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

**Solution:**

Hydrogen is the first element of the periodic table. The electronic configuration is \([1s^1]\). Due to the presence of only one electron in its 1s shell, hydrogen exhibits a dual behaviour, i.e., it resembles both alkali metals and halogens.

1. Like alkali metals, hydrogen contains one valence electron in its valency shell. Hence, it can lose one electron to form a unipositive ion.
2. Like halogens, it forms a diatomic molecule and several covalent compounds.

Though hydrogen shows some similarity with both alkali metals and halogens, it differs from them in some ways. 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 I) or with halogens (group VII). Also, it was established that \(\text{H}^+\) ions cannot exist freely as they are extremely small. \(\text{H}^+\) 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?

**Solution:**

Hydrogen has three isotopes. They are:

1. Protium, \(^1\text{H}\)
2. Deuterium, \(^2\text{H}\) or \(\text{D}\), and
3. Tritium, \(^3\text{H}\) or \(\text{T}\)

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?

**Solution:**

The ionization enthalpy of hydrogen atom is very high (1312 kJ mol\(^{-1}\)). Thus, it is very difficult to remove its only electron. As a result, its tendency to exist in the monoatomic
form is low. Therefore, hydrogen forms a covalent bond with another hydrogen atom and exists as a diatomic \((\text{H}_2)\) molecule.

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

**Solution:**

Dihydrogen is produced by coal gasification method as:

\[
\text{C}(s) + \text{H}_2\text{O}(g) \xrightarrow{\text{1270 K}} \text{CO}(g) + \text{H}_2(g)
\]

The production 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.

\[
\text{C}(s) + \text{H}_2\text{O}(g) \xrightarrow{\text{Catalyst 673 K}} \text{CO}_2(g) + \text{H}_2(g)
\]

The above 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?

**Solution:**

Dihydrogen is prepared by the electrolysis of acidified or alkaline water using platinum electrodes. Generally, 15 – 20% of an acid \((\text{H}_2\text{SO}_4)\) or a base \((\text{NaOH})\) is used.

Reduction of water occurs at the cathode as:

\[
2\text{H}_2\text{O} + 2e^- \rightarrow 2\text{H}_2 + 2\text{OH}^-
\]

At the anode, oxidation of \(\text{OH}^-\) ions takes place as:

\[
2\text{OH}^- \rightarrow \text{H}_2\text{O} + \frac{1}{2} \text{O}_2 + 2e^-
\]

∴ The net reaction can be represented as:

\[
\text{H}_2\text{O}(l) \rightarrow \text{H}_2(g) + \frac{1}{2} \text{O}_2(g)
\]

The electrical conductivity of pure water is very low because of the absence of ions in it. Therefore, the 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 and for electrolysis to take place. Hence an electrolyte is used.

6. Complete the following reactions:
   (i) \( \text{H}_2(\text{g}) + \text{M}_m\text{O}_n(\text{s}) \xrightarrow{\Delta} \text{mM}(\text{s}) + \text{H}_2\text{O}(\text{l}) \)
   (ii) \( \text{CO}(\text{g}) + \text{H}_2(\text{g}) \xrightarrow{\Delta \text{ catalyst}} \text{CH}_3\text{OH}(\text{l}) \)
   (iii) \( \text{C}_3\text{H}_8(\text{g}) + 3\text{H}_2\text{O}(\text{g}) \xrightarrow{\Delta \text{ catalyst}} 3\text{CO}(\text{g}) + 7\text{H}_2(\text{g}) \)
   (iv) \( \text{Zn}(\text{s}) + 2\text{NaOH}(\text{aq}) \xrightarrow{\text{heat}} \text{Na}_2\text{ZnO}_2(\text{aq}) + \text{H}_2(\text{g}) \)

