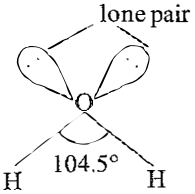
Boron hydrides are used as high energy fuels and propellants. Phosphine is used for making Holme's signals. H_2S is an important laboratory reagent.

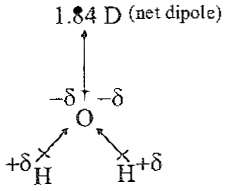
Metallic or Interstitial Hydrides

- Metallic hydrides are formed by most of the *d*-block elements (*i.e.*, transition elements), on reacting with hydrogen. These are interstitial compounds and may be regarded as **solid solutions**.
- Hydrides of *f*-block elements are non-stoichiometric in nature.
- Mainly transition and inner transition elements form metallic hydrides.
- **Characteristics of metallic hydrides**
  - ➢ They conduct electricity.
  - ➢ The density of such compound is less than that of the metal itself and their properties are not much different from their respective metal *i.e.*, they give out hydrogen easily and are strong reducing agents.
  - ➢ They are black powdery, hard, have a metallic lustre and magnetic properties.
- **Uses of metallic hydrides :** Metallic hydrides are widely used in catalytic reduction and hydrogenation for preparing large number of useful compounds.

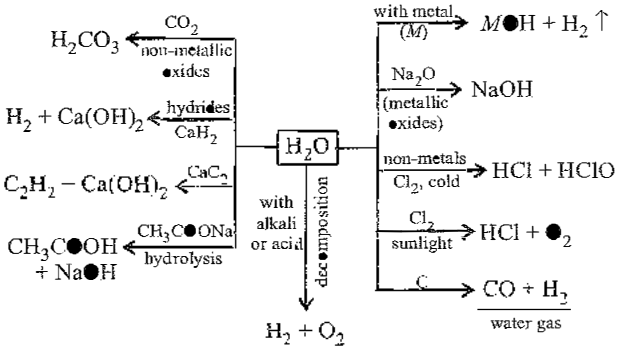
WATER

- **Occurrence :** About 75% of the Earth's surface consists of water. Water is present as either
  (a) **Solid :** In the form of ice, snow, etc.
  (b) **Liquid :** in the form of water in lakes, rivers and oceans, etc.
  (c) **Water vapour :** In the form of clouds or moisture in the air.
- **Structure :** Water is a covalent molecule in which oxygen undergoes sp^3 hybridisation and contains two lone pairs.
  Due to the presence of two lone pairs of electrons on the oxygen atom, the H— O —H bond angle is 104.5°. Molecule is angular or bent in shape.





  - ➢ In solid state (ice) water molecules are arranged in highly ordered three dimensional open cage like structure through hydrogen bonding.
  - ➢ This arrangement leads to a packing with large open spaces and results in lower density of ice than that of liquid water.
- **Physical properties**
  - ➢ Pure water is transparent, tasteless, colourless and odourless. It readily picks up the colour and flavour of any substance dissolved in it.
  - ➢ The freezing point, boiling point, heat of fusion and heat of vaporization of water are higher than those of hydrides other members of the oxygen group such as H_2S, H_2Se, H_2Te, etc., due to the presence of intermolecular hydrogen bonding in H_2O molecules.
  - ➢ Water has a high dielectric constant. So that, water can dissolve wide variety of compounds in it. That's why water is regarded as **universal solvent**.
  - ➢ Water is a poor conductor of heat and electricity. However, addition of a small quantity of an acid or alkali makes it conducting.
  - ➢ Water plays an important role in biosphere.
- **Chemical properties of water**



