Questions are for both separate science and combined science students unless indicated in the question

Q1.

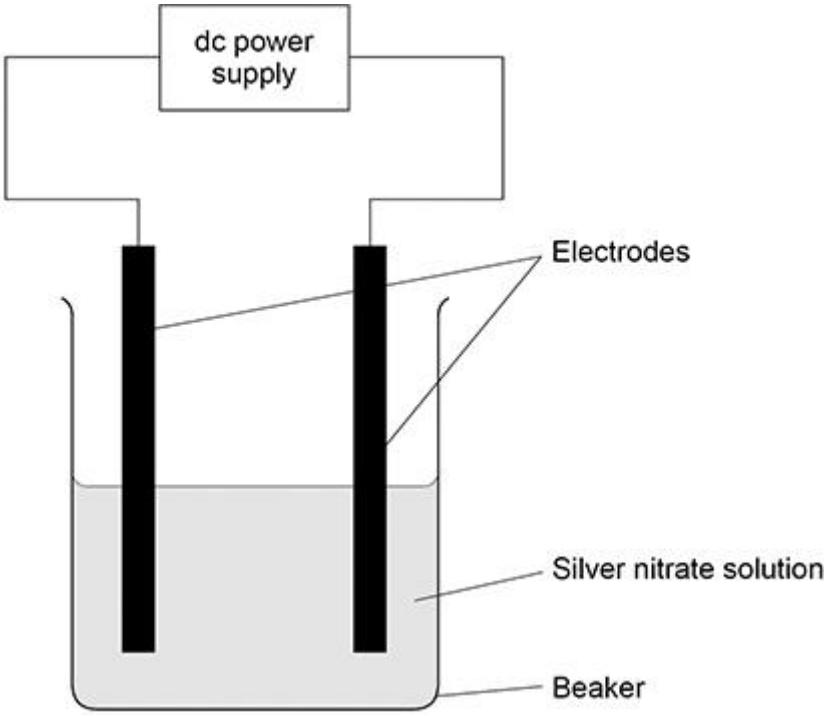
This question is about electrolysis.

Some students investigated the electrolysis of silver nitrate solution.

This electrolysis produces silver at the negative electrode.

Figure 1 shows the apparatus.

Figure 1



This is the method used.

1. Weigh the negative electrode.
2. Set up the apparatus shown in **Figure 1**.
3. Switch on the power supply.
4. Switch off the power supply after five minutes.
5. Rinse the negative electrode with water and allow to dry.
6. Reweigh the negative electrode.
7. Repeat steps 1 to 6 for different times.

(a) Some silver did not stick to the negative electrode but fell to the bottom of the beaker.

The students needed to weigh this silver.

How could the students separate the silver from the silver nitrate solution?

Tick (✓) **one** box.

By chromatography	☐
By crystallisation	☐
By distillation	☐
By filtration	☑

(1)

Table 1 shows the students' results.

Table 1

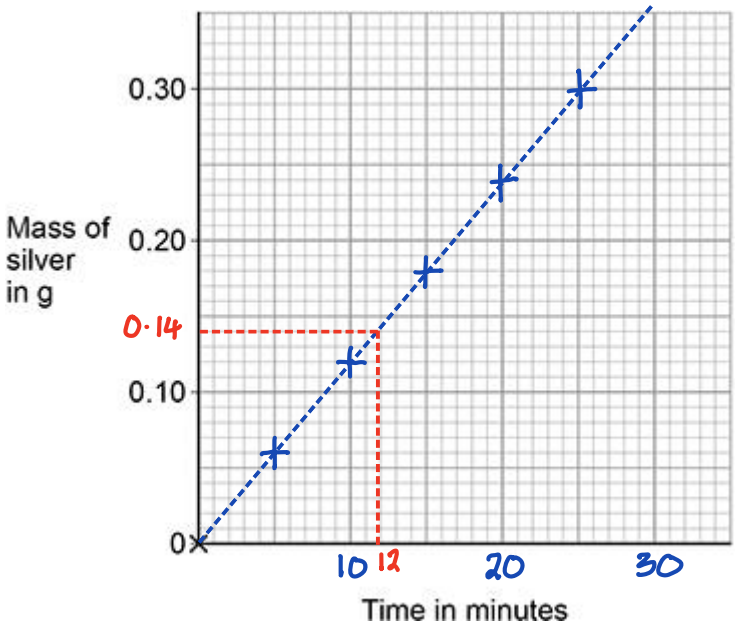
Time in minutes	Mass of silver in g
0	0.00
5	0.06
10	0.12
15	0.18
20	0.24
25	0.30

(b) Draw a graph on **Figure 2**.

You should:

- use a suitable scale for the x-axis
- plot the data from **Table 1**
- draw a line of best fit.

Figure 2



(4)

(c) Determine the mass of silver that would be produced after 12 minutes.

Use **Figure 2**.

Mass of silver = 0·14 g

(1)

(d) A student investigated the electrolysis of two aqueous salt solutions.

Hydrogen is produced at the negative electrode when the metal in the salt solution is more reactive than hydrogen.

Complete **Table 2** to show what the student would **observe** at the negative electrode for each salt solution.

Table 2

Salt solution	Observation at negative electrode
Copper sulfate	Solid metal Cu will plate electrode
Sodium chloride	Effervescence as H_2 produced

Na
⋮
H
Cu
↑ Reactivity

(2)

(e) A teacher demonstrates the electrolysis of molten lead bromide.

The products at the electrodes are lead and bromine.

Why should the teacher do the demonstration in a fume cupboard?

Toxic fumes released

(1)

(f) Two other molten compounds are electrolysed.

Complete **Table 3** to show the molten compounds and the products.

Table 3

Molten compound electrolysed	Product at the negative electrode	Product at the positive electrode
Zinc chloride	Zinc	Chlorine
Potassium iodide	Potassium	Iodine

(3)

(Total 12 marks)

Q2.

This question is about chemical reactions and electricity.

(a) Electrolysis and chemical cells both involve chemical reactions and electricity.

Explain the difference between the processes in electrolysis and in a chemical cell.

Electrolysis: uses electricity to produce a chemical reaction.

Cells: use a chemical reaction to produce electricity.

(2)

(b) A teacher demonstrates the electrolysis of molten lead bromide.

Bromine is produced at the positive electrode.

Complete the half equation for the production of bromine.

You should balance the half equation.

$$2\,Br^- \rightarrow Br_2 + 2\,e^-$$

(2)

(c) Two aqueous salt solutions are electrolysed using inert electrodes.

Complete the table below to show the product at each electrode.

