

Electrochemistry

IGCSE Chemistry 0620 · Topic 4 revision notes

Everything from the 4 lessons of this topic on a few pages: the key idea of each lesson, the diagram to remember, the points to learn and the traps examiners set. Read it, cover it, test yourself.

1. Electrolysis of molten compounds

3. Electroplating and refining copper

2. Electrolysis of aqueous solutions

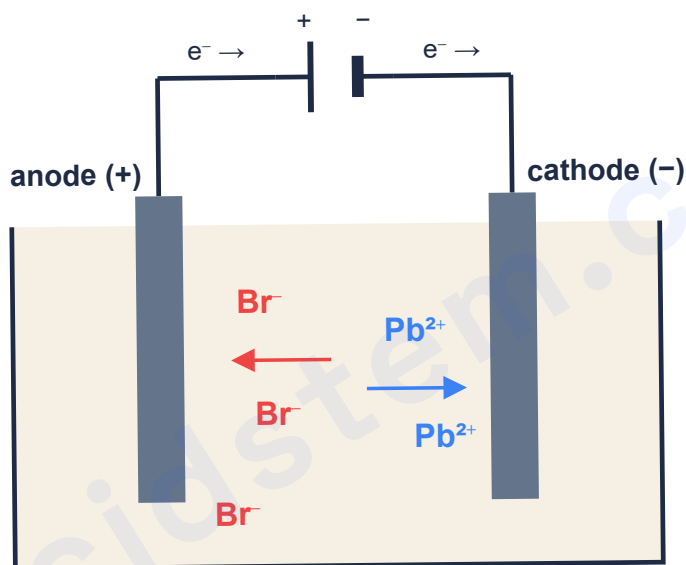
4. Hydrogen-oxygen fuel cells

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1 Electrolysis of molten compounds

Syllabus 4.1

Electrolysis is the decomposition of an ionic compound, when molten or in aqueous solution, by the passage of an electric current. The **electrolyte** is the liquid that conducts; the **anode** is the positive electrode and the **cathode** the negative electrode. In a molten binary compound, positive metal ions are attracted to the cathode and form the metal; negative non-metal ions are attracted to the anode and form the non-metal. Molten lead(II) bromide gives lead at the cathode and bromine at the anode.



molten lead(II) bromide: ions move in the liquid, electrons in the wires
brown bromine at the anode, molten lead at the cathode

Fig. 1: electrolysis of molten lead(II) bromide

PANCAKE: positive anode,
negative cathode.

- ✓ **Cations** (positive) go to the cathode (negative).
- ✓ **Anions** (negative) go to the anode (positive).
- ✓ **Molten binary compound:** metal at the cathode, non-metal at the anode.
- ✓ **Extended:** reduction at the cathode, oxidation at the anode.

Watch out!

Metals always form at the **cathode** and non-metals at the **anode** in a molten compound. Remember that opposite charges attract: positive metal ions go to the negative electrode. Also, a solid electrolyte does not conduct; if the question says the compound is solid, nothing happens until it melts.

2 Electrolysis of aqueous solutions

Syllabus 4.1

An aqueous solution also contains H^+ and OH^- ions from water. At the **cathode**, the metal forms only if it is less reactive than hydrogen (such as copper or silver); otherwise hydrogen gas forms. At the **anode**, a halogen forms from a concentrated halide solution; otherwise oxygen gas forms. So concentrated aqueous sodium chloride gives hydrogen at the cathode and chlorine at the anode, and dilute sulfuric acid gives hydrogen and oxygen.

cathode (-)

metal ion less reactive than hydrogen?

yes: the metal
(copper, silver)

no: hydrogen gas
(from Na^+ , K^+ , Mg^{2+} ... solutions)

anode (+)

concentrated halide (Cl^- , Br^- , I^-)?

yes: the halogen
(chlorine, bromine, iodine)

no: oxygen gas
(sulfates, nitrates, dilute halides)

inert electrodes (carbon or platinum) in an aqueous solution

Fig. 1: predicting the products at each inert electrode

Two rules, one per electrode.

- ✓ **Cathode:** metal only if less reactive than hydrogen; otherwise hydrogen.
- ✓ **Anode:** halogen from a concentrated halide; otherwise oxygen.
- ✓ **Tests:** hydrogen pops, oxygen relights a glowing splint, chlorine bleaches damp litmus.
- ✓ **Extended:** electrons on the left at the cathode, on the right at the anode.

