

Hydrogen

1. Justify the position of Hydrogen in the periodic table.

Ans. Hydrogen is the first element in the periodic table. Its atomic number is 1, and it has only one electron in its valence shell. So, it belongs to the first group and the first period of the periodic table

2. Why does hydrogen show dual nature?

Hydrogen shows dual nature because it resembles the alkali metals of Group IA and the halogens of Group VIIA.

3. Compare hydrogen with alkali metals on basis of:

- i. Ion formation
- ii. Reducing power
- iii. Reaction with oxygen
- iv. Oxide formation

Ans.

- i. Each of them can form a cation by loss of an electron.
 $H \rightarrow H^+ + e^-$
 $Li \rightarrow Li^+ + e^-$
- ii. Both alkali metals and hydrogen act as reducing agents.
 $CuO + H_2 \rightarrow Cu + H_2O$
 $CuO + Na \rightarrow Cu + Na_2O$
- iii. Hydrogen burns in oxygen to form its oxide. It burns with a pop sound.
 $2H_2 + O_2 \rightarrow 2H_2O$
Alkali metals also burn vigorously when heated in oxygen to form their respective oxides.
Lithium forms monoxide.
 $4Li + O_2 \rightarrow 2Li_2O$
- iv. Hydrogen burns in oxygen to form its oxide. It burns with a pop sound.
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Alkali metals also burn vigorously when heated in oxygen to form their respective oxides.
Lithium forms monoxide.
 $4Li + O_2 \rightarrow 2Li_2O$

4. In what respect does hydrogen differ from:

- i. alkali metals
- ii. halogens?

Ans.

- i. Oxides of alkali metals are basic in nature, whereas the oxide of hydrogen H_2O is a neutral oxide.
- ii. Hydrogen atom has only one shell, but halogens have two or more shells.

5. Give the general group study of hydrogen with reference to

- i. valence electrons
- ii. burning
- iii. reducing power

Ans.

- i. Hydrogen has one valence electron in its outermost orbit.
- ii. Hydrogen burns in oxygen to form its oxide. It burns with a pop sound.
$$2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$$
- iii. Hydrogen acts as a reducing agent.
$$\text{CuO} + \text{H}_2 \rightarrow \text{Cu} + \text{H}_2\text{O}$$

6. Why hydrogen was called 'inflammable air'?

Ans. Hydrogen was called inflammable air because of its combustible nature.

7. State some sources of hydrogen.

Ans. In the free state, hydrogen is found in traces in the earth's crust and atmosphere. In the combined state, plant and animal tissues are made of compounds of hydrogen with carbon, oxygen and nitrogen.

8. Compare hydrogen and halogens on the basis of:

- i. physical state
- ii. ion formation
- iii. valency
- iv. reaction with oxygen

Ans.

- i. Like halogens (fluorine and chlorine), hydrogen too is a gas.
- ii. Both show a tendency to form anions because they are one electron short of the nearest inert gas configuration.
$$\text{H} + \text{e}^- \rightarrow \text{H}^-$$
$$\text{Cl} + \text{e}^- \rightarrow \text{Cl}^-$$
- iii. Both have valency 1.
- iv. Hydrogen reacts with oxygen to form neutral oxide, H_2O . Halogens react with oxygen to form acidic oxides like Cl_2O and Cl_2O_7 .

9. Which metal is preferred for preparation of hydrogen

- i. from water?
- ii. from acid?

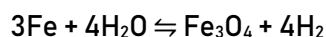
Ans.

- i. Reactive metals such as potassium, sodium and calcium.
- ii. Magnesium, aluminium, zinc and iron.

10. Write the reaction of steam with red hot iron.

- i. Why this reaction is considered as reversible reaction?
- ii. How the reaction can proceed continuously?

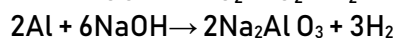
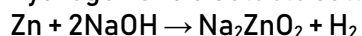
Ans.



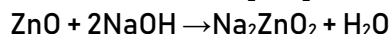
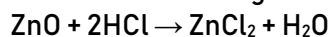
- i. The reaction is reversible because if hydrogen formed is not removed, then the iron oxide formed is reduced back to iron.
- ii. Because the reaction is a reversible reaction, equilibrium is attained at 700°C . At this stage, the number of reactants and products does not change.

11. Explain the unique nature of zinc and aluminium. Give balanced equations to support your explanation.

They react with acids and can even react with hot concentrated alkalis to form hydrogen and a soluble salt.



