Q1.

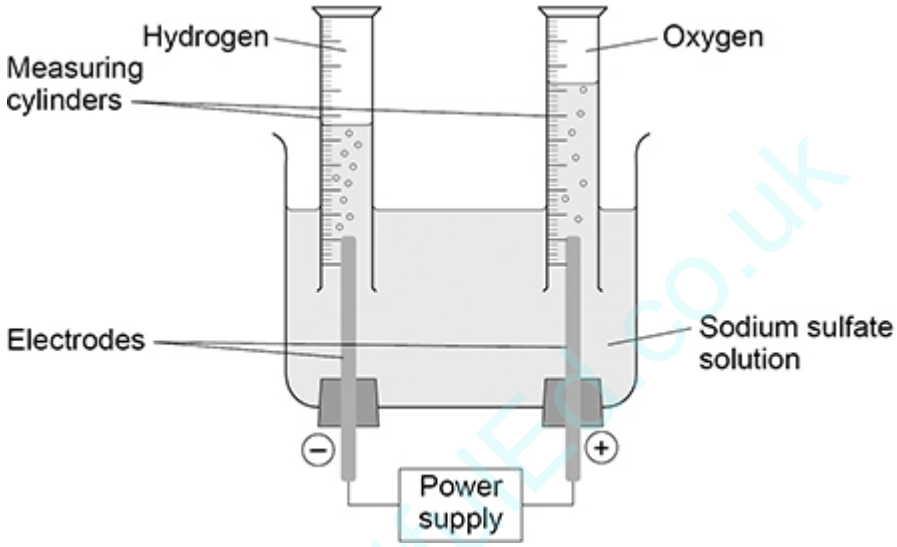
This question is about electrolysis.

Ionic compounds decompose when they are electrolysed.

A student electrolyses sodium sulfate solution.

Figure 1 shows the apparatus used.

Figure 1



(a) Sodium sulfate solution contains:

- hydrogen ions
- hydroxide ions
- sodium ions
- sulfate ions.

Oxygen is produced at the positive electrode.

Which ions are discharged at the positive electrode to produce oxygen?

Tick (✓) **one** box.

Hydrogen ions ☐

Hydroxide ions ☐

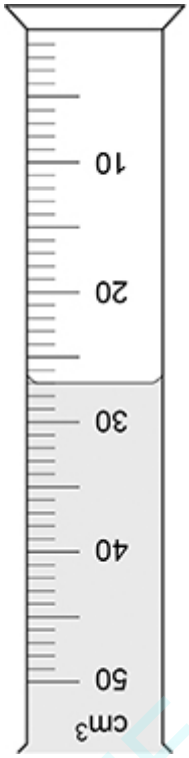
Sodium ions ☐

Sulfate ions ☐

(1)

(b) **Figure 2** shows one of the measuring cylinders during the electrolysis.

Figure 2



What is the volume of gas in the measuring cylinder?

Volume of gas = _____ cm^3

(1)

(c) Ionic compounds can be electrolysed when molten or dissolved in water.

Why can ionic compounds **not** be electrolysed when solid?

You should answer in terms of ions.

_____

_____

(1)

(d) The table below shows the products of electrolysis of two molten compounds.

Molten compound	**Product at negative electrode**	**Product at positive electrode**
Potassium iodide	Potassium	_____
Zinc bromide	_____	Bromine

Complete the table above.

(2)

(e) The electrolysis of molten sodium chloride is used to extract sodium metal.

Why is sodium metal extracted by electrolysis instead of by reduction with carbon?

Tick (✓) **one** box.

Carbon conducts electricity. ☐

Carbon is less reactive than sodium. ☐

Carbon reduction uses more energy. ☐

(1)

(f) What is the state symbol for molten sodium chloride?

Tick (✓) **one** box.

(aq) ☐ (g) ☐ (l) ☐ (s) ☐

(1)

Q2.

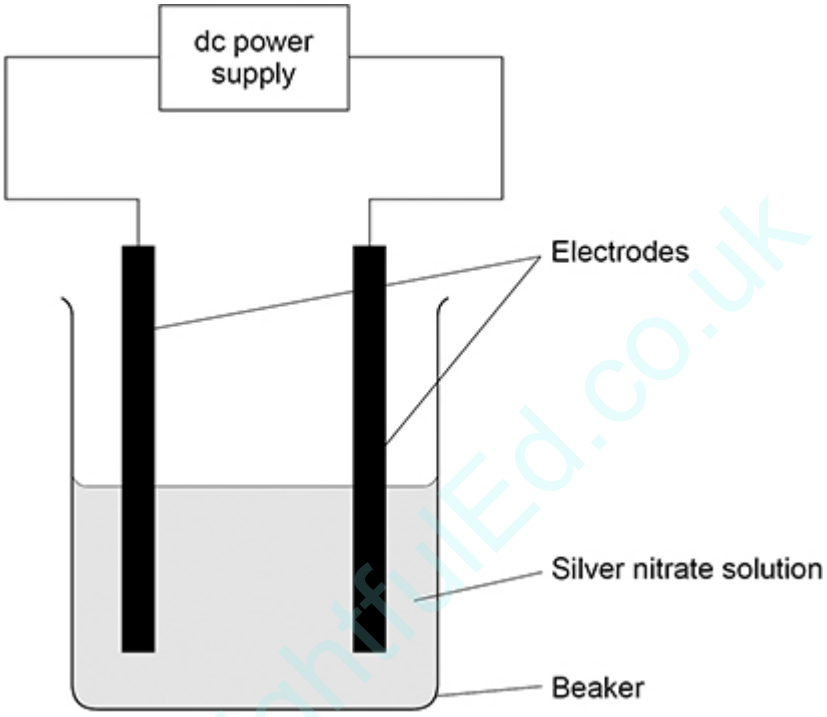
This question is about electrolysis.

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

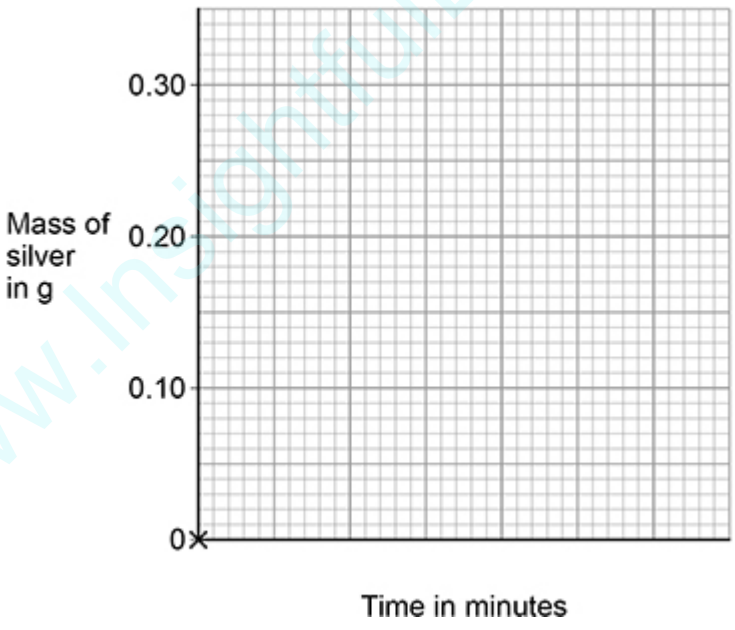
Time in minutes	Mass of silver in g
0	0.00
5	0.06
10	0.12
15	0.18
20	0.24
25	0.30

(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 = _____ 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	
Sodium chloride	

(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?

_____

_____

(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		
	Potassium	Iodine

(3)

(Total 12 marks)

Q3.

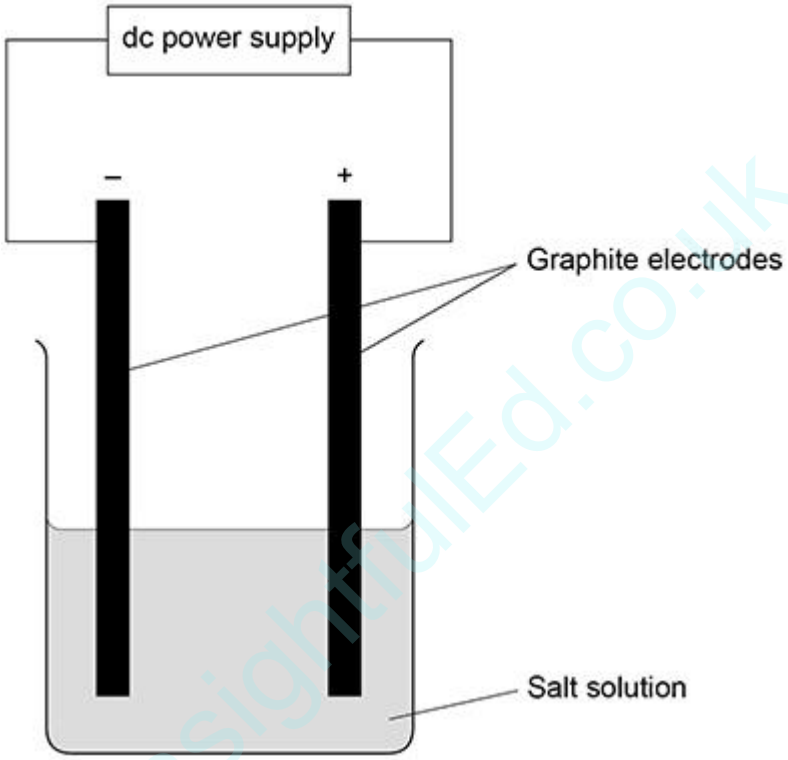
This question is about electrolysis.

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

_____

_____

Observation if gas produced at the positive electrode

_____

_____

(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 _____

Reason _____

_____

(2)

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

1 _____

_____

2 _____

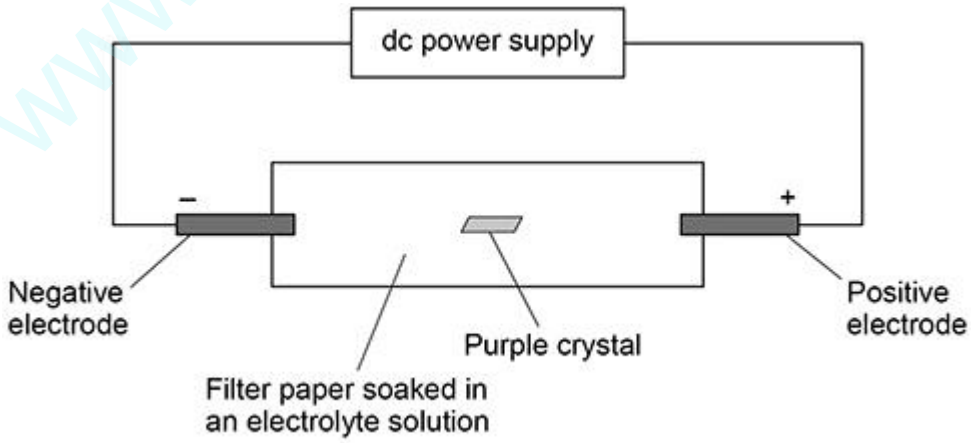
_____

(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 _____

_____

(2)

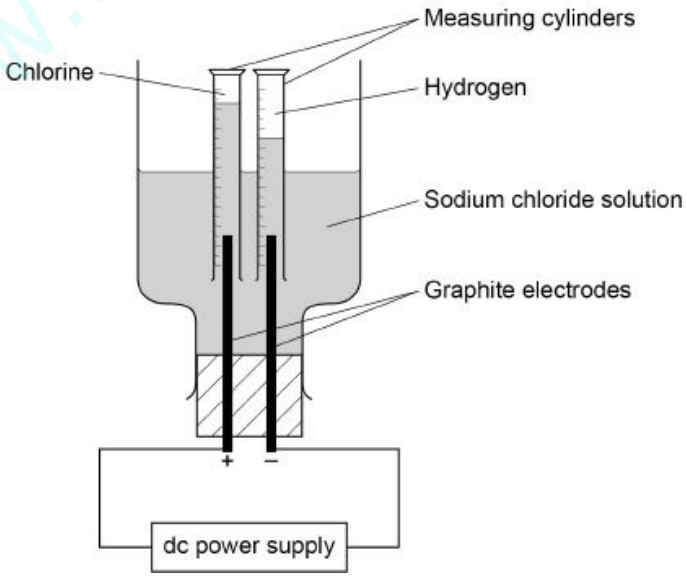
(Total 8 marks)

Q4.

A student investigated the electrolysis of sodium chloride solution.

Figure 1 shows the apparatus.

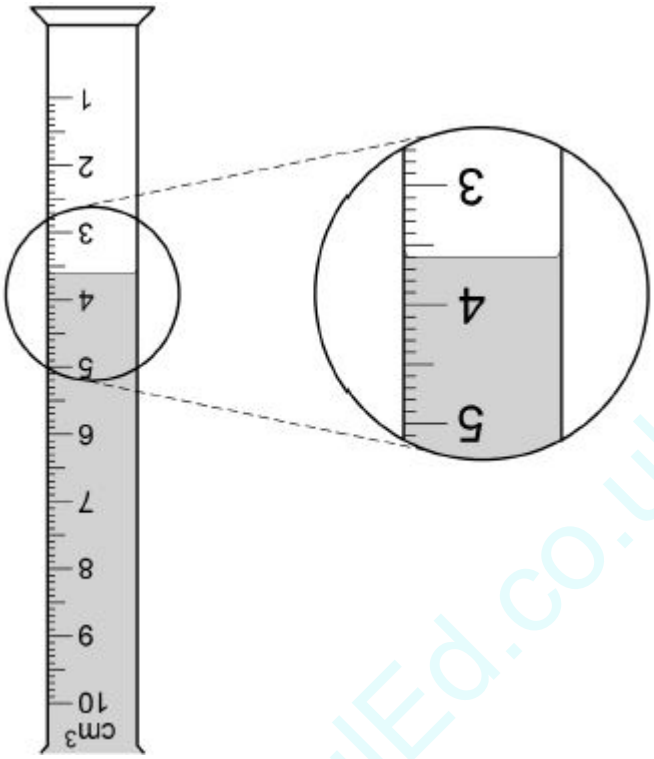
Figure 1



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



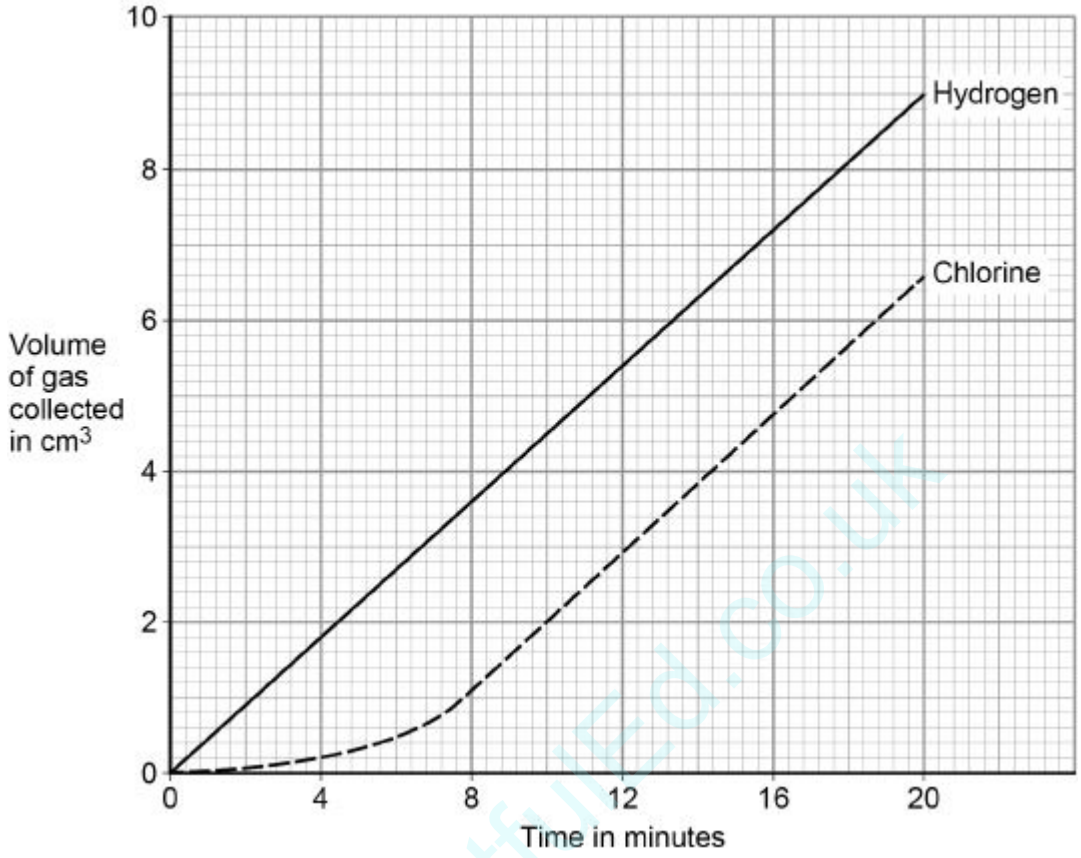
What is the volume of hydrogen gas collected?

Volume = _____ 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.

