

ST. LAWRENCE HIGH SCHOOL A JESUIT CHRISTIAN MINORITY INSTITUTION STUDY MATERIAL FOR CHEMISTRY (CLASS-11) TOPIC- HYDROGEN (PART-2) PREPARED BY: MR. ARNAB PAUL CHOWDHURY SET NUMBER-14 DATE: 08.02.2021



<u>Hydrides</u>

The compounds of hydrogen with metals and non-metals are called hydrides.

Ionic Hydrides

These are formed by elements of group I, II, (except Be and Mg) by heating them in hydrogen.

These are white colourless solids (crystalline) having high m.p. and b.p. easily decomposed by water, CO₂ or SO₂.

 $CaH_2 + 2H_2O \rightarrow Ca(OH)_2 + 2H_2$

 $CaH_2 + 2CO_2 \rightarrow (HCOO)_2Ca$

They are strong reducing agents. Alkali metal hydrides are used for making LiAIH₄, NaBH₄, etc and for removing last traces of water from organic compounds.

Molecular or Covalent Hydrides

These are formed by elements of p-block having higher electronegativity than hydrogen.

- 1. Electron deficient hydrides These are the hydrides which do not have sufficient number of electrons needed to form normal covalent bonds, e.g., BH₃, AlH₃, etc.
- 2. Electron precise hydrides These are the hydrides which have exact number of electrons needed to form normal covalent bonds. e.g. hydrides of group 14 (CH₄, SiH₄, etc.)
- 3. Electron rich hydrides These are the hydrides which have greater number of electrons than required to form normal covalent bonds. e.g., hydrides of group 15, 16, 17, (NH₃, PH₃, H₂S, HF, HCl, etc). The excess electrons in these hydrides are present as lone pairs of electrons.

Metallic or Interstitial Hydrides

The transition metals and rare earth metals combine with hydrogen to from interstitial hydrides. They exhibit metallic properties and are powerful reducing agents. They are non-stoicluometric hydrides and their composition varies with temperature and pressure for e.g., LaH_{2.76}, TiH_{1.73}.

Metals of group 7, 8 and 9 do not form hydrides and this region of the Periodic Table is called hydride gap.

Polymeric Hydrides and Complex Hydrides

Polymeric hydrides are formed by' elements having electronegativity in the range 1.4 to 2.0, e.g., (BeH₂)_n, (AIH₃)_n, etc. In complex hydrides H⁻ acts as ligand and is attached to central metal atom, e.g., LiAIH₄, LiBH₄, etc.

Water

Water is the most abundant and widely distributed on the earth. It occurs in all the three physical states. H₂O is a covalent molecule in which oxygen is sp³ hybridised. It has bent structure.



Physical Properties of Water

- 1. Water is a colourless, odourless, tasteless liquid. It has abnormally high b.p., f.p., heat of vaporisation due to hydrogea bonding.
- 2. Pure water is not a good conductor so it is made conductor by adding small amount of acid or alkali.
- 3. Density of ice (which is mass per unit volume) is lesser than that of water and it floats over water.
- 4. Water has maximum density at 4°0.
- 5. Water is a highly polar solvent with high dielectric constant 78.39. It interacts with polar or ionic substances effectively with the release of considerable amount of energy due to ion dipole interaction. The dissolution of covalent compounds like urea, glucose and C₂H₃OH, etc is due to the tendency of these molecules to form hydrogen bond with water.

Chemical Properties of Water

1. Water is amphoteric in nature.

 $\begin{array}{rcl} \mathrm{H}_{2}\mathrm{O}(l) + \mathrm{HCl}(aq) &\rightleftharpoons & \mathrm{H}_{3}\mathrm{O}^{+}(aq) + \mathrm{Cl}^{-}(aq) \\ & & \mathrm{acid} & & \mathrm{acid} & & \mathrm{base} \end{array}$ $\begin{array}{rcl} \mathrm{H}_{2}\mathrm{O}(l) + \mathrm{NH}_{3}(aq) &\rightleftharpoons & \mathrm{NH}_{4}^{+}(aq) + \mathrm{OH}^{-}(aq) \\ & & \mathrm{acid} & & \mathrm{base} & & & \mathrm{acid} & & \mathrm{base} \end{array}$

2. In redox reactions, water reacts with metals and non-metals both.

$$2\operatorname{Na}(s) + 2\operatorname{H}_2\operatorname{O}(l) \longrightarrow 2\operatorname{Na}\operatorname{OH}(aq) + \operatorname{H}_2(g)$$
$$2\operatorname{F}_2(g) + 2\operatorname{H}_2\operatorname{O}(l) \longrightarrow 4\operatorname{H}^+ + 4\operatorname{F}^- + \operatorname{O}_2(g)$$

3. In hydrated salts, water may remain in five types such as coordinated water, hydrogen bonded water, lattice water, clathrate water and zeolite water.
4. A number of compounds such as calcium hydride, calcium phosphide. etc., undergo hydrolysis with water.

