TOPICS TO BE COVERED

1. About Hydrogen and its isotopes
2. Types of Hydrides
3. H_2O_2 and Hard Water

Hydrogen exhibits a dual behavior

It resembles both alkali metals and halogens.

Alkali Metal

Electronic Configuration : ns^1

H : $1s^1$

Li : $2s^1$

$H^+ \xleftarrow{-e^-} H$

$Li^+ \xleftarrow{e^-} Li$

Halogens (F / Cl / Br / I)

Requires only one electron to have the configuration of the nearest noble gas.

$F \rightarrow [He]\,2s^2\,2p^5 \xrightarrow{+e^-} 2s^2\,2p^6$

$1s^1$ $\quad H \xrightarrow{+e^-} H^-\ (1s^2)$

molecule

H_2 | Cl_2 | F_2 | Br_2 | I_2

Isotopes of Hydrogen

	Protium	Deuterium D	Tritium T
Representation	Ordinary hydrogen $^{1}_{1}H$	Heavy hydrogen $^{2}_{1}H$	Radioactive $^{3}_{1}H$
Neutrons	Zero	1	2
Occurrence	99.98%	0.16%	10^{-15}%

Q. The total number of isotopes of hydrogen and number of radioactive isotopes among them, respectively, are :

(A) 3 and 1

(B) 3 and 2

(C) 2 and 1

(D) 2 and 0

3 & 1

Q. Hydrogen has three isotopes (A), (B) and (C). If the number of neutron(s) in (A), (B) and (C) respectively, are (x), (y) and (z), the sum of (x), (y) and (z) is :

(A) 3

(B) 2

(C) 4

(D) 1

$A \longrightarrow x$ (zero)

$B \longrightarrow y$ (1)

$C \longrightarrow z$ (2)

$1 + 2 + 0 = 3$

Preparation of H_2

Active metals (Na, K)

$Na \rightarrow Na^+ + e^-$

$H_2O \rightarrow H^+ / \bar{O}H$

$Na + H_2O \longrightarrow \frac{1}{2} H_2 \uparrow + NaOH$

Less active metals (Ca, Zn, Mg, Al)

$Al + H_2O \xrightarrow[\Delta]{H^+/\bar{O}H} H_2 \uparrow + Al(OH)_3$

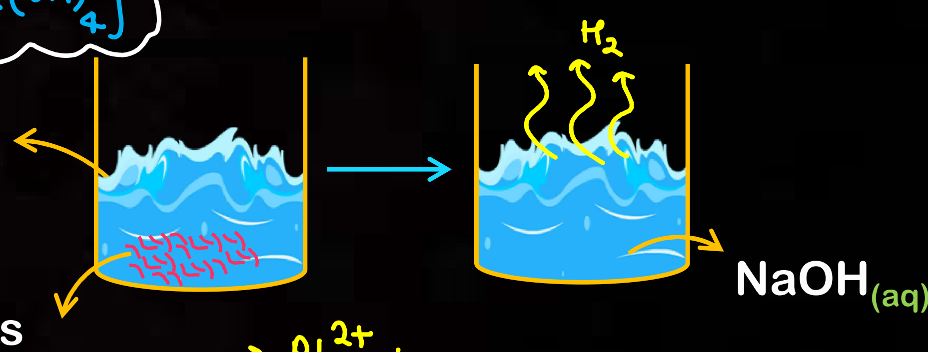
$Al \rightarrow Al^{3+} + 3e^-$

$Al(OH)_3 \xrightarrow[\bar{O}H]{NaOH} Na^+[Al(OH)_4]^-$

Reaction of NaOH with

$\boxed{Sn, Al, Pb, Zn, B, Si} = M$

Sn^{+4}, Al^{+3}, Pb^{2+}, Zn^{2+}, B^{3+}, Si^{4+}



$M + NaOH \longrightarrow Na_x M O_y + H_2 \uparrow$

$Zn + NaOH \longrightarrow Na_2 Zn O_2 + H_2 \uparrow$

$Pb \rightarrow Pb^{2+} + 2e^-$

Sod. plumbite

$Pb + NaOH \longrightarrow H_2 \uparrow + Na_2 Pb O_2$

$Al + NaOH \longrightarrow H_2 \uparrow + NaAlO_2 \cdot 2H_2O$

$Al \rightarrow Al^{+3} + 3e^-$

Gassing Reaction : $Fe + H_2O \xrightarrow{\Delta} Fe_2O_3 + H_2\uparrow$

$Fe^{+3} + 3e^-$

Bosch Process : Industrial Preparation

R.A.

