LESSON 4 HYDROGEN

IMPORTANT REACTIONS

1. $CO + H_2O \rightarrow CO_2 + H_2$
2. ${}^{6}_{3}Li + {}^{1}_{0}n \rightarrow He + {}^{3}_{1}T$
3. $2D_2O \xrightarrow{\text{Electrolysis}} 2D_2 + O_2$
4. $4LiH + AlCl_3 \rightarrow LiAlH_4 + 3LiCl$
5. $4NaH + B(OCH_3)_3 \rightarrow NaBH_4 + 3CH_3ONa$
6. ${}^{3}_{1}T \rightarrow {}^{3}_{2}He\ {}^{0}_{-1}e$
7. $CH_4 + 2D_2 \rightarrow CD_4 + 2H_2$
8. $2NH_3 + 3D_2 \rightarrow 2ND_3 + 3H_2$
9. $2Na + 2H_2O \rightarrow 2NaOH + H_2$
10. $3Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2$
11. $Cl_2 + H_2O \rightarrow HCl + HOCl$
12. $2F_2 + 2H_2O \rightarrow 4HF + O_2$
13. $SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$
14. $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$
15. $2NaOH + D_2O \rightarrow 2NaOH + HOD$
16. $HCl + D_2O \rightarrow DCl + HOD$
17. $NH_4Cl + 4\ D_2O \rightarrow ND_4Cl + 4HOD$
18. $H_3PO_2 + D_2O \rightarrow H_{FVFCCCGZ}DPO_2 + HOD$
19. $2NaOH + D_2O \rightarrow 2NaOH + HOD$
20. $CaC_2 + 2D_2O \rightarrow Ca(OD)_2 + C_2D_2$
21. $Mg_3H_2 + 6\ D_2O \rightarrow 3Mg(OD)_2 + 2ND_3$
22. $Ca_3P_2 + 6\ D_2O \rightarrow 3Ca(OD)_2 + 2PD_3$
23. $2FeSO_4 + H_2SO_4 + H_2O_2 \rightarrow Fe_2(SO_4)_3 + 2H_2O$

224. $2KMnO_4 + 3H_2O_2 \rightarrow 2MnO_2 + 2KOH + 2H_2O + 3O_2$

24. 25. $PbS + 4H_2O_2 \rightarrow PbSO_4 + 4H_2O$

IMPORTANT FORMULA

- Water Gas – $CO + H_2$ (Synthetic or syn gas)
- Heavy water – (D_2O)
- Protium or Ordinary hydrogen – ${}_1H^1$
- Deuterium or Heavy hydrogen – ${}_1D^2$
- Tritium or Radioactive hydrogen – ${}_1T^3$
- Lithium Aluminium Hydride – $LiAlH_4$
- Sodium borohydride – $NaBH_4$
- Deutero Methane – CD_4
- Deutero Ammonia – ND_3
- Copper sulphate pentahydrate – $CuSO_4.{}_5H2O$
- Hypochlorous acid – ND_3
- Zeolite or Hydrated sodium alumino silicate – $NaO.Al_2O_3.\ xSiO_2.\ yH_2O$, where x = 2 to 10 and y = 2 to 6.
- Sodium deuteroxide – NaOD

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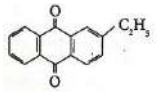
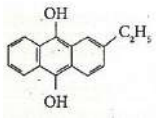
- Deuterium chloride – DCl
- Deuterium ammonium chloride – ND_4Cl
- Deutero acetylene – C_2D_2
- Deutero phosphine – PD_2
- Deutero hypophosphorous acid – H_2DPO_2
- 2 – ethyl anthro  quinine -
- 2 – ethyl anthro quinol- 
- Hydrogen peroxide – H_2O_2

Important Points to Remember

❖ **Occurrence of Hydrogen –** The sun and stars are composed of 85-95% Hydrogen. It is present in the form of water, organic compounds and in all living matter.

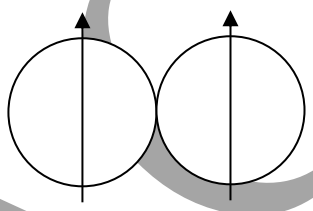
$H \rightarrow$ electrically neutral

$H^+ \rightarrow$ Proton

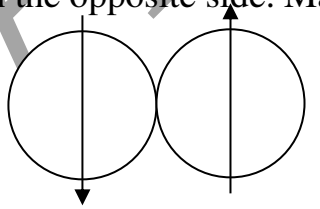
$H^- \rightarrow$ Hydride

$H_2 \rightarrow$ diatomic gaseous molecule.

