

Chapter - 9

Hydrogen

Part A

- Hydrogen is the first element in the periodic table and also the lightest element known.
- **Isotopes of hydrogen :**
 - (i) Protium (${}_1^1\text{H}$)
 - (ii) Deuterium (${}_1^2\text{H}$)
 - (iii) Tritium (${}_1^3\text{H}$)
- **Preparation of Dihydrogen :**
 - (i) Laboratory preparation : $\text{Zn} + 2\text{H}^+ \rightarrow \text{Zn}^{2+} + \text{H}_2$.
 - (ii) Commercial preparation : By electrolysis of acidified water.
 - (iii) High purity dihydrogen is obtained by electrolysis of warm aqueous barium hydroxide.
- **Water gas :** The mixture of $\text{CO} + \text{H}_2$ is known as **water gas**. It is also known as '**Syn**' Gas.
- **Water gas shift reaction :**

$$\text{CO(g)} + \text{H}_2\text{O(g)} \xrightarrow[\text{Catalyst}]{673 \text{ K}} \text{CO}_2\text{(g)} + \text{H}_2\text{(g)}$$
- **Properties of Dihydrogen :**

The H-H bond dissociation enthalpy is highest for a single bond dissociation enthalpy between two atoms of any element.

It is relatively inert at room temperature due to the high H-H bond enthalpy.
- **Uses of Dihydrogen :**
 - (i) For synthesis of Ammonia (NH_3)

(ii) For production of Methanol (CH_3OH)

(iii) In oxyhydrogen torches

(iv) In a fuel cell

- **Hydrides**

(i) Ionic or salt like or saline hydrides are formed with most of the *s*-block elements. Significant covalent character is found in LiH , BeH_2 and MgH_2 .

- Covalent or Molecular hydrides are formed with most of the *p*-block elements. There are further classified as :

(a) **Electron deficient hydrides** are formed by group 13 elements *e.g.*, B_2H_6 . These acts as Lewis acid.

(b) **Electron Precise hydrides** are formed by group 14 elements *e.g.*, CH_4 .

(c) **Electron rich hydrides** have lone pair of electrons on central atoms of the molecules. Elements of group 15-17 form these types of hydrides. NH_3 , HF has high m.p./b.p. due to presence of intermolecular hydrogen bonding.

(iii) **Metallic or Non-stoichiometric or Interstitial hydrides** are formed by *d* and *f* block elements. For example $\text{La H}_{2.87}$.

These are potential source of hydrogen.

Part-B

- **Water : (H_2O)**

Hard water : Hard water contains calcium and magnesium salts in the form of hydrogencarbonate, chloride and sulphate. Hard water does not give lathers with soap.

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

Types of Hardness :

Temporary hardness is due to presence of calcium or magnesium hydrogen carbonate in water.

Temporary hardness can be removed by :

(i) Boiling

(ii) Clark's Method

Permanent hardness :

Such hardness is due to presence of calcium or magnesium chlorides and sulphates.

Permanent hardness can be removed by :

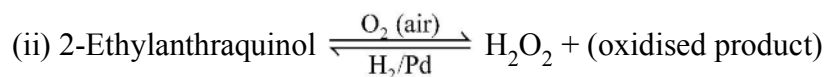
- (i) Calgon's method
- (ii) Ion exchange method.

Demineralised or Deionised water : Water free from all soluble mineral salts is known as **demineralised water**.

- **Hydrogen Peroxide (H_2O_2)**

Preperation :

- (i) By electrolytic oxidation of acidified sulphate solutions at high current density.



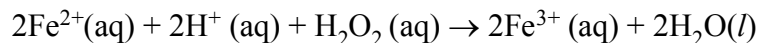
- **Physical Properties**

- (i) Miscible with water in all proportions.
- (ii) A 30% of H_2O_2 solution is marketed as '100 volume of hydrogen peroxide'.

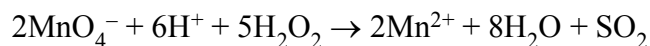
- **Chemical Properties :**

- (i) It acts as an oxidising as well as reducing agent.

- (ii) **Oxidising action in acidic medium :**



- (iii) **Reducing action in acidic medium :**



- **Storage of H_2O_2 :**

- (i) Stored in wax-lined glass or plastic vessels in dark. Urea can be added as a stabiliser.

- (ii) It is kept away from dust.

- **Uses of H_2O_2 :**

- (i) As an antiseptic it is sold in the market name perhydrol.
- (ii) In synthesis of hydroquinone.
- (iii) As a bleaching agent.

