



Hydrogen and its compounds

Henry Cavendish
1766

- * Hydrogen is the most abundant element in the Universe

92% of universe made up of H₂

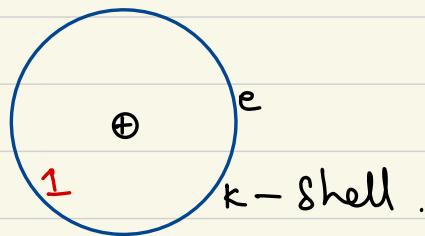
7% He

1% is remaining elements

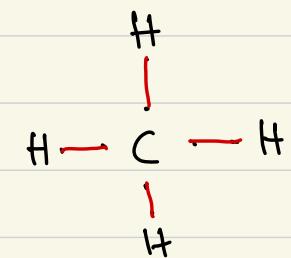
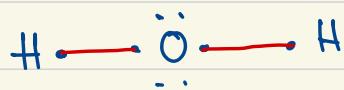
- * In the earth's atmosphere, 3rd most abundant element is H₂, 10th most abundant elements in the earth's crust

*

$$\boxed{H = 1s^1}$$



- * H can form covalent bonds.



*

$$H = 1s^1$$

$$\boxed{\begin{matrix} H^+ = 1s^0 \\ (\text{proton}) \end{matrix}}$$

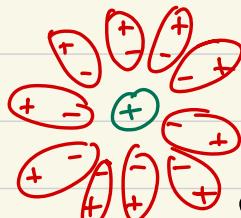
Size of H⁺ = 1Fm = $1.5 \times 10^{-15} \text{ m}$
 $= 1.5 \times 10^{-5} \text{ Å}^0$

Due to this small size, H⁺ ion has high polarising power (ϕ)

$$\boxed{\phi = \frac{\text{charge}}{(\text{radius})^2}}$$

\Rightarrow H_2SO_4 is dissolved in water.

\Rightarrow H^+ ion in aqueous solution exist as
 H_3O^+ , $H_2O_4^+$, ..., $H(H_2O)_n^+$



solvation / hydration.

* $H = 1s^1$

(hydride) $H^- = 1s^2 = [He]$

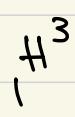
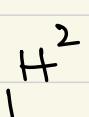
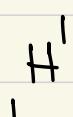
\Rightarrow Hydrogen can form crystalline solids like LiH , NaH , CaH_2 , MgH_2 called as hydrides.

* E.N. of $H = 2.1 \Rightarrow$ So it can exist in any of above three forms.

(Covalent, H^+ , H^-)

* Types of hydrogens:-

① Isotopes:-



protium

Deuterium

Tritium

H_2 , HD , HT

(H)

(D)

(T)

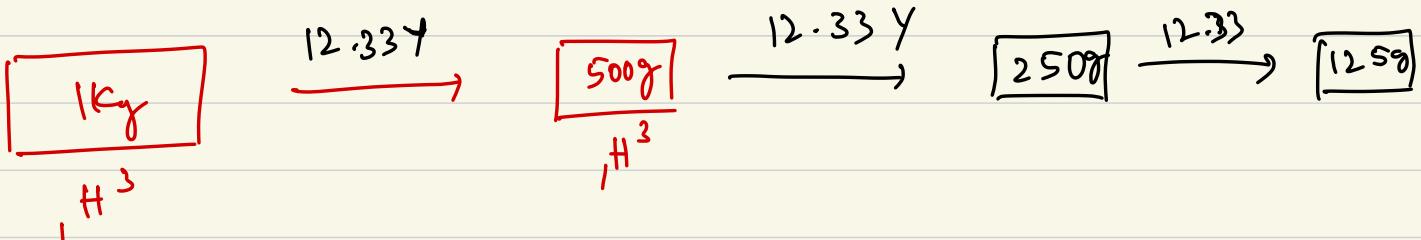
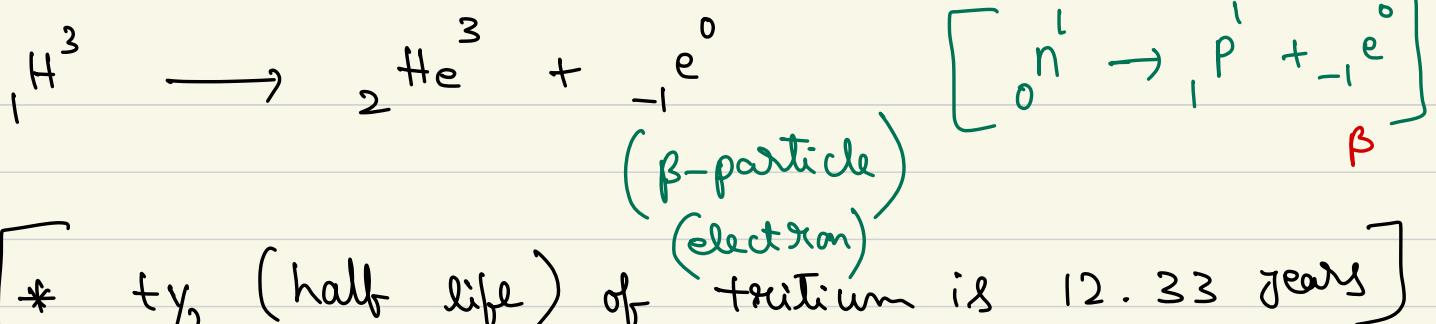
DT , D_2 , T_2

(99.89%)

(0.0156%)

$(1 \times 10^{-16} \%)$

Radio active



$$\Rightarrow \text{M.P. : } H_2 < D_2 < T_2$$

$$\text{B.P. : } H_2 < D_2 < T_2$$

$$\text{Density : } H_2 < D_2 < T_2$$

$$\Delta_f H : H_2 < D_2$$

$$\Delta_r H : H_2 < D_2$$

$$\Delta_a H : H_2 < D_2 \quad (\text{B.E.})$$

$$\text{Covalent radius : } H_2 = D_2 = T_2$$

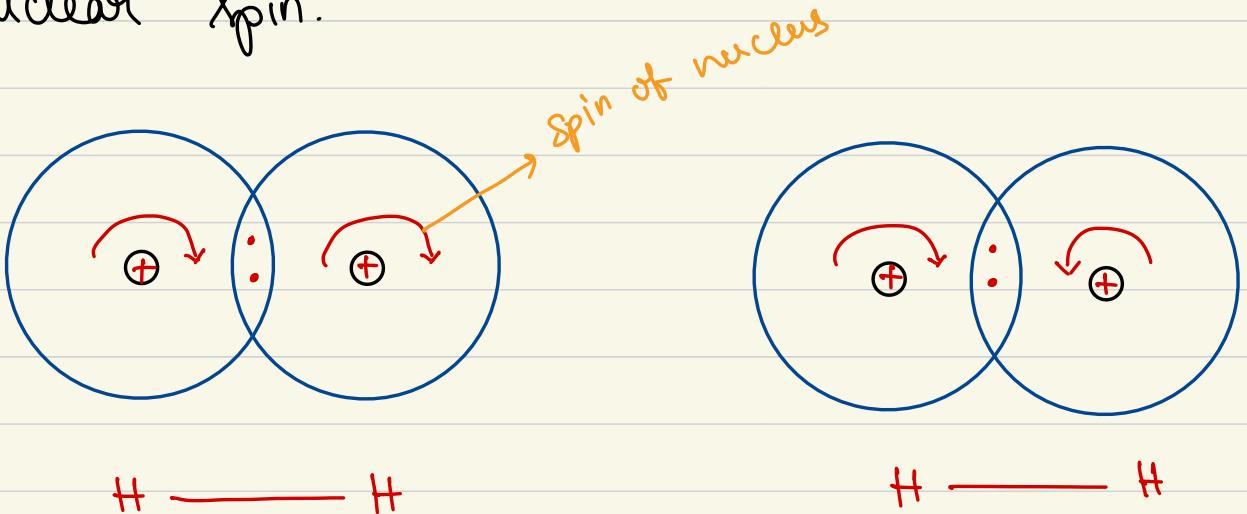
$$\text{Reactivity rate : } H_2 > D_2 > T_2$$

NOTE.. Terrestrial hydrogen ($H_2 + D_2$) contain 0.0156% of Deuterium in the form of HD ($H - D$)

② Ortho - para hydrogens:-

Nucleus of an atom rotate around its own

axis (like electrons). This is called as Nuclear spin.



parallel spin nuclei
Ortho hydrogen

Opposite spin nuclei
para hydrogen

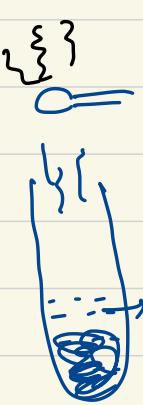
PPP

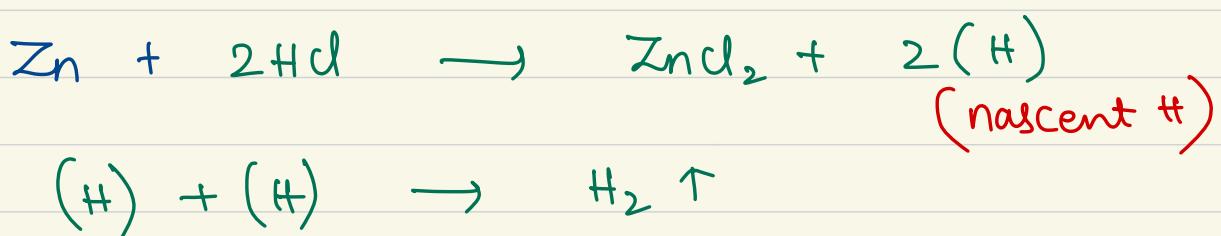
* Para form has lower energy.

at absolute zero temp. (0 K) = 100% para form exist.

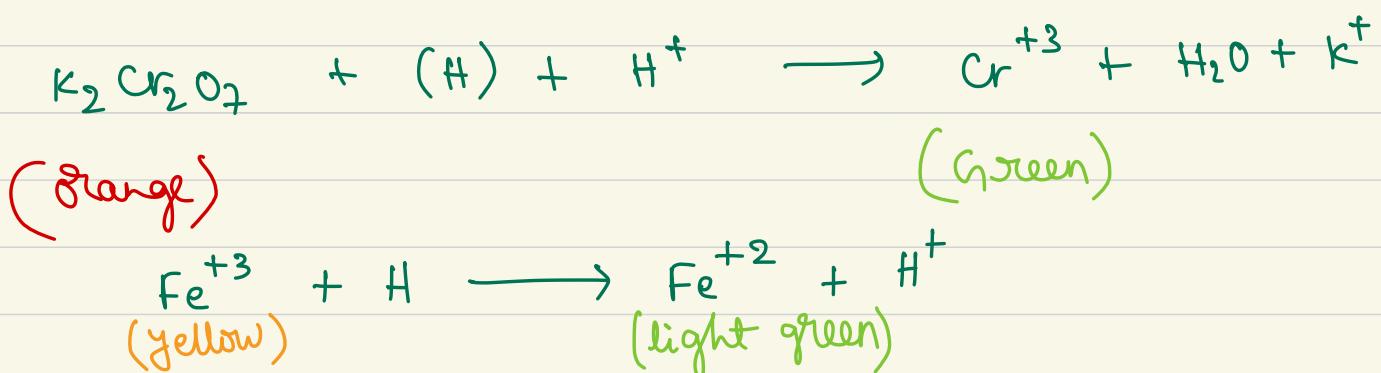
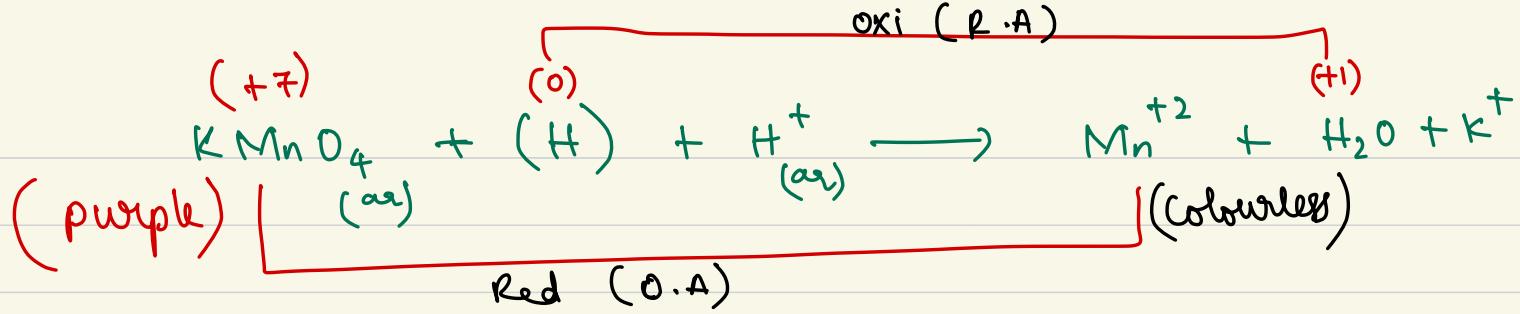
at normal room temp (25°C) = $\boxed{75\% \text{ Ortho}} \\ (298\text{K}) \quad \boxed{25\% \text{ para}}$

③ Nascent hydrogen:- [Newly born atomic H]

 It is generated in the solution by dissolving electro positive metals in dil. acids.



* (H) is more reactive, it acts as R.A.
it can decolorise KMnO_4 , $\text{K}_2\text{Cr}_2\text{O}_7$ (O.A.)



Position of Hydrogen in periodic Table :-

H_2 has similarities with halogens & alkali metals
 $(VIIA)$ (IA)

I Similarities with I_A group :-

$$\textcircled{1} \quad E \cdot C = ns^l \quad ; \quad H = ls^l$$

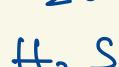
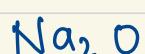
② it acts as R.A. like IA



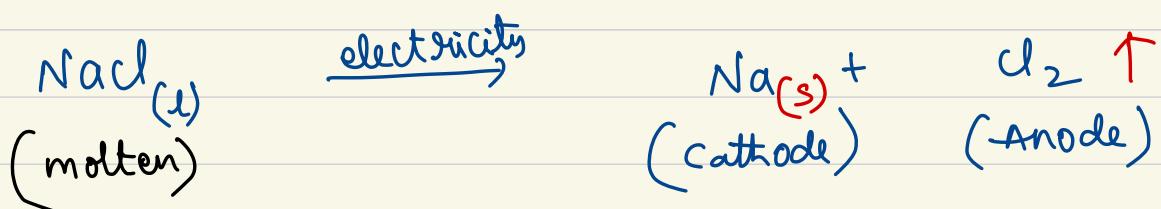
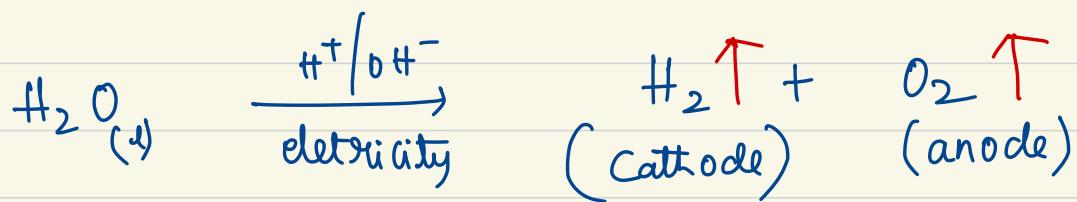
③ It is electropositive like I_A



(a) It can form binary compounds with E.N. atoms like I_A



⑤ During electrolysis, H_2 is liberated at cathode like I_A



Dissimilarities with alkali metals:-

①	H	Li	Na	K	
(I.E)	1312	520	495	418	(I.E/mol)
	(Very high) I.E				

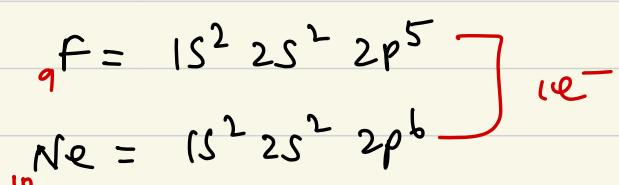
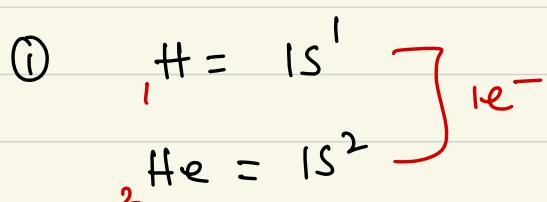
② H_2 is a non-metal ; I_A -group are metal
(gas) (solids)

③ H_2 is diatomic ; I_A -group monoatomic

④ H_2O - Neutral ; Na_2O is basic

II

Similarities with VIIA group:- (Halogens)



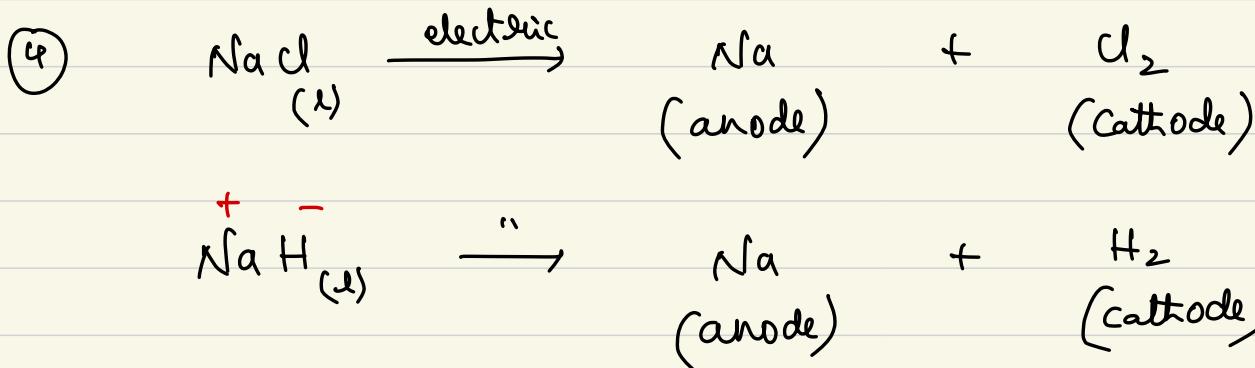
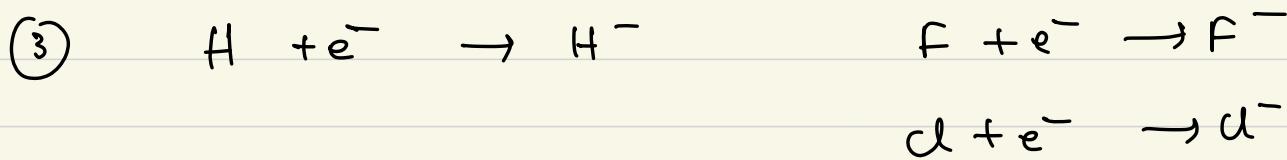
only one e^- less than nearest noble gas.

* H_2 is diatomic

F_2, Cl_2, Br_2, I_2 diatomic

② H₂ has high I.E like halogens.

H	F	Cl	Br	I
1312	1681	1255	1142	1009 (I.E - kJ/mol)



⑤ H shows -1 (ox. state) like halogens (-1)

⑥ H can form covalent compounds similar to halogens
Ex: CH₄ Cl₄

Dissimilarities with halogens:

① H is less E.N. than halogens.

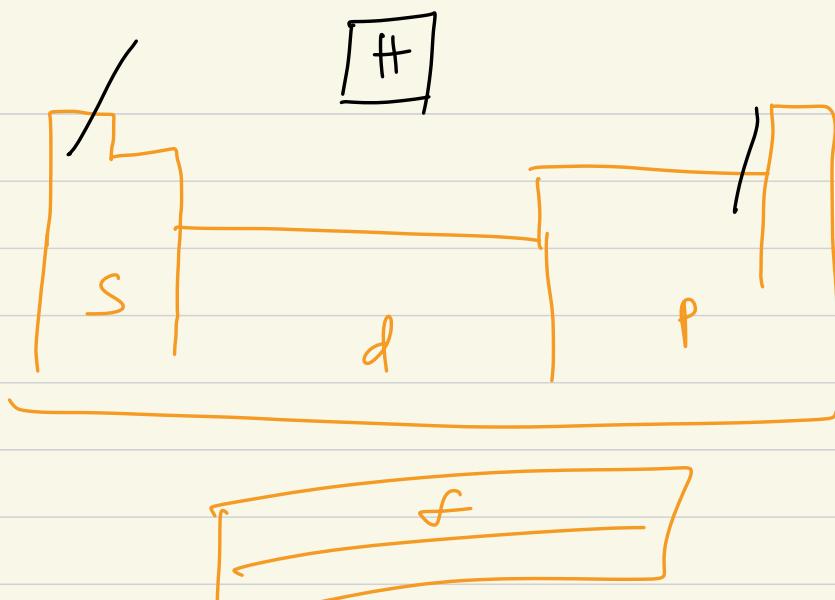
② H₂O - neutral

Cl₂O₇ - acidic

③ H - H no lp

:Cl—Cl: 6 lp

∴ Hydrogen is best treated as a group of its own.

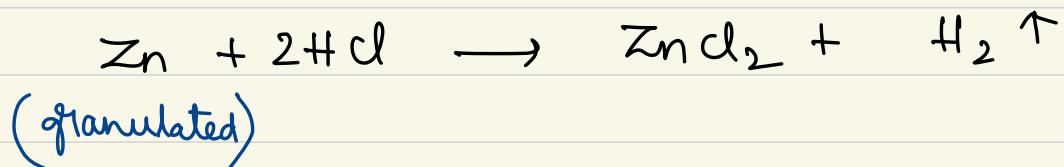


* Preparation of hydrogen:-

The main sources for H_2 prep. are

- (i) water (ii) acids (iii) Alkalies.

① Lab method :-



amphoteric metals like Zn , Pb , Al , Sn , Si ... react with boiling alkali $NaOH$, KOH , ...