❖ **Ortho hydrogen –** The hrdrogen molecule in which the nuclear spins of the two hydrogen atoms are in the same side. Magnetic moment of it is twice.

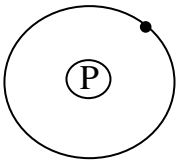
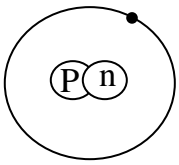
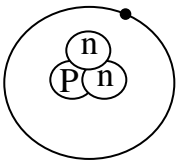


❖ **Para hydrogen –** The hydrogen molecule in which the nuclear spins of the two hydrogen atoms are in the opposite side. Magnetic moment of it is zero.



❖ **Isotopes of hydrogen –** Protium ${}_1^1H$, Deuterium ${}_1^2H$, and Tritium ${}_1^3H$.

Protium	Deuterium	Tritium
${}_1^1H$ (or)	${}_1^2H$ (or)	${}_1^3H$ (or)

H	D	T
No. of electrons 1	1	1
No. of Protons 1	1	1
No. of neutrons 0	1	2
Ordinary Hydrogen occurrence 99.984% 	Heavy Hydrogen 0.0156% 	Radioactive Hydrogen very little amount. 1 atom per 10^{18}H atoms. 

- **Half life period of Tritium –** 12.33 years.
- **Isotopic effect –** In a chemical reaction, when one of the atoms in the reactants is replaced by one of its isotoes.
- **Uses of Deuterium –** It is used to study the movement of ground water and the hydrogen atom transfer mechanism in chemical reactions.
- **Uses of Tritium –** It is used as a tracer element and it find applications such as emergency exit signs, illumination of wrist watches.
- **Preparation of Tritium –** It occurs naturally as a result of nuclear reactions induced by cosmic rays in the upper atmosphere.

$${}^{14}_{7}N + {}^{1}_{0}n \rightarrow {}^{12}_{6}C + {}^{3}_{1}H$$

$${}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{1}H + {}^{1}_{1}H$$

$${}_{3}Li^{6} + {}^{1}_{0}n \rightarrow {}_{2}He^{4} + {}_{1}H^{3}$$

- **Preparation of Hydrogen**
  - Electrolysis of water.
  - Action of dilute acids with metals like zinc, iron, tin.
  - Steam reforming of hydrocarbons.
  - Reaction of steam with red hot coke.
  - Reaction of carbon monoxide with water.
  - Cracking of long chain hydrocarbons.
- **Properties of hydrogen –** It is a colourless, odourless, tasteless, lightest and inflammable ges.

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❖ **Uses of hydrogen**

(i) In the manufacture of Ammonia and Nitric acid.

(ii) In the synthesis of methanol.

(iii) As hydrogenating agent.

(iv) As reducing agent in metallurgy.

(v) Calcium hydride is used as desiccant (drying agent).

(vi) $NaBH_4$, $LiAlH_4$ used as reducing agent in organic chemistry.

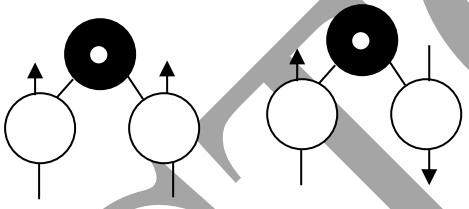
(vii) Atomic hydrogen and oxyhydrogen torches for cutting and welding.

(viii) Liquid hydrogen is used as rocket fuel.

(ix) H_2 is used in fuel cells for generating electricity.

❖ **Water –** H_2O. It is the universal solvent. It occurs in the form of rivers and oceans (97.33%).

❖ **Ortho H_2O and Pare H_2O –** At the temperature conditions of the earth (300K), the OPR of H_2O is 3. It is known that the OPR of water in interstellar clouds and comets has more para-H2O (OPR = 2.5) than on Earth.



❖ **Physical properties –** Water is a colourless and volatile liquid. Hydrogen bonding responsible for high melting and boiling points of water.

❖ **Chemical properties –** Water reacts with metals, non-metals and compounds.