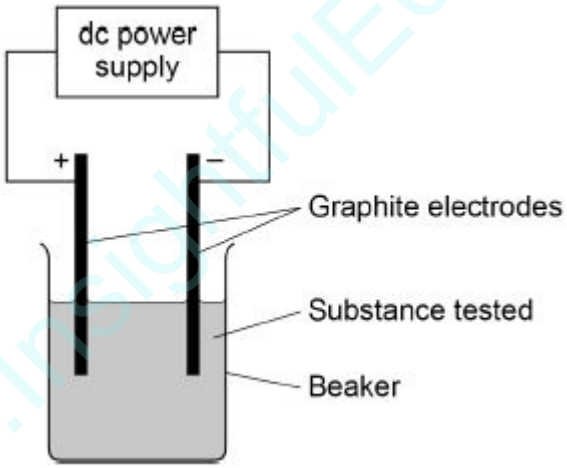
- Both lines ☐
- Chlorine line only ☐
- Hydrogen line only ☐
- Neither line ☐

(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

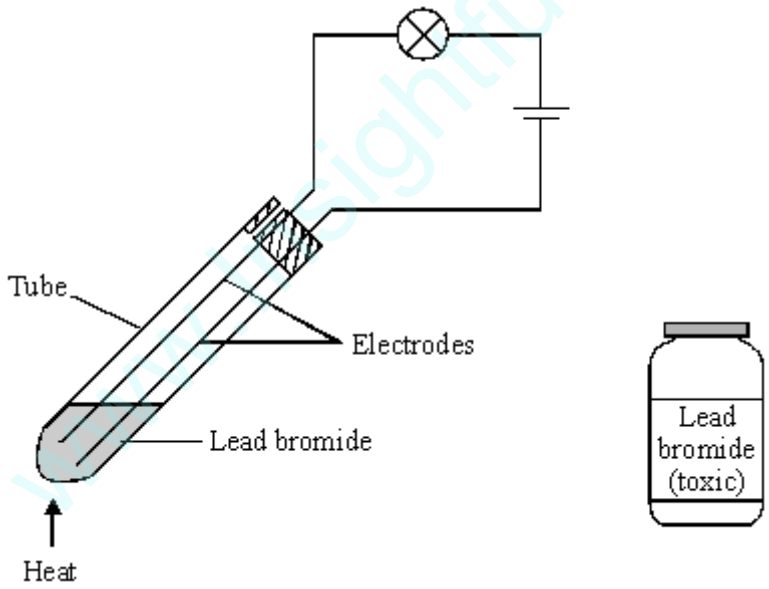
Substance electrolysed	Product at cathode (negative electrode)	Product at anode (positive electrode)
Molten zinc chloride		
Potassium bromide solution		

(4)

(Total 8 marks)

Q5.

A student investigated the *electrolysis* of lead bromide.



Lead bromide was placed in the tube and the circuit was switched on. The light bulb did not light up.

The tube was heated and soon the bulb lit up. The observations are shown in the table.

Positive electrode	Negative electrode
red-brown gas	silver liquid

(a) What is meant by *electrolysis?*

_____

(2)

(b) Why did the lead bromide conduct electricity when the tube was heated?

_____

(1)

(c) Name the substances formed at the:

positive electrode; _____

negative electrode. _____

(2)

(d) Suggest **one** safety precaution that should be taken during this investigation.

_____

(1)

(Total 6 marks)

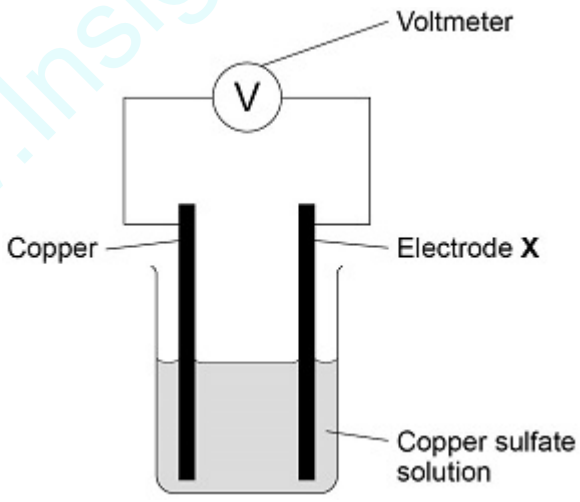
Q6.

This question is about chemical cells and batteries.

A student investigated the voltage produced by different chemical cells.

Figure 1 shows the apparatus.

Figure 1



This is the method used.

1. Use cobalt metal as electrode **X**.

2. Record the cell voltage.

3. Repeat steps 1 and 2 using different metals as electrode **X**.

(a) Suggest **two** variables the student should keep the same to make the investigation valid.

1 _____

_____

2 _____

_____

(2)

The following table shows the student's results.

Electrode X	**Voltage of the cell in volts**
cobalt	0.62
magnesium	2.71
zinc	1.10

(b) Write the three metals used for electrode X in order of reactivity.

Use the table above.

Most reactive _____

_____

Least reactive _____

(1)

(c) (TRIPLE) Copper is used as electrode **X** in **Figure 1**.

Predict the voltage of this cell.

Give **one** reason for your answer.

Voltage = _____ volts

Reason _____

_____

(2)

(d) (TRIPLE) Describe how to make a 12 V battery using 1.5 V cells.

_____

_____

_____

_____

(2)

(e) (TRIPLE) Which is the most suitable use for a non-rechargeable cell?

Tick (✓) **one** box.

Electric toy ☐

Laptop computer ☐

Mobile phone ☐

(1)

(f) (TRIPLE) Hydrogen fuel cells or rechargeable cells can be used to power electric vehicles.

Suggest **one** advantage and **one** disadvantage of using a hydrogen fuel cell compared with a rechargeable cell.

Advantage of hydrogen fuel cell _____

_____

Disadvantage of hydrogen fuel cell _____

_____

(2)

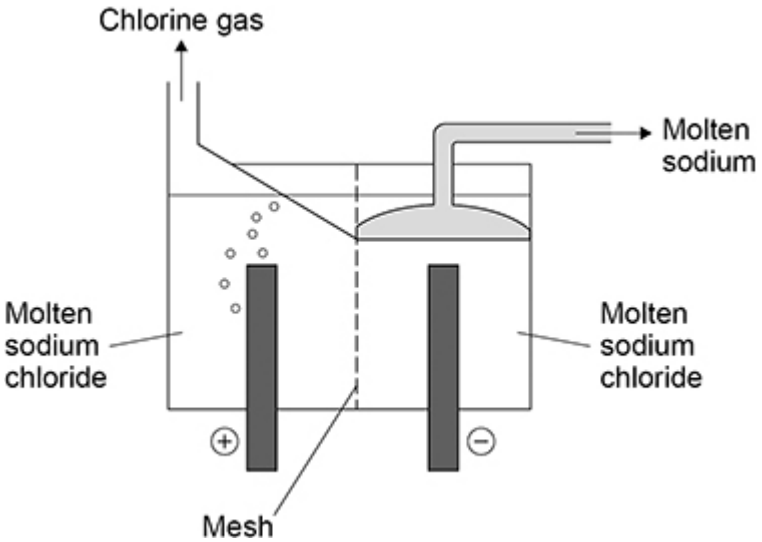
(Total 10 marks)

Q7.

This question is about electrolysis.

Molten sodium chloride is electrolysed in an industrial process to produce sodium.

The figure below shows a simplified version of the electrolysis cell used.



(a) Which is the correct half equation for the production of sodium?

Tick (✓) **one** box.

$Na + e^- \rightarrow Na^+$ ☐

$Na \rightarrow Na^+ + e^-$ ☐

$Na^+ + e^- \rightarrow Na$ ☐

$Na^+ \rightarrow Na + e^-$ ☐

(1)

A mesh is used to keep the products of the electrolysis apart.

(b) Suggest **one** reason why the products of the electrolysis must be kept apart.

_____

_____

(1)

(c) Which type of particle passes through the mesh in the electrolysis of molten sodium chloride?

Tick (✓) **one** box.

Atom ☐

Electron ☐

Ion ☐

Molecule ☐

(1)

Aqueous sodium chloride solution is electrolysed in a different industrial process.

Two gases and an alkaline solution are produced.

(d) Which **two** ions are present in aqueous sodium chloride solution in addition to sodium ions and chloride ions?

1 _____

2 _____

(2)

(e) Name the alkaline solution produced.

_____

(1)

(f) Explain how the alkaline solution is produced.

You should refer to the processes at the electrodes.

_____

_____

_____

_____

_____

_____

(3)

(Total 9 marks)

Q8.

This question is about displacement reactions.

Iron is extracted from iron oxide by a displacement reaction with carbon.

The equation for the reaction is:

$$Fe_2O_3 + 3\ C \rightarrow 2\ Fe + 3\ CO$$

(a) Which substance in the equation is reduced?

Give **one** reason for your answer.

Answer in terms of oxygen.

Substance reduced _____

Reason _____

_____

(2)

(b) Which expression shows how to calculate the mass of carbon needed to produce 1 mole of iron from iron oxide?

Relative atomic mass (A_r): C = 12

Tick (✓) **one** box.

$\frac{1}{3} \times 12\,g$ ☐

$\frac{3}{2} \times 12\,g$ ☐

$1 \times 12\,g$ ☐

$3 \times 12\,g$ ☐

(1)

A student investigated displacement reactions of four different metals represented by **A**, **B**, **C** and **D**.

A, **B**, **C** and **D** are **not** the actual chemical symbols for the metals.

The student:

- added each metal to aqueous solutions of the metal nitrates
- observed whether a reaction took place.

The table below shows information about three of the reaction mixtures.

Reaction	Metal	Metal nitrate solution	Equation
1	**A**	**B**NO_3	**A** + 2**B**NO_3 → 2**B** + **A**$(NO_3)_2$
2	**C**	**A**$(NO_3)_2$	2**C** + 3**A**$(NO_3)_2$ → 3**A** + 2**C**$(NO_3)_3$
3	**C**	**D**$(NO_3)_2$	no reaction

(c) The ionic equation for **Reaction 1** is:

$$\mathbf{A} + 2\,\mathbf{B}^{+} \rightarrow 2\,\mathbf{B} + \mathbf{A}^{2+}$$

Why is this a redox reaction?

Tick (✓) **one** box.

A gains electrons and $\mathbf{B}^{+}$ loses electrons.	☐
A loses electrons and $\mathbf{B}^{+}$ gains electrons.	☐
Both **A** and $\mathbf{B}^{+}$ gain electrons.	☐
Both **A** and $\mathbf{B}^{+}$ lose electrons.	☐

(1)

(d) Which of the four metals has the greatest tendency to form positive ions?

Use the table above.

Tick (✓) **one** box.

A ☐ **B** ☐ **C** ☐ **D** ☐

(1)

(e) The nitrate ion has the formula NO_3^-

Which of the four metals could be aluminium?

Explain your answer.

Use the table above.

Metal _____

Explanation _____

_____

_____

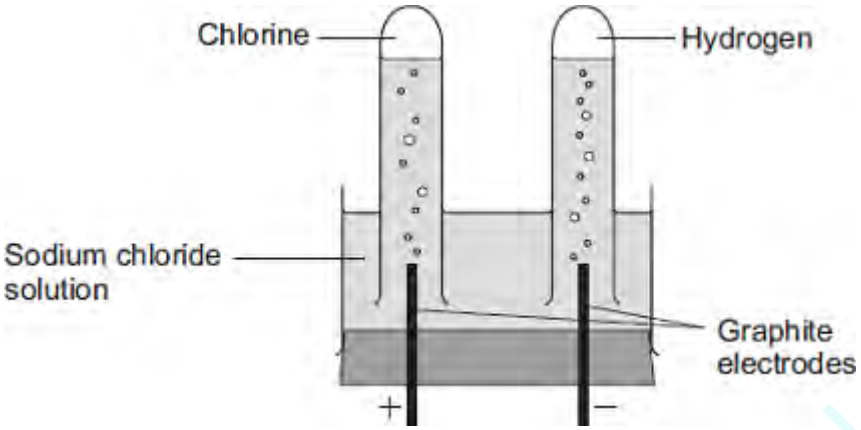
_____

(3)

Q9.

The electrolysis of sodium chloride solution is an industrial process.

The diagram shows the apparatus used in a school experiment.



(a) One of the products of the electrolysis of sodium chloride solution is hydrogen.

(i) Why do hydrogen ions move to the negative electrode?

_____

_____

(1)

(ii) How does a hydrogen ion change into a hydrogen atom?

_____

_____

(1)

(c) The table shows the ions in sodium chloride solution.

Positive ions	**Negative ions**
hydrogen	chloride
sodium	hydroxide

In industry, some of the waste from the electrolysis of sodium chloride solution is alkaline and has to be neutralised.

(i) Which ion makes the waste alkaline?

_____

(1)

(ii) This waste must be neutralised.

Write the ionic equation for the neutralisation reaction.

_____

(1)

(d) *In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.*

The electrolysis of sodium chloride solution also produces chlorine and sodium hydroxide.

In industry, the electrolysis of sodium chloride solution can be done in several types of electrolysis cell.

Some information about two different types of electrolysis cell is given below.

	Mercury cell	**Membrane cell**
Cost of construction	Expensive	Relatively cheap
Additional substances used	Mercury, which is recycled. Mercury is toxic so any traces of mercury must be removed from the waste	Membrane, which is made of a polymer. The membrane must be replaced every 3 years.
Amount of electricity used for each tonne of chlorine produced in kWh	3400	2950
Quality of chlorine produced	Pure	Needs to be liquefied and distilled to make it pure.
Quality of sodium hydroxide solution produced	50% concentration. Steam is used to concentrate the sodium hydroxide solution produced.	30% concentration. Steam is used to concentrate the sodium hydroxide solution produced.

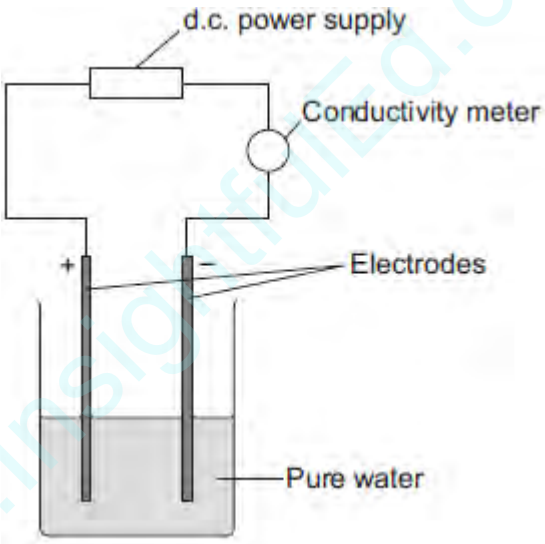
Use the information and your knowledge and understanding to compare the environmental and economic advantages and disadvantages of these **two** types of electrolysis cell.

(6)

Q10.

A student investigated the conductivity of different concentrations of sodium chloride solution.
The student set the apparatus up as shown in **Figure 1**.

Figure 1



The student measured the conductivity of the pure water with a conductivity meter.

The reading on the conductivity meter was zero.

(a) The student:

- added sodium chloride solution one drop at a time
- stirred the solution
- recorded the reading on the conductivity meter.

The student's results are shown in the table below.

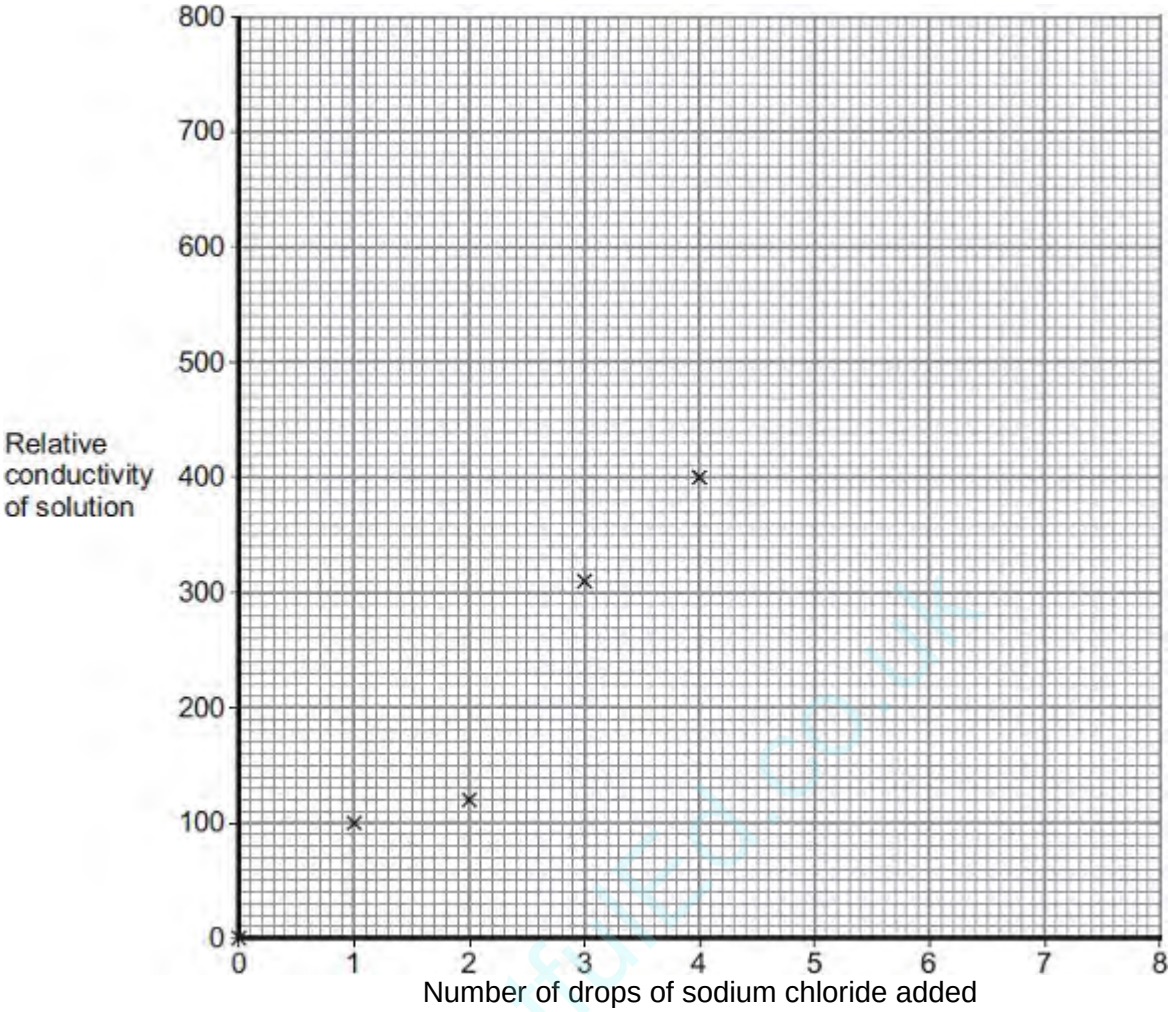
Number of drops of sodium chloride solution added	Relative conductivity of solution
0	0
1	100
2	120
3	310
4	400
5	510
6	590
7	710
8	800

(i) The student plotted the results on the grid shown in **Figure 2**.

Plot the four remaining results.

Draw a line of best fit, ignoring the anomalous result.

