HYDROGEN & IT'S COMPOUND

❑ POSITION OF HYDROGEN IN THE PERIODIC TABLE

Hydrogen is the first element in the periodic table. However, its placement in the periodic table has been a subject of discussion in the past. As you know by now that the elements in the periodic table are arranged according to their electronic configurations. Hydrogen has electronic configuration $1s^1$. On one hand, its electronic configuration is similar to the outer electronic configuration (ns^1) of alkali metals , which belong to the first group of the periodic table. On the other hand, like halogens (with ns^2np^5 configuration belonging to the seventeenth group of the periodic table), it is short by one electron to the corresponding noble gas configuration, helium ($1s^2$). Hydrogen, therefore, has resemblance to alkali metals, which lose one electron to form unipositive ions, as well as with halogens, which gain one electron to form uninegative ion. Like alkali metals, hydrogen forms oxides, halides and sulphides. However, unlike alkali metals, it has a very high ionization enthalpy and does not possess metallic characteristics under normal conditions. In fact, in terms of ionization enthalpy, hydrogen resembles more with halogens, $\Delta_i H$ of Li is 520 kJ mol^{-1}, F is 1680 kJ mol^{-1} and that of H is 1312 kJ mol^{-1}. Like halogens, it forms a diatomic molecule, combines with elements to form hydrides and a large number of covalent compounds. However, in terms of reactivity, it is very low as compared to halogens.

Inspite of the fact that hydrogen, to a certain extent resembles both with alkali metals and halogens, it differs from them as well. Now the pertinent question arises as where should it be placed in the periodic table? Loss of the electron from hydrogen atom results in nucleus (H^+) of ~1.510^{-3} pm size. This is extremely small as compared to normal atomic and ionic sizes of 50 to 200pm. As a consequence, H^+ does not exist freely and is always associated with other atoms or molecules. Thus, it is unique in behaviour and is, therefore, best placed separately in the periodic table.

❑ DIHYDROGEN, H_2

◆ Occurrence

Dihydrogen is the most abundant element in the universe (70% of the total mass of the universe) and is the principal element in the solar atmosphere. The giant planets Jupiter and Saturn consist mostly of hydrogen. However, due to its light nature, it is much less abundant (0.15% by mass) in the earth's atmosphere. Of course, in the combined form it constitutes 15.4% of the earth's crust and the oceans. In the combined form besides in water, it occurs in plant and animal tissues, carbohydrates, proteins, hydrides including hydrocarbons and many other compounds.

◆ Isotopes of Hydrogen

Hydrogen has three isotopes: **protium**, ${}_1^1H$, **deuterium**, ${}_1^2H$ or D and **tritium**, ${}_1^3H$ or T. These isotopes differ from one another in respect of the presence of neutrons. Ordinary hydrogen, protium, has no neutrons, deuterium (also known as heavy hydrogen) has one and tritium has two neutrons in the nucleus. In the year 1934, an American scientist, Harold C. Urey, got Nobel Prize for separating hydrogen isotope of mass number 2 by physical methods.

The predominant form is protium. Terrestrial hydrogen contains 0.0156% of deuterium mostly in the form of HD. The tritium concentration is about one atom per 1018 atoms of protium. Of these isotopes, only tritium is radioactive and emits low energy β^- particles.

Atomic and Physical Properties of Hydrogen

Property	Hydrogen	Deuterium	Tritium
Relative abundace (%)	99.985	0.0156	10^{-15}
Relative atomic mass (g mol^{-1})	1.008	2.014	3.016
Melting point / K	13.96	18.73	20.62
Boiling point /K	20.39	23.67	25.0
Density / gL^{-1}	0.09	0.18	0.27
Enthalpy of fusion/KJ mol^{-1}	0.117	0.197	–
Enthalpy of vaporization/kJ mol^{-1}	0.904	1.226	–
Enthalpy of bond dissociation/kJ mol^{-1} at 298.2K	435.88	443.35	–
Internuclear distance/pm	74.14	74.14	–
Ionization enthalpy/kJ mol^{-1}	1312	–	–
Electron gain enthalpy/kJ mol^{-1}	–73	–	–
Covalent radius/pm	37	–	–
Ionic radius(H^-)/pm	208		

Since the isotopes have the same electronic configuration, they have almost the same chemical properties. The only difference is in their rates of reactions, mainly due to their different enthalpy of bond dissociation. However, in physical properties these isotopes differ considerably due to their large mass differences.

◆ **Different forms of Hydrogen :**

(a) Based on oxidation Number.

There are three types of hydrogen

	H^+	H^-	H
	Proton	Hydride	Atomic hydrogen
Number of electron	0	2	1
Oxidation number	+1	–1	0
Formation	$H \rightarrow H^+ + e^-$	$H + e^- \rightarrow H^-$	$H_2 \xrightarrow{\Delta} 2H$

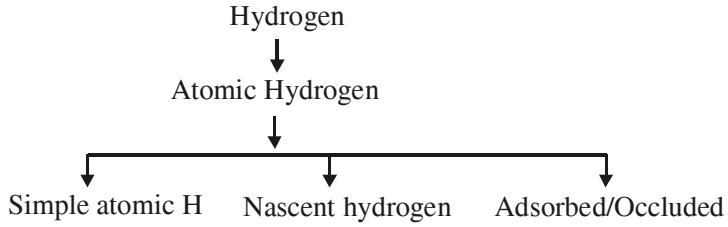
Note : In the aqueous state proton (H^+) exist as $H^+ (H_2O)_n$

Where n is a large number.

If n = 1 $\longrightarrow$ H_3O^+

n = 2 $\longrightarrow$ $H^+(H_2O)_2$

(b) Based on reactivity :



- **Atomic hydrogen :**

(i) Simple atomic hydrogen – It is formed by simple dissociation of hydrogen.

$$H_2 \underset{}{\overset{3000\text{-}5000}{\rightleftharpoons}} 2H$$

Favourable condition – Favourable condition are high temp & low pressure.

(ii) Nascent hydrogen – Hydrogen at the moment of its birth it called nascent hydrogen means which forms at the instant is known as Nascent hydrogen.

It is formed only by some specific chemical reaction.

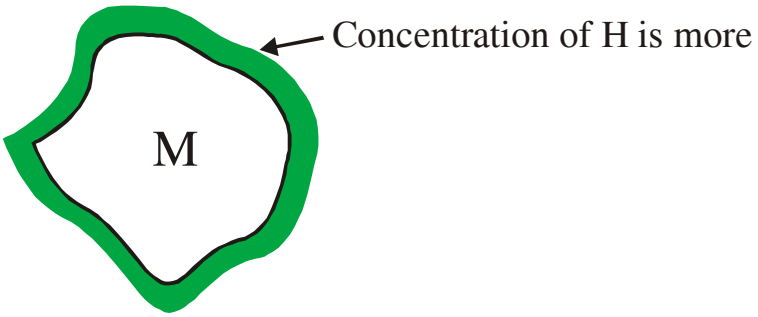
(a) Acid + Metals $\qquad Zn + H_2SO_4 \longrightarrow ZnSO_4 + 2H$

(b) Base + $\underset{\text{(Be, Zn, Al, Ga, Pb, Sn)}}{\text{amphoteric metal}}$ $\qquad 2NaOH + Be \longrightarrow Na_2BeO_2 + 2H$

(c) C_2H_5OH + Alkali metal

$$C_2H_5OH + Na \longrightarrow C_2H_5ONa + H$$

(iii) Adsorbed/Occluded hydrogens



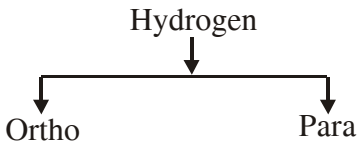
Adsorbed H is hydrogen present at the outer surface of metal.

- **Occlusion :** The property of metal to adsorb any gas is called occlusion.

Reactivity order

Atomic hydrogen > Nascent hydrogen > Molecular hydrogen

(iii) Based on Nuclear spin (Nuclear isomers)



(a) Ortho hydrogen : The molecular form of hydrogen having same spin of nucleus is called ortho hydrogen.

