Unit

9

HYDROGEN

I. Multiple Choice Questions (Type-I)

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.

2. Why does H^+ ion 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 smal size it cannot exist free.

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

4. Which of the following hydrides is electron-precise hydride?

(i) B_2H_6

(ii) NH_3

(iii) H_2O

(iv) CH_4

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

(i) Protium

(ii) Deuterium

(iii) Tritium

(iv) Hydronium

6. Consider the reactions

(A) $H_2O_2 + 2HI \longrightarrow I_2 + 2H_2O$ (B) $HOCl + H_2O_2 \longrightarrow H_3O^+ + Cl^- + O_2$

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

(i) an oxidising agent in both (A) and (B)

(ii) an oxidising 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)

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

8. Which of the following equations depict the oxidising nature of H_2O_2?

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

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

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

10. Hydrogen peroxide is _____.

(i) an oxidising agent

(ii) a reducing agent

(iii) both an oxidising and a reducing agent

(iv) neither oxidising nor reducing agent

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

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 sulphate and hydrogen peroxide

13. Hydrogen peroxide is obtained by the electrolysis of _____.

(i) water

(ii) sulphuric acid

(iii) hydrochloric acid

(iv) fused sodium peroxide

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

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

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

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

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

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

(i) Ca^{2+}

(ii) Na^{+}

(iii) Cl^-

(iv) K^+

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

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) Groups 15, 16, 17

(iv) Group 14

18. Only one element of _____ forms hydride.

(i) group 6

(ii) group 7

(iii) group 8

(iv) group 9

II. Multiple Choice Questions (Type-II)

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 compounds by losing an electron.

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) Syngas

(iii) Producer gas

(d) Industrial 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.

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(iii) Heavy water is more associated than ordinary water.
(iv) Heavy water has lower boiling point than ordinary water.

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 ion, H^+, exists freely in solution.
(iv) Dihydrogen does not act as a reducing agent.

23. Some of the properties of water are described below. Which of them is/are **not** correct?
(i) Water is known to be a 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.

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

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.

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.

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.

III. Short Answer Type

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

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

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

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

32. Complete the following equations:

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

33. Give reasons:

(i) Lakes freeze from top towards bottom.

(ii) Ice floats on water.

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

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

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

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

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

39. Calculate the strength of 5 volume H_2O_2 solution.

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

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

41. Melting point, enthalpy of vapourisation 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 (373 K)/ kJ mol^{-1}	40.66	41.61
Viscosity/centipoise	0.8903	1.107

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

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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.

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

44. When the first element of the periodic table is treated with dioxygen, 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?

45. Rohan heard that instructions were given to the laboratory attendent 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.

46. Give reasons why hydrogen resembles alkali metals?

47. Hydrogen generally forms covalent compounds. Give reason.

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

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.

50. What is the importance of heavy water?

51. Write the Lewis structure of hydrogen peroxide.

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

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

54. Why is water molecule polar?

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

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

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

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

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

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

61. Write redox reaction between fluorine and water.

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

IV. Matching Type

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

	Column 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

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.

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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

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

V. Assertion and Reason Type

In the following questions a statement of Assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the options given below each question.

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.

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.

VI. Long Answer Type

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

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.

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

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

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

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 of this solution.

74. A colourless liquid 'A' contains H and O elements only. It decomposes slowly on exposure to light. It is stabilised 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.

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.

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.

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ANSWERS

I. Multiple Choice Questions (Type-I)

1. (ii)	2. (iv)	3. (ii)	4. (iv)	5. (iii)	6. (ii)
7. (ii)	8. (iii)	9. (ii)	10. (iii)	11. (iii)	12. (iv)
13. (ii)	14. (iv)	15. (i)	16. (iii)	17. (i)	18. (i)

II. Multiple Choice Questions (Type-II)

19. (iii), (iv)	20. (i), (ii)	21. (i), (iii)
22. (i), (ii)	23. (iii), (iv)	24. (i), (ii)
25. (ii), (iii)	26. (i), (iv)	27. (i), (ii), (iii)

III. Short Answer Type

39. 5 volume H_2O_2 solution means that hydrogen peroxide contained in 1 volume of this solution will decompose to give 5 volumes of oxygen at STP i.e. if 1L of this solution is taken, then 5 L of oxygen can be produced from this at STP. Chemical equation for the decomposition of H_2O_2 is $2H_2O_2(l) \longrightarrow O_2(g) + H_2O(l)$.

    It shows that 68 g H_2O_2 gives 22.7 L of O_2 at STP, so 5 L oxygen will be obtained from :

$$\frac{68g \times 5L}{22.7L} = \frac{3400}{227} g\ H_2O_2 = 14.9\ g \approx 15\ g\ H_2O_2$$

    i.e., 15 g H_2O_2 dissolved in 1 L solution will give 5 L oxygen or 1.5 g H_2O_2/100 mL solution will give 500 mL oxygen. Thus 15 g/L or 1.5% solution is known as 5V solution of H_2O_2.

42. [***Hint :*** Heavy water; Bond dissociation energy of dihydrogen is less than dideuterium]

44. [***Hint :*** $H_2O + H_2O \longrightarrow H_3O^+ + {}^-OH$]

45. (i) H_2O_2

IV. Matching Type

63. (i) → (i), (j) (ii) → (d), (e), (g), (h), (i)

    (iii) → (f) (iv) → (a), (c)

    (v) → (b), (d) (vi) → (e)

64. (i) → (d) (ii) → (c) (iii) → (b) (iv) → (a)

65. (i) → (e) (ii) → (d) (iii) → (b) (iv) → (a)
(v) → (c)

66. (i) → (b), (d) (ii) → (c) (iii) → (a), (c)

V. Assertion and Reason Type

67. (i) 68. (i)

VI. Long Answer Type

73. 68 g, 3.2 g

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