Hydrogen

Quick Revision

1. **Occurrence of Hydrogen**

Dihydrogen (H_2) is the most abundant element in the universe (70% of the total mass of the universe) and is the principal element in the solar atmosphere. The giant planets Jupiter and Saturn consist of mainly hydrogen.

2. **Position of Hydrogen in the Periodic Table**

- Hydrogen is the first element in the periodic table with electronic configuration $1s^1$.
- In atomic form, it consists of one proton and one electron and in elemental form it exists as a diatomic (H_2) molecule and is called **dihydrogen**.
- Its position is not certain because it has resemblance to alkali metals which lose one electron to form unipositive ions as well as with halogens which gain one electron to form uninegative ion.

3. **Isotopes of Hydrogen**

(i) Hydrogen has three isotopes: protium ($_1^1H$), deuterium or heavy hydrogen ($_1^2H$ or D) and tritium ($_1^3H$ or T).

(ii) Tritium is radioactive and emits low energy β^--particles.

(iii) These three isotopes have different masses hence, their rates of reaction and equilibrium constants are different. This is known as **isotopic effect**. Because of the extreme temperature of sun fusion of hydrogen atoms occurs, which liberates large amount of energy.

$$4\,{}_1^1H \longrightarrow {}_2^4He + \underset{\text{Positron}}{2\,{}_1^0e} + \text{Energy}$$

4. **Compounds of Hydrogen**

(i) **Hydrides** Hydrogen combines with almost all the elements except noble gases under certain reaction conditions to give binary compounds. These binary compounds are called hydrides. Hydrides can be classified into following categories

(a) **Ionic, saline or salt like hydrides** They are formed by elements of group 1 and group 2.

They are crystalline, non-volatile and non-conducting in solid state.

e.g. Li^+H^-, Na^+H^-, $Ca^{2+}H_2^-$, etc.

(b) **Covalent or molecular hydrides** They are formed by *p*-block and *s*-block elements, e.g. HF. They are covalent, volatile and non-conducting. These are further classified as (i) electron deficient (ii) electron precise and (iii) electron rich hydrides.

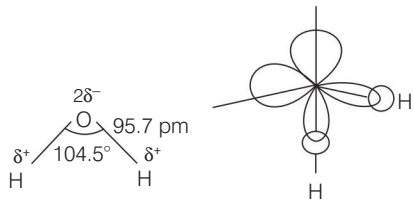
(c) **Metallic or non-stoichiometric hydrides** *d*-block elements of group 3, 4, 5, 10, 11, 12 and *f*-block elements on heating with H_2 under pressure form these hydrides.

They conduct heat and electricity and are mostly non-stoichiometric. e.g. $VH_{0.56}$, $NiH_{0.6\text{-}0.7}$ etc.

Hydride gap In group 6, only Cr forms the hydride Cr—H. The metals of group 7, 8 and 9 do not form hydrides.

(ii) **Water** It is a compound of hydrogen and oxygen, in which these are present in 1 : 8 by weight. Its formula is H_2O. It is very essential for existence of all forms of life.

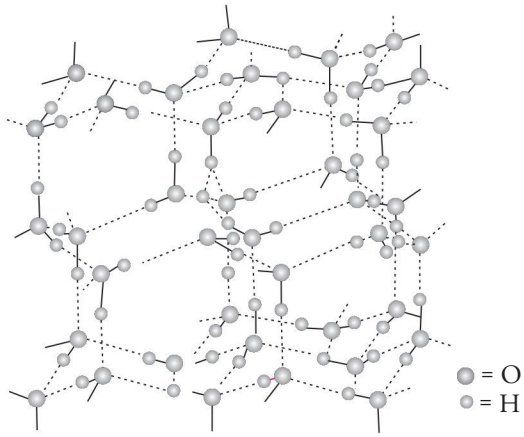
Structure of water in gaseous state



(a) The bent structure of water with dipole
(b) The orbital overlap picture in water

5. Structure of Ice

Here each oxygen atom is surrounded tetrahedrally by four other oxygen atom. Due to hydrogen bonding, ice has open structure with wide holes.



Three dimensional highly ordered hydrogen bonded structure of ice.

6. Physical Properties of Water

- It is transparent, colourless, tasteless and odourless substance.
- It is freezing point, boiling point, heat of vapourisation and heat of fusion is higher than hydrides of other elements of group 16.
- It has high specific heat thermal conductivity, surface tension and dielectric constant.
- It is regarded as universal solvent.

7. Chemical Properties of Water

(i) **Amphoteric nature**

$$\underset{\text{Acid}_1}{H_2O(l)} + \underset{\text{Base}_2}{NH_3(aq)} \rightleftharpoons \underset{\text{Acid}_2}{NH_4^+(aq)} + \underset{\text{Base}_1}{OH^-(aq)}$$

$$\underset{\text{Base}_2}{H_2O(l)} + \underset{\text{Acid}_2}{H_2S(aq)} \rightleftharpoons \underset{\text{Acid}_1}{H_3O^+(aq)} + \underset{\text{Base}_1}{HS^-(aq)}$$

(ii) **Auto-protolysis or self-ionisation**

$$\underset{\substack{\text{Acid}_1\\(\text{acid})}}{H_2O(l)} + \underset{\substack{\text{Base}_2\\(\text{base})}}{H_2O(l)} \rightleftharpoons \underset{\substack{\text{Acid}_2\\(\text{conjugate acid})}}{H_3O^+(aq)} + \underset{\substack{\text{Base}_1\\(\text{conjugate base})}}{OH^-(aq)}$$

(iii) **Redox reactions involving water**

$$2Na(s) + 2H_2O(l) \longrightarrow 2NaOH(aq) + H_2(g)$$

$$6CO_2(g) + 12H_2O(l) \longrightarrow C_6H_{12}O_6(aq) + 6H_2O(l) + 6O_2(g)$$

(iv) **Hydrolysis reactions**

$$\underset{\substack{\text{Silicon}\\\text{tetrachloride}}}{SiCl_4(l)} + 2H_2O(l) \longrightarrow \underset{\substack{\text{Silicon}\\\text{dioxide}}}{SiO_2(s)} + 4HCl(aq)$$

$$\underset{\substack{\text{Aluminium}\\\text{nitride}}}{AlN} + 3H_2O \longrightarrow \underset{\substack{\text{Aluminium}\\\text{hydroxide}}}{Al(OH)_3} + \underset{\text{Ammonia}}{NH_3}$$

8. Hard and Soft Water

Water that forms lathers with soap is called soft water, e.g. rain water, distilled water etc., and that does not do so is called hard water, e.g. sea water, well water, etc.