(b) Para hydrogen : The molecular form of hydrogen having opposite spin of nucleus is called para hydrgen.

In ortho hydrogen spin of nucleus is same, so they will repel each other & because of this repulsion, internal energy of ortho hydrogen increases. So ortho hydrogen has more internal energy.

◆ **Stability of ortho & Para hydrogen**

Stability of ortho & para hydrogen depends upon temperature condition.

At low temp : para hydrogen is more stable than ortho hydrogen while at high temp ortho hydrogen is more stable than para hydrogen.

$$P_{H_2} \underset{T\downarrow}{\overset{T\uparrow}{\rightleftharpoons}} O_{H_2}$$

	Ortho	Para
At high temperature	75%	25%
At absolute zero temp.	0	100%

◆ **Imp. Note :**

(i) We can obtain 100% pure para hydrogen at low temp but can't ortho because at high temp parahydrogen will dissociate into atomic hydrogen.

(ii) Ortho & Para hydrogen differs only in physical properties but have same chemical properites.

❑ PREPARATION OF DIHYDROGEN, H_2

There are a number of methods for preparing dihydrogen from metals and metal hydrides.

◆ **Laboratory Preparation of Dihydrogen**

(i) It is usually prepared by the reaction of granulated zinc with dilute hydrochloric acid.

$$Zn + 2H^+ \rightarrow Zn^{2+} + H_2$$

(ii) It can also be prepared by the reaction of zinc with aqueous alkali.

$$Zn + 2NaOH \rightarrow \underset{\text{Sodium zincate}}{Na_2ZnO_2} + H_2$$

◆ **Commercial Production of Dihydrogen**

The commonly used processes are outlined below :

(i) Electrolysis of acidified water using platinum electrodes gives hydrogen.

$$2H_2O(\ell) \xrightarrow[\text{Trances of acid/base}]{\text{Electrolysis}} 2H_2(g) + O_2(g)$$

(ii) High purity (>99.95%) dihydrogen is obtained by electrolysing warm aqueous barium hydroxide solution between nickel electrodes.

(iii) It is obtained as a byproduct in the manufacture of sodium hydroxide and chlorine by the electrolysis of brine solution. During electrolysis, the reactions that take place are: at anode:

$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$

at cathode: $2H_2O(\ell) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

The overall reaction is

$2Na^+(aq) + 2Cl^-(aq) + 2H_2O(\ell) \rightarrow Cl_2(g) + H_2(g) + 2Na^+(aq) + 2OH^-(aq)$

(iv) Reaction of steam on hydrocarbons or coke at high temperatures in the presence of catalyst yields hydrogen.

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

e.g.,

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

The mixture of CO and H_2 is called *water gas*. As this mixture of CO and H_2 is used for the synthesis of methanol and a number of hydrocarbons, it is also called *synthesis gas or* **'syngas'**. Nowadays 'syngas' is produced from sewage, saw-dust, scrap wood, newspapers etc. The process of producing 'syngas' from coal is called *'coal gasification'*.

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

The production of dihydrogen can be increased by reacting carbon monoxide of syngas mixtures with steam in the presence of iron chromate as catalyst (Fe_2O_3 and Cr_2O_3).

$$CO(g) + H_2O(g) \xrightarrow[\text{catalyst}]{673K} CO_2(g) + H_2(g)$$

This is called water-gas shift reaction **/Bosch process**. Carbon dioxide is removed by scrubbing with sodium arsenite solution. Presently ~77% of the industrial dihydrogen is produced from petro-chemicals, 18% from coal, 4% from electrolysis of aqueous solutions and 1% from other sources.

❑ PROPERTIES OF DIHYDROGEN

◆ **Physical Properties**

Dihydrogen is a colourless, odourless, tasteless, combustible gas. It is lighter than air and insoluble in water. Its other physical properties alongwith those of deuterium are given in Table.

- **Chemical Properties**

The chemical behaviour of dihydrogen (and for that matter any molecule) is determined, to a large extent, by bond dissociation enthalpy. The H–H bond dissociation enthalpy is the highest for a single bond between two atoms of any element. What inferences would you draw from this fact ? It is because of this factor that the dissociation of dihydrogen into its atoms is only ~0.081% around 2000K which increases to 95.5% at 5000K. Also, it is relatively inert at room temperature due to the high H–H bond enthalpy. Thus, the atomic hydrogen is produced at a high temperature in an electric arc or under ultraviolet radiations. Since its orbital is incomplete with $1s^1$ electronic configuration, it does combine with almost all the elements. It accomplishes reactions by (i) loss of the only electron to give H^+, (ii) gain of an electron to form H^-, and (iii) sharing electrons to form a single covalent bond. The chemistry of dihydrogen can be illustrated by the following reactions:

- ***Reaction with halogens :*** It reacts with halogens, X_2 to give hydrogen halides HX,

$$H_2(g) + X_2(g) \rightarrow 2HX(g) \ (X = F, Cl, Br, I)$$

While the reaction with fluorine occurs even in the dark, with iodine it requires a catalyst.

- ***Reaction with dioxygen:*** It reacts with dioxygen to form water. The reaction is highly exothermic.

$$2H_2(g) + O_2(g) \xrightarrow{\text{catalyst or heating}} 2H_2O(\ell); \Delta H^{\ominus} = -285.9 \text{ kJ mol}^{-1}$$

- ***Reaction with dinitrogen:*** With dinitrogen it forms ammonia.

$$3H_2(g) + N_2(g) \xrightarrow[Fe]{673K/200atm} 2NH_3(g) ; \Delta H^{\ominus} = -92.6 \text{ kJ mol}^{-1}$$

This is the method for the manufacture of ammonia by the Haber process.

- ***Reactions with metals :*** With many metals it combines at a high temperature to yield the corresponding hydrides.

$$H_2(g) + 2M(g) \rightarrow 2MH(s) ;$$

where M is an alkali metal

- ***Reactions with metal ions and metal oxides:*** It reduces some metal ions in aqueous solution and oxides of metals (less active than iron) into corresponding metals.

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

$$yH_2(g) + M_xO_y(s) \rightarrow xM(s) + yH_2O(\ell)$$

- ***Reactions with organic compounds:*** It reacts with many organic compounds in the presence of catalysts to give useful hydrogenated products of commercial importance. For example :

(i) Hydrogenation of vegetable oils using nickel as catalyst gives edible fats (margarine and vanaspati ghee)

(ii) Hydroformylation of olefins yields aldehydes which further undergo reduction to give alcohols.

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

$$H_2 + RCH_2CH_2CHO \rightarrow RCH_2CH_2CH_2OH$$

Problem-1

Comment on the reactions of dihydrogen with (i) chlorine, (ii) sodium, and (iii) copper(II) oxide.

Solution

(i) Dihydrogen reduces chlorine into chloride (Cl^-) ion and itself gets oxidised to H^+ ion by chlorine to form hydrogen chloride. An electron pair is shared between H and Cl leading to the formation of a covalent molecule.

(ii) Dihydrogen is reduced by sodium to form NaH. An electron is transferred from Na to H leading to the formation of an ionic compound, Na^+H^-.

(iii) Dihydrogen reduces copper(II) oxide to copper in zero oxidation state and itself gets oxidised to H_2O, which is a covalent molecule.

Uses of Dihydrogen

The largest single use of dihydrogen is in the synthesis of ammonia which is used in the manufacture of nitric acid and nitrogenous fertilizers.

