EXAMS ROAD

"Bringing Excellence to Students"

Handwritten Notes

On

Hydrogen

HYDROGEN

→ Hydrogen is most abundant element in the universe.
→ Saturn & Jupiter is full of hydrogen
→ Sun is mostly full of hydrogen. (so fusion rxn occurs)

$_1H^1 + {}_1H^1 \xrightarrow{\text{fusion}} {}_1H^2 + \text{Energy}$

→ Electronic configuration of hydrogen = $1s^1$
→ Atomic no. / mass no. of hydrogen = 1
→ Representation = $_1H^1$

Isotopes of Hydrogen

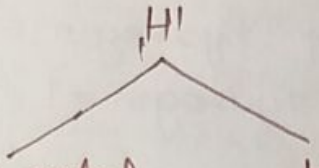
Isotopes of Hydrogen	No. of protons	No. of neutrons	Atomic mass	Symbol
Protium or Hydrogen-1	1	0	1	$_1^1H$ or ^1H
Deuterium or Hydrogen-2	1	1	2	$_1^2H$ or ^2H
Tritium or Hydrogen-3	1	2	3	$_1^3H$ or ^3H

→ The mass of these isotopes differ by large amount.
→ Deuterium has double atomic weight than protium & tritium has triple atomic weight than protium.
→ So, these isotopes differ largely in their physical and chemical property.

Reactivity of Hydrogen : H-H > H-D

POSITION OF HYDROGEN IN PERIODIC TABLE

→ Position of hydrogen in periodic table is not fixed.
→ Bcoz some of its properties resemble with alkali metals whereas some properties resembles with halogen.
→ So hydrogen is given a separate space in periodic table.



Alkali metal

→ Same electronic configuration
→ Both form x^+ ion.

Halogens

→ Both take one e^- to achieve octet
→ Both form X_2 type compound.
→ Both form X^- ion.

PREPARATION OF HYDROGEN

1. Laboratory method
   (i.) Rxn of metal with mineral acids
   (ii.) Rxn of metal with base.
2. Industrial method
   (i.) Electrolysis of water
   (ii.) Electrolysis of $Ba(OH)_2$
   (iii.) By Coal – gasification

LABORATORY METHOD

(i.) Rxn of metal with mineral acids :

→ Metals above H_2 in reactivity series release H_2 gas on with acid.

$$Zn\ (s) + HCl\ (aq) \longrightarrow ZnCl_2\ (aq) + H_2\ (g)$$

$$Fe\ (s) + H_2SO_4\ (aq) \longrightarrow Fe_2(SO_4)_3\ (aq) + H_2\ (g)$$

(ii.) Rxn of metal with base

→ Amphoteric metal (Sn, Pb, Zn, Al) on rxn with base; produces H_2

$$Zn(s) + NaOH \longrightarrow \underset{\text{sodium zincate}}{Na_2ZnO_2} + H_2(g)$$

$$Al(s) + NaOH \longrightarrow \underset{\text{sodium aluminate}}{NaAlO_2} + H_2(g)$$

$$Pb(s) + NaOH \longrightarrow \underset{\text{sodium plumbate}}{Na_2PbO_2} + H_2(g)$$

$$Sn(s) + NaOH \longrightarrow \underset{\text{sodium stannate}}{Na_2SnO_2} + H_2(g)$$

INDUSTRIAL METHOD

(i.) Electrolysis of water

→ It is carried out using Pt electrode.

Electrolyte = Distilled water / Pure water

\# Reaction at cathode : Reduction

$$2H_2O(l) + 2e^- \longrightarrow H_2(g) + 2OH^-(aq)$$

\# Reaction at Anode : Oxidation

$$2H_2O(l) \longrightarrow O_2(g) + 4H^+(aq) + 4e^-$$

$$2H_2O(l) + 2e^- \longrightarrow H_2(g) + 2OH^-(aq) \times 2$$

$$2H_2O(l) \longrightarrow O_2(g) + 4H^+(aq) + 4e^-$$

$$6H_2O(l) \longrightarrow O_2(g) + 2H_2(g) + 4H^+ + 4OH^-$$

$$6H_2O(l) \longrightarrow O_2(g) + 2H_2(g) + 4H_2O(l)$$

$$\boxed{2H_2O(l) \longrightarrow O_2(g) + 2H_2(g)}$$

(ii.) By electrolysis of $Ba(OH)_2$ (aq.)

→ Highly pure H_2 (99.95%) is produced by this method.

(iii.) By Coal - gasification

→ By reduction of steam on carbon :

$$C(s) + H_2O(g) \longrightarrow CO(g) + H_2(g)$$

Red hot — steam

CO & H_2 in 1:1 ratio = water gas

1:3 ratio = synthesis gas

syn gas

synthesis methanol.

New convention → other than 1:1 ratio it is called syn gas used to produce alcohol & hydrocarbon.

