PHYSICAL PROPERTIES

- Colourless
- Odourless
- Tasteless
- Combustible gas
- Lighter than oil
- Insoluble in water
- ?????????????
- ?

STD-XI SCIENCE-

UNIT 9: HYDROGEN

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http://www.usesof.net/wp-content/uploads/2012/05/uses-of-hydrogen.jpg

UNIT 9

HYDROGEN

- *Hydrogen, the most abundant element in the universe*
- *The third most abundant on the surface of the globe*
- *It is being visualised as the major future source of energy.*

POSITION OF HYDROGEN IN THE PERIODIC TABLE

- Hydrogen has electronic configuration $1s^1$
- electronic configuration (ns^1) of alkali metals
- Like alkali metals, hydrogen forms oxides, halides and sulphides.
- halogens (with $ns^2\ np^5$ configuration)
- very high ionization enthalpy.
- F_2 1680 kJ mol and that of H_2 is 1312 kJ mol .

OCCURRENCE

- earth's crust
- Oceans
- water, it occurs in plant and animal tissues
- carbohydrates, proteins

ISOTOPES OF HYDROGEN

- **Hydrogen has three isotopes:**
- Protium, H
- Deuterium, H or D
- Tritium, H or T

PREPARATION OF DIHYDROGEN, H_2

- **Laboratory Preparation of Dihydrogen**

Reaction with Acids :

- $Zn + 2H^{+} \rightarrow Zn^{+2} + H_2$

Reaction with aqueous Alkalies :

$Zn + 2\ NaOH \rightarrow Na_2\ ZnO_2 + H_2$

Sodium zincate

COMMERCIAL PREPARATION OF H_2

1) Electrolysis of **acidified water** ,using platinum electrode .

$$2H_2O(l) \xrightarrow[\text{Traces of acid / base}]{\text{Electrolysis}} 2H_2(g) + O_2(g)$$

2) **High Purity H_2**

By electrolysis of $Ba(OH)_2$,nickel electrodes.

1) **Reaction of steam on Hydrocarbons .**

$$C_nH_{2n+2} + nH_2O \xrightarrow[Ni]{1270K} nCO + (3n+1)H_2$$

e.g.,

$$CH_4(g) + H_2O(g) \xrightarrow[Ni]{1270K} CO(g) + 3H_2(g)$$

- **Water gas :** Mixture of CO and H_2
- **Syn gas or synthesis gas :** CO and H_2O used to prepare methanol and HC'S .
- **Coal gasification :**Process of obtaining syngas from coal .

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

- **Water gas shift reaction :** increasing the concentration of H_2 gas using steam .

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

- Industrial H_2 is produced from

- petrochemicals (77 %) , coal (18 %) .

CHEMICAL PROPERTIES

- H-H bond enthalpy is large .
- H atom is obtained at very high temperature.
- It takes part in reaction

1. By giving one electron
2. By gaining one electron
3. Sharing electrons between atoms ,form covalent bond .

CHEMICAL REACTIONS

- **Reaction with halogens :**

$$H_2(g) + X_2(g) \rightarrow 2HX(g) \quad (X = F, Cl, Br, I)$$

- **Reaction with Oxygen :**

$$2H_2(g) + O_2(g) \xrightarrow{\text{catalyst or heating}} 2H_2O(l)$$

- **Reaction with Nitrogen :**

$$3H_2(g) + N_2(g) \xrightarrow[Fe]{673K, 200atm} 2NH_3(g)$$

- **Reaction with metals :**

$$H_2(g) + 2M(g) \rightarrow 2MH(s)$$

- **Reaction with metal ions and metal oxide :**

$$H_2(g) + Pd^{2+}(aq) \rightarrow Pd(s) + 2H^+(aq)$$

$$yH_2(g) + M_xO_y(s) \rightarrow xM(s) + yH_2O(l)$$

- **Reaction with Organic compounds :**

1. **Hydrogenation** of vegetable oil using Ni Catalyst gives edibal ghee.
2. **Hydroformylation** of olefenes gives aldehydes, which on reduction gives alcohols .

$$H_2 + CO + RCH = CH_2 \rightarrow RCH_2CH_2CHO$$

$$H_2 + RCH_2CH_2CHO \rightarrow RCH_2CH_2CH_2OH$$

USES OF DIHYDROGEN

1. Systhesis of **ammonia** , which is used to manufacture **HNO_3 and fertilizers** .

2. Manufacture of **vanaspati** and **fats** from polyunsaturated vegetable oil by hydrogenation .

3. manufacture of organic chemicals eg **methanol** .

