UNIT-9
Hydrogen

NCERT–Examplar Problems with Solutions

SECTION-I: *Multiple Choice Questions (Type I)*

Note: In the following questions, only one option is correct.

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

(i) Its tendency to lose an electron to form a cation

(ii) Its tendency to gain a single electron in its valence shell to attain stable electronic configuration.

(iii) Its low negative electron gain enthalpy value

(iv) Its small size.

Ans. (ii)

Hydrogen and halogens both are short of just one electron to attain the nearest noble gas configuration.

2. Why does H^+ is always get associated with other atoms or molecules?

(i) Ionisation enthalpy of hydrogen resembles that of alkali metals

(ii) Its reactivity is similar to halogens.

(iii) It resembles both alkali metals and halogens.

(iv) Loss of an electron from hydrogen atom results in a nucleus of very small size as compared to other atoms or ions. Due to small size it cannot exist free.

Ans. (iv)

Due to externally small size of H^+ (no electron, no neutron), it exists in combination with other atoms or molecules.

For example: $H^+ + H_2O \longrightarrow H_3O^+$

$H^+ + NH_3 \longrightarrow NH_4^+$

3. Metal hydrides are ionic, covalent or molecular in nature. Among LiH, NaH, KH, RbH, CsH, the correct order of increasing ionic character is

(i) LiH > NaH > CsH > KH > RbH

(ii) LIH < NaH < KH < RbH < CsH

(iii) RbH > CsH > NaH >KH > LiH

(iv) NaH > CsH > RbH > LiH > KH

Ans. (ii)

As the size of alkali metal increases, electronegativity decreases but the electronegativity difference increases. Hence, percentage ionic character increases.

4. Which of the following hybrides is electron precise hydride?

(i) B_2H_6

(ii) NH_3

(iii) H_2O

(iv) CH_4

Ans. (iv)

Electron precise hydrides contains exact number of electrons to form normal $2e^- - 2c$ covalent bonds.

5. Radioactive elements emit α, β and γ rays and are characterized by their half lives. The radioactive isotope of hydrogen is

(i) Protium

(ii) Deuterium

(iii) Tritium

(iv) Hydronium

Ans. (iii)

Tritium, ${}_1^3H$ is a radioactive isotope of hydrogen with a half-life of 12.3 years.

6. Consider the reactions

[A] $H_2O_2 + 2HI \longrightarrow I_2 + 2H_2O$ **[B]** $HOCl + H_2O \longrightarrow H_3O^+ + Cl^- + O_2$

Which of the following statements is correct about H_2O_2 with reference to these reactions? Hydrogen perioxide is

(i) an oxidsing agent in both [A] and [B]

(ii) an oxidizing agent in [A] and reducing agent in [B]

(iii) a reducing agent in [A] and oxidising agent in [B]

(iv) a reducing agent in both [A] and [B]

Ans. (ii)

H_2O_2 act both as an oxidising agent and reducing agent. Whenever H_2O_2 changes to O_2, it acts as a reducing agent (oxidation state of O is changing from –1 to zero). In the first reaction (A), H_2O_2 acts as an oxidizing agent as O.S of O is changing from –1 to –2.

7. The oxide that gives H_2O_2 on treatment with dilute H_2SO_4 is

(i) PbO_2

(ii) $BaO_2.8H_2O + O_2$

(iii) MnO_2

(iv) TiO_2

Ans. (ii)

$BaO_2.8H_2O$ is hydrated barium peroxide

$$BaO_28H_2O + H_2SO_4 \longrightarrow BaSO_4 + H_2O_2 + 8H_2O$$

8. Which of the following equation depict the oxidizing nature of H_2O_2?

(i) $2MnO_4^- + 6H^+ + 5H_2O \longrightarrow 2Mn^{2+} + 8H_2O + 5O_2$

(ii) $2Fe^{3+} + 2H^+ + H_2O_2 \longrightarrow 2Fe^{2+} + 2H_2O + O_2$

(iii) $2I^- + 2H^+ + H_2O_2 \longrightarrow I_2 + 2H_2O$

(iv) $KIO_4 + H_2O_2 \longrightarrow KIO_3 + H_2O + O_2$

Ans. (iii)

Only in reaction (iii), oxidation state of O is changing from –1 in H_2O_2 to –2 in H_2O.

9. Which of the following equation depicts reducing nature of H_2O_2?

(i) $2[Fe(CN)_6]^{4-} + 2H^+ + H_2O_2 \longrightarrow 2[Fe(CN)_6]^{3-} + 2H_2O$

(ii) $I_2 + H_2O_2 + 2OH^- \longrightarrow 2I^- + 2H_2O + O_2$

(iii) $Mn^{2+} + H_2O_2 \longrightarrow Mn^{4+} + 2OH^-$

(iv) $PbS + 4H_2O_2 \longrightarrow PbSO_4 + 4H_2O$

Ans. (ii)

Whenever H_2O_2 act as a reducing agent, O_2 gas is released and the oxidation state of O changes from –1 in H_2O_2 to zero in O_2.

10. Hydrogen peroxide is

(i) an oxidsing agent

(ii) a reducing agent

(iii) both an oxidizing and a reducing agent

(iv) neither oxidizing nor reducing agent.

