Chapter 09

HYDROGEN

1. INTRODUCTION

Hydrogen in atomic form consists of one proton and one electron but, in elemental form it exists as a diatomic (H_2) molecule. H_2 is called as dihydrogen.

2. POSITION OF HYDROGEN IN THE PERIODIC TABLE

Hydrogen is the first element of the periodic table as its atomic number is 1. The single electron is present in the K shell i.e. first shell with electron configuration $1s^1$. Hydrogen resembles in many properties with alkali metals (1st group) as well as halogen (group 17). This dual behaviour of hydrogen may arise due to its electronic configuration i.e. $1s^1$

2.1 Properties Resembling with Alkali Metals

(a) Electronic Configuration : The valence shell electron configuration of hydrogen and alkali metals are similar i.e. ns^1.

(b) Formation of Unipositive ion : Hydrogen as well as alkali metals lose one electron to form unipositive ions.

(c) Formation of Oxides, Halides and Sulphides : Just like alkali metals hydrogen combines with electronegative elements such as oxygen, halogen and sulphur forming oxide, halide and sulphide respectively.

Example	Na_2O	NaCl	Na_2S
	H_2O	HCl	H_2S

(d) Reducing Nature : Like, alkali metals hydrogen also acts as reducing agent.

$$CuO + H_2 \xrightarrow{\Delta} Cu + H_2O\,;\ B_2O_3 + 6K \xrightarrow{\Delta} 3K_2O + 2B$$

2.2 Properties Resembling with Halogens

(a) Electronic Configuration

Both have one electron less than that of nearest inert gas configuration.

(b) Atomicity

Like halogens, hydrogen forms diatomic molecule too. For example, Cl_2, Br_2, I_2 etc.

(c) Ionization Enthalpy

Hydrogen as well as halogens both have higher ionization enthalpies.

H	**F**	**Cl**
1312 kJ/mol	1680 kJ/mol	1255 kJ/mol

(d) Formation of Uninegative ion

Both hydrogen as well as halogens have the tendency to gain one electron to form uninegative ion so as to have the nearest noble gas electronic configuration.

(e) Formation of Hydrides and Covalent Compounds

Hydrogen as well as halogens combine with elements to form hydrides and a larger number of covalent compounds.

For example ;	CCl_4	$SiCl_4$	NaCl
	CH_4	SiH_4	NaH

2.3 Difference from Alkali Metals

(a) Ionization enthalpy of hydrogen (1312 kJ mol^{-1}) is very high as compared to that of alkali metals.
(Li = 520 kJ mol^{-1}, Na = 495 kJ mol^{-1})

(b) Alkali metals possess metallic character but hydrogen does not possesses metallic character under normal conditions.

(c) The size of H^+ i.e. nucleus of H atom is 1.5×10^{-3} pm. Which is extremely small as compared to normal atomic and ionic sizes of alkali metals (50 to 200 pm). As a result, H^+ does not exist freely and is always associated with other atoms or molecules. It exists as hydrated proton with formula $H_3O^{\oplus}$ in aqueous solution.

2.4 Difference from Halogens

(a) The reactivity of hydrogen is very low as compared to halogens.

(b) Oxides of halogens are acidic while that of hydrogen is neutral.

3. DIHYDROGEN (H_2)

3.1 Occurence

It is most abundent element of the universe (70% of the total mass) but it is much less abundent element (0.15% by mass) in the earth atmospher due to its light nature. In combined form it constitutes 15.4% of the earth crust and the oceans.

3.2 Isotopes

Hydrogen has three isotopes namely protium $^{1}_{1}H$, deuterium $^{1}_{2}H$ or D and tritium $^{1}_{3}H$ or T. They differ from one another by the number of neutrons present in them, Protonium has no neutrons. Deuterium which is also known as heavy hydrogen has one neutron and Tritium has two neutrons in the nucleus.

Property	Hydrogen	Deuterium	Tritium
Relative abundance (%)	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 298.2 K	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	-	-

3.3 Preparation of Dihydrogen, (H_2)

(A) Laboratory Method

(i) From Acid : It is usually prepared by the reaction of granulated zinc with dil. HCl.

$$Zn(\text{granulated}) + 2H^+(\text{dilute}) \rightarrow Zn^{2+} + H_2$$

(ii) From Alkali : It can also be prepared by the reaction of Zn with aqueous NaOH.

$$Zn + 2NaOH \xrightarrow{\Delta} \underset{\text{Sodium Zincate}}{Na_2ZnO_2} + H_2$$

$$2Al + 2H_2O + 2NaOH \xrightarrow{\Delta} \underset{\text{Sodium meta aluminate}}{2NaAlO_2} + 3H_2$$

(B) Commericial Production of Dihydrogen

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

$$2H_2O(l) \xrightarrow[\text{Traces of acid/base}]{\text{electrolysis}} 2H_2(g) + O_2(g)$$

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

(iii) It is obtained as a by-product in the manufacture of sodium hydroxide and chlorine by the electrolysis of brine solution.

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

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

Overall Reaction is :

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

Coal Gasification Process :

(iv) By passing steam over hydrocarbons or coke at high temperature in the presence of catalyst yields dihydrogen.

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

Mixture of CO and H_2 is called water gas. It is used for the synthesis of methanol and a number of hydrocarbons, it is also called synthesis gas or "syngas". Syngas is obtained now a day from sewage, saw-dust, scrap wood, news papers 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 yield of dihydrogen can be increased by reacting CO of syngas mixture with steam in the presence of iron chromate as catalyst

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

This reaction which involves the oxidation of CO into CO_2 is called water - gas shift reaction. The CO_2 formed is removed by scrubbing with sodium arsenite solution.

(v) By Lane's process. It involves two steps –

(a) Oxidation Stage

$$Fe(\text{fillings}) + H_2O \text{ (super heated steam)} \underset{}{\overset{1025-1075K}{\rightleftharpoons}} Fe_3O_4 + 4H_2$$

(b) Reduction Stage

$$Fe_3O_4 + \underbrace{2H_2 + CO}_{\text{Coal gas}} \rightarrow 3Fe + 2H_2O + CO_2$$

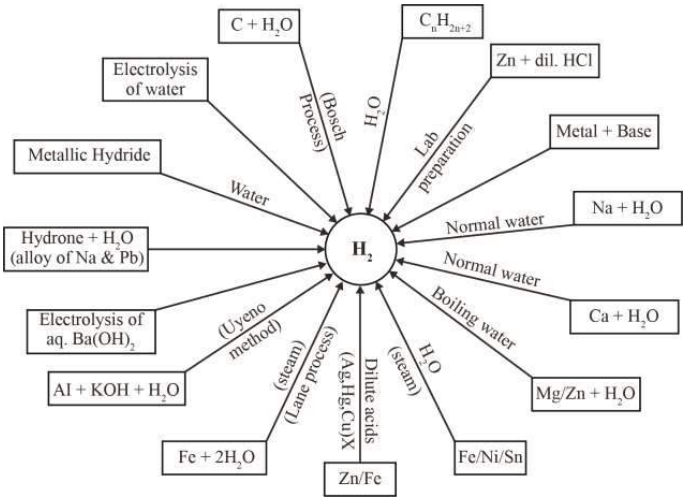
(vi) Common Methods

(i) Action of water with Na, K & Ca at room temperature .

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

(ii) Action of water with Mg, Al and Zn at boiling temperature of water.

$$Mg + H_2O \xrightarrow{\Delta} MgO + H_2$$



Preparation of Dihydrogen

3.4 Properties of Dihydrogen

3.4.1 Physical Properties

(a) It is a colourless, odourless tasteless gas.

(b) It is combustible gas; so it should be carefully handled with care while using.

(c) It is lighter than air (density = 1/24th that of air) and insoluble in water.

3.4.2 Chemical Properties

The chemical reactivity of dihydrogen is very low at room temperature. It is because of its very high H–H bond dissociation enthalpy (439.9 kJ mol^{-1}). This bond enthalpy infact is the highest for any single bond enthalpy between two atoms of any element. The relative inert nature of dihydrogen due to the high H–H bond enthalpy may be understood by the fact that the dissociation of dihydrogen into atoms is only 0.081 % at around 2000 K which increases to 95.5% at 5000 K. Thus, the atomic hydrogen is produced at a high temperature in an electric arc or under ultraviolet radiations with its incomplete $1s^1$ electronic configuration. It combine with almost all the elements with its incomplete electronic configuration to give hydrogen halide. It undergoes chemical reaction by :

(a) loss of the only electron to give H^+

(b) gain of an electron to form H^-

(c) sharing an electron to form a single covalent bond.

(1) Reaction with Halogens

It reacts with halogen, X_2

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

Reaction with fluorine occurs even in the dark while reaction with iodine occurs in the presence of a catalyst. Order of reactivity is F > Cl > Br > I

(2) Reaction with Dioxygen

It burns in air with a pale blue flame to form water This reaction is highly exothermic.

$$2H_2(g) + O_2(g) \xrightarrow[\text{heating}]{\text{catalyst}} 2H_2O(l) \quad ;$$

$$\Delta H^0 = -285\ KJ\ mol^{-1}$$

(3) Reaction with Nitrogen (Haber Process for Manufacture of NH_3) with Dinitrogen

$$3H_2(g) + N_2(g) \xrightarrow[Fe/Mo]{673K,200\,atm} 2NH_3(g) \quad ;$$

$$\Delta H^o = -92.6\ KJ\ mol^{-1}$$

At 673 k, 200 atm pressure, it gives NH_3

(4) Reaction with Metals

It combines with many metals at a high temperature to form the corresponding hydrides.

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

With metals like, Pt, Pd, Ni, etc, hydrogen forms interstitial hydrides in which hydrogen atoms get trapped in the intersitial voids in the metallic crystals. This property is referred to as occlussion. The occuluded hydrogen liberates on strong heating.

(5) Reaction with Metal ions and Metal Oxides

Dihydrogen reduces some metal ions (lying below hydrogen) in aqueous solution and oxides of metals which are less reactive than iron into corresponding metals.

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

$M_xO_y(s) + yH_2(g) \rightarrow xM(s) + y\,H_2O(l)$

$CuO(s) + H_2(g) \xrightarrow{\Delta} Cu(s) + H_2O(l)$

(6) Reaction with Organic Compounds

Dihydrogen combines with many organic compounds in the presence of catalyst to give useful hydrogenated products of commercial importance.

(a) Hydrogenation of Vegetable Oils

Vegetable oil + $H_2(g) \xrightarrow[Ni]{473K}$ Edible fats (margarine and vanaspati ghee)

(b) Hydroformylation of Olefins

It yields aldehydes which further undergo reduction to give alcohols.

$$RCH = CH_2 + H_2 + CO \xrightarrow{\text{Catalyst}} RCH_2CH_2CHO$$

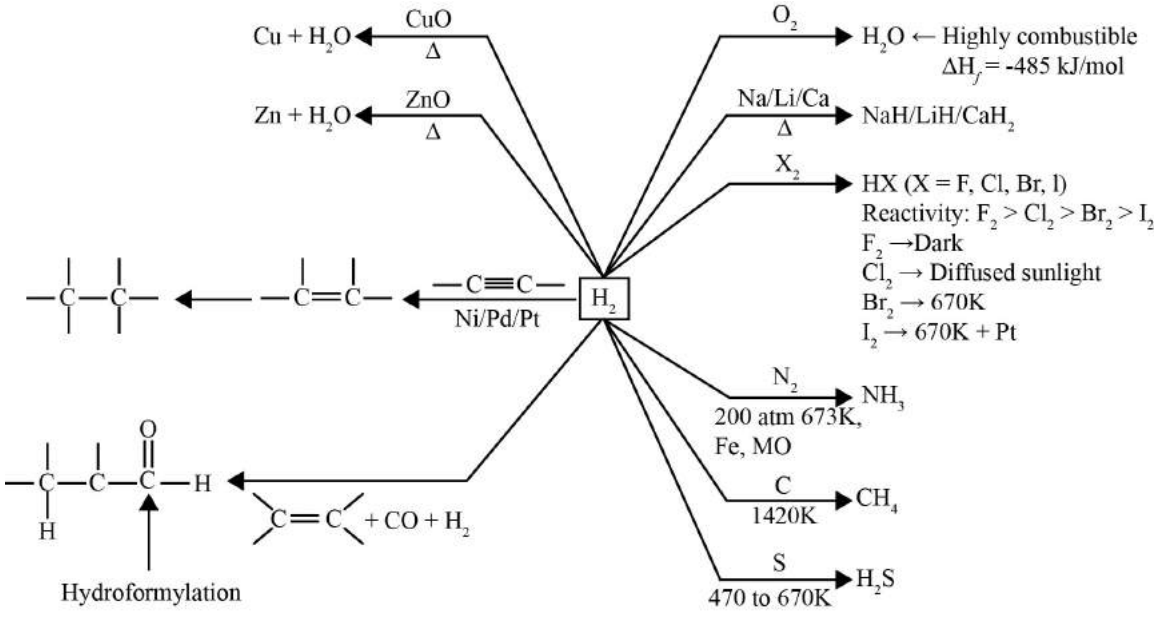
$$RCH_2CH_2CHO + H_2 \xrightarrow{\text{catalyst}} RCH_2CH_2CH_2OH$$

(c) Hydrogenation of Unsaturated Alkenes

Unsaturated hydrocarbons undergo hydrogenation in the presence of Ni/Pt to give saturated hydrocarbons

$$CH_2 = CH_2 + H_2 \xrightarrow[473K]{\text{Ni or Pt}} CH_3 - CH_3$$

$$CH \equiv CH + 2H_2 \xrightarrow[473K]{\text{Ni or Pt}} CH_3 - CH_3$$



Chemical Properties of Dihydrogen

3.5 Uses

(i) In the manufacture of ammonia which is used in the manufacture of nitric acid and nitrogenous fertilizers

(ii) In the manufacture of vanaspati ghee by hydrogenation of polyunsaturated vegetable oils like, soyabean, cotton seed etc.

(iii) In the manufacture of bulk organic chemical, particularly methanol.

$$CO(g) + 2H_2(g) \xrightarrow[\text{catalyst}, \Delta]{\text{Cobalt}} CH_3OH(l)$$

(iv) In preparation of metal hydrides and hydrogen chloride which are highly useful chemicals.

(v) It is used in the metallurgical process to reduce heavy metal oxides in to metals.

(vi) Atomic hydrogen (where temperature required is 2500 K) and oxy-hydrogen torches (where temperature required is 4000 K) are used for cutting and welding purposes.

Dissociation of dihydrogen with the help of an electric arc produces atomic hydrogen atoms. The atomic hydrogen atoms are allowed to recombine on the surface to be welded to regenerate the temperature of 4000K.

(vii) Mixed with liquid oxygen,it is used as a rocket fuel in space research.

(viii) It is used in fuel cells for generating electrical energy because it does not produce any pollution and releases greater energy per unit mass of fuel in comparision to gasoline and other fuels.

3.6 Dihydrogen as a Fuel

Dihydrogen on combustion liberates large quantities of heat. Following table gives the data on energy release by combustion of fuels like dihydrogen, methane, LPG etc. in terms of the some amounts in mole, mass and volume.

It reveals that on a mass for mass basis dihydrogen can release more energy than that of petrol (about three times). Further pollutants in combustion of dihydrogen will be less than petrol. The only pollutant in this will be the oxides of nitrogen which is formed due to the presence of dinitrogen as impurity with dihydrogen. This can be minimised by injecting a small amount of water into the cylinder to lower the temperature, so that the reaction between dinitrogen and oxygen may not take place. A cylinder of compressed dihydrogen weight 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 coastly insulated tanks of metal alloy, tanks of metal alloy like $NaNi_5$, $Ti–TiH_2$, $Mg–MgH_2$ etc, are used for storage of dihydrogen in small quantities. These limitations have prompted the scientists to search for alternative techniques to use dihydrogen in an efficient way. In this respect hydrogen economy is an alternative. The basic principle of hydrogen economy is the transportation and storage of energy in the form of liquid or gasseous dihydrogen. Advantage of hydrogen economy is that energy is transmitted in the form of dihydrogen and not as electric power.

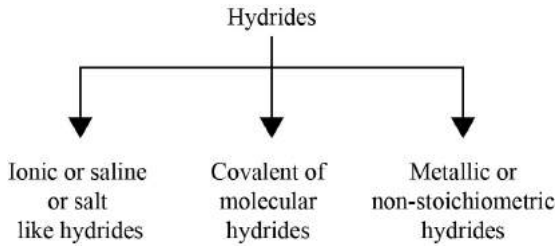
1. In india in october 2005 a pilot project using dihydrogen as fule was launched for running automobiles Initially 5% hydrogen has been mixed in CNG for use in four wheeler vehicles.
2. Now a days it is also used in fuel cells for generation of electric power.

