2
Properties and Uses of Hydrogen

PHYSICAL PROPERTIES OF HYDROGEN:

Hydrogen is lightest an simplest of all elements. It is fairly but not exceptionally reactive gas. It enters into chemical combination with most of the elements and hydrogen forms more compounds than any other element (3).

The spines of the atomic nuclei in a hydrogen molecule can be coupled in two distinct ways:

1) nuclear spines parallel (ortho)
2) nuclear spines anti parallel (Para)

Ortho & Para hydrogen insist in different quantum states this fact result in difference in many properties for the two forms of hydrogen. In particular, those properties that involve heat, such as enthalpy and entropy and thermal conductivity.

The conversion of ortho hydrogen to Para hydrogen is an endothermic process.

THERMODYNAMIC PROPERTIES:

The difference in the masses of isotopes is relatively large, so thst thermodynamics properties differ considerably. At low temperature P-H_2, O-D_2 can be present in a virtually pure state.

Hydrogen gas is color less, non poisonous odorless and tasteless. Contrary to most other gases, the inversion temperature of hydrogen lies below ambient temperature. Liquid hydrogen is colorless, very mobile liquid with low viscosity and surface tension.

Solid hydrogen is a colorless, and crystallizes in the hexagonal closest packed structure. At higher several phase transaction occurs under extremely high pressure a metallic, electrically conductive hydrogen phase with a density of >1,000kg/m^3 occurs

Solubility of hydrogen in liquids:

Hydrogen is only slightly soluble in liquids. In contrast to the highly soluble gases however the solubility generally increases with increasing temperature. The relative solubility differences in between hydrogen compound is few percent and diminish with increasing temperature.

Solubility's of hydrogen in metals:

Metals with not completely occupied inner electron levels have a particularly high solubility potential for hydrogen. Hydrogen is dissolved in metals and not in the molecular but in the atomic from where by non-stoichiometrical or stoichiometrical compound may be formed.

The solubility of hydrogen in metals at small hydrogen concentrations is proportional to the root of the hydrogen partial pressure. The hydrogen solubility decreases with increasing temperature. Impurities in the metals and in the hydrogen can lower the solubility or cancel it completely dissolved property, magnetic properties and can cause super conductivity.

Diffusion properties

Hydrogen is the element with highest diffusion capacity diffusion coefficient of hydrogen in gases and liquids are give. In metals with a high hydrogen solubility usually a high hydrogen diffusion coefficient is also found.

Physical and thermodynamic properties of Hydrogen

Property	Para	Normal
Density at 0 ^{0}C,(mol/cm)*10^3	0.05459	0.04460
Compressibility Factor Z= at 0^0 C	1.0005	1.00042
Adiabatic Compressibility at 300K , Mpa	7.12	7.03
Coefficient of volume expansion( ) at 300K , K	0.00333	.00333
Cp at 0 ^{0}C	30.35	28.59
Cv at 0 ^{0}C	21.87	20.30
Enthalpy at 0 ^{0}C, J/mol	7656.6	7749.2
Internal energy at 0 ^{0}C, J/mol	5384.5	5477.1
Entropy at 0 ^{0}C, J(mol-K)	127.77	139.59
Velocity of sound at 0 ^{0}C , m/s	1246	1246
Viscosity at 0 ^{0}C, mPas (=cP)	0.00834	.00834
Thermal conductivity at 0 ^{0}C , mW/(cm-K)	1.826	1.739
Dielectric constant at 0 ^{0}C	1.00027	1.000271
Isothermal compressibility ( ) , at 300k, Mpa	-9.86	-9.86
Self diffusion coefficient at 0 C, cm2/s		1.285
Gas diffusivity in water at 25 C, cm2/s		$4.8*10^{-5}$
Heat of dissociation at 298.16 K ,kJ/mol	435.935	435.881

Chemical properties

The first Electro shell can be filled with maximum of two electrons. Therefore the chemistry of hydrogen depends mainly on three processes,

1. Loss of the valency electron to yield the hydrogen ion H^+
2. Gain of an electron to form the hydride ion H^-
3. Formation of an electron pair bond

