Chapter 9. Study of the First Element – Hydrogen

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Solution 1:

1. **(a)** Symbol of hydrogen is 'H' and its molecular formula is H_2.
2. **(b)** 2 H means 2 atoms of hydrogen while H_2 means one molecule of hydrogen.
3. **(c)** Lavoisier gave "Hydrogen" its name because it means water product.

Solution 2:

Hydrogen is found in free state as well as in combined state.

1. In free state, it is found in traces in the earth's crust and atmosphere. On the sun and bright stars, hydrogen is very abundant.It is suggested that the source of sun's energy is fusion of hydrogen to helium.
2. In combined state it is found in the compounds like water, acids, organic materials and minerals. Natural gas coming out from oil wells, coal mines and volcanoes invariably contains this gas.

Solution 3:

Hydrogen resembles the alkali in following manner-

1. **Electronic configuration –** Hydrogen as well as alkali metals have one electron in their valence shell.
   H (1) = 1 ; Li(3)= 2, 1 ; Na(11) =2, 8, 1
2. **Ion formation –** Hydrogen loses one electron to form H^+ ion like the alkali metals which form Li^+, Na^+, K^+ etc.
3. **Valency electrons –** Like alkali metals, hydrogen exhibit valency of one in its compounds , as it has only one electron in its outermost shell.
4. **Combination with non-metals –** Like alkali metals, hydrogen combines with non-metals such as oxygen, chlorine and sulphur forming their oxides, chlorides and sulphides respectively.
5. **Reducing action –** Like alkali metals, hydrogen is also a very good reducing agent.

Solution 4:

Hydrogen resembles the alkali in following manner-

1. **Electronic configuration –** All the halogens have seven electrons in their outermost shell and need just one more electron to attain stable inert gas configuration. Similarly, hydrogen with one electron in its outermost shell requires one electron to attain a stable inert gas(Helium) configuration.
2. **Valency –** Hydrogen and halogen both show a valency of one.
3. **Non-metals –** Hydrogen is non-metallic like halogen.
4. **Atomicity –** Hydrogen as well as halogens are diatomic gases, e.g.H_2,Cl_2.Br_2 etc.
5. **Ion formation –** Halogens have a strong tendency to gain an electron to form halide ions.In similar way, hydrogen shows tendency to gain one electron to form hydride ion (H^-).

Solution 5:

By the action of dilute sulphuric acid or hydrochloric acid with zinc we can prepare hydrogen.

$$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$$

Zinc Sulphuric acid Zinc sulphate Hydrogen

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

Zinc Hydrochloric acid Zinc chloride Hydrogen

Zinc liberate hydrogen from hot concentrated solution of alkali.

$$Zn + 2NaOH \rightarrow Na_2ZnO_2 + H_2$$

Zinc Sodium hydroxide Sodium zincate Hydrogen

$$Zn + 2KOH \rightarrow K_2ZnO_2 + H_2$$

Zinc Potassium hydroxide Potassium zincate Hydrogen

Solution 6:

(i)Calcium-

$$Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$$

This reaction is vigorous but less vigorous as compared to reaction of sodium and potassium. So, not used for preparation of hydrogen. Also, Calcium is expensive.

(ii) Iron-

$$3Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2$$

This reaction is a reversible reaction. Hence, the hydrogen formed should be continuously drawn out. Otherwise, it will reduce the iron oxide (ferrous-ferric oxide) back to iron. And, also the hydrogen thus produced contains impurities like hydrogen sulphide and sulphur dioxide.

(iii) Aluminium-It forms a protective coating of Al_2O_3 due to its great affinity for oxygen. So, it does not give hydrogen with acid after the reaction has produced for some time.

(iv) Sodium-

$$2Na + 2H_2O \rightarrow 2NaOH$$

This reaction is violent. Sodium melts into silvery globules and darts about freely on the surface of water, making collection of hydrogen gas is difficult.

Solution 7:

(i) Reactants used- Zinc and sulphuric acid/Hydrochloric acid

(ii) Reaction-

$$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$$

Zinc Sulphuric acid Zinc sulphate Hydrogen

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

Zinc Hydrochloric acid Zinc chloride Hydrogen

(iii) Procedure-Some pieces of granulated zinc are placed in the Woulfe's bottle and the apparatus is made air tight. Now, dilute sulphuric acid or dilute hydrochloric acid is poured through thistle funnel. Hydrogen gas is evolved.

