Electrochemistry

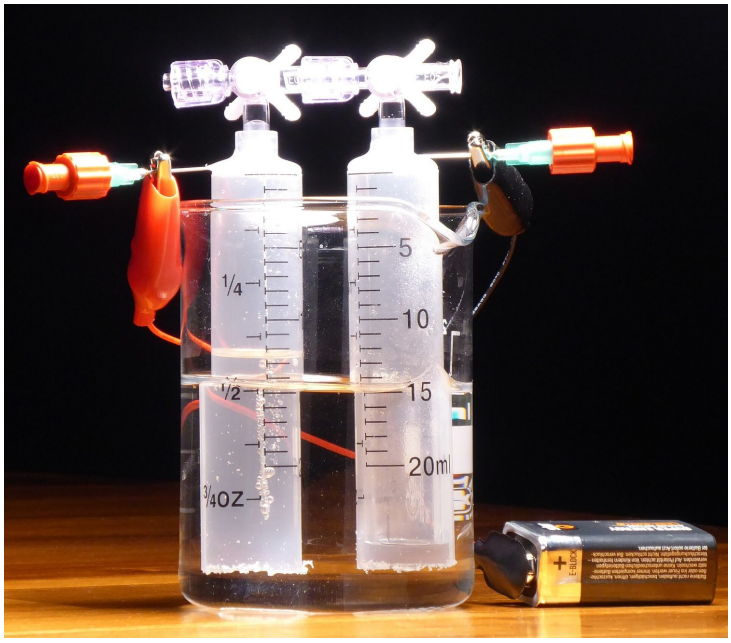
IGCSE Chemistry

Electrolysis

Electrolysis 电解 is the breaking down (**decomposition** 分解) of an **ionic compound** 离子化合物—when it is **molten** 熔融 or in **aqueous** 水溶液 solution —by passing an **electric current** 电流 through it.

An electrolysis cell splits a compound using an electric current.

It only works when the substance is molten or dissolved, because then the **ions** 离子 are free to move and carry the charge. A solid ionic compound cannot be electrolysed because its ions are locked in place.



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

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The electrolytic cell

The set-up is called an **electrolytic cell** 电解池. Two **electrodes** 电极 (solid conductors) dip into the **electrolyte** 电解质—the molten or aqueous substance being broken down.

- The **anode** 阳极 is the positive (+) electrode.
- The **cathode** 阴极 is the negative (−) electrode.

The electrodes are often **inert** 惰性 (they do not react), such as **platinum** 铂 or carbon/**graphite** 石墨.

What is formed at each electrode

There is a simple rule:

cathode (−) ⟶ metal or hydrogen

anode (+) ⟶ non-metal

Metals and hydrogen form at the cathode; non-metals at the anode

- **Metals** 金属 or **hydrogen** 氢气 are formed at the cathode.
- **Non-metals** 非金属 (other than hydrogen) are formed at the anode.

For aqueous solutions, the product can depend on whether the solution is **dilute** 稀 or **concentrated** 浓. Here are the three Core examples:

Electrolyte	At the cathode (−)	At the anode (+)
molten lead(II) bromide, $PbBr_2$	**lead** 铅 (silvery liquid)	**bromine** 溴 (red-brown vapour)
concentrated aqueous sodium chloride	hydrogen (bubbles of gas)	**chlorine** 氯气 (pale green gas)
dilute **sulfuric acid** 硫酸	hydrogen (bubbles of gas)	**oxygen** 氧气 (bubbles of gas)

Worked example. Predict the products of electrolysing **molten** zinc chloride, $ZnCl_2$. Because it is molten, only zinc ions and chloride ions are present - there is no water to complicate things. Zinc is a metal, so it forms at the **cathode**: Zn^{2+} ions gain electrons and silvery zinc appears. Chlorine is a non-metal, so it forms at the **anode**: pale green chlorine gas bubbles off. Always check the state first. A **molten** compound simply gives you its own two elements, while an **aqueous** one brings water into the competition - which is why concentrated sodium chloride solution gives hydrogen at the cathode rather than sodium.

How the charge moves

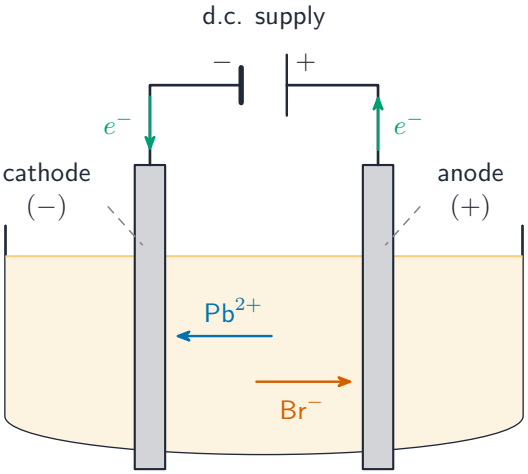
During electrolysis:

