NCERT TEXTUAL EXERCISE (SOLVED)

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

Ans. Hydrogen is the first element in the periodic table but its position is ambiguous because of following reason:

(i) Since it has 1 valence electron in its s-subshell it is placed in group-1 along with alkali metals.

(ii) It also shows properties of halogens of group-17 by picking up electron showing electronegative character like them.

(iii) In some yet another properties, hydrogen differs both from alkali metals and halogens.

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

Ans. Protium ${}_1H^1$, Deuterium ${}_1H^2$ or D, Tritium ${}_1H^3$ or T. The mass ratios of protium: deuterium: tritium = 1 : 2 : 3

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

Ans. Hydrogen atom has only one electron and thus has one electron less than the stable inert gas configuration of helium. Therefore, to achieve stable inert gas configuration of helium, it shares its single electron with electron of other hydrogen atom to form a stable diatomic molecule.

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

Ans. The process of producing syngas or synthesis gas from coal is called 'coal gasification'.

$$\underset{\text{Coal}}{C(s)} + \underset{\text{Steam}}{H_2O(g)} \xrightarrow[\text{Ni}]{1270\ K} \underbrace{CO(g) + H_2(g)}_{\text{Syngas}}$$

The production of hydrogen can be increased by reacting carbon monoxide of syngas with steam in presence of iron chromate as catalyst at 673 K.

$$CO(g) + H_2O(g) \xrightarrow[FeCrO_4]{673K} CO_2(g) + H_2(g)$$

The CO_2 thus produced is removed by scrubbing with a solution of sodium arsenite.

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

Ans. Dihydrogen of high purity is usually obtained by electrolysis of water in presence of small amount of acid or base. During electrolysis, dihydrogen is collected at cathode while dioxygen is collected at anode.

At cathode: $H^+ + e^- \rightarrow H$ $\quad H + H \rightarrow H_2$

At anode: $OH^- \rightarrow OH + e^-$ $\quad 4OH \rightarrow 2H_2O + O_2$

The role of the electrolyte is to make water conducting since pure water is bad conductor of electricity and is weakly ionised.

6. Complete the following reactions:

(i) $H_2(g) + M_mO_o(s) \xrightarrow{\Delta}$ (ii) $CO(g) + H_2(g) \xrightarrow[\text{Catalyst}]{\Delta}$

(iii) $C_3H_8(g) + 3H_2O(g) \xrightarrow[\text{Catalyst}]{\Delta}$

(iv) $Zn(s) + NaOH(aq) \xrightarrow[\text{Catalyst}]{\Delta}$

Ans. (i) $o\,H_2(g) + M_mO_o(s) \xrightarrow{\Delta} mM(s) + o\,H_2O(l)$

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

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

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

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

Ans. Due to high enthalpy of H–H bond, hydrogen is quite unreactive at room temperature. However, at high temperatures or in presence of catalysts, it combines with many metals and non-metals to form hydrides.

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. (i) Hydrides of group 13 (i.e., BH_3, AlH_3, etc.) do not have sufficient number of electrons to form normal covalent bonds and hence are called electron-deficient hydrides. To make up this deficiency, they generally exist in polymeric forms such as B_2H_6, B_4H_{10}, $(AlH_3)_n$, etc.

(ii) Hydrides of group 14 (i.e., CH_4, SiH_4, GeH_4, SnH_4, PbH_4) have exact number of electrons to form covalent bonds and hence are called electron-precise hydrides. All these hydrides have tetrahedral shapes.

(iii) Hydrides of group 15, 16 and 17 (i.e., NH_3, PH_3, H_2O, H_2S, HF, HCl, etc.) have more electrons than required to form normal covalent

bonds and hence are called electron-rich hydrides. The excess electrons in these hydrides are present as lone pairs of electrons.

9. What characteristics do you expect from electron deficient hydrides with respect to its structure and chemical reactivity.

