CHAPTER 6

HYDROGEN AND ITS COMPOUNDS

UNIT: 1

1 Position of Hydrogen in Periodic table
2 Occurrence, Isotopes of Hydrogen
3 Hydrogen preparation, properties and uses including as a fuel
4 Reaction of Hydrogen with different types of elements leading to ionic, molecular and non – stoichiometric hydrides

VERY SHORT ANSWER QUESTIONS:

1. Name the isotope of hydrogen. Give their symbols.

A. Hydrogen has three isotopes namely

1) Protium ${}_1^1H$

2) Deuterium ${}_1^2H$ or D

3) Tritium (${}_1^3H$ or T)

2. What is the equation for the nuclear reaction that takes place Tritium undergoes radio active decay ? Name the product ?

A. ${}_1^3T \longrightarrow {}_2^3He + {}_{-1}^{o}e$ (β - Decay). The product formed is an isotope of Heliumand a β -emission.

3. How many protons, neutrons and electrons are present in a tritium atom ?

A. Tritium is ${}_1H^3$ Number of protons: 1

Number of neutrons: 2

Number of electrons: 1

4. Complete the reaction $CO_{(g)} + H_{2(g)} \xrightarrow[cal]{\Delta}$

A. $CO_{(g)} + H_{2(g)} \xrightarrow[cal]{\Delta} CH_3OH$

5. Why does hydrogen occur as a diatomic molecule under normal conditions ?

A. H is one electron short of the nearest inert gas(He) structure. It has a tendency to pair up its electron and to get 'He' gas configuration. By sharing an electron pair, between two hydrogen atoms, diatomic molecule is formed.

6. Write the composition of the isotopes of hydrogen. Mention whether they can exhibit similar chemical properties ?

A. ${}_1^1H = (1P + 1n)$; ${}_1^2H = (1P + 1n)$; ${}_1^3H = (1P + 2n)$. All have only $1s^1$ configuration and are considerd as isotopes So they show similar chemical properties.

7. What do you understand by the term "Syngas" ?

A. A mixture of CO and H_2 is known as 'Water gas'. It is used for synthesis of 'methanol' and a number of hydrocarbons. It is also called as "synthesis gas" or "syngas". Syngas is obtained from coal. This process is called "coal gasification".

8. Do you expect the saturated hydrocarbons of the type C_nH_{2n+2} to act as Lewis acids or bases ? Give reasons.

A. The hydrocarbons C_nH_{2n+2} are saturated compounds with completed octet in carbon. The carbon cannot expand its octet by accepting electron pairs due to absenceof vacant d orbital.Hence, they cannot act as Lewis acids, they have no lone pairs to donate to act as Lewis bases.

SHORT ANSWER TYPE QUESTIONS:

1. Discuss briefly the position of hydrogen in periodic table.

A. Position of Hydrogen:

It resembles alkali metals and also halogens . Hence it can be placed either in IA group or in VIIA group along with halogens

Resemblances with alkali metals:

1) Hydrogen has only one electron in its valence shell, just like alkalimetals.

2) It forms monovalent cation. In this regard it resembles alkali metals.

Resemblances with halogens:

1) Hydrogen can take up one electron and can form anion H just like halogens.

2) Hydrogen has one electron short of nearest inert gas He. Halogens also have one electron short of respective nearest inert gases.

2. Name the isotope of hydrogen. How do they differ from each other?

A. Isotopes of Hydrogen

Atoms of the same element with different mass numbers are known as isotopes.

Hydrogen has '3' isotopes namely

1) Protium $_1{}^1H$

2) Deuterium $_1{}^2H$ or D

3) Trtium ($_1{}^3H$ or T)

Protium contains only one proton and no neutron. Deuterium contains one proton and one neutron. Tritium contains one proton and two neutrons.

Isotope of Hydrogen without neutron is Protium.

Isotopes of an element exhibit similar chemical properties because they posses similar electronic configuration. These isotopes of Hydrogen show much differences in their physical properties because of wide difference in their molecular mass. Chemical activity of these isotopes decreases with increasing in mass number.

Among these isotopes, protium is highly reactive compared to Deuterium because of low activation energy.

Tritium is radioactive and is non – toxic β – emitter ($t_{1/2}$ = 12.26 yrs). Deuterium and tritium are used as tracers in the study of mechanism of chemical reactions.

Deuterium is used as moderator in nuclear reactions.

Tritium is non – toxic, since it emits low energy β radiations and no ỳ radiations.

3. Hydrogen is widely used for synthesis of " industrial chemical". Support this by giving three different examples.

A. In the synthesis of industrial chemicals: -

In industries, Hydrogen is used in the synthesis NH_3, HCl, CH_3, OH, vanaspathi and synthetic petrol.

a) Haber's method(For NH_3): in Haber's method N_2 and H_2 gases are passed pver 'Fe' catalyst at $450°C$ and atmospheres

$$N_2 + 3H_2 \xrightarrow[\Delta]{Fe} 2NH_3$$

b) Synthesis of HCl: Hydrogen is burnt in chlorine gas and the product is absorbed in water to give HCl

$$H_{2(g)} + Cl_{2(g)} \longrightarrow 2\,HCl_{(g)}$$

c) Synthesis of CH_3OH : When a mixture of water gas and H_2 is passed over a catalyst $ZnO + Cr_2O_3$, CH_3OH is obtained

$$\underset{\text{water gas}}{(CO + H_2)} + H_2 \xrightarrow{ZnO+Cr_2O_3} CH_3OH$$

4. Explain the use of hydrogen as a fuel.

A. The heat of combustion of hydrogen is high $\left(242\,kJ\,mole^{-1}\right)$ and hence hydrogen is widely used as an industrial fuel.

