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Hydrogen

Department of Chemistry
The Open University of Sri Lanka

Hydrogen

Introduction

Hydrogen is the most abundant element in the *universe* and sun's energy is generated by *nuclear fusion of hydrogen*. Hydrogen forms more molecules or compounds than any other element in the Periodic Table. In this lesson, we will study the physical and chemical properties of hydrogen and chemistry of its important compounds. If you look up some text books on Periodic Table you may see that hydrogen is placed above the Group 1 elements and in some instances above the Group 17 elements but it is best to study the chemistry of hydrogen separately. In this lesson, we will also deal with the uses of hydrogen, industrial preparation of hydrogen, and physical and chemical properties of water. Water is the most important compound of hydrogen and without it life on earth is not possible.

1. Hydrogen and its physical properties

Hydrogen is the first element in the Periodic Table. Hydrogen atom has a very simple structure consisting of a *nucleus* with a *proton* and one *electron*. It is the only element in the Periodic Table without a *neutron*. Three isotopes of hydrogen are known. These isotopes are protium ($^{1}_{1}H$), deuterium ($^{2}_{1}D$), and tritium ($^{3}_{1}T$). Isotopes can be considered as different forms of the same element having different masses due to the different number of neutrons present in the nucleus. Isotope effect is highest for hydrogen and *n/p ratio* is zero and two for H and T, respectively. Thus, T is *radioactive* and *emits β-rays* form helium with a half-life is 12.3 years.

Q : How many neutrons are there in i) H ii) D and iii) T

A : i) Zero ii) One and iii) Two

Hydrogen is also an important element present in the sun which involves in nuclear reactions occurring in it. In the sun, the source of fuel is *hydrogen* and *helium* gas. The release of an enormous amount of heat is caused due to the burning of hydrogen gas by a special reaction called nuclear fusion. This reaction occurs due to the collision of tritium and deuterium in the interior of the sun under extremely hot conditions. Here, the hydrogen is converted into helium and a large amount of energy is given out.

$$^{2}_{1}D + ^{3}_{1}T \longrightarrow ^{4}_{2}He + n + Energy$$

Activity

1. Determine the number of electrons and neutrons in the following molecules.
(i) HD, (ii) DT and (iii) TT

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At room temperature, hydrogen is a diatomic, colourless, odourless gas. Some physical properties of hydrogen are given in Table 1.

Table 1 Some physical properties of hydrogen

Relative atomic mass	1.008 g mol^{-1}
Electron configuration	$1s^1$
Ionization energy	1312 kJ mol^{-1}
Electron affinity	-72 kJ mol^{-1}
Electronegativity	2.2
Molecular formula	H_2
Melting point	14 K (-259 ^oC)
Boiling point	20 K (-253 ^oC)
Density at STP	0.09 g dm^{-3}
Bond energy, H—H	436 kJ mol^{-1}
Bond length, H—H	74 pm
Natural abundance ^1H	99.9885%

Dihydrogen is the *lightest* molecule and its melting point is -259 ℃. Chemical properties of H, D and T are *very similar* and some of the physical properties such as boiling points, densities, and reaction rates vary slightly. The boiling point of D_2O is 101.4 °C compared to 100.0 °C for H_2O. D_2O can be separated from H_2O by *fractional distillation* and it is used to prepare HD. Heavy water (D_2O) is *toxic* to mammals and it is used in *nuclear reactors* as a *moderator*. Hydrogen is *insoluble* in water. According to Pauling scale, electronegativity of hydrogen is 2.2 which is much lower than F (4.0) and O (3.5). Electronegativity of hydrogen is comparable with those of P and As (2.1) and much higher than those of alkali metals (0.8 - 1.0).

Atomic Hydrogen

Hydrogen at ordinary temperatures and pressures is a *diatomic* gas (H_2). Atomic hydrogen, or the hydrogen radical ($H^{\cdot}$), can be produced from *molecular hydrogen* by subjecting it to an electric arc or a high temperature.

$$H_2 \xrightarrow{\Delta \text{ or } h\upsilon} 2H^{\cdot}$$

Atomic hydrogen is a powerful *reducing agent*. Non-metals such as sulphur or iodine are rapidly converted to the hydrides H_2S and HI respectively. Ethylene ($CH_2{=}CH_2$) is hydrogenated to ethane and with oxygen almost pure hydrogen peroxide (H_2O_2) is obtained.

Q: Write balanced equations for the reactions of atomic hydrogen with (i) S, (ii) I_2 and (iii) O_2

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A:

$$\text{i)}\quad 2H^{\cdot} + S \rightarrow H_2S$$
$$\text{ii)}\quad 2H^{\cdot} + I-I \rightarrow 2HI$$
$$\text{iii)}\quad 2H^{\cdot} + O_2 \rightarrow H_2O_2$$

2. Position of hydrogen in the Periodic Table

As we mentioned earlier, hydrogen has been placed above the Group 1 elements and in some instances above the Group 17 elements. Here we consider the reasons for the above classifications.

Reasons for placing hydrogen with the Group 1 elements are:

1. Hydrogen atom has *one electron* in the outermost shell similar to those of alkali metals.

2. Hydrogen forms a *mono-positive* ion, H^+, similar to alkali metal cations, M^+.

3. In electrolysis, hydrogen gets discharged at the *cathode* similar to alkali metals.

Reasons for placing hydrogen with the Group 17 elements are:

1. Hydrogen needs just *one* electron to attain the inert gas configuration. Halogens also need only *one* electron to achieve the *inert gas* configuration.

2. Hydrogen forms the *hydride ion*, H^-, with electropositive metals. Halogens also form *mono-negative* anions, X^-.

3. Hydrogen is a *diatomic* gas similar to most halogens.

Therefore, it is best to place hydrogen at top of the Periodic Table and to study the chemistry of hydrogen separately.

3. Reactive forms of hydrogen

There are *three reactive* forms of hydrogen: $H^{\cdot}, H^+, H^-$ (*hydrogen radical*, proton and hydride ion) respectively. Hydrogen radical and hydride ion are more reactive than the proton.