4. Manufacture of **metal hydrides** .

USES OF DIHYDROGEN

5. Preparation of **HCl** .
6. **Metallurgy** process ,reduce metal oxides to metals .
7. Atomic hydrogen and oxy-hydrogen for **cutting and welding .**
8. **Rocket fuel** .
9. **Fuel cell** for generating electrical energy ,no pollution ,more efficient ,produce more energy per little mass .

HYDRIDES

(i) Ionic or saline or saltlike hydrides

(ii) Covalent or molecular hydrides

(iii) Metallic or non-stoichiometric hydrides

IONIC OR SALINE

- Forms with s-block elements .
- Form covalent(Li ,Be,Mg) and ionic hydride .
- Ionic hydrides crystalline , non-volatile,non-conducting in solid state.
- conducting molten state .
- Electrolysis liberate H_2 gas at anode.

$$2H^-(\text{melt}) \xrightarrow{\text{anode}} H_2(g) + 2e^-$$

$$NaH(s) + H_2O(aq) \rightarrow NaOH(aq) + H_2(g)$$

COVALENT OR MOLECULAR

- Forms with p-block elements .
- Form covalent hydrides, form molecular compound

  CH_4, NH_3, H_2O and HF.
- Volatile

COVALENT OR MOLECULAR

Electron deficient	Electron precise	Electron rich
Less number of electrons . electropositive	Same number of electrons	Excess electrons Lone pairs Electronegative
Formed by group 13 elements B_2H_6 Polymeric structure.	Formed by group 14 elements CH_4 tetrahedral	Formed by group 15-17 elements NH_3 ,H_2O ,HF
Electron acceptor . Lewis acids	Neutral	Electron donor . Lewis base . H-bond

METALLIC OR NON-STECHIOMETRIC OR INTERSTITIAL HYDRIDES

- d and f-block elements (6,7,8,9 do not form).
- Conduct heat and electricity .
- Deficient in hydrogen .

example, $LaH_{2.87}$, $YbH_{2.55}$, $TiH_{1.5-1.8}$, $ZrH_{1.3-1.75}$, $VH_{0.56}$, $NiH_{0.6-0.7}$, $PdH_{0.6-0.8}$ etc. In such

- Occupy interstitial spaces without change in type .
- Transition metals act as good catalyst .
- Provide large surface area for Hydrogen .

WATER

- **Physical properties of water .**

1. Extensive H-bond .
2. High b.pt ,f.pt.
3. Heat of vaporisation ,fusion compare to H_2S ,H_2Se.
4. Thermal conductivity
5. Specific heat
6. Dipole moment
7. Surface tension