Energy released	**Dihydrogen (g)**	**Dihydrogen (ΔU)**	**LPG CH_4 (g)**	**octane (ΔU)**	**combustion in kJ**
Per mole	286	285	2220	880	5511
Per gram	143	142	50	53	47
Per litre	12	9968	25590	35 3	4005

4. HYDRIDES

Dihydrogen combines with a large number of non-metals and metals, except noble gases, (under certain suitable reaction conditions) to form binary compounds. These binary compounds are called hydrides. The hydrides can be represented by the general formula EH_x (e.g. MgH_2) or E_mH_n (e.g. B_2H_6)

4.1 Classification of Hydrides



4.1.1 Ionic or Saline Hydrides

There are hydrides of elements which are more electropositive than hydrogen. These are stoichiometric compounds of dihydrogen formed with most of the s-block elements which are highly electropositive in nature. However, the lighter metal hydrides such as LiH, BeH_2 and MgH_2 have significant covalent character. Infact BeH_2 and MgH_2 are polymeric in nature. Ionic hydrides are crystalline, nonvolatile and non conducting in solid state. But their molten state conduct electricity and on electrolysis, liberate dihydrogen gas at anode. .Which confirms the existence of H^- ion. $2H^-(melt) \rightarrow H2(g) + 2e^-$ at anode These hydrides react with water violently libereting dihydrogen gas.

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

Similarly with protonic solvent such as ethanol and ammonia, they combine and liberates dihydrogen gas.

$$LiH + CH_3OH \rightarrow LiOCH_3 + H_2 \uparrow$$

$$NaH + NH_3 \rightarrow NaNH_2 + H_2 \uparrow$$

NOTE

LiH is unreactive at moderate temperature with O_2 or C_{l2} and therefore, it is used in the synthesis of other useful hydrides, e.g. $8\,LiH + Al_2Cl_6 \rightarrow 2LiAlH_4 + 6LiCl$; $2\,LiH + B_2H_6 \rightarrow 2LiBH_4$

Ionic hydrides are powerful reducing agents

$$2CO + NaH \rightarrow HCOONa + C \ ;$$

$$PbSO_4 + 2CaH_2 \rightarrow PbS + 2Ca(OH)_2$$

4.1.2 Covalent or Molecular Hydrides

These are the binary compounds of hydrogen with most of the p-block elements which have relatively high electronegativity. Covalent hydrides involves the formation of covalent bonds between H–atoms and other atoms by sharing of electrons. Some important examples of covalent hydrides are HCl, H_2O, CH_4, PH_3,NH_3 etc. Being covalent they are volatile compounds and more soluble in organic solvents. Molecular hydrides are further classified according to the relative numbers of electrons and bond in their Lewis structures.

(a) Electon Deficient Hydrides they have too few electrons for writing their conventional lewis structures. Examples: C_2H_6 and all elements of group 13^{th} form electron deficient compounds. They acts as lewis acid i.e., electron acceptor.

(b) Electron Precise Hydrides they have required number of electron for writing their conventional Lewis structures. Example: CH_4 and hydrides or group 14^{th} elements. They have tetrahedral geometry.

(c) Electron Rich Hydrides they have excess of electrons which are present as lone pairs examples: Elements of group 15-17 form such hydrides NH_3-1 lone pair: H_2O-2 lone pairs HF -3 lone pairs They acts as lewis base. i.e. electron donors.

NOTE

The presence of lone pairs on highly electronegative atoms like N,O, and F in hydrides results in hydrogen bond formation between the molecules leading to the association of molecule.

4.1.3 Metallic or Non - Stoichiometric (Interstitial) Hydrides

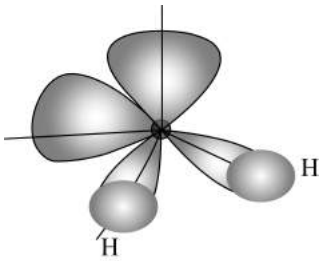
These are formed by many d-block and f-block elements however metal of group 7, 8 and 9 do not form hydride it called as hydride gap. Ratio is not fixed between metal and H_2. Chromium only the 6th group metals which form metallic hydrides, (CrH). These hydrides conduct electricity and heat not as efficiently as their parent metals do. They are almost always non-stoichiometric, being deficient in hydrogen. Examples : $LaH_{2.87}$, $YbH_{2.55,}$ $TiH_{1.5–1.8}$, $ZrH_{1.3–1.75}$, $VH_{0.56}$, $NiH_{0.6–0.7}$, $PdH_{0.6–0.8}$ etc. Earlier it was thought that in these hydrides , hydrogen occupies interstitial sites in the metal lattice producing distortion without any change in its type. This gave the name interstitial hydrides to this type of hydrides but 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 metals.This property of absorption of hydrogen on transition metal is largely used in the catalytic reduction, hydrogenation reaction for the preparation of large number of compounds. Pd, Pt etc. can accomodate a very large volume of hydrogen and therefore can be used as its storage media.

NOTE

The inability of metals of group 7,8,9 of periodic table to form hydrides is referred to as hydride gap of d-block.

5. WATER

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



5.1 Physical Properties

It is a colourless and tasteless liquid. It has some unique and unusual properties in the condensed phase (liquid and solid states) which are due to the presence of extensive hydrogen bonding between water molecules. Hydrogen bonding leads to high freezing point, high boiling point, high heat of vaporisation and high heat of fusion in comparision 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 than most of the other liquids. Because of these properties water play a vital and key role in the biosphere.

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 needed/essential for plant and animal metabolism. Polar molecules and also the covalent compounds like alcohol and carbohydrates dissolve in water due to hydrogen bonding. It is a highly polar molecule and in the liquid phase water molecules are associated together by hydrogen bonds. Its crystalline form is ice.

At atmospheric pressure ice crystallises in the hexagonal form, but at very low temperature it condenses to cubic form. Density of ice is less than that of water. Therefore, an ice floats on water.

NOTE

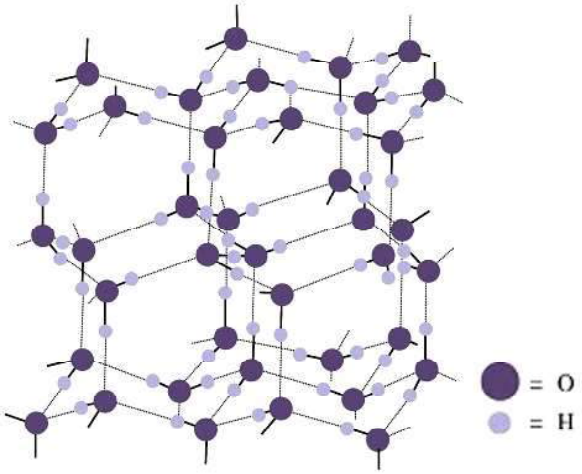
In winter season ice formed on the surface of a lake gives thermal insulation and this ensures the survival of the aquatic life.

Physical properties of Water

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) / KJ mol^{-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
Dielectric constant / $C^2/N.m^2$	78.39	78.06
Electrical conductivity	5.7×10^{-8}	-

Structure of Ice

Ice has a highly ordered three dimensional hydrogen bonded structure



According to X–rays analysis of ice crystals, each oxygen atom is surrounded tetrahedrally by four other oxygen atoms at a distance of 2.76 Å. There are four H atoms around each O atom. Two of the four H atmos are bonded by covalent bonds (bonds lengths 100 pm) where as the other two are bonded through H–bonds (bond lengths 176 pm) Hydrogen bonding gives ice open cage like structure with wide holes. As a consequence of this, ice has a relatively large volume for a given mass of liquid water.

5.2 Chemical Properties of H_2O

(1) Amphoteric Nature

It has the ability act as an acid as well as a base i.e., it behave as an amphoteric substance.

$H_2O(l) + NH_3(aq) \rightleftharpoons OH^-(aq) + NH_4^+(aq)$

$H_2O(l) + H_2S(aq) \rightleftharpoons H_3O^+(aq) + HS^-(aq)$

The auto -protolysis (self ionisation) of water occurs as :

$H_2O(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$

acid – 1 base –1 acid-2 base-2

(acid) (base) conjugate acid conjugate base

(2) Redox Reaction Involving Water

Water can be easily reduced dihydrogen by highly electropositive metals.

$2H_2O(l) + 2Na(s) \xrightarrow[reduction]{oxidation} 2NaOH(aq) + H_2(g)$

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

This reaction occurs during photosynthesis

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

(3) Hydrolysis Reaction

It has a very strong hydrating tendency because of its high dielectric constant. Hydrolysis of certain covalent and some ionic compounds takes place in water.

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

$SiCl_4(l) + 2H_2O(l) \xrightarrow{\Delta} SiO_2(s) + 4\,HCl(aq)$

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

(4) Hydrates Formation

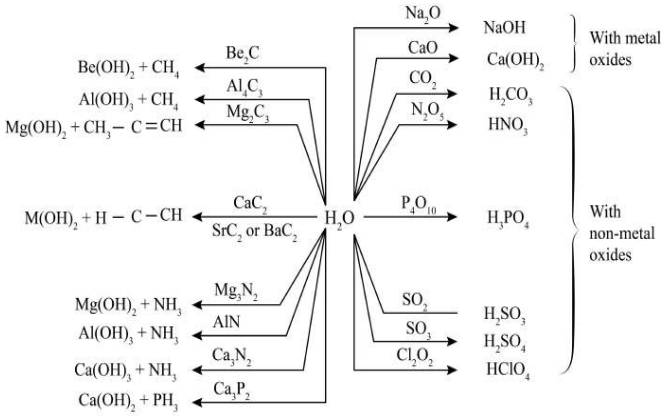
Many salts on crystallisation from their aqueous solutions yield hydrate salts. There are three ways of association of water as given below.

(i) Coordinated water : Attached to central metal ion through coordinate – covalent bond. $[Cr(H_2O)_6]^{3+}3Cl^-$

(ii) Interstitial water : Water molecules occupy the interstices of the crystal lattice of the compound e.g. $BaCl_2.2H_2O$.

(iii) Hydrogen bonded water : Water is attached to the compound making hydrogen bond .

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



Chemical Properties of H_2O

6. HARDNESS OF WATER

6.1 Temporary Hardness

It is due to the presence of the soluble bicarbonates of magnesium and calcium. Methods used for removing the temporary hardness of water are as follows -

(a) Boiling

Soluble salts converts to insoluble salt during boiling which forms ppt and can easily removed by filtration.

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

$Mg(OH)_2$ is precipitated because of high solubility product of $Mg(OH)_2$ as compared to that of $MgCO_3$

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

Filtrate is soft water.

(b) Clark's Method (Calcium Hydroxide/Lime Water Method)

$$Ca(HCO_3)_2 + Ca(OH)_2 \text{ (calculated amount)} \rightarrow 2CaCO_3 \downarrow + 2H_2O$$

$$Mg(HCO_3)_2 + 2Ca(OH)_2 \text{(calculated amount)} \rightarrow 2CaCO_3 \downarrow + Mg(OH)_2 \downarrow + 2H_2O$$

6.2 Permanent Hardness

It cannot be removed by boiling it is due to the presence of soluble salts of magnesium and calcium in the form of chlorides and sulphates.

Methods used for removing the permanent hardness of water are as follows -

(a) Addition of Washing Soda (Sodium Carbonate)

It reacts with chloride and sulphate of Mg^{2+} and Ca^{2+} to precipitate out as $MgCO_3$ and $CaCO_3$.

$$MCl_2 + Na_2CO_3 \rightarrow MCO_3 \downarrow + 2\,NaCl\ (M = Mg/Ca)$$

$$MSO_4 + Na_2CO_3 \rightarrow MCO_3 \downarrow + Na_2SO_4\ (M = Mg/Ca)$$

(b) Calgon's Method

Sodium hexametaphosphate ($Na_6P_6O_{18}$ or $Na_2[Na_4(PO_3)_6]$ is commerically called 'calgon' forms soluble complexes with Mg^{2+} and Ca^{2+} ions.

$$2Ca^{2+} + Na_2[Na_4(PO_3)_6] \rightarrow Na_2[Ca_2(PO_3)_6]\text{ (soluble complex)} + 4Na^+$$

Hard water

$$2Mg^{2+} + Na_2[Na_4(PO_3)_6] \rightarrow Na_2[Mg_2(PO_3)_6]\text{ (soluble complex)} + 4Na^+$$

Hard water

OR

$$Na_6P_6O_{18} \rightarrow 2Na^+ + Na_4P_6O_{18}^{2-}$$

$$M^{2+} + Na_4P_6O_{18}^{2-} \rightarrow [Na_2MP_6O_{18}]^{2-} + 2Na^+\ (M = Mg/Ca)$$

(c) Ion-exchange Method

(Zeolite/permutit method) With zeolite (hydrated sodium aluminium silicate) $NaAlSiO_4$, hard water gives following exchange reaction.

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

The exhausted zeolite is regenerated for further use by treating with aqueous solution of NaCl

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

(d) Synthetic Resin Method

This method is more efficient than zeolite. It involves the use of cation exchange resin and anion exchange resin for softening of water. Cation exchange resin contain large organic molecules with $-SO_3H$ group and are insoluble. Anion exchange resin contain large organic molecules with –OH group and are insoluble.

Reaction with Cation Exchange Resin

$$RSO_3H + NaCl \rightarrow RSO_3Na + HCl$$

$$2RNa(s) + M^{2+}(aq) \rightarrow R_2M(s) + 2Na^+(aq)\ (M^{2+} = Ca^{2+}/Mg^{2+})$$

Hard water

Exhausted resin is then regenerated by treating with NaCl solution. Pure de-mineralised water which is free from all soluble mineral salts is obtained by passing water successively through a cation exchange (in the H^+ form) and an anion exchange (in the OH^- form).

$2RH(s) + M^{2+}(aq) \rightleftharpoons MR_2(s) + 2H^+(aq)$ Here in this H^+ exchange for Na^+, Mg^{2+}, Ca^{2+} and other cation present in the water. This process results in the release of proton and thus makes the water acidic. In the anion exchange process as given below, OH^- exchanges for anion like, Cl^-, HCO_3^-, SO_4^{2-} etc, present in the water, this process results in the release of OH^- which neutralise the H^+ ions released in the cation exchange.

$$RNH_2(s) + H_2O(l) \rightleftharpoons RNH_3^+.OH^-(s)$$

$$RNH_3^+.OH^-(s) + X^-(aq) \rightleftharpoons RNH_3X^- + OH^-$$

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

The exhausted cation and anion exchange resin are regenerated by treatment with dilute acid and dilute alkali solutions respectively.

6.3 Difference between Hard Water and Soft Water

Hard water	Soft water
1. Water containing calcium and magnesium in the form of bicarbonates, chlorides and sulphates, does It gives lather with soap easily.	**1.** Water free from soluble salts of calcium and magnesium is called soft water. not give lather with soap. This typeof water is called hard water.
2. River water, sea water, tap water are common examples of hard water..	**2.** Distilled water and rain water are common examples of soft water.
3. It forms scum/precipitate with soap. It reacts with soap (containing sodium sterate) to precipitate out Ca/ Mg sterate. $2C_{17}H_{35}COONa(aq) + M^{+}(aq) \downarrow (C_{17}H_{35}COO)_2M \downarrow + 2Na^{+}(aq)$ M = Ca/Mg	**3.** It does not form scum/precipitate with soap.
4. It is not suitable for the laundary because of the above reason. It is also harmful for boilers because of the deposition of salt in the form of scales. The scale formation reduces the efficiency of the boiler.	**4.** It is suitable for laundry as well as for boilers.

7. HEAVY WATER (D_2O)

7.1 Preparation

(a) By prolonged/exhaustive electrolysis of water.

(b) Obtained as a by product in some fertilizer industries.

7.2 Properties

Heavy water is colourless, tasteless and odourless liquid. All physical constants of heavy water are higher than the corresponding values of ordinary water. Chemically heavy water is similar to ordinary water but the chemical reactions are slower than those of ordinary water.

7.3 Uses

(i) It is widely used as moderator in nuclear reactors.

(ii) It is used in exchange reactions for the study of the reaction mechanism.

(iii) It is used for the preparation of other deuterium compounds.

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

$SO_3 + D_2O \rightarrow D_2SO_4$

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

8. HYDROGEN PEROXIDE (H_2O_2)

It is an important chemical used in pollution control treatment of domestic and individual effluents.

8.1 Methods of Preparation

(A) Laboratory Method

$$BaO_2 + 2HCl \longrightarrow \underbrace{BaCl_2 + H_2O_2}_{\text{not possible to isolate } H_2O_2 \text{ from this solution}}$$

Anhydrous BaO_2 cannot be used, as $BaSO_4$ formed by the reaction with H_2SO_4, forms a thin protective film around BaO_2 and reaction slowly ceases and finally stops after sometime. So hydrated barium peroxide is used.

$$H_2O_2 + \underset{\text{sat.soln.}}{Ba(OH)_2} + 6H_2O \rightarrow BaO_2 \cdot 8H_2O$$

Acidifying barium peroxide and removing excess of water by evaporation under reduced pressure gives H_2O_2. $BaSO_4$ is removed by filteration.

$$BaO_2.8H_2O + \underset{\text{cold}}{H_2SO_4} \rightarrow \underset{\text{ppt.}}{BaSO_4} \downarrow + H_2O_2 + 8H_2O$$

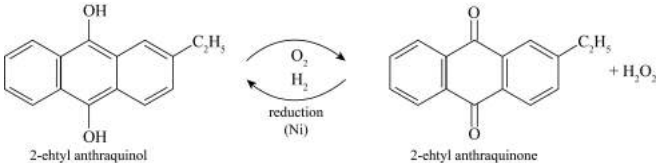
Since H_2SO_4 can decompose H_2O_2 at a higher temperature, therefore, this reaction should be carried out at low temperature. H_3PO_4 can be used in place of H_2SO_4.