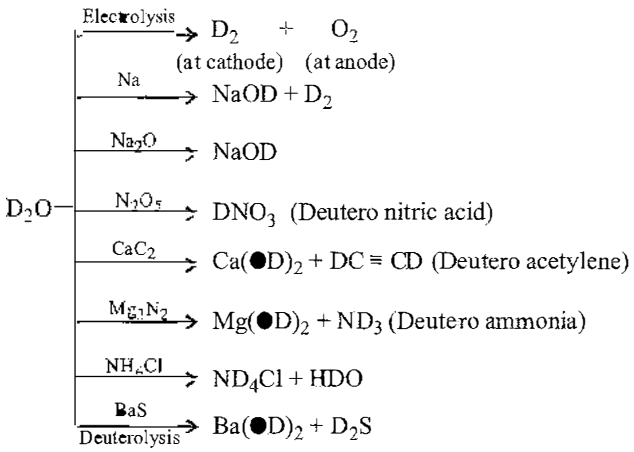
- **Uses of water :** Water is vital to life. Humans, plants and animals are made up of mostly water. All living things would die if there is no water. Water is mainly used for drinking, cleaning and irrigation crops and landscape.

HEAVY WATER

- Deuterium oxide (D_2O) is known as heavy water. It was discovered by Urey in 1932. It is present in trace amount in ordinary water (1 part in 6000 parts).
- Heavy water is prepared either by prolonged electrolysis or by fractional distillation of ordinary water.
- Heavy water may contain some heavier isotopes of oxygen also.
- **Physical properties**
  - ➢ Heavy water is colourless, tasteless and odourless liquid.
  - ➢ It has all higher values for physical constant than the corresponding values of ordinary water.

Physical properties of water and heavy water at 298 K

Property	H_2O	D_2O
Molecular mass (g mol^{-1})	18.015	20.028
Melting Point (K)	273.0	276.8
Boiling-point (K)	373.0	374.4
Maximum Density (g cm^{-3})	1.000	1.106
Density (g cm^{-3}) (at 298 K)	0.997	1.105
Heat of Vaporization (at 373 K)(kJ/mol^{-1})	40.66	41.61
Heat of Fusion (kJ mol^{-1})	6.01	5.68
Ionization Constant $[H^+][OH^-]$ (mol^2L^{-2})	1.008×10^{-14}	1.95×10^{-15}



Uses of heavy water

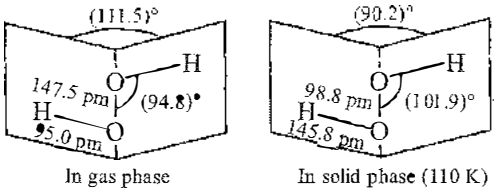
- As moderator and coolant in nuclear reactor.
- As a tracer compound to study various reaction mechanism.
- For the preparation of various deuterium compound.
- As a germicide and bactericide.

HARD WATER

- Water which does not produce lather with soap *e.g.* sea water, river water etc.
  Hardness of water is due to presence of bicarbonates, chlorides and sulphates of calcium and magnesium. Sodium stearate (soap) changes to corresponding Ca or Mg salt which precipitates out as
  $2C_{17}H_{35}COONa + Ca^{2+}/Mg^{2+} \longrightarrow (C_{17}H_{35}COO)_2Ca/Mg + 2Na^+$
  Metal stearate
- **Temporary hardness** is due to the presence of bicarbonates of Ca and Mg. It can be removed by
  - **Boiling:**
    $M(HCO_3)_2 \overset{\Delta}{\rightleftharpoons} MCO_3\downarrow + H_2O + CO_2\uparrow$
    soluble bicarbonates — insoluble carbonates (as precipitate)
    Here, M = Mg or Ca
  - **Clark's process:**
    $Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3\downarrow + 2H_2O$
- **Permanent hardness** is due to the presence of soluble chlorides and sulphates of Ca and Mg. It can be removed by treating it with Na_2CO_3.
  $CaSO_4 + Na_2C●_3 \rightleftharpoons CaCO_3\downarrow + Na_2SO_4$
  $MgCl_2 + Na_2CO_3 \rightleftharpoons MgCO_3\downarrow + 2NaCl$
  Also, removal of both types of hardness is affected by ion exchangers like zeolite, permutit and synthetic resins, etc.