Figure 2



(3)

(ii) One of the points is anomalous.

Suggest **one** error that the student may have made to cause the anomalous result.

_____

_____

(1)

(iii) The student wanted to compare the conductivity of sodium chloride solution with the conductivity of potassium chloride solution.

State **one** variable he should keep constant when measuring the conductivity of the two solutions.

_____

(1)

(ii) Explain why sodium chloride solution conducts electricity.

_____

_____

_____

_____

(2)

(iii) After he had added sodium chloride solution, the student noticed bubbles of gas at the negative electrode.

Complete the sentence.

The gas produced at the negative electrode is _____

(1)

Q11.

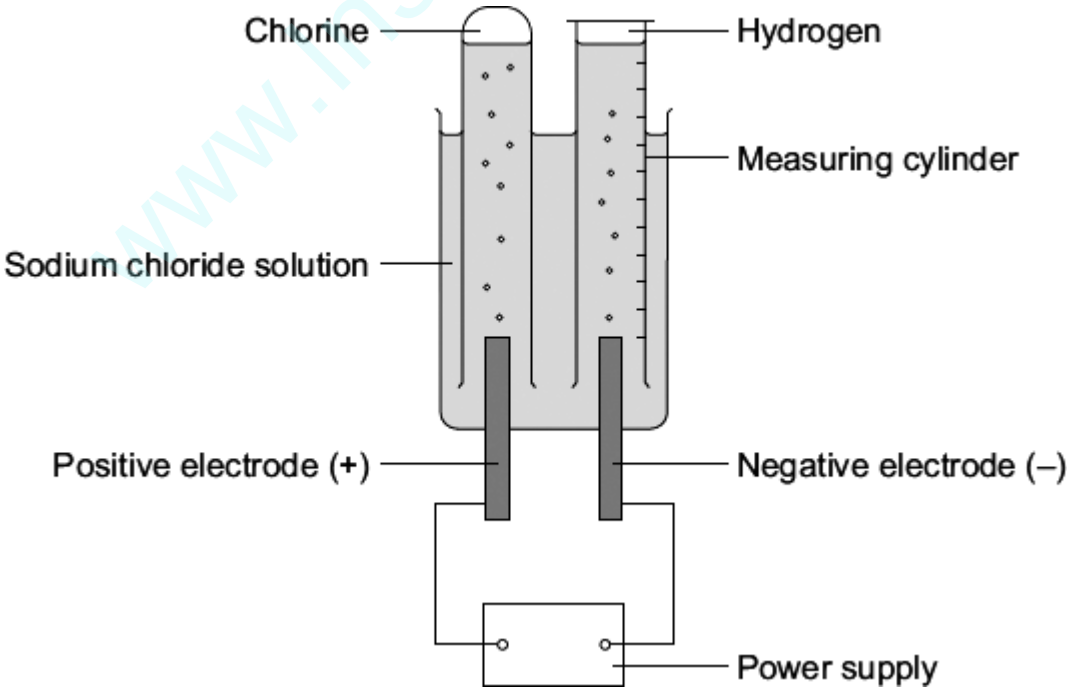
A student investigated the electrolysis of sodium chloride solution.

Five sodium chloride solutions were made. Each solution had a different concentration.

To make each solution the student:

- weighed the amount of sodium chloride needed
- dissolved it in water
- added more water until the total volume was one cubic decimetre (1 dm^3).

The solutions were placed one at a time in the apparatus shown below.



The student measured the volume of hydrogen gas produced in ten minutes.

The results are shown on the graph below.

(a) Sodium chloride does not conduct electricity when it is solid.

Explain, in terms of ions, why sodium chloride solution conducts electricity.

_____

_____

(1)

(b) Chlorine is produced at the positive electrode.

Why are chloride ions attracted to the positive electrode?

_____

(1)

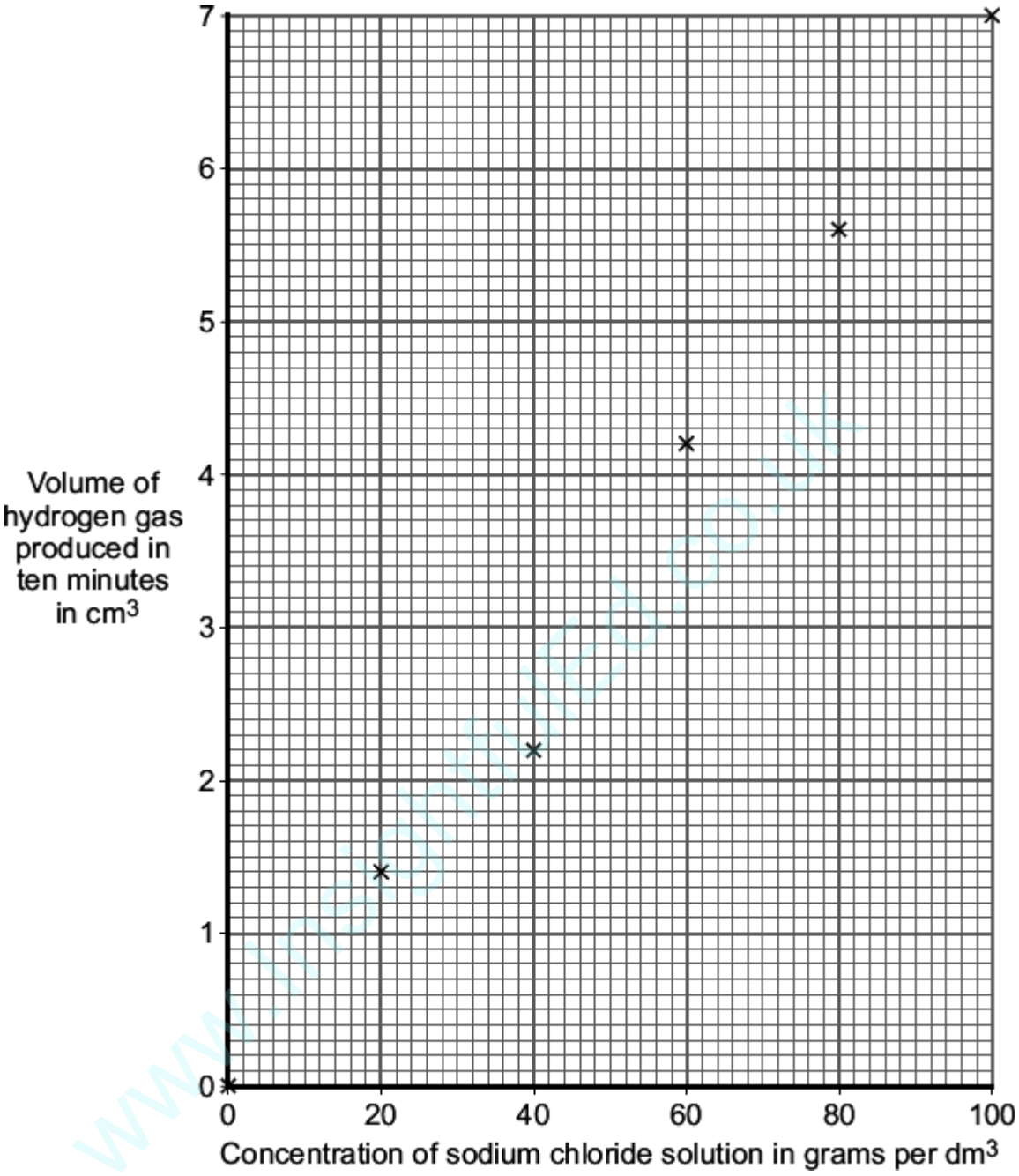
(c) The solution left at the end of each experiment contains sodium hydroxide.

Draw a ring around **one** number which could be the pH of this solution.

2 **5** **7** **13**

(1)

(d) The results for the experiment above are shown on the graph.



(i) Draw a line of best fit on the graph.

(1)

(ii) The result for one concentration is anomalous.
Which result is anomalous?

The result at concentration _____ grams per dm^3

(1)

(iii) Suggest **two** possible causes of this anomalous result.

1. _____

_____

2. _____

_____

(2)

(iv) Suggest how the student could check the reliability of the results.

_____

_____

(1)

(iv) How did an increase in the concentration of the sodium chloride solution affect the volume of hydrogen gas produced in ten minutes?

_____

_____

(1)

(Total 9 marks)

Q12.

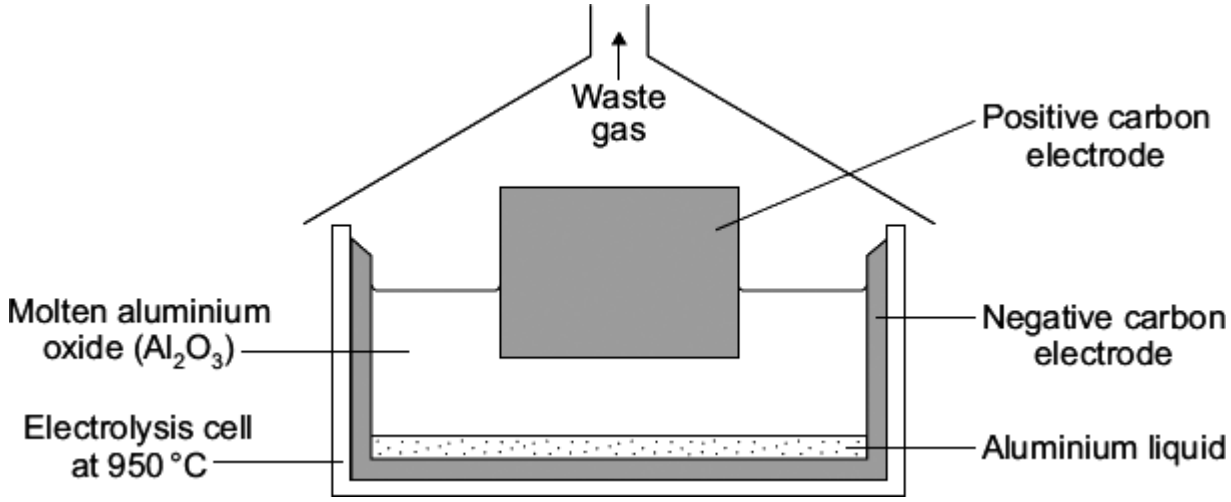
The flow diagram shows the main stages used to extract a metal from its ore.

mining the ore → purifying the ore → extracting the metal

The table shows some information about three metals.

Metal	Metal ore	Purified ore	% of metal in the ore	% of metal in the Earth's crust
aluminium	bauxite	aluminium oxide, Al_2O_3	28.0	8.0
copper	chalcocite	copper sulfide, Cu_2S	0.5	0.001
iron	haematite	iron oxide, Fe_2O_3	29.0	5.0

(b) Aluminium is used for drinks cans.
Aluminium is extracted from its purified ore by electrolysis.



(i) Suggest why the aluminium produced in the electrolysis cell is a liquid.

_____

_____

(1)

(ii) In this electrolysis, aluminium and oxygen gas are produced from the aluminium oxide.

Use the information in the diagram to suggest why most of the waste gas is carbon dioxide and not oxygen.

_____

_____

_____

_____

(2)

(iii) Aluminium is the most abundant metal in the Earth's crust.

Suggest **two** reasons why we should recycle aluminium drinks cans.

1. _____

_____

2. _____

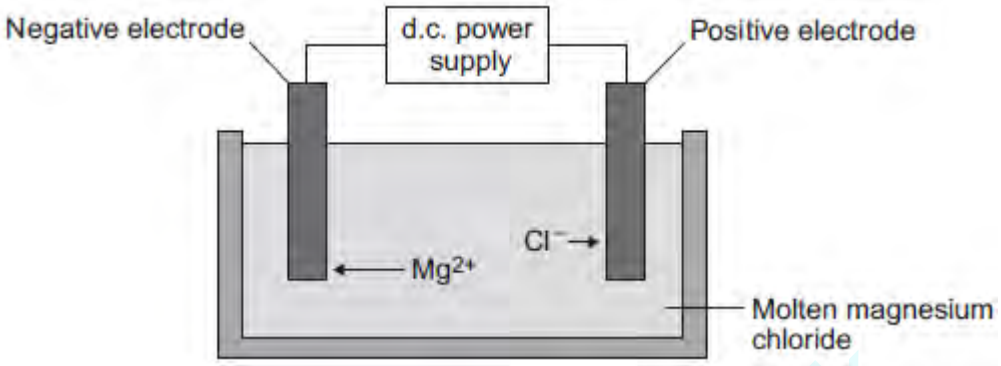
_____

(2)

Q13.

Some students investigated reactions to produce magnesium.

(a) The students used electrolysis to produce magnesium from magnesium chloride, as shown in the figure below.



(i) Magnesium chloride contains magnesium ions and chloride ions.

Why does solid magnesium chloride **not** conduct electricity?

_____

_____

(1)

(ii) One of the products of the electrolysis of molten magnesium chloride is magnesium.

Name the other product.

_____

(1)

(iii) Why do magnesium ions (Mg^{2+}) move to the negative electrode?

_____

_____

(1)

(iv) At the negative electrode, the magnesium ions (Mg^{2+}) gain electrons to become magnesium atoms.

How many electrons does each magnesium ion gain?

_____

(1)

(b) The students did the experiment four times and weighed the magnesium produced.

The table below shows their results.

Experiment	Mass of magnesium produced in grams
1	1.13
2	0.63
3	1.11
4	1.09

(i) There is an anomalous result.

Suggest **one** possible reason for the anomalous result.

_____

_____

(1)

(ii) Calculate the mean mass of magnesium produced, taking account of the anomalous result.

_____

_____

_____

Mean mass = _____ g

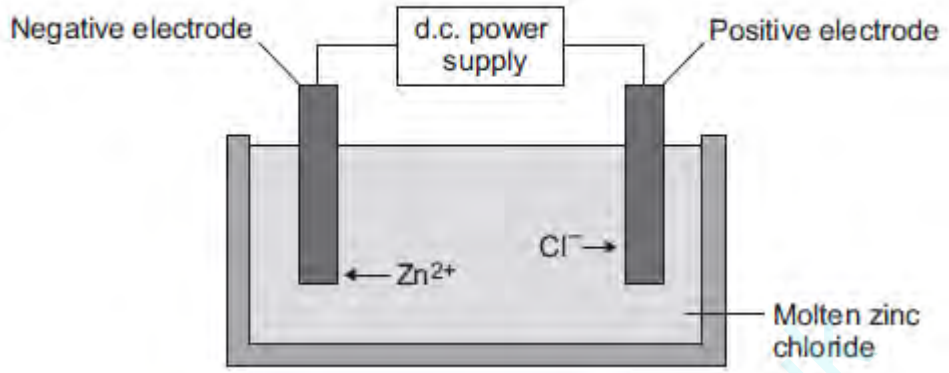
(2)

Q14.

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 _____ .

(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.

_____

(1)

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

_____

_____

_____

_____

(2)

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

Tick (✓) **one** box.

Neutralisation ☐

Oxidation ☐

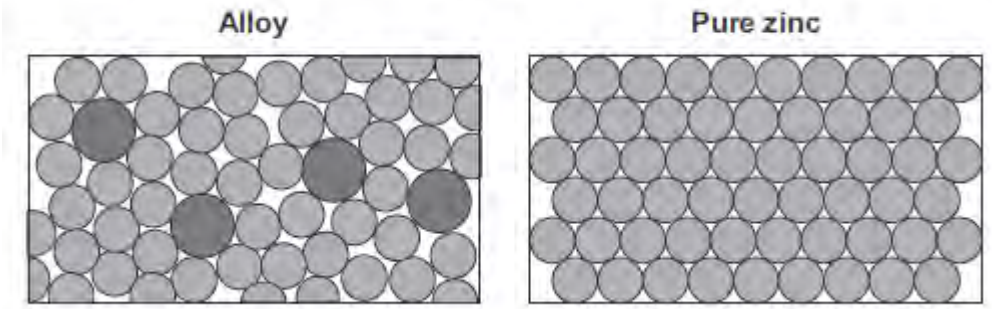
Reduction ☐

(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.

_____

_____

_____

_____

(2)

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

What name is used for these alloys?

_____

(1)

(Total 8 marks)

Q15.

This question is about electrolysis.

(a) Metal spoons can be coated with silver.
This is called electroplating.

Suggest **one** reason why spoons are electroplated.

_____

_____

(1)

(b) When sodium chloride solution is electrolysed the products are hydrogen and chlorine.

(i) What is made from chlorine?

Tick (✓) **one** box.

Bleach ☐

Fertiliser ☐

Soap ☐

(1)

(ii) Sodium chloride solution contains two types of positive ions, hydrogen ions (H^+) and sodium ions (Na^+).

Why is hydrogen produced at the negative electrode and **not** sodium?

Tick (✓) **one** box.

Hydrogen is a gas. ☐

Hydrogen is less reactive than sodium. ☐

Hydrogen ions move faster than sodium ions. ☐

(1)

(v) Why is hydrogen chloride a gas at room temperature (20 °C)?

Tick (✓) **two** boxes.

Hydrogen chloride has a low boiling point. ☐

Hydrogen chloride has a high melting point. ☐

Hydrogen chloride is made of simple molecules. ☐

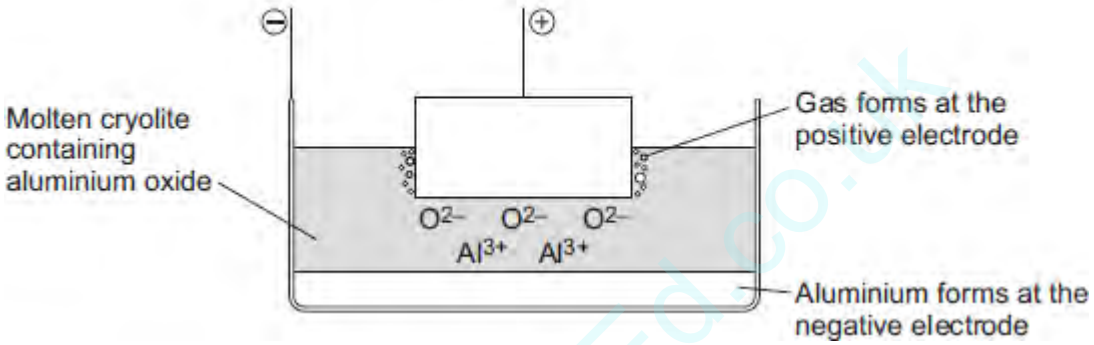
Hydrogen chloride does not conduct electricity. ☐

Hydrogen chloride has a giant structure. ☐

(2)

(c) Aluminium is produced by electrolysis of a molten mixture of aluminium oxide and cryolite.
This is shown in **Figure 3**.

