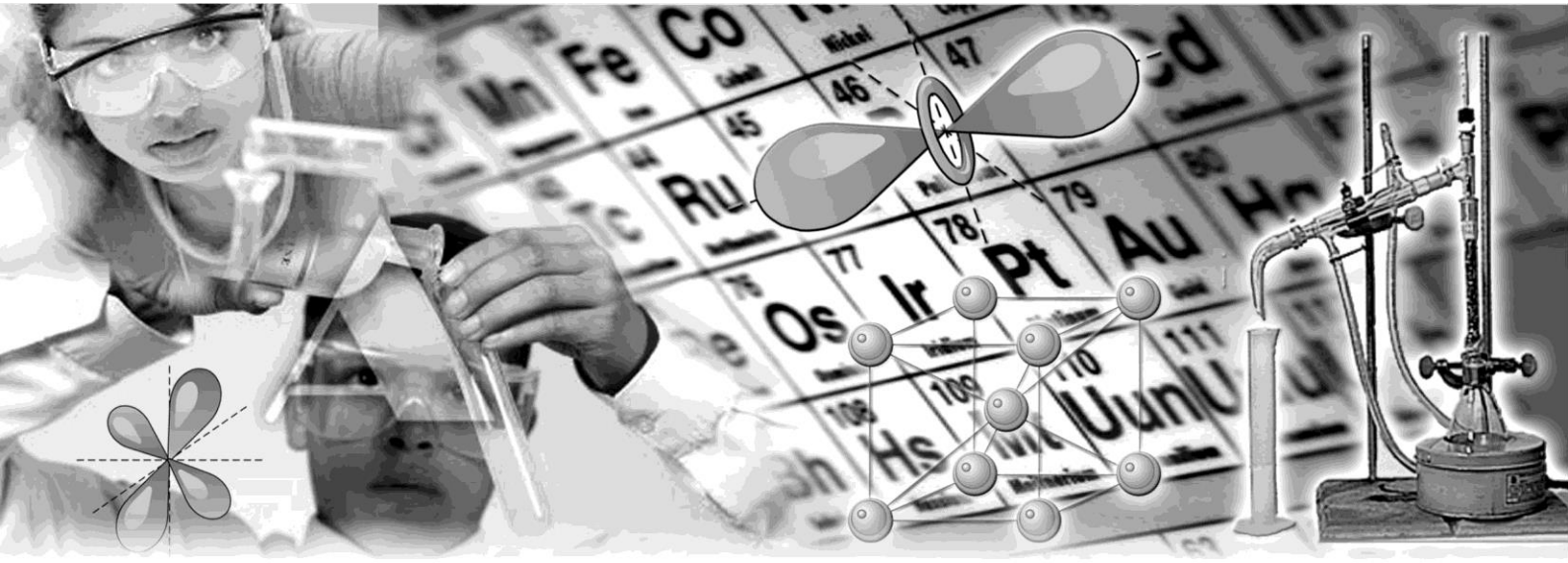


Chapter

17

Hydrogen and Its compounds

Hydrogen

(1) **Position of hydrogen in the periodic table**

Hydrogen is the first element in the periodic table. Hydrogen is placed in no specific group due to its property of giving electron (When H^- is formed) and also losing electron (When H^+ is formed).

(i) Hydrogen is placed in group I (Alkali metals) as,

(a) It has one electron in its (Outer) shell-$1s^1$ like other alkali metals which have (inert gas) ns^1 configuration.

(b) It forms monovalent H^+ ion like $Li^+, Na^+ \ldots$

(c) Its valency is also 1.

(d) Its oxide (H_2O) is stable as Li_2O, Na_2O.

(e) It is a good reducing agent (In atomic as well as molecular state) like $Na, Li \ldots$

(ii) Hydrogen also resembles halogens (Group VII A) as,

(a) It is also diatomic (H_2) like $F_2, Cl_2 \ldots$

(b) It also forms anion H^- like $F^-, Cl^- \ldots$ by gain of one electron.

(c) H^- has stable inert gas (He) configuration as CH_4, C_2H_6 like halogens CCl_4, SF_2Cl_2 etc.

(d) H is one electron short of duplet (Stable configuration) like $F, Cl, \ldots$ which are also one electron deficient than octet, $F - 2s^2 2p^5$; $Cl - 3s^2 3p^5$.

(e) (IE) of $H(1312\ kJ\ mol^{-1})$ is of the same order as that of halogens.

(iii) (IE) of H is very high in comparison with alkali metals. Also size of H^+ is very small compared to that of alkali metal ion. H forms stable hydride only with strongly electropositive metals due to smaller value of its electron affinity $(72.8\,kJ\ mol^{-1})$.

(iv) In view of the anomalous behaviour of hydrogen, it is difficult to assign any definite position to it in the periodic table. Hence it is customary to place it in group I (Along with alkali metals) as well as in group VII (Along with halogens).

(2) **Discovery and occurrence :** It was discovered by ***Henry Cavendish*** in 1766. Its name hydrogen was proposed by ***Lavoisier***. Hydrogen is the 9th most abundant element in the earth's crust.

Hydrogen exists in diatomic state but in triatomicstate it is called as Hyzone. Systematic name of water is oxidane.

(3) **Preparation of Dihydrogen :** Dihydrogen can be prepared by the following methods,

(i) *By action of water with metals*

(a) Active metals like *Na*, *K* react at room temperature

$$2M + 2H_2O \rightarrow 2MOH + H_2 \qquad [M = Na, K \text{ etc.}]$$

(b) Less active metals like *Ca*, *Zn*, *Mg*, *Al* liberate hydrogen only on heating.

$$2Al + 3H_2O \rightarrow Al_2O_3 + 3H_2$$

(c) Metals like *Fe*, *Ni*, *Co*, *Sn* can react only when steam is passed over red hot metals.

$$3Fe + 4H_2O(\text{steam}) \rightarrow \underset{\text{Ferrosoferric oxide}}{Fe_3O_4} + 4H_2$$

(ii) *By the action of water on alkali and alkaline earth metals hydrides*

$$NaH + H_2O \rightarrow NaOH + H_2$$

$$CaH_2 + 2H_2O \rightarrow Ca(OH)_2 + 2H_2$$

(iii) *By reaction of metals like Zn, Sn, Al with alkalies (NaOH or KOH)*

$$Zn + 2NaOH \xrightarrow{\Delta} \underset{\text{sod. zincate}}{Na_2ZnO_2} + H_2$$

$$Al + 2NaOH + H_2O \xrightarrow{\Delta} \underset{\text{Sod. meta-aluminate}}{2NaAlO_2} + 2H_2$$

$$\underset{\text{Silicon}}{Si} + 2NaOH + 2H_2O \xrightarrow{\Delta} Na_2SiO_3 + 3H_2$$

$$\underset{\text{Tin}}{Sn} + 2NaOH \xrightarrow{\Delta} \underset{\text{Sod. stannite}}{Na_2SnO_2} + H_2 \uparrow$$

(iv) ***By action of metal with acids*** : All active metals which lie above hydrogen in electrochemical series, can displace hydrogen gas from dilute mineral acids like HCl, H_2SO_4.

$$Fe + 2HCl \rightarrow FeCl_2 + H_2$$

(v) *By the electrolysis of acidified water*

$$2H_2O \xrightarrow{H^+/\text{Electrolysis}} \underset{\text{At cathode}}{2H_2 \uparrow} + \underset{\text{At anode}}{O_2 \uparrow}$$

(vi) ***Laboratory method*** : In laboratory, it is obtained by action of granulated zinc with dilute H_2SO_4.

$$Zn + \text{dil. } H_2SO_4 \rightarrow ZnSO_4 + H_2$$

It must be noted that

(a) Pure zinc is not used for the preparation of H_2 as rate of reaction of pure Zn with dil. H_2SO_4 is quite slow.

(b) Conc. H_2SO_4 is not used because then SO_2 gas is evolved instead of H_2.

(vii) ***Preparation of pure hydrogen***: It can be obtained by

(a) The action of pure dil. H_2SO_4 on pure magnesium ribbon.

$$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$$

(b) Hydrogen of high purity (> 99.95%) is obtained by electrolysing warm aqueous barium hydroxide between nickel electrodes.

(c) By the action of water on sodium hydride.

$$NaH + H_2O \rightarrow NaOH + H_2 \uparrow$$

(d) By the action of KOH (aq.) on aluminium.

$$2Al + 2KOH + 2H_2O \rightarrow 2KAlO_2 + 3H_2 \uparrow$$

(viii) *Commercial production of dihydrogen*

(a) **Bosch process :** In this method, water gas is mixed with twice its volume of steam and passed over heated catalyst Fe_2O_3 in the presence of a promoter Cr_2O_3 or ThO_2 at 773 K when CO_2 and H_2 are obtained. CO_2 is removed by dissolving it in water under pressure (20-25 *atm*) and H_2 left undissolved is collected.

$$C + H_2O \xrightarrow{1270\ K} \underbrace{CO + H_2}_{\text{Water gas}}$$

$$H_2 + CO + H_2O \xrightarrow[Fe_2O_3, Cr_2O_3]{773\ K} CO_2 + 2H_2$$

About 18% of the world's production of H_2 is obtained from coal.

(b) **Lane's process :** By passing steam over spongy iron at 773-1050 K.

$$3Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2$$

The ferrosoferric oxide (Fe_3O_4) so produced is reduced back to iron with water. this reaction is known as **Vivification reactions**

$$Fe_3O_4 + 4H_2 \rightarrow 3Fe + 4H_2O$$

$$Fe_3O_4 + 4CO \rightarrow 3Fe + 4CO_2$$

(c) **By electrolysis of water** : Electrolysis of acidified water using platinum electrodes is used for the bulk preparation of hydrogen.

(d) **From hydrocarbons** : Hydrocarbons (alkanes) react with steam at high temperature to produce carbon monoxide and hydrogen, *e.g.*,

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

The mixture of CO and H_2 so obtained can be converted into hydrogen as in Bosch process. About 77% of the world's production of H_2 is obtained from hydrocarbons.

(e) It is also produced as a by-product of the brine electrolysis process for the manufacture of Cl_2 and $NaOH$.

(4) **Physical properties of dihydrogen :** It is a colourless, tasteless and odourless gas. It is slightly soluble in water. It is highly combustible. The Physical constants of atomic hydrogen are,

Atomic radius (pm) – 37

Ionic radius of H^- ion (pm) – 210

Ionisation energy ($kJ\,mol^{-1}$) – 1312

Electron affinity $(kJ\,mol^{-1})$ –72.8

Electronegativity – 2.1

(5) **Chemical properties of dihydrogen :** Dihydrogen is quite stable and dissociates into hydrogen atoms only when heated above 2000 K, $H_2 \xrightarrow{2000\ K} H + H$. Its bond dissociation energy is very high, $H_2 \rightarrow H + H;\ \Delta H = 435.9\,kJ\,mol^{-1}$. Due to its high bond dissociation energy, it is not very reactive. However, it combines with many elements or compounds.

(i) ***Action with metals*** : To forms corresponding hydrides. $2Na + H_2 \xrightarrow{Heat} 2NaH$; $Ca + H_2 \xrightarrow{Heat} CaH_2$.

With transition metals (elements of *d* – block) such as *Pd, Ni, Pt* etc. dihydrogen forms interstitial hydrides in which the small molecules of dihydrogen occupy the interstitial sites in the crystal lattices of these hydrides. As a result of formation of interstitial hydrides, these metals adsorb large volume of hydrogen on their surface. This property of adsorption of a gas by a metal is called ***occlusion.*** The occluded hydrogen can be liberated from the metals by strong heating.

(ii) ***Reaction with Non-metals***

$$2H_2 + O_2 \xrightarrow{970\ K} 2H_2O$$

$$N_2 + 3H_2 \xrightarrow[750\ K,\text{Pressure}]{Fe,Mo} 2NH_3$$

$$H_2 + F_2 \xrightarrow{Dark} 2HF$$

$$H_2 + Cl_2 \xrightarrow[673\ K,\text{Pressure}]{Sunlight} 2HCl$$

$$H_2 + Br_2 \rightarrow 2HBr$$

$$H_2 + I_2 \xrightarrow[Pt]{673\ K} 2HI$$

The reactivity of halogen towards dihydrogen decreases as, $F_2 > Cl_2 > Br_2 > I_2$

As a result, F_2 reacts in dark, Cl_2 in the presence of sunlight, Br_2 reacts only upon heating while the reaction with I_2 occurs in the presence of a catalyst.

(iii) ***Reaction with unsaturated hydrocarbons*** : H_2 reacts with unsaturated hydrocarbons such as ethylene and acetylene to give saturated hydrocarbons.

$$\underset{Ethylene}{H_2C = CH_2} + H_2 \xrightarrow[473\ K]{Ni\ or\ Pt\ or\ Pd} \underset{Ethane}{CH_3 - CH_3}$$

$$\underset{Acetylene}{HC \equiv CH} + 2H_2 \xrightarrow[473\ K]{Ni\ or\ Pt\ or\ Pd} \underset{Ethane}{CH_3 - CH_3}$$

This reaction is used in the ***hydrogenation or hardening of oils***. The vegetable oils such as groundnut oil or cotton-seed oil are unsaturated in nature because they contain at least one double bond in their molecules. Dihydrogen is passed through the oils at about 473 *K* in the presence of catalyst to form solid fats. The vegetable ghee such as Dalda, Rath, etc. are usually prepared by this process.

$$\underset{(liquid)}{\text{Vegetable oil}} + H_2 \xrightarrow[473\ K]{Ni} \underset{(solid)}{Fat}$$

(6) **Uses of Dihydrogen**

(i) As a reducing agent

(ii) In the hydrogenation of vegetable oils

(iii) As a rocket fuel in the form of liquid H_2

(iv) In the manufacture of synthetic petrol

(v) In the preparation of many compounds such as $NH_3, CH_3OH,$ Urea etc.

(vi) It is used in the oxy-hydrogen torch for welding if temperature around 2500°*C* is required. It is also used in atomic hydrogen torch for welding purposes in which temperature of the order of 4000°*C* is required.

Different forms of hydrogen

(1) **Atomic hydrogen :** It is obtained by the dissociation of hydrogen molecules. The atomic hydrogen is stable only for a fraction of a second and is extremely reactive. It is obtained by passing dihydrogen gas at atmospheric pressure through an electric arc struck between two tungsten rods.

