

Electrolysis of aqueous solutions

4.4.3.4 · Chemical changes · revision notes

Predicting the products when a solution of an ionic compound in water is electrolysed with inert electrodes. Water provides H^+ and OH^- ions, so hydrogen or oxygen can form instead of the metal or non-metal. Required practical 3 is based on this.

Key facts

- Water provides H^+ and OH^- ions
- Anode: halide ions present → halogen; no halide ions → oxygen
- Copper(II) sulfate solution → copper (cathode) + oxygen (anode)
- Oxygen: relights a glowing splint
- Cathode: metal more reactive than hydrogen → hydrogen; less reactive → the metal
- Sodium chloride solution → hydrogen (cathode) + chlorine (anode), sodium hydroxide left
- Hydrogen: squeaky pop with a lit splint
- Chlorine: bleaches damp litmus paper

Notes

Ions in an aqueous solution

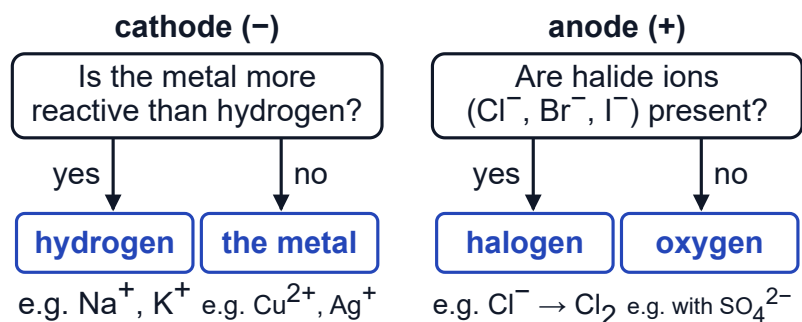
- A solution contains the ions of the compound **and** hydrogen ions (H^+) and hydroxide ions (OH^-), because a small number of water molecules break down into these ions.
- At each electrode only one product forms. Which one depends on the relative reactivity of the elements involved.

At the cathode (negative)

- Hydrogen** is produced if the metal is **more reactive than hydrogen**, e.g. with solutions of potassium, sodium, calcium or magnesium compounds.
- The **metal** is produced if it is **less reactive than hydrogen**, e.g. copper or silver. A coating of the metal forms on the cathode.

At the anode (positive)

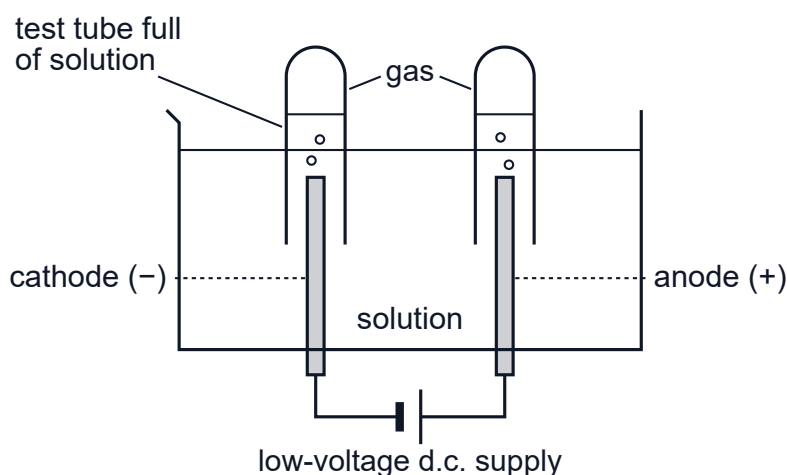
- If the solution contains **halide ions** (Cl^- , Br^- or I^-), the **halogen** is produced: chlorine, bromine or iodine.
- Otherwise, e.g. with sulfate or nitrate ions, **oxygen** is produced from the hydroxide ions.
- Examples: copper(II) chloride $\rightarrow$ copper + chlorine; copper(II) sulfate $\rightarrow$ copper + oxygen; sodium chloride $\rightarrow$ hydrogen + chlorine; sodium sulfate $\rightarrow$ hydrogen + oxygen.
- Ions that are not discharged stay in the solution: electrolysis of sodium chloride solution leaves sodium hydroxide solution.



Two questions decide the products of electrolysis of a solution with inert electrodes.

Required practical 3

- Put two inert electrodes (graphite rods) into the solution and connect them to a low-voltage d.c. supply.
- Collect any gas in small test tubes filled with the solution and placed over each electrode, then test it: hydrogen burns with a squeaky pop; oxygen relights a glowing splint; chlorine bleaches damp litmus paper.



Graphite electrodes, each under a test tube of the solution: any gas collects at the top of the tube, ready to test.

- Look for a metal coating on the cathode (copper is pink-brown) and colours near the anode (bromine is orange, iodine is brown).
- Start with a hypothesis, e.g. about how the reactivity of the metal affects the cathode product, and test several solutions under the same conditions.
- Chlorine is toxic: work in a well-ventilated room and run the electrolysis only for a short time.

How to answer each type of question

Predict the products of electrolysis of a solution

2 to 4 marks

Grade 5

1. Cathode: is the metal more reactive than hydrogen? Yes → hydrogen. No → the metal.
2. Anode: are halide ions present? Yes → the halogen. No → oxygen.
3. Name elements, e.g. chlorine, not chloride.

Example. Predict the product at each electrode when these solutions are electrolysed using inert electrodes.

- (a) potassium bromide solution
- (b) silver nitrate solution

Model answer. (a) Cathode: hydrogen (1); anode: bromine (1)
(b) Cathode: silver (1); anode: oxygen (1)

Don't lose marks

- ✗ Saying sodium forms when sodium chloride solution is electrolysed: it is hydrogen.
- ✗ Forgetting that sulfate and nitrate ions are not discharged: oxygen forms instead.
- ✗ Testing chlorine with a splint: use damp litmus paper, which is bleached.
- ✗ Writing 'chloride gas' instead of chlorine.
- ✗ Forgetting the H^+ and OH^- ions from water when listing the ions present.

More tips

Memory tricks

- Cathode rule: metal below hydrogen → metal; metal above hydrogen → hydrogen.
- Anode rule: halide → halogen; no halide → oxygen.
- In GCSE questions the metals that coat the cathode are usually copper and silver.

Exam technique

- List the ions present first, including H^+ and OH^- from water, then apply the two rules.
- In explanations, compare reactivity directly: 'sodium is more reactive than hydrogen'.
- In practical questions, give the observation or test for every product.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 4

State the products from sodium chloride solution

Hydrogen forms at the cathode and chlorine at the anode, leaving sodium hydroxide solution.

Grade 5

Predict the product at the cathode

Hydrogen forms if the metal is more reactive than hydrogen; otherwise the metal forms.

Grade 5

Predict the product at the anode

The halogen forms if halide ions are present; otherwise oxygen forms.

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