Hydrogen

→ Symbol: H

→ e^- $conf^n$: $1s^1$

→ lightest & most abundant element in universe.

→ 1st prepared by Sir Henry Cavandish by rxn of dil. H_2SO_4 on iron & named by Antoine Lavoisier since it produced water on burning. (Greek hydra → water, gennus → producer)

→ It can be placed in grp. 1 or grp. 17 due to similarities with alkalies or halogens. Like alkalies, H has $1s^1$ $conf^n$ & like halogens, H needs 1 e^- to be stable.

Isotopes of H:

ⓐ Protium, ^1_1H (no neutrons)

ⓑ deuterium, ^2_1H or D (one neutron)

ⓒ Tritium, ^3_1H or T (two neutrons)

Reactivity order → H > D > T (This is due to their different enthalpy of bond dissociation)

Radioactivity order → H < D < T

Prep^n →

① Lab prep^n —

(i) $Zn + 2 \text{ dil. } HCl \longrightarrow ZnCl_2 + H_2$

(ii) $Zn + 2NaOH\ (aq) \longrightarrow Na_2ZnO_2 + H_2$

Sod. zincate.

② Commercial method —

(i) $2H_2O\ (l) \xrightarrow[\text{traces of } \bar{a}/\bar{b}]{\text{Electrolysis}} 2H_2(g) + O_2(g)$

Electrolysis of acidified H_2O using Pt-electrode.

(ii) By electrolysis of brine sol^n (NaCl) using for prep^n of NaOH. where H_2 is obtained as byproduct.

$NaCl \rightleftharpoons Na^+ + Cl^-$

$NaCl + H_2O \longrightarrow NaOH + Cl_2 + H_2$

at ~~cathode~~ anode, $2Cl^-(aq) \longrightarrow Cl_2(g) + 2e^-$

at cathode, $2H_2O + 2e^- \longrightarrow H_2 + 2OH^\ominus$

Overall rxn is,

$$2Na^+ + 2Cl^- + 2H_2O$$

$$\downarrow$$

$$Cl_2 + H_2 + 2Na^+ + 2OH^\ominus$$

(iii)

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

e.g.

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

Mixture of CO and H_2 is called <u>water gas</u>. Since this is used for synthesis of methanol and a no. of hydrocarbons, it is ~~ca~~ also called 'synthesis gas' or 'syngas'.

Syn gas ~~can be~~ is produced from sewage, saw-dust, scrap wood etc.

It can also be prepared from coal which is called 'coal gasification'.

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

H_2 production can be increased by reacting CO of syngas mixture with steam in presence of iron chromate as catalyst.

$$CO(g) + H_2O(g) \xrightarrow[\substack{FeCrO_4 \\ \text{iron chromate}}]{673\ K} CO_2(g) + H_2(g)$$

This is called water gas shift rxn. CO_2 is removed by scrubbing with ~~[illegible]~~ sodium arsenite soln.

Chemical properties —

① Rxn with halogens —

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

With F_2, rxn occurs even in the dark.

With I_2, " " in presence of catalyst.

② Rxn with O_2 —

$$2H_2(g) + O_2(g) \xrightarrow{catalyst / \Delta} 2H_2O(l) \quad \Delta H = -285.9 \text{ kJ mol}^{-1}$$

③ Rxn with N_2 —

$$3H_2(g) + N_2(g) \xrightarrow[Fe]{700 K, 200 atm} 2NH_3(g)$$

(Haber's process) $\Delta H = -92.6 \text{ kJ mol}^{-1}$

④ Rxn with metals —

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

⑤ Rxn with metal ions & metal oxides —

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

(R.A.)

$$y H_2(g) + M_xO_y(s) \longrightarrow xM(s) + yH_2O(l)$$

Reduction of metals that are less active than iron

) Rxn with org. compds —

(i) Hydrogenation of vegetable oils to edible fats (margarine and vanaspati ghee) in presence of Ni-catalyst.

(ii) Hydroformylation of olefins to give alcohols.

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

$$H_2 + RCH_2CH_2CHO \longrightarrow RCH_2CH_2CH_2OH$$

Use of H_2 :

① Synthesis of NH_3, i.e. used for manufacture of HNO_3 & fertilizers.

② In prepⁿ of org. chemicals like CH_3OH.

$$CO(g) + 2H_2(g) \xrightarrow{Co\text{-}catalyst} CH_3OH(l)$$

③ Prepⁿ of HCl, metal hydrides etc.

④ As rocket fuel in space research.

③ Metallic / Non-stoichiometric / Interstitial Hydrides:

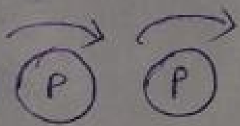
→ Compds of hydrides with d-block & f-block elements.

e.g. $LaH_{2.87}$ (i.e. non-stoichiometric being deficient in Hydrogen)

$YbH_{2.55}$, $TiH_{1.5-1.8}$, $NiH_{0.6-0.7}$ etc

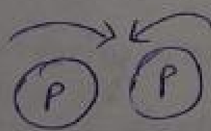
Forms of hydrogen:

Ortho hydrogen → When nuclear spins are in the same direction.



∴ nuclear spin $= \frac{1}{2} + \frac{1}{2} = 1$

Para hydrogen → When nuclear spins are in opposite directions in H_2

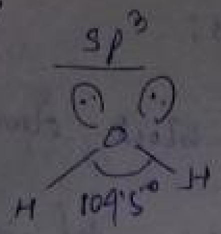


∴ nuclear spin $= \frac{1}{2} + \left(-\frac{1}{2}\right)$
$= 0$

— At RT, H_2 has 75% ortho & 25% para.