❖ **Hard water –** Water containing high amounts of bicarbonate, chloride and sulphate of magnesium and calcium is called hard water.

❖ **Soft water –** Water containing soluble salts of calcium and magnesium is called soft water.

❖ **Soap –** Sodium or Potassium salts of long chain fatty acids.

❖ **Temporary hardness –** It is due to the presence of soluble bicarbonates of magnesium and calcium. It is removed by heating or by treating with lime.

❖ **Permanent hardness –** It is due to the presence of soluble salts of magnesium and calcium in the form of chlorides and sulphates in water. It can be removed by washing soda or by ion exchange.

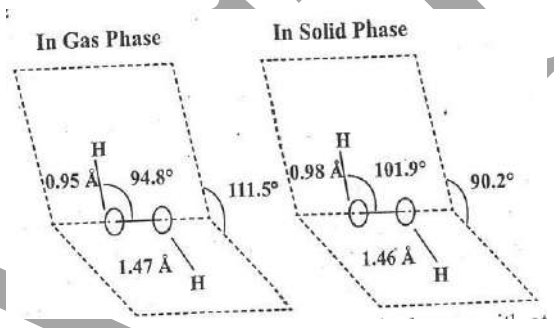
❖ **Ion exchange –** Hardness of water can be removed by passing through as ion exchange bed like zeolites or polymer (resin) containing column.

- **Zeolites –** Hydrated sodium alumino-silicates

  $NaO.Al_2O_3.xSiO_2.yH_2O$ (x = 2-10, y=2-6).

- **Premutit (or) zeolite process –** The softening of water process by using complex structure represented as $Na_2 – Z$ with sodium as exchangeable cations.

- **Methods used to soften hard water –** Chelating method and reverse osmosis.
- **Chelating method –** EDTA is used in this.
- **Reverse osmosis –** High pressure to force water through a semipermeable membrane.
- **Heavy water –** D_2O. It is present as one part in 5000 parts of ordinary water.
- **Proparation of D_2O –** It is prepared by continuous electrolysis of ordinary water. It undergoes exchange reactions.
- **Uses of D_2O – D_2O** is used in isotopic effect, used as moderator in nuclear reactors, used to prepare deuterium compounds.
- **Hydrogen peroxide (H_2O_2) –** It is a pale blue (almost colourless) liquid. It is prepared by the action of dilute acid with metal peroxide.
- **Uses of H_2O_2 –** Oxidising agent, mild antiseptic, as a bleaching agent in textile, paper and hair-care industry and used as reducing agent.
- **Structure of H_2O_2 –**



- **Hydrides –** A binary hydride is a compound formed by hydrogen with other electropositive elements. e.g. LiH, MgH_2.
- **Ternary hydrides –** Compounds in which molecule is constituted by hydrogen and two types of elements. e.g. $LiBH_4$, $LiAlH_4$.
- **Types of hydrides-**

Ionic hydrides	Covalent hydrides	Metallic hydrides
Electropositive metal + hydrogen	Non-metals + Hydrogen	Metals + Hydrogen
Formation of hydrogen by transfer of electrons.	Formation of hydride by equal sharing of electrons.	Hydrogen occupies voids in metals.