Oxyhydrogen blow torch:

When hydrogen is burnt with pure oxygen in oxyhydrogen blow torch a high temperature $(2800°C)$ flame is obtained. It is used for welding purposes and for melting platinum and quartz.

Water gas:

A mixture of (CO and H_2) obtained when steam is injected over white hot bed of coal or coke is known as water gas. The calorific value of gas is $13,000\,kj/m^3$

Carburetted water gas:

The calorific value of water gas is increased by adding gaseous hydrocarbons to it. This enriched mixture is called carbureted water gas.

Semi water gas:

A mixture of air and steam in appropriate proportions is passed thorugh red hot carbon. The heat generated by the combustion of carbon maintains the temperature necessary for the formation of water gas – by the action of steam or carbon which is endothermic. The gaseous mixture thus obtained contains hydrogen (10 – 12%), Carbon monoxide (25 – 28%), CO_2 (4 – 5%), nitrogen (50 – 55%) and methane (1 – 2%). It is used as fuel in steel industry. It has low calorific value.

5. What are fuel cells: Explain the working of a fuel cell.

A. In fuel cells: Cells which are designed to convert the energy from the combustion of fuels into electrical energy are called fuel cells.

Fuel cells use the reaction of hydrogen with oxygen to form water. In the fuel cell hydrogen and oxygen gases are bubbled through porous carbon electrodes into concentrated NaOH solution.

At anode: $\left[H_2(g) + 2OH^{(-)}(aq) \longrightarrow 2H_2O(\ell) + 2e^{(-)} \right] \times 2$

At anode: $O_2(g) + 2H_2O(\ell) + 4e^{(-)} \longrightarrow 4H^{(-)}(aq)$

overall cell reaction: $2H_2(g) + O_2(g) \longrightarrow 2H_2O(\ell)$

This cell runs continuously as long as the reactants are supplied. Fuel cell was used for electrical power in the Apollo space programme. The water vapour produced was condensed and added to the drinking water supplied to the astronauts.

6. "Hydrogen – a source for atomic energy". Explain with suitable examples. Give equations.

A. The union of two or more lighter nuclei to form a heavy nuclide along with the liberation of enormous amount of energy is called nuclear fusion. The simplest nuclear fusion reaction is ${}^{2}_{1}H + {}^{3}_{1}H \longrightarrow {}^{4}_{2}H + {}^{1}_{0}n + \text{energy}$. In order to unite nuclei together, a large amount of energy is required to overcome the repulsion forces among them. Hence the combining nuclei are to be heated initially to a very high temperature. Hence, nuclear fusion reactions are also called Thermo nuclear reactions.

The liberation of enormous amount of heat energy from the sun and the liberation of enormous amount of light energy from stars is due to the fusion reactions taking place in them. The principle involved in H – bomb is nuclear fusion.

7. Explain the working of atomic hydrogen torch in welding machinery.

A. Atomic hydrogen torches find use for cutting and welding purposes. Atomic hydrogen atoms (produced by dissociation of dihydrogen with the help of electric arc) are allowed to recombine on the surface to be welded to generate the temperature of 4000 K.

LONG ANSWER TYPE QUESTIONS:

1. Write an essay on the position of hydrogen in the periodic table.

A. **Position of Hydrogen**:

It resembles alkali metals and also halogens . Hence it can be placed either in IA group or in VIIA group along with halogens

Resemblances with alkali metals:

1) Hydrogen has only one electron in its valence shell, just like alkali metals.

2) It forms monovalent cation. In this regard it resembles alkali metals.

3) It forms hydrated cation like alkali metals.

Resemblances with halogens:

1) Hydrogen can take up one electron and can form anion H just like halogens.

2) Hydrogen has one electron short of nearest inert gas He. Halogens also have one electron short of respective nearest inert gases.

3) It is diatomic molecule like halogens.

HYDROGEN AND ITS COMPOUNDS

UNIT: 2

1 Physical and Chemical properties of water and heavy water

VERY SHORT ANSWER QUESTIONS:

1. What are the boiling point and melting point of heavy water?

A. Boiling point is $101.42°C$

Melting point is $3.82°C$

2. Give two uses of heavy water.

A. 1) It is used as moderator of neutrons in nuclear reactor

2) It is used as tracer to study mechanism of reactions

3. Give the chemical equation and name of the product when Calcium carbide reacts with heavy water.

A. The products formed in the reaction are Calcium deuteroxide and heavy acetylene gas.

$$CaC_2 + D_2O \longrightarrow \underset{\text{Calcium deuteroxide}}{Ca(OD)_2} + \underset{\text{deuteroacetylene}}{C_2D_2}$$