STRUCTURE OF WATER

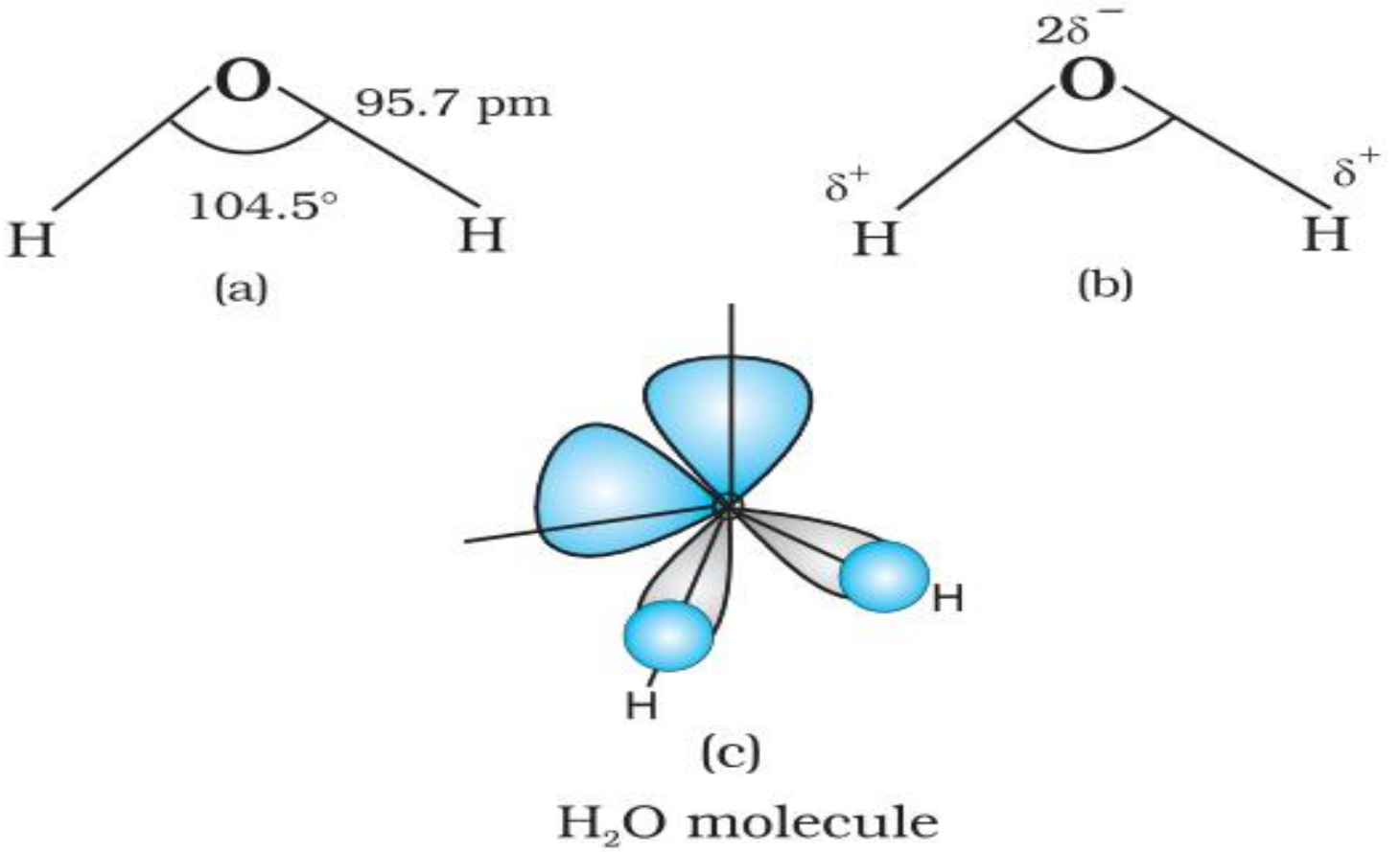

Fig. 9.1 *(a) The bent structure of water; (b) the water molecule as a dipole and (c) the orbital overlap picture in water*

- Extensive H-bonding
- Polar molecule .
- Has dipole moment .
- **Ice cube floats on water and density of water is more than ice:**
- Water has H-bond and Oxygen tetrahedrally surrounded by 4 H atoms.2 by covalent bond and 2 by H-bond .
- **Structure of ice :** open structure ,vacant spaces ,less density .
- Ice melts H-bonds broken down ,water enters the vacant spaces .