The electric arc maintains a temperature around 4000 – 4500°*C*. As the molecules of dihydrogen gas pass through the electric arc, these absorb energy and get dissociated into atoms as

$$H_2(g) \xrightarrow[arc]{Electric} 2H(g) : \Delta H = 435.90\,KJ\,mol^{-1}$$

This arrangement is also called atomic hydrogen torch.

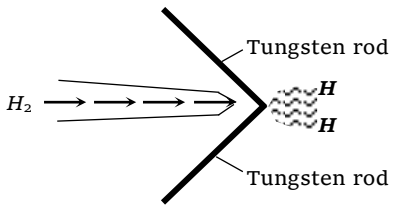


Fig. 17.1 Atomic hydrogen torch

(2) **Nascent hydrogen :** The hydrogen gas prepared in the reaction mixture in contact with the substance with which it has to react, is called nascent hydrogen. It is also called newly born hydrogen. It is more reactive than ordinary hydrogen. For example, if

ordinary hydrogen is passed through acidified $KMnO_4$ (pink in colour), its colour is not discharged. On the other hand, if zinc pieces are added to the same solution, bubbles of hydrogen rise through the solution and the colour is discharged due to the reduction on $KMnO_4$ by nascent hydrogen.

$$KMnO_4 + \underset{Molecular}{H_2} + H_2SO_4 \rightarrow No\ reaction$$

$$Zn + H_2SO_4 \rightarrow ZnSO_4 + \underset{Nascent\ hydrogen}{2[H]}$$

$$2KMnO_4 + 3H_2SO_4 + 10[H] \rightarrow K_2SO_4 + 2MnSO_4 + 8H_2O$$

(3) **Ortho and para hydrogen :** A molecule of dihydrogen contains two atoms. The nuclei of both the atoms in each molecule of dihydrogen are spinning. Depending upon the direction of the spin of the nuclei, the hydrogen is of two types,

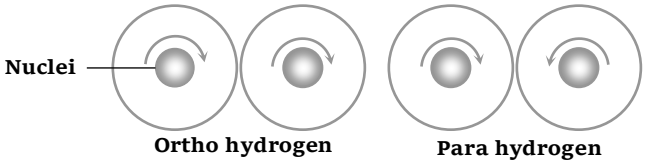


Fig. 17.2

(i) Molecules of hydrogen in which the spins of both the nuclei are in the same directions, called ortho hydrogen.

(ii) Molecules of hydrogen in which the spins of both the nuclei are in the opposite directions, called para hydrogen.

Ordinary dihydrogen is an equilibrium mixture of ortho and para hydrogen. Ortho hydrogen ⇌ Para hydrogen. The amount of ortho and para hydrogen varies with temperature as,

(a) At 0°*K*, hydrogen contains mainly para hydrogen which is more stable.

(b) At the temperature of liquefaction of air, the ratio of ortho and para hydrogen is 1:1.

(c) At the room temperature, the ratio of ortho to para hydrogen is 3:1.

(d) Even at very high temperatures, the ratio of ortho to para hydrogen can never be more than 3:1.

Thus, it has been possible to get pure para hydrogen by cooling ordinary hydrogen gas to a very low temperature (close to 20 *K*) but it is never possible to get a sample of hydrogen containing more than 75% of ortho hydrogen. i.e., Pure ortho hydrogen can not be obtained.

(4) **Hydrides :** Hydrogen forms binary hydrides of the type MH_x or M_mH_n with

(a) All main group elements except noble gases and probably indium and thallium.

(b) All lanthanoids and actinoids.

(c) Transition metals (*Sc*, *Y*, *La*, *Ac*, *Tc*, *Zr*, *Hf* and to a lesser extent *V*, *Nb*, *Ta*, *Cr*, *Cu* and *Zn*). In group 6 only *Cr* forms hydride (*CrH*).

Hydrides are classified into three main categories.

(i) ***Saline or ionic hydrides*** : Most of the *s*-block metals form this type of hydrides. These are non-volatile, non-conducting crystalline solids. However, BeH_2 and MgH_2 have covalent polymeric structure. These ionic hydrides have rock-salt structure. Thermal stability of 1st and 2nd group hydrides are in the order;

$$LiH > NaH > KH > RbH > CsH$$

$$CaH_2 > SrH_2 > BaH_2$$

BeH_2, MgH_2 and *LiH* have significant covalent character.

Electrolysis of solution of saline hydride in molten alkali halide produces H_2 at anode. Saline hydrides react explosively with water.

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

The fire so produced cannot be extinguished by CO_2 as it gets reduced by the hot metal hydride. Only sand is useful, as it is a solid.

Alkali metal hydrides are used for making $LiAlH_4, NaBH_4$ etc. Alkali metal hydrides are also used for the removal of last traces of water from organic compounds.

(ii) ***Metallic or interstitial hydrides*** : Elements of groups 3, 4, 5 (*d*-block) and *f*-block elements form metallic hydrides. In group 6, only *Cr* forms hydride (*CrH*). Metals of group 7, 8, 9 do not form hydrides. This region of periodic table from group 7 to group 9 is known as hydride gap. Examples of hydrides of group 3 to 5 are, $ScH_2, YH_2, YH_3, LaH_2, LaH_3, TiH_2, ZrH_2, HfH_2, VH,$

VH_2, NbH, NbH_2, TaH

The *f*-block metals form hydrides of limiting compositions of MH_2 and MH_3. All these hydrides are non-stoichiometric with variable composition *e.g.*,

$ZrH_x(1.30 \le x \le 1.75)$, $TiH_x(1.8 \le x \le 2.0)$.

Most of these hydrides are good conductors of electricity in solid state.

Metallic hydrides can be used to store hydrogen especially in cars working on fuel cells.

(iii) ***Molecular or covalent hydrides*** : Hydrogen form molecular compounds with *p*-block elements (*B*, *C*, *N*, *O*, *F*; *Si*, *P*, *S*, *Cl*; *Ga*, *Ge*, *As*, *Sb*, *Br*; *In*, *Sn*, *Sb*, *Te*, *I*; *Tl*, *Pb*, *At*). common examples of such hydrides are CH_4, NH_3, H_2O, HF etc. The stability of these hydrides decreases down the group. For example, $NH_3 > PH_3 > AsH_3 > SbH_3 > BiH_3$. In a period the stability increases with increasing electronegativity. For example, $CH_4 < NH_3 < H_2O < HF$. Molecular hydrides are classified as electron rich, electron precise and electron deficient hydrides.

(a) *Electron rich molecular hydrides* : These hydrides have one or more lone pairs of electrons around the central more electronegative element. For example

$H-\ddot{O}-H$, $H-\underset{\underset{H}{|}}{\ddot{N}}-H$, $H-\ddot{F}:$

(b) *Electron precise molecular hydrides* : Elements of group 14 form such hydrides. The bond length increases on going down the group. A common example of electron precise molecular hydrides is CH_4.

(c) *Electron deficient molecular hydrides* : These hydrides have lesser number of electrons than that required for writing the conventional Lewis structure. A common example of such molecular hydride is diborane, B_2H_6.

(d) *Systematic names of molecular hydrides* : The systematic names of these hydrides are obtained from the name of the element and the suffix –ane. For example,

PH_3	H_2O	NH_3
Phosphane	oxidane	ozane

Isotopes of Hydrogen

Isotopes are the different forms of the same element, which have the same atomic number but different mass numbers.

Table 17.1 *Isotopes of hydrogen*

Name	Symbol	Atomic number	Mass number	Relative abundance	Nature radioactive or non-radioactive
Protium or Hydrogen	${}_1^1H$ or H	1	1	99.985%	Non-radioactive
Deuterium	${}_1^2H$ or D	1	2	0.015%	Non-radioactive
Tritium	${}_1^3H$ or T	1	3	10^{-15} %	Radioactive

Table 17.2 *Physical constants of H_2, D_2 and T_2*

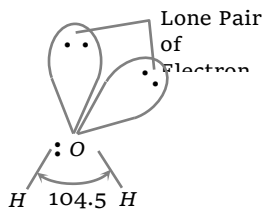
Property	H_2	D_2	T_2
Molecular mass	2.016	4.028	6.03
Melting point (K)	13.8	18.7	20.63
Boiling point (K)	20.4	23.9	25.0
Heat of fusion ($kJ\ mol^{-1}$)	0.117	0.197	0.250
Heat of vaporisation ($kJ\ mol^{-1}$)	0.994	1.126	1.393
Bond energy ($kJ\ mol^{-1}$)	435.9	443.4	446.9

Isotopic effect : In general chemical properties of isotopes are same but quantiative differences are noticed amongst them. For example, the reaction between H_2 and Cl_2 is 13.4 times faster between D_2 and Cl_2 under similar conditions. Such differences in chemical properties, which are due to difference in the mass numbers of isotopes is known as isotopic effect.

Water

Water is the oxide of hydrogen. It is an important component of animal and vegetable matter. Water constitutes about 65% of our body. It is the principal constituent of earth's surface.

(1) **Structure :** Due to the presence of lone pairs, the geometry of water is distorted and the $H-O-H$ bond angle is 104.5°, which is less than the normal tetrahedral angle (109.5°). The geometry of the molecule is regarded as angular or bent. In water, each $O-H$ bond is polar because of the high electronegativity of oxygen (3.5) in comparison to that of hydrogen (2.1). The resultant dipole moment of water molecule is 1.84D.



In ice, each oxygen atom is tetrahedrally surrounded by four hydrogen atoms; ***two by covalent bonds and two by hydrogen bonds***. The resulting structure of ice is open structure having a number of vacant spaces. Therefore, the density of ice is less than that of water and ice floats over water. It may be noted

that water has maximum density $(1 g\,cm^{-3})$ at 4°C (277 K).

(2) **Heavy water :** Chemically heavy water is deuterium oxide (D_2O). It was discovered by ***Urey***.

It is obtained as a by-product in some industries where H_2 is produced by the electrolysis of water.

Heavy water (D_2O) is used (*a*) as a moderator and coolant in nuclear reactors (*b*) in the study of mechanism of chemical reactions (*c*) as a starting material for the preparation of a number of deuterium compounds, *e.g.*,

$$SO_3 + D_2O \rightarrow \underset{\text{Deuteriosulphuric acid}}{D_2SO_4}$$

$$Al_4C_3 + 12\,D_2O \rightarrow \underset{\text{Deuteromethane}}{3CD_4} + 4\,Al(OD)_3$$

$$CaC_2 + 2D_2O \rightarrow \underset{\text{Deuterioacetylene}}{C_2D_2} + Ca(OD)_2$$

(3) **Physical properties :** Water is colourless, odourless and tasteless liquid at ordinary temperature.

At 273K water is in equilibrium with ice and vapour this point is known triple point.

Table 17.3 ***Some physical constants of H_2O and D_2O at 298 K***

Constant	Ordinary water H_2O	Heavy water D_2O
Molecular mass	18.015	20.028
Maximum density $(g\,cm^{-3})$	1.000	1.106
Melting point (K)	273.2	276.8
Boiling point (K)	373.2	374.4
Heat of fusion $(kJ\,mol^{-1})$ at 273K	6.01	6.28
Heat of vaporisation $(kJ\,mol^{-1})$ at 373K	40.66	41.61
Heat of formation $(kJ\,mol^{-1})$	– 285.9	– 294.6
Ionisation constant	1.008×10^{-14}	1.95×10^{-15}

(4) **Chemical properties :** Water shows a versatile chemical behaviour. It behaves as an acid, a base, an oxidant, a reductant and as ligand to metals.

(i) **Dissociation of water** : Water is quite stable and does not dissociate into its elements even at high temperatures. Pure water has a small but measurable electrical conductivity and it dissociates as,

$$H_2O + H_2O \rightleftharpoons \underset{\text{Hydronium ion}}{H_3O^+} + OH^-$$

$K_W = 1.0 \times 10^{-14}\ mol^2 L^2$ at $298K$

(ii) ***Amphoteric nature*** : Water can act both as an acid and a base and is said to be amphoteric. However, water is neutral towards litmus and its *p*H is 7.

(iii) ***Oxidising and reducing nature*** : Water can act both as an oxidising and a reducing agent in its chemical reactions. e.g.

$$2Na + \underset{\text{Oxidising agent}}{2H_2O} \rightarrow 2NaOH + H_2$$

$$2F_2 + \underset{\text{Reducing agent}}{2H_2O} \rightarrow 4HF + O_2$$

(iv) ***Hydrolytic reactions*** : Water can hydrolyse many oxides, halides, hydrides, carbides, nitrides, phosphides, carbonates etc. to give an acid or a base or both as shown below :

$$SO_2 + H_2O \rightarrow H_2SO_3$$

$$Mg_3N_2 + 6H_2O \rightarrow 3Mg(OH)_2 + 2NH_3$$

$$CaH_2 + 2H_2O \rightarrow Ca(OH)_2 + 2H_2$$

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

$$Na_2CO_3 + 2H_2O \rightarrow 2NaOH + H_2CO_3$$

$$SiCl_4 + 4H_2O \rightarrow Si(OH)_4 + 4HCl$$

$$Ca_3P_2 + 6H_2O \rightarrow 3Ca(OH)_2 + 2PH_3$$

$$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$$

(v) ***Water forms hydrates with metal salts*** : There are three main types of hydrates.

(a) Compounds in which water molecule are co-ordinated to the metal ion (complex compounds) $[Ni(OH_2)](NO_3)_2$, $Fe(OH_2)_6]Cl_3$ etc.

(b) Compound in which water molecule may be hydrogen bonded to oxygen to form oxo-anion. For example in $CuSO_4.5H_2O$, 4 molecules of water are co-ordinated to Cu^{2+} while the fifth molecule is hydrogen bonded to SO_4^{2-} ion.

(c) In some compounds, water molecule occupies, interstitial sites in the crystal lattice *e.g.*, $BaCl_2.2H_2O$.

(5) **Hard and Soft water**

Water which produces lather with soap solution readily is called ***soft water***. e.g. distilled water, rain water and demineralised water.

Water which does not produce lather with soap solution readily is called ***hard water***. e.g. sea water, river water, well water and tap water.

(i) ***Cause of hardness of water*** : The hardness of water is due to the presence of bicarbonates, chlorides and sulphates of calcium and magnesium.

Hard water does not produce lather because the cations (Ca^{+2} and Mg^{+2}) present in hard water react with soap to form insoluble precipitates,

$$\underset{\text{From hard water}}{M^{+2}} + 2\underset{\text{Sodium stearate(soap)}}{C_{17}H_{35}COONa} \rightarrow \underset{\text{Metal stearate(PPt.)}}{(C_{17}H_{35}COO)_2M} + 2Na^+$$

Where M = *Ca* or *Mg*

Therefore, no lather is produced until all the calcium and magnesium ions are precipitated. This also results into wastage of lot of soap.