Figure 3



(i) Name a gas produced at the positive electrode.

_____

(1)

(ii) Aluminium ions move to the negative electrode.

Explain why.

_____

_____

_____

_____

(2)

(iii) At the negative electrode, the aluminium ions gain electrons to produce aluminium.

What is this type of reaction called?

Tick (✓) **one** box.

Combustion ☐

Oxidation ☐

Reduction ☐

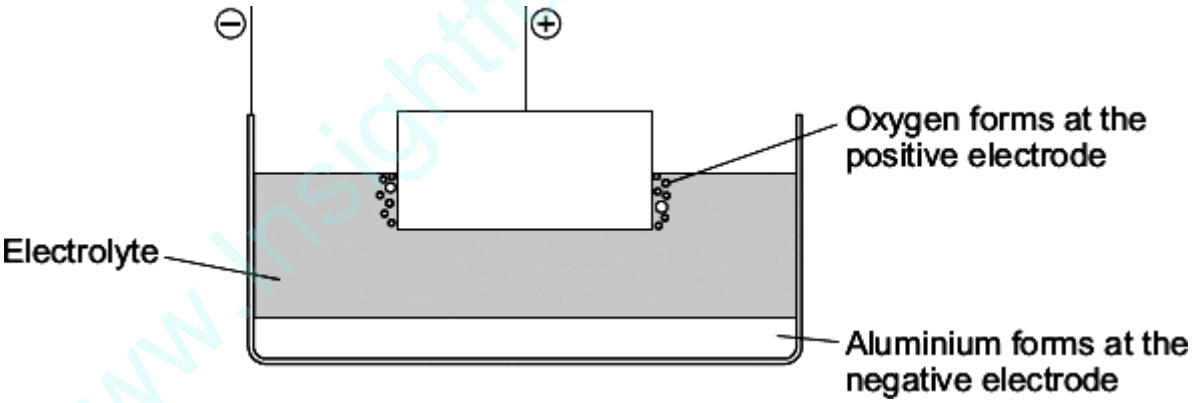
(1)

Q16.

Aluminium is extracted from aluminium oxide.

(b) Aluminium is extracted from aluminium oxide using electrolysis.

The diagram shows a cell used for the extraction of aluminium.



(i) The electrolyte contains cryolite.

Explain why.

_____

_____

_____

_____

(2)

(ii) Oxygen is formed at the positive electrode. Complete and balance the equation for this reaction.

___ O^{2-} → O_2 + _____

(2)

(iii) The positive electrode in the cell is used up during the process.

Explain why.

_____

_____

_____

_____

_____

_____

(2)

Q17.

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 _____

_____

Observation _____

_____

(5)

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

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

_____

_____

_____

_____

(2)

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

- sodium chloride solution
- copper sulfate solution.

Sodium chloride solution _____

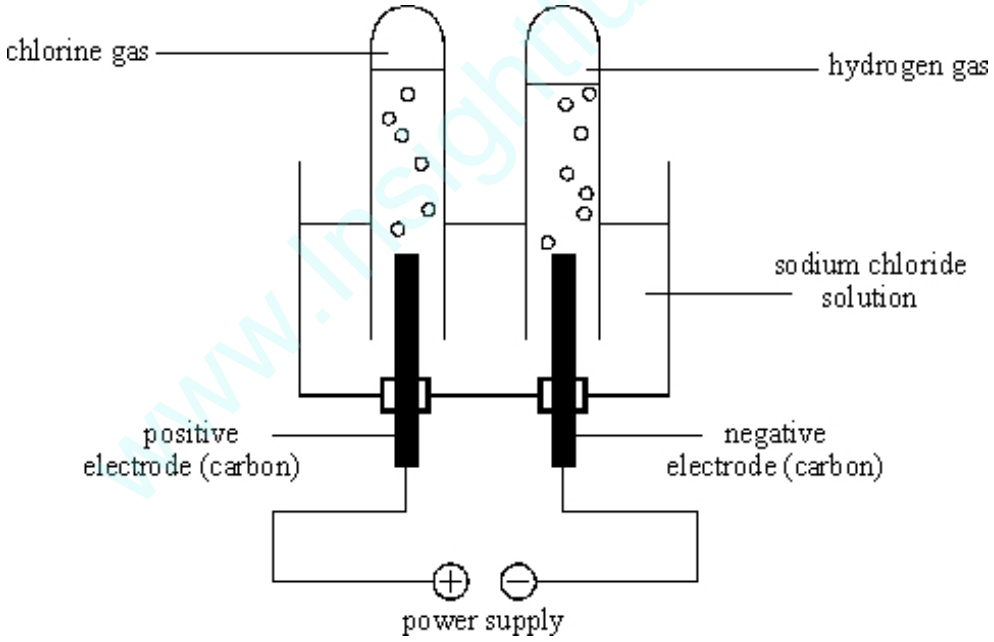
Copper sulfate solution _____

(2)

(Total 9 marks)

Q18.

The diagram shows electrolysis of sodium chloride solution.



(a) Complete and balance these equations to show the reactions during electrolysis.

At the positive electrode

$$Cl^- - e^- \rightarrow Cl_2$$

At the negative electrode

$$Na \rightarrow Na$$

(2)

(b) Silver halides such as silver chloride and silver bromide are used in photography. The equation shows a reaction to prepare a silver halide.

Name and describe the products of this reaction, in words, as fully as you can.

product 1

_____

_____

product 2

_____

_____

(4)

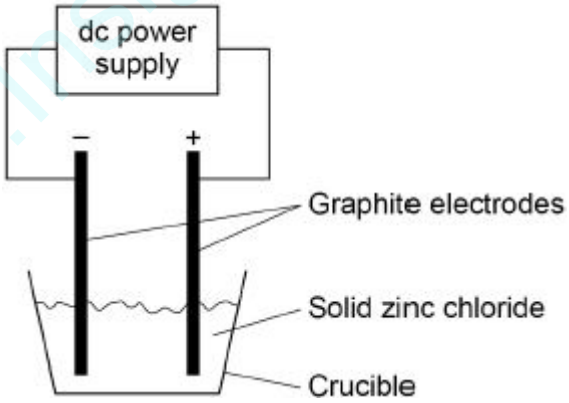
(Total 6 marks)

Q19.

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**.

_____

_____

_____

_____

(2)

(b) Explain why graphite conducts electricity.

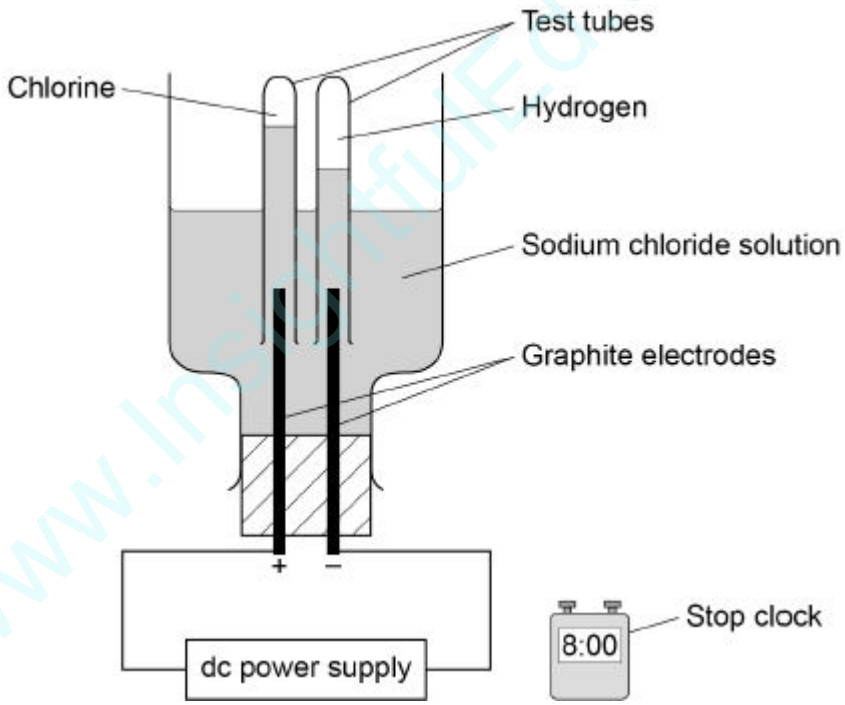
Answer in terms of the structure and bonding in graphite.

(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.

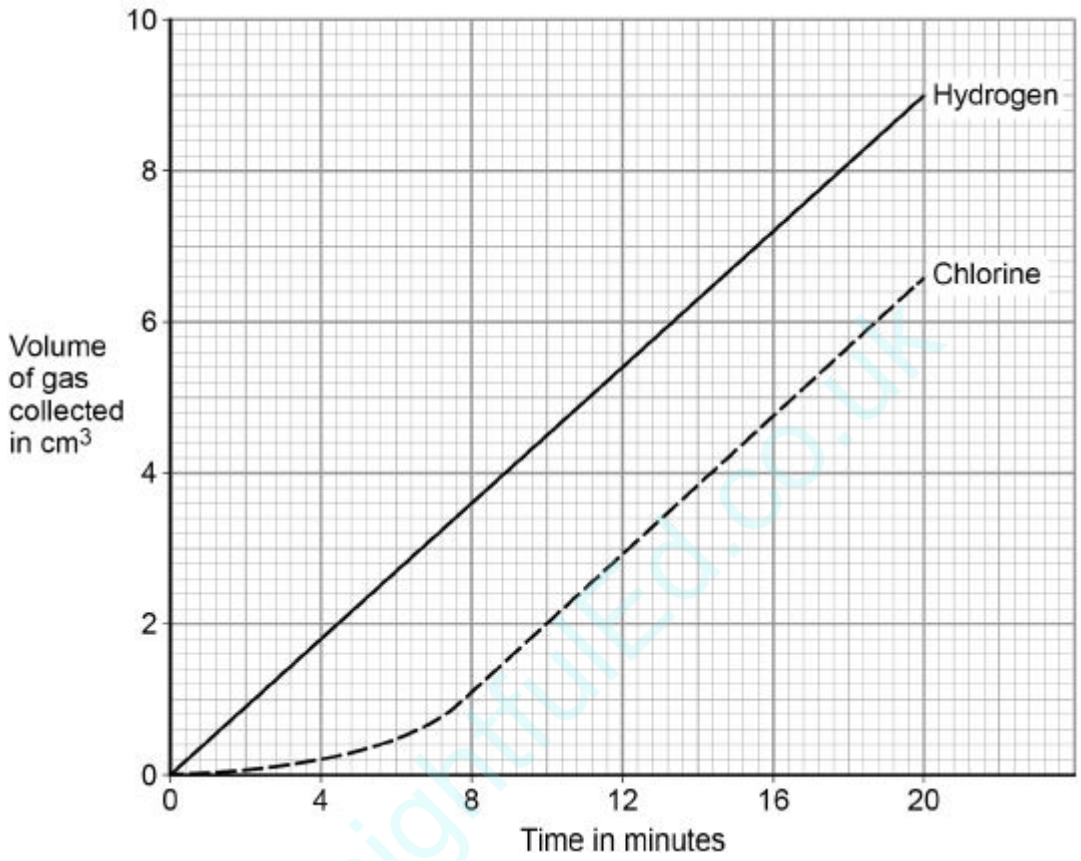
(2)

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



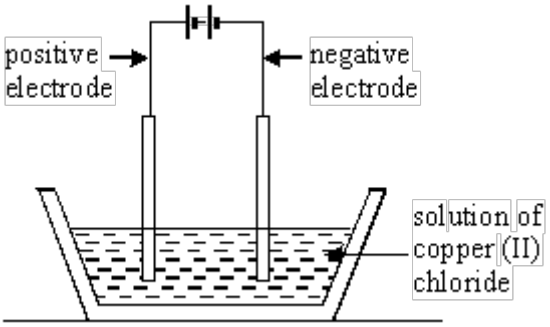
(d) Describe the trends shown in the results.

Use values from **Figure 3**.

(3)

Q20.

Copper metal can be extracted from a solution of copper(II) chloride.



Copper chloride is an ionic compound.

State where the copper would collect and explain your answer fully.

_____

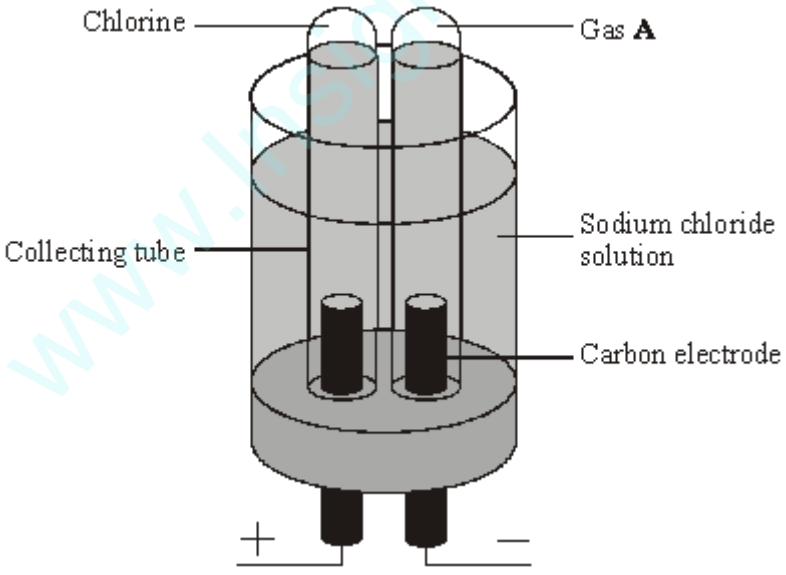
_____

_____

(Total 2 marks)

Q21.

The electrolysis of sodium chloride solution is an important industrial process. The apparatus shown below can be used to show this electrolysis in the laboratory.



(a) Name gas **A**. _____

(1)

b) Chlorine is produced at the positive electrode. Describe and give the result of a chemical test to prove that the gas is chlorine.

(2)

(c) Chloride ions move to the positive electrode. Explain why.

(1)

(d) A small quantity of chlorine is added to drinking water. Explain why.

(1)

(e) The solution around the negative electrode becomes alkaline. Name the ion which makes the solution alkaline.

(1)

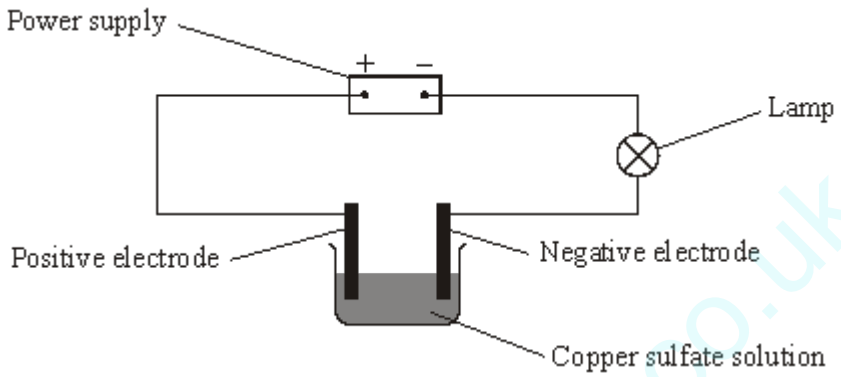
(Total 6 marks)

Q22.

A student investigated the electrolysis of copper sulfate solution.
The student's method is shown below.

Two clean pieces of copper were weighed. One piece was used as the positive electrode and the other piece was used as the negative electrode.

The circuit was set up as shown in the diagram.



After the electrolysis, the pieces of copper were:

- washed with distilled water
- washed with propanone (a liquid with a lower boiling point than water)
- allowed to dry
- weighed.

(a) Explain why the electrode would dry faster when washed with propanone instead of water.

_____

_____

(1)

(b) The student's results are given in the table.

	Positive electrode	**Negative electrode**
mass of electrode before electrolysis, in grams	16.41	15.46
mass of electrode after electrolysis, in grams	16.10	15.75

The mass of the positive electrode decreased by 0.31 g.

(i) What is the change in mass of the negative electrode?

_____ g

(1)

(ii) The mass lost by the positive electrode should equal the mass gained by the negative electrode.

Suggest **two** reasons why the results were **not** as expected.

1. _____

_____

2. _____

_____

(2)

(c) Describe and explain how electrolysis is used to make pure copper from a lump of impure copper.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(Total 8 marks)

Q23.

This question is about electrolysis.

Aluminium is manufactured by electrolysing a molten mixture of aluminium oxide (Al_2O_3) and cryolite (Na_3AlF_6).

(a) Complete the half equation for the reaction occurring at the negative electrode.

$$Al^{3+} + \_\_\_\_\_e^- \rightarrow Al$$

(1)

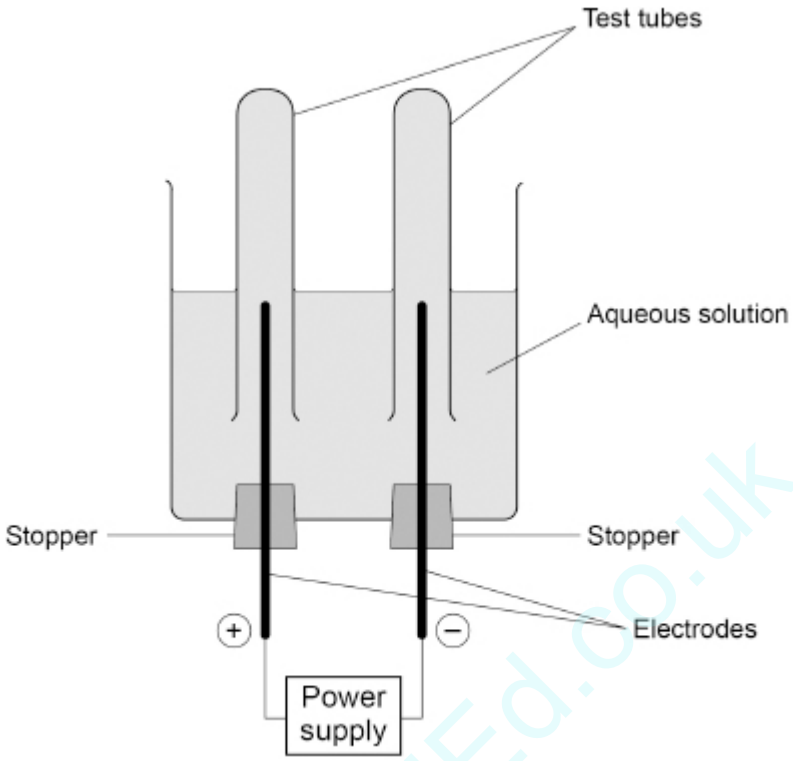
(b) Cryolite contains Na^+ ions as well as Al^{3+} ions.

