



# FUEL CELL

# WORKING PRINCIPLE

- A fuel cell is a device that uses hydrogen (or hydrogen-rich fuel) and oxygen to create electricity by an electrochemical process.
- A single fuel cell consists of an electrolyte sandwiched between two thin electrodes (a porous anode and cathode)
- Hydrogen, or a hydrogen-rich fuel, is fed to the anode where a catalyst separates hydrogen's negatively charged electrons from positively charged ions (protons)
- At the cathode, oxygen combines with electrons and, in some cases, with species such as protons or water, resulting in water or hydroxide ions, respectively

- The electrons from the anode side of the cell cannot pass through the membrane to the positively charged cathode; they must travel around it via an electrical circuit to reach the other side of the cell.
- This movement of electrons is an electrical current.
- The amount of power produced by a fuel cell depends upon several factors, such as fuel cell type, cell size, the temperature at which it operates, and the pressure at which the gases are supplied to the cell
- Still, a single fuel cell produces enough electricity for only the smallest applications. Therefore, individual fuel cells are typically combined in series into a fuel cell stack. A typical fuel cell stack may consist of hundreds of fuel cells.

# CLASSIFICATION

Based on the type of Electrolyte

- **1. Alkaline Fuel cell (AFC)**
- **2. Phosphoric Acid Fuel cell (PAFC)**
- **3. Polymer Electrolytic Membrane Fuel Cell (PEMFC) Solid Polymer Fuel Cell (SPFC) and Proton Exchange Membrane Fuel cell (PEMFC)**
- **4. Molten Carbonate Fuel Cell (MCFC)**
- **5. Solid Oxide Fuel Cell (SOFC)**



### Based on Types of Fuel and oxidant

- 1. Hydrogen (pure)-Oxygen (pure) fuel cell
- 2. Hydrogen rich gas-air fuel cell
- 3. Ammonia –air fuel cell
- 4. Synthesis gas- air fuel cell
- 5. Hydro carbon (gas)- air fuel cell

The background features a vertical gradient from dark blue at the bottom to dark red at the top. On the right side, there are several technical diagrams, including a large circular scale with numerical markings from 80 to 210 and a smaller circular diagram below it. On the left side, there are faint, semi-transparent circular diagrams, one of which is partially visible at the bottom left.

Based on operating temperature

low temperature(25-100 °C),

medium temperature (100-500 °C) ,

high temperature(500-1000°C) &

very high temperature(above 1000°C)

# ALKALINE FUEL CELLS (AFC)

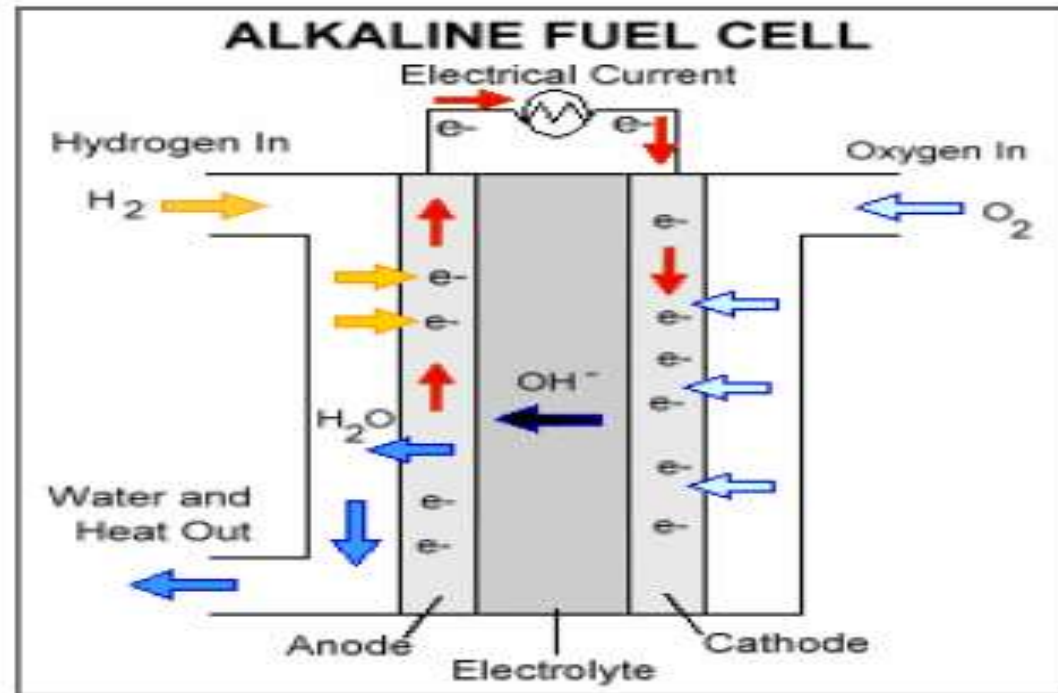
The alkaline fuel cell uses an alkaline electrolyte such as 40% aqueous potassium hydroxide. In alkaline fuel cells, negative ions travel through the electrolyte to the anode where they combine with hydrogen to generate water and electrons.