$3BaO_2 + 2H_3PO_4 \rightarrow Ba_3(PO_4)_2 \downarrow + H_2O_2; Ba_3(PO_4)_2 + 3H_2SO_4 \rightarrow$

$3BaSO_4 \downarrow + 2H_3PO_4$ (can be used again)

(B) Industrial Method

(i) Auto Oxidation



(ii) By electrolysis of Conc. H_2SO_4 (50%) at 0^0C using Inert Electrodes

Cathode : Platinum

Anode : Graphite

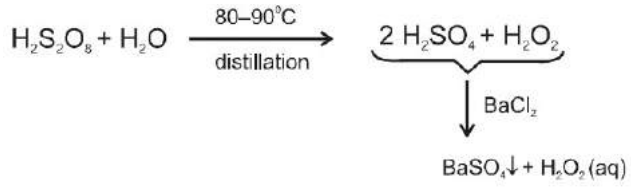
$H_2SO_4 \rightleftharpoons H^+ + HSO_4^-$

At Anode : $2\,HSO_4^- \rightarrow S_2O_8^{-2} + 2\,H^+ + 2e^-$

or

$(2\,HSO_4^-(aq) \rightarrow HO_3SOOSO_3)$

At Cathode : $H^+ + e^- \rightarrow \frac{1}{2}H_2$



$K_2S_2O_8(s) + 2\,D_2O(l) \rightarrow 2\,KDSO_4(aq) + D_2O_2(l)$

(iii) Modified Method

Equimolar mixture of sulphuric acid and ammonium sulphate is used for electrolysis. $(NH_4)_2\,SO_4 + H_2SO_4 \rightarrow 2\,NH_4HSO_4$ (ammonium hydrogen sulphate)

$NH_4HSO_4 \rightarrow NH_4SO_4^- + H^+$

At Cathode : $H^+ + e^- \rightarrow \frac{1}{2}H_2$

At Anode :

$2\,NH_4SO_4^- \rightarrow (NH_4)_2\,S_2O_8$ (ammonium persulphate) $+ 2e^-$

$(NH_4)_2\,S_2O_8 + H_2O \xrightarrow{\text{distillation}} 2\,NH_4HSO_4 + H_2O_2$

In this case 1% H_2O_2 is formed. It is extracted with water and concentrated to approximately 30% (by mass) by distillation under reduced pressure. It can be further concentrated by careful distillation under low pressure to approximately 85%. The remaining water can be frozen out to obtain pure H_2O_2 .

8.2 Properties of H_2O_2

(a) Physical Properties

(1) In pure state it is a colourless viscous liquid, which appears blue in the large quantity.

(2) It is H-bonded and therefore, miscible with water in all proportions and forms a hydrate H_2O_2 . H_2O has melting point 221 K.

(3) Its boiling point (144°C) is more than water , freezing point (–4°C) is less and density is more than water.

Its aqueous solution is more stable than the anhydrous liquid where it decomposes into water and O_2, slowlyon exposure to light.

$2\,H_2O_2 \rightleftharpoons 2\,H_2O + O_2$

H_2O_2 is not kept in glass/metal containers because traces of alkali metal ions and metal ions from the glass and metal surface respectively can catalyse the explosive decomposition of H_2O_2. Therefore, H_2O_2 aqueous solution is stored in the plastic or wax–lined glass containers in dark and some urea, phosphoric acid or glycerol is added to that solution because these compounds have been found to behave as negative catalyst for the decomposition of H_2O_2. It is also kept away from the dust because dust can also induce explosive decomposition. A 30% solution of H_2O_2 is marketed as 100 volume H_2O_2. It means that one mililitre of 30% H_2O_2 solution will give 100 volume of O_2 STP. Commercially it is marketed as 10 V, which means it contains 3% H_2O_2.

(b) Chemical Properties

(1) Acidic Nature

Aqueous H_2O_2 behaves as a weak acid according to following equation.

$H_2O_2(aq) \rightleftharpoons H^+ + HO_2^-$ $\quad Ka = 1.5 \times 10^{-12}$ at 25^0 C

A 30% soln. of H_2O_2 has pH = 4

Aqueous H_2O_2 turns blue litmus red, which is bleached by oxidising property of H_2O_2.

$Na_2CO_3 + H_2O_2 \rightarrow Na_2O_2 + H_2O + CO_2 \uparrow$

$Ba(OH)_2 + H_2O_2 + 6\,H_2O \uparrow BaO_2.8\,H_2O$

(2) Oxidising Nature of H_2O_2

$2e^- + 2\,H^+ + H_2O_2 \rightarrow 2\,H_2O$ $\quad$ SRP = + 1.77 V (in acidic medium)

$2e^- + H_2O_2 \rightarrow 2\,OH^-$ $\quad$ SRP = + 0.87 V (in basic medium)

On the basis of above potential, we can say that H_2O_2 is a stronger oxidising agent in acidic medium than in basic medium but kinetically it is found that reactions are faster in basic medium.

(a) Oxidising Action in Acidic Medium

$2\,Fe^{2+} + 2\,H^{+}\,(aq). + H_2O_2 \rightarrow 2\,Fe^{3+}\,(aq) + 2\,H_2O\,(l)$

$2H_2O_2 + NH_2.NH_2 \rightarrow N_2 + 4H_2O$. (reaction is explosive)

hydrazine

$H_2O_2 \rightarrow H_2O + [O] \times 4$

$PbS + 4[O] \rightarrow PbSO_4$

$PbS + 4H_2O_2 \rightarrow PbSO_4 + 4H_2O$

This property is utilized in restoring the white colour in old paintings which turns black due to the formation of PbS by the action of atmospheric H_2S.

$H_2O_2 \rightarrow H_2O + [O]$

$H_2S + [O] \rightarrow H_2O + S$

$H_2O_2 + H_2S \rightarrow 2\,H_2O + S$

(b) Oxidising Action in Basic Medium

$2\,Cr(OH)_3 + 4\,NaOH + 3\,H_2O_2 \rightarrow 2Na_2CrO_4 + 8\,H_2O$

or

$10\,OH^- + 3\,H_2O_2 + 2Cr^{3+} \rightarrow 2\,CrO_4^{2-} + 8\,H_2O$

$Pb^{2+}(aq) + CrO_4^{2-}$ (yellow solution) $\rightarrow PbCrO_4 \downarrow$ (yellow)

$2\,Fe^{2+} + H_2O_2 \rightarrow 2\,Fe^{3+} + 2\,OH^-$

$Mn^{2+} + H_2O_2 \rightarrow Mn^{4+} + 2\,OH^-$

(3) H_2O_2 as Reducing Agent

$H_2O_2 \rightarrow O_2 + 2\,H^+ + 2e^-$

$2\,OH^- + H_2O_2 \rightarrow O_2 + 2\,H_2O + 2e^-$

In alkaline medium, its reducing character is more than in acidic.

(a) Reducing action in acidic medium

$2\,MnO_4^- + 6\,H^+ + 5\,H_2O_2 \rightarrow 2\,Mn^{2+} + 8\,H_2O + 5\,O_2$

$HOCl + H_2O_2 \rightarrow H_3O^+ + Cl^- + O_2$

(b) Reducing action in basic medium

$I_2 + H_2O_2 + 2\,OH^- \rightarrow 2I^- + 2\,H_2O + O_2$

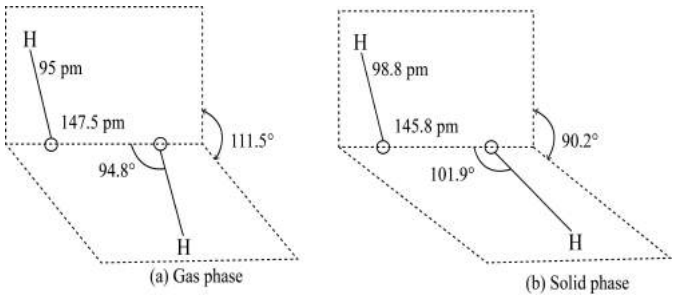
$2\,MnO_4^- + 3\,H_2O_2 \rightarrow 2\,MnO_2 + 3\,O_2 + 2\,H_2O + 2\,OH^-$

$2[Fe(CN)_6]^{3-}(s) + H_2O_2(aq) + 2OH^-(aq) \rightarrow 2[Fe(CN)_6]^{4-}(aq) + 2H_2O(l) + O_2(g)$

$Ag_2O + H_2O_2 \rightarrow 2\,Ag + H_2O + O_2$

8.3 Structure

Hydrogen peroxide is non planar structure. The two oxygen atoms are linked to each other by a single covalent bond and each oxygen is further linked to a hydrogen atom by a single covalent bond. The O–H bonds are in different planes due to repulsions between different bonding and antibonding orbitals.



8.4 Uses

(i) In daily life it is used as a hair bleach and as a mild disinfectant. As an antiseptic, it is sold in the market as perhydrol.

(ii) It is used to manufacture chemicals like sodium perborate and per carbonate used in high quality detergents.

(iii) It is used in synthesis of hydroquinone, tartaric acid and certain food products and pharmaceuticals (cephalosporin) etc.

(iv) It is employed in the industries as a bleaching agent for textiles, paper pulp, leather, oils, fats, etc.

(v) Also used in Environmental (Green) chemistry. e.g., in pollution control treatment of domestic and industrial effluents, oxidation of cyanides, restoration of aerobic conditions to sewage wastes, etc.

SUMMARY

Hydrogen

Hydrogen in atomic form consists of one proton and one electron but, in elemental form it exists as a diatomic (H_2) molecule. H_2 is called as dihydrogen.

Properties Resembling With Alkali Metals

(a) Electronic Configuration : The valence shell electron configuration of hydrogen and alkali metals are similar i.e. ns^1

(b) Formation of Unipositive ion : Hydrogen as well as alkali metals lose one electron to form unipositive ions.

(c) Formation of Oxides, Halides and Sulphides : Just like alkali metals hydrogen combines with electronegative elements such as oxygen, halogen and sulphur forming oxide, halide and sulphide respectively.

Properties Resembling With Halogens

(a) Electronic Configuration

Both have one electron less than that of nearest inert gas configuration.

(b) Atomicity

Like halogens, hydrogen forms diatomic molecule too. For example, Cl_2, Br_2, I_2 etc.

(c) Ionization Enthalpy

Hydrogen as well as halogens both have higher ionization enthalpies.

Isotopes

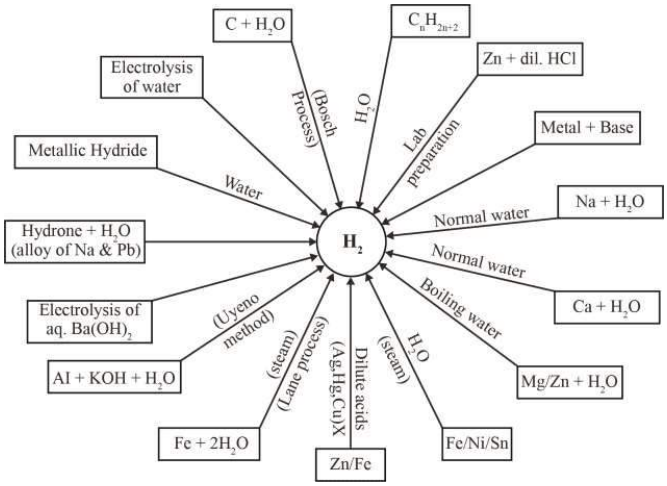
Hydrogen has three isotopes namely protium ${}^{1}_{1}H$, deuterium ${}^{1}_{2}H$ or D and tritium ${}^{1}_{3}H$ or T. They differ from one another by the number of neutrons present in them, Protonium has no neutrons. Deuterium which is also known as heavy hydrogen has one neutron and Tritium has two neutrons in the nucleus.

Dihydrogen (H_2)

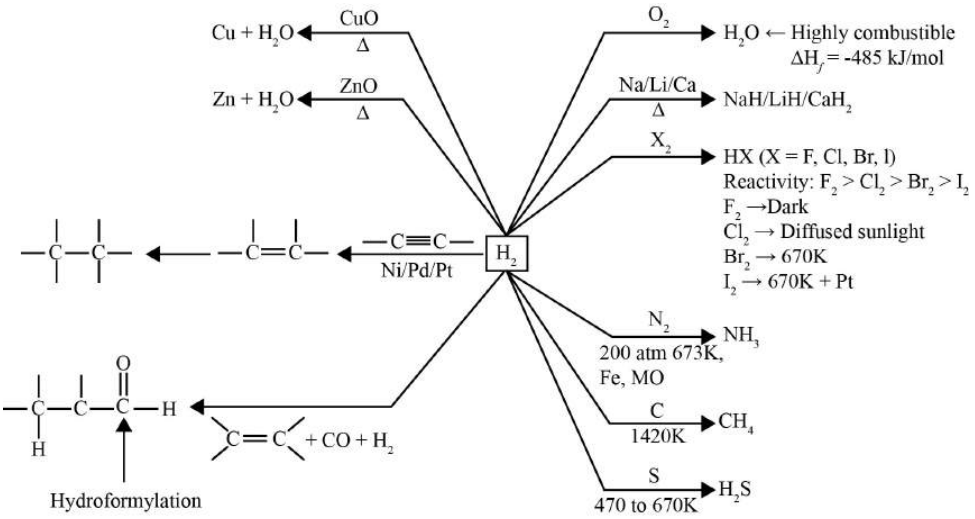
Occurence

It is most abundent element of the universe (70% of the total mass) but it is much less abundent element (0.15% by mass) in the earth atmospher due to its light nature. In combined form it constitutes 15.4% of the earth crust and the oceans.

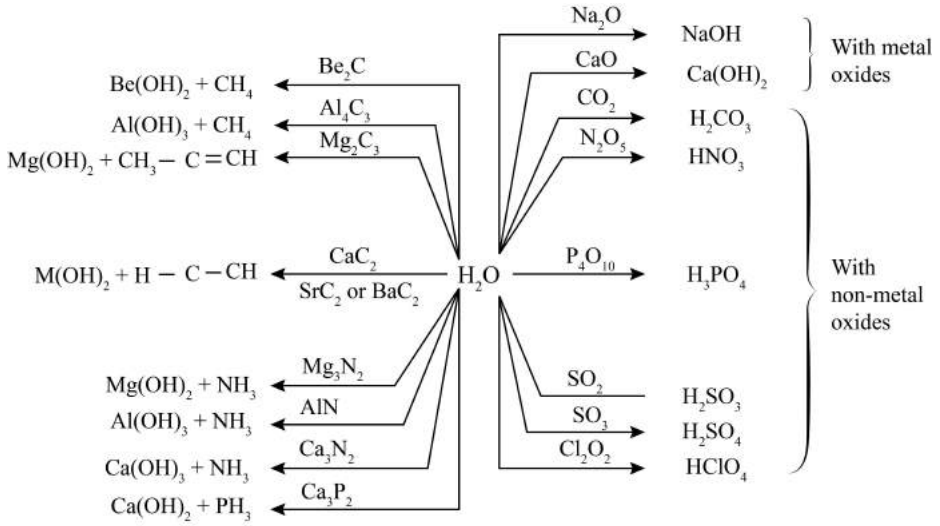
Preparation of Dihydrogen



Chemical Properties of Dihydrogen



Chemical Properties of H_2O



Hardness of Water

(1) Temporary Hardness

It is due to the presence of the soluble bicarbonates of magnesium and calcium.

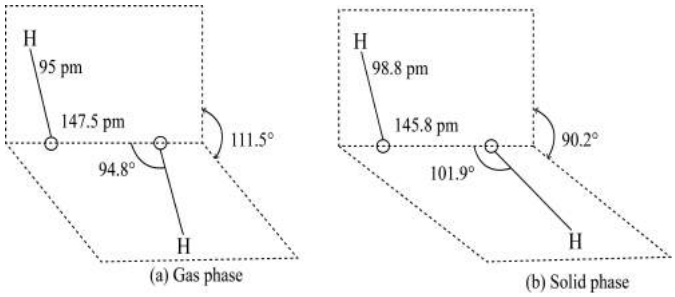
(2) Permanent Hardness

It cannot be removed by boiling it is due to the presence of soluble salts of magnesium and calcium in the form of chlorides and sulphates.

Hydrogen Peroxide (H_2O_2)

It is an important chemical used in pollution control treatment of domestic and individual effluents.