Solution:
   (i) \( \text{H}_2(\text{g}) + \text{M}_m\text{O}_n(\text{s}) \xrightarrow{\Delta} \text{mM}(\text{s}) + \text{H}_2\text{O}(\text{l}) \)
   (ii) \( \text{CO}(\text{g}) + 2\text{H}_2(\text{g}) \xrightarrow{\Delta \text{ catalyst}} \text{CH}_3\text{OH}(\text{l}) \)
   (iii) \( \text{C}_3\text{H}_8(\text{g}) + 3\text{H}_2\text{O}(\text{g}) \xrightarrow{\Delta \text{ catalyst}} 3\text{CO}(\text{g}) + 7\text{H}_2(\text{g}) \)
   (iv) \( \text{Zn}(\text{s}) + 2\text{NaOH}(\text{aq}) \xrightarrow{\text{heat}} \text{Na}_2\text{ZnO}_2(\text{aq}) + \text{H}_2(\text{g}) \)

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

Solution:

The ionization enthalpy of H–H bond is very high (1312 kJ mol\(^{-1}\)). This indicates that hydrogen has a low tendency to form H\(^+\) ions. Its ionization enthalpy value is 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 (lustre, ductility, etc.) like 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.

**Solution:**

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

1. Electron-deficient hydrides
2. Electron-precise hydrides
3. Electron-rich hydrides

An electron-deficient hydride is a hydride that has very few electrons, less than that required for representing its conventional Lewis structure.

Example is diborane (B₂H₆). In B₂H₆, 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 i.e., two electrons are shared by three atoms. Hence, its conventional Lewis structure cannot be drawn.

An electron-precise hydride is a hydride that has a sufficient number of electrons to be represented by its conventional Lewis structure.

Example is CH₄. The Lewis structure can be written as:

![Lewis structure of CH₄](image)

Four regular bonds are formed where two electrons are shared by two atoms.

An electron-rich hydride is a hydride that contains excess electrons as lone pairs.

Example is NH₃.

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

An electron-deficient hydride is a hydride that does not have sufficient electrons to form a regular bond in which two electrons are shared by two atoms. These hydrides cannot be represented by conventional Lewis structures.

Example: $B_2H_6$, $Al_2H_6$ etc.

$B_2H_6$ contains four regular bonds and two three centered-two electron bond. Its structure can be represented as:

```
H
 |
 B
 |
 H
 |
```

These types of hydrides are electron-deficient. So, they have a tendency to accept electrons.

Hence, they act as Lewis acids.

$$B_2H_6 + 2NMe \rightarrow 2BH_3 \cdot NMe_3$$
$$B_2H_6 + 2CO \rightarrow 2BH_3 \cdot CO$$

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

Solution:

For a hydride to act as a Lewis acid i.e., electron accepting, it should be electron deficient. Also, for it to act as a Lewis base i.e., electron donating, it should be electron rich.

Let us take $C_2H_6$ as an example of the $(C_nH_{2n+2})$ type hydride. The total number of electrons are 14 and the total covalent bonds are seven. Thus, the bonds are regular 2 electron–2 centered bonds.

```
H
 |
 C
 |
 H
```

```
H
 |
 C
 |
 H
```

C₂H₆ 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.

Solution:
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: LaH₂,87, YbH₂,55, TiH₁,5–1,8 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. Alkali metals will not form non-stoichiometric hydrides.

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

Solution:
Metallic hydrides are hydrogen deficient, i.e., they do not hold the law of constant composition. It has been established that in the hydrides of 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.

Solution:
The production of atomic hydrogen atoms is done by the dissociation of dihydrogen with the help of an electric arc. This releases a huge amount of energy (around 436 kJ mol\(^{-1}\)). This energy is used to generate a temperature of 4000 K, which is ideal for welding and cutting metals. The atomic hydrogen produced is allowed to recombine on the surface to be welded to generate the desired temperature.

\[
\text{H}_2(g) \xrightarrow{\text{Heat}} 2\text{H}(g); \Delta H = 436 \text{kJ mol}^{-1}
\]

14. Among NH\(_3\), H\(_2\)O and HF, which would you expect to have highest magnitude of hydrogen bonding and why?

**Solution:**

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 is \( \text{N} < \text{O} < \text{F} \). Thus, the order of the extent of hydrogen bonding expected is HF > H\(_2\)O > NH\(_3\). But, the actual order is found to be H\(_2\)O > HF > NH\(_3\).

