Chapter - Hydrogen

Topic-1: Preparation and Properties of Hydrogen and Hydrides

9 Assertion and Reason /Statement Type Questions

Each question contains **STATEMENT-1 (Assertion)** and **STATEMENT-2 (Reason)**. Each question has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct. Mark your answer as

(a) If both Statement -1 and Statement -2 are correct, and Statement -2 is the correct explanation of the Statement -2.

(b) If both Statement -1 and Statement -2 are correct, but Statement -2 is not the correct explanation of the Statement -1.

(c) If Statement -1 is correct but Statement -2 is incorrect.

(d) If Statement -1 is incorrect but Statement -2 is correct.

1. Read the following statement and explanation and answer as per the options given statement below :

Statement - 1 : The alkali metals can form ionic hydrides which contain the hydride ion H^-.

Statement - 2 : The alkali metals have low electronegativity; their hydrides conduct electricity when fused and liberate hydrogen at the anode. **[1994 - 2 Marks]**

Topic-2: Preparation and Properties of H_2O and D_2O

1 MCQs with One Correct Answer

1. Polyphosphates are used as water softening agents because they **[2002S]**

(a) form soluble complexes with anionic species
(b) precipitate anionic species
(c) form soluble complexes with cationic species
(d) precipitate cationic species

2. Heavy water is **[1983 - 1 Mark]**

(a) $H_2{}^{18}O$
(b) water obtained by repeated distillation
(c) D_2O
(d) water at 4°C

3. The temporary hardness of water due to calcium bicarbonate can be removed by adding – **[1979]**

(a) $CaCO_3$ (b) $Ca(OH)_2$ (c) $CaCl_2$ (d) HCl

6 MCQs with One or More than One Correct Answer

4. The reagent(s) used for softening the temporary hardness of water is (are) **[2010]**

(a) $Ca_3(PO_4)_2$ (b) $Ca(OH)_2$
(c) Na_2CO_3 (d) NaOCl

5. The species present in solution when CO_2 is dissolved in water are **[2006 - 5M, –1]**

(a) $CO_2, H_2CO_3, HCO_3^-, CO_3^{2-}$
(b) H_2CO_3, CO_3^{2-}
(c) CO_3^{2-}, HCO_3^-
(d) CO_2, H_2CO_3

6. When zeolite, which is hydrated sodium aluminium silicate, is treated with hard water the sodium ions are exchanged with **[1990 - 1 Mark]**

(a) H^+ ions (b) Ca^{++} ions
(c) SO_4^{--} ions (d) Mg^{++} ions
(e) OH^- ions

Topic-3: Preparation and Properties of H_2O_2

1 MCQs with One Correct Answer

1. Hydrogen peroxide in its reaction with KIO_4 and NH_2OH respectively, is acting as a **[Adv. 2014]**
   (a) Reducing agent, oxidising agent
   (b) Reducing agent, reducing agent
   (c) Oxidising agent, oxidising agent
   (d) Oxidising agent, reducing agent
2. The volume strength of 1.5 N H_2O_2 solution is **[1991 - 1 Mark]**
   (a) 4.8 (b) 8.4 (c) 3.0 (d) 8.0

3 Numeric / New Stem Based Questions

3. To a 25mL H_2O_2 solution, excess of acidified solution of potassium iodide was added. The iodine liberated required 20 mL of 0.3 N sodium thiosulphate solution. Calculate the volume strength of H_2O_2 solution. **[1997 - 5 Marks]**
4. A 5.0 cm^3 solution of H_2O_2 liberates 0.508 g of iodine from an acidified KI solution. Calculate the strength of H_2O_2 solution in terms of volume strength at STP. **[1995 - 2 Marks]**

