Unit 4B
Batteries and fuel cells

Sub: RES

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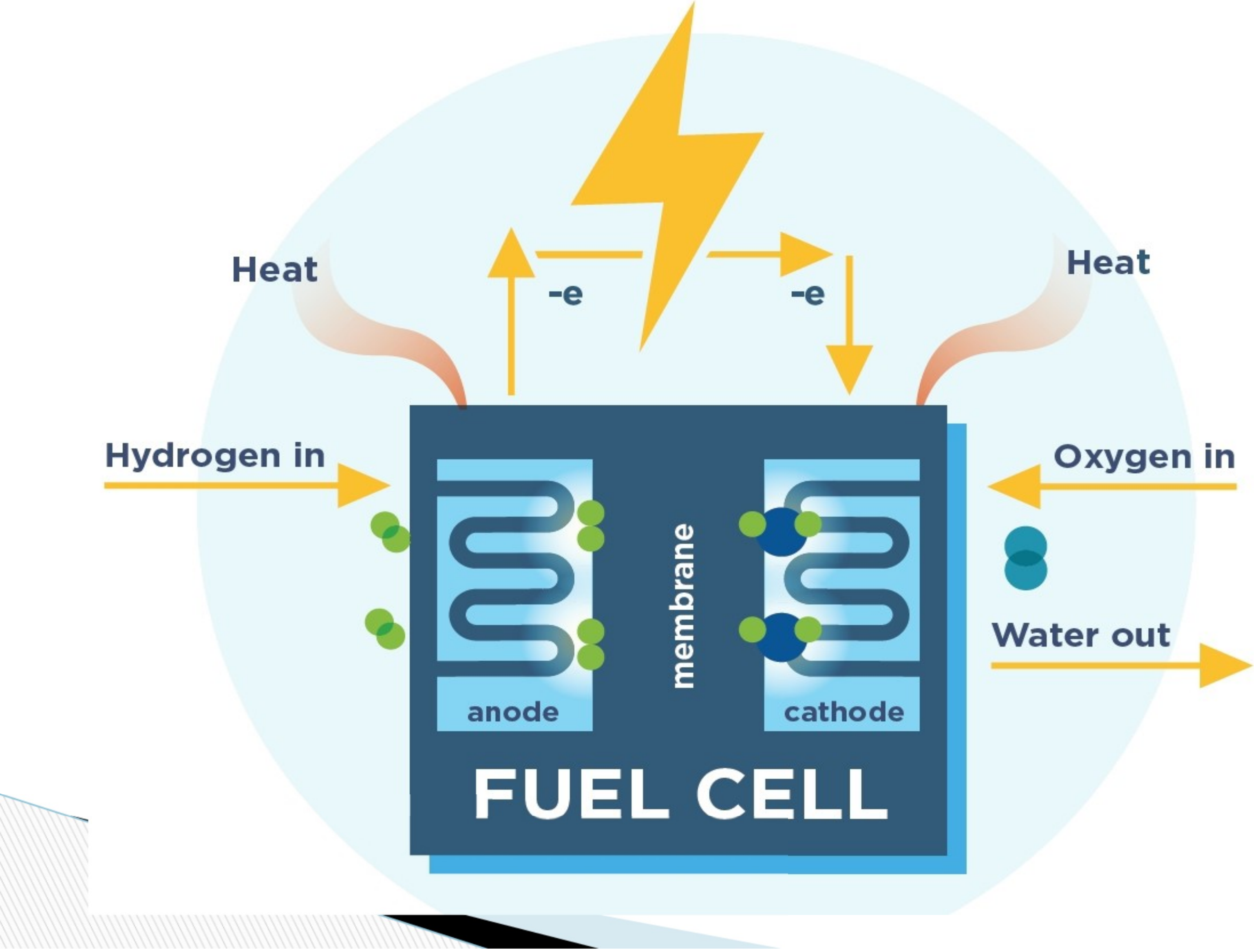
Syllabus:

- Batteries:
  - storage cell fundamentals,
  - Emerging trends in batteries,
  - storage cell definitions and specifications,

- Fuel cell:
  - Fundamentals,
  - Alkaline fuel cells,
  - Acidic fuel cells,
  - SOFC (Solid Oxide Fuel Cell) –emerging areas in fuel cells,
  - Applications –Industrial and commercial.