Although the electronegativity of fluorine is greater as compared to that of oxygen, the strength of bonding in water molecule is greater as compared to the bonding in HF molecule because the HF molecule has shortage of hydrogen atoms. Hence, water has more number of hydrogen atoms and thus forms a ring like structure and HF only forms a planar structure.

Whereas in ammonia, the extent of hydrogen bonding is limited because nitrogen has only one lone pair. Therefore, it cannot satisfy all hydrogens.
HF:

\[
\begin{array}{c}
\text{F} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{F}
\end{array}
\]

NH\(_3\):

\[
\begin{array}{c}
\text{H} \\
\text{N} \\
\text{H} \\
\text{H} \\
\text{N}
\end{array}
\]

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.

Solution:

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

\[\text{MH(s) + H}_2\text{O(aq) \rightarrow MOH(aq) + H}_2(\text{g})\]

The above reaction is very violent and produces fire. Carbon dioxide (CO\(_2\)) is heavier than dioxygen. It is used in 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 this case as well. It is heavier than hydrogen gas 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.

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


(iv) NaH, MgH\(_2\) and H\(_2\)O in order of increasing reducing property.
Solution:

(i) The electrical conductance of a molecule depends upon its ionic or covalent nature. Ionic compounds conduct electricity, 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: BeH$_2$ < CaH$_2$ < TiH$_2$.

(ii) The ionic character of compound is dependent on the electronegativities of the atoms involved. Higher the difference between the electronegativities of atoms, the smaller is the ionic character. Electronegativity decreases as we move down the group from Lithium to Caesium. Hence, the ionic character of their hydrides will increase in the following order: LiH < NaH < CsH.

(iii) The factors determining the Bond dissociation energy is the bond strength of a molecule and 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 molecular weight of D$_2$. The stronger the attraction, the greater will be the bond strength and the higher is the bond dissociation enthalpy. Hence, the bond dissociation enthalpy of D–D is higher than H–H. In the case of F – F, bond dissociation enthalpy is minimum. The bond pair present experiences a strong repulsion from the lone pairs present on each F. Therefore, the increasing order of bond dissociation enthalpy is as follows: F–F < H–H < D–D.

(iv) The reducing property of a hydride is dependent upon the nature of hydride (ionic or covalent). Ionic hydrides are strong reducing agents since they have the tendency to donate electrons. NaH can easily donate its electrons. Hence, it is most reducing in nature. Both, MgH$_2$ and H$_2$O are covalent hydrides. H$_2$O is less reducing than MgH$_2$ since the bond dissociation energy of H$_2$O is higher than MgH$_2$. Hence, the increasing order of the reducing property is H$_2$O < MgH$_2$ < NaH.

17. Compare the structures of H$_2$O and H$_2$O$_2$.

Solution:

In gaseous phase (water vapour), water molecule has a bent form with a bond angle of approximately 104.5° and the O–H bond length is 95.7 pm.

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

18. What do you understand by the term ‘auto-protolysis’ of water? What is its significance?

Solution:

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 (H₃O⁺). The reaction involved can be represented as:

\[
H_2O(l) + H_2O(l) \leftrightarrow H_3O^+(aq) + OH^-(aq)
\]

Hydronium ion

Hydroxide ion

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

The acid-base reaction can be written as:

\[
H_2O(l) + H_2O(l) \leftrightarrow H_3O^+(aq) + OH^-(aq)
\]

(Conjugate acid) (Conjugate acid)
19. Consider the reaction of water with \( F_2 \) and suggest, in terms of oxidation and reduction, which species are oxidised/reduced.

**Solution:**

The reaction between fluorine and water can be represented as:

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

This above reaction is an example of a redox reaction since water is getting oxidized to oxygen, while fluorine is being reduced to fluoride ion.