- Dihydrogen is used in the manufacture of vanaspati fat by the hydrogenation of polyunsaturated vegetable oils like soyabean, cotton seeds etc. . It is used in the manufacture of bulk organic chemicals, particularly methanol.

$$CO(g) + 2H_2(g) \xrightarrow[\text{catalyst}]{\text{cobalt}} CH_3OH(\ell)$$

- It is widely used for the manufacture of metal hydrides.
- It is used for the preparation of hydrogen chloride, a highly useful chemical.
- In metallurgical processes, it is used to reduce heavy metal oxides to metals.
- Atomic hydrogen and oxy-hydrogen torches find use for cutting and welding purposes. Atomic hydrogen atoms (produced by dissociation of dihydrogen with the help of an electric arc) are allowed to recombine on the surface to be welded to generate the temperature of 4000 K.
- It is used as a rocket fuel in space research.
- Dihydrogen is used in fuel cells for generating electrical energy. It has many advantages over the conventional fossil fuels and electric power. It does not produce any pollution and releases greater energy per unit mass of fuel in comparison to gasoline and other fuels.

❑ HYDRIDES

Dihydrogen, under certain reaction conditions, combines with almost all elements, except noble gases, to form binary compounds, called **hydrides**. If 'E' is the symbol of an element then hydride can be expressed as EH_x (e.g., MgH_2) or E_mH_n (e.g., B_2H_6).

The hydrides are classified into three categories :

(i) Ionic or saline or saltlike hydrides

(ii) Covalent or molecular hydrides

(iii) Metallic or non-stoichiometric hydrides

- **Ionic or Saline Hydrides**

These are stoichiometric compounds of dihydrogen formed with most of the *s*-block elements which are highly electropositive in character. However, significant covalent character is found in the lighter metal hydrides such as LiH, BeH_2 and MgH_2. In fact BeH_2 and MgH_2 are polymeric in structure. The ionic hydrides are crystalline, non-volatile and nonconducting in solid state. However, their melts conduct electricity and on electrolysis liberate dihydrogen gas at anode, which confirms the existence of H^- ion.

$$2H^-(\text{melt}) \xrightarrow{\text{anode}} H_2(g) + 2e^-$$

Saline hydrides react violently with water producing dihydrogen gas.

$$NaH(s) + H_2O(aq) \rightarrow NaOH(aq) + H_2(g)$$

Lithium hydride is rather unreactive at moderate temperatures with O_2 or Cl_2. It is, therefore, used in the synthesis of other useful hydrides, e.g.,

$$8LiH + Al_2Cl_6 \rightarrow 2LiAlH_4 + 6LiCl$$

$$2LiH + B_2H_6 \rightarrow 2LiBH_4$$

- **Covalent or Molecular Hydride**

Dihydrogen forms molecular compounds with most of the *p*-block elements. Most familiar examples are CH_4, NH_3, H_2O and HF. For convenience hydrogen compounds of nonmetals have also been considered as hydrides. Being covalent, they are volatile compounds. Molecular hydrides are further classified according to the relative numbers of electrons and bonds in their Lewis structure into :

(i) electron-deficient, (ii) electron-precise, and (iii) electron-rich hydrides.

An electron-deficient hydride, as the name suggests, has too few electrons for writing its conventional Lewis structure. Diborane (B_2H_6) is an example. In fact all elements of group 13 will form electron-deficient compounds. They act as Lewis acids i.e., electron acceptors.

Electron-precise compounds have the required number of electrons to write their conventional Lewis structures. All elements of group 14 form such compounds (e.g., CH_4) which are tetrahedral in geometry.

Electron-rich hydrides have excess electrons which are present as lone pairs. Elements of group 15-17 form such compounds. (NH_3 has 1- lone pair, H_2O – 2 and HF –3 lone pairs). They will behave as Lewis bases i.e., electron donors. The presence of lone pairs on highly electronegative atoms like N, O and F in hydrides results in hydrogen bond formation between the molecules. This leads to the association of molecules.

Problem -2

Would you expect the hydrides of N, O and F to have lower boiling points than the hydrides of their subsequent group members ? Give reasons.

Solution

On the basis of molecular masses of NH_3, H_2O and HF, their boiling points are expected to be lower than those of the subsequent group member hydrides. However, due to higher electronegativity of N, O and F, the magnitude of hydrogen bonding in their hydrides will be quite appreciable. Hence, the boiling points NH_3, H_2O and HF will be higher than the hydrides of their subsequent group members.

- **Metallic or Non-stoichiometric (or Interstitial) Hydrides**

These are formed by many *d*-block and *f*-block elements. However, the metals of group 7, 8 and 9 do not form hydride. Even from group 6, only chromium forms CrH. These hydrides conduct heat and electricity though not as efficiently as their parent metals do. Unlike saline hydrides, they are almost always nonstoichiometric, being deficient in hydrogen. For example, $LaH_{2.87}$, $YbH_{2.55}$, $TiH_{1.5–1.8}$, $ZrH_{1.3–1.75}$, $VH_{0.56}$, $NiH_{0.6–0.7}$, $PdH_{0.6–0.8}$ etc. In such hydrides, the law of constant composition does not hold good.

Earlier it was thought that in these hydrides, hydrogen occupies interstices in the metal lattice producing distortion without any change in its type. Consequently, they were termed as interstitial hydrides. However, recent studies have shown that except for hydrides of Ni, Pd, Ce and Ac, other hydrides of this class have lattice different from that of the parent metal. The property of absorption of hydrogen on transition metals is widely used in catalytic reduction / hydrogenation reactions for the preparation of large number of compounds. Some of the metals (e.g., Pd, Pt) can accommodate a very large volume of hydrogen and, therefore, can be used as its storage media. This property has high potential for **hydrogen storage** and as a **source of energy**.

- **WATER**

A major part of all living organisms is made up of water. Human body has about 65% and some plants have as much as 95% water. It is a crucial compound for the survival of all life forms. It is a solvent of great importance. The distribution of water over the earth's surface is not uniform. The estimated world water supply is given in Table.

Estimated World Water Supply

Source	% of total
Oceans	97.33
Saline lakes and inland seas	0.008
Polar ice and glaciers	2.04
Ground water	0.61
Lakes	0.009
Soil moisture	0.005
Atomspheric water vapour	0.001
Rivers	0.001

- **Physical Properties of Water**

It is a colourless and tasteless liquid. Its physical properties are given in Table along with the physical properties of heavy water. The unusual properties of water in the condensed phase (liquid and solid states) are due to the presence of extensive hydrogen bonding between water molecules. This leads to high freezing point, high boiling point, high heat of vaporisation and high heat of fusion in comparison to H_2S and H_2Se. In comparison to other liquids, water has a higher specific heat, thermal conductivity, surface tension, dipole moment and dielectric constant, etc. These properties allow water to play a key role in the biosphere.

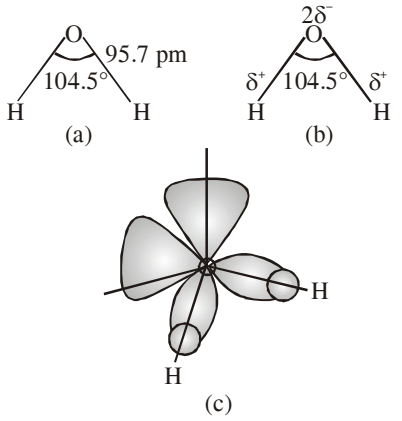
Physical Properties of H_2O and D_2O

Property	H_2O	D_2O
Molecular mass (g mol^{-1})	18.0151	20.0276
Melting point/K	273.0	276.8
Boiling point/K	373.0	374.4
Enthalpy of formation/kJ mol^{-1}	–285.9	–294.6
Enthalpy of vaporisation (373K)/kJmol^{-1}	40.66	41.61
Enthalpy of fusion/kJ mol^{-1}	6.01	-
Temp of max. density/K	276.98	284.2
Density(298K)/g cm^{-3}	1.0000	1.1059
Viscosity/centipoise	0.8903	1.107
Deielectric constant/$C^2/N.m^2$	78.39	78.06
Electrical conductivity (293K/ohm^{-1} cm^{-1})	5.7×10^{-8}	-

The high heat of vaporisation and heat capacity are responsible for moderation of the climate and body temperature of living beings. It is an excellent solvent for transportation of ions and molecules required for plant and animal metabolism. Due to hydrogen bonding with polar molecules, even covalent compounds like alcohol and carbohydrates dissolve in water.