Ans. (iii)

H_2O_2 act both as an oxidising agent and reducing agent. Whenever H_2O_2 changes to O_2, it acts as a reducing agent (oxidation state of O is changing from –1 to zero).

$$HOCl + H_2O_2 \longrightarrow H_3O^+ + Cl^- + O_2$$

In the first reaction (A), H_2O_2 acts as an oxidizing agent as O.S of O is changing from –1 to –2.

$$H_2O_2 + 2HI \longrightarrow I_2 + 2H_2O$$

11. Which of the following reactions increases production of dihydrogen from synthesis gas?

(i) $CH_4(g) + H_2O(g) \xrightarrow[Ni]{1270\,K} CO(g) + 3H_2(g)$

(ii) $C(s) + H_2O(g) \xrightarrow{1270\,K} CO(g) + H_2(g)$

(iii) $CO(g) + H_2O(g) \xrightarrow[Catalyst]{673\,K} CO_2(g) + H_2(g)$

(iv) $C_2H_6 + 2H_2O \xrightarrow[Ni]{1270\,K} 2CO + 5H_2$

Ans. (iii)

$$C(s) + H_2O(g) \longrightarrow \underbrace{CO(g) + H_2(g)}_{\text{water gas}}$$

To increase the production of H_2, CO has to be removed from the product side using Le-Chatelier's principle.

$$CO(g) + H_2O(g) \longrightarrow CO_2(g) + H_2(g)$$

12. When sodium peroxide is treated with dilute sulphuric acid, we get____

(i) sodium sulphate and water

(ii) sodium sulphate and oxygen

(iii) sodium sulphate, hydrogen and oxygen

(iv) sodium sulhpate and hydrogen peroxide

Ans. (iv)

$$Na_2O_2 + H_2SO_4 \longrightarrow \underset{\text{Sodium sulphate}}{Na_2SO_4} + \underset{\text{Hydrogen peroxide}}{H_2O_2}$$

13. Hydrogen peroxide is obtained by the electrolysis of

(i) water

(ii) sulphurica acid

(iii) hydrochloric acid

(iv) fused sodium peroxide

Ans. (ii)

$$H_2SO_4 \longrightarrow 2H^+ + SO_4^{2-}$$

$$2SO_4^{2-} \longrightarrow S_2O_8^{2-} + 2e^-$$

$$S_2O_8^{2-} + 2H_2O \longrightarrow H_2O_2 + 2SO_4^{2-} + 2H^+$$

14. Which of the following reaction is an example of use of water gas in the synthesis of other compounds?

(i) $CH_4(g) + H_2O(g) \xrightarrow[Ni]{1270K} CO(g)(g) + H_2(g)$

(ii) $CO(g) + H_2O(g) \xrightarrow[Catalyst]{673K} CO_2(g) + H_2(g)$

(iii) $C_nH_{2n+2} + nH_2O(g) \xrightarrow[Ni]{1270K} nCO + (2n+1)H_2$

(iv) $CO(g) + 2H_2(g) \xrightarrow[Catalyst]{Cobalt} CH_3OH(\ell)$

Ans. (iv)

Water gas or synthesis gas used in the production of methanol.

15. Which of the following ions will cause hardness in water sample?

(i) Ca^{2+}

(ii) Na^{+}

(iii) Cl^{-}

(iv) K^{+}

Ans. (i)

Harness of water is due to presence of Ca^{2+} and Mg^{2+} ions.

16. Which of the following compounds is used for water softening?

(i) $Ca_3(PO_4)_2$

(ii) Na_3PO_4

(iii) $Na_6P_6O_{18}$

(iv) Na_2HPO_4

Ans. (iii)

Sodium hexa metaphosphate is used for water softening

$$Na_6P_6O_{18} + M^{2+} \longrightarrow Na_2[Na_2MP_6O_{18}] + 2Na^{+}$$

(M = Ca, Mg)

17. Elements of which of the following group(s) of periodic table do not form hydrides.

(i) Groups 7, 8, 9

(ii) Group 13

(iii) Group 15, 16, 17

(iv) Group 14

Ans. (i)

Elements of group 7, 8 and 9 do not form hydride. This is known as hydride gap.

18. Only one element of _____forms hydride

(i) Group 6

(ii) Group 7

(iii) Group 8

(iv) Group 9

Ans. (i)

Only one element of group 6 (chromium) forms hydride (CrH)

SECTION-II: *Multiple Choice Questions (Type II)*

Note: In the following questions two or more options may be correct.

19. Which of the following statements are not true for hydrogen?

(i) It exists as diatomic molecule

(ii) It has one electron in the outermost shell

(iii) It can lose an electron to form a cation which can freely exist

(iv) It forms a large number of ionic compound by losing an electron

Ans. (iii), (iv)

H^+ ion does not exist alone freely. It combines with other ions and molecules.

It does not form large number of ionic compounds because it's high ionization enthalpy.

20. Dihydrogen can be prepared on commercial scale by different methods. In its preparation by the action of steam on hydrocarbons, a mixture of CO and H_2 gas is formed. It is known as

(i) Water gas

(ii) Syn gas

(iii) producer gas

(iv) Industrial gas

Ans. (i), (ii)

A mixture of CO(g) and H_2(g) is known as water gas or synthesis (or syn) gas.

21. Which of the following statement(s) is/are correct in the case of heavy water?

(i) Heavy water is used as a moderator in nuclear reactor

(ii) Heavy water is more effective as solvent than ordinary water

(iii) Heavy water is more associated than ordinary water

(iv) Heavy water has lower boiling point than ordinary water

Ans. (i), (iii)

Heavy water, D_2O is used as a moderator in nuclear reactor. It has a larger surface area than water and hence more associated via dispersion forces and hydrogen bonding.

22. Which of the following statements about hydrogen are correct?

(i) Hydrogen has three isotopes of which protium is the most common

(ii) Hydrogen never acts as cation in ionic salts.

(iii) Hydrogen, H^+, exists freely in solution

(iv) Dihydrogen does not act as a reducing agent.

Ans. (i), (ii)

Hydrogen has three isotopes: Protium ${}_1^1H$, deuterium ${}_1^2H$ and tritium ${}_1^3H$.

Hydrogen never acts as cation in ionic salts due to its very high ionization enthalpy (1312 kJ/mol)

23. Some of the properties of water are described below. Which of them is/are not correct?

(i) Water is known to be universal solvent

(ii) Hydrogen bonding is present to a large extent in liquid water

(iii) There is no hydrogen bonding in the frozen state of water

(iv) Frozen water is heavier than liquid water.

Ans. (iii), (iv)

In frozen state of water (ice), there is an extensive network of hydrogen bonding. Since ice has more open structure, ice is lighter than water and it floats over water.

