Hydrogen.

Unique Position of hydrogen in the Periodic table:
Hydrogen is the first element in the Periodic table. However, a Proper Position Could not be assigned to it either in the mendeleev's Periodic table or Long form of Periodic table. because.

1. Resembalance with alkali metals:-

a. Electronic Configuration:- Like alkali metals, hydrogen also Contains one electrons in its outermost shell.

b. Electropositive character:- Like alkali metals, hydrogen also loses its one electron to form hydrogen ion (H^+ proton)

c. oxidation state:- Like alkali metals hydrogen exhibits an oxidation state of +1 in its Compounds.

d. Combination with electronegative elements or non-metals:- Like alkali metals, hydrogen Combines with electronegative elements or non metals like oxygen, halogens and sulpher forming their oxides, halides and sulphides.

e. Liberation at Cathode:- When an aqueous solution of HCl is electrolysed. H_2 is liberated at the Cathode in the same way as alkali metals are liberated at the Cathode during the electrolysis of their fused halides.

f. Reducing character:- Like alkali metals, hydrogen also acts as a strong reducing agent.

2. Resemblance with Halogens:-

a. Electronic Configuration:- All the halogens have one electron less than the Stable Configuration of the nearest inert gas. Hydrogen has one electron in the outermost shell and thus has one electron less than the Stable Configuration of the nearest inert gas He.

b. Electronegative character — Halogens have a strong tendency to gain one electron to form halide ions. Hydrogen shows.

Some tendency to gain one electron to form hydride (H^-)

c. Ionization enthalpy — The ionization enthalpy of hydrogen is quite comparable with those of halogens but much higher than those of alkali metals.

d. Oxidation state — Like halogens, hydrogen show an oxidation state of (-1)

e. Liberation at anode — when fused alkali metal hydrides are subjected to electrolysis, hydrogen is liberated at the anode similarly, halogens are liberated at the anode when fused alkali metal halides are electrolysed.

f. Atomicity and non-metallic character — Like halogens, hydrogen also exists as a diatomic molecule, Like halogens hydrogen is also a typical non-metal

(g) Combine with metal — Hydrogen combines with highly electro-positive alkali and alkaline earth metals to form metallic hydrides. In a similar way, halogens combine with these metals to form metallic halides.

(h) Formation of Covalent Compound — Like halogens, hydrogen readily combines with non-metals such as (C, Si, N) etc. to form Covalent compounds.

(i) Replacement or Substitution reactions — In many compounds of Carbon, hydrogen can be replaced by halogens and halogens can be replaced by hydrogen.

3. Difference from alkali metals and halogens.

a. Hydrogen is comparatively less electropositive than alkali metal and less electronegative than halogens.

b Unlike halogens and alkali metals hydrogen contains only one Proton but no nutron in its nucleus. and one electron in the extranucleur Part.

c. The oxide of alkali metals are basic while oxides of halogens are acidic but the oxide of hydrogen is neutral.

d. The hydrogen atoms in hydrogen molecule do not have any unshared pair of electrons whereas each halogen atom in halogen molecule have three unshared pair of electron.

e. The compounds of hydrogen with halogens (hydrogen halides) are low boiling covalent compounds whereas alkali metal halides are high melting ionic solids.

f. The size of H^+ ion is much smaller than those of alkali metal cations. and the size of H^- ion is much smaller as compared to halide ions.

— Isotopes of hydrogen :- Isotopes are the different atoms of the same element which have the same atomic number but different mass numbers.

Hydrogen have three isotopes Protium, deuterium, tritium.

— occurance — The most abundant isotope of hydrogen is Protium ($_1^1H$). This occurs in natural hydrogen to an extent of 99.985%, and deuterium ($_1^2H$) .0156 %. and Tritium being unstable because of its radioactive

a. Protium ($_1^1H$) :- this is the most abundant isotope of hydrogen its atomic number is 1 and mass number is also 1. Its nucleus has only one Proton and one electron is revolving around the nucleus in its K-shell.

b. Deuterium or heavy hydrogen [$_1^2H$ or D] :- It is usually prepared by the electrolysis of heavy water (D_2O). Its atomic number is 1 and its mass number is 2 therefore its nucleus has one Proton and one neutron while one electron is present in the K-shell.

c. Tritium [$_1^3H$] : It is the least abundent (10^{-16}%) of all

the isotopes of hydrogen and is formed in the upper atmosphere by reactions induced by cosmic rays. It is radioactive with a short half life of 12.33 years. It decays by β-emission with no γ-radiations.