Salt solution	Product at positive electrode	Product at negative electrode
Copper nitrate	O_2 + H_2O	copper
Potassium iodide	Iodine	Hydrogen

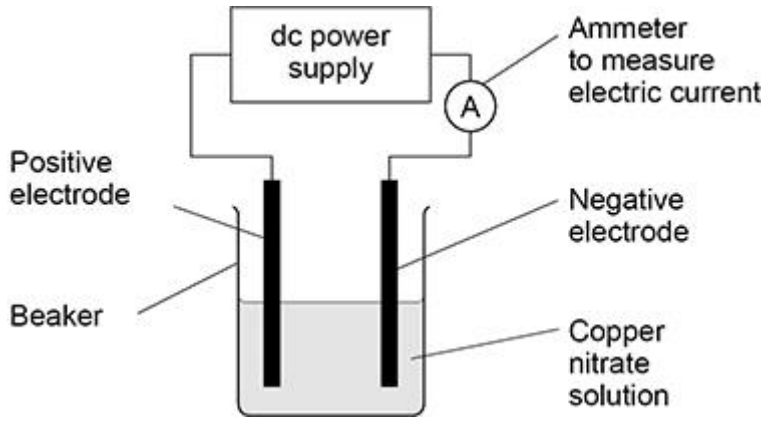
K
⋮
H
Cu
↑ Reactivity

(3)

Some students investigated the electrolysis of copper nitrate solution using inert electrodes.

Figure 1 shows the apparatus.

Figure 1



The students investigated how the mass of copper produced at the negative electrode varied with:

- time
- current.

This is the method used.

1. Weigh the negative electrode.
2. Set up the apparatus shown in **Figure 1**.
3. Adjust the power supply until the ammeter shows a current of 0.3 A
4. Switch off the power supply after 5 minutes.
5. Rinse the negative electrode with water and allow to dry.
6. Reweigh the negative electrode.
7. Repeat steps 1 to 6 for different times.
8. Repeat steps 1 to 7 at different currents.

(d) Some of the copper produced did not stick to the negative electrode but fell to the bottom of the beaker.

Suggest how the students could find the total mass of copper produced.

_____

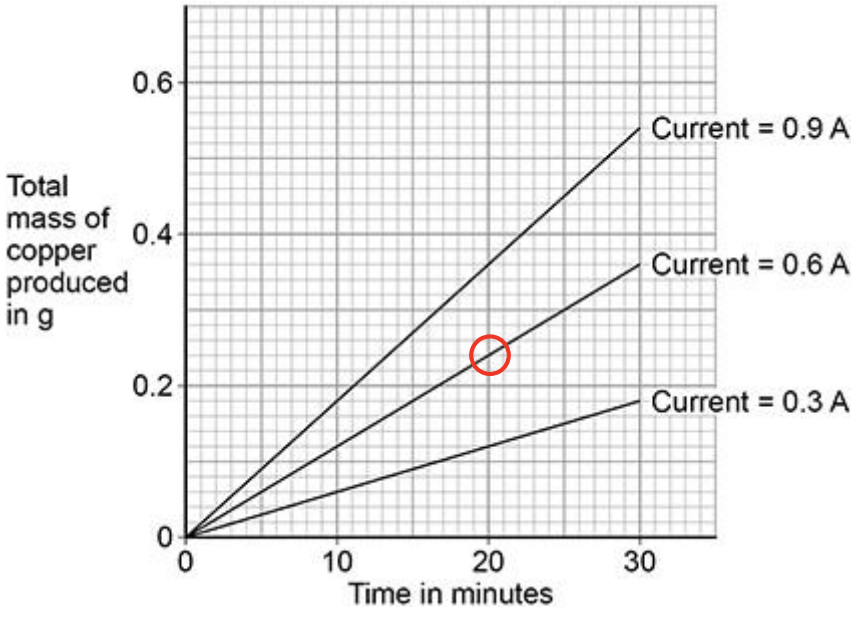
Filter the mixture
Wash and dry the copper residue
Weigh the copper collected
Add to the increase in mass of the electrode

(4)

The students plotted their results on a graph.

Figure 2 shows the graph.

Figure 2



A student correctly concluded that the total mass of copper produced is directly proportional both to the time and to the current.

(e) How do the results in **Figure 2** support the conclusion that the total mass of copper produced is directly proportional to the time?

For a given current, results show a straight line through the origin.

(1)

(f) How do the results in **Figure 2** support the conclusion that the total mass of copper produced is directly proportional to the current?

Use data from **Figure 2** in your answer.

For a given time, when current doubles, mass doubles. e.g. at 30 min: Current 0.3 × 2 = 0.6; Mass 0.18 × 2 = 0.36

(1)

(g) Copper nitrate solution is blue. $Cu(NO_3)_2$

Suggest why the blue colour of the copper nitrate solution fades during the electrolysis.

Copper ions (Cu^{2+}) are discharged from solution

(1)

(h) Determine the number of atoms of copper produced when copper nitrate solution is electrolysed for 20 minutes at a current of 0.6 A

Give your answer to 3 significant figures.

Use **Figure 2**.

Relative atomic mass (A_r): Cu = 63.5

The Avogadro constant = 6.02×10^{23} per mole

At a current of 0.6A, after 20 min: 0.24 g Cu

$$\text{No. mol Cu in } 0.24\text{g} = \frac{0.24\text{ g}}{63.5\text{ g/mol}} = 3.780 \times 10^{-3}\text{ mol}$$

$$\text{No. atoms} = 3.780 \times 10^{-3}\text{ mol} \times 6.02 \times 10^{23}\text{ mol}^{-1}$$

$$= 2.275 \times 10^{21}\text{ mol}$$

Number of atoms (3 significant figures) = 2.28×10^{21}

(3)

(Total 17 marks)

Q3.

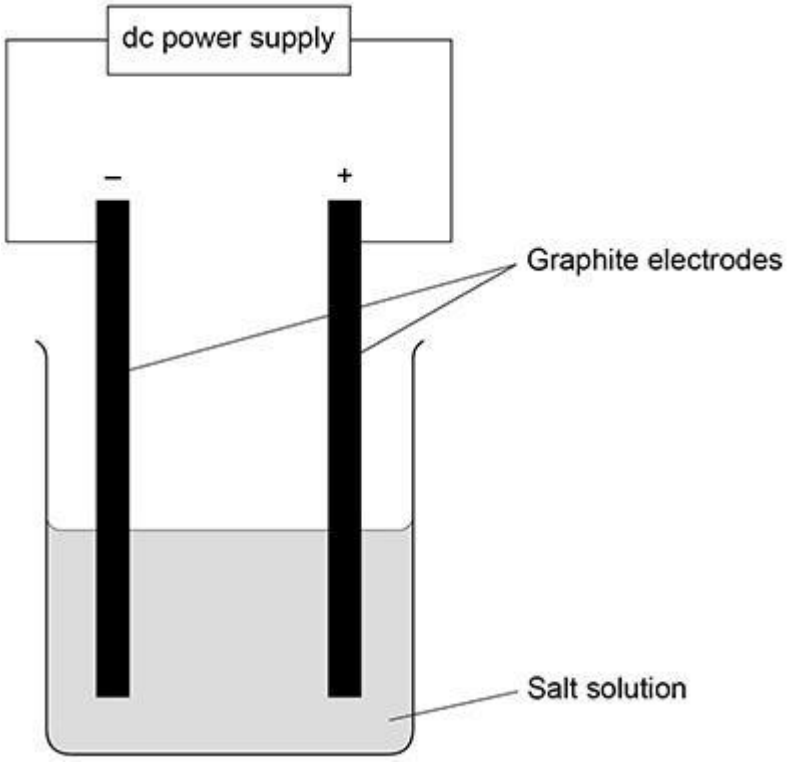
This question is about electrolysis.