Suggest **one** reason why sodium is **not** a product of the electrolysis.

_____ **(1)**

A student investigated the electrolysis of an aqueous solution of a different compound.

The figure below shows the apparatus.



Hydrogen was produced at the negative electrode and oxygen was produced at the positive electrode.

(c) Explain how oxygen was produced from water during the electrolysis of this aqueous solution.

(4)

(d) The student compared the volumes of the two gases collected.

How can the student change the apparatus in the figure above to compare the volumes of the two gases produced more accurately?

Give **one** reason for your answer.

Change _____

_____

Reason _____

_____

(2)

(e) The overall equation for the reaction is:

$$2\ H_2O(l) \rightarrow 2\ H_2(g) + O_2(g)$$

What is the volume of oxygen produced when 20 cm^3 of hydrogen has been produced?

Tick (✓) **one** box.

10 cm^3 ☐ 20 cm^3 ☐ 30 cm^3 ☐ 40 cm^3 ☐

(1)

(Total 9 marks)

Q24.

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.

_____

_____

_____

_____

(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.

$$Br^- \rightarrow \quad +$$

(2)

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

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

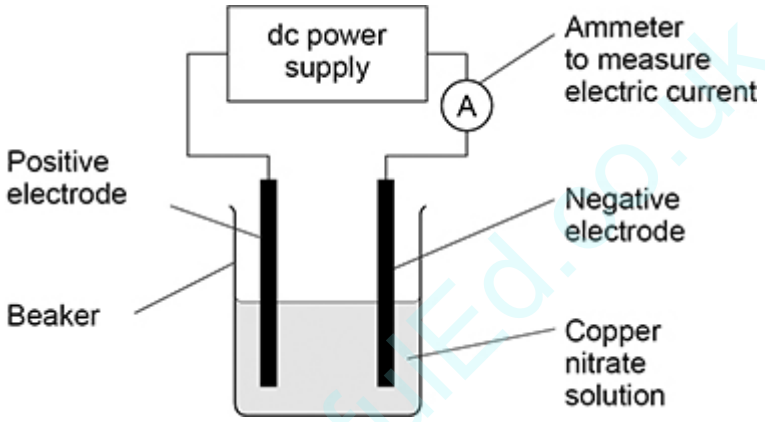
Salt solution	Product at positive electrode	Product at negative electrode
Copper nitrate		copper
Potassium iodide		

(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.

_____

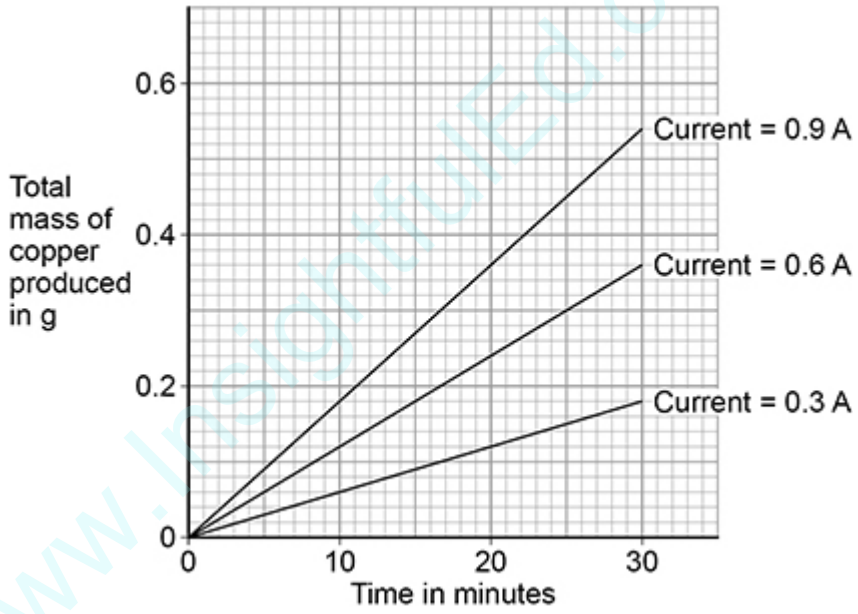
_____

(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?

(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.

_____

_____

(1)

(g) Copper nitrate solution is blue.

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

_____

_____

(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

_____

_____

_____

_____

_____

_____

Number of atoms (3 significant figures) = _____

(3)

(Total 17 marks)

Q25.

Cans for food and drinks are made from steel or aluminium.
The main metal in steel is iron.

(a) Reacting iron oxide with carbon produces iron.

Draw a ring around the correct answer to complete the sentence.

The reaction to produce iron from iron oxide is	decomposition. oxidation. reduction.

(1)

(b) Aluminium cannot be produced by reacting aluminium oxide with carbon.

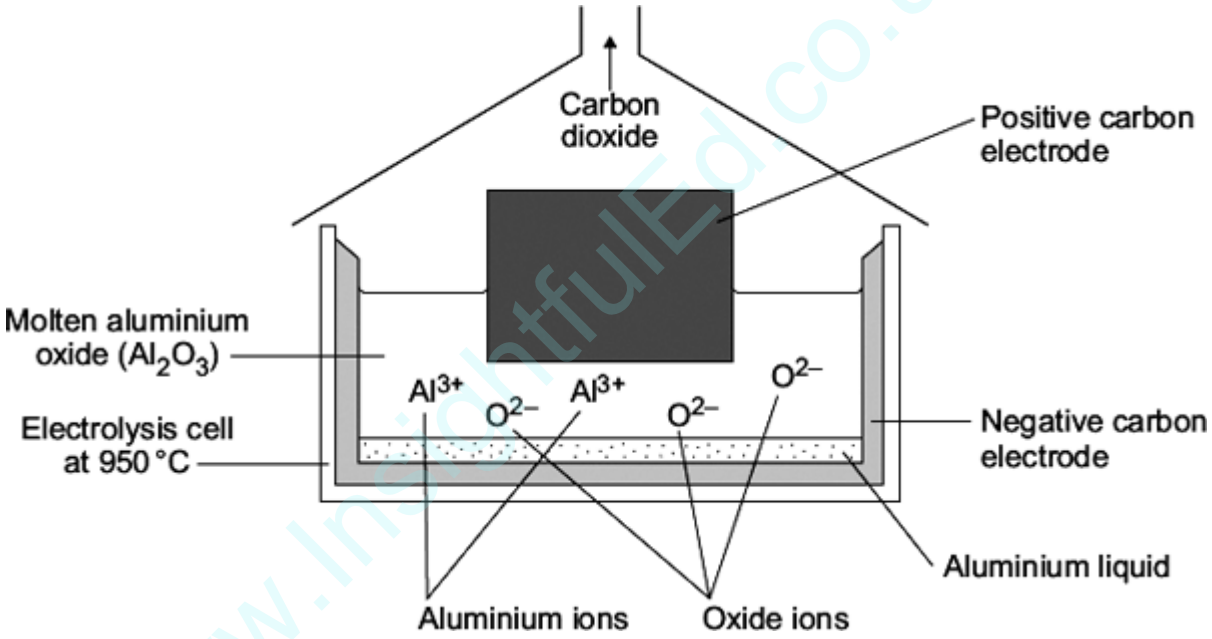
Why does aluminium oxide **not** react with carbon?

Tick (✓) the correct answer.

Answer	Tick (✓)
aluminium is less reactive than carbon	
carbon is less reactive than aluminium	
oxygen is more reactive than carbon	

(1)

(c) Aluminium can be produced by electrolysis.



Why do the aluminium ions collect at the negative electrode?

_____

_____

_____

_____

(2)

(d) Some statements about aluminium are given below.

Tick (✓) **two** statements that are correct reasons why aluminium is used to make cans.

Statement	Tick (✓)
aluminium conducts electricity	
aluminium is not a transition metal	
aluminium has a low density	
aluminium is resistant to corrosion	

(2)

(e) Recycling aluminium cans uses less fossil fuels than producing aluminium from its ore.

Tick (✓) **one** advantage and tick (✓) **one** disadvantage of recycling aluminium to make aluminium cans.

Statement	Advantage Tick (✓)	Disadvantage Tick (✓)
aluminium is the most common metal in the Earth's crust		
less carbon dioxide is produced		
more aluminium ore needs to be mined		
used aluminium cans have to be collected and transported		

(2)

(Total 8 marks)

Q26.

This question is about potassium.

(a) Humphrey Davy was a professor of chemistry.

In 1807 Davy did an electrolysis experiment to produce potassium.

(i) Davy first tried to electrolyse a solid potassium salt to produce potassium.

Explain why this electrolysis did **not** work.

_____

_____

_____

_____

(2)

(ii) Humphrey Davy was the first person to produce potassium.

Humphrey Davy's experiment to produce this new element was quickly accepted by other scientists.

Suggest why.

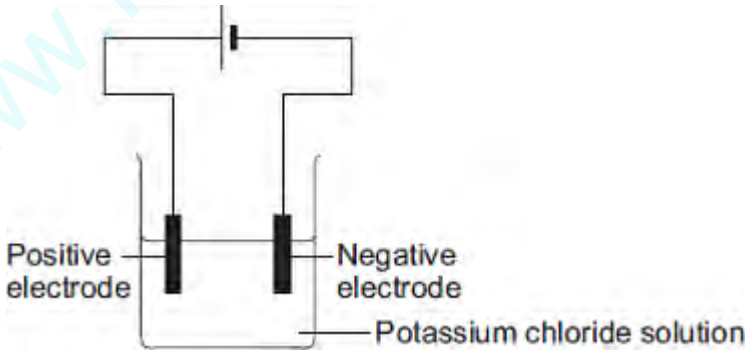
_____

_____

(1)

(b) A student dissolved some potassium chloride in water. The student tried to electrolyse the potassium chloride solution to produce potassium.

The apparatus the student used is shown in the diagram.



The student expected to see potassium metal at the negative electrode, but instead saw bubbles of a gas.

- Name the gas produced at the negative electrode.
- Explain why this gas was produced at the negative electrode **and** why potassium was not produced.

The reactivity series of metals on the Chemistry Data Sheet may help you to answer

this question.

(3)

(c) The student tried to electrolyse molten potassium chloride to produce potassium.

(i) Potassium metal was produced at the negative electrode.

Describe how potassium atoms are formed from potassium ions.

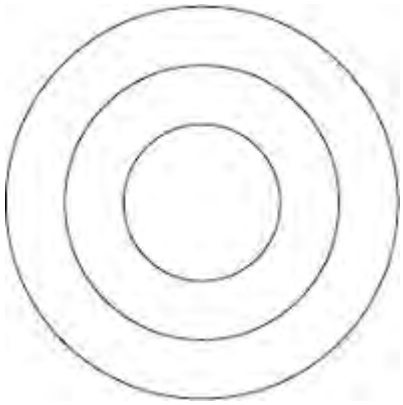
(2)

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

$$\_\_\_\_\_Cl^- \longrightarrow Cl_2 + \_\_\_\_\_$$

(1)

(iii) Complete the diagram to show the electronic structure of a chloride ion (Cl^-).



(1)

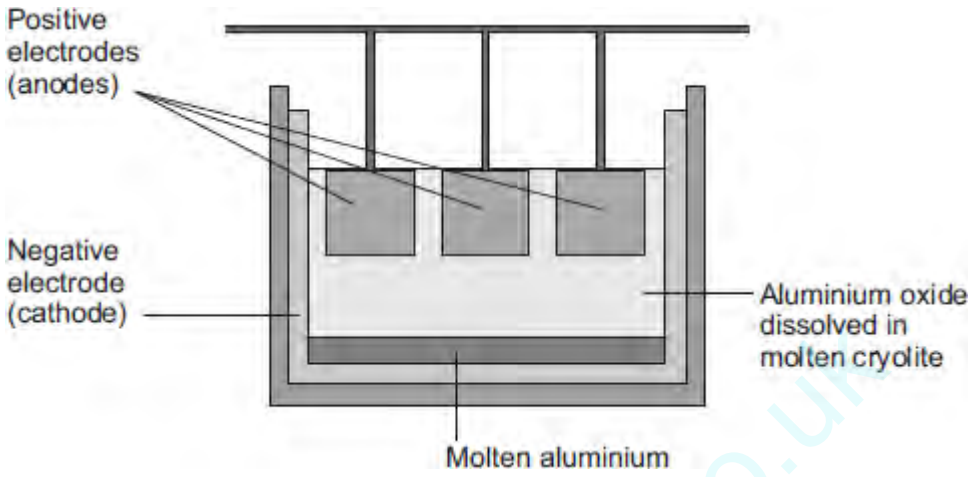
(Total 10 marks)

Q27.

This question is about iron and aluminium.

(b) Aluminium is extracted by electrolysis, as shown in **Figure 2**.

Figure 2



(i) Why can aluminium **not** be extracted by heating aluminium oxide with carbon?

_____

_____

(1)

(ii) Explain why aluminium forms at the negative electrode during electrolysis.

_____

_____

_____

_____

_____

_____

_____

(3)

(iii) Explain how carbon dioxide forms at the positive electrodes during electrolysis.

_____

_____

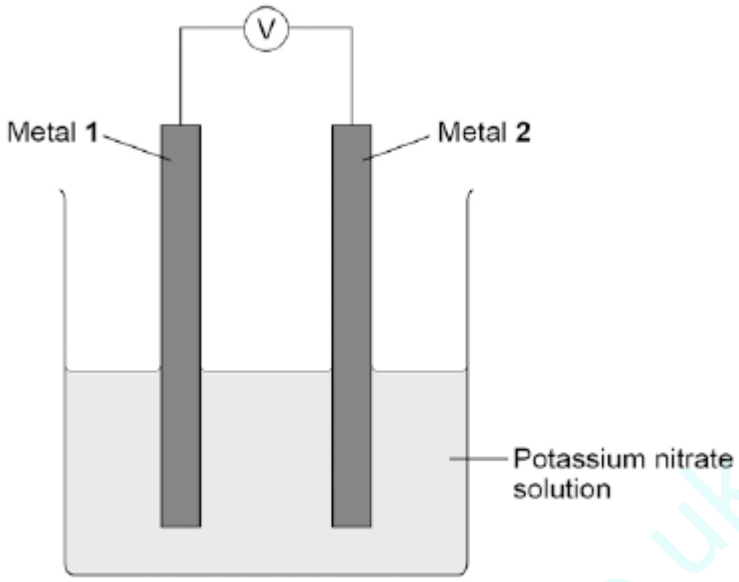
_____

_____

(3)

Q28.

A student investigated simple cells using the apparatus shown in the figure below.



- If metal **2** is more reactive than metal **1** then the voltage measured is positive.
- If metal **1** is more reactive than metal **2** then the voltage measured is negative.
- The bigger the difference in reactivity of the two metals, the larger the voltage produced.

The student's results are shown in the table below.

Metal 2 / Metal 1	Chromium	Copper	Iron	Tin	Zinc
Chromium	0.0 V				
Copper	1.2 V	0.0 V			
Iron	0.5 V	not measured	0.0 V		
Tin	0.8 V	-0.4 V	0.3 V	0.0 V	
Zinc	0.2 V	-1.0 V	-0.3 V	-0.6 V	0.0 V

(a) The ionic equation for the reaction occuring at the zinc electrode in the simple cell made using copper and zinc electrodes is:

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

Zinc is oxidised in this reaction.

Give a reason why this is oxidation.

_____

(1)

(b) Look at the table above.

Which **one** of the metals used was the least reactive?

Give a reason for your answer.

Metal _____

Reason _____

_____

_____

(2)

(c) Predict the voltage that would be obtained for a simple cell that has iron as metal **1** and copper as metal **2**.

Explain your answer.

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(d) Hydrogen fuel cells have been developed for cars.

Write a word equation for the overall reaction that takes place in a hydrogen fuel cell.

_____

(1)

(e) Write the **two** half equations for the reactions that occur at the electrodes in a hydrogen fuel cell.

_____

_____

_____

_____

(2)

(Total 9 marks)

Q29.

This question is about electrolysis.

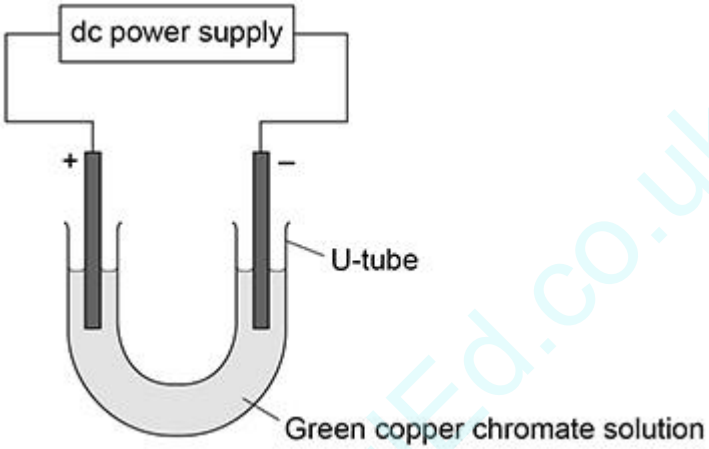
A student investigated the electrolysis of copper chromate solution.

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.

_____

_____

_____

_____

(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.

_____

(1)

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

_____

_____

_____

_____

_____

_____

(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

_____

Positive electrode

_____

(2)

(Total 8 marks)

Q30.

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.

_____

_____

_____

_____

(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.

$\rightarrow \quad O_2 \quad +$

(2)

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

_____

_____

_____

_____

_____

_____

(3)

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.

