

Hydrogen

9 Chapter

Exercise

1. **Justify the position of hydrogen in the periodic table on the basis of its electronic configuration.**

Ans: Hydrogen is the first element of the periodic table. Its electronic configuration is $[1s^1]$. Due to the presence of only one electron in its 1s shell, hydrogen exhibits a dual behavior, that means, it resembles both alkali metals and halogens.

Resemblance with alkali metals:

- Like alkali metals, hydrogen contains one valence electron in its outer (valence) shell.

H: $1s^1$

Li: $[\text{He}]2s^1$

Na: $[\text{Ne}]3s^1$

Hence, it can lose one electron to form a unipositive ion.

- Like alkali metals, hydrogen combines with electronegative elements to form oxides, halides, and sulphides.

Resemblance with halogens:

- Both hydrogen and halogens require one electron to complete their octets.

H : $1s^1$

F : $1s^2 2s^2 2p^5$

Cl : $1s^2 2s^2 2p^6 3s^2 3p^5$

Hence, hydrogen can gain one electron to form a uninegative ion.

- Like halogens, it forms a diatomic molecule and several covalent compounds.

Though hydrogen shows similarity with both alkali metals and halogens, it differs from them on some grounds. Unlike alkali metals, hydrogen does not possess metallic characteristics. On the other hand, it possesses a high ionization enthalpy. Also, it is less reactive than halogens.

Due to these reasons, hydrogen cannot be placed with alkali metals (group 1) or with halogens (group 17). In addition, it was also established that H^+ ions cannot exist freely as they are extremely small. H^+ ions are always associated with other atoms or molecules. Hence, hydrogen is best placed separately in the periodic table.

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

Ans: Hydrogen has three isotopes. They are:

- i. Protium, ${}_1^1H$;
- ii. Deuterium, ${}_1^2H$ or D, and
- iii. Tritium, ${}_1^3H$ or T

The mass ratio of protium, deuterium and tritium is 1:2:3.

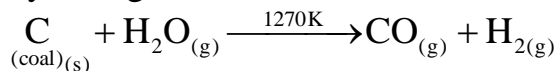
3. Why does hydrogen occur in a diatomic form rather than in a monoatomic form under normal conditions?

Ans: The ionization enthalpy of hydrogen atom is very high $(1312 \text{ kJ mol}^{-1})$.

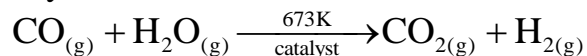
Hence, it is very hard to remove its only valence electron. As a result, its tendency to exist in the monoatomic form is rather low. Instead, hydrogen forms a covalent bond with another hydrogen atom and exists as a diatomic (H_2) molecule.

4. How can the production of dihydrogen, obtained from ‘coal gasification’, be increased?

Ans: Dihydrogen is produced by coal gasification method as:



The yield of dihydrogen (obtained from coal gasification) can be increased by reacting carbon monoxide (formed during the reaction) with steam in the presence of iron chromate as a catalyst. The reaction is as follows:

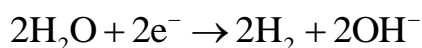


This reaction is called the water-gas shift reaction. Carbon dioxide is removed by scrubbing it with a solution of sodium arsenite.

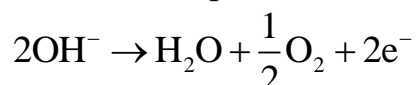
5. Describe the bulk preparation of dihydrogen by electrolytic method. What is the role of an electrolyte in this process?

Ans: Dihydrogen is prepared by the electrolysis of acidified or alkaline water using platinum electrodes. Generally, 15 – 20% of an acid (H_2SO_4) or a base (NaOH) is used.

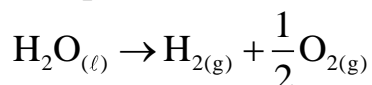
Reduction of water occurs at the cathode as follows:



At the anode, oxidation of OH^- ions takes place as follows:

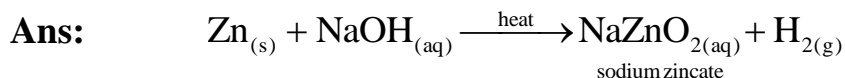
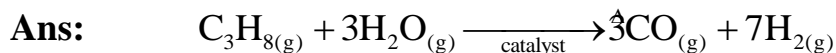
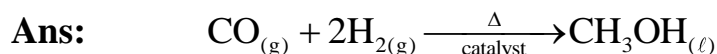
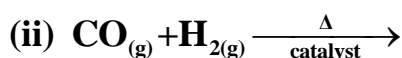
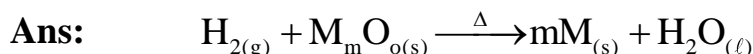


Therefore, the net reaction can be represented as follows:



Electrical conductivity of pure water is very low due to the absence of ions. Therefore, electrolysis of pure water also takes place at a low rate. If an electrolyte such as an acid or a base is added to the process, the rate of electrolysis increases. The addition of the electrolyte makes the ions available in the process for the conduction of electricity in pure water and for electrolysis to take place.