A student investigated the hypothesis:

'The electrolysis of a salt solution produces a metal at the negative electrode and a gas at the positive electrode.'

Figure 1 shows the apparatus used.

Figure 1



(a) What observation would be made at each electrode if the hypothesis is correct?

Observation if metal produced at the negative electrode

A solid would be produced.

Observation if gas produced at the positive electrode

Observe bubbles, effervescence.

(2)

The table below shows the student's results.

Salt solution	Product at the negative electrode	Product at the positive electrode
Copper chloride	Copper	Chlorine
Potassium nitrate	Hydrogen	Oxygen
Silver nitrate	Silver	Oxygen

(b) Which salt solution in table above does **not** match the student's hypothesis?

Give **one** reason why.

Salt solution Potassium nitrate

Reason Hydrogen produced at negative electrode which is not a metal.

(2)

(c) Give **two** reasons why graphite is used for the electrodes.

1 Graphite conducts electricity

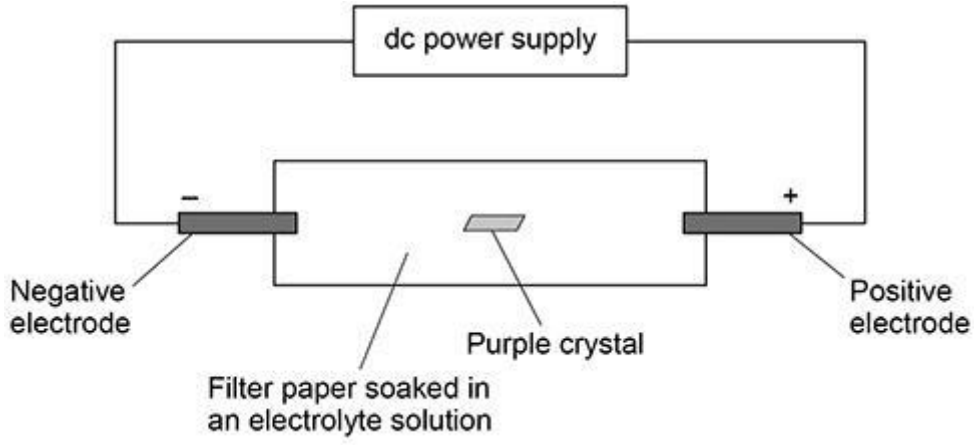
2 Graphite is inert. (Will not react)

(2)

A different student investigated what happens during electrolysis.

Figure 2 shows the apparatus.

Figure 2



The purple crystal contained:

- colourless positive ions
- purple coloured negative ions.

The purple crystal dissolved in the electrolyte solution.

(d) What happens to the purple coloured ions?

Give **one** reason for your answer.

Tick (✓) **one** box.

The ions do not move.	
The ions move towards the negative electrode.	
The ions move towards the positive electrode.	✓

Reason Ions are negatively charged and attracted to electrode of opposite charge.

(2)

(Total 8 marks)

Q4.

This question is about aluminium.

(a) Aluminium is a metal.

Draw **one** line from each property of aluminium to the correct reason for that property.

Property	Reason
Conducts electricity	Aluminium has delocalised electrons
	Aluminium has layers of atoms which can slide
High melting point	Aluminium has strong metallic bonds
	Aluminium has weak intermolecular forces
	Aluminium has a random arrangement of atoms

(2)

(b) Aluminium can be used to make alloys.

What is meant by an 'alloy'?

An alloy is a mixture of metals.

(1)

Aluminium is extracted from bauxite.

Bauxite is a mixture which contains aluminium oxide.

(c) Bauxite contains between 15% and 25% aluminium.

Aluminium oxide always contains 53% aluminium.

How does this show that bauxite is a mixture and **not** a compound?

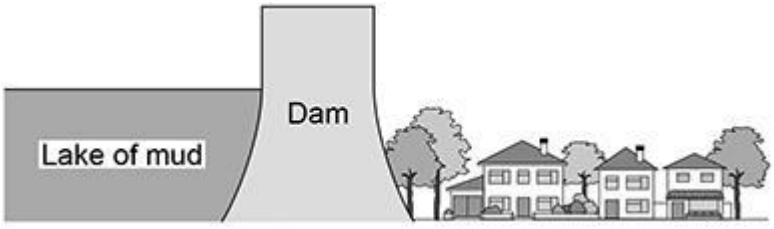
Bauxite contains a variable percentage of aluminium

(1)

(d) The waste material from the bauxite is stored in lakes of mud.

The lakes of mud are held in place by dams.

The **image** below shows one of these lakes.



Suggest **two** possible problems with storing the waste material in lakes of mud.

1 Danger of dam bursting

2 Leakage of toxic substances from mud to the environment.

(2)

Aluminium is extracted by electrolysis.

The aluminium oxide is mixed with cryolite and melted.

The mixture is then electrolysed.

(e) The formula of cryolite is Na_3AlF_6

Give the total number of atoms in the formula.

Na = 3
Al = 1
F = 6
10

Number of atoms = 10

(1)

(f) What is the reason for adding cryolite to the aluminium oxide?

Tick (✓) **one** box.

To increase the amount of aluminium extracted	☐
To lower the melting point of the mixture	✓
To reduce the amount of aluminium oxide needed	☐

(1)

(g) Complete the sentences.

Choose answers from the box.

aluminium	**carbon**	**fluorine**
oxygen	**sodium**	

When the molten aluminium oxide and cryolite mixture is electrolysed the product at

the positive electrode is Oxygen.

This product reacts with the positive electrode because the positive electrode is

made of Carbon.

(2)

(h) A sample of bauxite contains 25% aluminium.

Calculate the maximum mass of aluminium that can be extracted from 300 000 kg of the sample of bauxite.

Give your answer in standard form.

$\frac{25}{100} \times 300\,000\ kg = 75\,000\ kg$

$= 7.5 \times 10^4\ kg$

Maximum mass (in standard form) = 7.5×10^4 kg

(3)

(Total 13 marks)

Q5.

This question is about electrolysis.