Structure



SOLVED EXAMPLES

Example - 1

Number of proton and electron present in atomic form of hydrogen are respectively

(a) 2,1 (b) 1,2

(c) 1,1 (d) None of these

Ans. (c)

Sol. Atomic number of hydrogen is 1. In atomic form, hydrogen consists of only one proton and one electron.

Example - 2

Assertion (A) : Hydrogen is the first element in the Periodic Table.

Reason (R) : It has electronic configuration $1s^1$

(a) Both A and R are correct; R is the correct explanation of A.

(b) Both A and R are correct; R is not the correct explanation of A.

(c) A is correct; R is incorrect

(d) R is correct; A is incorrect.

Ans. (a)

Sol. Hydrogen is the first element in the Periodic Table, as it has the electronic configuration $1s^1$.

Example - 3

Which of the following is/are true statements (s) regarding characteristic of hydrogen?

I. Hydrogen resembles alkali metals due to the similar outer electronic configuration i.e. ns^1

II. Hydrogen is short by one electron to the corresponding noble gas configuration, of helium i.e. $1s^2$

(a) I only

(b) I and II

(c) II only

(d) None of the above is true.

Ans. (b)

Sol. Hydrogen resembles alkali metals due to the similar outer electronic configuration ns^1. On the other hand, it is short by one electron to the corresponding noble gas configuration of helium i.e.$1s^2$

Example - 4

Hydrogen does not posses the metallic characteristics under normal conditions because

(a) It has low ionisation enthalphy

(b) It has low electron gain enthalpy

(c) It has high electron gain enthalpy

(d) It has a very high ionisation enthalphy

Ans. (d)

Sol. Unlike alkali metals, hydrogen has a very high ionisation enthalpy and does not possess metallic characteristics under normal conditions.

Example - 5

Hydrogen resembles halogens in many respects for which several factors are responsible. Of the following factors which one is the most important in this respect?

(a) Its tendency to lose an electron to form a cation

(b) Its tendency to gain a single electron in its valence shell to attain stable electronic configuration

(c) Its low negative electron gain enthalpy value

(d) Its small size

Ans. (b)

Sol. Hydrogen resembles halogens in many respects for which several factors are responsible. The most important is its tendency to gain a single electron in its valence shell to attain stable electronic configuration.

Example - 6

Hydrogen has three isotopes-protium ($_1^1H$), deuterium ($_1^2H$), and tritium ($_1^3H$). These isotopes differ from one another in respect of the …X….What is X in the given statement?

(a) Presence of neutrons

(b) Presence of electrons

(c) Presence of protons

(d) Presence of neutron and proton

Ans. (a)

Sol. Hydrogen has three isotopes-protium Deuterium and tritium . These isotopes differ from one another in respect of the presence of neutrons.

Example - 7

$$Zn + 2NaOH(aq) \longrightarrow X + H_2$$

What is X in the above reaction?

(a) Zinc oxide

(b) Sodium carbonate

(c) Sodium zincate

(d) None of these

Ans. (c)

Sol. Hydrogen can also be prepared by the reaction of zinc with an aqueous alkali.

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

Example - 8

Approximately 77% of .....X..... is produced from petrochemicals, 18% from coal, 4% from the electrolysis of an aqueous solutions and 1% from other sources.

Here X refers to.

(a) Electrolytic dihydrogen

(b) Industrial nitrogen

(c) Steam

(d) Industrial dihydrogen

Ans. (d)

Sol. 77% of the industrial dihydrogen is produced from petrochemicals,18% from coal, 4% from electrolysis of aqueous solutions and 1% from other sources.

Example - 9

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

$$2H_2(g) + O_2(g) \xrightarrow[\text{heating}]{\text{catalyst}} 2H_2O(l)$$

$$3H_2(g) + N_2(g) \xrightarrow[Fe]{673K, 200atm} 2NH_3(g)$$

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

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

The correct reactions are

(a) II, III and V (b) IV and V

(c) I, II and IV (d) All of these

Ans. (d)

Sol. The chemistry of dihydrogen (H_2) is given by the following reactions. The chemistry of dihydrogen is given by the following reactions.

Reaction with halogens

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

Reaction with fluorine occurs in dark and with iodine it requires a catalyst

Reaction wih dioxygen

$$2H_2(g) + O_2(g) \xrightarrow[\text{heating}]{\text{Catalyst or}} 2H_2O(l);$$

$$\Delta H = -285.9\,kJmol^{-1}$$

Reaction with dinitrogen

$$3H_2(g) + N_2(g) \xrightarrow[Fe]{673K, 200atm} 2NH_3$$

$$\Delta H = -92.6\ KJmol^{-1}$$

This is known as Haber's process.

Reaction with metal

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

Reaction with metal ions and metal oxides

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

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

Example - 10

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

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

In the above reaction, NaH and LiH are the examples of

(a) Ionic or saline or salt like hydrides

(b) Covalent or molecular hydrides

(c) Metallic or non-stoichiometric hydrides

(d) Stoichiometric hydrides

Ans. (a)

Sol. Saline or ionic hydrides react violently with water producting dihydrogen gas.

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

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

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

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

Example - 11

The unusual properties of water in the condensed phase (liquid and solid states) are due to the

(a) Presence of hydrogen and covalent bonding between the water molecules

(b) presence of covalent bonding between the water molecules

(c) Presence of extensive hydrogen bonding between water molecules

(d) presence of ionic bonding

Ans. (c)

Sol. The unusual properties of water in the condensed phase (liquid and solid states)are due to the presence of extensive hydrogen bonding between the water molecules.

Example - 12

Which of the following is the incorrect reaction?

(a) $P_4O_{10}(s) + 6H_2O(l) \longrightarrow 4H_3PO_4(aq)$

(b) $SiCl_4(s) + 2H_2O(l) \longrightarrow Si(OH)_2(s) + 4HCl(aq)$

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

(d) $6CO_2(g) + 12H_2O \longrightarrow C_6H_{12}O_6(aq) + 6H_2O(l) + 6O_2(g)$

Ans. (b)

Sol. Hydrolysis reaction

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

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

$SiCl_4(s) + 2H_2O(l) \longrightarrow SiO_2 + 4HCl(aq)$

Redox reaction involving water

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

It is a great source of dihydrogen.

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

Water is oxidised to O_2 during photosynthesis.

Example - 13

Assertion (A) : Hard water does not give lather with soap.

Reason (R) : Hard water contains calcium and magnesium salts in the form of hydrogen carbonate, chloride and sulphate.

(a) Both A and R are correct; R is the correct explanation of A

(b) Both A and R are correct; R is not the correct explanation of A

(c) A is correct; R is correct

(d) R is correct; A is incorrect

Ans. (a)

Sol. Presence of calcium and magnesium salts in the form of hydrogen carbonate, chloride and sulphate in water makes water hard. Hard water does not give lather with soap.

Example - 14

A sample of water containing some dissolved sugar and table salt is passed through organic ion exchange resins.

The resulting water will be

(a) Sweet (b) Tasteless

(c) Bitter (d) Salty

Ans. (a)

Sol. Ionic impurities like Na^+ and Cl^- are removed by organic ion exchange leaving sugar in the water sample.

Example - 15

H_2O_2 is used

I. Aperhydrol.

II. In the manufacture chemicals like sodium perborate and per-carbonate

III. In the synthesis of hydroquinone.

IV. In the environmental (green) chemistry.

(a) I, II and IV

(b) I, III and IV

(c) I, II and III

(d) All the four statements are correct

Ans. (d)

Sol. H_2O_2 is used

I. As hair bleach disinfectant and an antiseptic as perhydrol.

II. In the manufacture chemicals like sodium perborate and per-carbonate.

III. In the synthesis of hydroquinone, tartaric acid, cephalosporin, in the pollution control treatment.

IV. In the environmental (green) chemistry in pollution control treatment.

Example - 16

Which of the following is almost colourless (very pale blue) liquid in the pure state?

(a) D_2O (b) H_2O_2

(c) H_2O (d) H_3O^+

Ans. (b)

Sol. H_2O_2 is an almost colourless (very pale blue) liquid in the pure state.

Example - 17

6 volume sample of H_2O_2

(a) Would give 6 volume of oxygen per unit volume H_2O_2 of sample at STP

(b) Will contain o6% v/v of H_2O_2

(c) Will contain 6% W/v of H_2O_2

(d) Would give 6 volumes of oxygen per unit weight of H_2O_2 sample at STP

Ans. (a)

Sol. 6 volume sample of H_2O_2 means 6 volume of oxygen are given out per unit volume of H_2O_2 sample at STP.

Example - 18

Study the reactions carefully

I. $HOCl + H_2O_2 \longrightarrow H_3O^+ + Cl^- + O_2$

II. $PbS + 4H_2O_2 \longrightarrow PbSO_4 + 4H_2O$

Point out the correct option.

(a) In (I), HOCl is reduced and in (II) PbS is oxidised

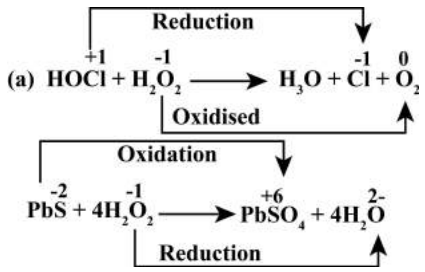
(b) In (I), HOCl is oxidised and (II) PbS is reduced

(c) In both (I) and (II), HOCl and PbS are reduced

(d) In both (I) and (II), HOCl and PbS are oxidised

Ans. (a)

Sol.



Example - 19

Which of the following is extensively used as a moderator in nuclear reactors and in exchange reactions for the study of reaction mechanisms ?

(a) H_2O (b) HD

(c) D_2O (d) H_2

Ans. (c)

Sol. D_2O is extensively used as a moderator in nuclear reactors and in exchange reaction for the study of reaction mechanism.

Example - 20

Dihydrogen is used in the

I. Manufacture of nitric acid and nitrogenous fertilizers.

II. Manufacture of vanaspati fat.

III. Manufacture of methanol.

IV. Preparation of hydrogen chloride.

Choose the correct option.

(a) I, II and IV (b) II, IIIand IV

(c) I, II and III (d) I,II, III and IV

Ans. (c)

Sol. Uses of dihydrogen

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

(ii) Dihydrogen is used in the manufacture of vanaspati fat by the hydrogenation of polyunsaturated vegetable oils like soyabean, cotton seeds etc.

(iii) It is used in the manufacture of bulk organic chemicals, particularly methanol.

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

(iv) It is widely used for the manufacture of metal hydrides.

(v) It is used for the preparation of hydrogen chloride, a highly useful chemical.

Example - 21

Can dihydrogen act as oxidising agent ? If so give chemical reactions to support the statement.

Sol. Dihydrogen can act as oxidising agent when it forms metal hydrides.

$2Li + H_2 \rightarrow 2LiH$

Example - 22

Can conc. H_2SO_4 be used for drying H_2 gas ? Justify.

Sol. Conc. H_2SO_4 cannot be used for drying H_2 gas because H_2SO_4 does absorb moisture from moist H_2, but the process is highly exothermic. The heat so produced causes hydrogen to catch fire because of its inflammable nature.

Example - 23

Complete the following reactions :

(i) $H_2(g) + M_mO_n(s) \xrightarrow{\Delta}$

(ii) $CO(g) + H_2(g) \xrightarrow{\Delta}$

(iii) $C_3H_8(g) + 3H_2O(g) \xrightarrow{\Delta}$

(iv) $Zn(s) + NaOH(aq) \xrightarrow{\Delta}$

Ans. (i) $nH_2(g) + M_mO_n(s) \xrightarrow{\Delta} mM(s) + nH_2O(l)$

(ii) $CO(g) + 2H_2(g) \xrightarrow[\text{Catalyst}]{\Delta} CH_3OH(l)$ (methanol)

(iii) $C_3H_8(g) + 3H_2O(g) \xrightarrow[1270K]{Ni} 3CO(g) + 7H_2(g)$

(iv) $Zn(s) + 2NaOH(aq) \xrightarrow{heat} Na_2ZnO_2(aq) + H_2(g)$

Example - 24

Describe the bulk preparation of hydrogen by electrolytic method. What is the role of an electrolyte in this process?

Sol. The electrolyte (15–20% NaOH solution) increases conductivity of water.

Cathode (iron) : Reduction of water occurs.

$2H_2O + 2e^- \rightarrow 2H_2 + 2OH^-$

Anode (nickel coated iron) : Oxidation of OH^- occurs.

$2OH^- \rightarrow H_2O + 1/2\, O_2 + 2e^-$

Example - 25

Which of the following can adsorb largest volume of hydrogen gas?

(1) Finely divided platinum (2) Finely divided nickel

(3) Colloidal palladium (4) Colloidal platinum

Ans. (3)

Sol. Order of adsorption of H_2(occlusion) is :

Colloidal Palladium > Palladium > Platinum > Gold > Nickel.

Example - 26

Why does hydrogen occur in a diatomic form rather than in a monoatomic form under normal conditions ?

Sol. Hydrogen atom has only one electron and thus, to achieve stable inert gas configuration of helium, it shares its single electron with electron of other hydrogen atom to form a stable diatomic molecule. The stability of H_2 is further confirmed by the fact, that formation of one mole of gaseous H_2 molecules results in the release of 435.8 kJ of energy

$$H(g) + H(g) \rightarrow H_2(g); \Delta H = -435.8\,KJ\,mol^{-1}$$

Example - 27

Write the names of isotopes of hydrogen. What is the mass ratio of these isotopes ?

Sol. The various, isotopes of hydrogen are :

^1_1H (Protium) ; ^2_1H or D(Deuterium) ; ^3_1H or T(Tritium)

The mass ratio of $^1_1H : ^2_1H : ^3_1H$ is 1 : 2 : 3

Example - 28

Arrange the following :

(i) CaH_2, BeH_2 and TiH_2 in order of increasing electrical conductance.

(ii) LiH, NaH and CsH in order of increasing ionic character

(iii) H–H, D–D and F–F in order of increasing bond dissociation enthalpy.

(iv) NaH, MgH_2 and H_2O in order of increasing reducing property.

Sol.

(i) BeH_2 is a covalent hydride, therefore, it does not conduct electricity at all. CaH_2 conducts electricity in the fused state while TiH_2 conducts electricity at room temperature. Thus, the order of increasing electrical conductance is : $BeH_2 < CaH_2 < TiH_2$.

(ii) Electronegativity decreases down the group from Li to Cs, therefore, the ionic character of their hydrides also increases in the same order, i.e., LiH < NaH < CsH.

(iii) F – F bond dissociation enthalpy is the minimum. This is due to high concentration of electron density around each F atom in the form of 3 lone pairs which cause significant repulsive interactions. The bond enthalpy of D–D bond is slightly higher than that of H–H bond. It is due to marginally smaller size of D. Thus, the bond dissociation enthalpy increases in the order : F–F < H–H < D–D.

(iv) Ionic hydrides are powerful reducing agents. Both MgH_2 and H_2O are covalent hydrides but the bond dissociation of O–H bonds in H_2O is much higher than that of Mg–H bond in MgH_2. Therefore, the reducing character increases in the order : $H_2O < MgH_2 <$ NaH.

Example - 29

Do you expect the carbon hydride of the type (C_nH_{2n+2}) to act as Lewis acid or base ? Justify your answer.

Sol. Carbon hydride of the type (C_nH_{2n+2}) are electron precise hydrides. In other words, they have exact numbers of electrons required to form covalent bonds. Therefore, they do not have tendency to either gain or lose electrons and hence, they do not act as Lewis acids or Lewis bases.

Example - 30

What characteristics do you expect from electron deficient hydrides with respect to their structure and chemical reactivity ?

Sol. Electron deficient hydrides do not have sufficient number of electrons to form normal covalent bonds. They generally exist in polymeric forms such as B_2H_6, B_4H_{10}, $(AlH_3)_n$, etc. Due to deficiency of electrons, these hydrides act as Lewis acids and thus, form complex entities with Lewis bases such as : NH_3, H^- ions, etc.

$$B_2H_6 + 2\ddot{N}H_3 \rightarrow \left[BH_2(NH_3)_2\right]^+ \left[BH_4\right]^-$$

$$B_2H_6 + 2NaH \rightarrow 2Na^+\left[BH_4\right]^- \text{(Sodium borohydride)}$$

Example - 31

Explain the following :

(a) Water is excellent solvent for ionic compounds.

(b) Lakes freeze from top to bottom.

Sol. (a) Water has a high dielectric constant (78.39) due to the polar character of its molecule. Water is an excellent solvent for many ionic as well as covalent compounds. Dissolution of ionic compounds takes place because of ion-dipole interactions. Dissolution of molecular compounds such as alcohols, amides, urea, sugar, glucose, honey, etc., in water takes place because of the tendency of these substances to form hydrogen bonds with water molecules.

(b) This is due to the fact that the frozen water does not sink to the bottom but keeps floating at the surface due to its lesser density. This provides thermal insulation to the water below it. The lesser density of ice can be attributed to open cage-like structure on account of hydrogen bonding.

Example - 32

Explain the meaning of term hydride gap.

Ans. Elements of group 7, 8, 9 of d-block do not form hydrides at all. This inability of metals of group 7, 8, 9 of periodic table to form hydrides is referred to as hydride gap of d-block.

