CHAPTER

9 Hydrogen and Its Compounds

Position of Hydrogen in Periodic Table

It resembles with alkali metals as well as with halogens. So it show both type of character.

Isotopes of Hydrogen

Protium	Deuterium	Tritium
(*a*) $_1H^1$ or H	$_1H^2$ or D	$_1H^3$ or T
(*b*) p =1, e = 1 n = 0	p =1, e = 1, n =1	p = 1, e =1 n = 2
(*c*) Abudance-99%	0.1% Heavy hydrogen	10^{-15}% Radioactive used as tracer to study reaction mechanism
(*d*) Ordinary hydrogen		

- Dihydrogen on the industrial sacle is prepared by the water gas shift reaction from petrochemical.
- Dihydrogen is quite stable and dissociate into hydrogen atom only when heated at 5000K.
- It has high bond dissociation enthlaply (435.9kJ/mol).

Different forms of H_2

(*i*) Nascent hydrogen

(*a*) Preparation- $Zn + H_2SO_4 \rightarrow ZnSO_4 + 2H$

(*b*) Property-This hydrogen is more reactive & powerful reducing agent than ordinary hydrogen.

(A) It decolourises yellow colour of $FeCl_3$(aq.)

$[H] + FeCl_3 \rightarrow FeCl_2 + HCl$

(yellow) Colourless

(B) Decolourise violet colour of $KMnO_4$.

(C) Turns $K_2Cr_2O_7$ (orange) solution to green.

$K_2Cr_2O_7 + 4H_2SO_4 + 6[H] \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + 7H_2O$

(orange) (green)

(*ii*) Adsorbed Hydrogen- Hydrogen on bubbling at the surface of Pt black, get adsorbed there and becomes capable of bringing out many chemical changes such as reduction and hydrogenation. This type of hydrogen is named as adsorbed hydrogen. While hydrogen occluded on Pd is very strong reducing agent and combines with halogens in dark. Occlusion decreases with rise in temperature.

(*iii*) Atomic Hydrogen

(*a*) Atomic hydrogen is best produced by passing ordinary hydrogen through an electric arc.

$$H_2 \xrightarrow[(200°C)]{\text{Electric Arc}} 2H;\ \Delta H = +104.5\text{Kcal};\ \text{(Endothermic)}$$

(*b*) Life period of atomic hydrogen is only one third of a second.

(*c*) This form of hydrogen is very - very reactive as it has the excited state of hydrogen atom.

Uses of hydrogen

- Dihydrogen is used in Haber's process in the synthesis of ammonia.
- In metallurgical process, it is used to reduce metal oxides.
- In space programmes, it is used as a rocket fuel.
- It is used in fuel falls for the generation of electrial energy.

Hydrides

Compounds of hydrogen with less electronegative elements are called hydrides.

(*i*) Ionic hydrides or saline hydrides-These are formed by combination of hydrogen with IA & II A (Highly reactive metals)

eg. LiH, NaH, KH, MgH_2, CaH_2etc.

$CaH_2 \rightarrow$ Hydrolith $\rightarrow$ Rich source of hydrogen

(*ii*) Covalent hydrides- compounds of hydrogen with less electronegative non metals like B & Si.

eg. SiH_4, B_2H_6

(*iii*) Interstitial hydrides-

Hydrogen + Transition metal

Hydrogen is held by vander waal force. These hydrides are non stoichiometric

Ti : H_2

1 : 1.67

Water

- The water molecule is highly polar in nature due to it's bent structure.
- Water molecules undergo extensive hydrogen bonding i.e. one H_2O molecule form four H-bonds.
- The density of water is maximum at 4°C.
- Water dissolve many salts, particularly in large quantity makes it hard and hazardous for industrial use.

- Both temporary and permanent hardness can be removed by the use of zeolites and synthetic ion-exchangers.

Synthetic Resins Method

Nowadays hard water is softened by using synthetic cation exchangers. This method is more efficient than zeolite process. Cation exchange resins contain large organic molccule with $-SO_3H$ group and are water insoluble, Ion exchange resin (RSO_3H) is changed to RNa by treating it with NaCl. The resin cxchanges Na^+ ions with Ca^{2+} and Mg^{2+} ions present in hard water to make

$$2RNa(s) + M^{2+}(aq) \rightarrow R_2M(s) + 2Na^+(aq)$$

The resin can be regenerated by adding aqueous NaCl solution. Pure de-mineralised (de-ionized) water free from all soluble mineral salts is obtained by passing water successively through a cation exchange (in the H^+ form) and an anion exchange (in the OH) resins:

$$2RH(s) + M^{2+}(aq) \rightleftharpoons MR_2(s) + 2H^+(aq)$$

In this cation exchange process, H^+ exchange for Na^+, Ca^{2+}, Mg^{2+} and other cations present in water. This process results in proton release and thus makes the water acidic. In the anion exchange process:

$$RNH_2(s) + H_2O(l) \rightleftharpoons RNH_3^+.OH^-(s)$$

$$RNH_3^+.OH^-(s) + X^-(aq) \rightleftharpoons RNH_3^+.X^-(s)\ OH^-(aq)$$

OH^- exchange for anions like Cl^-, HCO_3^-, SO_4^{2-} etc. present in water. OH^- ions, thus, liberated neutralize the H^+ ions set free in the cation exchange.

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

The exhausted cation and anion exchange resin beds are regenerated by treatment with ditute acid and alkali solution respectively.

Hydrogen peroxide

- H_2O_2 has non-polar open book like structure.
- It is widely used as an industrial bleach and in pharmaceutical and pollution control treatment of industrial and domestic effluents.

Physical Properties of H_2O_2

1. Pure H_2O_2 is weakly acidic in nature and exist as associated liquid due to hydrogen bonding.
2. Smell of H_2O_2 resembles like nitric acid.
3. It causes blisters on skin.
4. Stored in plastic containers after addition of stabilizers.
5. A dilute solution of H_2O_2 is concentrated by vaccum distillation or by distillation under pressure,

Uses of Hydrogen peroxide

(1) As germicide and antiseptic due to it's oxidising property.

(2) As fuel for rocket

(3) In refreshing old oil paintings due to formation of black PbS. H_2O_2 converts it into white $PbSO_4$.

$$\underset{\text{(White)}}{PbO} + H_2S \rightarrow \underset{\text{(Black)}}{PbS} + H_2O$$

$$PbS + 4H_2O_2 \rightarrow \underset{\text{(White)}}{PbSO_4} + 4H_2O$$

Heavy Water (D_2O)

- It is manufactured by the exhaustic electrolytic dissociation of ordinary water.
- It is essentially used as a moderator in nuclear reactor.