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Monday 29 November 2021 – 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 **24** pages.

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

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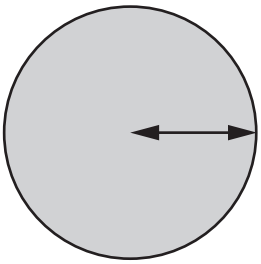
Answer **all** the questions.

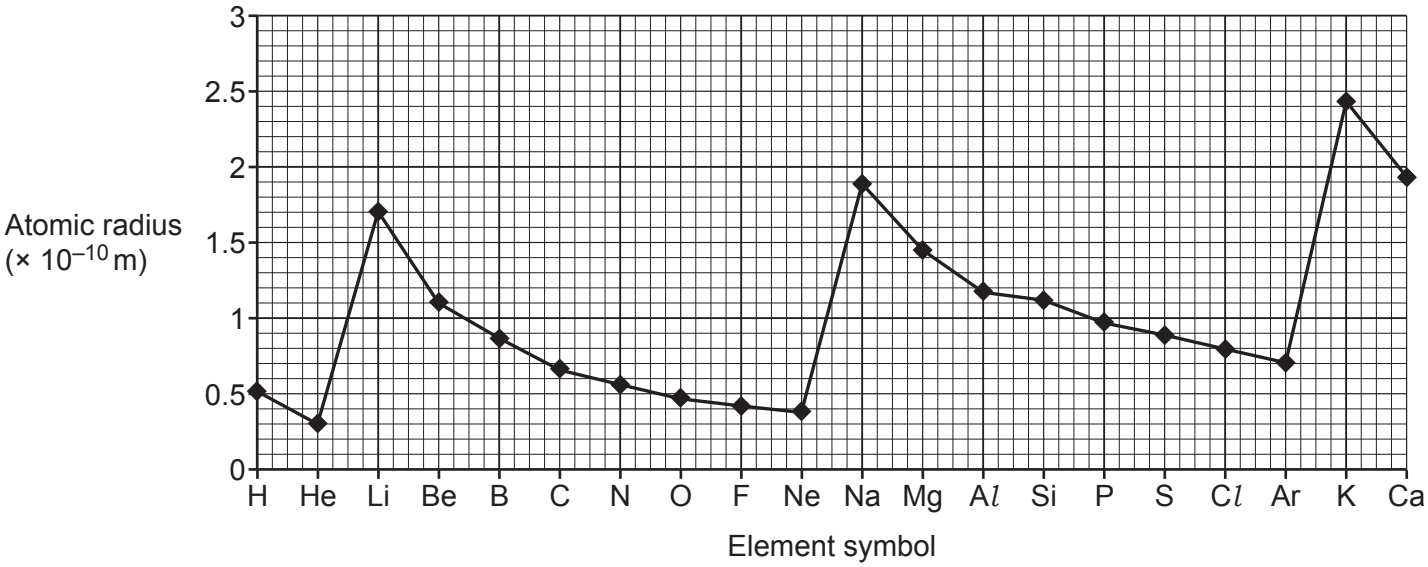
1 Kai wants to build scale models of atoms of the first 20 elements of the Periodic Table.

He finds out that the atomic radius of an atom is the distance from the centre of the atom to its outer shell of electrons.



Radius of atom

He finds this graph, which shows the atomic radius of the first 20 elements.



(a) Lithium (Li), sodium (Na) and potassium (K) are in Group 1 of the Periodic Table.

How does the atomic radius change down Group 1?
Use the graph.

.....

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

(b) **(i)** Give the symbols of the **two** elements which have the **smallest** atoms.
Use the graph.

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

(ii) Which group of the Periodic Table do the elements in **(b)(i)** belong to?
Use the Data Sheet.

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

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(c) Which statements in the table are **true** and which are **false**?

