Fuel Cells – GCSE Chemistry

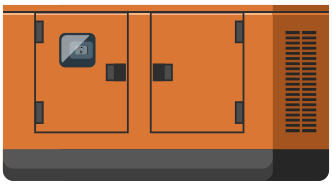
CONTENTS:

1. Introduction

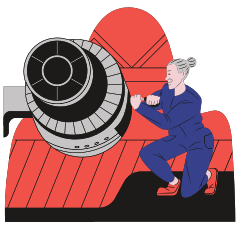
- A device used to convert Chemical energy into electrical energy is called **a cell**.
- A **fuel cell** is a special type of cell that works through electrochemical reactions, usually using hydrogen as fuel and oxygen as the oxidant.

Applications:

Transport



Stationary power



Aerospace & niche industry

Residential and commercial power generation

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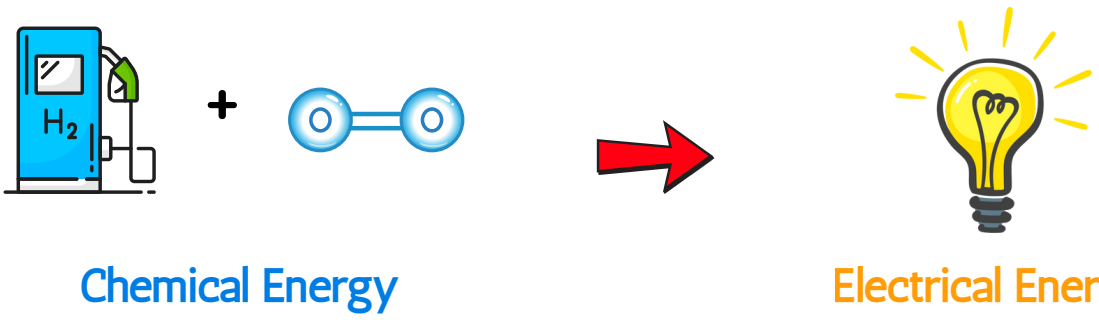
2. What is a Fuel Cell?

- A fuel cell is a device where fuel (such as hydrogen) reacts with oxygen to directly convert chemical energy into electrical energy, with water as the main by-product.
- Unlike ordinary batteries that store a limited amount of chemicals, fuel cells continuously generate electricity as long as they are supplied with fuel and oxygen.



Fuel cells are particularly important because:

- They produce clean energy with only water as waste.
- They reduce air pollution and greenhouse gases.
- They are more efficient than burning fuels.
- Used in cars and buses as eco-friendly fuel.
- They support a sustainable energy future using hydrogen from renewables.

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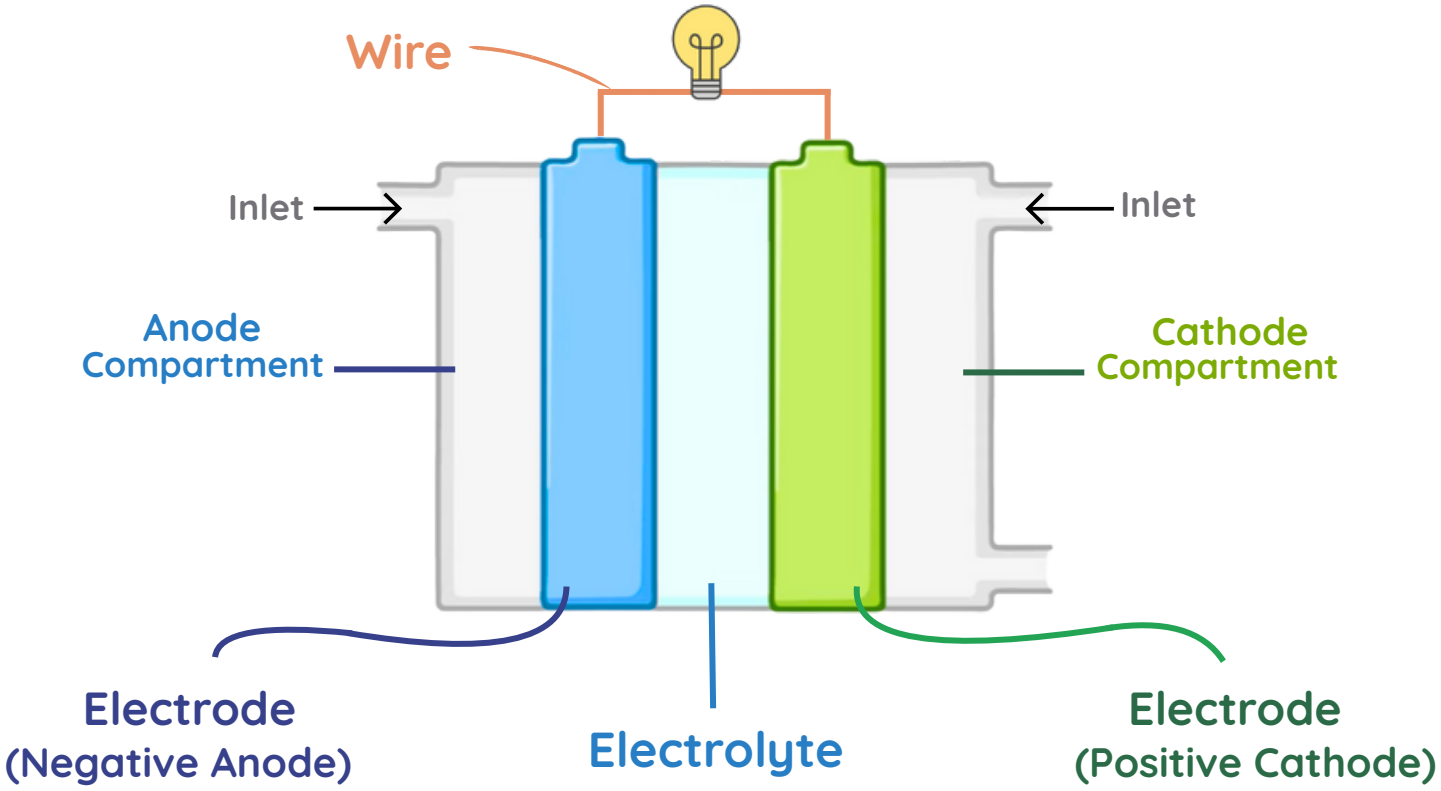
3. What is the Structure of a Fuel Cell?