Ans. Electron deficient hydrides do not have sufficient electrons to form normal covalent bonds. Therefore, to make up this deficiency they generally exist in polymeric forms such as B_2H_6, B_4H_{10}, $(AlH_3)_n$, etc. Further to make up this deficiency of electrons, they react with many metals, non-metals and their compounds. Hence, electron-deficient hydrides are very reactive as shown below:

$$B_2H_6(g) + 3O_2(g) \rightarrow B_2O_3(s) + 3H_2O(g)$$

$$2NaH(s) + B_2H_6(g) \xrightarrow{\text{Diethyl ether}} \underset{\text{Sod. borohydride}}{2Na^+[BH_4]^-(s)}$$

Being electron deficient compounds, they act as Lewis acids and thus form complex with Lewis bases.

For example, $\underset{\text{Diborane}}{B_2H_6} + \underset{\text{Trimethylamine}}{2NMe_3} \rightarrow \underset{\text{Complex}}{[2H_3B \leftarrow NH_3]}$

$$\underset{\text{Carbon monoxide}}{B_2H_6} + CO \rightarrow \underset{\text{complex}}{[2H_3B \leftarrow CO]}$$

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

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

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

Ans. Hydrides which are deficient in hydrogen and in which the ratio of the metal to hydrogen is fractional are called non-stoichiometric hydrides. Furthermore, this fractional ratio is not fixed but variable with the temperature and the pressure. This type of hydrides is formed by d-and f-block elements. In these hydrides, the hydrogen atoms occupy holes in the metal lattice. Usually some holes always remain unoccupied and hence these metals form non-stoichiometric hydrides. Since alkali metals are highly reducing, they transfer their lone electron to the Hydrogen atom, thereby forming H^- ions. In other words, alkali metal hydrides are ionic in which H^- ions occupy holes in the lattice. Since a hydride ion is formed by complete transfer of an electron,

therefore, the ratio of metal to hydrogen is always fixed and hence alkali metals form only stoichiometric hydrides. In other words, alkali metals do not form non-stoichiometric hydrides.

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

Ans. In metallic hydrides, hydrogen is absorbed as H atoms. Due to the inclusion of H atoms, the metal lattice expands and thus becomes less stable. Therefore, when the metallic hydride is heated, it decomposes to form hydrogen and very finely divided metal.

The hydrogen thus evolved can be used as a fuel. Thus, transition metals or their alloys can be used to store and transport hydrogen to be used as a fuel. This is called hydrogen economy.

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

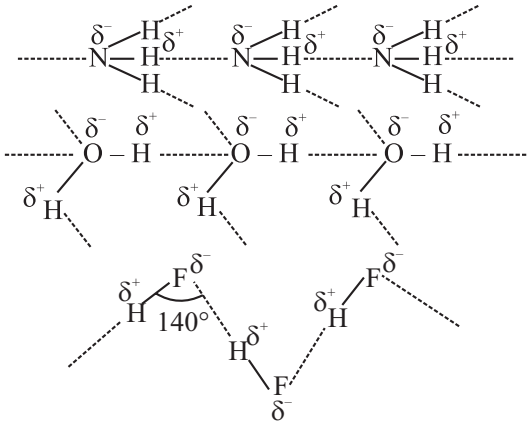
Ans. Atomic hydrogen is produced when molecular hydrogen is passed through an electric arc struck between tungsten electrodes (3773–4273 K).

$$H_2 \xrightarrow[3773-4273K]{\text{Electric arc,}} 2H; \Delta H = 435.9 \text{ kJ mol}^{-1}$$

The lifetime of atomic hydrogen is 0.3 sec and hence it immediately gets converted into the molecular form liberating a large amount of energy which is used for cutting and welding purposes in form of atomic hydrogen torch.

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

Ans. Due to greater electronegativity of N, O and F over H. All these molecules undergo H-bonding.



