

NCERT Solutions for Class 11 Chemistry Chapter 9 Hydrogen

Question 9.1 Justify the position of hydrogen in the periodic table on the basis of its electronic configuration

Answer :

Answer-The electronic configuration of the H atom is $1s^1$. Due to the presence of only one electron, it exhibits dual behaviour, i.e., it resembles both alkali metals of group 1 and also along with the halogens of group 17.

It can lose one electron to form a unipositive ion. Both H and alkali metals form monovalent cations by losing one electron from its outer shell. Both alkali and hydrogen shows +1 oxidation numbers. Both have an affinity towards electronegative elements and readily combine with them and forms oxide, halides, and sulphides.

It has a very high ionization enthalpy and does not possess metallic characteristics under normal conditions. In fact, in terms of ionization enthalpy, hydrogen resembles more with halogens, ionization enthalpy of Li is 520 kJ mol^{-1} , F is 1680 kJ mol^{-1} and that of H is 1312 kJ mol^{-1} . Like halogens, it forms a diatomic molecule, combines with elements to form hydrides and a large number of covalent compounds.

Question 9.2 Write the names of isotopes of hydrogen. What is the mass ratio of these isotopes ?

Answer :

Isotopes of Hydrogen are-

1. Protium (H_1^1)
2. Deuterium (H_1^2/D)

3. Tritium (H_1^3/T)

The mass ratio is 1:2:3

Question 9.3 Why does hydrogen occur in a diatomic form rather than in a monoatomic form under normal conditions ?

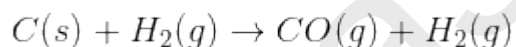
Answer :

Ionisation enthalpy of hydrogen is quite high (1312 kJ/mol). Hence it is very difficult to remove its only one electron. As a result, the tendency to exist in the monoatomic form is very low.

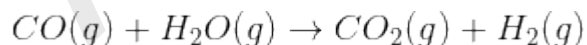
Question 9.4 How can the production of dihydrogen, obtained from 'coal gasification', be increased?

Answer :

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



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.

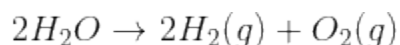


Question 9.5 Describe the bulk preparation of dihydrogen by an electrolytic method.

What is the role of an electrolyte in this process?

Answer :

The dihydrogen is prepared by electrolysis of acidified water using platinum electrodes. generally acid is sulphuric acid and base is sodium hydroxide is used.



Role of electrolyte-

The electrical conductivity of pure water is very low due to the absence of ions in it. Hence electrolysis of water takes place at slow rate. If we add an electrolyte as an acid or base it will increase the rate of electrolysis. Electrolytes provide ions in this process for the better conduction of electricity.

Question 9.6 Complete the following reactions

Answer :

Answer- Complete reactions are-

Question 9.7 Discuss the consequences of high enthalpy of H–H bond in terms of chemical reactivity of dihydrogen?

Answer :

The ionization enthalpy of the H-H bond is very high (1312kJ/mol). It means hydrogen has less tendency to form H^+ ions. Its ionization enthalpy is comparable to halogens. Hence it forms a diatomic molecule, hydrides with the elements, and a large number of covalent bonds. It does not possess any metallic character like metals

Question 9.8 What do you understand by (i) electron-deficient, (ii) electron-precise, and (iii) electron-rich compounds of hydrogen? Provide justification with suitable examples.

Answer :

(i)Electron-deficient hydrides-

Those compounds having fewer electrons to writing its conventional Lewis structure. examples B_2H_6 (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)

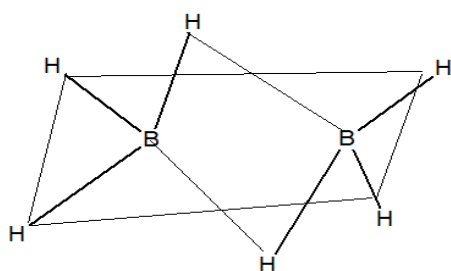
(iii)Electron-rich hydrides-

Electron-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.