Oxides and hydroxides of zinc and aluminium are amphoteric. They react with both bases and acids to give salt and water.



12. Write balanced equations for the following:

- Iron reacts with dil. HCl
- Zinc reacts with caustic soda solution
- Lead reacts with potassium hydroxide
- Aluminium reacts with fused sodium hydroxide

Ans.

- $\text{Fe} + 2\text{HCl} \rightarrow \text{FeCl}_2 + \text{H}_2$
- $\text{Zn} + 2\text{NaOH} \rightarrow \text{Na}_2\text{ZnO}_2 + \text{H}_2$
- $\text{Pb} + 2\text{KOH} \rightarrow \text{K}_2\text{PbO}_2 + \text{H}_2$
- $2\text{Al} + 6\text{NaOH} \rightarrow 2\text{Na}_2\text{AlO}_3 + 3\text{H}_2$

13. Write the balanced equations and give your observations when the following metals react:

- Sodium with cold water
- Calcium with cold water
- Magnesium with boiling water
- Magnesium with steam

Ans.

- The reaction is highly exothermic and vigorous with the evolution of hydrogen.
 $2\text{Na} + 2\text{H}_2\text{O} \rightarrow 2\text{NaOH} + \text{H}_2$
- Calcium sinks in water and the reaction is less vigorous.
 $\text{Ca} + 2\text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{H}_2$
- Magnesium reacts slowly with boiling water and forms a base, magnesium hydroxide, liberating hydrogen gas.
 $\text{Mg} + 2\text{H}_2\text{O} \rightarrow \text{Mg(OH)}_2 + \text{H}_2$
- Magnesium burns in steam with an intense white light liberating hydrogen gas and white ash, i.e. magnesium oxide.
 $\text{Mg} + \text{H}_2\text{O} \rightarrow \text{MgO} + \text{H}_2$

14. Under what conditions iron reacts with water.

- Give the balanced equation of the reaction.
- What is noticed if the products are not allowed to escape?

Ans. Iron is less reactive than zinc, but red-hot iron reacts with steam, forming ferric tetra-oxide and hydrogen gas.

- $3\text{Fe} + 4\text{H}_2\text{O} \rightleftharpoons \text{Fe}_3\text{O}_4 + 4\text{H}_2$
- If the product formed, i.e. hydrogen is not removed, then the iron oxide formed is reduced back to iron.

15. From the knowledge of activity series, name a metal which shows the following properties

- i. It reacts readily with cold water.
- ii. It displaces hydrogen from hot water.
- iii. It displaces hydrogen from dilute HCl.
- iv. It forms a base which is insoluble in water.

Ans.

- i. Sodium
- ii. Magnesium
- iii. Zinc
- iv. Calcium

16. Complete the following word equations:

- a. Sodium hydroxide + zinc \rightarrow hydrogen + _____
- b. Calcium + water \rightarrow calcium hydroxide + _____

Ans.

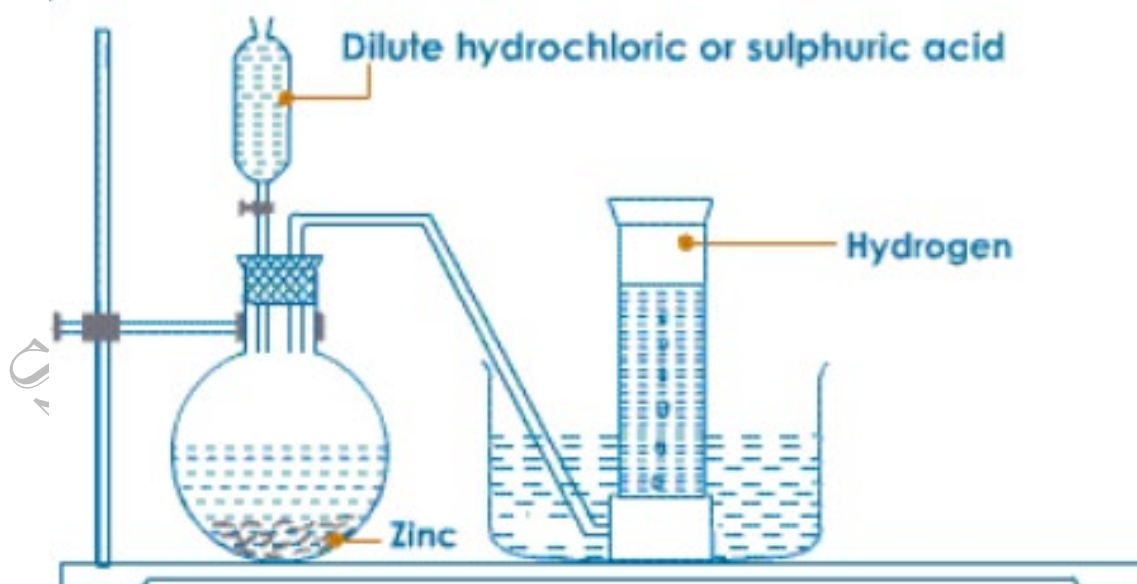
- a. Sodium hydroxide + zinc \rightarrow hydrogen + sodium zincate
- b. Calcium + water \rightarrow calcium hydroxide + hydrogen