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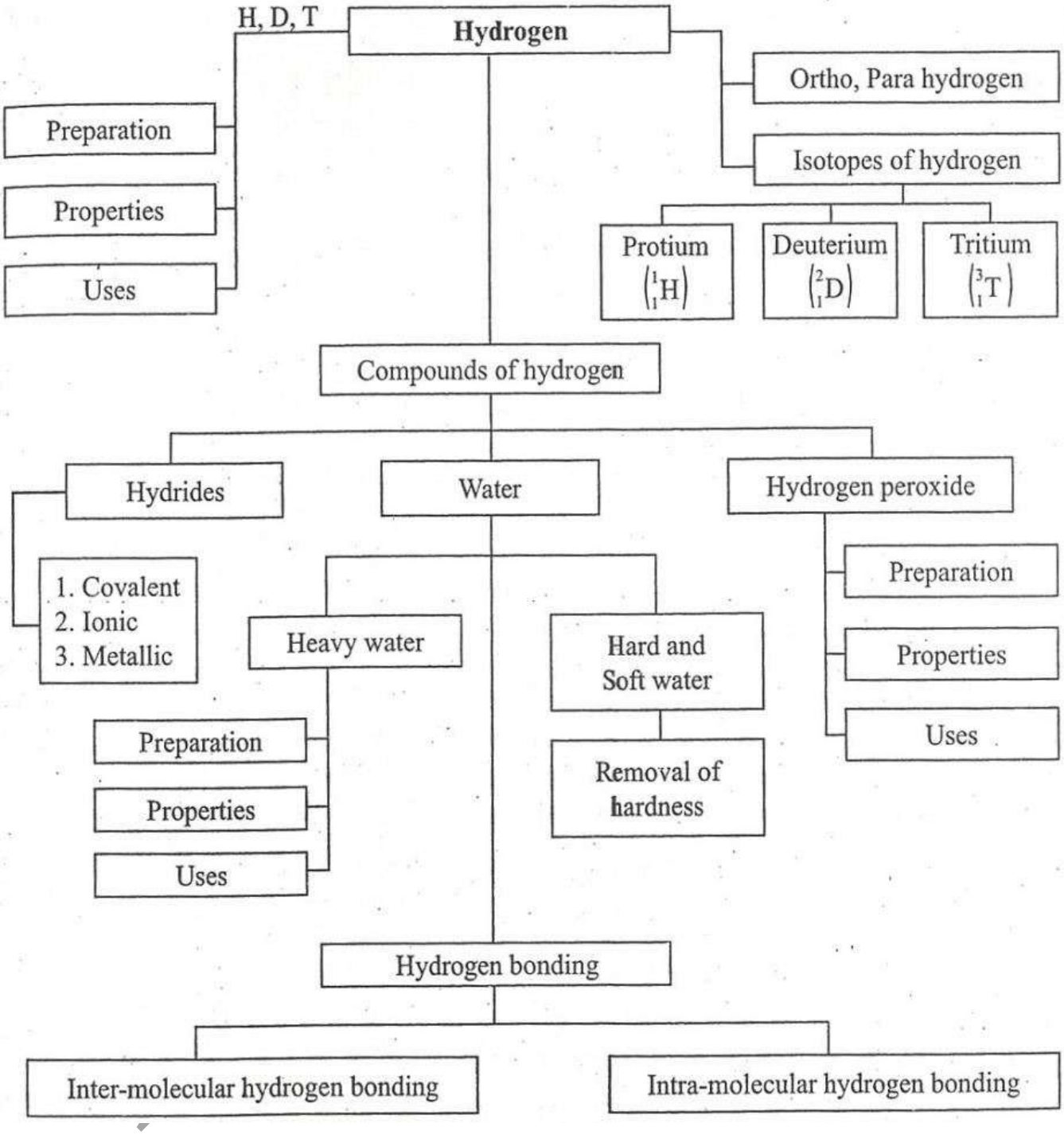
e.g. LiH, CaH_2	e.g. CH_4, SiH_4	e.g. ZnH_2, TiH.

- **Hydrogen sponge –** Metal hydride as (PdH) Palladium hydride. It is formed by a chemical reaction but it behaves like a physical storage method. i.e., it is absorbed and released like a water sponge.
- **Hydrogen bonding –** When a hydrogen atom is covalenty bonded to a highly electronegative atom [N (or) D (or) F], the bond is polarised in such a way that the hydrogen atom is able to form a weak bond between the hydrogen atom and the electronegative atom of a second molecule. This is called a hydrogen bond and denoted as dotted lines (……..).
- **Type of hydrogen bonding –** Intra molecular hydrogen bonding and inter molecular hydrogen bonding.
- **Intra molecular hydrogen bonding –** These bonds are those which occur within one single molecule. e.g., ortho-nitrophenol and salicylaldehyde.
- **Inter molecular hydrogen bonding –** These bonds are formed between two separate molecules. e.g., Ammonia, water, hydrogen fluoride, acetic acid.
- **Gas hydrates –** They are a kind of inclusion compounds, where gas molecules are trapped in a crystal lattice having voids of right size, with being chemically bonded. e.g., H_3O^+ in gas phase similar to methane hydrate.
- **Clatharate hydrate –** Gas hydrates in which guest molecules are not bonded chemically but retained by the structure of host is called Clatharate hydrates. e.g., Methane hydrate CH_420H_2O.
- **Crystalline hydrates –** In this type, hydrogen bonding is present. Water molecules serve to fill in the interstices and bind together structure. e.g., $CuSo_4.5H_2O$, $Na_2CO_3.10H_2O$, $FeSO_4.7H_2O$.
- **The atomic bomb –** The hydrogen bomb uses both nuclear fission and fusion is called atom bomb or Thermonuclear bombs.
- **The future fuel –** Hydrogen is considered as a potential fuel as it is a clean burning fuel. This fuel is free from pollutants.

