Chemistry Study Materials for Class 11
(NCERT Based Notes of Chapter 09)
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Hydrogen

Hydrogen shows resemblance with both Alkali metals of the first group and halogens of the 17^{th} group. Like alkali metals it has one electron in the outer most shell and forms uni positive ions. Hydrogen forms oxides, halides and sulphides similar to alkali metals.

Like halogens, it requires only one electron to complete the valence shell configuration. So it gains one electron to form uninegative ion. It exists as diatomic molecule, combines with metals to form hydrides and form a large number of covalent compounds with non-metals.

At the same time it shows some differences from alkali metals and halogens. Unlike alkali metals it has very high ionization enthalpy, exists as diatomic molecule and is a typical non-metal. Unlike halogens, it has very low reactivity and readily forms positive ions.

So even though Hydrogen resemblance with both alkali metals and halogens, it differs from them as well. So it is placed separately in the periodic table.

Isotopes of Hydrogen

Hydrogen has three isotopes – Protium ($_1H^1$), Deuterium ($_1H^2$) and Tritium ($_1H^3$). These isotopes differ from one another in number of neutrons only. Ordinary Hydrogen (protium) has no neutrons, Deuterium has one neutron and Tritium has two neutrons in the nucleus.

The major form is Protium. The abundance of Deuterium is 0.0156% and that of Tritium is about 1 atom per 10^{18} atoms of protium. Only Tritium is radioactive. Since these isotopes have same electronic configuration, they have almost the same chemical properties.

Preparation of Dihydrogen or Hydrogen (H_2)

In the laboratory, H_2 is prepared by the following methods:

1. The reaction between granulated zinc and dilute HCl. $Zn + HCl \rightarrow ZnCl_2 + H_2$
2. The reaction of Zn with aqueous alkali

   $Zn + 2NaOH \rightarrow Na_2ZnO_2 + H_2$

   (Sodium zincate)

Commercially Hydrogen is prepared by the following methods:

1. Electrolysis of acidified water with platinum electrodes

   $2H_2O(l) \xrightarrow{\text{electrolysis}} 2H_2(g) + O_2(g)$
2. It is obtained as a byproduct in the manufacture of NaOH and Chlorine by the electrolysis of brine solution (NaCl solution).

   At anode: $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$

   At cathode: $2H_2O(l) + 2e^- \longrightarrow H_2(g) + 2OH^-(aq)$

   The overall reaction is

   $2Na^+(aq) + 2Cl^-(aq) + 2H_2O(l) \rightarrow Cl_2(g) + H_2(g) + 2Na^+(aq) + 2OH^-(aq)$
3. By the reaction of steam on hydrocarbons or coke at high temperature in the presence of catalyst. $CH_4(g) + H_2O(g) \rightarrow CO(g) + 3H_2(g)$

The mixture of CO and H_2 is called water gas. Since it is used for the synthesis of methanol and large number hydrocarbons, it is also called ***synthesis gas or syn gas***.

Now syngas is also produced from sewage, saw-dust, scrap wood, newspapers etc. The process of producing 'syngas' from coal is called ***'coal gasification'***.

$C(s) + H_2O(g) \xrightarrow{1270K} CO(g) + H_2(g)$

The production of dihydrogen can be increased by reacting carbon monoxide of syngas mixtures with steam in the presence of iron chromate as catalyst. This is called ***water-gas shift reaction***.

$CO(g) + H_2O(g) \xrightarrow{673K,\ \text{catalyst}} CO_2(g) + H_2(g)$

Properties of dihydrogen

Chemical Properties

1. **Reaction with halogens**

   Dihydrogen reacts with halides to form hydrogen halides (HX).

   $H_2(g) + X_2(g) \rightarrow 2HX(g)$

2. **Reaction with O_2:** $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

3. **Reaction with N_2**

   $$N_2(g) + 3H_2(g) \xrightarrow[\text{Fe/Mo}]{\text{773K, 200 atm}} 2NH_3(g)$$

4. **Reaction with metals**

Dihydrogen combines with metals at higher temperature to form metal hydrides.

$2M + H_2 \rightarrow 2MH$; where M is an alkali metal.

5. **Reaction with organic compounds**

   It reacts with many organic compounds in presence of catalyst to form hydrogenated compounds.

   e.g. $H_2 + CO + R\text{-}CH = CH_2 \rightarrow R\text{-}CH_2\text{-}CH_2\text{-}CHO$ (aldehyde)

   $H_2 + R\text{-}CH_2\text{-}CH_2\text{-}CHO \rightarrow R\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}OH$

Uses of Dihydrogen

1. Dihydrogen is mainly used for the synthesis of ammonia which is used in the manufacture of nitric acid and nitrogenous fertilizers.
2. It is used in the manufacture of vanaspathi fat by the hydrogenation of vegetable oils.
3. It is widely used for the manufacture of metal hydrides
4. It is used for the preparation of hydrogen chloride, methanol etc.
5. In metallurgical processes, it is used to reduce heavy metal oxides to metals.
6. Atomic hydrogen and oxy-hydrogen torches are used for cutting and welding purposes.
7. It is used as a rocket fuel in space research.
8. It is used in fuel cells for generating electrical energy.

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