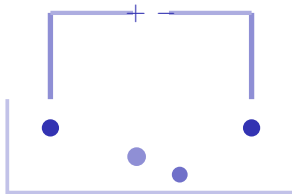


Electrochemistry

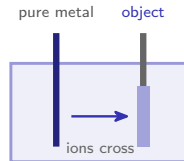
IGCSE Chemistry ■ Topic 4

IGCSE Chemistry



What we will cover

- 1 What electrolysis is
- 2 The electrolytic cell
- 3 Products at each electrode
- 4 Half-equations
- 5 Electroplating
- 6 Hydrogen fuel cells



electroplating



What electrolysis is, and what it needs

Electrolysis splits an ionic compound by passing a current through it.

- it works only when the substance is **molten or dissolved**, because only then are the **ions** free to move and carry the charge
- a **solid** ionic compound cannot be electrolysed at all – its ions are locked in place

That single fact answers a whole family of questions: "why does solid lead bromide not conduct?"

The electrolytic cell

Two electrodes in an **electrolyte** . The **cathode** is negative (cations go there and gain electrons – reduction). The **anode** is positive (anions lose electrons – oxidation).

Products at each electrode

cathode (−) $\longrightarrow$ metal or hydrogen

anode (+) $\longrightarrow$ non-metal

Cathode: metals & **hydrogen** . **Anode:**
non-metals .

molten PbBr_2 : lead | bromine

conc. $\text{NaCl}(\text{aq})$: hydrogen |
chlorine

dilute H_2SO_4 : hydrogen | oxy-
gen

What is formed at each electrode

the simple rule

metals and hydrogen go to the cathode; non-metals go to the anode

molten compounds

only two ions are present, so the products are always the metal and the non-metal

concentrated NaCl solution

hydrogen at the cathode, chlorine at the anode

dilute sulfuric acid

hydrogen at the cathode, oxygen at the anode

copper sulfate with copper electrodes

copper deposits at the cathode and dissolves from the anode – purification

why it varies

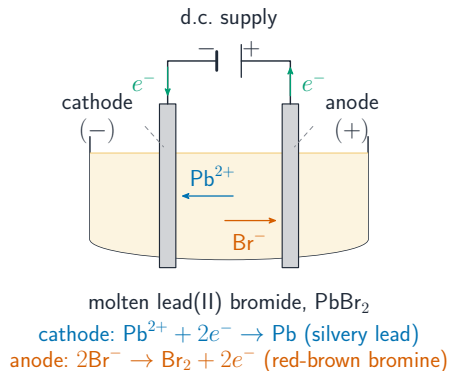
in solution, water can be **decomposed** too, so what wins depends on concentration and on the ions present

The **electric current** is carried by **ions moving** in the electrolyte and by **electrons** in the wires – never by electrons through the liquid.

How the charge moves

- **Electrons** move through the wires (the **external circuit**) from the power supply.
- At the cathode, positive ions gain electrons. Gaining electrons is **reduction** .
- At the anode, negative ions lose electrons. Losing electrons is **oxidation** .
- Inside the electrolyte, the ions move: positive ions go to the cathode and negative ions go to the anode.

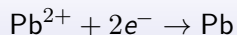
How the charge moves, in detail



At the cathode, positive ions gain electrons.

Half-equations

cathode – reduction (gain e^-)

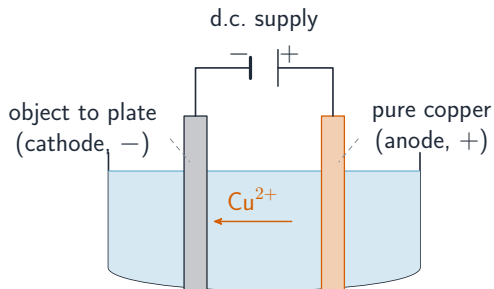


anode – oxidation (lose e^-)



Electrons travel the **wires**; ions travel the **electrolyte** – positive to the cathode, negative to the anode.

Electroplating



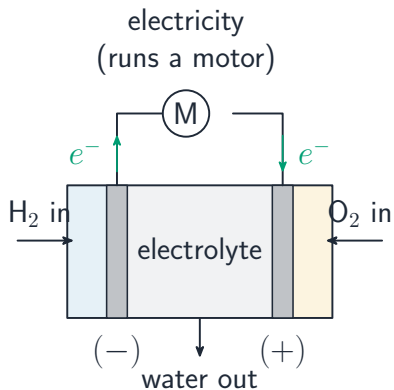
electrolyte: copper(II) sulfate solution
copper coats the object at the
cathode; the copper anode
slowly dissolves to replace it

Electroplating coats an object to
improve looks & resist **corrosion** .