What is a fuel cell?

- A fuel cell is a device that generates electricity by a chemical reaction.
- Every fuel cell has two **electrodes**, one positive (**Cathode**) and one negative (**Anode**).
- The **reactions** that produce electricity take place at the **electrodes**.
- Every fuel cell also has an **electrolyte**, which carries electrically charged particles from one electrode to the other, and a **catalyst**, which speeds the reactions at the electrodes.
- **Hydrogen** is the basic fuel, but fuel cells also require **oxygen**.
- One great appeal of fuel cells is that they generate electricity with **very little pollution**—much of the hydrogen and oxygen used in generating electricity ultimately combine to form a harmless **byproduct**, namely **water**.


Heat
-e
-e
Heat
Hydrogen in
Oxygen in
membrane
Water out
anode
cathode
FUEL CELL

Advantages:

The main advantages of a fuel cell are: (i) it is quiet in operation as it is a static device, (ii) it is less pollutant, (iii) its conversion efficiency is more due to direct single-stage energy conversion, (iv) fuel cell plant can be installed near the point of use, thus transmission and distribution losses are avoided, (v) no cooling water is needed as required in the condenser of a conventional steam plant. The heat generated can be easily removed and discharged to the atmosphere or used locally, (vi) because of modular nature, any voltage/current level can be realised and the capacity can be added later on as the demand grows, (vii) fuel-cell plants are compact and require less space, (viii) availability of choice from large number of possible fuels, (ix) can be used efficiently at part load from 50% to 100%, and (x) no charging is required.

Alkaline fuel cells:

working:

- Hydrogen atom enter fuel cell at anode where a platinum catalyst causes the Hydrogen to split into positive Hydrogen ions (protons)and negatively charge electrons.
- The positively charge Hydrogen ions react with Hydroxyl (OH-)ions in the electrolyte to form water.
- The negatively charge electrons can not flow through the electrolyte to reach the positively charge cathode, so they must flow through an external circuit, forming an electrical current.
- Oxygen enter the fuel cell at cathode and picks up electrons and then travel through electrolytes to The anode , where it combines with hydrogen atom.
- Oxygen with electron combine hydrogen at anode and form water which drains from the cell.

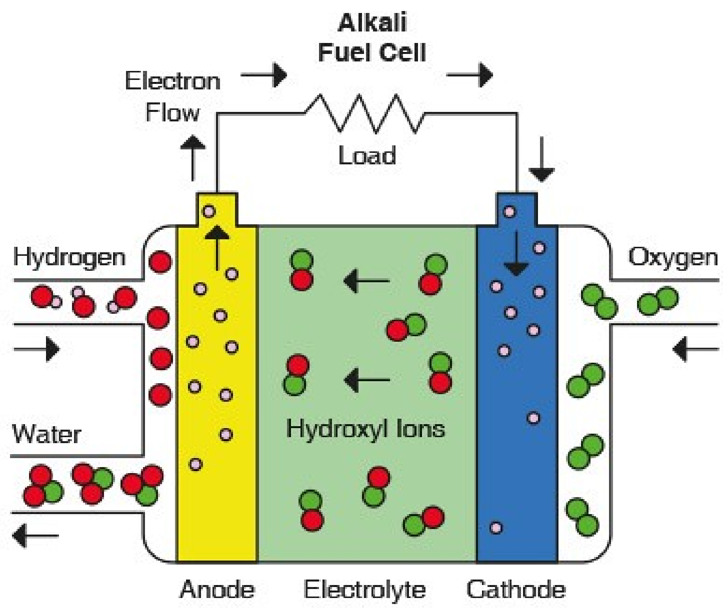


Figure 1: Alkaline Fuel Cell

$$\tfrac{1}{2} O_2 + H_2O + 2e^- \longrightarrow 2\,OH^-$$

These OH^- ions migrate from the positive to the negative electrode through the electrolyte. On reaching the positive electrode, these OH^- ions combine with H_2 to produce water. An equivalent number of electrons are liberated that flow through the external load towards positive electrode. Thus,

$$H_2 + 2\,OH^- \longrightarrow 2\,H_2O + 2e^-$$

The overall reaction is same as that with PAFC. That is,

$$H_2 + \tfrac{1}{2} O_2 \longrightarrow H_2O$$

Phosphoric Acid Fuel Cell:

