

Electrolysis – Moderate to Challenging

Mark Scheme



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1. Electrolysis is the process of using a direct electric current to break down an ionic compound, either molten or in aqueous solution, into its constituent elements.

- a. The figure below shows a circuit for the electrolysis of aqueous and molten lithium chloride.
At which electrode is hydrogen formed?

B – is the correct answer.	1 mark
	Total: 1 mark

- b. Which figure below shows the direction of movement of ions and electrons during the electrolysis of molten sodium chloride?

B – is the correct answer.	1 mark
	Total: 1 mark

- c. During the electrolysis of aqueous copper(II) sulfate with copper electrodes, copper(II) ions are reduced at the negative electrode. What is a balanced half-equation to show this reduction.

B – is the correct answer.	1 mark
	Total: 1 mark

- d. The figure below shows the electrolysis of hydrochloric acid and potassium fluoride.
At which electrodes does hydrogen gas form?

B – is the correct answer.	1 mark
	Total: 1 mark

- e. Molten aluminium oxide is electrolysed to produce aluminium.
What is the half-equation for the reaction that occurs at the anode?

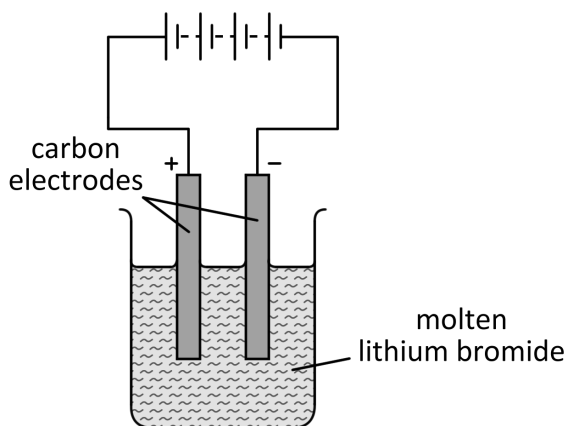
C – is the correct answer.	1 mark
	Total: 1 mark

- f. The figure below shows the electrolysis of sodium fluoride. Fluorine is produced at P and sodium at Q.
Which labels are correctly identified?

A – is the correct answer.	1 mark
	Total: 1 mark

(Total for Question 1 is 6 marks)

2. The diagram shows the apparatus used for the electrolysis of molten lithium bromide (LiBr).



- a. Explain why the lithium bromide must be **molten** for this electrolysis to occur.

An explanation to include:	
In the solid state, the ions are in fixed positions / not free to move.	1 mark
Do not accept: no free electrons or any answer that refers to electrons.	
When molten, the ions are free to move (and carry the charge).	1 mark
Accept: mobile ions.	
	Total: 2 marks

- b. Name the product formed at the anode.

Bromine. Accept: Br ₂	1 mark
	Total: 1 mark

- c. Write the balanced half-equation for the reaction taking place at the cathode.

$\text{Li}^+ + \text{e}^- \rightarrow \text{Li}$	
Award 1 mark for correct reactants.	1 mark
Award 1 mark for the electron on the correct side of the reaction.	1 mark
	Total: 2 marks

- d. The carbon electrodes are described as **inert**.
What is meant by the term 'inert' in this context?

The electrodes <u>do not react</u> / take part in the reaction.	1 mark
Accept: unreactive.	
	Total: 1 mark

(Total for Question 2 is 6 marks)

3. An impure copper foil can be purified by electrolysis.

Explain all three observations. In your answer, you should refer to the processes occurring at each electrode and the relative reactivity of the metals.

Marking guidance		
Level	Marks	Descriptor
Level 1	1 - 2	A simple statement is made that explains one of the observations. The answer may describe copper moving from one electrode to the other but with little or no detail about the process. The explanation may be confused or contain significant errors.
Level 2	3 - 4	A good explanation is given that covers at least two of the observations correctly. The processes at the anode and cathode are described, but the explanation may lack detail or contain minor errors. The explanation for the sludge may be simplistic (e.g., 'the impurities fall off') without reference to reactivity. The answer shows a good understanding but is not fully developed.
Level 3	5 - 6	A detailed and coherent explanation of all three observations is given. The processes at both the anode and cathode are correctly described in terms of oxidation/reduction of copper atoms and ions. The formation of the sludge is correctly linked to the lower reactivity of gold and platinum compared to copper. The answer is well-structured and uses appropriate scientific terminology throughout.

