Class 11 Chemistry Chapter 9 HYDROGEN

- Hydrogen is the first element in the periodic table and also the lightest element known. Electronic configuration of Hydrogen is $1s^1$.

  (1) Position of hydrogen in the periodic table Hydrogen is the first element in the periodic table. Hydrogen is placed in no specific group due to its property of giving electron (When – H is formed) and also losing electron (When + H is formed).

  Similarities with alkali metals-

  (a) It has one electron in its (Outer) shell1 1s like other alkali metals which have (inert gas) 1 ns configuration.

  (b) It forms monovalent H^+ ion like Li^+, Na^+ K^+

  (c) Its valency is also 1.

  (d) Its oxide (H_2O) is stable as Li_2O, Na_2O.

  (e) It is a strong reducing agent (In atomic as well as molecular state) like Na, LiK

Similarities with Halogens –

1. Hydrogen has only Ionisation energy less than noble gases.
2. Ionisation energies of Hydrogen is 1312 $kJmol^{-1}$ close to chlorine.
3. Oxidation state of Hydrogen is -1 in many compounds.
4. H_2 is diatomic.
5. Hydrogen is non-metallic and exists in gaseous state.

Difference with alkali metals –

Ionisation energy of Hydrogen is high as compared to alkali metals	Ionisation Energy of alkali is less.
Shows non -metallic behaviour	metallic behaviour
Diatomic molecule as gas	monoatomic
Hydrogen mostly forms covalent bonds	Ionic bonds

- **Isotopes of hydrogen:**

(i) Protium ($_1^1H$)

(ii) Deuterium ($_1^2H$ or $_1^2D$)

(iii) Tritium ($_1^3H$ or $_1^3T$)

- **Isotopic Effect:** In general, chemical properties of isotopes are same but quantitative differences are noticed amongst them. For example, the reaction between H2 and Cl2 is 13.4 times faster between D2 and Cl2 under similar conditions. Such differences in chemical properties, which are due to difference in the mass numbers of isotopes is known as isotopic effect.

- **Preparation of Dihydrogen:**

(i) **Laboratory preparation:** $Zn + 2H^+ \rightarrow Zn^{2+} + H_2$.

(ii) **Commercial preparation:** By electrolysis of acidified water.

(iii) High purity dihydrogen is obtained by electrolyzing warm aqueous barium hydroxide.

- **Properties:**

* Reaction with halogen: $H_2 + X_2 \longrightarrow 2HX$ [X = F, Cl, Br, I]

* Reaction with oxygen: $H_2(g) + O_2(g) \xrightarrow{\Delta} 2H_2O(l)$;

$$\Delta H^{\circ} = -285.9 \text{ kJ mol}^{-1}$$

* Reaction with nitrogen: $3H_2(g) + N_2(g) \xrightarrow{\Delta} 2NH_3(g)$;

$$\Delta H^{\circ} = -92 \text{ kJ mol}^{-1}$$

* Reaction with alkali metals: $H_2(g) + 2M(g) \xrightarrow{\Delta} 2MH(s)$

It is relatively inert at room temperature due to the high H-H bond enthalpy.

- **Uses of Dihydrogen:**

(i) For synthesis of Ammonia (NH_3)

(ii) For production of Methanol (CH_3OH)

(iii) In oxyhydrogen torches

(iv) In a fuel cell.

• Hydrides

(i) **Ionic or salt like or saline hydrides** are formed with most of the *s*-block elements. Significant covalent character is found in LiH, BeH_2 and MgH_2.

(ii) **Covalent or Molecular hydrides** are formed with most of the *p*-block elements. There are further classified as :

(a) **Electron deficient hydrides** are formed by group 13 elements *e.g.*, B_2H_6. They act as Lewis's acid.

(b) **Electron Precise hydrides** are formed by group 14 elements *e.g.*, CH_4.

(c) **Electron rich hydrides** have lone pair of electrons on central atoms of the molecules. Elements of group 15-17 form these types of hydrides.

NH_3, HF has high m.p./b.p. due to presence of intermolecular hydrogen bonding.

(iii) **Metallic or Non-stoichiometric or Interstitial hydrides** are formed by *d* and *f* -block elements. For example La $H_{2.87}$ or $NiH_{0.6–0.7}$.

• Water: (H_2O)

Hard water: Hard water contains calcium and magnesium salts in the form of hydrogen carbonate, chloride and sulphate. Hard water does not give lathers with soap.

Soft water: Water free from soluble salts of calcium and magnesium is soft water.

Types of Hardness:

Temporary hardness is due to presence of calcium or magnesium hydrogen carbonate in water. Temporary hardness can be removed by :

(i) Boiling

(ii) Clark's Method

Permanent hardness:

Such hardness is due to presence of calcium or magnesium chlorides and sulphates.

Permanent hardness can be removed by:

(i) Treatment with washing soda

(ii) Calgon's method

(iii) Ion exchange method.

Demineralized or Deionized water: Water free from all soluble mineral salts is known as **demineralized water.**

- **Hydrogen Peroxide (H_2O_2)**

Preparation:

(i) By electrolytic oxidation of acidified sulphate solutions at high current density.

(ii) 2-Ethylanthraquinol $\underset{H_2/Pd}{\overset{O_2\ (air)}{\rightleftharpoons}}$ H_2O_2 + (Oxidized product)

- **Physical Properties**

(i) Pure H_2O_2 is pale blue syrupy liquid which freezes at -0.5°C and has density of 1.4.