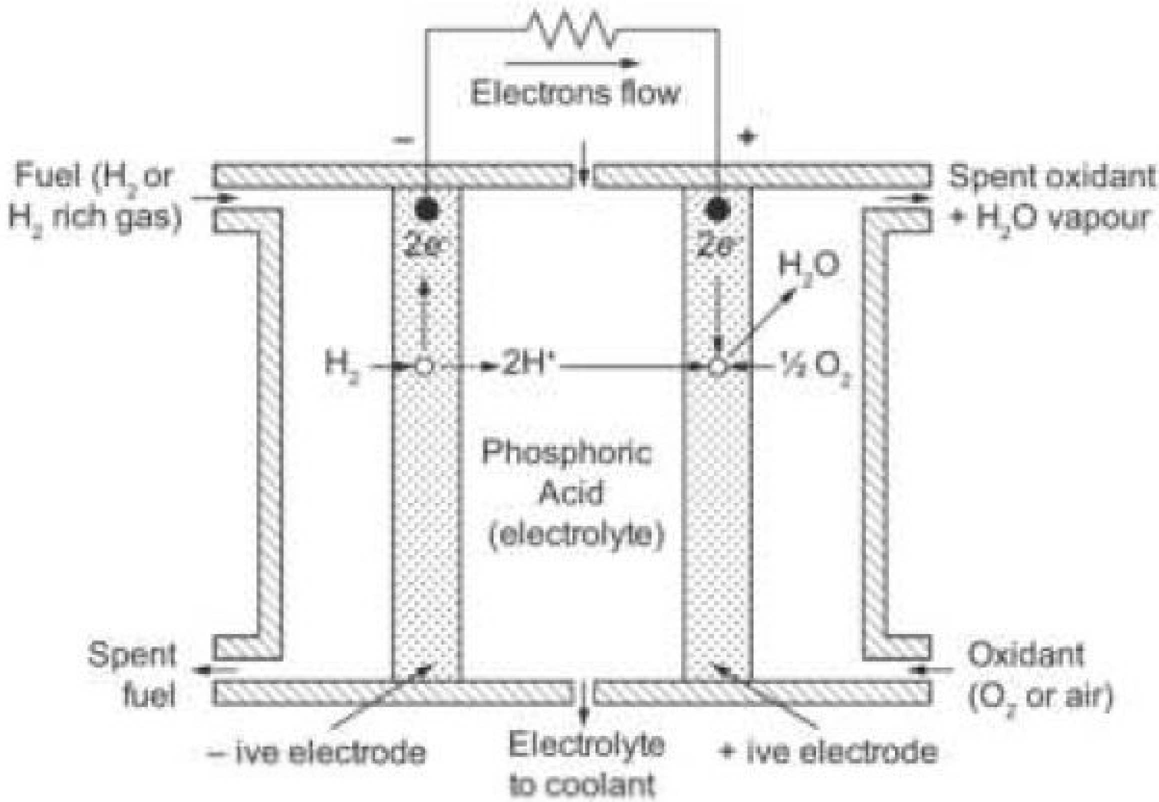


Fig. 12.1 *Phosphoric Acid Fuel Cell*

At the negative electrode, hydrogen gas is converted to hydrogen ions (H^+) and an equal number of electrons (e^-). Thus,

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

The electrons originating at the negative electrode flow through the external load to the positive electrode. Also, the H^+ ions migrate from the negative electrode towards the positive electrode through the electrolyte. On reaching the positive electrode, they interact with O_2 to produce water. Thus,