— At low temp., more para.

H_2O :

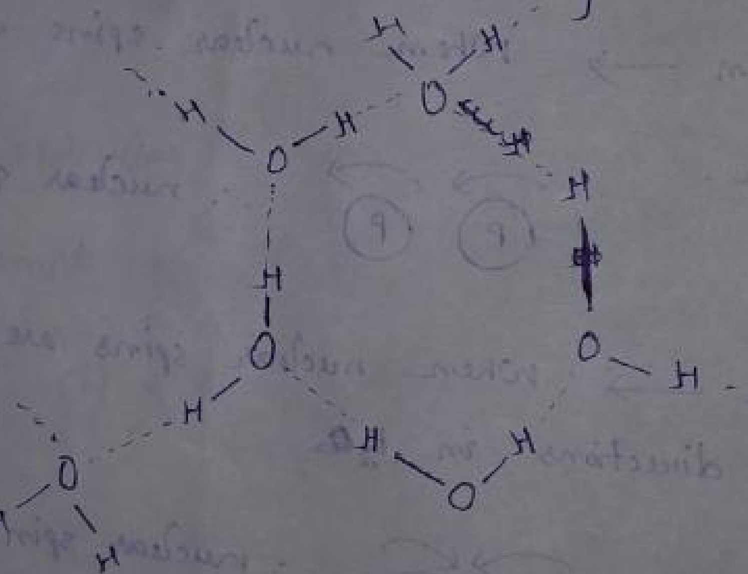


Str. of ice :

→ ice has 3-D str.

→ H_2O molecules are H-bonded.

→ Each O atom is surrounded tetrahedrally & by four other O-atoms at a distance of 276 pm.



→ H-bonding gives ice an open type str. with holes. These holes can entrap some other molecules of appropriate size interstitially.

Chemical Properties of H_2O :

① Amphoteric Nature –

From Bronstep concept, it can act both as $\hat{a}$ & as $\hat{b}$.

13/11/09 09/15

$H_2O + NH_3 \rightleftharpoons OH^- + NH_4^+$

$\hat{a}$

$H_2O + H_2S \rightleftharpoons H_3O^+ + HS^-$

$\hat{b}$

Self-ionisation of H_2O.

$H_2O + H_2O \rightleftharpoons H_3O^{\oplus} + OH^{\ominus}$

$\hat{a}$ $\hat{b}$

② Redox rxns — (easily reduced to dihydrogen by highly electropositive metals)

$2H_2O(l) + 2Na(s) \longrightarrow 2NaOH(aq) + H_2(g)$

photosynthesis,

$6CO_2 + 12H_2O \longrightarrow C_6H_{12}O_6 + H_2O + O_2$

With F_2, it is oxidised to O_2,

$2F_2 + 2H_2O \longrightarrow 4H^+ + 4F^- + O_2$

③ Hydrolysis —

$$P_4O_{10} + 6H_2O \longrightarrow 4H_3PO_4$$

$$SiCl_4 + 2H_2O \longrightarrow SiO_2 + HCl$$

$$N^{3-} + 3H_2O \longrightarrow NH_3 + 3OH^{\ominus}$$

④ Hydrate formation — (many salts crystallize as hydrated salts)

e.g. $[Cr(H_2O)_6]^{3+} 3Cl^-$, $BaCl_2 . 2H_2O$,

coordinated water. Interstitial water

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

Hard & Soft water:

Soft water ⟶ it produces lather with soap readily.

e.g. rain water, distilled water & demineralised water.

Hard water ⟶ It does not produce lather with soap readily e.g. sea water, river water, spring water, lake water, well water etc.

Hardness of water is due to ⟶ presence of bicarbonates, chlorides, & sulphates of Ca & Mg in it.

617772 (1)

Serial No. CA ~~610018~~ **Additional Script**
Countersigned on verification

Signature

GAUHATI UNIVERSITY

OFFICER-IN-CHARGE INVIGILATOR
Date..................

_______________ EXAMINATION 20_______

CODE NO._______________ ROLL NO._______________

G.U. REGISTRATION NUMBER_______________ OF_______________

It does not produce lather becoz ~~water~~

Soap → Na^+/K^+ salt of certain fatty âs such as stearic â, palmitic â, oleic â etc.

∴ Hard water + soap solⁿ : immediate formation of curdy white ppt. but no lather.

$$2C_{17}H_{35}COO^-Na^+ + CaCl_2 \longrightarrow (C_{17}H_{35}COO)_2Ca\downarrow + NaCl$$

Cal. stearate
(curdy white ppt.)

$$2C_{17}H_{35}COO^-Na^+ + MgSO_4 \longrightarrow (C_{17}H_{35}COO)_2Mg\downarrow + Na_2SO_4$$

Magnesium stearate
(curdy white ppt.)

However, when all Ca^{2+} & Mg^{2+} ions in hard water is ppted by sufficient amt. of soap, the resulting water becomes soft & thus produced lather.

Hard water is not suitable for washing purpose as lots of soap is wated.

Types of hardness of water —

(a) Temporary hardness: (or carbonate hardness)

→ due to bicarbonates of Ca & Mg.

i.e. $Ca(HCO_3)_2$ & $Mg(HCO_3)_2$.

→ called temporary as it can be simply removed by boiling & filtering the water.

(b) Permanent hardness: (or non-carbonate hardness)

→ due to soluble chlorides & sulphates of Ca & Mg i.e. $CaCl_2$, $CaSO_4$, $MgCl_2$ & $MgSO_4$.

→ called permanent as it can't be simply removed by boiling.