DAY ELEVEN

Hydrogen

Learning & Revision for the Day

- Occurrence
- Isotopes of Hydrogen
- Hydrides
- Water (H_2O)
- Hydrogen Peroxide (H_2O_2)

Occurrence

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. It is the most important element and constituent of most of the compounds.

Position of Hydrogen in Periodic Table

The position of hydrogen in periodic table is uncertain as it shows resemblance with alkali metals as well as with halogens. However, on the basis of electronic configuration ($1s^1$), it is placed above lithium in the periodic table but still, it is not considered as the member of that group. It is the lightest element known.

Isotopes of Hydrogen

- Hydrogen has three isotopes : protium (${}_1^1H$), deuterium or heavy hydrogen (${}_1^2H$ or D) and tritium (${}_1^3H$ or T).
- Tritium is radioactive and emits low energy β^- particles.
- 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.

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

Preparation of Dihydrogen

- In **laboratory**, dihydrogen is produced by the reaction of Zn with dil. H_2SO_4.

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2\uparrow$$

- **By the electrolysis of** acidified water is using platinum electrodes.

$$\underset{\substack{\text{Containing small}\\ \text{amount of acid}\\ \text{or alkali}}}{\text{Water}} \xrightleftharpoons[\text{Traces of acid / base}]{\text{Electrolysis}} \underset{\text{Cathode}}{H_2\uparrow} + \underset{\text{Anode}}{O_2\uparrow}$$

- **High purity** (>99.95%) **dihydrogen** is obtained by electrolysing warm aqueous barium hydroxide solution between nickel electrodes.

- Certain metals like Zn, Al reacts with alkali to evolve H_2 as,

$$2Al + 2NaOH + 2H_2O \longrightarrow 2NaAlO_2 + 3H_2 \uparrow$$

$$Zn + 2NaOH \longrightarrow Na_2ZnO_2 + H_2 \uparrow$$

- The ionic hydrides of alkali metals and alkaline earth metals (*s*-block elements) also evolve H_2 on reaction with water as,

$$CaH_2 + 2H_2O \longrightarrow Ca(OH)_2 + 2H_2 \uparrow$$

- In the **Bosch process**, H_2 is prepared through the reaction of water vapours (steam) by carbon as

$$\underset{\substack{\text{Coke}\\(\text{at } 400\text{-}660^\circ\text{C})}}{C} + \underset{\substack{\text{Superheated}\\\text{steam}}}{H_2O} \longrightarrow \underset{\substack{\text{Water gas}\\\text{or } syn \text{ gas}}}{CO + H_2}$$

Reacts with steam again in the presence of catalyst like Fe, Cr and Co

$$CO_2 + H_2$$

- In the **Lane process**, H_2 is produced as

$$\underset{(900^\circ\text{C})}{3Fe} + \underset{\substack{\text{Superheated}\\\text{steam}}}{4H_2O} \longrightarrow \underset{\substack{(\text{CO is passed over}\\\text{it and reduces to Fe})}}{Fe_3O_4} + 4H_2 \uparrow$$

- In **Nelson** or **Castner-Kellner** cell, H_2 is also produced by the electrolysis of brine solution (NaCl) in them.

Properties of Dihydrogen

- It is colourless, tasteless, odourless gas. It is lightest and slightly soluble in water.
- It is a neutral and highly combustible gas, so in the presence of air it burns with pale blue flame to form water.
- Hydrogen reduces the oxides of less electropositive elements but cannot reduces the oxides of alkali metals and alkaline earth metals.

$$ZnO(s) + H_2(g) \longrightarrow Zn + H_2O$$

$$Fe_3O_4(s) + 4H_2(g) \longrightarrow 3Fe + 4H_2O$$

Hydrogenation

$$\text{Vegetable oil} + H_2 \xrightarrow{Ni/473K} \text{Vegetable ghee}$$

$$CH_2 = CH_2 + H_2 \xrightarrow{Ni \text{ or } Pt/\Delta} CH_3 - CH_3$$

Reaction with CO

$$CO(g) + 2H_2(g) \xrightarrow[\Delta]{ZnO/Cr_2O_3} CH_3OH(l)$$

- With dinitrogen, it forms ammonia (Haber's process).

$$N_2(g) + 3H_2(g) \xrightarrow[Fe,\ Mo]{673\ K,\ 200\ atm} 2NH_3(g)$$

Uses of Dihydrogen

(i) In hydrogenation of oils.
(ii) In the preparation of synthetic petrol.
(iii) In oxy-hydrogen flame.
(iv) In hydrogen-oxygen fuel cells to produce electricity.
(v) Liquid hydrogen is used as rocket fuel.
(vi) As a reducing agent in the extraction of metals.