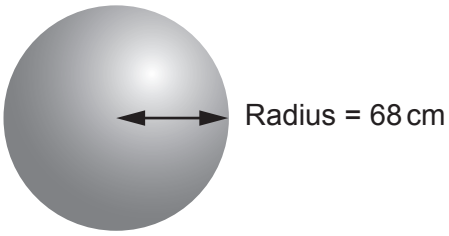
Tick **one** box (✓) in each row.
Use the graph.

Statement	**True (✓)**	**False (✓)**
Potassium (K) is the largest atom.		
Atomic radius gets smaller across every period of the Periodic Table.		
As proton number increases, atomic radius always decreases.		

[2]

(d) Kai makes a scale model of a lithium (Li) atom.

(i) The diagram shows the radius of his model of a lithium atom.



Model of a lithium (Li) atom

Kai makes a model of a **sodium (Na)** atom to the same scale.

Calculate the radius of the sodium atom model, in **cm**.

Use the graph.

Radius = ... cm **[3]**

(ii) Kai makes his lithium model red to match the flame test colour of lithium.

What colour should he make his sodium model?

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

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(e) Kai designs a sign to tell people about the particles inside a sodium atom.

Complete the missing information on the sign.

Particles inside a sodium atom

11
Na
sodium
23.0

Number of protons	.....
Number of neutrons	.....
Number of electrons	.....

More information about the particles

Type of particle	Charge	Relative Mass
Proton	+1	.....
Neutron	.....	1
Electron	.....	0

[3]

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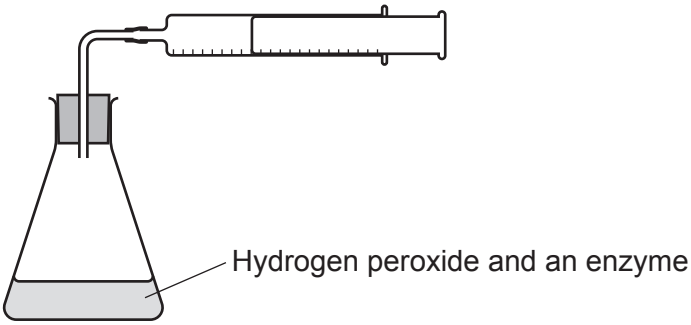
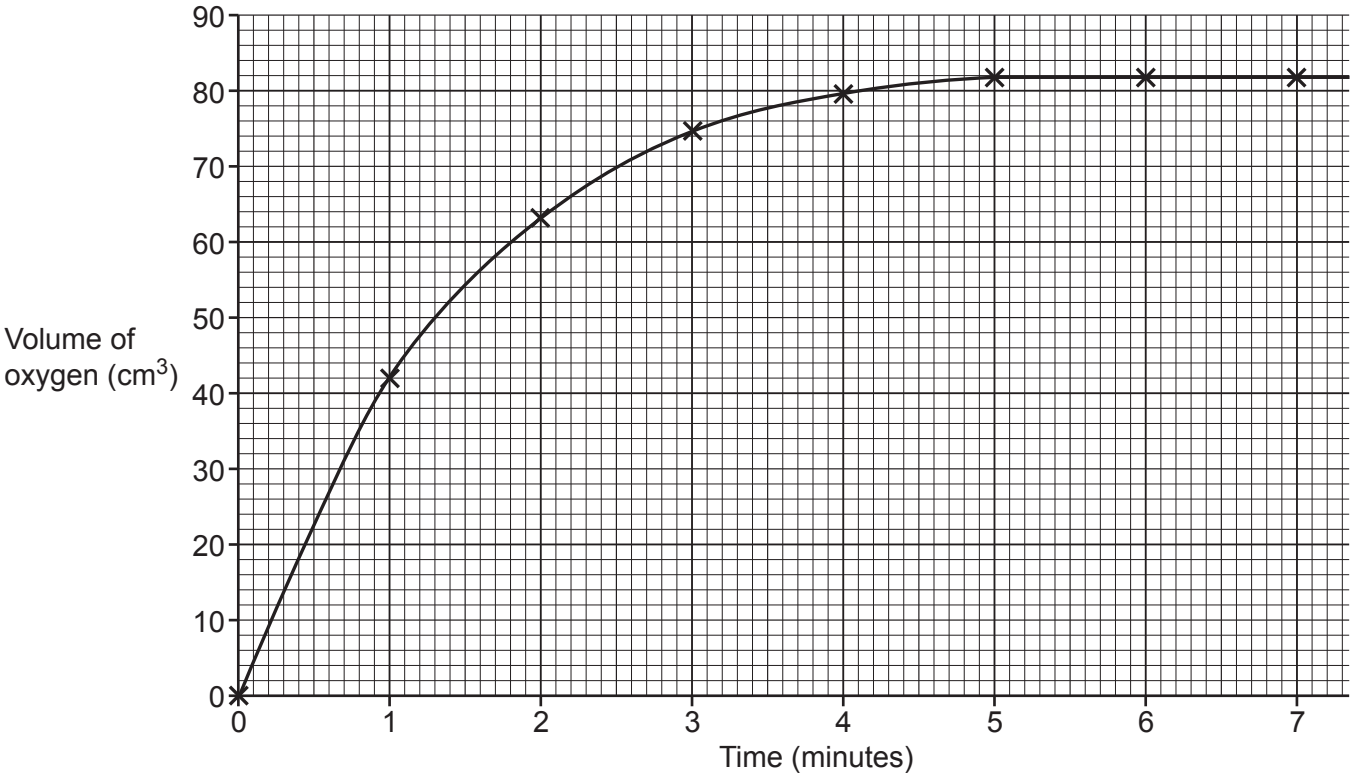
2 Hydrogen peroxide is a waste product produced by cells in our bodies. Hydrogen peroxide is broken down by an enzyme to form water and oxygen.