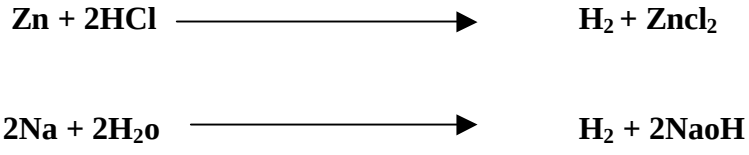
Properties

1. Hydrogen is not exceptionally reactive, although hydrogen atoms with all other elements with the exception of noble gases.
2. Hydrogen oxidizer leas electronegative elements and reduces more electronegative ones.
3. The strength of the H – X bond in covalent hydrides depends on the electronegativity and size of the element X.
4. The strength decreases in a group with increasing atomic number and generally increases across any period.
5. The most stable covalent bond are those formed between two hydrogen atoms, or with hydrogen, oxygen carbon and nitrogen (2)

CHEMICAL REACTION'S

1. Hydrogen producing reactions:

On a laboratory scale, hydrogen can be made from the action of an aqueous acid on a metal or from the reaction of an alkali metal in water.



2. Hydrogen gas can also be produced on laboratory scale by the electrolysis of an acidic solution.

$$H^+ + e^- \longrightarrow \tfrac{1}{2} H_2$$

3. Hydrogen can also produced by steam reforming using hydrocarbons such as natural gas, petroleum, and coal

$$CH_4 + H_2o \xrightarrow[\text{30 Mpa (30 atm)}\ \text{Ni Catalyst}]{800^0\ C} CO + 3H_2$$

Reactions leading to hydrogen often have carbon monoxide as a product

4. Reaction with hydrogen and other elements:

Hydrogen forms components with almost every other element possible in many cases.

a) Hydrogen combines directly with increasing relatively iodine, bromine, chlorine, and fluorine. The reaction with fluorine occurs spontaneously and explosively even in dark at low temp and generally used in reocket propellant system.

$$\text{E.g.: } -H_2 + F_2 \longrightarrow 2HF$$

Hydrogen reacts with oxygen

Hydrogen combines directly with oxygen, either thermally or with an aid of catalyst.

$$2H_2 + O_2 \longrightarrow 2H_2$$

Above 550^0C, the reaction occurs with flame propagation explosion or detection

Hydrogen reaction with nitrogen:

At elevated temperature in presence of catalysts, hydrogen will react with nitrogen to form ammonia.

Reaction with hydrocarbon's:

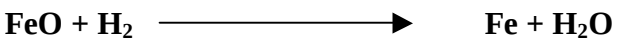
Unsaturated hydrocarbons are converted to saturated or partially saturated hydrocarbons by hydrogenation.

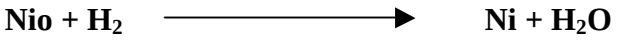
Reaction with metal

A great number of metals react with hydrogen to form hydrides. Saline hydrides are made using pure metals reacting with H_2 at elevated temp. They are salt like in character and contained hydride ion. Saline hydrides are very reactive and are strong reducing agent and often decompose into water to form hydrogen.

Hydrogen as a reducing agent**:**

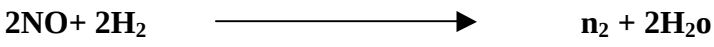
Hydrogen reacts with a number of metals oxides at elevated temperature to produce metal.





Photochemical smog:

Under certain conditions hydrogen reacts with nitric oxide, an atmospheric pollutant and contributor to photochemical smog to produce N_2.



Atomic Hydrogen:

Atomic hydrogen is much more reactive than the molecular form. The dissociation reaction is highly endothermic.

$$H_2 \longrightarrow 2Hj \quad \Delta H^6 = 432.2 \text{ kJ / mol.}$$

Atomic hydrogen can be produced by supplying sufficient energy. The hydrogen atom has a short life and reacts even at room temperature with non-metallic element such as halogen, oxygen etc. At room temperature it reduces many oxides to elements. The heat of recombination of hydrogen molecules from hydrogen atoms leads o a very high temperature. Atomic hydrogen can be absorbed in the metallic structure of some element. The suitability of many catalysts for reactions involving hydrogen is based on the dissociation and solubility of hydrogen is the atomic form.

Hydrogen ion:

$$H \longrightarrow H^+ e^{-v} \qquad \Delta H = 1310 \text{ kJ/mol}$$

The ionization potential of above reaction is 13.595eV, which is even higher then first ionization potential of noble gas Xenon. The solution process, Process provides energy for bond rapture.