- **Structure of Water**

In the gas phase water is a bent molecule with a bond angle of 104.5° and O–H bond length of 95.7 pm as shown in Fig (a).



H_2O molecule

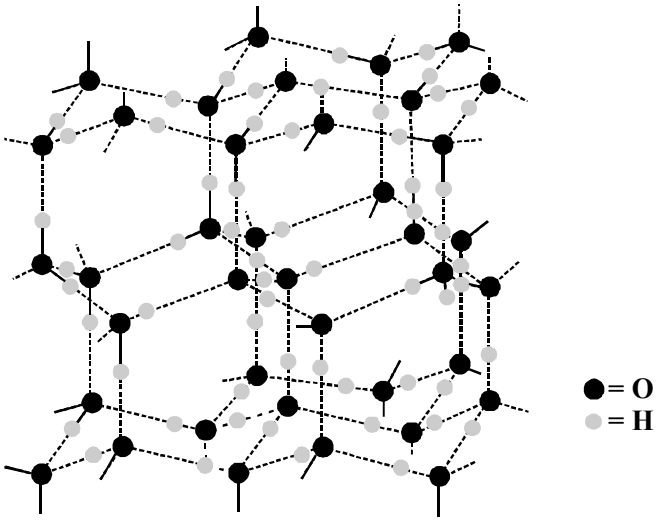
(a) The bent structure of water; (b) the water molecule as a dipole and (c) the orbital overlap picture in water molecule.

It is a highly polar molecule, (Fig (b)). Its orbital overlap picture is shown in Fig. (c). In the liquid phase water molecules are associated together by hydrogen bonds.

The crystalline form of water is ice. At atmospheric pressure ice crystallises in the hexagonal form, but at very low temperatures it condenses to cubic form. Density of ice is less than that of water. Therefore, an ice cube floats on water. In winter season ice formed on the surface of a lake provides thermal insulation which ensures the survival of the aquatic life. This fact is of great ecological significance.

- **Structure of Ice**

Ice has a highly ordered three dimensional hydrogen bonded structure as shown in Fig. Examination of ice crystals with X-rays shows that each oxygen atom is surrounded tetrahedrally by four other oxygen atoms at a distance of 276 pm. Hydrogen bonding gives ice a rather open type structure with wide holes. These holes can hold some other molecules of appropriate size interstitially.



The Structure of Ice

◆ **Chemical Properties of Water**

Water reacts with a large number of substances. Some of the important reactions are given below.

(1) Amphoteric Nature :

It has the ability to act as an acid as well as a base i.e., it behaves as an amphoteric substance. In the Brönsted sense it acts as an acid with NH_3 and a base with H_2S.

$H_2O(\ell) + NH_3(aq) \rightarrow OH^-(aq) + NH_4^+(aq)$

$H_2O(\ell) + H_2O(aq) \rightarrow H_3O^+(aq) + HS^-(aq)$

The auto-protolysis (self-ionization) of water takes place as follows :

$H_2O(\ell) + H_2O(\ell) \rightarrow H_3O^+(aq) + OH^-(aq)$

acid-1 (acid)	base-2 (base)	acid-2 (conjugate acid)	base-1 (conjugate base)

(2) Redox Reactions Involving Water:

Water can be easily reduced to dihydrogen by highly electropositive metals.

$2H_2O(\ell) + 2Na(s) \rightarrow 2NaOH(aq) + H_2(g)$

Thus, it is a great source of dihydrogen.

Water is oxidised to O_2 during photosynthesis.

$6CO_2(g) + 12H_2O(\ell) \rightarrow C_6H_{12}O_6(aq) + 6H_2O(\ell) + 6O_2(g)$

With fluorine also it is oxidised to O_2.

$2F_2(g) + 2H_2O(\ell) \rightarrow 4H^+(aq) + 4F^-(aq) + O_2(g)$

(3) Hydrolysis Reaction:

Due to high dielectric constant, it has a very strong hydrating tendency. It dissolves many ionic compounds. However, certain covalent and some ionic compounds are hydrolysed in water.

$P_4O_{10}(s) + 6H_2O(\ell) \rightarrow 4H_3PO_4(aq)$

$SiCl_4(\ell) + 2H_2O(\ell) \rightarrow SiO_2(s) + 4HCl(aq)$

$N^{3-}(s) + 3H_2O(\ell) \rightarrow NH_3(g) + 3OH^-(aq)$

(4) Hydrates Formation:

From aqueous solutions many salts can be crystallised as hydrated salts. Such an association of water is of different types viz.,

(i) coordinated water e.g.,
$[Cr(H_2O)_6]^{3+}\ 3Cl^-$

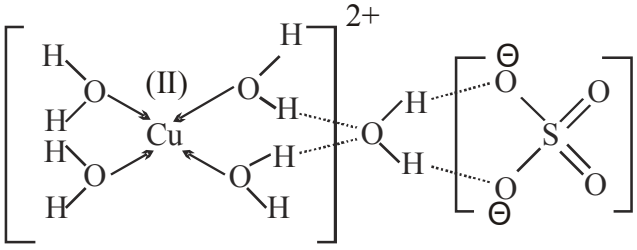
(ii) interstitial water e.g., $BaCl_2.2H_2O$

(iii) hydrogen-bonded water e.g.,
$[Cu(H_2O)_4]^{2+}\ SO_4^{2-}$. H_2O in $CuSO_4.5H_2O$.

Problem -3

The number of water molecule(s) directly bonded to the metal centre in $CuSO_4.5H_2O$ is - **[JEE 2009]**

Solution. 3 ,



- **Hard and Soft Water**

Rain water is almost pure (may contain some dissolved gases from the atmosphere). Being a good solvent, when it flows on the surface of the earth, it dissolves many salts. Presence of calcium and magnesium salts in the form of hydrogencarbonate, chloride and sulphate in water makes water **'hard'**. **Hard water** does not give lather with soap. Water free from soluble salts of calcium and magnesium is called **Soft water**. It gives lather with soap easily.

Hard water forms scum/precipitate with soap. Soap containing sodium stearate ($C_{17}H_{35}COONa$) reacts with hard water to precipitate out Ca/Mg stearate.

$$2C_{17}H_{35}COONa(aq) + M^{2+}(aq) \rightarrow (C_{17}H_{35}COO)_2M \downarrow + 2Na^+(aq) \text{ ; M is Ca/Mg}$$

It is, therefore, unsuitable for laundry. It is harmful for boilers as well, because of deposition of salts in the form of scale. This reduces the efficiency of the boiler. The hardness of water is of two types: (i) temporary hardness, and (ii) permanent hardness.

- **Temporary Hardness :**

Temporary hardness is due to the presence of magnesium and calcium hydrogencarbonates. It can be removed by :

(i) ***Boiling :*** During boiling, the soluble $Mg(HCO_3)_2$ is converted into insoluble $Mg(OH)_2$ and $Ca(HCO_3)_2$ is changed to insoluble $CaCO_3$. It is because of high solubility product of $Mg(OH)_2$ as compared to that of $MgCO_3$, that $Mg(OH)_2$ is precipitated. These precipitates can be removed by filtration. Filtrate thus obtained will be soft water.

$$Mg(HCO_3)_2 \xrightarrow{\text{Heating}} Mg(OH)_2 \downarrow + 2CO_2 \uparrow$$

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

(ii) ***Clark's method :*** In this method calculated amount of lime is added to hard water. It precipitates out calcium carbonate and magnesium hydroxide which can be filtered off.

$$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 \downarrow + 2H_2O$$

$$Mg(HCO_3)_2 + 2Ca(OH)_2 \rightarrow 2CaCO_3 \downarrow + Mg(OH)_2 \downarrow + 2H_2O$$

- **Permanent Hardness**

It is due to the presence of soluble salts of magnesium and calcium in the form of chlorides and sulphates in water. Permanent hardness is not removed by boiling. It can be removed by the following methods:

(i) ***Treatment with washing soda (sodium carbonate) :*** Washing soda reacts with soluble calcium and magnesium chlorides and sulphates in hard water to form insoluble carbonates.