Isotope effect :- The difference in properties due to difference in atomic masses is called isotope effect.

Uses of Tritium :- It is used to make thermonuclear devices. It is widely used as a radioactive tracer since it is relatively cheap and easy to work with.

- Preperation of Dihydrogen :-

1 From water.

a. By the action of water on active metals.

- Cold water — very active metals, alkali and certain alkaline earth metals reacts with water at room temperature evolving dihydrogen.

The reaction with alkali metals is so vigorous and exothermic that the hydrogen evolved catches fire. In order to slow down the reaction, Amalgams (alloys with mercury) of these metals are generally used. In these amalgams only a small surface area of the metal comes in contact with water and therefore the reaction is slowed down.

- Boiling water — Less active metals like Zn, Mg, Al etc. decompose boiling water liberating dihydrogen
- Steam — Still less active metals like Fe, Sn, Ni etc decompose steam at high temperature evolving dihydrogen.

b. By electrolysis of water :- Dihydrogen of high purity is usually obtained by the electrolysis of water in presence of small amount of an acid or a base. During electrolysis Dihydrogen is collected at Cathode.

2. From Alkalies:- metals like Be, Zn, Al reacts with boiling alkali solutions liberating dihydrogen.

3. From Acids:- Metals which are more electropositive than hydrogen, lie above hydrogen in the electrochemical series such as Zn, Fe, Mg etc. react with dilute mineral acids to liberate dihydrogen gas.

— Laboratory Preparation of dihydrogen:- In the laboratory, dihydrogen is Prepared by action of dil H_2SO_4 on granulated zinc.

— Properties of dihydrogen:-

1 Physical Properties.

a. It is the lightest substance. Its density is approx $\frac{1}{14}$ of that of air.

b. It is slightly soluble in water since its molecules are non-polar.

c. It is a colourless, tasteless and orderless gas.

d. It can be liquefied under low temperature and Pressure.

2. Chemical Property

Dihydrogen is quite stable and relatively inert at room temperature due to its high H-H Bond dissociation enthalpy. Therefore most of the reactions of dihydrogen occur at high temperature.

Atomic hydrogen is very reactive and combines with almost all the elements. It reacts in three ways.

(i) By loss of its single electron to form H^+

(ii) By gain of one electron to form H^-

(iii) By sharing its electron with other atom to form single Covalent bond.

Properties.

a. Neutral character:- It is neutral to litmus.

b. Combustibility — It is a highly combustible gas and burn in air or dioxygen with a pale blue flame to form water.

c. Reaction with metals:- Dihydrogen reacts with strongly electropositive metals like Sodium, Potassium etc. at high temperature to form salt like metal hydrides in which the oxidation state of hydrogen is (−1).

d. Reaction with non-metals:- Dihydrogen combines with many non-metals at high temperature in presence of catalysts to form covalent or molecular hydrides.

e. Reduction of metal oxides and ions:- Dihydrogen acts as a reducing agent and hence reduces oxide of certain metals less electropositive than zinc such as those of Cu, Pb, Fe etc. to the corresponding metals.

The oxide of strongly electropositive metals such as those of alkali and alkaline earth metals are not reduced Dihydrogen also reduces some metal ions in aqueous solution like Pd^{+2}, Cu^{+2}.

f. Hydrogenation of unsaturated hydrocarbons:- Unsaturated hydrocarbons such as Alkenes and Alkynes add dihydrogen in presence of a catalyst to form saturated hydrocarbons.

(i) Hydroformylation of olefins:- Olefins react with carbon monoxide and dihydrogen in presence of octacarbonyl dicobalt as catalyst under high temperature and pressure to form aldehydes. This process is called Hydroformylation or the oxo-process.

(ii) Hydrogenation of oils — Dihydrogen is bubbled through edible oils in presence of finely divided nickel at 473K when the oils are converted into solid fats. This process is called hydrogenation or hardening of oil.