6. Complete the following reactions:



7. Discuss the consequences of high enthalpy of H–H bond in terms of chemical reactivity of dihydrogen.

Ans: The ionization enthalpy of H–H bond is very high with a value 1312 kJ mol^{-1} . This indicates that hydrogen has a low tendency to form H^+ ions. Its ionization enthalpy value is relatively comparable to that of halogens. Hence, it forms diatomic molecules (H_2), hydrides with elements, and a large number of covalent bonds. Since ionization enthalpy is very high, hydrogen does not possess metallic characteristics such as lustre, ductility, etc. like that of metals.

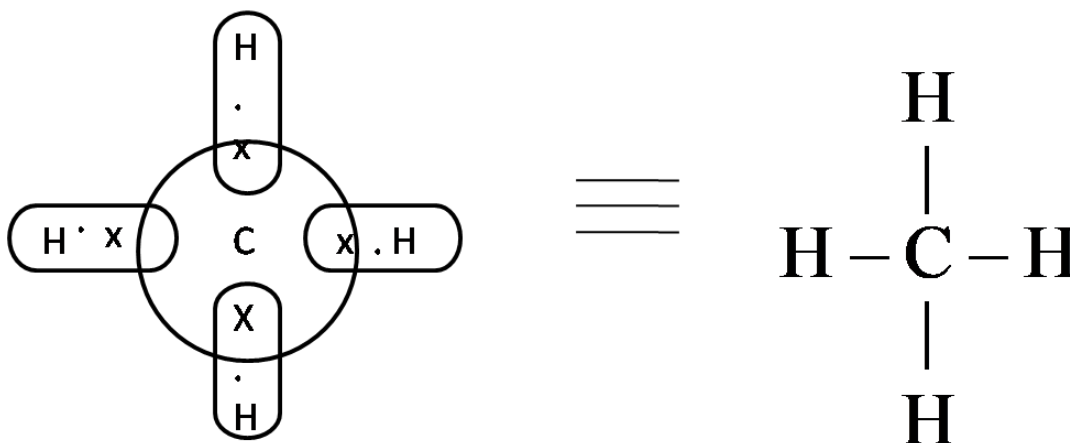
8. What do you understand by (i) electron-deficient, (ii) electron-precise, and (iii) electron rich compounds of hydrogen? Provide justification with suitable examples.

Ans: Molecular hydrides are classified on the basis of the presence of the total number of electrons and bonds in their Lewis structures as:

- (i) Electron-deficient hydrides
- (ii) Electron-precise hydrides
- (iii) Electron-rich hydrides

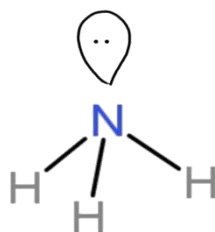
An electron-deficient hydride has very few electrons that is less than that required for representing its conventional Lewis structure example diborane (B_2H_6). In diborane (B_2H_6), there are six bonds in all, out of which only four bonds are regular two centered-two electron bonds. The remaining two bonds are three centered-two electron bonds which means, two electrons are shared by three atoms. Hence, its conventional Lewis structure cannot be drawn.

An electron-precise hydride has a sufficient number of electrons to be represented by its conventional Lewis structure example CH_4 . The Lewis structure can be written as:



In this structure, four regular bonds are formed where two electrons are shared by two atoms.

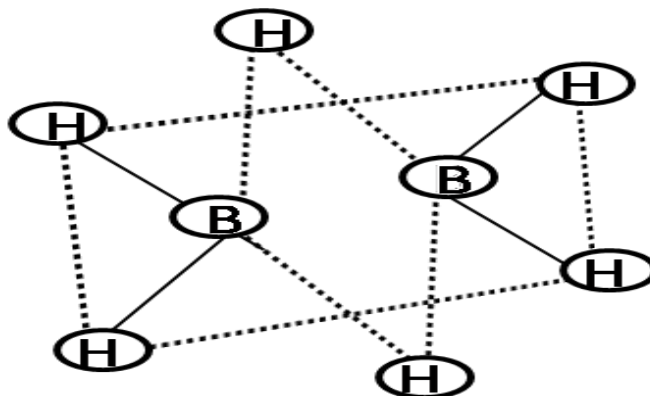
An electron-rich hydride contains excess electrons as lone pairs like that in NH_3 . The structure is as follows:



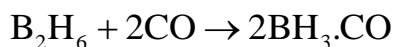
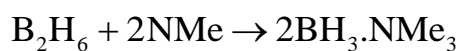
There are three regular bonds in all with a lone pair of electrons on the nitrogen atom.

9. What characteristics do you expect from an electron-deficient hydride with respect to its structure and chemical reactions?

