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Simplified Fuel Cells

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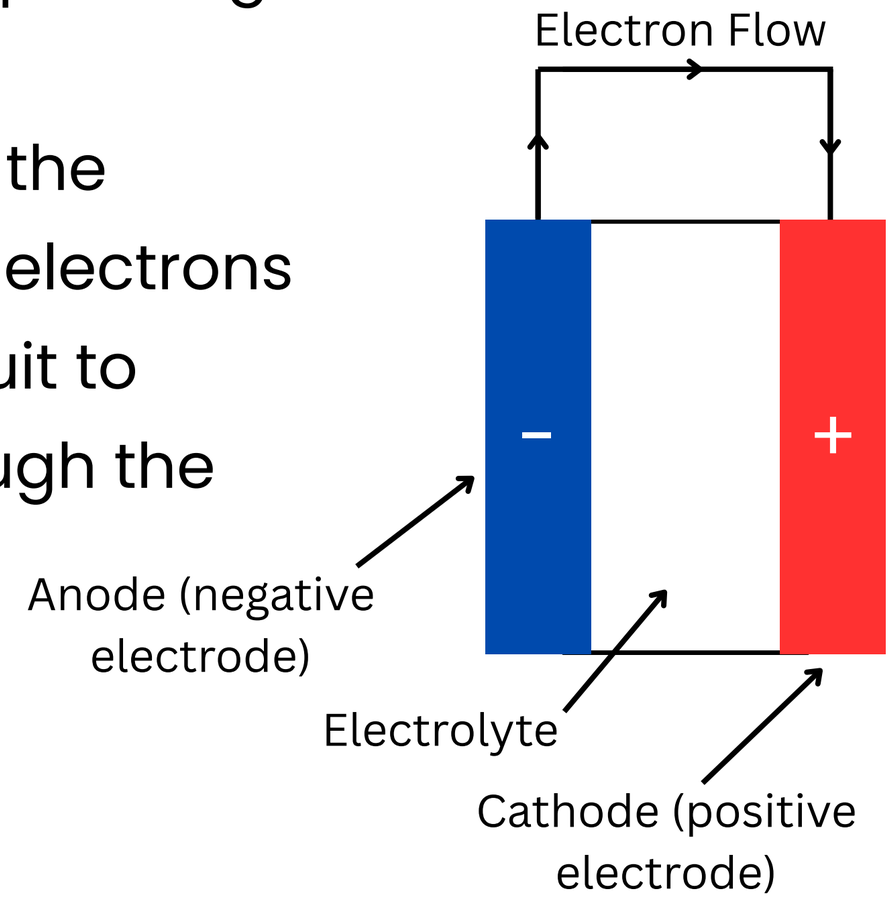
What is a Fuel Cell?

- Like batteries and combustion engines, fuel cells convert chemical energy to electrical energy
- To generate electricity, a fuel (e.g. hydrogen) reacts electrochemically with oxygen (usually from the air) inside the fuel cell
- The only product of this process is water:

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

How do Fuel Cells Work?

- Fuel cells consist of 2 electrodes (the positive cathode and negative anode) with an electrolyte separating them
- A fuel (typically hydrogen) enters at one of the electrodes and reacts to produce ions and electrons
- The electrons flow through an external circuit to generate electricity and the ions pass through the electrolyte to the other electrode
- Now let’s go a bit deeper into this!!



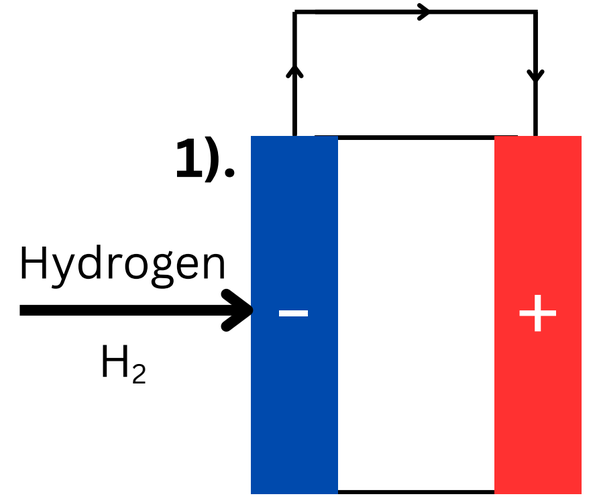
How do Fuel Cells Work?