_____

_____

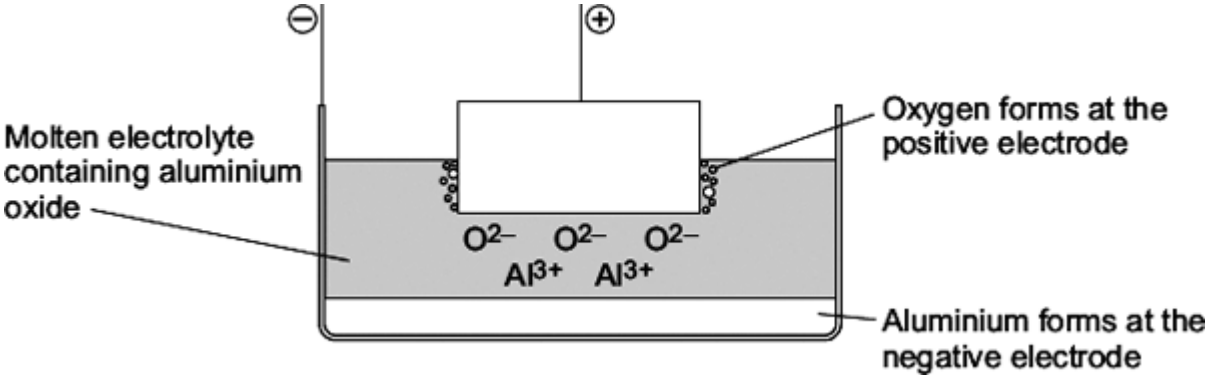
_____

_____

(2)

Q31.

The diagram represents an electrolysis cell for extracting aluminium.
The current will only flow when the electrolyte is molten.



(a) The electrolyte is aluminium oxide mixed with another substance.

(i) What is the name of the other substance in the electrolyte?

Draw a ring around the correct answer.

cryolite **rock salt** **limestone**

(1)

(ii) Draw a ring around the correct answer to complete the sentence.

This other substance is added to

condense the aluminium oxide.
lower the melting point of the aluminium oxide.
raise the boiling point of the aluminium oxide.

(1)

(b) (i) Oxide ions (O^{2-}) move to the positive electrode.

Explain why.

_____

_____

_____

_____

(2)

(ii) Oxygen is formed at the positive electrode. The oxygen then forms carbon dioxide.

The equation for the reaction is shown below.

$$C + O_2 \rightarrow CO_2$$

Complete the sentence.

The name of the element which reacts with oxygen is _____

(1)

(iii) The positive electrode gets smaller.

Suggest why.

_____

_____

(1)

Q32.

Humphrey Davy was a professor of chemistry.

In 1807 Humphrey Davy did an electrolysis experiment to produce potassium.

(a) (i) Humphrey Davy was the first person to produce potassium.

Draw a ring around the correct answer to complete each sentence.

Humphrey Davy's experiment to produce this new element was quickly

accepted by other scientists because he

had a lot of money.
had a lot of staff to help.
was well qualified.

(1)

(ii) Other scientists were able to repeat Davy's experiment.

Draw a ring around the correct answer to complete each sentence.

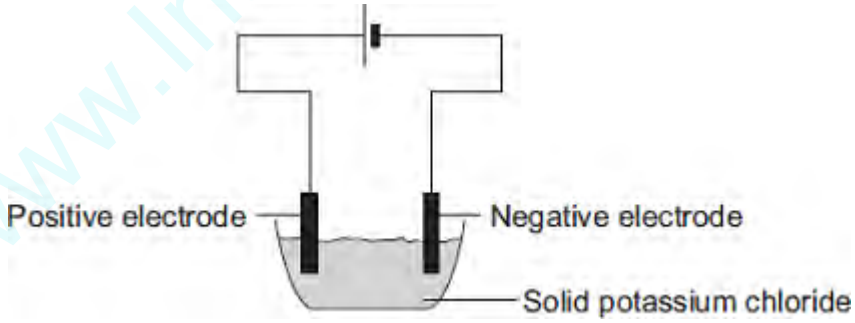
Being able to repeat Davy's experiment is important because

other scientists can

check the results of the experiment.
see if the experiment is safe.
take the credit for the discovery.

(1)

(b) A student tried to electrolyse potassium chloride.



Potassium chloride contains potassium ions (K^+) and chloride ions (Cl^-).

(i) The student found that solid potassium chloride does not conduct electricity.

Use the correct answer from the box to complete the sentence.

are too big	**cannot move**	**have no charge**

Solid potassium chloride does not conduct electricity because

the ions _____ .

(1)

(ii) What could the student do to the potassium chloride to make it conduct electricity?

_____

(1)

(iii) During electrolysis why do potassium ions move to the negative electrode?

_____

(1)

(iv) Draw a ring around the correct answer to complete the sentence.

When the potassium ions reach the negative electrode

they turn into potassium

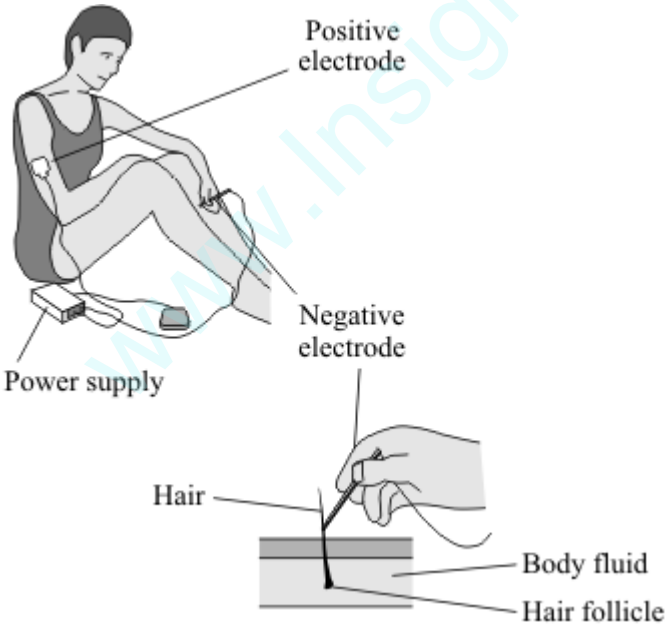
atoms.
electrodes.
molecules.

(1)

(Total 6 marks)

Q33.

Electrolysis can be used to remove unwanted hair from the skin.



The positive electrode is connected by a patch to the skin.

The negative electrode is connected to the hair.

The body fluid is a solution that contains sodium chloride. The electricity causes the electrolysis of a small amount of this solution.

(a) In this solution hydrogen ions move to the negative electrode.

Complete the sentence using **one** word from the box.

negative	**neutral**	**positive**

Hydrogen ions move to the negative electrode because they have a

_____ charge.

(1)

(b) Draw a ring around the name of the gas produced at the positive electrode during the electrolysis of sodium chloride solution.

chlorine **hydrogen** **nitrogen**

(1)

(c) The electrolysis of the sodium chloride solution forms a strong alkali around the hair follicle.

(i) Complete the name of this strong alkali using **one** of the words from the box.

chloride **hydroxide** **nitrate**

The name of this strong alkali is sodium _____ .

(1)

(ii) Suggest how this strong alkali helps to remove the hair.

_____

_____

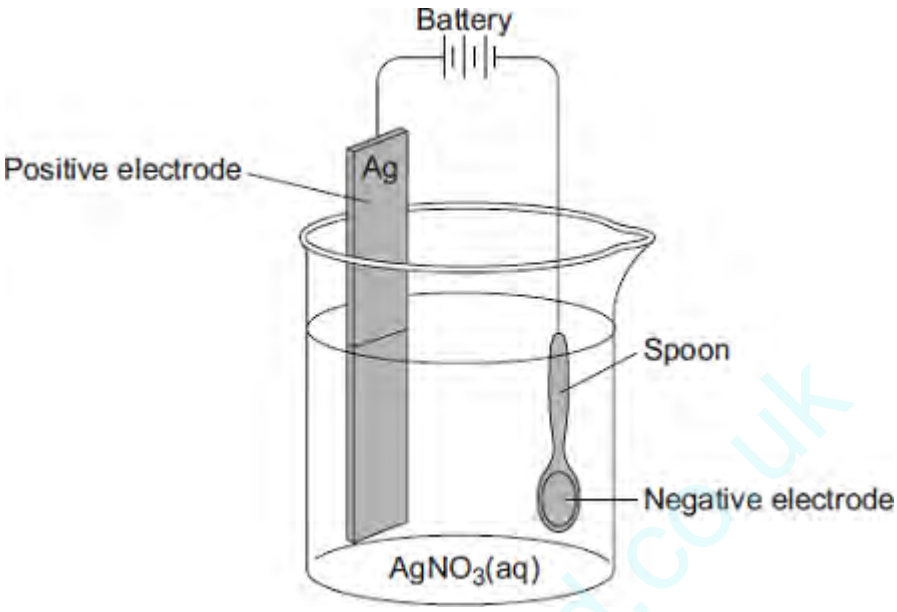
(1)

(Total 4 marks)

Q34.

(TRIPLE) Electroplating is used to coat a cheap metal with a thin layer of an expensive metal.

In the diagram a teaspoon made of nickel is being coated with silver.



Silver nitrate ($AgNO_3$) contains silver ions (Ag^+) and nitrate ions (NO_3^-).

(a) Solid silver nitrate, $AgNO_3(s)$, does **not** conduct electricity.

Choose the correct answer in the box to complete the sentence.

are too big	**cannot move**	**are too small**

Solid silver nitrate does **not** conduct electricity because the ions _____

_____

(1)

(b) Draw a ring around the correct answer to complete each sentence.

(i) Silver ions move to the negative electrode because

they have

no charge.
a negative charge.
a positive charge.

(1)

(ii) When silver ions reach the negative electrode they turn into silver

atoms.
compounds.
molecules.

(1)

(Total 3 marks)

Q35.

(TRIPLE) Some cars are powered by hydrogen fuel cells.

Figure 1

(a) What type of energy is released by hydrogen fuel cells?

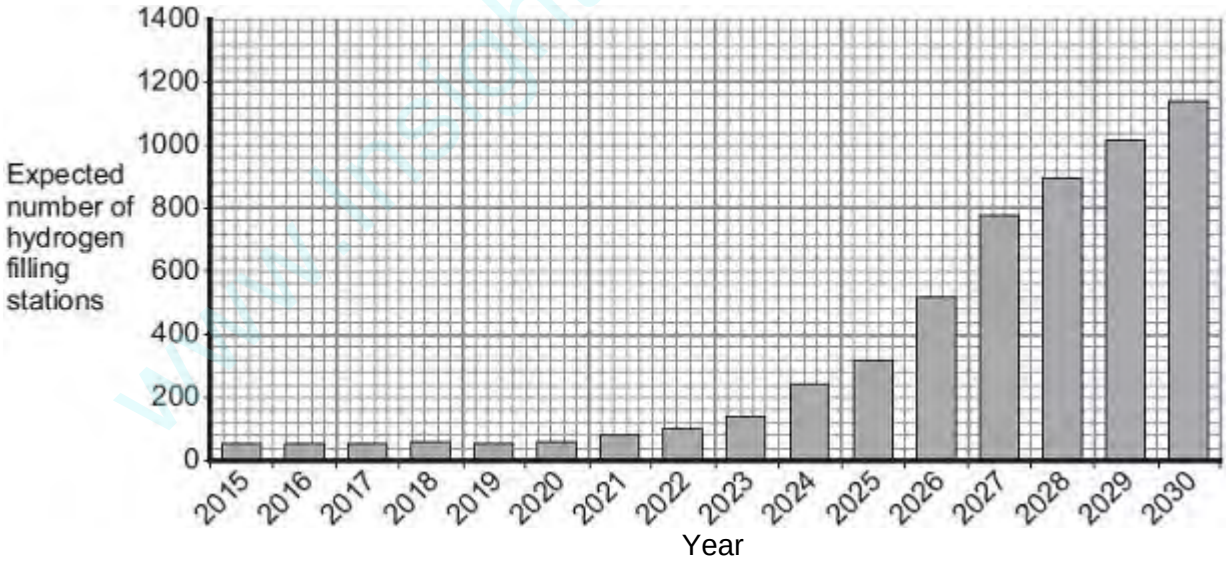
_____

(1)

(b) Owners of cars powered by fuel cells buy hydrogen from hydrogen filling stations.

Figure 2 shows how the number of hydrogen filling stations in the UK is expected to increase up to the year 2030.

Figure 2



Use the information in **Figure 2** and your own knowledge to answer this question.

Suggest **two** reasons why the UK government might encourage the building of more hydrogen filling stations.

_____

_____

(2)

(c) The equation for the reaction of hydrogen with oxygen is:

$$2\ H_2 + O_2 \longrightarrow 2\ H_2O$$

During the reaction, energy is used to break the bonds of the reactants.

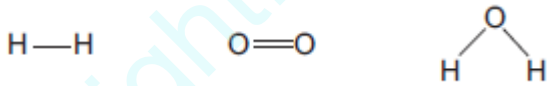
Energy is released when new bonds are made to form the product.

Bond energies for the reaction are given in the table below.

Bond	Bond energy in kJ
H—H	436
O=O	498
O—H	464

The structures of the reactants and product are shown in **Figure 3**.

Figure 3



hydrogen oxygen water

(i) Calculate the energy change for the reaction:

$$2\ H_2 + O_2 \longrightarrow 2\ H_2O$$

Energy change = _____ kJ

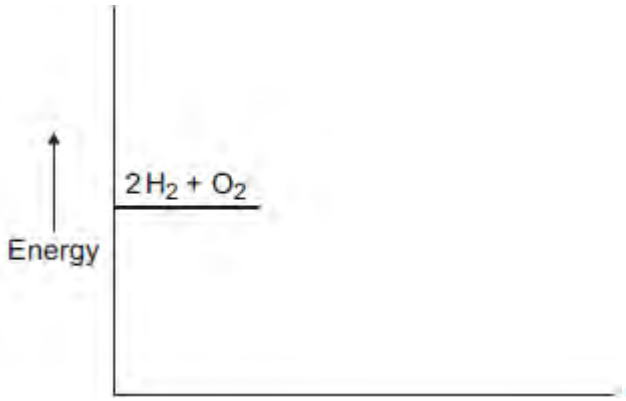
(3)

(ii) The reaction of hydrogen with oxygen is exothermic.

Complete the energy level diagram for this reaction on **Figure 4**.

Clearly label the activation energy.

Figure 4



(3)

(Total 9 marks)

Q36.

(TRIPLE) Cells contain chemicals which react to produce electricity.

(a) Why can a rechargeable cell be recharged?

_____

_____

(1)

(b) Give **two** factors that affect the voltage produced by a cell.

1. _____

2. _____

(2)

(c) Balance the half-equation for the reaction occurring at an electrode in one type of hydrogen fuel cell.

$$H_2 \quad + \quad OH^- \quad \longrightarrow \quad H_2O \quad + \quad e^-$$

(1)

(d) Why is the fuel cell in Question (c) described as an alkaline fuel cell?

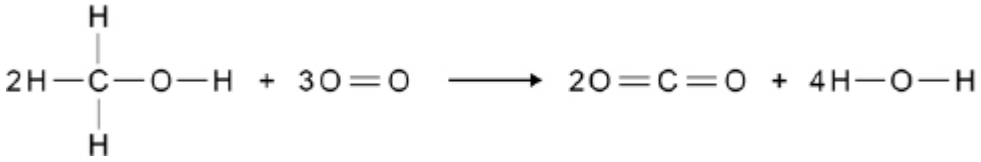
_____

_____

(1)

(e) Another type of fuel cell uses methanol instead of hydrogen.

The diagram represents the reaction in this fuel cell.



The table shows the bond energies for the reaction.

	C–H	C–O	O–H	O=O	C=O
Bond energy in kJ / mol	412	360	464	498	805

Calculate the overall energy change for the reaction.

Use the diagram and the table above.

Overall energy change = _____ kJ / mol

(3)

(Total 8 marks)

Q37.

(TRIPLE) This question is about chemical cells and batteries.

(a) Three different types of battery can be used to power a TV remote control.

The table below gives information about these batteries.

	Zinc-carbon battery	Alkaline battery	Nickel-metal hydride battery
Cost of battery in £ (pounds)	0.17	0.50	1.50
Rechargeable?	No	No	Yes
Time before needing to replace or recharge in months	5	12	8

Give **one** advantage of each type of battery.

Zinc-carbon _____

Alkaline _____

_____

Nickel-metal hydride _____

_____

(3)

(b) **Figure 1** shows a symbol printed on batteries.

Figure 1

This symbol shows that batteries should not be put in household waste.

Suggest why batteries should **not** be put in household waste.

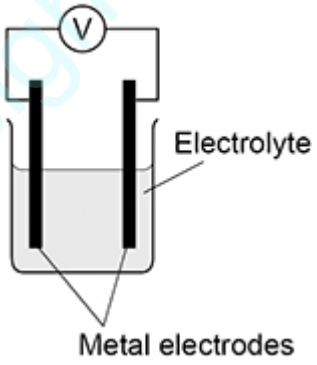
_____

_____

(1)

Figure 2 shows a chemical cell.

Figure 2



(c) The order of reactivity of three metals is shown below.

Iron	(Most reactive)
Tin	↑
Copper	(Least reactive)

Which combination of metal electrodes would give the highest voltage in the chemical cell in **Figure 2**?

Tick (✓) **one** box.

Copper and iron ☐

Iron and tin ☐

Tin and copper ☐

(1)

(d) The voltage produced by the cell in **Figure 2** depends on the type of electrodes and the type of electrolyte.

Suggest **one** other factor that could affect the voltage produced.

_____

_____

(1)

(e) Water is produced in a hydrogen fuel cell.

Complete the word equation to show the reaction that produces water in a hydrogen fuel cell.

_____ + _____ → water

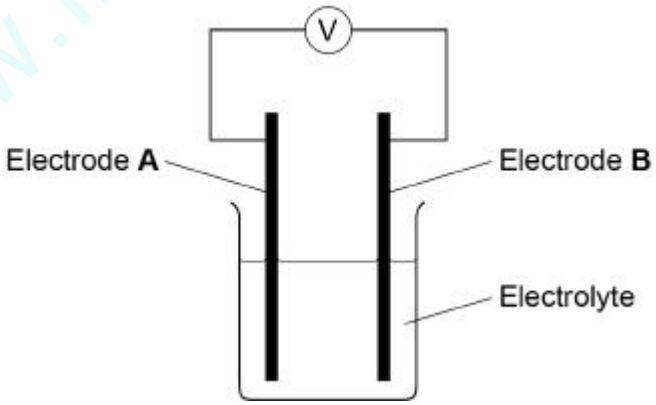
(2)

(Total 8 marks)

Q38.