17. For laboratory preparation of hydrogen, give the following:

- a. materials used
- b. method of collection
- c. chemical equation
- d. fully-labelled diagram

Ans.

- a. Granulated zinc, dilute HCl or dil. H_2SO_4
- b. It is collected by the downward displacement of water.
- c. $\text{Zn} + \text{HCl} \rightarrow \text{ZnCl}_2 + \text{H}_2$
- d.



- 18. Name the impurities present in hydrogen prepared in the laboratory.
How can these impurities be removed?**

Ans. Hydrogen sulphide, sulphur dioxide, oxides of nitrogen, phosphine, arsine, carbon dioxide and water vapour are impurities present in the laboratory.

The impurities can be removed from hydrogen by passing it through

- Silver nitrate solution to remove arsine and phosphine.
$$\text{AsH}_3 + 6\text{AgNO}_3 \rightarrow \text{Ag}_3\text{As} + 3\text{AgNO}_3 + 3\text{HNO}_3$$
$$\text{PH}_3 + 6\text{AgNO}_3 \rightarrow \text{Ag}_3\text{P} + 3\text{AgNO}_3 + 3\text{HNO}_3$$
- Lead nitrate solution to remove hydrogen sulphide.
$$\text{Pb}(\text{NO}_3)_2 + \text{H}_2\text{S} \rightarrow \text{PbS} + 2\text{HNO}_3$$
- Caustic potash solution to remove sulphur dioxide, carbon dioxide and oxides of nitrogen.
$$\text{SO}_2 + 2\text{KOH} \rightarrow \text{K}_2\text{SO}_3 + \text{H}_2\text{O}$$
$$\text{CO}_2 + 2\text{KOH} \rightarrow \text{K}_2\text{CO}_3 + \text{H}_2\text{O}$$
$$2\text{NO}_2 + 2\text{KOH} \rightarrow \text{KNO}_2 + \text{KNO}_3 + \text{H}_2\text{O}$$

A drying agent used to dry the gas. Common drying agents such as fused calcium chloride, caustic potash stick and phosphorus pentoxide remove water vapour. So, the gas is purified and dried and then collected over mercury because mercury does not react with it.

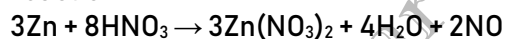
- 19. Which test should be made before collecting hydrogen in a gas jar?**

Test: Collect some amount of gas in a test tube and take it to a flame.

If the gas burns quietly, then there is no more air in the flask.

- 20. Why nitric acid is not used in the preparation of hydrogen?**

Ans. Nitric acid is a powerful oxidising agent, and the oxygen formed due to its decomposition oxidises hydrogen to give water thus defeating the purpose of the reaction.



- 21. Why hot concentrated sulphuric acid is not used in the preparation of hydrogen?**

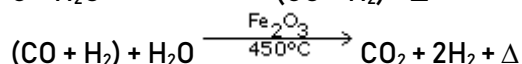
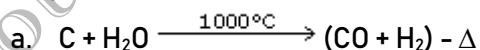
Ans. Conc. sulphuric acid is not used in the preparation of hydrogen as it will produce sulphur dioxide.



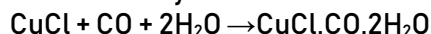
- 22. Hydrogen is manufactured by 'Bosch Process'.**

- Give the equations with conditions.
- How can you obtain hydrogen from a mixture of hydrogen and carbon monoxide?

Ans.