$C + H_2O \xrightarrow{1270\ K} CO + H_2$: Water gas

Syn gas : Methanol prep^n

R.A.

$H_2 + CO + H_2O \xrightarrow[Fe_2O_3.Cr_2O_3]{773\ K} \underbrace{CO_2 + 2H_2}$

[Acidic]

NAS $\rightarrow H_2\uparrow$

Water gas shift reaction

CO_2 gas is removed by sodium arsenite solution, and this process is called as scrubbing.

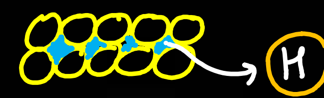
Preparation of pure hydrogen

(1) The electrolysis of a solution of $\boxed{Ba(OH)_2}$ using Ni electrodes ~~gives~~ extra pure H_2

(2) $\overset{Na^+\ H^-}{NaH} + \overset{H^+ / \bar{O}H}{H_2O} \longrightarrow H_2\uparrow + NaOH$

Types of Hydrides

H: Non Metal



Saline / Salt Hydride

Ionic Hydride $Na^{\oplus} H^{\ominus}$

S block Metal & H

Crystalline solids

High M.P. & B.P.

Good conductor of electricity.

Covalent / Molecular Hydrides

P block (Non-metal) + H

HCl , H_2O , CH_4 , PH_3

CH_4 CH_4

Less M.P. & B.P.

Poor conductor of electricity.

Interstitial Hydrides

Metallic Hydrides

D block Metal & H

Fe_3H , $VH_{0.56}$ and $TiH_{1.7}$

High M.P. & B.P.

Nonstoichiometric in nature

T.S. : LiH > NaH > KH > RbH > CsH

H_2O Vs D_2O

$\oplus$ ε $\ominus$

$F \propto \frac{1}{\varepsilon}$

Property	H_2O		D_2O
Molecular mass ($g\ mol^{-1}$)	18.0151	<	20.0276
Melting point/K	273.0	<	276.8
Boiling point/K	373.0	<	374.4
Temp of max. density/K 4°C	276.98	<	11°C 284.2
Density (298K)/$g\ cm^{-3}$	1.0000	<	1.1059
Viscosity/centipoise	0.8903	<	1.107
Dielectric constant/$C^2/N.m^2$	78.39	>	78.06

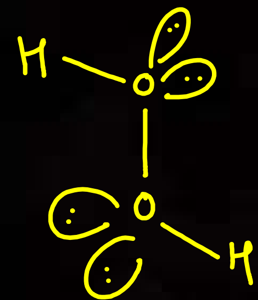
D_2O is extensively used as a moderator in nuclear reactors and in exchange reactions for the study of reaction mechanisms.