CHAPTER MAP



Choose the correct answer:

1. **Which of the following statements about hydrogen is incorrect ? (NEET - 2016)**

a) Hydrogen ion, H_3O^+ exists freely in solution. b) Dihydrogen acts as a reducing agent.

c) Hydrogen has three isotopes of which tritium is the most common.

d) Hydrogen never acts as cation in ionic salts.

2. Water gas is

a) $H_2O_{(g)}$ b) $CO + H_2O$ **c) $CO + H_2$** d) $CO + N_2$

3. Which one of the following statements is incorrect with regard to ortho and para dihydrogen?

a) They are nuclear spin isomers

b) Ortho isomer has zero nuclear spin whereas the para isomer has one nuclear spin

c) The para isomer is favoured at low temperatures

d) The thermal conductivity of the para isomer is 50% greater than that of the ortho isomer.

4. Ionic hydrides are formed by

a) halogens b) chalogens c) inert gases **d) group one elements**

5. Tritium nucleus contains

a) 1p + 0 n b) 2 p + 1n **c) 1p + 2n** d) none of these

6. Non-stoichiometric hydrides are formed by

a) palladium, vanadium b) carbon, nickel c) manganese, lithium d) nitrogen, chlorine

7. Assertion : Permanent hardness of water is removed by treatment with washing soda.

Reason : Washing soda reacts with soluble calcium and magnesium chlorides and sulphates in hard water to form insoluble carbonates

a) Both assertion and reason are true and reason is the correct explanation of assertion.

b) Both assertion and reason are true but reason is not the correct explanation of assertion.

c) Assertion is true but reason is false d) Both assertion and reason are false

8. If a body of a fish contains 1.2 g hydrogen in its total body mass, if all the hydrogen is replaced with deuterium then the increase in body weight of the fish will be

a) 1.2 g b) 2.4 g c) 3.6 g d) $\sqrt{4.8}$ g

9. **The hardness of water can be determined by volumetrically using the reagent**

a) sodium thio sulphate b) potassium permanganate c) hydrogen peroxide **d) EDTA**

10. **The cause of permanent hardness of water is due to**

a) $Ca(HCO_3)_2$ b) $Mg(HCO_3)_2$ **c) $CaCl_2$** d) $MgCO_3$

11. **Zeolite used to soften hardness of water is, hydrated**

a) Sodium aluminium silicate b) Calcium aluminium silicate

c) Zinc aluminium borate d) Lithium aluminium hydride

12. **A commercial sample of hydrogen peroxide marked as 100 volume H_2O_2, it means that**

a) 1 ml of H_2O_2 will give 100 ml O_2 at STP b) 1 L of H_2O_2 will give 100 ml O_2 at STP

c) 1 L of H_2O_2 will give 22.4 L O_2 d) 1 ml of H_2O_2 will give 1 mole of O_2 at STP

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13. **When hydrogen peroxide is shaken with an acidified solution of potassium dichromate in presence of ether, the ethereal layer turns blue due to the formation of**

a) Cr_2O_3 b) CrO_4^{2-} **c) $CrO(O_2)_2$** d) none of these

14. **For decolourisation of 1 mole of acidified $KMnO_4$, the moles of H_2O_2 required is**

a) 1/2 b) 3/2 **c) 5/2** d) 7/2

15. **Volume strength of 1.5 N H_2O_2 is**

a) 1.5 b) 4.5 c) 16.8 **d) 8.4**

16. **The hybridisation of oxygen atom is H_2O and H_2O_2 are, respectively**

a) sp and sp^3 b) sp and sp c) sp and sp^2 **d) sp^3 and sp^3**

17. **The reaction $H_3PO^2 + D_2O \rightarrow H_2DPO_2 + HDO$ indicates that hypo-phosphorus acid is**

a) tribasic acid b) dibasic acid **c) mono basic acid** d) none of these

18. **In solid ice, oxygen atom is surrounded**

a) tetrahedrally by 4 hydrogen atoms

b) octahedrally by 2 oxygen and 4 hydrogen atoms

c) tetrahedrally by 2 hydrogen and 2 oxygen atoms d) octahedrally by 6 hydrogen atoms