Hydrides

Dihydrogen, under certain reaction conditions, combines with almost all elements, except noble gases, to form binary compounds, called hydrides. Based upon their physical and chemical properties, hydrides are of the following three types

- **Ionic hydrides** are stoichiometric compounds of dihydrogen formed with most of the *s*-block elements, which are highly electropositive in character, e.g. LiH, BeH_2 and MgH_2.
  (i) In fact, BeH_2 and MgH_2 are polymeric in structure.
  (ii) Due to their high reactivity with water ionic hydrides are used to remove traces of water from organic solvents.
- **Covalent or molecular hydrides** are formed with most of the *p*-block elements.
  Most familiar examples are CH_4, NH_3, H_2O and HF etc.
- **Interstitial hydrides** or **metallic** or **non-stoichiometric** are formed by many *d*-block and *f*-block elements, however, the metals of group 7, 8 and 9 do not form hydride (hydride gap). These hydrides are mainly formed by
  (i) transition metals of group 3, 4, 5 of *d*-block
  (ii) Cr metal of group 6
  (iii) *f*-block elements, e.g. $LaH_{2.87}$, $YbH_{2.55}$ etc.
- Metallic hydrides are non-stoichiometric
- They have metallic lattice and hydrogen is present at the interstitial sites.
- These conduct heat and electricity just like metals except hydrides of Eu and Yb. (EuH_2 and YbH_2 are ionic and stoichiometric)

Water (H_2O)

The water molecule contains one oxygen and two hydrogen atoms connected by covalent bonds.

Physical Properties of Water

- Water (H_2O) is polar in nature.
- It exists in liquid state at room temperature due to intermolecular hydrogen bonding.
- HOH bond angle is 104.5° and O—H bond length is 95.7 pm.
- H_2O (ice) has four hydrogen bonds per molecule and hence, has a highly ordered three dimensional cage like structure.
- Ice has lower density than H_2O (liquid) but H_2O has maximum density at 3.98°C.

Chemical Properties of Water

- Water is **amphoteric** in nature.

$$\underset{\text{Base}}{H_2O(l)} + \underset{\text{Acid}}{HCl(aq)} \rightleftharpoons \underset{\text{Acid}}{H_3O^+(aq)} + \underset{\text{Base}}{Cl^-(aq)}$$

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

- Water reacts with metals and non-metals both.

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

$$2F_2(g) + 2H_2O(l) \longrightarrow 4H^+ + 4F^- + O_2(g)$$

- In hydrated salts, water may remain in five types such as coordinated water, hydrogen bonded water, lattice water, clathrate water and zeolite water.
- A number of compounds such as calcium hydride, calcium phosphide etc., undergo hydrolysis with water.
  (i) The hydrolysis of hydrides with H_2O is highly exothermic and may be explosive as H_2 catches fire.
  (ii) CO_2 is reduced by hot metal hydride, so it cannot use to extinguish such fire.

Hard and Soft Water

The water which lathers with soap is soft, if not, it is hard. Hardness of water is of two types:

- **Temporary Hardness of Water** is due to the presence of magnesium and calcium hydrogen carbonates. It can be removed either by **boiling**, through which the soluble $Mg(HCO_3)_2$ and $Ca(HCO_3)_2$ is converted into $Mg(OH)_2$, $CaCO_3$. (the precipitates can be removed by filtration), or by **Clark's method**, which involves the addition of calculated amount of lime to hard water.

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

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

- **Permanent Hardness of Water** is due to the presence of soluble salts of magnesium and calcium in the form of chlorides and sulphates. It can be removed by the Calgon's method, ion-exchange (or permutit) process and the synthetic resin method.

Heavy Water (D_2O)

- It has quite similar physical and chemical properties to those of H_2O.
- Dielectric constant of D_2O is lower than that of H_2O and rate of reactions are much slower than H_2O.
- It is used as a moderator in nuclear reactions, as trace compound for studying reaction mechanism, for the preparation of deuterium.