H_2O_2

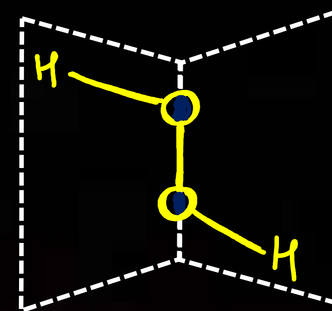
Hydrogen peroxide

Non-planar

Hydrogen bonding



peroxide ion
O_2^{2-}



$\boxed{\text{open-book structure}}$

Laboratory Method

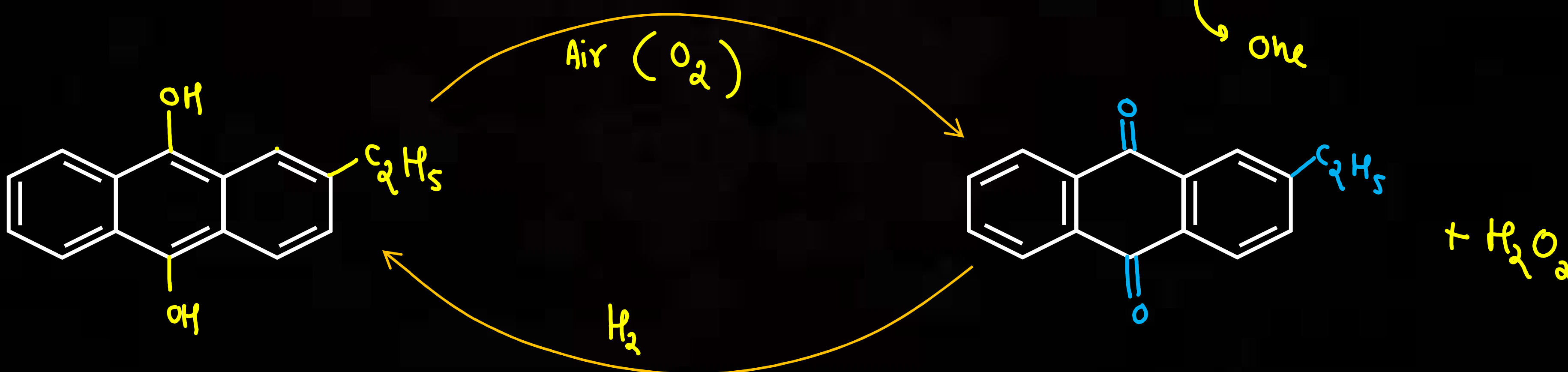
$$\overset{Ba^{2+}\ O_2^{2-}}{BaO_2\cdot 8H_2O} + \overset{2H^+\ SO_4^{2-}}{H_2SO_4} \longrightarrow H_2O_2 + BaSO_4$$

Industrial Method

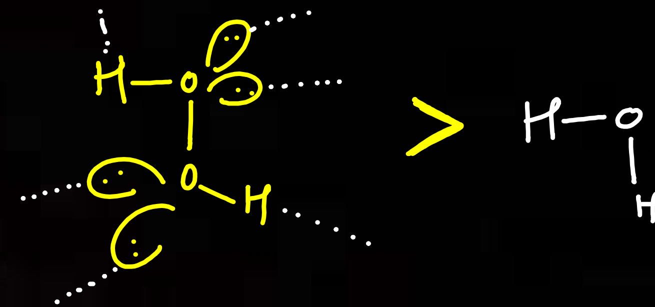
Auto oxidation of 2-Ethyl anthraquinol

one

C–OH → C=O



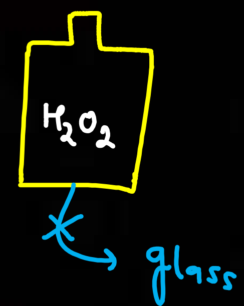
Physical Properties of H_2O_2



Density $\uparrow$

Viscosity $\uparrow$ w.r.t. H_2O

Boiling point $\uparrow$ wrt H_2O



Dielectric constant $\longrightarrow$ $\boxed{H_2O > H_2O_2}$

Not used as solvent

$$H_2O_2 \xrightarrow{NaCl} H_2O + \frac{1}{2}O_2\uparrow$$

Aqueous solution is stored in plastic or wax-lined glass containers

Strength of hydrogen peroxide solution

20% H_2O_2

$\frac{w}{v}$ (20 g H_2O_2 / 100 ml aq.)

Percentage strength :

20% aqueous solution (w/v) of H_2O_2 : 20g of hydrogen peroxide is present in 100 ml of the solution

$H_2O_2 \longrightarrow H_2O + \frac{1}{2}O_2$ → Volume of O_2 (ml)

(1 ml)

"Jwala OP"

[Molarity = M] → M mol/L

1L gas

22.4 L

Volume strength : The volume (in ml) of oxygen liberated at N.T.P. by the decomposition of 1 ml sample of hydrogen peroxide.