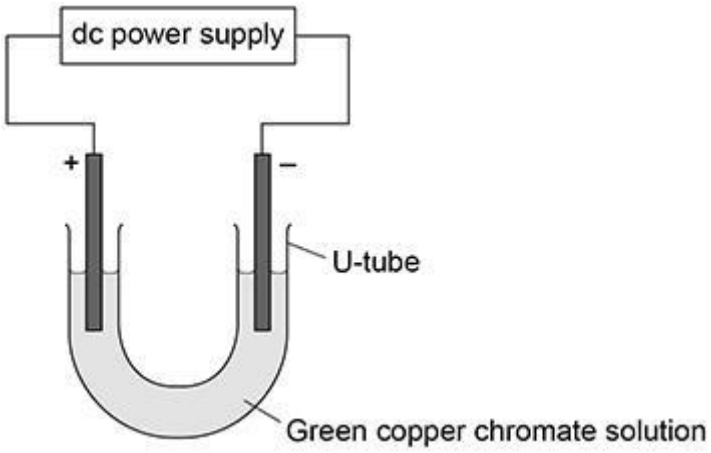
A student investigated the electrolysis of copper chromate solution.

Copper chromate solution is green.

Copper chromate contains:

- blue coloured Cu^{2+} ions
- yellow coloured CrO_4^{2-} ions.

The diagram below shows the apparatus used.



The student switched the power supply on.

The student observed the changes at each electrode.

The table below shows the student's observations.

Changes at positive electrode	Changes at negative electrode
Solution turned yellow Bubbles formed at the electrode	Solution turned blue Solid formed on the electrode

(a) Explain why the colour changed at the positive electrode.

Yellow CrO_4^{2-} ions moved to the positive electrode.

(2)

(b) The gas produced at the positive electrode was oxygen.

The oxygen was produced from hydroxide ions.

Name the substance in the solution that provides the hydroxide ions.

Water

(1)

(c) Describe how the solid forms at the negative electrode.

Copper Cu^{2+} ions gain $2e^-$ and are reduced to form Cu atoms.

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

(3)

(d) The student repeated the investigation using potassium iodide solution instead of copper chromate solution.

Name the product at each electrode when potassium iodide solution is electrolysed.

Negative electrode

H_2 hydrogen

Positive electrode

I_2 Iodine

(2)

(Total 8 marks)

Q6.

This question is about electrolysis.

Aluminium is produced by electrolysing a molten mixture of aluminium oxide and cryolite.

(a) Explain why a mixture is used as the electrolyte instead of using only aluminium oxide.

The mixture has a lower melting point than aluminium oxide

So less energy is needed to melt.

(2)

(b) What happens at the negative electrode during the production of aluminium?

Tick (✓) **one** box.

Aluminium atoms gain electrons.	☐
Aluminium atoms lose electrons.	☐
Aluminium ions gain electrons.	☑
Aluminium ions lose electrons.	☐

(1)

(c) Oxygen is produced at the positive electrode.

Complete the balanced half-equation for the process at the positive electrode.

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

(2)

(d) Explain why the positive electrode must be continually replaced.

The electrode reacts with oxygen
The electrode is made from carbon / graphite
so carbon dioxide is produced, and
the graphite electrode is worn away.

(3)

(e) The overall equation for the electrolysis of aluminium oxide is:

$$2\ Al_2O_3 \rightarrow 4\ Al + 3\ O_2$$

Calculate the mass of oxygen produced when 2000 kg of aluminium oxide is completely electrolysed.

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

2000 kg = 2000 × 1000 = 2×10^6 g

$M_r\ Al_2O_3 = ((27 \times 2) + (16 \times 3)) = 102\ g\ mol^{-1}$

$M_r\ O_2 = 16 \times 2 = 32\ g\ mol^{-1}$

No. moles of Al_2O_3 = $\frac{2 \times 10^6 \text{ g}}{102 \text{ g mol}^{-1}}$ = 1.96×10^4 mol

2 moles of Al_2O_3 produce 3 moles O_2

1 " " " " $\frac{3}{2}$ " "

1.96×10^4 mol " " $\frac{3}{2} \times 1.96 \times 10^4$ mol "

= 2.94×10^4 mol O_2

Mass of 2.94×10^4 mol O_2 = 2.94×10^4 mol $\times$ 32 g mol^{-1}

= $\frac{9.412 \times 10^5 \text{ g}}{1000}$ = 9.41×10^2 kg

Mass of oxygen = 941 kg

(4)

Sodium metal and chlorine gas are produced by the electrolysis of molten sodium chloride.

(f) Explain why sodium chloride solution **cannot** be used as the electrolyte to produce sodium metal.

Because sodium is more reactive than hydrogen Hydrogen gas would be produced instead of sodium.

(2)

(g) Calculate the volume of 150 kg of chlorine gas at room temperature and pressure.

The volume of one mole of any gas at room temperature and pressure is 24.0 dm^3

Relative formula mass (M_r): Cl_2 = 71 **(separate only)**

Mass of chlorine gas Cl_2 = 150 kg = 150 × 1000

= 1.5×10^5 g

No. moles of Cl_2 = $\frac{1.5 \times 10^5 \text{ g}}{71 \text{ g mol}^{-1}}$ = 2112.68 mol

Volume of Cl_2: Volume = 50 700 dm^3

2112.68 mol × 24.0 dm^3 = 50704 dm^3

(2)

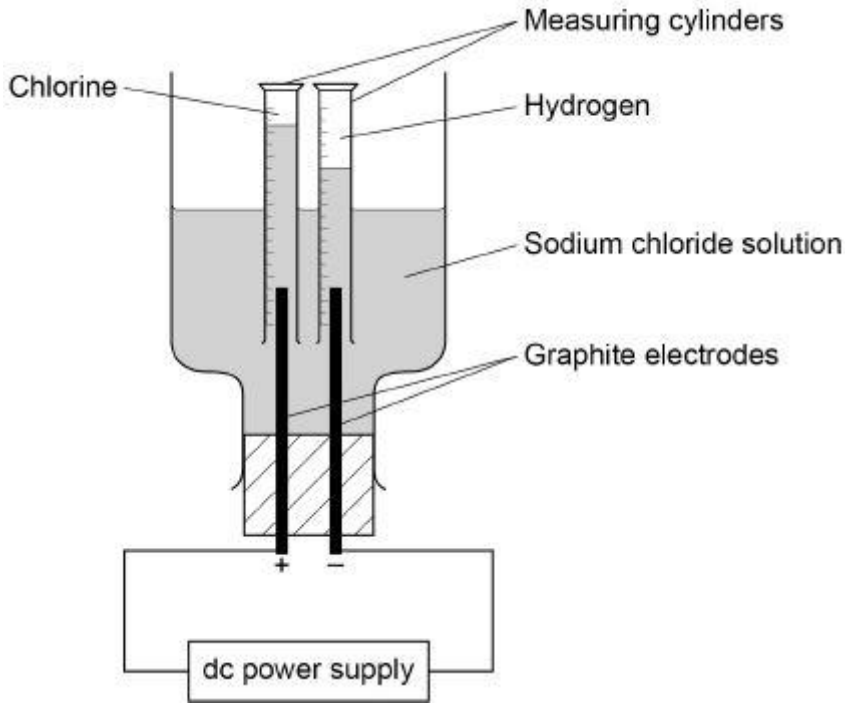
(Total 16 marks)

Q7.