Ans: An electron-deficient hydride does not have sufficient electrons to form a regular bond in which two electrons are shared by two atoms for example, B_2H_6 , Al_2H_6 etc. These hydrides cannot be represented by conventional Lewis structures. For instance, diborane B_2H_6 contains four regular bonds and two three centered-two electron bond. Its structure can be represented as:

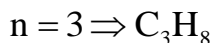
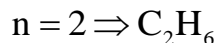
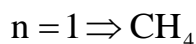


Since these hydrides are electron-deficient, they have a tendency to accept electrons. Hence, they act as Lewis acids as follows:



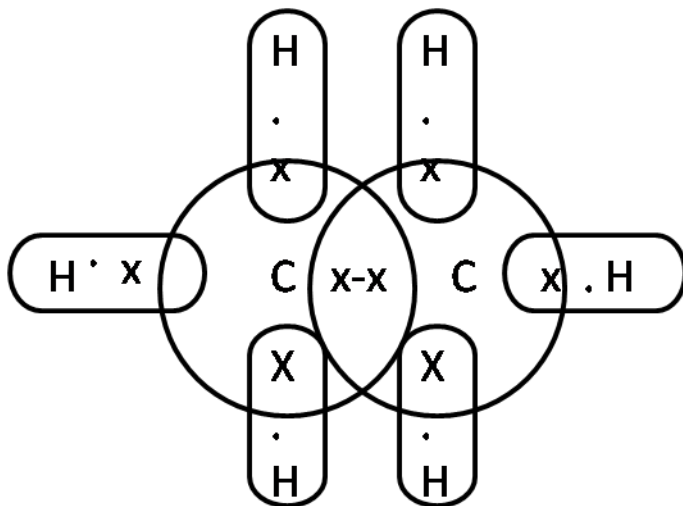
10. Do you expect the carbon hydrides of the type (C_nH_{2n+2}) to act as ‘Lewis’ acid or base? Justify your answer.

Ans: For carbon hydrides of type C_nH_{2n+2} , the following hydrides are possible as:



And so on.

For a hydride to act as a Lewis acid that is electron accepting, it should be electron-deficient. Also, for it to act as a Lewis base that is electron donating, it should be electron-rich. Taking instance of C_2H_6 , the total number of electrons are 14 and the total covalent bonds are seven. Hence, the bonds are regular $2e^-$ -2 centered bonds as follows.



Hence, hydride C_2H_6 has sufficient electrons to be represented by a conventional Lewis structure. Therefore, it is an electron-precise hydride, having all atoms with complete octets. Thus, it can neither donate nor accept electrons to act as a Lewis acid or Lewis base

11. What do you understand by the term “non-stoichiometric hydrides”? Do you expect this type of the hydrides to be formed by alkali metals? Justify your answer.

Ans: Non-Stoichiometric hydrides are hydrogen-deficient compounds formed by the reaction of dihydrogen with d-block and f-block elements. These hydrides do

not follow the law of constant composition. For example: $\text{LaH}_{2.87}$, $\text{YbH}_{2.55}$, $\text{TiH}_{1.5-1.8}$ etc.

Alkali metals form stoichiometric hydrides. These hydrides are ionic in nature. Hydride ions have comparable sizes (208 pm) with alkali metal ions. Hence, strong binding forces exist between the constituting metal and hydride ion. As a result, stoichiometric hydrides are formed.

Hence, alkali metals will not form non-stoichiometric hydrides.

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

Ans: Metallic hydrides are hydrogen deficient that is they do not hold the law of constant composition. It has been established that in the hydrides of d- block elements like Ni, Pd, Ce, and Ac, hydrogen occupies the interstitial position in lattices allowing further absorption of hydrogen on these metals. Metals like Pd, Pt, etc. have the capacity to accommodate a large volume of hydrogen. Therefore, they are used for the storage of hydrogen and serve as a source of energy.

13. How does the atomic hydrogen or oxy-hydrogen torch function for cutting and welding purposes? Explain.

Ans: Atomic hydrogen atoms are produced by the dissociation of dihydrogen with the help of an electric arc. This releases a huge amount of energy ($435.88 \text{ kJ mol}^{-1}$). This energy can be used to generate a temperature of 4000 K, which is ideal for welding and cutting metals. Hence, atomic hydrogen or oxy-hydrogen torches are used for these purposes. Thus, atomic hydrogen is allowed to recombine on the surface to be welded to generate the desired temperature.

14. Among NH_3 , H_2O and HF , which would you expect to have highest magnitude of hydrogen bonding and why?

Ans: The extent of hydrogen bonding depends upon electronegativity and the number of hydrogen atoms available for bonding. Among nitrogen, fluorine, and oxygen, the increasing order of their electronegativities are $\text{N} < \text{O} < \text{F}$.

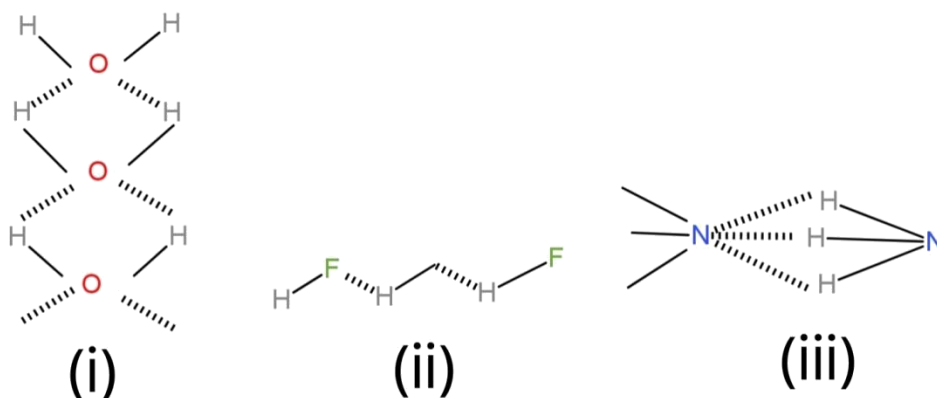
Hence, the expected order of the extent of hydrogen bonding is $\text{HF} > \text{H}_2\text{O} > \text{NH}_3$.

