Hydrogen

Hydrogen is the most abundant element in the universe.

It is the 9th most abundant element in the earth's crust.

It occurs only in the combined state except in volcanic gases where it occurs in free state.

- It is the first element in the periodic table.
- It is the lightest of all the elements.
- It is the only element without neutrons i.e. Protium.
- It is the element with ambiguious position in the periodic table, as it resembles both I-A and VII-A group elements.
- Hydrogen should belong to the s-block as its electron configuration is $1s^1$.
- The properties in which hydrogen resembles alkali metals are
  a) Like alkali metals it has one electron in s-orbital of valence shell.
  b) Like Alkali metals, it forms H^+ ion.
  c) Like Alkali metals it forms monoxides and peroxides.
  d) Like Alkali metals, it acts as reductant.
- The properties in which Hydrogen resembles Halogens are
  a) Like Halogens it exists as diatomic molecule (H_2)
  b) Like Halogens it gains one electron to attain inert gas configuration
  c) The I.P value of "H" is similar to that of Halogens.
  d) Like halogens it forms univalent anion i.e H^-.
- Hydrogen has 3 isotopes. They are

Protium	$1H^1$
Deuterium	$1H^2$
Tritium	$1H^3$

- Theoritically the number of possible Hydrogen molecules is six. They are H_2, D_2, T_2, HD, HT and DT.
- Ordinary Hydrogen contains only 0.02% Deuterium.
- Hydrogen and Deuterium can be separated by gas diffusion principle.
- Hydrogen is more reactive than Deuterium.
- All the isotopes of Hydrogen have
  a) same chemical properties
  b) same atomic radii
  c) same bond lengths
- The isotopes of Hydrogen differ widely due to large difference in mass numbers.
  a) Number of neutrons b) Chemical reactivity
  c) Physical properties d) Nuclear radii

e) Bond energy

- The properties or physical constants which are lower for hydrogen than that of deuterium are

  i) Molecular weight ii) Boiling point

  iii) Melting point iv) Latent heat of fusion

  v) Latent heat of vaporisation

  vi) Bond energy

  vii) Activation energy

  Chemical reactivity is higher for hydrogen than that of Deuterium.

  On electrolysis of water, H_2 is released six times faster than that of D_2.
- Ordinary Hydrogen contains Tritium and protium in the ratio 1 : 10^{17}.
- Tritium can be obtained in the nuclear transformations such as

  ${}_7N^{14} + {}_0n^1 \rightarrow {}_6C^{12} + {}_1T^3$ (occurs in nature)

  ${}_3Li^6 + {}_0n^1 \rightarrow {}_2He^4 + {}_1T^3$ (takes place in nuclear reactors)
- The radioactive isotope of Hydrogen is **Tritium**. It is a beta emitter and its half life is 12.26 years

  ${}_1T^3 \rightarrow {}_2He^3 + {}_{-1}e^0$ (β - particle)
- Tritium is harmless, as it emits only low energitic β-radiation and will not emit harmful γ-rays.
- In the study of mechanism of various chemical reactions, Deuterium and Tritium are used as tracers.
- As the mass number increases the chemical reactivity decreases. So chemically least reactive isotope of Hydrogen is Tritium.

Uses of Hydrogen

Hydrogen is used

i) in the manufacture of chemicals

ii) in metallurgy

iii) as a source of atomic energy

iv) as a fuel.

a) Synthesis of Ammonia by Haber's process.

$$N_{2(g)} + 3H_{2(g)} \leftrightarrows 2\ NH_{3(g)}$$

b) Preparation of HCl

$$H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)} \xrightarrow{water} \underset{acid}{2HCl_{(aq)}}$$

c) Synthesis of Methyl alcohol:

$$H_2 + \underset{\text{water gas}}{(CO + H_2)} \xrightarrow[(catalyst)]{ZnO.CrO_3} CH_3OH$$

d) In the production of vanaspathi or Margarine:

- Synthetic petrol is prepared by Fischer-Tropsch process. Here Iron oxide is used to remove sulphur from a mixture of water gas and Hydrogen.
- Synthetic petrol is obtained by passing a mixture of water gas and Hydrogen free from sulphur over Cobalt catalyst.
- The heat of combustion of H_2 gas is high (242 KJ/mole). Hence it is used as an industrial fuel.
- Liquid Hydrogen is used as fuel in the rocket. In "SATURN-V" that took Neil Armstrong to the moon liquid hydrogen is used.

OXY hydrogen torch produces a very high temperature of 2800^0C. It is used for welding purpose and for melting platinum and Quartz.

- The fuel gases containing H_2 is the important constituent of many fuel gases such as
  a) Coal gas b) Water gas
  c) Carburetted water gas d) Semi water gas

Coal gas: It is obtained by the destructive distillation of coal

- The composition of Coal gas is
- H_2 = 45 - 55% CH_4 = 25-35% CO = 4 - 11%
- Coal gas has highest calorific value

Water gas: It contains H_2 and CO in 1 : 1 ratio by volumes. It is prepared by passing steam over white hot coke or coal.

- Carburetted water gas is obtained by adding gaseous Hydrocarbons to water gas.
- The calorific value of carburetted water gas is more than that of water gas due to the presence of Hydrocarbons.

Semi water gas: It is obtained by passing a mixture of air and steam over red hot coke.

- It is the mixture of CO, H_2, N_2.
  % by volume : N_2 > CO > H_2
- The calorific value of semi water gas is low. It is used as a fuel in steel industry.

Fuel cells:- In these cells heat energy produced by burning of fuel gases is converted into electrical energy.

- The fuel cell which involves the burning of H_2 and O_2 is used in Apollo series of rockets. The water formed in the combustion of Hydrogen is condensed and used as drinking water by astronauts.
- In Hydrogen - oxygen fuel cell, carbon electrodes and NaOH electrolyte is used.
  Electrode reactions:

At anode : $2(H_2+2OH^- \rightarrow 2H_2O + 2e^-)$

At cathode : $O_2 + 2H_2O \xrightarrow{4e^-} 4OH^-$

Cell reaction : $2H_2 + O_2 \rightarrow 2H_2O$

- The efficiency of fuel cells is very high because the heat energy is directly converted into electrical energy. Theoretically the efficiency of fuel cell should be 100 % but practically an efficiency of 60 - 70% has been achieved so far.
- Hydrogen is used as a reducing agent in the extraction of heavier metals like Molybdenum and Tungsten.

$$WO_3 + 3H_2 \rightarrow W + 3H_2O$$

- The energy emitting from sun and stars is due to nuclear fusion reactions involving Hydrogen nuclei.

Fusion reaction	Energy released
${}_1H^2 + {}_1H^2 \rightarrow {}_2He^4$	23×10^8 KJ / mole of "He"
${}_1H^2 + {}_1H^3 \rightarrow {}_2He^4 + {}_0n^1$	17.2×10^8 KJ / mole of "He"
$4\,{}_1H^1 \rightarrow {}_2He^4 + 2\,{}_1e^0$	26×10^8 KJ / mole of "He"

- Hydrogen bomb involves hydrogen nuclei fusion.