(TRIPLE) Chemical reactions can produce electricity.

(a) The diagram below shows a simple cell.



Which of these combinations would not give a zero reading on the voltmeter in the diagram above?

Tick **one** box.

Electrode A **Electrode B** **Electrolyte** ☐

Copper	Copper	Sodium chloride solution	☐
Zinc	Zinc	Water	☐
Copper	Zinc	Sodium chloride solution	☐
Copper	Zinc	Water	☐

(1)

Alkaline batteries are non-rechargeable.

(b) Why do alkaline batteries eventually stop working?

_____

_____

(1)

(c) Why can alkaline batteries **not** be recharged?

_____

_____

(1)

Hydrogen fuel cells and rechargeable lithium-ion batteries can be used to power electric cars.

(d) Complete the balanced equation for the overall reaction in a hydrogen fuel cell.

_____ H_2 + _____ ⟶ _____ H_2O

(2)

(e) The table below shows data about different ways to power electric cars.

	Hydrogen fuel cell	**Rechargeable lithium-ion battery**
Time taken to refuel or recharge in minutes	5	30
Distance travelled before refuelling or recharging in miles	Up to 415	Up to 240
Distance travelled per unit of energy in km	22	66
Cost of refuelling or recharging in £	50	3

Minimum cost of car in £	60 000	18 000

Evaluate the use of hydrogen fuel cells compared with rechargeable lithium-ion batteries to power electric cars.

Use the table above and your own knowledge.

(6)

(Total 11 marks)

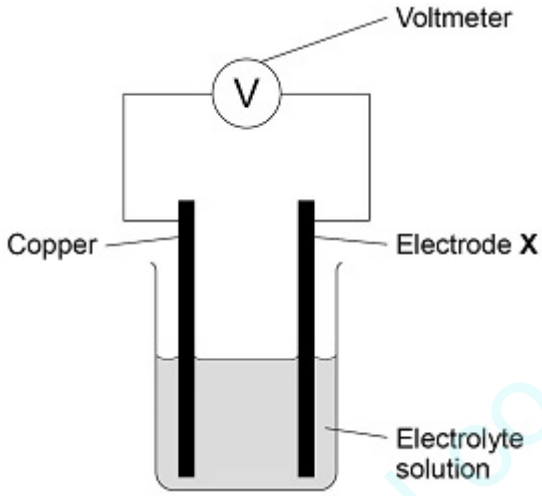
Q39.

(TRIPLE) This question is about chemical cells.

A student investigated the voltage produced by different chemical cells.

Figure 1 shows the apparatus.

Figure 1



This is the method used.

1. Use cobalt as electrode **X**.

2. Record the cell voltage.

3. Repeat steps 1 and 2 using different metals as electrode **X**.

(a) Suggest **two** control variables used in this investigation.

1 _____

_____

2 _____

_____

(2)

The following table shows the student's results.

Electrode X	Voltage of cell in volts
cobalt	+0.62
copper	0.00
magnesium	+2.71
nickel	+0.59
silver	−0.46

tin	+0.48

(b) Write the six metals used for electrode **X** in order of reactivity.

Use the table above.

Justify your order of reactivity.

Most reactive _____

_____

_____

_____

_____

Least reactive _____

Justification _____

_____

_____

_____

_____

(4)

(c) Which of the following pairs of metals would produce the greatest voltage when used as the electrodes in the cell?

Use the table above.

Tick (✓) **one** box.

Magnesium and cobalt ☐

Magnesium and tin ☐

Nickel and cobalt ☐

Nickel and tin ☐

(1)

(d) Hydrogen fuel cells can be used to power different forms of transport.

Some diesel trains are being converted to run on hydrogen fuel cells.

A newspaper article referred to the converted trains as the new ‘steam trains’.

Suggest why.

_____

_____

_____

_____

(2)

(Total 9 marks)

Mark schemes

Q1.

(a) hydroxide ions

1

(b) 27 (cm^3)

1

(c) ions cannot move (freely in a solid)

allow ions are fixed in place (in a solid)

1

(d)

Molten compound	**Product at negative electrode**	**Product at positive electrode**
Potassium iodide	Potassium	**Iodine**
Zinc bromide	**Zinc**	Bromine

2

(e) carbon is less reactive than sodium

1

(f) (l)

1

Q2.

(a) by filtration

1

(b) 10 minutes per 2 cm on x-axis

allow 5 minutes per 1 cm on x-axis

1

all points plotted correctly

allow a tolerance of ± ½ a small square

*allow **1** mark for 3 or 4 points plotted correctly*

2

line of best fit

allow line of best fit drawn using incorrect plots

1

(c) 0.14 (g)

*allow ecf from question **(b)***

allow a tolerance of ± ½ a small square

1

(d) (copper sulfate solution) pink / orange / red / brown solid

allow copper plating

allow metal for solid

1

(sodium chloride solution) bubbles / effervescence / fizzing

*if no other mark awarded allow **1** mark for copper **and** hydrogen*

1

(e) toxic / poisonous (fumes)

allow harmful / corrosive (fumes)
ignore dangerous / deadly / lethal

1

(f)

Molten compound electrolysed	Product at the negative electrode	Product at the positive electrode
(zinc chloride)	zinc (1)	chlorine (1)
potassium iodide	(potassium)	(iodine)

allow **1** mark if zinc and chlorine the wrong way round

2
1

[12]

Q3.

(a) (negative electrode) solid produced

allow the electrode changes colour
ignore metal produced

1

(positive electrode) bubbles / fizzing / effervescence

ignore gas produced

1

(b) potassium nitrate

1

hydrogen is not a metal

allow hydrogen is a gas
allow hydrogen is not a solid
allow the products at both electrodes are gases
allow the product at the negative electrode is not potassium
allow potassium is more reactive than hydrogen

1

(c) (graphite) conducts (electricity)

allow (graphite) has delocalised / free electrons

1

(graphite) is inert

allow (graphite) is unreactive

1

(d) the ions move towards the positive electrode

1

the electrode attracts ions of the opposite charge

allow opposite charges attract

1

[8]

Q4.

(a) 3.6 (cm^3)

1

(b) hydrogen line only

1

(c) both lines

1

(d) graphite has delocalised electrons

1

(e) **cathode** **anode**

zinc (1) chlorine (1)

*do **not** accept chloride*

*allow **1** mark if chlorine and zinc the wrong way around*

1+1

hydrogen (1) bromine (1)

*do **not** accept bromide*

*allow **1** mark if bromine and hydrogen the wrong way around*

1+1

[8]

Q5.

(a) breakdown / decomposition / splits into elements /

***not** ions*

separates into elements / produce a chemical reaction

1

using electricity

1

(b) lead bromide melted / free ions

not electrolyte

1

(c) (+) bromine

element must be appropriate to electrode

1

(–) lead

element must be appropriate to electrode

1

(d) fume cupboard / protective clothing

allow safety glasses
***not** safety mat*

1

[6]

Q6.

(a) concentration (of solution / electrolyte)

1

temperature (of solution / electrolyte)

ignore room temperature
allow volume (of solution / electrolyte)
allow size of electrodes
allow distance between electrodes
*do **not** accept electrode **X** unqualified*
*do **not** accept (measured) voltage*

1

(b) (most reactive) magnesium

allow Mg

zinc

allow Zn

(least reactive) cobalt

allow Co

1

(c) 0 (volts)

1

two different metals are needed to produce a voltage

dependent on voltage being given as 0 volts
allow the two electrodes are the same metal
allow there is no difference in reactivity (between the electrodes)

1

(d) connect cells (in series)

ignore putting cells together

1

use $\left(\frac{12}{1.5} =\right)$ 8 cells

1

(e) electric toy

1

(f) (advantage)
any **one** from:

- faster to refuel (than recharging)

- can travel further (before refuelling)
  allow lasts longer
- hydrogen can be renewable
  allow hydrogen is renewable
- produces a constant voltage
- no toxic chemicals released after disposal
  allow the only product is water
  ignore no emissions

1

(disadvantage)
any **one** from:

- hydrogen is made from fossil fuels
- hydrogen is made from non-renewable resources
- hydrogen is difficult to store
- hydrogen is flammable / explosive
- costs more to refuel (than recharging)
- costs more to manufacture
  ignore expensive unqualified
- not many hydrogen filling stations

1

[10]

Q7.

(a) $Na^+ + e^- \rightarrow Na$

1

(b) so the products do not react (to reform sodium chloride)

1

(c) ion

1

(d) hydrogen / H^+ (ions)

1

hydroxide / OH^- (ions)

1

(e) sodium hydroxide
allow NaOH

1

(f) sodium ions and hydroxide ions are left (in solution)

1

(because) hydrogen ions are discharged / reduced (at the negative electrode to form hydrogen)
allow (because) hydrogen ions gain electrons (at the negative electrode to form hydrogen)
allow (because at the negative electrode) $2 H^+ + 2 e^- \rightarrow H_2$

1

(and because) chloride ions are discharged / oxidised (at the positive electrode to form chlorine)
allow (and because) chloride ions lose electrons (at the positive electrode to form chlorine)

allow (and because at the positive electrode) 2 Cl^- → Cl_2 + 2 e^-

1

[9]

Q8.

(a) (substance reduced) Fe_2O_3

allow iron oxide

1

(reason)
(Fe_2O_3) loses oxygen

MP2 is dependent upon MP1 being awarded

ignore Fe^{3+} gains electrons

1

(b) $\frac{3}{2} \times 12g$

1

(c) **A** loses electrons and $\mathbf{B}^+$ gains electrons

1

(d) **D**

1

(e) (metal) **C**

1

(explanation) aluminium forms ions with a charge 3+

allow aluminium forms Al^{3+} (ions)

1

(so) 3 nitrate ions are needed for 1 aluminium ion

allow (so) 3 nitrate ions are needed to balance the 3+ charge on 1 aluminium (ion)

1

Q9.

(a) (i) because they are positively charged

accept they are positive / H^+

*accept oppositely charged **or** opposites attract*

ignore they are attracted

1

(ii) gains one / an electron

accept $H^+ + e^- \rightarrow H$ or multiples

allow gains electrons

1

(c) (i) hydroxide / OH^-

*do **not** accept sodium hydroxide*

1

(ii) $H^+ + OH^- \rightarrow H_2O$

ignore state symbols

ignore word equation

1

(d) Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response. Examiners should also refer to the information in the Reference material.

0 marks
No relevant content.

Level 1 (1-2 marks)
There are basic descriptions of advantages or disadvantages of the electrolysis cells.

Level 2 (3-4 marks)
There are clear descriptions of environmental or economic advantages or disadvantages of the electrolysis cells. Comparisons may be implied.

Level 3 (5-6 marks)
There are detailed descriptions of environmental and economic advantages and disadvantages, comparing the electrolysis cells.

Examples of chemistry points made in the response:

Accept converse where appropriate.

- mercury cell is more expensive to construct
- mercury is recycled but membranes must be replaced
- mercury is toxic but membrane / polymer is not
- removing traces of mercury from waste is expensive
- mercury cell uses more electricity
- mercury cell produces chlorine that is purer
- mercury cell produces higher concentration / better quality of sodium hydroxide (solution)

6

[12]

Q10.

(a) (i) points correctly plotted (± ½ small square)

*four points = **2** marks*

*three points = **1** mark*

Max 2

straight line of best fit using full range of points from 0,0

1

(ii) any **one** from:

must explain why the point is below the line

- the solution may not have been properly stirred
- the electrodes may have been a larger distance apart
- the drop of sodium chloride may have been a smaller volume / smaller

allow not enough sodium chloride added

allow smaller amount of sodium chloride

*do **not** allow too few drops added*

ignore the student may have misread the conductivity meter

1

(iii) any **one** from:

- the volume of pure water

allow amount

- the concentration (of the solutions added)
- the volume (of the drops) of solution added

ignore number of drops

- the distance between the electrodes
- the same electrodes **or** electrodes made of the same material
- same depth **or** surface area of electrodes in the water
- constant power supply

ignore current

- stirred

1

(ii) because there are ions in sodium chloride

*allow Na^+ and / or Cl^-(ions) **or** ionic bonding.*

Ignore particles other than ions for MP1.

1

which can move **or** carry the current / charge

MP2 must be linked to ions only.

1

(iii) Hydrogen

allow H_2 / H

1

[10]

Q11.

(a) the ions can <u>move</u> / <u>travel</u> / <u>flow</u> /are <u>free</u>

accept particles / they for ions
allow delocalised ions

or

ignore delocalised / free electrons
ignore references to collisions
accept converse with reference to solid

the ions <u>carry</u> the charge / current

ignore ions carry electricity

1

(b) any **one** from:

- because they are negative / anion
  allow Cl^-
  ignore chlorine
- opposite charges / attract

1

(c) 13

1

(d) (i) reasonable attempt at straight line which misses the anomalous point

must touch all five crosses
*do **not** allow multiple lines*

1

(ii) 40

ignore 2.2

1

(iii) any **two** sensible errors from:

ignore systematic / human / apparatus / zero /experimental / random / measurement / reading errors unless qualified

- gas escapes
- weighing error
  allow NaCl not measured correctly
- error in measuring (volume / amount) of hydrogen
- error in measuring (volume / amount) of water
  *allow error in measuring volume / scale for **1** mark if neither hydrogen or water mentioned*
- incorrect concentration
  *allow NaCl not fully dissolved **or** spilled **or** impure*
- timing error

- change in voltage / current
  allow faulty power supply
- change in temperature
- recording / plotting error

2

(iv) any **one** from:
ignore 'do more tests'

- repeat the experiment
- results compared with results from /other students / other groups / other laboratories / internet / literature.
- results compared with another method

1

(v) increases owtte
allow directly proportional or positive correlation
allow rate / it is faster / quicker

1

[9]

Q12.

(ii) any **one** from
(it = iron)

- iron uses less energy / fuel for extraction
  ignore electrolysis / uses electricity / reactivity
- iron has more uses
- more demand for iron
  ignore high abundance in the Earth's crust / high percentage of metal in ore
- iron is stronger
  ignore harder
- cheaper / costs less
- easier to extract

1

(b) (i) has melting point lower than 950°C
(it = aluminium)
allow has a low melting point
ignore boiling point

1

(ii) electrode(s) made of carbon

1

oxygen reacts with electrode(s) / carbon

accept $C + O_2 (\rightarrow CO_2)$

NB oxygen reacts with the carbon electrode(s) = ***2*** *marks*

1

(iii) any **two** from:

- saves resources / non-renewable
  accept aluminium / ore will run out ***or*** *conserves aluminium*
- landfill problem
  accept aluminium does not corrode
- saves energy / fuel / electricity
  ignore global warming
- less carbon dioxide / carbon emissions **or** reduces carbon footprint
  ignore consequences of quarrying / mining
- less quarrying / mining
  ignore pollution / harms environment / costs / easy to recycle

2

[7]

Q13.

(a) (i) ions cannot move

allow only conducts as a liquid

1

(ii) chlorine

1

(iii) they are positively / oppositely charged

or

they are attracted

1

(iv) 2

1

(b) (i) any **one** from:

- not all the magnesium was collected
  allow some magnesium was lost
- *used less time* ***or*** *lower current* ***or*** *different battery / power pack* ***or*** *different balance* ***or*** *lower voltage*
- error in reading balance
- error in recording result

1

(ii) 1.11

correct answer with or without working gains ***2*** *marks.*

if answer incorrect, allow ***1*** *mark for 0.99*

or *for 1.13 + 1.11 + 1.09*

2

Q14.

(a) electricity

allow an electric current

1

(b) (i) chlorine/Cl_2

*do **not** accept chloride*

1

(ii) (zinc ions are) positive

ignore to gain electrons

1

and (opposite charges) attract

1

(iii) reduction

1

(c) (i) in alloy:

accept converse

different sized atoms/particles

or

no layers/rows

accept layers distorted

1

so cannot slide

1

(ii) shape memory (alloys)

accept smart

1

[8]

Q15.

(a) any **one** from:

- protection / improve lifespan
- improve appearance.

1

(b) (i) Bleach

1

(ii) Hydrogen is less reactive than sodium

1

(v) Hydrogen chloride has a low boiling point.

1

Hydrogen chloride is made of simple molecules.

1

(c) (i) oxygen

accept carbon dioxide

1

(ii) aluminium ions are positive

1

so are attracted (to the negative electrode)

allow opposites attract

1

(iii) Reduction

1

Q16.

(b) (i) because it lowers the melting point (of the aluminium oxide)

allow lowers the temperature <u>needed</u>

*do **not** accept lowers boiling point*

1

so less energy is needed (to melt it)

accept so that the cell / equipment does not melt

1

(ii) **2** O^{2-} on left hand side

accept correct multiples or fractions

1

4e^{-} on right hand side

*accept **–4e**$^{-}$ on left hand side*

1

(iii) because the electrode reacts with oxygen **or**

because the electrode burns

1

to form carbon dioxide **or**

electrode made from carbon / graphite

1

[8]

Q17.

(a) **(diagram)**
complete circuit with power supply

1

test solution in beaker or other appropriate apparatus

1

electrodes

allow carbon, platinum or inert electrodes

1

(independent variable)
salt solutions (with different metal ions)

1

(observation)
solid / metal deposit on the negative electrode

1

(b) (sometimes) hydrogen is produced

1

(because) the metal is more reactive than hydrogen

1

(c) chlorine

1

oxygen

1

[9]

Q18.

(a) $\underline{2}Cl^- - \underline{2}e^- \rightarrow Cl_2$ (allow unaltered LHS to produce $\underline{\frac{1}{2}}\ Cl_2$)
$Na^+ + \underline{e^-} \rightarrow Na$ (allow × 2 for **all** terms)

(*credit* candidates who point out that hydrogen / H_2 is in fact produced)

for 1 mark each

2

(b) for <u>product 1*</u>, *idea of* a solid / precipitate **or** silver bromide

gains 1 mark

but solid / a precipitate of silver bromide

gains 2 marks

<u>for product 2*</u>, *idea of* aqueous / a solution / dissolved (in water) / **or** sodium nitrate

gains 1 mark
(do not allow liquid)

but aqueous / a solution / dissolved (in water) of sodium nitrate

(*do not credit formulae)

gains 2 marks

4

[6]

Q19.