Example - 33

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

Sol. 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.

Example - 34

What is 'demineralised water' and how can it be obtained?

Sol. Water which is free from all cations and anions is called demineralised water. It is obtained by passing hard water first through cation exchange resin and then through anion exchange resin.

Example - 35

What causes the temporary and permanent hardness of water ?

Sol. Temporary hardness is caused by presence of soluble bicarbonates of calcium and magnesium, i.e. $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$ in water whereas permanent hardness is caused by presence of soluble chlorides and sulphates of calcium and magnesium, i.e. $CaCl_2$, $CaSO_4$, $MgCl_2$ and $MgSO_4$ in water.

Example - 36

What happens when ?

(i) Heavy water reacts with magnesium nitride.

(ii) Heavy water reacts with sodium.

Sol. (i) $Mg_3N_2 + 6D_2O \rightarrow Mg(OD)_2 + 2ND_3$ (Deutrammonia)

(ii) $Na + 2D_2O \rightarrow 2NaOD + D_2$

Example - 37

Explain the following :

(i) Soft water lathers with soap but not hard water.

(ii) Temporary hard water becomes soft on boiling.

(iii) Water can extinguish most fires but not petrol fire.

(iv) Hard water is softened before use in boilers.

Sol. (i) Hard water contains calcium and magnesium salts. These react with soap to form insoluble calcium and magnesium salts of fatty acids, i.e., form scum and not lather.

$2RCOONa\,(soap) + Ca^{2+} \rightarrow$

$(RCOO)_2Ca\,(insoluble) + 2Na^+$

$2RCOONa\,(soap) + Mg^{2+} \rightarrow$

$(RCOO)_2Mg\,(insoluble) + 2Na^+$

(ii) Temporary hardness of water is due to the presence of soluble bicarbonates of calcium and magnesium. On boiling, the bicarbonates are converted into insoluble carbonates which can be removed by filtration.

$Ca(HCO_3)_2(soluble) \rightarrow CaCO_3 \downarrow + H_2O + CO_2$

$Mg(HCO_3)_2\,(soluble) \rightarrow MgCO_3 \downarrow + H_2O + CO_2$

(iii) When water poured over petrol fire, petrol being lighter than water floats over water and thus fire spreads instead being extinguished.

(iv) Hard water consists bicarbonates and other soluble salts of calcium and magnesium. When hard water is evaporated in boilers, scales of precipitated carbonates of calcium and magnesium

along with other salts such as sulphates, chlorides, etc., are formed. In order to avoid the formation of scales hard water is first softened before use in boilers.

Example - 38

Assertion (A) : Anhydrous BaO_2 is not used for preparing H_2O_2.

Reason (R) : H_2O_2 is prepared on large scale by air oxidation of 2-Ethyl anthraquinol.

(a) If both Assertion and Reason are true and Reason is a correct explanation of Assertion.

(b) If both Assertion and Reason are true and Reason is not a correct explanation of Assertion.

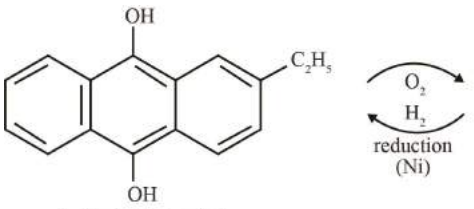
(c) If Assertion is true but Reason is false.

(d) If Assertion is false but Reason is true.

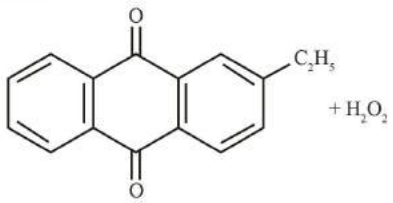
Sol. **Assertion :** $BaO_2 + H_2SO_4 \rightarrow BaSO_4 \downarrow$ (white) $+ H_2O_2$

Insoluble $BaSO_4$ forms a thin layer around BaO_2 and therefore reaction occurs slowly and finally stops. So anhydrous BaO_2, is not used.

Reason : Industrial method (Auto oxidation)



2-ethyl anthraquinol



2-ethyl anthraquinone

It is cheaper method as only O_2 from air and H_2 are consumed. So, both Assertion and Reason are true and Reason is not a correct explanation of Assertion.

Example - 39

Knowing the properties of H_2O and D_2O, do you think that D_2O can be used for drinking purposes?

Sol. Heavy water is injurious to human beings, plants and animals since it slows down the rates of reactions occuring in them. Thus, heavy water does not support life. In fact it retards

certain cellular process, such as mitosis, cell division, etc, Thus, prolonged use of D_2O leads to degeneration of tissues.

Example - 40

Explain the following :

(i) Why hydrated barium peroxide is used in the preparation of hydrogen peroxide instead of the anhydrous variety ?

(ii) Phosphoric acid is preferred to sulphuric acid in the preparation of H_2O_2 from barium peroxide.

(iii) Statues coated with white lead on long exposure to atmosphere turns black and the original colour can be restored on treatment with H_2O_2.

Sol. (i) If anhydrous barium peroxide is used in the preparation, the barium sulphate, thus formed, forms an insoluble protective coating on the surface of solid barium peroxide hydrated. This prevents the further reaction of the acid, i.e., causing the reaction to stop. If, however, hydrated barium peroxide (in the form of the paste) is used, the water causes to dislodge the insoluble $BaSO_4$ from the surface of BaO_2. Hence $BaSO_4$ settles at the bottom of the reaction vessel and the reaction continues without any difficulty.

(ii) When phosphoric acid is used in the preparation of H_2O_2 from BaO_2, it plays the dual role. It liberates H_2O_2 and also acts as a preservator by retarding its decomposition.

(iii) White lead is used as a pigment. The statues coated with white lead get blackened due to the action of H_2S present in atmosphere in traces.

$$Pb(OH)_2\,(\text{white lead}).2PbCO_3 + 3H_2S \rightarrow 3PbS + 2CO_2 + 4H_2O$$

EXERCISE - 1 : BASIC OBJECTIVE QUESTIONS

Introduction of Hydrogen

1. Which of the following is not an isotope of hydrogen?

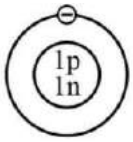
(a) Protium

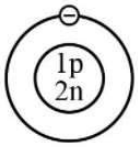
(b) Ortho-para hydrogen

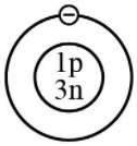
(c) Deuterium

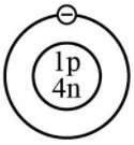
(d) Tritium

2. Which of the following is an atom of tritium ?

(a) 

(b) 

(c) 

(d) 

3. In what respect electronic configuration of hydrogen and halogens are similar ?

(a) Hydrogen and halogens have one electron in their outermost shell.

(b) Hydrogen and halogens have one electron less than the noble gas configuration.

(c) Hydrogen and halogens can lose one electrons to form positive ions.

(d) Hydrogen and halogens show noble gas configuration.

4. Which of the following properties of hydrogen is incorrect ?

(a) Like halogens, hydrogen exists as a diatomic gas

(b) Like halogens hydrogen exhibits-1 oxidation state in its compounds with metals.

(c) Like halogens, hydrogen is liberated at cathode

(d) The ionization energy of hydrogen is quite close to halogens.

Preparation and Properties of Dihydrogen

5. Which of the following is laboratory preparation of dihydrogen?

(a) $3Fe + 4H_2O$ (steam) '! $Fe_3O_4 + 4H_2$

(b) $2Na + 2H_2O$ '! $2NaOH + H_2$

(c) $CaH_2 + 2H_2O$ '!$Ca(OH)_2 + 2H_2$

(d) $Zn + H_2SO_4$ (dil.) '! $ZnSO_4 + H_2$

6. Which of the following metals does not liberate hydrogen from acids ?

(a) Fe (b) Cu

(c) Mg (d) Zn

7. Very pure hydrogen (99.9%) can be made by which of the following processes?

(a) Mixing natural hydrocarbons of high molecular weight

(b) Electrolysis of water.

(c) Reaction of salt like hydrides with water

(d) Reaction of methane with steam.

8. Which of the following metals will react with NaOH and KOH to liberate hydrogen gas ?

(a) Zn, A*l*, Fe and Mg

(b) A*l*, Fe, Mg and Sn

(c) Zn, Sn and A*l*

(d) Fe, Mg and A*l*

9. In context with the industrial preparation of hydrogen from water gas (CO + H_2), which of the following is the correct statement?

(a) CO is oxidized to CO_2 with steam in the presence of a catalyst followed by absorption of CO_2 in alkali.

(b) CO and H_2 are fractionally separated using differences in their densities.

(c) CO is removed by absorption in aqueous Cu_2Cl_2 solution.

(d) H_2 is removed through occlusion with Pd.

10. Which of the following is not a property of hydrogen?

(a) It is a colourless, odourless gas

(b) It is highly combustible.

(c) It is highly poisonous gas

(d) It is lighter than air.

11. Match the column I with column II and mark the appropriate choice.

Column - I		Column - II	
(A)	Syngas	(i)	$Na_6P_6O_{18}$
(B)	Calgon	(ii)	$NaAlSiO_4$
(C)	Permutit	(iii)	$CO + H_2$
(D)	Producer gas	(iv)	$CO + N_2$

(a) $(A) \rightarrow (i),\ (B) \rightarrow (ii),\ (C) \rightarrow (iii),\ (D) \rightarrow (iv)$

(b) $(A) \rightarrow (iii),\ (B) \rightarrow (i),\ (C) \rightarrow (ii),\ (D) \rightarrow (iv)$

(c) $(A) \rightarrow (iii),\ (B) \rightarrow (ii),\ (C) \rightarrow (iv),\ (D) \rightarrow (i)$

(d) $(A) \rightarrow (iii),\ (B) \rightarrow (ii),\ (C) \rightarrow (i),\ (D) \rightarrow (iv)$

12. Which property of hydrogen is shown by the following reactions ?

(i) $Fe_3O_4 + 4H_2 \rightarrow 3Fe + 4H_2O$

(ii) $CO + H_2 \xrightarrow[Cr_2O_3]{ZnO} CH_3OH$

(a) Reducing character (b) Oxidising character

(c) Combustibility (d) High reactivity

13. If a mole of hydrogen molecule is heated to a high temperature then which of the following reaction take place ?

(a) $H_{2(g)} + 436\ kJ\ mol^{-1} \rightarrow H_{(g)} + H_{(g)}$

(b) $2H_{2(g)} + 820\ kJ\ mol^{-1} \rightarrow 2H_{2(g)}$

(c) $H_{2(g)} + H_{2(g)} + 436\ kJ\ mol^{-1} \rightarrow H^+_{(aq)} + H^-_{(aq)}$

(d) $H_{2(g)} + 200\ kJ\ mol^{-1} \rightarrow H_{(g)} + H_{(g)}$

14. Phosphorus cannot form PH_5 with its outer electronic configuration as $3s^2$, $3p^3$ because

(a) phosphorus cannot show + 5 oxidation state

(b) PH_5 is not a stable compound.

(c) $\Delta_a H$ value of dihydrogen and $\Delta_{eg} H$ value of hydrogen do not favour higher oxidation state of phosphorus.

(d) phosphorus is not very reactive hence does not form PH_5.

Hydrides

15. Which of the following hydrides is electron deficient?

(a) NaH (b) CaH_2

(c) CH_4 (d) B_2H_6

16. On moving from left to right in a period what is the order of acidic character of hydrides ?

(a) $NH_3 < H_2O < HF$ (b) $HF < H_2O < NH_3$

(c) $H_2O < HF < NH_3$ (d) $H_2O < NH_3 < HF$

17. Which of the following metals directly combine with hydrogen gas to give a hydride ?

(a) Au (b) Ni

(c) Ca (d) Cu

18. Match the column I with column II and mark the appropriate choice.

Column - I		Column - II	
(A)	NaH	(i)	Interstitial hydride
(B)	CH_4	(ii)	Molecular hydride

(a) $(A) \rightarrow (iii),\ (B) \rightarrow (iv),\ (C) \rightarrow (ii),\ (D) \rightarrow (i)$

(b) $(A) \rightarrow (ii),\ (B) \rightarrow (iv),\ (C) \rightarrow (iii),\ (D) \rightarrow (i)$

(c) $(A) \rightarrow (i),\ (B) \rightarrow (ii),\ (C) \rightarrow (iv),\ (D) \rightarrow (iii)$

(d) $(A) \rightarrow (iii),\ (B) \rightarrow (ii),\ (C) \rightarrow (i),\ (D) \rightarrow (iv)$

19. What is the trend of boiling points of hydrides of N, O and F ?

(a) Due to lower molecular masses, NH_3, H_2O and HF have lower boiling points than those of the subsequent group member hydrides.

(b) Due to higher electronegativity of N, O and F; NH_3, H_2O and HF show hydrogen bonding and hence higher boiling points than the hydrides of their subsequent group members.

(c) There is no regular trend in the boiling points of hydrides.

(d) Due to higher oxidation states of N, O and F, the boiling points of NH_3, H_2O and HF are higher than the hydrides of their subsequent group members.

Properties of Water

20. Water plays a key role in the biosphere. It is due to certain properties of H_2O as compared to other liquids. These are except.

(a) higher specific heat

(b) lesser thermal conductivity

(c) high dielectric constant

(d) high surface tension.

21. Which is not a property of water ?

(a) It is a colourless and tasteless liquid

(b) There is no hydrogen bonding in solid state of water.

(c) It is an excellent solvent for transportation of ions in plants and animals.

(d) Frozen water is lighter than liquid water.

22. In which of the following reactions H_2O acts as a Bronsted acid ?

(a) $H_2O_{(l)} + NH_{3(aq)} \rightleftharpoons OH^-_{(aq)} + NH^+_{4(aq)}$

(b) $H_2O_{(l)} + H_2S_{(aq)} \rightleftharpoons H_3O^+_{(aq)} + HS^-_{(aq)}$

(c) $H_2O_{(l)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$

(d) $H^+_{(aq)} + OH^-_{(aq)} \rightleftharpoons H_2O_{(l)}$

23. The density of water is less in its solid state because

(a) in solid state (ice), water molecules are arranged in highly order open cage like structure.

(b) more extensive hydrogen bonding is present in solid state ice

(c) the water molecules are closest in solid state of water.

(d) water in rigid crystalline, closely packed structure in its solid state.

24. Liquid water is denser than ice due to

(a) higher surface tension (b) hydrogen bonding

(c) van der Waals forces (d) covalent bonding

25. The maximum number of hydrogen bonds formed by a water molecule in ice is

(a) 4 (b) 1

(c) 2 (d) 3

26. How many hydrogen bonded water molecules are associated with $CuSO_4.5H_2O$?

(a) Five (b) One

(c) Four (d) Three

27. During hydrate formation from aqueous solution, water can be associated in different forms. Indicate the wrong combination.

(i) Coordinated water – $[Cr(H_2O)_6]^{3+}\,3Cl^-$

(ii) Interstitial water – $BaCl_2.2H_2O$

(iii) Hydrogen bonded water– $[Cu(H_2O)_4]^{2+}\,SO_4^{2-}.\,H_2O$

(a) (i) (b) (ii)

(c) (iii) (d) None of these

28. Match the reaction of column I with their types given in column II and mark the appropriate choice.

	Column - I		Column - II
(A)	$H_2O + NH_3 \rightleftharpoons NH_4^+ + OH^-$	(i)	Self ionisation of H_2O
(B)	$FeCl_3 + 3H_2O \rightarrow Fe(OH)_3 + 3HCl$	(ii)	Decomposition
(C)	$H_2O + H_2O \rightleftharpoons H_3O^+ + OH^-$	(iii)	Acidic nature of H_2O
(D)	$2H_2O \rightarrow 2H_2 + O_2$	(iv)	Hydrolysis

(a) $(A) \rightarrow (ii),\ (B) \rightarrow (i),\ (C) \rightarrow (iii),\ (D) \rightarrow (iv)$

(b) $(A) \rightarrow (iii),\ (B) \rightarrow (ii),\ (C) \rightarrow (iv),\ (D) \rightarrow (i)$

(c) $(A) \rightarrow (i),\ (B) \rightarrow (ii),\ (C) \rightarrow (iv),\ (D) \rightarrow (iii)$

(d) $(A) \rightarrow (iii),\ (B) \rightarrow (iv),\ (C) \rightarrow (i),\ (D) \rightarrow (ii)$

29. Study the following reactions and mark the correct properties shown by water.

(i) $SO_3 + H_2O$ '! H_2SO_4

(ii) $Cl_2O_7 + H_2O$ '!$2HClO_4$

(iii) $CaO + H_2O$ '!$Ca(OH)_2$

(iv) $Na_2O + H_2O$ '!$2NaOH$

(a) All oxides react with water to give hydroxides

(b) Acidic oxides are formed by metals and basic oxides by non-metals.

(c) Non-metal oxides combine with water to form acids while metallic oxides combine with water to form alkalies.