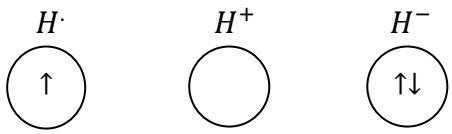

Figure 1 Reactive forms of hydrogen

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4. Occurrence and isolation of hydrogen

Only a *trace* of hydrogen is present in the atmosphere. Natural gas from oil wells may contain about 10% of hydrogen. However, hydrogen is an abundant element on earth because it is present in the combined state. It has been found that the percentage of the hydrogen in universe is 92%. It is present in water, in hydrocarbons and in many organic constituents of plants and animals.

In the laboratory, hydrogen can be prepared by reacting *dilute acids* with *metals*.

$$Zn(s) + 2\,HCl(l) \longrightarrow ZnCl_2(s) + H_2(g)$$

Group 1 elements liberate hydrogen when it is reacted with *water*.

$$2\,Na(s) + 2\,H_2O(l) \longrightarrow 2\,NaOH(aq) + H_2$$

Metals such as magnesium, iron and tin give out hydrogen when heated with *steam*.

$$Mg(s) + H_2O(g) \longrightarrow MgO(s) + H_2(g)$$

Some elements react with *alkaline solutions* to yield hydrogen. (*e.g.* aluminium, zinc)

$$2\,Al(s) + 6\,H_2O(l) + 2NaOH(aq) \longrightarrow 2\,NaAl(OH)_4(aq) + 3\,H_2(g)$$

$$2\,Zn(s) + 6\,H_2O(l) + 2\,NaOH(aq) \longrightarrow 2\,NaZn(OH)_4(aq) + 3H_2\,(g)$$

Industrial production of hydrogen

(i) There are several processes where hydrogen is obtained as a *by-product* from other chemical processes.

a) In electrolytic processes of the production of NaOH from *brine*, hydrogen is produced at the *cathode* as a by-product.

$$2\,NaCl(aq) + 2\,H_2O(l) \longrightarrow Cl_2(g) + H_2(g) + 2\,NaOH$$

b) It can also be obtained by electrolyzing a dilute solution (20%) of *NaOH*. Here hydrogen is liberated at the *cathode* while oxygen is liberated at the anode.

At the cathode - $2H^+(aq) + 2e \longrightarrow H_2(g)$

At the anode - $4OH^-(aq) + 4e \longrightarrow O_2(g) + 2H_2O(l)$

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(ii) Hydrogen can also be produced by the *Bosch process* where steam is reduced by passing it over *hot coke* (carbon) to produce *water gas* (CO and H_2).

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

The above gas mixture (water gas) is mixed with more steam and the resulting gas mixture is passed over a catalyst (usually a transition metal oxide) to obtain a mixture of carbon dioxide and hydrogen.

$$CO(g) + H_2(g) + H_2O(g) \xrightarrow{Catalyst} CO_2(g) + 2\,H_2(g)$$

(iii) Hydrogen is produced as a by-product in the *cracking of petroleum*. During this process crude oil is converted into products such as petrol, diesel and kerosene *etc*.

$$\underset{\text{(alkane)}}{C_nH_{2n+2}} \xrightarrow{\Delta} \underset{\text{(alkene)}}{C_nH_{2n}} + H_2(g)$$

5. Oxidation numbers of hydrogen and its compounds

The oxidation number of hydrogen in H_2 is zero. The oxidation number of hydrogen in hydrocarbon is +1. The oxidation number of hydrogen in metal hydride is -1.

Activity

2. Determine the oxidation number of hydrogen in the following compounds
   H_2 , H_2O, CH_4, H_2S, KH, CaH_2 and HCOOH

6. Hydrogen Bonding

Hydrogen bonding (X-H·⋯Y) occurs between a covalently bonded *hydrogen* and an *electronegative* atoms such as X and Y, *e.g*. X = Y = F, O, N or Cl. In other words hydrogen effectively acts as a bridge between two electronegative atoms. Hydrogen bonding plays an important role in biology and the changing properties of the synthetic material. For example, (i) formation of double strands in DNA and RNA; (ii) water has a higher boiling point than H_2S; (iii) *ortho*-nitrophenol has a lower boiling point than *para*-nitrophenol; and (iv) strength and hardness of polyamide *e.g*. Kevlar.

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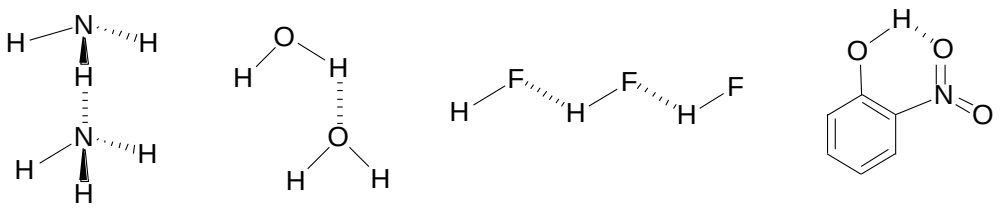

Figure 2 Hydrogen bonding (X-H····Y) in NH_3, H_2O, HF and *ortho*-nitrophenol

7. Uses of hydrogen

The most important use of hydrogen is for the synthesis of ammonia by the Haber process and the production of hydrochloric acid. It is also used to synthesize methyl alcohol from carbon monoxide. Hydrogen is also used for the conversion of vegetable oils to give edible fats (*e.g.* margarine). Here the hydrogenation of unsaturated fatty acids to saturated or partially saturated fatty acids takes place. It is used as a fuel for rockets and vehicles and also for welding. It is a good reducing agent and is used to reduce metal oxides/ores into pure metals.

Activity

3. Write equations for the above mentioned chemical processes.

Hydrogen is sometimes used as a reducing agent in the extraction of metals. For example, molybdenum and tungsten oxides can be reduced by using hydrogen. Other uses include a fuel for hydrogen powered car, oxy-hydrogen gas for welding and preparation of organic compounds.