(a) solid (zinc chloride) does not conduct (electricity)
or
zinc chloride needs to be in solution **or** molten
allow liquid / aqueous

1

(because) ions cannot move in the solid
or
(as) ions can (only) move in liquid / solution
*do **not** accept references to movement of electrons in zinc chloride*

1

(b) each carbon / atom forms 3 (covalent) bonds

1

one electron per carbon / atom is delocalised

1

(so) these electrons carry charge through the graphite
or
(so) these electrons move through the structure
ignore carry current / electricity

1

*if no other mark scored, allow **1** mark for delocalised / free electrons*
allow free electrons for delocalised electrons

(c) use measuring cylinders (instead of test tubes)
allow use burettes
allow use (gas) syringes
allow Hoffmann voltameter

1

(because) test tubes cannot measure volume
or
(because) test tubes have no graduations / scale
allow (so that) volume can be measured

1

(d) any **three** from:

- the volume of hydrogen collected is directly proportional to the time
  allow the (volume of) hydrogen is collected at a constant / steady rate
- the rate of collection of hydrogen is 0.45 (cm^3/min)
- up to 8 minutes chlorine is collected at an increasing rate
  allow any value from 6 to 8 minutes
  allow initially chlorine is collected at an increasing rate

- after 8 minutes the rate of collection of chlorine is the same as that of hydrogen

  allow any value from 6 to 8 minutes

  or

  after 8 minutes the rate of collection of chlorine is 0.45 (cm^3/min)

  allow after 8 minutes the (volume of) chlorine is collected at a constant / steady rate

  *if neither bullet point 3 nor bullet point 4 is awarded allow **1** mark for chlorine is collected slowly up to 8 minutes and then more quickly*

  allow any value from 6 to 8 minutes

3

Q20.

copper collects at the negative electrode
copper positive ions

each for 1 mark

[2]

Q21.

(a) hydrogen

accept H_2
*do **not** accept H*

1

(b) litmus paper / Universal Indicator paper / pH paper

allow any suitable named indicator

1

bleached / turns white **or** loses its colour

*do **not** accept bleached cloth / leaves etc.*

allow second mark unless incorrect indicator given

allow starch iodide paper (1)
goes black / blue black (1)

allow potassium iodide solution (1) goes brown / orange / black precipitate (1)

1

(c) because they have a negative charge **or** opposite charges attract

accept (because) it is Cl^-
*accept chlorine, Cl **or** chlorine ions has a negative charge*

*do **not** accept Cl^- on its own*
*do **not** accept Cl_2 o.e. has negative charge*

1

(d) kill bacteria / germs, etc. **or** sterilise / disinfect

accept destroys bacteria etc.
ignore clean / purify water (owtte)
*do **not** accept just gets rid of bacteria*

1

(e) hydroxide (ion)

accept OH^-

1

[6]

Q22.

(a) (propanone) has a low(er) boiling point

***or** water has a high(er) boiling point **or** water evaporates slow(er)*

or (propanone) evaporates fast(er) owtte

allow propane / solution / it

*allow evaporates at lower temperature **or** boils quicker*

ignore density / reactivity / melting point

1

(b) (i) 0.29

*ignore + **or** –*

ignore units

1

(ii) any **two** sensible suggestions eg:

- weighing error
  *accept human error **or** inaccurate measurements*
- (copper) lost during washing owtte
  allow different washing of electrodes
- (copper) lost during electrolysis / reaction owtte
- electrodes not completely dry
- impurities in the electrode
- copper falling off when removing electrode / copper from cell

ignore timing errors

ignore 'fair test'

ignore sludge

ignore gases produced

2

(c) any **four** from:

- impure copper is anode / positive (electrode)
- pure copper is cathode / negative (electrode)
- copper sulfate solution **or** any soluble copper salt in solution
- copper loses electrons **or** copper is oxidised(*)
- copper forms positive ions / particles(*)

*(*)as alternative to these two points $Cu \rightarrow Cu^{2+} + 2e^-$ = **2** marks*

- copper gains electrons **or** copper reduced at negative electrode
  or *$Cu^{2+} + 2e^- \rightarrow Cu$ at negative electrode*
- copper attracts to / collects at negative electrode
- sludge / impurities collect at the bottom owtte
  *allow sludge left behind **or** sludge left in solution **or** impurities separated from copper*
- impurities not attracted to electrode
  ignore get rid of impurities

4

Q23.

(a) $Al^{3+} + \mathbf{3}\ e^- \rightarrow Al$
allow multiples

1

(b) sodium is more reactive than aluminium

1

(c) water (molecules) break down

1

(to) produce (H^+ and) OH^- (ions)

1

(so) OH^- (ions) are attracted / move to the positive electrode

1

(where) OH^- (ions) are discharged / oxidised to give oxygen (molecules)
allow (where) OH^- (ions) lose electrons to give oxygen (molecules)

1

allow hydroxide ions for OH^- throughout

(d) (change)
use measuring cylinders (instead of test tubes)
allow (inverted) burettes for measuring cylinders
allow gas syringes for measuring cylinders

1

(reason)
because there is a scale (on the measuring cylinders)
allow measuring cylinder(s) measure volume

1

(e) 10 cm^3

1

[9]

Q24.

(a) electrolysis uses electricity to produce a chemical reaction

allow voltage for electricity

allow potential difference for electricity

allow (electrical) current for electricity

allow electrolysis uses electricity to decompose a compound / electrolyte

1

(but) cells use a chemical reaction to produce electricity

1

(b) $2Br^- \rightarrow Br_2 + 2e^-$

allow multiples

*allow **1** mark for Br_2 **and** e^-*

2

(c)

Salt solution	**Product at positive electrode**	**Product at negative electrode**
(copper nitrate)	oxygen (1)	(copper)
(potassium iodide)	iodine (1)	hydrogen (1)

1
2

(d) filter the mixture

1

wash and dry the copper / residue

1

weigh the copper collected

1

add to the increase in mass of the electrode

1

(e) (for given current) straight line through the origin

allow (for given current) when time doubles, mass doubles

1

(f) (for given time) when current doubles, mass doubles with supporting data

1

(g) copper ions are discharged (from the solution)

allow the solution becomes less concentrated

allow copper ions are removed (from the solution)

allow copper ions are used up (from the solution)

1

(h) (number of moles = $\frac{0.24}{63.5}$ =)

3.78×10^{-3} **or** 0.00378

1

(number of atoms =)
$0.00378 \times 6.02 \times 10^{23}$

allow correct use of an incorrectly calculated number of moles

1

$= 2.28 \times 10^{21}$

allow a correct evaluation to 3 significant figures of an incorrect expression which involves only a mass from the graph, the A_r of copper and the Avogadro constant

1

[17]

Q25.

(a) reduction

1

(b) carbon is less reactive than aluminium

1

(c) aluminium (ions) / they are positively charged

they = aluminium ions
ignore particle names
accept aluminium (ions) / they are cations
allow aluminium (ions they have an opposite charge

1

so they are attracted **or** they move towards the negative electrode

OR

aluminium (ions) / they need to gain electrons (1)

which come from the negative electrode (1)

*if no other marks awarded allow 'opposites attract' for **1** mark*

1

(d) aluminium has a low density

1

aluminium is resistant to corrosion

1

(e) **advantage** less carbon dioxide is produced

1

disadvantage used aluminium cans have to be collected and transported

1

[8]

Q26.

(a) (i) current / charge couldn't flow

allow could not conduct (electricity)

1

because the ions / particles couldn't move

*do **not** accept electrons/ molecules / atoms*

or

(salt) needs to be molten / (1) dissolved (to conduct electricity)

so that the ions / particles can move (1)

*do **not** accept electrons / molecules / atoms*

1

(ii) he had status

*accept he had authority **or** experience*

or

he had evidence / proof

accept the experiment could be repeated

1

(b) hydrogen / H_2

*do **not** allow hydrogen ions*

1

the ions are positive

accept because opposite (charges) attract

1

potassium is more reactive (than hydrogen)

accept potassium ions are less easily discharged (than hydrogen)

***or** potassium ions are less easily reduced (than hydrogen)*

1

(c) (i) gain electron(s)

*accept fully balanced correct equation for **2** marks*

1

one electron

*if no other marks awarded allow (potassium ions) reduced for **1** mark*

1

(ii) $2\ Cl^- \rightarrow Cl_2 + \mathbf{2e^-}$

must be completely correct, including charge on electron

accept correct multiples

1

(iii) 2, 8, 8

accept any combination of dots, crosses, "e" or any other relevant symbol

ignore any charges if given

1

[10]

Q27.

(iii) 210 (tonnes)

*award **3** marks for the correct answer with or without working*

allow ecf for arithmetical errors

*if answer incorrect allow up to **2** marks for any of the steps below:*

160 → 112

300 → 112 / 160 × 300

or

moles Fe_2O_3 = 1.875 (× 10^6) or 300 / 160

moles of Fe = 3.75 (× 10^6) or 2 × moles Fe_2O_3

mass Fe = moles Fe × 56

105 (tonnes) scores 2 (missing 1:2 ratio)

420 (tonnes) scores 2 − taken M_r of iron as 112

3

(b) (i) aluminium is more reactive than carbon **or** carbon is less reactive than aluminium

must have a comparison of reactivity of carbon and aluminium

accept comparison of position in reactivity series.

1

(ii) (because) aluminium ions are positive

ignore aluminium is positive

1

and are attracted / move / go to the negative electrode / cathode

1

where they gain electrons / are reduced / $Al^{3+} + 3e^- \rightarrow Al$

accept equation or statements involving the wrong number of electrons.

1

(iii) (because) the anodes **or** (positive) electrodes are made of carbon / graphite

1

oxygen is produced (at anode)

1

which reacts with the electrodes / anodes

*do **not** accept any reference to the anodes reacting with oxygen from the air*

*equation $C + O_2 \rightarrow CO_2$ gains **1** mark (M3)*

1

[13]

Q28.

(a) (zinc has) lost electron(s)

accept loss of electrons

1

(b) copper is the least reactive

1

because it gave the most negative voltage when it was metal 2
or
it gave the biggest voltage with chromium
or
it gave the most positive voltage when it was metal 1

1

(c) −0.7 V

1

The voltage with chromium and copper is 1.2

accept use of other cell pairings such as tin with copper and tin with iron

1

The voltage with chromium and iron is 0.5 and copper is less reactive (than iron)

1

(d) hydrogen + oxygen = water

1

(e) $H_2 \rightarrow 2H^+ + 2e^-$

1

$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

1

[9]

Q29.

(a) CrO_4^{2-} / chromate ions moved to the positive electrode

allow anode for positive electrode

allow yellow (coloured) ions moved to the positive electrode

1

(because) opposite charges attract

allow (because) negative ions are attracted to the positive electrode

1

(b) water

ignore copper chromate solution

1

(c) copper ions gain two electrons

allow Cu^{2+} for copper ions

*allow **1** mark for copper ions gain electrons*

or

*allow **1** mark for copper ions are reduced*
*do **not** accept copper ions are oxidised*

2

(to) form copper (atoms)

allow Cu for copper (atoms)

the equation:
$Cu^{2+} + 2e^- \rightarrow Cu$
*scores **3** marks*

1

(d) (negative electrode) hydrogen

allow H_2

1

(positive electrode) iodine

allow I_2

1

[8]

Q30.

(a) mixture has a lower melting point (than aluminium oxide)

allow cryolite lowers melting point (of aluminium oxide)

ignore boiling point

*do **not** accept cryolite is a catalyst*

1

(so) less energy needed

ignore cost

1

(b) aluminium ions gain electrons

1

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

allow multiples
*allow **1** mark for an unbalanced equation containing correct species*

2

(d) the electrode reacts with oxygen

1

the electrode is carbon / graphite

1

(so) carbon dioxide is produced

allow (so) the electrode / carbon / graphite is used up
allow (so) the electrode / carbon / graphite is burned away

ignore (so) the electrode / carbon / graphite is worn away ignore (so) the electrode / carbon / graphite is corroded

1

(f) hydrogen (gas) would be produced (instead of sodium)

1

(because) sodium is more reactive than hydrogen

1

Q31.

(a) (i) cryolite

1

(ii) lower the melting point of the aluminium oxide

1

(b) (i) opposite charges **or** oxide ions are negative

1

attract

1

(ii) carbon

1

(iii) <u>reacts</u> with oxygen **or** forms carbon dioxide

accept burns

1

Q32.

(a) (i) was well qualified

1

(ii) check the results of the experiment

1

(b) (i) cannot move

1

(ii) melt it / make it a liquid

allow heat it

allow dissolve (in water) / make a solution

1

(iii) they are positive

*allow opposites attract **or** opposite charges*

1

(iv) atoms

1

[6]

Q33.

(a) positive

*accept + **or** +ve **or** plus*

1

(b) chlorine

1

(c) (i) hydroxide

Any indication of hydro…

1

(ii) destroys / damages / dissolves (owtte) the hair / follicle / root

allow burns / reacts with the hair

ignore incorrect name of compound

1

[4]

Q34.

(a) cannot move

1

(b) (i) a positive charge

1

(ii) atoms

1

[3]

Q35.

(a) electrical

1

(b) using hydrogen saves petrol / diesel / *crude oil*

allow crude oil is non-renewable

ignore hydrogen is renewable

1

using hydrogen (in fuel cells) does not cause pollution

accept no carbon dioxide produced

allow less carbon dioxide produced

allow hydrogen produces <u>only</u> water

1

(c) (i) (–)486

*correct answer with or without working gains **3** marks*

if answer is incorrect:

*(2 × 436) + 498 **or** 1370 gains **1** mark*

*4 × 464 **or** 1856 gains **1** mark*

*correct subtraction of ecf gains **1** mark*

3

(ii) products lower than reactants

1

reaction curve correctly drawn

1

activation energy labelled

1

[9]

Q36.

(a) the chemical reaction is reversible

1

(b) any **two** from:
- type of electrode
- electrolyte
- concentration of electrolyte
- temperature

2

(c) $H_2 + \mathbf{2}OH^- \rightarrow \mathbf{2}H_2O + \mathbf{2}\ e^-$

allow multiples

1

(d) contains OH^- ions

1

(e) (bonds broken)

((6 × 412) + (2 × 360) + (2 × 464) + (3 × 498)) = 5614

1

(bonds made)
((4 × 805) + (8 × 464)) = 6932

1

(overall energy change)
(6932 − 5614) = −1318 (kJ / mol)

allow ecf from marking point 1 and / or marking point 2

1

*an answer of 1318 (kJ / mol) scores **3** marks*

[8]

Q37.

(a) (zinc-carbon) cheap(est)

1

(alkaline) long(est) lasting

1

(nickel-metal hydride) rechargeable

allow do not have to be thrown away

1

(b) any **one** from:

- (metal / alkaline waste) can be toxic / harmful / corrosive

  allow (batteries) can ignite / explode
- (metal / alkaline waste) could cause pollution in landfill sites
- recycling would save resources

  ignore dangerous

1

(c) copper and iron

1

(d) any **one** from:
- temperature (of electrolyte / solution)
- concentration (of electrolyte / solution)

ignore type of electrode / electrolyte

allow size / mass / length of electrode

allow surface area of electrode

allow distance between electrodes

allow volume of solution / electrolyte

1

(e) hydrogen

allow H_2

1

oxygen

allow O_2

1

[8]

Q38.

(a) copper, zinc, sodium chloride solution

1

(b) a reactant is used up

allow the reaction stops

allow electrolyte / electrode / ions / metal / metal hydroxide / alkali for reactant

1

(c) the reaction is not reversible

1

(d) $2H_2 + O_2 \longrightarrow 2H_2O$

allow fractions / multiples

*allow **1** mark for O_2*

2

(e) **Level 3:** A judgement, strongly linked and logically supported by a sufficient range of correct reasons, is given.

5–6

Level 2: Some logically linked reasons are given. There may also be a simple judgement.

3–4

Level 1: Relevant points are made. This is not logically linked.

1–2

No relevant content

0

Indicative content

reasons why fuel cells could be judged as better

from the table	from other knowledge
• time for refuelling a fuel cell is faster than recharging **or** a fuel cell does not need to be recharged • a fuel cell has a greater range	• hydrogen can be renewable if made by electrolysis using renewable energy • lithium-ion batteries can catch fire • produces only water **or** no pollutants produced • lithium-ion batteries may release toxic chemicals on disposal • lithium-ion batteries (eventually cannot be recharged so) have a finite life

reasons why the lithium-ion battery could be judged as better

from the table	from other knowledge
• lithium-ion uses energy more efficiently • cost of lithium-ion car much less • cost of recharging much less than refuelling with hydrogen	• hydrogen is often made from fossil fuels so is not renewable • charging points are more widely available than hydrogen filling stations • hydrogen takes up a lot of space **or** is difficult to store • hydrogen can be highly flammable / explosive • no emissions produced • (catalyst in the hydrogen fuel-cell eventually becomes poisoned so) have a finite life

[11]

Q39.

(a) any **two** from:

- temperature (of solution)
  ignore room temperature
- concentration of electrolyte / solution
- compound / ions in electrolyte / solution

allow volume of electrolyte / solution

allow size of electrode

allow distance between electrodes

*do **not** accept electrode **X** unqualified*
*do **not** accept (measured) voltage*

2

(b) order:
(most reactive) magnesium
cobalt
nickel
tin
copper
(least reactive) silver

*allow **1** mark for magnesium, cobalt, nickel, tin in order at top*
*allow **1** mark for copper and silver in order at the bottom*

2

justification:
the higher the (positive) voltage, the more reactive (the metal)

allow the most reactive (metal) has the highest voltage

1

silver has a negative voltage because silver is less reactive than copper

1

(c) magnesium and tin

1

(d) (in a fuel cell) hydrogen is oxidised (to produce water)

allow (in a fuel cell) hydrogen reacts with oxygen (to produce water)

1

water is produced / released as gas / vapour / steam

*if no other mark awarded, allow **1** mark for fuel cells produce water*

1

[9]