A student investigated the electrolysis of sodium chloride solution.

Figure 1 shows the apparatus.

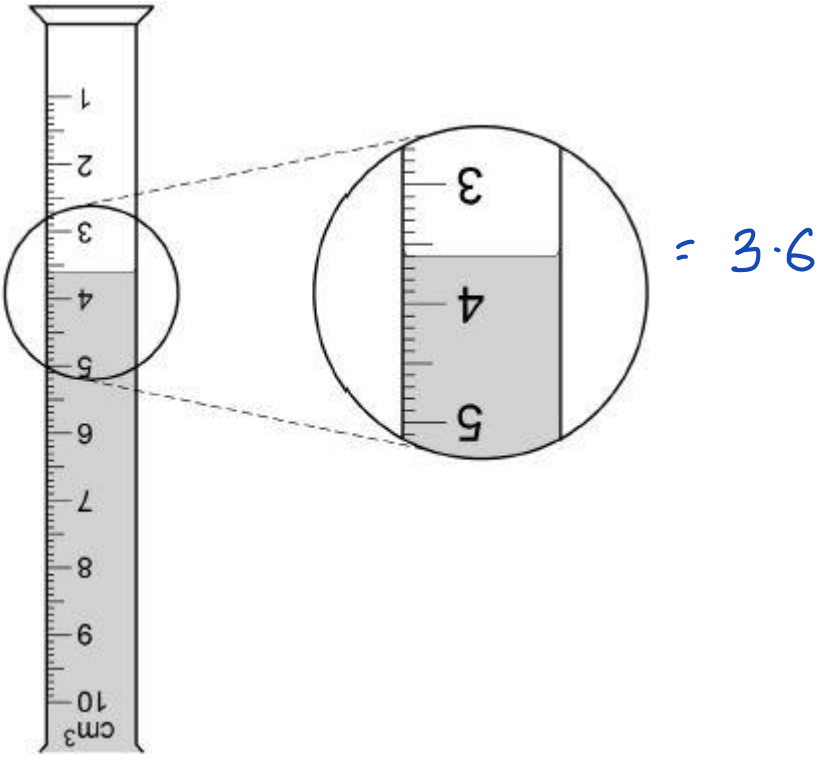
Figure 1



The student measured the volume of gas collected in each measuring cylinder every minute for 20 minutes.

(a) **Figure 2** shows the volume of hydrogen gas collected in the measuring cylinder after 8 minutes.

Figure 2



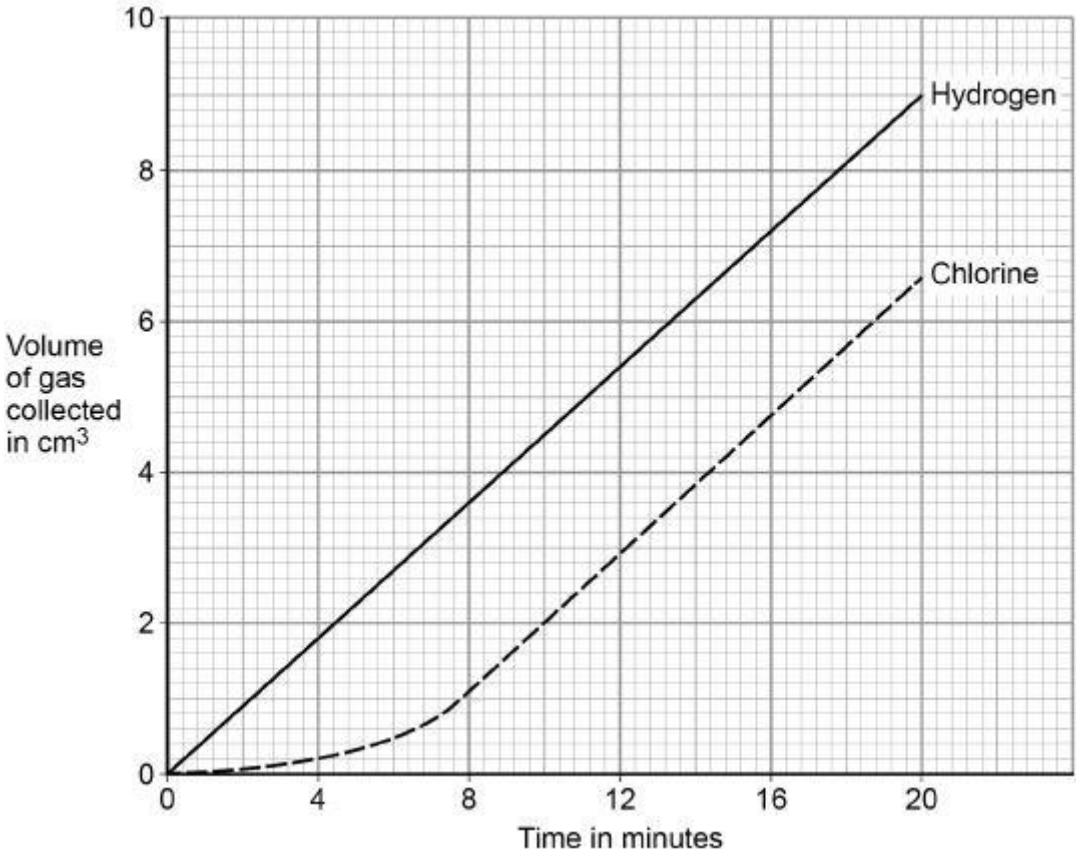
What is the volume of hydrogen gas collected?

Volume = 3·6 cm^3

(1)

Figure 3 shows the results of the investigation.

Figure 3



(b) Which of the lines on **Figure 3** show that the volume of gas collected is directly proportional to the time?

Tick **one** box.

- Both lines ☐
- Chlorine line only ☐
- Hydrogen line only ☑
- Neither line ☐

(1)

(c) Which of the lines on **Figure 3** show a positive correlation between the volume of gas collected and time?

Tick **one** box.