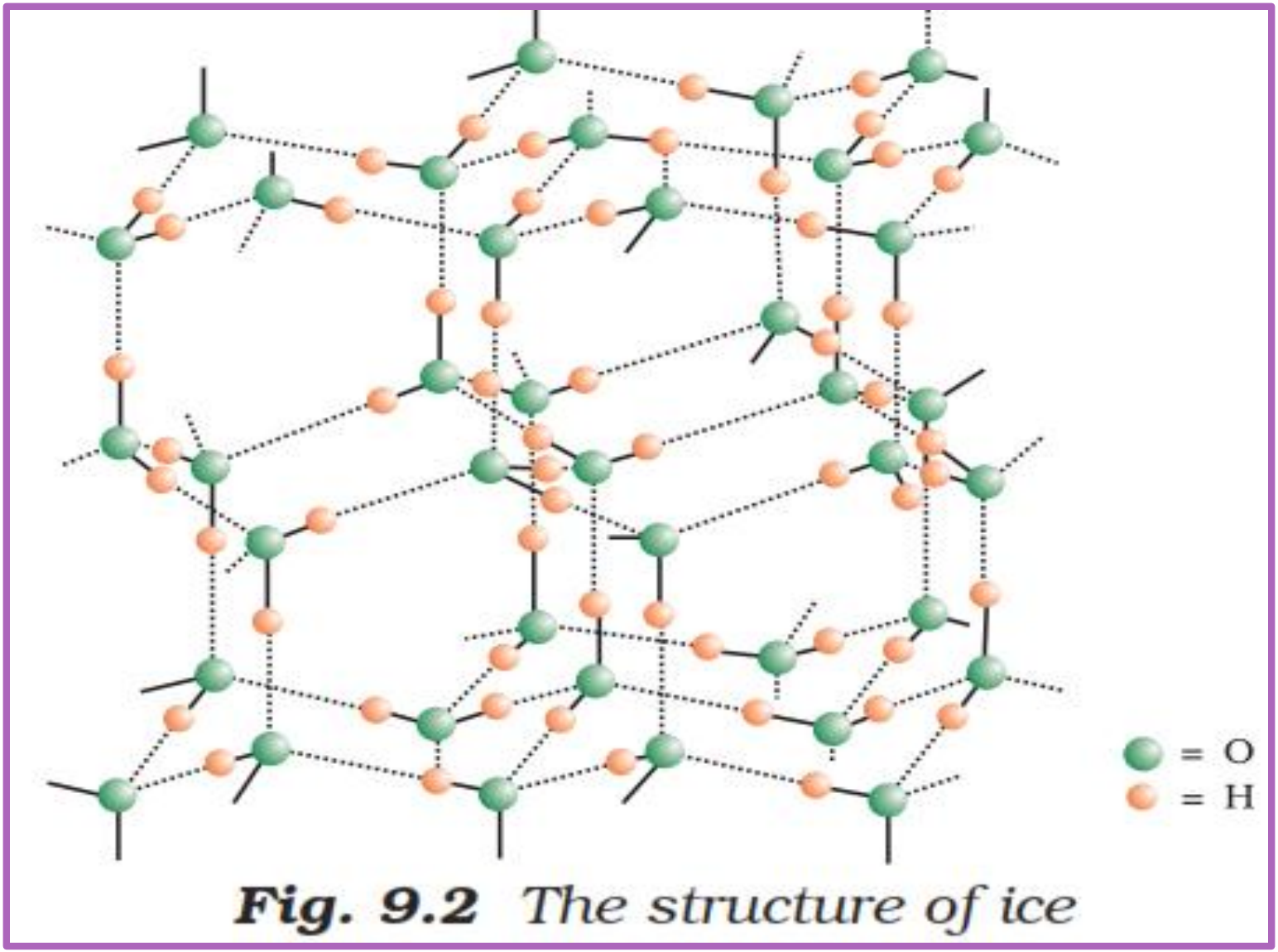

Fig. 9.2 *The structure of ice*

CHEMICAL PROPERTIES

- **Amphoteric nature :**

$$H_2O(l) + NH_3(aq) \rightleftharpoons OH^-(aq) + NH_4^+(aq)$$

$$H_2O(l) + H_2S(aq) \rightleftharpoons H_3O^+(aq) + HS^-(aq)$$

- **Hydrates formation :**

(i) coordinated water e.g.,

$$[Cr(H_2O)_6]^{3+}\ 3Cl^-$$

(ii) interstitial water e.g., $BaCl_2.2H_2O$

(iii) hydrogen-bonded water e.g.,

$$[Cu(H_2O)_4]^{2+}\ SO_4^{2-}.H_2O \text{ in } CuSO_4.5H_2O,$$

- **Hard water :**
- Water containing Ca and Mg salts of hydrogencarbonates ,chlorides ,sulphates .