Types of hardness The hardness of water is of two types :

(i) **Temporary hardness** It is because of the presence of bicarbonates (hydrogen carbonates) of calcium and magnesium, so it is also called carbonate hardness.

The methods used to remove temporary hardness are as follows:

(a) **By boiling**

$$\underset{\substack{\text{Magnesium}\\\text{bicarbonate}}}{Mg(HCO_3)_2} \xrightarrow{\text{Heating}} \underset{\substack{\text{Magnesium}\\\text{hydroxide}}}{Mg(OH)_2}\downarrow + 2CO_2\uparrow$$

$$\underset{\substack{\text{Calcium}\\\text{bicarbonate}}}{Ca(HCO_3)_2} \xrightarrow{\text{Heating}} \underset{\substack{\text{Calcium}\\\text{carbonate}}}{CaCO_3}\downarrow + H_2O + CO_2\uparrow$$

(b) **Clark's method**

$$\underset{\substack{\text{Calcium}\\\text{bicarbonate}}}{Ca(HCO_3)_2} + \underset{\substack{\text{Calcium}\\\text{hydroxide}}}{Ca(OH)_2} \longrightarrow \underset{\substack{\text{Calcium}\\\text{carbonate}}}{2CaCO_3}\downarrow + 2H_2O$$

$$\underset{\text{Magnesium bicarbonate}}{Mg(HCO_3)_2} + 2Ca(OH)_2 \longrightarrow \underset{\text{Calcium carbonate}}{2CaCO_3\downarrow} + \underset{\text{Magnesium hydroxide}}{Mg(OH)_2\downarrow} + 2H_2O$$

(ii) **Permanent hardness** It is because of the presence of chlorides and sulphates of calcium and magnesium in the water. Following methods can be employed to remove this type of hardness:

(a) **By using washing soda** (sodium carbonate)

$$MCl_2 + \underset{\text{Sodium carbonate}}{Na_2CO_3} \longrightarrow MCO_3\downarrow + \underset{\text{Sodium chloride}}{2NaCl}$$

(where, M = Mg, Ca)

$$MSO_4 + \underset{\text{Sodium carbonate}}{Na_2CO_3} \longrightarrow MCO_3\downarrow + \underset{\text{Sodium sulphate}}{Na_2SO_4}$$

(b) **Calgon's method** (sequestration)

$$\underset{\text{Sodium hexametaphosphate}}{Na_6P_6O_{18}} \longrightarrow 2Na^+ + Na_4P_6O_{18}^{2-}$$

(where, M = Mg, Ca)

$$M^{2+} + Na_4P_6O_{18}^{2-} \longrightarrow [Na_2M\,P_6O_{18}]^{2-} + 2Na^+$$

The trade name for sodium hexametaphosphate is calgon (which means calcium gone), thus, the process is called **Calgon process**.

(c) **Ion-exchange method** When sodium aluminium silicate ($NaAlSiO_4$) is added in hard water, then exchange reactions take place.

$$\underset{\text{Sodium aluminium silicate}}{2NaZ(s)} + M^{2+}(aq) \longrightarrow MZ_2(s) + 2Na^+(aq)$$

(where, M = Mg, Ca)

where, $Z = Al_2Si_2O_8 \cdot xH_2O$

(d) **Synthetic resin method** In this method, all types of cations (Na^{2+}, Ca^{2+}, Mg^{2+} etc.) and anions (Cl^-, SO_4^{2-}, HCO_3^- etc.) can be removed.

The water obtained from this process is called demineralised water.

$$2R\text{—}H(s) + M^{2+}(aq) \longrightarrow MR_2(s) + 2H^+(aq)$$

(where, M = Ca or Mg)

$$RNH_2(s) + H_2O(l) \longrightarrow RNH_3^+OH^-(l)$$

$$RNH_3^+OH^-(s) + X^-(aq) \longrightarrow RNH_3^+X^-(s) + OH^-(aq)$$

9. Heavy Water

It is the oxide of heavy hydrogen, i.e. deuterium and thus, has the formula D_2O. Its molecular mass is 20. It was discovered by **Harold C. Urey**, an American chemist in 1932.

(i) **Physical properties** Some important properties are as follows :

- It is colourless, odourless, tasteless liquid. It has maximum density –1.1073 g mL^{-1} at 11.6°C (water at 4°C).
- Solubility of salts in heavy water is less than in ordinary water because it is more viscous than ordinary water.

(ii) **Chemical properties** Heavy water gives all the reactions that are shown by ordinary water but the rate of these reactions is slower. This is called isotopic effect.

e.g. $\underset{\text{Sodium}}{2Na} + 2D_2O \longrightarrow \underset{\text{Sodium deuteroxide}}{2NaOD} + D_2$

$$\underset{\text{Calcium carbide}}{CaC_2} + 2D_2O \longrightarrow \underset{\text{Calcium deuteroxide}}{Ca(OD)_2} + \underset{\text{Deutero acetylene}}{C_2D_2}$$

$$\underset{\text{Sodium hydroxide}}{NaOH} + D_2O \rightleftharpoons \underset{\text{Sodium deuteroxide}}{NaOD} + \underset{\text{Semiheavy water}}{HOD}$$

$$\underset{\text{Chloroform}}{CHCl_3} + D_2O \rightleftharpoons \underset{\text{Deutero chloroform}}{CDCl_3} + HOD$$

10. Hydrogen as a Fuel : Hydrogen Economy

- Dihydrogen is an abundant element in the nature and on combustion produces a large amount of heat energy which is much more than that is obtained by combustion of fuels like methane, LPG, petrol.
- Hydrogen economy involves safe transportation and storage of energy in the form of H_2.