- Both lines ☑

Chlorine line only ☐

Hydrogen line only ☐

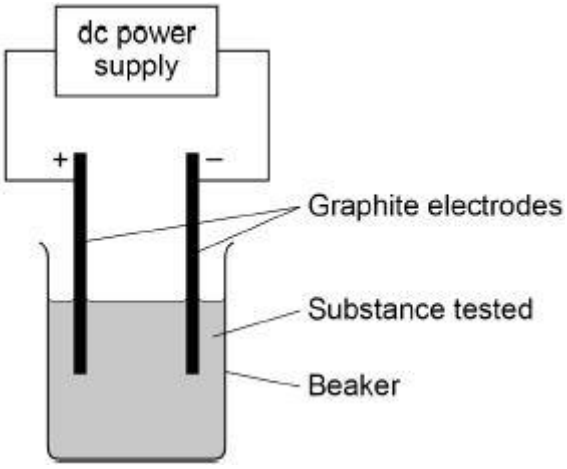
Neither line ☐

(1)

A teacher demonstrates the electrolysis of different substances using graphite electrodes.

Figure 4 shows the apparatus used.

Figure 4



(d) Why can graphite conduct electricity?

Tick **one** box.

Graphite exists in layers of atoms. ☐

Graphite has a giant structure. ☐

Graphite has a high melting point. ☐

Graphite has delocalised electrons. ☑

(1)

(e) The teacher demonstrates the electrolysis of:

- molten zinc chloride
- potassium bromide solution.

Complete the table below to predict the products.

Choose answers from the box.

chlorine	bromine	hydrogen	oxygen	potassium	zinc

Substance electrolysed	Product at cathode (negative electrode)	Product at anode (positive electrode)
Molten zinc chloride	Zinc	Chlorine
Potassium bromide solution	Hydrogen	Bromine

(4)

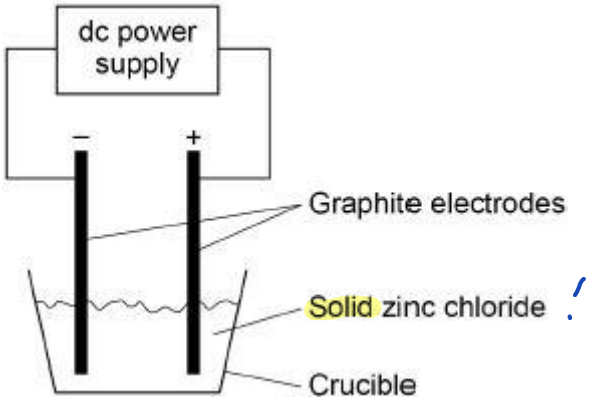
(Total 8 marks)

Q8.

A student investigated the electrolysis of different substances.

Figure 1 shows the apparatus.

Figure 1



(a) Explain why electrolysis would not take place in the apparatus shown in **Figure 1**.

Solid zinc chloride does not conduct electricity because the ions cannot move in a solid.

(2)

(b) Explain why graphite conducts electricity.

Answer in terms of the structure and bonding in graphite.

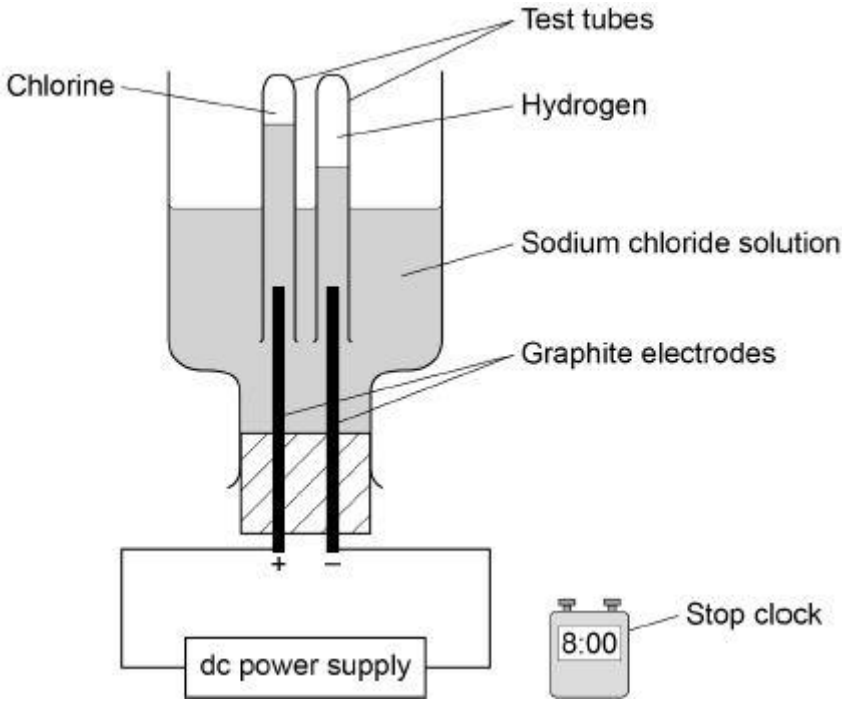
C is in Group 4 ∴ Has 4 valence e^-
Each C in graphite is bound to 3 C atoms forming 3 covalent bonds.
The remaining (4th) e^- is delocalised so these electrons carry charge through the structure.

(3)

The student investigated how the volume of gases produced changes with time in the electrolysis of sodium chloride solution.

Figure 2 shows the apparatus.

Figure 2



(c) The student made an error in selecting the apparatus for this investigation.

How should the apparatus be changed?

Give **one** reason for your answer.

Use measuring cylinders instead of test tubes because test tubes cannot measure volume. (test tubes have no graduations)

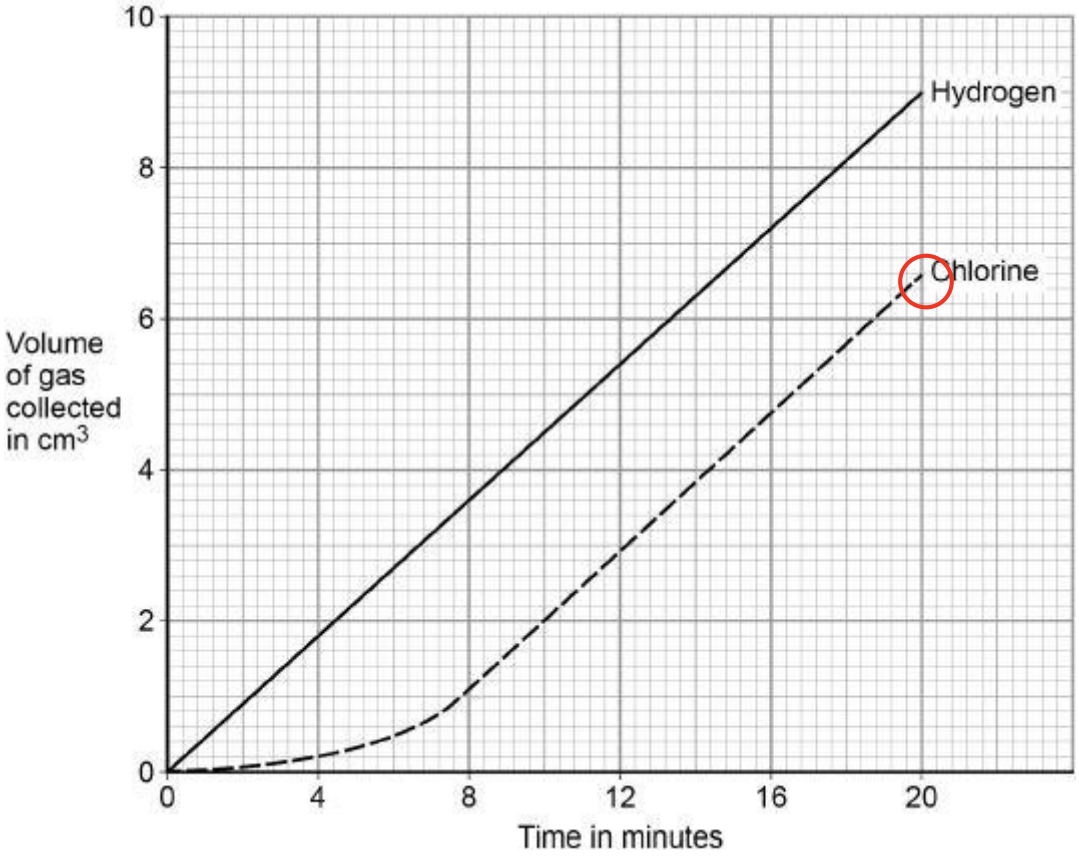
(2)