Hydrogenation reduces the number of double bonds but-

does not Completely eliminate them.

Uses of dihydrogen.

a. In the manufacture of Ammonia.
b. In the hydrogenation of vegetable oils
c. In the manufacture of bulk chemicals like methanol.
d. In the manufacture of hydrogen chloride.
e. In the manufacture of metal hydride.
f. In metallurgy to reduce heavy metal oxides to metals.
g. In the atomic hydrogen and oxy hydrogen torches for cutting and welding.
h. Liquid hydrogen is used as a rocket fuel

— Some Important Points.

1. Hydrogen under very high Pressure behave like a metal.
2. The name dihydrogen is commonly used for H_2 molecules. but while referring to the isotopic mixture with natural abundance for H and D, the name diprotium is preferred.
3. The name Proton is used for H^+, but while reffering to the isotopic mixture of H^+, D^+ and T^+, the name hydron is preferred.
4. Heavy hydrogen or Deuterium was separated from liquid hydrogen by fractional evaporation.

— Hydride :- Dihydrogen Combines with a number of elements to form binary Compounds Called hydrides.

a. Ionic hydride :- these are formed by alkali metal and alkaline earth metals on heating at high temperatures

Properties.

1. These are formed by transfer of electrons from the metals to the hydrogen atoms and thus Contain hydride ion H^-.
2. These are white crystalline solids and their crystal.

Structures consist of ions.

3. The density of these hydrides is higher than those of the metals from which they are formed.
4. They have high melting and boiling points and conducts electricity in the fused state, liberating dihydrogen at anode.
5. Except LiH, they burn in air on strong heating due to their decomposition into hydrogen which is inflammable.
6. They react violently with water to form the corresponding metal hydroxides with the liberation of dihydrogen, they act as a strong base.
7. They have high heats of formation and are always stoichiometric.
8. They are powerful reducing agent at high temperature.
9. Lithium hydride is unstable at moderate temperatures. It is used in the synthesis of other useful complex metal hydride such as $LiAlH_4$ and $LiBH_4$.
10. They are used as a solid fuels.

b. Metallic hydrides:- D block elements of groups 3, 4, 5, 10, 11 12 and F-block elements on heating with H_2 under pressure form hydrides. In group 6, Cr alone form hydride. The metals of group 7, 8, 9 donot form hydride and referred to as the hydride gap.

These hydrides generally have properties similer to those of the parent metals and hence are called metallic hydrides.

Properties.

1. They are hard, have a metallic lustre, conducts electricity and have magnetic properties.
2. The density of these hydrides is lower than those of metals from which they are formed.

3. These hydrides are often non-stoichiometric, so these hydrides law of Constant Composition does not hold good.
Uses:- Due to interstitial hydride formation, these metals absorb large volumes of hydrogen on their surface. This property of absorption of gas by a metal is known as occlusion.

c Molecular or Covalent hydrides:- These hydrides usually consist of discrete Covalent molecules which are held together by weak van der waals forces of attraction and hence are called Covalent or molecular hydrides.
Properties:-
1. Covalent hydrides are usually volatile compounds having low melting and boiling points and do not conduct electricity.
2. Hydrides of group 13 do not have sufficient number of electrons to form normal Covalent bond and hence are called electron-deficient hydrides.
3. Hydrides of group 14 have exact number of electrons to form normal Covalent bonds and hence are called electron exact or electron precise hydrides.
4. Hydrides of group 15, 16, and 17 have more electrons than required to form normal Covalent bonds and hence are called electron rich hydrides.
5. The lighter elements of group 14, 15, 16 form Polynuclear hydrides in which two or more atoms of the same element are linked together, This property of self linking of atoms is called Catenation and is maximum for Carbon.

d. Polymeric hydrides: These are formed by elements having electronegativity in the range 1.40-2.0. These usually exist in the Polymeric form in which the monomer molecules are held together in two or three dimensions by hydrogen bridges. These are amorphous solids.

(e) Complex hydrides :- In these hydrides, the hydride ion (H^-) acts as the ligand and is attached to the central metal atom by coordinate bond. These are formed both by transition and non transition elements. Among the non transition elements the most important complex hydrides are formed by elements of group 13.

These are versatile reducing agents and are widely used for reducing of organic compounds.