Objective Questions

Multiple Choose Questions

1. Which of the following statements is incorrect?

(a) Hydrogen is the most abundant element in the universe
(b) The giant planets Jupiter and Saturn consist mostly hydrogen
(c) The isotopes of hydrogen have different physical properties
(d) Hydrogen is used to reduce lighter metal oxides (more active than iron) to metals

2. In which of the following respect, electronic configuration of hydrogen has resemblance to alkali metals and halogens respectively?

(a) It lose one electron to form unipositive ion and gain one electron to form uninegative ion
(b) It gain one electron to form uninegative ion and lose one electron to form unipositive ion
(c) It has the ability to gain one electron only
(d) None of the above

3. Which of the following properties of hydrogen does not resemble with that of halogens ?

(a) It forms a diatomic molecule
(b) It combines with elements to form hydrides
(c) It forms large number of covalent compounds
(d) It has same reactivity as halogens

4. Most common isotope of hydrogen (non-radioactive) is

(a) protium (b) deuterium
(c) tritium (d) All of these

5. Which of the following does not react with hydrogen even at high temperature to form corresponding hydrides ?

(a) Alkali (b) Noble gases
(c) Transition metals (d) All of these

6. Deuterium atom contains how many proton and neutron(s) respectively?

(a) 0, 1 (b) 1, 2 (c) 1, 0 (d) 1, 1

7. Dihydrogen, under certain reaction conditions, combines with almost all elements except noble gases to form binary compounds. The binary compounds are called ……

(a) oxides (b) halides
(c) carbides (d) hydrides

8. Saline hydrides are known to react with water violently producing fire. Can CO_2, a well known fire extinguisher, be used in this case ?

(a) No, because CO_2 gets oxidised by metal hydride
(b) Yes, because CO_2 gets oxidised by metal hydride
(c) No, because CO_2 gets reduced by metal hydride
(d) Yes, because CO_2 gets reduced by metal hydride

9. The saline hydrides, remove traces of water from organic compounds because

(a) in saline hydrides, the H^- ion is a strong Bronsted base
(b) in saline hydrides, the H^- ion is a weak Bronsted base
(c) in saline hydrides, the M^+ ion is a strong Bronsted acid
(d) in saline hydrides, the M^+ ion is a weak Bronsted acid

10. Which of the following is covalent and polymeric in structure?

(a) LiH (b) BeH_2
(c) MgH_2 (d) Both (b) and (c)

11. The *d*-block elements forms ……

(a) ionic hydrides
(b) non-stoichiometric hydrides
(c) molecular hydrides
(d) covalent hydrides

12. Recent studies show that the metallic hydrides have different lattice from that of the parent metal except …… .

(a) Cu (b) Pt (c) K (d) Ac

13. Which of the following statements is correct regarding metallic or non-stoichiometric hydrides?

(a) These are formed by all *d* and *f*-block elements
(b) These hydrides conduct heat and electricity
(c) Like saline hydrides they are almost always stoichiometric
(d) None of the above

14. Metal hydrides are ionic, covalent or molecular in nature. Among LiH, NaH, KH, RbH, CsH, the correct order of increasing ionic character is ***(NCERT Exemplar)***

(a) LiH > NaH > CsH > KH > RbH
(b) LiH < NaH < KH < RbH < CsH
(c) RbH > CsH > NaH > KH > LiH
(d) NaH > CsH > RbH > LiH > KH

15. Which of the following is incorrect statement ?

(a) *s*-block elements, except Be and Mg form ionic hydrides
(b) BeH_2, MgH_2, CuH_2, ZnH_2, CaH_2 and HgH_2 are intermediate hydrides
(c) *p*-block elements form covalent hydrides
(d) *d*- and *f*-block elements form ionic hydrides

16. Match the Column I with Column II and choose the correct option from the codes given below.

	Column I		Column II
A.	Electron-deficient molecular hydride	1.	CH_4
B.	Electron-precise molecular hydride	2.	B_2H_6
C.	Electron-rich molecular hydride	3.	NH_3

Codes

	A	B	C
(a)	1	3	2
(c)	3	2	1

	A	B	C
(b)	2	1	3
(d)	1	2	3

17. Which of the following is the correct statement about the structure of water?

(a) In gas phase, H—O—H bond angle is 109°, 28′
(b) O—H bond length is 95.7 pm
(c) In liquid phase, there occurs intramolecular H-bonding
(d) All of the above

18. The density of water is less in its solid state because

(a) in solid state, water molecules are arranged in highly ordered open cage like structure
(b) more extensive hydrogen bonding is present in solid state
(c) the water molecules are closest in solid state of water
(d) water is a rigid crystalline, closely packed structure in its solid state

19. In which of the following reactions H_2O acts only as a Bronsted acid? ***(NCERT Exemplar)***

(a) $H_2O(l) + NH_3(aq) \rightleftharpoons OH^-(aq) + NH_4^+(aq)$
(b) $H_2O(l) + H_2S(aq) \rightleftharpoons H_3O^+(aq) + HS^-(aq)$
(c) $H_2O(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + O\bar{H}\ (aq)$
(d) None of the above

20. Choose the incorrect statement.

(a) The H—O—H angle in water molecule is 104.5°
(b) The maximum number of hydrogen bonds formed by a water molecule in ice is 2
(c) Each oxygen in ice crystal is surrounded tetrahedrally by four other O-atoms
(d) The density of liquid water is higher than that of ice due to hydrogen bonding

21. What is reason of temporary hardness of water ?

(a) Na_2SO_4 (b) $CaCl_2$
(c) NaCl (d) $Ca(HCO_3)_2$

22. The temporary hardness of a water sample is due to compound X. Boiling this sample converts X to compound Y. X and Y, respectively, are

(a) $Mg(HCO_3)_2$ and $Mg(OH)_2$
(b) $Ca(HCO_3)_2$ and $Ca(OH)_2$
(c) $Mg(HCO_3)_2$ and $MgCO_3$
(d) $Ca(HCO_3)_2$ and CaO