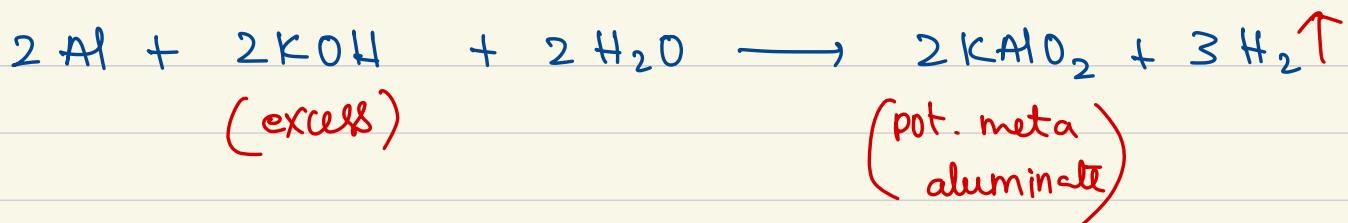


caustic soda = NaOH
" potash = KOH

② Uyeno's method:-

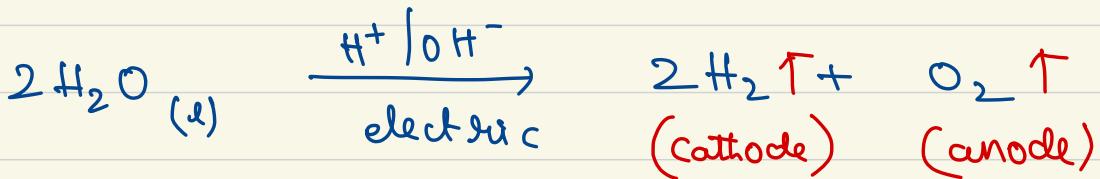
Very pure form of hydrogen

is obtained by reaction of scrap Al. with caustic potash (KOH)



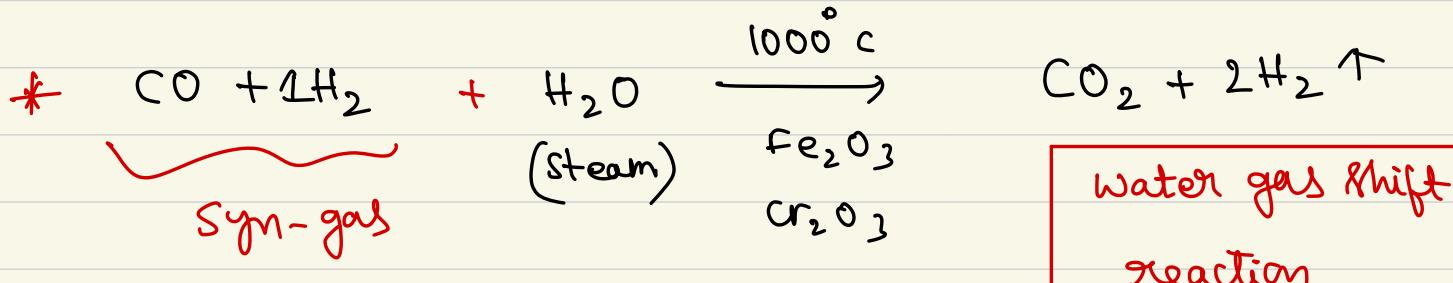
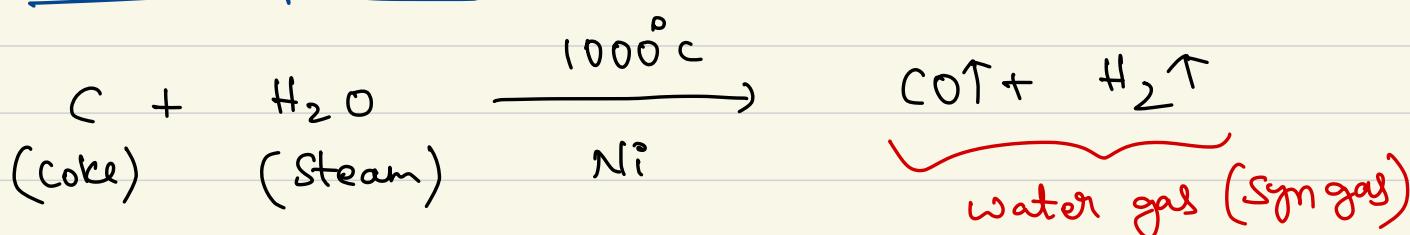
③ Commercial production of H₂ :- (Industrial)

(a) electrolysis of water having small amount of H⁺/OH⁻ in presence of inert electrode (Pt) (Ni)

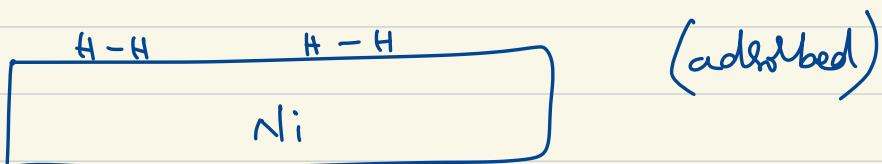
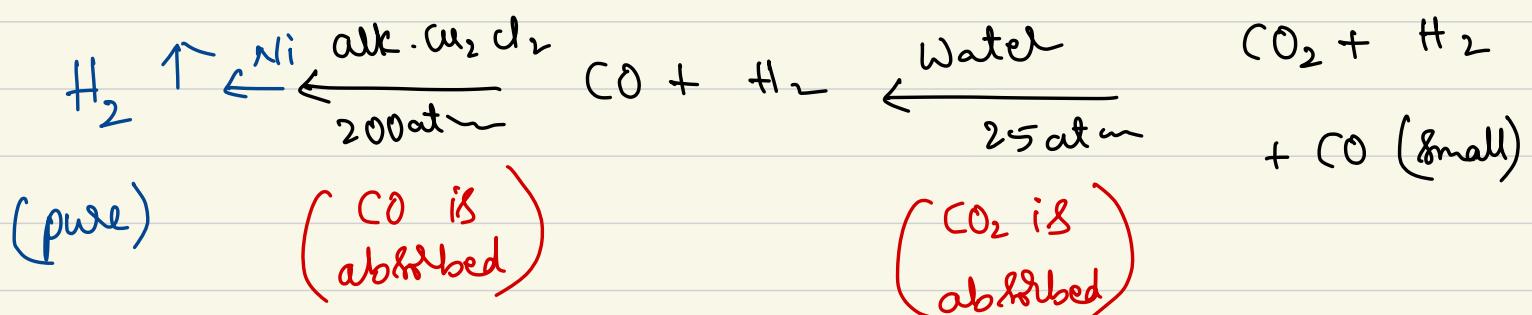
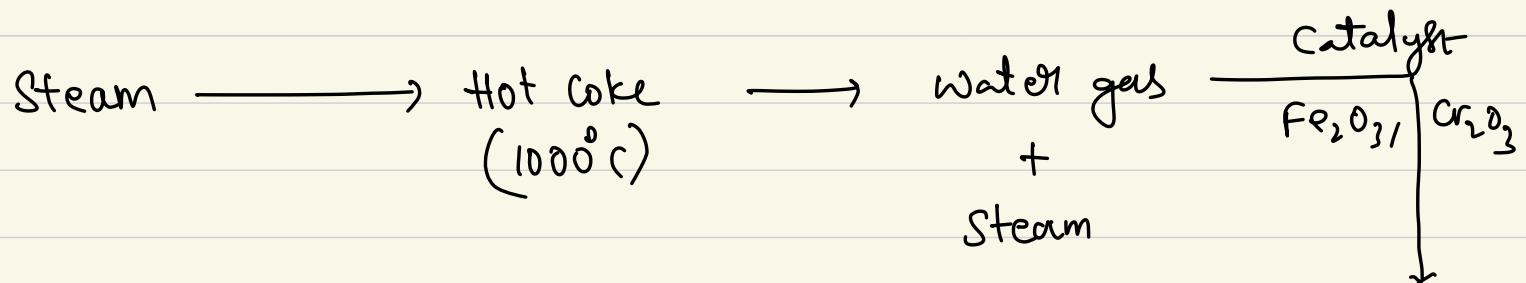


99.95% pure H₂↑ is produced by electrolysis of warm Ba(OH)₂ (aq) in presence of Ni

⑥ Bosch's process:- (Coal gasification)



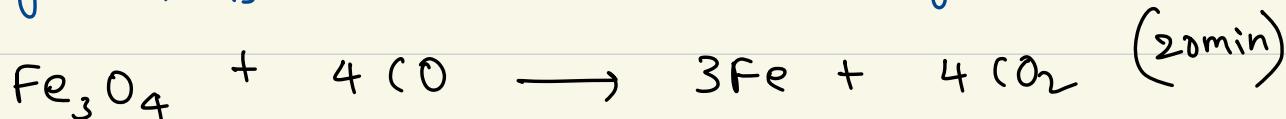
* **SYN gas:-** The mix. of CO + H₂ is used for the synthesis of methanol, methanal & no. of hydrocarbons, Hence it is called Synthesis gas; (Syn gas)

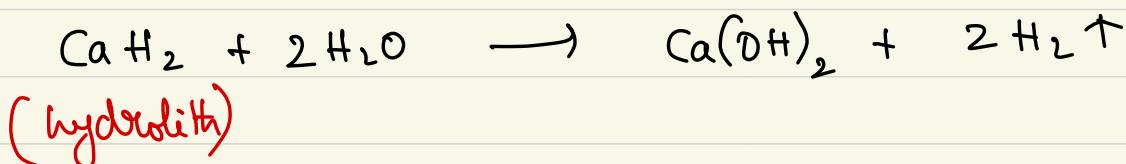
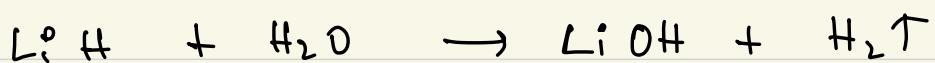
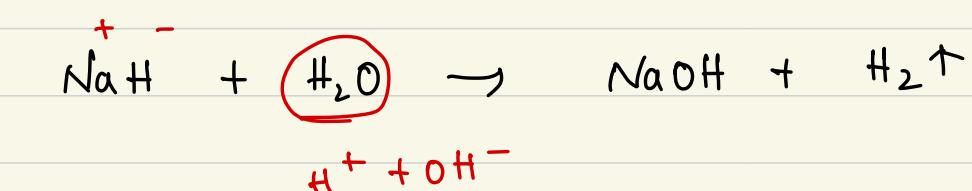
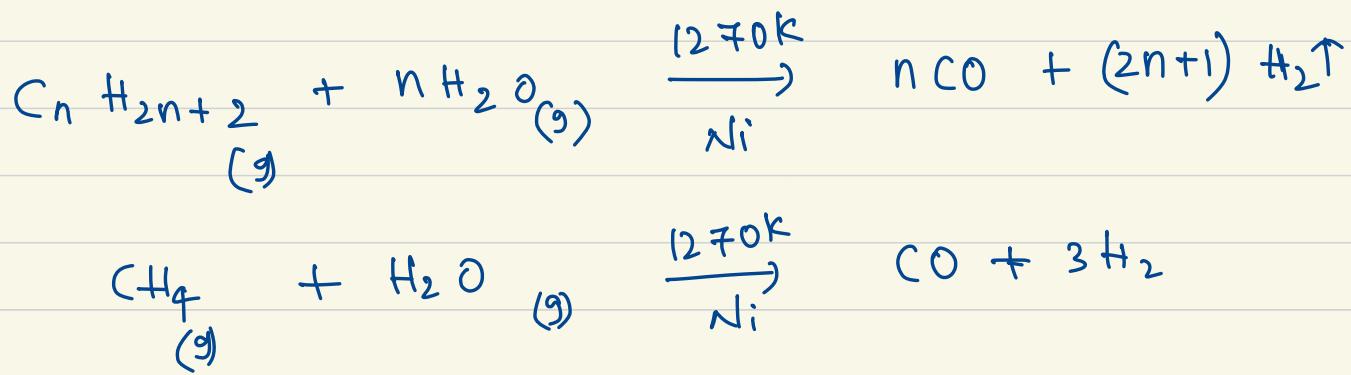
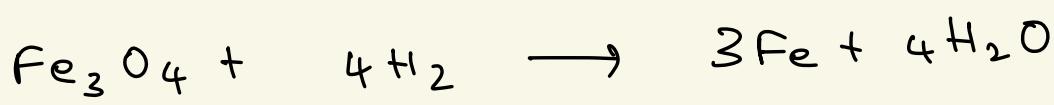


(c) Lane's process:- Steam is passed over hot iron. Then iron decomposes steam to H_2 at $550 - 800^{\circ}C$. This reaction is called Gassing reaction (10 min).

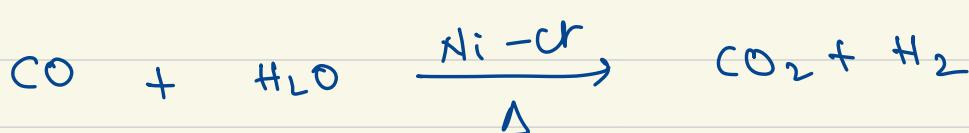
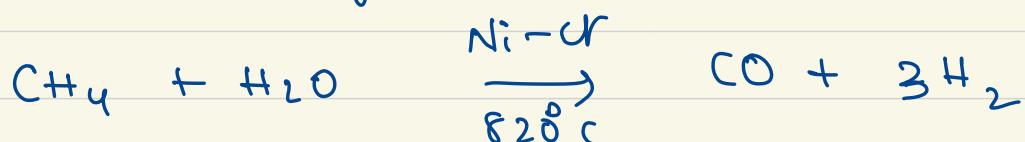


Iron is regenerated by reducing Fe_3O_4 with water gas. This is called as Vitrification reaction.





Steam - Reforming process:-



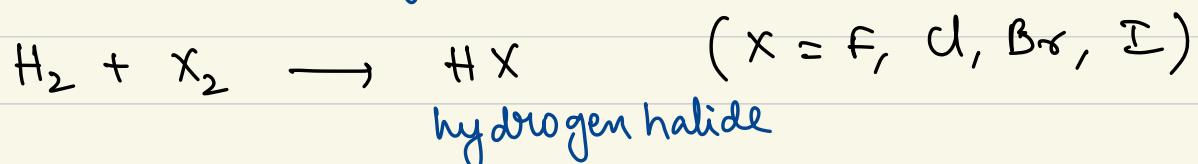
Physical prop:-

- (1) H_2 is colourless, odourless & tasteless gas.
- (2) It is lighter than air & slightly soluble

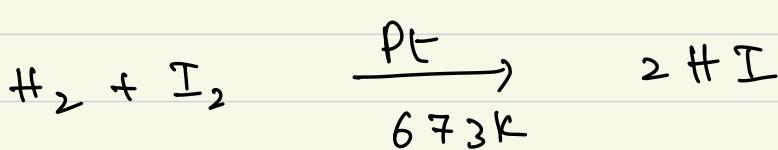
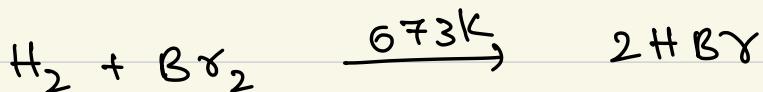
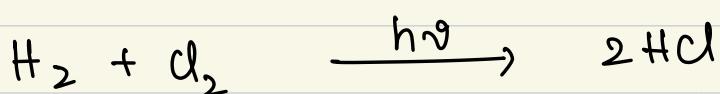
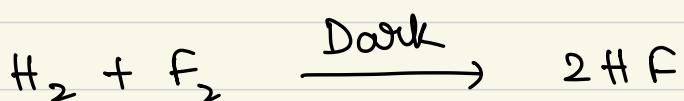
in water about 2 volumes in 100 volumes of water at 0°C

Chemical prop:

① Reaction with halogen:



The reactivity order : $\text{F}_2 > \text{Cl}_2 > \text{Br}_2 > \text{I}_2$



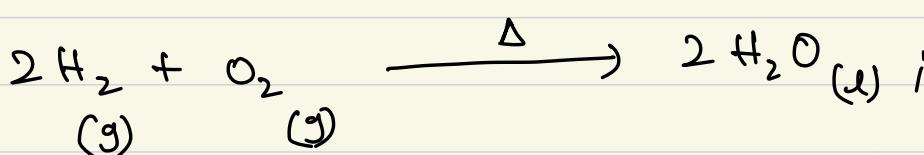
(pt = catalyst)

② Reaction with O_2 :

Combustion

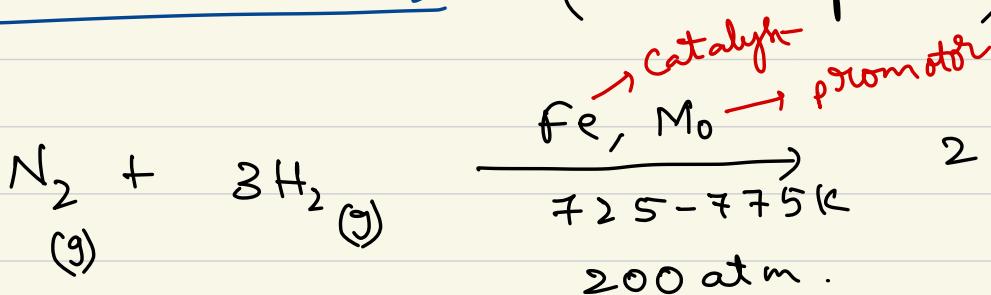
Hydrogen is inflammable

It burns with blue flame



$$\Delta H = -285.9 \text{ kJ/mol.}$$

③ Reaction with N_2 : (Haber's process)

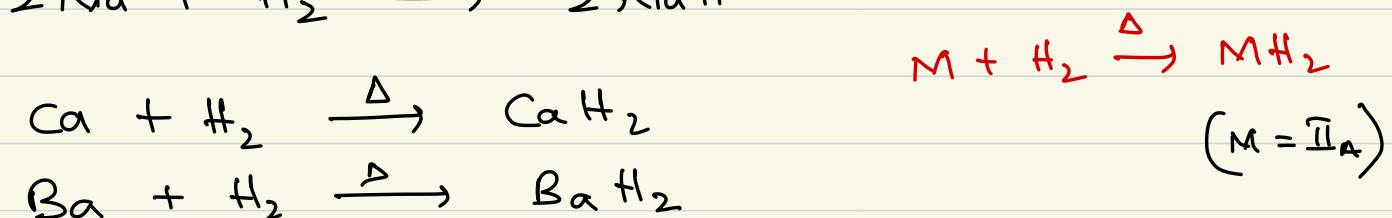
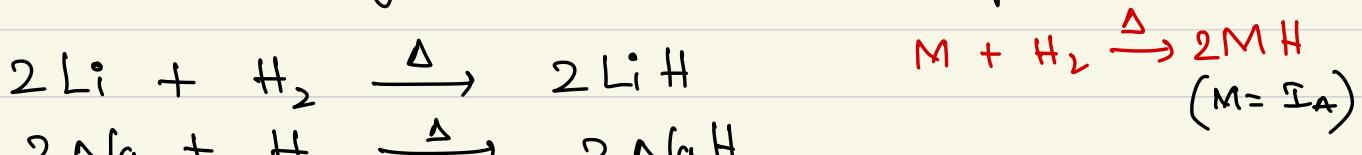


$$\Delta H = -92.6 \text{ kJ}$$

$$= -46.3 \text{ kJ/mol.}$$

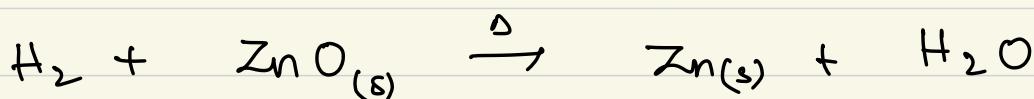
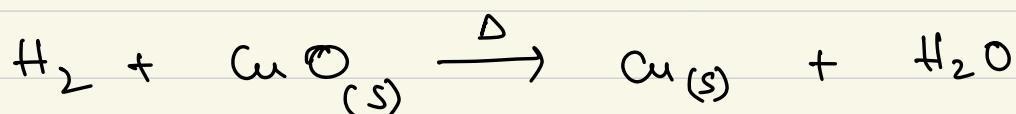
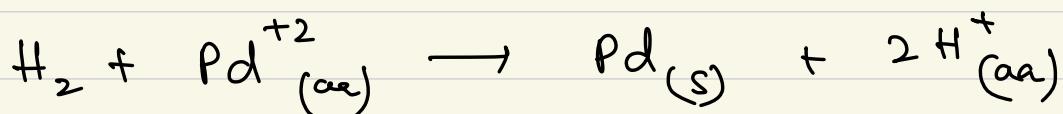
⑤ Reaction with metals:- highly reactive metals

like Li, Na, Ca, Ba... react with H₂ and produce hydrides at high temperature

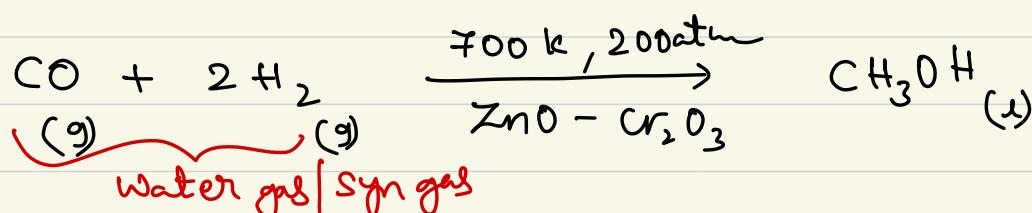


⑥ with metal ions & metal oxides:- (H₂ acts as R.A)

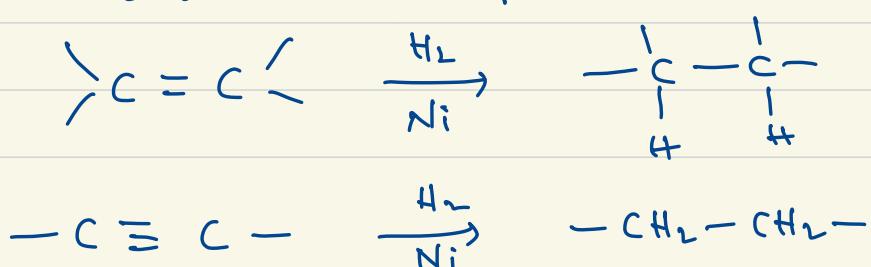
H₂ acts as reducing agent. It reduces metal ions & metal oxides to metal.

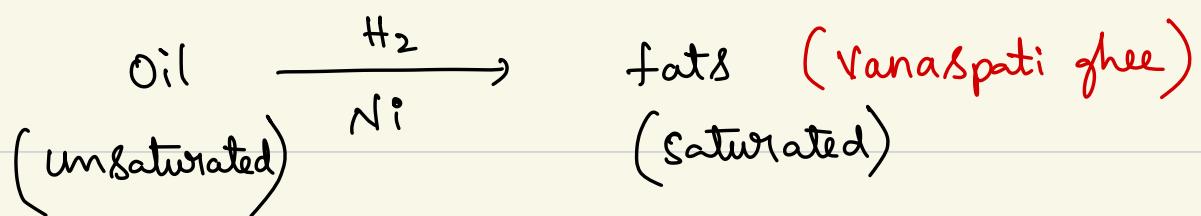


⑦ It is used in the preparation of CH₃OH



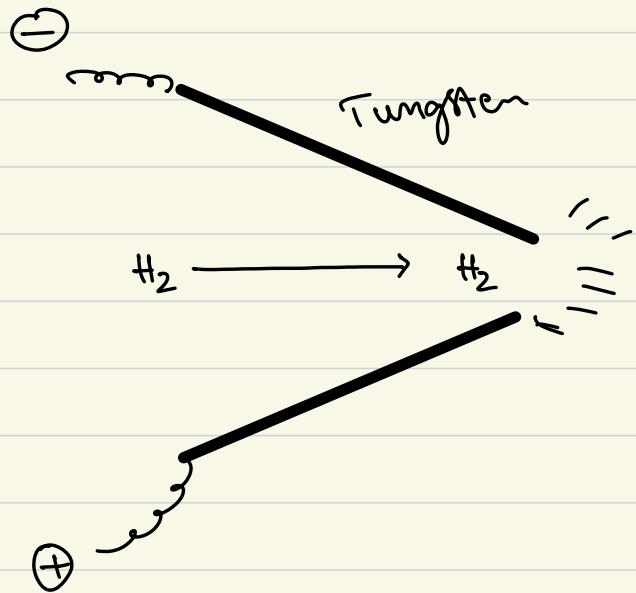
⑧ H₂ converts unsaturated comp to saturated compounds





Uses:-

- ① used in Synthesis of NH_3 , HCl
- ② " " preparation of Vanaspati fats
- ③ used to reduce heavy metal oxides to metals in metallurgy; (acts as R.A)
- ④ used as Rocket fuel.
- ⑤ used for preparation of metal hydrides
- ⑥ Atomic hydrogen & oxyhydrogen torches find use for cutting & welding purpose



$$\Delta H = +458.1 \text{ kJ/mol}$$



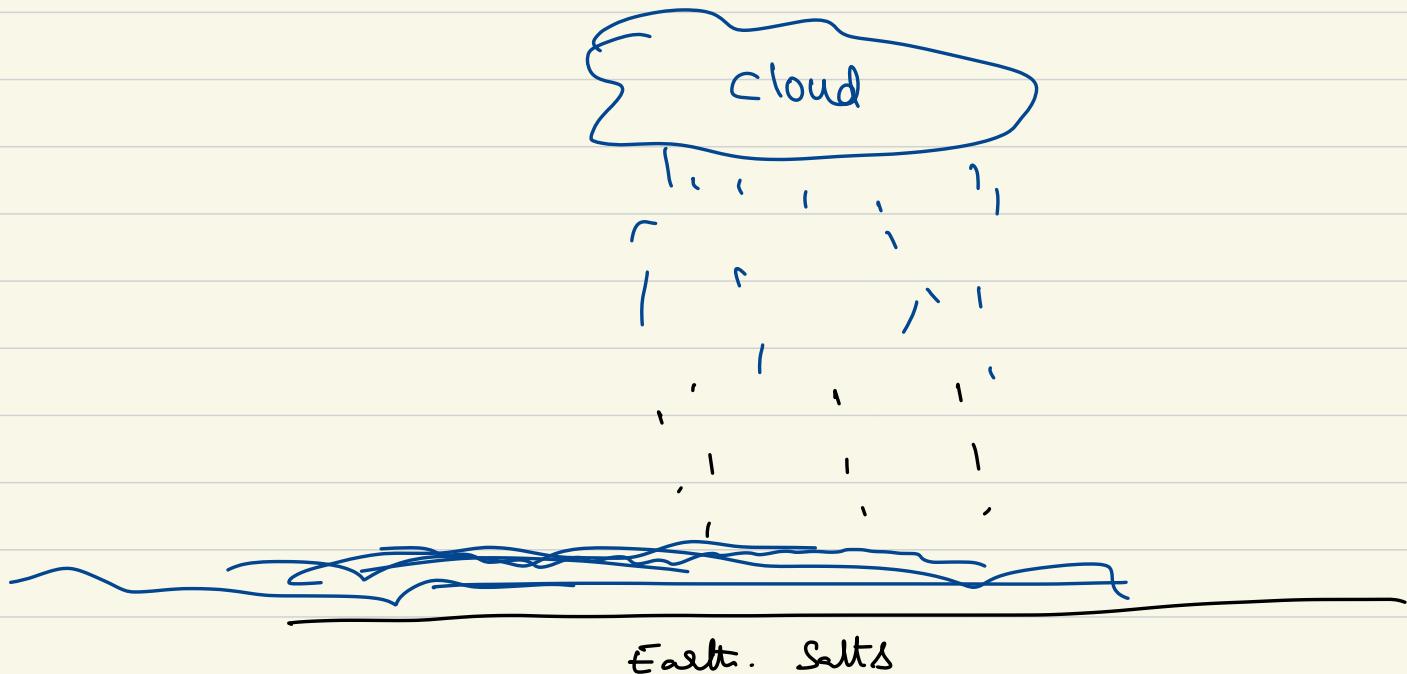
Compounds of Hydrogen:-

Hard water:- The water which does not produce good lather readily with soap.

Soft water:- The water which produce good lather readily with soap.

* This water is free from soluble salts of Ca & Mg. due to this it produce good lather with soap.