24. Hardness of water may be temporary or permanent. Permanent hardness is due to the presence of

(i) Chlorides of Ca and Mg in water

(ii) Sulphates of Ca and Mg in water

(iii) Hydrogen carbonates of Ca and Mg in water

(iv) Carbonates of alkali metals in water

Ans. (i), (ii)

Permanent hardness of water is due to chlorides and sulphates of Mg^{2+} and Ca^{2+}.

25. Which of the following statements is correct?

(i) Elements of group 15 form electron deficient hydrides

(ii) All elements of group 14 form electron precise hydrides.

(iii) Electron precise hydrides have tetrahedral geometries

(iv) Electron rich hydrides can act as Lewis acids.

Ans. (ii), (iii)

Group-14 elements uses all four electrons in the formation of normal covalent bonds. These are called electron precise hydrides with general formula MH_4. These hydrides have tetrahedral geometries, e.g., CH_4, SiH_4.

26. Which of the following statements is correct?

(i) Hydrides of group 13 act as Lewis acids

(ii) Hydrides of group 14 are electron deficient hydrides

(iii) Hydrides of group 14 act as Lewis acids

(iv) Hydrides of group 15 act as Lewis bases.

Ans. (i), (iv)

Hydrides of group-13 like B_2H_6, AlH_3 in which the central atom has less than eight electrons, are electron deficient. These hydrides are electron pair acceptor, hence Lewis acids.

Hydrides of group 15 like NH_3, PH_3 have one lone pair of electrons. These are electron pair donor and hence acts as Lewis bases.

27. Which of the following statements is correct?

(i) Metallic hydrides are deficient of hydrogen

(ii) Metallic hydrides conduct heat and electricity

(iii) ionic hydrides do not conduct electricity in solid state

(iv) Ionic hydrides are very good conductors of electricity in solid state.

Ans. (i), (ii) & (iii)

Metallic hydrides are formed by d-block elements and are non-stiochiometric with deficiency of hydrogen. Since these are metallic hydrides, so, good conductor of heat and electricity.

Ionic hydrides do not conduct electricity in solid state as ions are very tightly held.

SECTION-III: *Short Answer Type*

28. How can production of hydrogen from water gas be increased by using water gas shift reaction?

Ans. Water gas is produced when coke reacts wth superheated steam at 1270 K

$$C(s) + H_2O(g) \xrightarrow{1270K} \underbrace{CO(g) + H_2(g)}_{\text{water gas}}$$

The production of H_2 gas can be increased by absorbing CO(g) in steam to oxidize CO to CO_2 gas (Le-Chatelier principle)

$$CO(g) + H_2O(g) \longrightarrow CO_2(g) + H_2(g)$$

29. What are metallic/interstitial hydrides? How do they differ from molecular hydrides?

Ans. Metallic hydrides or interstitial hydrides are formed by d-block elements but group 7, 8 and 9 elements of d-block do not form hydrides. This is known as **hydride gap**.

	Metallic hydrides	**Molecular hydrides**
(i)	Hard solids, conducts electricity	Usually volatile compound, do not conduct electricity
(ii)	Have magnetic properties	No magnetic properties

30. Name the classes of hydrides to which H_2O, B_2H_6 and NaH belong.

Ans. $H_2\ddot{O}:$ ⟶ molecular hydride/covalent hydride/electron rich

B_2H_6 ⟶ molecular hydride/covalent hydride/electron-deficient

NaH ⟶ Ionic or saline hydride

31. If same mass of liquid water and a piece of ice of taken, then why is the density office less than that of liquid water?

Ans. Water expands on freezing and the volume for the same mass of water increases, density decreases. Hence, ice is lighter than water and floats over water.

32. Complete the following equations:

(i) $\mathbf{PbS(s) + H_2O_2(aq) \longrightarrow}$ **(ii)** $\mathbf{CO(g) + 2H_2(g) \xrightarrow[Catalyst]{Cobalt}}$

Ans. (i) $PbS(s) + 4H_2O_2(aq) \longrightarrow PbSO_4(s) + 4H_2O(\ell)$

(ii) $CO(g) + 2H_2(g) \xrightarrow[Catalyst]{Cobalt} CH_3OH(g)$

33. Give reasons:

(i) Lakes freeze from top towards bottom

(ii) Ice floats on water

Ans. (i) The temperature of water in the lake keep on decresing during winter. Cold water is heavier and keep on going into the interior of the lake while warm water is lighter comes to the top. The process continues till the temperature of entrie water of the lake becomes 277 K. At this temperature, water has maximum density, any further decreases in the temperature of the surface water will decrease its density. As a result, the temperature of the surface keep on decreasing and ultimately freezes while the temperature water

underneath the surface remains at 277 K. Further decrease in the temperature of water below 277 K lying underneath of the surface of water. This process continues and as a result, the lake keep as freezing from top to bottom.

(ii) Water expands on freezing and the volume for the same mass of water increases, density decreases. Hence, ice is lighter than water and floats over water.

34. What do you understand by the term auto protolysis of water? What is its significance?

Ans. Auto protolysis of water means self ionization of water

$$H_2O(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$$

The reaction contains two conjugate acid-base pairs.

$[H_2O, H_3O^+]$ and $[H_2O, OH^-]$

Due to this, water shows amphoteric nature; it can act as an acid as well as base.

$$\underset{\text{acid}}{H_2O} + \underset{\text{base}}{NH_3} \rightleftharpoons NH_4^+ + OH^-$$

$$\underset{\text{base}}{H_2O} + \underset{\text{acid}}{HCl} \rightleftharpoons H_3O^+ + Cl^-$$

35. Discuss briefly de-mineralisation of water by ion exchange resin.

Ans. De-mineralised water means water free from all cations and anions. Water can be changed into de-mineralised water by using ion-exchange resins.