23. The method used to remove temporary hardness of water is
(a) Clark's method
(b) ion-exchange method
(c) synthetic resins method
(d) Calgon's method

24. Permanent hardness of water is due to the presence of
(a) bicarbonates of sodium and potassium
(b) chlorides and sulphates of sodium and potassium
(c) chlorides and sulphates of calcium and magnesium
(d) bicarbonates of calcium and magnesium

25. The formula of Calgon, used for water softening is …… .
(a) $Na_2[Na_4(PO_3)_6]$
(b) $Na_4[Na_2(PO_3)_6]$
(c) $Na_2[Na_4(PO_4)_5]$
(d) $Na_4[Na_4(PO_4)_6]$

26. When zeolite is treated with hard water, the sodium ions are exchanged with
(a) H^+ ions
(b) H^+ and Ca^{2+} ions
(c) OH^- and Mg^{2+} ions
(d) Ca^{2+} and Mg^{2+} ions

27. In comparison to the zeolite process for the removal of permanent hardness, the synthetic resins method is
(a) more efficient as it can exchange only cations
(b) less efficient as it exchange only anions
(c) less efficient as the resins cannot be regenerated
(d) more efficient as it can exchange both cations as well as anions

28. Which of the following soften hard water?
(a) Passing through cation exchange resin
(b) Passing through lime water
(c) Passing through sand
(d) Passing through alumina

29. Match the reactions given in Column I with the suitable method given in Column II. Select the correct option from the codes given below.

Column I	Column II
A. $Mg(HCO_3)_2 \xrightarrow{\text{Heating}} Mg(OH)_2\downarrow + 2CO_2\uparrow$	1. Clark's method
B. $Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3 + 2H_2O$	2. Calgon's method
C. $M^{2+} + Na_4P_6O_{18}^{2-} \longrightarrow [Na_2MP_6O_{18}]^{2-} + 2Na^+$	3. Boiling
D. $2NaZ(s) + M^{2+}(aq) \longrightarrow MZ_2(s) + 2Na^+(aq)$	4. Ion-exchange method

Codes

	A	B	C	D
(a)	3	1	2	4
(b)	4	3	2	1
(c)	4	1	2	3
(d)	3	2	4	1

30. Match the items given in Column I with the relevant item given in Column II.

Column I	Column II
A. Hydrogen peroxide is used as a	1. Zeolite
B. Used in Calgon method	2. Perhydrol
C. Permanent hardness of hard water is removed by	3. Sodium hexametaphosphate
	4. Propellant

Codes

	A	B	C
(a)	2, 4	3	1, 3
(b)	1	3	2
(c)	2, 1	4	3
(d)	3	1, 2	4

31. The degree of hardness of water is usually expressed in terms of
(a) ppm by weight of $MgSO_4$
(b) g/L of $CaCO_3$ and $MgCO_3$ present
(c) ppm by weight of $CaCO_3$ irrespective of whether it is actually present or not
(d) ppm of $CaCO_3$ actually present in water

32. The hardness of water is estimated by ……

(a) EDTA method
(b) titrimetric method
(c) conductivity method
(d) distillation method

33. The moderator used in nuclear reactor is

(a) TEL (b) D_2O
(c) *R*—O—*R* (d) None of these

34. Which of the following is/are the use(s) of heavy water?

(a) It is extensively used as a moderator in nuclear reactor
(b) It is used in exchange reactions for the study of reaction mechanism
(c) It is used for the preparation of other deuterium compounds
(d) All of the above

35. Which compound is formed when calcium carbide reacts with heavy water?

(a) CH_4 (b) C_2H_2
(c) C_2HD (d) C_2D_2

36. Which one of the following statements is correct about D_2O and H_2O ?

(a) D_2O has lower dielectric constant than H_2O
(b) NaCl is more soluble in D_2O than in H_2O
(c) Both (a) and (b) are correct
(d) None of the above

37. Select the correct statement.

(a) Melting point of H_2O is greater than that of D_2O
(b) Hardness of water depends on the soap consuming power
(c) Marine species can survive in distilled water
(d) Permanent hardness is due to soluble sulphates chlorides and nitrates of Ca and Mg

38. The fuel used for running the automobiles first time in the history of India during October 2005 is …… .

(a) D_2O (b) H_2O_2
(c) D_2 (d) H_2

39. Temperature of maximum density of H_2O and D_2O is respectively …… and ……

(a) 4 °C and 11.6 °C (b) 11.6 °C and 4 °C
(c) 4 °C and 12.5 °C (d) 12.5 °C and 4 °C

40. Advantage of hydrogen economy is the

(a) transmission of energy in the form of electric power
(b) transmission of energy in the form of chemical energy
(c) transmission of energy in the form of dihydrogen and not as electric power
(d) transmission of mechanical energy

Assertion-Reasoning MCQs

Directions In the following questions (Q.No. 41-52) a statement of Assertion followed by a statement of Reason is given. Choose the correct answer out of the following choices.

(a) Both Assertion and Reason are correct statements and Reason is the correct explanation of the Assertion.
(b) Both Assertion and Reason are correct statements, but Reason is not the correct explanation of the Assertion.
(c) Assertion is correct, but Reason is incorrect statement.
(d) Assertion is incorrect but Reason is correct statement.

41. **Assertion** Hydrogen shows resemblance with alkali metals as well as halogens.

Reason Hydrogen exists in atomic form only at high temperature.

42. **Assertion** Deuterium is also known as heavy hydrogen.

Reason Deuterium is a good conductor of heat and electricity.

43. **Assertion** Saline hydrides are non-volatile, non-conducting and crystalline solids.

Reason Saline hydrides are compounds of hydrogen with most of the *p*-block elements.

44. **Assertion** Ammonia and water are electron rich hydrides.

Reason They have electrons more than required for bonding.

45. **Assertion** Lithium hydride is used in the synthesis of other useful hydrides.

Reason Lithium hydride is unreactive at moderate temperature with O_2 or Cl_2.

46. **Assertion** Water has high boiling point.

Reason Water shows hydrogen bonding.