A practical fuel cell is made by stacking many small cells together, and each cell has several important layers:



- **Electrolyte**
  - The electrolyte is the middle layer that allows ions to pass but blocks electrons, forcing them to move through the wire to create current.
  - In **alkaline fuel cells**,

Potassium Hydroxide (KOH)

is commonly used as the electrolyte.

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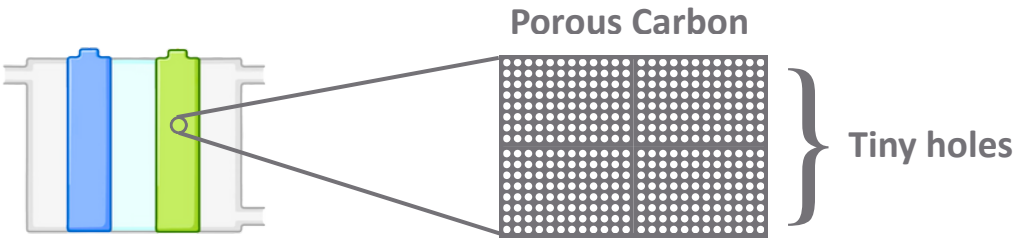
- **Electrodes**
  - There are two electrodes: the anode (negative) and the cathode (positive).
  - At **the anode**, hydrogen is supplied and split into protons and electrons.
  - At **the cathode**, oxygen reacts with these protons and electrons to form water.
- **Compartments**
  - The anode compartment carries hydrogen to the anode, while the cathode compartment carries oxygen to the cathode.
  - These spaces ensure gases reach the right place for reaction.
- **Inlets**
  - Inlets are openings for gases to enter the cell.
  - Hydrogen enters at the anode side and oxygen at the cathode side.
- **Wire (External Circuit)**
  - The wire connects the anode and cathode outside the cell.
  - Electrons travel through this wire, producing electric current to power devices.
- **Tiny Holes in Electrodes**
  - The electrodes are porous (full of tiny holes).
  - These holes spread gases evenly and also let water pass out, preventing blockage.



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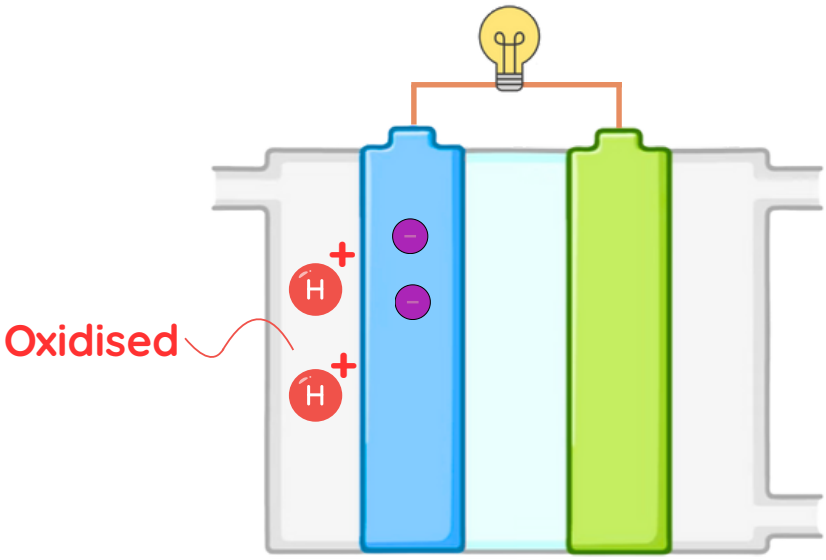
4. How Does a Fuel Cell Work?