$MCl_2 + Na_2CO_3 \rightarrow MCO_3 \downarrow + 2NaCl$ (m + Mg, Ca)

$MSO_4 + Na_2CO_3 \rightarrow MCO_3 \downarrow + Na_2SO_4$

(ii) ***Calgon's method :*** Sodium hexametaphosphate ($Na_6P_6O_{18}$), commercially called 'calgon', when added to hard water, the following reactions take place.

$Na_6P_6O_{18} \rightarrow 2Na^+ + Na_4P_6O_{18}^{2-}$ (M = Mg. Ca)

$M^{2+} + Na_4P_6O_{18}^{2-} \rightarrow [Na_2MP_6O_{18}]^{2-} + 2Na^+$

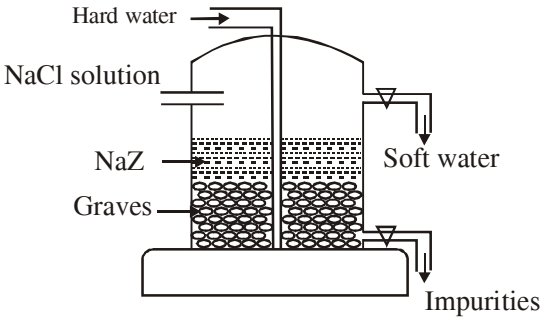
The complex anion keeps the Mg^{2+} and Ca^{2+} ions in solution.

(iii) Ion-exchange method (By Zeolite) : This method is also called zeolite / permutit process.

$[Na_2Al_2Si_2O_8.\ xH_2O]$

$[Na_2O.Al_2O_3.2SiO_2.xH_2O]$

Hydrated sodium aluminium silicate is zeolite/ permutit. For the sake of simplicity, sodium aluminium silicate ($NaAlSiO_4$) can be written as NaZ. When this is added in hard water, exchange reactions take place.



$2NaZ(s) + M^{2+}(aq) \rightarrow MZ_2(s) + 2Na^+(aq)$ (M=Mg, Ca)

Permutit/zeolite is said to be exhausted when all the sodium in it is used up. It is regenerated for further use by treating with an aqueous sodium chloride solution.

$MZ_2(s) + 2NaCl(aq) \rightarrow 2NaZ(s) + MCl_2(aq)$

(iv) Ion exchange method (By synthetic resins) : Ion exchanges resins are the most popular water softener these days. This resins are synthetic substance. The **cation exchanger** consists of granular insoluble organic acid resins having giant molecules with $-SO_3H$ or $-COOH$ groups (represented as RH) while the **anion exchanger** contains giant organic molecules with basic groups derived from amine (represented as ROH). Ion exchange resins remove all soluble mineral from water.

Reaction at Cation exchanger

$Ca^{2+} + RH \longrightarrow R_2Ca + 2H^{\oplus}$

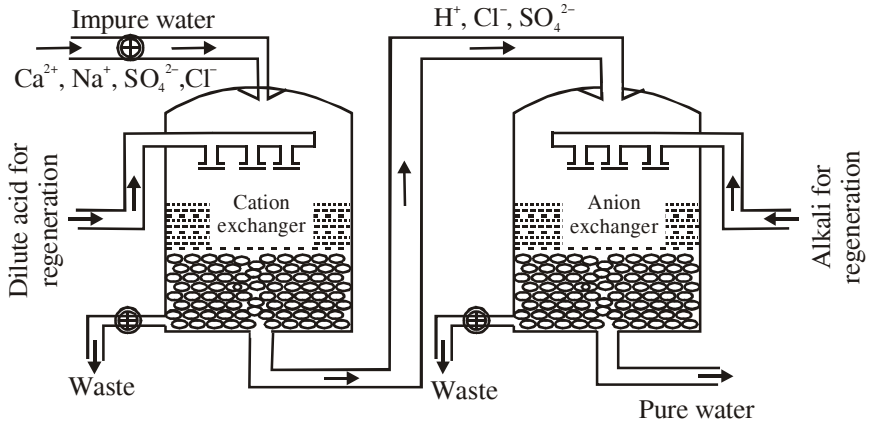
$Mg^{2+} + RH \longrightarrow R_2Mg + 2H^{\oplus}$

Reaction at Anion exchanger

$$ROH + Cl^- \longrightarrow RCl + OH^-$$

$$2ROH + SO_4^{2-} \longrightarrow R_2SO_4 + 2OH^-$$

The water coming from cation exchanger is acidic due to $H^{\oplus}$. This water is then passed through another bed containing anion exchanger. This exchanger removes anion like Cl^-, SO_4^{2-}, NO_3^- by exchanging with OH^- ions.



$$H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$$

This water is free from impurities & can be used for drinking purpose.

After some times when both resin gets exhausted process is stopped.

Regenration of resin :

(i) Cation exchange resin : We use dil acid.

$$2HCl + R_2Ca \longrightarrow RH + CaCl_2$$

(ii) Anion exchange resin : We use dil NaOH solution

$$NaOH + RCl \longrightarrow NaCl + ROH$$

❑ HYDROGEN PEROXIDE (H_2O_2)

This article has been taken in p-block chapter.

❑ HEAVY WATER, D_2O :

It can be prepared by exhaustive electrolysis of water or as a by-product in some fertilizer industries.

◆ Physical properties :

(a) Heavy water is a colourles, odourless and tasteless mobile liquid, (b) Nearly all the physical constants are higher than the corresponding values of ordinary water.

It is used for the preparation of other deuterium compounds, for example:

$$CaC_2 + 2D_2O \rightarrow C_2D_2 + Ca(OD)_2$$

$$SO_3 + D_2O \rightarrow D_2SO_4$$

$$Al_4C_3 + 12D_2O \rightarrow 3CD_4 + 4Al(OD)_3$$

- **Uses :** It is extensively used as a moderator & coolant in nuclear reactors and in exchange reactions for the study of reaction mechanisms. **As a neutron moderator :** Fission in uranium-235 is brought by slow speed neutrons. The substances which are used for slowing down the speed of neutrons are called moderators. Heavy water is used for this purpose in nuclear reactors.

❑ DIHYDROGEN AS A FUEL

Dihydrogen releases large quantities of heat on combustion. The data on energy released by combustion of fuels like dihydrogen, methane, LPG etc. are compared in terms of the same amounts in mole, mass and volume, are shown in Table.

From this table it is clear that on a mass for mass basis dihydrogen can release more energy than petrol (about three times). Moreover, pollutants in combustion of dihydrogen will be less than petrol. The only pollutants will be the oxides of dinitrogen (due to the presence of dinitrogen as impurity with dihydrogen).

This, of course, can be minimised by injecting a small amount of water into the cylinder to lower the temperature so that the reaction between dinitrogen and dioxygen may not take place. However, the mass of the containers in which dihydrogen will be kept must be taken into consideration. A cylinder of compressed dihydrogen weighs about 30 times as much as a tank of petrol containing the same amount of energy. Also, dihydrogen gas is converted into liquid state by cooling to 20K. This would require expensive insulated tanks. Tanks of metal alloy like $NaNi_5$, $Ti–TiH_2$, $Mg–MgH_2$ etc. are in use for storage of dihydrogen in small quantities. These limitations have prompted researchers to search for alternative techniques to use dihydrogen in an efficient way.

In this view Hydrogen Economy is an alternative. The basic principle of hydrogen economy is the transportation and storage of energy in the form of liquid or gaseous dihydrogen. Advantage of hydrogen economy is that energy is transmitted in the form of dihydrogen and not as electric power. It is for the first time in the history of India that a pilot project using dihydrogen as fuel was launched in October 2005 for running automobiles. Initially 5% dihydrogen has been mixed in CNG for use in four-wheeler vehicles. The percentage of dihydrogen would be gradually increased to reach the optimum level.

Nowadays, it is also used in fuel cells for generation of electric power. It is expected that economically viable and safe sources of dihydrogen will be identified in the years to come, for its usage as a common source of energy.