19. **The type of H-bonding present in ortho nitro phenol and p-nitro phenol are respectively**

a) inter molecular H-bonding and intra molecular H-bonding

b) intra molecular H-bonding and inter molecular H-bonding

c) intra molecular H - bonding and no H - bonding

d) intra molecular H - bonding and intra molecular H - bonding

20. **Heavy water is used as**

a) modulator in nuclear reactions b) coolant in nuclear reactions

c) both (a) and (b) d) none of these

21. Water is a

a) basic oxide b) acidic oxide **c) amphoteric oxide** d) none of these

Answer the following:

22**. Explain why hydrogen is not placed with the halogen in the periodic table.**

(i) Hydrogen has a tendency to gain one electron to from hydride ion whose electronic configuration is similar to the noble gas (He).

(ii) However the electron affinity of hydrogen is much less than that of halogen atoms.

(iii) Hence hydrogen is less reactive as compared to halogens.

(iv) Due to this unique behavior hydrogen is not placed with halogens in the periodic table.

23. Discuss the three types of Covalent hydrides.

Covalent hydrides are compounds in which hydrogen is attached to another element by sharing of electrons.

Covalent hydrides are further divided into three categories, viz.,

- electron precise (CH_4, C_2H_6, SiH_4, GeH_4),
- electron-deficient (B_2H_6), and

- electron-rich hydrides (NH_3,H_2O)

24. Predict which of the following hydrides is a gas on a solid (a) HCl (b) NaH. Give your reason.

- HCl is a gas because of absence of intermolecular hydrogen bonding
- NaH is a solid because of electron transfer.

(OR)

(a) Gas- due to the absence of their molecular hydrogen bonding.

(b) Solid- Reason : NaH is a ionic hydride formed by transfer of electrons from metal to hydrogen. They have high lattice enthalpy and high density since hydride ions occupy holes in the lattice of metal without distorting the metal lattice.

25. Write the expected formulas for the hydrides of 4th period elements. What is the trend in the formulas? In what way the first two numbers of the series different from the others ?

(i) The first two elements of period 4, K and Ca form hydrides with the formula MH and MH_2 ie,(MHn). They are ionic hydrides and have high melting and boiling points.

(ii) Elements from Sc to Zn form metallic or interstitial hydrides are non stoichiometric hydrides which do not follow the law of constant composition.

(iii) Elements from Ga to Br, the general formula is XH_{8-n}, where n is the number of valence electrons.

26. Write chemical equation for the following reactions.

i) reaction of hydrogen with tungsten (VI) oxide NO_3 on heating.

ii) hydrogen gas and chlorine gas.

(i) $WO_3 + 3H_2 \rightarrow W + 3H_2O$

(ii) $H_2 + Cl_2 \rightarrow 2HCl$.

27. Complete the following chemical reactions and classify them in to (a) hydrolysis (b) redox (c) hydration reactions.

1) $KMnO_4 + H_2O_2 \rightarrow 2MnO_2 + 2KOH + 2H_2O + 3O_2$

2) $CrCl_3 + H_2O \rightarrow CrCl_3.6H_2O$ (hydration)

3) $CaO + H_2O \rightarrow Ca(OH)_2$ (hydrolysis)

28. Hydrogen peroxide can function as an oxidising agent as well as reducing agent. substantiate this statement with suitable examples.

Hydrogen peroxide can act both as an usually performed in acidic medium while the reduction reactions are performed in basic medium.

In acidic conditions:

$H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$ ($E^\circ = +1.77$ V)

For example

$2FeSO_4 + H_2SO_4 + H_2O_2 \rightarrow Fe_2(SO_4)_3 + 2H_2O$

In basic conditions:

$HO^{2-} + OH^- \rightarrow O_2 + H_2O + 2e^-$ ($E^\circ = +0.08$ V)

For example

$2KMnO_{4(aq)} + 3H_2O_{2(aq)} \rightarrow MnO_2 + 2KOH + 2H_2O + 3O_{2(g)}$

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29. Do you think that heavy water can be used for drinking purposes ?

(i) The chemical reactions shown by water and heavy water are nearly identical.

(ii) However, due to differences in masses of hydrogen and deuterium, such reactions occur at different rates.