However, since electronegativity of Fluorine is highest, therefore, magnitude of the +ve charge on hydrogen and –ve charge on Fluorine is the highest and hence electrostatic attraction or the H-bonding is strongest in H–F.

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 (such as NaH, CaH_2, etc.), react with water violently to form the corresponding metal hydroxides with the evolution of dihydrogen.

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

$CaH_2(s) + 2\ H_2O\ (l) \rightarrow Ca(OH)_2(aq) + 2\ H_2(g)$

The reactions are so much exothermic that the evolved H_2 catches fire. The fire so produced cannot be extinguished by CO_2 because it gets reduced by the hot metal hydride.

$NaH + CO_2 \rightarrow HCOONa.$

However, sand is useful since it is a highly stable solid.

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

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

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

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

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

(iii) Due to smaller size of Deuterium as compared to Hydrogen, D–D bond has the highest bond dissociation enthalpy followed by H–H. However, due to repulsions between lone pairs of F and the bond pair, F–F bond dissociation enthalpy is the minimum. Thus the bond dissociation enthalpy increases in the order: F–F < H–H < D–D.

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

17. Compare the structure of H_2O and H_2O_2.

Ans. In water, oxygen is, sp^3-hybridised. Due to stronger lone pair–lone pair repulsions than bond pair–bond pair repulsions, the H-O-H bond angle decreases from 109.5° to 104.5°. Thus, water is a bent molecule. H_2O_2 has a non-planar structure. The two oxygen atoms are linked to each other by a single covalent bond (i.e., peroxide bond and each oxygen is further linked to a hydrogen atom by a single covalent bond). The two O–H bonds are, however, in different planes. The dihedral angle between the two planes being 111.5° in the gas phase. Thus, the structure of H_2O_2 is like that of an open book.

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

Ans. Autoprotolysis means self ionisation of water. It may be represented as

$$\underset{\text{Acid1}}{H_2O(l)} + \underset{\text{Base 2}}{H_2O(l)} \longrightarrow \underset{\text{Acid 2}}{H_3O^+(aq)} + \underset{\text{Base1}}{OH^-(aq)}$$

Due to autoprotolysis, water is amphoteric in nature, i. e., it reacts with both acids and bases. It acts as a base towards acids stronger than itself and as an acid towards bases stronger than itself. For example,

$$\underset{\text{Acid1}}{H_2O(l)} + \underset{\text{Base1}}{NH_3(aq)} \longrightarrow \underset{\text{acid 2}}{NH_4^+(aq)} + \underset{\text{Base2}}{OH^-(aq)}$$

* $\underset{\text{Base 2}}{H_2O(l)} + \underset{\text{Acid1}}{H_2S(aq)} \longrightarrow \underset{\text{Acid 2}}{H_3O^+(aq)} + \underset{\text{Base1}}{HS^-(aq)}$

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

Ans. $\underset{\text{(Oxidant)}}{2\,F_2(g)} + \underset{\text{(Reductant)}}{2H_2O(l)} \rightarrow O_2(g) + 4\,H^+(aq)^+ 4\,F^-(aq)$

or $\underset{\text{(Oxidant)}}{3F_2(g)} + \underset{\text{(Reductant)}}{3H_2O(l)} \rightarrow O_3(g) + 6H^+(aq) + 6\,F^-(aq)$

In these reactions, water acts as a reducing agent and hence itself gets oxidised to either O_2 or O_3 on the other hand, F_2 acts as an oxidising agent and hence itself gets to reduced F^-ion.