8. Compounds of Hydrogen

Hydrogen containing compounds can be classified into three general types depending on the electronegativity of the other element which is bonded to. The types of hydrides are:

1. Metal hydrides containing the hydride anion (H^-)

2. Strong acids giving protons (H^+); *i.e.* when hydrogen is attached to electronegative elements.

3. Covalent compounds; when hydrogen is bonded to atoms with similar electronegativity.

The alkali metals react readily with hydrogen to give hydrides.

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$$2\ Na(s) + H_2(g) \longrightarrow 2NaH(s)$$

The free proton, H^+ occurs only in the gas phase in discharge tubes. In water it is present as the hydroxonium ion, H_3O^+.

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

Hydrogen gas is not very reactive although it burns in air (O_2) giving water and it readily reacts with halogens in the presence of sunlight.

Hydrogen can be used as a reducing agent for a wide variety of reactions. For example the oxides of weakly electropositive metals such as copper, tin and lead can be reduced to the metal by passing hydrogen over the heated oxide of the metal.

$$PbO(s) + H_2(g) \longrightarrow Pb(s) + H_2O(l)$$

Iron is the most electropositive metal that can be obtained in this manner.

$$Fe_3O_4(s) + 4\ H_2(g) \rightleftharpoons 3\ Fe(s) + 4\ H_2O(l)$$

This equilibrium can be shifted to the right by continually passing fresh hydrogen and removing the steam produced in a flow of hydrogen.

Hydrogen can reduce *alkenes* and *alkynes* by adding across the multiple bonds, this is called *hydrogenation*, thus H_2 is a *hydrogenating agent*. For example, the carbon-carbon double bond in olefins is reduced by hydrogen in the presence of a metal *catalyst*.

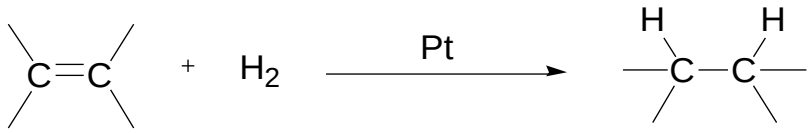

Figure 3 Hydrogenation of olefins

Q: What would you get when you reduce propene ($CH_3CH{=}CH_2$) with hydrogen?

A: Propane, $CH_3CH_2CH_3$.

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9. Hydrides

Organic chemistry deals with hydrocarbons which can be considered as *hydrides of carbon* where the bonding between carbon and hydrogen is covalent in nature. The simplest hydrides of B and N are BH_3 and NH_3. Electron deficient BH_3 *dimerises* rapidly to form diborane (B_2H_6), which contains two *bridging hydrogen* ligands. Beryllium hydride $[BeH_2]_n$, is also a *covalent polymer* having Be–H–Be bridges. HF shows strong hydrogen bonds between them. Noble gases *do not form hydrides*. Most electropositive metals such as Group 1 elements form salt-like metal hydrides.

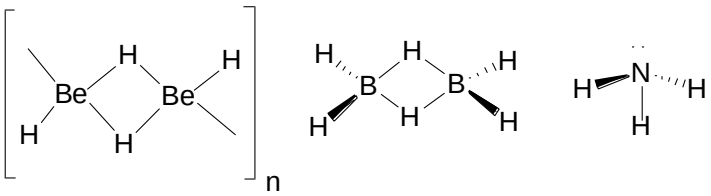

Figure 4 Structures of $[BeH_2]_n$, B_2H_6 and NH_3

In this lesson, we will look at hydrides of *metals*, *halogen* and *oxygen*. Some hydrides of Group 1, 2, 13-17 elements are given in the Table 2.

Table 2 Some hydrides of Group 1, 2, 13-17 elements

1	2			13	14	15	16	17	18
H_2								H_2	
LiH	BeH_2			B_2H_6	CH_4	NH_3	H_2O	HF	
NaH	MgH_2			AlH_3	SiH_4	PH_3	H_2S	HCl	
KH	CaH_2			GaH_3	GeH_4	AsH_3	H_2Se	HBr	
RbH	SrH_2				SnH_4	SbH_3	H_2Te	HI	
CsH	BaH_2				PbH_4	PbH_4	H_2Po	HAt	

9.1 Hydrides of metals

Ionic hydrides are obtained with highly *electropositive* metals, *e.g.* NaH, CaH_2. Here the hydrogen atom gains an electron to form the hydride anion, H^-. H^- has two electrons in the first energy level (K shell) similar to the electron configuration of helium (He). The electron configuration of He is $1s^2$. Most other metals and non-metals form covalent compounds with

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hydrogen where the bonding electron pair is shared by both elements.

Saline (or ionic) hydrides are prepared as given below.

$$2\,M(l) + H_2(g) \longrightarrow 2\,MH(s) \qquad M = Li, Na, K, Rb, Cs$$

$$M(l) + H_2(g) \longrightarrow MH_2(s) \qquad M = Ca, Sr, Ba$$

9.2 Hydrides of halogens

All hydrogen halides are known, and their *stability decreases down* the group.

(i) Direct combination of hydrogen and halogen. Hydrogen fluoride, (HF) cannot be prepared by this method.

$$H_2(g) + X_2(g) \longrightarrow 2\,HX(aq) \qquad X = Cl, Br, I$$

(ii) By the reaction of a halide with conc. H_2SO_4.

$$2\,NaX(aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2\,HX(aq)$$

(iii) Hydrolysis of covalent halides (X = Br or I).

$$PX_3(g) + 3\,H_2O(l) \longrightarrow H_3PO_3(aq) + 3\,HX(aq)$$

HF is the most important compound of fluorine. It is a colourless fuming liquid and causes severe burn. In the presence of moisture it attacks glass.

It is generally prepared by reacting CaF_2 with conc. H_2SO_4.

$$CaF_2(s) + \text{conc. } H_2SO_4(aq) \longrightarrow CaSO_4\,(s) + 2\,HF(aq)$$

This reaction is generally carried out in a lead container as HF attacks glass. In the liquid state, *HF is heavily hydrogen bonded*. Thus, its boiling point is higher than other hydrogen halides.