(iii) The rates of reactions involving D_2O are slower than those involving H_2O

(iv) If D_2O is consumed, the enzyme catalyzed biochemical reactions will occur slower than their optimum rate.

(v) The enzymes may than lose their ability to catalyze a biochemical reaction

(vi) Thus heavy water will interfere and disturb the biological process and hence it is not suitable for drinking purposes.

30. What is water-gas shift reaction ?

The carbon monoxide of the water gas can be converted to carbon dioxide by mixing the gas mixture with more steam at 400° C and passed over a shift converter containing iron/copper catalyst. This reaction is called as water-gas shift reaction.

$$CO + H_2O \rightarrow CO_2 + H_2$$

The CO_2 formed in the above process is absorbed in a solution of potassium carbonate.

$$CO_2 + K_2CO_3 + H_2O \rightarrow 2KHCO_3$$

31. Justify the position of hydrogen in the periodic table ?

(i) Hydrogen has the electronic configuration of $1s^1$ which resembles with ns^1 general valence shell configuration Of alkali metals and shows similarity with them as follows:

1. It forms unipositive ion (H^+) like alkali metals (Na^+, K^+, Cs^+)

2. It forms halides (HX), oxides (H_2O), peroxides (H_2O_2) and sulphides (H_2S) like alkali metals(NaX, Na_2O, Na_2O_2, Na_2S)

3. It also acts as reducing agent.

(ii) Since, hydrogen has similarities with alkali metals as well as the halogens ; it is difficult to find the right right position in the periodic table. However, in most of its compounds hydrogen exists in +1 oxidation state. Therefore, it is reasonable to place the hydrogen in group 1 along with alkali metals as shown in the latest periodic table published by IUPAC.

(iii) Unlike alkali metals hydrogen has higher ionization energy.

(iv) Hydrogen also has a tendency to gain one electron to form hydride ion (H^-) whose electronic configuration is similar to the noble gas, helium. However, the electron affinity of hydrogen is much less than that of halogen atoms.

32. What are isotopes? Write the names of isotopes of hydrogen.

Isotopes: Atoms of the same element having same atomic number but different mass number are called isotopes.

	Isotopes of Hydrogen	Symbol	Atomic No	Mass No
(i)	Protium or hydrogen	$_1H^1$	1	1
(ii)	Deuterium	$_1H^2$	1	2

(iii)	Tritium	$_1H^3$	1	3

33. Give the uses of heavy water.

i. Heavy water is widely used as moderator in nuclear reactors.
ii. It is commonly used as a tracer to study element reaction mechanisms.
iii. It is used as a coolant in nuclear reactors.
iv.

34. Explain the exchange reactions of deuterium.

Deuterium can replace reversibly hydrogen in compounds either partially or completely depending upon the reaction conditions.

$CH_4 + 2D_2 \rightarrow CD_4 + 2H_2$

Deutero methane

$2NH_3 + 3D_2 \rightarrow 2ND_3 + 3H_2$

Deutero ammonia

35. How do you convert parahydrogen into ortho hydrogen ?

i. By treatment with catalyst like Pt **or** Fe
ii. By passing an electric discharge
iii. By heating to 800° C or more
iv. By mixing with paramagnetic molecules like O_2, NO, NO_2.
v. By mixing with nascent hydrogen or atomic hydrogen.

36. Mention the uses of deuterium.

i. It is used as tracers in the study of mechanism of chemical reactions
ii. High speed deuterons are used in artificial radioactivity
iii. Deuterium is mainly used in the preparation of heavy water (D_2O). Which is employed as moderator in nuclear reactor to slow down the speed of fast moving neutrons.

37. Explain preparation of hydrogen using electrolysis.

Obtained by electrolysis of water

i. **Electrolyte:** Water containing traces of acids or alkali or the electrolysis of aqueous solution of sodium hydroxide or potassium hydroxide
ii. **Anode:** Nickel
iii. **Cathode:** Iron
iv. **At anode:** $2OH^- \rightarrow H_2O + ½\ O_2 + 2e^-$
v. **At Cathode :** $2H_2O + 2e^- \rightarrow 2OH^- + H_2$
vi. **Overall reaction:** $H_2O \rightarrow H_2 + ½\ O_2$

38. A groups metal (A) which is present in common salt reacts with (B) to give compound (C) in which hydrogen is present in –1 oxidation state. (B) on reaction with a gas (D) to give universal solvent (E). The compound (E) on reacts with (A) to give (B), a strong base. Identify A, B, C, D , E and F. Explain the reactions.