These fuel cells use a solution of potassium hydroxide in water as the electrolyte and can use a variety of non-precious metals as a catalyst at the anode and cathode. High-temperature AFCs operate at temperatures between 100°C and 250°C.

AFCs are high-performance fuel cells due to the rate at which chemical reactions take place in the cell. They are also very efficient, reaching efficiencies of 60 percent in space applications.

The disadvantage of this fuel cell type is that it is easily poisoned by carbon dioxide (CO<sub>2</sub>). In fact, even the small amount of CO<sub>2</sub> in the air can affect the cell's operation, making it necessary to purify both the hydrogen and oxygen used in the cell. CO<sub>2</sub> can combine with KOH to form potassium carbonate which will increase the resistance. This purification process is costly. Susceptibility to poisoning also affects the cell's lifetime (the amount of time before it must be replaced), further adding to cost.

# SCHEMATIC OF AFC



**Anode Reaction:**  $2H_2 + 4OH^- \rightarrow 4H_2O + 4e^-$

**Cathode Reaction:**  $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

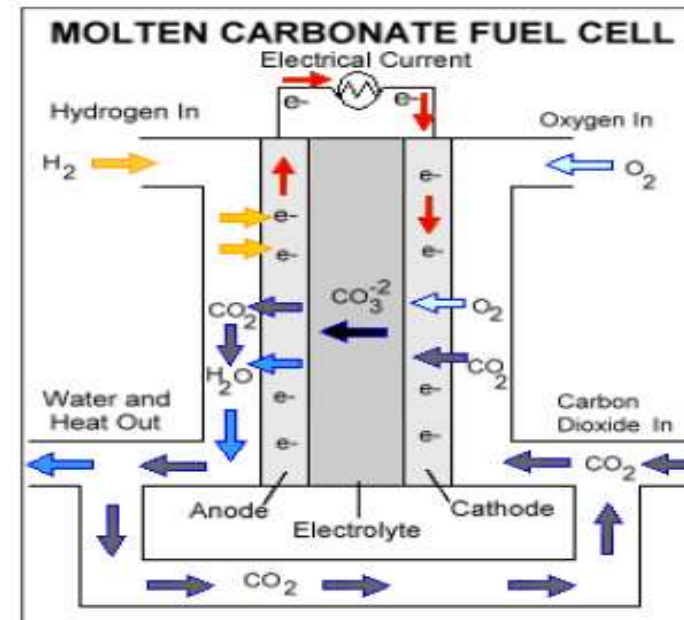
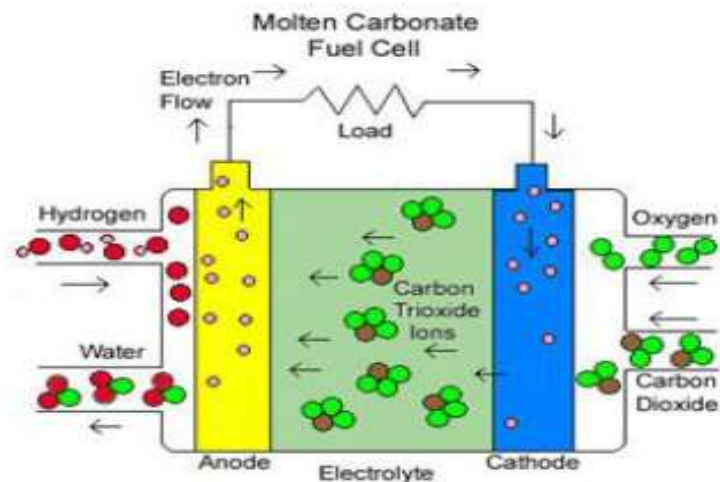
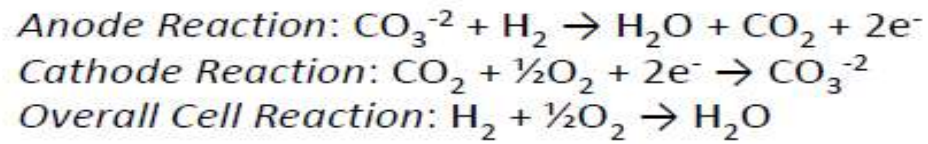