4. What is the cause of hardness of water?

A. Bicarbonates, Chlorides and Sulphates of calcium and Magnesium cause hardness.

5. What is deuterolysis? Give an equation for deuterolysis.

A. Reaction of a salt with heavy water is known as deuterolysis

$$AlCl_3 + 3D_2O \longrightarrow Al(OD)_3 + 3DCl$$

6. Write the equation for reactions in cation exchange resin and anion exchange resin.

A. Cation exchange resin

$$\underset{\text{Resin}}{2RCOOH} + \underset{\text{From hard water}}{Ca^{2+}} \longrightarrow \underset{\text{anion}}{(RCOO)_2} + \underset{\text{exchange resin}}{2H^+}$$

$$RNH_3OH + Cl^- \longrightarrow RNH_3Cl + OH^-$$

$$H^+ + OH^- \longrightarrow H_2O$$

7. For what reasons water has become useful as solvent?

A. The polar character of water and its high dielectricconstant makes it solvent. .

8. Why D_2O cannot be used as drinking water?

A. Heavy water in higher concentration is poisonous, due to the slower rate of reaction of D^+ ions. Hence, it cannot be used for drinking water.

9. What is the difference between the terms "hydrolysis" and "hydration"?

A. Hydrolysis is a chemical reaction of a salt with water

$$\underset{(\text{hydrolysis})}{PCl_3 + 3H_2O} \longrightarrow H_3PO_3 + 3HCl$$

Addition of H_2O through a physical process is hydration

$$CuSO_4 + 5H_2O \longrightarrow CuSO_4.5H_2O$$

10. What is "deionized water"? How is it prepared ?

A. Water that is free from all the dissolved mineral salts is known as "deionized water". This is obtained by passing hard water through cationic and anionic exchange resins.

11. Can the demineralised water be used for drinking purposes? What should be done to make it useful for drinking ?

A. Demineralised water cannot be used as potable water(drinking water). Some salts must be added to it to make as useful for drinking water.

12. How are the D_2O molecules in deuterates present? Give example each.

A. Three types of deuterates may be formed on similar lines with H_2O. They are

i) Deutero bonded compounds (similar to hydrogen bonded compounds)

Example : $CuSO_4.5D_2O$

ii) Interstitial deuterates

Ex : $BaCl_2.2D_2O$

iii) Coordination compounds

Ex : $CrCl_3.6D_2O$

13. Write the reaction that takes place when $BiCl_3$ is dissolved in excess of D_2O

A. $$\underset{(\text{Deuterohydrolysis})}{BiCl_3 + D_2O} \longrightarrow BiOCl + 2DCl$$

SHORT ANSWER TYPE QUESTIONS:

1. What do you mean by hardness of water? Give the reactions in the permutit process.

A. **Hard water:**

Water, which does not give lather immediately with soap, is known as hard water.

Permutit process: Permutit is artificial zeolite. Permutit is sodium aluminium orthosilicate $\left(Na_2Al_2Si_2O_8.xH_2O\right)$. Permutit is prepared by fusing sodium carbonate, alumina and silica.

A suitable container is packed with permutit. Hard water is allowed to percolate through the permutit. Sodium ions of permutit are replaced by calcium and magnesium ions of hard water. Thus hardness of water is removed and soft water is collected from the outlet. Chemical reactions involved in the process are :

$$Na_2Al_2Si_2O_8.X\,H_2O + Ca^{+2}{}_{(aq)} \longrightarrow CaAl_2Si_2O_8.X\,H_2O + 2Na^{+}{}_{(aq)}$$

$$Na_2Al_2Si_2O_8.X\,H_2O + Mg^{+2}{}_{(aq)} \longrightarrow Mg\,Al_2Si_2O_8.X\,H_2O + 2Na^{+}{}_{(aq)}$$

After sometime, all the sodium ions in the permutit are replaced by Ca^{+2} or Mg^{+2} ions. Such permutit is known as 'exhausted' permutit.

The exhausted permutit can be regenerated by washing with 10% brine solution

$$CaAl_2Si_2O_8.X\,H_2O + 2Na^{+}{}_{(g)} \longrightarrow Na_2Al_2Si_2O_8.X\,H_2O + Ca^{+2}{}_{(aq)}$$

$$Mg\,Al_2Si_2O_8.X\,H_2O + 2Na^{+}{}_{(aq)} \longrightarrow Na_2Al_2Si_2O_8.X\,H_2O + Mg^{+2}{}_{(aq)}$$

2. Describe one method for the preparation of heavy water.

A. 'Deuterium oxide' is known as heavy water $\left(D_2O\right)$:

1 part of heavy water is present in 6000 parts of normal water

Preparation of heavy water:

Heavy water is prepared by prolonged electrolysis of water. The electrolytic cell consists of a steel vessel which acts as cathode. A perforated Ni sheet acts as anode and 0.5M NaOH solution acts as electrolyte. The electrolysis is carried out in 7 stages.

In the first stage, electrolysis is continued till the electrolyte is reduced to $1/6^{th}$ of its original volume. The alkali is partly neutralized by passing CO_2. The residue is shifted to second stage of the cell and thus the process is repeated till 90% of heavy water is obtained after seventh stage.

