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; ${}_{1}^{1}H$

Deuterium (Heavy hydrogen); ${}_{1}^{2}H$ or D

Tritium; ${}_{1}^{3}H$ or T

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

Dihydrogen

Laboratory preparation:

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

Commercial preparation:

- Electrolysis of acidified water

$$2H_2O_{(l)} \xrightarrow[\text{Traces of acid/base}]{\text{Etedrolysis}} 2H_{2(g)} + O_{2(g)}$$

- High purity H_2 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 Cl_2 by electrolysis of brine solution.
- Obtained by the reaction of steam on hydrocarbons at high temperatures

$$C_nH_{2n+2} + nH_2O \xrightarrow[Ni]{1270K} n\underbrace{CO + (2n+1)H_2}_{\text{Water gas}}$$

The mixture of CO and H_2 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*.

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

Physical properties: Colourless, odourless, tasteless, combustible gas

It is lighter than air and insoluble in water.

Chemical properties:

- **Reaction with halogen:**

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

- **Reaction with O_2:**

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

- **Reaction with N_2:**

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

- **Reaction with metals:**

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

- **Reaction with metal ions and metal oxides**

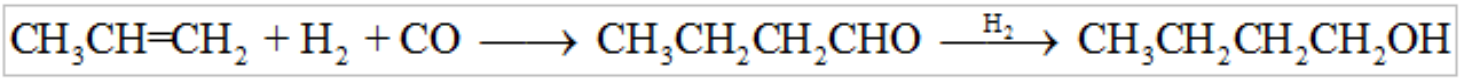
It reduces less reactive metals in aqueous solution and oxides.

$$H_{2(g)} + Pd^{2+}{}_{(aq)} \longrightarrow Pd_{(s)} + 2H^{+}{}_{(aq)}$$
$$yH_{2(g)} + M_xO_{y(s)} \longrightarrow xM_{(s)} + yH_2O_{(l)}$$

- **Reaction with organic compounds**

(i) Hydrogenation of vegetable oils

(ii) Hydroformylation of alkenes to produce aldehydes, which further gives alcohols



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, CaH_2, AlH_3, 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 $LaH_{2.87}$, $TiH_{1.5\text{-}1.8}$, $VH_{0.56}$, etc.

Hydrogen peroxide:

Preparation:

1. $2BaO_2.8H_2O(s) + H_2SO_4(aq) \xrightarrow{\text{Catalyst}} BaSO_4(s) + H_2O_2(aq) + 8H_2O$

2. $2HSO_4^-(aq) \xrightarrow{\text{Electrolysis}} HO_3SOOSO_3H(aq)$

$\xrightarrow{\text{Hydrolysis}} 2HSO_4^-(aq) + 2H^+(aq) + H_2O_2(aq)$

Structure: Non–planar

Physical properties:

- Almost colourless (very pale blue) liquid
- Miscible with water and forms a hydrate ($H_2O.H_2O$)

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 (D_2O):

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