Indicative content:	
Explanation for Observation 1: The mass of the impure copper anode decreases... - The impure anode is positive. - At the anode, copper atoms lose electrons / are oxidised. - They form positive copper(II) ions (Cu^{2+}) which enter the solution. - The half-equation is: $\text{Cu(s)} \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{e}^-$ - As the solid metal turns into ions in solution, the anode dissolves and its mass decreases. Explanation for Observation 2: The mass of the pure copper cathode increases... - The pure cathode is negative. - Positive copper(II) ions (Cu^{2+}) from the electrolyte are attracted to the cathode. - At the cathode, the copper(II) ions gain electrons / are reduced. - They form copper atoms, which deposit as a layer of pure metal on the cathode. - The half-equation is: $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu(s)}$ - As solid metal is added to the cathode, its mass increases. Explanation for Observation 3: A solid sludge containing silver and platinum collects... - Silver and platinum are present as impurities in the anode. - Silver and platinum are less reactive than copper. - This means they are more difficult to oxidise / lose electrons than copper. - As the more reactive copper atoms around them are oxidised and dissolve, the unreacted silver and platinum atoms fall to the bottom of the beaker.	
	Total: 6 marks

(Total for Question 3 is 6 marks)

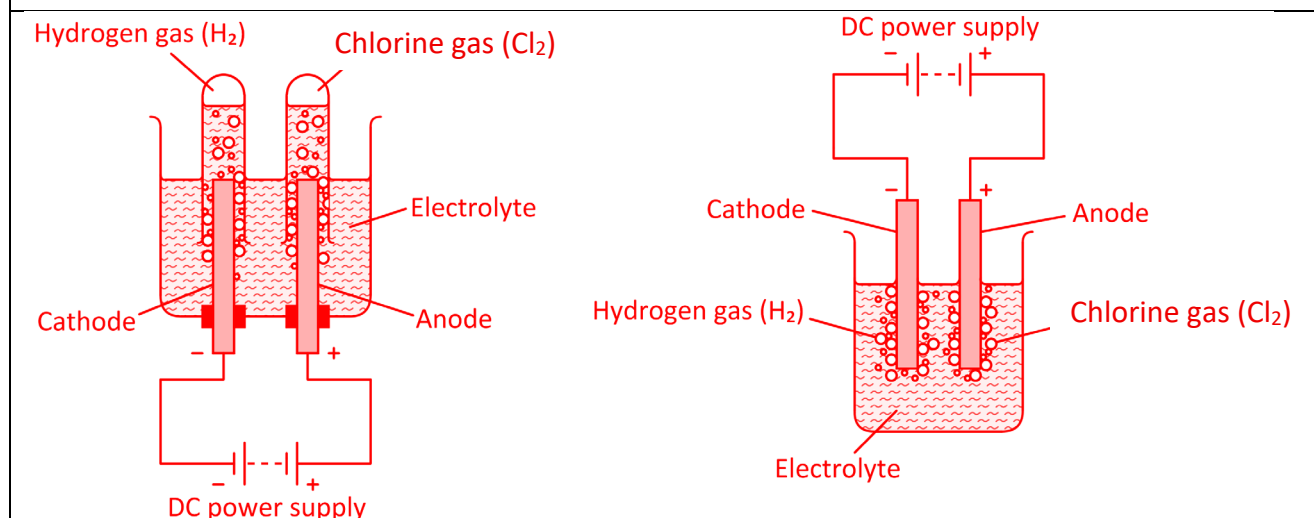
4. A student was conducting an electrolysis of aqueous zinc chloride (ZnCl_2).

a) Draw a **labelled diagram** of the apparatus that the student could use to carry out the electrolysis of aqueous zinc chloride (ZnCl_2) using graphite electrodes.