Hydrogen Peroxide (H_2O_2)

It is a compound with an oxygen-oxygen single bond. It is also a strong oxidiser.

Preparation

- By the reaction of sulphuric acid or phosphoric acid on hydrated barium peroxide (BaO_2)

(i) $BaO_2 \cdot 8H_2O + H_2SO_4 \longrightarrow BaSO_4 \downarrow + H_2O_2 + 8H_2O$

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

$Ba_3(PO_4)_2 + 3H_2SO_4 \longrightarrow 3BaSO_4 \downarrow + 2H_3PO_4$

NOTE (i) Anhydrous barium peroxide does not react readily with sulphuric acid because a coating of insoluble barium sulphate is formed on its surface which stops further action of the acid.

(ii) Treatment with phosphoric acid is preferred to H_2SO_4 because soluble impurities like barrium persulphate (from $BaO_2 \cdot 8H_2O + H_2SO_4$) tends to decompose H_2O_2 while H_3PO_4 acts as a preservative [negative catalyst for H_2O_2].

- By adding calculated quantity of sodium peroxide to a 20% ice cold sulphuric acid solution.

$$Na_2O_2 + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O_2$$

- **Merck's process** H_2O_2 can be obtained by passing a current of CO_2 through a cold pasty solution of barium peroxide in water.

$$BaO_2 + CO_2 + H_2O \longrightarrow \underset{\text{(Insoluble)}}{BaCO_3} + H_2O_2$$

- **The electrolysis of 50% sulphuric acid** to give perdisulphuric acid ($H_2S_2O_8$), which on distillation yields 30% solution of hydrogen peroxide.

$$2H_2SO_4 \rightleftharpoons 2H^+ + 2HSO_4^-$$

(i) **At cathode** (Cu coil) $2H^+ + 2e^- \longrightarrow 2H \longrightarrow H_2 \uparrow$

(ii) **At anode** (Pt) $2HSO_4^- \longrightarrow \underset{\substack{\text{Perdisulphuric acid} \\ \downarrow \text{ Hydrolysis } (2H_2O).}}{H_2S_2O_8}$

$$2HSO_4^- + 2H^+ + H_2O_2$$

- **By the auto-oxidation of 2-ethylanthraquinol** when, air is passed through 10% solution of 2-ethylanthraquinol in a mixture of benzene and a higher alcohol.

$$\text{2-ethyl anthraquinol} \xrightarrow[H_2/Pd]{\text{Air}} \text{2-ethylanthraquinone} + H_2O_2$$

Properties of H_2O_2

(i) Pure H_2O_2 is a pale blue syrupy liquid.
(ii) It freezes at – 0.5°C and has a density of 1.4 in pure state.
(iii) It is diamagnetic in nature.
(iv) Its dipole moment is 2.1 D.
(v) Due to auto-oxidation property, it cannot be used as a polar solvent.

Reaction of H_2O_2

(i) Oxidising action in acidic medium,

$$2Fe^{2+}(aq) + 2H^+(aq) + H_2O_2(aq) \longrightarrow 2Fe^{3+}(aq) + 2H_2O(l)$$

$$PbS(s) + 4H_2O_2 \longrightarrow PbSO_4(s) + 4H_2O(l)$$

(ii) Reducing action in acidic medium,

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

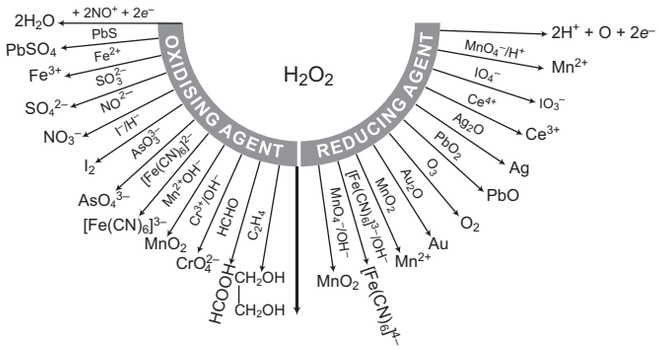
(iii) Oxidising action in basic medium,

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

(iv) Reducing action in basic medium,
$I_2 + H_2O_2 + 2OH^- \longrightarrow 2I^- + 2H_2O + O_2$

(v) Many reactions of H_2O_2 are radical reactions, therefore a mixture of H_2O_2 and Fe (II) is a source of hydroxyl radicals for organic reactions.