- The type of fuel cell impacts the chemistry and reactions that occur in the fuel cell
- In the following slides, 2 types of fuel cells are explained
  - Proton exchange membrane (PEM) fuel cells
  - Alkaline fuel cells

How do Fuel Cells Work? - PEM

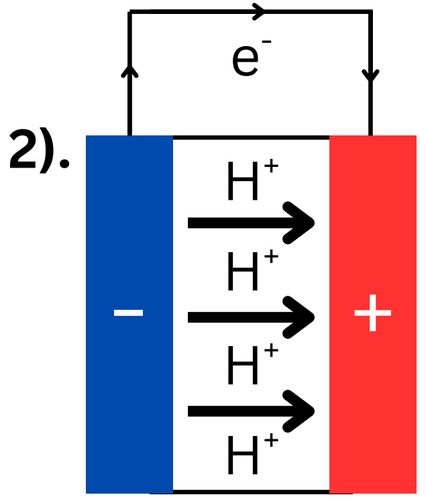
Hydrogen enters the fuel cell at the anode (negative electrode) and is **oxidised** to form hydrogen ions and electrons

Anode half-cell equation: $\mathbf{2H_2 \rightarrow 4H^+ + 4e^-}$



The hydrogen ions pass through the electrolyte, which is a polymer membrane for PEM fuel cells

Electrons pass through an external circuit to produce electricity



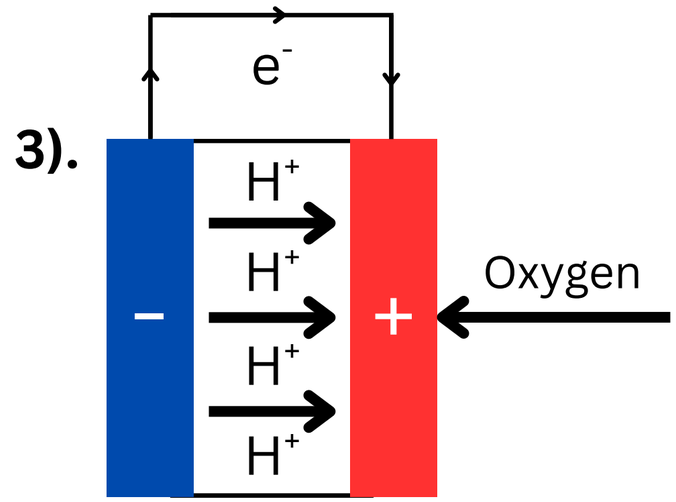
How do Fuel Cells Work? - PEM

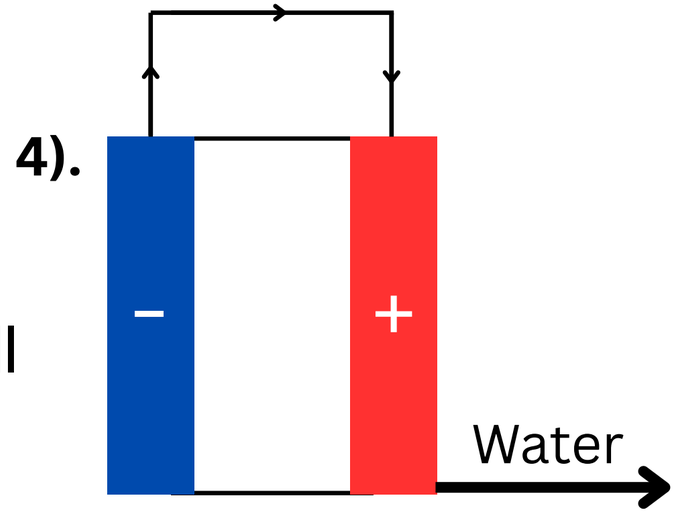
Oxygen enters the fuel cell at the cathode (positive electrode) and reacts with the hydrogen ions that passed through the membrane (electrolyte) and electrons from the external circuit

In this reaction oxygen is **reduced** to form water

Cathode half-cell equation: $\mathbf{O_2 + 4H^+ + 4e^- \rightarrow 2H_2O}$

Water is formed from the reaction and exits the fuel cell





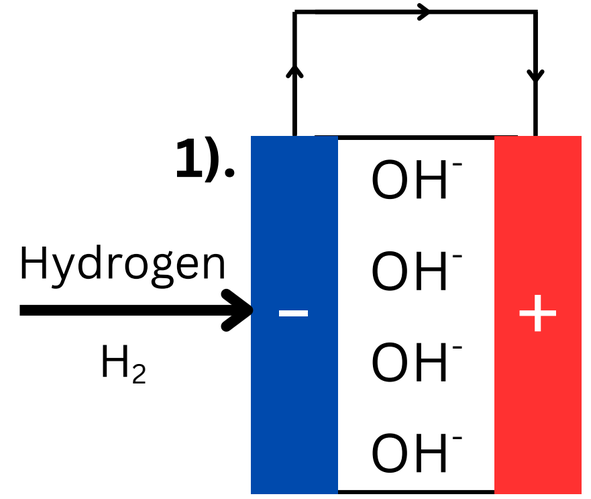
How do Fuel Cells Work? - Alkaline

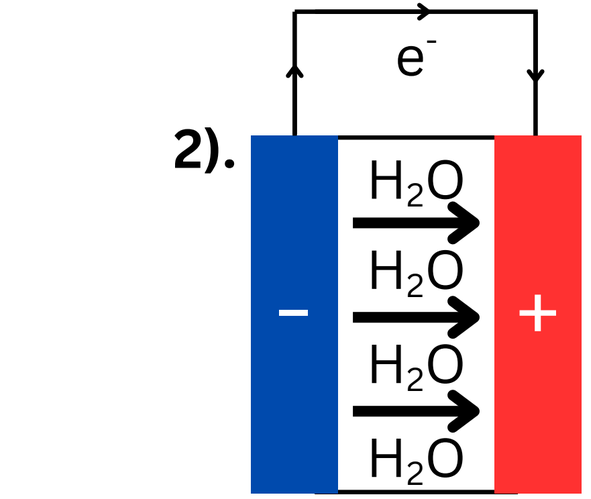
Hydrogen enters the fuel cell at the anode (negative electrode) and reacts (is **oxidised**) with hydroxide ions from the aqueous alkaline electrolyte to form water and electrons