10 Subjective Problems

5. Hydrogen peroxide acts both as an oxidising and as a reducing agent in alkaline solution towards certain first row transition metal ions. Illustrate both these properties of H_2O_2 using chemical equations. **[1998 - 4 Marks]**
6. Give reactions for the oxidation of hydrogen peroxide with potassium permanganate in acidic medium. **[1997 - 1 Mark]**
7. Give reasons for the following :
   (*i*) Hydrogen peroxide acts as an oxidising as well as a reducing agent. **[1992 - 1 Mark]**
   (*ii*) Hydrogen peroxide is a better oxidising agent that water. **[1986 - 1 Mark]**
8. The mixture of hydrazine and hydrogen peroxide with a copper(II) catalyst is used as a rocket propellant. **[1987 - 1 Mark]**
9. Write down the balanced equations for the reactions when: An alkaline solution of potassium ferricyanide is reacted with hydrogen peroxide. **[1982 - 1 Mark]**

Answer Key

Topic-1 : Preparation and Properties of Hydrogen and Hydrides

1. (a)

Topic-2 : Preparation and Properties of H_2O and D_2O

1. (c) 2. (c) 3. (b) 4. (b, c, d) 5. (a) 6. (b, d)

Topic-3 : Preparation and Properties of H_2O_2

1. (a) 2. (b) 3. (1.344) 4. (4.48)

Hints & Solutions

Topic-1: Preparation and Properties of Hydrogen and Hydrides

1. **(a)** The alkali metals are highly electropositive elements, hence, the hydrides, hydrogen exist as hydride ion H^-. This is the reason why hydrogen liberate at anode.

Topic-2: Preparation and Properties of H_2O and D_2O

1. **(c)** $2Ca^{2+} + Na_2[Na_4(PO_3)_6] \longrightarrow 4Na^+ + \underset{\text{water soluble}}{Na_2[Ca_2(PO_3)_6]}$

2. **(c)** Heavy water is D_2O, deuterium oxide.

3. **(b)** Temporary hardness of water is due to presence of bicarbonates of Ca and Mg and it is removed by adding $Ca(OH)_2$ to hard water and precipitating these soluble bicarbonates in the form of insoluble salts.

$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow CaCO_3\downarrow + 2H_2O$

$Mg(HCO_3)_2 + 2Ca(OH)_2 \longrightarrow 2CaCO_3\downarrow + Mg(OH)_2\downarrow + 2H_2O$

4. **(b, c, d)** Temporary hardness is due to bicarbonates of calcium and magnesium. Temporary hardness can be removed by Clark's process, which involves the addition of slaked lime, $Ca(OH)_2$. Washing soda (Na_2CO_3) removes both the temporary and permanent hardness by converting soluble calcium and magnesium compounds into insoluble carbonates.

$Ca(HCO_3) + Ca(OH)_2 \longrightarrow 2CaCO_3\downarrow + 2H_2O$

$Ca(HCO_3) + Na_2CO_3 \longrightarrow CaCO_3\downarrow + 2NaHCO_3$

NaOCl can remove the hardness as :

$2OCl^- + 2H_2O \rightleftharpoons 2HOCl + 2OH^-$

$Ca(HCO_3)_2 + 2OH^- \longrightarrow CaCO_3\downarrow + CO_3^{2-} + 2H_2O$

5. **(a)** $CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$

6. **(b, d)** $Na_2Al_2Si_2O_8 \cdot xH_2O + Ca^{2+} \rightarrow CaAl_2Si_2O_8 \cdot xH_2O + 2Na^+$

$Na_2Al_2Si_2O_8 \cdot xH_2O + Mg^{2+} \rightarrow MgAl_2Si_2O_8 \cdot xH_2O + 2Na^+$

Topic-3: Preparation and Properties of H_2O_2

1. **(a)** $KIO_4 + H_2O_2 \rightarrow KIO_3 + H_2O + O_2$

Thus, H_2O_2 is acting as a reducing agent

$2NH_2OH + H_2O_2 \rightarrow N_2 + 4H_2O$

Here H_2O_2 is acting as an oxidising agent

2. **(b)** Volume strength = Normality $\times$ 5.6 = 1.5 $\times$ 5.6 = 8.4 L

3. **(1.344)** By law of equivalence:

Meq. of H_2O_2 = Meq. of $Na_2S_2O_3$ = Meq. of I_2 = Meq. of KI

$\frac{w}{17} \times 1000 = 20 \times 0.3$

$\therefore\ w = 0.102$ g (equating Meq. in 25 mL solution)