# MOLTEN CARBONATE FUEL CELLS

- The molten carbonate fuel cell uses a molten carbonate salt as the electrolyte. It has the potential to be fuelled with coal- derived fuel gases, methane or natural gas. These fuel cells can work at up to 60% efficiency.
- In molten carbonate fuel cells, negative ions travel through the electrolyte to the anode where they combine with hydrogen to generate water and electrons.
- Molten carbonate fuel cells (MCFCs) are currently being developed for natural gas and coal-based power plants for electrical utility, industrial, and military applications.
- MCFCs are high-temperature fuel cells that use an electrolyte composed of a molten carbonate salt mixture suspended in a porous, chemically inert ceramic lithium aluminum oxide ( $\text{LiAlO}_2$ ) matrix. Since they operate at extremely high temperatures of  $650^\circ\text{C}$  and above, nonprecious metals can be used as catalysts at the anode and cathode, reducing costs.

- Unlike alkaline, phosphoric acid, and polymer electrolyte membrane fuel cells, MCFCs don't require an external reformer to convert more energy-dense fuels to hydrogen. Due to the high temperatures at which they operate, these fuels are converted to hydrogen within the fuel cell itself by a process called internal reforming, which also reduces cost.
- Although they are more resistant to impurities than other fuel cell types, scientists are looking for ways to make MCFCs resistant enough to impurities from coal, such as sulfur and particulates.
- The primary disadvantage of current MCFC technology is durability. The high temperatures at which these cells operate and the corrosive electrolyte used accelerate component breakdown and corrosion, decreasing cell life.