Beth adds a small amount of an enzyme to some hydrogen peroxide. She collects the oxygen given off in a gas syringe. She records the total volume of oxygen every minute.



The graph shows her results.



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(a) Use the graph to help you answer **(a)**.

(i) How long does it take for the reaction to finish?

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

(ii) How much oxygen is given off by the end of the reaction?

..... cm^3 **[1]**

(iii) Calculate the average volume of oxygen given off **per second**.

..... cm^3/s **[2]**

(b) The reaction that breaks down hydrogen peroxide does not start until the enzyme is added. When the enzyme is added, oxygen is given off quickly.

Explain this statement.

Use ideas about rates of reaction in your answer.

.....

.....

.....

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

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3 Some brands of tablets that treat stomach upsets contain calcium carbonate, $CaCO_3$.

Jane does experiments to measure the mass of calcium carbonate in each tablet for two different brands of tablets.

EasyCalm	**FeelRight**
Pack size: 25 tablets	Pack size: 40 tablets

(a) Jane wants to make sure that the samples she tests are representative of all the tablets in each brand.

(i) Why is it important to make sure that the samples are **representative**?

.....

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

(ii) What should Jane do to make sure her choice of tablets is representative?

Tick (✓) **two** boxes.

- Choose tablets at random from each box. ☐
- Choose tablets from more than one box of each brand. ☐
- Choose tablets that look the same. ☐
- Test each tablet under the same conditions. ☐
- Test every tablet from one box of each brand. ☐
- Test one tablet from each brand. ☐

[2]

(b) Jane reacts dilute hydrochloric acid with a tablet.
The equation shows the reaction that happens:

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

Which **two** statements explain why this reaction is a neutralisation reaction?

Tick (✓) **two** boxes.

- Carbon dioxide is made. ☐
- A solid reacts to form a solution. ☐
- A salt and water form. ☐
- The pH changes during the reaction. ☐
- The reaction fizzes. ☐

[2]

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(c) Jane crushes each tablet and adds it to water. She adds an indicator to the water, then adds dilute hydrochloric acid from a burette until the indicator changes colour.