- The fuel cell works by using hydrogen and oxygen to produce electricity, with water as the only by-product.
- Its working can be understood in the following steps:

- **Hydrogen supply at the anode –**
  - Hydrogen gas enters the cell from the fuel inlet and reaches the anode.
  - Here, with the help of a catalyst, each hydrogen molecule splits into protons (**H^+ ions**) and electrons (**e^-**).



$$H_2 \rightarrow 2H^+ + 2e^-$$

- **Movement of protons and electrons –**
  - The protons (**H^+**) pass through the electrolyte (commonly KOH or a proton-exchange membrane) to reach the cathode.
  - The electrons (**e^-**) cannot cross the electrolyte, so they travel through the external wire, creating an electric current that can power devices.

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- **Oxygen supply at the cathode –**
    - Oxygen gas enters from the oxidant inlet and reaches the cathode. Here, oxygen molecules combine with the incoming protons (H^+) and the returning electrons (e^-) from the wire.

$$\frac{1}{2}O_2 + 2H^+ + 2e^- \rightarrow H_2O$$

- **Formation of water and removal –**
    - The product formed at the cathode is water, which comes out as a by-product through the outlet.
    - Any excess water is removed from the bottom of the fuel cell to keep the system running smoothly.
- **Continuous process –**
    - As long as hydrogen and oxygen are supplied, this process continues, providing a steady flow of electricity and heat.

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5.Chemical Reactions and Equations in a Fuel Cell

- In a fuel cell, the reactions occur in two parts: half-reactions at each electrode, and then the overall cell reaction.
- **At the Anode (oxidation of hydrogen):**

$$H_2 \rightarrow 2H^+ + 2e^-$$

Oxygen of Hydrogen

Hydrogen molecules split into protons (which move through the electrolyte) and electrons (which travel through the external circuit).

- **At the Cathode (reduction of oxygen):**

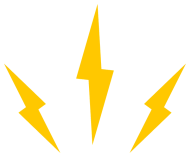
Oxygen from the inlet reacts with the protons and electrons to form water.

$$\frac{1}{2} O_2 + 2H^+ + 2e^- \rightarrow H_2O$$

Reduction of Oxygen

- **Overall Cell Reaction:**

$$H_2 + \frac{1}{2} O_2 \rightarrow H_2O + \text{Heat} + \text{Electricity}$$



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6. Pros and Cons of Fuel Cells

- **Pros of Fuel Cells**
  - Only need hydrogen and oxygen, which are abundant.
  - Do not produce carbon dioxide or pollutants as waste.

  - Produce water as the only by-product.
  - More efficient than combustion engines.
  - Simple design can last longer than batteries.
  - Less polluting to dispose of compared to batteries.
  - Operates quietly without noise.
  - Can provide continuous power as long as fuel is supplied.
  - Can be used in homes, vehicles, industries, and space missions.

- **Cons of Fuel Cells**
  - Hydrogen is a gas and needs more space to store than fossil fuels or batteries.
  - Storage and transport of hydrogen is dangerous and costly.
  - Hydrogen is explosive when mixed with air.
  - Making hydrogen fuel itself requires energy.
  - Fuel cells are expensive due to costly materials like platinum.
  - Need special infrastructure for refueling stations.
  - Limited durability, can degrade over time.
  - If hydrogen is made from fossil fuels, it can still cause pollution indirectly.

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7. FAQs

1. What is a fuel cell?

A fuel cell is a device that converts chemical energy from a fuel (like hydrogen) into electrical energy through a chemical reaction with oxygen.

2. How is a fuel cell different from a battery?

Unlike batteries, fuel cells do not run out or need recharging — they produce electricity continuously as long as fuel and oxygen are supplied.

3. What are the main parts (structure) of a fuel cell?

A fuel cell has two electrodes (anode and cathode) and an electrolyte between them that allows ions to move while keeping gases separate.

4. What happens at the anode of a hydrogen fuel cell?

At the anode, hydrogen gas is split into protons and electrons.

5. What happens at the cathode of a hydrogen fuel cell?

At the cathode, oxygen reacts with protons and electrons to form water.

6. What is the overall chemical equation for a hydrogen fuel cell?

$2H_2 + O_2 \rightarrow 2H_2O$ + energy (electricity + heat)

7. What are the main advantages of fuel cells?

They are efficient, produce clean energy, and the only by-product is water — making them environmentally friendly.

8. What are the disadvantages of fuel cells?

They are expensive to make, require pure hydrogen (hard to store), and the production of hydrogen may release carbon emissions.