The Energy Released by Combustion of Various Fuels in Moles, Mass and Volume

Energy released on Combustion in kJ state)	Dihydrogen in gaseous state)	Dihydrogen (in liuqid)	LPG	CH_4 gas	Octance (in liuquid state)
per mole	286	285	2220	880	5511
per gram	143	142	50	53	47
per litre	12	9968	25590	35	34005

EXERCISE # O-1

DIHYDROGEN

1. The sum number of neutrons and protons in one of the isotopes of hydrogen is :-

(A) 3 (B) 4 (C) 5 (D) 6

HY0001

2. The catalyst used in Bosch process of manufacture of H_2 is :-

(A) Finely divided Ni (B) V_2O_5 (C) Pb (D) $Fe_2O_3 + Cr_2O_3$

HY0002

3. The most abundant isotope of hydrogen is :-

(A) Tritium (B) Deuterium (C) Protium (D) Para hydrogen

HY0003

4. The n/p ratio for $_1H^1$ is :-

(A) 1 (B) 2 (C) 3 (D) Zero

HY0004

5. Ordinary hydrogen at high temperature is a mixture of :-

(A) 75% o-Hydrogen + 25% p-Hydrogen (B) 25% o-Hydrogen + 75% p-Hydrogen

(C) 50% o-Hydrogen + 50% p-Hydrogen (D) 1% o-Hydrogen + 99% p-Hydrogen

HY0005

6. Hydrogen is behave as :-

(A) Electropositive

(B) Electronegative

(C) Both electropositive as well as elecctro-negative

(D) Neither electropositive nor electronegative

HY0006

7. At high temperature Para hydrogen is :-

(A) Less stable than ortho hydrogen

(B) More stable than ortho hydrogen

(C) As stable as ortho hydrogen

(D) None of these

HY0007

8. When the same amount of zinc is treated separately with excess of sulphuric acid and excess of sodium hydroxide, the ratio of volumes of hydrogen evolved is :-

(A) 1 : 1 (B) 1 : 2 (C) 2 : 1 (D) 9 : 4

HY0008

9. The lightest gas is :-

(A) Nitrogen (B) Helium (C) Oxygen (D) Hydrogen

HY0009

10. The ratio of electron, proton and neutron in tritium is :-

(A) 1 : 1 : 1 (B) 1 : 1 : 2 (C) 2 : 1 : 1 (D) 1 : 2 : 1

HY0010

11. The nuclei of tritium (H^3) atom would contain neutrons :-

(A) 1 (B) 2 (C) 3 (D) 4

HY0011

12. The adsorption of hydrogen by metals is called :-

(A) Dehydrogenation (B) Hydrogenation (C) Occlusion (D) Adsorption

HY0012

13. At absolute zero :-

(A) Only para hydrogen exists (B) Only ortho hydrogen exists

(C) Both para and ortho hydrogen exist (D) None

HY0013

WATER (H_2O)

14. Only temporary hardness in water is removed by :-

(A) Boiling (B) Filtration (C) Calgon's process (D) None of these0

HY0014

15. Both temporary and permanent hardness is removed on boiling water with :-

(A) $Ca(OH)_2$ (B) Na_2CO_3 (C) $CaCO_3$ (D) CaO

HY0015

16. Temporary hardness is caused due to the presence of :-

(A) $CaSO_4$ (B) $CaCl_2$ (C) $CaCO_3$ (D) $Ca(HCO_3)_2$

HY0016

17. High boiling point of water is due to :-

(A) Its high specific heat (B) Hydrogen bonding

(C) High dielectric constant (D) Low dissociation constant

HY0017

18. Calgon is an industrial name given to :-

(A) Normal sodium phosphate (B) Sodium meta-aluminate

(C) Sodium hexametaphosphate (D) Hydrated sodium aluminium silicate

HY0018

19. Permutit is :-

(A) Hydrated sodium aluminium silicate (B) Sodium hexametaphosphate

(C) Sodium silicate (D) Sodium meta-aluminate

HY0019

20. Heavy water has found application in atomic reactor as :-

(A) Coolant (B) Moderator

(C) Both coolant and moderator (D) Neither coolant nor moderator

HY0020

21. Calgon (a water softener) is :-

(A) $Na_2[Na_4(PO_3)_6]$ (B) $Na_4[Na_2(PO_3)]_6$ (C) $Na_2[Na_4(PO_4)]_6$ (D) $Na_4[Na_2(PO_4)_6]$

HY0021

22. The hardness of water is due to.....metal ions

(A) Ca^{2+} and Na^+ (B) Mg^{2+} and K^+ (C) Ca^{2+} and Mg^{2+} (D) Zn^{2+} and Ba^{2+}

HY0022

23. The formula of heavy water is :-

(A) H_2O^{18} (B) D_2O (C) T_2O (D) H_2O^{17}

HY0023

24. Pure de-mineralised water can be obtained by -

(A) Na^+ cation exchanger and Cl^- anion exchanger

(B) H^+ cation exchanger only

(C) H^+ cation exchanger and OH^- anion exchanger

(D) Na^+ cation exchanger only

HY0024

HYDROGEN PEROXIDE (H_2O_2)

25. The bleaching properties of H_2O_2 are due to its :-

(A) Reducing properties (B) Oxidising properties

(C) Unstable nature (D) Acidic nature

HY0025

26. Hydrogen peroxide has a :-

(A) Linear structure (B) Pyramidal structure

(C) Closed book type structure (D) Half open book type structure

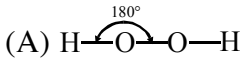
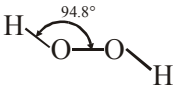
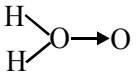
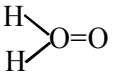
HY0026

27. Hydrogen peroxide is a :-

(A) Liquid (B) Gas (C) Solid (D) Semi-solid

HY0027

28. Which of the following is a true structure of H_2O_2

(A)  (B)  (C)  (D) 

HY0028

29. Decomposition of H_2O_2 is retarded by :-

$2H_2O_2(\ell) \rightarrow 2H_2O(\ell) + O_2(g)$

(A) Acetanilide (B) MnO_2

(C) Zinc (D) Finely divided metals

HY0029

30. H_2O_2 is :-

(A) An oxiding agent (B) Both oxidising and reducing agent

(C) Reducing agent (D) None of the above

HY0030

31. H_2O_2 is always stored in black bottles because :-

(A) It is highly unstable

(B) Its enthalpy of decomposition is high

(C) It undergoes auto-oxidation on prolonged standing

(D) None of these

HY0031

32. Acidified solution of $K_2Cr_2O_7$ on treatment with H_2O_2 yields :-

(A) $CrO_3 + H_2O + O_2$ (B) $Cr_2O_2 + H_2O + O_2$

(C) $CrO_5 + H_2O + K_2SO_4$ (D) $H_2Cr_2O_7 + H_2O + O_2$

HY0032

33. H_2O_2 restores the colour of old lead paintings, blackened by the action of H_2S gas by :-

(A) Converting PbO_2 to Pb (B) By oxidising PbS to $PbSO_4$

(C) Converting $PbCO_3$ to Pb (D) Oxidising $PbSO_3$ to $PbSO_4$

HY0033

34. The reaction, $H_2S + H_2O_2 \longrightarrow S + 2H_2O$ manifests:

(A) Acidic nature of H_2O_2 (B) Alkaline nature of H_2O_2

(C) Oxidising nature of H_2O_2 (D) Reducing nature of H_2O_2

HY0034

35. Hydrogen peroxide is now generally prepared on industrial scale by the :-

(A) Action of H_2SO_4 on barium peroxide (B) Action of H_2SO_4 on sodium peroxide

(C) auto-oxidation of 2-alklylanthraquinols (D) Burning hydrogen in excess of oxygen