The table shows the mean volume of dilute hydrochloric acid needed to neutralise one tablet from each brand.

Brand of tablet	**Mean volume of dilute hydrochloric acid needed (cm^3)**	**Mean mass of calcium carbonate in one tablet (g)**
EasyCalm	10.5	1.05
FeelRight	15.8	

(i) Calculate the mean mass of calcium carbonate in **one FeelRight** tablet.

Use the formula: mean mass of calcium carbonate (g) = mean volume of hydrochloric acid (dm^3) × relative formula mass of $CaCO_3$

$1\,dm^3 = 1000\,cm^3$

Mean mass of calcium carbonate in one tablet = ... g **[3]**

(ii) Jane thinks her results are inaccurate because the tablets contain other ingredients. The labels show the other ingredient in each brand of tablet.

EasyCalm Tablets
Contains:
calcium carbonate
citric acid

FeelRight Tablets
Contains:
calcium carbonate
magnesium hydroxide

Explain how each of the other ingredients will affect the volume of acid needed to neutralise each tablet.

Citric acid .....

.....

.....

Magnesium hydroxide .....

.....

.....
[3]

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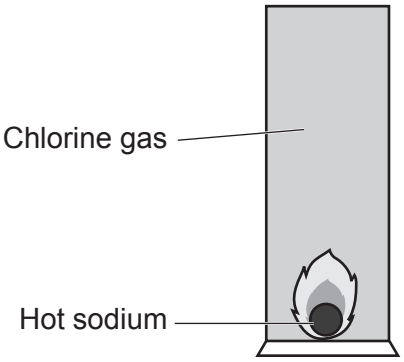
4 Layla heats a small piece of sodium. She then puts it in a jar of chlorine gas, as shown:



The sodium burns with a bright flame. A white solid is formed.

She repeats the experiment using different Group 1 and Group 7 elements. She uses jars containing group 7 gases.

(a) Complete the table of information about the reactions between Group 1 and Group 7 elements.

Group 1 element	**Group 7 element**	**Colour of Group 7 gas before the reaction**	**Name of product**
Sodium	Chlorine	Green	Sodium chloride
Potassium	Iodine	.....	.....
Lithium	Chlorine	Green	Lithium chloride
Potassium	Chlorine	Green	Potassium chloride
Lithium	Iodine	.....	.....
Sodium	.....	Orange	Sodium bromide

[3]

(b) Which of the reactions from the table do you expect to be the fastest?

Explain your choice.

Reaction between ..... and .....

Explanation .....

.....

.....

[3]

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(c) Layla tests some of the salts formed in the reactions. She collects samples of solid sodium chloride and solid sodium bromide.

She uses silver nitrate solution to test the salts, to show that they contain chloride and bromide ions.

Describe the steps she should follow to test each salt **and** state what results she should expect.

.....

.....

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

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5 **Table 5.1** and **Table 5.2** show information about the structures and uses of diamond and graphene.

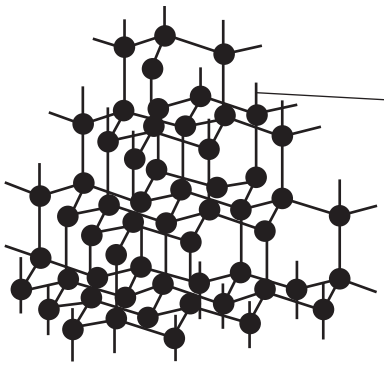
	Diamond
Structure: Giant covalent	 Many carbon atoms. Each carbon atom is bonded to four others with covalent bonds in a 3-dimensional lattice.
Uses	Tips of high speed drilling machinery.