Step-(i) Passing water through cation exchange resins. Cation exchange resins are long chain carboxylic acids or sulphonic acid and exchange H^+ ions with Ca^{2+}/Mg^{2+} ions.

$$\underset{\substack{\text{cation exchange}\\ \text{resin}}}{2RCOOH} + Ca^{2+} \longrightarrow (RCOO)_2Ca + 2H^+$$

$$2R-SO_3H + Mg^{2+} \longrightarrow (RSO_3)_2Mg + 2H^+$$

Step-(ii) Passing water through anion exchange resin which removes the anions Cl^-, SO_4^{2-}.

Anion exchange resins are substituted ammonium hydroxides

$$\underset{\substack{\text{anion exchange}\\ \text{resin}}}{R-NH_3^+OH^-} + Cl^- \longrightarrow RNH_3^+Cl^- + OH^-$$

Finally, the H^+ ions obtained in step (i) and OH^- ions obtained in step–(ii) combines to give H_2O free from ions.

36. Molecular hydrides are classified as electron deficient, electron precise and electron rich compounds. Explain each type with two examples.

Ans.

Electron deficient hydrides	**Electron precise hydrides**	**Electrons rich hydrides**
They do not have sufficient number of electrons to form normal covalent bonds.	They have sufficient number of electron to form normal covalent bonds.	They have more electrons than required to form normal covalent bonds.
They have incomplete octet.	They have complete octet without any lone pair of electrons.	They have one or more lone pair of electrons.
They are Lewis acids and are mainly formed by group 2 and group 13 elements. B_2H_6, AlH_3, BeH_2	Mainly formed by group 14 elements CH_4, SiH_4.	They are Lewis bases and are mainly formed by group 15, 16 and 17 elements $2NH_3$, $H_2\ddot{O}$:

37. How is heavy water prepared? Compare its physical properties with those of ordinary water.

Ans. Heavy water (D_2O) is produced by the prolonged electrolysis of water which contains traces of D_2O (1 part in 6000 parts).

Some of the physical properties of heavy water and ordinary water are:

	Heavy water	**Ordinary water**
Boiling point	374.4 K	373 K
Density at 298 K	1.106 g/cm^3	1.00 g/cm^3
Δ_{vap} H°	41.61 KJ/mol	40.66 KJ/mol
Dielectric constant	78.06	78.39

38. Write one chemical reaction for the preparation of D_2O_2.

Ans. D_2O_2 (deuterium perioxde) is prepared by the action of deuterated sulphuric acid on Barium peroxide.

$$BaO_2 + D_2SO_4 \longrightarrow D_2O_2 + BaSO_4$$

39. Calculate the strength of 5 volume H_2O_2 solution.

Ans. $2H_2O_2 \longrightarrow 2H_2O + O_2$

5V H_2O_2 means 1L of H_2O_2 produces 5 L of O_2 at STP

$$\therefore \quad n_{O_2} = \frac{5}{22.4} \text{ moles}$$

and $$n_{H_2O_2} = 2\,n_{O_2} = \frac{2\times 5}{22.4} = \frac{5}{11.2} \text{ mol}$$

$$V_{H_2O_2} = 1\text{L}$$

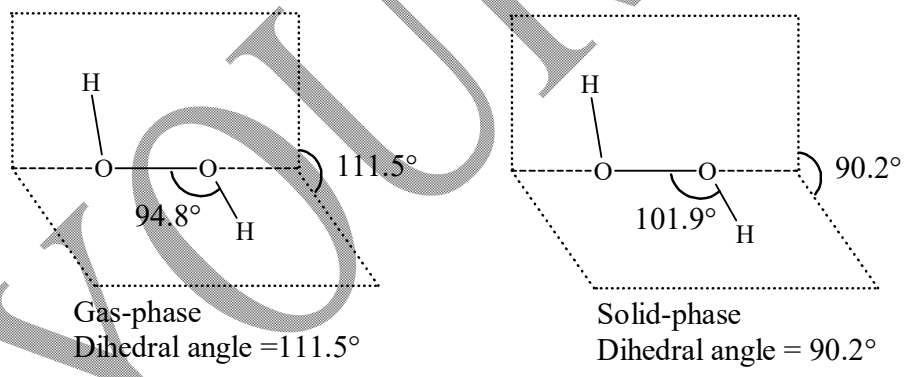
$$\text{Molarity of } H_2O_2 = \frac{n_{H_2O_2}}{V} = \frac{5}{11.2}\text{M}$$

Strength of H_2O_2 solution = molarity × molecular mass $= \frac{5}{11.2}\times 34 = 15.17\,\text{g/L}$

40. (i) Draw the gas phase and solid phase structure of H_2O_2.

(ii) H_2O_2 is a better oxidsing agent than water. Explain

Ans. (i)



(ii) H_2O_2 is a better oxidizing agent than water as Oxygen is in –1 oxidation state in H_2O_2 and gain one electron to attain –2 oxidation state. In water, oxygen is already in –2 oxidation state.

H_2O_2 oxidises PbS to $PbSO_4$

$$PbS + 4H_2O_2 \rightarrow PbSO_4 + 4H_2O$$

H_2O_2 oxidises I^- to I_2

$$H_2O_2 + 2I^- + 2H^+ \rightarrow I_2 + 2H_2O$$

41. Melting point, enthalpy of vapoursiation and viscosity data of H_2O and D_2O is given below:

	H_2O	D_2O
Melting point/K	**373.0**	**374.4**
Enthalpy of vapourisation at (373K)/kJ mol^{-1}	**40.66**	**41.61**
Viscosity/centipoise	**0.8903**	**1.107**

On the basis of this data explain in which of these liquid intermolecular forces are stronger?

Ans. All these values indicates that heavy water has a stronger intermolecular forces of attraction than the ordinary water.

42. Dihydrogen reacts with dioxygen (O_2) to form water. Write the name and formula of the product when the isotope of hydrogen which has one proton and one neutron in its nucleus is treated with oxygen. Will the reactivity of both the isotopes be the same towards oxygen? Justify your answer.