Most fluorides are prepared by reacting HF with a metal halide. For example,

$$FeCl_2(s) + 2\,HF(aq) \longrightarrow FeF_2(s) + 2\,HCl(g)$$

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9.3 Hydrides of oxygen and sulphur

Hydrogen sulphide is a *colourless*, *poisonous* gas causing death at 100 ppm. Its *antidote* is *chlorine*. It smells like rotten eggs and it is *heavier* than air. Its boiling point is -60 ^{o}C whereas its oxygen analogue, (H_2O) is a liquid at room temperature. The higher boiling point (100 ^{o}C) of water is due to stronger hydrogen bonding between water molecules. H_2S is a weak acid in aqueous solutions. In the laboratory, H_2S can be prepared by reacting hydrogen chloride with FeS.

$$FeS(s) + 2\,HCl(aq) \longrightarrow FeCl_2(aq) + H_2S(g)$$

H_2S dissolves in alkali to give sulphides (S^{2-}) and hydrogen sulphide (HS^-).

$$2\,HO^-(aq) + H_2S(g) \rightleftharpoons S^{2-}(aq) + 2\,H_2O(l)$$

$$HO^-(aq) + H_2S(g) \rightleftharpoons HS^-(aq) + H_2O(l)$$

Hydrogen sulphide as a reducing agent

H_2S acts as a good *reducing agent*, some of the examples are listed below.

1. Chlorine is reduced to chloride ions.
   $Cl_2(g) + H_2S\,(g) \longrightarrow 2\,HCl(g) + S(s)$

2. H_2SO_4 is reduced to S and SO_2. Therefore conc. H_2SO_4 cannot be used to dry H_2S.
   $H_2SO_4(l) + H_2S(g) \longrightarrow S(s) + SO_2(g) + 2\,H_2O(l)$

3. In acid solutions, the dichromate ion is reduced to Cr^{3+}; and the sulphide ion is oxidized to S.

4. In acid solutions, the permanganate ion is reduced to Mn^{2+} ion.
   $2MnO_4(aq) + 6\,H^+(aq) + 5\,H_2S(g) \longrightarrow 2\,Mn^{2+}(aq) + 5\,S(s) + 8\,H_2O(l)$

5. Ferric ions can be reduced to ferrous ions.
   $2\,Fe^{3+}(aq) + H_2S(g) \longrightarrow 2\,Fe^{2+}(aq) + 2\,H^+\,(aq) + S(s)$

H_2S is used in *qualitative analysis* to precipitate metal sulphides.

Hydrogen sulphide as an oxidizing agent

In the above section we looked at some reactions of H_2S in which H_2S is a *reducing agent*. In those reactions, the sulphide ion got *oxidised to sulphur*. Note that H_2S can also be used as an oxidizing agent in which H^+ ions get reduced to hydrogen. For example, sodium reduces H_2S to give hydrogen and sodium sulphide.

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$$2\,Na(s) + H_2S(g) \longrightarrow Na_2S(s) + H_2(g)$$

10. Water and water cycle

Water is essential for all forms of life. It has three forms: *ice*, *water* and *steam (water vapour*). 71% of the earth's surface is covered with water. On earth, it is found mostly in oceans and other large water bodies. Water moves continually through a cycle of *evaporation* or *transpiration*, *precipitation* or *condensation*, and *runoff*, usually reaching the sea. Winds carry water vapour over land at the same rate as runoff into the sea. In other words, water cycle (or the *hydrologic* cycle) refers to the continuous exchange of water within the hydrosphere, among the atmosphere, soil water, surface water, ground water, and plants.

Clean, fresh drinking water is essential to human and to other life forms. Access to safe drinking water has improved steadily and substantially over the last decades in almost every part of the world. Water plays an important role in the world economy, as it functions as a solvent for a wide variety of chemical substances and facilitates industrial cooling and transportation. Approximately 70 percent of freshwater is consumed by agriculture.

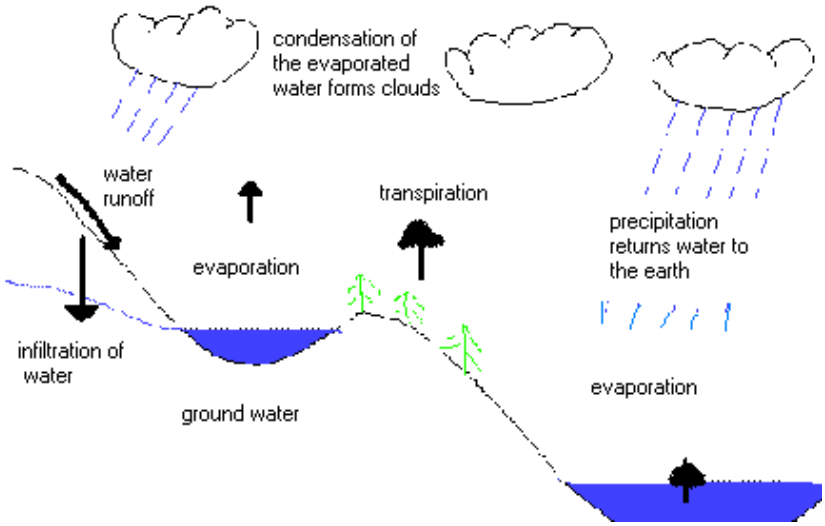

Figure 5 Water cycle[7] (i) evaporation from oceans and transpiration from land plants and animals; (ii) precipitation and falling to earth or ocean; (iii) runoff to sea.

Chemical and physical properties of water

The major chemical and physical properties of given below:

- Water is a *tasteless*, *odourless* liquid at standard temperature and pressure. Water is transparent, and thus aquatic plants can live within the water because sunlight can reach them. Only strong UV light is slightly absorbed.

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- Water is a *polar molecule* as oxygen has a higher electronegativity than hydrogen. Oxygen has a slight negative charge while the hydrogen atoms have a slight positive charge giving the molecule a strong *effective dipole moment*. The interactions between the different dipoles of each molecule cause a net attraction force associated with water's high amount of *surface tension*.