20. Complete the following chemical reactions:

(i) $PbS(s) + H_2O_2(aq) \rightarrow$ (ii) $MnO_4^-(aq) + H_2O_2\,(aq) \rightarrow$

(iii) $CaO(s) + H_2O(g) \rightarrow$ (iv) $AlCl_3(g) + H_2O\,(l) \rightarrow$

(v) $Ca_3N_2(s) + H_2O(l) \rightarrow$

Classify the above into (a) Hydrolysis (b) Redox (c) Hydration reaction

Ans. (i) $PbS(s) + 4\ H_2O_2(aq) \rightarrow PbSO_4(s) + 4H_2O\ (l)$

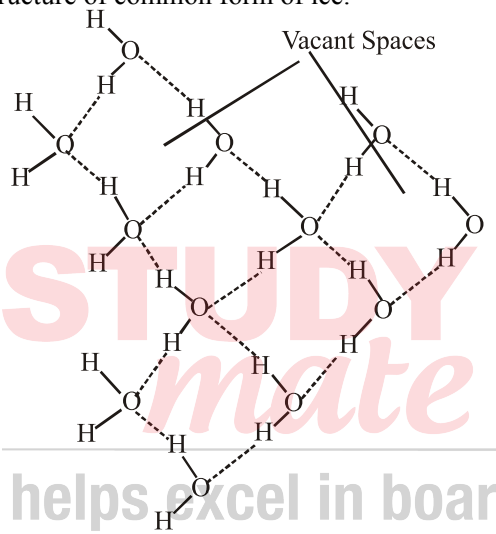
(ii) $2\ MnO_4^-(aq) + 5H_2O_2(l) + 6H^+(aq) \rightarrow 2Mn^{2+}\ (aq) + 8\ H_2O\ (l) + 5\ O_2\ (g)$

(iii) $CaO(s) + H_2O(g) \rightarrow Ca(OH)_2(aq)$

(iv) $AlCl_3(s) + 3H_2O(l) \rightarrow Al(OH)_3(s) + 3HCl(aq)$

(v) $Ca_3N_2(s) + 6H_2O(l) \rightarrow 3Ca(OH)_2(aq) + 2NH_3(g)$

21. Describe the structure of common form of ice.



Ans. Ice, the solid form of water, can exist in nine structurally different crystalline forms depending on the conditions employed for freezing the water. In the normal hexagonal ice, each oxygen atom is tetrahedrally surrounded by four other oxygen atoms, i.e., there is a hydrogen atom between each pair of oxygen atoms. This gives ice an open cage like structure.

It is clear that each oxygen is surrounded by four hydrogen atoms, two by strong covalent lines (shown by solid lines) and two by weak hydrogen bond (shown by dotted lines). Since H-bonds are longer than the covalent bonds, the molecules of water are not closely packed in crystal lattice and hence exists a number of vacant spaces.

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

Ans. Presence of bicarbonates of calcium and magnesium, i.e., $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$ in water causes temporary hardness and presence of soluble chlorides and sulphates of calcium and magnesium, i.e., $CaCl_2$, $CaSO_4$, $MgCl_2$ and $MgSO_4$ in water causes permanent hardness.

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

Ans. Synthetic ion exchange resins are of two types: Cation exchange resins and anion exchange resins.

Cation exchange resins are either carboxylic acids or sulphonic acids having the general formula, R–COOH or R–SO_2OH where R represents the giant hydrocarbon framework. These resins exchange their H^+ ions with Ca^{2+} and Mg^{2+} ions present in hard water.

$$\underset{\text{Cation exchange resin}}{2R-COO^-H^+} + \underset{\text{From hard water}}{CaCl_2} \longrightarrow \underset{\text{Exhausted resin}}{(RCOO)_2Ca} + 2H^+ + 2Cl^-$$

$$\underset{\text{Cation exchange resin}}{2R-SO_2O^-H^+} + \underset{\text{From hard water}}{MgSO_4} \longrightarrow \underset{\text{Exhausted resin}}{(RSO_2O)_2Mg} + 2H^+ + SO_4^{2-}$$

Anion exchange resins, on the other hand, are substituted ammonium hydroxides having the general formula, $NH_3^+OH^-$ where R denotes the giant hydrocarbon framework. These resins exchange their OH^- ions with Cl^- and SO_4^- ions present in hard water.