3. Give any three important properties of D_2O

A. Chemical properties of D_2O :

1) **With non-metallic oxides**: - Heavy water gives deuteroacids with non metallic oxides

$$SO_2 + D_2O \longrightarrow \underset{(\text{Deutero sulphuric acid})}{D_2SO_4}$$

2) With nitrides: Heavy water gives deuteron ammonia with nitrides

$$Mg_3N_2 + 6D_2O \longrightarrow 2Mg(OD)_2 + 2ND_3 \uparrow$$

3**) With phosphides:** Heavy water gives deuteron phosphides

$$Ca_3P_2 + 6D_2O \longrightarrow 3Ca(OD)_2 + 2PD_3 \uparrow$$

4) With carbides: Heavy water gives deutero hydrocarbons with carbides

$$CaC_2 + 2D_2O \longrightarrow 2Ca(OD)_2 + \underset{(\text{Deutero acetylene})}{C_2D_2}$$

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

4. A sample of water contains 1.0×10^{-3} moles of $CaCl_2$ per 10 kg of water. Calculate the degree of hardness of water. (Assume that no other salt that causes hardness to water are present in the same)

A. 10 kg $\left(10\times10^3 \text{ gm}\right)$ of water contains 10×10^{-3} moles of $CaCl_2$

1 million $\left(10^6\right)$ gm of water contains ------- ?

$$= \frac{10^6\times10^{-3}}{10\times10^3} = \frac{1}{10} = 0.1\text{mole}$$

1 mole of $CaCl_2$ = 1 mole of $CaCO_3$

111 gm of $CaCl_2$ = 100 gm of $CaCO_3$

11.1 gm of $CaCl_2$ = 10 gm of $CaCO_3$

Degree of hardness = 10 ppm

5. What do you understand by "auto protolysis" of water?What is its significance ?

A. The auto – protolysis i.e, self ionisation of water

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

Significance: From the above reaction, it is clear that water has the ability to act as an acid as well as a base i.e, it behaves as an amphoteric substance.

6. Give examples to show the amphoteric nature of H_2O

A. Amphoteric nature

H_2O has the ability to act as a Bronsted acid when dissolving alkalies and as a Bronsted base when an acid is dissolved in it. This is due to autoprotolysis i.e, self ionisation of water.

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

And water is amphoteric in nature

Examples:

Reaction with acid

$$HCl + H_2O \longrightarrow H_3O^+ + Cl^-$$

Reaction with base

$$NH_3 + H_2O \longrightarrow NH_4^+ + OH^-$$

LONG ANSWER TYPE QUESTIONS:

1. What is hardness of water?Explain one method each for the removal of temperory hardness and permanent hardness of H_2O.

1) Water, which does not give good lather with soap immediately, is called hard water

2) The hardness of water is of two types

3) Temporary hardness is due to the presence of bicarbonates of Ca and Mg

4) Permanent hardness is due to the presence of chlorides and sulphates of Ca and Mg

5) Temporary hardness can be removed by (a) Boiling (b) Clark's process

(a) Boiling: When hard water is boiled the bicarbonates will be converted into insoluble carbonates

$$Mg(HCO_3)_2 \xrightarrow{\text{boiling}} MgCO_3 \downarrow + H_2O + CO_2 \uparrow$$

(b) Clark's process: When a required quantity of milk of lime is added to hard water to remove temporary hardness. It forms insoluble carbonates and hydroxides.

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

Permanent hardness can be removed by (a) Permutit process (b) Calgon method and (c) Ion exchange method

Permutit process: Permutit is artificial zeolite, chemically it is sodium aluminium orthosilicate. Its formula is

$$Na_2Al_2Si_2O_8 . x\,H_2O$$

Permutit is packed in a suitable container and hard water is percolated through it. Calcium and magnesium ions which cause hardness in water are replaced by sodium ions which do not cause hardness. Thus water is softened and is taken out through the outlet of the container. Chemical reactions that take place during this process are:

i) $Na_2Al_2Si_2O_8 . xH_2O + Ca^{2+}_{(aq)} \longrightarrow Ca\,Al_2Si_2O_8 . xH_2O_{(s)} \downarrow + 2Na^{+}_{(aq)}$

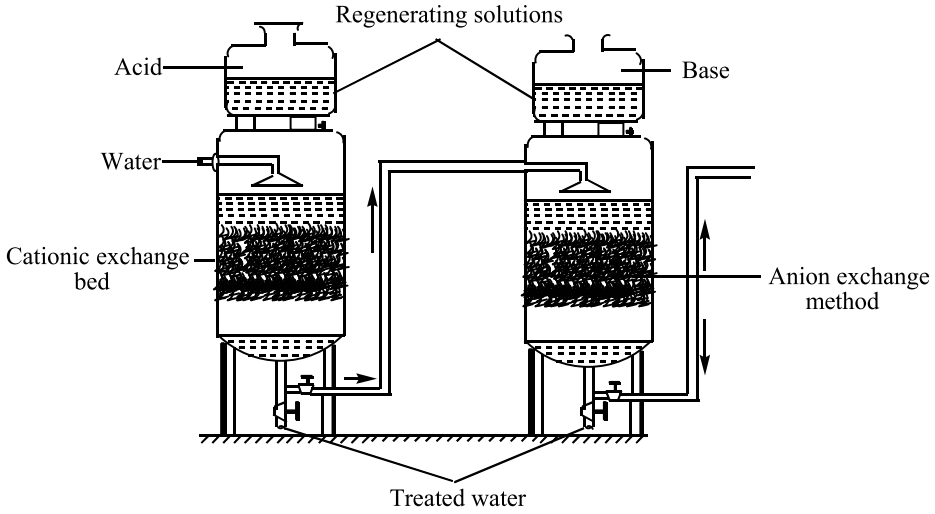
ii) $Na_2Al_2Si_2O_8 . xH_2O + Mg^{2+}_{(aq)} \longrightarrow Mg\,Al_2Si_2O_8 . xH_2O_{(s)} \downarrow + 2Na^{+}_{(aq)}$

