NCERT Solutions for Class-XI Chemistry

Chapter-9
NCERT Chemistry Class 11

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

1. 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 behaviour, i.e., it resembles both alkali metals and halogens.

Resemblance with alkali metals:

1. Like alkali metals, hydrogen contains one valence electron in its valency shell.

H : $1s^1$

Li : [He] $2s^1$

Na : [Ne]$3s^1$

:

:

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

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

Resemblance with halogens:

1. 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.

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 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.

Owing to these reasons, hydrogen cannot be placed with alkali metals (group I) or with halogens (group VII). 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?

2. Isotopes of Hydrogen are-

1. Protium $\left(H_1^1\right)$

2. Deuterium $\left(H_1^2 / D\right)$

3. Tritium $\left(H_1^3 / T\right)$

The mass ratio is 1:2:3

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

3. The ionization enthalpy of hydrogen atom is very high (1312 kJ mol^{-1}). Hence, it is very hard to remove its only 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?

4. The process of producing syngas from coal is known as 'coal gasification'

$$C(s)+H_2(g)\longrightarrow CO(g)+H_2(g)$$

The production of dihydrogen can be increased by reacting carbon monoxide of syngas mixture with the steam in the presence of iron chromate as a catalyst. This is called 'water gas shift reaction '. carbon dioxide can be removed by scrubbing with a sodium solution.

$$CO(g)+H_2O(g)\longrightarrow CO_2(g)+H_2(g)$$

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

5. 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:

$$2H_2O+2e^-\longrightarrow 2H_2+2OH^-$$

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

$$2OH^-\longrightarrow H_2O+\frac{1}{2}O_2+2e^-$$

$\therefore$ Net reaction can be represented as:

$$H_2O_{(l)}\longrightarrow H_{2(g)}+\frac{1}{2}O_{2(g)}$$

Electrical conductivity of pure water is very low owing to the absence of ions in it. 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 and for electrolysis to take place.

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) $Zn_{(s)}+NaOH_{(aq)}\xrightarrow{\text{heat}}$

6. Complete reactions are–

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

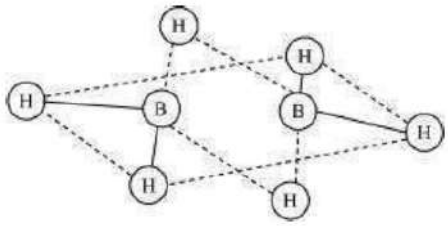
7. The ionization enthalpy of H–H bond is very high (1312 kJ mol^{-1}). This indicates that hydrogen has a low tendency to form H^+ ions. Its ionization enthalpy value is comparable to that of halogens. Hence, it forms diatomic molecules (H_2), hydrides with elements, and a large number of covalent bonds. 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) electronrich compounds of hydrogen? Provide justification with suitable examples.

8. (i) Electron-deficient hydrides–
Those compounds having fewer electrons to writing its conventional Lewis structure. examples B_2H (all the elements of group 13 form electron deficient hydrides)
(ii) Electron-precise hydrides-
Those compounds have the required number of electrons to write their conventional Lewis structure. ex- CH_4 (all elements of group 14 form such compounds)
(iii) Electron-rich hydridesElectron-
rich hydrides have excess electrons which are present as lone pairs. Elements of group 15-17 form such compounds like $NH_3.H_2O$ has one lone pair and two lone pair respectively.