Its other oxidation and reduction properties may be summarised as:



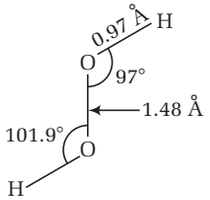
Uses of H_2O_2

(i) Aqueous solution of H_2O_2 is used as germicide, antiseptic, preservative for milk and wine, bleaching agent for soft materials. 30% H_2O_2 is called **perhydrol.** Its volume strength is 100 (also) called 100 volume and molarity is 8.8.

(ii) It is used as an antichlor and in refreshing old oil paintings which becomes black.

Structure of H_2O_2

Figure given below shows the molecular structure of H_2O_2.



Hydrogen peroxide

DAY PRACTICE SESSION 1

FOUNDATION QUESTIONS EXERCISE

1 The most common substance by mass, in our solar system is
(a) hydrogen (b) helium (c) water (d) carbon

2 Which pair does not show hydrogen isotopes?
(a) Atomic hydrogen and dihydrogen
(b) Protium and deuterium
(c) Deuterium and tritium
(d) Tritium and protium

3 Which of the following is the most rare isotope of hydrogen?
(a) Protium (b) Deuterium
(c) Tritium
(d) All of above are found in almost equal proportion

4 Hydrogen is not obtained when zinc reacts with
(a) dil. HCl (b) hot NaOH solution
(c) cold water (d) conc. H_2SO_4

5 Hydrogen can be prepared by the action of dil. H_2SO_4 on
(a) copper (b) iron (c) lead (d) mercury

6 Hydrogen gas is not liberated when the following metal is added to dil. HCl.
(a) Ag (b) Zn (c) Mg (d) Sn

7 Very pure hydrogen (99.9) can be made by which of the following processes?
(a) Reaction of methane with steam
(b) Mixing natural hydrocarbons of high molecular weight
(c) Electrolysis of water
(d) Reaction of salts like hydrides with water

8 The adsorption of hydrogen by metals is called
(a) chemisorption (b) occlusion
(c) hydrogenation (d) dehydrogenation

9 Most of the properties of hydrogen resemble with those of
(a) alkali metals (b) halogens
(c) noble gases (d) Both (a) and (b)

10 Elements of which of the following group(s) of periodic table do not form hydrides?
(a) Groups 7, 8, 9 (b) Group 13
(c) Groups 15, 16, 17 (d) Group 17

11 When electric current is passed through an ionic hydride in the molten state
(a) hydrogen is liberated at the cathode
(b) hydrogen is liberated at the anode
(c) no reaction takes place
(d) hydride ion migrates towards cathode

12 An element reacts with hydrogen to form a compound *A* which on treatment with water liberates hydrogen gas.The element can be
(a) Cl (b) Se (c) N (d) Ca

13 Hydrogen usually has an oxidation state of +1 in combined state. Exception to this statement include
(a)hydrocarbon (b) metal hydrides
(c)ammonia (d) All of these

14 The increasing order of reducing property of NaH, MgH_2 and H_2O is
(a) $NaH < H_2O < MgH_2$ (b) $MgH_2 < H_2O < NaH$
(c) $H_2O < MgH_2 < NaH$ (d) $NaH < MgH_2 < H_2O$

15 The incorrect statement about water is
(a) water is a universal solvent
(b) density of ice is lower than liquid water
(c) water has hydrogen bonding
(d) water is a non-polar covalent compound

16 The critical temperature of water is higher than O_2 because H_2O molecules have
(a) fewer electrons than oxygen
(b) two covalent bonds
(c) dipole moment
(d) V-shaped

17 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?
(a) Because ice is a solid
(b) Because molecules of ice are closely packed
(c) Because vacant spaces are present in the crystal lattice
(d) The given statement is wrong

18 Which of the following pairs of ions make the water hard?
(a) NH_4^+, Cl^- (b) Ca^{2+}, HCO_3^-
(c) Ca^{2+}, NO_3^- (d) Na^+, SO_4^{2-}

19 The hardness of water is estimated by
(a) EDTA method (b) titrimetric method
(c) conductivity method (d) distillation method

20 Consider the following assertion (A) and reason (R) and choose the correct option.

Assertion (A) Hard water has more utilisation than soft water

Reason (R) Hard water find application in steam boilers.
(a) Both (A) and (R) are true and (R) is the correct explanation for (A)
(b) Both (A) and (R) are true but (R) is not the correct explanation for (A)
(c) (A) is true but (R) is false
(d) Both (A) and (R) are false.