After some use all the sodium ions in the permutit are replaced by Ca^{2+} or Mg^{2+} ions and then it is said that the permutit is exhausted. The exhausted permutit can be regenerated for subsequent use by shaking it with 10% brine solution. (NaCl solution)

Chemical reactions during revival of the exhausted permutit is

$$\left\{\begin{matrix} CaAl_2Si_2O_{8.}xH_2O_{(s)}\downarrow \\ MgAl_2Si_2O_8.xH_2O_{(s)} \end{matrix}\right\} + 2Na^{+}_{(aq)} \longrightarrow Na_2Al_2Si_2O_8.xH_2O + \left\{Ca^{+2}_{(aq)}\,(\text{or})\,Mg^{+2}_{(aq)}\right\}$$

Spent permutit Regenerated permutit

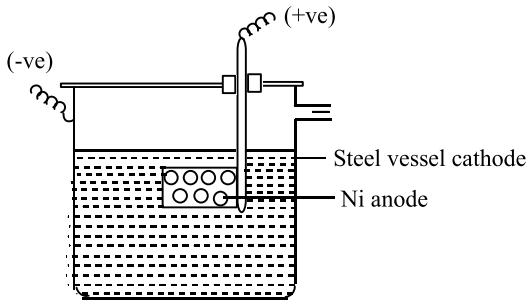


Ion exchange method

2. How is heavy water prepared? Write any four chemical properties. Give 2 uses of heavy water.

A. Heavy water can be prepared by the exhaustive electrolysis of water containing alkali. The electrolytic cell is made of steel and acts as cathode. A nickel cylindrical sheet having perforations acts as anode. A group of cells are used for electrolysis. This process involves seven stages. In the first stage 3 lit of $N/2$ NaOH solution is taken in an electrolytic cell and is electrolysed till the volume of the electrolyte reduces to $1/6^{\text{th}}$ of its original volume.

The alkali present is partly neutralized by passing CO_2 gas through the electrolyte. It is then distilled and the distillate is added to cells of II stage. At the end of seventh stage 99% D_2O is obtained.



Electrolytic method
Preparation of D_2O

Chemical Properties:

1) It reacts with nitrides and liberates Deutero ammonia

$$Mg_3N_2 + 6\,D_2O \longrightarrow 3\,Mg(OD)_2 + 2\,ND_3$$

2) It reacts with Calcium carbide and liberates heavy acetylene

$$CaC_2 + 2\,D_2O \longrightarrow Ca(OD)_2 + \underset{\text{Heavy acetylene}}{C_2D_2}$$

3) It reacts with active metals like Na, Ca, etc and liberates Deuterium

$$2Na + 2\,D_2O \longrightarrow 2NaOD + \underset{\text{Deuterium}}{D_2}$$

4) It reacts with Aluminium chloride and forms Aluminium deuteroxide. The process is called Deuterolysis.

$$AlCl_3 + 3\,D_2O \longrightarrow \underset{\text{Aluminium deuteroxide}}{Al(OD)_3} + 3\,DCl$$

Uses:

1) Used as a moderator in Nuclear reactors.

2) Used as a tracer for studying reaction mechanisms.

HYDROGEN AND ITS COMPOUNDS

UNIT: 3

1. 1 Hydrogen Peroxide – preparation methods, physical and chemical properties – oxidation, reduction – decomposition- disproportionate and addition reaction
2. Detection of Hydrogen peroxide. Structure of H_2O_2, uses of H_2O_2

VERY SHORT ANSWER QUESTIONS:

1. What is perhydrol?

A. Perhydrol is 30% W/V hydrogen peroxide (or) 100 V H_2O_2.

2. When ozone is passed into a solution of H_2O_2. What is the substance that is reduced?

A. $H_2O_2 + O_3 \longrightarrow H_2O + 2O_2$

H_2O_2 is reduced to water. The oxidation of O_2 changes from -1to 0

3. Calculate the volume of oxygen liberated at STP when 3.4gm of H_2O_2 is heated.

A. $2H_2O_2 \longrightarrow 2H_2O + O_2$

2×34gm $\longrightarrow$ liberates 22.4 Lit O_2 gas at STP

3.4gm of H_2O_2 liberates

$$= \frac{3.4 \times 22.4}{2 \times 34} = 1.12 \text{ Lit of } O_2$$

4. Mention two uses of hydrogen peroxide.

A. 1) H_2O_2 is used as oxidant in the lab

2) It is used to restore the colour of tarnished lead paintings.