— Water — In Nature water is found in all the three Phases. In the gaseous state, water exists as discrete molecules. It is a bent molecule with bond angle of 104°5° and bond length of 95.7 pm

In the liquid state, the H_2O molecules are held together by inter-molecular H-bond.

When water freezes, it forms ice which is the crystalline form of water. Depending upon the conditions employed Nine crystalline forms of ice is known. At atmospheric pressure ice crystallizes in the normal hexagonal form. In hexagonal ice, each oxygen atom is tetrahedrally surrounded by four other oxygen atoms, there is a hydrogen atom between each pair of oxygen atom. This give ice an open cage like structures. So there exist a number of vacant space in the crystal lattice and hence the density of ice is lower than water. As the temperature is raised gradually above 273 K, more and more of H-bond breaks and more and more H_2O molecules start coming closer resulting in decrease in volume and hence increase in density. At the 277 K the density is maximum. This Property helps aquatic animals to survive during winter months. In severe cold, the upper layer of sea water freezs while the water remains as liquid under the surface of ice.

Physical Property.

1. The freezing point and boiling point are higher than those of hydrides of the other elements of the same group 16 because of H-bond.
2. Water has a higher specific heat, thermal conductivity and surface tension.
3. Water because of its high dielectric constant has the ability to dissolve most of the inorganic (ionic) compounds. and is therefore regarded as a universal solvent.
4. Heavy water (D_2O) has slightly higher value of Physical Constants because of its higher molecular mass

Chemical Properties.

1. Stability :- Due to high negative heat of formation, water is quite stable at ordinary temperature.
2. Acid-base character :- Amphoteric character :- water is a weak electrolyte, It undergoes ionization to a small extent to give H_3O^+ and OH^- ions. As a result Pure water has very low electrical conductivity. Water acts both as an acid and as a base and hence said to be amphoteric in character due to its self ionization.
3. Water acts as an oxidising agent as well as reducing agent.
4. Hydrolytic reactions - Water can hydrolysed many oxides and other salts. to the formation of an acid or base or both.
5. Hydrate formation :- Many ionic compounds crystallise from water with one or more molecules of water associated with them. This water in combination with ionic salts is called water of crystallisation and such crystals are called hydrated salts.

a. Co-ordinated water :- water molecules are coordinated to the central metal ion to form complex ion. like $[Cr(OH_2)_6]^{+3}3Cl^-$

b Hydrogen bonded water :- water molecules are linked to some oxygen containing anions by hydrogen bonding like $CuSO_4.5H_2O$ may be represented as $[Cu(H_2O)_4]^{+2}SO_4^{-2}.H_2O$

c. Interstitial water :- water molecules are present in interstitial sites or voids in the crystal lattice.

— Soft water — water that produce lather with soap is called soft water.

— Hard water — water which does not produced lather with soap is called hard water.

- Causes of hardness :- Hardness of water is due to the presence of bicarbonates, chlorides and sulphates of calcium and magnesium in it.

— Scum :- when hard water is treated with soap solution Ca^{+2} and Mg^{+2} ions present in hard water reacts with anions of fatty acids present in soap to form scum or curdy white precipitates.

— Temporary hardness :- It is due to the presence of bicarbonates of calcium and magnesium. It can be easily removed by simply boiling and filtering of water. It is also called carbonate hardness.

— Permanent hardness — It is due to the presence of soluble chlorides and sulphates of calcium and magnesium. It can not be removed by simply boiling the water. It is also called non-carbonate hardness.

— Softening of Hard water :- The process of removing hardness of water is called softening of water.

— For temporary hard water:

1 By boiling — when temporary hard water is boiled, bicarbon-

- ates of Calcium and Magnesium decompose to form insoluble Calcium and Magnesium Carbonates which are removed by filtration.

2. By Clark's Process :- In this Process Calculated amount of quick lime is added, the bicarbonates present in the hard water react with lime to form insoluble Calcium and Magnesium Carbonates which can removed by filtration. If excess of lime is added, water will again become hard due to absorption of CO_2 from the atmosphere by unused Slaked lime to form Soluble Calcium bicarbonates.

— For Permanent hard water.