47. **Assertion** Water is an amphoteric substance.

Reason Water has a tendency to accept and donate a proton easily.

48. **Assertion** Temporary hardness can be removed by boiling.

Reason On boiling, the soluble bicarbonates change to carbonates which being insoluble, get precipitated.

49. **Assertion** An ice cube floats on water.

Reason Density of ice is less than that of water.

50. **Assertion** In winter season, ice formed on the surface of a lake provides thermal insulation.

Reason It ensures the death of the aquatic life and this fact is of great ecological significance.

51. **Assertion** Heavy water is used as a moderator in nuclear reactors.

Reason Heavy water is made up of an isotope of helium.

52. **Assertion** Permanent hardness of water is removed by treatment with washing soda.

Reason Washing soda results with soluble magnesium and calcium sulphate to form insoluble carbonates.

Case Based MCQs

53. Read the passage given below and answer the following questions :

Hydrogen can exist in three isotopic forms, *viz.,* protium, deuterium and tritium, which differ from each other in the number of neutrons.

Out of these three isotopes, tritium is formed in the upper atmosphere by reactions induced by cosmic rays. It decays to emit low energy β-particles.

$$\underset{\text{Tritium}}{{}^{3}_{1}\text{H}} \longrightarrow {}^{3}_{2}\text{He} + \underset{\beta\text{-particle}}{{}_{-1}e^{0}}$$

Tritium is used for making thermonuclear devices and for carrying out researches in fusion reactions as a source of energy. It is also used as a radioactive tracer as it is relatively cheap and easy to work with.

The following questions (i-iv) are multiple choice questions. Choose the most appropriate answer :

(i) The relative atomic mass of isotopes of hydrogen is

(a) 1:2:3 (b) 1:1:2
(c) 2:4:5 (d) 1:2:4

(ii) The n/p ratio for ${}_{1}H^{2}$ is

(a) 1:2 (b) 1:1
(c) 2:1 (d) 2:3

(iii) Which is the most reactive isotope of hydrogen?

(a) Tritium
(b) Deuterium
(c) Protium
(d) All are equally reactive

(iv) What type of reactions are generated by tritium?

(a) Chemical reaction
(b) Radioactive reaction
(c) Addition reaction
(d) All of these

Or The isotope of hydrogen are differs in

(a) chemical properties
(b) physical properties
(c) Both (a) and (b)
(d) None of these

54. Read the passage given below and answer the following questions:

Water is the main constituent of earth's hydrosphere and fluids of all known living organisms. It is vital for all known forms of life, even though it provides no chlorines or organic nutrients.

Water cover approximately 70.9% of earth's surface, mostly in seas and oceans. Water plays an important role in the world economy. Approximately 70% of the fresh water used by humans goes to agriculture.

Water is the excellent solvent for a wide variety of substance both mineral and organic; as such it is widely used in industrial processes and in cooking and washing.

Water, ice and snow are also central to many sports and other forms of entertainment pure water has a low electrical conductivity, which increases with the dissolution of a small amount of ionic material such as common salt.

The following questions (i-iv) are multiple choice questions. Choose the most appropriate answer :

(i) Which one of the following statements about water is incorrect?

(a) Water can act both as an acid and as a base

(b) Water can be easily reduced to dihydrogen by highly electronegative elements.

(c) Ice formed by heavy water sinks in normal water

(d) Presence of water can be detected by adding a drop to anhydrous $CuSO_4$

(ii) In nuclear reactors, ordinary water is not used as a moderator because

(a) it cannot slow down the fast moving neutrons

(b) it cannot remove the heat from the reactor core

(c) it has corrosive action on the metallic parts of the nuclear reactor

(d) None of the above

(iii) Consider the following statements about intermolecular and intramolecular hydrogen bonding.

I. Both types of H-bonds are temperature dependent.

II. Water exhibits amphoteric nature.

III. The boiling points of compounds having intramolecular H-bond are lower than those having intermolecular H-bond.

Which of the statements given above are correct?

(a) I and III (b) Both II and III

(c) I and II (d) All of these

(iv) Consider the following statements regarding water.

I. There is extensive hydrogen bonding between water molecules .

II. Water has high melting point in comparison to H_2S and H_2Se.

III. High heat of vaporisation and heat capacity of water are responsible for moderation of climate and body temperature of living beings.

IV. Covalent compounds like alcohol and carbohydrates dissolve in water.

Select the correct statements among above.

(a) Both I and II (b) Both II and IV

(c) I, II and III (d) All of these

Or

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 then liquid water.

Choose the correct option.

(a) I and II (b) II and III

(c) III and IV (d) II and III

55. Read the passage given below and answer the following questions :

Hydrogen combines with almost all the elements except noble gases under certain reaction condition to give binary compounds. These binary compounds are called **hydrides**. These are generally represented by the formula EH_x (where E is the other element and x is the number of hydrogen atoms e.g. CaH_2) or E_mH_n (here also E is the element and m and n show the number of E and H atoms respectively), e.g. B_2H_6.

Depending upon the nature of element with which dihydrogen combine to form hydride, hydrides can be classified into following types, i.e.

(i) Ionic (ii) Covalent (iii) Metallic

Ionic hydrides are stoichiometric compounds of hydrogen and the elements which are more electropositive than hydrogen. These hydrides are formed by the transfer of electrons from metal to hydrogen, thus they have hydrogen in the form of hydride ion (H^-).

Metallic hydrides are the hydrides of elements of d and f-blocks.

In other words, these hydrides do not follow law of constant composition.

When dihydrogen combines with p-block elements or non-metals, it results in the formation of covalent hydrides. Further these hydrides have molecular lattices.

In these questions (i-iv) a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

(a) Assertion and Reason both are correct statements and Reason is correct explanation for Assertion.

(b) Assertion and Reason both are correct statements but Reason is not correct explanation for Assertion.

(c) Assertion is correct statement but Reason is incorrect statement.

(d) Assertion is incorrect statement but Reason is correct statement.

(i) **Assertion** LiH is an ionic hydride.
Reason Lithium is more electropositive than hydrogen and there is transfer of electron from metal to hydrogen.