- Another very important feature that causes the water molecules to stick to one another is the formation of *hydrogen bonds* among them. Thus, the boiling point of water is higher than H_2S. Water is miscible with many liquids, for example ethanol, methanol, in all proportions, forming a single homogeneous liquid.

- The boiling point of water (and all other liquids) is directly related to the barometric pressure. For example, on the top of mountain Everest, water boils at 68 ℃ when compared to 100 ℃ at sea level.

- Water is an important *polar solvent* dissolving many types of substances. Substances that will mix well and dissolve in water, *e.g.* salts, sugars, acids, alkalis, and some gases: especially oxygen, carbon dioxide (carbonation), are known as "hydrophilic" (water-loving) substances, while those that do not mix well with water (*e.g.* fats and oils), are known as "hydrophobic" (water-fearing) substances. Most of the major components in cells (proteins, DNA and polysaccharides) are also dissolved in water.

- Pure water has a *low* electrical conductivity, but this increases significantly upon the solvation of a small amount of ionic material such as sodium chloride. Water can be split by electrolysis into hydrogen and oxygen.

- The maximum density of water is 0.99999 g cm^{-3} at 3.98 °C (39.16 °F). Water becomes even less dense upon freezing, expanding 9%. This causes an unusual phenomenon: ice floats upon water.

- Water is an oxide of hydrogen, formed when hydrogen or hydrogen-containing compounds are burnt with hydrogen or hydrogen-containing compounds burn or react with oxygen or oxygen-containing compounds. Water is not a fuel, it is an end-product of the combustion of hydrogen.

Summary

- Hydrogen is the lightest diatomic gas with many uses in industry. Three isotopes of hydrogen are protium, deuterium and tritium.

- Hydrogen is a source of hydrogen radicals, protons and hydride ions. The hydrogen radical and the hydride ion are more reactive than a proton.

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- Hydrogen is used in the synthesis of ammonia by the Haber process and for hydrogenating unsaturated fats and oils. It can be used to reduce oxides of less electropositive metals to the metal.

- Hydrogen containing compounds can be classified into three general types depending on the electronegativity of the other element which is bonded to.

- Water is a universal solvent and it dissolves in salts, sugars, acids, alkalis, and some gases. It forms hydrogen bonds with O, N, and halogens. Thus, the boiling point of water is higher than that of H_2S. Hydrogen bonding (X-H$\cdots$Y) occurs between a covalently bonded hydrogen and an electronegative atoms such as X and Y; X or Y = F, O, N or Cl.

- The water cycle refers to the continuous exchange of water within the hydrosphere, among the atmosphere, soil water, surface water, ground water, and plants.

- Hydrogen is used for the synthesis of ammonia, hydrochloric acid, methyl alcohol and also to convert vegetable oils into edible fats.

Learning Outcomes

At the end of this lesson, you should be able

- to explain the properties of hydrogen and its compounds including water.
- to describe the methods of preparation of hydrogen.
- to identify reactive forms of hydrogen.
- to list uses of hydrogen and its compounds.
- to identify the synthesis and reactions of hydrides.

Activity

1) How do you prepare hydrogen using aqueous NaOH?

2) Give two methods which can be used to produce hydrogen industrially.

3) How do you produce hydrogen in the laboratory?

4) How would you identify hydrogen produced in the laboratory?

5) What are the three types of hydrides?

6) What is the use of $LiAlH_4$ and $NaBH_4$?

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7) Draw the structure of beryllium hydride. How do you relate it to the structure of B_2H_6.

8) How do you extract lead from lead oxide?

9) Write a short account on uses of hydrogen?

10) H_2O is reduced at a cathode to give H_2. Write the balanced equation.

11) What is the molecular formula of heavy water?

12) What is meant by "Dehydrogenation"?

13) What are the components of "water gas "?

14) What is the molecular mass of deuterium oxide in g mol^{-1}?

15) Predict the product(s) for the following reactions.

i) between CaH_2 and H_2O
ii) between Fe and dil. H_2SO_4
iii) between Na and H_2
iv) between FeS and dil. HCl
v) between MgH_2 and H_2O
vi) reduction of water at a cathode
vii) between styrene and H_2
viii) between B_2H_6 and LiH
ix) between BCl_3 and $LiAlH_4$
x) between acetone and $NaBH_4$
xi) between Zn and NaOH
xii) between Mg and steam
xiii) between Cl_2 and H_2S

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Study Questions

Indicate whether the following statements are **true** or **false**.

1. H_2O^{18} is called heavy water. (T/F)
2. Hydrogen is evolved at the anode when molten KH is electrolyzed. (T/F)
3. Hydrogen is the most abundant element in the universe. (T/F)
4. Hydrogen cannot be obtained by reacting Mg with dilute HNO_3 at room temperature. (T/F)
5. Heated CuO can be reduced to Cu by molecular Hydrogen. (T/F)
6. Al_2O_3 cannot be reduced to Al by hydrogen gas. (T/F)
7. $LiAlH_4$ is an ionic hydride. (T/F)
8. BeH_2 and CaH_2 are ionic hydrides. (T/F)
9. Hydrogen cannot act as an oxidizing agent. (T/F)
10. Atomic hydrogen is produced when molecular hydrogen is passed over an electric arc. (T/F)
11. NaH reacts with D_2O to give D_2. (T/F)
12. NaH reacts with D_2O to give NaOD. (T/F)
13. Tritium is a β-emitter. (T/F)
14. The bond energy of molecular hydrogen is 436 $kjmol^{-1}$. (T/F)
15. Heavy water has a lower boiling point than ordinary water. (T/F)

MCQs

1). The most uncommon isotope of hydrogen is tritium, which has

1. 1 proton, no electrons & 1 neutron
2. 1 proton, 1 electron & no neutrons
3. 2 protons, 1 electron & 1 neutron
4. 1 proton, 1 electron & 2 neutrons

2). The primary reason for filling balloons with helium instead of hydrogen is

1. Hydrogen is flammable
2. Hydrogen is toxic
3. Helium is lighter than hydrogen
4. Hydrogen seeps through the balloon material too quickly

3). Approximately the percentage of hydrogen in the universe is

1. 25%
2. 50%
3. 75%
4. 90%

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4). The usual valency of hydrogen is

1. two
2. +1 or sometimes (-1)
3. zero
4. one

5). The oxidation number of hydrogen in H_2O_2 is

1. -1
2. +1
3. 0
4. +2

6). Hydrogen is a good …….. agent.