(ii) It is diamagnetic in nature.

(iii) Miscible with water in all proportions.

(iv) A 30% of H_2O_2 solution is marked as **'100 volume' hydrogen peroxide.**

- **Chemical Properties:**

(i) It acts as an oxidizing as well as reducing agent.

(ii) Oxidizing action in acidic medium:

$$2Fe^{2+}(aq) + 2H^+(aq) + H_2O_2(aq) \longrightarrow 2Fe^{3+}(aq) + 2H_2O(l)$$

(iii) Reducing action in acidic medium:

$$2MnO_4^- + 6H^+ + 5H_2O_2 \longrightarrow 2Mn^{2+} + 8H_2O + SO_2$$

- **Storage of H_2O_2:**

(i) Stored in wax-linked glass or plastic vessels in dark. Urea can be added as a stabilizer.

(ii) It is kept away from dust because dust can induce explosive decomposition of the compound.

(i) feather, ivory etc.

(ii) It is used as an aerating agent I the production of spong rubber.

Heavy Water, D_2O: It is extensively used as a moderator in nuclear reactors and in exchange reactions for the study of reaction mechanisms. It can be prepared by exhaustive electrolysis of water or as a by-product in some fertilizer industries. It is

- **Uses of H_2O_2:**

(iii) As an antiseptic it is sold in the market name **perhydrol**.

(iv) In synthesis of hydroquinone.

As a bleaching agent for bleaching delicate articles like wool, hair,

used for the preparation of other deuterium compounds.

Some physical constants of Heavy Water (D_2O) and Ordinary Water (H_2O)

Property	Heavy Water(D_2O)	Ordinary Water (H_2O)
Density at 293 K	1.017	0.998
Melting point	276.8 K	273 K
Boiling point	374.4 K	373 K
Dielectric constant	80.5	82
Refractive index at 293 K	1.3284	1.3329
Viscosity at 293 K(milli poise)	12.6	10.09
Solubility NaCl/100 g at 298 K	30.5	35.9

1. **Auto–protolysis of water:** Water accepts a proton from other water molecule to from H_3O^+ and OH^- this porous is called auto – protolysis of water

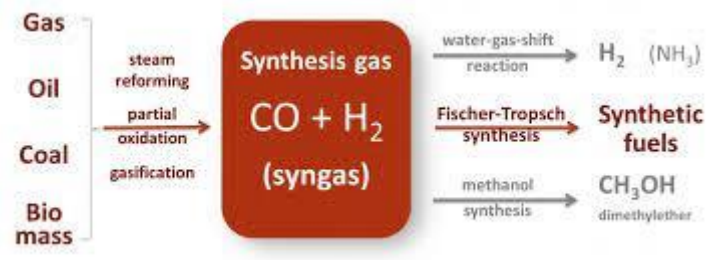
$$H_2O(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$$

Its significance is that water can act as acid as well as base i.e. it is amphoteric in nature.

$$\text{Vegetable oil} + H_2 \xrightarrow[473K]{Ni} \text{Vanaspati ghee (fat).}$$

2. **Syngas:** It is a mixture of CO and H_2 in 1:1 ratio and also known as water gas or synthesis gas.

3. **Hydrogen economy:** It is transportation and storage of energy in the form of liquid or gaseous hydrogen. Advantage of hydrogen economy is that energy is transmitted in the form of dihydrogen and not as electric power
4. **Hydrogenation:** It is a process of converting polyunsaturated oils in edible fats.

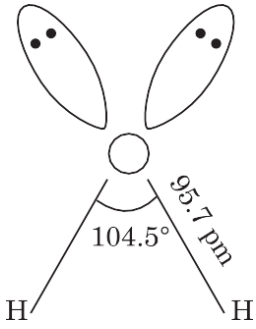


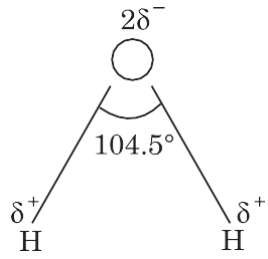
5. Water gas shift reaction.

$$CO + H_2O \xrightarrow[\text{iron chromate as catalyst}]{673\ K} CO_2 + H_2$$

6. **Fuel-cell:**– Fuel cell is a cell in which chemical energy of fuel is converted into electrical energy.

7. **Structure of water:** It is bent molecule in gas phase with HOH bond angle 104.5° and O–H bond length of 95.7 pm as shown if figure





8. **Calgon:–** It is sodium polymetaphosphate $(NaPO_3)_n$ it is used to remove. Permanent hardness of water.

9. **De-ionized water:–** Pure di-mineralized (ionized water) free from all soluble mineral matter is obtained by passing water successively through a cation exchanger (in the H^+ form) and an anion exchanger for removal by cation and anions.

$$2RH + M^{2+} \rightleftharpoons MR_2 + 2H^+$$

(R is the resin anion M^{2+} is cation)

$$RNH_2 + H_2O \rightleftharpoons RNH_3^+ \; OH^-$$

$$RNH_3^+ + OH^- + X^- \rightleftharpoons RNH^+_3.\, X^- + OH^-$$

$$H^+ + OH^- \longrightarrow H_2O$$

HYDROGEN: Things to remember