→ Removal of CO gas is done by treating water gas mixture with steam in presence of $FeCrO_4$ catalyst.

$$CO(g) + H_2(g) \xrightarrow{Fe(CrO_4)} CO_2 + 2H_2 \xrightarrow{NaOH} Na_2CO_3$$

→ CO is shifted from water gas therefore it is called water gas shift rxn.

PHYSICAL PROPERTIES OF HYDROGEN

(i.) Colourless, odourless, tasteless & combustible gas.

(ii.) It is used as fuel in rocket in liquid form.

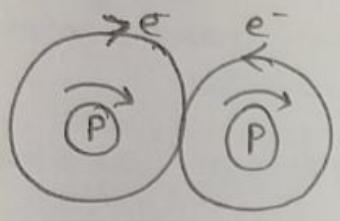
(iii.) Reactivity is low due to high bond energy of H-H & small bond length of H-H bond.

(iv.) H-H Bond energy → 439 kJ/mol & Bond length → 74 Pm

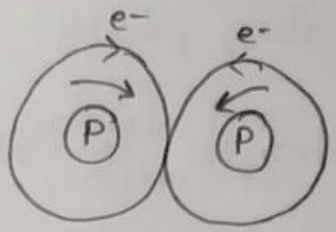
(v.) H-H bond length is shortest among all single bonds.

ORTHO & PARA HYDROGEN

→ Each charged particle shows spin
→ Electron & proton both shows spin.
→ Electron has opposite spin.
→ Proton can show same / opposite spin.
→ Ortho & para form combinedly b/a nuclear isomers of each other.



ortho - hydrogen
(parallel spin)



para- hydrogen
(opp. spin)

Ortho form of H_2

→ When the proton in nucleus have spin in same direction.
→ More stable.
Para form has tendency to get converted into ortho.
→ It exist at high temp.
→ At a room temp.
para : ortho = 1 : 3

Para form of H_2

→ When the proton in nucleus have spin in opp. direction.
→ Less stable.
→ It exist at low temp.
→ (below room temp.) at freezing point H_2 exist in para form only.

COMPOUNDS OF HYDROGEN

1. Hydrides
   (i.) Ionic (ii.) Covalent (iii.) Non- stoichiometric
2. Oxides (H_2O, D_2O)
3. Per- oxides (H_2O_2)

HYDRIDES

(i.) Ionic Hydride

→ It is also k/a salt like or saline hydride or ionic hydrides.

→ S- block metals combine with hydrogen to form ionic hydride. except Be & Mg (predominantly covalent)

Ex→ LiH, NaH, KH, RbH, CsH : Alkali metal hydrides

CaH_2, SrH_2, BaH_2 : Alkaline earth metal hydrides.

→ The ionic structure of these hydrides resemble with NaCl.

→ So they are k/a salt like or saline hydrides (saline : sea water : NaCl)

LiH > NaH > KH > RbH > CsH : Boiling pt. & melting pt.

$$L.E \propto \frac{Charge}{size}$$

→ Due to increase in size of metal atom, lattice energy decreases as a result MP & BP decrease on moving down the group.

Properties of Ionic Hydride

→ These hydrides produce H_2 gas on hydrolysis

$$NaH + H_2O \longrightarrow NaOH + H_2(g)$$

→ On electrolysis of these hydrides $H_2(g)$ is released at anode.

→ These hydrides makes complex compounds (Reducing agent)

$$4LiH + AlCl_3 \longrightarrow \underset{\text{strong R.A}}{LiAlH_4} + 3LiCl$$

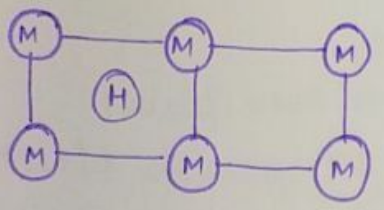
(Lithium aluminium hydride)

$$NaH + B_2H_6 \longrightarrow \underset{\text{strong R.A}}{2NaBH_4}$$

(Sodium boro hydride)

(ii.) Metallic Hydrides

→ These hydrides are formed by d & f block metals.
→ Hydrogen due to small size occupy some space of the interstitial sites & therefore they are also interstitial hydrides.



Interstitial lattice site

→ These hydrides are always non-stoichiometric i.e, they will have variable composition.

Ex → $TiH_{1.5 \text{ to } 1.8}$ $ZrH_{1.3 \text{ to } 1.5}$

→ Among D-block metal, group 7, 8, 9, do not form hydrides & this is also hydride gap. (Fe, Co, Ni shows hydride gap).

(iii.) Covalent or Non-metallic Hydride

→ These are formed by P-block element except noble gas.