<u>Purification of Water</u> It involves two processes

- 1. Removal of suspended impurities
- 2. Destroying the bacteria.

Suspended particles are removed by coagulation with alum followed by filtration.

Exposure to sunlight, boiling, chlorination (treatment with liquid Cl₂ or bleaching powder), ozonisation and addition of CuSO₅ are some processes which are employed to destroy bacteria.

Heavy Water [D₂O]

It was discovered by Urey in 1932. It can be prepared by exhaustive electrolysis of ordinary water using nickel electrodes. It is colourless, odourless, tasteless liquid.

Chemical Reactions of Heavy Water



Usesof Heavy Water It is used

- 1. in nuclear reactors to slow down the speed of neutrons and called moderator.
- 2. as a tracer compound to study the mechanisms of many reactions.

Soft and Hard Water

The water which produces large amount of lather with soap is known as soft water and which forms a scum with soap is known as hard water.

Typesof Hardness of Water

 Temporary hardness It is due to the presence of bicarbonates of calcium and magnesium. Permanent hardness Tt is due to the presence of chlorides and sulphates of calcium and magnesium.

<u>Removal of Temporary Hardness</u> It can be achieved:

(a) By boiling The soluble bicarbonates are converted into insoluble carbonates.

$$M(\text{HCO}_3)_2 \longrightarrow MCO_3 \downarrow + H_2O + CO_2 \uparrow$$

(where, $M = Ca, Mg$)

(b) By Clark's process By adding lime water or milk of lime.

$$M(HCO_3)_2 + Ca(OH)_2 \longrightarrow MCO_3 \downarrow + 2H_2O + CaCO_3$$

Removal of Permanent Hardness

(i) By adding washing soda The calcium or magnesium salts are precipitated as carbonates.

 $MgCl_2 + Na_2CO_3 \longrightarrow MgCO_3 \downarrow + 2NaCl$

(ii) By adding caustic soda The temporary and permanent hardness can be removed by adding caustic soda.

 $\begin{array}{rcl} CaSO_4 + 2NaOH & \longrightarrow & Ca(OH)_2 \downarrow + Na_2SO_4 \\ MgCl_2 + 2NaOH & \longrightarrow & Mg(OH)_2 \downarrow + 2NaCl \end{array}$

(iii) By adding sodium phosphate (Na₃PO₄) The phosphates of calcium and magnesium are precipitated.

$$3CaCl_{2} + 2Na_{3}PO_{4} \longrightarrow Ca_{3}(PO_{4})_{2} \downarrow + 6NaCl$$

$$3CaSO_{4} + 2Na_{3}PO_{4} \longrightarrow Ca_{3}(PO_{4})_{2} \downarrow + 3Na_{2}SO_{4}$$

Similarly, magnesium also precipitate out in the form of magnesium phosphate, $Mg_{3}(PO_{4})_{2}$.

(iv) Calgon's process Calgon is sodium hexa metaphosphate ($Na_6P_6O_{18}$). This calgon when added to hard water form soluble complex.

$$2CaSO_4 + Na_2[Na_4(PO_3)_6] \longrightarrow 2Na_2SO_4 + Na_2[Ca_2(PO_3)_6]$$

calgon soluble

Similarly. Mg^{2+} can also precipitate as $Na_2[Mg_2(PO_3)_6]$ and water becomes free from Ca^{2+} and Mg2+ lons.

(v) **Permutit process** Permutit is hydrated sodium aluminium silicate $Na_2Al_2Si_2O_8.xH_2O$. It exchanges its sodium ions for divalent ions Ca^{2+} and Mg^{2+} .

$Na_2Al_2Si_2O_8 + MCl_2 \longrightarrow MAl_2Si_2O_8 + 2NaCl(M = Ca or Mg)$

Permutit when fully exhausted can be regenerated by treating with 10% solution of sodium chloride. It is most efficient method to gel water with zero degree of hardness.

(vi) By synthetic resins

These are of two types:

(a) Cation exchange resins are big molecules containing sulphonic acid group (-SO₃H). It is first changed into sodium salt with the general formula RNa. The hard water is passed through it so Ca^{2+} and M^{2+} are exchanged and removed.

