

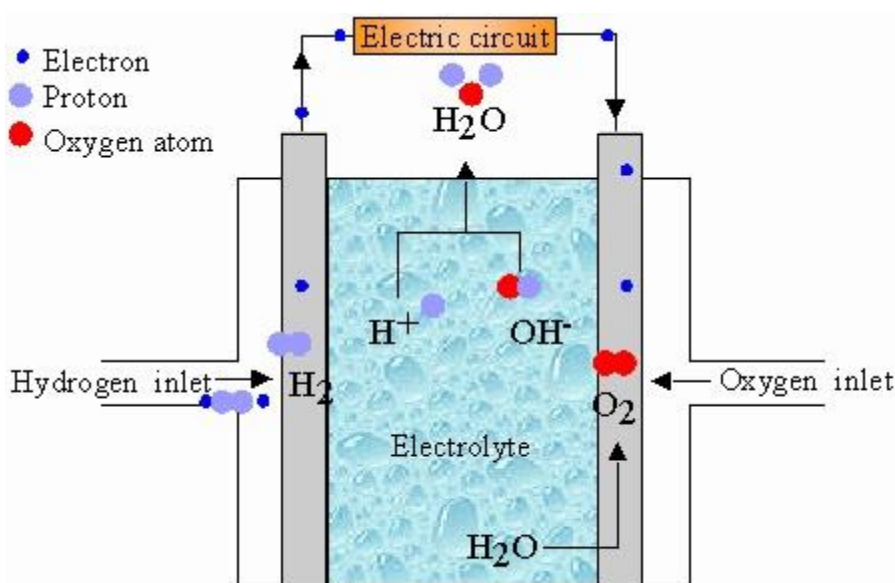
Fuel Cells –

A fuel cell is an electrochemical cell that converts the chemical energy of a fuel (often hydrogen) and an oxidizing agent (often oxygen) into electricity through a pair of redox reactions.

A fuel cell is like a battery, it generates electricity from an electrochemical reaction. Both batteries and fuel cells convert chemical energy into electrical energy and also, as a by-product of this process, into heat. However, a battery holds a closed store of energy within it and once this is depleted the battery must be discarded, or recharged by using an external supply of electricity to drive the electrochemical reaction in the reverse direction.

A fuel cell, on the other hand, uses an external supply of chemical energy and can run indefinitely, as long as it is supplied with a source of hydrogen and a source of oxygen (usually air). The source of hydrogen is generally referred to as the fuel and this gives the fuel cell its name, although there is no combustion involved. Oxidation of the hydrogen instead takes place electrochemically in a very efficient way. During oxidation, hydrogen atoms react with oxygen atoms to form water; in the process electrons are released and flow through an external circuit as an electric current. Fuel cells can vary from tiny devices producing only a few watts of electricity, right up to large power plants producing megawatts. All fuel cells are based around a central design using two electrodes separated by a solid or liquid electrolyte that carries electrically charged particles between them. A catalyst is often used to speed up the reactions at the electrodes. Fuel cell types are generally classified according to the nature of the electrolyte they use. Each type requires particular materials and fuels and is suitable for different applications.

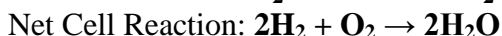
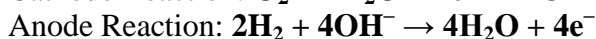
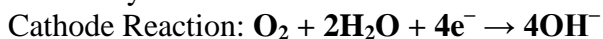
A schematic of the basic fuel cell ($\text{H}_2\text{-O}_2$) components is shown below



Working of Fuel Cell

The reaction between hydrogen and oxygen can be used to generate electricity via a fuel cell. Such a cell was used in the Apollo space programme and it served two different purposes – It was used as a fuel source as well as a source of drinking water (the water vapour produced from the cell, when condensed, was fit for human consumption).