But, the actual order is $\text{H}_2\text{O} > \text{HF} > \text{NH}_3$.

Although fluorine is more electronegative than oxygen, the extent of hydrogen bonding is higher in water. There is a shortage of hydrogen atoms in HF, whereas there are exactly the right numbers of hydrogen atoms in water. As a result, only

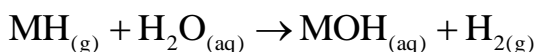
straight chain bonding takes place. On the other hand, oxygen forms a huge ring-like structure through its high ability of hydrogen bonding.

In case of ammonia, the extent of hydrogen bonding is limited because nitrogen has only one lone pair. Therefore, it cannot satisfy all hydrogen atoms.



- 15. Saline hydrides are known to react with water violently producing fire. Can CO_2 , a well known fire extinguisher, be used in this case? Explain.**

Ans: Saline hydrides like NaH , LiH , etc. react with water to form a base and hydrogen gas. The chemical equation used to represent the reaction can be written as:



The reaction is violent and produces fire.

CO_2 is heavier than dioxygen. It is used as a fire extinguisher because it covers the fire as a blanket and inhibits the supply of dioxygen, thereby dousing the fire.

CO_2 can be used in the case of saline hydrides as well. It is heavier than dihydrogen and will be effective in isolating the burning surface from dihydrogen and dioxygen.

- 16. Arrange the following**

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

Ans: The electrical conductance of a molecule depends upon its ionic or covalent nature. Ionic compounds conduct, whereas covalent compounds do not. BeH_2 is a covalent hydride. Hence, it does not conduct electricity. CaH_2 is

an ionic hydride, which conducts electricity in the molten state. Titanium hydride, TiH_2 is metallic in nature and conducts electricity at room temperature. Hence, the increasing order of electrical conductance is as follows:



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

Ans: The ionic character of a bond depends upon the electronegativities of the atoms involved.

The higher the difference between the electronegativities of atoms, the smaller is the ionic character.

Electronegativity decreases down the group from Lithium to Caesium. Hence, the ionic character of their hydrides will increase (as shown below):



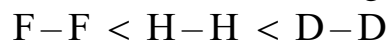
(iii) H–H, D–D and F–F in order of increasing bond dissociation enthalpy.

Ans: Bond dissociation energy depends upon the bond strength of a molecule, which in turn depends upon the attractive and repulsive forces present in a molecule.

The bond pair in D–D bond is more strongly attracted by the nucleus than the bond pair in H–H bond. This is because of the higher nuclear mass of D_2 . The stronger the attraction the greater will be the bond strength and the higher will be the bond dissociation enthalpy. Hence, the bond dissociation enthalpy of D–D is higher than H–H.

However, bond dissociation enthalpy is the minimum in the case of F–F. The bond pair experiences strong repulsion from the lone pairs present on each F-centre.

Therefore, the increasing order of bond dissociation enthalpy is as follows:



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

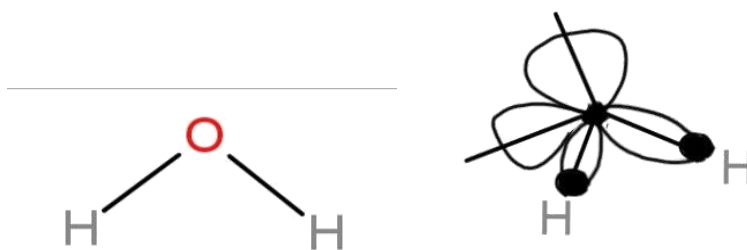
Ans: Ionic hydrides are strong reducing agents. NaH can easily donate its electrons. Hence, it is most reduced in nature.

Both, MgH_2 and H_2O are covalent hydrides. H_2O is less reducing than MgH_2 since the bond dissociation energy of H_2O is higher than MgH_2 . Hence, the increasing order of the reducing property is as follows:

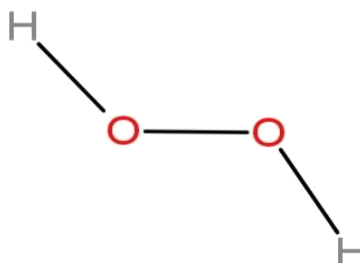


17. Compare the structures of H_2O and H_2O_2 .

Ans: In gaseous phase, water molecule has a bent form with a bond angle of 104.5° . The O–H bond length is 95.7 pm. The structure can be shown as:

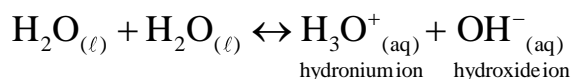


Hydrogen peroxide has a non-planar structure both in gas and solid phase. The dihedral angle in gas and solid phase is 111.5° and 90.2° respectively. The structure can be shown as:



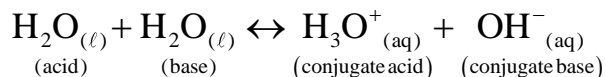
18. What do you understand about the term 'auto-protolysis' of water? What is its significance?