The oxidation numbers of various species can be represented as:

\[
\begin{align*}
\text{Fluorine} & : \quad \text{From} \ 0 \ \text{to} \ -1 \\
\text{Water} & : \quad \text{From} \ -2 \ \text{to} \ 0
\end{align*}
\]

Fluorine is reduced from zero to \((-1)\) oxidation state and Water is oxidized from \((-2)\) to zero oxidation state.

20. Complete the following chemical reactions.

   (i) \( \text{PbS(s)} + H_2O_2(aq) \rightarrow \)
   
   (ii) \( \text{MnO}_4^-(aq) + H_2O_2(aq) \rightarrow \)
   
   (iii) \( \text{CaO(s)} + H_2O(g) \rightarrow \)
   
   (iv) \( \text{AlCl}_3(g) + H_2O(l) \rightarrow \)
   
   (v) \( \text{Ca}_3N_2(s) + H_2O_2(l) \rightarrow \)

Classify the above into (A) hydrolysis, (B) redox and (C) hydration reactions.

**Solution:**

(i) \( \text{PbS(s)} + H_2O_2(aq) \rightarrow \text{PbSO}_4(s) + H_2O(l) \)

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

(ii) \( 2\text{MnO}_4^-(aq) + 5H_2O_2(g) \rightarrow 6H^+(aq) \rightarrow 2\text{Mn}^{2+}(aq) + 8H_2O(l) + 5O_2(g) \)
H\textsubscript{2}O\textsubscript{2}(aq) is acting as a reducing agent in the acidic medium, thereby oxidizing MnO\textsubscript{4}\textsuperscript{−}(aq).

Hence, the given reaction is a redox reaction.

(iii) CaO(s) + H\textsubscript{2}O(g) \rightarrow Ca(OH)\textsubscript{2}(aq)

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

(iv) 2AlCl\textsubscript{3}(g) + 3H\textsubscript{2}O(l) \rightarrow Al\textsubscript{2}O\textsubscript{3}(s) + 6HCl(aq)

The reactions in which a compound reacts with water to produce other compounds are called hydrolysis reactions. The above reaction represents hydrolysis of AlCl\textsubscript{3}.

(v) Ca\textsubscript{3}N\textsubscript{2}(g) + 6H\textsubscript{2}O(l) \rightarrow 3Ca(OH)\textsubscript{2}(aq) + 2NH\textsubscript{3}(g)

The reactions in which a compound reacts with water to produce other compounds are called hydrolysis reactions. The given reaction represents hydrolysis of Ca\textsubscript{3}N\textsubscript{2}.

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

Solution:

Ice is the crystalline form (solid form) of water. It takes a hexagonal form if crystallized at atmospheric pressure, but condenses to cubic form if the temperature is very low. 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?

Solution:

Temporary hardness of water is caused due to the presence of soluble salts of magnesium and calcium in the form of hydrogen carbonates (MHCO\textsubscript{3}, where M = Mg or 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.

Solution:

The permanent hardness of water can be treated using synthetic resins that involve exchange of cations (e.g., Na\(^+\), Ca\(^{2+}\), Mg\(^{2+}\) etc) and anions (e.g., Cl\(^-\), SO\(_4^{2-}\), HCO\(_3^-\) etc) present in water by H\(^+\) and OH\(^-\) ions respectively. Synthetic resins are of two types:

1) Cation exchange resins

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

\[
2RNa + M^{2+}(aq) \rightarrow R_2M(s) + 2Na^+(aq)
\]

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

\[
2RH + M^{2+}(aq) \rightarrow R_2M(s) + 2H^+(aq)
\]

Anion exchange resins exchange hydroxyl ions for anions like Cl\(^-\), HCO\(_3^-\), and SO\(_4^{2-}\) present in water.

\[
\text{RNH}_2(s) + H_2O(l) \xrightarrow{X^- (aq)} \text{RNH}_3^+\cdot\text{OH}^-(s) + X^- (aq)
\]

During the treatment process, water is first passed 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 hydroxyl ions neutralize the H\(^+\) ions and de-ionize the water obtained.