(ii) ***Type of hardness of water*** : The hardness of water is of two types,

(a) *Temporary hardness* : This is due to the presence of bicarbonates of calcium and magnesium. It is also called carbonate hardness.

(b) *Permanent hardness* : This is due to the presence of chlorides and sulphates of calcium and magnesium. It is also called non-carbonate hardness.

(iii) ***Softening of water*** : The process of the removal of hardness from water is called softening of water.

(a) *Removal of temporary hardness* **:** It can be removed by the following methods,

• By boiling **:** During boiling, the bicarbonates of *Ca* and *Mg* decompose into insoluble carbonates and give CO_2. The insoluble carbonates can be removed by filtration.

$$\underset{\text{Cal.bicarbonate}}{Ca(HCO_3)_2} \xrightarrow{Heat} \underset{\text{PPt.}}{CaCO_3} + CO_2 + H_2O$$

$$\underset{\text{Mag.bicarbonate}}{Mg(HCO_3)_2} \xrightarrow{Heat} \underset{\text{PPt.}}{MgCO_3} + CO_2 + H_2O$$

• Clark's method **:** This process is used on a commercial scale. In this process, calculated amount of lime $[Ca(OH)_2]$ is added to temporary hard water.

$$\underset{\text{Soluble}}{Ca(HCO_3)_2} + \underset{\text{Lime}}{Ca(OH)_2} \longrightarrow \underset{\text{Insoluble}}{2CaCO_3} \downarrow + 2H_2O$$

$$\underset{\text{Soluble}}{Mg(HCO_3)_2} + \underset{\text{Lime}}{Ca(OH_2)} \longrightarrow \underset{\text{(Insoluble)}}{MgCO_3} \downarrow + CaCO_3 \downarrow + 2H_2O$$

(b) *Removal of permanent hardness* : Permanent hardness can be removed by the following methods,

• By washing soda method : In this method, water is treated with a calculated amount of washing soda (Na_2CO_3) which converts the chlorides and sulphates of *Ca* and *Mg* into their respective carbonates which get precipitated.

$$CaCl_2 + Na_2CO_3 \longrightarrow \underset{ppt.}{CaCO_3} + 2NaCl$$

$$MgSO_4 + Na_2CO_3 \longrightarrow \underset{ppt.}{MgCO_3} + Na_2SO_4$$

• Permutit method : This is a modern method employed for the softening of hard water. hydrated sodium aluminium silicate ($Na_2Al_2Si_2O_8.xH_2O$) is called permutit. These complex salts are also known as zeolites.

The permutit as loosely packed in a big tank over a layer of coarse sand. Hard water is introduced into the tank from the top. Water reaches the bottom of the tank and then slowly rises through the permutit layer in the tank. The cations present in hard water are exchanged for sodium ions. Therefore this method is also called ion exchange method.

$$\underset{\text{Sodium zeolite}}{Na_2Z} + \underset{\text{(From hard water)}}{Ca^{+2}} \longrightarrow \underset{\text{Cal zeolite}}{CaZ} + 2Na^+$$

$$\underset{\text{Sodium zeolite}}{Na_2Z} + \underset{\text{(From hard water)}}{Mg^{+2}} \longrightarrow \underset{\text{Magnesium zeolite}}{MgZ} + 2Na^+$$

where $Z = Al_2Si_2O_8.\ xH_2O$

Hydrogen peroxide

Hydrogen peroxide (H_2O_2) was discovered by French chemist ***Thenard***.

(1) **Preparation :** It is prepared by

(i) ***Laboratory method*** : In laboratory, H_2O_2 is prepared by Merck's process. It is prepared by adding calculated amounts of sodium peroxide to ice cold dilute (20%) solution of H_2SO_4.

$$Na_2O_2 + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O_2$$

(ii) By the action of sulphuric acid or phosphoric acid on hydrated barium peroxide $BaO_2.8H_2O$

(a) $BaO_2.8H_2O + H_2SO_4 \rightarrow BaSO_4 \downarrow + H_2O_2 + 8H_2O$

It must be noted that anhydrous barium peroxide does not react readily with sulphuric acid (because a coating of insoluble barium sulphate is formed on its surface which stops further action of the acid). Therefore, hydrated barium peroxide, $BaO_2.8H_2O$ must be used.

(b) $3BaO_2 + 2H_3PO_4 \rightarrow Ba_3(PO_4)_2 + 3H_2O_2$

$$Ba_3(PO_4)_2 + 3H_2SO_4 \rightarrow 3BaSO_4 + 2H_3PO_4$$

Phosphoric acid is preferred to H_2SO_4 because soluble impurities like barium persulphate (from $BaO_2.8H_2O + H_2SO_4$) tends to decompose H_2O_2 while

H_3PO_4 acts as preservative (negative catalyst) for H_2O_2.

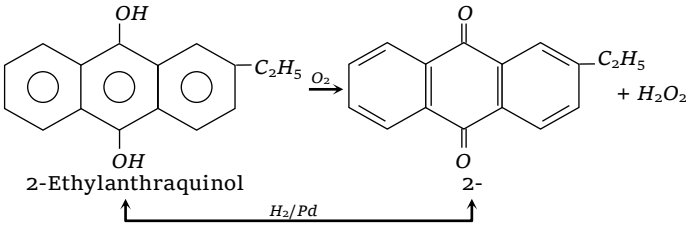
(iii) ***Industrial method*** : On a commercial scale, H_2O_2 can be prepared by the electrolysis of 50% H_2SO_4 solution. In a cell, peroxy disulphuric acid is formed at the anode.

$$2H_2SO_4 \xrightarrow[\text{Elecrolysis}]{} \underset{\text{Peroxy disulphuric acid}}{H_2S_2O_8(aq.)} + H_2(g)$$

This is drawn off from the cell and hydrolysed with water to give H_2O_2.

$H_2S_2O_8 + 2H_2O \longrightarrow 2H_2SO_4 + H_2O_2$ The resulting solution is distilled under reduced pressure when H_2O_2 gets distilled while H_2SO_4 with high boiling point, remains undistilled.

(iv) ***By redox process*** : Industrially H_2O_2 is prepared by the auto-oxidation of 2-alkylanthraquinols. The process involves a cycle of reactions. The net reaction is the catalytic union of H_2 and O_2 to give H_2O_2.



The H_2O_2 formed (about 1%) is extracted with water and concentrated.

(2) **Physical properties**

(i) Pure hydrogen peroxide is a pale blue syrupy liquid.

(ii) It freezes at – 0.5°*C* and has a density of 1.4 in pure state.

(iii) Hydrogen peroxide is diamagnetic.

(iv) It is more highly associated via hydrogen bonding than water.

(v) Although it is a better polar solvent than H_2O. However, it can't be used as such because of strong autooxidation ability.

(vi) Dipole moment of H_2O_2 is 2.1 *D*.

(3) **Chemical properties**

(i) ***Decomposition*** : Pure H_2O_2 is an unstable liquid and decomposes into water and O_2 either upon standing or upon heating, $2H_2O_2 \longrightarrow 2H_2O + O_2;\ \Delta H = -196.0\,kJ$

(ii) ***Oxidising nature*** : It is a powerful oxidising agent. It acts as an oxidising agent in neutral, acidic or in alkaline medium. *e.g.* $2KI + H_2O_2 \longrightarrow 2KOH + I_2$ [In neutral medium]

$2FeSO_4 + H_2SO_4 + H_2O_2 \longrightarrow Fe_2(SO_4)_3 + 2H_2O$ [In acidic medium]

$MnSO_4 + H_2O_2 + 2NaOH \longrightarrow MnO_2 + Na_2SO_4 + 2H_2O$ [In alkaline medium]

(iii) ***Reducing nature*** : H_2O_2 has tendency to take up oxygen from strong oxidising agents and thus, acts as a reducing agent, $H_2O_2 + \underset{\text{From oxidising agent}}{O} \longrightarrow H_2O + O_2$. It can act as a reducing agent in acidic, basic or even neutral medium.

In acidic medium, $H_2O_2 \longrightarrow 2H^+ + O_2 + 2e^-$

In alkaline medium,

$H_2O_2 + 2OH^- \longrightarrow 2H_2O + O_2 + 2e^-$

(iv) ***Bleaching action*** : H_2O_2 acts as a bleaching agent due to the release of nascent oxygen.

$$H_2O_2 \longrightarrow H_2O + O$$

Thus, the bleaching action of H_2O_2 is due to oxidation. It oxidises the colouring matter to a colourless product, Colouring matter $+O \rightarrow$ Colour less matter.

H_2O_2 is used to bleach delicate materials like ivory, silk, wool, leather etc.

(v) ***Acidic nature*** : Anhydrous hydrogen peroxide is acidic in character ($K_a = 1.55 \times 10^{-12}$ at 298 *K*). its dissociation in aqueous solution may be given as

$$H_2O_2 + H_2O \rightarrow H_3O^+ + HO_2^-$$

It forms two types of salts

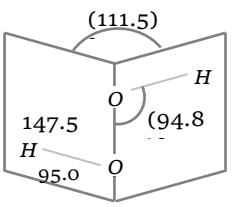
$$NaOH + H_2O_2 \rightarrow \underset{\substack{\text{Sod. hydroperoxide}\\(\text{Acidic salt})}}{NaHO_2} + H_2O$$

$$2NaOH + H_2O_2 \rightarrow \underset{\substack{\text{Sod. peroxide}\\(\text{Normal salt})}}{Na_2O_2} + 2H_2O$$

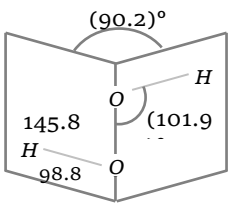
(vi) ***Addition reactions*** : Hydrogen peroxide is capable of adding itself to ethylenic linkage.

$$\underset{\text{Ethylene}}{CH_2 \| CH_2} + H_2O_2 \rightarrow \underset{\text{Ethylene glycol}}{CH_2OH | CH_2OH}$$

(4) **Structure of H_2O_2 :** Hydrogen peroxide is non-linear, non-planar molecule. It has a open book structure. The $-O-O-$ linkage is called peroxy linkage. The structure is shown below.



In gas



In solid phase (110

(5) **Concentration of H_2O_2 :** Dilute H_2O_2 is concentrated to about 50% by slow evaporation on a water bath. It is further concentrated to 90% in a vacuum desiccator using conc. H_2SO_4 as dehydrating agent. Further concentration to 99% is obtained by distillation under reduced pressure. Last traces of moisture in 99% of H_2O_2 are removed or anhydrous H_2O_2 is obtained by cooling it to 263 *K* in a cold bath of ether and dry ice followed by seeding with a few crystals of solid H_2O_2 when needle-shaped crystals of 100% H_2O_2 separate out. These crystals are removed, dried and melted to get 100% H_2O_2.

(6) **Storage of H_2O_2 :** H_2O_2 is not stored in glass bottles since the alkali metal oxides present in glass catalyse its decomposition. It is, therefore, stored in paraffin wax coated glass, plastic or teflon bottles. Small amounts of acid, glycerol, alcohol, acetanilide and H_3PO_4 are often used as stablizers to check its decomposition.

Uses of hydrogen peroxide

(i) For bleaching delicate articles like wool, hair, feather, ivory, etc.

(ii) For restoring colour of old lead paintings whose white lead has blackened due to formation of *PbS* by H_2S of atmosphere. Hydrogen peroxide converts the black lead sulphide to white lead sulphate

(iii) As an aerating agent in production of spong rubber.

(iv) As an antiseptic and germicide for washing wounds, teeth and ears, under the name of perhydrol.

(v) In the manufacture of sodium perborate, sodium percarbonate. These are used in high quality detergents.

(vi) As an antichlor.

(vii) As an oxidant for rocket fuel.

(viii) In the detection of *Ti*, *V* and *Cr* ions with which it forms peroxides of characteristics colours.

(ix) In the production of epoxides, propylene oxide and polyurethanes.

(x) In the synthesis of hydroquinone, pharmaceuticals (cephalosoporin) and food products like tartaric acid.

(xi) For pollution control of domestic effluents where it restores the aerobic conditions of sewage wastes. For pollution control of industrial effluents containing CN^- ions. H_2O_2 oxidises CN^- ions to harmless products.

Tips & Tricks

✍ Hydrogen forms more compounds than even carbon.

✍ Metals like *Pd, Pt, Au* etc., have the property of absorbing large quantity of hydrogen at normal or higher temperature. Colloidal *Pd* can absorb 2950 times its own volume of hydrogen and *Pd* metal can absorb 900 times its own volume of hydrogen.

This phenomenon is known as occlusion of hydrogen. the occlusion property of these metals is in the order

Colloidal Palladium > Palladium > Platinum > Gold > Nickel.

✍ In solids, water molecules can also be present as zeolite water and clathrate water.

✍ Ice is a good thermal insulator.

✍ 30% H_2O_2 is called perhydrol. Its volume strength is 100 and molarity is 8.8.

Ordinary Thinking

Objective Questions

Hydrogen

1. Which is used hydrogen generators **[CPMT 1999]**
(a) *NaH* (b) *HI*
(c) S_6H_3 (d) None of these

2. Metal hydride on treatment with water gives **[Bihar CEE 1995]**
(a) H_2O_2 (b) H_2O
(c) Acid (d) Hydrogen

3. Hydrogen burns in air with a **[RPET 2003]**
(a) Light bluish flame (b) Yellow flame
(c) Green flame (d) None of these

4. Which pair does not show hydrogen isotopes **[UPSEAT 2003]**
(a) Ortho hydrogen and para hydrogen
(b) Protium and deuterium
(c) Deuterium and tritium
(d) Tritium and protium

5. Which is distilled first **[Pb. PMT 2002]**
(a) Liquid CO_2 (b) Liquid N_2
(c) Liquid O_2 (d) Liquid H_2

6. On reaction with *Mg*, very dilute nitric acid produces **[CPMT 2003]**
(a) NH_3 (b) Nitrous oxide
(c) Nitric oxide (d) Hydrogen

7. Among the following, identify the compound which cannot act as both oxidising and reducing agents **[AMU 2002]**

(a) H_2O_2 (b) H_2

(c) SO_2 (d) Cl_2

8. Which of the following reaction produces hydrogen **[AIIMS 2002]**

(a) $Mg + H_2O$ (b) $BaO_2 + HCl$

(c) $H_2S_4O_8 + H_2O$ (d) $Na_2O_2 + 2HCl$

9. Hydrogen resembles in many of its properties **[MH CET 2001]**

(a) Halogen (b) Alkali metals

(c) Both (a) and (b) (d) None of these

10. Ortho and para hydrogen differ in **[AFMC 2001]**

(a) Proton spin (b) Electron spin

(c) Nuclear charge (d) Nuclear reaction

11. Action of water or dilute mineral acids on metals can give **[Kerala (Med.) 2002]**

(a) Monohydrogen (b) Tritium

(c) Dihydrogen (d) Trihydrogen

12. Hydrogen from *HCl* can be prepared by **[Pb. CET 1997]**

(a) *Mg* (b) *Cu*

(c) *P* (d) *Pt*.