The working of this fuel cell involved the passing of hydrogen and oxygen into a concentrated solution of sodium hydroxide via carbon electrodes. The cell reaction can be written as follows:



However, the reaction rate of this electrochemical reaction is quite low. This issue is overcome with the help of a catalyst such as platinum or palladium. In order to increase the effective surface area, the catalyst is

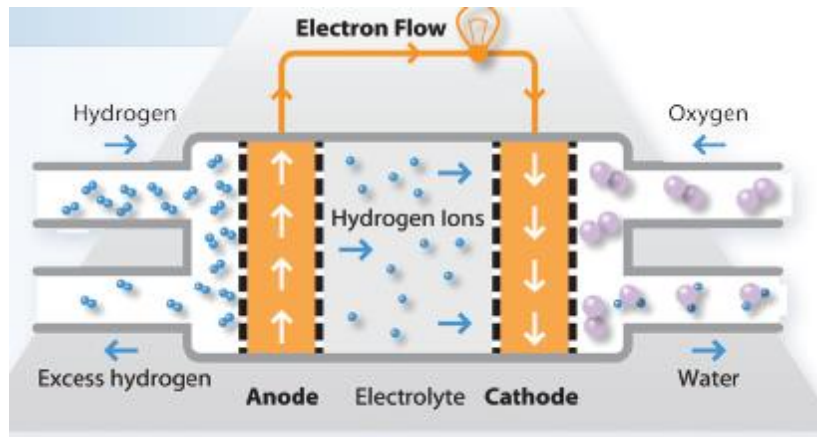
finely divided before being incorporated into the electrodes. A block diagram of this fuel cell is provided above

Types of Fuel Cells

Despite working in a similar manner, there exist many varieties of fuel cells. Some of these types of fuel cells are discussed in this subsection.

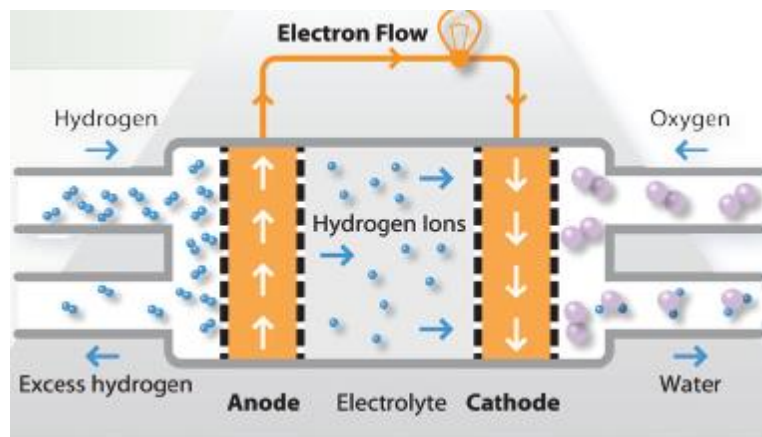
The Polymer Electrolyte Membrane (PEM) Fuel Cell

- These cells are also known as proton exchange membrane fuel cells (or PEMFCs).
- The temperature range that these cells operate in is between 50°C to 100°
- The electrolyte used in PEMFCs is a polymer which has the ability to conduct protons.
- A typical PEM fuel cell consists of bipolar plates, a catalyst, electrodes, and the polymer membrane.
- Despite having eco-friendly applications in transportation, PEMFCs can also be used for the stationary and portable generation of power.



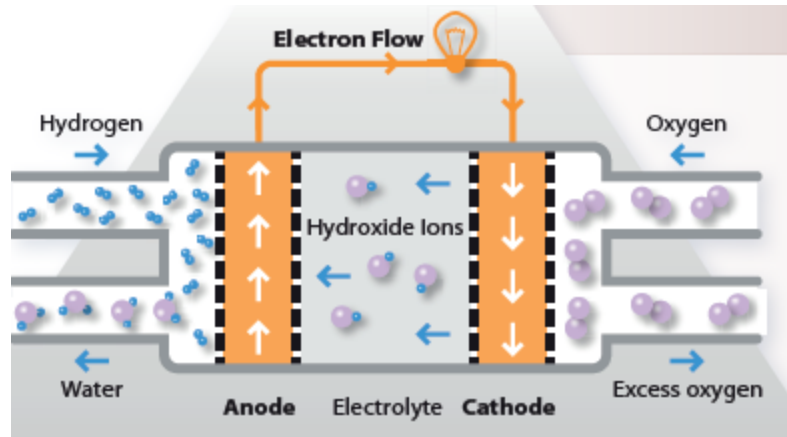
Phosphoric Acid Fuel Cell

- These fuel cells involve the use of phosphoric acid as an electrolyte in order to channel the H^+
- The working temperatures of these cells lie in the range of 150°C – 200°
- Electrons are forced to travel to the cathode via an external circuit because of the non-conductive nature of phosphoric acid.
- Due to the acidic nature of the electrolyte, the components of these cells tend to corrode or oxidize over time.