Part-A

1-Mark Questions

1. Name the isotope of hydrogen which is radioactive in nature. [Ans. Tritium]

2. H^+ ions does not exist freely and is always associated with other atoms or molecule. Explain.
3. Give the composition of water gas. [Ans. CO, H_2]
4. Name the compound whose electrolysis in aqueous state, give high purity (99.95%) dihydrogen. [Ans. aq $\text{Ba}(\text{OH})_2$ solution]
5. Give the main purpose of water gas shift reaction.
6. Write the chemical reaction occurring during coal gasification.
7. Name the element used in fuel cell for generating electricity. [Ans. H_2]
8. Give an example of electron deficient covalent hydride. [Ans. B_2H_6]
9. Name the hydrides which have high potential for hydrogen storage. [Ans. Metallic hydrides]
10. Name the groups in *d*-block elements which do not form metallic hydrides. [Ans. 7, 8, 9]
11. H_2 is relatively inert at room temperature. Explain.
12. Complete the reaction :

$$\text{C}(s) + \text{H}_2\text{O}(g) \xrightarrow{1270\text{ K}} \text{CO}(g) + \text{H}_2(g)$$
13. Name the phenomenon as a reason of which water has unusual boiling point. [Ans. Extensive hydrogen bonding]
14. Draw structure of water.
15. At atmospheric pressure ice crystallised in the form but at very low temperature it condenses to form. [Ans. Hexagonal, cubic]
16. Mention the temperature at which density of ice is maximum. [Ans. 4°C]
17. Density of ice than density of liquid water. [Ans. Less]
18. Complete the reaction :

$$2\text{H}_2\text{O}(l) + 2\text{Na}(s) \longrightarrow$$
19. How many hydrogen-bonded water molecules (*s*) are associated in $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$. [Ans. One]
20. Name the compound used in Clark's method to remove temporary hardness of water. [Ans. Lime]
21. Write the chemical formula of "Calgon". [Ans. $\text{Na}_4\text{P}_6\text{O}_{18}$]
22. A 30% solution of H_2O_2 is marketed as volume. [Ans. 100 volume]

23. Draw gas phase structure of H_2O_2 .
24. Name the organic compound whose auto-oxidation is used to produce H_2O_2 commercially or industrially. [Ans. 2-Ethylanthraquinol]

Part-A

2-Mark Questions

1. Complete the following reactions :
- (i) $\text{CO(g)} + \text{H}_2\text{(g)} \xrightarrow[\text{Catalyst}]{\Delta}$
- (ii) $\text{Zn(s)} + \text{NaOH(aq)} \xrightarrow{\Delta}$
2. Among NH_3 , H_2O and HF which would you expect to have highest magnitude of hydrogen bonding and why ?
3. How do you expect the metallic hydrides to be useful for hydrogen storage? Explain.
4. How can the production of dihydrogen obtained from “Coal gasification” can be increased ?
5. Write the name of isotopes of hydrogen. What is the mass ratio of these isotopes ?
6. Complete the reactions :
- (i) $\text{CO(g)} + 2\text{H}_2\text{(g)} \xrightarrow[\text{Catalyst}]{\text{Cobalt}}$
- (ii) $\text{CH}_4\text{(g)} + \text{H}_2\text{O(g)} \xrightarrow[\text{Ni}]{1270\text{K}}$
7. Comment on the reactions of dihydrogen with :
- (i) Chlorine, (ii) Sodium.
8. Arrange the following :
- (i) LiH , NaH , CsH (In increasing order of ionic character)
- (ii) H—H , D—D , F—F (In decreasing order of bond dissociation enthalpy)
9. Give two uses of dihydrogen.
10. Complete the reactions :
- (i) $\text{H}_2 + \text{CO} + \text{RCH} = \text{CH}_2 \longrightarrow$
- (ii) $\text{H}_2 + \text{RCH}_2\text{CH}_2\text{CHO} \longrightarrow$

Part-B

11. Give two reactions to show photolytic nature of water.
12. Complete the reactions :
 - (i) $2\text{F}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) \longrightarrow$
 - (ii) $6\text{CO}_2(\text{g}) + 12\text{H}_2\text{O}(\text{l}) \longrightarrow$
13. What is the difference between the term hydrolysis and hydration.
14. What do you understand by term 'autoprotolysis' of water ? What is its significance ?
15. What causes the temporary and permanent hardness of water ?
16. Is demineralised or distilled water useful for drinking purposes ? If not, how can it be made useful ?
17. Explain the terms : (i) Hydrogen economy. (ii) Fuel cell.
18. Write chemical reactions to justify that hydrogen peroxide can function as an oxidising as well as reducing agent.
19. Compare the structure of H_2O and H_2O_2 .
20. How does H_2O_2 behave as a bleaching agent ?