13. Which of the following can adsorb largest volume of hydrogen gas

(a) Finely divided platinum (b) Finely divided nickel

(c) Colloidal palladium (d) Colloidal platinum

14. The nuclei of tritium (H^3) atom would contain neutrons

(a) 1 (b) 2

(c) 3 (d) 4

15. The colour of hydrogen is **[MP PET 2004]**

(a) Black (b) Yellow

(c) Orange (d) Colourless

16. Ordinary hydrogen at room temperature is a mixture of

(a) 75% of *o*-Hydrogen + 25% of *p*-Hydrogen

(b) 25% of *o*-Hydrogen + 75% of *p*-Hydrogen

(c) 50% of *o*-Hydrogen + 50% of *p*-Hydrogen

(d) 1% of *o*-Hydrogen + 99% of *p*-Hydrogen

17. Hydrogen cannot reduce

(a) Hot *CuO* (b) Fe_2O_3

(c) Hot SnO_2 (d) Hot Al_2O_3

18. Hydrogen does not combine with

(a) Antimony (b) Sodium

(c) Bismuth (d) Helium

19. The adsorption of hydrogen by metals is called **[EAMCET 1999; Manipal PMT 1999]**

(a) Dehydrogenation (b) Hydrogenation

(c) Occlusion (d) Adsorption

20. Which of the following produces hydrolith with dihydrogen

(a) *Mg* (b) *Al*

(c) *Cu* (d) *Ca*

21. The metal which displaces hydrogen from a boiling caustic soda solution is

(a) *As* (b) *Zn*

(c) *Mg* (d) *Fe*

22. Metals like platinum and palladium can absorb large volumes of hydrogen under special conditions. Such adsorbed hydrogen by the metal is known as

(a) Adsorbed hydrogen (b) Occluded hydrogen

(c) Reactive hydrogen (d) Atomic hydrogen

23. Which is poorest reducing agent

(a) Nascent hydrogen

(b) Atomic hydrogen

(c) Dihydrogen

(d) All have same reducing strength

24. The sum of protons, electrons and neutrons in the heaviest isotope of hydrogen is

(a) 6 (b) 5

(c) 4 (d) 3

25. Number of nucleons in D_2 molecule is

(a) 1 (b) 2

(c) 3 (d) 4

26. An ionic compound is dissolved simultaneously in heavy water and simple water. Its solubility is

(a) Larger in heavy water (b) Smaller in heavy water

(c) Solubility is same in both (d)

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

(a) Thermal conductivity (b) Magnetic properties

(c) Chemical properties (d) Heat capacity

28. The difference between heat of adsorption of ortho and para hydrogen is

(a) 0.4 $kJ\ mol^{-1}$ (b) 0.8 $kJ\ mol^{-1}$

(c) Zero (d) None of these

29. Hydrogen ion H^- is isoelectronic with

(a) *Li* (b) *He*

(c) H^+ (d) Li^-

30. Hydrogen can be fused to form helium at **[AFMC 2005]**

(a) High temperature and high pressure

(b) High temperature and low pressure

(c) Low temperature and high pressure

(d) Low temperature and low pressure

31. Hydrogen can be prepared by mixing steam, and water gas at 500°*C* in the presence of Fe_3O_4 and Cr_2O_3. This process is called

(a) Nelson process (b) Serpeck's process

(c) Bosch process (d) Parke's process

32. Which of the following metal do not liberate hydrogen from dilute hydrochloric acid

(a) Zn (b) Mg

(c) Fe (d) Au

33. An element reacts with hydrogen to form a compound A which on treatment with water liberates hydrogen gas. The element can be

(a) Nitrogen (b) Chlorine

(c) Selenium (d) Calcium

34. Hydrogen combines with other elements by

(a) Losing an electron

(b) Gaining an electron

(c) Sharing an electron

(d) Losing, gaining or sharing electron

35. Which of the following explanation is best for not placing hydrogen with alkali metals or halogen

(a) The ionization energy of hydrogen is high for group of alkali metals or halogen

(b) Hydrogen can form compounds

(c) Hydrogen is a much lighter element than the alkali metals or halogens

(d) Hydrogen atom does not contain any neutron

36. Which of the following terms is not correct for hydrogen

(a) Its molecule is diatomic

(b) It exists both as H^+ and H^- in different chemical compounds

(c) It is the only species which has no neutrons in the nucleus

(d) Heavy water is unstable because hydrogen is substituted by its isotope deuterium

37. When electric current is passed through an ionic hydride in the molten state

(a) Hydrogen is liberated at the anode

(b) Hydrogen is liberated at the cathode

(c) No reaction takes place

(d) Hydride ion migrates towards cathode

38. Which of the halogen has maximum affinity for hydrogen

(a) F_2 (b) Cl_2

(c) Br_2 (d) I_2

39. Which of the following statements is most applicable to hydrogen

(a) It can act as a reducing agent

(b) It can act as an oxidising agent

(c) It can act both as oxidising and reducing agent

(d) It can neither act as oxidising nor as a reducing agent

40. Hydrogen is

(a) Electropositive

(b) Electronegative

(c) Both electropositive as well as electronegative

(d) Neither electropositive nor electronegative

41. Ionization energy of hydrogen is

(a) Equal to that of chlorine

(b) Lesser than that of chlorine

(c) Slightly higher than that of chlorine

(d) Much higher than that of chlorine

42. Hydrogen acts as a reducing agent and thus resembles

(a) Halogen (b) Noble gas

(c) Radioactive elements (d) Alkali metals

43. Which position for hydrogen explain all its properties

(a) At the top of halogen

(b) At the top of alkali metals

(c) At the top of carbon family

(d) None of these

44. Hydrogen readily combines with non-metals and thus it shows its

(a) Electronegativity character

(b) Electropositive character

(c) Both (a) and (b)

(d) None of these

45. The oxidation states shown by hydrogen are

(a) –1 only (b) Zero only

(c) +1, –1, 0 (d) +1 only

46. Hydrogen readily combines with metals and thus shows its

(a) Electropositive character (b) Electronegative character

(c) Both (a) and (b) (d) None of these

47. Electrolysis of fused sodium hydride liberate hydrogen at the

(a) Anode

(b) Cathode

(c) Cathode and anode both

(d) None of these

48. Protonic acid is

(a) A compound that form solvated hydrogen ion in polar solvent

(b) An acid which accepts the proton

(c) A compound that forms hydride ion in polar solvent

(d) An acid which donates the proton

49. In all its properties, hydrogen resembles

(a) Alkali metals only

(b) Halogen only

(c) Both alkali metals and halogens

(d) Neither alkali metals nor halogens

50. Hydrogen molecule differs from chlorine molecule in the following respect

(a) Hydrogen molecule is non-polar but chlorine molecule is polar

(b) Hydrogen molecule is polar while chlorine molecule is non-polar

(c) Hydrogen molecule can form intermolecular hydrogen bonds but chlorine molecule does not

(d) Hydrogen molecule cannot participate in coordination bond formation but chlorine molecule can

51. Which of the following statements concerning protium, deuterium and tritium is not true

(a) They are isotopes of each other

(b) They have similar electronic configurations

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

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

52. When SO_3 is treated with heavy water the product is/are

(a) Deuterium and sulphuric acid

(b) Deuterium and sulphurous acid

(c) Only deuterium

(d) Dideuterosulphuric acid

53. Hydrogen has three isotopes, the number of possible diatomic molecules will be

(a) 2 (b) 6

(c) 9 (d) 12

54. In which of the compounds does hydrogen have an oxidation state of –1

(a) CH_4 (b) NH_3

(c) HCl (d) CaH_2

55. Pure hydrogen is obtained by carrying electrolysis of

(a) Water containing H_2SO_4

(b) Water containing $NaOH$

(c) $Ba(OH)_2$ solution

(d) KOH solution

56. In Bosch's process which gas is utilised for the production of hydrogen gas

(a) Producer gas (b) Water gas

(c) Coal gas (d) None of these

57. Deuterium differs from hydrogen in

(a) Chemical properties

(b) Physical properties

(c) Both physical and chemical properties

(d) Radioactive properties

58. Tritium undergoes radioactive decay giving

(a) α-particles (b) β-particles

(c) Neutrons (d) γ-rays

59. The gas used in the hydrogenation of vegetable oils in the presence of nickel as catalyst is

(a) Methane (b) Ethane

(c) Ozone (d) Hydrogen

60. The conversion of atomic hydrogen into ordinary hydrogen is

(a) Exothermic change

(b) Endothermic change

(c) Nuclear change

(d) Photochemical change

61. The name hydrogen was given by

(a) Cavendish (b) Lavoisier

(c) Urey (d) None of these

62. The ratio C_p / C_v for H_2 is

(a) 1.40 (b) 1.67

(c) 1.33 (d) None of these

63. Triatomic hydrogen is called

(a) Deuterium (b) Hyzone

(c) Ortho form (d) Hydronium ion

64. $LiAlH_4$ is obtained by reacting an excess of .... With an ethereal solution of $AlCl_3$

(a) $LiCl$ (b) LiH

(c) Li (d) $LiOH$

65. Alkali metal hydrides react with water to give

(a) Acidic solution (b) Basic solution

(c) Neutral solution (d) Hydride ion

66. Ionic hydrides are usually

(a) Good electrically conductors when solid

(b) Easily reduced

(c) Good reducing agents

(d) Liquid at room temperature

67. When $NaBH_4$ is dissolved in water

(a) It decomposes with the evolution of H_2

(b) Na^+ and BH_4^- are formed which are stable

(c) BH_4^- ions formed initially decompose to produce OH^- ions, which prevent further decomposition

(d) NaH and B_2H_6 are produced

68. Systematic name of H_2O (oxide of hydrogen) is

(a) Water (b) Hydrogen oxide

(c) Oxidane (d) None of these

69. Group 2 hydrides with significant covalent character is/are

(a) BeH_2 (b) MgH_2

(c) Both (a) and (b) (d) None of these

70. Limiting compositions of *f*-block hydrides are

(a) MH_2 and MH_3 (b) MH_3 and MH_5

(c) MH_2 and MH_8 (d) MH_2 and MH_6

71. Hydrogen directly combines with **[Roorkee Entrance 1990]**

(a) Au (b) Cu

(c) Ni (d) Ca

72. Chemical A is used for water softening to remove temporary hardness. A reacts with sodium carbonate to generate caustic soda. When CO_2 is bubbled through a solution of A, it turns cloudy. What is the chemical formula of A

[Pb. CET 1990; AIIMS 1999]

(a) $CaCO_3$ (b) CaO

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

73. When same amount of zinc is treated separately with excess of sulphuric acid and excess of sodium hydroxide solution the ratio of volumes of hydrogen evolved is **[CPMT 1991]**

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

(c) 2 : 1 (d) 9 : 4

74. Which one of the following substances is used in the laboratory for a fast drying of neutral gases **[CBSE PMT 1992]**

(a) Phosphorus pentoxide

(b) Active charcoal

(c) Anhydrous calcium chloride

(d) Na_3PO_4

75. Which is the lightest gas **[CPMT 1993]**

(a) Nitrogen (b) Helium

(c) Oxygen (d) Hydrogen

76. The composition of tritium is **[UGET Manipal 1995]**

(a) 1 electron, 1 proton, 1 neutron

(b) 1 electron, 2 protons, 1 neutron

(c) 1 electron, 1 proton, 2 neutrons

(d) 1 electron, 1 proton, 3 neutrons

77. The property of hydrogen which distinguishes it from alkali metals is

(a) Its electropositive character

(b) Its affinity for non metal

(c) Its reducing character

(d) Its non-metallic character

78. The hydride ion H^- is a stronger base than its hydroxide ion OH^-. Which of the following reactions will occur if sodium hydride (NaH) is dissolved in water **[CBSE PMT 1997]**

(a) $H^-(aq) + H_2O \rightarrow H_3O^-(aq)$

(b) $H^-(aq) + H_2O(l) \rightarrow OH^-(aq) + H_2(g)$

(c) $H^-(aq) + H_2O(l) \rightarrow$ No reaction

(d) None of these

79. Hydrogen accepts an electron to form inert gas configuration. In this it resembles **[Pb. PMT 1997]**

(a) Halogen (b) Alkali metals

(c) Chalcogens (d) Alkaline earth metals

80. Which of the following is correct for hydrogen **[AFMC 1997; BHU 1997]**

(a) It can form bonds in +1 as well as –1 oxidation state

(b) It is always collected at cathode

(c) It has a very high ionization potential

(d) It has same electronegativity as halogens

81. Which of the following will not displace hydrogen **[Pb. PMT 1999]**

(a) Ba (b) Pb

(c) Hg (d) Sn

82. Which of the following gas is insoluble in water **[Pb. CET 2003]**

(a) SO_2 (b) NH_3

(c) H_2 (d) CO_2

83. Which element forms maximum compound in chemistry **[Pb. CET 2004]**

(a) O (b) H

(c) Si (d) C

84. Hydrogen is not obtained when zinc reacts with **[J & K 2005]**

(a) Cold water (b) Hot $NaOH$ solution

(c) Conc. sulphuric acid (d) dilute HCl

Water or hydride of oxygen

1. Synthetic detergents are more effective in hard water than soaps because **[AMU 2002]**

(a) They are highly soluble in water

(b) Their Ca^{++} and Mg^{++} salts are water soluble

(c) Their Ca^{++} and Mg^{++} salts are insoluble in water

(d) None of these

2. D_2O is used more in **[BHU 1997; CPMT 1997]**

(a) Chemical industry

(b) Nuclear reactor

(c) Pharmaceutical preparations

(d) Insecticide preparation

3. Heavy water (D_2O) is **[RPET/PMT 2000; CPMT 2000]**

(a) A product of oxygen and hydrogen

(b) Water of mineral springs

(c) Water obtained by repeated distillation and condensation

(d) Ordinary water containing dissolved salts heavy metals

4. Temporary hardness may be removed from water by adding **[Pb. PMT 2002]**

(a) $CaCO_3$ (b) $Ca(OH)_2$

(c) $CaSO_4$ (d) HCl

5. Heavy water is **[AFMC 1997; UPSEAT 2003 MH CET 2003; Pb. CET 2001]**

(a) Water containing Fe, Cr, Mn

(b) Water at $0°C$

(c) D_2O

(d) Water obtained after a number of distillations

6. Heavy water is compound of **[DPMT 2001; DCE 2002]**

(a) Oxygen and heavier isotopes of hydrogen

(b) Hydrogen and heavier isotopes of oxygen

(c) Heavier isotopes of oxygen and hydrogen

(d) None of these

7. Which of the following pair of ions makes the water hard **[AMU 2002]**

(a) Na^+, SO_4^{2-} (b) K^+, HCO_3^-

(c) Ca^{2+}, NO_3^- (d) NH_4^+, Cl^-

8. Temporary hardness of water can be removed by **[Pb. PMT 2001]**

(a) Addition of potassium permagenate

(b) Boiling

(c) Filtration

(d) Addition of chlorine

9. When zeolite (Hydrated sodium aluminium silicate) is treated with hard water the sodium ions are exchanged with **[DPMT 2000]**