Ans. Isotope of hydrogen which has one proton and one neutron in its nucleus is called deuterium (D).

$2D_2 + O_2 \rightarrow 2D_2O$ (heavy water or deuterium oxide)

D – D bond is stronger than H – H bond, hence, D_2 will be less reactive than H_2 towards O_2.

43. Explain why HCl is a gas and HF is a liquid.

Ans. Due to large size and less electronegaivity of Cl than F, H – Cl bond is less polar than H – F. As a result, there is no association via hydrogen bonding in H – Cl. So, H – Cl is a discrete molecule and the intermolecular forces of attraction are the weak dispersion forces.

Hence, HCl is a gas.

HF is highly associated via intermolecular hydrogen bonding, hence HF is a liquid.

44. When the first element of the periodic table is treated with dioxgyen, it gives a compound whose solid state floats on its liquid state. This compound has an ability to act as an acid as well as a base. What products will be formed when this compound undergoes autoionisation?

Ans. First element → Hydrogen (H) exists as H_2.

Reaction with O_2

$2H_2 + O_2 \rightarrow 2H_2O$ (water)

Solid form of H_2O is called ice which has less density than H_2O hence ice floats over water.

H_2O undergo auto ionization to give H_3O^+ and OH^-

$$H_2O + H_2O \rightleftharpoons H_3O^+ + OH^-$$

Hydronium ion Hydroxyl ion

Hence, H_2O act as an acid as well as base

H_2O is amphoteric is nature.

$$HCl + \underset{\text{base}}{H_2O} \longrightarrow H_3O^+ + Cl^-$$

$$NH_3 + \underset{\text{acid}}{H_2O} \longrightarrow NH_4^+ + OH^-$$

45. Rohon heard that instructions were given to the laboratory attendant to store a particular chemical i.e., keep it in the dark room, add some urea in it, and keep it away from dust. This chemical acts as an oxidising as well as a reducing agent in both acidic and alkaline media. This chemical is important for use in the pollution control, treatment of domestic and industrial effluents.

(i) Write the name of this compound.

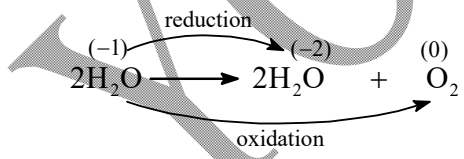
(ii) Explain why such precautions are taken for storing this chemical.

Ans. (i) Name of the compound is **hydrogen peroxide,** H_2O_2

(ii) H_2O_2 decomposed in the presence of dust or light into H_2O_2 and O_2

$$2H_2O_2 \longrightarrow 2H_2O + O_2$$

To slow down or prevent this reaction, we store H_2O_2 in the dark room, adding some urea (act an inhibitor). Since, H_2O_2 undergoes disproportionation reaction, H_2O_2 can act as an oxidizing agent as well as reducing agent.



46. Give reasons why hydrogen resembles alkali metals?

Ans. Hydrogen resembles alkali metals because

(i) Like alkali metals, hydrogen also has one electron in the valence shell

Na: [Ne] $3s^1$ H: $1s^1$

(ii) Like alkali metals, hydrogen loses one electron to form unipositve cation

$Na \longrightarrow Na^+ + e^-$ $H \longrightarrow H^+ + e^-$

(iii) Like alkali metals, hydrogen combines with oxygen form oxide, with halogen form halides

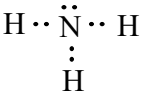
$Na \longrightarrow Na_2O$ $\quad\quad$ $H \longrightarrow H_2O$

$Na \longrightarrow NaCl$ $\quad\quad$ $H \longrightarrow HCl$

47. Hydrogen generally forms covalent compounds. Give reasons.

Ans. Although hydrogen has one electron in its valence shell which it can lose or share to attain stability. It can also gain one electron to attain helium configuration. Since, ionization enthalpy of H is very high (1312 KJ/mol), it cannot lose electron easily. Also, its electron gain enthalpy is very less negative (–73 KJ/mol), it cannot gain electron easily.

Hence, hydrogen can only share its one electron and form covalent compounds.

H – H, $\quad\quad$ 

48. Why is the ionization enthalpy of hydrogen higher than that of sodium?

Ans. The ionization enthalpy of hydrogen is higher than that of sodium due to extremely small size of hydrogen and the electron is very strongly bound to the nucleus.

49. Basic principle of hydrogen economy is transportation and storage of energy in the form of liquid or gaseous hydrogen. Which property of hydrogen may be useful for this purpose? Support your answer with the chemical equation if required.

Ans. Hydrogen is a gas at room temperature. Because of its large volume, it is difficult to transport H_2 by rail or road.

H_2 can be transported in small containers by cooling the gas by applying presence and converting H_2 gas into liquid H_2.

The basic property of hydrogen which can be used in hydrogen economy is its ability to get converted into liquid on applying high pressure.

50. What is the importance of heavy water?

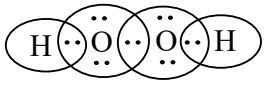
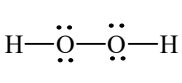
Ans. Heavy water, D_2O

(i) is used as a moderator in nuclear reactor.

(ii) is used in the preparation of D_2.

51. Write the Lewis structure of hydrogen peroxide?

Ans. Lewis structure of hydrogen peroxide is

 $\quad\quad$ 

52. An acidic solution of hydrogen peroxide behaves as an oxidizing as well as reducing agent. Illustrate it with the help of a chemical equation.