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

Solution:

The amphoteric nature of water can be explained on the basis of the following reactions:
1) Reaction with NH₃:

The reaction takes place as:

\[ \text{H}_2\text{O}(l) + \text{NH}_3(aq) \rightleftharpoons \text{OH}^-(aq) + \text{NH}_4^+(aq) \]

In the forward reaction, H₂O(l) donates its proton to NH₃(aq). Hence, it acts as a Lewis acid.

2) Reaction with H₂S:

The reaction takes place as:

\[ \text{H}_2\text{O}(l) + \text{H}_2\text{S}(aq) \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{HS}^-(aq) \]

Base  Acid  Conjugate Acid  Conjugate Base

accepts a proton from H₂S(aq). Hence, it acts in the forward reaction, as a Lewis base.

3) Self-ionization of water:

The auto-protolysis reaction of water molecule exhibits the amphoteric nature of water molecule. In the reaction, two water molecules react as:

\[ \text{H}_2\text{O}(l) + \text{H}_2\text{O}(l) \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{OH}^-(aq) \]

Acid  Base

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

Solution:

Hydrogen peroxide, H₂O₂ acts as an oxidizing as well as a reducing agent in both acidic and alkaline media. Reactions involving oxidizing actions are:

1) PbS + 4H₂O₂ → PbSO₄ + 4H₂O
2) 2Fe²⁺ + 2H⁺ + H₂O₂ → 2Fe³⁺ + 2H₂O (acidic medium)
3) Mn²⁺ + H₂O₂ → Mn⁴⁺ + 2OH⁻ (basic medium)

Reactions involving reduction actions are:

1) 2MnO₄⁻ + 6H⁺ + 5H₂O₂ → 2Mn²⁺ + 8H₂O + 5O₂ (acidic medium)
2) I₂ + H₂O₂ + 2OH⁻ → 2I⁻ + 2H₂O + O₂ (basic medium)
3) 2MnO₄⁻ + 3H₂O₂ → 2MnO₂ + 3O₂ + 2H₂O + 2OH⁻ (basic medium)
26. What is meant by ‘demineralised’ water and how can it be obtained?

**Solution:**

Demineralised water is the water that is free from all soluble mineral salts. It does not contain any dissolved anions, cations and salts in it. 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.

\[
2RH(s) + M^{2+}(aq) \rightleftharpoons MR_2(s) + 2H^+(aq) \quad (1)
\]

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

\[
RNH_2(s) + H_2O(l) \rightleftharpoons RNH_3^+ \cdot OH^-(s)
\]

\[
RNH_3^+ \cdot OH^-(s) + X^-(aq) \rightleftharpoons RNH_3^+ \cdot X^-(s) + OH^-(aq) \quad (2)
\]

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

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

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

**Solution:**

Drinking water 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 the biosphere and biological systems.

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

Solution:
A high value of dielectric constants (78.39 C^2/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 dissolve in water. Water can hydrolyze metallic and non-metallic oxides, hydrides, phosphides, carbides, nitrides and various other salts. During hydrolysis, H^+ and OH^- ions of water interact with the reacting molecule.

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

Solution:
Heavy water (D_2O) acts as a moderator. It slows down the rate of a reaction. Due to this property of D_2O, it cannot be used for drinking purposes because it will slow down metabolic (anabolic and catabolic) reactions taking place in the body. Hence heavy water cannot be used for drinking purposes.

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

Solution:
Hydrolysis is defined as a chemical reaction in which hydrogen and hydroxide ions (H^+ and OH^- ions) of water molecule react with a compound to form products.
For example:
NaH + H₂O → NaOH + H₂

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

For example:
CuSO₄ + 5H₂O → CuSO₄ · 5H₂O

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

**Solution:**
Saline hydrides (hydrides like NaH, LiH) are ionic in nature. These hydrides 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:

\[ MH(s) + H₂O(l) \rightarrow MOH(aq) + H₂(g) \]

(\( M = Na, Ca, \ldots \))

When these hydrides are added to an organic solvent, they react with water present in it. Hydrogen escapes into the atmosphere leaving behind the metallic hydroxide and the dry organic solvent distils 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.