(a) OH^- ions (b) SO_4^{2-} ions

(c) Ca^{2+} ions (d) H^+ ions

10. Which of the following statements do not define the characteristic property of water "Water is a universal solvent"

(a) It can dissolve maximum number of compounds

(b) It has very low dielectric constant

(c) It has high liquid range

(d) None of these

11. The velocity of neutrons in nuclear reactor is slowed down by

(a) Heavy water (D_2O) (b) Ordinary water (H_2O)

(c) Zinc rod (d) Fused caustic soda

12. Temporary hardness of water is due to the presence of

(a) Magnesium bicarbonate (b) Calcium chloride

(c) Magnesium sulphate (d) Calcium carbonate

13. Which of the following is not true

(a) Hardness of water depends on its behaviour towards soap

(b) The temporary hardness is due to the presence of *Ca* and *Mg* bicarbonates

(c) Permanent hardness is due to the presence of soluble *Ca* and *Mg* sulphates, chlorides and nitrates

(d) Permanent hardness can be removed by boiling the water

14. The molarity of pure water at 4°*C* is

(a) 1 *M* (b) 2.5 *M*

(c) 5 *M* (d) 55.5 *M*

15. Which of the following is not a hard water

(a) Water containing $CaCl_2$

(b) Water containing dil. HCl

(c) Water containing $MgSO_4$

(d) None of these

16. Heavy water is used in atomic reactor as

(a) Coolant

(b) Moderator

(c) Both moderator and coolant

(d) Neither coolant nor moderator

17. Heavy water freezes at

(a) 0°*C* (b) 3.8°*C*

(c) 38°*C* (d) – 0.38°*C*

18. The *pH* of D_2O and H_2O at 298 *K* is

(a) 7.0, 7.0 (b) 7.35, 7.0

(c) 7.0, 6.85 (d) 6.85, 7.35

19. Which of the following is not true

(a) Ordinary water is electrolysed more rapidly than D_2O

(b) Reaction between H_2 and Cl_2 is much faster than D_2 and Cl_2

(c) D_2O freezes at lower temperature than H_2O

(d) Bond dissociation energy for D_2 is greater than H_2

20. Which of the following will determine whether the given colourless liquid is water or not

(a) Melting

(b) Tasting

(c) Phosphthalein

(d) Adding a pinch of anhydrous $CuSO_4$

21. Lead pipes are not used for carrying drinking water because

(a) They are covered with a coating of lead carbonate

(b) They are corroded by air and moisture

(c) Water containing dissolved air attacks lead forming soluble hydroxide

(d) None of these

22. Which one of the following removes temporary hardness of water

(a) Slaked lime (b) Plaster of Paris

(c) Cuprous (d) Hydrolith

23. Which of the following will cause softening of hard water

(a) Passing it through cation exchange resin

(b) Passing it through anion exchange resin

(c) Passing it through sand

(d) Passing it through alumina

24. which of the following process permanent hardness of water can be removed, by adding **[AFMC 2005]**

(a) Sodalime (b) Sodiumbicarbonate

(c) Washing soda (d) Sodium chloride

25. Permutit is technical name given to

(a) Aluminates of calcium and sodium

(b) Silicates of calcium and sodium

(c) Hydrated silicates of aluminium and sodium

(d) Silicates of calcium and magnesium

26. The approximate mass of tritium oxide molecule is

(a) 18 *amu* (b) 20 *amu*

(c) 22 *amu* (d) 24 *amu*

27. Molecular weight of heavy water is

(a) 19 (b) 18

(c) 17 (d) 20

28. Water is said to be permanently hard when it contains

(a) Sulphates of *Mg* and *Ca*

(b) Bicarbonates of *Mg* and *Ca*

(c) Sulphates of *Cu* and *Hg*

(d) Carbonates and bicarbonates of *Mg* and *Ca*

29. Sodium sulphate is soluble in water but barium sulphate is insoluble because **[Pb. PMT 1995]**

(a) The hydration energy of Na_2SO_4 is more than its lattice energy

(b) The lattice energy of $BaSO_4$ is more than its hydration energy

(c) The lattice energy has no role to play in solubility

(d) The hydration energy of Na_2SO_4 is less than its lattice energy

(e) Both (a) and (b)

30. The alum used for purifying water is **[EAMCET 1999]**

(a) Ferric alum (b) Chrome alum

(c) Potash alum (d) Ammonium alum

31. Which of the following metal will not reduce H_2O **[CPMT 1999]**

(a) *Ca* (b) *Fe*

(c) *Cu* (d) *Li*

32. Which of the following is correct about heavy water **[DCE 2002]**

(a) Water at $4°C$ having maximum density is known as heavy water

(b) It is heavier than water (H_2O)

(c) It is formed by the combination of heavier isotope of hydrogen and oxygen

(d) None of these

33. The boiling point of water is exceptionally high because **[KCET 2001]**

(a) There is covalent bond between *H* and *O*

(b) Water molecule is linear

(c) Water molecules associate due to hydrogen bonding

(d) Water molecule is not linear

34. Match list I with list II and select the correct answer using the codes given below the lists **[SCRA 2001]**

	List I	List II
1.	Heavy water	(a) Bicarbonates of *Mg* and *Ca* in water
2.	Temporary hard water	(b) No foreign ions in water
3.	Soft water	(c) D_2O
4.	Permanent hard water	(d) Sulphates and chlorides of *Mg* and *Ca* in water

Codes

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

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

35. The $H-O-H$ angle in water molecule is about **[AFMC 2001]**

(a) 90° (b) 180°

(c) 102° (d) 105°

36. When two ice cubes are pressed over each other, they unite to form one cube. Which of the following forces is responsible to hold them together **[AFMC 2001]**

(a) Hydrogen bond formation

(b) Van der Waals forces

(c) Covalent attraction

(d) Ionic interaction

37. What is formed when calcium carbide reacts with heavy water **[Manipal PMT 2001; Pb. CET 2000]**

(a) C_2D_2 (b) CaD_2

(c) Ca_2D_2O (d) CD_2

38. Pure water can be obtained from sea water by **[CBSE PMT 2001]**

(a) Centrifugation (b) Plasmolysis

(c) Reverse osmosis (d) Sedimentation

39. Action of water or dilute mineral acids on metals can give **[Kerala PMT 2002]**

(a) Monohydrogen (b) Tritium

(c) Dihydrogen (d) Trihydrogen

(e) D_2

40. Metal which does not react with cold water but evolves H_2 with steam is **[DCE 2002]**

(a) *Na* (b) *K*

(c) *Pt* (d) *Fe*

41. *pH* of neutral water at room temperature nearly

(a) 0 (b) 14

(c) 7 (d) 10^{-7}

42. Maximum number of hydrogen bonding in H_2O is **[DCE 2004; MP PET 2004; MP PMT 2004; BHU 2004]**

(a) 1 (b) 2

(c) 3 (d) 4

43. The low density of ice compared to water is due to **[Pb. CET 2004]**

(a) Induced dipole-induced dipole interactions

(b) Dipole-induced dipole interaction

(c) Hydrogen bonding interactions

(d) Dipole-dipole interactions

44. Which of the following acid is formed when SiF_4 reacts with water **[BHU 2004]**

(a) SiF_4 (b) H_2SiF_4

(c) H_2SO_4 (d) H_2SiF_6

45. Triple point of water is **[AFMC 2004]**

(a) $273\,K$ (b) $373\,K$

(c) $203\,K$ (d) $193\,K$

46. Hardness of water is due to presence of salts of **[BHU 2005]**

(a) Na^+ and K^+ (b) Ca^{2+} and Mg^{2+}

(c) Ca^{2+} and K^+ (d) Ca^{2+} and Na^+

Hydrogen peroxide

1. In which of the following reaction hydrogen peroxide is a reducing agent **[BHU 1995]**

(a) $2FeCl_2 + 2HCl + H_2O_2 \rightarrow 2FeCl_3 + 2H_2O$

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

(c) $2HI + H_2O_2 \rightarrow 2H_2O + I_2$

(d) $H_2SO_3 + H_2O_2 \rightarrow H_2SO_4 + H_2O$

2. There is a sample of 10 volume of hydrogen peroxide solution. Calculate its strength **[UPSEAT 2001]**

(a) 3.00% (b) 4.045%

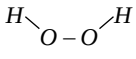
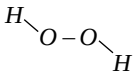
(c) 2.509% (d) 3.035%

3. In lab H_2O_2 is prepared by **[CPMT 2002; MH CET 2003; Pb. PMT 2004; BCECE 2005]**

(a) Cold $H_2SO_4 + BaO_2$ (b) $HCl + BaO_2$

(c) Conc. $H_2SO_4 + Na_2O_2$ (d) $H_2 + O_2$

4. The structure of H_2O_2 is **[UPSEAT 2001]**

(a)  (b) 

(c) $H-O-O-H$ (d) 

5. HCl is added to the following oxides which one would give H_2O_2 **[Kurukshetra CEE 1998]**

(a) MnO_2 (b) PbO_2

(c) BaO_2 (d) None of these

6. The oxide that gives hydrogen peroxide (H_2O_2) on the treatment with a dilute acid (H_2SO_4) is **[Pb. PMT 1999]**

(a) MnO_2 (b) PbO_2

(c) Na_2O_2 (d) TiO_2

7. Hydrogen peroxide is reduced by **[CPMT 2000; CBSE PMT 2000; KCET 2002]**

(a) Ozone

(b) Barium peroxide

(c) Acidic solution of $KMnO_4$

(d) Lead sulphide suspension

8. The reaction of $H_2S + H_2O_2 \rightarrow S + 2H_2O$ manifests **[UPSEAT 2000]**

(a) Acidic nature of H_2O_2

(b) Alkaline nature of H_2O_2

(c) Oxidising nature of H_2O_2

(d) Reducing action of H_2O_2

9. What is the product of the reaction of H_2O_2 with Cl_2 **[RPET 2003]**

(a) $O_2 + HOCl$ (b) $HCl + O_2$

(c) $H_2O + HCl$ (d) $HCl + H_2$

10. H_2O_2 will oxidise **[Roorkee 1995]**

(a) $KMnO_4$ (b) PbS

(c) MnO_2 (d) H_2S

11. Fenton's reagent is **[MP PET 2000; RPET 2000]**

(a) $FeSO_4 + H_2O_2$ (b) $Zn + HCl$

(c) $Sn + HCl$ (d) None of these

12. The structure of H_2O_2 is **[CBSE 1999; AFMC 2004]**

(a) Planar (b) Linear

(c) Spherical (d) Non-planar

13. The volume strength of 1.5 N H_2O_2 solution is **[BHU 2004; Pb. CET 2004]**

(a) 8.4 *litres* (b) 4.2 *litres*

(c) 16.8 *litres* (d) 5.2 *litres*

14. The volume of oxygen liberated from 15 *ml* of 20 volume H_2O_2 is **[MH CET 2003]**

(a) 250 *ml* (b) 300 *ml*

(c) 150 *ml* (d) 200 *ml*

15. The strength in volumes of a solution containing 30.36 *g/litre* of H_2O_2 is **[UPSEAT 2004]**

(a) 10 volume (b) 20 volume

(c) 5 volume (d) None of these

16. Hydrogen peroxide is used as

(a) Oxidising agent

(b) Reducing agent

(c) Both as oxidising and reducing agent
(d) Drying agent

17. Equivalent weight of H_2O_2 is
(a) 17 (b) 34
(c) 68 (d) 18

18. 20 volume H_2O_2 solution has a strength of about
(a) 30% (b) 6%
(c) 3% (d) 10%

19. H_2O_2 is manufactured these days **[DCE 2004]**
(a) By the action of H_2O_2 on BaO_2
(b) By the action of H_2SO_4 on Na_2O_2
(c) By electrolysis of 50% H_2SO_4
(d) By burning hydrogen in excess of oxygen

20. Which one of the following is a true peroxide
(a) NO_2 (b) MnO_2
(c) BaO_2 (d) SO_2

21. 1 *ml* of H_2O_2 solution gives 10 *ml* of O_2 at NTP. It is
(a) 10 vol. H_2O_2 (b) 20 vol. H_2O_2
(c) 30 vol. H_2O_2 (d) 40 vol. H_2O_2

22. Which substance does not speed up decomposition of H_2O_2
(a) Glycerol (b) *Pt*
(c) Gold (d) MnO_2

23. Which of the following cannot be oxidised by H_2O_2
(a) O_3 (b) KI/HCl
(c) *PbS* (d) Na_2SO_3

24. Which substance cannot be reduced by H_2O_2
(a) $KMnO_4/H_2SO_4$ (b) $K_2Cr_2O_7/H_2SO_4$
(c) Ag_2O (d) Fe^{3+}

25. Which of the following statements is incorrect
(a) H_2O_2 can act as an oxidising agent
(b) H_2O_2 can act as a reducing agent
(c) H_2O_2 has acidic properties
(d) H_2O_2 has basic properties

26. H_2O_2 is
(a) Poor polar solvent than water
(b) Better polar solvent than H_2O
(c) Both have equal polarity
(d) Better polar solvent but its strong auto oxidising ability limits its use as such