1. Hydrolyzing
2. Reducing
3. Acidifying
4. Oxidizing

7). The atomic weights of isotopes of hydrogen are different due to the different number of

1. Electrons
2. Neutrons
3. Protons
4. Electrons and neutrons

8). The covalent bond of molecular hydrogen is

1. 104 kJ
2. 104 kcal
3. 140 kcal
4. 114 kJ

9). The freezing point of hydrogen is

1. -250 ^{o}C
2. -253 ^{o}C
3. -255 ^{o}C
4. -259 ^{o}C

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10). The boiling point of Hydrogen is

1. -253 ^{o}C
2. -250 ^{o}C
3. -255 ^{o}C
4. -259 ^{o}C

11). Hydrogen burns in air with a ……. flame.

1. White
2. Orange
3. Light blue
4. Colourless

12). ……..is called heavy hydrogen.

1. Deuterium
2. Tritium
3. Protium
4. Deuterium dioxide

13). The atomic mass of tritium is ……amu.

1. 3
2. 2
3. 4
4. 1

14). From the following atoms which atom is least likely to form hydrogen bonding?

1. Oxygen
2. Nitrogen
3. Fluorine
4. Chlorine

15). When molten NaH is electrolyzed

1. H_2 and O_2 evolve at the anode
2. Na deposits at the anode
3. H_2 evolves at the anode

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4. H_2 and Na are generated at the cathode

16). The most abundant element in the universe is

1. Hydrogen
2. Oxygen
3. Silicon
4. Carbon

17). Which oxide is not reduced by hydrogen?

1. AgO
2. SnO
3. PbO
4. BaO

18). Which one of the following is an ionic hydride?

1. CaH_2
2. BeH_2
3. $LiAlH_4$
4. PdH_2

19). Industrial preparation of hydrogen is done

1. using methane
2. using water gas
3. by the action of acids on metals
4. oxidizing water

20). Why hydrogen is considered to have similar properties of halogens?

1. It forms the H^- ion
2. It can form the H^+(aq) ion
3. It can form the H_3O^+(aq) ion
4. All of the above

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21). The main product of the reaction between CaH_2 and D_2O is

1. H_2
2. D_2
3. H_2 and D_2
4. $Ca(OD)_2$

22). What is the molecular mass of deuterium oxide (in g mol^{-1})

1. 20
2. 2
3. 18
4. 21

23). Which isotope of hydrogen is radioactive?

1. Protium
2. Tritium
3. Deuterium
4. Both deuterium & tritium

24). Which of the following statements is not true for hydrogen?

1. It has one electron in the outer most shell
2. It can lose an electron to form a cation
3. It forms a large number of ionic compounds by losing an electron
4. It needs only one electron to have a noble gas configuration

25). Hydrogen resembles halogens in many respects for which several factors are responsible. Of the following factors which one is the most important in this respect?

1. Its tendency to lose an electron to form a cation
2. Its oxidizing ability
3. Its tendency to gain a single electron in its valence shell to attain stable electronic configuration
4. Its low negative electron gain enthalpy value

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Abbreviations

(aq)	- Aqueous; dissolved in water
(g)	- Gas state
Δ	- Heat
(l)	- Liquid state
(s)	- Solid state
b.p.	- Boiling point
eV	- Electron Volt
J	- Joule
M(g)	- Element in gas state
m.p.	- Melting point
nm	- nanometres
O.N.	- Oxidation number
pm	- Picometres
X	- Halogen

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Glossary

Alkali metal : The Group 1 elements, lithium (Li), sodium (Na), potassium (K), rubidium (Rb), cesium (Cs), and francium (Fr).

ක්ෂාරලෝහ : පළමු කාණ්ඩයේ ලෝහ ලිතියම් (Li), සෝඩියම් (Na), පොටෑසියම් (K), රුබිඩියම් (Rb), සීසියම් (Cs), ෆ්‍රැන්සියම් (Fr).

காரஉலோகம் : லிதியம் (Li),சோடியம் (Na),பொட்டாசியம் (K), ருபீடியம் (Rb),சீசியம் (Cs) மற்றும் பிரான்சியம் (Fr)ஆகியன கூட்டம் 1 மூலகங்கள் ஆகும்.

Alkaline earth metal : The Group 2 elements, beryllium (Be), magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba), and radium (Ra).

ක්ෂාරපාංශු ලෝහ : දෙ වන කාණ්ඩයේ ලෝහ බෙරිලියම් (Be), මැග්නීසියම් (Mg), කැල්සියම් (Ca), ස්ට්‍රොන්ටියම් (Sr), බේරියම් (Ba), සහ රේඩියම් (Ra).

காரமண்உலோகம் : பெரிலியம் (Be), மக்னீசியம் (Mg), கல்சியம் (Ca), ஸ்ரொஞ்சியம் (Sr),பேரியம் (Ba),ரேடியம்(Ra)ஆகியன கூட்டம் 2 மூலகங்களாகும்.

Atom : The smallest object that retains properties of an element. It is composed of electrons and a nucleus containing protons and neutrons.

පරමාණුව : මූලද්‍රව්‍යයක පවතින, තව දුරටත් බෙදා වෙන් කළ නො හැකි කුඩාම අංශුව

அணு : ஒரு மூலகத்தின் இயல்புகளைக் கொண்டிருக்கின்ற மிகச்சிறிய பொருள். இது புரோத்திரன்,நியூத்திரன் ஆகியவற்றைக் கொண்டிருக்கின்ற கருவையும் இலத்திரன்களையும் கொண்டிருக்கின்றது.

Basicity : The state of being a base.