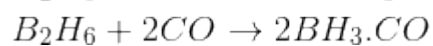
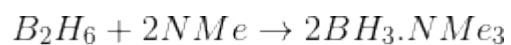
Question 9.9 What characteristics do you expect from an electron-deficient hydride with respect to its structure and chemical reactions

Answer :

Electron-deficient hydrides do not have required electrons to form a regular bond in which two electrons are shared by two atoms. e.g. B_2H_6 , Al_2H_6 etc



Because of electron deficiency, they have the tendency to accept electrons. hence they act as Lewis acid.



Question 9.10 Do you expect the carbon hydrides of the type (C_nH_{2n+2}) to act as 'Lewis' acid or base? Justify your answer.

Answer :

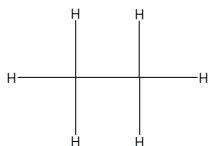
the general term C_nH_{2n+2}

for $n = 1, 2, 3..$ we get $CH_4, C_2H_6, C_3H_8 \dots$

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



Question 9.11 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

Answer :

Non-stoichiometric hydrides are hydrogen deficient compounds. they are formed by d & f block elements. Such hydrides do not follow the law of constant composition.

Examples- $LaH_{2.87}$, $YbH_{2.55}$, $ZrH_{1.3-1.75}$ etc.

Alkali metals do not form these types of hydrides. Alkali metals form stoichiometric hydrides. These hydrides are ionic in nature.

Question 9.12 How do you expect the metallic hydrides to be useful for hydrogen storage? Explain

Answer :

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.

Question 9.13 How does the atomic hydrogen or oxy-hydrogen torch function for cutting and welding purposes? Explain.

Answer :

Atomic hydrogen can be prepared by dissociation of a bond of dihydrogen with the help of an electric arc. This release a huge amount of energy around 135 kJ/mol and this energy can be used to generate a high temperature of 4000K, which is desirable for welding and cutting of metals. Therefore, atomic hydrogen or oxy-hydrogen torch are used for welding purpose.

Question 9.14 Among NH_3 , H_2O and HF , which would you expect to have highest magnitude of hydrogen bonding and why?

Answer :

The strength of hydrogen bonding depends on the electronegativity of an atom

electronegativity order $N < O < F$

The expected order should be $\text{NH}_3 < \text{H}_2\text{O} < \text{HF}$

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

This is because of the extent of H bonding in a water molecule is more due to the presence of one extra hydrogen atom. Also, Oxygen atom forms a huge ring like structure through its high ability of hydrogen bonding

Question 9.15 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.

Answer :

Saline hydrides are known to react with water violently and produce fire.

$MH(s) + H_2O \rightarrow MOH(aq) + H_2(g)$ this is the general reaction formula. We see that the product is a base and hydrogen gas.

Carbon dioxide is heavier than oxygen. It is used in fire extinguisher because it cuts the supply of oxygen by acting as a blanket on fire.

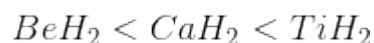
Carbon dioxide can be used in nowadays and it is heavier than dihydrogen also so that it will isolate the burning surface from H_2 and O_2

Question 9.16(i) Arrange the following

CaH_2 , BeH_2 and TiH_2 in order of increasing electrical conductance

Answer :

increasing order of electrical conductance-



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.

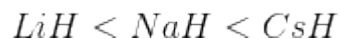
we also know that greater is the size of cation more is the ionic in nature.

Question 9.16(ii) Arrange the following

LiH , NaH and CsH in order of increasing ionic character

Answer :

the increasing order of ionic character -



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.

Question 9.16(iii) arrange the following

H-H, D-D and F-F in order of increasing bond dissociation enthalpy

Answer :



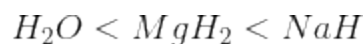
In F-F high repulsion force is acting so breaking should be easy.

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 D₂. we know that higher the attraction high is the bond strength.

Question 9.16(iv) Arrange the following NaH , MgH_2 , and H_2O in order of increasing reducing property

Answer :

increasing order of reducing property-



Na can easily donate electrons so it has a higher reducing property.

