* Hydrogen gas has the highest calorific value of 150 K.J among all the fuels
* Very high efficiency (60 - 85 %)

Hydrogen

Hydrogen (H_2) is a colorless, odorless gas that accounts for 75 percent of the entire universe's mass. Hydrogen is found on Earth only in combination with other elements such as oxygen, carbon and nitrogen. Hydrogen can be considered as the simplest element in existence. Hydrogen is also one of the most abundant elements in the earth's crust. Hydrogen as a gas is not found naturally on Earth and must be manufactured. This is because hydrogen gas is lighter than air and rises into the atmosphere as a result. Natural hydrogen is always associated with other elements in compound form such as water, coal and petroleum. Hydrogen has the highest energy content of any common fuel by weight. On the other hand, hydrogen has the lowest energy content by volume. It is the lightest element, and it is a gas at normal temperature and pressure

Hydrogen as fuel

Hydrogen is considered as a secondary source of energy, commonly referred to as an energy carrier. Energy carriers are used to move, store and deliver energy in a form that can be easily used. Electricity is the most well known example of an energy carrier. Hydrogen as an important energy carrier in the future has a number of advantages. For example, a large volume of hydrogen can be easily stored in a number of different ways. Hydrogen is also considered as a high efficiency, low polluting fuel that can be used for transportation, heating, and power generation in places where it is difficult to use electricity. In some instances, it is cheaper to ship hydrogen by pipeline than sending electricity over long distances by wire.

As hydrogen burns in air, it combines with oxygen to form water and a large amount of energy (150 kilojoules per gram) is released. Due to its high, rather the highest calorific value, hydrogen can serve as an excellent fuel. Moreover, it is non-polluting and can be easily produced.

$H_2 + \frac{1}{2} O_2 \longrightarrow H_2O + \text{Energy}$

It is must to separated hydrogen from its compounds like water, hydrocarbon, etc. for its future use as fuel.

Production of Hydrogen

Hydrogen can be produced by following methods:

(i) By thermal dissociation of water (at 3000°K or above) hydrogen (H_2) is produced.

(ii) Steam reforming basically used in industries in which hydrogen is separated from hydrocarbons. $CH_4 + H_2O \xrightarrow{Ni} 3H_2 + CO$

(iii) Electrolytic method dissociates water into hydrogen (H_2) and oxygen (O_2) by making a current flow through it (Water splitting by electrolysis).

(iv) Photo-electrolysis of water involves breakdown of water in the presence of sun light to release hydrogen. Green plants also have photolysis of water during photosynthesis. Efforts are underway to trap hydrogen molecule which is produced during photosynthesis However, hydrogen is highly inflammable and explosive in nature. Hence, safe handling is required for using H_2 as a fuel.

(v) Biomass gasification

(vi) Microbial production by algae and bacteria.

Hydrogen production by water splitting (Electrolysis by electrolytic cell)

Electrolysis involves passing an electric current through water to separate water into its basic elements, hydrogen and oxygen. Hydrogen is then collected at the negatively charged cathode and oxygen at the positive anode. Hydrogen produced by electrolysis is extremely pure, and results in no emissions since electricity from renewable energy sources can be used. Unfortunately, electrolysis is currently a very expensive process.

In electrolysis process, Water reacts at the anode to form oxygen and positively charged hydrogen ions (protons). The electrons flow through an external circuit and the hydrogen ions selectively move across the PEM to the cathode. At the cathode, hydrogen ions combine with electrons from the external circuit to form hydrogen gas.

Polymer electrolyte membrane (PEM)

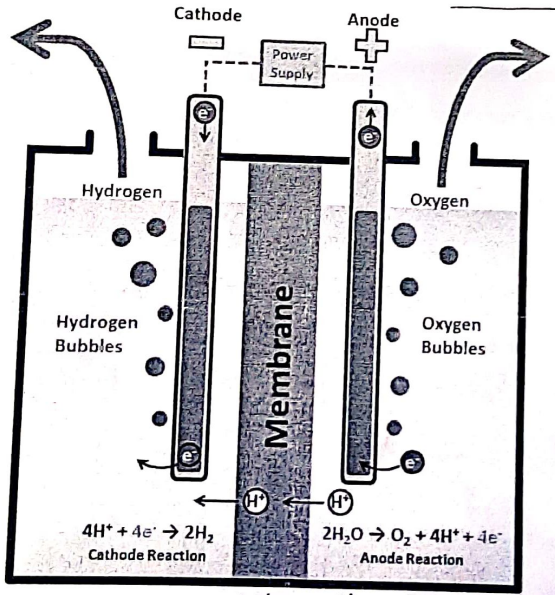
Anode Reaction: $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

Cathode Reaction: $4H^+ + 4e^- \rightarrow 2H_2$

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

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

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



In PEM, Electrolyte is a solid specially plastic material

Fig: Electrolytic cell

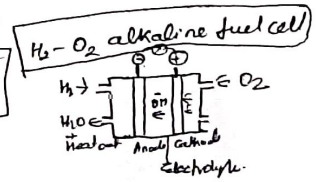
Energy/electricity production by hydrogen (Fuel Cell)

A fuel cell is an electrochemical cell that converts the chemical energy from a fuel into electricity through an electrochemical reaction of hydrogen fuel with oxygen or another

oxidizing agent. Fuel cells are different from batteries in requiring a continuous source of fuel and oxygen (usually from air) to sustain the chemical reaction, whereas in a battery the chemical energy comes from chemicals already present in the battery. Fuel cells can produce electricity continuously for as long as fuel and oxygen are supplied. There are many types of fuel cells, but they all consist of an anode, a cathode, and an electrolyte that allows positively charged hydrogen ions (protons) to move between the two sides of the fuel cell. At the anode a catalyst causes the fuel to undergo oxidation reactions that generate protons (positively charged hydrogen ions) and electrons. The protons flow from the anode to the cathode through the electrolyte after the reaction. At the same time, electrons are drawn from the anode to the cathode through an external circuit, producing direct current electricity. At the cathode, another catalyst causes hydrogen ions, electrons, and oxygen to react, forming water.

At anode $H_2 + 2OH^- \longrightarrow 2H_2O + 2e^-$

At cathode $O_2(g) + 2H_2O + 4e^- \longrightarrow 4OH^-$



PEMFC Electrode Reactions are:

At anode: $H_2 \rightarrow 2H^+ + 2e^-$

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

Overall Reaction: $H_2 + \frac{1}{2}O_2 \rightarrow H_2O$

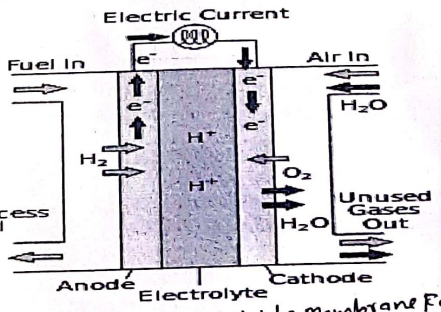


Fig: Polymer Electrolyte Membrane Fuel Cell (PEMFC)

Significance of Hydrogen Energy

In the future, hydrogen will join electricity as an important energy carrier, since it can be made safely from renewable energy sources and is virtually nonpolluting. It will also be used as a fuel for 'zero-emissions' vehicles, to heat homes and offices, to produce electricity, and to fuel aircraft. Hydrogen has great potential as a way to reduce reliance on imported energy sources such as oil. Before hydrogen can play a bigger energy role and become a widely used alternative to gasoline, many new facilities and systems must be built.