Hydrogen

1. **Hydrogen-occurrence, Isotopes, Preparation, Properties and uses**
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Occurrence:

It is the most abundant element in the universe. It is rarely found in the free state in the earth's atmosphere. However, in the combined state, it is the third most abundant element on the earth's surface.

Isotopes of Hydrogen:

Hydrogen has three isotopes: protium $\left({}_{1}^{1}\mathrm{H}\right)$, deuterium $\left(\mathrm{D}\text{ or }{}_{1}^{2}\mathrm{H}\right)$ and tritium $\left(\mathrm{T}\text{ or}{}_{1}^{3}\mathrm{H}\right)$. Amongst these three, only tritium is radioactive. In spite of its resemblance both with alkali metals and halogens,it occupies a separate position in the periodic table because of its unique properties.

Properties:

Hydrogen is the lightest atom with only one electron. Loss of this electron results in an elementary particle, the proton. Thus, it is unique in character.

Hydrogen resembles both with alkali metals and halogens. It occupies separate position in the periodic table because of its unique properties.

Hydrogen is a colorless, odourless and a tasteless gas. It is non metal and diatomic. It is slightly soluble in water. Hydrogen should be handled with care as it is highly combustible.

Resemblance with alkali metals:

- Show electropositive character: H+, Na+, K+, etc.
- It shows oxidation state of +1
- It forms binary compounds with electronegative elements like alkali metals.
- It reacts with halogens to form halides: HCl, NaCl, KCl, etc.

Difference from alkali metals:

- Hydrogen is diatomic, alkali metals are monoatomic.
- The ionization enthalpy of hydrogen is very high while that of alkali metals is less.
- Hydrogen is non-metal while alkali metals are typical metals.
- The compounds of hydrogen are covalent while compounds of alkali metals are ionic. For example: HCl is covalent, NaCl is ionic.
- The oxides of hydrogen are neutral. Oxides of alkali metals are basic

Resemblance with halogens:

- Electronic configuration: both contain one electron less than the nearest noble gas configuration.

Difference from halogens:

- Water has less tendency for hydride formation. Halogens from halide ions very easily.
- Unshared pairs of electrons are absent.
- Hydrogen oxide is neutral but oxides of halogens are acidic.

In the elemental form Hydrogen exists as a diatomic molecule H2 and is called dihydrogen.

Production of dihydrogen

- The process of producing 'syngas' from coal is called 'coal gasification.'
- Water gas is the name given to the mixture of carbon monoxide and hydrogen. Water gas is also known as synthesis gas or syngas.
- The production of dihydrogen can be increased by reacting carbon monoxide of syngas mixtures with steam in the presence of iron chromate as catalyst. This reaction is called as water gas shift reaction.

The H–H bond dissociation enthalpy of dihydrogen $(435.88\ \text{kJ mol}^{-1})$ is the highest for a single bond between two atoms of any elements. This property is made use of in the atomic hydrogen torch which generates a temperature of ~4000K and is ideal for welding of high melting metals.

Though dihydrogen is rather inactive at room temperature because of very high negative dissociation enthalpy, it combines with almost all the elements under appropriate conditions to form hydrides.

Hydrogen forms ionic hydrides with s- block elements which are highly electropositive. It forms Covalent hydrides with elements of higher electronegativity such as p-block elements.

All the type of hydrides can be classified into following three categories:

- ionic or saline hydrides
- covalent or molecular hydrides
- metallic or non-stoichiometric hydrides

Alkali metal hydrides are good reagents for preparing other hydride compounds. Molecular hydrides $(\text{e.g.}, \ \text{B}_2\text{H}_5, \ \text{CH}_4, \ \text{NH}_3, \ \text{H}_2\text{O})$ are of great importance in day-to-day life. Metallic hydrides are useful for ultra purification of dihydrogen and as dihydrogen storage media.

Among the other chemical reactions of dihydrogen, reducing reactions leading to the formation hydrogen halides, water, ammonia, methanol, vanaspati ghee, etc. are of great importance. In metallurgical process, dihydrogen is used to reduce metal oxides. In space programmes, it is used as a rocket fuel. In fact, it has promising potential for use as a non-polluting fuel of the near future (Hydrogen Economy).

Water

Water is the most common and abundantly available substance. It is of a great chemical and biological significance. The ease with which water is transformed from liquid to solid and to gaseous state allows it to play a vital role in the biosphere. The water molecule is highly polar in nature due to its bent structure. This property leads to hydrogen bonding which is maximum in ice and least in water vapour.

The polar nature of water makes it:

(a) a very good solvent for ionic and partially ionic compounds

(b) to act as an amphoteric (acid as well as base) substance; and

(c) to form hydrates of different types. Its property to dissolve many salts, particularly in large quantity, makes it hard and hazardous for industrial use.

Self ionization of water: One water molecule acts as an acid by donating a proton to another water molecule which acts as a base. This is also known as autoprotolyis of water.

Water free from soluble salts of calcium and magnesium is called soft water.

Water containing soluble salts of calcium and magnesium in form of hydrogen carbonate, chlorides and sulphates is called hard water.

Temporary hardness in water is due to soluble salts of hydrogen carbonates of magnesium and calcium.

Permanent hardness in water is due to soluble salts of chlorides and sulphates of calcium and magnesium.

Temporary and permanent hardness of water can be removed by the use of zeolites, and synthetic ion-exchangers.

Heavy water, D2O is another important compound which is manufactured by the electrolytic enrichment of normal water. It is essentially used as a moderator in nuclear reactors.

Hydrogen peroxide, H_2O_2 has an interesting non-polar structure and is widely used as an industrial bleach and in pharmaceutical and pollution control treatment of industrial and domestic effluents.