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

9. An electron-deficient hydride does not have sufficient electrons to form a regular bond in which two electrons are shared by two atoms e.g., B_2H_6, Al_2H_6 etc.
These hydrides cannot be represented by conventional Lewis structures. B_2H_6, for example, 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.

$$B_2H_6 + 2NMe \longrightarrow 2BH_3 \cdot NMe_3$$

$$B_2H_6 + 2CO \longrightarrow 2BH_3 \cdot CO$$

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

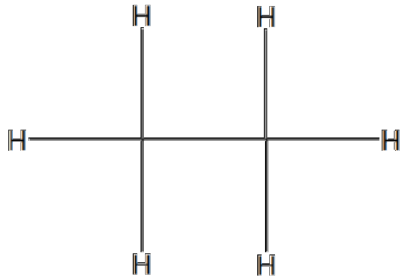
10. the general term C_nH_{2n+2}

for n = 1, 2, 3.. we get ... CH_4,C_2H_6,C_3H_8…

Lewis acids are an electron acceptor, So the above compound should be electron deficient species.

C_2H_6 taking an example

Here we can directly count that both the Carbon atom has perfect 8 electrons in sharing. they follow the octet rule. It is electron precise hydride and it neither donate or accept electrons to act Lewis acid or 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.

11. 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: $LaH_{2.87}$, $YbH_{2.55}$, $TiH_{1.5-1.8}$ 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.

Alkali metals will not form non-stoichiometric hydrides.

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

12. Metallic hydrides are hydrogen deficient and they don't hold the law of constant composition.it is established that hydrides of nickel, palladium, and Ce have lattice different where hydrogen occupies the interstitial position in the lattices allowing further absorption of hydrogen on these metals. Some of the metals like Pd and Pt accommodate a very large volume of hydrogen and therefore, can be used for hydrogen storage.

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

13. 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 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. For this reason, 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?

14. The strength of hydrogen bonding depends on the electronegativity of an atom
electronegativity order N < O < F
The expected order should be $NH_3 < H_2O < HF$
But the actual order is $NH_3 < HF < H_2O$

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.

15. Saline hydrides (i.e., 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:

$$MH_{(s)} + H_2O_{(aq)} \longrightarrow MOH_{(aq)} + H_{2(g)}$$

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 present case as well. It is heavier than dihydrogen and will be effective in isolating the burning surface from dihydrogen and dioxygen.

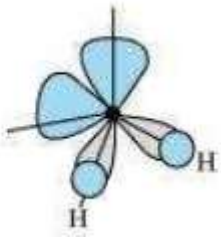
16. Arrange the following
(i) CaH_2, BeH_2 and TiH_2 in order of increasing electrical conductance.
(ii) LiH, NaH and CsH in order of increasing ionic character.
(iii) H–H, D–D and F–F in order of increasing bond dissociation enthalpy.
(iv) NaH, MgH2 and H_2O in order of increasing reducing property.

16. (i) Arrange the following
CaH_2, BeH_2 and TiH_2 in order of increasing electrical conductance
increasing order of electrical conductance–
$BeH_2 < CaH_2 < TiH_2$
electrical conductivity depends on its ionic nature . more is the ionic more is the conductivity.
Berrium hydride is covalent in nature so it has least conductivity. Titanium hydride is metallic in nature so it will also conduct. we also know that greater is the size of cation more is the ionic in nature.
(ii) Arrange the following
LiH, NaH and CsH in order of increasing ionic character
the increasing order of ionic character –
LiH < NaH < CsH
The ionic character can be measured by the electronegativity difference between the atom. we know that down the group electronegativity decreases. Therefore, Cs has most electronegative character then Na then Li.
(iii) arrange the following
H–H, D–D and F–F in order of increasing bond dissociation enthalpy

F – F < H – H < D – D increasing order of bond dissociation enthalpy In F-F high repulsion force is acting so breaking should be easy. while in case of H-H and D-D, bond pair of D-D is more strongly attracted by the nucleus because of the higher nucleus mass in D_2. we know that higher the attraction high is the bond strength.

17. Compare the structures of H_2O and H_2O_2.

17. 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.