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

You can write a **half-equation** 半反应式 for each electrode. For molten lead(II) bromide:

$$Pb^{2+} + 2e^- \rightarrow Pb \quad \text{(cathode, reduction)}$$

$$2Br^- \rightarrow Br_2 + 2e^- \quad \text{(anode, oxidation)}$$



molten lead(II) bromide, $PbBr_2$

cathode: $Pb^{2+} + 2e^- \rightarrow Pb$ (silvery lead)

anode: $2Br^- \rightarrow Br_2 + 2e^-$ (red-brown bromine)

In molten lead(II) bromide, Pb^{2+} moves to the cathode and Br^- to the anode, where each is discharged

Electrolysis of copper(II) sulfate

The product at the anode depends on the electrode:

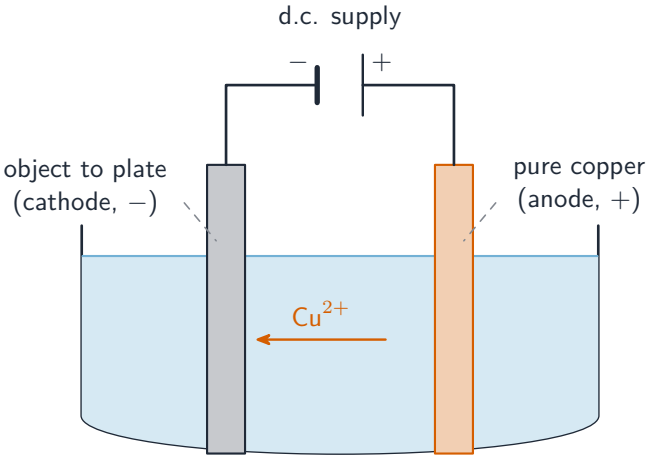
- With **inert** carbon electrodes: **copper** 铜 forms at the cathode and oxygen forms at the anode. The blue colour of the solution slowly fades as copper is removed.
- With copper electrodes: copper forms at the cathode, while the anode itself dissolves into the solution. The blue colour stays the same. This is used to purify copper.

Electroplating

Electroplating 电镀 means covering a metal object with a thin layer of another metal. This improves its appearance and its resistance to **corrosion** 腐蚀 (rusting and wearing away).

To electroplate an object:

- the object to be coated is made the **cathode**;
- the plating metal is made the **anode**;
- the electrolyte is a solution containing ions of the plating metal.



electrolyte: copper(II) sulfate solution

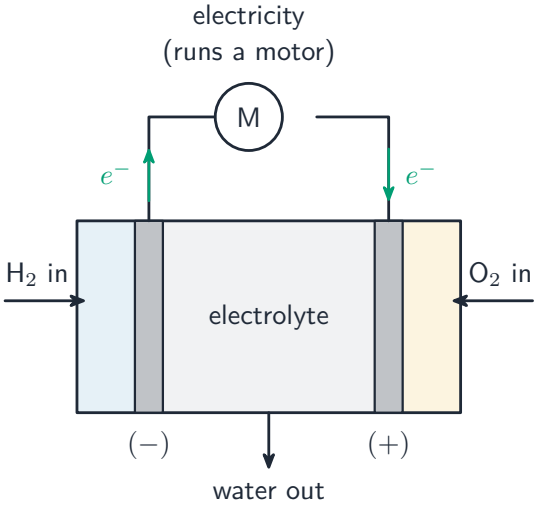
copper coats the object at the cathode; the copper anode slowly dissolves to replace it

To electroplate, make the object the cathode and the plating metal the anode, in a solution of the plating-metal ions

Hydrogen–oxygen fuel cells

A **fuel cell** 燃料电池 uses hydrogen and oxygen to make electricity directly. The only chemical product is water.

$$2H_2 + O_2 \rightarrow 2H_2O$$



overall: $2H_2 + O_2 \rightarrow 2H_2O$

A hydrogen–oxygen fuel cell turns chemical energy straight into electricity, with water as the only product

It is useful to compare a fuel cell with a normal petrol (gasoline) engine in a vehicle.

	Hydrogen–oxygen fuel cell	**Petrol engine**
Main product	water only	carbon dioxide and **pollutants** 污染物
Effect on air	clean	adds to air pollution
Fuel storage	hydrogen is hard and dangerous to store (flammable, needs high pressure)	petrol is easy to store
Source	hydrogen may be made using fossil fuels	made from crude oil

Advantages of the fuel cell: the only product is water, so it does not pollute the air, and it changes chemical energy into electricity efficiently. **Disadvantages**: hydrogen is hard to store and transport safely, and producing the hydrogen can still use energy from fossil fuels.

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: $Pb^{2+} + 2e^- \rightarrow Pb$ (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.