Anode half-cell equation: $\mathbf{2H_2 + 4OH^- \rightarrow 4H_2O + 4e^-}$

Water passes through the aqueous alkaline electrolyte

Electrons pass through an external circuit to produce electricity





How do Fuel Cells Work? - Alkaline

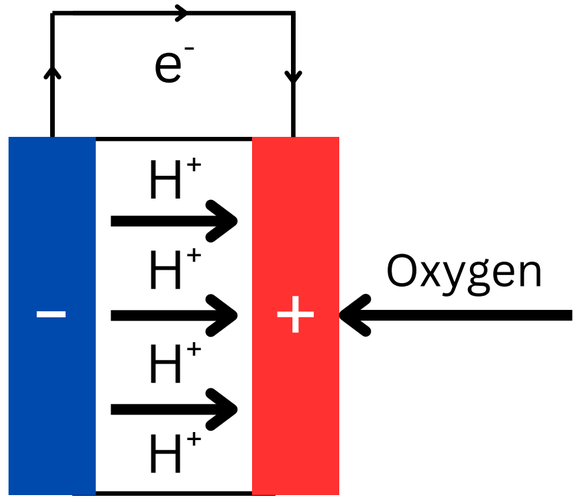
Oxygen enters the fuel cell at the cathode (positive electrode) and reacts with the water in the electrolyte and electrons from the external circuit

In this reaction oxygen is **reduced** to reform hydroxide ions

Cathode half-cell equation: $\mathbf{O_2 + 2H_2O + 4e^- \rightarrow 4OH^-}$

2 water molecules remain unreacted from the anode half cell reaction so are the product of the fuel cell

3).



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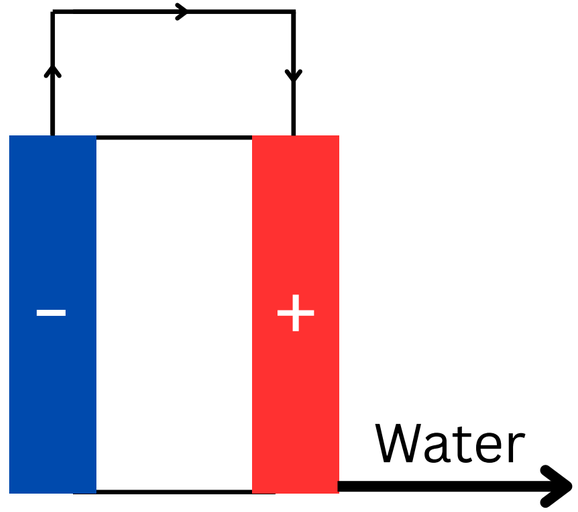

Half Cell Equations

- By summing each side of the half cell equations for a fuel cell and cancelling/simplifying repeated terms, we obtain the overall equation:

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

- PEM Fuel Cells
  - Anode: $\mathbf{2H_2 \rightarrow 4H^+ + 4e^-}$
  - Cathode: $\mathbf{O_2 + 4H^+ + 4e^- \rightarrow 2H_2O}$
- Alkaline Fuel Cells
  - Anode: $\mathbf{2H_2 + 4OH^- \rightarrow 4H_2O + 4e^-}$
  - Cathode: $\mathbf{O_2 + 2H_2O + 4e^- \rightarrow 4OH^-}$

Fuel Cell Components

- **Anode** - negative electrode
- **Cathode** - positive electrode
- **Electrolyte** - a medium that conducts electricity through the movement of ions
- **External Circuit** - an electrical circuit that does not include the power source (fuel cell)
- **Reactants** - hydrogen and oxygen, but alternatives to hydrogen can be used
- **Products** - water, electricity and heat

Fuel Cell Uses

- Transport: cars, trucks, boats, trains, etc.
- Producing electricity for the National Grid or individual buildings in the transition away from fossil fuel technology

Advantages and Disadvantages

Advantages

- No harmful emissions that cause climate change or impact local health
- Clean energy which benefits the drive for net zero energy
- Fast vehicle refuelling times
- Continuous power for stationary electricity production

Disadvantages

- High cost to build fuel cells
- The infrastructure for hydrogen refuelling stations needs improving before fuel cell vehicles are commercial
- Sources of hydrogen are not always environmentally friendly
- Hydrogen is flammable so must be stored safely

What’s Next?

- Complete the worksheet to reinforce your knowledge of fuel cells!

This resource was developed as part of the HyAcademy.eu project.

Thank You!

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