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

18. It means water molecules can react with each other and form hydronium ion and hydroxide ion.
(self-ionization)

$$H_2O(l) + H_2O(l) \longrightarrow H_3O^+(aq) + OH^-(aq)$$

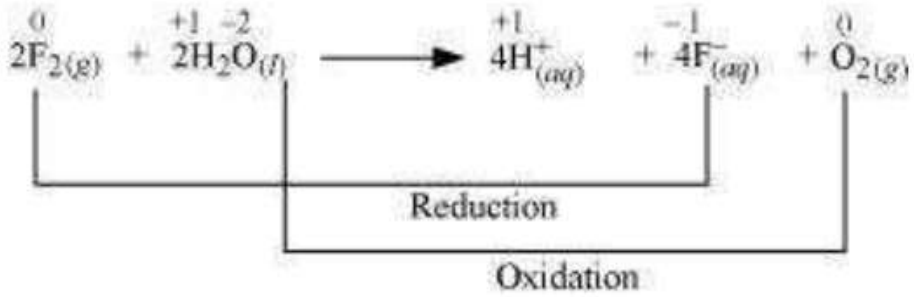
it indicates its amphoteric nature; means behave as acid as well as the base. the Hydronium Ion - conjugate acid the hydroxide ion - conjugate base

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

19. The reaction between fluorine and water can be represented as:

$$2F_{2(g)} + 2H_2O_{(t)} \longrightarrow 4H^+_{(aq)} + 4F^-_{(aq)} + O_{2(g)}$$

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.

(i) $PbS_{(s)} + H_2O_2(aq) \rightarrow$

(ii) $MnO^-_{4(aq)} + H_2O(g) \rightarrow$

(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 and (c) hydration reactions.

20. (i) Complete the following chemical reactions.

(i) $PbS(s) + H_2O_2(aq) \longrightarrow$

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

(i) $PbS(s) + H_2O_2(aq) \longrightarrow PbSO_4(s) + H_2O(l)$

Here hydrogen peroxide oxidizes the lead sulfide, act as an oxidising agent. Hence it is a redox reaction.

(ii) Complete the following chemical reactions.

$MnO^-_4(aq) + H_2O_2(aq) \longrightarrow$

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

Reaction is–

$MnO^-_4(aq) + H_2O_2(aq) \longrightarrow 6H^+(aq) + Mn^{2+}(aq) + 8H_2O(l) + 5O_2(g)$

Here hydrogen peroxide reduces the MnO^-_4 into Mn^{2+} act as reducing agent. Hence it's a redox reaction.

Complete the following chemical reactions.

$CaO(s) + H_2O(g) \longrightarrow$

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

The reaction is - $CaO(s) + H_2O(g) \longrightarrow Ca(OH)_2(aq)$

it is a hydrolysis reaction because we know that the reaction in which water reacts with water to produce another compound is hydrolysis.

(iv) Complete the following chemical reactions

$AlCl_3(g) + H_2O(l) \longrightarrow$

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

The complete reaction is -

$AlCl_3(g) + H_2O(l) \longrightarrow Al_2O_3(s) + 6HCl(aq)$

The given reaction is hydrolysis reaction.