Classification of covalent hydride

(i.) e^--Deficient
(ii.) e^--Precise
(iii.) e^--Rich hydrides

e^--Deficient

→ Do not follow Lewis octet rule.
→ Less than 8 e^- in the valence shell.
→ Ex. AlH_3, BH_3
→ Generally formed by 13th group element.
→ These act as Lewis acid
→ AlH_3 & BH_3 exist in dimer for stability.

e^- Precise

→ Follow Lewis octet rule.
→ Generally formed by 14th group element
→ Ex. CH_4, SiH_4, GeH_4, PbH_4

e^- Rich Hydrides

→ These contain extra e^- pair (lone pair)
→ Generally formed by 15, 16, 17 group element.
→ These follow Lewis octet rule.
→ Ex → NH_3, PH_3, H_2O, H_2S, HF, HCl
→ These act as Lewis base.

COMPOUNDS OF HYDROGEN

1. H_2O (Normal water)
2. D_2O (Heavy water)
3. H_2O_2 (Hydrogen per oxide)

H_2O (NORMAL WATER)

→ 80% of earth contains water in it.
→ Molecular mass = 18
→ Molecular mass is low so it has low attractive forces.
→ Melting pt. = 273K
→ Boiling pt. = 373K
→ shows H- bonding

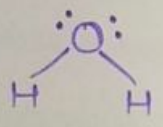
D_2O (HEAVY WATER)

→ Molecular mass = 20
→ Molecular mass is ~~more~~ high so it has more attractive forces.
→ Melting pt. = 274 K
→ Boiling pt. = 376 K
→ shows D- bonding

STRUCTURE OF WATER

Gas

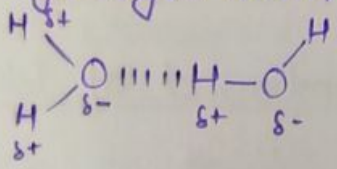
1. Discrete units H_2O molecules present.



2. Due to l.p - l.p repulsion bond angle = 104°5
3. Hybridization : sp^3
   Shape : Bent / angular

Liquid

1. Water molecules are bonded together through Hydrogen bond



Solid

1. Water molecules are tetrahedrally Hydrogen bonded.
2. Cage like str. form with voids.

→ Due to voids in str. ice density of ice is low. So it floats over water.

→ One water molecule in ice form can make max. 4 H-bond

Density of water

→ Density of water is max. at 4°C & decrease above & below of 4°C.

$$(d)_{4°C} = \frac{1\,gm}{ml}$$

Polar nature of water

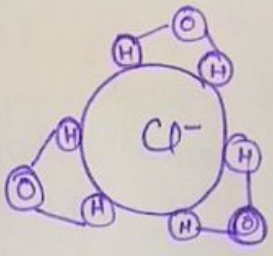
→ H_2O is polar solvent bcoz net dipole is not zero.

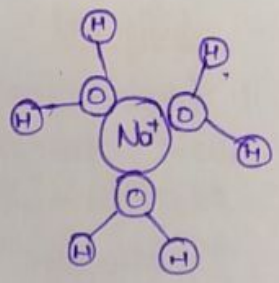
→ Like dissolve like : water dissolves ionic & polar comp.

→ H_2O has highest dielectric constant (84) so it is a universal solvent.

→ The dipole moment of H_2O is 1.84 D

HYDRATION OF NaCl IN WATER





Hydrated Compound of Water

→ Anhydrous salt : $CuSO_4$

→ Hydrated salt : $CuSO_4 \cdot 5H_2O$ (Blue vitriol)

This water of crystallization can be in 3 form :-

(1.) Coordinated Water

(2.) H- bonded Water

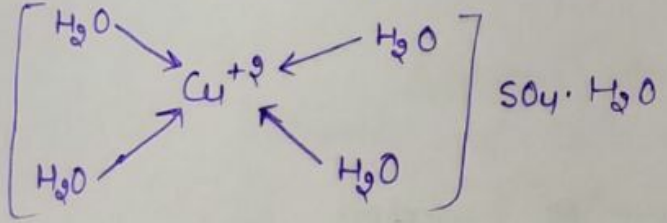
(3.) Interstitial water

1. Coordinated Water :- H_2O bonded with coordinate bond.

Ex → $[Cu(H_2O)_6]^{+3}$, $[Ni(H_2O)_6]^{+2}$

2. H- Bonded Water :- H_2O bonded with H bond.

Ex → $CuSO_4 \cdot 5H_2O$, $FeSO_4 \cdot 7H_2O$, $ZnSO_4 \cdot 5H_2O$



$CuSO_4 \cdot 5H_2O \xrightarrow{\Delta} CuSO_4 \cdot 4H_2O + H_2O$

$CuSO_4 \cdot 4H_2O \xrightarrow[\text{strong}]{\Delta} CuSO_4 + 4H_2O$

3. Interstitial Water :- H_2O occupy interstitial site in $BaCl_2$ lattice.

Ex → $BaCl_2 \cdot 2H_2O$