5. What happens when titanium dioxide reacts with H_2O_2 in the presence of conc. H_2SO_4?

A. Orange colour is formed. It is due to formation of pertitanic acid

$Ti(SO_4)_2 + H_2O_2$ ----------) $H_2TiO_4 + 2H_2SO_4$

6. How is Hydrogen peroxide prepared by auto oxidation method?

A. 2 – ethyl anthraquinol is oxidized by air into hydrogen peroxide and 2 – ethyl anthraquinone.It is a cyclic process.The anthraquinone is reduced to anthraquinol with hydrogen using Pt (or) Pd (or) Ni catalyst

7. A white painting has turned black over the years. What do you do to restore its original colour?

A. Original colour of tarnished lead painting is restored by washing with H_2O_2

$$\underset{\text{black}}{PbS} + 4H_2O_2 \longrightarrow \underset{\text{white}}{PbSO_4} + 4H_2O$$

8. Name the product formed when chlorine reacts with H_2O_2. Give the chemical equation.

$$H_2O_2 + Cl_2 \longrightarrow 2HCl + O_2$$

9. $A + H_2O_2 \longrightarrow B + O_2$. In this reaction, what is the role of H_2O_2/oxidant or reductant. Why?

A. H_2O_2 acts as reductant in this reaction. Because it undergoes oxidation

10. Will H_2O_2 be formed if H_2SO_4 ionizes into H^+ and SO_4^{-2} ions? Give the corresponding reaction.

A. $H_2SO_4 \longrightarrow 2H^+ + SO_4^{-2}$

$2SO_4^{-2} \longrightarrow S_2O_8^{-2} + 2e^-$ (at anode)

$2H^+ + 2e^- \longrightarrow H_2$ (at cathode)

11. How are the different units of the strengths of H_2O_2 related? Express.

A. The different ways of expressing the strength of H_2O_2 are % $[w/v]$; M, N and volume strength. The inter relation between them can be written as

10 vol $H_2O_2 = 3.036\%[w/v] = 0.893M = 1.786N$

12. Write the partial equations for the reaction of $KMnO_4$ with H_2O_2

A. $H_2O_2 \longrightarrow H_2O + [O] \longrightarrow \left[2H^+ + O_3 + 2e^-\right] \times 5$

$MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O \times 2$

Adding

$2MnO_{4(aq)}^- + 6H^+{}_{(aq)} + 5H_2O_{2(aq)} \longrightarrow 2Mn^{-2}{}_{(aq)} + 8H_2O_{(1)} + 5O_{2(g)}$

13. Complete and balance the following equation.

A. $I_2 + H_2O_2 \longrightarrow I^- + H_2O + O_2$

The balanced equation is

$$I_{2(s)} + H_2O_{2(aq)} + 2OH^-{}_{(aq)} \longrightarrow 2I^-{}_{(aq)} + H_2O + O_{2\,(g)}$$

14. What is the nature of H_2O_2? Oxidant or Reductant?

A. H_2O_2 is oxidized to O_2. Hence H_2O_2 is reductant. (since I_2 is reduced to I^-), the other half reaction must be oxidation)

Moist silver oxide is reduced to silver by H_2O_2

$$Ag_2O + H_2O_2 \longrightarrow 2Ag + H_2O + O_2$$

15. What happens when hydrogen peroxide is added to Au_2O?

A Au_2O is similar to Ag_2O. So it gives Au metal with H_2O_2

16. Identify the oxidant and reductant in the following reaction.

$$\underset{(0)}{O_3} + \underset{(-1)}{H_2O_{2(aq)}} \longrightarrow \underset{(-2)}{H_2O_{(\ell)}} + \underset{(0)}{2O_{2(g)}}$$

A. H_2O_2 is oxidant as it is reduced to H_2O. The oxidation number of oxygen changes from '-1' to '-2'. H_2O_2 is reductant as it is oxidized to O_2. The oxidation number of oxygen changes from '-1' to '0'

SHORT ANSWER TYPE QUESTIONS:

1. How is pure H_2O_2 prepared in the laboratory?

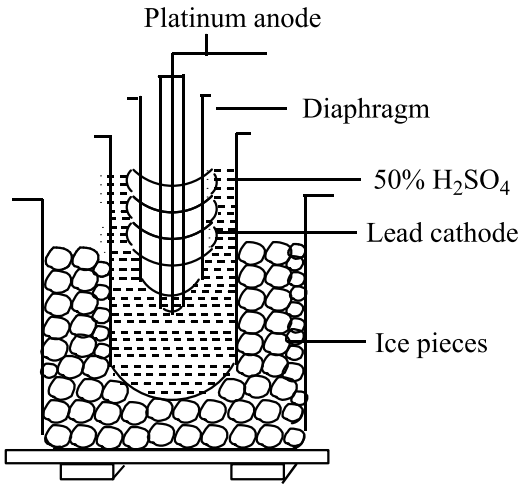
A. **From** Na_2O_2: When calculated quantity of Na_2O_2 is added in small quantities to 20% ice cold solution of H_2SO_4, H_2O_2 obtained

$$Na_2O_2 + H_2SO_4 \longrightarrow \underset{(\text{Glauber's salt crystals})}{Na_2SO_4.10H_2O} + H_2O_2$$

H_2O_2 is separated by decantation

2. Describe electrolytic method for the preparation of H_2O_2

A. Hydrogen peroxide is manufactured by the electrolysis of 50% sulphuric acid using platinum anode and lead wire as cathode separated by a porcelain diaphragm. The electrolytic cell is a stoneware vessel.