Or

Assertion Ionic hydrides are good conductor of electricity in molten state.
Reason Free ions are present in ionic hydrides in molten state.

(ii) **Assertion** Covalent hydrides are volatile compound with lower melting and boiling point.
Reason Covalent hydrides are held together by weak var der Waals' force.

(iii) **Assertion** Metallic hydrides are always stoichiometric.
Reason Metallic hydrides do not follow law of constant composition.

(iv) **Assertion** Elements of groups 7, 8, 9 forms by hydrides.
Reason This region of periodic table is called hydride gap.

56. Read the passage given below and answer the following questions:

Water is classified as either soft or hard. Soft water contains relatively few minerals and hard water is rich in minerals. Water hardness is usually expressed as the number of part per million (ppm) of calcium carbonate. Regions with soft water include the Pacific Northwest from Oregon up through British Columbia. The hard water region (100 + pm) include the Canadian Prairies, the U.S Midwest, and the Southwester states of New Mexico and Arizona.

In a sense, the hardness of water is the other side of the coin to alkalify. In general terms, rainy climates such as the Pacific Northwest have acid water. Rain leaches out much of the minerals ions in the soil, replacing them with hydrogen ions. The result is that the water is rich in hydrogen and thus acidic (soft). The reverse is the case in the dry regions, where moisture

evaporates, leaving the minerals intact. The result is water rich in minerals and thus alkaline (hard).

In the questions (i-iv), a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices on the basis of the above passage.

(a) Assertion and Reason both are correct statements and Reason is correct explanation for Assertion.
(b) Assertion and Reason both are correct statements but Reason is not correct explanation for Assertion.
(c) Assertion is correct statement but Reason is wrong statement.
(d) Assertion is incorrect statement but Reason is correct statement.

(i) **Assertion** Pure demineralised water is obtained by passing water successively through a cation exchange and an anion exchange resins.

Reason In cation exchange process, H^+ exchanges for Na^+, Ca^{2+}, Mg^{2+} and other cations present in water. In anion exchange process, OH^- exchanges anions like Cl^-, HCO_3^-, SO_4^{2-} present in water.

(ii) **Assertion** Hard water does not lather with soap.

Reason Hard water contains calcium and magnesium salts in the form of hydrogen carbonate, chloride and sulphate.

(iii) **Assertion** Soft water is free from the soluble salts of calcium and magnesium.

Reason It does not lather with soap easily.

(iv) **Assertion** Calgon is used for removing Ca^{2+} and Mg^{2+} ions from hard water.

Reason Calgon forms precipitate with Ca^{2+} and Mg^{2+} ions.

Or

Assertion Permanent hardness of water is removed by treatment with washing soda.

Reason Washing soda reacts with soluble calcium and magnesium chlorides and sulphates in hard water to form insoluble carbonates.

ANSWERS

Multiple Choice Questions

1. (d)	2. (a)	3. (d)	4. (a)	5. (b)	6. (d)	7. (d)	8. (c)	9. (a)	10. (d)
11. (b)	12. (d)	13. (b)	14. (b)	15. (d)	16. (b)	17. (b)	18. (a)	19. (b)	20. (b)
21. (d)	22. (a)	23. (a)	24. (c)	25. (c)	26. (d)	27. (d)	28. (a)	29. (a)	30. (a)
31. (c)	32. (a)	33. (b)	34. (d)	35. (d)	36. (a)	37. (b)	38. (d)	39. (a)	40. (c)

Assertion-Reasoning MCQs

41. (b)	42. (c)	43. (c)	44. (a)	45. (a)	46. (a)	47. (a)	48. (a)	49. (a)	50. (c)
51. (c)	52. (a)								

Case Based MCQs

53. (i)-(a), (ii)-(b), (iii)-(a), (iv)-(b or b)
54. (i)-(b), (ii)-(d), (iii)-(d), (iv)-(c or a)
55. (i)-(a or a), (ii)-(a), (iii)-(a), (iv)-(d)
56. (i)-(a), (ii)-(a), (iii)-(c), (iv)-(a or a)

EXPLANATIONS

1. Statement (d) is incorrect.

It's correct form is as follows :

Hydrogen is used in metallurgical processes, it is used to reduce heavy metal oxides to metals.

Rest other statements are correct.

2. Hydrogen has resemblance to the alkali metals, which lose one electron to form unipositive ions, as well as with halogens, which gain one electron to form uninegative ion.

3. The property of hydrogen which does not resemble with that halogen is given in statement (d).

Because it is very low reactive as compared to halogens.

Rest other statements are correct.

4. Protium (^1_1H), deuterium or heavy hydrogen (^2_1H or D) and tritium (^3_1H or T) are the isotopes of hydrogen.

Protium or ordinary hydrogen has one proton and no neutron in the nucleus and one electron revolves around the nucleus. It is the most abundant and common form of hydrogen (approximately 99.98%).

5. Noble gases do not react with dihydrogen even at higher temperature to yield the corresponding hydrides.

6. Deuterium nucleus (^2_1D) has 1-proton, 1-neutron and 1-electron.

7. Dihydrogen, under certain reaction conditions, combine with almost all elements except noble gases to form binary compounds, called hydrides.

If '*E*' is the symbol of an element then hydride can be expressed as EH_x (e. g. MgH_2) or E_mH_n (e. g. B_2H_6).

8. Saline hydrides (such as NaH, CaH_2 etc.) react with water violently to form the corresponding metal hydroxides with the evolution of dihydrogen.

$$NaH(s) + H_2O(l) \longrightarrow NaOH(aq) + H_2(g)$$

$$CaH_2(s) + 2H_2O(l) \longrightarrow Ca(OH)_2(aq) + 2H_2(g)$$

These reactions are so much exothermic that the evolved H_2 catches fire. This type of fire cannot be extinguished by CO_2 because it gets reduced by the hot metal hydride to form sodium formate.

$$NaH + CO_2 \longrightarrow HCO\overset{-}{O}\overset{+}{N}a$$

9. Saline hydrides such as NaH, CaH_2, etc., react with traces of water present in organic compounds and form their corresponding metal hydroxides with the evolution of hydrogen gas.

$$NaH(s) + H_2O(aq) \longrightarrow NaOH(aq) + H_2(g)$$

This is because in saline hydrides (M^+H^-), the H^- ion is a strong Bronsted base and, thus it reacts with water easily.