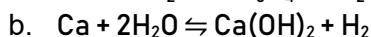
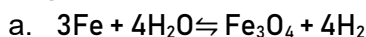
- The mixture is passed through ammoniacal cuprous chloride solution in order to dissolve any uncombine carbon monoxide.



- 23. Give equations to express the reaction between:**

- Steam and red-hot iron
- Calcium and water

Ans.



24. A small piece of calcium metal is put into a small trough containing water. There is effervescence and white turbidity is formed.

- a. Name the gas formed in the reaction. How would you test the gas?**
- b. Write an equation for the reaction.**
- c. What do you observe when a few drops of red litmus solution are added to the turbid solution?**

Ans.

- a. Hydrogen gas. When red litmus is introduced in the solution, it turns blue.
- b. $\text{Ca} + 2\text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{H}_2$
- c. The solution turns blue.
- d. If dilute hydrochloric acid is added to the turbid solution, then they **react** and neutralise each other, forming the soluble salt **calcium chloride** (CaCl_2) and water.
 $\text{Ca(OH)}_2 + 2\text{HCl} \rightarrow \text{CaCl}_2 + 2\text{H}_2\text{O}$

25. Thin strips of magnesium, copper and iron are taken.

a. Write down what happens when these metals are treated as follows:

- i. Heated in presence of air
- ii. Heated with dil.HCl
- iii. Added to an aqueous solution of zinc sulphate

b. Arrange these metals in descending order of reactivity.

Ans.

- i. On heating thin strips of magnesium, copper and iron, they form oxides.
- ii. Magnesium and iron react with HCl liberating hydrogen and forming their respective salts. Hydrogen cannot be prepared from metals which are below it in the activity series of metals (such as copper) because only metals which are more reactive than hydrogen can displace it from acids.
- iii. Only magnesium will displace zinc from zinc sulphate solution because magnesium is more reactive than zinc in the activity series of metals. No reaction takes place in case of copper and iron because they are less reactive than zinc.
- iv. $\text{Mg} > \text{Fe} > \text{Cu}$
- v.

26. Give reasons for the following:

- a. Zinc granules are used in lab preparation of hydrogen.
- b. Purified and dried hydrogen is collected over mercury.
- c. The end of the thistle funnel should be dipped under acid
- d. Dilute sulphuric acid cannot be replaced by concentrated acid in the preparation of hydrogen.

Ans.

- a. Zinc granules are preferred over pure zinc in the lab preparation of hydrogen because the impurity present in granulated zinc is copper, whose catalysing effect speeds up the rate of the reaction.
- b. Purified and dried hydrogen is collected over mercury because mercury has no reaction with it.
- c. The end of the thistle funnel should be dipped under acid so as to prevent the gas from escaping from the thistle funnel.
- d. Dilute sulphuric acid cannot be replaced by concentrated acid in the preparation of hydrogen because it is a strong oxidising agent and it will produce sulphur dioxide.

27. Where does hydrogen occur in free state?

How did the name 'hydrogen' originate?

Ans. In the free state, hydrogen is found in traces in the earth's crust and atmosphere. Volcanic gases contain 0.025%, the earth's crust 0.98%, the earth's atmosphere 0.01% and the atmosphere of the Sun and stars 1.1%.

The name 'hydrogen' originated on account of its ability to form water.

28. Hydrogen can be prepared with the help of cold water. Give a reaction of hydrogen with:

- a. A monovalent metal
- b. A divalent metal

Ans.

- a. $2K + 2H_2O \rightarrow 2KOH + H_2$
- b. $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$

29. Which metal is preferred for collecting hydrogen from:

- a. Cold water
- b. Hot water
- c. Steam

Ans. Metal preferred for collecting hydrogen from

- a. Cold water: Sodium
- b. Hot water: Magnesium
- c. Steam: Aluminium

30. Hydrogen may be prepared in the laboratory by the action of a metal on an acid.

- a. Which of the metals copper, zinc, magnesium or sodium would be the most suitable?
- b. Which of the acids dilute sulphuric, concentrated sulphuric, dilute nitric acid and concentrated nitric acid would you choose? Explain why you would not use the acids you reject.
- c. How would you modify your apparatus to collect dry hydrogen? Which drying agent would you employ for this purpose?

Ans.

- a. Zinc is the most preferred metal in the laboratory preparation of hydrogen.
- b. Dilute sulphuric acid.