Manufacture of H_2O_2
Electrolytic process

The vessel is placed in a trough of ice to maintain $0°C$ temperature

On passing current the following reactions takes place

$$2H_2SO_4 ----)2H^+ + 2HSO_4^- \left(\text{ionization }\right)$$

Reaction at anode: $2HSO_4^- \longrightarrow H_2S_2O_8 + 2e^-$

Bisulphate ions gets discharged by losing electrons and forms perdisulphuric acid. This is taken in a special apparatus and distilled under vacuum. The perdisulphuric acid gets hydrolysed first to permono sulphuric acid and then to H_2O_2

$$H_2S_2O_8 + H_2O \longrightarrow H_2SO_5 + H_2SO_4$$

$$H_2SO_5 + H_2O \longrightarrow H_2SO_4 + H_2O_2$$

Reaction at cathode: $2H^+ + 2e^- \longrightarrow H_2 \uparrow$

3. What for auto – oxidation method is used. Describe it.

A. H_2O_2 is manufactured by this method. It is a modern method. In this method 2 – ethyl anthraquinol is oxidized by air to 2 – ethyl anthraquinol and H_2O_2

2 – ethyl anthraquinone is reduced with H_2 in the presence of Pd of Pt catalyst. 2 – ethyl anthraquinol is formed. Thus, this is a cyclic process

4. Give the salient features of concentrating a dilute solution of H_2O_2

A. The concentration of H_2O_2 involves three stages

Stage (1): The dilute solution of H_2O_2 solution is carefully evaporated on a water bath under reduced pressure. Then 30% H_2O_2 solution is obtained.

Stage (2): The 30% H_2O_2 solution is heated in a distillation flask under reduced pressure. Then 90% H_2O_2 is obtained.

Stage (3): The 90% H_2O_2 is subjected to crytallisation using solid CO_2 and ether, 100% pure H_2O_2 separates out.

5. Give the different methods of expressing the strengths of H_2O_2 solution

A. **i) Strength of H_2O_2 expressed in volumes:**

Eg : 10 vol H_2O_2, 20 vol H_2O_2 and 100 vol H_2O_2

20 vol H_2O_2 means 1ml of this solution liberates 20ml of O_2 gas at STP

$\therefore$ 10ml of 20 vol liberates 200ml of oxygen at STP

10 vol H_2O_2 solution means 1ml of this solution liberates 10ml of O_2 gas at STP

ii) To express the strength in % (W/V) :

H_2O_2 decomposes, as shown below

$$\underset{2\,\text{moles}}{2H_2O_2} \longrightarrow 2H_2O + \underset{1\,\text{mole}}{O_2}$$

1 mole of O_2 gas is liberated from 2 moles of H_2O_2

i.e, 22.4 lit of O_2 is given by 2 × 34g of H_2O_2

$\therefore$ 10 lit of O_2 gas at STP can be given by?

Weight of H_2O_2 in 1 lit of solution = $\dfrac{2\times 34\times 10}{22.4} = 30.36\,g$

30.36 g (W/V) refers to the weight of H_2O_2 in 1000 ml of solution

6. Give any three oxidising properties of H_2O_2

A. **Oxidising properties:**

1) It oxidizes black PbS into white $PbSO_4$

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

2) It liberates I_2 from aqueous KI solution

$$2KI_{(aq)} + H_2O_2 \longrightarrow 2KOH + I_2$$

3) It oxidizes mercury to mercuric oxide (HgO) in acidic medium

$$Hg + H_2O_2 \xrightarrow{H_2SO_4} HgO + H_2O$$

7. Give any three reducing properties of H_2O_2

A. **Reducing properties:**

1) H_2O_2 reduces Cl_2 or Br_2 to HCl or HBr

$$H_2O_2 + Cl_2 \longrightarrow 2HCl + O_2$$

$$H_2O_2 + Br_2 \longrightarrow 2HBr + O_2$$

2) H_2O_2 reduces moist Ag_2O to white metallic Ag

$$Ag_2O + H_2O_2 \longrightarrow 2Ag + H_2O + O_2$$

3) H_2O_2 reduces PbO_2 to PbO (yellow coloured litharge)

$$PbO_2 + H_2O_2 \longrightarrow PbO + H_2O + O_2$$

8. Give any four uses of H_2O_2

A. **Uses of H_2O_2 : H_2O_2 is used**

1) As bleaching agent for delicate materials like silk, wool, ivory

2) Highly concentrated H_2O_2 acts as rocket fuel

3) As an antiseptic in medical field (Disinfectant)

4) To restore the colour of old oil paintings which contain lead

9. Draw the structure of hydrogen peroxide molecule.

A. **Structure of H_2O_2 :**

H_2O_2 has open book structure. It is non – linear and non – planar molecule. The two oxygen atoms can be considered to be present on the spine of a book. The two hydrogen atoms can be considered to be present on the two covers