Table 5.1

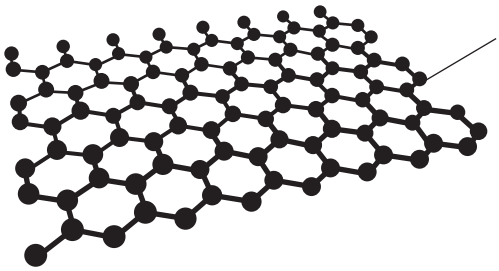
	Graphene
Structure: Nanoparticle	 Each sheet contains a single layer of carbon atoms bonded together with covalent bonds. Structure contains delocalised electrons.
Uses	Making micro-scale electronic components and batteries.

Table 5.2

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(a)* Discuss the similarities and differences between the properties of diamond and graphene in terms of their structures and explain why they have different uses.

Use information from **Table 5.1** and **Table 5.2** in your answer.

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

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(b) New types of batteries that contain nanoparticles of graphene have been available for less than 10 years.

Some people are concerned about the health effects of using new products that contain nanoparticles.

(i) Why are people concerned about the health effects of nanoparticles?

.....

.....

.....

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

(ii) Life cycle assessments are done to evaluate the sustainability of making new products.

Suggest **two** factors that are important to consider in evaluating the sustainability of graphene batteries.

1. .....

.....

2. .....

.....

[2]

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6 Some diesel cars have a system which uses a solution of urea, $(NH_2)_2CO$, to remove nitrogen oxides from their exhaust gases.

(a) Urea solution reacts in a two stage process.

Stage 1: At temperatures above 100 °C, urea solution breaks down to make ammonia.

$(NH_2)_2CO(aq) + H_2O(g) \rightarrow CO_2(g) + 2NH_3(g)$

Stage 2: Ammonia then reacts with nitrogen oxide.

$4NO(g) + 4NH_3(g) + O_2(g) \rightarrow 4N_2(g) + 6H_2O(g)$

(i) The overall reaction that happens in Stage 1 and Stage 2 produces **three waste** gases which leave the exhaust.

Name these **three** gases.

1. .....

2. .....

3. .....
[1]

(ii) The urea solution is sprayed into the hot exhaust gases before they leave the car.

Explain why the **two** equations show the state symbol for water as (g) rather than (l).

.....

.....

.....

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

(iii) In the car, the urea solution is stored in a tank. The tank is kept cool by being kept far away from the hot engine.

Why is it important to keep the urea solution cool?

.....

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

(iv) A redox reaction happens when oxidation and reduction happen in the same equation.

Explain why the reaction in **Stage 2** is a redox reaction.

.....

.....

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

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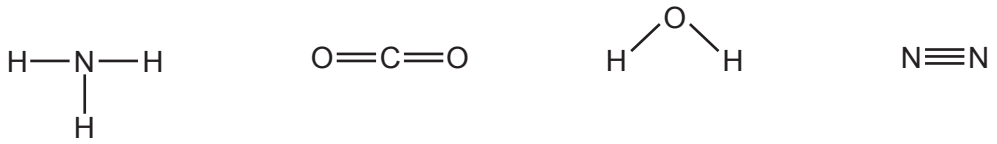
(b) Amir draws the displayed formulae of some of the substances involved in the reactions.



NH_3 **CO_2** **H_2O** **N_2**

Amir says that the number of bonds formed by each element can be calculated by using this equation:

Number of bonds formed = (18 – x)

where x = group number of the element shown on the Periodic Table.

(i) Show that this equation works for the number of bonds formed by nitrogen and oxygen.

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.....

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

(ii) Suggest **one** reason why this equation **cannot** be used for hydrogen.

.....

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

(iii) Urea, $(NH_2)_2CO$, contains one double bond.

Draw the displayed formula of urea.