Part-A

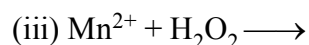
3-Mark Questions

1. Complete the chemical reactions :
 - (i) $8\text{LiH} + \text{Al}_2\text{Cl}_6 \longrightarrow$
 - (ii) $2\text{LiH} + \text{B}_2\text{H}_6 \longrightarrow$
2. What do you understand by : (i) electron deficient, (ii) Electron precise, (iii) Electron rich compounds of hydrogen ? Provide justifications with suitable examples.
3. What do you understand by the term "non stoichiometric hydrides" ? Do you expect this type of the hydrides to be formed by alkali metals. Explain and Justify your answer.
4. Arrange the following :
 - (i) CaH_2 , BeH_2 , TiH_2 (in order of increasing electrical conductance)
 - (ii) NaH , MgH_2 , H_2O (in order of increasing bond dissociation enthalpy)
 - (iii) Li , F , H (in order of increasing ionisation enthalpy)

5. What do you understand by the terms :
- (i) Syn gas
 - (ii) Water gas shift reaction
 - (iii) Producer gas.
6. Would gas except the hydrides of N, O and F to have lower boiling point than the hydrides of their subsequent group members ? Give reasons.
7. Can phosphorous with outer electronic configuration $3s^23p^3$ form PH_5 ? Explain.
8. Why and how the hydrogen is regarded as a fuel of future ? Explain.
9. Write the reactions when dihydrogen reacts with (i) O_2 (ii) N_2 (iii) Cl_2 under specific conditions.
10. Name the hydrides :
- (i) Which is non stoichiometric in nature ?
 - (ii) Which are stoichiometric compounds ?
 - (iii) Which has electron rich type hydrides ?

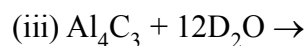
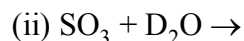
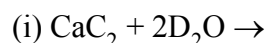
Part-B

11. Complete the reactions :
- (i) $\text{CaO}(s) + \text{H}_2\text{O}(g) \longrightarrow$
 - (ii) $\text{AlCl}_3(g) + \text{H}_2\text{O}(l) \longrightarrow$
 - (iii) $\text{Ca}_3\text{N}_2(s) + \text{H}_2\text{O}(l) \longrightarrow$
12. Discuss the principle and method of softening of hard water by synthetic exchange of resin method.
13. What is meant by 'demineralised' water and how can it be obtained ?
14. What properties of water make it useful as a solvent ? What types of compound can it (i) dissolved (ii) hydrolyse ?
15. Calculate the strength of 10 volume solution of H_2O_2 .
16. Complete the reactions :
- (i) $2\text{Fe}^{2+}(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{H}_2\text{O}_2(\text{aq}) \longrightarrow$
 - (ii) $\text{HOCl} + \text{H}_2\text{O}_2 \longrightarrow$



17. Give three uses of H_2O_2 .

18. Complete the reactions :



19. Give the limitations of using H_2 as a fuel.

20. H_2O_2 is stored in a wax lined glass or plastic vessels. Explain an equation showing decomposition of H_2O_2 on exposure to light.

Part-C

5-Mark Questions

1. Answer the following :

(a) Name the most abundant form of hydrogen isotope. [Ans. ${}_1^1\text{H}$]

(b) Name the particles emitted by tritium. [Ans. β^-]

(c) Mixture of CO and H_2 is used for preparation [Ans. Methanol]

(d) Name the catalyst used in Haber's Process for manufacture of $\text{NH}_3(\text{g})$.
[Ans. Fe]

(e) Name two electron rich hydrides. [Ans. NH_3 , H_2O]

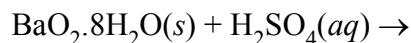
Part-B

2. Answer the following :

(a) During Clark's method. Name the compound in which Mg is precipitated out. [Ans. Magnesium Hydroxide]

(b) Give the formula of Zeolite used in ion exchange method to remove permanent hardness of water. [Ans. NaAlSiO_4]

(c) Complete the reaction :



(d) H_2O_2 is miscible with water. Assign reason.

(e) Name the compound when can be used as a hair beach, mild antiseptic in the form of perhydrol. [Ans. H_2O_2]