Conc. nitric acid, even in its dilute form, is not used in the preparation of hydrogen from metals because it is a powerful oxidising agent and oxygen formed due to its decomposition oxidises hydrogen to give water, thus defeating the purpose of the reaction.

Conc. sulphuric acid is not used in the preparation of hydrogen as it will produce sulphur dioxide.

- c. The gas is collected by the downward displacement of water.

Common drying agents such as fused calcium chloride, caustic potash stick and phosphorus pentoxide remove water vapour.

31. Why are the following metals not used in the lab. preparation of hydrogen?

- a. Calcium
- b. Iron
- c. aluminium
- d. sodium

Ans.

- a. Calcium is expensive.
- b. Iron has to be heated, and hydrogen thus produced contains impurities such as hydrogen sulphide and sulphur dioxide.
- c. Aluminium 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 occurred for some time.
- d. Sodium reacts violently with acid.

32. Based on the reactions of water on metals, arrange the following metals in increasing order of reactivity: iron, sodium, magnesium, zinc, calcium

Ans. Increasing order of reactivity of metals:

Iron < Zinc < Magnesium < Calcium < Sodium

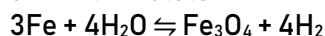
33. Hydrogen is evolved when dilute HCl reacts with magnesium, but nothing happens in the case of mercury and silver. Explain.

Ans. Hydrogen is evolved when dilute HCl reacts with magnesium which is placed above hydrogen in the activity series. However, this does not occur for metals below hydrogen such as mercury and silver. This is because only metals which are more reactive than hydrogen can displace it from HCl.

34. Steam can react with metal and non-metal to liberate hydrogen. Give necessary conditions and equations for the same.

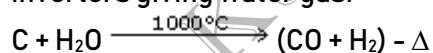
Ans.

- a. With metals:

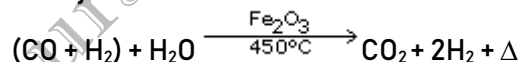


- b. With non-metals:

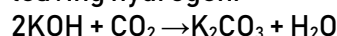
Steam is passed over hot coke (1000°C) in furnaces of a special design called inverters giving water gas.



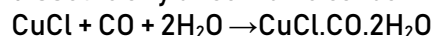
Water is mixed with excess steam and passed over heated ferric oxide which acts as a catalyst and chromic oxide which acts as a promoter.



The above mixture $\text{CO}_2 + \text{H}_2$ is formed through cold water under pressure (30 atm) or through caustic potash solution, which dissolves the more soluble carbon dioxide leaving hydrogen.



The mixture is passed through ammoniacal cuprous chloride solution in order to dissolve any uncombine carbon monoxide.



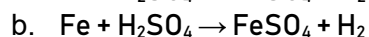
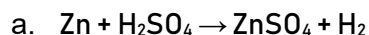
35. Hydrogen is obtained by displacement from:

- a. dilute sulphuric acid
- b. dilute hydrochloric acid

Write equations using zinc and iron.

Why does copper not show similar behaviour?

Ans.



Hydrogen cannot be prepared from metals which are below it in the activity series of metals such as copper because only metals which are more reactive than hydrogen can displace it from acids.

36. Give reason for the following:

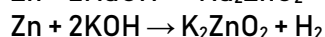
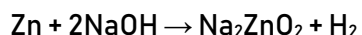
- a. Though lead is above hydrogen in the activity series, it does not react with dilute hydrochloric acid or dilute sulphuric acid.
- b. Potassium and sodium are not used for reaction with dilute hydrochloric acid or dilute sulphuric acid in laboratory preparation of hydrogen.

Ans.

- a. It forms an insoluble coating of lead sulphate or lead chloride. So, further reaction is prevented.
- b. Potassium and sodium react violently with acid. Hence, potassium and sodium are not used for reaction with dilute hydrochloric acid or dilute sulphuric acid in the laboratory preparation of hydrogen.

37. Name two alkalis that can displace hydrogen. Give balanced equations for the same. Why are the metals you have used considered to have unique nature?

Ans. NaOH and KOH



Metals such as zinc, lead and aluminium have a unique nature. They react with acids and can even react with hot alkalis to form hydrogen and a soluble salt.

38. If the following are kept in closed vessels at over 400°C, what would happen to them?

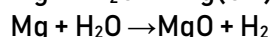
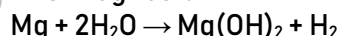
- a. iron filing and steam
- b. hydrogen and magnetic oxide of iron?

Ans.