[2]

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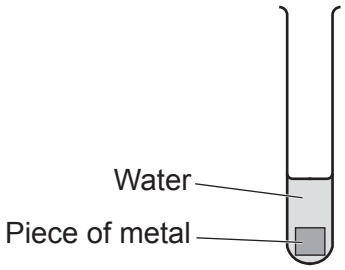
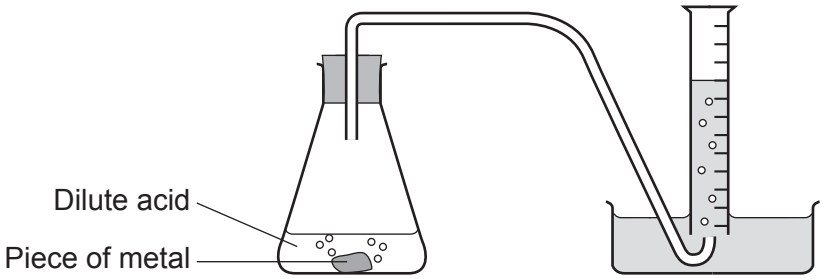
7 Kareem investigates the order of reactivity of five metals, aluminium, magnesium, calcium, copper and zinc. He does two experiments, as shown.



Experiment 1



Experiment 2

In **experiment 1** he puts small pieces of each of the metals into water.
He observes the metals over five minutes.

In **experiment 2** he puts small pieces of each metal into dilute acid.
He measures the time taken to collect 10 cm^3 of gas.

Table 7.1 and **Table 7.2** show Kareem's results.

Experiment 1	
Metal	**Observations**
Aluminium	No bubbles seen
Magnesium	Bubbles appear on surface of metal
Calcium	Rapid fizzing
Copper	No bubbles seen
Zinc	Bubbles appear on surface of metal

Table 7.1

Experiment 2	
Metal	**Time taken to collect 10 cm^3 gas (s)**
Aluminium	30
Magnesium	45
Calcium	5
Copper	No gas collected
Zinc	70

Table 7.2

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(a)* Explain what conclusions can be made about the reactivity of the five metals from Kareem's experiment.

Include any uncertainties in your conclusions.

Use information from **Table 7.1** and **Table 7.2** to support your answer.

.....

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

(b) Which **two** statements explain why some metals are more reactive than others?

Tick (✓) **two** boxes.

Some metals form positive ions more easily. ☐

Some metals have lower melting points. ☐

Some metals are oxidised more easily. ☐

Some metals conduct electricity more easily. ☐

Some metals form ions with higher charges. ☐

[2]

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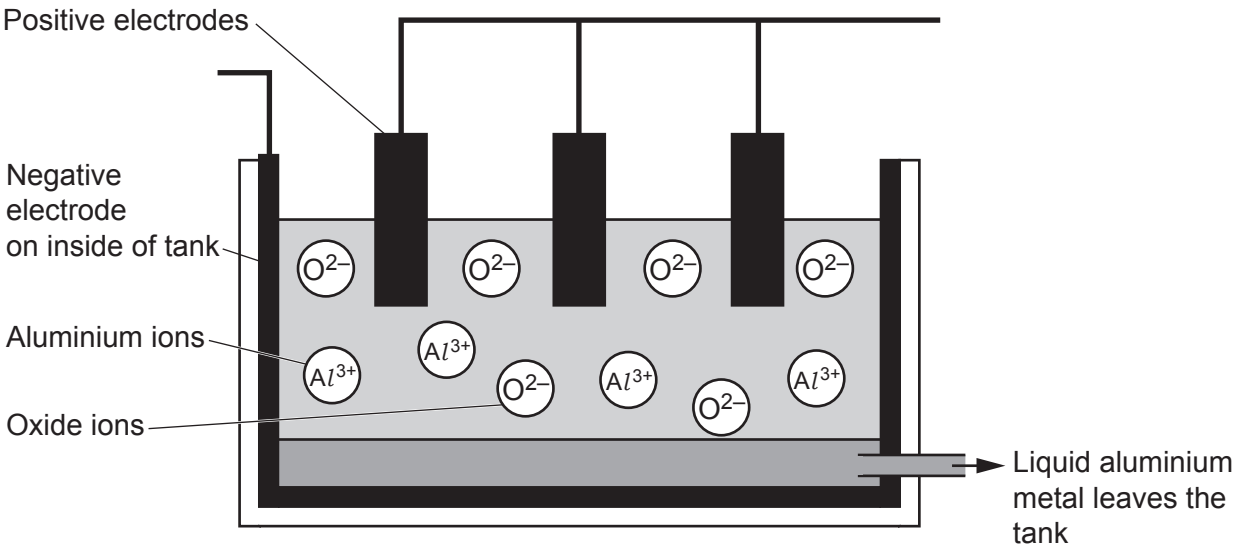
8 Aluminium is extracted from aluminium oxide by electrolysis.