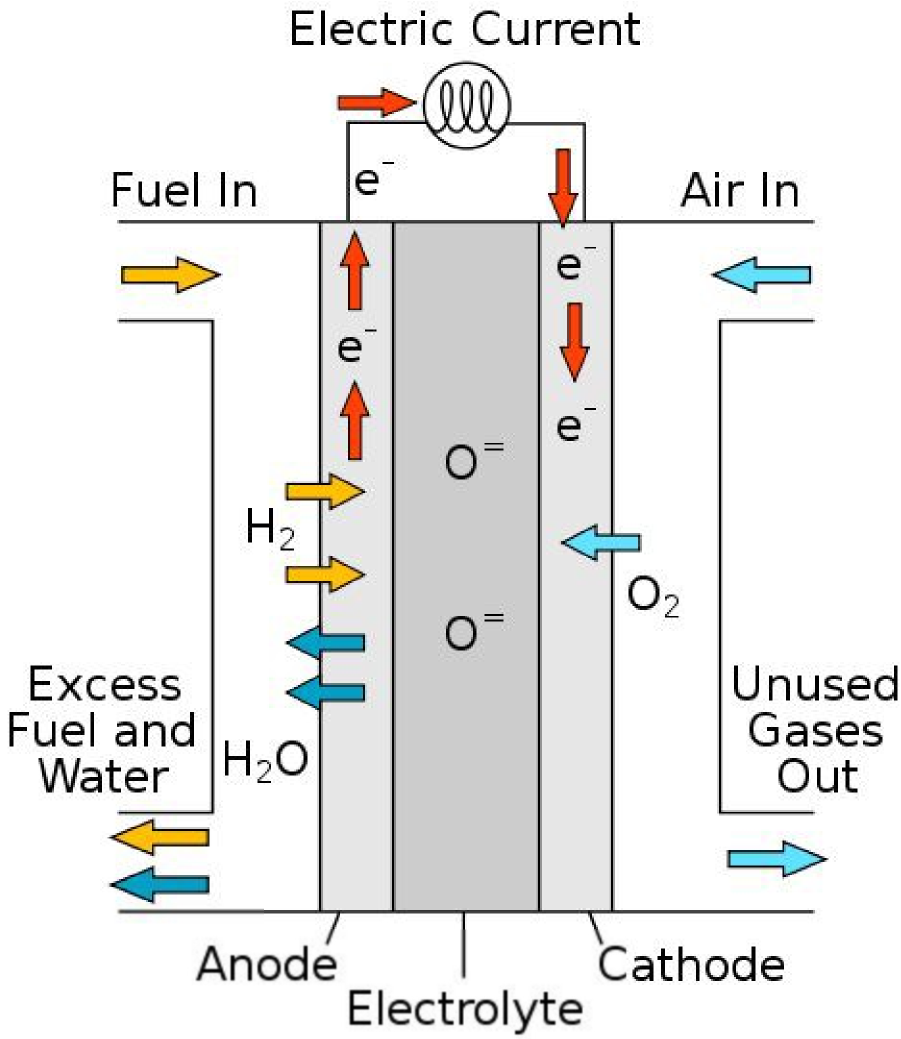
$$\tfrac{1}{2}\,O_2 + 2\,H^+ + 2e^- \longrightarrow H_2O$$

Combining the above equations indicates that a fuel cell combines H_2 and O_2 to produce water (plus electrical energy). The overall reaction is therefore,

$$H_2 + \tfrac{1}{2}\,O_2 \longrightarrow H_2O$$

Solid Oxide Fuel Cell Components

- Solid Oxide Fuel Cells (SOFC) are a type of fuel cell that use a solid oxide material as the electrolyte.
- SOFCs use a solid oxide electrolyte to conduct negative oxygen ions from the cathode to the anode.
- The electrochemical oxidation of the oxygen ions with hydrogen or carbon monoxide thus occurs on the anode side.
- Solid Oxide Fuel Cells (SOFC) operate at very high temperatures (500 - 1,000°C). At these temperatures, SOFCs do not require costly platinum catalyst, as is currently necessary for lower-temperature fuel cells such as Proton Exchange Membrane Fuel Cells (PEMFC), and are not vulnerable to carbon monoxide catalyst poisoning. However, vulnerability to sulfur poisoning has been widely observed and the sulfur must be removed before entering the cell through the use of adsorbent beds or other means.
- SOFCs have a wide variety of applications from use as auxiliary power units in vehicles to stationary power generation with outputs from 100W to 2MW. Higher operating temperatures make SOFCs suitable candidates for application with heat engine energy recovery devices or combined heat and power, which increases overall fuel efficiency.


Electric Current
Fuel In
Air In
e⁻
O=
H2
O2
H2O
Excess Fuel and Water
Unused Gases Out
Anode
Electrolyte
Cathode