Ans: Auto-protolysis (self-ionization) of water is a chemical reaction in which two water molecules react to produce a hydroxide ion (OH^-) and a hydronium ion (H_3O^+). The reaction involved can be represented as:



Auto-protolysis of water indicates its amphoteric nature, that is, its ability to act as an acid as well as a base.

The acid-base reaction can be written as:

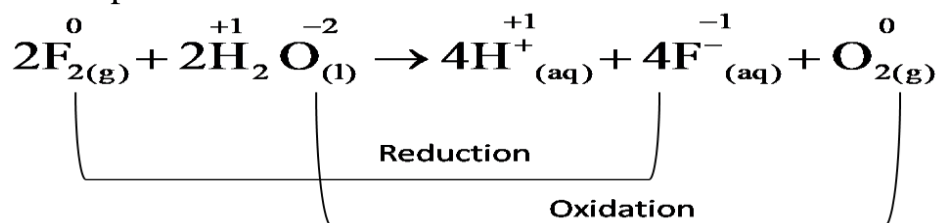


19. Consider the reaction of water with F_2 and suggest, in terms of oxidation and reduction, which species are oxidized/ reduced.

Ans: The reaction between fluorine and water can be represented as:

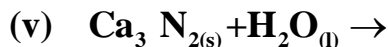
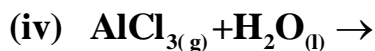
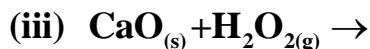
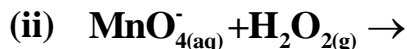
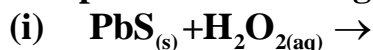


This is an example of a redox reaction as water is getting oxidized to oxygen, while fluorine is being reduced to fluoride ion. The oxidation numbers of various species can be represented as:



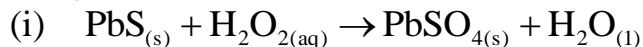
Fluorine is reduced from zero to (-1) oxidation state. A decrease in oxidation state indicates the reduction of fluorine. Water is oxidized from (-2) to zero oxidation state. An increase in oxidation state indicates oxidation of water.

20. Complete the following chemical reactions.

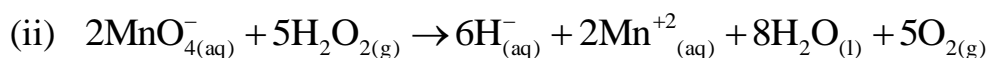


Classify the above into (a) hydrolysis, (b) redox and (c) hydration reactions.

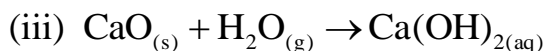
Ans: The given chemical reactions are as follows:



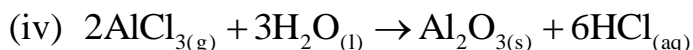
H_2O_2 is acting as an oxidizing agent in the reaction. Hence, it is a redox reaction.



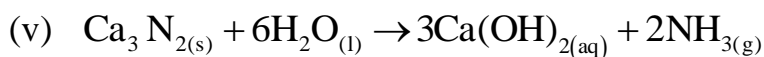
H_2O_2 is acting as a reducing agent in the acidic medium, thereby oxidizing $\text{MnO}_4^- (\text{aq})$. Hence, the given reaction is a redox reaction.



The reactions in which a compound reacts with water to produce other compounds are called hydrolysis reactions. The given reaction is hydrolysis.



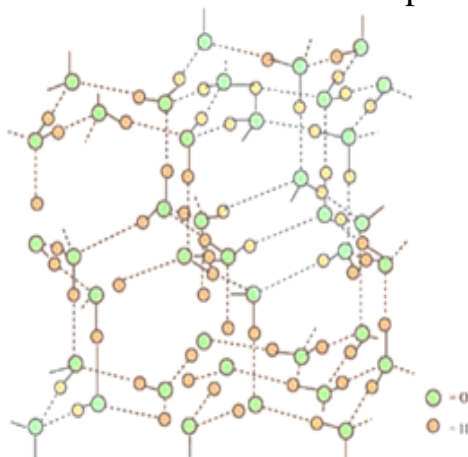
The reactions in which a compound reacts with water to produce other compounds are called hydrolysis reactions. The given reaction represents hydrolysis of AlCl_3 .



The reactions in which a compound reacts with water to produce other compounds are called hydrolysis reactions. The given reaction represents hydrolysis of Ca_3N_2 .

21. Describe the structure of the common form of ice.

Ans: Ice is the crystalline form of water. It takes a hexagonal form if crystallized at atmospheric pressure, but condenses to a cubic form if subjected to low temperature. The three-dimensional structure of ice is represented as:



The structure is highly ordered and has hydrogen bonding. Each oxygen atom is surrounded tetrahedrally by four other oxygen atoms at a distance of 276 pm. The structure also contains wide holes that can hold molecules of appropriate sizes interstitially.

22. What causes the temporary and permanent hardness of water?

Ans: Temporary hardness of water is due to the presence of soluble salts of magnesium and calcium in the form of hydrogen carbonates (MHCO_3 , where $\text{M} = \text{Mg, Ca}$) in water. Permanent hardness of water is because of the presence of soluble salts of calcium and magnesium in the form of chlorides in water.