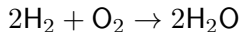
- object = the **cathode**
- plating metal = the **anode**
- electrolyte = that metal's ions



Hydrogen–oxygen fuel cells



A **fuel cell** makes electricity directly; the only product is water.



Clean, but hydrogen is hard to store safely.

Fuel cell against petrol engine

main product

fuel cell: **water only**. Engine: carbon dioxide and **pollutants**

effect on air

fuel cell: **clean**. Engine: adds to air pollution

efficiency

fuel cell converts chemical energy to electricity **efficiently**; the engine loses much of it as heat

fuel storage

hydrogen is **hard and dangerous** to store – flammable, and needs high pressure. Petrol is easy

the source

hydrogen **may be made using fossil fuels**; petrol is made from crude oil

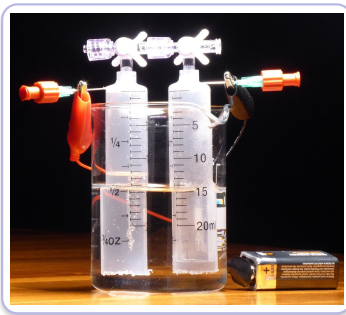
The fuel cell is clean *at the vehicle*. Whether it is clean overall depends entirely on how the hydrogen was made – and that is the evaluation mark.

Electrolysis



The set-up is an **electrolytic cell** : two **electrodes** dipping into the **electrolyte** – the molten or aqueous substance being broken up. The electrodes are usually **inert** , **platinum** or **graphite** , so they take no part in the reaction.

Electrolysis, continued



Electrolysis of water: gas bubbles off at each electrode and collects in the tubes above, with about twice as much hydrogen as oxygen

Exam tips

- At the **cathode** (negative) you get a metal or hydrogen; at the **anode** (positive) you get a non-metal. Positive ions move to the cathode, negative ions to the anode.
- A **molten** compound just gives its two elements. An **aqueous** solution can give something different (concentrated sodium chloride gives hydrogen and chlorine, not sodium).
- **Reduction** is *gain* of electrons (at the cathode); **oxidation** is *loss* of electrons (at the anode). Remember OIL RIG.
- In a **half-equation** the atoms and the charges must balance, with the electrons on the correct side: $\text{Pb}^{2+} + 2\text{e}^{-} \rightarrow \text{Pb}$ (cathode).
- To **electroplate** an object, make it the cathode, make the plating metal the anode, and use a solution containing ions of the plating metal.



Worked example – predicting electrolysis products

Give the products of electrolysis of concentrated aqueous sodium chloride with inert electrodes.

- Ions present: Na^+ , H^+ (cations) and Cl^- , OH^- (anions).
- Cathode (–): the **less reactive** cation is discharged. Na is more reactive than H $\Rightarrow$ **hydrogen**.
- Anode (+): the halide is **concentrated**, so it wins over $\text{OH}^- \Rightarrow$ **chlorine**.
- Na^+ and OH^- stay behind as sodium hydroxide solution.

Cathode = **reduction** (gain electrons), anode = **oxidation**. Dilute halide $\Rightarrow$ oxygen at the anode; concentrated $\Rightarrow$ the halogen.

Topic 4 – key takeaways

1

Electrolysis

splits ionic compounds; needs free ions

2

Electrodes

anode + (oxidation), cathode – (reduction)

3

Products

cathode: metals/H; anode: non-metals

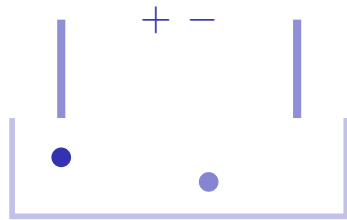
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Fuel cell

$\text{H}_2 + \text{O}_2$; water is the only product

Check yourself

- 1 Why must an electrolyte be molten or aqueous?
- 2 Which electrode is the anode: + or -?
- 3 What forms at the cathode in molten PbBr_2 ?
- 4 What is the only product of a hydrogen fuel cell?



Answers 1. so the ions are free to move 2. the positive (+) 3. lead 4. water