Another student used the correct apparatus.

This student measured the volumes of gases collected every minute for 20 minutes.

Figure 3 shows the student's results.

Figure 3



(d) Describe the trends shown in the results.

Use values from **Figure 3**.

Volume of hydrogen collected is directly proportionate to time.

Up to 8 min, chlorine collected at increasing rate

After 8 min, collection of chlorine same rate as hydrogen.

(3)

(e) The number of moles of each gas produced at the electrodes is the same.

No gas escapes from the apparatus.

Suggest **one** reason for the difference in volume of each gas collected.

Chlorine reacts with water
(or dissolves in solution)

(1)

(f) Calculate the amount in moles of chlorine collected after 20 minutes.

Use **Figure 3**.

The volume of one mole of any gas at room temperature and pressure is 24.0 dm^3

Give your answer in standard form. **(separate only)**

After 20 min. 6.6 cm^3 collected

Volume of chlorine $= \frac{6.6\ cm^3}{1000} = 0.0066\ dm^3$

No. of moles $= \frac{0.0066\ dm^3}{24.0\ dm^3} = 2.75 \times 10^{-4}$ mol

Moles of chlorine = 2.75×10^{-4} mol

(3)

(Total 14 marks)

Q9.

A student makes a hypothesis:

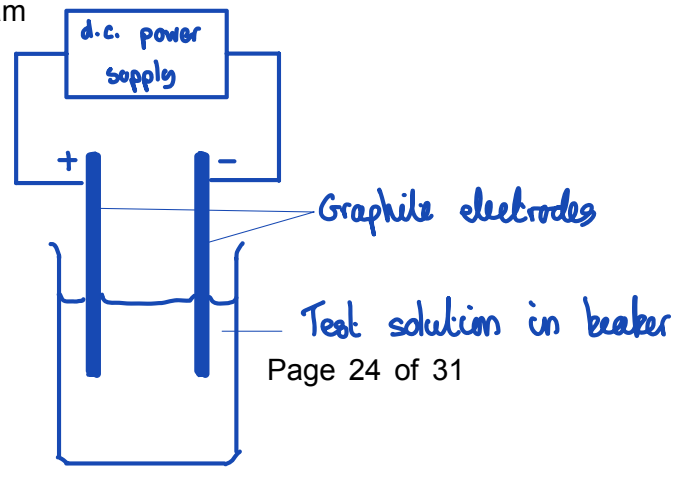
'When different salt solutions are electrolysed with inert electrodes, the product at the negative electrode is always a metal'.

(a) Describe how you would test this hypothesis in the laboratory.

You should:

- draw a labelled diagram of the apparatus
- give the independent variable
- describe what you would see at the negative electrode if the hypothesis is true.

Diagram



Independent variable Salt solutions

Observation Solid metal deposit on the negative electrode.

(5)

(b) The student's hypothesis is only partially correct.

Explain why the product at the negative electrode is not always a metal.

If the metal is more reactive than hydrogen then hydrogen will be produced.

(2)

(c) Predict the product at the positive electrode in the electrolysis of:

- sodium chloride solution OH^- Cl^-
- copper sulfate solution. SO_4^- OH^-

Sodium chloride solution Chlorine

Copper sulfate solution Oxygen

(2)

(Total 9 marks)

Q10.

This question is about halogens and their compounds.

The table below shows the boiling points and properties of some of the elements in Group 7 of the periodic table.

Element	Boiling point in °C	Colour in aqueous solution
Fluorine	−188	colourless
Chlorine	−35	pale green
Bromine	X	orange

Iodine	184	brown

(a) Why does iodine have a higher boiling point than chlorine?

Tick **one** box.

- Iodine is ionic and chlorine is covalent ☐
- Iodine is less reactive than chlorine ☐
- The covalent bonds between iodine atoms are stronger ☐
- The forces between iodine molecules are stronger ☑

(1)

(b) Predict the boiling point of bromine.

$\frac{184 - (-35)}{2} = \frac{219}{2} \sim 110^{\circ}C$

(1)

(c) A redox reaction takes place when aqueous chlorine is added to potassium iodide solution.

The equation for this reaction is:

$$Cl_2(aq) + 2KI(aq) \rightarrow I_2(aq) + 2KCl(aq)$$

Look at table above.

What is the colour of the final solution in this reaction?

Tick **one** box.

- Brown ☑
- Orange ☐
- Pale green ☐
- Colourless ☐

(1)

(d) What is the ionic equation for the reaction of chlorine with potassium iodide?

Tick **one** box.

$Cl_2 + 2K \rightarrow 2KCl$ ☐

$2I^- + Cl_2 \rightarrow I_2 + 2Cl^-$ ☑

$I^- + Cl \rightarrow I + Cl^-$ ☐

$I^- + K^+ \rightarrow KI$ ☐

(1)

(e) Why does potassium iodide solution conduct electricity?

Tick **one** box.

It contains a metal ☐

It contains electrons which can move ☐

It contains ions which can move ☑

It contains water ☐

(1)

(f) What are the products of electrolysing potassium iodide solution?

Tick **one** box.