$$\underset{\text{Anion exchange resin}}{R-NH_3^+OH^-} + \underset{\text{From hard water}}{Cl^-} \longrightarrow \underset{\text{Exhausted resin}}{R-\overset{+}{N}H_3Cl^-} + OH^-$$

$$\underset{\text{Anion exchange resin}}{2R-NH_3^+OH^-} + \underset{\text{From hard water}}{SO_4^{2-}} \longrightarrow \underset{\text{Exhausted resin}}{(R-NH_3)_2SO_4} + 2OH^-$$

Similarly, the H^+ ions produced from cation exchange resins and OH^- ions produced from anion exchange resins combine to form H_2O.

The hard water is first passed through cation exchange resin and then through anion exchange resin. The resulting water is freed from both cations and anions and hence is called demineralised water or deionised water and is as good as distilled water.

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

Ans. Water is amphoteric in character, i.e., it behaves both as an acid as well as a base. With acids (e.g. H_2S) stronger than itself, it behaves as a base and with bases (e.g., NH_3) stronger than itself, it acts as an acid.

$$\underset{\text{Base 1}}{H_2O\ (l)} + \underset{\text{Acid 2}}{H_2S\ (aq)} \longrightarrow \underset{\text{Acid 1}}{H_3O^+\ (aq)} + \underset{\text{Base 2}}{HS^-\ (aq)}$$

*

$$\underset{\text{Acid 1}}{H_2O\ (l)} + \underset{\text{Base 1}}{NH_3\ (aq)} \longrightarrow \underset{\text{Acid 2}}{NH_4^+\ (aq)} + \underset{\text{Base 2}}{OH^-\ (aq)}$$

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

Ans. H_2O_2 can act as an oxidising as well as a reducing agent both in acidic and basic media as illustrated below:

(i) Oxidising agent in acidic medium

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

(ii) Oxidising agent in basic medium

$$Mn^{2+}(aq) + H_2O_2(aq) + 2\ OH^-(aq) \rightarrow \underset{\text{Manganese dioxide}}{MnO_2\ (s)} + 2\ H_2O\ (l)$$

(iii) Reducing agent in acidic medium

$$2MnO_4^-(aq) + 6H^+(aq) + 5H_2O_2(aq) \rightarrow 2Mn^{2+}(aq) + 8H_2O\ (l) + 5O_2\ (g)$$

(iv) Reducing agent in basic medium

$$I_2(s) + H_2O_2(aq) + 2\ OH^-(aq) \rightarrow 2I^-(aq) + 2\ H_2O(l) + O_2(g),$$

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

Ans. Water which is free from all cations and anions is called demineralised water. It is obtained by passing hard water first through cation exchange resin and then through anion exchange resin. (For details refer to Answer to Question 23.)

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

Ans. Demineralised or distilled water is not useful for drinking purposes since it does not contain even useful minerals. Therefore, to make it useful for drinking purposes, useful minerals in proper amounts should be added.

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

Ans. Water is essential for all forms of life. It constitutes about 65–70% of the body weight of animals and plants. In comparison to other liquids, water has a high specific heat, thermal conductivity, surface tension, dipole moment and dielectric constant, etc. These properties allow water to play a key role in biosphere. The high heat of vaporisation and heat capacity are responsible for moderation of the climate and body temperature of living beings. It is an excellent solvent for transportation of minerals and other nutrients for plant and animal metabolism. Water is also required for photosynthesis in plants which releases O_2 into the atmosphere.

29. What properties of water make it useful as a solvent? What type of compounds can it (i) dissolve (ii) hydrolyse?

Ans. Water has a high dielectric constant (79.39) and high dipole moment (1.84 D). Because of these properties, water dissolves most of the inorganic (ionic) compounds and many covalent compounds. That is why water is called a universal solvent whereas ionic compounds dissolve in water due to ion–dipole interaction or solvation of ions, covalent compounds such as alcohols, amines, urea, glucose, sugar, etc. dissolve in water due to H-bonding.