Both H_2O and MgH_2 are covalent hydrides. water has less reducing property because it has high bond dissociation energy than MgH_2

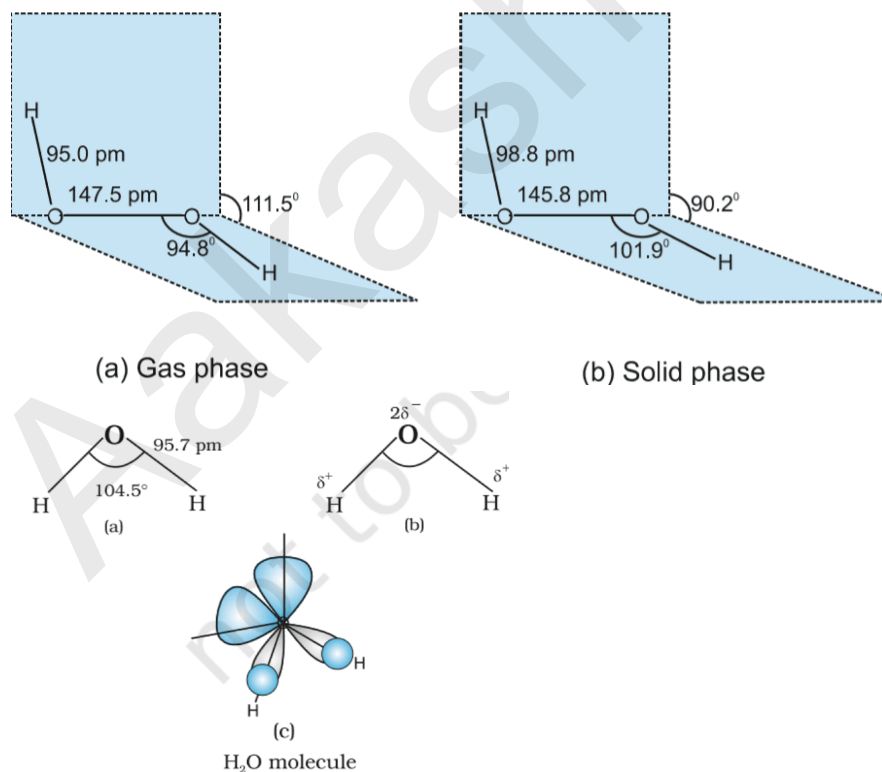
Question 9.17 Compare the structures of H_2O and H_2O_2 .

Answer :

In the gaseous phase water is a bent molecule with a bond angle of 104.5° , and O-H bond length of 95.7 pm . It is a highly polar molecule.

Hydrogen peroxide has a non-planar structure both in the gas phase and solid phase. The dihedral angle in the gas phase is 115.5° and in the solid phase is 90.2° degree.

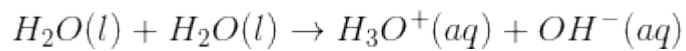
fig-



Question 9.18 What do you understand by the term 'auto-protolysis' of water? What is its significance?

Answer :

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



it indicates its amphoteric nature; means behave as acid as well as the base.

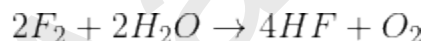
the Hydronium Ion - conjugate acid

the hydroxide ion - conjugate base

Question 9.19 Consider the reaction of water with F₂ and suggest, in terms of oxidation and reduction, which species are oxidized/reduced.

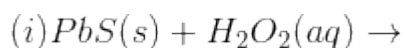
Answer :

The reaction of fluorine with water-



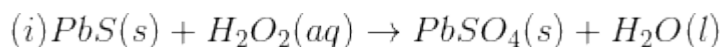
Fluorine reduced by gaining an electron and water oxidized by losing an electron.

Question 9.20(i) Complete the following chemical reactions.



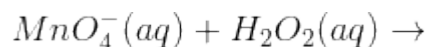
Classify the above into (a) hydrolysis, (b) redox and (c) hydration reactions

Answer :



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

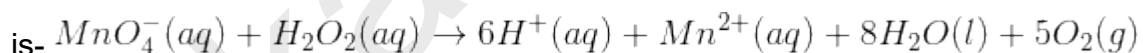
Question 9.20(ii) Complete the following chemical reactions.



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

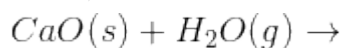
Answer :

Reaction



Here hydrogen peroxide reduces the MnO_4^- into Mn^{2+} act as reducing agent. Hence it's a redox reaction.

Question 9.20(iii) Complete the following chemical reactions.