Ans. (i) Acidified H_2O_2 oxidises Fe^{2+} to Fe^{3+}

$$2Fe^{2+} + H_2O_2 + 2H^+ \longrightarrow 2Fe^{3+} + 2H_2O$$

(ii) Acidified H_2O_2 reduces MnO_4^- **to Mn^{2+}**

$$2MnO_4^- + 5H_2O_2 + 6H^+ \longrightarrow 2Mn^{2+} + 8H_2O + 5O_2$$

53. With the help of suitable examples, explain the property of H_2O_2 that is responsible for its bleaching action?

Ans. Bleaching action of H_2O_2 is due to its oxidizing nature. H_2O_2 on decomposition releases nascent oxygen, which helps in bleaching of coloured matter like silk, wool, ivory and feather etc.

$$H_2O_2 \longrightarrow H_2O + [O]$$

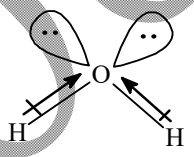
Coloured substance + [O] $\longrightarrow$ colourless substance

54. Why is water molecule polar?

Ans. Water molecule is polar. This is due to

(i) electronegativity difference, each H – O bond is polar.

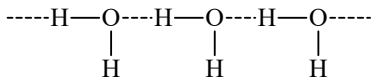
(ii) bent structure, two bond dipoles and orbital dipole moments add up to give very high value of dipole moment of 1.84 D.



$\mu = 1.84\,D$

55. Why does water show high boiling point as compared to hydrogen sulphide? Give reasons for your answer.

Ans. Due to high electronegatvity of oxygen, H – O bond is highly polar and H_2O is highly associated via intermolecular hydrogen bonding.



Due to large size and less electronegativity of sulphur, there is no association via hydrogen bonding in H_2S. Hence, H_2S is a discrete molecule, gas with very low boiling point.

56. Why can dilute solutions of hydrogen peroxide not be concentrated by heating? How can a concentrated solution of hydrogen peroxide be obtained?

Ans. This is because on heating, H_2O_2 decompsoe to give H_2O and O_2

$$2H_2O \longrightarrow 2H_2O + O_2$$

Therefore, H_2O_2 can be concentrated by using following steps:

(i) evaporation on a water both

(ii) dehydration in a vacuum dessicator

(iii) distillation under reduced pressure

(iv) finally removal of last traces of water

57. Why is hydrogen peroxide stored in wax lined bottles?

Ans. H_2O_2 decomposed by rough surfaces of glass or the alkali metal oxides present in it or light to form H_2O and O_2

$$2H_2O_2 \longrightarrow 2H_2O + O_2$$

To prevent this decomposition, we store H_2O_2 in dark coloured paraffin wax coated plastic or Teflon bottles.

58. Why does hard water not form lather with soap?

Ans. Hard water contains bicarbonates, chlorides and sulphates of calcium and magnesium ions. These combines with soap molecules to form curdy white precipitate called **scum.**

As a result, soap is wasted and does not form lather

$$\underset{\text{soap}}{2C_{17}H_{35}COONa} + \underset{(M = Mg,\ Ca)}{M^{2+}} \longrightarrow \underset{\text{curdy white ppt}}{(C_{17}H_{35}COO)_2M} + 2Na^+$$

59. Phosphoric acid is preferred over sulphuric acid in preparing hydrogen peroxide from peroxides. Why?

Ans. H_2SO_4 is a strong acid and may results in the decomposition of H_2O_2 by acting as a catalyst

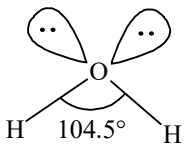
$$2H_2O \xrightarrow{H_2SO_4} 2H_2O + O_2$$

So, we prefer weaker acids like H_3PO_4 in the preparation of H_2O_2.

$$3BaO_2 + 2H_3PO_4 \longrightarrow Ba_3(PO_4)_2 + 3H_2O_2$$

60. How will you account for 104.5° bond angle in water?

Ans. In H_2O, O is sp^3 hybridised, the geometry is tetrahedral and the bond angle should be 109°. But due to lone pair-lone pair repulsions, H-atoms comes closer and bond angle decreases to 104.5°. H_2O is AX_2E_2 type molecule according to VSEPR theory and has a bent structure.



61. Write redox reaction between fluorine and water.

Ans. $2F_2 + 2H_2O \longrightarrow 4HF + O_2$

F_2 is the strongest oxidizing agent and oxidizes H_2O to O_2 gas.

62. Write two reactions to explain amphoteric nature of water.

Ans. (i) With NH_3, H_2O act as an acid

$$\underset{\text{acid}}{H_2O} + \underset{\text{base}}{NH_3} \rightleftharpoons NH_4^+ + OH^-$$

With Na_2O, H_2O act as an acid

$$\underset{\text{acid}}{H_2O} + \underset{\text{base}}{Na_2O} \longrightarrow 2NaOH$$

(ii) With HCl, H_2O act as base

$$\underset{\text{base}}{H_2O} + HCl \longrightarrow H_3O^+ + Cl^-$$

With CO_2, H_2O act as base

$$\underset{\text{base}}{H_2O} + CO_2 \longrightarrow H_2CO_3$$

SECTION-IV: *Matching Type*

Note: In some of the following questions, one option of left column may be correlated to more than one option in the right column.

63. Correlate the items listed in column-I with those listed in column-II. Find out as many correlations as you can.

	Colum-I		Column-II
(i)	Synthesis gas	(a)	$Na_2[Na_4(PO_3)_6]$
(ii)	Dihydrogen	(b)	Oxidising agent
(iii)	Heavy water	(c)	Softening of water
(iv)	Calgon	(d)	Reducing agent
(v)	Hydrogen peroxide	(e)	Stoichiometric compounds of s-block elements
(vi)	Salt like hydrides	(f)	Prolonged electrolysis of water
		(g)	Zn + NaOH
		(h)	Zn + dil. H_2SO_4
		(i)	Synthesis of methanol
		(j)	Mixture of CO and H_2

Ans.	(i)	(ii)	(iii)	(iv)	(v)	(vi)
	(i),(j)	(d), (e) (g), (h) (i)	(f)	(a),(c)	(b), (d)	(e)

64. Match column-I with column-II for the given properties/applications mentioned therein.

	Column-I		Column-II
(i)	H	(a)	Used in the name of perhydrol
(ii)	H_2	(b)	Can be reduced to dihydrogen by NaH.
(iii)	H_2O	(c)	Can be used in hydroformylation of olefin
(iv)	H_2O_2	(d)	Can be used in cutting and welding