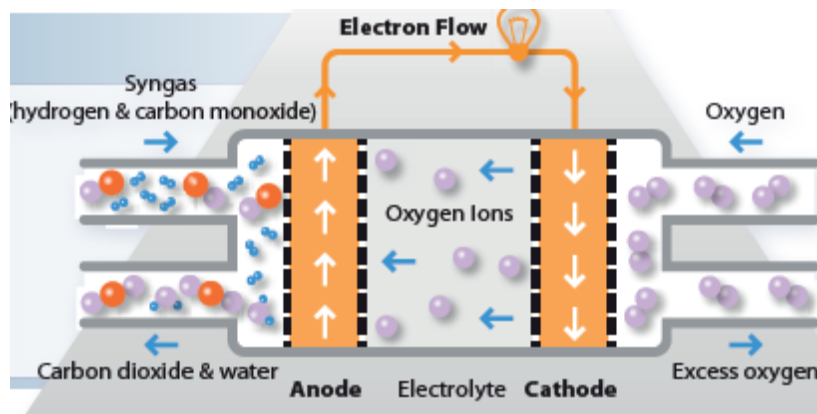
Alkaline Fuel Cell

- This was the fuel cell which was used as the primary source of electricity in the Apollo space program.
- In these cells, an aqueous alkaline solution is used to saturate a porous matrix, which is in turn used to separate the electrodes.
- The operating temperatures of these cells are quite low (approximately 90°C).
- These cells are highly efficient. They also produce heat and water along with electricity.



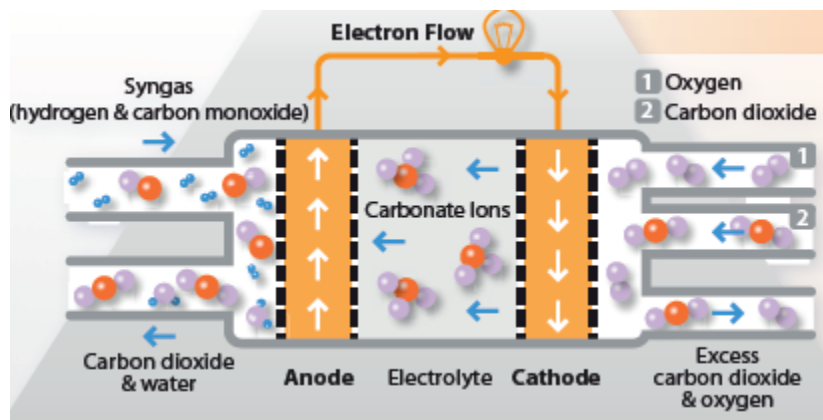
Solid Oxide Fuel Cell

- These cells involve the use of a solid oxide or a ceramic electrolyte (such as yttria-stabilized zirconia).
- These fuel cells are highly efficient and have a relatively low cost (theoretical efficiency can even approach 85%).
- The operating temperatures of these cells are very high (lower limit of 600°C, standard operating temperatures lie between 800 and 1000°C).
- Solid oxide fuel cells are limited to stationary applications due to their high operating temperatures.



Molten Carbonate Fuel Cell

- The electrolyte used in these cells is lithium potassium carbonate salt. This salt becomes liquid at high temperatures, enabling the movement of carbonate ions.
- Similar to SOFCs, these fuel cells also have a relatively high operating temperature of 650°
- The anode and the cathode of this cell are vulnerable to corrosion due to the high operating temperature and the presence of the carbonate electrolyte.
- These cells can be powered by carbon-based fuels such as natural gas and biogas.



Applications of fuel cell

Fuel cell technology has a wide range of applications. Currently, heavy research is being conducted in order to manufacture a cost-efficient automobile which is powered by a fuel cell. A few applications of this technology are listed below.

- Fuel cell electric vehicles, or FCEVs, use clean fuels and are therefore more eco-friendly than internal combustion engine-based vehicles.
- They have been used to power many space expeditions including the Appolo space program.
- Generally, the byproducts produced from these cells are heat and water.
- The portability of some fuel cells is extremely useful in some military applications.
- These electrochemical cells can also be used to power several electronic devices.
- Fuel cells are also used as primary or backup sources of electricity in many remote areas.

Questions –

1. **Define fuel cell and with diagram discuss working of H_2 - O_2 fuel cell.**
2. **With diagram list features of Alkaline, polymer membrane, solid oxide, phosphoric acid, molten carbonate, fuel cell.**
3. **List applications of fuel cell.**