Water can hydrolyse many oxides (metallic or non-metallic), hydrides, carbides, nitrides, phosphides and other salts. In these reactions, H^+ and OH^- ions of water interact with anions and cations respectively leading to the formation of an acid or base or both as shown below:

$$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq) + SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$$

$$CaH_2(s) + 2\,H_2O(l) \rightarrow Ca\,(OH)_2(aq) + 2H_2(g)$$

$$CaC_2(s) + 2\,H_2O(s) \longrightarrow \underset{\text{Acetylene}}{HC \equiv CH}\,(g) + Ca(OH)_2(aq)$$

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 is injurious to human beings, plants and animals since it slows down the rates of reactions occurring in them. Thus, heavy water does not support life so well as does ordinary water.

31. What is the difference between 'hydrolysis' and 'hydration'?

Ans. Interaction of H^+ and OH^- ions of H_2O with the anion and the cation of a salt respectively to give the original acid and the original base is called hydrolysis. For example,

$$\underset{\text{Salt}}{Na_2CO_3} + 2H_2O \longrightarrow \underset{\text{Base}}{2NaOH} + \underset{\text{Acid}}{H_2CO_3}$$

Hydration, on the other hand, means addition of H_2O to ions or molecules to form hydrated ions or hydrated salts. For example,

$$\underset{\text{Colourless}}{CuSO_4} + 5H_2O \longrightarrow \underset{\text{Blue}}{CuSO_4.5H_2O}$$

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

Ans. Saline hydrides (i.e., NaH, CaH_2, etc.) react with water forming their corresponding metal hydroxides with the liberation of H_2 gas. Thus, traces of water present in organic solvents can be easily removed by distilling them over saline hydrides when H_2 escapes into the atmosphere, metal hydroxide is left in the flask while dry organic solvent distils over.

Alternatively, organic compounds containing traces of water can be dried by placing them in a desicator containing saline hydrides at the bottom for a few hours or preferably overnight.

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

Ans. (i) Element with Z = 15 is a non-metal (i.e., P) and hence forms covalent hydride (i.e., PH_3).

(ii) Element with Z = 19 is a alkali metal (i.e. K) and hence forms saline or ionic hydride (i.e., $K^+ H^-$).

(iii) Element with atomic number Z = 23 is a transition metal (i.e., V) of group 3 and hence forms a metallic or interstitial hydride (i.e., $V_1H_{0.56}$)

(iv) Element with Z = 44 is a transition metal of group 8 and hence does not form any hydride.

Behaviour towards water: only ionic hydrides react with water evolving H_2 gas. Thus, $2KH(s) + 2H_2O(s) \rightarrow 2KOH(aq) + 2H_2(g)$

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?

Ans. KCl is the salt of a strong acid and a strong base. It does not undergo hydrolysis in normal water. It just dissociates to give K^+ (aq) and Cl^-(aq) ion.

$$KCl(s) \xrightarrow{\text{Water}} K^+(aq) + Cl^-(aq)$$

Since the aqueous solution of KCI is neutral, therefore, in acidified water or in alkaline water, the ions do not react further and stay as such.

$AICl_3$, on the other hand, is a salt of a weak base and a strong acid. Therefore, in normal water, it undergoes hydrolysis to form, weak base $Al(OH)_3$ and a strong acid HCl.

$$AlCl_3(s) + 3H_2O(l) \rightarrow Al(OH)_3(s) + 3H^+(aq) + 3Cl^-(aq)$$

In acidic water, the H^+ ions react with $Al(OH)_3$ to form Al^{3+} (aq) ions and H_2O. Thus, in acidic water, $AlCl_3$ exists as Al^{3+}(aq) and Cl^-(aq) ions.