27. H_2O_2 used in rockets has the concentration
(a) 50% (b) 70%
(c) 30% (d) 90%

28. H_2O_2 is a
(a) Weak acid (b) Weak base
(c) Neutral (d) None of these

29. Nitrates of all metals are
(a) Soluble in water (b) Insoluble
(c) Coloured (d) Unstable

30. Decomposition of H_2O_2 is prevented by
(a) *NaOH* (b) MnO_2
(c) Acetanilide (d) Oxalic acid

31. H_2O_2 is always stored in black bottles because
(a) It is highly unstable
(b) Its enthalpy of decomposition is high
(c) It undergo autooxidation on prolonged standing
(d) None of these

32. H_2O_2 on reacting with ethene gives
(a) Ethane (b) Ethanal
(c) Ethylene glycol (d) Ethanol

33. Which of the following is wrong about H_2O_2? It is used
(a) As aerating agent in production of spong rubber
(b) As an antichlor
(c) For restoring white colour of blackened lead painting
(d) None of these

34. $H_2O_2 \rightarrow 2H^+ + O_2 + 2e^-$; $E° = -0.68\ V$. This equation represents which of the following behaviour of H_2O_2
(a) Reducing (b) Oxidising
(c) Acidic (d) Catalytic

35. The structure of H_2O_2 is
(a) Open book like (b) Linear
(c) Closed book (d) Pyramidal

36. On shaking H_2O_2 with acidified potassium dichromate and ether, ethereal layer becomes
(a) Green (b) Red
(c) Blue (d) Black

37. K_a of H_2O_2 is of the order of **[MP PMT 1994]**
(a) 10^{-12} (b) 10^{-14}
(c) 10^{-16} (d) 10^{-10}

38. In which of the following reactions, H_2O_2 acts as a reducing agent **[EAMCET 2001]**
(a) $PbO_2(s) + H_2O_2(aq) \rightarrow PbO(s) + H_2O(l) + O_2(g)$
(b) $Na_2SO_3(aq) + H_2O_2(aq) \rightarrow Na_2SO_4(aq) + H_2O(l)$
(c) $2KI(aq) + H_2O_2(aq) \rightarrow 2KOH(aq) + I_2(s)$

(d) $KNO_2(aq)+H_2O_2(aq)\rightarrow KNO_3(aq)+H_2O(l)$

39. H_2O_2 acts as an oxidising agent in **[Kerala PMT 2004]**

(a) Neutral medium
(b) Acidic medium
(c) Alkaline medium
(d) Alkaline and neutral medium
(e) Acidic and alkaline medium

40. The $H-O-O$ bond angle in H_2O_2 is **[Kerala PMT 2004]**

(a) 107.28^o (b) 109.28^o
(c) 104.5^o (d) 106^o
(e) 97^o

41. The volume of oxygen liberated from $0.68\,gm$ of H_2O_2 is **[Pb. PMT 2004]**

(a) 112 *ml* (b) 224 *ml*
(c) 56 *ml* (d) 336 *ml*

Critical Thinking
Objective Questions

1. Polyphosphates are used as water softening agents because they
(a) Form soluble complexes with anionic species
(b) Precipitate anionic species
(c) Forms soluble complexes with cationic species
(d) Precipitate cationic species

2. The critical temperature of water is higher than that of O_2 because H_2O molecule has **[IIT 1997]**
(a) Fewer electrons than oxygen
(b) Two covalent bonds
(c) V-shape
(d) Dipole moment

3. One mole of calcium phosphide on reaction with excess water gives **[IIT 1999]**
(a) One mole of phosphene
(b) Two moles of phosphoric acid
(c) Two moles of phosphene
(d) One mole of phosphorus pentaoxide

4. When zeolite, which is hydrated sodium aluminium silicate, is treated with hard water the sodium ions are exchanged with
(a) H^+ ions (b) Ca^{2+} ions
(c) Mg^{2+} ions (d) Both Ca^{2+} and Mg^{2+}

5. Hydrogen peroxide is
(a) A stronger acid than water
(b) A weaker acid than water
(c) An oxidising agent
(d) A reducing agent

6. Hydrogen can be obtained from water by
(a) Reaction with metal oxides
(b) Reaction with non-metal oxides
(c) Reaction with metals
(d) Reaction with metal hydrides

7. Which of the following is/are hard water(*s*)
(a) Water containing some potash alum
(b) Water containing a few drops of *HCl*
(c) Water containing common salt
(d) Water containing calcium nitrate

8. Pick the odd one out
(a) Sodium borohydride reacts very slowly with cold water
(b) Sodium borohydride reacts very violently with cold water to produce H_2
(c) Solubility of sodium borohydride in water at 25°*C* is 10.05 *g*/*mL*
(d) Melting point of sodium borohydride is 500°*C*

9. Hydrogen can be obtained from water, by the action of water on
(a) Calcium carbide (b) Calcium hydride
(c) Calcium oxide (d) Calcium

10. What is true about ice
(a) Its density is more than water
(b) It is a good conductor of heat **[IIT JEE (Screening) 2002]**
(c) It is a thermal insulator
(d) Its density is less than water

11. Hydrogen will not reduce **[IIT 1985]**
(a) Heated cupric oxide (b) Heated ferric oxide
(c) Heated stannic oxide (d) Heated aluminium oxide

12. *HCl* is added to following oxides. Which one would give H_2O_2 **[IIT 1980]**
(a) MnO_2 (b) PbO_2
(c) BaO (d) None of these

13. Which of the following pair will not produce dihydrogen gas **[IIT 1994]**
(a) $Cu+HCl(dil.)$ (b) $Fe+H_2SO_4$
(c) $Mg+\text{steam}$ (d) $Na+\text{alcohol}$

14. The amount of H_2O_2 present in 1 *L* of 1.5 *N* H_2O_2 solution is **[IIT 1990]**
(a) 2.5 *g* (b) 25.5 *g*
(c) 3.0 *g* (d) 8.0 *g*

15. Hydrogen is evolved by the action of cold dil. HNO_3 on **[IIT 1998]**
(a) *Fe* (b) *Mn*

(c) Cu (d) Al

16. Hydrogen can behave as a metal

(a) At very high temperature (b) At very low temperature

(c) At very high pressure (d) At very low pressure

17. D_2O is preferred to H_2O, as a moderator, in nuclear reactors because

(a) D_2O slows down fast neutrons better

(b) D_2O has high specific heat

(c) D_2O is cheaper

(d) None of these

18. Out of the two allotropic forms of dihydrogen, the form with lesser molecular energy is

(a) Ortho (b) Meta

(c) Para (d) All have same energy

19. Saline hydrides react explosively with water, such fires can be extinguished by

(a) Water (b) Carbon dioxide

(c) Sand (d) None of these

20. Metals of groups 7, 8 and 9 do not form metallic hydrides. This is termed as

(a) Hydride gap (b) Hydride shift

(c) Anhydride (d) Dehydride

21. When temporary hard water containing $Mg(HCO_3)_2$ is boiled the ppt. formed is of

(a) $MgCO_3$ (b) MgO

(c) $Mg(OH)_2$ (d) None of these

22. Permanent hardness due to Mg^{2+} ions is best removed by

(a) $Ca(OH)_2$ (b) Na_2CO_3

(c) $Na_2CO_3 + Ca(OH)_2$ (d) None of these

23. The most abundant element in the universe is

(a) Carbon (b) Silicon

(c) Hydrogen (d) Helium

24. Pick out the correct statement

(a) By decreasing the temperature pure para-hydrogen can be obtained

(b) By increasing the temperature pure ortho-hydrogen can be obtained

(c) By decreasing the temperature pure ortho-hydrogen can be obtained

(d) By increasing the temperature pure para-hydrogen can be obtained

25. Hydrogen can be produced by heating

(a) Cu with H_2SO_4 (b) Sodium formate

(c) Sodium oxalate (d) None of these

26. Plumbosolvency is a health hazard in the transportation of

(a) Hard water only

(b) Soft water only

(c) Both (a) and (b)

(d) Water containing plum juice

27. A sample of water contains sodium chloride. It is

(a) Hard water (b) Soft water

(c) Moderately hard (d) None of these

28. Hardness producing salt, whose solubility in water decreases with rise of temperature is

(a) $CaCl_2$ (b) $CaSO_4$

(c) $Ca(HCO_3)_2$ (d) $MgSO_4$

29. A sample of water containing some dissolved table sugar and common salt is passed through organic ion exchange resins. The resulting water will be

(a) Tasteless (b) Sweet

(c) Salty (d) None of these

30. Water obtained by purification with organic ion exchange resins is

(a) Pure water

(b) Free from only Ca^{2+}, Mg^{2+} ions

(c) Free from HCO_3^-, SO_4^{2-} and Cl^- ions only

(d) None of these

31. Which of the following can effectively remove all types of hardness of water

(a) Soap (b) Washing soda

(c) Slaked lime (d) None of these

32. A commercial sample of hydrogen peroxide is labelled as 10 volume. Its percentage strength is nearly **[KCET 2005]**

(a) 1% (b) 3%

(c) 10% (d) 90%

A R Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below :

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.
(c) If assertion is true but reason is false.
(d) If the assertion and reason both are false.
(e) If assertion is false but reason is true.

1. Assertion : Hydrogen combines with other elements by losing, gaining or sharing of electrons.

Reason : Hydrogen forms electrovalent and covalent bonds with other elements.

2. Assertion : Calgon is used for removing Ca^{2+} and Mg^{2+} ions from hard water.

Reason : Calgon forms precipitates with Ca^{2+} and Mg^{2+}.

3. Assertion : Decomposition of H_2O_2 is a disproportionation reaction.

Reason : H_2O_2 molecule simultaneously undergoes oxidation and reduction.

4. Assertion : H_2O_2 has higher boiling point than water.

Reason : H_2O_2 has stronger dipole-dipole interactions than water.

5. Assertion : H_2O_2 is not stored in glass bottles.

Reason : Alkali oxides present in glass catalyse the decomposition of H_2O_2.

6. Assertion : H_2O_2 reduces Cl_2 to HCl.

Reason : H_2O_2 is called antichlor.

7. Assertion : In acidic medium, H_2O_2 reacts with MnO_2 to give O_2.

Reason : H_2O_2 is a strong oxidising agent.

8. Assertion : In alkaline solution, H_2O_2 reacts with potassium ferricyanide.

Reason : H_2O_2 is a strong reducing agent.

9. Assertion : Acidulated water is an example of hard water.

Reason : In the presence of an acid, soap is converted into insoluble free fatty acids.

10. Assertion : Hydrogen peroxide forms only one series of salts called peroxides.

Reason : Hydrogen peroxide molecule has only one replaceable hydrogen atom.

Answers

Hydrogen

1	a	2	d	3	a	4	a	5	d
6	d	7	b	8	a	9	c	10	a
11	c	12	a	13	c	14	b	15	d
16	a	17	d	18	d	19	c	20	d
21	b	22	b	23	c	24	c	25	d
26	b	27	c	28	a	29	b	30	a
31	c	32	d	33	d	34	d	35	c
36	d	37	a	38	a	39	c	40	c
41	c	42	d	43	d	44	b	45	c
46	b	47	a	48	a	49	c	50	d
51	c	52	d	53	b	54	d	55	c
56	b	57	b	58	b	59	d	60	a
61	b	62	a	63	b	64	b	65	b
66	c	67	c	68	c	69	c	70	a
71	d	72	c	73	a	74	c	75	d
76	c	77	d	78	b	79	a	80	a
81	c	82	c	83	b	84	c		

Water or hydride of oxygen

1	b	2	b	3	c	4	b	5	c
6	a	7	b	8	b	9	c	10	b
11	a	12	a	13	d	14	d	15	d
16	c	17	b	18	b	19	c	20	d
21	c	22	a	23	a	24	c	25	c
26	c	27	d	28	a	29	e	30	c
31	c	32	c	33	c	34	d	35	d
36	a	37	a	38	c	39	c	40	d
41	c	42	d	43	c	44	b	45	a
46.	b								

Hydrogen peroxide

1	B	2	d	3	a	4	b	5	c
6	c	7	d	8	c	9	b	10	b
11	a	12	d	13	a	14	b	15	a
16	c	17	a	18	b	19	c	20	c
21	a	22	a	23	a	24	d	25	d
26	d	27	d	28	a	29	a	30	c
31	c	32	c	33	d	34	a	35	a
36	c	37	a	38	a	39	e	40	e
41	b								

Critical Thinking Questions

1	c	2	d	3	c	4	d	5	acd
6	cd	7	abd	8	b	9	bd	10	cd
11	d	12	d	13	a	14	b	15	b
16	c	17	d	18	c	19	c	20	a
21	c	22	c	23	c	24	b	25	b
26	b	27	b	28	b	29	b	30	d
31	a	32	b						

Assertion & Reason

1	a	2	d	3	a	4	c	5	a
6	a	7	b	8	a	9	a	10	d

Answers and Solutions

Hydrogen and its preparation

1. (a) $NaH + H_2O \rightarrow NaOH + H_2 \uparrow$

2. (d) $KH + H_2O \rightarrow KOH + H_2 \uparrow$

3. (a) Hydrogen burns in air with a light bluish flame.

4. (a) Ortho and para hydrogen show different spin in a hydrogen molecule it does not show hydrogen isotopes.

5. (d) Boiling point of liquid hydrogen is lowest of given substances so it is distilled first.

6. (d) $Mg + 2HNO_3 \rightarrow Mg(NO_3)_2 + H_2 \uparrow$

8. (a) $Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2 \uparrow$

10. (a) Ortho and para hydrogen differ in proton spin.

11. (c) $Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2 \uparrow$

12. (a) $Mg + 2HCl \rightarrow MgCl_2 + H_2 \uparrow$

13. (c) Order of adsorption of H_2 (occlusion) is

Colloidal Palladium > Palladium > Platinum > Gold > Nickel

14. (b) Number of neutrons = Mass number – Atomic number

= 3 – 1 = 2

17. (d) Because *Al* has more affinity for oxygen than hydrogen.

18. (d) Helium is a noble gas and does not combine with hydrogen.

19. (c) Occlusion is the phenomenon of adsorption of hydrogen by metal.

20. (d) CaH_2 is known as hydrolith.

21. (b) *Zn* displaces hydrogen from the boiling solution of *NaOH*.

$Zn + 2NaOH + 2H_2O \rightarrow Na_2[Zn(OH)_4] + H_2 \uparrow$

22. (b) Occluded hydrogen is the hydrogen absorbed by the metal.