Molarity and Volume Strength : Molarity = Volume Strength / 11.2

$(11.2)\,M = VS$

Q. Calculate the $\boxed{\text{volume strength}}^{100}$ of 8.9 M H_2O_2 solution at 273 K and 1 atm ? Write the answer in nearest integer. $(R = 0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1})$

$M = 8.9$

$M(11.2) = VS$

$(8.9)(11.2) \approxeq 100$

Q. The strength of 5.6 volume hydrogen peroxide (of density 1g/mL) in terms of mass percentage and molarity (M), respectively, are :
(molar mass of H_2O_2 : 34g /mol)

(A) 1.7 and 0.5

(B) 0.85 and 0.25

(C) 1.7 and 0.25

(D) 0.85 and 0.5

$d = \frac{1g}{ml}$

$VS = 5.6$

$M = \frac{5.6}{11.2} = 0.5$

$\text{mass \%} = \frac{m_{solute}}{m_{sol^n}} \times 100$

0.5 mol ⟶ 1 L Sol^n

(0.5) 34 gm ⟶ 1000 gm Sol^n

$\% = \frac{17 \text{ gm}}{1000} \times 100$

$= 1.7$

Hard water & Soft water

Ca^{2+} Mg^{2+} HCO_3^- | SO_4^{2-} | Cl^-

Hardness is due to presence of the bicarbonates, sulphates and chlorides of Ca and Mg.

bicarbonates → T.H.

sulphates and chlorides → P.H.

$HCO_3^- \longrightarrow CO_3^{2-} + H_2O + CO_2\uparrow$

Temporary Hardness → Bicarbonates of Ca and Mg

By Boiling

Bicarbonates decompose in insoluble carbonates (ppt)

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

$$Mg(HCO_3)_2 \xrightarrow{\text{Boil}} Mg(OH)_2\downarrow$$

Clark's Method → It can be removed by addition of slaked lime [$Ca(OH)_2$]

→ $Ca(OH)_2$

$$\underset{Ca^{2+}\ 2HCO_3^-}{Ca(HCO_3)_2} + \underset{Ca^{2+}\ 2\bar{O}H}{Ca(OH)_2} \longrightarrow CaCO_3\downarrow$$

Permanent Hardness

Sulphates ,Chlorides of Ca , Mg

$CaCl_2$
$MgCl_2$
$CaSO_4 / MgSO_4$

This type of hardness cannot be removed by boiling or by the addition of slaked lime.

Hard $\longrightarrow$ Soft

$\boxed{\text{Water Softeners :}}$

Washing Soda $\rightarrow Na_2CO_3 \cdot 10H_2O$

Calgon $[NaPO_3]_6$

Permutit (Hyd. Zeolite)

Ion Exchange Resins

Organic Chemical

$\overset{+5}{HPO_3}$
meta phosphoric Acid

$NaPO_3$

Ca^{2+}/Mg^{2+}
Hard
H_2O

Cation Exch.

$H^{\oplus}$
H_2O

Washing Soda

$Na_2CO_3 \cdot 10H_2O$

It removes both the temporary and permanent hardness by converting soluble calcium and magnesium compounds into insoluble carbonates.

$$CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3 \downarrow + 2NaCl$$

$$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3 \downarrow + Na_2SO_4$$

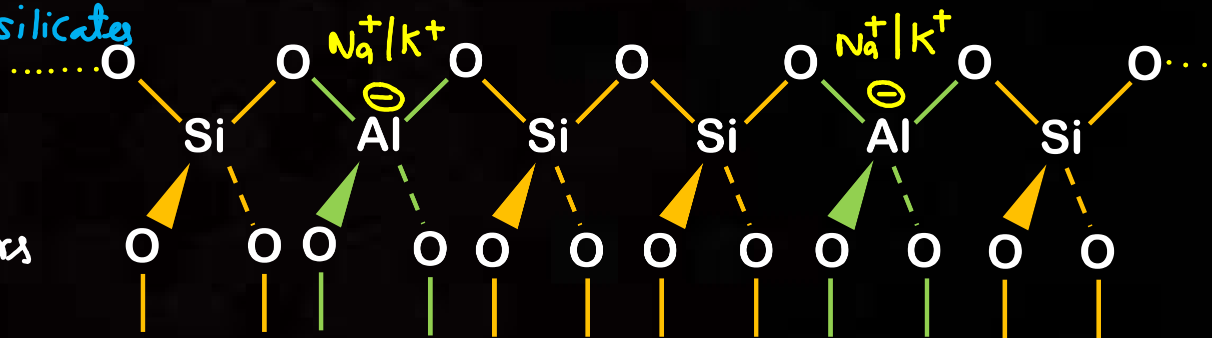
T.H.