10. LiH, BeH_2 and MgH_2 are all covalent in nature. LiH molecules do not associate with each other, while the molecules of BeH_2 and MgH_2 exhibit aggregation among themselves and form polymeric chains of molecules, thus BeH_2 and MgH_2 are polymeric in structure.

11. *d*-block elements forms non-stoichiometric hydrides. These hydrides are formed by adsorbing hydrogen directly at appropriate temperatures by metal. The composition of these hydrides may not correspond to simple whole number ratio. Their composition varies with temperature and pressure.

12. Except Ni, Pd, Ce and Ac, other metallic hydrides have different lattice from that of the parent metal.

13. Statement (b) is correct, while the other statements are incorrect.

Corrected form are as follows :

(a) Metallic hydrides are formed by many *d* and *f*-block elements except group 7, 8 and 9 elements.

However, even from group 6, chromium forms CrH.

(c) Unlike saline hydrides, they are almost always non-stoichiometric, being deficient in hydrogen.

14. Ionic character increases as the size of the metal atom increases or the electronegativity of the metal atom decreases.

The correct order of increasing ionic character is,

$$LiH < NaH < KH < RbH < CsH$$

15. Statement (d) is incorrect.

It's correct form is as follows :

d and *f*-block elements form metallic hydrides.

Rest other statements are correct.

16. A → (2); B → (1); C → (3).

17. Statement (b) is correct, while the other statements are incorrect.

Corrected form are as follows :

(a) In gas phase, H—O—H is a bent molecule with a bond angle of 104.5.

(c) In liquid phase, intermolecular H-bonding takes place.

18. When water is converted to ice, an open cage like three dimensional structure is formed which has void filled with air. That's why, density of ice is less than that of water.

19. H_2O has the ability to act as an acid as well as base, i.e. it behaves as an amphoteric substance. In the context of Bronsted theory, it acts as an acid with NH_3 and a base with H_2S as shown below :

(a) $H_2O(l) + NH_3(aq) \rightleftharpoons OH^-(aq) + NH_4^+(aq)$

(b) $H_2O(l) + H_2S(aq) \rightleftharpoons H_3O^+(aq) + HS^-(aq)$

20. Statement (b) is incorrect.

It's correct form is as follows :

In liquid state, water molecules form two hydrogen bonds with their neighbouring water molecules. In solid state (ice), it contains four H-bonds due to spatial arrangement of molecules to form an open cage like structure.

Rest other statements are correct.

21. Temporary hardness of water is due to $Ca(HCO_3)_2$.

22. The temporary hardness of a water sample is due to compound X [i.e. $Mg(HCO_3)_2$]. Boiling of this sample converts X [i.e. $Mg(HCO_3)_2$] to compound Y[i.e. $Mg(OH)_2$].

Generally,temporary hardness is due to presence of magnesium and calcium hydrogen carbonates. It can be removed by boiling. During boiling, the soluble $Mg(HCO_3)_2$ is converted into insoluble $Mg(OH)_2$ and $Ca(HCO_3)_2$ changed to insoluble $CaCO_3$. These precipitates can be removed by filteration.

$$Mg(HCO_3)_2 \xrightarrow{\text{Heating}} Mg(OH)_2 \downarrow + 2CO_2 \uparrow$$

$$Ca(HCO_3)_2 \xrightarrow{\text{Heating}} CaCO_3 \downarrow + H_2O + CO_2 \uparrow$$

23. Temporary hardness in water is due to presence of magnesium and calcium hydrogen carbonates.

Temporary hardness in water can be removed by Clark's method.

In this method, calculated amount of lime is added to hard water. It precipitates out calcium carbonate and magnesium hydroxide which can be filtered off.

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

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

Besides this, temporary hardness can also be removed by boiling. All the other given methods are used to remove permanent hardness of water.

24. Permanent hardness of water is due to the presence of chlorides and sulphates of calcium and magnesium. Hardness can be removed by adding Na_2CO_3 or by passing the water through an ion-exchange column.

25. Calgon is used for water softening. Its formula is $Na_2[Na_4(PO_3)_6]$. It removes dissolved minerals of water which reduces the cleaning efficiency of water.

26. When zeolite is treated with hard water, the sodium ions are exchanged with Ca^{2+} and Mg^{2+} ions.

$$\underset{\text{Zeolite}}{Na_2Z} + M^{2+} \longrightarrow 2Na^+ + MZ \quad (M = \text{Ca or Mg})$$

27. Zeolites exchange their Na^+ ions with Ca^{2+} or Mg^{2+} in hard water. But, they can't exchange anions.

$$2NaZ(s) + \underset{\text{From hard water}}{Mg^{2+}(\text{or } Ca^{2+})}(aq) \longrightarrow MgZ_2(s)(\text{or } CaZ_2)(s) + 2Na^+(aq)$$

In synthetic resin method, all types cations (Na^+, Ca^{2+}, Mg^{2+} etc.) and anions (Cl^-, SO_4^{2-} etc.) can be removed.

Thus, this method is more efficient than zeolite process.

28. Cation exchange resins are used to remove Na^+, Ca^{2+}, Mg^{2+} electrons these contain large organic molecules with reactive acidic group which are water insoluble.

29. A → (3); B → (1); C → (2); D → (4).

30. A → (2, 4); B → (3); C → (1, 3).

31. Degree of hardness of water is measured in terms of ppm by weight of $CaCO_3$ irrespective of whether it is actually present or not.

32. Ethylene diamine tetraacetate (EDTA) when treated with water forms stable complex with metal ions and hence, it is used to measure hardness of water.

33. D_2O is used as moderator in nuclear reactor.

Uses of other given options are as follows :

(a) TEL (tetraethyl lead) is used as antiknock agent in petrol engine.

(c) R—O—R (ether) is used as a solvent.

