Electrochemistry

IGCSE Chemistry ▪ Topic 4

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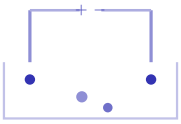
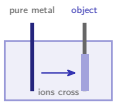


What we will cover

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



electroplating

1 Electrolysis

What electrolysis is, and what it needs

Electrolysis 电解 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** 离子 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** 电解质. The **cathode** 阴极 is negative (cations go there and gain electrons – reduction). The **anode** 阳极 is positive (anions lose electrons – oxidation).

Products at each electrode

cathode (−) ⟶ metal or hydrogen

anode (+) ⟶ non-metal

Cathode: metals & **hydrogen** 氢气.

Anode: **non-metals** 非金属.

molten $PbBr_2$: lead | bromine

conc. NaCl(aq): hydrogen | **chlorine** 氯气

dilute H_2SO_4: hydrogen | oxygen

What is formed at each electrode

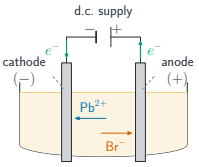
the simple rule	metals and hydrogen go to the cathode; non-metals go to the anode
molten compounds	only two ions are present, so the products are always the metal and the non-metal
concentrated 浓 NaCl solution	hydrogen at the cathode, chlorine at the anode
dilute 稀 sulfuric acid 硫酸	hydrogen at the cathode, oxygen at the anode
copper 铜 sulfate with copper electrodes	copper deposits at the cathode and dissolves from the anode – purification
why it varies	in solution, water can be **decomposed** 分解 too, so what wins depends on concentration and on the ions present

The **electric current** 电流 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** 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.

How the charge moves, in detail



molten lead(II) bromide, $PbBr_2$
cathode: $Pb^{2+} + 2e^- \rightarrow Pb$ (silvery lead)
anode: $2Br^- \rightarrow Br_2 + 2e^-$ (red-brown bromine)

At the cathode, positive ions gain electrons.

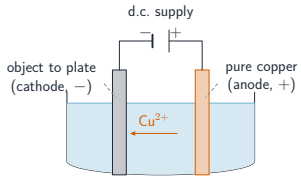
Half-equations

cathode – reduction 还原 (gain e^-)
$Pb^{2+} + 2e^- \rightarrow Pb$

anode – oxidation 氧化 (lose e^-)
$2Br^- \rightarrow Br_2 + 2e^-$

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

Electroplating



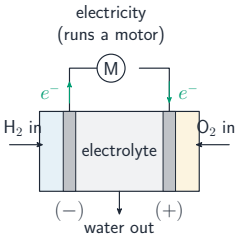
electrolyte: copper(II) sulfate solution
copper coats the object at the cathode; the copper anode slowly dissolves to replace it

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

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

2 Fuel cells

Hydrogen–oxygen fuel cells



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

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

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

Clean, but hydrogen is hard to store safely.

Fuel cell against petrol engine

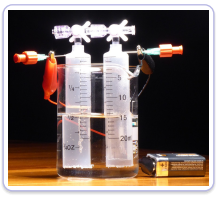
main product	fuel cell: water only. Engine: carbon dioxide and **pollutants** 污染物
effect on air	fuel cell: clean. Engine: adds to air pollution
efficiency	fuel cell converts chemical energy to electricity efficiently; the engine loses much of it as heat
fuel storage	hydrogen is hard and dangerous to 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** 电解池: two **electrodes** 电极 dipping into the **electrolyte** 电解质 – the molten or aqueous substance being broken up. The electrodes are usually **inert** 惰性, **platinum** 铂 or **graphite** 石墨, 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: $Pb^{2+} + 2e^- \rightarrow Pb$ (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.

3 Recap

Worked example – predicting electrolysis products

Give the products of electrolysing 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 ⇒ hydrogen.
- Anode (+): the halide is concentrated, so it wins over OH^- ⇒ chlorine.
- Na^+ and OH^- stay behind as sodium hydroxide solution.

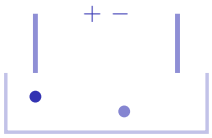
Cathode = reduction (gain electrons), anode = oxidation. Dilute halide ⇒ oxygen at the anode; concentrated ⇒ the halogen.

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
4. **Fuel cell** — $H_2 + O_2$; 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