(d) Acidic oxides are stronger than basic oxides since they form strong acids.

30. Given below two reactions of water with sodium and carbon dioxide. What is the nature of water in these reactions ?

(i) $2Na + 2H_2O$ '! $2NaOH + H_2$

(ii) $6CO_2 + 12H_2O$ '!$C_6H_{12}O_6 + 6H_2O + 6O_2$

(a) In (ii) water acts as an oxidizing agent while in (i) it acts as a reducing agent.

(b) In (i) water acts as an oxidizing agent while in (ii) it acts as a reducing agent.

(c) In both, (i) and (ii) hydrogen acts as a reducing agent.

(d) In both, (i) and (ii) hydrogen acts as an oxidizing agent.

31. Which of the following reactions shows reduction of water ?

(a) $2H_2O + 2Na$ '! $2NaOH + H_2$

(b) $6CO_2 + 12H_2O$ '! $C_6H_{12}O_6 + 6H_2O + 6O_2$

(c) $2F_2 + 2H_2O$ '! $4H^+ + 4F^- + O_2$

(d) $P_4O_{10} + 6H_2O$ '! $4H_3PO_4$

32. Fluorine decomposes cold water to give

(a) $4H^+ + 4F^-$ and O_2 (b) HF and H_2

(c) HF only (d) H_2F_2 and HFO_4

33. Which of the statements given below are true for the water molecule structure ?

(i) Oxygen undergoes sp^3 hybridisation.

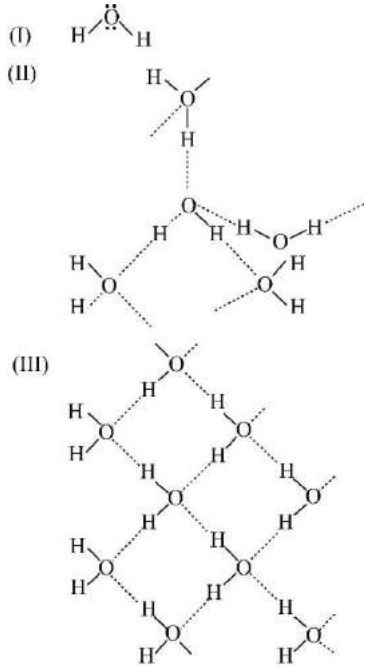
(ii) Due to presence of two lone pairs of electrons on oxygen the H"O"H bonds angle is 118.4°.

(iii) Due to angular geometry the net dipole moment of water is not zero, $\mu = 1.84$ D.

(a) (i) and (ii) (b) (ii) and (iii)

(c) (i) and (iii) (d) only (ii)

34. Choose the correct statement about the given figures.



(a) (II) represents solid state while (III) represents liquid state.

(b) (II) represents liquid state while (III) represents solid state.

(c) (I) represents solid state while (III) represents liquid state.

(d) (I) represents liquid state while (III) represents solid state.

35. Presence of water can be detected by

(a) adding a drop to anhydrous copper sulphate which changes its colour from white to blue

(b) by boiling & testing for the presence of H_2& O_2

(c) by seeing its colour and transparency

(d) by checking the production of lather when mixed with soap.

Hardness of Water

36. A water sample is said to contain permanent hardness if water contains

(a) sulphates & chlorides of calcium and magnesium

(b) carbonates of calcium and magnesium

(c) bicarbonates of calcium and magnesium

(d) sulphates & chlorides of sodium and potassium.

37. Which of the following is not a disadvantage of using hard water ?

(a) In production of steam in boilers

(b) Formation of scales in cooking utensils

(c) In cooking, bathing and washing

(d) In ion exchangers

38. Which one of the following processes will produce hard water ?

(a) Saturation of water with $CaCO_3$.

(b) Saturation of water with $CaSO_4$.

(c) Saturation of water with $MgCO_3$.

(d) Addition of Na_2SO_4 to water.

39. The temporary hardness of water due to calcium bicarbonate can be removed by adding

(a) $CaCO_3$ (b) $CaCl_2$

(c) HCl (d) $Ca(OH)_2$

40. The process used for the removal of hardness of water is

(a) Baeyer (b) Calgon

(c) Hoope (d) Serpeck

41. The formula for permutit or zeolite which is used as softner in ion-exchange method is

(a) $NaAlSiO_4$ (b) $NaAlO_2$

(c) $Ca_3(PO_4)_2$ (d) Na_2SO_4

42. Match the column I with column II and mark the appropriate choice.

	Column I		Column II
(A)	Clark's method	(i)	$Na_6P_6O_{18}$
(B)	Calgon's method	(ii)	$NaAlSiO_4$
(C)	Ion-exchange method	(iii)	RSO_3H
(D)	Synthetic resins method	(iv)	$Ca(OH)_2$

(a) $(A) \rightarrow (i),\ (B) \rightarrow (iii),\ (C) \rightarrow (iv),\ (D) \rightarrow (ii)$

(b) $(A) \rightarrow (ii),\ (B) \rightarrow (iii),\ (C) \rightarrow (iv),\ (D) \rightarrow (i)$

(c) $(A) \rightarrow (iii),\ (B) \rightarrow (ii),\ (C) \rightarrow (i),\ (D) \rightarrow (iv)$

(d) $(A) \rightarrow (iv),\ (B) \rightarrow (i),\ (C) \rightarrow (ii),\ (D) \rightarrow (iii)$

43. In a permutit, the calcium and magnesium ions of hard water are exchanged by

(a) CO_3^{2-} and HCO_3^- ions of permutit

(b) Na^+ ions of permutit

(c) Al^{3+} ions of permutit

(d) Si^{4+} ions of permutit

44. Which of the following represents calgon ?

(a) $Na_2Al_2Si_2O_8$ (b) $Mg_3(PO_4)_2$

(c) $Na_2[Na_4(PO_3)_6]$ (d) $Na_2[Mg_2(PO_3)_6]$

Heavy Water

45. What is heavy water ?

(a) H_2O^{18} (b) D_2O

(c) H_2O^{17} (d) H_2O

46. Which compound is formed when calcium carbide reacts with heavy water ?

(a) C_2D_2 (b) CaD_2

(c) CD_2 (d) Ca_2D_2

47. Heavy water is used as

(a) drinking water (b) detergent

(c) washing water (d) a moderator

48. Heavy water (D_2O) freezes at

(a) "3.8°C (b) 3.8°C

(c) 0°C (d) 38°C

49. Which of the following reactions is not used in preparation or deuterium compounds using heavy water ?

(a) $CaC_2 + 2D_2O$ '! $C_2D_2 + Ca(OD)_2$

(b) $SO_3 + D_2O$ '! D_2SO_4

(c) $AlN+3D_2O$'!$Al(OD)_3+ND_3$

(d) $Al_4C_3 + 12D_2O$ '! $3CD_4 + 4Al(OD)_3$

50. Some of the major uses of heavy water are given below. Which one is not correct ?

(a) It is used as a moderator in nuclear reactors.

(b) It is used as a tracer compound for studying reaction mechanism.

(c) High concentration of heavy water accelerates the growth of plants

(d) It is used in preparing deuterium.

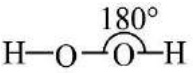
Introduction, Preparation and Properties of H_2O_2

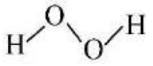
51. Which of the following act as a stabilizer for the storage of H_2O_2 ?

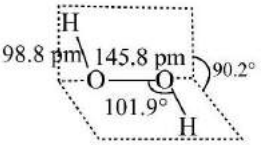
(a) Alkali (b) Dust

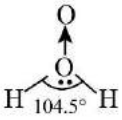
(c) Urea (d) None of these

52. Which of the following is a true structure of H_2O_2 in solid phase ?

(a) 

(b) 

(c) 

(d) 

53. Which of the following is not a process of preparation of hydrogen peroxide ?

(a) Auto-oxidation of 2-ethylanthraquinol

(b) By passing oxygen through boiling water

(c) By oxidation of isopropyl alcohol

(d) By reaction of barium peroxide with dil. H_2SO_4.

54. Which of the following represents the chemical equation involved in the preparation of H_2O_2 from barium peroxide ?

(a) $BaO_2.8H_2O + H_2SO_4$'! $BaSO_4 + H_2O_2 + 8H_2O$

(b) $CH_3CHOHCH_3 + O_2$'! $CH_3COCH_3 + H_2O_2$

(c) $BaO_2 + CO_2 + H_2O$ '! $BaCO_3 + H_2O_2$

(d) $Ba_3(PO_4)_2 + 3H_2SO_4$'! $3BaSO_4 + 2H_3PO_4$

55. Which of the following reagents cannot be used for the preparation of hydrogen peroxide ?

(a) Sodium peroxide (b) 2-Ethylanthraquinol

(c) Sodium thiosulphate (d) Barium peroxide

56. 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?

(a) KI (b) $Cr_2O_7^{2-}$

(c) SO_3^{2-} (d) MnO_4^-

57. H_2O_2 acts as a bleaching agent because of

(a) reducing nature of H_2O_2

(b) oxidizing nature of H_2O_2

(c) acidic nature of H_2O_2

(d) basic nature of H_2O_2

58. Which of the following easily catalyse the decomposition of H_2O_2 when stored ?

(i) Rough surface (ii) Sunlight

(iii) Dust particles (iv) Metals

(a) (i) and (ii) (b) (i), (ii) and (iii)

(c) (ii) and (iii) (d) All of these

59. Statues and paintings coated with white lead turn black on long exposure to atmosphere. The original colour can be restored by treating them with H_2O_2. The reason behind this

(a) blackened statues get coated with PbS which on reaction with H_2O_2 is oxidized to white $PbSO_4$.

(b) H_2O_2 dissolves the coating of white lead and exposes the inner surface.

(c) white lead reacts with H_2O_2 to form white $PbSO_4$

(d) Blackened statues get coated with lead sulphate which reacts with H_2O_2 to give PbS.

60. Which of the following reactions shows reducing nature of H_2O_2 ?

(a) $PbS + 4H_2O_2$'! $PbSO_4 + 4H_2O$

(b) $Ag_2O + H_2O_2$'! $2Ag + H_2O + O_2$

(c) $2HCHO + H_2O_2$'! $2HCOOH + H_2O$

(d) $Na_2SO_3 + H_2O_2$'! $Na_2SO_4 + H_2O$

EXERCISE - 2 : PREVIOUS YEAR JEE MAINS QUESTIONS

1. Which physical property of dihydrogen is wrong ? **(2015)**

(a) Odourless gas (b) Tasteless gas

(c) Colourless gas (d) Non-inflammable gas

2. Permanent hardness in water cannot be cured by: **(2015)**

(a) Treatment with washing soda

(b) Boiling

(c) Calgon's method

(d) Ion exchange method

3. From the following statements regarding H_2O_2, choose the incorrect statement : **(2015)**

(a) It has to be stored in plastic or wax lined glass bottles in dark

(b) It has to be kept away from dust

(c) It can act only as an oxidizing agent

(d) It decomposes on exposure to light

4. Which one of the following statements about water is FALSE? **(2016)**

(a) Water can act both as an acid and as a base.

(b) There is extensive intramolecular hydrogen bonding in the condensed phase.

(c) Ice formed by heavy water sinks in normal water.

(d) Water is oxidized to oxygen during photosynthesis.

5. Identify the incorrect statement regarding heavy water : **(2016)**

(a) It reacts with Al_4C_3 to produce CD_4 and $Al(OD)_3$.

(b) It is used as a coolant in nuclear reactors.

(c) It reacts with CaC_2 to produce C_2D_2 and $Ca(OD)_2$.

(d) It reacts with SO_3 to form deuterated sulphuric acid (D_2SO_4).

6. Identify the reaction which does not liberate hydrogen : **(2016)**

(a) Reaction of zinc with aqueous alkali.

(b) Electrolysis of acidified water using Pt electrodes

(c) Reaction of zinc with HCl.

(d) Reaction of lithium hydride with B_2H_6

7. In which of the following reactions, hydrogen peroxide acts as an oxidizing agent ? **(2017)**

(a) $HOCl + H_2O_2 \rightarrow H_3O^+ + Cl^- + O_2$

(b) $I_2 + H_2O_2 + 2OH^- \rightarrow 2I^- + 2H_2O + O_2$

(c) $2MnO_4^- + 3H_2O_2 \rightarrow 2MnO_2 + 3O_2 + 2H_2O + 2OH^-$

(d) $PbS + 4H_2O_2$ '! $PbSO_4 + 4H_2O$

8. Hydrogen peroxide oxidises $[Fe(CN)_6]^{-4}$ to $[Fe(CN)_6]^{3-}$ in acidic medium but reduces $[Fc(CN)_6]^{3-}$ to $[Fe(CN)_6]^{4-}$ in alkaline medium. The other products formed are respectively: **(2018)**

(a) $(H_2O + O_2)$ and H_2O

(b) $(H_2O + O_2)$ and $(H_2O + OH^-)$

(c) H_2O and $(H_2O + O_2)$

(d) H_2O and $(H_2O + OH^-)$

9. The metal that gives hydrogen gas upon treatment with both acid as well as base is : **(2019)**

(a) magnesium (b) mercury

(c) zinc (d) iron

10. The correct statements among (a) to (d) are: **(2019)**

(i) saline hydrides produce H_2, gas when reacted with H_2O.

(ii) reaction of $LiAlH_4$ with BF_3 leads to B_2H_6.

(iii) PH_3 and CH_4 are electron – rich and electron – precise hydrides, respectively,

(iv) HF and CH_4 are called as molecular hydrides.

(a) (i), (ii), (iii) and(iv)

(b) (iii) and (iv)only

(c) (i), (iii) and (iv) only

(d) (i), (ii) and (iii) only

11. The correct statements among (a) to (d) regarding H_2 as a fuel are: **(2019)**

(i) It produces less pollutants than petrol.

(ii) A cylinder of compressed dihydrogen weighs – 30 times more than a petrol tank producing the same amount of energy.

(iii) Dihydrogen is stored in tanks of metal alloys like $NaNi_5$.

(iv) On combustion, values of energy released per gram of liquid di hydrogen and LPG are 50 and 142 kJ, respectively.

(a) (ii) and (iv) only (b) (i) and (iii) only

(c) (ii), (iii) and (iv) only (d) (i), (ii) and (iii) only

12. NaH is an example of: **(2019)**

(a) Electron-rich hydride (b) Metallic hydride

(c) Saline hydride (d) Molecular hydride

13. The total number of isotopes of hydrogen and number of radioactive isotopes among them, respectively, are: **(2019)**

(a) 3 and 1 (b) 3 and 2

(c) 2 and 1 (d) 2 and 0

14. Among the following reactions of hydrogen with halogens, the one that requires a catalyst is: **(2019)**

(a) $H_2 + I_2 \rightarrow 2HI$ (b) $H_2 + Cl_2 \rightarrow 2HCl$

(c) $H_2 + Br_2 \rightarrow 2HBr$ (d) $H_2 + F_2 \rightarrow 2HF$

15. The isotopes of hydrogen are: **(2019)**

(a) Tritium and protium only

(b) Protium and deuterium only

(c) Protium, deuterium and tritium

(d) Deuterium and tritium only

16. The temporary hardness of a water sample is due to a compound X. Boiling this sample converts X to compound Y. X and Y, respectively, are: **(2019)**

(a) $Mg(HCO_3)_2$ and $Mg(OH)_2$

(b) $Ca(HCO_3)_2$ and $Ca(OH)_2$

(c) $Mg(HCO_3)_2$ and $MgCO_3$

(d) $Ca(HCO_3)_2$ and CaO

17. The synonym for water gas when used in the production of methanol is: **(2019)**

(a) natural gas (b) fuel gas

(c) laughing gas (d) syn gas

18. The number of water molecules(s) not coordinated to copper ion directly in $CuSO_4.5H_2O$. is: **(2019)**

(a) 2 (b) 3

(c) 1 (d) 4

19. 100 ml of a water sample contains 0.81 g of calcium bicarbonate and 0. 73 g of magnesium bicarbonate. The hardness of this water sample expressed in terms of equivalents of $CaCO_3$ is:

(molar mass of calcium bicarbonate is 162 g mol^{-1} and magnesium bicarboante is 146 g mol^{-1}) **(2019)**

(a) 5,000 ppm (b) 1,000ppm

(c) 100 ppm (d) 10,000 ppm

20. The temporary hardness of water is due to: **(2019)**

(a) Na_2SO_4 (b) NaCl

(c) $Ca(HCO_3)_2$ (d) $CaCl_2$

21. The volume strength of 1 M H_2O_2 is :

(Molar mass of H_2O_2 = 34 g mol^{-1}) **(2019)**

(a) 5.6 (b) 16.8

(c) 11.2 (d) 22.4

22. The chemical nature of hydrogen peroxide is : **(2019)**

(a) Oxidising agent in acidic medium, but not in basic medium.

(b) Reducing agent in basic medium, but not in acidic medium.

(c) Oxidising and reducing agent in acidic medium, but not in basic medium.

