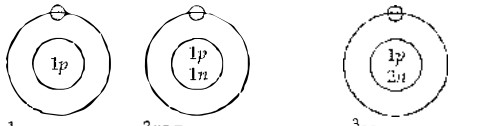
Unit

9 Hydrogen

- **Hydrogen** is the first element in the periodic table and is the lightest known element. It was prepared by Henry Cavendish in 1766 by the action of acids on metals. Earlier it was named as inflammable air then Lavoisier named it hydrogen (in Greek hydro means water, gen means producing) because it produces water on burning with oxygen.
- **Occurrence of hydrogen :** Hydrogen is the most abundant element in the universe. It occurs in nature in both free state as well as combined state.

  Free state → In air, volcanic gases, natural gases
  Combined state → In water, mineral oils, hydrocarbons, fats, proteins, alkalies, acids, etc.

  As such H_2 gas is not found in our atmosphere because of its lighter nature. Sun's atmosphere contains 90% of hydrogen.
- **Isotopes**

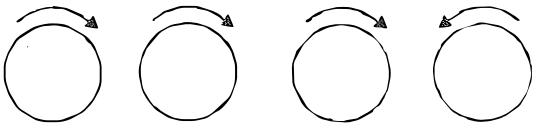


^1_1H Protium (Hydrogen) ^2_1H Deuterium (Heavy hydrogen) ^3_1H Tritium (Radioactive hydrogen)

Molecular forms : $^1H_2$ (dihydrogen)
$^2H_2$ or D_2 (dideuterium)
$^3H_2$ or T_2 (ditritium)
alongwith HD, HT, DT, etc.

Name	Symbol	Atomic mass	p	n	Percentage	Nuclear stability	Nuclear spin quantum number	Relative atomic mass
Protium	^1_1H	1	1	0	99.986	Stable	1/2	1.007825
Deuterium	^2_1H(D)	2	1	1	0.014	Stable	1	2.014102
Tritium	^3_1H (T)	3	1	2	7×10^{-16}	Radioactive	1/2	3.106049

- **Allotropes :** *Ortho* hydrogen and *para* hydrogen

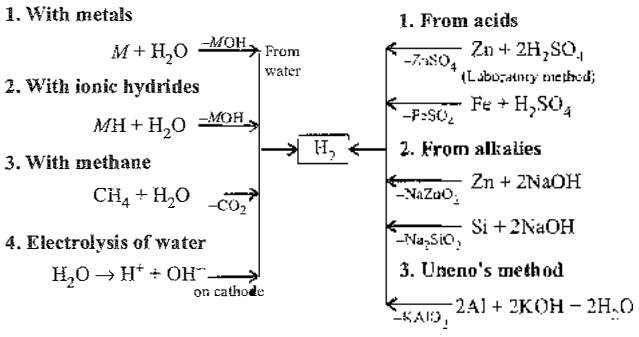


(*Ortho* hydrogen) (*Para* hydrogen)

At room temperature, ordinary hydrogen contains 75% *ortho*-hydrogen and 25% *para* hydrogen. As the temperature decreases, the percentage of *ortho* hydrogen in the mixture decreases. Pure *para* hydrogen can be prepared by cooling nearly to absolute zero but pure *ortho* hydrogen cannot be prepared.

- **Stability :** *Ortho* hydrogen > *Para* hydrogen
- Differences in physical properties of both is because of differences in internal energy of both. Internal energy of *ortho* H_2 > *para* H_2.

Preparation

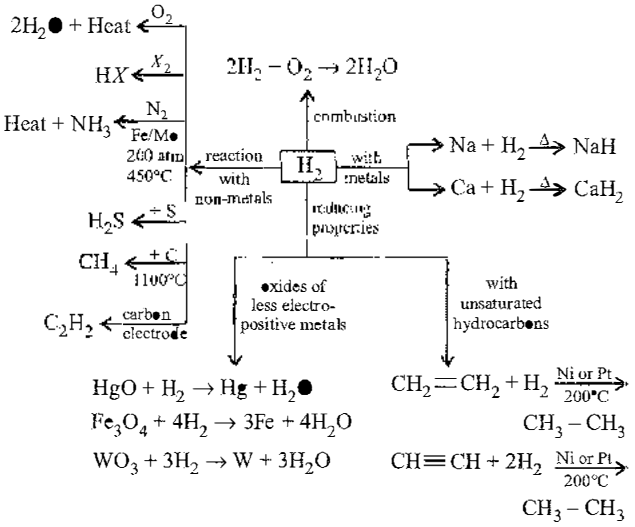


Properties

- **Physical properties :** The important physical properties of dihydrogen are:
  - It is a colourless, tasteless and odourless gas.