Complete the following chemical reactions

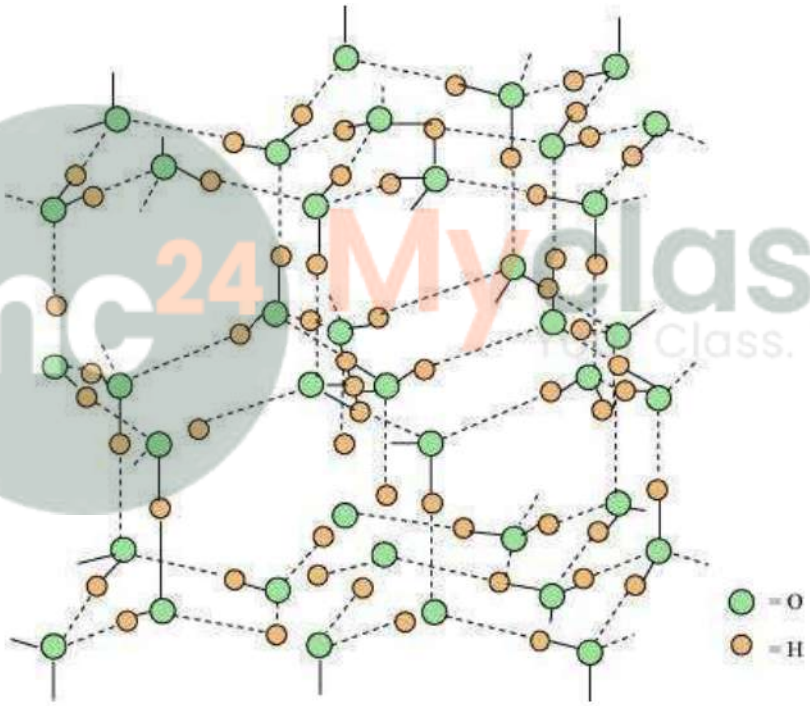
$Ca_3N_2(s) + H_2O(l) \longrightarrow$

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

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

21. Ice is the crystalline 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 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?

22. Answer- Temporary hardness of water is because of the presence of salts of magnesium and calcium hydrogen carbonates. ($MHCO_3$) [M = Mg,Ca]. Permanent hardness is due to the presence of soluble salts of magnesium and calcium in the form of chlorids and sulphates in water. e.g, MCl_2/MSO_4

[M = Mg and Ca]

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

23. The process of treating permanent hardness of water using synthetic resins is based on the 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

2) Anion exchange resins

Cation exchange resins are large organic molecules that contain the $-SO_3H$ group. The resin is firstly 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.

$$2RNa + M^{2+}_{(aq)} \longrightarrow R_2M_{(s)} + 2Na^+_{(aq)}$$

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

$$2RH + M^{2+}_{(aq)} \rightleftharpoons MR_{2(s)} + 2H^+_{(aq)}$$

Anion exchange resins exchange OH^- ions for anions like Cl^-, HCO_3^-, and SO_4^{2-} present in water.

$$RNH_{2(s)} + H_2O_{(l)} \rightleftharpoons RNH_3^+ \cdot OH^-_{(s)}$$

$$\downarrow + X^-_{(aq)}$$

$$RHN_3^+ \cdot X^-_{(s)} + OH^-_{(aq)}$$

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.

24. It has the ability to act as an acid as well as a base. In the Bronsted sense, it acts as an acid with ammonia and a base with hydrogen sulphide.

Reactions to show the amphoteric nature of water –

$$H_2O(l) + NH_3(aq) \rightleftharpoons OH^-(aq) + NH_{4+}(aq)$$

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

25. The reaction takes place as:

In the forward reaction, $H_2O_{(l)}$ denotes its proton to $NH_{3(aq)}$. Hence it acts as a Lewis acid.

(3) Self-ionization of water

In the reaction, two water molecules react as:

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

26. Demineralized water means free from all types of cations and anions and also soluble mineral salts.

It can be obtained by passing water successively through a cation exchange (in the H^+ ion form) and anion exchange (in the form of OH^- ion) resins:

Cation exchange process-

$2RH(s) + M^{2+} \rightleftharpoons MR_2(s) + 2H^+(aq)$ {exchange for Na^+, Ca^{2+}, Mg^{2+} and other cation present in water.}

Anion exchange process–

OH^- exchanges for anions like Cl^-, HCO_3^-, SO_4^{2-} etc present in the water

OH^- ions liberated in anion exchange neutralizes the H^+ ions liberated in cation exchange, thereby forming water

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

27. 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.

28. Water is essential for all living beings. It plays an important role in the biosphere. its has high specific heat, thermal conductivity, surface tension, dipole moment, and dielectric constant.