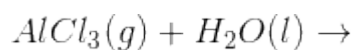
Classify the above into (a) hydrolysis, (b) redox and (c) hydration reactions

Answer :

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

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

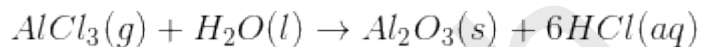
Question 9.20 (iv) Complete the following chemical reactions



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

Answer :

The complete reaction is -



The given reaction is hydrolysis reaction.

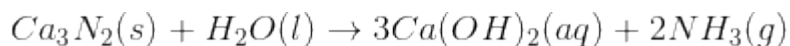
Question 9.20(v) Complete the following chemical reactions



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

Answer :

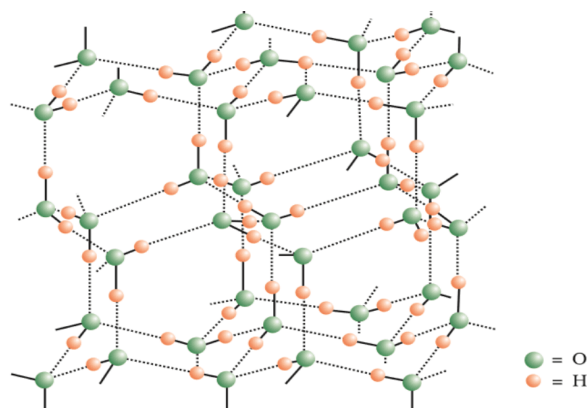
the complete reaction is -



The reaction in which water reacts with water and produce other compound are called hydrolysis reaction.

Question 9.21 Describe the structure of the common form of ice.

Answer :



Ice is a crystalline form of water. At atmospheric pressure, ice crystallizes in the hexagonal form, but at low temperature, it condenses to cubic form. The density of ice is less than water; therefore it floats on the water surface. Ice has a highly ordered three-dimensional hydrogen-bonded structure. (shown above) Each Oxygen atom is surrounded by four H atom tetrahedrally.

Question 9.22 What causes the temporary and permanent hardness of water ?

Answer :

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]

Question 9.23 Discuss the principle and method of softening of hard water by synthetic ionexchange resins.

Answer :

The treatment process of permanent hard water using synthetic resin is based on cations exchange (Ca^{2+} , Mg^{2+} , Na^{+}) and anion exchange (Cl^{-} , SO_4^{2-} , HCO_3^{-}); present in water by H^{+} ions and OH^{-} ions.

There are two types-

(i) Cation exchange resins

(ii) anion exchange resins

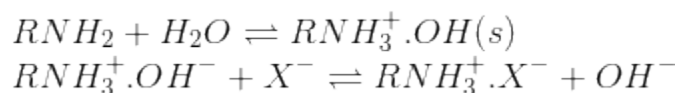
Cation exchange resin is large organic molecules contain $-SO_3H$ group and are water-insoluble. Ion exchange resin (RSO_3H) is changed to RNa by treating it with $NaCl$. The resin exchanges Na^{+} ions with Ca^{2+} and Mg^{2+} ions present in hard water to make the water soft.



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



Anion exchange resins exchanges OH^{-} ions for anions like (Cl^{-} , SO_4^{2-} , HCO_3^{-})



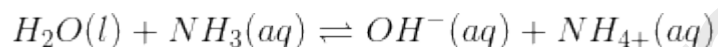
Water first passes through the cation exchange process. The water obtained is acidic in nature and this acidic water then passed through anion exchange process where OH^- ions neutralize the H^+ ions

Question 9.24 Write chemical reactions to show the amphoteric nature of water.

Answer :

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 -



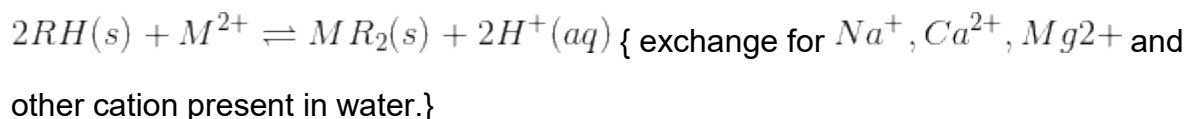
Question 9.26 What is meant by 'demineralised' water and how can it be obtained?

Answer :

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-



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

Question 9.27 Is demineralized or distilled water useful for drinking purposes? If not, how can it be made useful?