(d) Oxidising and reducing agent in both acidic and basic medium,

23. The strength of 11.2 volume solution of H_2O_2 is: [Given that molar mass of H = 1 g mol^{-1} and O = 16 g mol^{-1}] **(2019)**

(a) 3.4% (b) 1.7%

(c) 13.6% (d) 34%

24. Dihydrogen of high purity (> 99.95%) is obtained through : **(2020)**

(a) the reaction of Zn with dilute HCl.

(b) the electrolysis of acidified water using Pt electrodes.

(c) the electrolysis of bringe solution.

(d) the electrolysis of warm $Ba(OH)_2$ solution using Ni electrodes.

25. The equation that represents the water-gas shift reaction is: **(2020)**

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

(b) $2C(s) + O_2(g) + 4N_2(g) \xrightarrow{1273\ K} 2CO(g) + 4N_2(g)$

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

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

26. 5 g of zinc is treated separately with an excess of

(A) dilute hydrochloric acid and

(B) aqueous sodium hydroxide.

The ratio of the volumes of H_2 evolved in these two reactions is: **(2020)**

(a) 1 : 2 (b) 1 : 1

(c) 1 : 4 (d) 2 : 1

27. 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) and (z) is: **(2020)**

(a) 3 (b) 2

(c) 4 (d) 1

28. The one that is NOT suitable for the removal of permanent hardness of water is: **(2020)**

(a) Clark's method

(b) Ion-exchange method

(c) Calgon's method

(d) Treatment with sodium carbonate

29. Amongst the following, the form of water with the lowest ionic conductance at 298 K is: **(2020)**

(a) distilled water

(b) saline water used for intravenous injection

(c) water from a well

(d) sea water

30. In comparison to the zeolite process for the removal of permanent hardness, the synthetic resins method is: **(2020)**

(a) less efficient as it exchanges only anions

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

(c) less efficient as the resins cannot be regenerated

(d) more efficient as it can exchange only cations

31. Hydrogen peroxide, in the pure state is : **(2020)**

(a) non-planar and almost colorless

(b) linear and blue in color

(c) linear and almost colorless

(d) planar and blue in color

32. The strengths of 5.6 volume hydrogen peroxide (of density 1 g/ mL) in terms of mass percentage and molarity (M), respectively, are: **(2020)**

(Take molar mass of hydrogen peroxide as 34 g/ mol)

(a) l.7 and 0.5 (b) 0.85 and 0.25

(c) l.7 and 0.25 (d) 0.85 and 0.5

33. Among statements (A)-(D), the correct ones are: **(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 liberate dioxygen.

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

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

(a) (A) (B), (C) and (D) (b) (A), (B) and (C) only

(c) (A), (C) and (D) only (d) (A) and (C) only

34. (A) $HOCl + H_2O_2 \rightarrow H_3O^+ + Cl^- + O_2$

(B) $I_2 + H_2O_2 + 2OH^- \rightarrow 2I^- + 2H_2O + O_2$

Choose the correct option. **(2021-02-24-Shift-1)**

(a) H_2O_2 acts as reducing agent in equations (A) and (B)

(b) H_2O_2 acts as reducing and oxidising agent respectively in equations (A) and (B)

(c) H_2O_2 acts as oxidising agent in equations (A) and (B)

(d) H_2O_2 act as oxidizing and reducing agent respectively in equations (A) and (B)

35. Which of the following equation depicts the oxidizing nature of H_2O_2? **(2021-02-25-Shift-1)**

(a) $2I^- + H_2O_2 + 2H^+ \rightarrow I_2 + 2H_2O$

(b) $Cl_2 + H_2O_2 \rightarrow 2HCl + O_2$

(c) $KIO_2 + H_2O_2 \rightarrow KIO_3 + H_2O + O_2$

(d) $I_2 + H_2O_2 + 2OH^- \rightarrow 2I^- + 2H_2O + O_2$

36. Statements about heavy water are given below. **(2021-02-26-Shift-1)**

A. Heavy water is used in exchange reactions for the study of reaction mechanisms.

B. Heavy water is prepared by exhaustive electrolysis of water.

C. Heavy water has higher boiling point than ordinary water.

D. Viscosity of H_2O is greater than D_2O.

Choose the most appropriate answer from the options given below :

(a) A, B and C only (b) A and D only

(c) A and C only (d) A and B only

37. Calgon is used for water treatment. Which of the following statement is not true about Calgon? **(2021-02-26-Shift-2)**

(a) It is also known as Graham's salt

(b) Calgon contains the 2nd most abundant element by weight in the Earth's crust

(c) It is polymeric compound and is water soluble

(d) It doesnot remove Ca^{2+} ion by precipitation

38. Which of the following forms of hydrogen emits low energy β^- particles? **(2021-02-26-Shift-2)**

(a) Protium $^{1}_{1}H$ (b) Proton H^+

(c) Tritium $^{3}_{1}H$ (d) Deuterium $^{2}_{1}H$

39. The incorrect statement(s) about heavy water is (are) **(2021-03-17-Shift-1)**

(A) used as a moderator in nuclear reactor

(B) obtained as a by-product in fertilizer industry

(C) used for the study of reaction mechanism

(D) has a higher dielectric constant than water

(a) (B) only (b) (D) only

(c) (C) only (d) (B) and (D) only

40. In basic medium, H_2O_2 exhibits which of the following reactions? **(2021-02-18-Shift-2)**

(A) $Mn^{2+} \rightarrow Mn^{4+}$ (B) $I_2 \rightarrow I^-$

(C) $PbS \rightarrow PbSO_4$

Choose the most appropriate answer from the options given below:

(a) (A), (B) only (b) (A), (C) only

(c) (B) only (d) (A) only

41. The secondary valency and the number of hydrogen bonded water molecule(s) in $CuSO_4$Å"$5H_2O$, respectively, are: **(2021-03-18-Shift-2)**

(a) 6 and 5 (b) 6 and 4

(c) 5 and 1 (d) 4 and 1

42. The single largest industrial application of dihydrogen is: **(2021-07-20-Shift-2)**

(a) Manufacture of metal hydrides

(b) Rocket fuel in space research

(c) In the synthesis of ammonia

(d) In the synthesis of nitric acid

43. Isotope(s) of hydrogen which emits low energy $\beta-$ particles with $t_{1/2}$ value > 12 years is/are **(2021-07-22-Shift-2)**

(a) Protium (b) Tritium

(c) Deuterium (d) Deuterium and Tritium

44. At 298.2 K the relationship between enthalpy of bond dissociation (in kJ mol"1) for hydrogen (E_H) and its isotope, deuterium (E_D), is best described by: **(2021-07-25-Shift-1)**

(a) $E_H = \frac{1}{2}E_D$ (b) $E_H = E_D$

(c) $E_H \simeq E_D - 7.5$ (d) $E_H = 2E_D$

45. Which one of the following metals forms interstitial hydride easily? **(2021-07-25-Shift-2)**

(a) Cr (b) Fe

(c) Mn (d) Co

46. The number of neutrons and electrons, respectively, present in the radioactive isotope of hydrogen is **(2021-07-27-Shift-2)**

(a) 1 and 1 (b) 3 and 1

(c) 2 and 1 (d) 2 and 2

47. Which one of the following methods is most suitable for preparing deionized water? **(2021-08-26-Shift-1)**

(a) Synthetic resin method (b) Clark's method

(c) Calgon's method (d) Permutit method

48. Deuterium resembles hydrogen in properties but: **(2021-01-27-Shift-1)**

(a) reacts slower than hydrogen

(b) reacts vigorously than hydrogen

(c) reacts just as hydrogen

(d) emits β^+ particles

49. Which one of the following statements is **incorrect?** **(2021-08-31-Shift-2)**

(a) Atomic hydrogen is produced when H_2 molecules at a high temperature are irradiated with UV radiation.

(b) At around 2000 K, the dissociation of dihydrogen into its atoms is nearly 8.1%.

(c) Bond dissociation enthalpy of H_2 is highest among diatomic gaseous molecules which contain a single bond.

(d) Dihydrogen is produced on reacting zinc with HCl as well as $NaOH_{(aq)}$

50. Hydrogen peroxide reacts with iodine in basic medium to give **(2021-09-01-Shift-2)**

(a) $IO_4^{"}$ (b) $IO^{"}$

(c) I^- (d) $IO_3^{"}$

51. The correct statements about H_2O_2 are : **(2021-03-16-Shift-2)**

(A) used in the treatment of effluents.

(B) used as both oxidising and reducing agents.

(C) the two hydroxyl groups lie in the same plane.

(D) miscible with water.

Choose the correct answer from the options given below :

(a) (A), (B) and (D) only (b) (A), (B), (C) and (D)

(c) (B), (C) and (D) only (d) (A), (C) and (D) only

52. The functional groups that are responsible for the ion-exchange property of cation and anion exchange resins, respectively, are: **(2021-03-17-Shift-2)**

(a) $-SO_3H$ and $-NH_2$ (b) $-NH_2$ and $-COOH$

(c) $-SO_3H$ and $-COOH$ (d) $-NH_2$ and $-SO_3H$

53. The hardness of a water sample containing 10^{-3} M $MgSO_4$ expressed as $CaCO_3$ equivalents (in ppm) is _____ .

(molar mass of $MgSO_4$ is 120.37 g/mol) **(2020)**

54. The volume strength of 8.9 M H_2O_2 solution calculated at 273 K and 1 atm is _____ . ($R = 0.0821$ L atm K^{-1} mol^{-1}) (rounded off to the nearest integer) **(2020)**

55. Given below are two statements: one is labelled as **Assertion A** and the other is labelled as **Reason R**.

Assertion (A) : Hydrogen is the most abundant element in the Universe, but it is not the most abundant gas

Reason (R): Hydrogen is the lightest element.

In the light of the above statements, choose the correct answer from the options given below:**(2021-02-24-Shift-2)**

(a) Both A and R are true and R is the correct explanation of A

(b) Both A and R are true but R is NOT the correct explanation of A

(c) A is false but R is true

(d) A is true but R is false

56. Given below are two statements:

Statement I: H_2O_2 can act as both oxidising and reducing agent in basic medium.

Statement II: In the hydrogen economy, the energy is transmitted in the form of dihydrogen. In the light of the above statements, choose the correct answer from the options given below: **(2021-03-16-Shift-1)**

(a) Both statement I and statement II are true

(b) Statement I is false but statement II is true

(c) Statement I is true but statement II is false

(d) Both statement I and statement II are false

57. Given below are two Statements: One is labelled as Assertion A and the other is labelled as Reason R : **(2021-03-18-Shift-1)**

Assertion (A): During the boiling of water having temporary hardness, $Mg(HCO_3)_2$ is converted to $MgCO_3$.

Reason (R) : Temporary Hardness can be removed by Boiling.

In the light of the above statements, choose the most appropriate answer from the options given below:

(a) Both A and R are true but R NOT the correct explanation of A

(b) Both A and R are true and R is the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

58. Given below are two statements: one is labelled as **Assertion (A)** and the other is labelled as **Reason (R).** **(2021-08-26-Shift-2)**

Assertion (A): Heavy water is used for the study of reaction mechanism.

Reason (R): The rate of reaction for the cleavage of O – H bond is slower than that of O–D bond.

Choose the most appropriate answer from the options given below:

(a) Both (A) and (R) are true but (R) is not the true explanation of (A).

(b) Both (A) and (R) are true and (R) is the true explanation of (A).

(d) (A) is false but (R) is true.

(d) (A) is true but (R) is false.

59. Given below are two statements:

(2021-08-31-Shift-1)

Statement-I: The process of producing syn-gas is called gasification of coal.

Statement-II: The composition of syn-gas is CO + CO_2 + H_2 (1 : 1 : 1)

In the light of the above statements, choose the most appropriate answer from the options given below:

(a) **Statement-I** is false, but **Statement-II** is true

(b) **Statement-I** is true, but **Statement-II** is false

(c) Both **Statement-I** and **Statement-II** are false

(d) Both **Statement-I** and **Statement-II** are true

60. Given below are two statements: One is labelled as **Assertion A** and other is labelled as **Reason R**.

(2021-07-20-Shift-1)

Assertion (A): The dihedral angles in H_2O_2 in gaseous phase is 90.2° and in solid phase is 111.5°.

Reason (R): The change in dihedral angle in solid and gaseous phase is due to the difference in the intermolecular forces.

Choose the most appropriate answer from the options given below for A and R.

(a) A is correct but R is not correct.

(b) Both A and R are correct but R is not the correct explanation of A.

(c) Both A and R are correct and R is the correct explanation of A.

(d) A is not correct but R is correct.

EXERCISE - 3 : ADVANCED OBJECTIVE QUESTIONS

Objective Questions I [Only one correct option]

1. The isotopes of hydrogen have different physical properties due to difference in mass. They have almost same chemical properties with a difference in their rates of reactions which is mainly due to

(a) their different enthalpy of bond dissociation

(b) different electronic configurations

(c) different atomic masses

(d) different physical properties.

2. A deuterium is

(a) an electron with a positive charge

(b) a nucleus having two protons

(c) a nucleus containing a neutron & two protons

(d) a nucleus containing a neutron & a proton

3. Hydrogen burns in air with a

(a) light bluish flame (b) yellow flame

(c) crimson red flame (d) green flame.

4. Which of the following statements is correct regarding hydrogen ?

(a) Hydrogen shows +1 and -1 oxidation states.

(b) Hydrogen is never liberated at anode

(c) Hydrogen has same ionization enthalpy as that of alkali metal

(d) Hydrogen has same electronegativity as of halogens.

5. The order of reactivity of halogens towards hydrogen is

(a) $F_2 > Cl_2 > Br_2 > I_2$ (b) $I_2 > Br_2 > Cl_2 > F_2$

(c) $Cl_2 > Br_2 > I_2 > F_2$ (d) $Br_2 > Cl_2 > F_2 > I_2$

6. Given below are the elements and the type of hydrides formed by them. Mark the incorrect match

(a) Phosphorus-Molecular hydride

(b) Potassium-Ionic hydride

(c) Vanadium-Interstitial hydride

(d) Nitrogen-Electron-deficient covalent hydride

7. In complex hydrides, hydride ions act as ligand and are coordinated to metal ions. These hydrides are good reducing agents. Which of the following hydrides is not complex hydride ?

(a) $LiAlH_4$ (b) $NaBH_4$

(c) $(AlH_3)_n$ (d) $LiBH_4$

8. Carbon hydride of the type, C_nH_{2n+2} do not act as Lewis acid or Lewis base. They behave as normal covalent hydrides because

(a) carbon hydrides are electron-rich hydrides

(b) carbon hydrides are electron-deficient hydrides

(c) carbon hydrides are electron-precise hydrides

(d) carbon hydrides are non-stoichiometric hydrides

9. Pure nascent hydrogen is best obtained by

(a) Na and C_2H_5OH

(b) A*l* and NaOH

(c) Zn and dil. H_2SO_4

(d) All of these

10. Among NH_3, H_2O, HF and H_2S which would have highest magnitude of hydrogen bonding ?

(a) HF due to maximum polarity

(b) H_2O due to lone pairs of electrons.

(c) NH_3 due to small size of nitrogen

(d) H_2S due to higher electron affinity of sulphur.

11. From group 6 only one metal forms hydride. This metal is

(a) Mo (b) W

(c) Cr (d) Co

12. Which of the following reactions of hydrogen with non-metals represents Haber's process ?

(a) $2H_2 + O_2 \xrightarrow{\text{heat}} 2H_2O;\ \Delta H = -285.9\,kJ\,mol^{-1}$

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

(c) $H_2 + Cl_2 \xrightarrow{hv} 2HCl$

(d) $2H_2 + C \xrightarrow{1100°C} CH_4$

13. In which of the following properties hydrogen does not show similarity with alkali metals ?

(a) Electropositive character

(b) Reducing nature

(c) Electronic configuration (ns^1)

(d) Diatomic nature of molecule

14. What is meant by demineralized water ?

(a) Water free from cations and anions

(b) Water free from minerals dissolved in it

(c) Water free from impurities

(d) Water free from Na^+ and K^+ ions.

15. The boiling point of heavy water is

(a) 100° C (b) 101.4° C

(c) 99° C (d) 110° C

16. Heavy water is obtained by

(a) boiling water

(b) heating H_2O_2

(c) prolonged electrolysis of H_2O

(d) All these.

17. What is the reaction given below called ?

$$H_2O_{(l)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$$

(a) Hydrolysis of water

(b) Hydration of water

(c) Disproportional of water

(d) Auto-protolysis of water

18. Which gas is produced when calcium nitride (Ca_3N_2) is hydrolysed by water ?

(a) N_2 (b) NH_3

(c) H_2 (d) O_2

19. The H?O?H angle in water molecule is about

(a) 90° (b) 180°

(c) 102° (d) 105°

20. Syngas is a mixture of

(a) $CO_2 + H_2$ (b) $CO + H_2$

(c) $CO + CO_2$ (d) $CO + O_2$

21. The production of dihydrogen obtained from coal gasification can be increased by reacting carbon monoxide of syngas mixture with steam in presence of a catalyst iron chromate. What is this process called ?