(iv) Complete labelled diagram-

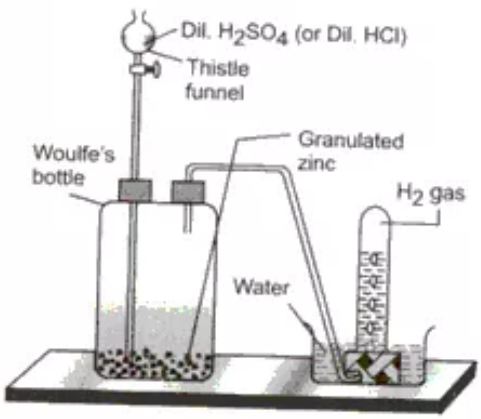

Fig-Laboratory preparation of hydrogen

(v) Method of collection-Hydrogen is collected by downward displacement of water

(vi) Drying agent for gas-Hydrogen gas is dried by passing it through anhydrous calcium chloride or P_2O_5.

Solution 8:

Hydrogen gas obtained in the laboratory by dilute H2SO4 and granulated zinc have following impurities-

1. Hydrogen sulphide (H_2S),
2. Sulphur dioxide (SO_2),
3. Oxides of nitrogen,
4. Phosphine (PH_3),
5. Arsine (AsH_3),
6. Carbon dioxide, Nitrogen oxides,

7. Water vapour
   They are removed by passing through-

1. Lead nitrate solution-It absorbs H_2S.
2. Silver nitrate solution ($AgNO_3$)-It absorbs PH_3, AsH_3
3. Caustic potash (solid KOH)-It absorbs CO_2, SO_2, oxides of nitrogen
4. Anhydrous calcium chloride or P_2O_5-It absorbs moisture.

Solution 9:

(a) When passed over heated metallic oxides, hydrogen reduces the oxides to the metals by taking away oxygen.

(i) $CuO + H_2 \rightarrow Cu + H_2O$

(ii) $ZnO + H_2 \rightarrow Zn + H_2O$

(b) MgO and PbO cannot be reduced to metal by hydrogen.

Solution 10:

Potassium hydroxide on reaction with zinc produces potassium zincate and hydrogen.

$$Zn + 2KOH \rightarrow K_2ZnO_2 + H_2$$

Zinc Potassium hydroxide Potassium zincate Hydrogen

Bosch Process-

The various steps involved in the process are as follows:

(1)Super heated steam is passed over heated coke at about 1000°C in special furnaces called converters to form water gas.

$$C + H_2O \xrightarrow{1000^\circ C} CO + H_2$$

White hot coke Super heated steam Water gas

This reaction is endothermic.

(2)The water gas is so obtained is then mixed with more steam and passed over heated ferric oxide and chromic oxide at a temperature of about 450°C.Ferric oxide acts as a catalyst and chromic oxide acts as promoter. The CO from water gas takes away the oxygen from steam to produce carbon dioxide and more hydrogen. In this reaction poisonous carbon monoxide is converted to non-poisonous carbon dioxide and more hydrogen is produced.

$$\underline{CO + H_2} + H_2O \xrightarrow[450^\circ C]{Fe_2O_3/Cr_2O_3} CO_2 + 2H_2(g)$$

Water gas Steam Carbon dioxide Hydrogen

(3)Separation of hydrogen from a mixture of CO_2 and H_2 is carried out by-

(a)Both the carbon dioxide and hydrogen obtained are then passed through water under high pressure to form carbonic acid. Hydrogen hardly dissolves in carbonic acid, so easily collected.

$$CO_2 + H_2O \xrightarrow{\text{under high pressure}} H_2CO_3$$

Carbon dioxide Water Carbonic acid

(b)The mixture of CO_2 and H_2 can also be passed through caustic potash which reacts with CO_2.Hydrogen gas does not react and can be collected.

$$2\,KOH + CO_2 \rightarrow K_2CO_3 + H_2$$

Caustic potash

(4)**Separation of carbon monoxide**: Hydrogen gas is generally contaminated with carbon monoxide. In order to remove it hydrogen is dissolved in ammonical cuprous chloride solution. This solution absorbs any carbon monoxide gas present in the mixture. Finally, H_2 gas is dried over by passing through anhydrous $CaCl_2$ or P_2O_3.