1 Washing Soda Process :- In this Process hard water is treated with a Calculated amount of washing Soda. When Chlorides and Sulphates of Calcium and magnesium present in hard water get Precipitated as insoluble Calcium and magnesium Carbonates which can be easily filtered off and water become Soft.

2 Ion exchange method :- In this method, the Ca^{+2} and Mg^{+2} ions Present in hard water are exchanged by those Present in complex inorganic and organic compounds called ion exchange.

a. Inorganic ion - exchangers — Permubit method

Complex inorganic salts like hydrated Sodium aluminium Silicates have the interesting Property of exchanging Ca^{+2} and Mg^{+2} ions Present in hard water with sodium present in Complex salts. The naturally occuring Complex salts are called Zeolites. They may also be Prepared by artificially by fusing Strongly a mixture of washing Soda, alumina and Silica. The fused mass is washed with water to remove Soluble impurities and the Porous mass thus obtain is called Permubit. Both Zeolite and Permubit can be represented by the general formula Na_2Z where $Z = Al_2Si_2O_8 . xH_2O$.

Advantages of Permutits Process.

1. It is an efficient Process.
2. This is a very cheap Process.
3. It can be used to remove both temperary and permanent hardness.

b. Organic ion exchange :- One of the major drawback of the inorganic ion exchangers is that these can remove only Ca^{+2} and Mg^{+2}. Recently it has been found that certain Synthetic organic exchangers also called ion-exchange resin are superior of zeolites. Since they can remove all types of cations and anions, the resulting water is called deminer-alised water or deionised water.

1. Cation exchange resins :- These resins consist of gaint hydro-Carbon attached to acidic group and represented by the general formula - R-COOH. These resins can exchange H^+ ions with cations such as Ca^{+2} and Mg^{+2} ions present in hard water, they are called cation exchange resins.
2. Anion exchange resins - These resins consist of gaint hydro Carbon attached to basic group such as OH^- ions usually in form of substituted Ammonium hydroxides. Represented by general formula $R-\overset{+}{N}H_3OH^-$. Since these resins can exchange OH^- ions with anions such as Cl^- and SO_4^{-2} ions present in hard water, they are called anion exchange resins.

c. Calgon Process :- The trade name for sodium hexametaphos phate is called Calgon which means Calcium gone.

When calgon is added to hard water the Ca^{+2} and Mg^{+2} ions present in it combine with Calgon to form soluble Complex of Calcium and Magnesium salt. These salt do not form any precipitate with soap and hence produce lather with soap solution.

— Degree of hardness :- It is defined as the number of parts of Calcium Carbonates or equivalent to various Calcium and magnesium salts present in a million parts of water by mass. It is expressed in PPm.

— Heavy water.

Preperation of heavy water.

① By Prolonged electrolysis :- this method is based upon the principle that when ordinary water is electrolysed, protium is liberated much more readily than deuterium because

a Being smaller in size, H^+ ions have greater mobility as compared to D^+ ions.

b Because of lower discharge Potential, H^+ ions are discharged at the Cathode more easily than D^+ ions.

c. Hydrogen atoms combine much more rapidly to form molecules hydrogen than deuterium atoms to form D_2

If electrolysis is continued till only a small volume remains, then almost Pure D_2O is obtained. About 20000 liters of water must be electrolyed to get 1 liter of 99 %. D_2O.

② By fractional distillation.

— Properties of heavy water.

a. Physical Property :- It is a colourless, orderless and tasteless mobile liquid heavier than water. Dielectric constant of D_2O is lower than H_2O so ionic compounds are less soluble in D_2O.

b. Chemical Property : the chemical Property of heavy water is similar to ordinary water.

1 Electrolysis :- when heavy water is electrolysed

Deuterium is obtained at the Cathode.

2. Action with alkali and alkaline earth metals :- Heavy water reacts slowly with alkali and alkaline earth metals to producing their respective deuteroxides.

3. Action with metallic oxides :- The oxides of active metals like Sodium and Calcium react slowly with heavy water to form their respective deuteroxides.

4. Action with non-metallic oxides :- Non-metallic oxides readily dissolve in heavy water forming their corresponding deuteroacids.