(a) Hydrogen reaction

(b) Water-gas shift reaction

(c) Coal-gas shift reaction

(d) Syn gasification

22. Last traces of water is removed from H_2O_2 by

(a) electrolysis (b) crystallisation

(c) condensation (d) evaporation

23. When CO_2 is bubbled through a solution of barium peroxide in water

(a) carbonic acid is formed

(b) H_2O_2 is formed

(c) H_2O is formed

(d) Barium hydroxide is formed.

24. Polyphosphates like sodium hexametaphosphate (calgon) are used as water softening agents because they

(a) forms soluble complexes with anionic species

(b) precipitate anionic species

(c) form soluble complexes with cationic species

(d) precipitate cationic species.

25. Water gas is mixed with steam and the mixture is passed over heated Fe_2O_3 in presence of Cr_2O_3. The mixture when passed in water dissolves CO_2 and dihydrogen left undissolved is collected. This method of preparation of hydrogen gas is known as

(a) Bosch process (b) Lane process

(c) Kellner (d) Hall process

26. Mark the following statements as true or false.

(i) Ordinary hydrogen is a mixture of 75% ortho and 25% para forms.

(ii) All the four atoms of molecule of H_2O_2 lie in the same plane.

(iii) Hydrogen peroxide is neutral like water.

(iv) H_2O_2 can be prepared from BaO_2 but not from MnO_2 and PbO_2.

(a) (i) and (iv) – true, (ii) and (iii) – false

(b) (i) and (ii) – true, (iii) and (iv) – false

(c) (iii) and (iv) – true, (i) and (ii) – false

(d) (i) and (iii) – true, (ii) and (iv) – false

27. A metal (M) produces a gas (N) on reaction with alkalies like NaOH and KOH. Same gas is produced when the metals reacts with dilute sulphuric acid. Gas (N) reacts with another toxic gas (P) to form methanol at high temperature and pressure. (N) also reacts with metals like (Q) to form electrovalent hydrides. M, N, P and Q respectively are

(a) Zn, H_2, CO, Na (b) Na, H_2, Cl_2, Ca

(c) Al, H_2, H_2S, B (d) Mg, H_2, NO_2, Al

28. Alkenes combine with carbon monoxide and hydrogen in presence of octacarbonyldicobalt as catalyst under high temperature and pressure to form

(a) aldehydes which can further reduced to alcohols by hydrogen

(b) alkanes which are formed by addition of hydrogen.

(c) alcohols formed by reaction of CO & hydrogen

(d) ketones which can be further reduced to aldehydes by hydrogen.

29. Dihydrogen forms three types of hydrides.

(i) hydrides are formed by alkali metals and alkaline earth metals. (ii) hydrides are formed by non-metals and (iii) hydrides are formed by d and

f-block elements at elevated temperature. Complex metal hydrides such as (iv) and (v) are powerful reducing agents.

	(i)	(ii)	(iii)	(iv)	(v)
(a)	Covalent	Molecular	Saline	NaH	LiH
(b)	Molecular	Covalent	Ionic	$LiAlH_4$	CaH_2
(c)	Ionic	Covalent	Interstitial	$LiAlH_4$	$NaBH_4$
(d)	Covalent	Saline	Interstitial	$LiAlH_4$	$NaBH_4$

30. Which of the following statements regarding hydrides is not correct ?

(a) Ionic hydrides are crystalline, non-volatile and non-conducting in solid state.

(b) Electron-deficient hydrides act as Lewis acids or electron acceptors.

(c) Elements of group-13 form electron-deficient hydrides.

(d) Elements of group 15-17 form electron-precise hydrides.

31. Peroxodisulphate, on hydrolysis yields

(a) water

(b) dihydrogen

(c) hydrogen peroxide

(d) deuterium

32. Which of the following statements regarding hydrogen peroxide is false ?

(a) It is a strong oxidizing agent

(b) It is decomposed by MnO_2

(c) It behave as a reducing agent

(d) It is more stable in basic solution.

33. Given below are the two reactions of H_2O_2. Mark the correct statement which follows.

(i) $2KMnO_4 + 3H_2SO_4 + 5H_2O_2 \rightarrow$

$K_2SO_4 + 2MnSO_4 + 8H_2O + 5O_2$

(ii) $2Cr(OH)_3 + 4NaOH + 3H_2O_2 \rightarrow 2Na_2CrO_4 + 8H_2O$

(a) (i) Shows oxidizing nature of H_2O_2 and (ii) shows reducing nature of H_2O_2.

(b) In (i) H_2O_2 acts as a reducing agent and in (ii) it acts as an oxidizing agent.

(c) In both (i) & (ii), H_2O_2 acts as an oxidising agent.

(d) In both (i) & (ii), H_2O_2 acts as a reducing agent.

34. What happens when an alkaline solution of potassium ferricyanide is reacted with H_2O_2 ?

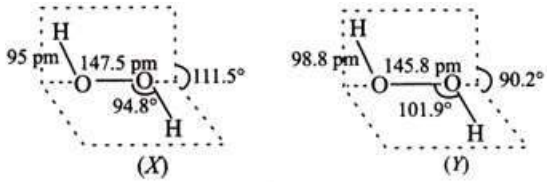
(a) Potassium ferricyanide is oxidized to potassium ferrocyanide and H_2O_2 is oxidized

(b) Potassium ferricyanide becomes colourless and H_2O_2 is oxidised to O_2.

(c) Potassium ferricyanide is reduced to ferric hydroxide and H_2O_2 is oxidised to H_2O.

(d) Potassium ferricyanide is reduced to potassium ferrocyanide and H_2O_2 is oxidized to O_2

35. Two structure of H_2O_2 and drawn below. Identify the phases X and Y of H_2O_2.



(a) (X) is the structure of H_2O_2 in gas phase and

(Y) in solid phase

(b) (X) is the structure of H_2O_2 in solid phase and

(Y) in gas phase

(c) (X) & (Y) are structures of H_2O_2 in gas phase

(d) (X) & (Y) are structures of H_2O_2 in solid phase

36. What will be the mass of oxygen liberated by decomposition of 200 mL hydrogen peroxide solution with a strength of 34g per litre ?

(a) 25.5 g (b) 3.0 g

(c) 3.2 g (d) 4.2 g

37. A commercial sample of hydrogen peroxide is labeled as 10 volume. Its percentage strength is nearly

(a) 3% (b) 1%

(c) 90% (d) 10%

38. Strength of 10 volume hydrogen peroxide solution means

(a) 30.35 g L^{-1} (b) 17 g L^{-1}

(c) 34 g L^{-1} (d) 68 g L^{-1}

Objective Questions II
[One or more than one correct option]

39. Which of the following option regarding heavy water is correct?

(a) 1 molecule of heavy water contains 10 neutrons.

(b) It is used as a moderator

(c) It is used in tracer technique

(d) None of the above

40. Which one is correct statement for H_2O_2

(a) It decomposes slowly on exposure to light

(b) It has a non-planar structure

(c) It is immiscible in water

(d) It shows its oxidizing action both in acidic and basic medium

41. Molecular hydrides are

(a) NaH (b) H_2S

(c) LaH (d) HF

Numerical Value Type Questions

42. What is the number of hydrogen atoms present in hydrolith?

43. 'Calgon' is a salt to remove hardness of water. It is a salt of an oxyacid of phosphorous. What is the basicity of the oxyacid?

Assertion Reason

(A) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(B) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.

(C) If Assertion is true but Reason is false.

(D) If Assertion is false but Reason is true.

44. **Assertion (A) :** Hydrogen is the first element in the Periodic Table.

Reason (R) : It has electronic configuration $1s^1$.

(a) A (b) B

(c) C (d) D

45. **Assertion (A) :** Hydrogen is extremely small in size as compared to the normal atomic and ionic sizes of 50 to 200 pm. As a consequence, H^+ does not exist freely and is always associated with other atoms or molecules.

Reason (R) : It has unique behaviour and, therefore, best placed separately in the Periodic Table.

(a) A (b) B

(c) C (d) D

46. **Assertion (A) :** The crystalline form of water is ice.

Reason (R) : At atmospheric pressure ice crystallizes in the hexagonal form but at very low temperature it condenses to the cubic form.

(a) A (b) B

(c) C (d) D

47. **Assertion (A) :** In winter season ice formed on the surface of a lake provides thermal insultation.

Reason (R) : It ensures the death survival of the destroy aqatic. Life. This fact is of great ecological significance.

(a) A (b) B

(c) C (d) D

48. **Assertion (A) :** Hard water does not give lather with soap.

Reason (R) : Hard water contains calcium and magnesium salts in the form of hydrogen carbonate, chloride and sulphate.

(a) A (b) B

(c) C (d) D

49. **Assertion (A) :** Reducing power of nascent hydrogen is more than atomic hydrogen

Reason (R) : Bond energy of H_2 is maximum.

(a) A (b) B

(c) C (d) D

50. **Assertion (A) :** Hard water forms scum/precipitate with soap.

Reason (R) : Formation of scum occurs as

$$2C_{17} + H_{35}COONa\,(aq) + M^{2+}\,(aq) \rightarrow$$

$$(C_{17}H_{35}COO)_2\,M \downarrow + 2Na^+\,(aq);$$

M is Ca/Mg

(a) A (b) B

(c) C (d) D

51. **Assertion (A) :** Permanent hardness of water is removed by treatment with washing soda.

Reason (R) : Washing soda reacts with soluble magnesium and calcium sulphate to form insoluble carbonate.

(a) A (b) B

(c) C (d) D

52. **Assertion (A) :**

$$2Fe^{2+}\,(aq) + 2H^+\,(aq) + H_2O_2\,(aq) \rightarrow 2Fe^{3+}\,(aq) + 2H_2O\,(l)$$

Reason (R) : H_2O_2 acts as an oxidising agent in the acidic medium.

(a) A (b) B

(c) C (d) D

53. **Assertion (A) :**

$$2MnO_4^- + 3H_2O_2 \rightarrow 2MnO_2 + 3O_2 + 2H_2O + 2OH^-$$

Reason (R) : H_2O_2 acts as reducing agent in the medium.

(a) A (b) B

(c) C (d) D

54. Assertion (A) :

$HOCl + H_2O_2 \rightarrow H_3O^+ + Cl^- + O_2$

Reason (R) : H_2O_2 acts as a reducing agent in the acidic medium.

(a) A (b) B

(c) C (d) D

Match the Following

Each question has two columns. Four options are= given representing matching of elements from= Column-I and Column-II. Only one of these four options corresponds to a correct matching, for each question.

55. Match the following Column I and with Column II

Column - I	**Column - II**
A. Enthalpy of fusion	1. 0.904 kJ mol^{-1}
B. Entalpy of vaporisation	2. 0.117kJ mol^{-1}
C. Ionisation enthalpy	3. 1312kJ mol^{-1}
D. Entahlpy of bond dissociation	4. 435.88 mol^{-1}

56. Match the following Column I and with Column II

Column - I	**Column - II**
A. Electron-deficient molecular hydrides	1. CH_4
B. Electron-precise molecular hydrides	2. B_2H_6
C. Electron-rich molecular hydrides	3. NH_3,HF

57. Match the following Column I and with Column II

Column - I	**Column - II**
A. 10 vol H_2O_2	1. Perthydrol
B. 20 vol H_2O_2	2. 5.358 N
C. 30 vol H_2O_2	3. 1.785 M
D. 100 vol H_2O_2	4. 3 .03%

Fill in the Blanks

58. ..... in the combined form, it constitutes 15.4 % of the earth's crust and the oceans.

59. The isotopes have the same electronic configuration, chemical properties. The only difference is in their rates of reaction, mainly due to their different…… .

60. Number of parts by weight of calcium carbonate present in ……. defined as the degree of hardness of water.

EXERCISE - 4 : PREVIOUS YEAR JEE ADVANCED QUESTIONS

Objective Questions I [Only one correct option]

1. Polyphosphates are used as water softening agents because they **(2002)**

   (a) form soluble complexes with anionic species

   (b) precipitate anionic species

   (c) form soluble complexes with cationic species

   (d) precipitate cationic species

2. A sodium salt on treatment with $MgCl_2$ gives white precipitate only on heating. The anion of the sodium salt is **(2004)**

(a) HCO_3^- (b) CO_3^{2-}

(c) NO_3^- (d) SO_2^{4-}

3. Hydrogen peroxide in its reaction with KIO_4 and NH_2OH respectively, is acting as a **(2014)**

(a) Reducing agent, oxidising agent

(b) Reducing agent, reducing agent

(c) Oxidising agent, oxidising agent

(d) Oxidising agent, reducing agent

Objective Questions II

[One or more than one correct option]

4. The reagent(s) used for softening the temporary hardness of water is (are) **(2010)**

(a) $Ca_3(PO_4)_2$ (b) $Ca(OH)_2$

(c) Na_2CO_3 (d) NaOCl

5. Fe^{3+} is reduced to Fe^{2+} by using **(2015)**

(a) H_2O_2 in presence of NaOH

(b) Na_2O_2 in water

(c) H_2O_2 in presence of H_2SO_4

(d) Na_2O_2 in presence of H_2SO_4

Answer Key

CHAPTER -9 | HYDROGEN

EXERCISE - 1 :
BASIC OBJECTIVE QUESTIONS

1. (b)	**2.** (b)	**3.** (b)	**4.** (c)	**5.** (d)
6. (b)	**7.** (b)	**8.** (c)	**9.** (a)	**10.** (c)
11. (b)	**12.** (a)	**13.** (a)	**14.** (c)	**15.** (d)
16. (a)	**17.** (c)	**18.** (d)	**19.** (b)	**20.** (b)
21. (b)	**22.** (a)	**23.** (a)	**24.** (b)	**25.** (a)
26. (d)	**27.** (d)	**28.** (d)	**29.** (c)	**30.** (b)
31. (a)	**32.** (a)	**33.** (c)	**34.** (b)	**35.** (a)
36. (a)	**37.** (d)	**38.** (b)	**39.** (d)	**40.** (b)
41. (a)	**42.** (d)	**43.** (b)	**44.** (c)	**45.** (b)
46. (a)	**47.** (d)	**48.** (b)	**49.** (c)	**50.** (c)
51. (c)	**52.** (c)	**53.** (b)	**54.** (a)	**55.** (c)
56. (d)	**57.** (b)	**58.** (d)	**59.** (a)	**60.** (b)

EXERCISE - 2 :
PREVIOUS YEAR JEE MAINS QUESTIONS

1. (d)	**2.** (b)	**3.** (c)	**4.** (b)	**5.** (b)
6. (d)	**7.** (d)	**8.** (c)	**9.** (c)	**10.** (a)
11. (d)	**12.** (c)	**13.** (a)	**14.** (a)	**15.** (c)
16. (a)	**17.** (d)	**18.** (c)	**19.** (d)	**20.** (c)
21. (c)	**22.** (d)	**23.** (a)	**24.** (d)	**25.** (d)
26. (b)	**27.** (a)	**28.** (a)	**29.** (a)	**30.** (b)
31. (a)=	**32.** (a)=	**33.** (a)=	**34.** (a)=	**35.** (a)
36. (a)=	**37.** (b)=	**38.** (c)	**39.** (b)=	**40.** (a)
41. (d)	**42.** (c)	**43.** (b)	**44.** (c)	**45.** (a)
46. (c)	**47.** (a)	**48.** (a)	**49.** (b)	**50.** (c)
51. (a)	**52.** (a)	**53.** (100.00)		
54. (100.00)		**55.** (c)	**56.** (a)	**57.** (d)
58. (d)	**59.** (b)	**60.** (d)		

EXERCISE - 3 : ADVANCED OBJECTIVE QUESTIONS

1. (a) **2.** (d) **3.** (a) **4.** (a) **5.** (a)
6. (d) **7.** (c) **8.** (c) **9.** (d) **10.** (a)
11. (c) **12.** (b) **13.** (d) **14.** (a) **15.** (b)
16. (c) **17.** (d) **18.** (b) **19.** (d) **20.** (b)
21. (b) **22.** (b) **23.** (b) **24.** (c) **25.** (a)
26. (a) **27.** (a) **28.** (a) **29.** (c) **30.** (d)
31. (c) **32.** (d) **33.** (b) **34.** (d) **35.** (a)
36. (c) **37.** (a) **38.** (a) **39.** (a,b,c) **40.** (a,b,d)
41. (b,d) **42.** (2.00) **43.** (1.00) **44.** (a) **45.** (a)
46. (a) **47.** (c) **48.** (a) **49.** (d) **50.** (a)
51. (a) **52.** (a) **53.** (b) **54.** (a)

55. $(A \rightarrow 2; B \rightarrow 1; C \rightarrow 3; D \rightarrow 4)$

56. $(A \rightarrow 2; B \rightarrow 1; C \rightarrow 3)$

57. $(A \rightarrow 4; B \rightarrow 3; C \rightarrow 2; D \rightarrow 1)$

EXERCISE - 4 : PREVIOUS YEAR JEE ADVANCED QUESTIONS

1. (c) **2.** (a) **3.** (a) **4.** (b,c,d) **5.** (c,d)