භාෂ්මිකතාවය : භෂ්මයක් ලෙස පැවතීමේ හැකියාව

மூலத்திறன் : மூலமாக தொழிற்படும் நிலை

Element : A substance consisting of only one type of atoms.

මූලද්‍රව්‍යය : එක ම ආකාරයේ පරමාණු වලින් සමන්විත ද්‍රව්‍ය

மூலகம் : ஒரு வகையான அணுக்களை மட்டும் கொண்டிருக்கின்ற பதார்த்தம்.

Electron affinity : The amount of energy released when an electron is added to a neutral gaseous atom.

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ඉලෙක්ට්‍රෝන බන්ධුතාවය : වායුමය උදාසීන පරමාණුවකට ඉලෙක්ට්‍රෝනයක් ලබා දීමේ දී නිකුත් වන ශක්ති ප්‍රමාණය

இலத்திரன் நாட்டம் : நடுநிலையான வாயுநிலை அணுவிற்கு இலத்திரனை சேர்க்கும் போது வெளியேற்றப்பட்ட சக்தியின் அளவு.

Electronegativity : The tendency of an atom to attract electrons to itself when combined in a molecule.

විද්‍යුත් සෘණතාවය : අණුවක ඇති එක් පරමාණුවක් සතු, එයට බැඳී ඇති අනෙක් පරමාණුවට සාපේක්ෂව, ඉලෙක්ට්‍රෝන ඇද ගැනීමේ හැකියාව

மின்னெதிரியல்பு : மூலக்கூறுகள் இணையும் போது அணு இலத்திரன்களை தன்னை நோக்கி கவரும் தன்மை.

Electrode potential : The measure of individual potential of a reversible electrode at standard state, (E°)

ඉලෙක්ට්‍රෝඩ විභවය : සම්මත තත්ව යටතේ දී ප්‍රත්‍යාවර්ත ඉලෙක්ට්‍රෝඩයක විභවය පිළිබඳ මිනුමකි.

மின்வாயழுத்தம் : நியம நிலையிலுள்ள மீளும் மின்வாயின் தனிப்பட்ட அழுத்த அளவு

Electron configuration : Specific distribution of electrons in atomic orbitals of atoms or ions.

ඉලෙක්ට්‍රෝනික වින්‍යාසය : පරමාණුවක හෝ අයනයක කාක්ෂිකවල ඉලෙක්ට්‍රෝන පැතිරී ඇති ආකාරයි

இலத்திரனிலையமைப்பு : அணுக்களினது/அயன்களினது அணுவொழுக்கில் இலத்திரன்களின் குறிப்பிட்ட பரம்பல்.

Electropositive : The tendency of an atom to remove valence electrons.

විද්‍යුත් ධනතාවය : සංයුජතා කවචයේ පවතින ඉලෙක්ට්‍රෝන ඉවත් කිරීමට පරමාණුවක් සතු හැකියාවයි.

மின்னேரியல்பு : வலுவளவு இலத்திரன்களை அகற்றும் அணுக்களின் தன்மை.

First ionization energy : The energy needed to remove an electron from an isolated, neutral gaseous atom.

පළමු අයණීකරණ ශක්තිය : නිදහස්, උදාසීන, වායුමය පරමාණුවකට බැඳී ඇති ඉලෙක්ට්‍රෝනය ඉවත් කිරීමට අවශ්‍ය ශක්තිය

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முதலாவது அயனாக்கற்சக்தி : தனிப்படுத்தப்பட்ட நடுநிலையான வாயுநிலை அணுவிலிருந்து இலத்திரனை நீக்குவதற்கு தேவையான சக்தி.

Fractional distillation : A process by which components in a chemical mixture are separated according to their different boiling points.

භාගික ආසවනය : මිශ්‍රණයක පවතින සංයෝග ඒවායේ තාපාංක අනුව වෙන් කිරීමේ ක්‍රියාවලියයි.

பகுதிபட காய்ச்சி வடித்தல் : இரசாயன கலவையிலுள்ள சேர்வைகளை அவற்றின் வேறுபட்ட கொதிநிலைகளின் அடிப்படையில் பிரித்தெடுக்கும் முறை.

Halogen : Elements of Group 18. Fluorine (F), chlorine (Cl), bromine (Br), iodine (I), and astatine (At) are known at this time.

හැලජන : 18 වන කාණ්ඩයේ මූලද්‍රව්‍ය ෆ්ලෝරීන් (F), ක්ලෝරීන් (Cl), බ්‍රෝමීන් (Br), අයඩීන් (I), සහ ඇස්ටටීන් (At)

அலசன்கள் : புளோரின் (F) , புரோமின் (Br), அயடீன் (I) , அஸ்டதைன் (At)

ஆகியன இந்த நேரத்தில் அறியப்பட்ட கூட்டம் 18 இன் மூலகங்களாகும்.

Hydrolysis : The breaking down of a chemical compound into two or more simpler compounds by reacting with water.

ජල විච්ඡේදනය : ජලය සමඟ ප්‍රතික්‍රියා කර රසායනික සංයෝගයක් සරල සංයෝග දෙකක් හෝ කිහිපයක් බවට බිඳ හෙලීම

நீர்ப்பகுப்பு : நீருடன் தாக்கமடைவதன் மூலம் இரசாயனச் சேர்வைகள் 2 அல்லது அதற்கு மேற்பட்ட பகுதிகளாக உடையும் பொறிமுறை.

Ionic radius : The radii of anions and cations in crystalline ionic compounds, as determined by consistently partitioning the center-to-center distance of ions in those compounds.

අයනික අරය : ස්ඵටිකීය අයනික සංයෝගයක ඇනායන සහ කැටායනවල කේන්ද්‍ර අතර දුර

அயனாரை : பளிங்குருவான அயன் சேர்வைகளின் மறை அயன், நேர் அயன்களிற்கான ஆரை அந்த சேர்வைகளின் தொடர்ச்சியாகப் பங்கிடப்படுகின்ற அயன்களின் மையத்துக்குமான தூரத்தினால் தீர்மானிக்கப்படுகின்றது.