Ex:- Distilled water, Rain water

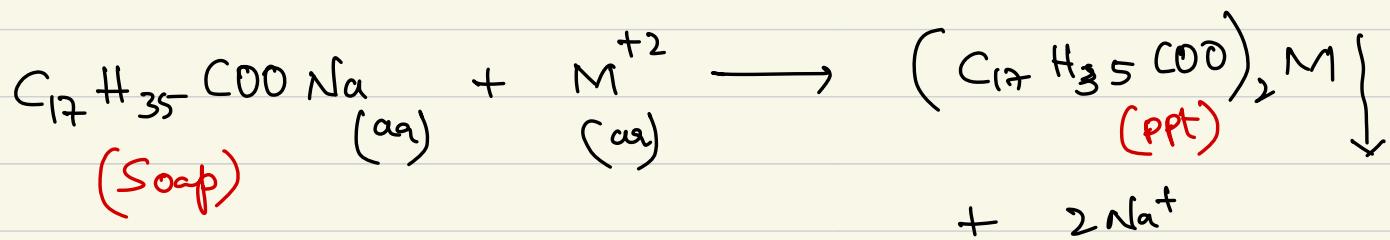


Cause of Hardness to Water:- The hardness of water is due to presence of soluble salts of Ca & Mg

Ex:- $\text{Ca}(\text{HCO}_3)_2$ CaCl_2 CaSO_4
 $\text{Mg}(\text{HCO}_3)_2$ MgCl_2 MgSO_4

(e) What are the effects of Hard water?

Ans.: ① Hard water form scum / ppt with soap.



$$\left[M^{+2} = Ca^{+2} / Mg^{+2} \right]$$

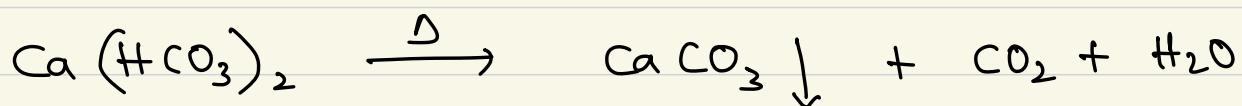
② It is harmful for boilers because of deposition of salts in the form of scales. This reduces efficiency of boilers.

Types of hardness:

(a) Temporary hardness:- It is due to the presence of soluble bicarbonates of Ca & Mg in water
[i.e., $Ca(HCO_3)_2$ & $Mg(HCO_3)_2$]

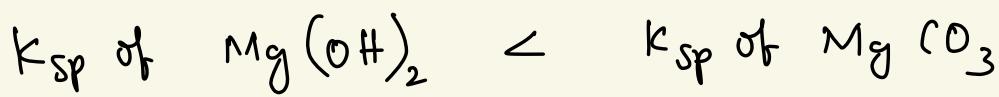
* This temporary hardness is removed by

(i) Boiling:

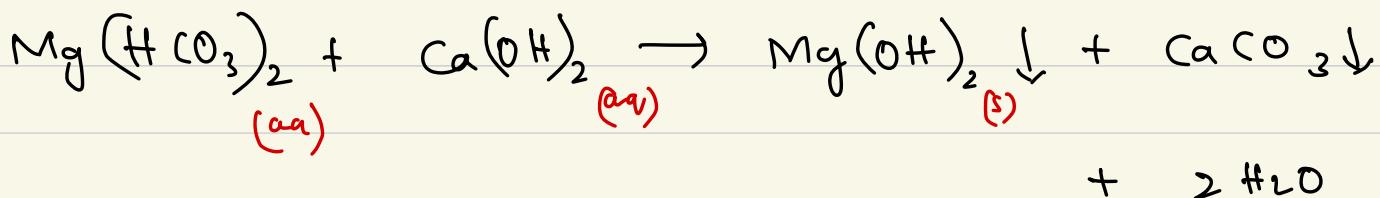
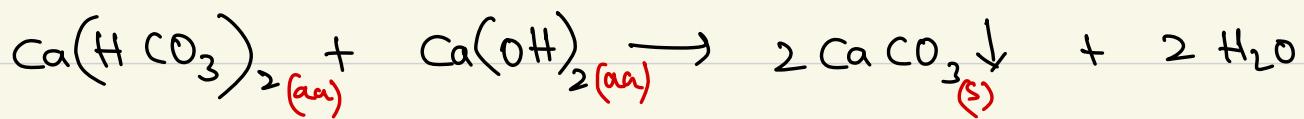


NOTE: K_{sp} of $Mg(OH)_2 = 18 \times 10^{-11}$

K_{sp} of $MgCO_3 = 3.5 \times 10^{-8}$



(ii) Clark's method (Treatment with lime) Ca(OH)_2

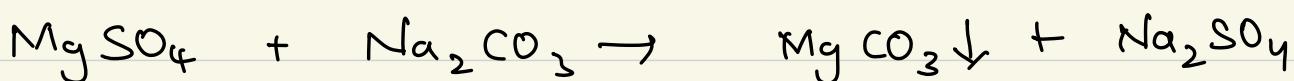
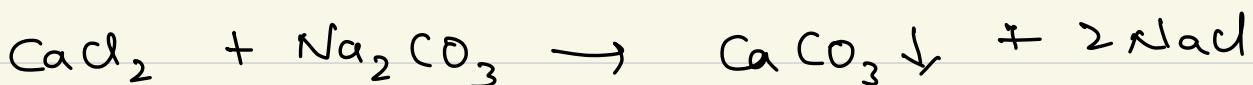


(b) Permanent Hardness:-

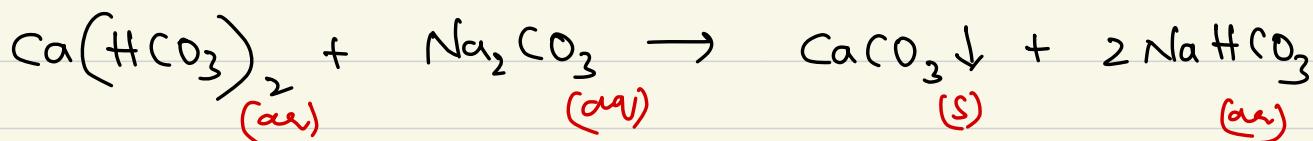
This is caused due to presence of soluble CaCl_2 , CaSO_4 , MgCl_2 , MgSO_4 which can not be removed by simple boiling.

This permanent hardness is removed by

(i) Treatment with Washing soda:- (Na_2CO_3)

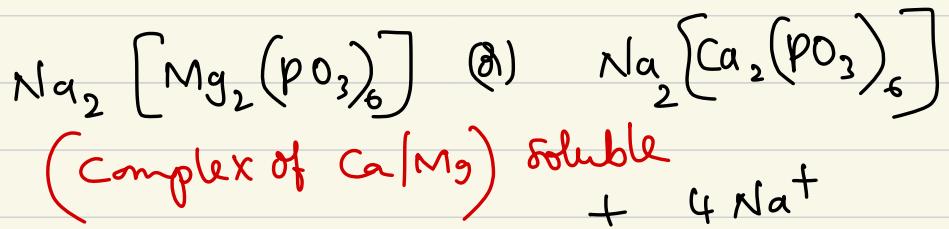
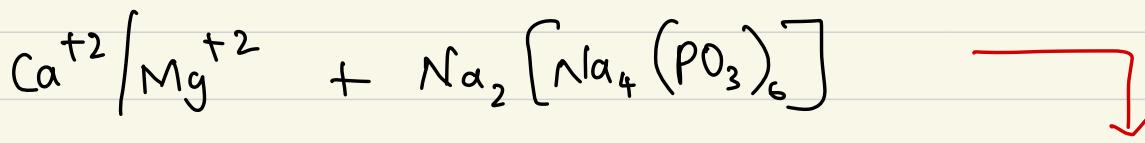
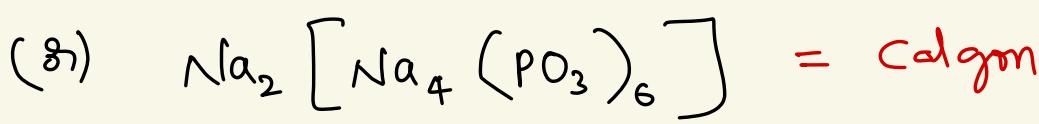


* This method is also used for removal of temporary hardness.



(ii) Calgon method:-

Calgon is a commercial name of Sodium hexametaphosphate. $\text{Na}_6\text{P}_6\text{O}_{18}$ (8) $(\text{NaPO}_3)_6$

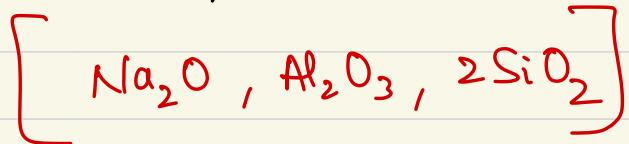
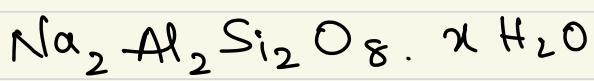


* This complex do not form any ppt with soap

(iii) Ion-Exchange method:- (Permutit method)

This method is called Zeolite / permuntit method.

Permutit is an artificial Zeolite.,



(81)

$\text{Na Al Si O}_4 \cdot x \text{H}_2\text{O}$. = Sodiumaluminium
orthosilicate

(81)

Na Z ($Z = \text{Al Si O}_4 \cdot x \text{H}_2\text{O}$)



$$M^{+2} = \text{Ca}^{+2} / \text{Mg}^{+2}$$

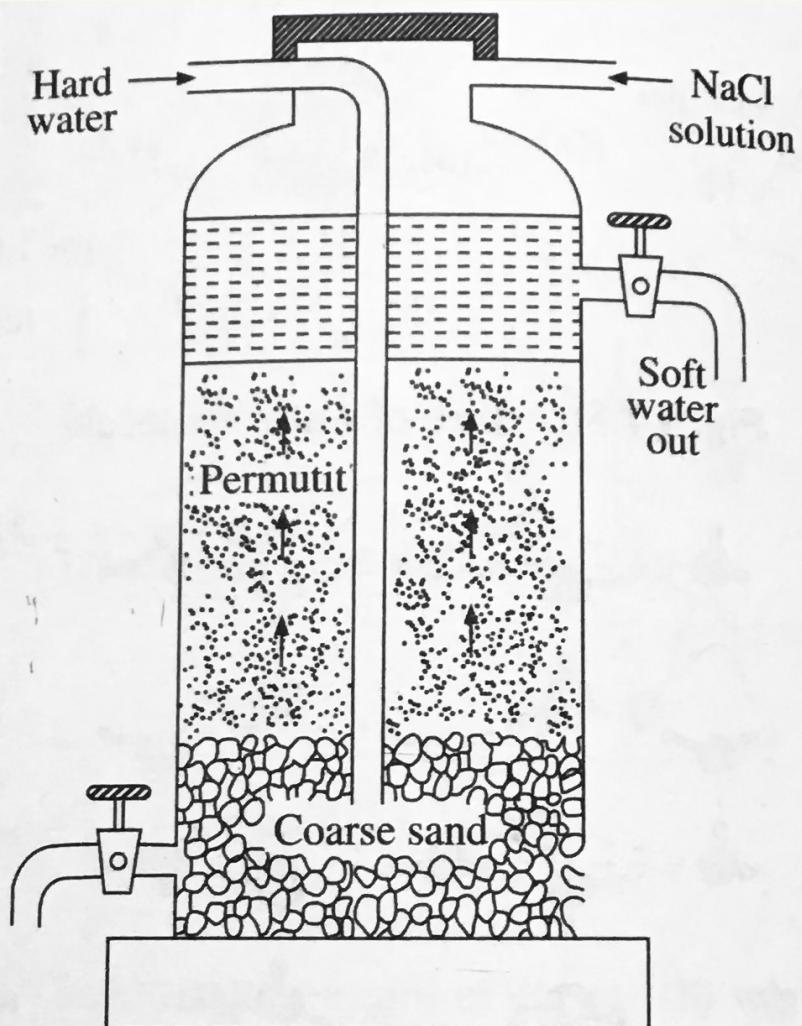
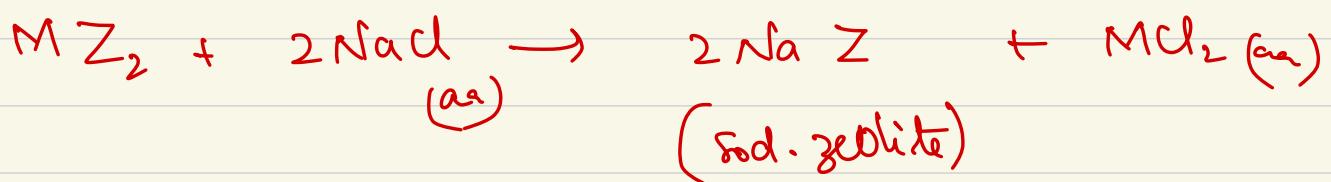
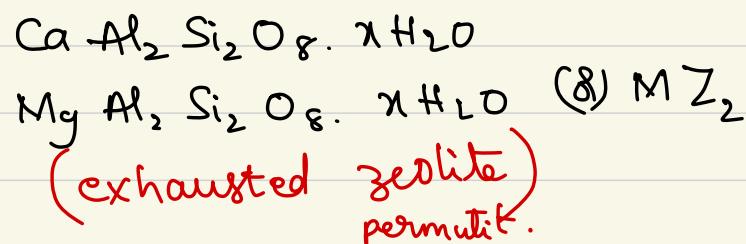


Fig. 4.9 Permutit process for softening of hard water

Regeneration of permuntit :-

As the reaction proceeds, Zeolite gets exhausted because whole of sodium zeolite gets converted to Ca/Mg zeolite



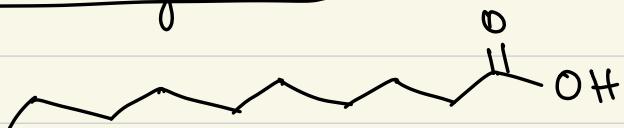
(iv) Synthetic Resin exchange method:-

This is also called as organic ion exchange method. most superior method to permuntit method.

In this method,

Cation exchange Resin :-

It removes Ca^{+2} , Mg^{+2}



Anion exchange Resin :-

It removes anions (Cl^- , SO_4^{2-} , ...)

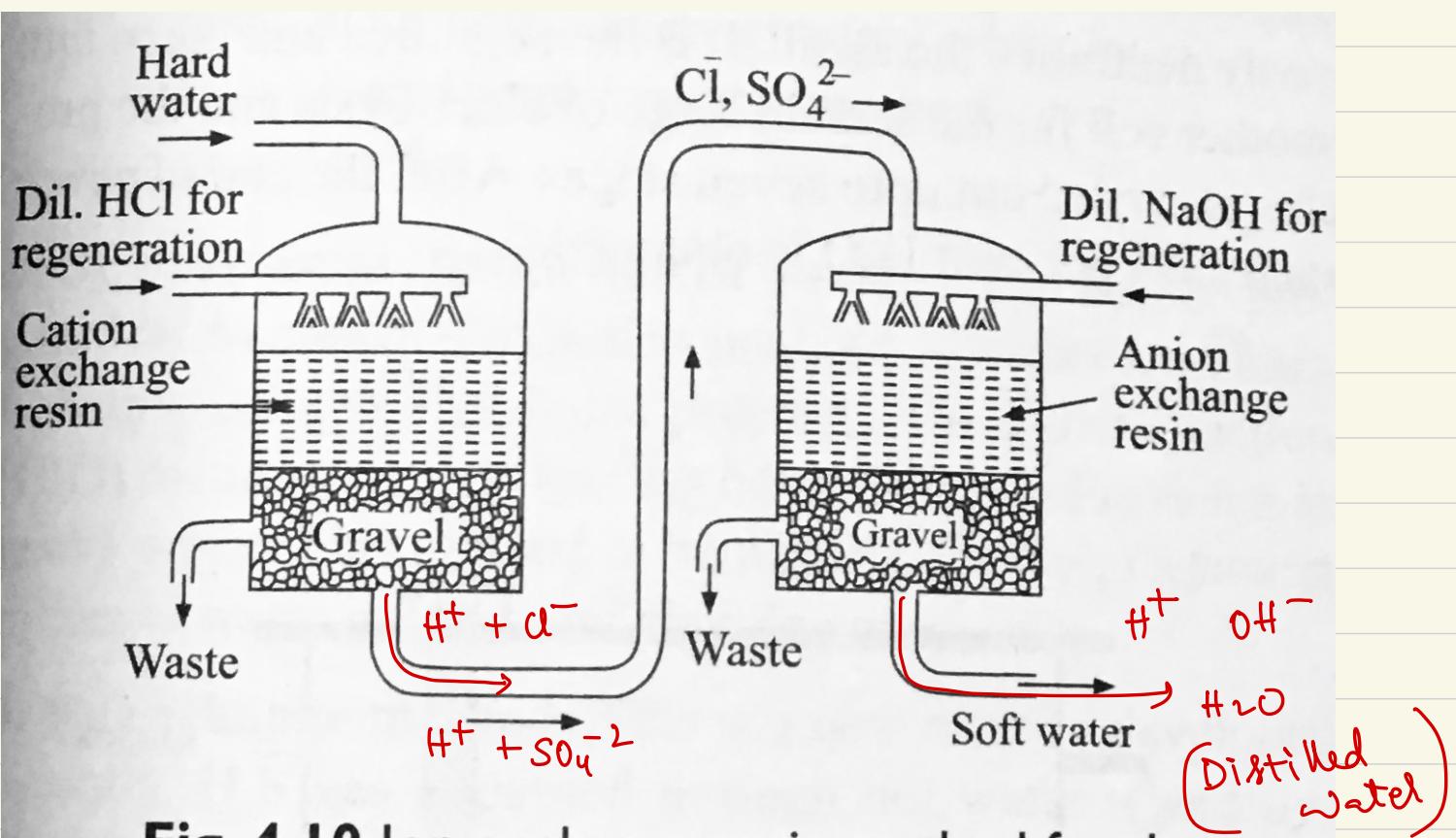
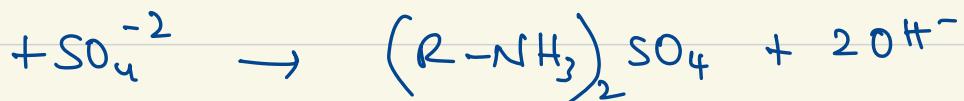
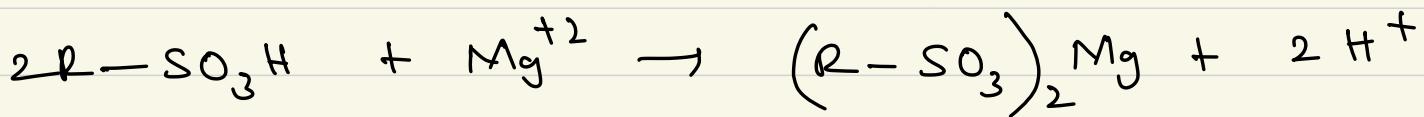
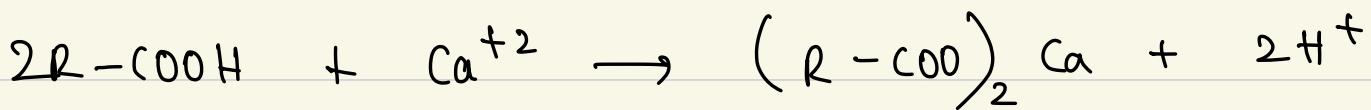
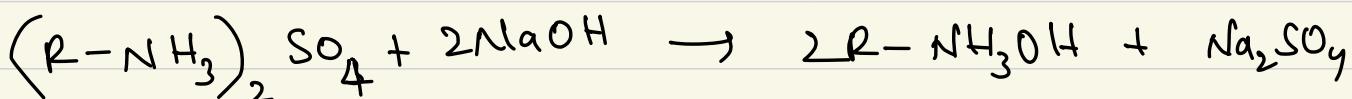
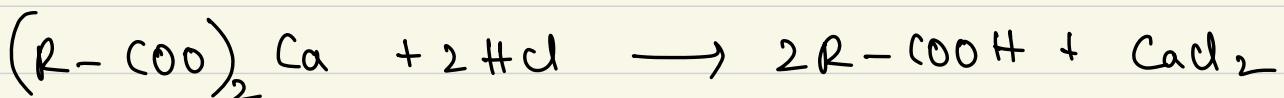


Fig. 4.10 Ion exchange resin method for the removal of hardness of water



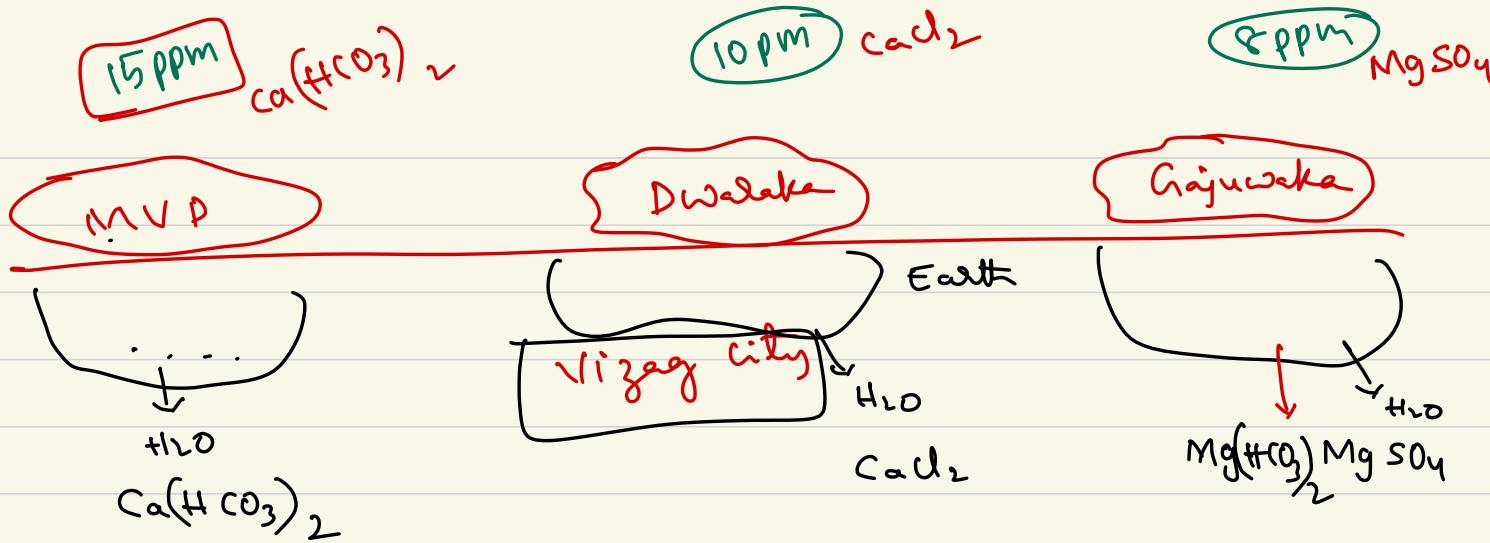
cation anion
exchange exchange
resin resin

Regeneration of Resins:-



Degree of Hardness: It is defined as number of parts by weight of CaCO_3 [(g)] equivalent to various calcium & magnesium salts present in 10^6 parts by mass of water

It is expressed in ppm



$$\text{Ca}(\text{HCO}_3)_2 \quad \frac{\text{M.Wt}}{162} \quad \frac{n_f}{2} \quad \frac{\text{Eq. wt}}{81} = \frac{\text{M.Wt}}{n_f}$$

$$\text{Mg}(\text{HCO}_3)_2 \quad 146 \quad 2 \quad 73$$

$$\text{CaSO}_4 \quad 136 \quad 2 \quad 68$$

$$\text{MgSO}_4 \quad 120 \quad 2 \quad 60$$

$$\text{CaCl}_2 \quad 111 \quad 2 \quad \frac{111}{2} = 55.5$$

$$\text{MgCl}_2 \quad 95 \quad 2 \quad \frac{95}{2} = 47.5$$

$$\text{CaCO}_3 \quad 100 \quad 2 \quad 50$$

$$100 \text{ g of } \text{CaCO}_3 \equiv 162 \text{ g of } \text{Ca}(\text{HCO}_3)_2$$

$$\equiv 146 \text{ g of } \text{Mg}(\text{HCO}_3)_2$$

$$\equiv 136 \text{ g of } \text{CaSO}_4$$

$$\equiv 120 \text{ g of } \text{MgSO}_4$$

$$\equiv 111 \text{ g of } \text{CaCl}_2$$

$$\equiv 95 \text{ g of } \text{MgCl}_2$$

Ex: If 10^3 g of substance $\rightarrow 10^6$ g of water.

$$D.H = 10^3 \text{ ppm}$$

Ex: If 3 g of substance $\rightarrow 10^6$ g of water

$$D.H = 3 \text{ ppm}$$

Ex: 162 g of $\text{Ca}(\text{HCO}_3)_2$ $\rightarrow 10^6$ g of water

$$D.H = 100 \text{ ppm}$$

(a) A sample of hard water contain 6g MgSO_4 per 100 kg of water then calculate degree of hardness

Sol: method-1

$$120 \text{ g of } \text{MgSO}_4 \equiv 100 \text{ g of } \text{CaCO}_3$$

$$6 \text{ g of } \text{MgSO}_4 \equiv \frac{100 \times 6}{120} = 5 \text{ g of } \text{CaCO}_3$$

$$\Rightarrow 5 \text{ g of } \text{CaCO}_3 \rightarrow 100 \text{ kg of water}$$

$$5 \text{ g of } \text{CaCO}_3 \rightarrow 10^5 \text{ g of water}$$

$$x \text{ g of } \text{CaCO}_3 \rightarrow 10^6 \text{ g of water}$$

$$x = \frac{5 \times 10^6}{10^5} = 50 \text{ ppm}$$

$$\therefore D.H = 50 \text{ ppm}$$

method-2

$$D.H = n_{\text{salt}} \times \frac{10^8}{W_{H_2O}(\text{g})} = \frac{W_{\text{salt}}}{g.m.W_{\text{salt}}} \times \frac{10^8}{W_{H_2O}(\text{g})}$$

$$= \frac{6}{120} \times \frac{10^8}{10^5} = \frac{1}{20} \times \frac{10^3}{1} = \frac{100}{2} = 50 \text{ ppm}$$

(a) A sample of hard water contains 12 g of $MgSO_4$ and 11.1 g of $CaCl_2$ in 100 kg of water. What is the total hardness of water.