34. All the given statements are the uses of heavy water.

35. D_2O is used for the preparation of deuterium containing compounds. The reaction is similar to H_2O.

$$CaC_2 + 2D_2O \longrightarrow C_2D_2 + Ca(OD)_2$$

36. Statement (a) is correct, while statement (b) is incorrect. It's correct form is as follows :

The molecular mass of H_2O is slightly less than that of D_2O, hence rate of diffusion of NaCl (i.e. solubility) is slightly higher in the case of H_2O.

37. (b) Among the given option, option (b) is the correct statement. Correct statements of other options are as follows

(a) Melting point of D_2O is higher than H_2O.

(b) Marine species cannot servive in distilled water.

(d) Permanent hardness is due to soluble sulphates of calcium and magnesium.

38. Hydrogen (H_2)

39. H_2O and D_2O have maximum density at 4°C and 11.6°C respectively.

40. Advantage of hydrogen economy is the transmission of energy in the form of dihydrogen and not as electric power.

41. Both Assertion and Reason are correct but Reason is not a correct explanation of Assertion.

Hydrogen can gain an electron to form the H^- ion to get stable noble gas configuration of helium. It can also lose its electron to give H^+ ion, i.e. univalent ion like alkali metals.

Hydrogen, therefore has resemblance to the halogens as well as to the alkali metals which gain or lose an electron respectively to form univalent negative and positive ions with noble gas configurations.

Hydrogen exists in atomic form at high temperatures. At normal temperature is exists as a diatomic molecule.

42. Assertion is correct but Reason is incorrect. It's correct form is as follows :

Deuterium is a bad conductor of heat and electricity.

43. Assertion is correct but Reason is incorrect. It's correct form is as follows.

Saline or ionic hydrides are compounds of hydrogen with most of the *s*-block metals. However, with *p*-block metals hydrogen forms molecular or covalent hydrides.

44. Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

The excess electrons being present as lone pairs of electrons (ammonia–one lone pair and water - two lone pairs).

45. Lithium hydride is rather unreactive at moderate temperature with O_2 or Cl_2. It is therefore, used in the synthesis of other useful hydrides.

e.g. $8LiH + Al_2Cl_6 \longrightarrow 2LiAlH_4 + 6LiCl$

$2LiH + B_2H_6 \longrightarrow 2LiBH_4$

Thus, both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

46. Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

The high boiling point of water is due to hydrogen bonding which holds the water molecules together rather than leaving them free.

Molecules having hydrogen, bonded to an electronegative atom, can, interact with another electronegative atom having a lone pair, leading to the formation of a hydrogen bond.

47. Both Assertion and Reason are correct and Reason is the correct explanation of the Assertion.

According to Bronsted, a substance having an ability to accept or donate a proton is known as amphoteric substance.

As an acid, $H_2O + NH_3 \longrightarrow OH^- + NH_4^+$

As a base, $H_2O + H_2S \longrightarrow H_3O + HS^-$

48. Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

Temporary hardness is due to presence of bicarbonates of calcium and magnesium which can be removed by boiling.

49. Density of ice is less than that of water because it has open cage like structures which consists of air filled voids.

Therefore, an ice cube floats on water.

Thus, both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

50. In winter season, ice formed on the surface of a lake provides thermal insulation which ensures the survival of the aquatic life. This fact is of great ecological significance.
Thus, Assertion is correct but Reason is incorrect.

51. Assertion is a correct but Reason is incorrect.
It's correct form is as follows :
Heavy water is made up of an isotope of hydrogen, i.e. deuterium.

52. Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

$$Na_2CO_3 + \underset{\text{or } CaSO_4 \text{ (from hard water)}}{MgSO_4} \longrightarrow Na_2SO_4 + \underset{\text{or } CaCO_3 \text{ (insoluble)}}{MgCO_3}$$

53. (i) 1 : 2 : 3

(ii) Number of protons in $_1H^2 = 1$

Number of neutrons = 1

$\therefore$ n/p ratio = 1 : 1

(iii) Tritium

(iv) Radioactive reactions

Or

The isotopes of hydrogen differ in their physical properties due to large difference in atomic masses. This type of difference in properties due to difference in atomic masses is called isotope effect.

54. (i) Statement (b) is incorrect.
It's correct form is as follows :
Water can be easily reduced to dihydrogen by highly electropositive metals as shown below :

$$2H_2O(l) + 2Na(s) \longrightarrow 2NaOH(aq) + H_2(g)$$

Rest other statements are correct.

(ii) Ordinary water stops the nuclear fission by absorbing the fast moving neutrons.

(iii) All the given statements are correct.

(iv) I, II and III statements are correct.
Statement IV is incorrect covalent compounds like alcohol and carbonates doesnot dissolves in water.

Or

Water is a universal solvent and exists to a larger extent in liquid state. It also contains H-bonding in frozen state. The density of ice is lower than that of water due to the presence of vacant spaces.

55. (i) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

Or

Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(ii) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(iii) Assertion is incorrect but Reason is correct.
Metallic hydrides are almost always non-stoichiometric. They do not follow law of constant composition.

(iv) Assertion is incorrect but Reason is correct. It's correct form is as follows :
The elements of group 7, 8, 9 do not forms hydrides but Reason is correct with hydrogen.

56. (i) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(ii) Presence of calcium and magnesium salts in the form of hydrogen carbonate, chloride and sulphate in water makes water 'hard'. These salts react with soap molecules to form a precipitate called scum.
That's why, hard water does not lather with soap.
Thus, both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(iii) Soft water gives lather with soap easily as it is free from soluble salts of calcium and magnesium.
Thus, Assertion is correct but Reason is incorrect.

(iv) Calgon is used for making Ca^{2+} and Mg^{2+} ions present in hard water ineffective. It forms soluble complex with Ca^{2+} and Mg^{2+} ions.
Thus, both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

Or

$$MCl_2 + Na_2CO_3 \longrightarrow MCO_3 \downarrow + 2NaCl$$
$$MSO_4 + Na_2CO_3 \longrightarrow MCO_3 \downarrow + Na_2SO_4$$

(where, M = Mg, Ca)