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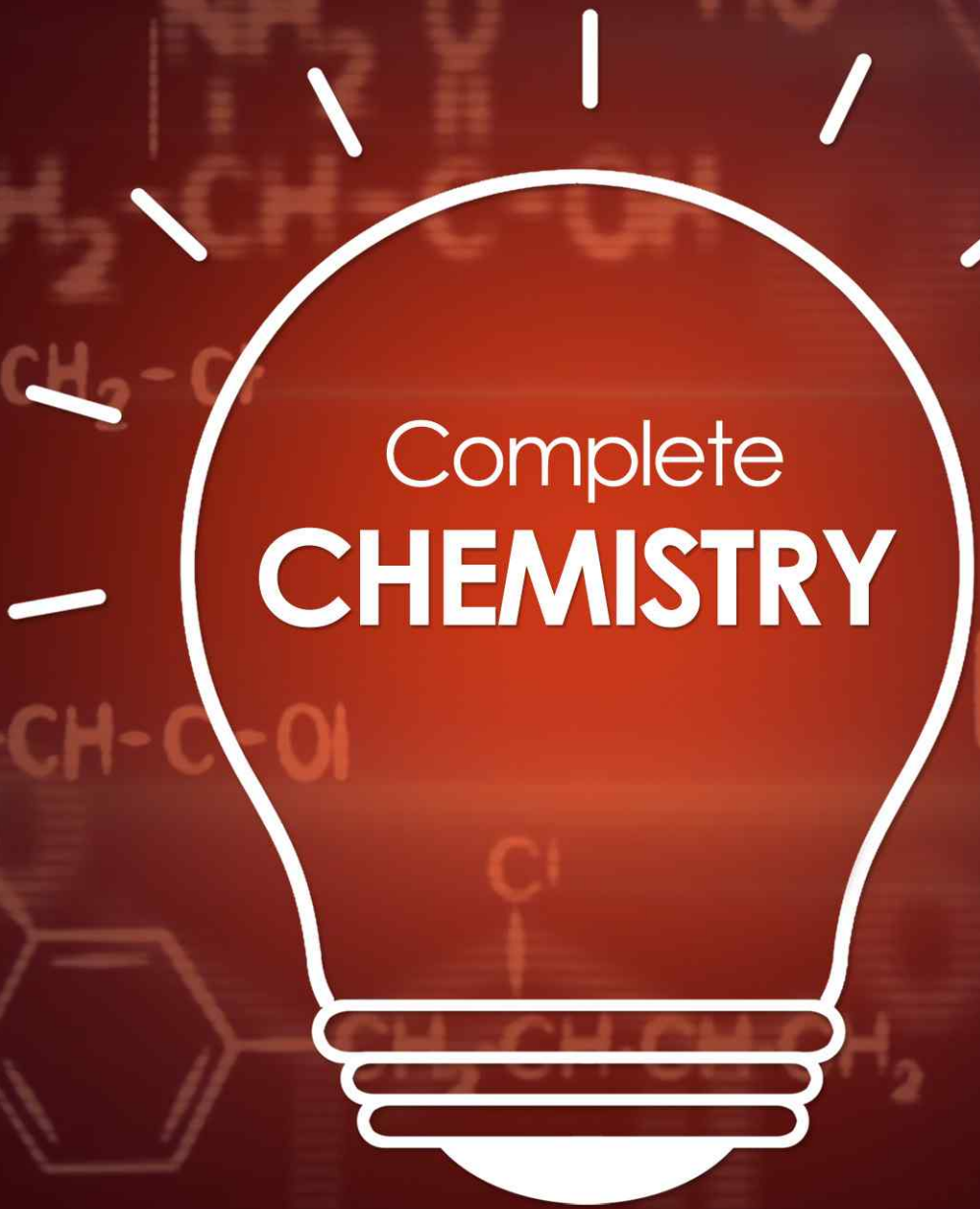

# Complete CHEMISTRY

## IIT-JEE · NEET · CBSE eBOOKS

CLASS 11&12th

CLASS 11th

# Hydrogen and Its Compounds

## 01. Introduction

**Atomic process of isotopes of hydrogen.**

| S.No. | Property | H | D | T |
|---|---|---|---|---|
| (i) | Relative atomic mass | 1.007825 | 2.014102 | 3.016049 |
| (ii) | Nuclear spin quantum number | 1/2 | 1 | 1/2 |
| (iii) | Radioactive stability | Stable | Stable | Unstable |

Hydrogen forms more compounds than even carbon. Use of alkali metals and water to produce $H_2$ is very dangerous. These reactions are highly exothermic and as such $H_2$ produced can easily catch fire. To prevent such mishaps, amalgams of alkali metals are used for the preparation of $H_2$. It reduces the activity of alkali metals. It also increases the density of the alkali metals as such, these amalgams no longer float over water like pure alkali metals. Thus, the heat liberated is easily absorbed by water, there by preventing the alkali metal and $H_2$ from catching fire. Para-hydrogen has lesser molecular energy than *ortho*-hydrogen. Therefore, at lower temperatures *para*-hydrogen is more stable than *ortho*-hydrogen. However at room temperature *ortho*-hydrogen predominates due to its higher molecular energy. Do not use dilute nitric acid for producing hydrogen. Active metals like Zn, Al, Mg, Fe do not produce hydrogen with dilute $HNO_3$. It is because dilute $HNO_3$ is an oxidizing agent and it oxidizes the hydrogen produced to water. Hydrogen is the lightest element known. Metals like Pd, Pt, Au etc. have the property of absorbing large quantity of hydrogen at normal or higher temperature. e.g., colloidal Pd can absorb 2950 times its own volume of hydrogen and Pd metal can absorb 900 times its own volume of hydrogen. Part of this absorbed hydrogen exist as an interstitial hydride and part is physically occluded. This phenomenon is known as occlusion of hydrogen. The occlusion property of these metals is in the order.