$$AlCl_3(s) \xrightarrow{\text{Acidified water}} Al^{3+}(aq) + 3Cl^-(aq)$$

In alkaline water, $Al(OH)_3$ reacts to form soluble tetrahydroxoaluminate complex or metaaluminate ion, i.e.,

$Al(OH)_3(s) + OH^-(aq) \rightarrow [Al(OH)_4]^-(aq)$ or $AlO_2^-(aq)^+ + 2\,H_2O(l)$

Tetrahydroxoaluminate metaaluminate ion

The complete equation may be written as:

$$AlCl_3(s) \xrightarrow[\text{water}]{\text{Alkaline}} Al(OH)_4^- + 3Cl^-(aq)$$

$$\downarrow$$

$$AlO_2^{-1}(aq) + 2H_2O(l) + 3Cl^-(aq)$$

35. How does H_2O_2 behave as a bleaching agent?

Ans. The bleaching action of H_2O_2 is due to the nascent oxygen which it liberates on decomposition.

$H_2O_2 \rightarrow H_2O + O$

The nascent oxygen combines with colouring matter which, in turn, gets oxidised. Thus, the bleaching action of H_2O_2 is due to the oxidation of colouring matter by nascent oxygen. It is used for the bleaching of delicate materials like ivory, feather, silk, wool, etc.

36. What do you understand by the term:

(i) Hydrogen economy (ii) Hydrogenation

(iii) Syngas (iv) Water–gas shift reaction and

(v) Fuel cell.

Ans. (i) **Hydrogen economy:** The proposal to use hydrogen as a fuel in industries, power plants and also in homes and motor vehicles is called hydrogen economy. The basic principle of hydrogen economy is the transportation and storage of energy in the form of liquid or gaseous dihydrogen.

(ii) **Hydrogenation**: It means addition of hydrogen across double and triple bonds to form saturated compounds. The vegetables oils such as soyabean oil, cotton seed oil, groundnut oil, etc. are called polyunsaturated oils since they contain many C = C bonds. When these oils are exposed to air for prolonged periods, the double bonds present in them undergo oxidation, and develop unpleasant taste. To avoid this, double bonds are hydrogenated. For this purpose, dihydrogen is bubbled through edible oils in presence of finely divided nickel at 473 K when the oils are converted with solid fats.

$$\text{Vegetable oil} + H_2 \xrightarrow{Ni,\,473K} \text{Vegetable Ghee}$$

This process is called hydrogenation or hardening of oils and is used in the manufacture of vegetable ghee like Dalda, Gagan, Rath, etc. from vegetable oils. It may, however, be noted that hydrogenation

reduces the number of double bonds but does not completely eliminate them.

(iii) **Syngas.** The mixtures of CO and H_2 are called synthesis gas or syngas. It can be produced by the reaction of steam on hydrocarbon or coke at high temperature in the presence of nickel as catalyst

$$C_nH_{2n+2} + nH_2O(g) \xrightarrow[Ni]{1270\,K} nCO + (2n+1)H_2$$

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

These days 'syngas' is produced from sewage, saw dust, scrap wood, newspapers, etc. The process producing syngas form coal is called 'coal gasification' $C(s) + H_2O(g) \xrightarrow[Ni]{1270K} CO(g) + H_2(g)$

(iv) **Water–gas shift reaction:** The amount of hydrogen in the syngas can be increased by reacting CO of syngas mixtures with steam in the presence of iron chromate as catalyst.

$$CO(g) + H_2O(g) \xrightarrow[FeCrO_4]{673\ K} CO_2(g) + H_2(g)$$

This is called water–gas shift reaction.

(v) **Fuel cell:** Fuel cell is a device which converts the energy produced during the combustion of a fuel directly into electrical energy. Dihydrogen is used in hydrogen–oxygen fuel cells for generating electrical energy. It has many advantages over the conventional fossil fuels. It does not produce any pollution, releases more amount of energy per unit mass of fuel as compared to gasoline and other fuels.