Hydrogen bond:

Substance containing hydrogen coupled to most electronegative elements exhibit. Properties that can be best explained by assuming that the hydrogen atom of an H – X bond still has a small but significant affinity for other electronegative atom. This relatively weak secondary bond is called a hydrogen bond

X – H ----

1. Hydrogen bonds results in molecular association

   E.g. NH_3, H_2O, HF

2. The presence of hydrogen bonds also causes formation of crystalline hydrateThe existence of H bond can be shown by infrared spectroscopy

Uses of Hydrogen:

CONVENTIONAL USES:

Hydrogen in the chemical industry:

Hydrogen is all-important raw material for the chemical industry. It takes part in reaction either by addition or by means of its reduction potential. Most of hydrogen is used for these hydrogenation and reduction process. In utilization sector, hydrogen production is stagnating. A part from ammonia synthesis, synthesis with hydrogen-carbon monoxide gas mixture to produce methanol, hydrocarbons and Oxon synthesis products are of particular importance large quantities of hydrogen are needed in coal processing is just beginning. The use of hydrogen in metallurgy is based in particular on its reducing properties. At present, pure hydrogen is not used directly to reduce energy. Mixtures with hydrogen however have been used for a long time combustion purposes.

In comparing, the hydrogen production or usage data, a distinction must be made between the so-called merchant and captive hydrogen. Captive hydrogen uses, such as for ammonia and methanol synthesis or in various hydro-treating processes, relate to onsite hydrogen production and immediate Consumption of hydrogen. The designation merchant hydrogen is given to those quantities, which are sold on the market merchant sales of hydrogen account for 10% or less of total hydrogen production

Different process in which Hydrogen is used are: -

1. Ammonia synthesis
2. Hydrogen in refinery processes
3. Hydrogen in coal refinement
4. Hydro pyrolysis.
5. Hydro gasification of coal.
6. Methanol synthesis.
7. Fischer-Tropsch synthesis

8. Methane synthesis
9. Hydro formulation of olefins
10. Hydrogen in organic synthesis.
11. Hydrogen in inorganic synthesis
12. Hydrogen in metallurgy
13. Hydrogen in non-ferrous metallurgy.

Other uses:

1. Use of the high temperature of the only hydrogen flame.
2. Hydrogen plasma as heating agent.
3. Hydrogen in metal processing.
4. Semiconductor technology.
5. Water treatment.
6. Other uses.
7. Hydrogen energy.

Great quantities are required commercially for the fixation of nitrogen from the air in the Haber ammonia process and for the hydrogenation of fats and oils. It is also used in large quantities in methanol production, in hydrodealkylation, hydrocracking, and hydrodesulfurization. Other uses include rocket fuel, welding, producing hydrochloric acid, reducing metallic ores, and filling balloons.

The lifting power of 1 cubic foot of hydrogen gas is about 0.07 lb at 0C, 760 mm pressure. The Hydrogen Fuel cell is a developing technology that will allow great amounts of electrical power to be obtained using a source of hydrogen gas. Consideration is being given to an entire economy based on solar- and nuclear-generated hydrogen. Public acceptance, high capital investment, and the high cost of hydrogen with respect to today's fuels are but a few of the problems facing such an economy. Located in remote regions, power plants would electrolyze seawater; the hydrogen produced would travel to distant cities by pipelines. Pollution-free hydrogen could replace natural gas, gasoline, etc., and could serve as a reducing agent in metallurgy, chemical processing, refining, etc. It could also be used to convert trash into methane and ethane

Industrial uses of Hydrogen

Hydrogen finds use in diverse applications covering many industries, including:

- Food to hydrogenate liquid oils (such as soybean, fish, cottonseed and corn), converting them to semisolid materials such as shortenings, margarine and peanut butter.

- Chemical processing primarily to manufacture ammonia and methanol, but also to hydrogenate non-edible oils for soaps, insulation, plastics, ointments and other specialty chemicals.

- Metal production and fabrication to serve as a protective atmosphere in high-temperature operations such as stainless steel manufacturing; commonly mixed with argon for welding austenitic stainless. Also used to support plasma welding and cutting operations.

- Pharmaceuticals ... to produce sorbitol used in cosmetics, adhesives, surfactants, and vitamins A and C.

- Aerospace ... to fuel spacecraft, but also to power life-support systems and computers, yielding drinkable water as a by-product.

- Electronics ... to create specially controlled atmospheres in the production of semiconductor circuits.

- Petroleum Recovery and Refinery ... to enhance performance of petroleum products by removing organic sulfur from crude oil, as well as to convert heavy crude to lighter, easier to refine, and more marketable products. Hydrogen's use in reformulated gas products helps refiners meet Clean Air Act requirements.

- Power Generation ... to serve as a heat transfer medium for cooling high speed turbine generators. Also used to react with oxygen in the cooling water system of boiling water nuclear reactors to suppress intergranular stress corrosion cracking in the cooling system.