Colloidal Palladium > Palladium < Platinum > Gold > Nickel

Properties of natural hydrogen resembles with protium because it is present in largest quantity. The existence of heavy hydrogen (deuterium) was first of all proposed by Urey.

Nascent and Atomic hydrogen :

Nascent hydrogen is the hydrogen at the moment of its generation in a chemical reaction. It consist of atoms of hydrogen and hence has more energy and so it is more reactive and is a stronger reducing agent than ordinary hydrogen. Atomic hydrogen. At high temperature (about 3000°C) and low pressure molecules of dihydrogen dissociate to form atoms of hydrogen known as atomic hydrogen. Nascent hydrogen can be produced even at room temperature but atomic hydrogen is produced at elevated temperatures. Nascent hydrogen can never be isolated but atomic hydrogen can be isolated. Reducing power of atomic hydrogen is much greater than that of nascent hydrogen.

## 02. Methods of Preparation of Hydrogen ($H_2$)

(i) **By action of water with metals.**

(a) Active metals like Na, K react at room temeprature.

$$2M + 2H_2O \rightarrow 2MOH + H_2$$

(b) Less active metals like Ca, Zn, Mg, Al liberate hydrogen only on heating.

$$2Al + 3H_2O \rightarrow Al_2O_3 + 3H_2$$

(ii) **Lane's Process :**

In this process, steam is passed over hot iron. Iron decomposes steam with the formation of magnetic oxide ($Fe_3O_4$) and hydrogen. The temperature of iron is maintained between 550 to 800°C. This reaction is termed *gassing reaction* and time alloted for this reaction is about 10 minutes.

$$3Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2$$

Iron is generated by reducing magnetic oxide with water gas ($CO + H_2$). This reaction is called vivification and time alloted for this reaction is about 20 minutes.

$$\left.\begin{aligned} Fe_3O_4 + 4CO &= 3Fe + 4CO_2 \\ Fe_3O_4 + 4H_2 &= 3Fe + 4H_2O \end{aligned}\right\} \text{ Vivifaction}$$

(iii) **By reaction of metals like Zn, Sn, Al with alkalies.**

$$Zn + 2NaOH \rightarrow Na_2ZnO_2 + H_2$$

$$Al + 2NaOH + 2H_2O \rightarrow 2NaAlO_2 + 3H_2$$

$$Si + 2NaOH + H_2O \xrightarrow[\text{(Silicon)}]{} Na_2SiO_3 + 2H_2$$

(iv) **By action of metals with acids.** All active metals which lie above hydrogen in electrochemical series, can displace hydrogen gas from dilute mineral acids.

$$Fe + 2HCl \rightarrow FeCl_2 + H_2$$

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

$$Zn + \text{dil. } H_2SO_4 \rightarrow ZnSO_4 + H_2$$

It must be noted that

(a) Pure zinc is not used for preparation.

(b) Conc. $H_2SO_4$ is not used as it oxidizes the liberated $H_2$ and produce $SO_2$

(v) **By electrolysis of water**

$$H_2O \xrightarrow{\text{electricity}} \underset{\text{Cathode)}}{H^+} + \underset{\text{(Anode)}}{OH^-}$$

At cathode : $H^+ + e^- \rightarrow 1/2\ H_2\uparrow$

(vi) Preparation of pure hydrogen. It can be obtained by

(a) The action of pure dil. $H_2SO_4 \rightarrow MgSO_4 + H_2$

(b) The electrolysis of a solution of barium hydroxide using nickel electrodes.

(c) By the action of water on NaH.

$NaH + H_2O \rightarrow NaOH + H_2$

(d) Very pure form of hydrogen is obtained by the action of KOH on scrap aluminium.

$2Al + 2KOH + 2H_2O \rightarrow 2KAlO_2 + 3H_2\uparrow$

(vii) Industrial preparation

- Bosch process – In this method water gas is mixed with steam and passed over heated catalytic mixture of $Fe_2O_3$ and $Cr_2O_3$ at 773 K when $CO_2$ and $H_2$ are obtained. The mixture is compressed to 25 atmospheric pressure and passed into water, $CO_2$, dissolves while $H_2$ is set free.

$$C + H_2O \xrightarrow{1270K} \underset{\text{water gas}}{CO + H_2}$$

$$\underset{\text{water gas}}{H_2 + CO} + \underset{\text{steam}}{H_2O} \xrightarrow[Fe_2O_3,Cr_2O_3]{773K} CO_2 + 2H_2$$