5. Action with metallic Carbides :- Heavy water reacts with metallic Carbides forming deuterohydrocarbons.

6. Action with metallic Nitrides, Phosphides and arsenides :- Heavy water react with metallic nitrides, Phosphides and arsenides liberating deuteroammonia, deuterophosphine and deuteroarsine.

7. Formation of Deuterates :- Heavy water Combine with many Compounds as heavy water of crystallization. The heavy hydrates thus obtained are called deuterates.

8. Biological Property :- Heavy water is injurous to human beings, Plants, and animals since it slow down the rate of reactions occuring in them.

Uses

1. As a moderator :- Heavy water is extensively used as a moderator in nuclear reactions because it slow down the fast moving neutrons.

2. As a trace Compound.

3. For the Preperation of deuterium.

- Hydrogen Peroxide (H_2O_2).
- Preperation of H_2O_2.

1. From Sodium Peroxide (Merck's method) :- Calculated amount of Sodium Peroxide is gradually added to an ice cold solution of 20% H_2SO_4

$$Na_2O_2 + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O_2$$

2. From barium Peroxide – Laboratory method.

a. By the action of dil Sulphuric acid – A thin Paste of hydrated barium Peroxide is Prepared in ice-cold water and then added slowly to an ice-cold solution of 20% H_2SO_4.

$$BaO_2.8H_2O + H_2SO_4 \rightarrow BaSO_4 + H_2O_2 + 8H_2O.$$

b. By the action of Carbon dioxide or Carbonic acid – when a rappid Steam of CO_2 is bubbled through a thin Paste of BaO_2 in ice cold water, H_2O_2 and $BaCO_3$ Produced.

$$BaO_2 + H_2O + CO_2 \longrightarrow BaCO_3 + H_2O_2$$

c. By the action of Phosphoric acid – H_2O_2 can Prepared by the action of Phosphoric acid on barium Peroxide.

$$3BaO_2 + 2H_3PO_4 \rightarrow Ba_3(PO_4)_2 + 3H_2O_2.$$

- Manufacture of H_2O_2.

1. By electrolysis of 50% H_2SO_4 : an equimolar mixture of H_2SO_4 and ammonium Sulphate is electrolysed, a more Concentrated Solution of H_2O_2 is obtained.

2. By Autoxidation of 2-ethylanthraquinol – In this Process air is bubbled through a 10% solution of 2-ethylanthraquinol in benzene and cyclohexene, when 2-ethylanthraquinal is oxidised H_2O_2 is formed.

— Concentration of H_2O_2 — H_2O_2 prepared by any methods is in the form of dilute solution. Concentration of H_2O_2 is carried out by these Proces.

1. Evaporation on a water bath —
2. Dehydration in a vacuum desiccator
3. Distillation under reduced Pressure
4. Removel of last traces of water.

— Storage of H_2O_2 — H_2O_2 can not be stored in glass bottles since the rough surface of glass, alkali oxide present in it and exposure to light catalyse its decomposition, so H_2O_2 is usually stored in coloured paraffin wax coated Plastic or Teflon bottles.

— Strength of H_2O_2 Solution —

1. Percentage Strength — It express the amount of H_2O_2 by weight present in 100 ml of the solution.
2. Volume Strength — The most common method of expressing the strength of an aqueous solution of H_2O_2 is in term of the volume (in mL) of oxygen liberated at N.T.P. by the decomposition of 1 mL of that sample of H_2O_2.

— Physical Properties.

1. Pure H_2O_2 is a thick syrupy liquid with Pale bule colour.
2. It has a bitter taste.
3. H_2O_2 is more dense and more viscous than water Due to more hydrogen bonds.
4. It is completely miscible with water, alcohol and ether in all Proportions.
5. The dipole moment of H_2O_2 is more than H_2O.

Chemical Properties.

1. Decomposition — Pure H_2O_2 is an unstable liquid and decomposes into water and oxygen on long standing or heating.
2. Acidic nature — Pure H_2O_2 turn blue litmus to Red but its dilute solution is neutral to litmus.
3. oxidising and reducing character — H_2O_2 is a powerful oxidising agent but a weak reducing agent.
4. Bleaching action — The bleaching action of H_2O_2 is due to the nascent oxygen which it liberate on decomposition.
5. Addition reaction — H_2O_2 reacts with alkenes to form glycols.