21 Which of the following is not true about deuterium?
(a) D_2O freezes at lower temperature than H_2O
(b) Reaction between H_2 and Cl_2 is much faster than D_2 and Cl_2
(c) Ordinary water electrolysed more rapidly than D_2O
(d) Bond dissociation energy is greater than H_2

22 Heavy water is used as
1. moderator 2. controller
3. coolant 4. fuel rods

Chose the correct option.
(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3

23 Perhydrol is the common name for
(a) a fuel containing hydrogen and oxygen
(b) 30.3% (by volume) hydrogen peroxide
(c) 100% pure hydrogen peroxide
(d) a compound of carbon resembling hydrogen peroxide in its structure.

24 Hydrogen peroxide can be reduced by
(a) O_3 (b) KI (c) PbS (d) acidic $KMnO_4$

25 In the reaction,

$$Ag_2O + H_2O_2 \longrightarrow 2Ag + H_2O + O_2$$

H_2O_2 acts as
(a) reducing agent (b) oxidising agent
(c) bleaching agent (d) None of these

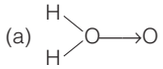
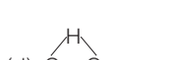
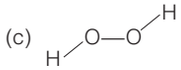
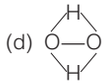
26 Consider the following Assertion (A) and Reason (R) and choose the correct option.

Assertion (A) H_2O_2 undergoes disproportionation on heating.

Reason (R) It gives H_2O and O_2 on heating.
(a) Both (A) and (R) are true and (R) is the correct explanation of (A)
(b) Both (A) and (R) are true but (R) is not the correct explanation of (A)
(c) (A) is true but (R) is false
(d) Both (A) and (R) are false.

27 (A) $H_2O_2 + O_3 \longrightarrow H_2O + 2O_2$
(B) $H_2O_2 + Ag_2O \longrightarrow 2Ag + H_2O + O_2$, H_2O_2 is
→ CBSC AIPMT 2014
(a) Oxidising agent in (A) and reducing agent in (B)
(b) Reducing agent in (A) and oxidising agent in (B)
(c) Reducing agent in (A) and (B)
(d) Oxidising agent in (A) and (B)

28 Which of the following equations depict the oxidising nature of H_2O_2?
(a) $2MnO_4^- + 6H^+ + 5H_2O_2 \longrightarrow 2Mn^{2+} + 8H_2O + 5O_2$
(b) $2Fe^{3+} + 2H^+ + H_2O_2 \longrightarrow 2Fe^{2+} + 2H_2O + O_2$
(c) $2I^- + 2H^+ + H_2O_2 \longrightarrow I_2 + 2H_2O$
(d) $KIO_4 + H_2O_2 \longrightarrow KIO_3 + H_2O + O_2$

29 What is the structure of H_2O_2?
(a) 
(b) 
(c) 
(d) 

30 In open book structure of H_2O_2, what will be the angle between the planes of the book?
(a) 93° (b) 97° (c) 107° (d) 109°

DAY PRACTICE SESSION 2

PROGRESSIVE QUESTIONS EXERCISE

1 Which one of the following is/are correct order?

(A) $T_2 > D_2 > P_2$ (order of BP)
(B) $T_2 > D_2 > P_2$ (order of BE)
(C) $T_2 = D_2 = P_2$ (order of BL)
(D) $T_2 < D_2 < P_2$ (order of reactivity with Cl_2)

(a) A, B and C
(b) A, B, C and D
(c) A and B
(d) B, C and D

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

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

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

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

(d) $CO(g) + 2H_2\,(g) \xrightarrow[catalyst]{Cobalt} CH_3OH\,(l)$

3 The hydride ion H^- is a stronger base than its hydroxide ion OH^-. Which of the following reaction will occur, if sodium hydride is dissolved in water?