(iii)Account for the following facts:

(a)Lead reacts with dilute sulphuric or hydrochloric acid and forms an insoluble coating of lead sulphate or lead chloride .Therefore further reaction is prevented.

(b) Potassium and sodium are not used to react with dilute hydrochloric acid or dilute sulphuric acid in the laboratory preparation of hydrogen since they react with acid violently.

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Solution 11:

(a) Sodium>Calcium>Magnesium>Iron

(i) Sodium

$$2Na + 2H_2O \rightarrow 2NaOH + H_2$$

(ii) Calcium

$$Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$$

(iii) Magnesium

$$Mg + H_2O \rightarrow MgO + H_2$$

(iv) Iron

$$3Fe + 4H_2O \rightleftharpoons Fe_3O_4 + 4H_2$$

(b) Copper is not used to prepare hydrogen by the action of dilute HCl or dilute H_2SO_4 on the metal since it is less reactive than hydrogen so cannot displace hydrogen from acid. Only the metals that are more reactive than the hydrogen itself can displace hydrogen from acids.

Solution 12:

(a) (i) When magnesium is heated in air, it reacts with oxygen. During this oxidation reaction, magnesium oxide is produced.

$2Mg + O_2 \rightarrow 2MgO\,(s)$

When copper is heated, copper oxide is formed.

$Cu + O_2$ --> CuO

When iron is heated in presence of air, it will also form iron oxide.

$4Fe + 3O_2 \rightarrow Fe_2O_3$

(ii) Magnesium and iron will form chlorides whereas copper does not show any reaction

$Mg + 2HCl \rightarrow MgCl_2 + H_2$

$Cu + HCl \rightarrow$ No reaction

$Fe + 2HCl \rightarrow FeCl_2 + H_2$

(iii) Magnesium being at the higher position than zinc in the reactivity series will displace Zinc from zinc sulphate.

$Mg + ZnSO_4 \rightarrow MgSO_4 + Zn$

Copper and iron being at lower position than zinc will not displace zinc from zinc sulphate.

$Cu + ZnSO_4 \rightarrow$ No reaction

$Fe + ZnSO_4 \rightarrow$ No reaction

(b) Magnesium > Iron > Copper

Solution 13:

1. **(a)** Nickel, hydrogen
2. **(b)** above, dilute mineral
3. **(c)** covalent, electronegative
4. **(d)** CuO, hydrogen, water
5. **(e)** CO, H_2
6. **(f)** alkali
7. **(g)** nascent hydrogen
8. **(h)** water

Solution 14:

1. **(a)** False
2. **(b)** False
3. **(c)** True
4. **(d)** True
5. **(e)** True
6. **(f)** True
7. **(g)** True
8. **(h)** False

Solution 15:

(a) Although hydrogen is lighter than air yet it cannot be collected by the downward displacement of air as it forms an explosive mixture with air. So, it is collected by downward displacement of water not air.

(b) Hydrogen is highly inflammable and forms explosive mixture with air so apparatus for the laboratory preparation of hydrogen should be air tight and away from the flame.

(c) Nitric acid is not used in preparation of hydrogen because it is strong oxidizing agent and oxidises H_2 to H_20.

Hot concentrated H_2SO_4 is not used in preparation of hydrogen as a part of it is reduced to SO_2.

(d) As sodium reacts violently with water.

$$2Na + 2\ H_2O \rightarrow 2NaOH + H_2$$

This reaction is very violent .Sodium melts into silvery globules and darts about freely on the surface of water ,making collection of hydrogen gas is difficult so large piece of sodium should not be placed in water.

(e) Na, K and Ca cannot be used to prepare hydrogen from acids because these displace hydrogen from dilute acids with explosive violence.

(f) In the laboratory preparation of hydrogen zinc granules are preffered over pure zinc metal because copper is present as impurity in granulated zinc, which catalyse the reaction and increase its rate.

(g) This process requires heat (endothermic). So the steam should not be passed over hot coke as it may cool down the coke. So after some time steam is alternatively replaced by air stream.

2nd-

This reaction is- $C(\text{white hot}) + H_2O(\text{steam}) \rightarrow CO + H_2$

if steam is passed for a long time, it may react with carbon mono oxide(CO) and make carbon dioxide which is not a required product.