Sol: method-1
 $MgSO_4$

$$120 \text{ g of } MgSO_4 \equiv 100 \text{ g of } CaCO_3$$

$$12 \text{ g of } MgSO_4 \equiv 10 \text{ g of } CaCO_3$$

$$111 \text{ g of } CaCl_2 \equiv 10 \text{ g of } CaCO_3$$

$$11.1 \text{ g of } CaCl_2 \equiv 10 \text{ g of } CaCO_3$$

$$20 \text{ g of } CaCO_3 \longrightarrow 100 \times 10^3 \text{ g of } H_2O$$

$$x \text{ g of } CaCO_3 \xrightarrow{\times} 10^6 \text{ g of } H_2O$$

$$x = \frac{20 \times 10^8}{10^8} \times 10 = 200 \text{ ppm}$$

method-2

$$D.H = \left(\frac{W_{\text{salt}}}{m.W_{\text{salt}}} \times \frac{10^8}{W_{H_2O}(\text{g})} \right)_{MgSO_4} + \left(\frac{W_{\text{salt}}}{m.W_{\text{salt}}} \times \frac{10^8}{W_{H_2O}(\text{g})} \right)_{CaCl_2}$$

$$= \frac{12}{120} \times \frac{10^8}{10^5} + \frac{11.1}{111} \times \frac{10^8}{10^5}$$

$$= \frac{1}{10} \times 10^3 + \frac{1}{10} \times 10^3$$

$$= 100 + 100 = 200 \text{ ppm.}$$

(e) 10 ml of standard soap solution ($1\text{ml} = 0.001\text{g}$ of CaCO_3) was required in titrating 50 ml of a sample of hard water to produce good lather. Calculate the degree of hardness. [$d_{H_2O} = 1\text{g/cc}$]

Sol: 1 ml of Soap $\equiv 0.001\text{g}$ of CaCO_3

$$\begin{array}{c} 50\text{ml} \\ = 50\text{g} \end{array}$$

$$\begin{aligned} 10\text{ml of Soap} &\equiv 0.001 \times 10\text{ g of } \text{CaCO}_3 \\ &= 0.01\text{ g of } \text{CaCO}_3 \end{aligned}$$

$$D.H = \frac{WT}{g.m.Wt} \times \frac{10^8}{W_{H_2O}(\text{g})}$$

$$\begin{array}{l} 0.01\text{g} \rightarrow 50\text{g} \\ \times \rightarrow 10^6\text{g} \end{array}$$

$$\begin{aligned} n &= \frac{0.01 \times 10^6}{50} \\ &= 200\text{ ppm} \end{aligned}$$

$$\begin{aligned} &= \frac{0.01}{100} \times \frac{10^8}{50} = \frac{1}{100 \times 100} \times \frac{10^8}{50} \\ &= \frac{1}{10^4} \times \frac{10^8}{50} = \frac{10^4}{50} = \frac{10^3}{5} = 200\text{ ppm}. \end{aligned}$$

(e) A MgCl_2 aq. solution is 10^{-3} molar. Degree of hardness is. [Ans: 100 ppm]

(e) Hardness of water sample is 150 ppm. It's hardness is due to $\text{Ca}(\text{HCO}_3)_2$. The weight of Ca(OH)_2 that required to remove hardness of 1L of hard water. [Ans: 111 mg.]

NOTE: 100 - 150 ppm of hardness is tolerable.

Water: A major part of living organisms is made up of water.

Source:- Oceans - 97.33%

Some plants - 95 yr.

Human body - 65%

ground water - 0.61%.

polar ice - 2.04%

physical properties :-

- ① It is colourless, odourless & tasteless liquid.
 - ② unusual properties of Water in liq & solid state are due to presence of extensive H - bonding.



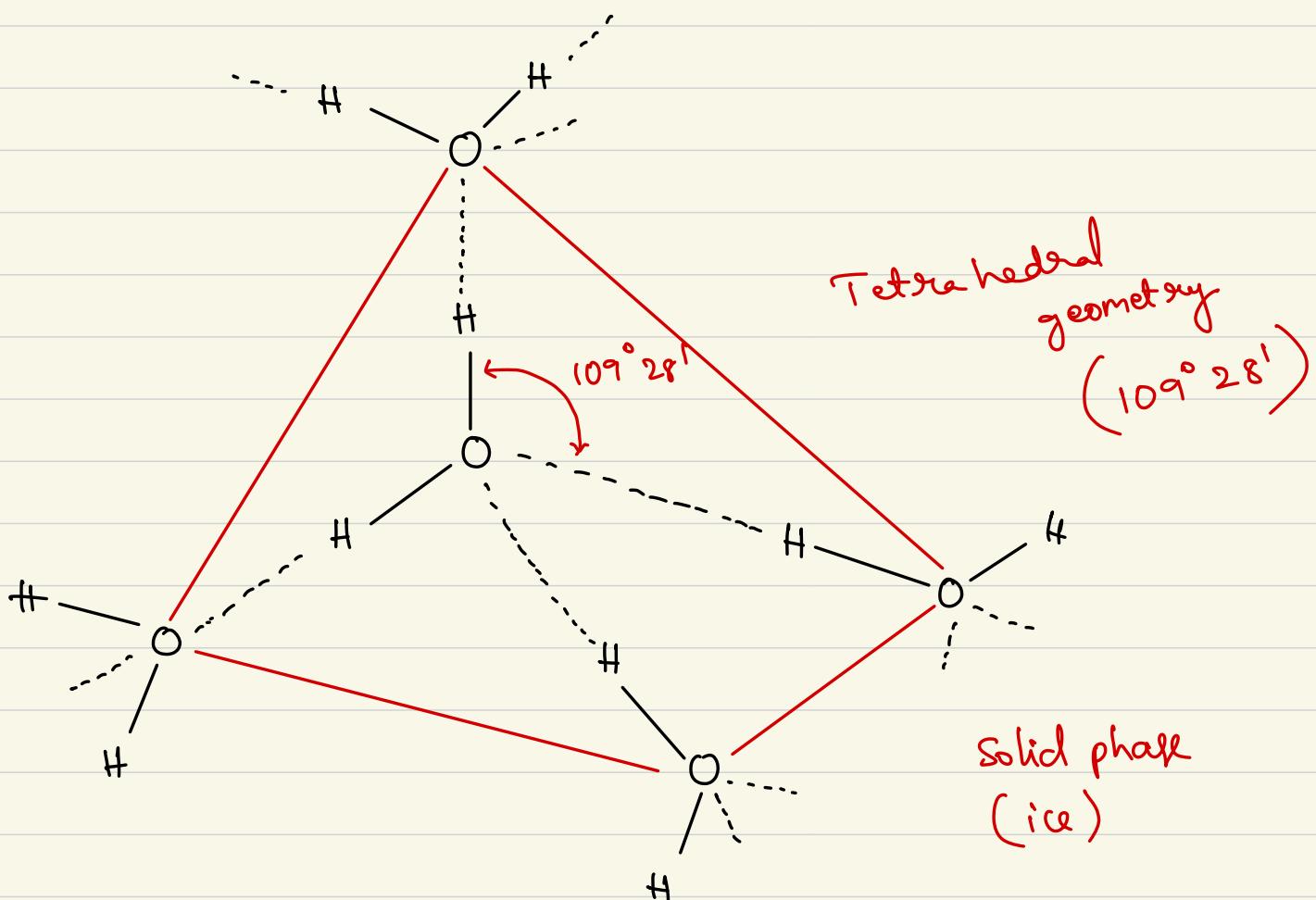
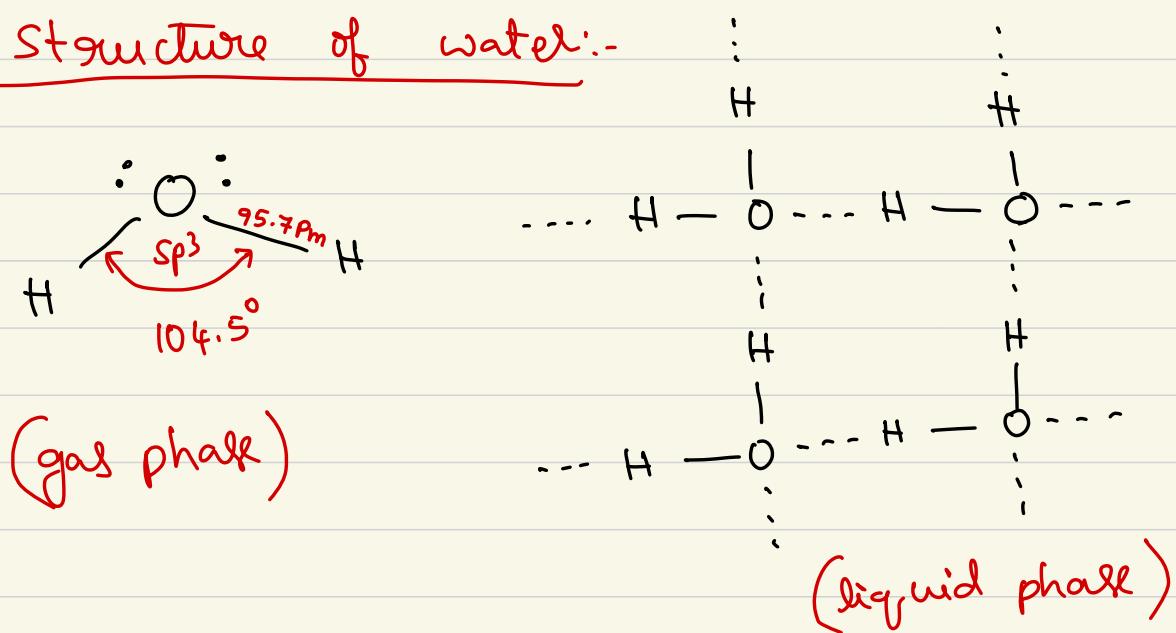
- ③ Due to H-bonding, it has high F.P, B.P
ε high heat of vapourisation (540 cal/g)
ε high heat of fusion (80 cal/g) in comparison
to H_2S and H_2Se

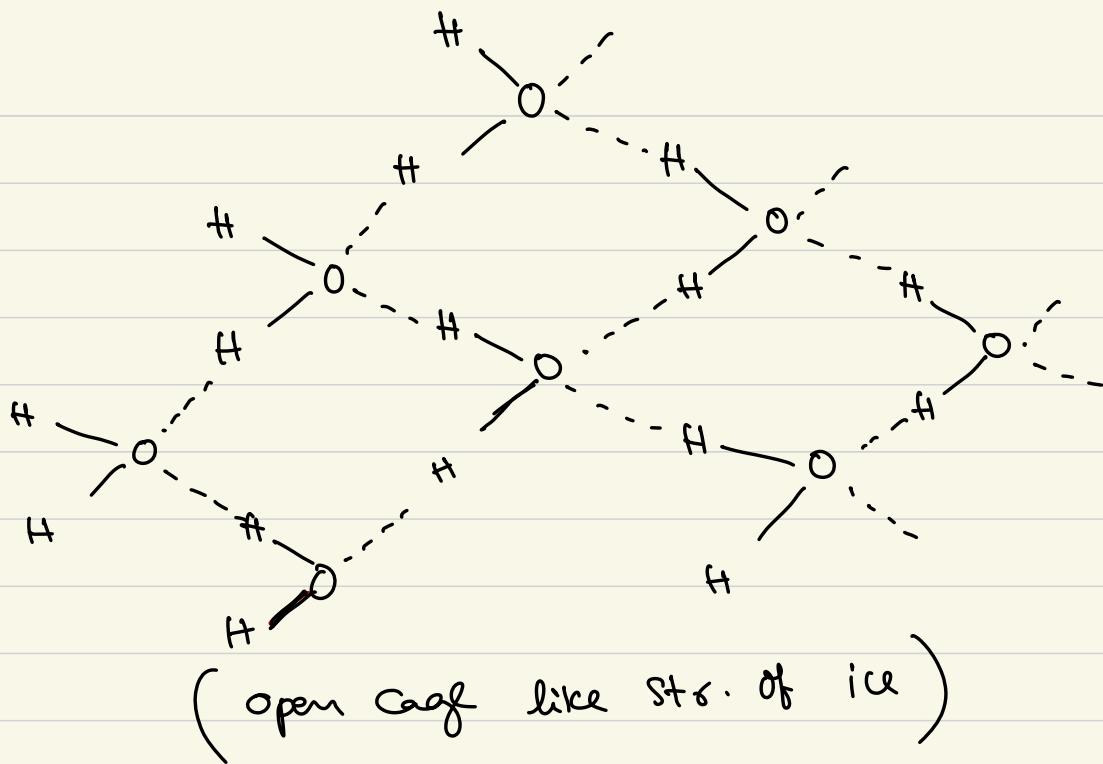
④ The high heat of Vapourisation & heat capacity
are responsible for moderation of the climate &
body temp of living organisms.

⑤ It is a universal solvent. It is useful
for transportation of ions & molecules required
for plant and animal metabolism.

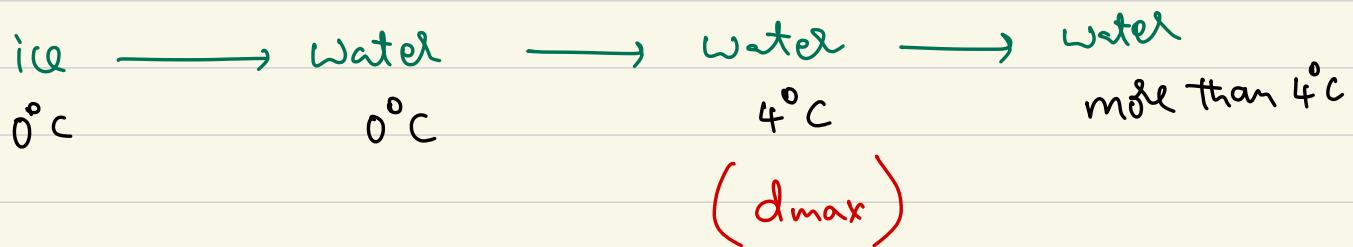
⑥ Some covalent compounds like alcohols, carbohydrates dissolve in water due to H-bond.

Structure of water:-



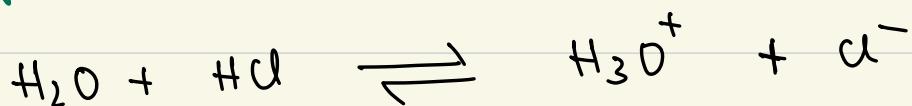


* Due to this open cage like structure, it has vacant spaces which pack less no. of water molecules per ml. So density of ice is less than water.

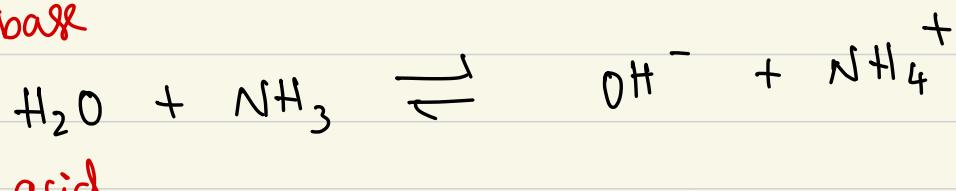


Chemical properties:-

① Amphoteric nature : Based on Brønsted-Lowry.

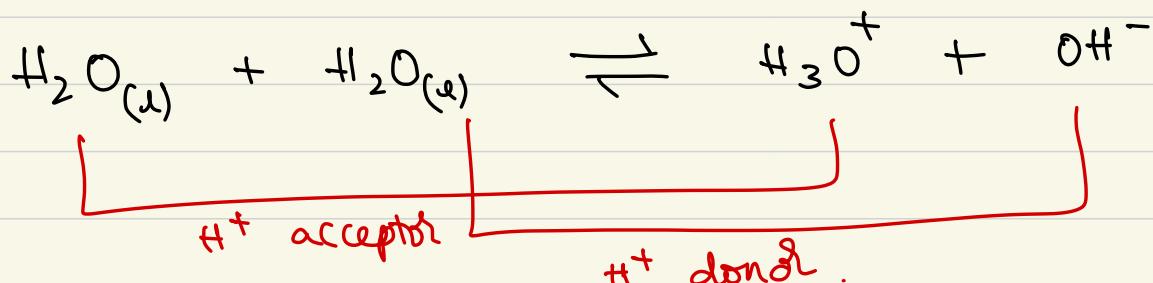


barr



acid

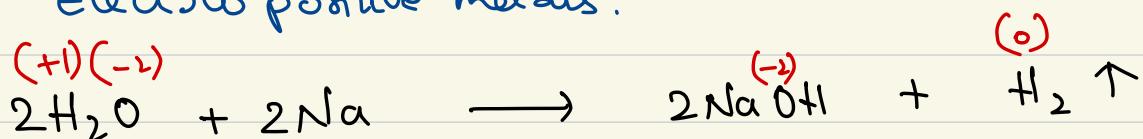
② Autoprotolysis: Self ionisation.



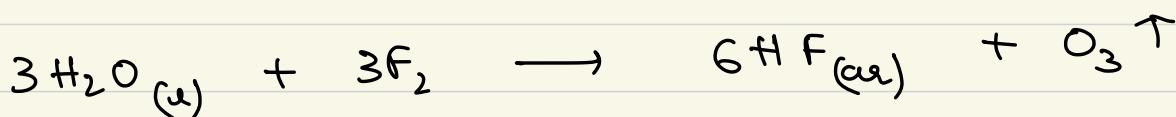
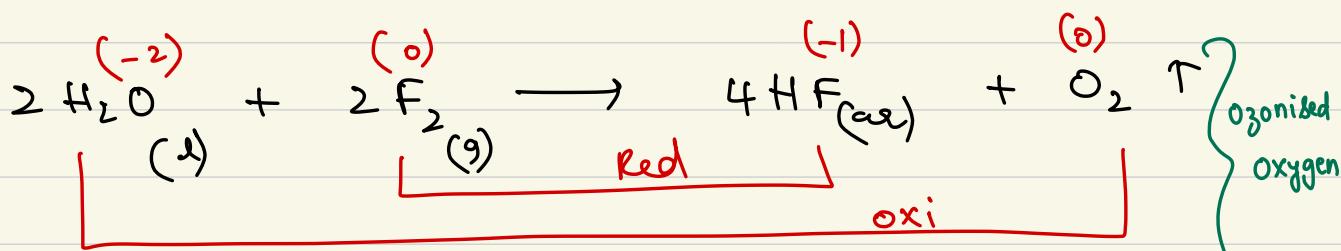
\therefore Water is neutral towards litmus $\boxed{\rho\text{H} = 7}$

③ Redox reactions:-

It can be easily reduced to H_2 with highly Electro positive metals.

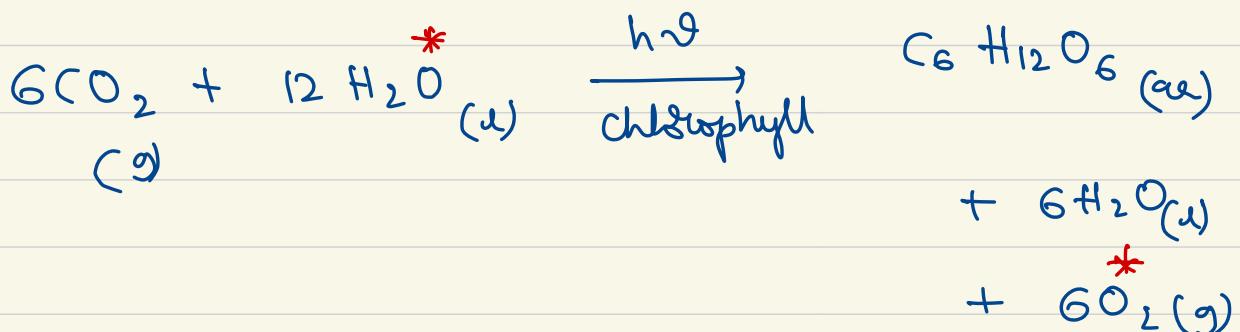


with F_2 , it is oxidised to O_2

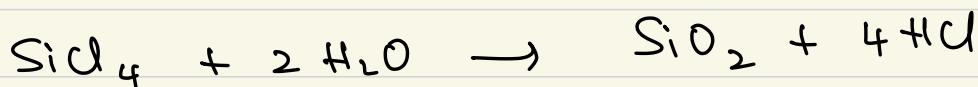


④ photosynthesis:-

water is oxidised to O_2 during this reaction



(5) Hydrolysis reactions:-

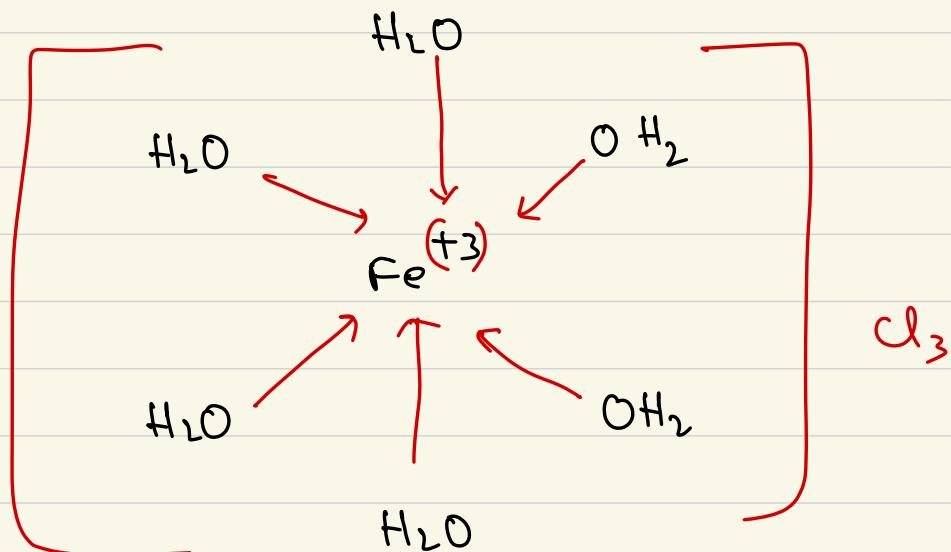
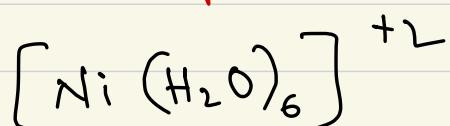
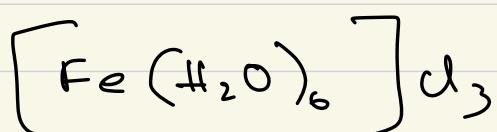
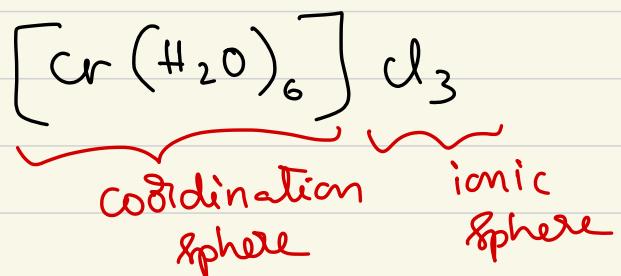


(6) Hydrate formation:-

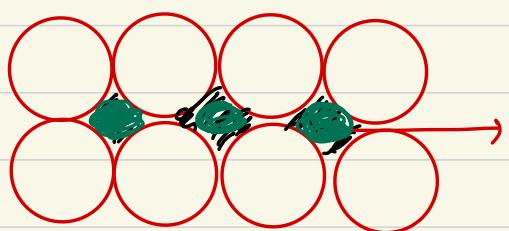
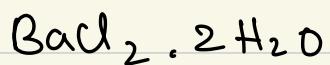
Salt (powder)

$\xrightarrow[H_2O]{\text{evaporated}}$ Salt (crystalline)

(i) Coordinated water:-

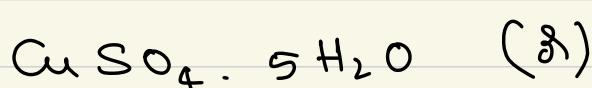


(ii) Interstitial water:-

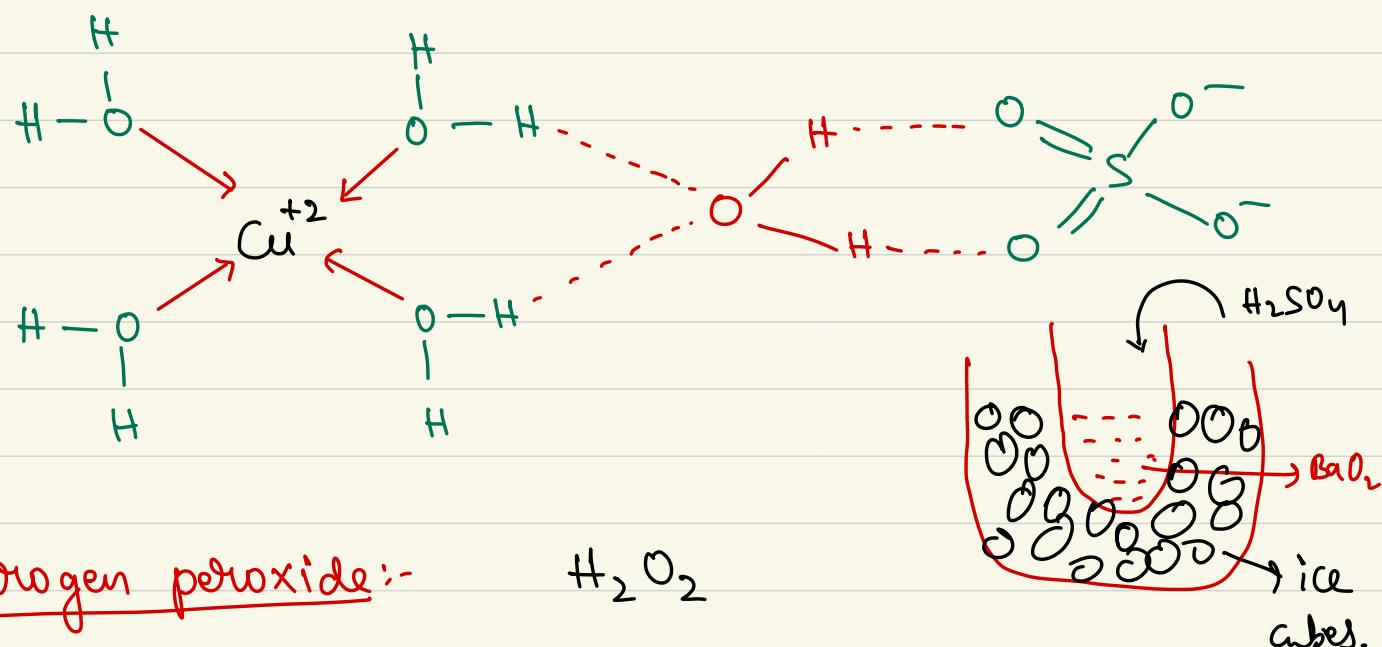
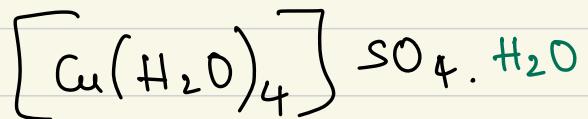


Interstitial site

(iii) Hydrogen bonded water:-



(g)

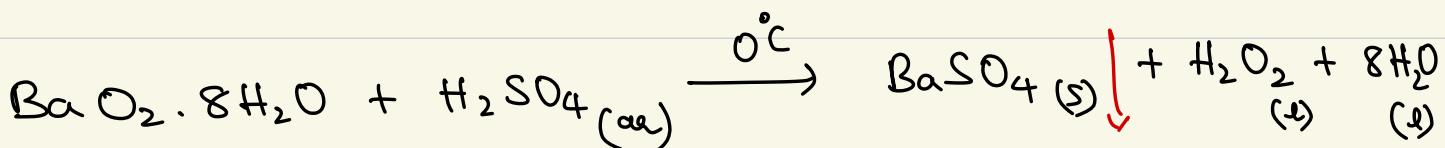


It is an important chemical used in pollution control treatment.