 $2R^{-}Na^{+} + Ca^{2+} \longrightarrow R_2Ca + 2Na^{+}$ $2R^{-}Na^{+} + Mg^{2+} \longrightarrow R_2Mg + 2Na^{+}$

The resins like permutit can be regenerated with a solution of NaCl.

(b) Anion exchange resins are also big molecules and can exchange anions. They contain an amino group.

 $RNH_{2} + H_{2}O \longrightarrow RNH_{3}\ddot{O}H$ $2RNH_{3}^{*}\ddot{O}H + CO_{3}^{2-} \rightleftharpoons (RNH_{3}^{*})_{2}CO_{3} + 2OH^{-}$ $2RNH_{3}^{*}OH^{-} + CI^{-} \rightleftharpoons RNH_{3}^{*}CI^{-} + OH^{-}$

The water is first passed through cation resins and then through anion tesin and pure distilled water is obtained.

Measurement of Degree of Hardness

Degree of hardness is defined as the number of parts of calcium carbonate or equivalent to various calcium and magnesium salts present in one million parts of water by mass. It is expressed in ppm.

Degree of hardness (in ppm) = (wt. of CaCO₃ (g)/ wt. of hard water (g)) x 10⁶ The molecular wt. of Ca(HCO₃)₂, Mg(HCO₃)₂, CaCl₂, MgCl₂, CaSO₄ and MgSO₄ is 162, 146, 111, 95, 136 and 120 respectively. The mol. wt. of CaCO₃ is 100. Thus, 162 g Ca(HCO₃)₂, 146 g Mg(HCO₃)₂, 111 gCaCl₂, 95 g MgCl₂ 136 g CaSO₄ and 120 g MgSO₄ are equivalent to 100 g CaCO₃.

Hydrogen Peroxide [H₂O₂]

 H_2O_2 was discovered by J.L. Thenard in 1818. It is an important compound used in pollution control treatment of domestic and industrial effluents.

Methods of Preparation



Strength of Hydrogen Peroxide

The most common method to express the strength of H_2O_2 is in terms of the volume (in mL) of oxygen liberated at NTP by decomposition or 1 mL of that sample of H Z 0 2. A solution of H_2O_2 labelled as '10 volume' actually means "1 mL of such a solution of H_2O_2 on decomposition by heat produces 10 mL of oxygen at NTP". (i) Strength of H_2O_2 in terms of normality (68 x X/22.4) = 17 x N \Rightarrow X = 5.6 x N

where, X is volume strength of H_2O_2 . (ii) % strength = (17/56) x volume strength

(iii) X = 11.2 x molarity.

Storage of Hydrogen Peroxide (H₂O₂)

It is stored in the presence of traces of alcohol, acetanilide or sodium pyrophosphate which slow down the rate of decomposition of hydrogen peroxide.

Chemical Properties of H₂O₂

- 1. Acidic nature It is weakly acidic in nature and pure hydrogen peroxide turns blue litmus red.
- 2. Oxidising agent It acts as a strong oxidising agent in acidic as well as in basic medium.

 $H_2O_2 + 2H^+ + 2e^- \longrightarrow 2H_2O$ $H_2O_2 + OH^- + 2e^- \longrightarrow 3OH^-$

e.g., oxidising action of HzOz is

$$2Cr^{3^{+}} + 3H_2O_2 + 10OH^{-} \longrightarrow 2CrO_4^{2^{-}} + 8H_2O$$
$$Mn^{2^{+}} + H_2O_2 + 2OH^{-} \longrightarrow MnO_2 + 2H_2O$$

(iii) Reducing agent

(a) In acidic medium

 $2\mathrm{MnO}_4^- + 6\mathrm{H}^+ + 5\mathrm{H}_2\mathrm{O}_2 \longrightarrow 2\mathrm{Mn}^{2+} + 8\mathrm{H}_2\mathrm{O} + 5\mathrm{O}_2$ $\mathrm{Cr}_2\mathrm{O}_7^{2-} + 8\mathrm{H}^+ + 3\mathrm{H}_2\mathrm{O}_2 \longrightarrow 2\mathrm{Cr}^{3+} + 7\mathrm{H}_2\mathrm{O} + 3\mathrm{O}_2$

(b) In basic medium

$$2K_{3}[Fe(CN)_{6}] + 2KOH + H_{2}O_{2} \longrightarrow \\ 2K_{4}[Fe(CN)_{6}] + 2H_{2}O + O_{2}$$

(iv) Bleaching properties Its bleaching action is due to oxidation by atomic oxygen and permanent.

 H_2O_2 rarr; H_2O + [O] dye + [O] \rightarrow dye is oxidised and bleached

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