She wants to make sure that she removes any traces of other dissolved substances from the precipitate.

(i) Describe how she can separate pure copper hydroxide from the final mixture.

.....

.....

.....

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

(ii) Jane leaves the copper hydroxide to dry in a warm oven. After 30 minutes she weighs the copper hydroxide on a balance.

Jane is not sure if the copper hydroxide is completely dry.

Suggest how Jane can use the oven and the balance to show that the copper hydroxide is completely dry.

.....

.....

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

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(c) Jane does more experiments.

She adds a different volume of sodium hydroxide solution to 20 cm^3 of copper sulfate solution each time.

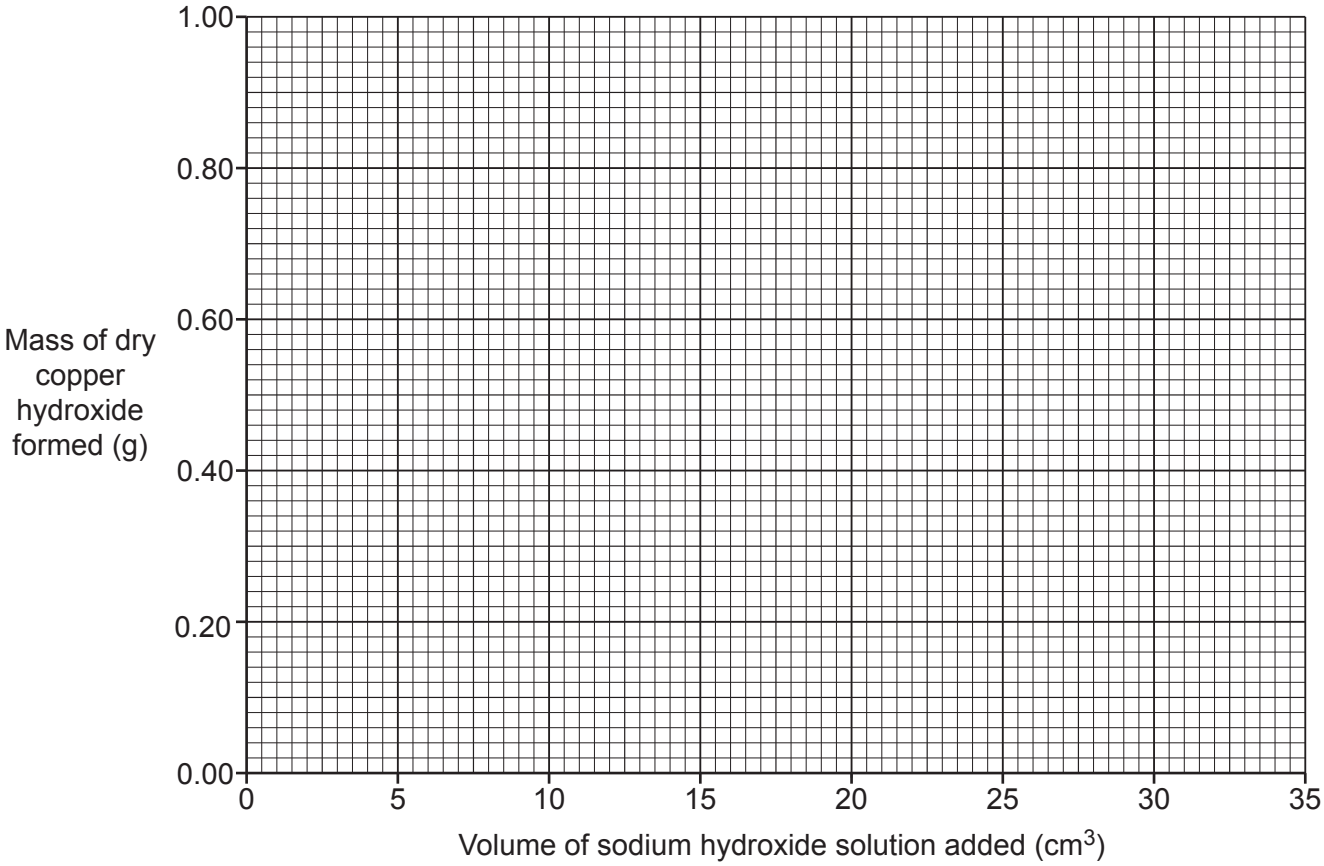
She records the mass of dry copper hydroxide that forms in each experiment.