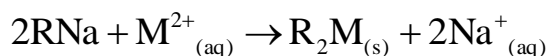
23. Discuss the principle and method of softening of hard water by synthetic ion-exchange resins.

Ans: The process of treating permanent hardness of water using synthetic resins is based on the exchange of cations (example, Na^+ , Ca^{2+} , Mg^{2+} etc) and anions (example, Cl^- , SO_4^{2-} , HCO_3^- etc) present in water by H^+ and OH^- ions respectively.

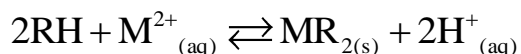
Synthetic resins are of two types:

- i. Cation exchange resins
- ii. Anion exchange resins

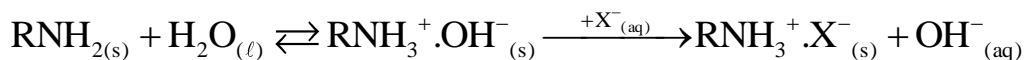
Cation exchange resins are large organic molecules that contain the $-\text{SO}_3\text{H}$ group. The resin is first changed to RNa (from RSO_3H) by treating it with NaCl . This resin then exchanges Na^+ ions with Ca^{2+} and Mg^{2+} ions, thereby making the water soft.



There are cation exchange resins in H^+ form. The resins exchange H^+ ions for Na^+ , Ca^{2+} and Mg^{2+} ions.



Anion exchange resins exchange OH^- ions for anions like Cl^- , SO_4^{2-} etc. present in water.



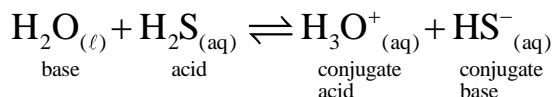
During the complete process, water first passes through the cation exchange process. The water obtained after this process is free from mineral cations and is acidic in nature. This acidic water is then passed through the anion exchange process where OH^- ions neutralize the H^+ ions and de-ionize the water obtained.

24. Write chemical reactions to show the amphoteric nature of water.

Ans: The amphoteric nature of water can be described on the basis of the following reactions:

- Reaction with H_2S

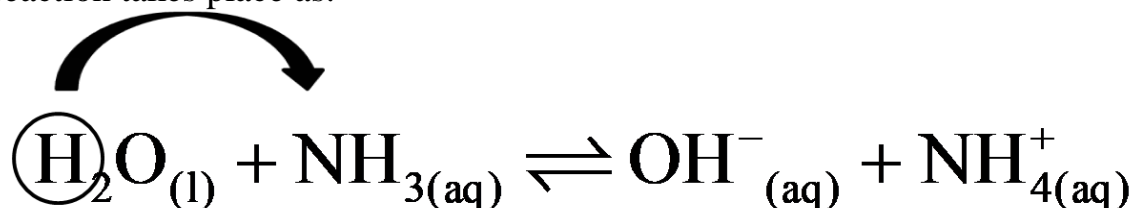
The reaction takes place as:



In the forward reaction, $\text{H}_2\text{O}_{(\ell)}$ accepts a proton from $\text{H}_2\text{S}_{(\text{aq})}$. Hence, it acts as a Lewis base.

- Reaction with NH_3

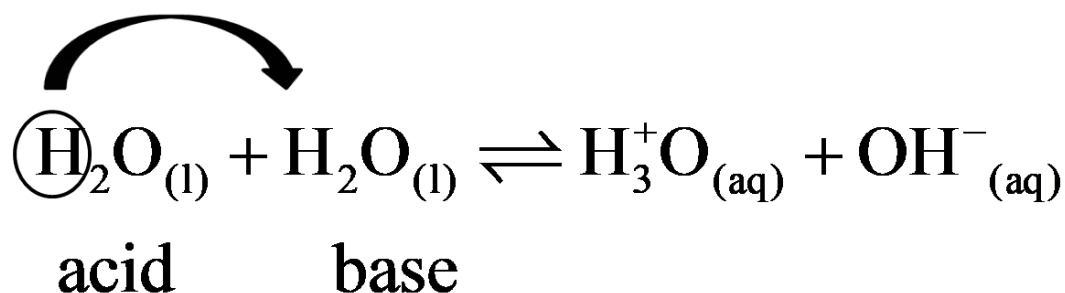
The reaction takes place as:



In the forward reaction, $\text{H}_2\text{O}_{(\ell)}$ donates its proton to $\text{NH}_{3(\text{aq})}$. Hence, it acts as a Lewis acid.

- Self-ionization of water

In the reaction, two water molecules react as:

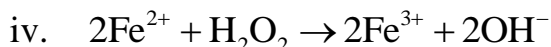
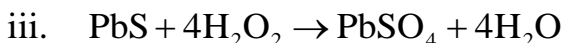


25. Write chemical reactions to justify that hydrogen peroxide can function as an oxidizing as well as reducing agent.

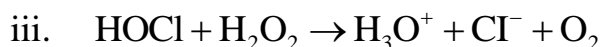
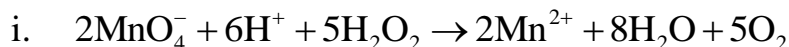
Ans: Hydrogen peroxide, H_2O_2 acts as an oxidizing as well as a reducing agent in both acidic and alkaline media.

