Hydrogen

Hydrogen:

- First element in the periodic table
- Electronic configuration is $1s^1$.
- It resembles with both alkali metals and halogens to a certain extent.
- It is present in the atmosphere as dihydrogen, which is the most abundant element in the universe and the principal element in the solar atmosphere.

Isotopes of hydrogen:

Protium; ¹H

Deuterium (Heavy hydrogen); ² Hor D

Tritium; ³H or T

Tritium is radioactive. ($t_{1/2} = 12.33$ years)

Dihydrogen

Laboratory preparation:

$$H_{2(g)} + 2M_{(g)} \xrightarrow{673K,200 \text{ atm}} 2MH_{(s)}$$
; M is metal

Commercial preparation:

• Electrolysis of acidified water

$$2H_2O_{(1)} \xrightarrow{\text{Etedrolysis}} 2H_{2(g)} + O_{2(g)}$$

- High purity H₂ is obtained by electrolysis of warm aqueous Ba(OH)₂ between nickel electrodes.
- It is also obtained as a by-product in the manufacture of NaOH and Cl₂ by electrolysis of brine solution.
- Obtained by the reaction of steam on hydrocarbons at high temperatures

$$C_nH_{2n+2} + nH_2O \xrightarrow{1270K} n\underbrace{CO + (2n+1)H_2}_{Water eas}$$

The mixture of CO and H₂ is also called water gas. It is also called *synthetic gas* or *syngas*. [The process of producing *syngas* from coal is called *coal gasification*.]

If carbon monoxide of *syngas* mixtures is treated with steam in the presence of iron chromate as catalyst, then the production of dihydrogen increases. This reaction is called *water-gas shift* reaction.

$$CO_{(g)} + H_2O_{(g)} \xrightarrow{673K} CO_{2(g)} + H_{2(g)}$$

Physical properties: Colourless, odourless, tasteless, combustible gas

It is lighter than air and insoluble in water.

Chemical properties:

• Reaction with halogen:

$$H_{2(g)} + X_2(g) \longrightarrow 2HX_{(g)} (X=F,Cl,Br,I)$$

• Reaction with O₂:

$$2H_{2(g)} + O_{2(g)} \xrightarrow{\Delta \text{ or catalyst}} 2H_2O_{(I)} + Heat$$

• Reaction with N₂:

$$3H_{2(g)} + N_{2(g)} \xrightarrow{673 \text{ K}, 200 \text{ atm}} 2NH_{3(g)}$$

• Reaction with metals:

$$H_{2(g)} + 2M_{(g)} \xrightarrow{673K,200 \text{ atm}} 2MH_{(s)}$$
; M is metal

Reaction with metal ions and metal oxides

It reduces less reactive metals in aqueous solution and oxides.

$$H_{2(g)} + Pd^{2+}_{(aq)} \longrightarrow Pd_{(s)} + 2H^{+}_{(aq)}$$

 $yH_{2(g)} + M_{x}O_{y(s)} \longrightarrow xM_{(s)} + yH_{2}O_{(l)}$

• Reaction with organic compounds

- (i) Hydrogenation of vegetable oils
- (ii) Hydroformylation of alkenes to produce aldehydes, which further gives alcohols

$$CH_3CH=CH_2 + H_2 + CO \longrightarrow CH_3CH_2CH_2CHO \xrightarrow{H_2} CH_3CH_2CH_2CH_2OH$$

Uses:

- Used in the synthesis of ammonia, methanol, metal hydrides, hydrogen chloride, and vanaspati fat.
- Used as rocket fuel in space research
- Used in fuel cells for generating electricity.
- Used in atomic hydrogen and oxy-hydrogen torches, which are used for cutting and welding purposes.

Hydrides (Binary compounds with other elements):

- Ionic or saline hydrides: Stoichiometric compounds with highly electropositive *s*-block elements. Example: NaH, CaH₂, AlH₃, etc.
- Covalent or molecular hydrides: Compounds with p-block elements such as CH_4 , NH_3 , H_2O

Molecular hydrides are further classified into:

- Electron-deficient hydrides
- Electron-precise hydrides
- Electron-rich hydrides
- Metallic or non-stoichiometric hydrides LaH_{2.87}, TiH_{1.5-1.8}, VH_{0.56}, etc.

Hydrogen peroxide:

Preparation:

1.
$$2\text{BaO}_2.8\text{H}_2\text{O}(s) + \text{H}_2\text{SO}_4(aq) \xrightarrow{\text{Catalyst}} \text{BaSO}_4(s) + \text{H}_2\text{O}_2(aq) + 8\text{H}_2\text{O}(s)$$

2. $2\text{HSO}_4^-(aq) \xrightarrow{\text{Electrolysis}} \text{HO}_3\text{SOOSO}_3\text{H}(aq)$
 $\xrightarrow{\text{Hydrolysis}} 2\text{HSO}_4^-(aq) + 2\text{H}^+(aq) + \text{H}_2\text{O}_2(aq)$

Structure: Non-planar

Physical properties:

- Almost colourless (very pale blue) liquid
- Miscible with water and forms a hydrate (H₂O.H₂O)

Chemical properties:

• Acts as an oxidising as well as reducing agent in both acidic and alkaline medium

Storage:

• Stored in wax-linked glass or plastic vessel in dark as it decomposes on exposure to light

Uses:

- As hair bleach, disinfectant, antiseptic
- In manufacture of chemicals used in high quality detergent
- Widely used as an industrial bleach
- In synthesis of food products and pharmaceuticals
- In pollution control treatment

Heavy water (D₂O):

Preparation:

- By the electrolytic enrichment of normal water
- As by-product in some fertiliser industries

Uses:

- As moderator in nuclear reactors
- In exchange reactions to study mechanism of reactions
- To prepare other deuterium compounds