Ans.	(i)	(ii)	(ii)	(iv)
	(d)	(c)	(b)	(a)

65. Match the terms in column-I with the relevant item in column-II

	Column-I		Column-II
(i)	**Electrolysis of water produces**	**(a)**	**atomic reactor**
(ii)	**Lithium aluminium hydride is used as**	**(b)**	**polar molecule**
(iii)	**Hydrogen chloride is a**	**(c)**	**recombines on metal surface to generate high temperature**
(iv)	**Heavy water is used in**	**(d)**	**reducing agent**
(v)	**Atomic hydrogen**	**(e)**	**hydrogen and oxygen**

Ans. (i) (ii) (ii) (iv) (v)

(e) (d) (b) (a) (c)

66. Match the items in column-I with the relevant item in column-II

	Column-I		Column-II
(i)	**Hydrogen peroxide is used as a**	**(a)**	**zeolite**
(ii)	**Used in Calgon method**	**(b)**	**perhydrol**
(iii)	**Permanent hardness of hard water is removed by**	**(c)**	**Sodium hexametaphosphate**
		(d)	**propellant**

Ans. (i) (ii) (ii)

(b),(d) (c) (a),(c)

SECTION-V: *Assertion and Reason Type*

Note: In the following questions a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

67. Assertion(A): Permanent hardness of water is removed by treatment with washing soda.

Reason (R): Washing soda reacts with soluble magnesium and calcium sulphate to form insoluble carbonates.

(i) Statements A and R both are correct and R is the correct explanation of A.

(ii) A is correct but R is not correct

(iii) A and R both are correct but R is not the correct explanation of A

(iv) A and R both are false.

Ans. (i)

Permanent hardness is due to chlorides and sulphates of magnesium and calcium. This can be removed by using washing soda.

$$Na_2CO_3 + \underset{(M = Ca,\ Mg)}{M^{2+}} \longrightarrow MCO_3 + 2Na^+$$

$$Na_2CO_3 + CaSO_4 \longrightarrow Na_2SO_4 + CaCO_3$$

68. Assertion(A): Some metals like platinum and palladium, can be used as storage media for hydrogen.

Reason (R): Platinum and palladium can absorb large volumes of hydrogen.

(i) Statements A and R both are correct and R is the correct explanation of A.

(ii) A is correct but R is not correct

(iii) A and R both are correct but R is not the correct explanation of A

(iv) A and R both are false.

Ans. (i)

Both assertion and reason given are correct.

Ni, Pt and Pd are used as a catalyst in the hydrogenation and absorb large volumes of hydrogen.

SECTION-VI: *Long answer Type*

69. Atomic hydrogen combines with almost all elements but molecular hydrogen does not. Explain.

Ans. Atomic hydrogen has only one valence electron, smallest atom. So, the atomic hydrogen is highly reactive and combines with almost all elements exothermically, on the other hand, molecular hydrogen has strongest single bond between two H-atoms with a bond dissociation energy of 436 KJ/mol.

As a result, molecular hydrogen is unreactive and combines with few elements and that also under drastic conditions.

70. How can D_2O be prepared from water? Mention the physical properties in which D_2O differs from H_2O. Give at least three reactions of D_2O showing the exchange of hydrogen with deuterium.

Ans. Preparation

Heavy water is prepared by pronged electrolysis of ordinary water. The method is based on the principle that when ordinary water is electrolysed, hydrogen is liberated much more readily than deuterium because of

(i) smaller size of H^+.

(ii) lower discharge potential of H^+

(iii) more reactivity of H to combine with itself to give H_2.

Physical properties

Properties	H_2O	D_2O
(i) Boiling point	373 K	374.4 K
(ii) Density	1.00 g/cm^3	1.105 g/cm^3
(iii) Δ_{vap} H	40.66 KJ/mol	41.61 KJ/mol
(iv) specific heat	4.177 Jg^{-1} K^{-1}	—
(v) Dielectric constant	78.39	78.06

Exchange reactions

(i) $HCl + D_2O \rightleftharpoons DCl + HOD$

(ii) $CHCl_3 + D_2O \rightleftharpoons CDCl_3 + HOD$

(iii) $NH_3 + D_2O \rightleftharpoons ND_4^+ + OD^-$

71. How will you concentrate H_2O_2? Show difference between structures of H_2O_2 and H_2O by drawing their spatial structures. Also mention three important uses of H_2O_2.

Ans. Concentration of hydrogen peroxide solution

The concentration of hydrogen peroxide is done carefully in number of steps.

(i) **Evaporation of dilute aqueous solution** of H_2O_2 in a water both. This results in the concentration of H_2O_2 to 50% H_2O_2.

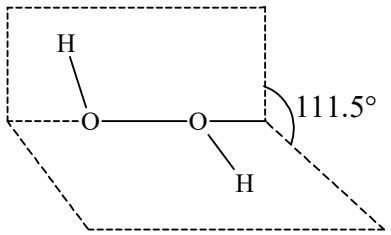
(ii) **Dehydration** in a vacuum desiccator

This 50% H_2O_2 solution is further dehydrated in a vacuum desiccators using conc. H_2SO_4. This gives H_2O_2 of 90% concentration.

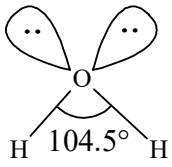
(iii) **Distillation** under reduced pressure results in H_2O_2 of 99% concentration.

(iv) **Last traces of water** can be removed by freezing it in a freezing mixture consisting of dry ice and ether when crystals of H_2O_2 separates out.

Structure of H_2O_2 and H_2O



gas phase H_2O_2



Uses of H_2O_2

(i) H_2O_2 is used as bleaching agent for delicate materials like silk, wool, paper, ivory.

(ii) It is used as an important antiseptic under the name perhydrol for washing wounds, teeth and ears.