Reactions involving oxidizing actions are:

- $2\text{Fe}^{2+} + 2\text{H}^+ + \text{H}_2\text{O}_2 \rightarrow 2\text{Fe}^{3+} + 2\text{H}_2\text{O}$
- $\text{Mn}^{2+} + \text{H}_2\text{O}_2 \rightarrow \text{Mn}^{4+} + 2\text{OH}^-$



Reactions involving reduction actions are:



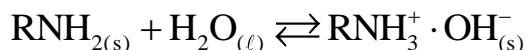
26. What is meant by ‘demineralised’ water and how can it be obtained?

Ans: Demineralised water is free from all soluble mineral salts. It does not contain any anions or cations. Demineralised water is obtained by passing water successively through a cation exchange (in the H^+ form) and an anion exchange (in the OH^- form) resin.

During the cation exchange process, H^+ exchanges for Na^+ , Mg^{2+} , Ca^{2+} , and other cations present in water.



In the anion exchange process, OH^- exchanges for anions such as CO_3^{2-} , SO_4^{2-} , Cl^- , HCO_3^- etc. present in water.



OH^- ions liberated in reaction (2) neutralize H^+ ions liberated in reaction (1), thereby forming water.

27. Is demineralised or distilled water useful for drinking purposes? If not, how can it be made useful?

Ans: Water is an important part of life. It contains several dissolved nutrients that are required by human beings, plants, and animals for survival. Demineralised water is free of all soluble minerals. Hence, it is not fit for drinking.

It can be made useful only after the addition of desired minerals in specific amounts, which are important for growth.

28. Describe the usefulness of water in biosphere and biological systems.

Ans: Water is essential for all forms of life. It constitutes around 65% of the human body and 95% of plants. Water plays an important role in the biosphere due to its high specific heat, thermal conductivity, surface tension, dipole moment, and dielectric constant.

The high heat of vapourization alongside heat of capacity of water helps in moderating the climate and body temperature of all living beings.

It acts as a carrier of various nutrients required by plants and animals for various metabolic reactions.

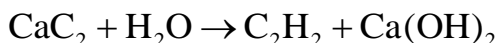
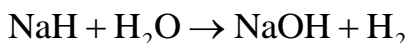
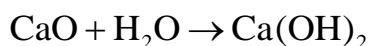
29. What properties of water make it useful as a solvent? What types of compound can it (i) dissolve, and (ii) hydrolyse?

Ans: A high value of dielectric constants ($78.39 \text{ C}^2 / \text{Nm}^2$) and dipole moment make water a universal solvent.

Water is able to dissolve most ionic and covalent compounds. Ionic compounds dissolve in water because of the ion-dipole interaction, whereas covalent compounds form hydrogen bonding and have the ability to dissolve in water.

Water can hydrolyze metallic and non-metallic oxides, hydrides, carbides, phosphides, nitrides and various other salts. During hydrolysis, H^+ and OH^- ions of water interact with the reacting molecule.

Some reactions are:

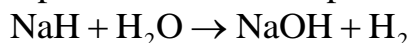


30. Knowing the properties of H_2O and D_2O , do you think that D_2O can be used for drinking purposes?

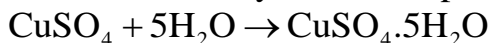
Ans: Heavy water (D_2O) acts as a moderator, which means it can slow the rate of a reaction. Due to this property of D_2O , it cannot be used for drinking purposes because it will slow down anabolic and catabolic reactions taking place in the body and lead to a casualty.

31. What is the difference between the terms ‘hydrolysis’ and ‘hydration’?

Ans: Hydrolysis is defined as a chemical reaction in which hydrogen and hydroxide ions (H^+ and OH^- ions) of water molecules react with a compound to form products. For example:

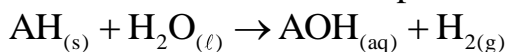


Hydration is defined as the addition of one or more water molecules to ions or molecules to form hydrated compounds. For example:



32. How can saline hydrides remove traces of water from organic compounds?

Ans: Saline hydrides are ionic in nature. They react with water to form a metal hydroxide along with the liberation of hydrogen gas. The reaction of saline hydrides with water can be represented as:



(where, A = Na, Ca, etc.)

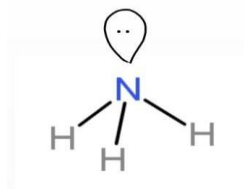
When added to an organic solvent, saline hydrides react with water present in it. Hydrogen escapes into the atmosphere leaving behind the metallic hydroxide. Furthermore, the dry organic solvent distills over.

33. What do you expect the nature of hydrides is, if formed by elements of atomic numbers 15, 19, 23 and 44 with dihydrogen? Compare their behaviour towards water.