* It was discovered by L.J. Thengard
preparation:

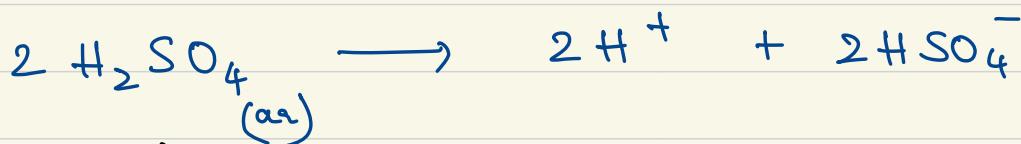
① Lab method:-

By the action of H_2SO_4 on hydrated BaO_2 (Barium peroxide)



- * BaO_2 is made into thin paste in ice cold water
 - * after filtration; BaSO_4 removed as residue
 - * The rate of reaction is low with anhy. BaO_2

② Electrolysis:- Electrolytic oxidation of acidified Sulphate solution (SO_4^{2-}) (50%) at high current density gives peroxodisulphate which on further hydrolysis, gives H_2O_2



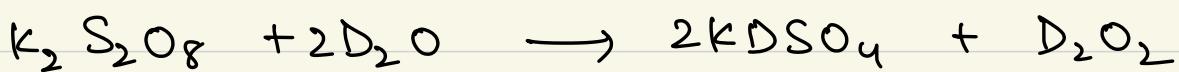
anode: (oxi) (LeO)



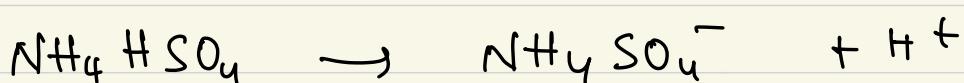
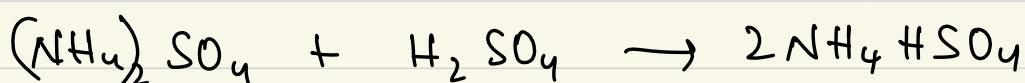
Cathode : (Red) (Get)



D_2O_2 can also be prepared by this method.
by using $K_2S_2O_8$ & D_2O (K_2SO_4)



* In modern methods, equimolar mix of H_2SO_4 + $(\text{N}^{+4})_2\text{SO}_4$



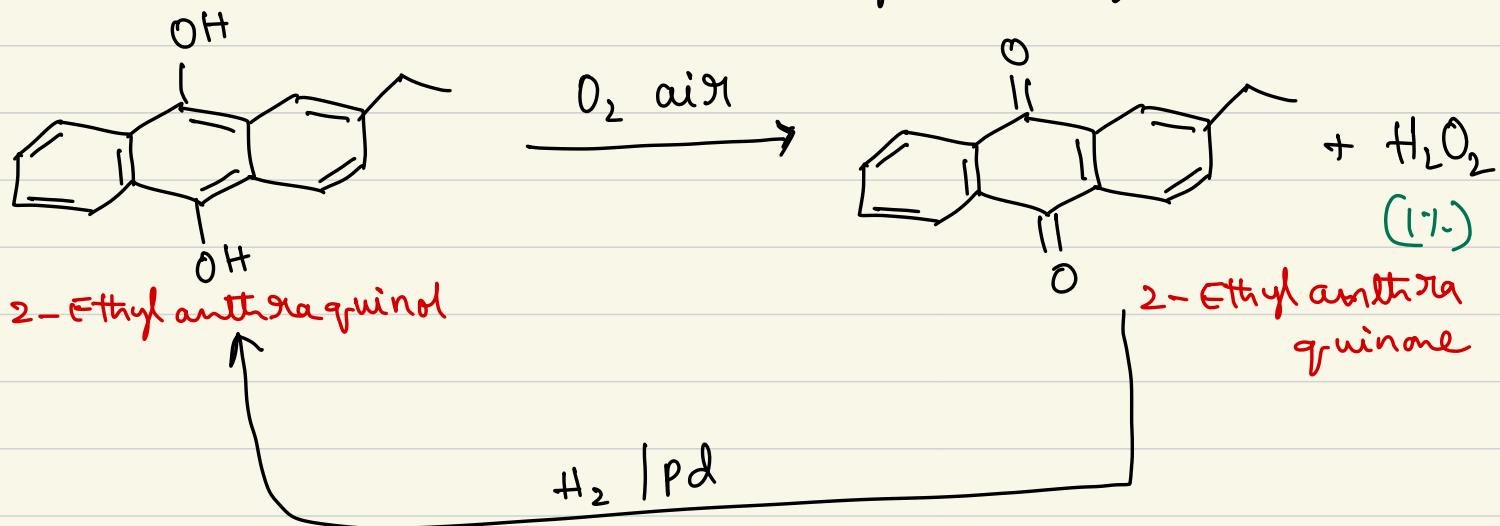
anode: $2 \text{NH}_4^+ \text{SO}_4^- \longrightarrow (\text{NH}_4)_2 \text{S}_2\text{O}_8 + 2e^-$

$\downarrow \text{H}_2\text{O}$

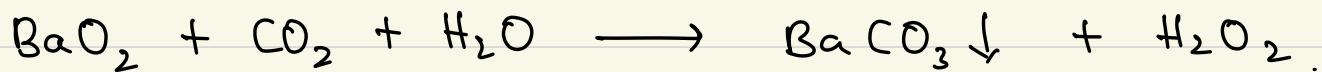
$(\text{NH}_4)_2 \text{SO}_4 + \text{H}_2\text{O}_2$



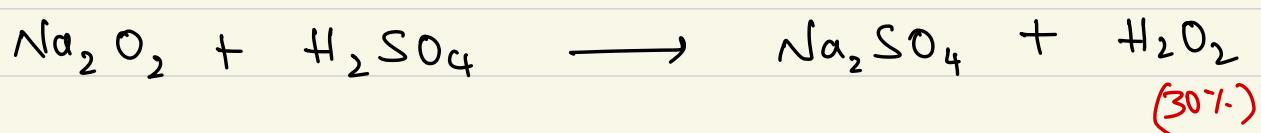
③ Industrial method:- By Auto oxidation of
2-Ethylanthraquinol



④ Merck's process:- By passing current of CO₂ through cold partly solution of BaO₂



H₂O₂ is prepared by adding small amount of Na₂O₂ to ice cold water, add dil H₂SO₄ (20%)



Concentration of H₂O₂:

The H₂O₂ obtained by above process is about 1% H₂O₂ (in aq. sol.)

↓ evaporation on water bath

30% H₂O₂

↓ dehydration in vacuum desicator

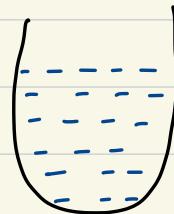
90% H_2O_2

↓ distillation under reduced pressure

99% pure H_2O_2

↓ Fraction crystallization.

100% pure needle like crystals of
 H_2O_2 obtained.



physical prop:

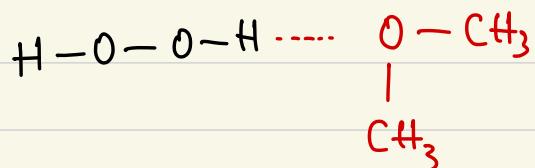
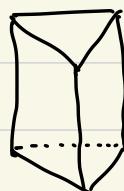
① pure H_2O_2 is a syrupy liquid. It is colourless but given bluish tinge in thick layer.

② It is soluble in water, ether & alcohol in all proportions.

* with water; H_2O_2 form a hydrate $H_2O_2 \cdot H_2O^{(s)}$
(m.p. = 221K)

③ It is more viscous than water due to π -bond

④ It forms prismatic crystal at $-2^{\circ}C$



(5) A 30% (w/v) sol. of H_2O_2 is marked as "100 Volumes" of H_2O_2

$$(\text{w/v}) \times = \frac{17}{56} \times \text{Volume Strength}$$

$$M = \frac{\text{Volume Strength}}{11.2}$$

$$N = n_f M = 2 \times M = 2 \times \frac{\text{Volume Strength}}{11.2}$$

$$N = \frac{\text{Volume Strength}}{5.6}$$

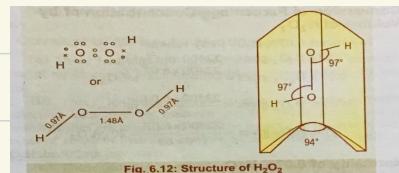
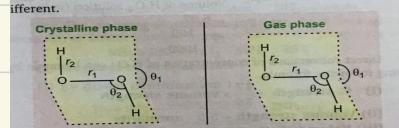
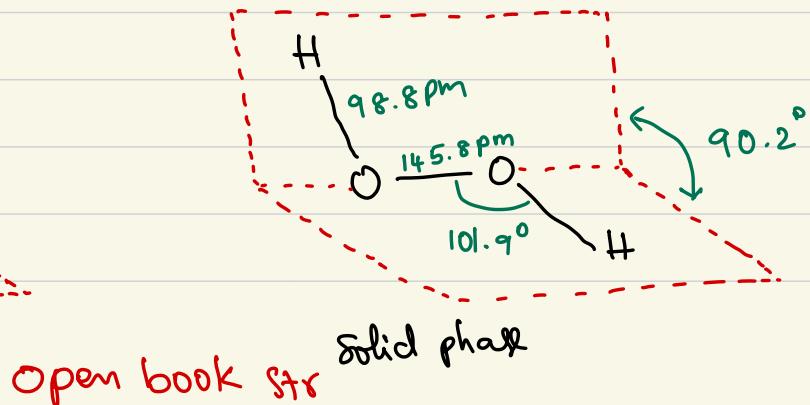
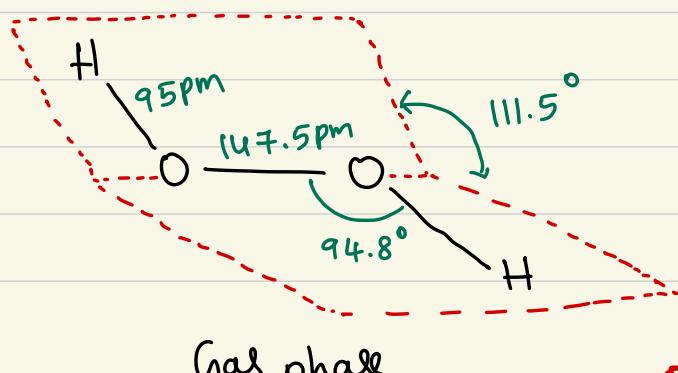
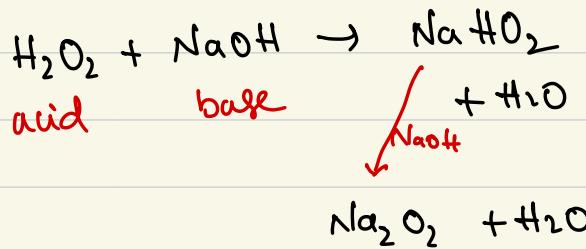
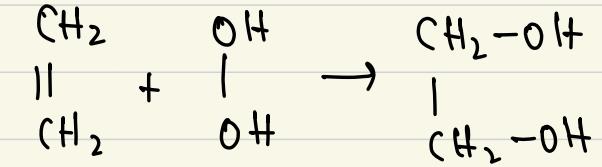
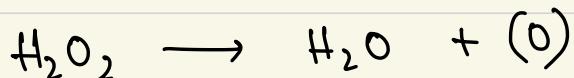
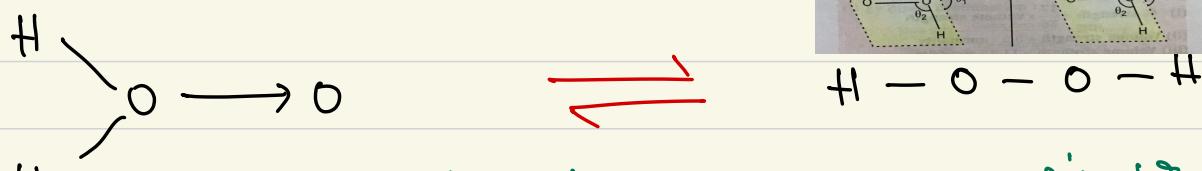


Fig. 6.12: Structure of H_2O_2
Structure of H_2O_2 is different in crystalline as well as in vapour state.
The two structures are compared below.



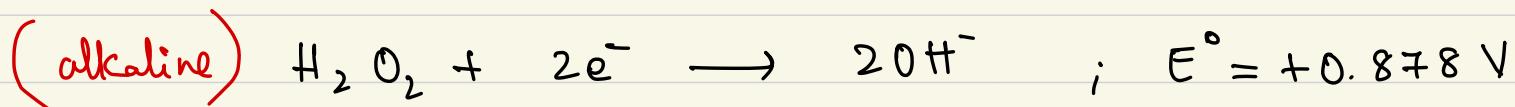
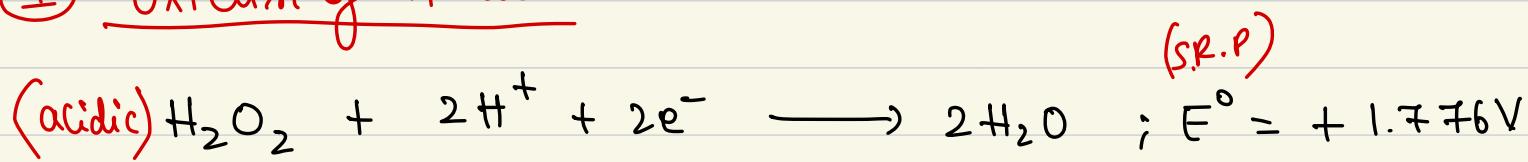
Structure of H_2O_2 :



Chemical prop:-

H_2O_2 acts as an oxidising and reducing agent in both acidic & alkaline media.

(I) Oxidising nature :-

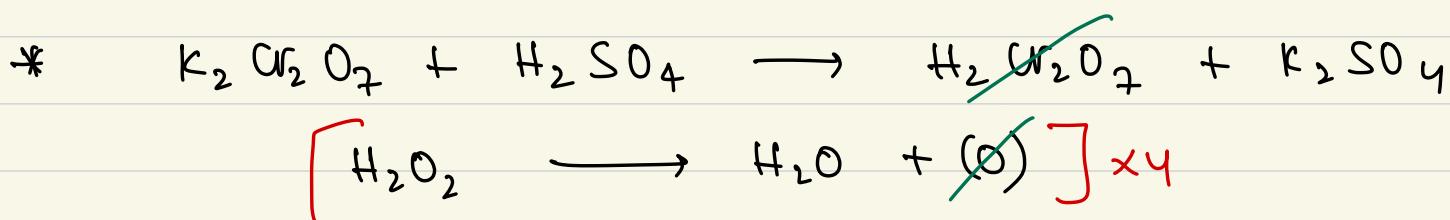
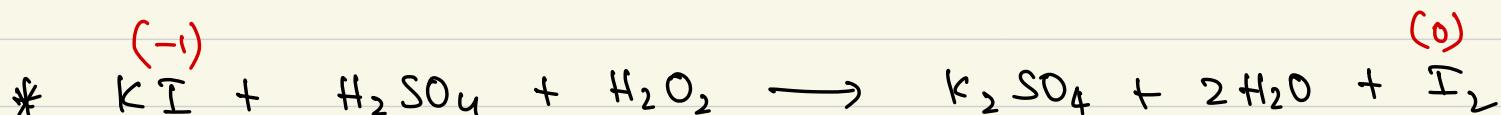
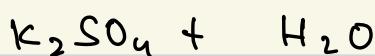
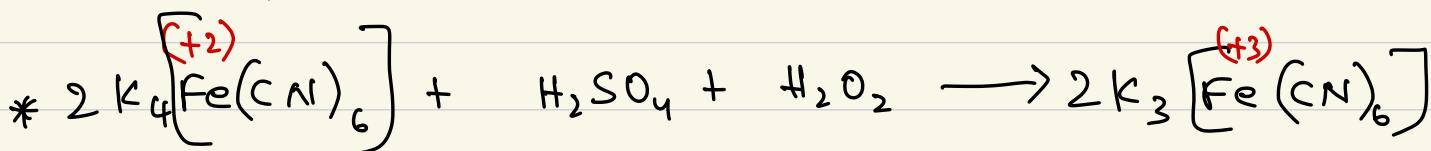
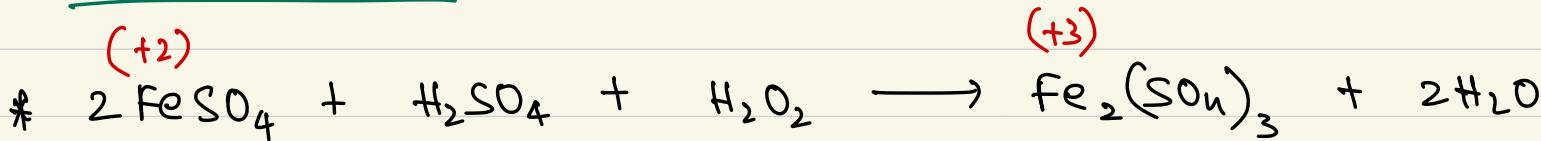


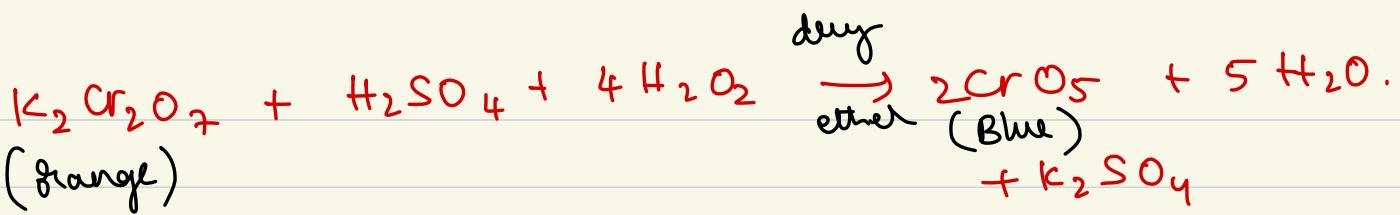
Standard reduction potential values (SRP)

of oxidising nature

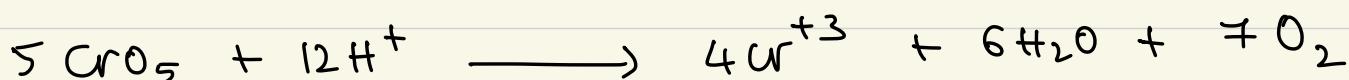
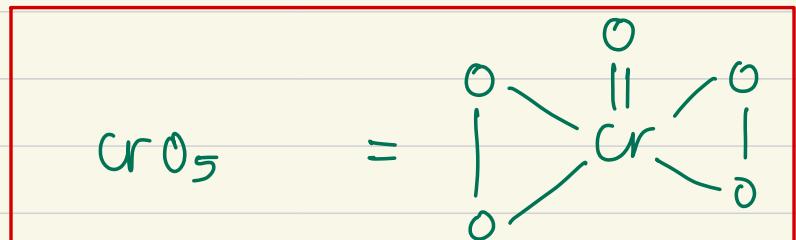
$\therefore \text{H}_2\text{O}_2$ acts as strong O.A in acidic medium but it is kinetically slower than in basic medium.

acidic medium:-

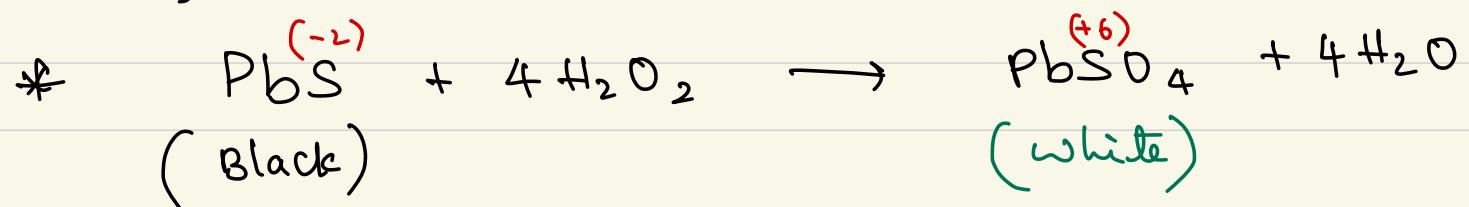
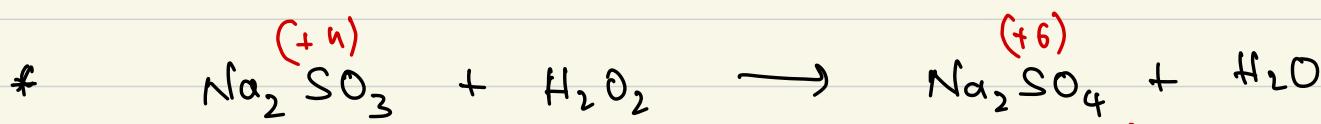
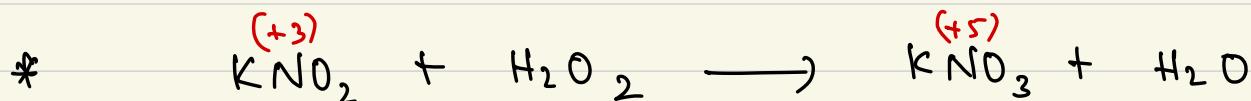
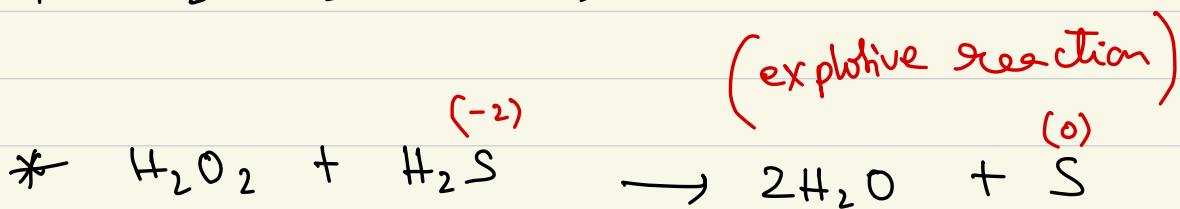
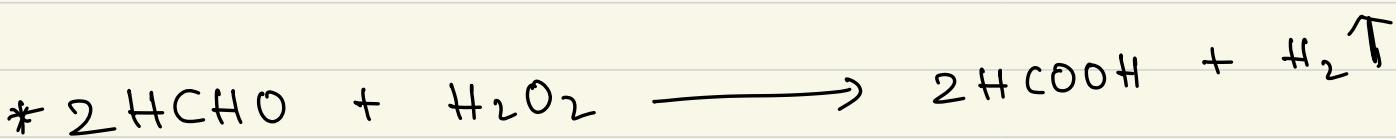




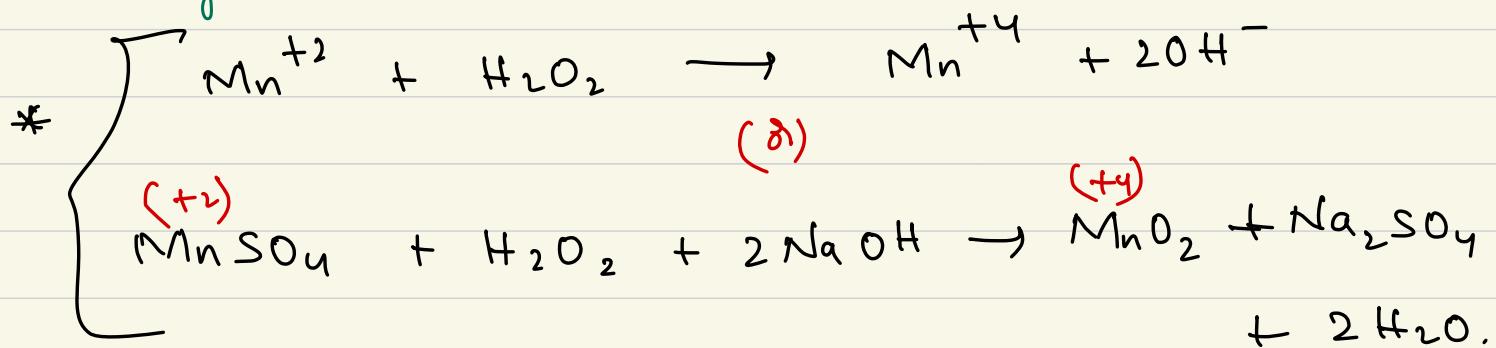
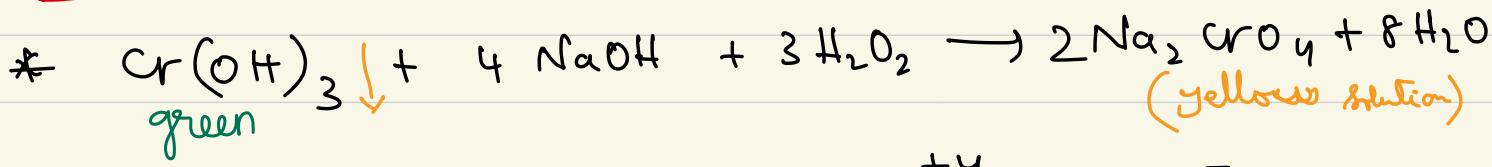
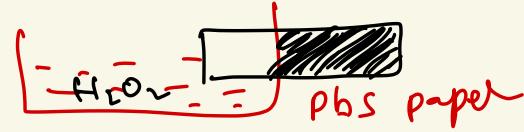
In presence of ethel (as solvent), CrO₅ (chromium peroxide) dissolved and form a blue coloured sol.