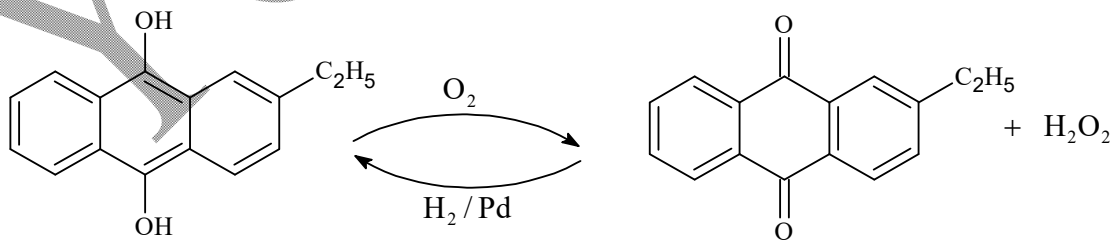
(iii) It is also used in restoring original white colour of the painting.

72. (i) Give a method for the manufacture of hydrogen peroxide and explain the reactions involved therein.

(ii) Illustrate oxidizing, reducing and acidic properties of hydrogen peroxide with equations.

Ans. (i) **Preparation of H_2O_2**

The most important method used for the preparation of H_2O_2 is the oxidation of 2-ethyl anthraquinol.



2-ethylanthraquinol 2-ethylanthraquinone

(ii) **Oxidising properties of H_2O_2**

H_2O_2 oxidises Fe^{2+} to Fe^{3+} in acidic medium

$$H_2O_2 + 2H^+ + 2Fe^{2+} \longrightarrow 2Fe^{3+} + 2H_2O$$

H_2O_2 oxidises PbS to $PbSO_4$

$$PbS + 4H_2O_2 \longrightarrow PbSO_4 + 4H_2O$$

Reducing properties of H_2O_2

H_2O_2 reduces acidified $KMnO_4$ to Mn^{2+}

$$2MnO_4^- + 5H_2O_2 + 6H^+ \longrightarrow 2Mn^{2+} + 8H_2O + 5O_2$$

Acidic properties of H_2O_2

$$2NaOH + \underset{\text{acid}}{H_2O_2} \longrightarrow Na_2O_2 + 2H_2O$$

73. What mass of hydrogen peroxide will be present in 2 litres of a 5 molar solution? Calculate the mass of oxygen which will be liberated by the decomposition of 200 mL is this solution.

Ans. (i)

M = 5.0 M

V = 2.0 L

$n_{H_2O_2} = MV = 10.0$ moles

But $n_{H_2O_2} = \dfrac{\text{mass of } H_2O_2}{\text{molar mass}}$

Mass of $H_2O_2 = n_{H_2O_2} \times$ molar mass

= 10.0 × 34 = 340 g

(ii) $n_{H_2O_2}$ in 200 ml (0.2 L) solution = 5.0 × 0.2 = 1.0 mol

$$2H_2O_2 \longrightarrow 2H_2O + O_2$$

2 moles H_2O_2 on decomposition gives 1 mol O_2 = 32g

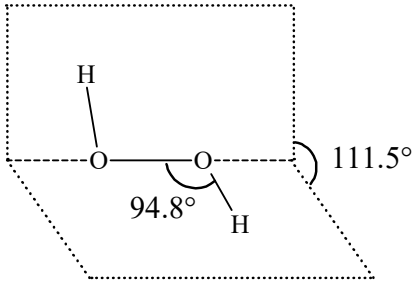
$\therefore$ 1.0 mol H_2O_2 on decomposition will give ½ mol O_2 = 16 g O_2

74. A colourless liquid 'A' contains H and O elements only. It decomposes slowly on exposure to light. It is stabilized by mixing urea to store in the presence of light.

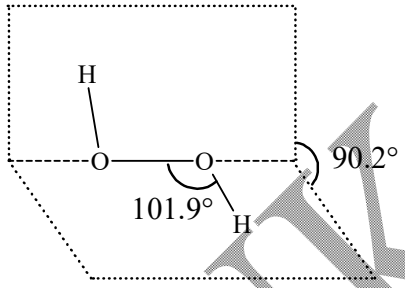
(i) Suggest possible structure of A

(ii) Write chemical equations for its decomposition reaction in light.

Ans. (i)



Gas-phase
Dihedral angle =111.5°



Solid-phase
Dihedral angle = 90.2°

(ii) $2H_2O_2 \xrightarrow{\text{light}} 2H_2O + O_2$

75. An ionic hydride of an alkali metal has significant covalent character and is almost unreactive towards oxygen and chlorine. This is used in the synthesis of other useful hydrides. Write the formula of this hydride. Write its reaction with Al_2Cl_6.

Ans. (i) Alkali metal hydride with significant covalent character is Lithium hydride, LiH.

(ii) LiH reacts with Al_2Cl_6 gives lithium aluminium hydride (a mixed hydrides) used as a reducing agent.

$$8LiH + Al_2Cl_6 \longrightarrow 2LiAlH_4 + 6LiCl$$

76. Sodium forms a crystalline ionic solid with dihydrogen. The solid is non-volatile and non-conducting in nature. It reacts violently with water to produce dihydrogen gas. Write the formula of this compound and its reaction with water. What will happen on electrolysis of the melt of this solid.

Ans. $2Na + H_2 \longrightarrow 2NaH$ (sodium hydride)

NaH is non-volatile and non-conducting in the solid state. It reacts violently with H_2O to liberate hydrogen gas

$$NaH + H_2O \longrightarrow NaOH + H_2$$

On electrolysis of fused NaH, H_2 gas liberates at anode and sodium is obtained at cathode

$$2NaH \xrightarrow{\text{electrolysis}} 2Na^+ + 2H^-$$

$$2Na^+ + 2e^- \longrightarrow 2Na(l) \text{ (at cathode)}$$

$$2H^- \longrightarrow H_2(g) + 2e^- \text{ (at anode)}$$