$$Ca(HCO_3)_2 + Na_2CO_3 \longrightarrow CaCO_3 \downarrow + 2NaHCO_3$$

Alumino-silicates

Permutit / Hydrated Zeolite

$Na_2O \cdot Al_2O_3 \cdot 2SiO_2$ Cation Exchangers



[Hard Water]

$$Na_2Al_2Si_2O_8 \cdot xH_2O + Ca^{2+} \longrightarrow CaAl_2Si_2O_8 \cdot xH_2O + 2Na^+$$

$Na^{\oplus}$

$$CaAl_2Si_2O_8 \cdot xH_2O + NaCl \longrightarrow Na_2Al_2Si_2O_8 \cdot xH_2O + Ca^{2+}$$

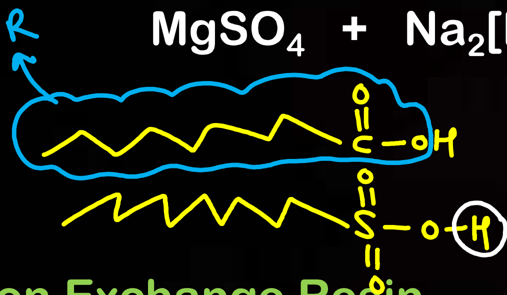
(Brine Solⁿ)

Calgon Sodium Hexametaphosphate = $Na_2[Na_4(PO_3)_6]$ $[NaPO_3]_6$

CER Ca^{2+}

$$CaSO_4 + Na_2[Na_4(PO_3)_6] \longrightarrow Na_2[Ca_2(PO_3)_6] + 4Na^{\oplus}$$

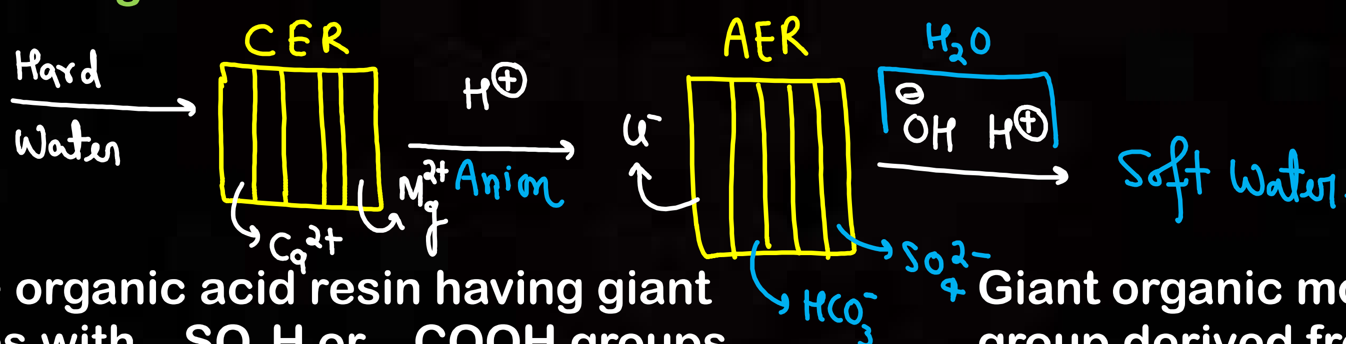
$$MgSO_4 + Na_2[Na_4(PO_3)_6] \longrightarrow Na_2[Mg_2(PO_3)_6] + Na_2SO_4$$



Ion Exchange Resins

Synthetic Substance

Cation Exchange Resin | **Anion Exchange Resin**



Insoluble organic acid resin having giant molecules with – SO_3H or – COOH groups

Giant organic molecules with basic group derived from amines

$$R-H + Ca^{2+} \longrightarrow CaR_2 + H^+$$

$$R-\overset{+}{N}H_3\overset{-}{O}H + Cl^- \xrightarrow{\overset{-}{O}H} R-\overset{\oplus}{N}H_3Cl^{\ominus}$$

Q. The one that is NOT suitable for the removal of permanent hardness of water is :

(A) Clark's method T.H.

(B) Ion-exchange method

(C) Calgon's method

(D) Treatment with sodium carbonate

Q. The temporary hardness of water is due to :

(A) Na_2SO_4

(B) $NaCl$

(C) $\boxed{Ca(HCO_3)_2}$

(D) $CaCl_2$