Answer :

Water contains several minerals that are necessary or required by human beings, plants, animals for survival. And we know that demineralized water is free from all these minerals. So it is not useful for drinking purpose.

It can be made useful by adding desired minerals in a certain amount which are favourable for growth.

Question 9.28 Describe the usefulness of water in biosphere and biological systems.

Answer :

Water is essential for all living beings. It plays an important role in the biosphere. It 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.

Question 9.29 What properties of water make it useful as a solvent? What types of a compound can it (i) dissolve, and (ii) hydrolyze?

Answer :

Water has **high dielectric constant** ($78.4C^2/Nm^2$) and dipole moment which makes it universal solvent. It dissolves the most ionic as well as covalent compounds. [ionic compound because of **ion-dipole interaction** and covalent due to their tendency to form a **hydrogen bond** with water.] Water is also able to hydrolyze the metallic and non-metallic oxides, hydrides and nitrides, etc.

Question 9.30 Knowing the properties of H₂O and D₂O, do you think that D₂O can be used for drinking purposes?

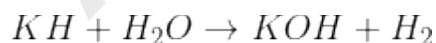
Answer :

*D*₂*O* is 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.

Question 9.31 What is the difference between the terms 'hydrolysis' and 'hydration' ?

Answer :

Hydrolysis - it means the reaction of the water molecule (H^+/OH^-) with another compound and forming a new product. for example.



Hydration - It means the addition of one or more than one water molecule to form a hydrated compound.

ex. $CuSO_4 + 5H_2O \rightarrow CuSO_4 \cdot 5H_2O$

Question 9.32 How can saline hydrides remove traces of water from organic compounds?

Answer :

The saline hydrides react with water to form metal hydroxide and liberate hydrogen gas.

reaction- $MH + H_2O \rightarrow MOH + H_2$ [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.

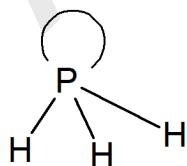
Question 9.33 What do you expect the nature of hydrides is, if formed by elements of atomic numbers 15, 19, 23 and 44 with dihydrogen? Compare their behaviour towards water

Answer :

Atomic Number 15 19 23 and 44 are phosphorus, potassium, vanadium, and ruthenium respectively.

hydrides of these elements are

(i) PH_3 - its an electron rich species also a covalent molecule.



a lone pair of electron.

(ii) Hydrides of potassium- dihydrogen forms an ionic hydride. It is crystalline and non-volatile in nature

(iii) **hydrides of vanadium and ruthenium**- Both elements belong to d- block. They form metallic and non-stoichiometric hydrides. They are metallic in nature.

Behavior towards water-

- D block element does not react with water
- phosphorus reacts with water (behave as Lewis base and accept H^+ and form PH_4^+)
- potassium react with water and form KOH and liberate hydrogen gas

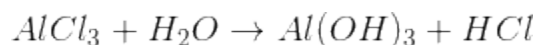
Question 9.34 Do you expect different products in solution when aluminum (III) chloride and potassium chloride treated separately with (i) normal water (ii) acidified water, and (iii) alkaline water? Write equations wherever necessary.

Answer :

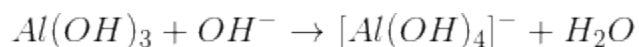
- KCl is salt of KOH(strong base) and HCl(strong acid). So it does not hydrolyze in normal water because it is neutral in nature. It just simply ionizes in water.

$KCl \rightarrow K^+ + Cl^-$ 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.



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.



Question 9.35 How does H_2O_2 behave as a bleaching agent?

Answer :

Hydrogen peroxide (H_2O_2) act as an oxidizing agent in basic as well as the acidic medium. In the exposure of light, it decomposes and gives nascent oxygen which combines with coloring matter which in turn gets oxidized. So the bleaching action of (H_2O_2) is mainly due to the oxidation of coloring matter.

Question 9.36 What do you understand by the terms: (i) hydrogen economy (ii) hydrogenation (iii) 'syngas' (iv) water-gas shift reaction (v) fuel-cell ?

Answer :

(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. $CO(g) + H_2O(g) \rightarrow H_2 + CO_2$ 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. dihydrogen can be used in these cells to produce electrical energy. It is eco-friendly in nature.