On your diagram, you must include and clearly label:

- The anode and the cathode.
- The DC power supply, with the correct polarity (+ and –).
- The electrolyte.
- The named gaseous product formed at each electrode.

Marking note: students could produce either one of these diagrams as both are a correct representation of the electrolysis in this questions.



Beaker with two electrodes (labelled 'graphite electrodes' or 'electrodes') shown in a liquid.	1 mark
Electrolyte is correctly labelled as electrolyte or aqueous zinc chloride (ZnCl_2).	1 mark
A DC power supply is shown connected to the electrodes.	1 mark
Electrodes are correctly labelled 'anode' and 'cathode' with correct polarity (+ for anode, - for cathode).	1 mark
Gas at the anode (+) is correctly labelled as Chlorine (Cl_2).	1 mark
Gas at the cathode (–) is correctly labelled as Hydrogen / H_2	1 mark
	Total: 6 marks

b) A different electrolysis of molten zinc chloride was conducted by another student. Explain why it must be molten to be electrolysed.

An explanation to include:	
In the solid state, the ions are in fixed positions / not free to move.	1 mark
Must refer to ions. Accept: ions are held in a lattice.	
When molten, the ions are free to move (and carry the charge).	1 mark
Accept: mobile ions.	
	Total: 2 marks

c) At the anode, a colourless gas is produced.

i. Name the colourless gas produced.

Chlorine. Accept: Cl₂	1 mark
	Total: 1 mark

ii. Write the half-equation for the formation of this gas.

$2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$	
Award 1 mark for correct species on the correct sides.	1 mark
Award 1 mark for correct balancing of charge.	1 mark
	Total: 2 marks

iii. State the name of the process that occurs at the anode and define it in terms of electrons.

Oxidation.	1 mark
Loss of electrons	1 mark
	Total: 2 marks

d) A silvery substance is formed at the cathode.

i. Write the half-equation for the formation of the product at the cathode.

$\text{Zn}^{2+} + 2\text{e}^- \rightarrow \text{Zn}$	
Award 1 mark for correct species on the correct sides.	1 mark
Award 1 mark for correct balancing of charge.	1 mark
	Total: 2 marks

ii. The melting point of zinc is 420 °C and the melting point of zinc chloride is 290 °C.
Use this information to predict and explain the physical state of the zinc produced.

Prediction: Solid	1 mark
Explanation: Because the operating temperature (350 °C) is below the melting point of zinc (420 °C).	1 mark
	Total: 2 marks

e) In one experiment, 13.0 g of zinc was produced at the cathode.

Calculate the volume of gas, in dm³, produced at the anode.

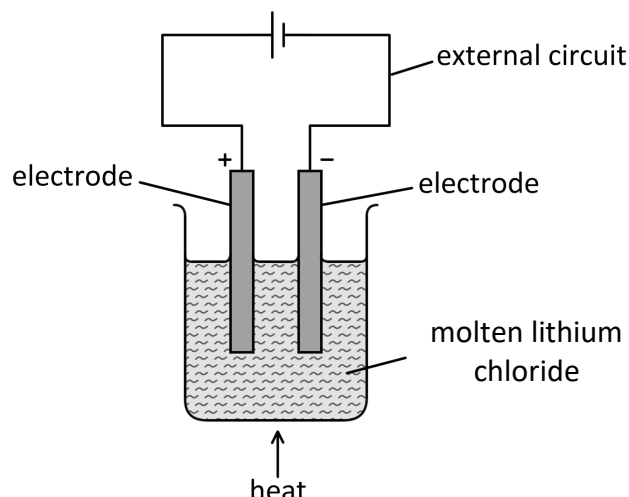
Moles of Zn = mass ÷ A _r = 13.0 ÷ 65 = 0.2 mol	1 mark
Use the half-equations to find the moles of electrons. From half-equations, mole ratio of Zn : Cl ₂ is 1:1.	1 mark
Therefore, moles of Cl ₂ = 0.2 mol	1 mark
Volume of Cl ₂ = moles × 24 = 0.2 × 24 Volume = 4.8 dm ³	1 mark
	Total: 4 marks

f) This experiment should be carried out in a fume cupboard. Suggest why.