23. (c) Because dihydrogen is less reactive.

24. (c) ${}_1H^3$ has 3 nucleons (1 proton + 2 neutrons) and one electron so sum of these is 3 + 1 = 4.

25. (d) ${}^2_1D_2$ = (2 neutrons + 2 protons) = 4 nucleons.

26. (b) Solubility of ionic compound is lower in heavy water.

27. (c) These allotropic forms have similar chemical properties.

28. (a) It is 0.4 *kJ/mol*.

29. (b) $H^- = 1s^2; He = 1s^2$

30. (a) A fusion reaction is difficult to occur because positively charged nuclei repel each-other. At very high temperatures of the order of 10^6 to $10^7 K$, the nuclei may have sufficient energy to overcome the repulsive forces and fuse. It is for this reason, fusion reactions are also called thermonuclear reactions. Hence, hydrogen can be fused to form helium at high temperature and high pressure.

31. (c) It is Bosch process.

32. (d) Gold is a noble metal.

33. (d) $Ca + H_2 \rightarrow CaH_2 \xrightarrow{2H_2O} Ca(OH)_2 + 2H_2$

34. (d) Hydrogen can loose one electron (*e.g. HF*). It can gain one electron (*e.g. NaH*), Hydrogen can also share one electron (*e.g. H – H*).

35. (c) Hydrogen is a much lighter element than alkali metals or halogen.

36. (d) Heavy water is not unstable.

37. (a) $M^+H^- \rightarrow M^+ + \underset{\text{Hydride ion}}{H^-}$

$H^- \rightarrow \frac{1}{2}H_2 + e^-$ (At anode)

38. (a) F_2 has maximum tendency to react with hydrogen. the decreasing order of reactivity is $F_2 > Cl_2 > Br_2 > I_2$.

39. (c) It acts both as a reducing agent and oxidising agent.

40. (c) $H \rightarrow H^+ + e^-$

$H + e^- \rightarrow H^-$

41. (c) IE of *H* is 1312 *kJ/mole*.

IE of *Cl* is 1255 *kJ/mole*.

42. (d) Alkali metals are good reducing agents because of low ionization energy and hydrogen also shows same character.

43. (d) Position of hydrogen in the periodic table is not fully justified.

44. (b) $H_2 + Cl_2 \rightarrow H^+Cl^-$. In this hydrogen has positive oxidation state.

45. (c) For example $\underset{+}{HF}, \underset{-}{NaH}, \underset{(0)}{H_2}$

46. (b) $2Na + H_2 \rightarrow 2Na^+H^-$

Hydrogen has –*ve* (–1) oxidation state.

47. (a) $NaH \rightleftharpoons Na^+ + H^-$

At anode : $H^- \rightarrow H + e^-$

$H + H \rightarrow H_2$

48. (a) For example *HCl* is a protonic acid

$HCl + H_2O \rightleftharpoons [H_3O]^+ + Cl^-$

49. (c) Hydrogen resembles both alkali metals and halogens.

50. (d) Chlorine has lone pair which it can donate to form co-ordinate bond while hydrogen cannot.

51. (c) Actually these exist in the ratio.

Protium	:	Deuterium	:	Tritium
1	:	1.56×10^{-2}	:	1×10^{-17}

52. (d) $SO_3 + D_2O \rightarrow D_2SO_4$ dideutero-sulphuric acid.

53. (b) $H^1H^1, H^1H^2, H^2H^2, H^3H^3, H^2H^3$

54. (d) $\overset{+2}{Ca}\,\overset{x}{H}_2$ *i.e.*, $2 + 2x = 0$, $x = -1$

$2x = -2$ or $x = \frac{-2}{2} = -1$

55. (c) Pure hydrogen is obtained by the electrolysis of $Ba(OH)_2$ solution in a *U*-tube using nickel electrode. The gas is liberated at the cathode and is passed over heated platinum gauze to remove oxygen if present as impurity.

56. (b) $\underbrace{CO + H_2}_{\text{water gas}} + H_2O \xrightarrow{\text{catalyst}} CO_2 + 2H_2$

57. (b) Deuterium ($_1^2H$) and hydrogen ($_1^1H$) both have same atomic number but different mass number so they have similar chemical but different physical properties.

58. (b) $_1^3H \rightarrow {}_2^3He + {}_{-1}^0e$

59. (d) $V.\text{oil} + H_2 \xrightarrow[\Delta]{Ni} \text{Fat}$

60. (a) $2H \rightleftharpoons H_2$; $\Delta H = -104.5\,kcal$

61. (b) Lavoisier give the name hydrogen which means water maker.

62. (a) For diatomic gases (*e.g.* H_2) $r = C_p / C_v = 1.40$

For monoatomic gases $r = 1.66$

For triatomic gases $r = 1.33$

63. (b) H_3 is also called Hyzone.

64. (b) $4LiH + AlCl_3 \xrightarrow{\text{Ether}} LiAlH_4 + 3LiCl$

65. (b) Alkali metal hydrides react with water to give metal hydroxide and H_2 *e.g.*,

$NaH + H_2O \rightarrow NaOH + H_2$

Alkali metal hydroxides are strongly basic in nature.

66. (c) Ionic hydrides are good reducing agents.

68. (c) Systematic name of water is oxidane.

69. (c) BeH_2 and MgH_2 have significant covalent character.

70. (a) Limiting composition of *f* block hydrides are MH_2 and MH_3.

71. (d) H_2 does not react with *Au*, *Cu* or *Ni* with *Ca* it gives CaH_2. $Ca + H_2 \rightarrow CaH_2$

72. (c) $Ca(OH)_2$ is used for the softening of temporary hard water.

$Ca(OH)_2(aq) + CO_2(g) \rightarrow \underset{\text{cloudiness}}{CaCO_3(s)} + H_2O(l)$

73. (a) $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$

$Zn + 2NaOH \rightarrow Na_2ZnO_2 + H_2$

$\therefore$ Ratio of volumes of H_2 evolved is 1 : 1.

74. (c) Anhydrous $CaCl_2$ is used for fast drying of neutral gases.

75. (d) Hydrogen is the lightest gas.

76. (c) An atom of tritium contains 1 proton, 1 electron and 2 neutrons.

77. (d) Hydrogen is a non-metal while all other members of group 1 (alkali metals) are metals.

78. (b) $\underset{\text{base 1}}{H^-(aq)} + \underset{\text{acid 2}}{H_2O(l)} \rightarrow \underset{\text{base 2}}{OH^-(aq)} + \underset{\text{acid 1}}{H_2(g)}$

79. (a) $\underset{1s^1}{H} + e^- \rightarrow \underset{1s^2 \text{ or } [He]^2}{H^-}$

$\underset{[He]^2\,2s^2\,2p^5}{F} + e^- \rightarrow \underset{[He]^2\,2s^2\,2p^6 \text{ or } [Ne]^{10}}{F^-}$

80. (a) Hydrogen from bonds in +1 and –1 oxidation state.

81. (c) Mercury (*Hg*) will not displace hydrogen.

82. (c) Hydrogen is the lightest gas. It is insoluble in water.

83. (b) Hydrogen forms maximum number of compounds in chemistry comparison than carbon.

84. (c) $Zn + H_2O \rightarrow ZnO + H_2$

$Zn + 2NaOH \rightarrow Na_2ZnO_2 + H_2$

$Zn + 2HCl \rightarrow ZnCl_2 + H_2$

$Zn + 2H_2SO_4 \rightarrow ZnSO_4 + SO_2 + 2H_2O$.

Water or hydride of oxygen

4. (b) $Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow \underset{\text{ppt.}}{2CaCO_3\downarrow} + 4H_2O$

5. (c) D_2O in which $D = {}_1H^2$

7. (b) HCO_3^- is main reason of temporary hardness of water.

8. (b) By boiling temporary hardness of water can be removed.

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

9. (c) $\underset{\text{Zeolite}}{Na_2Al_2Si_2O_8 .xH_2O} + Ca^{+2} \rightarrow$

$$CaAl_2Si_2O_8.xH_2O + 2Na^+$$

10. (b) Water has high dielectric constant *i.e.*, 82, high liquid range and can dissolve maximum number of compounds. That is why it is used as universal solvent.

11. (a) Heavy water *i.e.*, D_2O slows down the speed of neutrons in nuclear reactors..

12. (a) Chlorides and sulphates of *Mg* and *Ca* produces permanent hardness and bicarbonates of *Mg* and *Ca* produces temporary hardness.

13. (d) Permanent hardness cannot be removed by boiling of water but temporary hardness can be removed.

14. (d) The density of water is $1\,g\,cm^{-3}$ at 4°*C*

so molarity $= \frac{1000}{18} = 55.5\,M$.

15. (d) Water containing Ca^{+2}, Mg^{+2} and $H^+(>10^{-7}m)$ is a hard water.

$$H^+(aq) + CH_3COONa(aq) \rightleftharpoons CH_3COOH(s) + Na^+(aq)$$

16. (c) Heavy water is used as a moderator to slow down the speed of fast moving neutrons and as well as a coolant.

17. (b) Heavy water freezes at a slightly higher temperature than water.

18. (b) *pH* of heavy water is slightly more than seven.

19. (c) D_2O actually has higher freezing point (3.8°*C*) than water H_2O (0°*C*).

20. (d) Colourless anhydrous $CuSO_4$ becomes blue on reaction with water.

21. (c) Due to plumbosolvancy, lead dissolves in water to a small extent to form soluble hydroxide which is poisonous so lead pipe is not used for carrying drinking water.

22. (a) Slaked lime removes temporary hardness of water.

$$\underset{\text{From hard water}}{Ca(OH)_2 + Ca(HCO_3)_2} \rightarrow 2CaCO_3 \downarrow + 2H_2O$$

23. (a) In cation exchange resin Mg^{+2} and Ca^{+2} (cations) are replaced by Na^+ ions.

24. (c) Washing soda removes both the temporary and permanent hardness by converting soluble calcium and magnesium compounds into insoluble carbonates.

$$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl$$

$$CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 + Na_2SO_4$$

$$Ca(HCO_3)_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaHCO_3.$$

25. (c) It is $Na_2Al_2Si_2O_8.xH_2O$

26. (c) ${}_1H_2^3O = 16 + 2 \times 3 = 22\,amu$

27. (d) $H_2O(H = {}_1H^2)$

$16 + 2 \times 2 = 20\,amu$

30. (c) $K_2SO_4.Al_2(SO_4)_3.24H_2O$

Potash alum is generally used for purifying water.

31. (c) Copper will not reduce H_2O to H_2 because of low reducing power of copper comparison than hydrogen.

32. (c) Heavy water is formed by the combination of heavier isotope (${}_1H^2$ or *D*) with oxygen.

$$2D_2 + O_2 \rightarrow \underset{\text{Heavy water}}{2D_2O}$$

33. (c) Water molecule associate due to inter molecular hydrogen bonding.

34. (d) Heavy water is D_2O (1 – c)

Temporary hard water contains bicarbonates of Ca^{2+} and $Mg^{2+}(2-a)$

Soft water may have no foreign ions $(3-b)$.

Permanent hard water contains sulphates and chlorides of Ca^{+2} and $Mg^{2+}(4-d)$

35. (d) The $H-O-H$ angle in water molecule is about 105° (due to two lone pair of electron).

36. (a) Two ice cubes when pressed over each other unite due to hydrogen bond formation.

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

38. (c) Pure water can be obtained from sea water by reverse osmosis.

39. (c) Action of water on dil. Mineral acids (HCl, H_2SO_4) can give dihydrogen.

40. (d) Iron (*Fe*) does not react with cold water to give H_2. However, iron reacts with steam to give H_2.

41. (c) *pH* of neutral water at room temperature is seven.

43. (c) The low density of ice compared to water is due to hydrogen bonding interactions.

44. (b) Silicon tetra fluoride on hydrolysis furnish ortho silicic acid and hydrogen silicofluoride.

$$\underset{\text{(Silicontetra Fluoride)}}{3SiF_4} + \underset{\text{(Water)}}{4H_2O} \longrightarrow \underset{\text{(Ortho Silicicacid)}}{H_2SiO_4} + \underset{\text{(Hydrogen Silico Fluoride)}}{2H_2SiF_4}$$

45. (a) The triple point of any substance is that temperature and pressure at which the material can exist in all three phases (Solid, liquid and gas) in equilibrium specifically the triple point of water is $273.16\,K$ at $611.2\,Pa$.

46. (b) Hardness of water is due to the presence of bicarbonates, chlorides and sulphates of *Ca*

and Mg on it. These Ca^{2+} and Mg^{2+} ions react with the anions of fatty acids present in soaps to form curdy white precipitates. As a result, hard water does not produce lather with soap immediately.

Hydrogen peroxide

1. (b) $\underset{0}{Cl_2} + H_2O_2 \rightarrow 2\underset{-1}{HCl} + O_2$

In this reaction H_2O_2 works as reducing agent

2. (d) $[H_2O_2 \rightarrow H_2O + \frac{1}{2}O_2] \times 2$

$\underset{68\,g}{2H_2O_2} \rightarrow 2H_2O + O_2$ 22.4 *litre* at N.T.P.

$\because$ 22.4 *litre* O_2 at N.T.P. obtained by 68 *gm* of H_2O_2

$\therefore$ 10 *litre* O_2 at N.T.P. obtained by

$\frac{68}{22.4} \times 10 = 30.35\ gm/litre$

$\therefore$ 1000 *ml* O_2 at N.T.P. obtained by = 30.35 *gm*

$\therefore$ 100 *ml* O_2 at N.T.P. obtained by

$= \frac{30.35}{1000} \times 100 = 3.035\%$

3. (a) $H_2SO_4 + BaO_2 \rightarrow BaSO_4 + H_2O_2$

5. (c) $BaO_2 + 2HCl \rightarrow BaCl_2 + H_2O_2$

6. (c) $Na_2O_2 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O_2$

7. (d) $PbS + 4H_2O_2 \rightarrow PbSO_4 + 4H_2O$

8. (c) $\underset{-2}{H_2S} + H_2O_2 \rightarrow \underset{0}{S} + 2H_2O$

In this reaction H_2O_2 shows oxidising nature.

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

13. (a) Volume strength $= 5.6 \times$ Normality

$= 5.6 \times 1.5 = 8.4\ litre$

14. (b) Quantity of $H_2O_2 = 15\ ml$ and volume of $H_2O_2 = 20$

We know that 20 volume of H_2O_2 means 1 *litre* of this solution will give 20 *litre* of oxygen at N.T.P.