The diagram shows the tank used to electrolyse aluminium oxide.



(a) **(i)** Before electrolysis, solid aluminium oxide is dissolved in a hot, molten compound called cryolite.
The formula for cryolite is Na_3AlF_6.

Explain why the formula for cryolite contains six fluoride ions.

Use ideas about charges in your answer.

.....

.....

.....

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

(ii) The hot cryolite dissolves the aluminium oxide to form a molten solution.

Explain why solid aluminium oxide has to be made into a molten solution before electrolysis.

.....

.....

.....

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

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(b) **(i)** Describe what happens at each electrode during the electrolysis.

.....

.....

.....

.....

.....

.....

.....

..... **[4]**

(ii) The melting point of aluminium metal is 660 °C.

What temperature should the inside of the tank be to make sure that aluminium leaves the tank as a liquid?

Put a ring around the correct answer.

<< 660 °C **> 660 °C** **< 660 °C** **~ 660 °C**

[1]

(c) Aluminium is used to make overhead cables. Copper is used to make underground cables.

The table shows some properties of each metal.

Metal	**Electrical conductivity (MS / m)**	**Density (g / cm^3)**
Copper	58	9.0
Aluminium	35	2.7

Explain why the metals are used in different ways.

.....

.....

.....

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

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9 The table shows the hydrogen ion concentration and the pH for different concentrations of **two** dilute acids.

(a) Complete the information in the table.

Name of acid	**Concentration of acid (mol/dm^3)**	**Concentration of hydrogen ions in solution (mol/dm^3)**	**pH**
Hydrochloric acid	0.50	5.0×10^{-1}	0.3
	0.10	1.0×10^{-1}	1.0
	0.02	2.0×10^{-2}	1.7
	.....	1.0×10^{-2}	2.0
	0.001	1.0×10^{-3}	.....
Sulfuric acid	0.30	6.0×10^{-1}	0.2
	0.10	.....	0.7
	0.01	2.0×10^{-2}	1.7

[2]

(b) Which acid in the table shows the **highest** concentration of hydrogen ions in solution?

Tick (✓) **one** box.

0.50 mol/dm^3 hydrochloric acid ☐

0.10 mol/dm^3 hydrochloric acid ☐

0.30 mol/dm^3 sulfuric acid ☐

0.10 mol/dm^3 sulfuric acid ☐

[1]

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(c) Sundip writes this relationship:

pH α concentration of hydrogen ions

(i) What does Sundip's relationship mean?

.....

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

(ii) Do you agree with Sundip's relationship?

Yes ☐

No ☐

Use data from the table to support your answer.

.....

.....

.....

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

(d) **(i)** Complete the **symbol** equations to show what happens when hydrochloric acid and sulfuric acid each form ions.

hydrochloric acid	→	hydrogen ions	+	chloride ions
HCl	→	H^+	+	.....
sulfuric acid	→	hydrogen ions	+	sulfate ions
H_2SO_4	→	$2H^+$	+	.....

[2]

(ii) Explain why the same concentration of hydrochloric acid and sulfuric acid have different concentrations of hydrogen ions and different pH values.

.....

.....

.....

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

END OF QUESTION PAPER

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