(i) Metallic **sodium (A)** reacts with **hydrogen (B)** to give **sodium hydride (C).**

$2\ Na + H_2 \rightarrow 2NaH$

(A) (B) (C)

(ii) Hydrogen reacts with a gas (oxygen) to give **water (D)**

$2H_2 + O_2 \rightarrow 2H_2O$

(B) (D) (E)

(iii) Water reacts with sodium to give **sodium hydroxide (E)** and hydrogen (B)

$2H_2O + 2Na \rightarrow 2NaOH + H_2$

(E) (A) (F) (B)

A	Na	Sodium
B	H_2	Hydrogen
C	NaH	Sodium Hydride
D	O_2	Oxygen
E	H_2O	Water
F	NaOH	Sodium hydroxide

39. An isotope of hydrogen (A) reacts with diatomic molecule of element which occupies group number 16 and period number 2 to give compound (B) is used as a modulator in nuclear reaction. (A) adds on to a compound (C), which has the molecular formula C_3H_6 to give (D). Identify A, B, C and D.

(i) Isotope of hydrogen reacts with which is oxygen to give **heavy water (B)**

$2D_2 + O_2 \rightarrow 2D_2O$

(A) (B)

(ii) Deuterium (A) undergoes addition reaction with **propane (C)** to give **propane deuteride (D)**

$CH_3CH = CH_2 + D_2 \rightarrow CH_3 - CHD - CH_2D$

A	D_2	Deuterium
B	D_2O	Heavy water or deuterium oxide
C	$CH_3 - CH = CH_2$	Propene
D	$CH_3 - CHD - CH_2D$	Propane deuteride

40. NH_3 has exceptionally high melting point and boiling point as compared to those of the hydrides of the remaining element of group 15 - Explain.

- **NH_3** has higher boiling and melting point **compared to** all other hydrides of **group 15** elements due to intermolecular hydrogen bonding**.**
- Each molecule can from a maximum of 4 hydrogen bonds but on average 1 hydrogen bond per molecule as there is only one lone pair on NH_3 available for hydrogen bonding.
- Hydrogen bonding is strong intermolecular attraction as H on NH_3 acts like a proton due to partial positive on it whole N atom in another NH_3 molecule, a very strong hydrogen bond is formed.
- Due to much strong intermolecular interactions compared to weaker permanent dipole-dipole interactions between other XH_3 molecules in group 15, large amount of energy are required to overcome the forces, giving it the highest point and highest melting point.

41. Why interstitial hydrides have a lower density than the parent metal.

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Metallic hydrides or interstitial hydrides are less dense than the parent metal. This is due to slight expansion of the lattice during the formation of their hydrides.

22. How do you expect the metallic hydrides to be useful for hydrogen storage ?

In some of the transition metal hydrides, hydrogen is absorbed as H-atoms. Due to the inclusion of H-atoms , the metal lattice expands and thus becomes less stable . Therefore, when such metallic hydride is heated, it decomposes to release hydrogen gas and very finely divided metal. The hydrogen evolved in this manner can be used as a fuel. Thus, transition metals or their alloys can act as sponge and can be used to store and transport hydrogen to be used as a fuel.

43. Arrange NH_3, H_2O and HF in the order of increasing magnitude of hydrogen banding and explain the basis for your arrangement.

i. The order of increasing magnitude of H-bonding is, **NH_3 < H_2O < HF**
ii. Strength of H bond depends upon the atomic size and electronegativity of the other atom to which H atom is covalently bonded. Smaller size and higher electronegativity favour H bonding
iii. Among N, F and O the order of electronegativity is **F > O > N.**
iv. Hence HF will have highest magnitude of H bonding.

44. Compare the structures of H_2O and H_2O_2.

STRUCTURE OF H_2O	STRUCTURE OF H_2O_2
H_2O has a bent structure	**H_2O_2** has a open book like structure
The **HOH** bond angle is 104.5^o	The **H-O-O** bond angle is 94.8^o and the dihedral angle 111.5^o in gas phase.
It is a polar molecule **O 95.7 pm** **104.5°** **H H**	H_2O_2 has a non polar structure