Since, oxygen liberated from 1000 *ml* (1 *litre*) of $H_2O_2 = 20\ litre$, therefore oxygen liberate from 15 *ml* of H_2O_2

$= \frac{20}{1000} \times 15 = 0.3\ litre = 300\ ml$

15. (a) E.W. of $H_2O_2 = 17$

$N = \frac{30.36}{17} = 1.78\ N$

Volume strength $= 5.6 \times$ Normality

$= 5.6 \times 1.78 = 10\ litre$

17. (a) Equivalent weight of H_2O_2 is 17.

18. (b) $\because$ 22.4 *litre* O_2 at N.T.P. obtained by 68 *gm* of H_2O_2

$\therefore$ 1 *litre* O_2 at N.T.P. obtained by $\frac{68}{22.4}$ *gm* of H_2O_2

$\therefore$ 20 *litre* O_2 at N.T.P. obtained by

$\frac{68}{22.4} \times 20\ gm$ of $H_2O_2 = 60.71\ gm$ of H_2O_2

$\therefore$ 1000 *ml* O_2 at N.T.P. obtained by = 60.71 *gm* of H_2O_2

$\therefore$ 100 *ml* O_2 at N.T.P. obtained by

$= \frac{60.71}{1000} \times 100 = 6.71\%$

19. (c) Electrolysis of 50% sulphuric acid gives per disulphuric acid ($H_2S_2O_8$) which on distillation yields 30% solution of hydrogen peroxide.

20. (c) Due to $O-O$ bond.

21. (a) 10 volume of H_2O_2 means 10 *ml* of O_2 is obtained from 1 *ml* of H_2O_2.

22. (a) Glycerol, phosphoric acid or acetanilide is added to H_2O_2 to check its decomposition.

23. (a) H_2O_2 reduces O_3 to O_2

$O_3 + H_2O_2 \rightarrow H_2O + 2O_2$

24. (d) Fe^{+3} cannot be reduced by H_2O_2 while all other get reduced.

25. (d) Hydrogen peroxide does not show basic properties.

26. (d) Although H_2O_2 is a better polar solvent than H_2O. However it cannot be used as such because of the strong autooxidation ability.

27. (d) H_2O_2 is used as an oxidant for rocket fuel and has 90% concentration to be used in rockets.

28. (a) $\underset{\text{weak acid}}{H_2O_2} \rightarrow H_2O + [O]$

29. (a) Lattice energy of all metal nitrate are less than that of their solvation energy so nitrates of metals soluble in water.

31. (c) H_2O_2 is unstable liquid and decomposes into water and oxygen either on standing or on heating.

32. (c) $\underset{\|}{CH_2}{}_{CH_2} + H_2O_2 \rightarrow \overset{|}{CH_2OH}{}_{CH_2OH}$

33. (d) H_2O_2 show all these properties.

34. (a) As H_2O_2 is loosing electrons so it is acting as reducing agent.

36. (c) This is due to the formation of CrO_5.

$$K_2Cr_2O_7 + H_2SO_4 + 4H_2O_2 \rightarrow K_2SO_4 + \underset{\text{Blue}}{2CrO_5} + 5H_2O$$

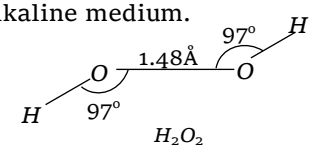
37. (a) K_a of $H_2O_2 = 1.55 \times 10^{-12}$

38. (a) In the following reaction H_2O_2 acts as a reducing agent.

$$PbO_2(s) + H_2O_2(aq) \rightarrow PbO(s) + H_2O(l) + O_2(g)$$

39. (e) H_2O_2 acts as an oxidising agent in acidic and alkaline medium.

40. (e)



H_2O_2

41. (b) We know that

$2H_2O_2 \longrightarrow 2H_2O + O_2$

$2 \times 34\ g \qquad 22400\ ml$

$\because\ 2 \times 34\ gm = 68\ gm$ of H_2O_2 liberates

$22400\ ml\ O_2$ at STP

$\therefore\ .68\ gm$ of H_2O_2 liberates

$$= \frac{.68 \times 22400}{68} = 224\ ml$$

Critical Thinking Questions

1. (c) Polyphosphates (sodium hexametaphosphates, sodium tripolyphosphate or STPP) from soluble complexes with Ca^{+2}, Mg^{+2} present in hard water.

2. (d) Critical temperature of water is more than O_2 due to its dipole moment (Dipole moment of water = 1.84 D; Dipole moment of $O_2 = \text{zero}\ D$).

3. (c) $\underset{\substack{\text{(Cal. phosphide)}\\ \text{1 mole}}}{Ca_3P_2} + 6H_2O \rightarrow \underset{\substack{\text{phosphene}\\ \text{(2 moles)}}}{2PH_3} + 3Ca(OH)_2$

4. (d) Zeolite when treated with hard water exchange Cu^{+2} and Mg^{+2} ions (present in hard water) with Na^+ ions.

6. (c,d) $Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2 \uparrow$

$LiH + H_2O \rightarrow LiOH + H_2 \uparrow$

7. (a,b,d) Water containing any cation other than NH_4^+ and alkali metal is a hard water.

8. (b) Reaction of $NaBH_4$ with cold water is very slow. All other statements except (b) are correct.

9. (b,d) $CaH_2 + 2H_2O \rightarrow Ca(OH)_2 + 2H_2 \uparrow$

$Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2 \uparrow$

10. (c,d) Ice is a poor conductor of heat (a good thermal insulator) and its density is less than water.

11. (d) H_2 will not reduce heated Al_2O_3.

12. (d) MnO_2, PbO_2 and BaO will not give H_2O_2 with HCl. MnO_2 and PbO_2 will give Cl_2 and BaO will react with HCl to give $BaCl_2$ and water.

13. (a) Cu and dil. HCl will not produce H_2.

14. (b) Strength = Normality × Eq. mass

$= 1.5 \times 17$ (eq. mass of H_2O_2)

$= 25.5\ gL^{-1}$

15. (b) $Mn + 2HNO_3(dil.) \rightarrow Mn(NO_3)_2 + H_2$

16. (c) Hydrogen behaves as a metal at very high pressure.

17. (d) H_2O absorbs neutrons more than D_2O and this decreases the number of neutrons for the fission process.

18. (c) The para form of H_2 has lesser energy than the ortho form.

19. (c) Fire due to action of water on saline hydrides cannot be extinguished with water or CO_2. These hydrides can reduce CO_2 at high temperature to produce O_2.

21. (c) $Mg(OH)_2$ is less soluble than $MgCO_3$. On boiling temporary hard water containing Mg^{+2} ions, the ppt. obtained is of $Mg(OH)_2$ are not that of $MgCO_3$.

22. (c) $Ca(OH)_2$ removes the permanent hardness due to Mg^{2+} ion, but it produces Ca^{2+} ions which are removed by Na_2CO_3.

$Mg^{2+} + Ca(OH)_2 \rightarrow Mg(OH)_2 \downarrow + Ca^{2+}$

$Ca^{2+} + Na_2CO_3 \rightarrow CaCO_3 \downarrow + 2Na^+$

$Ca(OH)_2$ or Na_2CO_3 alone cannot remove the permanent hardness.

25. (b) $\underset{\text{Sod. formate}}{2HCOONa(s)} \xrightarrow{\Delta} H_2(g) \uparrow + \underset{\text{Sod. oxalate}}{\overset{|}{COONa}{}_{COONa}}(s)$

26. (b) Presence of CO_3^{2-} and SO_4^{2-} ions in water reduced the tendency of dissolution of *Pb* in water as $Pb(OH)_2$.

27. (b) *NaCl* does not make water hard.

28. (b) Solubility of $CaSO_4$ in water decreases with increase in temperature.

29. (b) Organic ion exchange resins can remove only ionic impurities.

30. (d) Water obtained from organic ion-exchange resins is free from all ionic impurities.

31. (a) Soap can remove all types of hardness of water as it converts the hardness producing cations into insoluble ppt.

32. (b) 10 volume solution of H_2O_2 is 3.035% solution

i.e., 3.035 *g* of H_2O_2 is present in $100ml$ of the solution.

Assertion & Reason

2. (d) Both assertion (*A*) and reason (*R*) are not true.

Correct Assertion : Calgon mask the properties of Ca^{2+} and Mg^{2+} ions present in water without removing them as ppt.

Correct Reason : Calgon forms soluble complexes with Ca^{2+} and Mg^{2+} in which properties of these ions are masked.

3. (a) Both assertion (*A*) and reason (*R*) are true and *R* is the correct explanation of *A*.

Correct Reason : H_2O_2 is a strong reducing agent.

4. (c) Assertion (*A*) is correct but reason (*R*) is not the correct explanation of *A*.

10. (d) Both assertion (*A*) and reason (*R*) are not true.

Correct Assertion : Hydrogen peroxide forms two series of salts called hydroperoxides and peroxides.

Correct Reason : Hydrogen peroxide molecule has two replaceable hydrogen atoms.

Hydrogen and Its compounds

SET Self Evaluation Test - 17

1. Temperature of maximum density in H_2O and D_2O respectively are

(a) 277.15 K, 284.75 K

(b) 273.15 K, 277.15 K

(c) 277.15 K, 285.75 K

(d) 284.75 K, 277.15 K

2. Non-metallic oxides dissolves in water to form

(a) Acidic solution

(b) Alkaline solution

(c) Neutral solution

(d) None of these

3. Ordinary water is not used as a moderator in nuclear reactors because

(a) It cannot slow down fast moving neutrons

(b) It cannot remove the heat from the reactor core

(c) It absorbs the fast moving neutrons

(d) Of its corrosive action on the metallic parts of the nuclear reactor

4. Brackish water mostly contains

(a) Calcium chloride (b) Barium sulphate

(c) Sodium chloride (d) Mineral acids

5. $TiH_{1.73}$ is an example of

(a) Ionic hydride

(b) Covalent hydride

(c) Metallic hydride

(d) Polymeric hydride

6. The volume strength of perhydrol is

(a) 20 (b) 30

(c) 100 (d) 10

7. The solubility of an ionic compound is compared in heavy and simple water. It is

(a) Higher in heavy water

(b) Lower in heavy water

(c) Same in heavy water and simple water

(d) Lower in simple water

8. Which of the following cannot be reduced by H_2O_2

(a) Ag_2O

(b) Fe^{3+}

(c) Acidified $KMnO_4$

(d) Acidified $K_2Cr_2O_7$

9. Hydrogen can be prepared by the action of dil. H_2SO_4 on

(a) Copper (b) Iron

(c) Lead (d) Mercury

10. The element whose hydride contains maximum number of hydrogen per atom of the element is

(a) Na (b) O

(c) B (d) Si

11. Indicator type silica gel used as a dehumidifier contains

(a) Cu^{2+} ions (b) Ni^{2+} ions

(c) Co^{2+} ions (d) Fe^{2+} ions

12. To an aqueous solution of $AgNO_3$ some $NaOH(aq)$ is added, till a brown ppt. is obtained. To this H_2O_2 is added dropwise. The ppt. turns black with the evolution of O_2. The black ppt. is

(a) Ag_2O (b) Ag_2O_2

(c) $AgOH$ (d) None of these

13. Atomic hydrogen reacts with oxygen to give

(a) Almost pure water

(b) Almost pure hydrogen peroxide

(c) A mixture of water and hydrogen peroxide

(d) None of these

14. Which of the following cannot be used for the preparation of H_2

(a) $Zn + HCl(dil.) \rightarrow$

(b) $NaH + H_2O \rightarrow$

(c) $Zn + HNO_3(dil.) \rightarrow$

(d) $HCOONa \xrightarrow{\Delta}$

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

[EAMCET 2001]

(a) Calgon (b) Baeyer

(c) Serpeck (d) Hoope

Answers and Solutions

(SET -17)

1. (a) Temperature of maximum density of H_2O is 277.15 K.

Temperature of maximum density of D_2O is 284.75 K.

2. (a) Non metallic oxides in water are form acidic solutions *e.g.* $P_2O_5 + 3H_2O \rightarrow \underset{\text{phosphoric acid}}{2H_3PO_4}$

3. (c) Ordinary water absorbs fast moving neutrons, thus stopping the process of nuclear fission.

4. (c) Brackish water mostly contains sodium chloride.

5. (c) It is a metallic hydride.

6. (c) The volume strength of perhydral is 100

perhydral is 30% H_2O_2

10 vol. $H_2O_2 \equiv 3\% H_2O_2$

$\therefore$ 30% of $H_2O_2 \equiv 100$ vol. H_2O_2

7. (b) The solubility of an ionic compound is more in simple water and less in heavy water.

8. (b) H_2O_2 cannot reduce Fe^{3+}. All other compounds are reduced by H_2O_2.

9. (b) Hydrogen cannot be prepared by the action of dil. H_2SO_4 on copper or mercury as these two metals cannot displace hydrogen from acids. Action of dil. H_2SO_4 are stops after sometimes due to the formation of insoluble $PbSO_4$. Only, iron reacts rapidly with dil. H_2SO_4 to give H_2.

10. (d) Hydride of $Si(SiH_4)$ contains more hydrogen atoms than hydrides of $Na(NaH), O(H_2O), B(BH_3)$.

11. (c) Indicator type of gel used as a dehumidifier contains CO^{2+} ions, when dry it is blue in colour and on absorbing moisture it becomes pink.

12. (d) $2AgNO_3(aq) + 2NaOH(aq) \rightarrow \underset{\text{Brown ppt.}}{Ag_2O(s)} + H_2O(l) + 2NaNO_3(aq)$

$Ag_2O(s) + H_2O_2(aq) \rightarrow H_2O(l) + O_2(g) + \underset{\text{Black ppt.}}{2Ag(s)}$

The finely divided Ag is black in colour.

13. (b) Atomic hydrogen reacts with oxygen to give almost pure hydrogen peroxide.

$2[H] + O_2 \rightarrow H_2O_2$

14. (c) $Zn + 2HCl(dil.) \rightarrow ZnCl_2 + H_2$

$NaH + H_2O \rightarrow NaOH + H_2$

$2HCOONa \xrightarrow{\Delta} \underset{\text{sodium oxalate}}{Na_2C_2O_4} + H_2$

$4Zn + 10HNO_3 dil. \rightarrow 4Zn(NO_3)_2 + N_2O + 5H_2O$

*****15.** (a) Calgon process is used for the removal of hardness of water.