(h) Since hydrogen is a non-supporter of combustion so it does not allow substances to burn in it and hence when a burning splinter is introduced into a jar of hydrogen, the splinter gets extinguished.

(i) In nature, most dietary fats and oils exist in a structural form which is called the "cis" form. When these natural cis form fats are processed by bubbling hydrogen gas through them at high temperatures, they become partially hydrogenated which changes their structure to the "trans" form. The natural cis fat has a bend and the processed trans fat is a straight molecule. This difference in cis and trans shapes is of major significance. When eaten, fats and oils are incorporated into cell membranes altering the composition of these delicate structures. When they interact with normal fat metabolism, they disturb function in a most deleterious manner. Hence, these substances meet the definition of a poison." Trans fats interfere with important, normal functions by inhibiting enzymes which are necessary for the body's normal metabolism of fats and they keep doing it for a long time.

(j) Since hydrogen is highly inflammable in nature so inspite of being the lightest element it is not used in weather balloons.

(k) Lead reacts with dilute sulphuric acid or hydrochloric acid and forms an insoluble coating of lead sulphate or lead chloride which prevents further reaction.

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Solution 16:

(a) When hydrogen is passed over heated copper oxide reddish brown copper and water is obtained.

$$CuO + H_2 \rightarrow Cu + H_2O$$

Copper oxide — black

Reddish brown — copper

(b) When hydrogen is passed over heated sodium, sodium hydride is obtained.

$$2Na + H_2 \rightarrow 2NaH$$

Sodium

Sodium hydride

Solution 17:

$$H_2 + Cl_2 \rightarrow 2HCl$$

In **diffused sunlight**, the reaction takes place smoothly and forms HCl gas. While, in direct sunlight, the reaction occurs with an explosion.

Solution 18:

(a) Occlusion-

Adsorption of gases at the surface of finely divided metal is called occlusion. Hydrogen gas is readily adsorbed or occluded by the metals like palladium, platinum or nickel at ordinary temperature.

(b) Hydrogenation-

Unsaturated compounds combine with hydrogen in presence of catalyst like palladium, platinum or nickel to form saturated compounds. These reactions are known as hydrogenation reactions.

$$C_2H_2 + 2H_2 \xrightarrow[\Delta]{Ni} C_2H_6$$

Acetylene

$$C_2H_4 + H_2 \xrightarrow[\Delta]{Ni} C_2H_6$$

Ethylene

(c) Nascent hydrogen-

It means newly born hydrogen. Hydrogen which is just formed at the time of its generation is called nascent hydrogen .It is more powerful reducing agent than molecular hydrogen.

Solution 19:

Some pieces of zinc granules are placed in Woulfe's bottle and the apparatus is made in air tight. Now dilute sulphuric acid is poured through the thistle funnel.

Observation: The reaction takes place at room temperature even without heating. A brisk effervescence with the evolution of gas is seen inside the bottle.

If burning candle is brought near the bubbles of hydrogen gas, they explode.This proves that bubbles were full of hydrogen gas and they move up in the air because they are lighter than air.

Solution 20:

1. **(a) Meteorological balloons –** The low density and high lifting power of hydrogen made it useful in meteorological balloons used for studying air currents and weather conditions. However, due to its highly inflammable nature it has been replaced by helium which has a lifting only slightly less than that of hydrogen.
2. **(b) In metallurgy –** Hydrogen acts as a very good reducing agent. It is used to obtain metals by reducing their oxides.

3. **(c) In fuel –** Hydrogen has very high heat of combustions, therefore it is used as fuel in the form of coal gas, water gas and liquid hydrogen(for rocket propulsion).
4. **(d) In making fertilizers –** A large quantity of hydrogen is used in the manufacture of ammonia by Haber process. Ammonia is used in manufacture of HCl and methyl alcohol.

Solution 21:

(a) **As an oxidizing agent**-With metals hydrogen acts as an oxidizing agent. When dry hydrogen is passed over heated reactive metals (K, Na and Ca) the corresponding metal hydrides, are formed.

$$2Na + 2H_2 \rightarrow 2NaH$$

(b) **As a reducing agent**-

When passed over heated metallic oxides, hydrogen reduces the oxides to the metals by taking away oxygen.

$$CuO + H_2 \rightarrow Cu + H_2O$$