Ionization energy : The minimum amount of energy required to remove the most loosely held electron of an isolated gaseous atom or ion.

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අයනීකරණ ශක්තිය : නිදහස් වායුමය අවස්ථාවේ පවතින පරමාණුවක ලිහිල්වම බැඳී ඇති ඉලෙක්ට්‍රෝනයක් ඉවත් කිරීමට අවශ්‍ය අවම ශක්ති ප්‍රමාණය

அயனாக்கற் சக்தி : தனிப்பட்ட வாயு அவத்தையில் உள்ள அணு அல்லது அயனில் வலிமையற்று பிணைக்கப்பட்டு இருக்கும் ஒரு இலத்திரனை அகற்றுவதற்காக் தேவைப்படும் மிகக்குறைந்த சக்தி.

Liquefaction : The act or process of turning a gas into a liquid.

ද්‍රව කිරීම : වායුවක් ද්‍රවයක් බවට පත් කිරීමේ ක්‍රියාවලිය

திரவமாக்கல் : வாயுவானது திரவமாக மாற்றப்படும் ஒரு பொறிமுறை.

Melting point : The point at which the crystals of a pure substance are in equilibrium with the liquid phase at atmospheric pressure.

ද්‍රවාංකය : වායුගෝලීය පීඩනය යටතේ දී සංශුද්ධ ද්‍රව්‍යයක ස්ඵටික එහි ද්‍රව කලාපය සමග සමතුලිතව පවතින උෂ්ණත්වයයි.

உருகு நிலை : பளிங்குருவான தூய பதார்த்தமானது வளிமண்டல அமுக்கத்தில் அதன் திரவ அவத்தையுடன் சமநிலையில் இருக்கும் புள்ளி.

Molten : The phase change of a substance from a solid to a liquid.

ද්‍රව වීම : ද්‍රවයක් ඝන අවස්ථාවක සිට ද්‍රව අවස්ථාවක් දක්වා කලාප මාරු වීමයි.

உருகுதல் : சில பதார்த்தம் திண்ம அவத்தையிலிருந்து திரவ அவத்தைக்கு மாறும் செயற்பாடு

Mass number : The total number of protons and neutrons in the nucleus of an atom.

ස්කන්ධ ක්‍රමාංකය : පරමාණුවක න්‍යෂ්ටියේ ඇති ප්‍රෝටෝන හා නියුට්‍රෝනවල එකතුව

திணிவெண் : அணுவொன்றின் கருவிலுள்ள புரோதன், நியூத்திரன்களின் மொத்த எண்ணிக்கை.

Metal : It is a substance that conducts heat and electricity, it is shiny and can be hammered into sheets or drawn into wire. Metals lose electrons easily to form cations.

ලෝහය : විදුලිය සහ තාපය සන්නයනය කළ හැකි, දිලිසෙන සුළු, ඇදීමේ හෝ තැලීමේ ගුණ ඇති ද්‍රව්‍යයකි. ඉතා පහසුවෙන් ඉලෙක්ට්‍රෝන නිදහස් කර කැටායන සාදයි.

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உலோகம் : வெப்பம், மின் ஆகியவற்றைக் கடத்துகின்ற ஒரு பதார்த்தமாகும், பளபளப்பானது அடித்து தாளாகவும் அல்லது இழுத்து வயராகவும் மாற்ற முடியும். உலோகங்கள் இலகுவாக இலத்திரன்களை இழந்து நேர் அயன்களை உருவாக்கும்.

Neutron : A neutral particle in the nuclus of an atom.

නියුට්‍රෝනය : පරමාණුවක න්‍යෂ්ටියේ ඇති උදාසීන අංශුව

நியூத்திரன் : அணுக்கருவினுள் உள்ள நடுநிலையான துணிக்கைகள்

Orbital : A region around the nucleus where there is a high probability of finding an electron.

කාක්ෂික : ඉලෙක්ට්‍රෝන පැවතීමේ වැඩි සම්භාවිතාව ඇති න්‍යෂ්ටිය වටා වූ ප්‍රදේශය

ஒழுக்கு : அதிகளவு நிகழ்தகவு இலத்திரன் காணப்படும் கருவை சூழவுள்ள பகுதி

Oxidation number: A number assigned to each atom to help keep track of the electrons during a redox-reaction.

ඔක්සිකරණ අංකය : රෙඩොක්ස් ප්‍රතික්‍රියාවක දී අදාළ වන ඉලෙක්ට්‍රෝන ප්‍රමාණය පෙන්වන ලෙස එක් එක් පරමාණුවට සතු අංකය

ஒட்சியேற்ற எண் : ஒட்சியேற்ற தாழ்த்தல் தாக்கத்தின் போது சுவட்டில் இலத்திரன்களை வைத்திருப்பதற்கு உதவுகின்ற ஒவ்வொரு அணுவிற்கும் ஒதுக்கப்பட்ட ஒரு இலக்கம்.

Proton : A positively charged particle in the nucleus of an atom.

ප්‍රෝටෝනය : පරමාණුක න්‍යෂ්ටියේ ඇති ධන ආරෝපිත අංශු

புரோத்தன் : அணுக்கருவிலுள்ள நேரேற்ற துணிக்கை

Reducing agent : A substance that causes another substance to undergo reduction and that is oxidized in the process.

ඔක්සිහාරක ද්‍රව්‍ය : වෙනත් ද්‍රව්‍යයක් ඔක්සිහරණය කරවනු ලබන සහ එම ද්‍රව්‍යය ම ඔක්සිකරණය වීම සිදුවන ද්‍රව්‍යයන්

தாழ்த்தும் கருவி : இது தான் ஒட்சியேற்றப்படுவதன் மூலம் ஏனையவற்றை தாழ்த்தும் ஒரு பதார்த்தம்.

Valence electrons : The electrons in the outermost shell of an atom.

සංයුජතා ඉලෙක්ට්‍රෝන : පරමාණුවක බාහිරතම කවචයේ ඇති ඉලෙක්ට්‍රෝන

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