H – O – O bond angle is $94°48'$

O – O bond length is $1.48\,A°$. Dihedral angle in gaseous state is $111°30'$ and in solid state this angle reduces to $90°$

10. Calculate the percentage strength and normality of 20vol H_2O_2

A. 20 volume H_2O_2 solution means 1ml of H_2O_2 decomposes to give 20ml of O_2 at STP

1 litre of H_2O_2 decomposes to give 20 lit of O_2

$$\underset{2\,\text{moles}}{2H_2O_2} \longrightarrow 2H_2O + \underset{1\,\text{mole}}{O_2}$$

1 mole of O_2 is given by 2 moles of H_2O_2

22.4 mole of O_2 is given by 2 × 34gm of H_2O_2

$\therefore$ 20 lit of O_2 is given by ----------?

$$= \frac{20 \times 2 \times 34}{22.4} = 60.71\,gm$$

$\therefore$ weight of H_2O_2 in 1 litre of solution = 60.71 gm

$$\therefore \text{Normality} = \frac{\text{weight of } H_2O_2}{\text{equivalent weight of } H_2O_2} \times \frac{1}{V_{(lit)}}$$

$$= \frac{60.71}{17} \times \frac{1}{1} = 3.57\,N$$

LONG ANSWER TYPE QUESTIONS:

1. How is hydrogen peroxide prepared by electrolytic method? Write any 2 oxidising and 2 reducing properties of H_2O_2.

A. Manufacture of H_2O_2 by electrolytic method:

1) H_2O_2 is manufactured by the electrolysis of 50% ice cold H_2SO_4 solution which acts as electrolyte

2) Electrolyte is taken in a porcelain vessel

3) It is electrolysed by using a platinum anode and lead cathode. Electrodes are separated by a porus diaphragm.

4) The vessel is placed in a ice box to maintain the temperature at 0^oC

5) On passing electric current through electrolyte, the following reactions take place perdisulphuric acid $H_2S_2O_8$ is formed at anode

$$2H_2SO_4 \text{ on ionisation} \rightarrow 2H^{(+)} + 2HSO_4^{(-)}$$

AT ANODE: $2HSO_4^{(-)} \rightarrow H_2S_2O_8 + 2e^{(-)}$

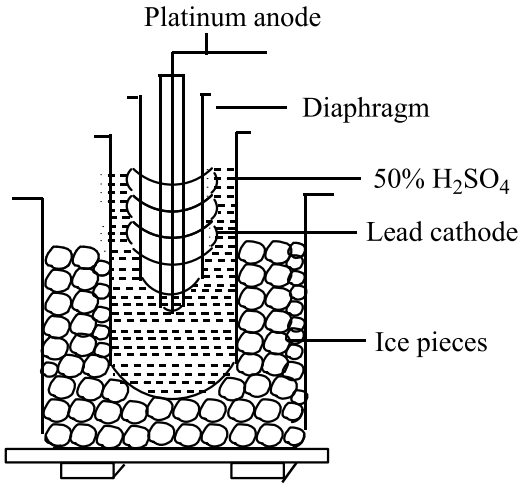
AT CATHODE: $2H^{(+)} + 2e^{(-)} \rightarrow H_2$

Net reaction

$$2H_2SO_4 \rightarrow H_2S_2O_8 + H_2$$

On distillation of an aqueous solution solution of perdisulphuric acid, 30% H_2O is obtained

$$H_2S_2O_8 + 2H_2O \rightarrow 2H_2SO_4 + H_2O_2$$



Manufacture of H_2O_2
Electrolytic process

Chemical Properties of H_2O_2:

Oxidising properties:

1) It oxidizes black PbS into white $PbSO_4$

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

2) It liberates I_2 from aqueous KI solution

$$2KI_{(aq)} + H_2O_2 \rightarrow 2KOH + I_2$$

3) It oxidizes potassium ferrocynaide to potassium ferricyanide in acidic solution

$$2K_4[Fe(CN)_6] + H_2SO_4 + 2H_2O \rightarrow 2K_3[Fe(CN)_6] + K_2SO_4 + 2H_2O$$

(potassium ferrocyanide) (potassium ferricyanide)

4) It oxidizes formaldehyde [HCHO] to formic acid [HCOOH] in alkaline solution in the presence of pyrogallol. Pyrogallol is 1,2,3 trihydroxybenzene

$2HCHO + H_2O_2$ in the presence of Alkali $\rightarrow 2HCOOH + H_2$

Note: In the oxidation of formaldehyde, H_2O_2 utilizes its two oxygen atoms hence H_2 is liberated.

Reducing properties:

1) H_2O_2 reduces Cl_2 or Br_2 to HCl or HBr

$$H_2O_2 + Cl_2 \rightarrow 2HCl + O_2$$

$$H_2O_2 + Br_2 \rightarrow 2HBr_2 + O_2$$

2) H_2O_2 reduces moist Ag_2O to white metallic Ag

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

3) H_2O_2 reduces acidified $KMnO_4$ and decolourises its pink colour

$2KMnO_4 + 3H_2SO_4 + 5H_2O_2 \rightarrow K_2SO_4 + 2MnSO_4 + 8H_2O + 5O_2$

4) In alkaline medium $KMnO_4$ is reduced to MnO_2

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