- It is slightly soluble in water.
- It is lightest substance known. For example, one litre of hydrogen at NTP weighs only 0.0980 g.
- It is highly combustible and therefore should be handled carefully.
- It is non-poisonous and lighter than air (vapour density = 1 while vapour density of air = 14.5).
- Hydrogen is inflammable and does not help in burning.

- **Chemical properties**



Uses

- Used as a reducing agent in industry and laboratories.
- Used to prepare hydrogenated vegetable solid fats.
- Used for welding purposes in both the oxy-hydrogen torch and the atomic-hydrogen torch, when temperature of the order of 2500 °C and 4000 °C are required respectively.
- Used as a rocket fuel in the form of liquid hydrogen.
- Used in the manufacture of synthetic petrol.
- Used in the preparation of many compounds such as methane, ammonia, water gas, and fertilizers such as urea, ammonium sulphate, etc.
- Used in metallurgy.
- Used in preparation of metal hydrides.

HYDRIDES

- The binary compounds formed by hydrogen with other elements, are called hydrides. Hydrogen combines with most of the metals and non-metals (except noble gases). Hydrides are classified into three main groups, depending upon their physical and chemical properties and the types of bonding:
  1. Ionic or salt like or saline hydrides
  2. Covalent or molecular hydrides
  3. Metallic or interstitial hydrides

Ionic Hydrides or Saline Hydrides

- These are formed by highly electropositive metals elements of group IA (alkali metals) and group IIA (alkaline earth metals with the exception of Be and Mg). BeH_2 and MgH_2 have covalent polymeric structure. The hydrogen atom exists as H^- ion.

  Ionic hydrides are prepared by the direct combination of the metals with hydrogen at high temperatures of 750°C.

  $$2Li + H_2 \longrightarrow \underset{\text{Molten}}{2Li^+H^-}$$

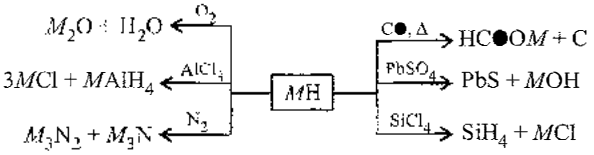
  $$Ca + H_2 \xrightarrow{800°C} Ca^{2+}(H^-)_2$$

- **Characteristics of ionic hydrides**
  - Ionic hydrides are white or light grey crystalline solids. They behave like salts.
  - They have high melting and boiling points.
  - They conduct electricity in fused state.
  - The thermal stability of the alkali metal and alkaline earth metal hydrides follow the order:

    $LiH > NaH > KH > RbH > CsH$

    and $CaH_2 > SrH_2 > BaH_2$
  - Aqueous solution of ionic hydrides is basic in nature.

    $$LiH + H_2O \longrightarrow LiOH + H_2$$



- **Uses of ionic hydrides :** Ionic hydrides and their complexes are used as reducing agents. They evolve hydrogen when heated. Hence, they are used as solid fuels as they ignite spontaneously.

Molecular or Covalent Hydrides

- Molecular hydrides are formed mainly by elements of comparatively higher electronegativity as of *p*-block elements. These hydrides, have molecular lattices held together by weak van der Waals forces. In some cases, hydrogen bonds are also formed. The general formula for covalent hydrides is XH_{8-n} where X stands for the symbol of a metal and 'n' is number of valence electrons.
- **Characteristics of covalent hydrides**
  - Molecular hydrides are soft.
  - They have low electrical conductivity.
  - The electronegativity difference between hydrogen and the atom bonded to it, determines the properties of covalent hydrides. On moving from left to right in a period, hydrides become increasingly acidic in character. For example NH_3 is a weak base, H_2O is neutral and HF is acidic.
  - The hydrides of Group III (*e.g.*, BH_3 and AlH_3) are electron deficient compounds and exist in polymeric forms [*e.g.*, B_2H_6 and $(AlH_3)_n$]. Hydrides of group-14 (*e.g.* CH_4, SiH_4, GeH_4, etc.) have exact number of electrons and hence called electron precise hydrides. Hydrides of group-15, 16, 17 (*i.e.* NH_3, PH_3, H_2O, H_2S, HF, HCl, etc.) have one or more lone pairs of electron around central atom and hence called electron rich hydrides.
- **Uses of molecular hydrides :** Molecular hydrides have wider applications. Some of them are mentioned here.