Uses of H_2O_2.

1. It is used as a bleaching agent for delicate materials
2. It is used as a hair bleach and as a mild disinfectant.
3. It is extensively used to manufacture inorganic chemicals.
4. It is used in the production of epoxides, Propylene oxide etc.

Tests of H_2O_2.

1. H_2O_2 on treatment with an acidified solution of titanium salt gives a yellow or orange colour due to the formation of Pertitanic acid.
2. It Produce Iodine from KI solution which, in turn, give blue colour with Starch solution.
3. When an ethereal solution of H_2O_2 is shaken with acidified solution of $K_2Cr_2O_7$, blue colour appears in the ethereal layer due to the formation of chromium Pentoxide.
4. When brought in contact with H_2O_2 solution, a filter paper with black stain of PbS turn white.
5. It decolourised acidified $KMnO_4$ solution.

— Peroxides — Metallic oxides which on treatment with dilute acids produce hydrogen peroxide are called peroxides. All the peroxides are diamagnetic

— Superoxides — Besides peroxides, alkali metals also form higher oxides called superoxides. All superoxides contain an odd number of electrons and hence are paramagnetic.

— Normal oxides — Those oxides in which the oxidation number of the element can be deduced from the empirical formula by taking the oxidation number of oxygen as (−2) are called normal oxides.

— Polyoxides — These oxides contain more oxygen than would be expected from the oxidation number of the element. These have been further classified into peroxides and superoxides.

— Hydrogen economy — One proposed way to meet the need for new energy source is to burn hydrogen as a fuel in industry and power plants and possibly also in homes and motor vehicles. This proposal is referred to hydrogen economy.

— Syngas — The mixture of CO and H_2 are called synthesis gas or syngas. It can be produce by the reaction of steam on hydrocarbon or coke at high temperature in the presence of nickel as catalyst. The process of producing syngas from coal is called coal gasification.

— Water-gas shift reaction — The amount of hydrogen in the syngas can be increased by reacting CO of syngas mixture with steam in the presence of iron chromate as catalyst.

$$CO + H_2O \longrightarrow CO_2 + H_2$$

This is called water-gas shift reaction.

— Fuel cell — It 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 and release more amount of energy per unit mass of fuel as compared to gasoline and other fuels.

— Hydrolysis — 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 hydro-lysis

— Hydration — Addition of H_2O to ions or molecules to form hydrated ions or hydrated salts is called Hydration.

— Water gas — An equimolar mixture of CO and H_2 is called water gas. It is prepared by passing steam over red hot coke.

$$C(s) + H_2O(g) \xrightarrow{1270K} CO(g) + H_2(g)$$

— Autoprotolysis of water — It means self ionization of water, Two molecules of water reacts with each other through proton transfer. one acts as the acid and other acts as a base. The molecule which accept a proton is converted into H_3O^+ while loses a proton is converted into OH^- ion.

— ortho and Para hydrogen — Dihydrogen has two nuclear Spin isomers called ortho and Para hydrogen.
When the spins of the nuclei are in the same direction dihydrogen is called ortho dihydrogen.
When the spins of the nuclei are in the opposite direction, dihydrogen is called Para dihydrogen.

Note - It is Possible to obtain Pure Para dihydrogen but it is not Possible to obtain Pure ortho dihydrogen.

Proof.

① Thermal Conductivity of $P\text{-}H_2$ is greater than $O\text{-}H_2$.

② The melting Point of $P\text{-}H_2$ is less than $O\text{-}H_2$.

— Atomic hydrogen is very reactive and hence it acts as a Powerful reducing agent.

— Nascent hydrogen — The hydrogen Produced in contact with the substance to be reduced is called nascent hydrogen.

— Comparison between Atomic and nascent hydrogen.

1. Nascent hydrogen can be Produced at room temperature but atomic hydrogen is Produced at elevated temperatures.
2. Nascent hydrogen can never be isolated but Atomic hydrogen can be isolated.
3. Reducing Power of atomic hydrogen is much greater than nascent hydrogen.

— Active hydrogen — It is obtained by Subjecting a Stream of molecular hydrogen at ordinary temperature to Silent electric discharge at about 30,000 volts. It is very reactive in nature.