HY0035

EXERCISE # O-2

1. Which of the following is / are same for Ortho and Para hydrogen :-

(A) In the number of protons

(B) In the molecular mass

(C) In the nature of spins of nucleus

(D) In the nature of spins of electrons

HY0036

2. In Bosch's process which gas is **NOT** utilised for the production of hydrogen :-

(A) Producer gas (B) Water gas (C) Coal gas (D) Natural gas

HY0037

3. The gas(es) used in the hydrogenation of oils in presence of nickel as a catalyst is / are :-

(A) Methane (B) Ethane (C) Ozone (D) Hydrogen

HY0038

4. Water softening by Clarke's process does **NOT** uses :-

(A) Calcium bicarbonate (B) Sodium bicarbonate

(C) Potash alum (D) Calcium hydroxide

HY0039

5. Which of the following produces hydrolith with dihydrogen :-

(A) Mg (B) Al (C) Cu (D) Ca

HY0040

6. Which process is/are used to remove permanent hardness :-

(A) Boiling (B) Clark's method

(C) On reaction with with NaOH (D) Permutit process

HY0041

7. Ionic hydrides is/are usually :-

(A) Good electrically conductors when solid (B) Easily reduced

(C) Good reducing agents (D) Liquid at room temperature

HY0042

8. Which of the following will produce hydrogen gas :-

(A) Reaction between Fe and dil. HCl

(B) Reaction between Zn and conc. H_2SO_4

(C) Reaction between Zn and NaOH

(D) Electrolysis of NaCl (aq.) in Nelson's cell

HY0043

9. Ortho-hydrogen and para-hydrogen resembles in which of the following property :-

(A) Thermal conductivity (B) Magnetic properties

(C) Chemical properties (D) Heat capacity

HY0044

10. Which of the following statements concerning protium, deuterium and tritium is / are true :-

(A) They are isotopes of each other

(B) They have similar electronic configurations

(C) They exist in the nature in the ratio of 1 : 2 : 3

(D) Their mass numbers are in the ratio of 1 : 2 : 3

HY0045

11. Ionic hydrides are formed by :-

(A) Transition metals

(B) Elements of very high electropositivity

(C) Elements of very low electropositivity

(D) Metalloids

HY0046

12. Which of the following statements is/are correct :

(A) Atomic hydrogen is obtained by passing hydrogen gas through an electric arc

(B) 30% (w/v) or 100V H_2O_2 solution is not called per hydrol.

(C) Finely divided palladium absorbs large volume of hydrogen gas.

(D) Ortho and para hydrogen have same physical properties.

HY0047

13. Which hydride is/are an ionic hydride :-

(A) NH_3 (B) H_2S (C) $TiH_{1.73}$ (D) NaH

HY0048

14. Which of the following hydride is/are "electron-precise' type ?

(A) HF (B) H_2O (C) SiH_4 (D) PH_3

HY0049

15. Hydrogen peroxide can act as a :-

(A) A reducing agent (B) An oxidising agent

(C) A dehydrating agent (D) A bleaching agent

HY0050

EXERCISE # S-1

Integer Type

1. Find out the sum of protons, electrons and neutrons in the heaviest isotope of hydrogen.

HY0051

2. Find out the number of following orders which are correct against the mentioned properties :

(i) $H_2 < D_2 < T_2$ (Number of protons)

(ii) $H_2 < D_2$ (Bond energy)

(iii) $H_2 < D_2 < T_2$ (Boiling point)

(iv) $H_2 < D_2 < T_2$ (No. of neutrons)

HY0052

3. Find out the number of following orders which are **NOT** correct against the mentioned properties :

(i) $CaH_2 < BeH_2$ (Electrical conductance in molten condition)

(ii) $LiH < NaH < CsH$ (Ionic character)

(iii) $H_2 < D_2 < F_2$ (Bond dissociation enthalpy)

(iv) $NaH < MgH_2 < H_2O$ (Reducing property)

HY0053

4. What is the oxidation state of oxygen of H_2O_2 in the final product when it reacts with ClO_3^-.

HY0054

5. Find out the value of 'x' in ion $[H_xO_4]^+$:

HY0055

EXERCISE # S-2

Matrix Match Type

1. Match List I with List II and select the correct answer using the codes given below the lists :-

List – I	**List II**
P. Heavy water	1. Bicarbonates of Mg and Ca in water
Q. Temporary hard	2. No foreign ions in water
R. Soft water	3. D_2O
S. Permanent hard	4. Sulphates and chlorides of Mg and Ca in water

Code :

P	**Q**	**R**	**S**
(A) 3	1	2	4
(B) 3	4	2	3
(C) 3	2	1	4
(D) 2	3	1	4

HY0056

2. Match List I with List II and select the correct answer using the codes given below the lists :-

List – I	**List II**
P. Calgon	1. Metallic hydride
Q. Non-stoichiometric compound	2. Polymetaphosphate of sodium
R. Covalent hydride	3. Hydrolith
S. Salt-like hydride	4. Hydrogen compounds of non-metals

Code :

P	**Q**	**R**	**S**
(A) 2	1	3	4
(B) 3	4	2	3
(C) 2	1	4	3
(D) 2	3	1	4

HY0057

Comprehenstion Type :

Passage for Q.3 to Q.5

Hydrogen accounts for approximately 75% of the mass of the universe. Hydrogen serves as the nuclear fuel of our Sun and other stars, and these are mainly composed of hydrogen.

Hydrogen has three isotopes : hydrogen or protium ($^{1}_{1}H$), deuterium or heavy hydrogen (D or $^{2}_{1}H$), tritium (T or $^{3}_{1}H$).

3. Which of the following is radioactive in nature ?

(A) hydrogen only (B) deuterium only

(C) tritium only (D) deuterium and tritium

HY0058

4. Hydrogen, H_2, is very less abundant in the atmosphere due to -

(A) inflammable nature of H_2

(B) weak earth's gravity which is not able to hold light H_2 molecules

(C) diatomic nature of hydrogen

(D) very rapid reaction between hydrogen and atmospheric oxygen

HY0058

5. Liquid H_2 has been used as rocket fuel as

(A) its reaction with oxygen is highly exothermic

(B) it occupies small space

(C) it has high thrust

(D) all of the above

HY0058

MATCHING LIST TYPE 1 × 3 Q. (THREE LIST TYPE Q.)

Column - I Name	Column - II] Formula	Column - III Specification
(1) Calogen	(P) $Na_6P_6O_{18}$	(i) Used to Remove temporary Hardness
(2) Permutit	(Q) $Na_2Al_2Si_2O_8.xH_2O$	(ii) Used to remove permanent hardness
(3) Perhydrol	(R) '100 V' H_2O_2	(iii) Used in Rockect propelent
(4) Washing Soda	(S) $Na_2CO_3.10H_2O$	(iv) Also named as zeolite

6. Which combination is **NOT** related to removal of Ca^{+2}/Mg^{+2} form the sample of water

(A) (1)-(P)-(i)(ii) (B) (2)-(Q)-(i)(ii)(iv) (C) (3)-(R)-(i)(ii) (D) (4)-(S)-(i)(ii)

HY0059

7. Which of the following is **INCORRECT** between column I & II

(A) 1–P (B) 2–Q (C) 3–R (D) 2–S

HY0059

8. Which of the following is **INCORRECT** matching between column III & column II

(A) (iii) – R (B) (iv) – Q (C) (iv) – P (D) none of these

HY0059

EXERCISE # JEE-MAIN

1. Which one of the following processes will produce hard water :- **[AIEEE 2003]**

(1) Saturation of water with $CaSO_4$ (2) Addition of Na_2SO_4 to water

(3) Saturation of water with $CaCO_3$ (4) Saturation of water with $MgCO_3$

HY0060

2. Very pure hydrogen (99.9%) can be made by which of the following processes?**[AIEEE 2012]**

(1) Reaction of salt like hydrides with water

(2) Reaction of methane with steam

(3) Mixing natural hydrocarbons of high molecular weight

(4) Electrolysis of water

HY0061

3. In which of the following reaction H_2O_2 acts as a reducing agent ? **[JEE(Main) 2014]**

(a) $H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$ (b) $H_2O_2 - 2e^- \rightarrow O_2 + 2H^+$

