# HYDROGEN

Cavendish is regarded as the discoverer of hydrogen because he was the first (in 1766) to prepare it in the pure state, describe its properties and recognize it as an element. He found that the gas was flammable and that it burned in air to produce water. Therefore, Lavoisier named it hydrogen, meaning water former.

## Occurrence

Hydrogen is found free only in very small amounts (0.01%) in the atmosphere and in volcanic gases; although recent spectroscopic studies show that large amounts are present in the sun and the stars. Hydrogen is widely distributed in combination with other elements. It makes up one-ninth by mass of water and is an important constituent of all acids and alkalis. Combined with carbon, hydrogen is found in natural gas, kerosene, gasoline and other petroleum products. It is also a constituent of most organic substances including proteins,

carbohydrates, and fats, which are essential components of all living matter.

## Physical Properties

1. Hydrogen is a colourless, odourless, and tasteless gas.
2. It is neutral to litmus paper.
3. It is relatively insoluble in water, which is 0.02 at stp.
4. Hydrogen is the lightest known substance. It is 14.4 times less dense than air.
5. It has a very low boiling point of -253$^{o}$C.

## Chemical Properties

Hydrogen is an unusual element. It has a single valence electron like the Group I alkali metals, yet it is clearly a gas with non-metallic properties like Group 7 halogens. In the Periodic Table, hydrogen is usually placed in Group 1 for convenience, but sometimes it is placed between Groups 1 and 7 to depict its unusual nature.

Combination Reactions: Hydrogen combines with certain metals and non-metals to form electrovalent and covalent hydrides respectively. Hydrogen combines directly with several of the more active metals to form ionic hydrides, i.e. compounds which contain the hydride ion, $H^-$. E.g.

$$2Na_{(s)} + H_{2\,(g)} \rightarrow 2NaH_{(s)}$$

Hydrogen combines directly with the halogens to produce halides. For example:

$$Cl_{2\,(g)} + H_{2\,(g)} \rightarrow 2HCl_{(g)}$$

$$Br_{(g)} + H_{2\,(g)} \rightarrow 2HBr_{(g)}$$

Reducing Agent: Hydrogen reduces the oxides of copper (Cu), lead (Pb), iron (Fe), and zinc (Zn) to the respective metals when they are heated in a stream of the gas. At the same time, the hydrogen itself is oxidized to form water ($H_2O$).

$$CuO_{(s)} + H_{2\,(g)} \rightarrow Cu_{(s)} + H_2O_{(g)}$$

## Laboratory Preparation

The three (3) methods commonly used for the preparation of hydrogen in the laboratory are as follows:

Action of Zinc on an Acid. Dilute HCl or $H_2SO_4$ acid attacks metallic zinc with the liberation of hydrogen gas. No heating is necessary.

$$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2\ (aq)} + H_{2\ (g)}$$

$$Zn_{(s)} + H_2SO_{4\ (aq)} \rightarrow ZnSO_{4\ (aq)} + H_{2\ (g)}$$

Action of Sodium on cold water. Sodium liberates hydrogen from cold water. This reaction is very vigorous and should be carried out with extreme care using only a small piece of sodium.

$$2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2\ (g)}$$

Action of Iron on steam. Iron, at red heat liberates hydrogen from steam. Iron (II), diiron (iii) oxide, $Fe_3O_4$, is formed at the same time. This reaction is reversible:

$$3Fe_{(s)} + 4H_2O_{(g)} \rightleftharpoons Fe_3O_{4\ (s)} + 4H_{2\ (g)}$$

## Industrial Preparation

Hydrogen is prepared industrially through the processes:

- Bosch process,
- From Methane, and
- Electrolytic method.

## Uses of Hydrogen

1. Hydrogen is used in the manufacture of $NH_3$, HCl acid, and $CH_3OH$ (methanol).
2. Hydrogen under high pressure is passed through vegetable oils (e.g. palm oil, corn oil, cotton seed oil, or soybean oil) in the presence of a nickel catalyst to give solid fats, which are used as margarine or as lard substitutes and in the manufacture of soap and candles.
3. Since hydrogen has a low density, it is used for filling balloons. Its highly flammable nature, however, limits this use to meterological studies and other scientific purposes.

4. Hydrogen is a constituent of many gaseous fuel such as water gas and coal gas. Liquid hydrogen is also used as a rocket fuel.
5. Hydrogen gives out a lot of heat when it burns. Thus, it is used in oxy-hydrogen flames to produce high temperatures (over 2000$^{o}$C) that can melt metals.