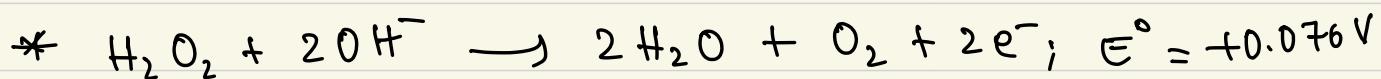
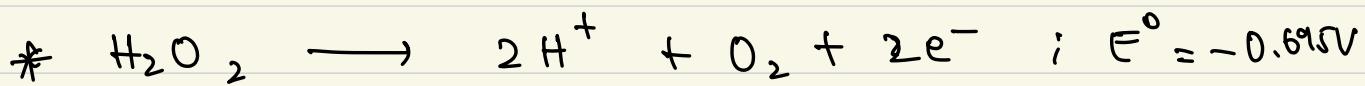
Neutral medium:



Basic medium :-

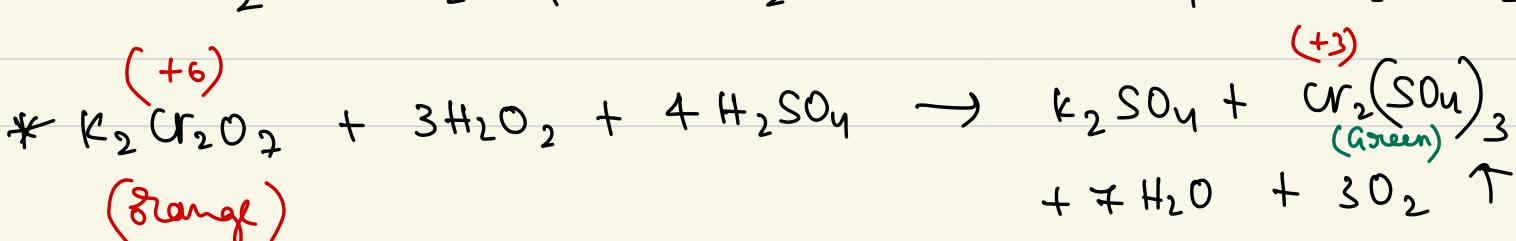
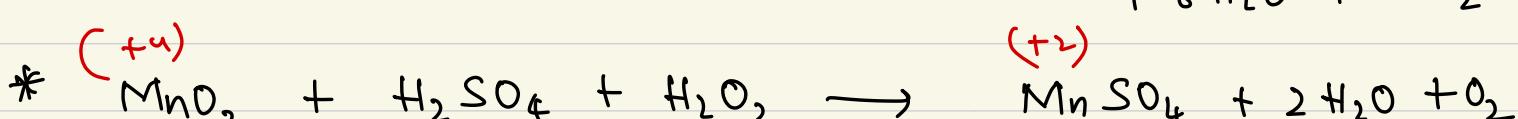
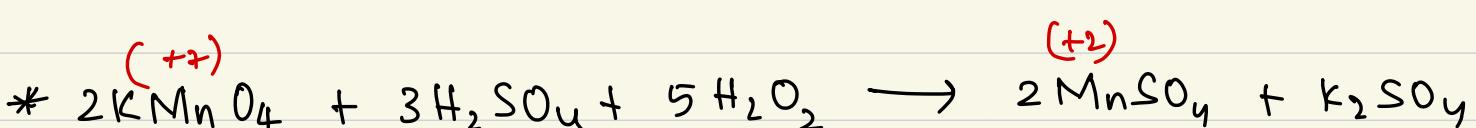
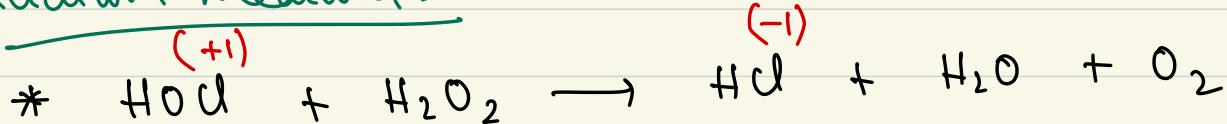


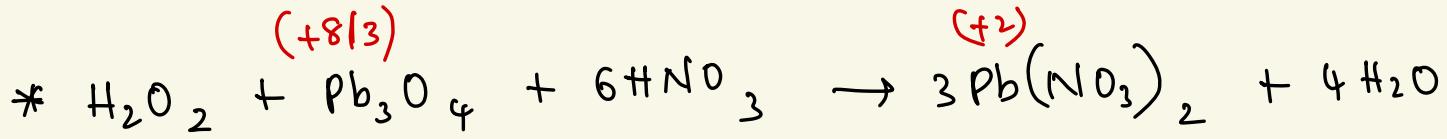
(ii) Reducing nature :- (H_2O_2 acts as R.A)



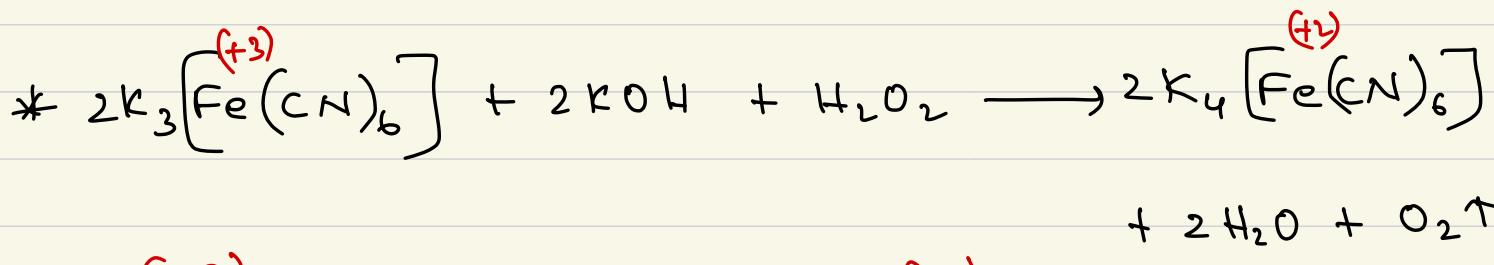
* H_2O_2 act as strong R.A in basic medium.

acidium medium :-

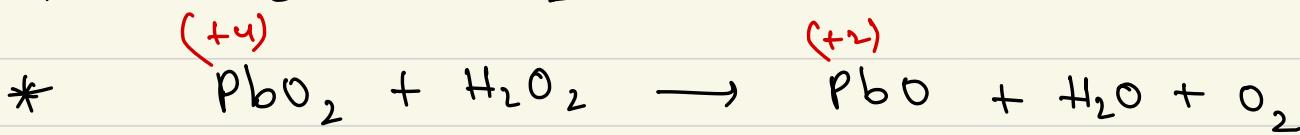
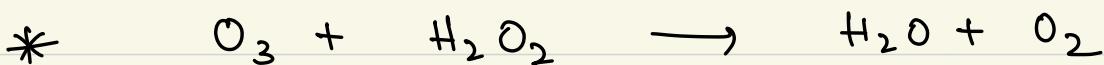
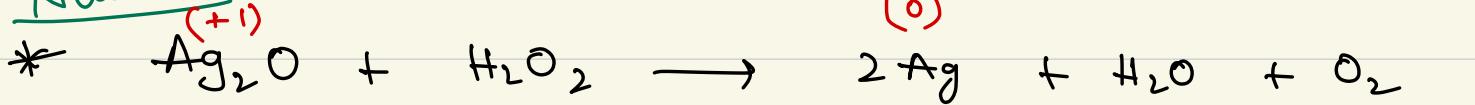




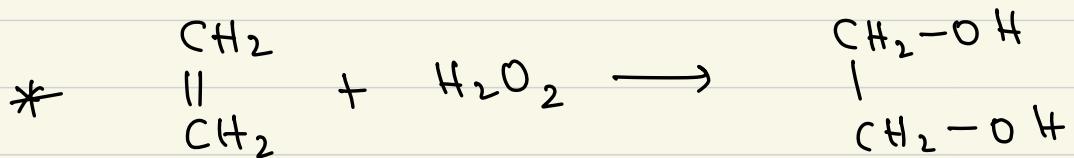
Basic medium:-



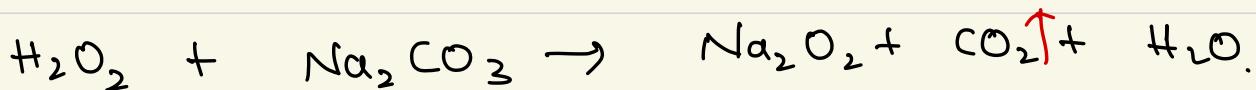
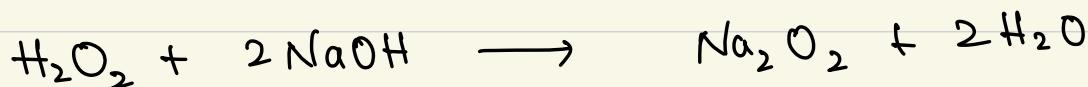
Neutral (+1)



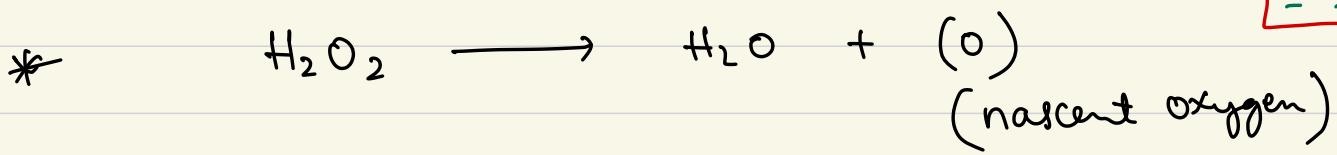
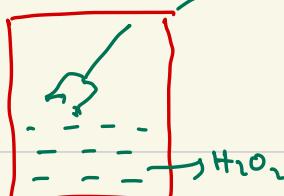
Addition Reactions:-



Acidic nature :- Pure liq. H_2O_2 has weak acidic nature but in aq. solution, it is neutral towards litmus.



Bleaching action:-

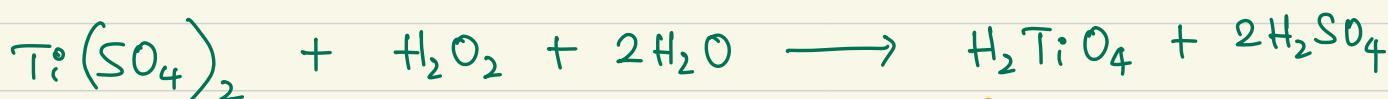


Coloured organic matter + (O) \rightarrow colourless.

It bleaches wool, Ivory, silk, cotton, hair

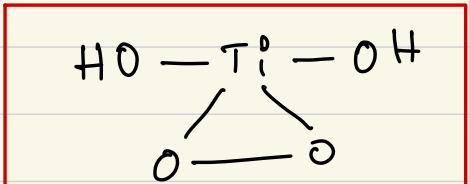
Test for H_2O_2 :

- An acidified solution of Ti salt when treated with H_2O_2 an yellow / orange colour is developed due to formation of per titanate acid



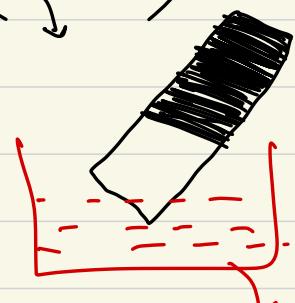
(g) $Ti(OH)_4$

(g) $Ti(NO_3)_4$



- It liberate I_2 from KI solution. (Starch)

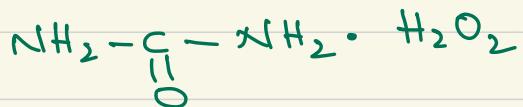
- Black PbS paper changed to white.



NOTE:- ① H_2O_2 form addition products as follows.

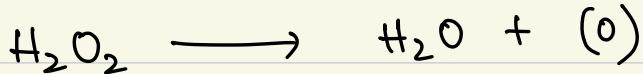


② Addition product of H_2O_2 with urea is called as hyperol



30% (w/v) H_2O_2
= perhydrool

Storage of H_2O_2 :



Decomposition of H_2O_2 is catalysed by Sunlight, metal surfaces, glass, alkali, dust etc. So storage of H_2O_2 in appropriate containers away from Sunlight is necessary.

H_2O_2 is stored in wax lined glass or plastic vessels in dark. Urea is often added as stabiliser (which inhibit the decomposition of H_2O_2)

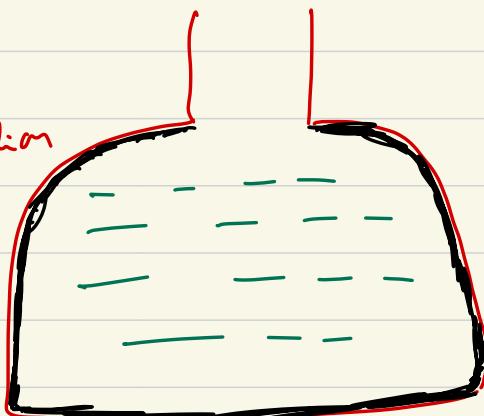
Ex: Inhibitors for decomposition of H_2O_2

Urea, Glycerol, H_3PO_4 , Acetanilide,
Sodium stannate

positive catalyst = Speed up the reaction

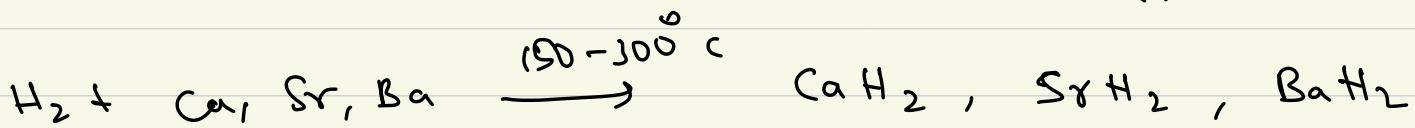
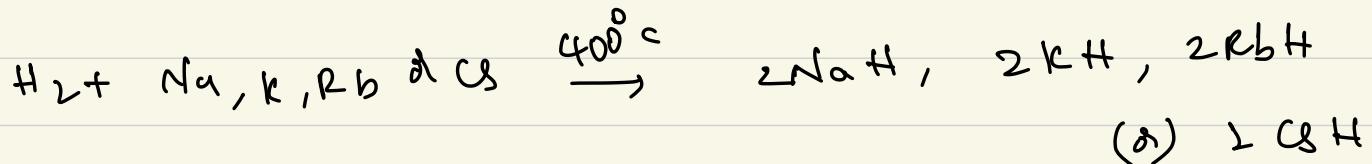
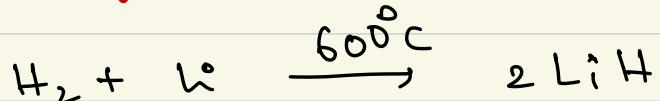
Negative catalyst = Slow down the reaction

= (Inhibitor)



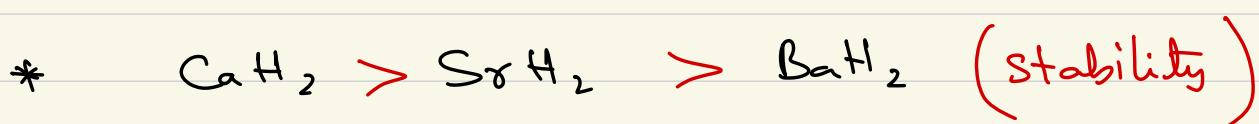
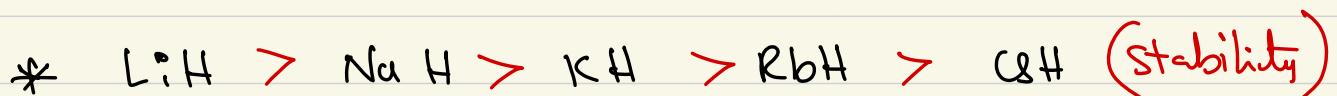
Hydrides:- H_2 forms binary compounds in which it has usually an oxidation state -1 are called hydride.

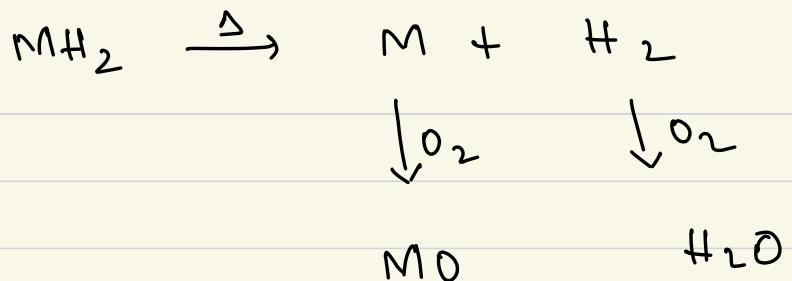
ionic hydrides:- Saline | Salt like hydrides:



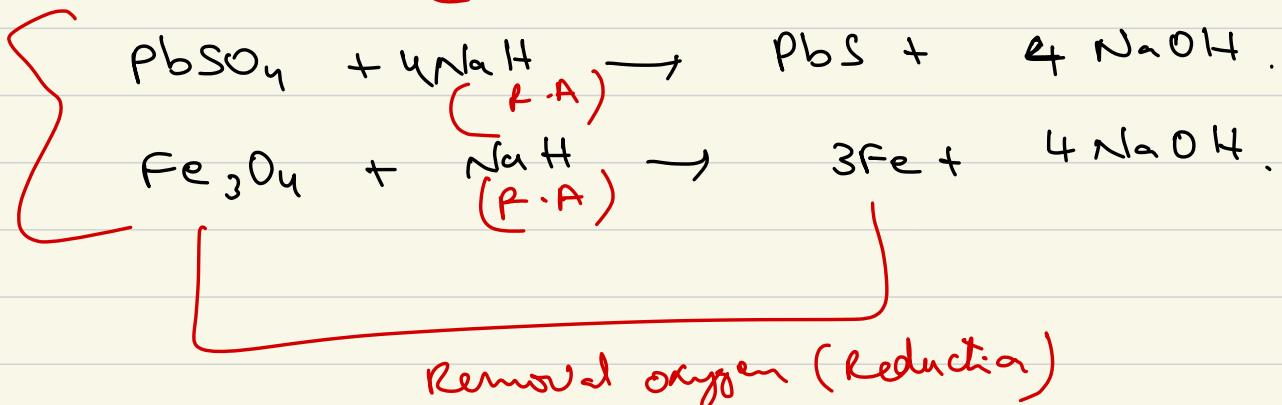
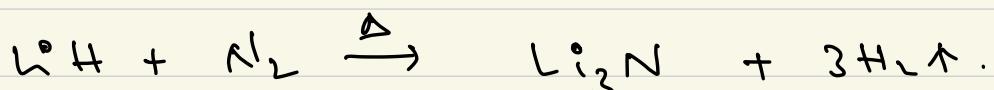
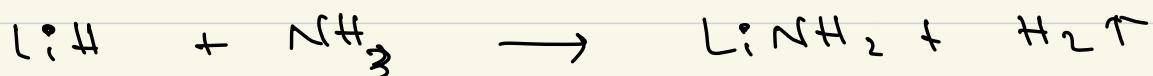
Properties:-

- ① They are colourless or greyish colour crystalline solids.
All alkali metal hydrides have rock-salt structure ($NaCl$ - Face centred cubic lattice) (FCC)
- ② They have high M.P & B.P.
- ③ They conduct electricity in their molten state
- ④ As size of cation increases, stability of hydrides decreases.





(lithium sulphophide)



HYDROGEN AND ITS COMPOUNDS

①

Hard and soft water: Rain water is a pure form of water, when it flows on surface of earth, it dissolves many salts. Presence of some specific salts make the water hard.

Hard water: The water which does not produce good lather readily with soap. This is due to presence of Ca and Mg salts in the form of their chlorides, Sulphates and bicarbonates.

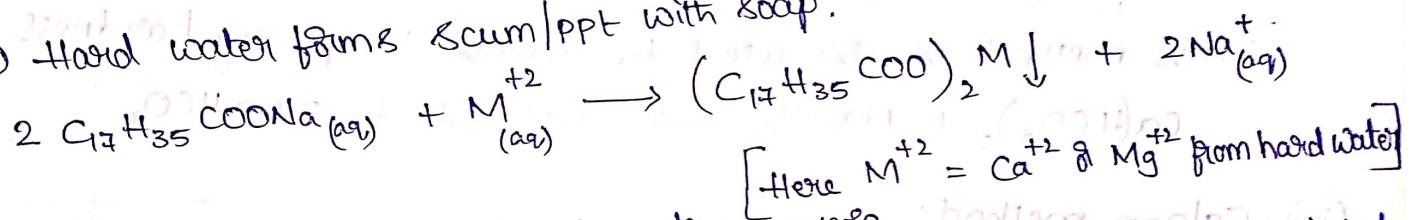
Ex: $\text{Ca}(\text{HCO}_3)_2$, $\text{Mg}(\text{HCO}_3)_2$, CaCl_2 , MgCl_2 , CaSO_4 , MgSO_4 .

Soft water: The water which is free from the soluble salts of Ca and Mg and gives good lather with soap easily.

Ex: Rain water, Distilled water.

(Q) What are effects of Hard water?

(A) ① Hard water forms scum/PPT with soap.



Hence it is unsuitable for laundry purpose. No lather is produced until all the Ca and Mg ions precipitated

This results in wastage of lot of soap.

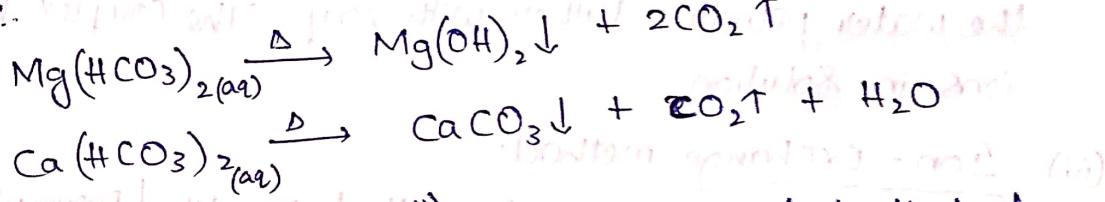
② It is harmful for boilers because of deposition of salts in the form of scales. This reduces the efficiency of boilers.

(Q) What are the types of Hardness of water?