Ans: The elements of atomic numbers 15, 19, 23, and 44 are nitrogen, potassium, vanadium, and ruthenium respectively.

i. Hydride of nitrogen

Hydride of nitrogen (NH_3) exist as a covalent molecule. It is an electron-rich hydride owing to the presence of excess electrons as a lone pair on nitrogen.



ii. Hydride of potassium

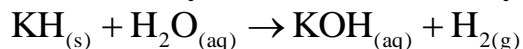
Dihydrogen forms an ionic hydride with potassium owing to the high electropositive nature of potassium. It is crystalline and non-volatile in nature.

iii. Hydrides of Vanadium and Ruthenium

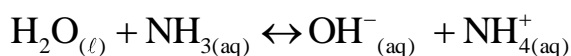
Both vanadium and ruthenium belong to the *d*-block of the periodic table. The metals of *d*-block form metallic or non-stoichiometric hydrides. Hydrides of vanadium and ruthenium are therefore metallic in nature having a deficiency of hydrogen.

iv. Behaviour of hydrides towards water

Potassium hydride reacts violently with water as:



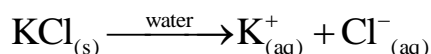
Ammonia (NH_3) behaves as a Lewis base and reacts with water as:



Hydrides of vanadium and Ruthenium do not react with water. Hence, the increasing order of reactivity of the hydrides is (V, Ru) $\text{H} < \text{NH}_3 < \text{KH}$.

34. Do you expect different products in solution when aluminium (III) chloride and potassium chloride are treated separately with (i) normal water (ii) acidified water, and (iii) alkaline water? Write equations wherever necessary.

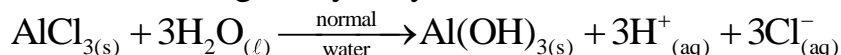
Ans: Potassium chloride (KCl) is the salt of a strong acid (HCl) and strong base (KOH). Hence, it is neutral in nature and does not undergo hydrolysis in normal water. It dissociates into ions as follows:



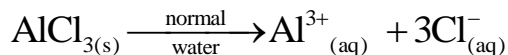
In acidified and alkaline water, the ions do not react and remain as such.

Aluminium (III) chloride is the salt of a strong acid (HCl) and weak base $[\text{Al}(\text{OH})_3]$.

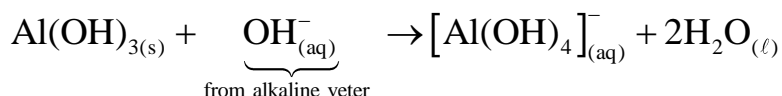
Hence, it undergoes hydrolysis in normal water.



In acidified water, H^{+} ions react with $[\text{Al}(\text{OH})_3]$ forming water and giving Al^{3+} ions. Hence, in acidified water, AlCl_3 will exist as $\text{Al}^{3+}_{(aq)}$ and $\text{Cl}^{-}_{(aq)}$ ions.



In alkaline water, the following reaction takes place:



35. How does H_2O_2 behave as a bleaching agent?

Ans: Hydrogen peroxide (H_2O_2) acts as a strong oxidizing agent both in acidic and basic media.

When applied on a cloth, it breaks the chemical bonds of the chromophores (colour producing agents). Hence, the visible light is not absorbed and the cloth gets whitened.

36. What do you understand by the terms:

(i) Hydrogen economy

Ans: Hydrogen economy is a technique of using dihydrogen in an efficient way. It involves transportation and storage of dihydrogen in the form of liquid or gas.

Dihydrogen releases more energy than petroleum and is more eco-friendly. Hence, it can be used in fuel cells to generate electric power. Hydrogen economy is about the transmission of this energy in the form of dihydrogen.

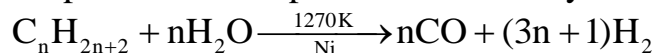
(ii) Hydrogenation

Ans: Hydrogenation is the addition of dihydrogen to another reactant. This process is used to reduce a compound or to obtain a saturated compound. It takes place in the presence of a suitable catalyst. For example, hydrogenation of vegetable oil using nickel as a catalyst gives edible fats such as vanaspati, ghee etc.

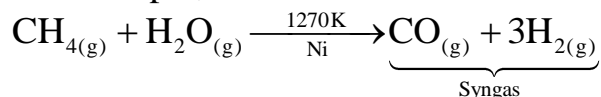
(iii) Syngas

Ans: Syngas is a mixture of carbon monoxide and dihydrogen. Since the mixture of the two gases is used for the synthesis of methanol, it is called syngas, synthesis gas, or water gas.

Syngas is produced on the action of steam with hydrocarbons or coke at a high temperature in the presence of a catalyst.

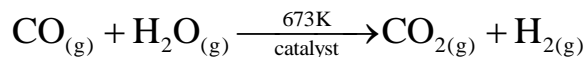


For example,

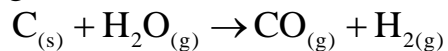


(iv) Water shift reaction

Ans: It is a reaction of carbon monoxide of syngas mixture with steam in the presence of a catalyst as:



This reaction is used to increase the yield of dihydrogen obtained from the coal gasification reaction as:



(v) Fuel cells

Ans: Fuel cells are devices that are used for producing electricity from fuel in the presence of an electrolyte. Dihydrogen can be used as a fuel in these cells. It is preferred over other fuels because it is eco-friendly and releases greater energy per unit mass of fuel as compared to gasoline and other fuels.