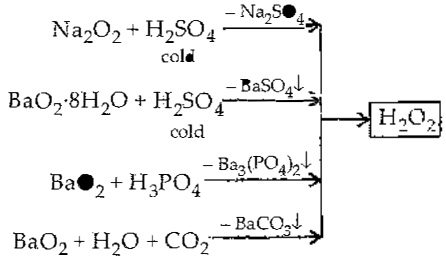
HYDROGEN PEROXIDE

- H_2O_2 is known as hydrogen peroxide or oxygenated water.
- **Structure of hydrogen peroxide :** Hydrogen peroxide is a non-planar molecule. It has an open book like structure. In gaseous phase the dihedral (interplanar) angle between two planes is 111.5° but in crystalline state it reduces to 90.2° due to hydrogen bonding.

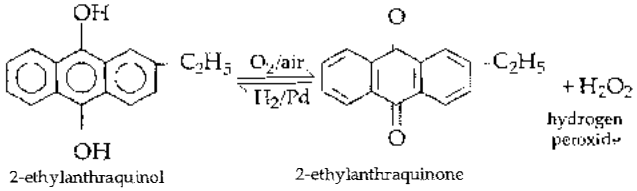


In gas phase — In solid phase (110 K)

Preparation



- **By autoxidation of 2-ethylanthraquinol :** Industrially used process for the manufacture of H_2O_2 is autoxidation of 2-ethylanthraquinol. This method, involves alternate oxidation and reduction steps of 2-ethylanthraquinol.



2-ethylanthraquinol — 2-ethylanthraquinone

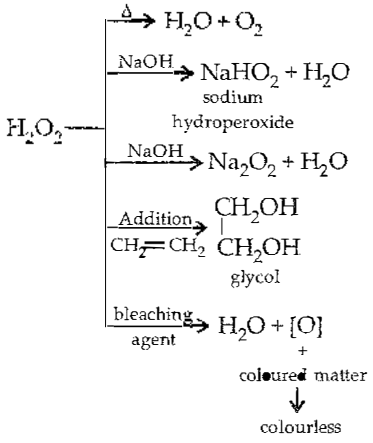
The hydrogen peroxide formed in this reaction is extracted with water, and concentrated to obtain H_2O_2 of the required strength.

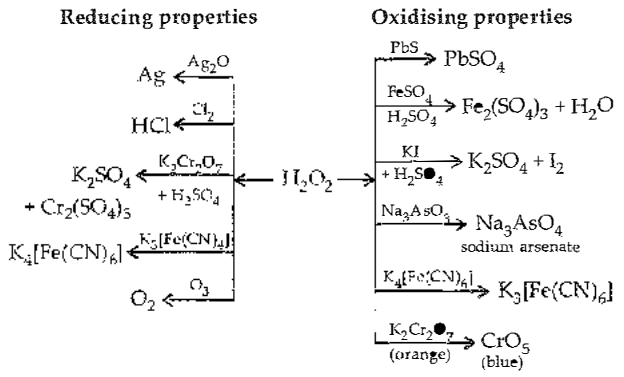
Physical properties

- Its boiling point is higher than H_2O● due to the presence of stronger intermolecular hydrogen bonding than in water.

Property	H_2O_2	H_2O
Colour	Light blue	Colourless
b.pt.	152°C (decomposes)	100°C
m.pt.	– 0.4°C	0°C
Density	1.4 g cm^{-3}	1.0 g cm^{-3}
Magnetism	Diamagnetic	Paramagnetic

Chemical properties





- **Concentration determination**

Concentration of H_2O_2 is expressed in terms of "volume of O_2".