(A) a) Temporary Hardness: It is due to the presence of bicarbonates

of Mg and Ca. The temporary hardness can be easily removed by

(i) Boiling:



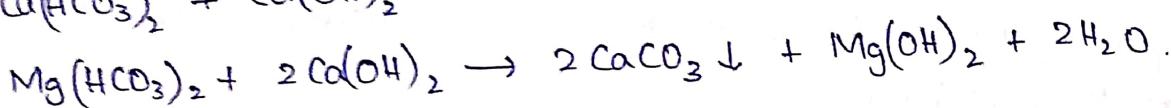
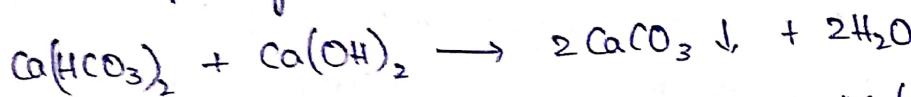
NOTE: K_{sp} of $\text{Mg}(\text{OH})_2$ (18×10^{-11}) is low compared to that of

MgCO_3 (3.5×10^{-8}).

(2)

(ii) Treatment with lime :- (Clark's method).

Temporary hardness can also be removed by treating with lime.



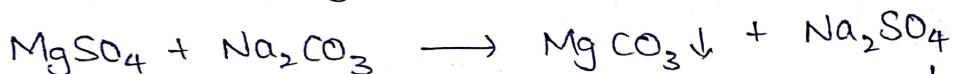
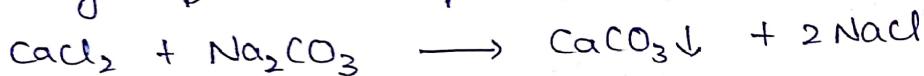
(b) Permanent Hardness:- It is due to the presence of chlorides,

sulphates of Ca & Mg dissolved in water which can not be removed by simple boiling.

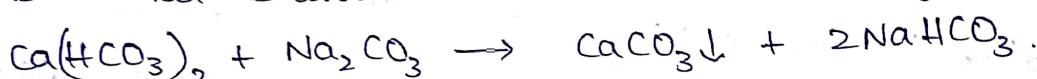
Methods to remove permanent hardness

(i) Treatment with Washing Soda (Na_2CO_3):

When calculated amount of Na_2CO_3 is added to hard water containing ~~soluble~~ soluble sulphates / chlorides of Mg / Ca.

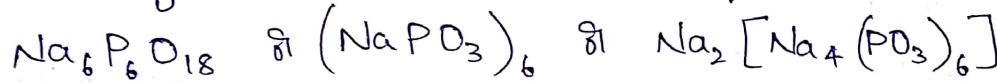


This method is also used to remove temporary hardness

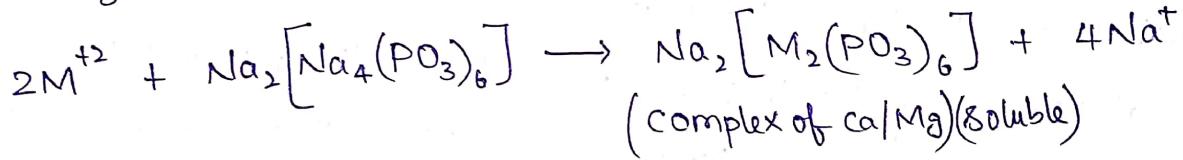


(ii) Calgon method:

Calgon is a commercial name of Sodium hexametaphosphate



When Calgon is added to hard water, the M^{+2} ions (Ca^{+2} or Mg^{+2}) present in it combine with $(\text{NaPO}_3)_6$ to form a soluble complex of Ca & Mg salts



The complex ion do not form any ppt with soap & hence the water produce lather with soap. The complex keeps the Ca^{+2} & Mg^{+2} ions in solution.

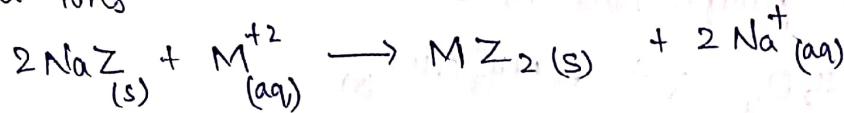
(iii) Ion-Exchange method:

This method is also called Zeolite / Permutit method.

Permutit is an artificial zeolite, chemically it is $\text{Na}_2\text{Al}_2\text{Si}_2\text{O}_8 \cdot x\text{H}_2\text{O}$

$\text{or NaAlSiO}_4 \cdot x\text{H}_2\text{O}$ called Sodiumaluminium sillosilicate.

For the sake of simplicity, it is written as Na₂Z. When zeolite is added to hard water, the cations present in hard water are exchanged by Na⁺ ions.



Regeneration of permuntit:

As the reaction proceeds, zeolite gets exhausted because whole of sodium zeolite gets converted to Ca/Mg zeolite forming $\text{CaAl}_2\text{Si}_2\text{O}_8 \cdot x\text{H}_2\text{O}$ & $\text{MgAl}_2\text{Si}_2\text{O}_8 \cdot x\text{H}_2\text{O}$ & MZ₂.

This exhausted permuntit can be converted to permuntit by treating with aq. NaCl solution.



(iv) Synthetic Resin Exchange method:

This is also called Organic ion exchanger method. This is most superior method to zeolite method, because this removes all types of unwanted cations as well as anions present in water.

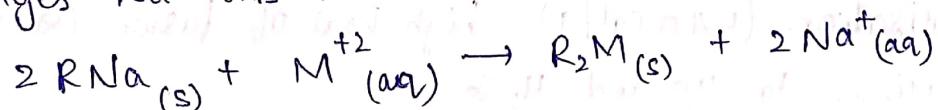
Synthetic Resin:

These are the insoluble polymeric solids having giant hydrocarbon network containing reactive acidic & basic groups. These resins are of two types

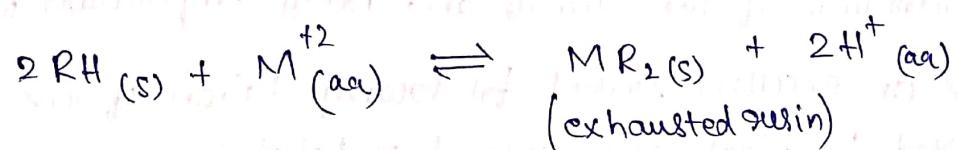
(1) cation exchange resin (2) Anion Exchange Resin

Cation exchange Resin:

These contain large organic molecule with $-\text{SO}_3\text{H}$ group and are water insoluble and can be represented as R-SO₃H which gets changed to RNa after treating with NaCl. Now RNa resin exchanges Na⁺ ions with Ca⁺² and Mg⁺² ions present in hard water.



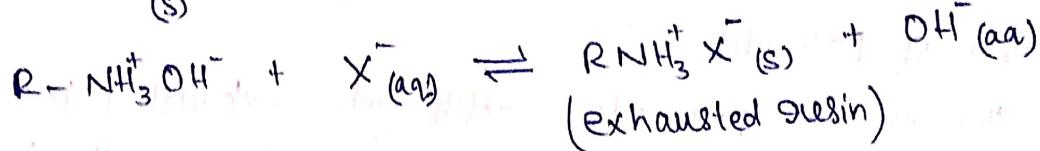
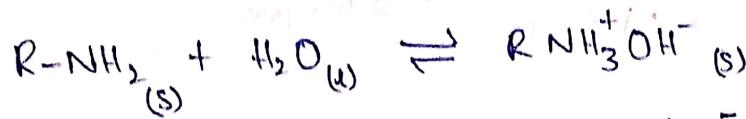
In order to obtain pure demineralised water, which is free from all soluble mineral salts, RSO₃H & RH is used.



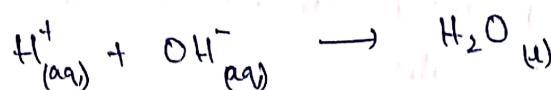
In above process, proton is released and makes water acidic which then passes through bed containing anion exchanger.

Anion Exchange Resin:

These resins contain giant hydrocarbon framework attached to basic groups such as $-NH_2$ & $-OH$ groups.



In the above reaction, OH^- ion exchanges for anions (Cl^- & SO_4^{2-}) in water. OH^- ions produced, neutralise the H^+ ions



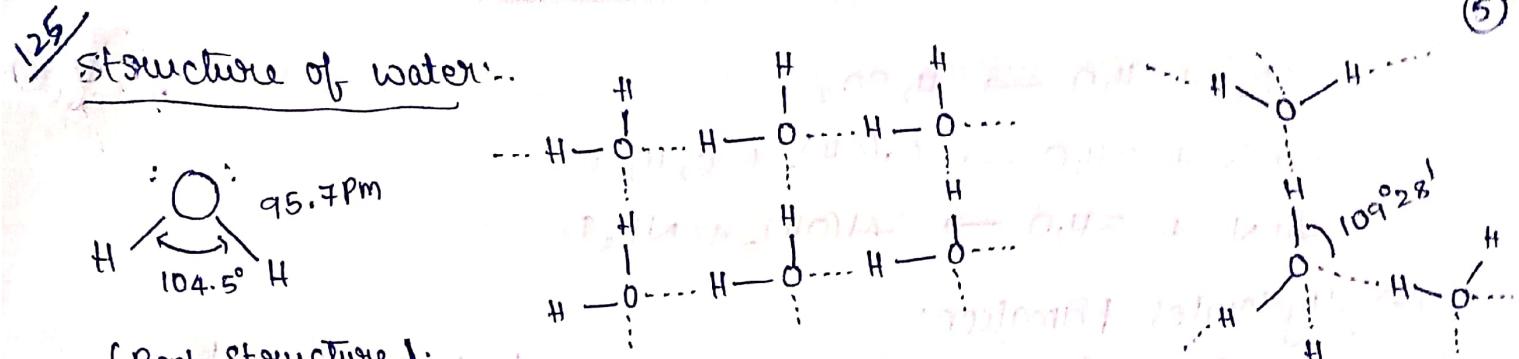
Regeneration of Resin:

cation exchanger is regenerated by action of dilute acid and anion exchanger is regenerated by treating with dil. alkali

* Water :- A major part of living organisms is made up of water. It is a solvent of great importance. Sources of water are oceans (97.33%), some plants (95%), Human body (65%), ground water (0.61%); polar ice (2.04%).

Physical properties:-

- ① It is colourless, tasteless and odourless liquid
- ② Unusual properties of water in liquid and solid state are due to presence of extensive hydrogen bonding.
- ③ Due to H-bonding, it has high F.P., B.P., high heat of vapourisation (540 cal/g), high heat of fusion (80 cal/g) in comparison to H_2S and H_2Se
- ④ The high heat of vapourisation and heat capacity are responsible for moderation of the Climate and Body temperature of living beings
- ⑤ It is an excellent solvent for transportation of ions and molecules required for plant and animal metabolism
- ⑥ Some covalent compounds like alcohol & carbohydrates dissolve in water due to H-bonding.



(Bent/Structure):

(Gas phase) (liquid phase) (Solid phase)

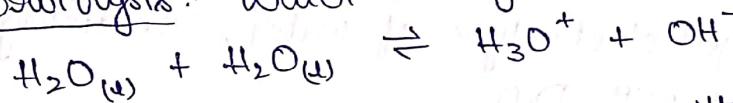
* Ice has an open cage like structure that crystallises in hexagonal forms with vacant spaces which pack less number of molecules per ml. So density of ice is less than water and floats on it.

Chemical properties:

① Amphoteric Nature: $\text{H}_2\text{O} + \text{HCl} \rightleftharpoons \text{H}_3\text{O}^+ + \text{Cl}^-$

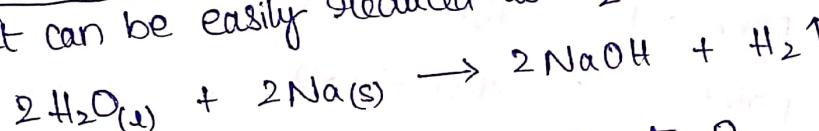
Factors for amphoterism in water:-
(Base) $\text{H}_2\text{O} + \text{NH}_3 \rightleftharpoons (\text{OH})^- + \text{NH}_4^+$

② Autoprotolysis: Water undergoes self ionisation.

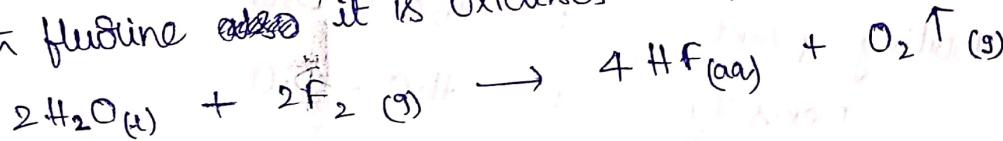


∴ water is Neutral towards litmus with $\text{pH} = 7$

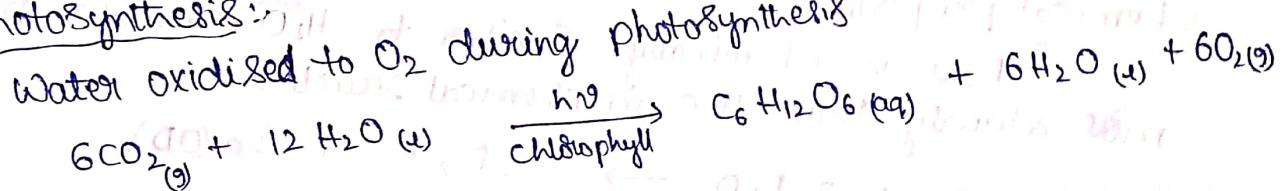
③ Redox Reactions: It can be easily reduced to H_2 with highly electropositive metals



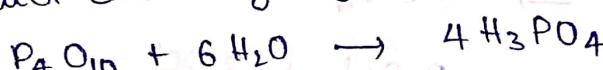
④ With fluorine ~~it is reduced~~ it is oxidised to O_2

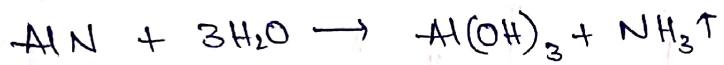
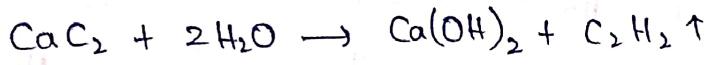


⑤ photosynthesis:



⑥ Hydrolysis Reactions: Water can easily hydrolyse many ionic and covalent compounds





⑦ Hydrates Formation:

Many salts can be crystallised as hydrated salts from its aq. solutions. There are three types of hydrates

(i) Coordinated water:- $[Cr(H_2O)_6]Cl_3$; $[Ni(H_2O)_6]^{+2}$

$[Fe(H_2O)_6]Cl_3$

(ii) Interstitial water:- $BaCl_2 \cdot 2H_2O$; $LiCl \cdot 2H_2O$; $KF \cdot 2H_2O$

(iii) Hydrogen bonded water:

$CuSO_4 \cdot 5H_2O$ (s) $[Cu(H_2O)_4]SO_4 \cdot H_2O$

Heavy water (D_2O) :- (Deuterium oxide)

Preparation:- It is prepared by exhaustive electrolysis of water.

It was shown that ordinary water contains very small portion of D_2O . On prolonged electrolysis of water, remaining water becomes enriched with D_2O * 1 part of D_2O is present in 6000 parts of ordinary water

Physical properties:

Dielectric constant : $H_2O > D_2O$

Freezing point : $H_2O < D_2O$

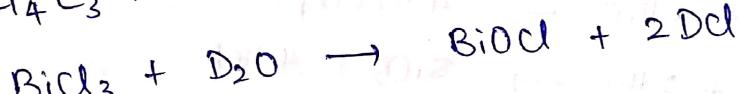
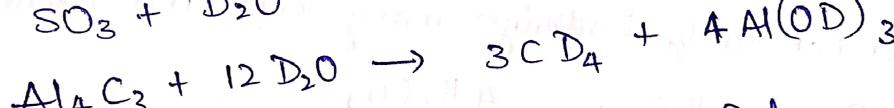
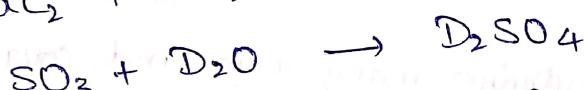
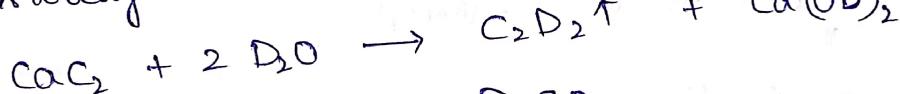
Boiling point : $H_2O < D_2O$

Density : $H_2O < D_2O$

$$H-O < D-O$$

B.E.

Chemical properties: D_2O is chemically similar to H_2O . However, D_2O reacts more slowly than H_2O in chemical reaction.



Uses of D₂O: ① As a moderator in nuclear reactors

② As a Germicide

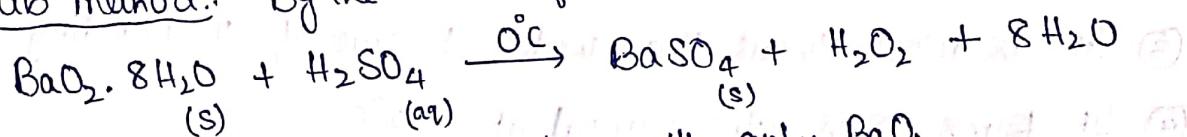
③ As a tracer to study reaction mechanism

* Hydrogen peroxide:

It is an important chemical used in pollution control & treatment

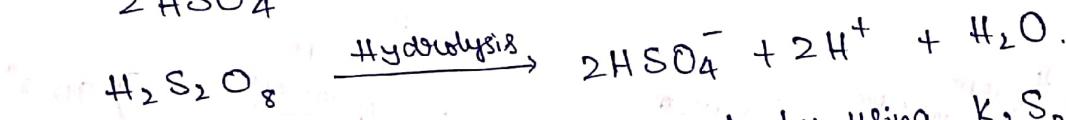
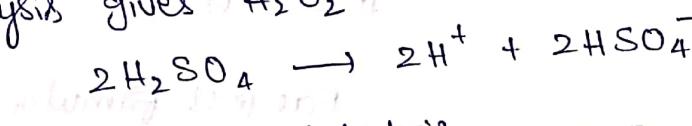
Preparation:

① Lab method: By the action of H₂SO₄ on hydrated BaO₂



* The rate of reaction is low with anhy. BaO₂

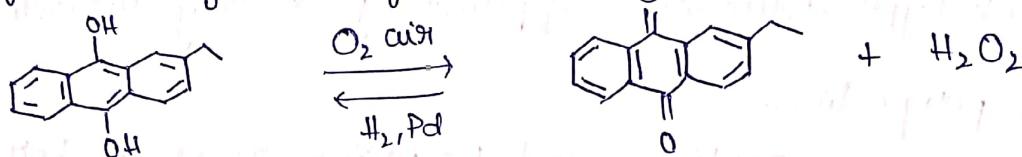
② Electrolysis: Electrolytic oxidation of acidified Sulphate soln (50%) at high current density gives peroxodisulphate which on further hydrolysis gives H₂O₂



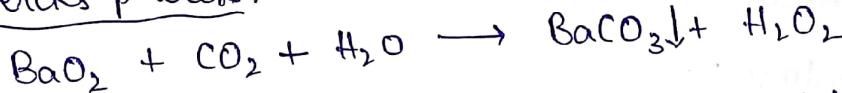
D₂O₂ can also be prepared by this method by using K₂S₂O₈



③ Industrial method: H₂O₂ is prepared by the auto-oxidation of 2-Ethylanthraquinone



④ Merck's process:



By passing current of CO₂ through a cold partly soln of BaO₂

⑤ By Na₂O₂:

It is prepared in the laboratory by adding small amounts of Na₂O₂ to ice cold water

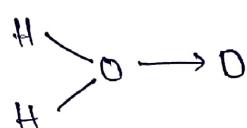
In place of cold water, dil. H_2SO_4 (20%) can be used



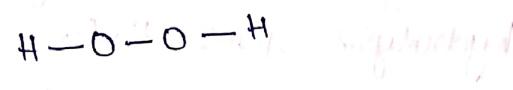
Physical properties:

- ① Pure H_2O_2 is a syrupy liquid. It is colourless but given bluish tinge in thick layers
- ② It is soluble in water, ether and alcohol in all proportions [with water, forms hydrate $H_2O_2 \cdot H_2O$ (m.p. = 221K)]
- ③ It is more viscous than water because of H-bonding
- ④ It forms perimatic crystal at $-2^\circ C$
- ⑤ A 30% sol. of H_2O_2 is marked as "100 Volume's of H_2O_2 "

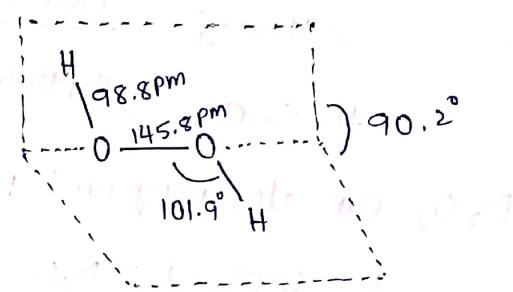
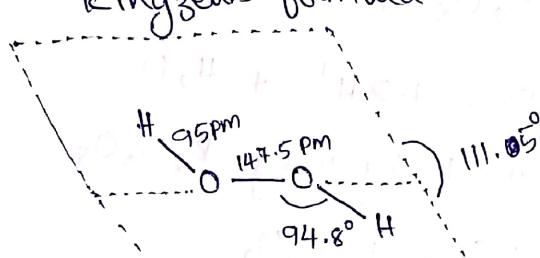
Structure of H_2O_2 :



Kingzett's formula



Baeyer's formula



Gas phase

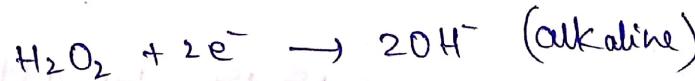
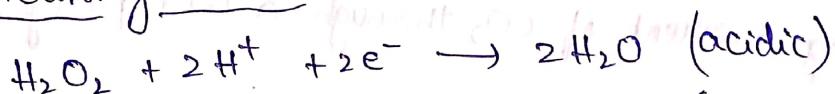
Solid phase

H_2O_2 is a non-linear and non-planar molecule having open book type structure supported by X-ray diffraction technique

Chemical properties:

It acts as an oxidising and Reducing agent in both acidic and alkaline media

① Oxidising nature:



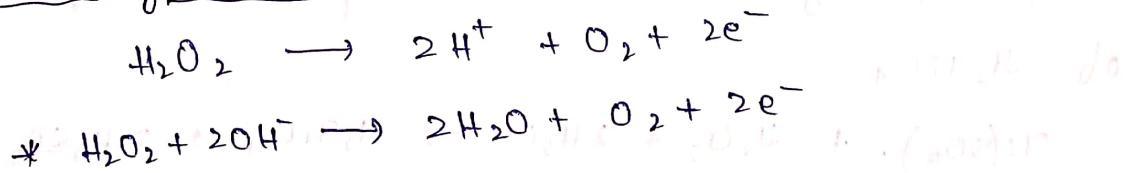
Neutral

- ① $\text{PbS} + 4\text{H}_2\text{O}_2 \rightarrow \text{PbSO}_4 + 4\text{H}_2\text{O}$
(black) (white)
- ② $\text{Na}_2\text{SO}_3 + \text{H}_2\text{O}_2 \rightarrow \text{Na}_2\text{SO}_4 + \text{H}_2\text{O}$
- ③ $\text{H}_2\text{S} + \text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{S}$
- ④ $2\text{KI} + \text{H}_2\text{SO}_4 + \text{H}_2\text{O}_2 \rightarrow \text{K}_2\text{SO}_4 + \text{I}_2 + 2\text{H}_2\text{O}$
- ⑤ $2\text{K}_4[\text{Fe}(\text{CN})_6] + \text{H}_2\text{SO}_4 + \text{H}_2\text{O}_2 \rightarrow 2\text{K}_3[\text{Fe}(\text{CN})_6] + \text{K}_2\text{SO}_4 + 2\text{H}_2\text{O}$
- ⑥ $\text{K}_2\text{Cr}_2\text{O}_7 + \text{H}_2\text{SO}_4 \rightarrow \text{H}_2\text{Cr}_2\text{O}_7 + \text{K}_2\text{SO}_4$
 $[\text{H}_2\text{O}_2 \rightarrow \text{H}_2\text{O} + \text{O}]^{\times 4}$
 $\text{H}_2\text{Cr}_2\text{O}_7 + 4(\text{O}) \rightarrow 2\text{CrO}_5 + \text{H}_2\text{O}$
 $4\text{CrO}_5 + 6\text{H}_2\text{SO}_4 \rightarrow 2\text{Cr}_2(\text{SO}_4)_3 + 6\text{H}_2\text{O} + 7\text{O}_2$

Alkaline:

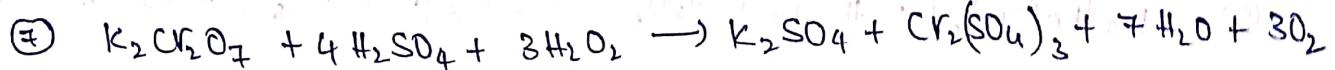
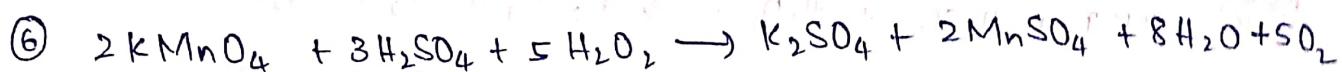
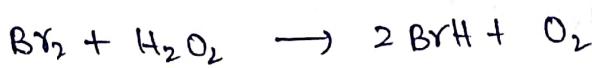
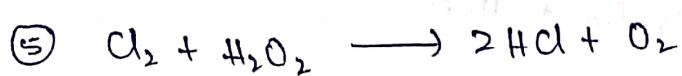
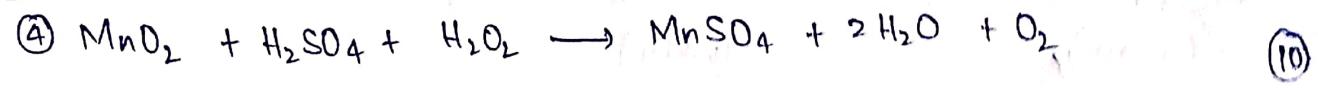
- ⑦ $\text{KI} + \text{H}_2\text{O}_2 \rightarrow 2\text{KOH} + \text{I}_2$
- ⑧ H_2O_2 oxidises the formaldehyde to formic acid in alkaline pyrogallol
 $\text{HCHO} + \text{H}_2\text{O}_2 \rightarrow \text{HCOOH} + \text{H}_2\text{O}$
- ⑨ $2\text{HCHO} + \text{H}_2\text{O}_2 \rightarrow 2\text{HCOOH} + \text{H}_2$
- ⑩ $2\text{Cr(OH)}_3 + 4\text{NaOH} + 3\text{H}_2\text{O} \rightarrow 2\text{Na}_2\text{CrO}_4 + 8\text{H}_2\text{O}$
(yellow soln)

- ⑪ Reducing nature: H_2O_2 also acts as a reducing agent

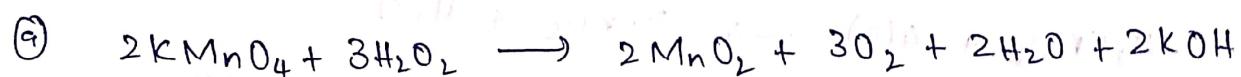
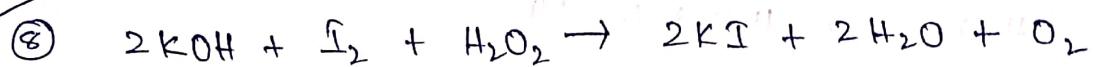
Neutral:

- ① $\text{Ag}_2\text{O} + \text{H}_2\text{O}_2 \rightarrow 2\text{Ag} + \text{H}_2\text{O} + \text{O}_2$
- ② $\text{O}_3 + \text{H}_2\text{O}_2 \rightarrow \text{H}_2\text{O} + 2\text{O}_2$
- ③ $\text{KIO}_4 + \text{H}_2\text{O}_2 \rightarrow \text{KIO}_3 + \text{H}_2\text{O} + \text{O}_2$

Acidic:

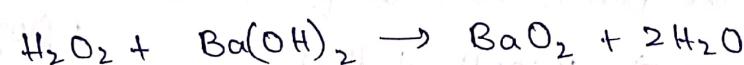
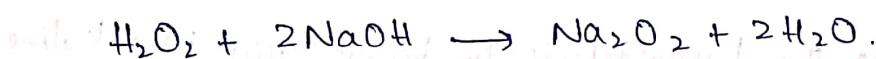


Alkaline:

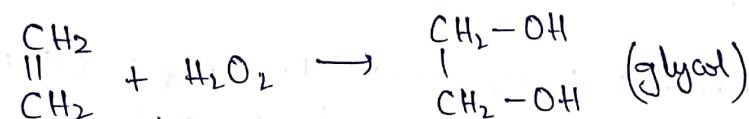


Acidic Nature:

Pure liquid is weak acidic in nature

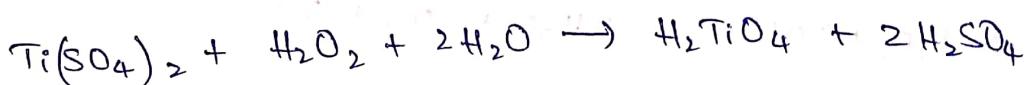


Addition reaction:



(Q) Give three tests for H_2O_2 detection.

- (A) ① An acidified soln of Ti salt when treated with H_2O_2 , an yellow/orange colour soln is developed due to formation of H_2TiO_4



- ② It liberates I_2 from KI solution, which turns starch soln to blue

- ③ Black lead sulphide paper turns to white when it is exposed to H_2O_2

Uses of H_2O_2 :

- ① It is used to bleach delicate materials like hair, cotton, wool etc.
- ② It is used in high quality detergents.
- ③ It is used as a mild disinfectant and also as an antiseptic and sold under the name "Perhydrol" [30% (w/v) H_2O_2]

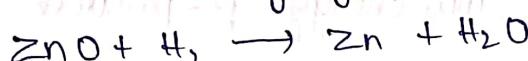
* Hydrogen: It was discovered by H. Cavendish (1766). It is most abundant element in universe & 10th most in earth crust.

Position of Hydrogen in periodic Table: Its position is uncertain as it has similar properties with both alkali metals and halogens.

Similarities with IIA group:

① Electronic configuration = ns^1

② Acts as reducing agent like alkali metals

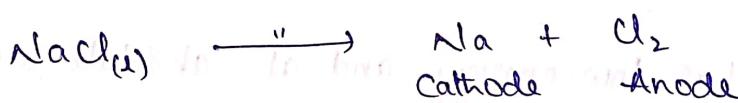
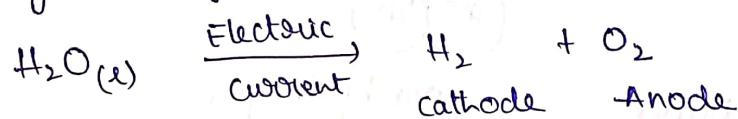


③ It is electropositive like alkali metals



④ It can form binary compounds with electronegative elements like IIA group metals

⑤ During electrolysis, H_2 is liberated at Cathode like alkali metals



Similarities with Halogens:

① It (H_2) has one electron less than nearest noble gas like halogens

- ② It has high I.E. like halogens
- ③ It can accept one electron to become hydride ion.
- It can form binary compounds with metals like halogens
- Na⁺ Cl⁻ NaCl Ca²⁺ Cl⁻ CaCl₂
- NaH CaH₂
- ④ like halogens, H shows -1 oxidation number in hydrides

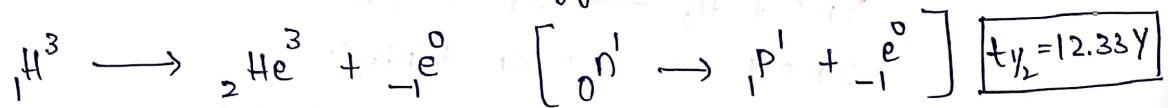
∴ Hydrogen is best treated as a group of its own

* Types of Hydrogen:

① Isotopes of Hydrogen:

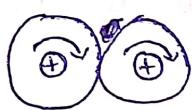
Naturally occurring hydrogen contains three isotopes

Protium, H^1 (99.89 %) ; Deuterium, H^2 or D (0.0156 %) and
Tritium, H^3 or T (1×10^{-6} %). Out of these isotopes, T is
radioactive and emits low energy β -particle

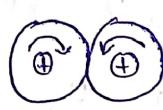


② Ortho and para hydrogen:

The nucleus of an atom has nuclear spin, in a similar way to electron spin. In H_2 molecule, the two nuclei may be spin in either same direction or opposite direction.



Ortho hydrogen

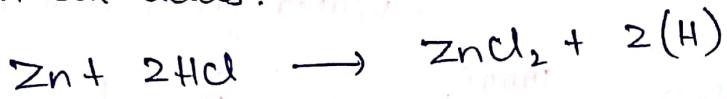


para hydrogen

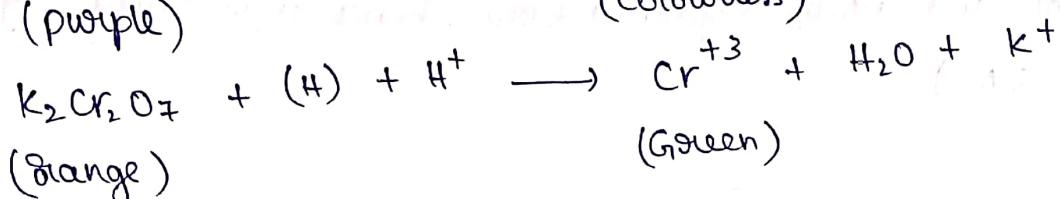
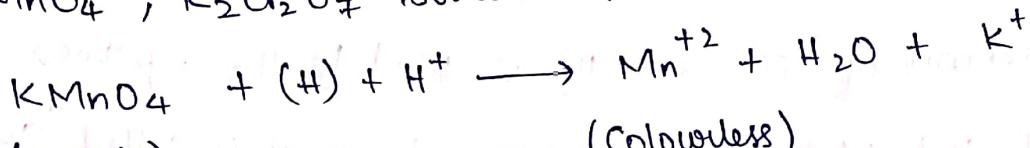
Para form has low energy and at absolute zero, the gas contains 100% of para form. Under ordinary atmospheric conditions, 75% ortho and 25% para form present.

③ Nascent hydrogen:-

It is generated in the solution by dissolving electropositive metals in dil. acids.



The nascent hydrogen is more reactive, it can decolourise KMnO_4 , $\text{K}_2\text{Cr}_2\text{O}_7$ solutions.

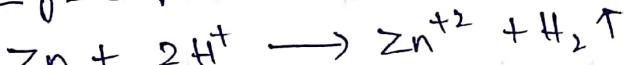


(Orange)

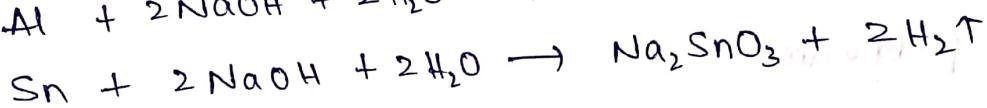
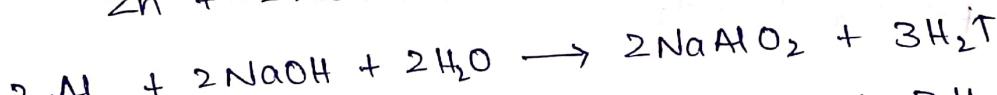
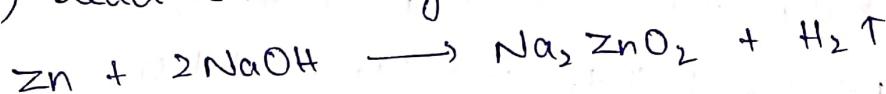
Preparation of H_2 :

The main sources of H_2 are i) water ii) Acids iii) Alkalies

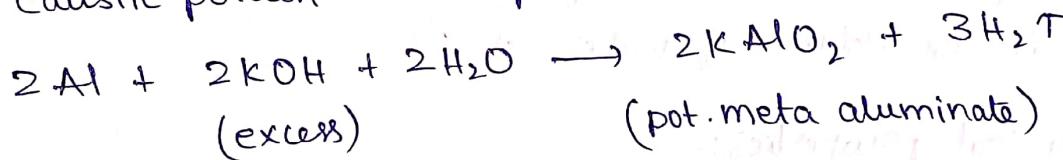
① Laboratory preparation:- Action of Zn with dil. acids



It can also be prepared by the reaction of Zn, Al, Sn (amphoteric metals) react with boiling alkalies (NaOH/KOH)

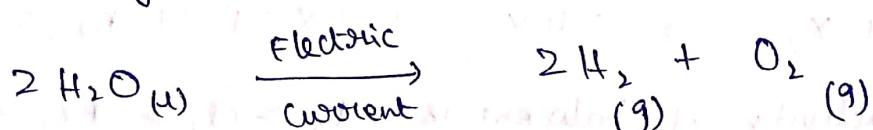


② Oxyen's method:- Very pure hydrogen is obtained by action of caustic potash on scrap aluminium:

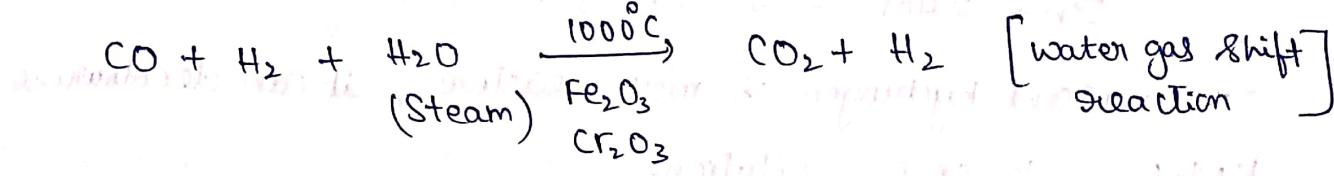
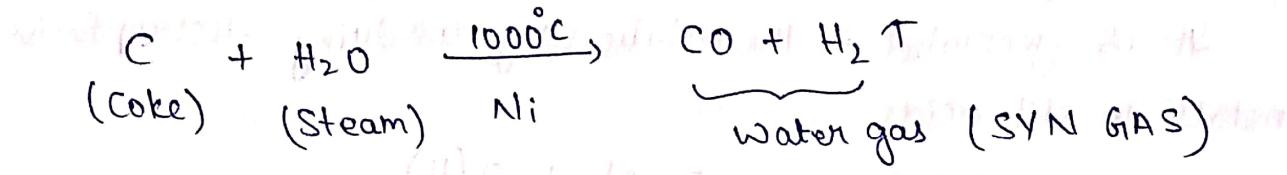


③ Commercial production of H_2 :

(a) Electrolysis of acidified / alkaline water using inert electrode

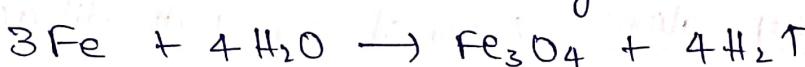


(b) Bosch's process:

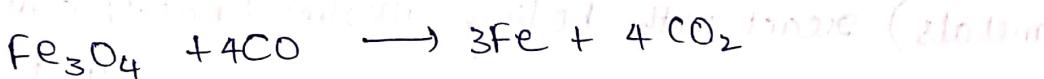


The mixture of CO and H₂ is used for the synthesis of methanol and no. of hydrocarbons, hence it is called "Synthesis gas" (SYN GAS)

(c) Lane's process: In this process, steam is passed over hot iron. Iron decomposes the steam to H₂ at 550 - 800°C. This reaction is called Gassing reaction



Iron is regenerated by reducing Fe₃O₄ with water gas. This is called Vivification reaction.



Physical properties:

- It is a colourless, odourless and tasteless gas
- lighter than air & slightly soluble in water (about 2 Volumes in 100 Volumes of water at 0°C)

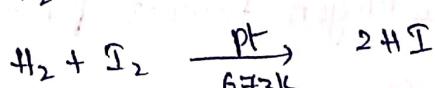
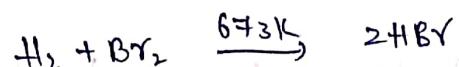
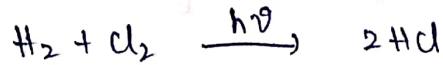
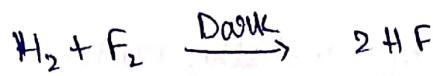
Chemical properties:

① Reaction with halogens:

It reacts with halogens to give HX



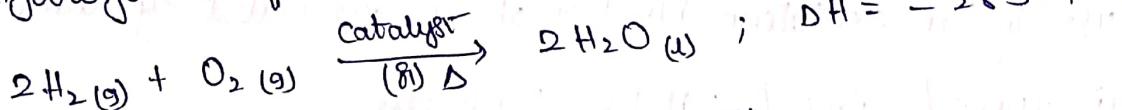
The reactivity of halogens is F₂ > Cl₂ > Br₂ > I₂



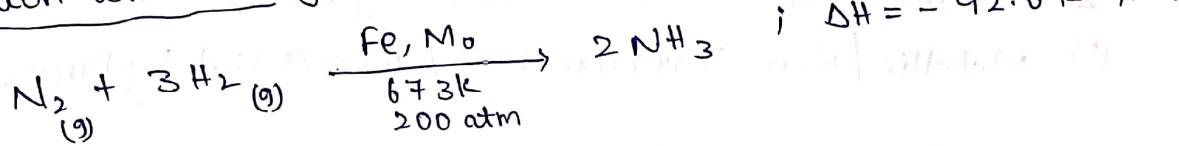
(15)

② Reaction with oxygen combustion:

Hydrogen is inflammable gas. It burns with blue flame.

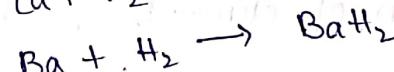
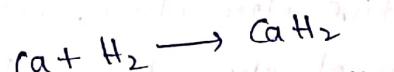
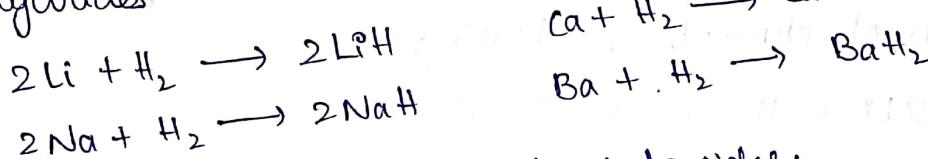


③ Reaction with Nitrogen: (Haber's process).



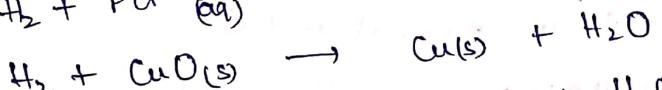
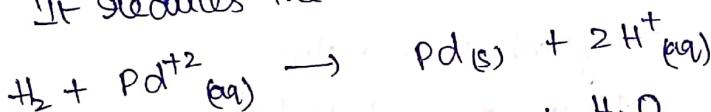
④ Reaction with metals:

With highly reactive metals, hydrogen yield the corresponding hydrides

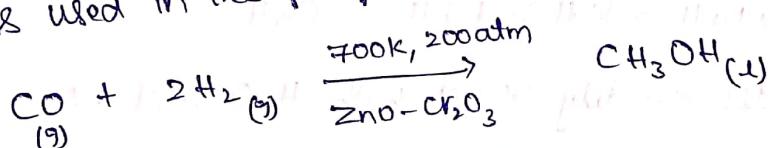


⑤ Reaction with metal ions and metal oxides:

It reduces the metal ions & metal oxides to metals.



⑥ It is used in the preparation of CH₃OH.



Uses of H₂:

① It is used in synthesis of NH₃, HCl,

② It is used in the preparation of vanaspati fat

③ Used to reduce heavy metal oxides to metals in Metallurgy

④ Used as Rocket fuel

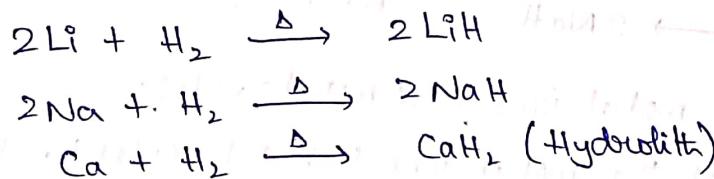
- ⑤ used for the manufacture of metalhydrides
- ⑥ used in fuel cells
- ⑦ Atomic hydrogen and oxyhydrogen torches find use for cutting and welding purpose.

Hydrides: H₂ forms binary compounds in which it has usually an oxidation number of -1. are called hydrides. They are

- ① Ionic / saline / Salt like hydrides
- ② Covalent hydrides / Molecular hydrides
- ③ Metallic / Non-stoichiometric / Interstitial hydrides

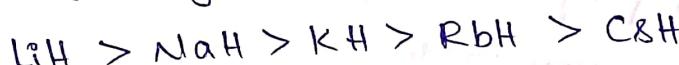
① Ionic Hydrides: [E.N. difference = 0.9 - 1.2] (I_A, II_A)

These are stoichiometric hydrides, formed by S-block elements (electropositive elements). These are prepared by direct combination of elements on heating

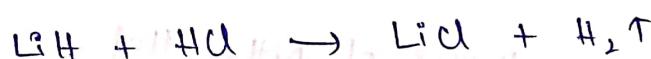
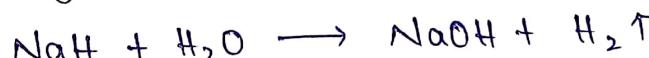


They have M.P & B.P. high

- These hydrides are crystalline in nature
- These are more dense than original metal
- They can conduct electricity in molten state
- Stability of hydride decreases as the size of cation increases



- These hydrides readily react with H₂O, HCl, O₂



- These are acts as strong Reducing agents



large size anion
stabilized by large size cation

group-I hydrides are more reactive than group-II
reactivity increases down the group. (17)

② Covalent hydrides:

Generally these are formed by p-block elements in which hydrogen is covalently bonded to another element.

The formula of these hydrides are XH_n & XH_{8-n} [n = group number of X]

These are of three types:-

a) Electron deficient:

These have less no. of electrons for forming conventional Lewis structure around central atom.

Ex: BH_3 , AlH_3 , B_2H_6 etc. (Lewis acids)

b) Electron precise:

These have required no. of electrons around central atom to get octet configuration

Ex: CH_4 , SiH_4

c) Electron rich:

These have excess electrons (as lone pair) around central atoms

Ex: $\ddot{N}H_3$, $H\ddot{F}$; $H_2\ddot{O}$ (Lewis Bases)

③ Interstitial Hydrides: [E.N. difference 1.2 - 1.4]

These are formed by many of d & f-block elements. However, the metals of group 7, 8 and 9 do not form hydrides.

In these hydrides, hydrogen atom occupy interstitial site in metal crystal. even in 6th group, or only form hydride

→ These are Non-Stoichiometric hydrides

Ex: $TiH_{1.8}$; $LaH_{2.87}$; $YbH_{2.55}$

→ These can conduct heat and electricity even in solid state

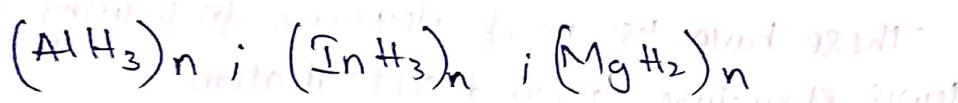
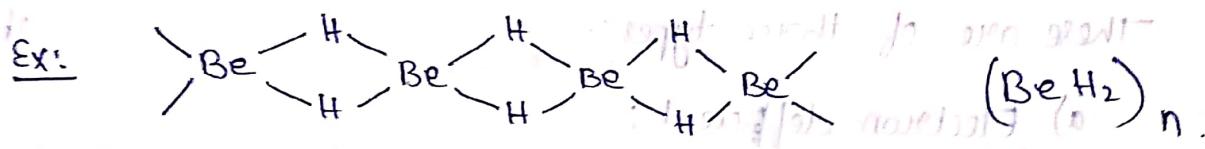
→ Except Ni, Pd, Ce, Ac, other hydrides of this class

have lattices different from those of the parent metal

* They are used as source for H_2

Polymeric hydrides: [E.N. difference 1.4 - 2.0]

These hydrides have covalent network throughout the structure of crystal. The monomers are repeated through bridge hydrogen X (also called small for almost 2.0)



1 H (2.1) - 2.0 = 0.1 (small for almost 2.0)

2 Li Be (2.1) - 2.0 = 0.1 (small for almost 2.0)

3 Mg Sc Ti V Cr Mn Fe Co Ni Cu Zn (2.1) - 2.0 = 0.1 (small for almost 2.0)

4 Al In (2.1) - 2.0 = 0.1 (small for almost 2.0)

5 B (2.1) - 2.0 = 0.1 (small for almost 2.0)

6 C (2.1) - 2.0 = 0.1 (small for almost 2.0)

7 N (2.1) - 2.0 = 0.1 (small for almost 2.0)

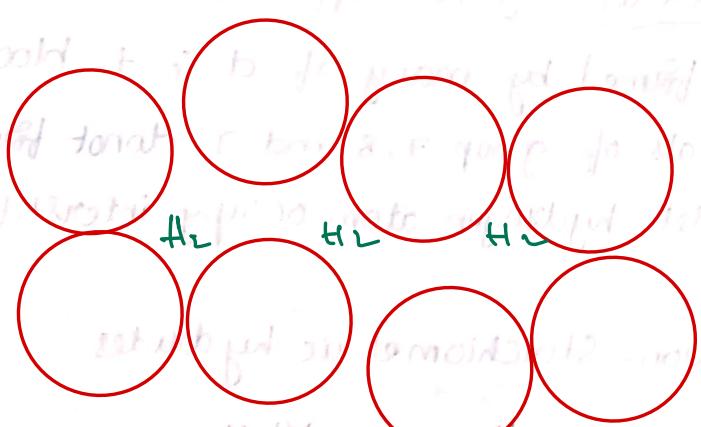
8 O (2.1) - 2.0 = 0.1 (small for almost 2.0)

9 F (2.1) - 2.0 = 0.1 (small for almost 2.0)

10 Ne (2.1) - 2.0 = 0.1 (small for almost 2.0)

11 Ar (2.1) - 2.0 = 0.1 (small for almost 2.0)

12 Cl (2.1) - 2.0 = 0.1 (small for almost 2.0)



Hydrogen bond is also formed between H_2 and H_3 molecules.

Hydrogen bond for H_2 and H_3 is about 2.0 to 2.1.

Hydrogen bond for H_3 and H_3 is about 2.0 to 2.1.