Chlorine (gas) is toxic / poisonous / harmful.	1 mark
	Total: 1 mark

(Total for Question 4 is 22 marks)

5. The diagram shows the apparatus used for the electrolysis of molten lithium chloride (LiCl). When the current is switched on, a pale green gas is observed at the positive electrode and a silvery liquid is observed at the negative electrode.



- a) Name the product formed at:

- i. The anode.

Chlorine.	Accept: Cl ₂	1 mark
		Total: 1 mark

- ii. The cathode.

Lithium.	Accept: Li	1 mark
		Total: 1 mark

- b) Write a balanced half-equation for the reaction occurring at the positive electrode (anode).

$2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$	
Award 1 mark for correct species on the correct sides, including balancing of atoms.	1 mark
Award 1 mark for correct balancing of charge.	1 mark
Total: 2 marks	

- c) Explain why the substance formed at the negative electrode is a good conductor of electricity. Refer to its structure and bonding in your answer.

An explanation to include the following:	
Lithium is a metal / has a giant metallic structure / consists of a lattice of positive ions.	1 mark
It has delocalised electrons / a 'sea' of free electrons.	1 mark
These electrons are mobile / free to move and carry charge (through the structure).	1 mark
Total: 3 marks	

- d) The gas produced at the positive electrode is hazardous.

- i. State **one** safety precaution that should be taken.

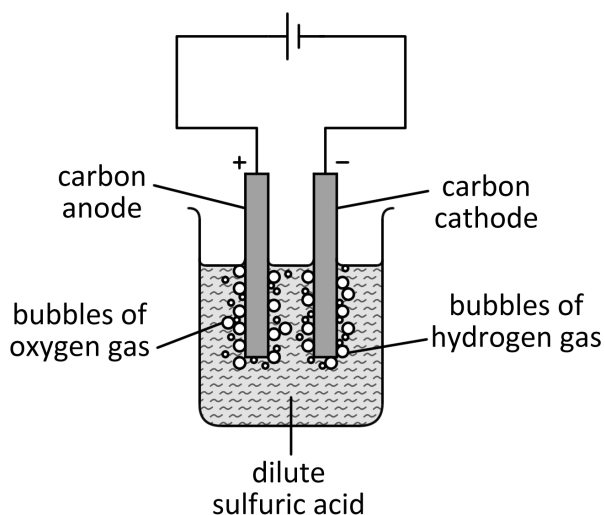
Carry out the experiment in a fume cupboard.	
Accept: ensure the room is well-ventilated.	
Total: 1 mark	

ii. Describe the positive test to identify this gas.

A description to include:	
Place damp / moist litmus paper into the gas.	1 mark
The litmus paper turns red and is then bleached white or turns white.	1 mark
	Total: 2 marks

The diagram below shows the electrolysis of dilute sulfuric acid.

Hydrogen is formed at the cathode, oxygen at the anode and the concentration of sulfuric acid increases as the electrolysis is occurring.



e) The ions present in the dilute acid are $\text{H}^+(\text{aq})$, $\text{OH}^-(\text{aq})$ and $\text{SO}_4^{2-}(\text{aq})$.

i. Write an equation for the reaction at the cathode.

$2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$	
Award 1 mark for correct species on the correct sides, including balancing of atoms.	1 mark
Award 1 mark for correct balancing of charge.	1 mark
	Total: 2 marks

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

$4\text{OH}^-(\text{aq}) \rightarrow \text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^-$	
Award 1 mark for the correct value of H_2O .	1 mark
Award 1 mark for the correct number and charge on electrons.	1 mark
	Total: 2 marks

iii. Explain why the concentration of the sulfuric acid increases as the electrolysis occurs.

Water is removed from the solution (as H_2 and O_2).	1 mark
	Total: 1 mark

(Total for Question 5 is 15 marks)