The table shows her results.

Volume of copper sulfate solution (cm^3)	Volume of sodium hydroxide solution added (cm^3)	Mass of dry copper hydroxide formed (g)
20	5	0.25
20	10	0.49
20	15	0.75
20	20	0.98
20	25	0.98
20	30	0.98

(i) Plot Jane's results on the graph.

Draw lines of best fit to show the pattern in the results. **[3]**



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(ii) Suggest why the mass of the dry precipitate does not continue to increase when more than 20 cm^3 of sodium hydroxide solution is added.

.....

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

(iii) Jane and Alex look at the table and the equation for the reaction:

$$CuSO_4 + 2NaOH \rightarrow Cu(OH)_2 + Na_2SO_4$$

They disagree about the results.

Jane says, 'I think the concentration of copper sulfate solution is the same as the concentration of sodium hydroxide solution.'

Alex says, 'I think the sodium hydroxide solution is double the concentration of the copper sulfate solution.'

Who is right?

Jane ☐

Alex ☐

Use information from the table and the equation to explain your choice.

.....

.....

.....

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

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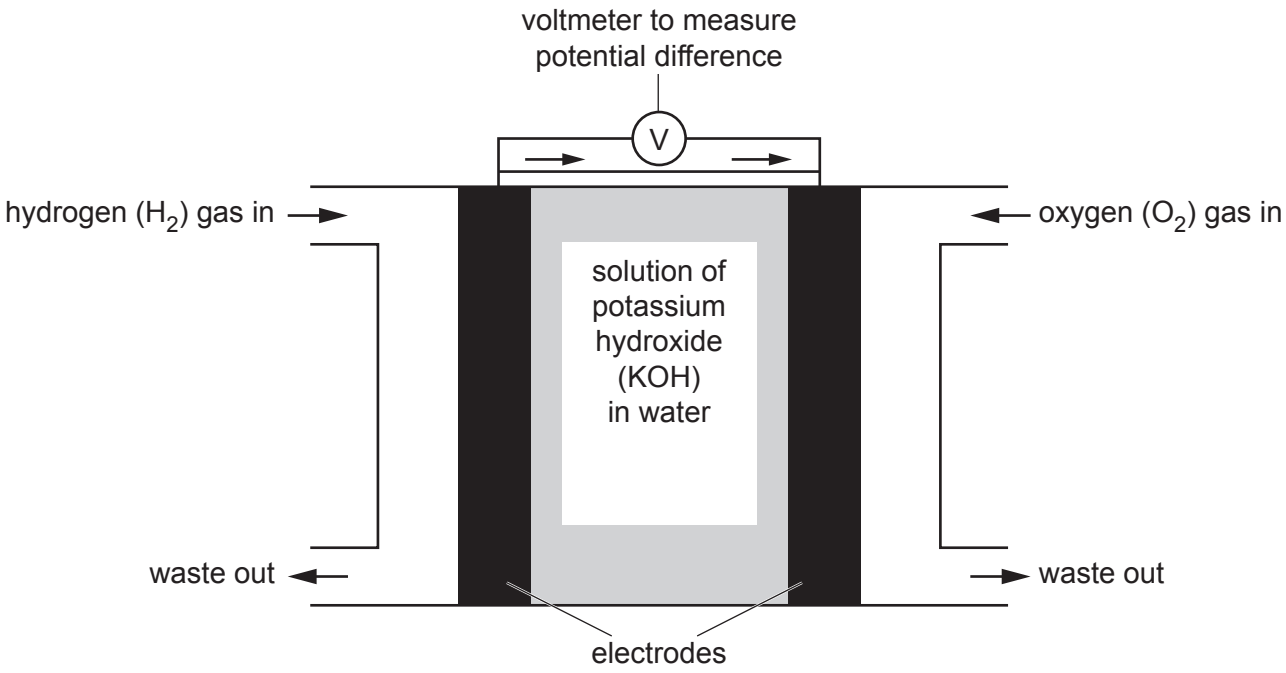
8 Beth works for a company that makes hydrogen fuel cells.

She measures the potential difference of the cell shown.



(a) Before she sets up the cell, Beth tests each gas to check its identity.

Describe the tests and the results for hydrogen and oxygen gas.

hydrogen test .....

result .....

oxygen test .....

result .....