# SCHEMATIC OF MOLTEN CARBONATE FUEL CELL





# PHOSPHORIC ACID FUEL CELLS (PAFC)

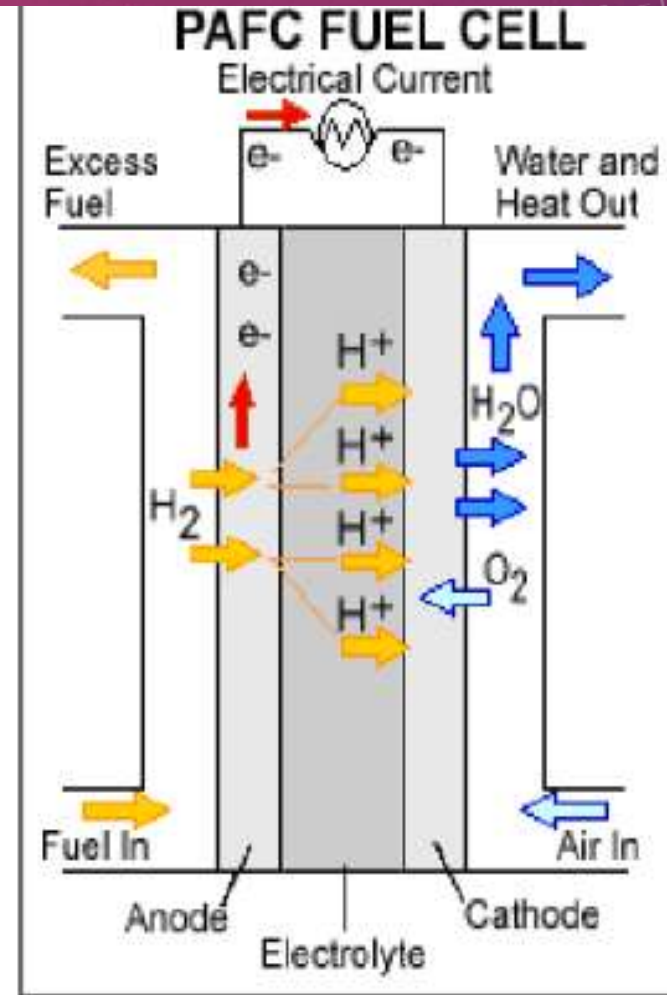
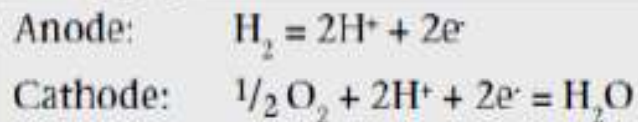
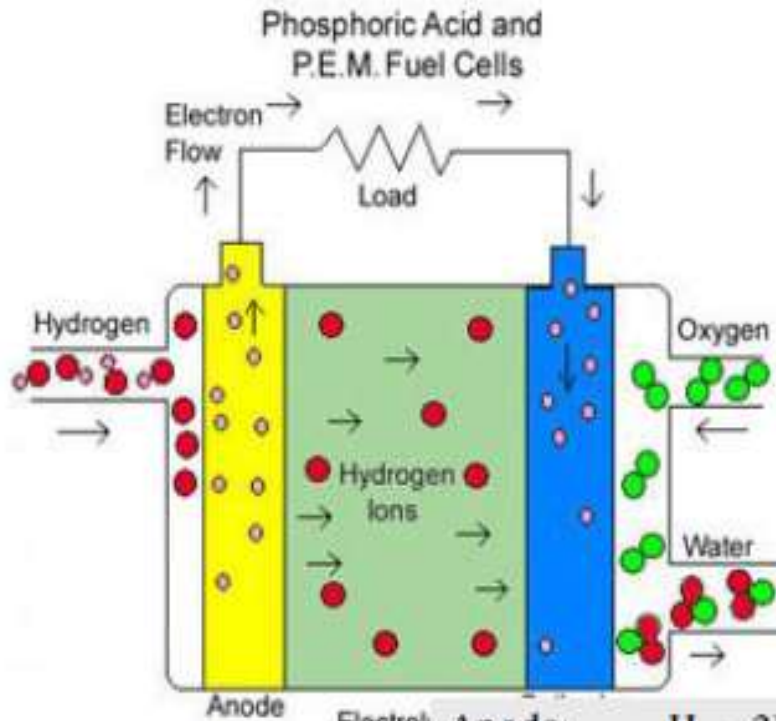
- A phosphoric acid fuel cell (PAFC) consists of an anode and a cathode made of a finely dispersed platinum catalyst on carbon and a silicon carbide structure that holds the phosphoric acid electrolyte. In phosphoric acid fuel cells, protons move through the electrolyte to the cathode to combine with oxygen and electrons, producing water and heat .
- Phosphoric acid fuel cells use liquid phosphoric acid as an electrolyte—the acid is contained in a Teflon-bonded silicon carbide matrix—and porous carbon electrodes containing a platinum catalyst.
- PAFCs are more tolerant of impurities.



- They are 85 percent efficient when used for the co-generation of electricity and heat, but less efficient at generating electricity alone (37 to 42 percent).
- PAFCs are also less powerful than other fuel cells, given the same weight and volume. As a result, these fuel cells are typically large and heavy. PAFCs are also expensive.
- Like PEM fuel cells, PAFCs require an expensive platinum catalyst, which raises the cost of the fuel cell.

# SCHEMATIC OF PHOSPHORIC ACID FUEL CELL

This is the most commercially developed type of fuel cell and is being used to power many commercial premises



# POLYMER ELECTROLYTE MEMBRANE (PEM) FUEL CELLS (PEMFC)

- In polymer electrolyte membrane (PEM) fuel cells, protons move through the electrolyte to the cathode to combine with oxygen and electrons, producing water and heat.
- Polymer electrolyte membrane (PEM) fuel cell uses a polymeric membrane as the electrolyte, with platinum electrodes. These cells operate at relatively low temperatures.
- Polymer electrolyte membrane (PEM) fuel cells—also called proton exchange membrane fuel cells—deliver high power density and offer the advantages of low weight and volume, compared to other fuel cells. PEM fuel cells use a solid polymer as an electrolyte and porous carbon electrodes containing a platinum catalyst. They only hydrogen, oxygen from the air, and water to operate and do not require corrosive fluids like some fuel cells.



**Polymer electrolyte membrane** fuel cells operate at relatively low temperatures, around 80°C (176°F).

**Low temperature operation** allows them to start quickly (less warm-up time) and results in less wear on system components, resulting in better durability.

However, **it requires that a noble metal catalyst (typically platinum)** be used to separate the hydrogen's electrons and protons, adding to system cost.

The **platinum catalyst is also extremely sensitive to CO poisoning**, making it necessary to employ an additional reactor to reduce CO in the fuel gas if the hydrogen is derived from an alcohol or hydrocarbon fuel. This also adds cost.

Developers are currently exploring platinum/ruthenium catalysts that are more resistant to CO.