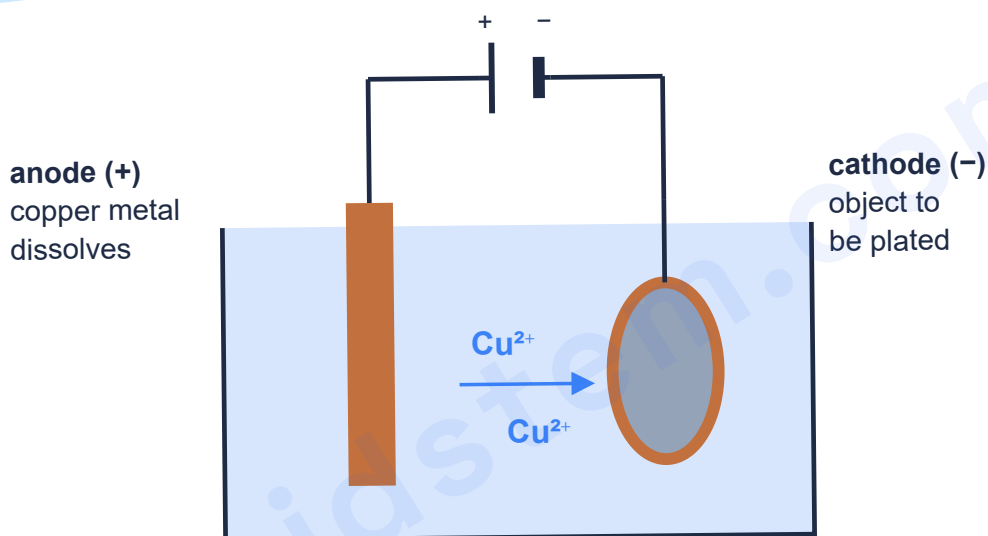
Watch out!

Sodium is **never** produced at the cathode from an aqueous solution: it is more reactive than hydrogen, so hydrogen gas is released instead. Sodium metal only forms when molten sodium chloride is electrolysed.

3 Electroplating and refining copper

Syllabus 4.1

In **electroplating** the object to be plated is the **cathode**, the plating metal is the **anode**, and the electrolyte is a solution containing ions of the plating metal. Metal ions gain electrons at the cathode and coat the object, while the anode dissolves to replace them. Metals are electroplated to improve appearance and to resist corrosion. **Extended:** copper is refined the same way, with an impure copper anode and a pure copper cathode in copper(II) sulfate solution.



electrolyte: copper(II) sulfate solution, contains ions of the plating metal
 $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$ at the object; the blue colour stays the same

Fig. 1: copper-plating an object

Object at the cathode.

- ✓ **Cathode:** object to be plated (or pure copper sheet).
- ✓ **Anode:** plating metal (or impure copper), which dissolves.
- ✓ **Electrolyte:** contains ions of the plating metal.
- ✓ **Extended:** copper electrodes keep the blue colour constant.

Watch out!

The object being plated must be the **cathode**. Metal ions are positive, so they are attracted to the negative electrode. Connect the object to the positive terminal and it dissolves instead of being coated.

4 Hydrogen-oxygen fuel cells

Syllabus 4.2

A **hydrogen-oxygen fuel cell** uses hydrogen and oxygen to produce electricity, with **water as the only chemical product**. The overall reaction is $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$. **Extended:** compared with a petrol engine, a fuel-cell vehicle produces no carbon dioxide or other pollutants at the point of use and is more efficient, but hydrogen is difficult to store, is often made using fossil fuels or electricity, and there are few refuelling stations.

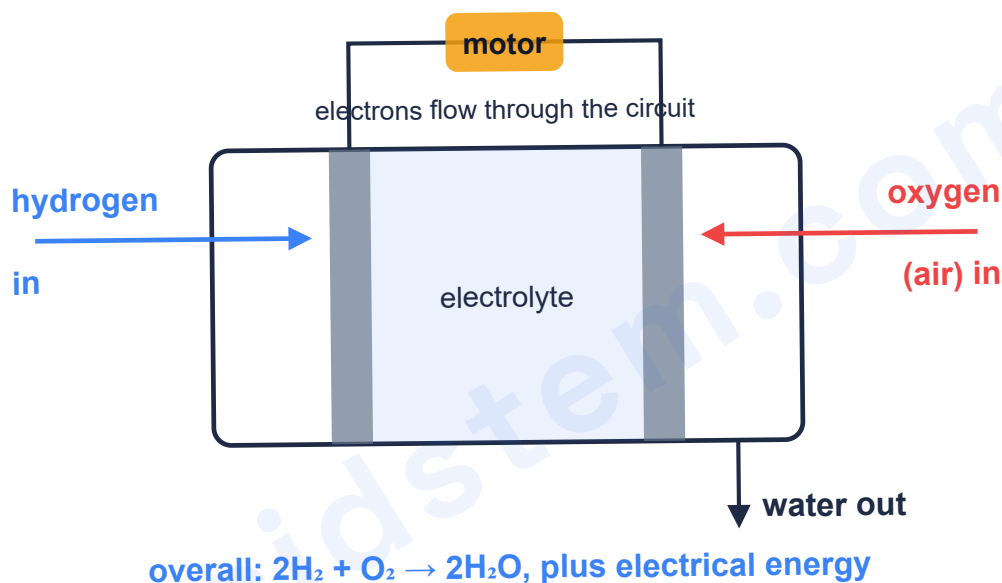


Fig. 1: a hydrogen-oxygen fuel cell driving a motor

Hydrogen in, water and electricity out.

- ✓ **Reactants:** hydrogen and oxygen.
- ✓ **Product:** water only; energy out as electricity.
- ✓ **For:** no CO_2 at the point of use, efficient, quiet.
- ✓ **Against:** storage, flammability, hydrogen production, few stations, cost.

Watch out!

"Fuel cells produce no pollution" is not quite right. The **vehicle** emits only water, but making the hydrogen can release carbon dioxide, for example when it is produced from methane or when the electricity for electrolysis comes from burning fossil fuels. Say "no carbon dioxide at the point of use".