- Does not produce leather with soap .

- **Soft water :**
- Water free from Ca and Mg salts of hydrogencarbonates ,chlorides ,sulphates .

- produce leather with soap .

HARD WATER AND SOAP

- **Hard water does not produce lather with soap .**
- Clothes are not washed in hard water .
- **Because :** Soap contain Na/K stearate (C_{17} H_{35} COONa) reacts with hard water and form Ca /Mg Stearate.
- Hard water form scum /ppt with soap .
- Sticks on clothes .

Temporary Hardness

- Contain Ca/Mg hydrogen carbonate.
- Removed by Boiling and by Clarks method.

- **Boiling :**

$$Mg(HCO_3)_2 \xrightarrow{\text{Heating}} Mg(OH)_2 \downarrow + 2CO_2 \uparrow$$

$$Ca(HCO_3)_2 \xrightarrow{\text{Heating}} CaCO_3 \downarrow + H_2O + CO_2 \uparrow$$

- **Clarks method :**

$$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 \downarrow + 2H_2O$$

Permanent Hardness

- Contain Ca/mg Chlorides and sulphates .
- Removed by treatment with **washing soda** ,Calgons method, ion exchange ,Synthetic resin method .

- **Washing soda :**

$$MCl_2 + Na_2CO_3 \rightarrow MCO_3 \downarrow + 2NaCl \quad (M = Mg, Ca)$$

$$MSO_4 + Na_2CO_3 \rightarrow MCO_3 \downarrow + Na_2SO_4$$

- **Ion exchange method :**

$$2NaZ(s) + M^{2+}(aq) \rightarrow MZ_2(s) + 2Na^+(aq) \quad (M = Mg, Ca)$$

HYDROGEN PEROXIDE

- Non-planar structure .
- **Storage : In Dark**
- decompose in presence of light .

$$2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$$

- **H_2O_2 is stored in wax lined glass or plastic vessel in dark .**
- **Because :** metal surfaces or traces present in glass container ,H_2O_2 decomposes to give H_20 and O_2 .

USES

- Hair bleach ,mild disinfectant ,antiseptic
- Manufacture of chemicals like sodium perborate and per-carbonate .
- High quality detergents .
- Tartaric acid ,food products ,pharmaceuticals .
- Bleaching agent for textile ,paper,pulp ,leather ,oil, fats .
- Environmental green chemistry .domestic and industrial effluents .
- Oxidation of cyanides ,aerobic oxidation of sewage waste.

HEAVY WATER (D_2O)

- Prepared as by-product in fertilizer industry .
- Electrolysis of water .
- **Uses :**
- Study of reaction mechanism .
- Preparation of Deuterated compounds .

$$SO_3 + D_2O \rightarrow D_2SO_4$$

$$Al_4C_3 + 12D_2O \rightarrow 3CD_4 + 4Al(OD)_3$$

DIHYDROGEN AS FUEL

- **Advantages of H_2 as Fuel :**
- Release large amount of heat or energy .
- Less pollution (Pollutants –N_2 form oxides of N).

- **Limitations:**
- Heavy weight of cylinders .
- Expensive insulated Tanks to store .

HYDROGEN ECONOMY

- **Principle :**
- Transportation and storage of energy in the form of liquid and gases .

- **Advantage :**

- Energy is transmitted in form of Dihydrogen and not as electric power .
- H_2 used as fuel to run automobiles .
- 5% H_2 used in CNG ,increase to optimum level .

THANK YOU