- a. Iron oxide is formed with the evolution of hydrogen gas.
- b. Hydrogen reduces heated magnetic oxide of iron.

39. A metal in the powdered form reacts very slowly with boiling water, but it decomposes in steam. Name the metal. Write a balanced equation for the reaction.

Ans. Magnesium



40. What do you observe when hydrogen gas is passed through a soap solution?

Ans. On passing hydrogen gas through soap solution, soap bubbles filled with hydrogen fly high and burst. This behaviour proves that hydrogen is lighter than air.

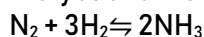
41. Under what conditions can hydrogen be made to combine with?

- a. nitrogen?
- b. chlorine?
- c. sulphur?
- d. oxygen?

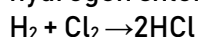
Name the products in each case and write the equation for each reaction.

Ans.

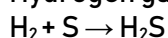
- a. Three volumes of hydrogen and one volume of nitrogen react at temperature 450-500°C and pressure 200-900 atm in the presence of finely divided iron catalyst with molybdenum as promoter to give ammonia.



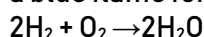
- b. Equal volumes of hydrogen and chlorine react slowly in diffused sunlight to form hydrogen chloride.



- c. Hydrogen gas on passing through molten sulphur reacts to give hydrogen sulphide.



- d. Hydrogen burns in the presence of electric spark with a 'pop' sound in oxygen and with a blue flame forming water.



42. When hydrogen is passed over a black solid compound A, the products are a 'colourless liquid' and a 'reddish brown metal B'.

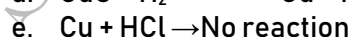
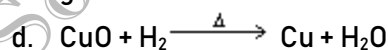
Substance B is divided into two parts each placed in separate test tubes.

Dilute HCl is added to one part of substance B and dilute HNO₃ to the other.

- a. Name the substances A and B.
- b. Give two tests for the colourless liquid formed in the experiment.
- c. What happens to substance A when it reacts with hydrogen? Give reasons for your answer.
- d. Write an equation for the reaction between hydrogen and substance A.
- e. Is there any reaction between substance B and dilute hydrochloric acid? Give reasons for your answer.

Ans.

- a. A = CuO, B = Cu
- b. Blue and red litmus paper when dipped in the colourless liquid do not change colour. This confirms the liquid formed is neutral and is water. It changes white anhydrous copper sulphate to blue salt.
- c. Black copper oxide (A) on heating with hydrogen reduces copper oxide to reddish brown copper and itself gets oxidised to water. Hydrogen is a strong reducing agent and removes oxygen from less active metals, i.e. it removes oxygen from heated metal oxides when passed over them and itself gets oxidised to water.

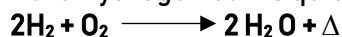


Copper is less reactive than hydrogen and hence cannot displace it from HCl.

43. What are the Properties of Hydrogen?

Ans. The properties of hydrogen are

- Hydrogen is colourless, odourless and lighter than air.
- It is very slightly soluble in water.
- Difficult to liquefy, combustible and non-supporter of combustion.
- It is neither acidic nor alkaline.
- Pure Hydrogen burns quietly in air with a pale blue flame and forms Water.



- Hydrogen and Air mixture burns with 'pop sound'.

44. What are the uses of Hydrogen?

Ans. The uses of Hydrogen are:

a. As a fuel

Hydrogen is used as a fuel in the form of Coal Gas, Water Gas and Liquid Hydrogen. because combustion of hydrogen is a highly exothermic reaction and liquid hydrogen is non-polluting and easy to store.

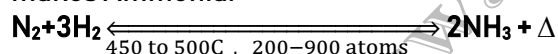
b. In meteorological balloons

Hydrogen is used in meteorological balloons to study weather conditions. Because Hydrogen is lighter than air.

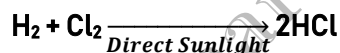
But hydrogen is replaced by helium because Hydrogen is inflammable.

c. Manufacture of

- Ammonia:** On 450° to 500°C temp under 200–900 atoms pressure with the presence of Iron and Molybdenum Nitrogen and Hydrogen reacts and makes Ammonia.



- Hydrogen Chloride:** With the presence of direct sunlight Hydrogen and Chlorine reacts and make Hydrogen Chloride.



- Hydrogen reacts with Sulphur vapours to form Hydrogen Sulphide.



- Hydrogen burns quietly in air to form water.