(c) $H_2O_2 + 2e^- \rightarrow 2OH^-$ (d) $H_2O_2 + 2OH^- - 2e^- \rightarrow O_2 + 2H_2O$

(1) (a), (c) (2) (b), (d) (3) (a), (b) (4) (c), (d)

HY0062

4. Which of the following statements about Na_2O_2 is **not** correct ? **[JEE(Main) 2014]**

(1) Na_2O_2 oxidises Cr^{3+} to CrO_4^{2-} in acid medium

(2) It is diamagnetic in nature

(3) It is the super oxide of sodium

(4) It is a derivative of H_2O_2

HY0063

5. Hydrogen peroxide acts both as an oxidising and as a reducing agent depending upon the nature of the reacting species. In which of the following cases H_2O_2 acts as a reducing agent in acid medium ? :- **JEE(Main)Online-2014]**

(1) MnO_4^- (2) SO_3^{2-} (3) KI (4) $Cr_2O_7^{2-}$

HY0064

6. Permanent hardness in water cannot be cured by: **JEE(Main)Online-2015]**

(1) Treatment with washing soda (2) Calgon's method

(3) Boiling (4) Ion exchange method

HY0065

7. From the following statements regarding H_2O_2, choose the incorrect statement :

(1) It has to be stored in plastic or wax lined glass bottles in dark **JEE(Main)Online-2015]**

(2) It has to be kept away from dust

(3) It can act only as an oxidizing agent

(4) It decomposes on exposure to light

HY0066

8. In which of the following reaction, hydrogen peroxide acts as an oxidizing agent ?
(1) $I_2 + H_2O_2 + 2OH^- \rightarrow 2I^- + 2H_2O + O_2$ **JEE(Main)-2017]**
(2) $HOCl + H_2O_2 \rightarrow H_3O^+ + Cl^- + O_2$
(3) $PbS + 4H_2O_2 \rightarrow PbSO_4 + 4H_2O$
(4) $2MnO_4^- + 3H_2O_2 \rightarrow 2MnO_2 + 3O_2 + 2H_2O + 2OH^-$

HY0067

9. Hydrogen peroxide oxidises $[Fe(CN)_6]^{4-}$ to $[Fe(CN)_6]^{3-}$ in acidic medium but reduces $[Fe(CN)_6]^{3-}$ to $[Fe(CN)_6]^{4-}$ in alkaline medium. The other products formed are, respectively :
(1) $(H_2O + O_2)$ and $(H_2O + OH^-)$ **JEE(Main) -2018]**
(2) H_2O and $(H_2O + O_2)$
(3) H_2O and $(H_2O + OH^-)$
(4) $(H_2O + O_2)$ and H_2O

HY0068

10. The chemical nature of hydrogen preoxide is :- **JEE(Main) -2019]**
(1) Oxidising and reducing agent in acidic medium, but not in basic medium.
(2) Oxidising and reducing agent in both acidic and basic medium
(3) Reducing agent in basic medium, but not in acidic medium
(4) Oxidising agent in acidic medium, but not in basic medium.

HY0069

11. The total number of isotopes of hydrogen and number of radioactive isotopes among them, respectively, are : **JEE(Main) -2019]**
(1) 2 and 0 (2) 3 and 2 (3) 3 and 1 (4) 2 and 1

HY0070

12. Th correct statements among (a) to (d) regarding H_2 as a fuel are : **JEE(Main) -2019]**
(a) It produces less pollutant than petrol
(b) A cylinder of compressed dihydrogen weighs ~ 30 times more than a petrol tank producing the same amount of energy
(c) Dihydrogen is stored in tanks of metal alloys like $NaNi_5$
(d) On combustion, values of energy released per gram of liquid dihydrogen and LPG are 50 and 142 kJ, respectively
(1) b and d only (2) a, b and c only (3) b, c and d only (4) a and c only

HY0071

13. The correct statements among (a) to (b) are: **JEE(Main) -2019]**
(a) saline hydrides produce H_2 gas when reacted with H_2O.
(b) reaction of $LiAH_4$ with BF_3 leads to B_2H_6.
(c) PH_3 and CH_4 are electron - rich and electron-precise hydrides, respectively.
(d) HF and CH_4 are called as molecular hydrides.
(1) (c) and (d) only (2) (a), (b) and (c) only
(3) (a), (b), (c) and (d) (4) (a), (c) and (d) only

HY0072

14. In comparison to the zeolite process for the removal of permanent hardness, the synthetic resins method is : **JEE(Main) -2020]**

(1) less efficient as it exchanges only anions

(2) more efficient as it can exchange only cations

(3) less efficient as the resins cannot be regenerated

(4) more efficient as it can exchange both cations as well as anions

HY0073

15. Hydrogen has three isotopes (A), (B) and (C). If the number of neutron(s) in (A), (B) and (C) respectively, are (x), (y) and (z), the sum of (x), (y) an (z) is : **JEE(Main) -2020]**

(1) 4 (2) 3 (3) 2 (4) 1

HY0074

16. Among the statements (a) - (d), the correct ones are - **JEE(Main) -2020]**

(a) Decomposition of hydrogen peroxide gives dioxygen

(b) Like hydrogen peroxide, compounds , such as $KClO_3$, $Pb(NO_3)_2$ and $NaNO_3$when heated liberated dioxygen

(c) 2-Ethylanthraquinone is useful for the industrial preparation of hydrogen peroxide.

(d) Hydrogen peroxide is used for the manufacture of sodium perborate

(1) (a), (b) and (c) only (2) (a) and (c) only

(3) (a), (b) , (c) and (d) (4) (a), (c) and (d) only

HY0075

EXERCISE # JEE ADVANCED

1. When zeolite (hydrated sodium aluminium silicate) is treated with hard water, the sodium ions are exchanged with :- **[IIT 1990]**

(A) H^+ ions (B) Ca^{2+} ions (C) SO_4^{2-} ions (D) OH^- ions

HY0076

2. Which of the following statement is correct :-

(A) Hydrogen has same ionisation potential as sodium

(B) H has same electronegativity as halogens

(C) It will not be liberated at anode

(D) H has oxidation state + 1, zero and – 1

HY0077

3. Polyphosphates are used as water softening agent becuase they :- **[IIT 2002]**

(A) Form soluble complexes with anionic species

(B) Precipitate anionic species

(C) Form soluble complexes with cationic species

(D) Precipitate cationic species.

HY0078

4. Hydrogen peroxide in its reaction with KlO_4 and NH_2OH respectively, is acting as a **[JEE Adv. 2014]**

(A) reducing agent, oxidising agent (B) reducing agent, reducing agent

(C) oxidising agent, oxidising agent (D) oxidising agent, reducing agent

HY0079

5. Which of the following combination will produce H_2 gas? **[JEE Adv. 2017]**

(A) Zn metal and NaOH(aq.) (B) Au metal and NaCN(aq.) in the presence of air

(C) Cu metal and conc. HNO_3 (D) Fe metal and conc. HNO_3

HY0080

ANSWERS KEY

EXERCISE : O-1

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	A	D	C	D	A	C	A	A	D	B	B	C	A	A	B
Que.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ans.	D	B	C	A	C	A	C	B	C	B	D	A	B	A	B
Que.	31	32	33	34	35										
Ans.	C	C	B	C	C										

EXERCISE : O-2

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	A,B,D	A,C,D	D	A,B,C	D	D	C	A,C,D	C	A,B,D
Que.	11	12	13	14	15					
Ans.	B	A,C	D	C	A,B,D					

EXERCISE : S-1

Que.	1	2	3	4	5
Ans.	4	3	3	0	9

EXERCISE : S-2

Que.	1	2	3	4	5	6	7	8
Ans.	A	C	C	B	D	C	D	C

EXERCISE : JEE-MAINS

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	1	4	2	3	1	3	3	3	2	2
Que.	11	12	13	14	15	16				
Ans.	3	2	3	4	2	3				

EXERCISE : JEE-ADVANCED

Que.	1	2	3	4	5
Ans.	B	D	C	A	A