$H_2O_2 \rightarrow H_2O + \frac{1}{2}O_2$

$\therefore$ Volume of $O_2 = \frac{11200 \times 0.102}{34} = 33.6$ mL

$\therefore$ Volume strength $= \frac{33.6}{25} = \mathbf{1.344}$

4. **(4.48)**

$\underset{\substack{34\text{ g}\\5\text{ cm}^3\text{ or mL}}}{H_2O_2} + H_2SO_4 + \underset{\substack{\text{Acidified}\\\text{KI sol}}}{2KI} \longrightarrow K_2SO_4 + \underset{\substack{254\text{ g}\\0.508\text{ g}}}{I_2} + 2H_2O$

i.e. 254 g of I_2 is released by 34 g H_2O_2

$\therefore$ 0.508 g of I_2 will be released by

$= \frac{34}{254} \times 0.508 = 0.068$ g

5 mL of H_2O_2 sol. contains 0.068 g of H_2O_2.

$\therefore$ 1 mL of H_2O_2 sol contains $\frac{0.068}{5}$ g H_2O_2

The strength of H_2O_2 is generally calculated in terms of **volume strength**. According to which, 10 volume of H_2O_2 means that 1 mL of H_2O_2 sol gives 10 mL of O_2 at STP.

$\underset{2\times 34\text{ g}}{2H_2O_2} \longrightarrow 2H_2O + \underset{\substack{32\text{ g or}\\22{,}400\text{ mL at STP}}}{O_2}$

i.e., 68 g of H_2O_2 gives 22,400 mL of O_2 at STP

or 1 mL of H_2O_2 sol

or $\frac{0.068}{5}$ g of H_2O_2 gives $\frac{22{,}400}{68} \times \frac{0.068}{5} = 4.48$ mL

or 1 mL of H_2O_2 sol gives 4.48 mL of O_2 *i.e.* strength of H_2O_2 sol is **4.48 volumes.**

5. Example of oxidising character of H_2O_2 in alkaline medium

$$2Cr(OH)_3 + 4NaOH + 3H_2O_2 \rightarrow 2Na_2CrO_4 + 8H_2O$$

Here, Cr^{3+} (Cr is a first row transition metal) is oxidised to Cr^{6+}.

Example of reducing character of H_2O_2 in alkaline medium:

$$2K_3[Fe(CN)_6] + 2KOH + H_2O_2 \rightarrow 2K_4[Fe(CN)_6] + 2H_2O + O_2$$

Here, Fe^{3+} (Fe is a first row transition metal) is reduced to Fe^{2+}.

6. $2KMnO_4 + 3H_2SO_4 \rightarrow K_2SO_4 + 2MnSO_4 + 3H_2O + 5[O]$

$$[H_2O_2 + [O] \rightarrow H_2O + O_2] \times 5$$

$$2KMnO_4 + 5H_2O_2 + 3H_2SO_4 \rightarrow K_2SO_4 + 2MnSO_4 + 8H_2O + 5O_2$$

7. (*i*) The oxidation state of oxygen in H_2O_2 (*i.e.* –1) can be changed to 0 or –2 *i.e.* oxygen in H_2O_2 exists in an intermediate oxidation state with respect to O_2 and O^{2-}. Hence, it acts both as an oxidising and reducing agent.

(*ii*) H_2O_2 is a better oxidising agent than H_2O because oxidation number of oxygen in H_2O_2 is –1 and that in water it is –2. So, H_2O_2 easily reduces to –2 oxidation number.

8. The mixture of N_2H_4 and H_2O_2 (in presence of Cu (II) catalyst) is used as a rocket propellant because the reaction is highly exothermic and large volume of gases are evolved, which can propel a rocket.

$$\underset{\text{Hydrazine}}{N_2H_4} + \underset{\substack{\text{Hydrogen}\\ \text{peroxide}}}{2H_2O_2} \xrightarrow{Cu(II)} N_2(g)\uparrow + 4H_2O(g)\uparrow$$

9. Ferricyanide is oxidised to ferrocyanide on treatment with alkali:

$$2K_3[Fe(CN)_6] + H_2O_2 + 2KOH \rightarrow 2K_4[Fe(CN)_6] + 2H_2O + O_2$$