**Solution:**
The atomic numbers 15, 19, 23, and 44 represent nitrogen, potassium, vanadium, and ruthenium respectively.

1) Hydride of nitrogen:
Hydride of nitrogen (NH₃) is a covalent molecule. It is an electron-rich hydride due to the presence of excess electrons as a lone pair on nitrogen.
2) Hydride of potassium:
Dihydrogen forms an ionic hydride with potassium due to the high electropositive nature of potassium. It is crystalline and non-volatile in nature.

3) Hydrides of Vanadium and Ruthenium:
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.

The behaviour of the above hydrides towards water:
Potassium hydride reacts violently with water as:
\[
\text{KH(s) + H}_2\text{O(aq) } \rightarrow \text{KOH(aq) + H}_2\text{(g)}
\]
Ammonia (NH$_3$) behaves as a Lewis base and reacts with water as:
\[
\text{H}_2\text{O(l) + NH}_3\text{(aq) } \rightleftharpoons \text{OH}^-\text{(aq) + NH}_4^+(aq)
\]
Hydrides of vanadium and Ruthenium do not react with water.
Hence, the increasing order of reactivity of the hydrides is (V, Ru) H < NH$_3$ < KH.

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

Solution:
Potassium chloride (KCl) is the salt of a strong acid (HCl) and a strong base (KOH).
Hence, it is neutral and does not undergo hydrolysis in normal water. It dissociates into ions as follows:
\[
\text{KCl(s) } \xrightarrow{\text{water}} \text{K}^+(aq) + \text{Cl}^-(aq)
\]
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 a weak base [Al(OH)₃].

Hence, it undergoes hydrolysis in normal water.

\[
\text{AlCl}_3 (s) + 3\text{H}_2\text{O}(l) \xrightarrow{\text{Normal Water}} \text{Al(OH)}_3(s) + 3\text{H}^+(aq) + 3\text{Cl}^-(aq)
\]

In acidified water, \(\text{H}^+\) ions react with \(\text{Al(OH)}_3\) forming water and giving \(\text{Al}^{3+}\) ions.

Hence, in acidified water, \(\text{AlCl}_3\) will exist as \(\text{Al}^{3+}(aq)\) and \(\text{Cl}^-(aq)\) ions.

\[
\text{AlCl}_3 (s) \xrightarrow{\text{Acidified Water}} \text{Al}^{3+}(aq) + 3\text{Cl}^-(aq) \text{ ions.}
\]

In alkaline water, the following reaction takes place:

\[
\text{Al(OH)}_3 (s) + \text{OH}^-(aq) \rightarrow \left[\text{Al(OH)}_4\right]^-(aq) + 2\text{H}_2\text{O}(l)
\]

**35. How does \(\text{H}_2\text{O}_2\) behave as a bleaching agent?**

**Solution:**

\(\text{H}_2\text{O}_2\) or hydrogen peroxide acts as a strong oxidizing agent both in acidic and basic medium.

When added to 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

(ii) hydrogenation

(iii) ‘syngas’

(iv) water-gas shift reaction

(v) fuel-cell?

**Solution:**

(i) Hydrogen economy

Hydrogen economy refers to the techniques 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 as compared to petrol 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
Hydrogenation is the addition of dihydrogen to a given reactant. This process is used to reduce a compound 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
The mixture of carbon monoxide and hydrogen is termed as syngas. 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.

(iv) Water shift reaction:
It is the reaction of carbon monoxide of syngas mixture with steam in the presence of a catalyst. This reaction is used to increase the yield of dihydrogen obtained from the coal gasification reaction.

(v) Fuel cells:
Fuel cells are devices for producing electricity from fuel in the presence of an electrolyte. Hydrogen is considered to be one of the best fuel for fuel cells as it is eco-friendly and also gives more energy per unit mass of fuel as compared to other substitutes like petrol or diesel etc.