Study of the First Element Hydrogen

Occurrence of Hydrogen

- **Free state:**

1. It is found entrapped in rocks and minerals.
2. It is found in traces in volcanic eruptions.
3. It is found in stars.

- **Combined state:**

1. It is a vital constituent of cells and tissues of plants and animals.
2. It is present in large amount in minerals such as coal and petroleum.
3. It is found in water.
4. It is found mixed with natural gas in coal mines.

Similarities Between Hydrogen and Alkali metals

- One electron in the valence shell.
- Same valency (+1)
- Acts as reducing agents
- Burns in oxygen to form oxides

Similarities Between Hydrogen and Halogens

- One less electron than inert gas configuration
- Same valency
- Forms anions
- Electronegative in nature
- Same physical state
- Exists as diatomic molecule

Preparation of hydrogen

- **By the action of dilute acids on metals:**

  E.g. $Fe\ (s) + H_2SO_4\ (aq) \rightarrow FeSO_4\ (aq) + H_2\ (g)$

- **By the action of water on metals**

- **Action of cold water:**

Metal + Water (Cold) → Metal Hydroxide + Hydrogen

$2Na\ (s) + 2H_2O\ (l) \rightarrow 2NaOH\ (aq) + H_2\ (g)$

- **Action of hot water:**

Metal + Steam → Metal Oxide + Hydrogen

$2Mg\ (s) + 2H_2O\ (g) \rightarrow 2MgO\ (s) + 2H_2\ (g)$

- **By the action of caustic alkalies on metals:**

$$\text{Metal + Caustic alkali solution} \xrightarrow{Boiling} \text{Metal salt + Hydrogen}$$

$$Zn_{(s)} + 2NaOH_{(aq.)} \xrightarrow{Boiling} Na_2ZnO_{2(aq.)} + H_{2(g)}$$

- **Laboratory preparation:** In the laboratory hydrogen is prepared by reacting zinc with dilute sulphuric acid.

$$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$$

The series in which various metals are arranged in the order of their decreasing reactivity is called a Reactivity series.

Salient Features of Reactivity Series

- Metals are arranged in the decreasing order of their electropositive character.
- Metals at the top have greater reducing power. This power decreases, moving down the series.
- Metals at the top show greater tendency to get oxidised.
- Metals above hydrogen in the reactivity series liberate hydrogen gas from mineral acids.
- Metals at the top displace metals lower in the series from the aqueous solution of their salts.
- Metal oxides above Al, cannot be reduced by common reducing agents, the reverse is true for metal oxides below Al.
- Metals at the top having most electropositive nature combines with the most electronegative elements.

K	These elements displace hydrogen from dil. acids (H_2SO_4 or HCl) with

Na Ca	explosive violence
Mg Al Zn	These elements displace hydrogen from dil. acids (H_2SO_4 or HCl) vigorously
F Ni Sn Pb	These elements displace hydrogen from dil. acids (H_2SO_4 or HCl) gently
H	
Cu Hg Ag Au	These elements do not displace hydrogen from dil. acids (H_2SO_4 or HCl)

Properties of hydrogen

Physical properties:

- It is the lightest element known.
- It is a colourless, tasteless and odourless gas.
- It is sparingly soluble in water.
- It is difficult to liquefy.

Chemical properties:

- It is neutral to litmus.
- It burns with a pale blue flame and does not support combustion.
- It reacts with heated metals, it reacts with them to form corresponding hydrides.

$$2\,M + H_2 \xrightarrow{\Delta} 2\underset{M = K,\ Na}{MH}$$ 2 M + H2 → Δ 2 MHM = K, NaCa + H2 –

$$Ca + H_2 \xrightarrow{\Delta} CaH_2$$

- It combines with oxygen to form water. The reaction is exothermic to the extent of explosion.

  $2H_2 + O_2 \rightarrow 2H_2O$

- It combines with chlorine in the presence of diffused sunlight to form hydrogen chloride gas.

  $H_2 + Cl_2 \rightarrow 2HCl$

- It reacts reversibly with nitrogen in the presence of finely divided iron as a catalyst and molybdenum as a promoter maintained at 450 ^oC to 500 ^oC to form ammonia. The reaction is reversible and exothermic.
- When hydrogen is passed through molten sulphur it forms hydrogen sulphide.

  $8H_2 + S_8 \rightarrow 8H_2S$

- It reacts with unsaturated hydrocarbons in the presence of suitable catalyst to form saturated hydrocarbons. This process is known as **hydrogenation**.

  $C_nH_{2n} + H_2 \rightarrow C_nH_{2n+2}$

Uses

- In the manufacture of ammonia by Haber's process.
- In the hydrogenation of vegetable oils.
- In the manufacture of hydrochloric acid.
- As a reducing agent.
- In the production of high temperature flame.
- In automatic lighters and self lighting gas jets.
- To produce artificial petrol from coal
- In extraction of metals by reducing the heated metallic oxides(less active metals) to metal
- In meteorological balloons, for studying weather conditions

Oxidation is always accompanied by reduction.

Oxidation: Loss of electron(s) by any species

Reduction: Gain of electron(s) by any species

Oxidising agent (oxidant): Acceptor of electron(s)

Reducing agent (reductant): Donor of electron(s)

Differences between oxidation and reduction

Oxidation	Reduction
It is addition of oxygen	It is removal of oxygen
It is removal of hydrogen	It is addition of hydrogen
It is addition of an electronegative atom/ion	It is removal of an electronegative atom/ion
It is removal of electropositive atom/ion	It is addition of electropositive atom/ion
There is an increase in positive valency	There is a decrease in positive valency
There is a decrease in negative valency	There is an increase in negative valency
Loss of electrons occur	Gain of electrons occur