Product at cathode	**Product at anode**	
hydrogen	iodine	☑
hydrogen	oxygen	☐
potassium	iodine	☐
potassium	oxygen	☐

(1)

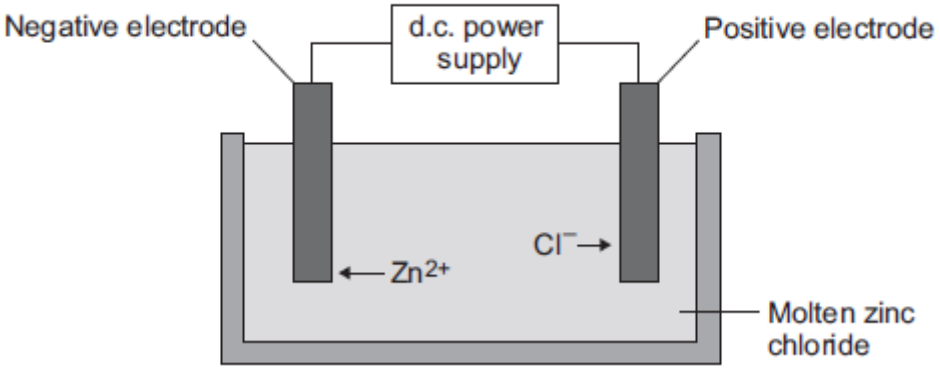
(Total 6 marks)

Q11.

This question is about zinc.

Figure 1 shows the electrolysis of molten zinc chloride.

Figure 1



(a) Zinc chloride is an ionic substance.
Complete the sentence.

When zinc chloride is molten, it will conduct
electricity .

(1)

(b) Zinc ions move towards the negative electrode where they gain electrons to produce zinc.

(i) Name the product formed at the positive electrode.

Chlorine Cl_2

(1)

(ii) Explain why zinc ions move towards the negative electrode.

Zinc ions are positive Zn^{2+}
and opposite charges attract.

(2)

(iii) What type of reaction occurs when the zinc ions gain electrons?

OILRIG
Reduction

Tick (✓) **one** box.

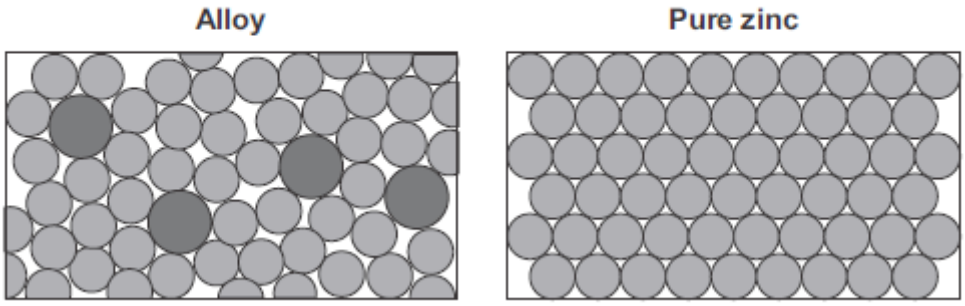
Neutralisation	
Oxidation	
Reduction	✓

(1)

(c) Zinc is mixed with copper to make an alloy.

(i) **Figure 2** shows the particles in the alloy and in pure zinc.

Figure 2



Use **Figure 2** to explain why the alloy is harder than pure zinc.

Different sized atoms in the alloy distort the layers of atoms, so they cannot slide over each other

(2)

(ii) Alloys can be bent. Some alloys return to their original shape when heated.

What name is used for these alloys? **(separate only)**

Shape memory alloys

(1)

(Total 8 marks)

Q12.

This question is about magnesium and magnesium chloride.

(a) Magnesium chloride contains magnesium ions (Mg^{2+}) and chloride ions (Cl^-).

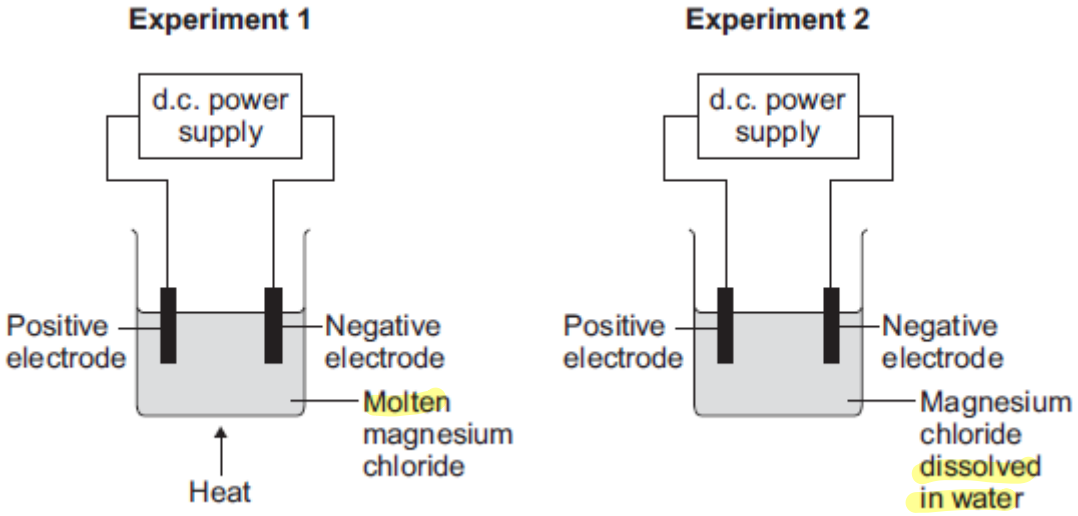
Describe, in terms of electrons, what happens when a magnesium atom reacts with chlorine atoms to produce magnesium chloride.

Magnesium atoms lose 2 e^- to form Mg^{2+} ions
Chlorine atoms gain 1 e^- each to form Cl^- ions
Magnesium chloride is formed from 1 Mg^{2+} and 2 Cl^-
$MgCl_2$. Ions bound by ionic bonds.

(4)

(b) Magnesium chloride can be electrolysed.

The diagram below shows two experiments for electrolysing magnesium chloride.



(i) Explain why magnesium chloride must be molten or dissolved in water to be electrolysed.

In order for the ions to move to the electrodes.

(2)

(ii) Explain how magnesium is produced at the negative electrode in **Experiment 1**.

Mg^{2+} ions attracted to the -ve electrode
Mg^{2+} ions gain $2e^-$
to form Mg metal atoms

$MgCl_2$ (aq)

+	−
Cl^-	Mg^{2+}
OH^-	H^+

(3)

(iii) In **Experiment 2** a gas is produced at the negative electrode.
Name the gas produced at the negative electrode.

Hydrogen

(1)

(iv) Suggest why magnesium is **not** produced at the negative electrode in **Experiment 2**.

Mg is more reactive than hydrogen.

(1)

(v) Complete and balance the half equation for the reaction at the positive electrode.

$$\underline{2}\ Cl^- \longrightarrow Cl_2 + \underline{2e^-}$$

(1)

(c) Magnesium is a metal.

Explain why metals can be bent and shaped.

Metal lattice comprises layers of metal ions which can slide over each other.

(2)

(Total 14 marks)