The high heat of vaporisation and heat capacity are responsible for the moderation of the climate and body temperature of living beings. It is an excellent solvent for transportation of ions and molecules required for plant and animal metabolism.

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

29. 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, carbides, phosphides, nitrides and various other salts. During hydrolysis, H^+ and OH^- ions of water interact with the reacting molecule.

Some reactions are:

$$CaO + H_2O \longrightarrow Ca(OH)_2$$
$$NaH + H_2O \longrightarrow NaOH + H_2$$
$$CaC_2 + H_2O \longrightarrow C_2H_2 + Ca(OH)_2$$

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

30. D_2O s heavy water, it acts as a moderator which slow down the rate of the chemical reaction. Due to this property, we cannot use it for drinking purpose. if we use, it will slow down our metabolic reaction happens in the body.

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

31. 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:

$$NaH + H_2O \longrightarrow NaOH + H_2$$

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

$$CuSO_4 + 5H_2O \longrightarrow CuSO_4 \cdot 5H_2O$$

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

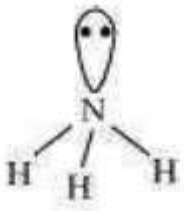
32. The saline hydrides react with water to form metal hydroxide and liberate hydrogen gas.
reaction- $MH + H_2O \longrightarrow MOH + H_2$ [M = Na, K, Ca...]
when added to the organic compounds they form metal hydroxide along with the liberation of hydrogen gas (escape into the atmosphere) and leave behind only hydroxide part.

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.

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

(1) Hydride of nitrogen

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



(2) 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.

(3) 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.

(4) 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:

$$KH_{(s)} + H_2O_{(aq)} \longrightarrow KOH_{(aq)} + H_{2(g)}$$

$$H_2O_{(l)} + NH_{3(aq)} \longleftrightarrow OH^-_{(aq)} + NH^+_{4(aq)}$$

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.

34. • KCl is salt of KOH(strong base) and HCl (strong acid). So it does not hydrolyze in normal water because it is neutral in nature. It just simply ionizes in water.

KCl $\longrightarrow$ K^+ + Cl^- in acidified and alkaline water they do not dissociate into ions and remains the same.

• $AlCl_3$ is the salt of a weak base $Al(OH)_3$ and HCl (strong acid). So it hydrolyzes in normal water.

$AlCl_3 + H_2O \longrightarrow Al(OH)_3 + HCl$

In acidic water, there are H^+ ions which react with $Al(OH)_3$ and form water molecule and give Al^{3+} ions. In alkaline water, OH^- ions react with $Al(OH)_3$ and form $[Al(OH)_4]^-$ and water molecules.

$$Al(OH)_3 + OH^- \longrightarrow [Al(OH)_4]^- + H_2O$$

35. How does H_2O_2 behave as a bleaching agent?

35. H_2O_2 or hydrogen peroxide acts as a strong oxidizing agent both in acidic and basic media.

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) fuelcell?

36. (i) Hydrogen Economy - Technique of using dihydrogen in an efficient way. The basic principle of the hydrogen economy is the transportation and storage of energy in the form of liquid or gaseous dihydrogen.

(ii) Hydrogenation- The addition of dihydrogen to the reactant. This process can be done with the help of a suitable catalyst like nickel and palladium.

(iii) Syngas- The mixture of CO & H_2. This mixture of carbon monoxide and dihydrogen is used for the synthesis of methanol and a number of hydrocarbons, its called syngas, water gas or synthesis gas.

(iv) Water gas shift reaction- To increase the production of dihydrogen, by reacting with carbon monoxide of syngas mixture with steam in the presence of iron chromate as a catalyst $CO(g) + H_2O(g) \longrightarrow H_2 + CO_2$. This is called water gas shift reaction.

(v) Fuel-cell- These are the devices that produce electrical energy from the liquid fuel with the help of suitable electrolytes.dihdrogen can be used in these cells to produce electrical energy. It is eco-friendly in nature.