[2]

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(b) These half equations show the reactions that happen at each electrode in the fuel cell:

at the hydrogen electrode: $2H_2 + 4OH^- \rightarrow 4H_2O + 4e^-$

at the oxygen electrode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

(i) Beth wants to make sure that she gets the highest possible potential difference from the fuel cell.

She makes sure that she uses double the volume of hydrogen compared to oxygen.

Use the half equations to explain why she needs to do this.

.....

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

(ii) Use the half equations to write an overall equation for the reaction that happens in the fuel cell.

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

(iii) A fuel cell filled with potassium hydroxide solution works better than a fuel cell filled with pure water.

One reason it works better is because potassium hydroxide solution is a better electrical conductor than pure water.

Explain why potassium hydroxide solution is a better electrical conductor than pure water.

.....

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

(iv) Use the equations to suggest one other reason why using potassium hydroxide solution helps the fuel cell to work better.

.....

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

(c) Beth uses a fixed amount of hydrogen and oxygen gas. After a time the potential difference of the cell decreases.

Explain why this happens.

.....

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

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(d) Beth's company want to use the cell to provide power for a submarine.

Submarines travel deep under the surface of the sea.

Most submarines have engines that burn diesel fuel.

Beth thinks that submarines that burn diesel fuel produce waste that is much more harmful to the sea than submarines that use hydrogen fuel cells.

(i) Explain why she is correct.

.....

.....

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

(ii) Give one **disadvantage** of using a hydrogen fuel cell rather than diesel for a submarine.

.....

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

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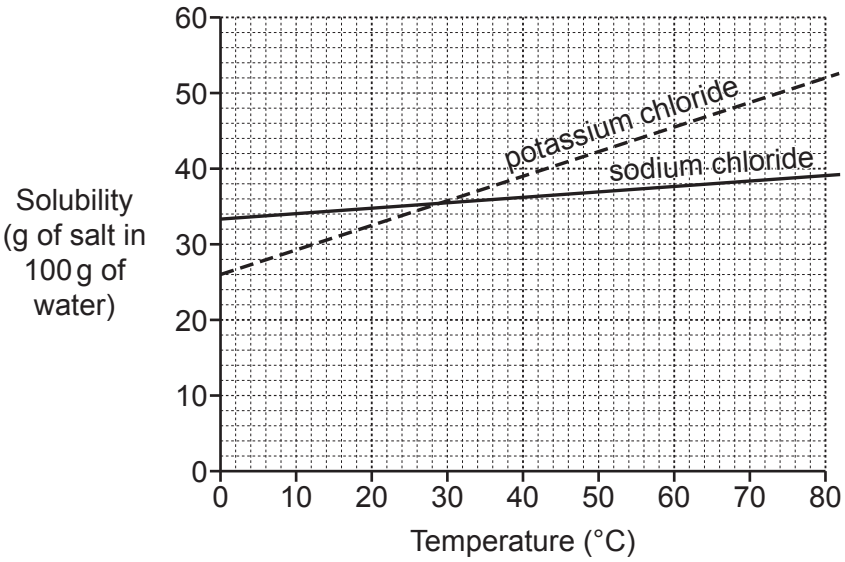
9 The graph shows the solubility of some Group 1 salts in water.



(a) **(i)** Use data from the graph to calculate the solubility of sodium chloride at 50 °C.

Use the information:
100 g of water = 100 cm^3 of water.

Give your answer in g/dm^3.

Solubility of sodium chloride at 50 °C ..... g/dm^3 **[2]**

(ii) Calculate the concentration of sodium chloride at 50 °C in mol/dm^3.

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

and concentration (mol/dm^3) = $\frac{\text{number of moles of solute}}{\text{volume } (dm^3)}$

Use your answer to **(a)(i)**.

Give your answer to **3** significant figures.

Concentration of sodium chloride at 50 °C ..... mol/dm^3 **[3]**

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(b) Kai looks at the graph and writes down a mathematical relationship.

(i) Kai writes:

solubility of potassium chloride α temperature

Use the graph to explain in words why this relationship is **incorrect**.

.....

.....

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

(ii) Use data from the graph to do a calculation to predict the solubility of potassium chloride at 100 °C.

Solubility ..... g in 100 g of water **[3]**

END OF QUESTION PAPER

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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).

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