"10 volume" H_2O_2 means that 1 mL of H_2O_2 at NTP gives 10 mL O_2 gas.

$$2H_2O_2 \longrightarrow 2H_2O + O_2$$
$$2(2 + 32) = 68 \text{ g} \qquad 22400 \text{ mL at NTP}$$
$$? \qquad x \text{ mL}$$

22400 mL of O_2 at NTP are obtained from 68 g of H_2O_2.

x mL of O_2 at NTP obtained from

$$= \frac{68}{22400} \times x \text{ g of } H_2O_2$$

$$\text{Conc. in g/L} = \frac{68x}{22400} \times 1000 = \frac{680x}{224} \text{ g/L}$$

$$\text{Normality } (N) = \frac{\text{conc. in g/L}}{\text{equiv. wt.}} = \frac{680x}{224} \times \frac{1}{17} = \frac{x}{5.6}$$

$$\text{Molarity } (M) = \frac{\text{conc. in g/L}}{\text{mol. wt.}} = \frac{680x}{224} \times \frac{1}{34} = \frac{x}{11.2}$$

Illustration 1

Calculate the volume strength of 1.5 N H_2O_2 solution.

Soln.: $\text{Normality} = \dfrac{\text{Volume strength}}{5.6}$

Volume strength = $1.5 \times 5.6 = 8.4$

Illustration 2

Calculate the volume strength of 1.6 M H_2O_2 solution.

Soln.: As the solution is 1.6 M, its 1000 mL will have

$= 1.6 \times 34 = 54.4$ g of H_2O_2

$$2H_2O_2 \longrightarrow 2H_2O + O_2$$
$$68 \text{ g} \qquad 1 \text{ mol}$$
$$22400 \text{ mL at STP}$$

Now, 68 g of H_2O_2 gives 22400 mL of O_2 at STP.

$\therefore$ 54.4 g of H_2O_2 will give

$$\frac{22400 \times 54.4}{68} \text{ mL of } O_2 \text{ at STP}$$

Hence, 1000 mL of H_2O_2 solution will give

$$= \frac{22400 \times 54.4}{68} \text{ mL of } O_2 \text{ at STP}$$

$\therefore$ 1 mL of H_2O_2 solution will give

$$= \frac{22400 \times 54.4}{68 \times 1000} = 17.92 \text{ mL of } O_2 \text{ at STP}$$

Hence, volume strenth of 1.6 M H_2O_2 solution = 17.92

Illustration 3

What mass of hydrogen peroxide will be present in 2 litres of a 5 molar solution? Calculate the mass of oxygen which will be liberated by the decomposition of 200 mL of this solution.

Soln.: Molar mass of $H_2O_2 = 34 \text{ g mol}^{-1}$

Mass of H_2O_2 present in 2 L of 5 molar H_2O_2 solution

$= 2 \times 5 \times 34 = 340$ g H_2O_2

Mass of H_2O_2 present in 200 mL of 5 molar H_2O_2 solution

$$= \frac{340}{2000} \times 200 = 34 \text{ g}$$

$2H_2O_2 \rightarrow O_2 + H_2O$

So, 68 g of H_2O_2 on decomposition will give 32 g O_2

$\therefore$ 34 g of H_2O_2 on deocompostion will give

$$= \frac{32 \times 34}{68} = 16 \text{ g } O_2$$

Uses of hydrogen peroxide

- H_2O_2 is germicide and antiseptic.
- Its dilute solution is used in the bleaching of cotton, wool, silk, hair, ivory, paper, pulp, etc.
- It is used in the preparation of organic and inorganic compounds. Na_2O_2, sodium perborate, epoxides, peracids such as H_2SO_5 (permonosulphuric acid, Caro's acid), $H_2S_2O_8$ (perdisulphuric acid, Marshall's acid), etc.
- It is used as propellent for rockets, torpedoes, etc., and as a fuel. As a propellant is used to oxidise alcohol, petrol, hydrazine, etc.

  $N_2H_4 + 2H_2O_2 \longrightarrow N_2 + 4H_2O$
- H_2O_2 is used as antichlor to remove Cl_2 etc., present in a solution.