(a) $H^-(aq) + H_2O \longrightarrow H_3O^+(aq)$
(b) $H^-(aq) + H_2O\,(l) \longrightarrow$ no reaction
(c) $H^-(aq) + H_2O(l) \longrightarrow OH^-(aq) + H_2(g)$
(d) None of the above

4 In which of the following reaction, hydrogen peroxide acts as a reducing agent?

(a) $H_2SO_3 + H_2O_2 \longrightarrow H_2SO_4 + H_2O$
(b) $2HI + H_2O_2 \longrightarrow 2H_2O + I_2$
(c) $2FeCl_2 + 2HCl + H_2O_2 \longrightarrow 2FeCl_3 + 2H_2O$
(d) $Cl_2 + 3H_2O_2 \longrightarrow 2HCl + 2O_2 + 2H_2O$

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

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

6 When zeolite which is hydrated sodium aluminium silicate is treated with hard water, the sodium ions are exchanged with

(a) H^+ ions (b) Mg^{2+} ions
(c) Ca^{2+} ions (d) Both Ca^{2+} and Mg^{2+}

7 Phosphoric acid is preferred over sulphuric acid in preparing hydrogen peroxide from peroxides because

(a) H_2SO_4 acts as a reducing agent
(b) H_2SO_4 gives $BaSO_4$ which is difficult to separate
(c) H_2SO_4 act as catalyst
(d) Both (b) and (c)

8 Which one of the following reactions represents the oxidising property of H_2O_2?

(a) $2KMnO_4 + 3H_2SO_4 + 5H_2O_2 \longrightarrow K_2SO_4 + 2MnSO_4 + 8H_2O + 5O_2$

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

(c) $PbO_2 + H_2O_2 \longrightarrow PbO + H_2O + O_2$

(d) $2KI + H_2SO_4 + H_2O_2 \longrightarrow K_2SO_4 + I_2 + 2H_2O$

9 Hydrogen can be obtained from water, by the action of water on

1. calcium carbide 2. calcium hydride
3. calcium oxide 4. calcium

Choose the correct option
(a) 1, 2 and 3 (b) 1 and 2 (c) 2 and 4 (d) 1 and 3

10 Saline hydrides are known to react with water violently producing fire. The fire cannot be extinguished by CO_2 because

(a) CO_2 is lighter than the gas evolved
(b) CO_2 is heavier than the gas evolved
(c) CO_2 gets reduced by the evolved gas
(d) CO_2 gets oxidised by the evolved gas

11 Which of the following statements about hydrogen is incorrect? **→ NEET 2016**

(a) Hydrogen never acts as cation in ionic salts
(b) Hydronium ion, H_3O^+ exists freely in solution
(c) Dihydrogen does not act as a reducing agent
(d) Hydrogen has three isotopes of which tritium is the most common

ANSWERS

SESSION 1

1 (a)	**2** (a)	**3** (c)	**4** (d)	**5** (b)	**6** (a)	**7** (d)	**8** (b)	**9** (d)	**10** (a)
11 (b)	**12** (d)	**13** (b)	**14** (c)	**15** (d)	**16** (c)	**17** (c)	**18** (b)	**19** (a)	**20** (d)
21 (a)	**22** (c)	**23** (b)	**24** (c)	**25** (a)	**26** (a)	**27** (a)	**28** (c)	**29** (c)	**30** (b)

SESSION 2

1 (b)	**2** (d)	**3** (c)	**4** (d)	**5** (b)	**6** (d)	**7** (c)	**8** (d)	**9** (c)	**10** (c)
11 (c,d)									

Hints and Explanations

SESSION 1

1 Hydrogen is the most abundant substance not only in our solar system but also in the universe. In our solar system, the sun, the jupiter and the saturn consist of mainly hydrogen gas.

2 Only three isotopes of hydrogen is known *viz*. protium deuterium and tritium. The atomic hydrogen (1-atom) and dihydrogen (2-atoms) differ in atomicity. Moreover, these may be constitute of any of the above mentioned isotopes.

3 Tritium is the radioactive isotope of hydrogen, which disintegrate in short span. Hence, it is the most rare isotope.

4 (a) $Zn + 2HCl \longrightarrow ZnCl_2 + H_2$

(b) $Zn + 2NaOH \longrightarrow Na_2ZnO_2 + H_2$

(c) $Zn + H_2O \longrightarrow ZnO + H_2$

(d) $Zn + 2H_2SO_4$ (conc.) $\longrightarrow$ $ZnSO_4 + SO_2 + 2H_2O$

5 (b) Cu and Hg cannot displace hydrogen and reaction of dil. H_2SO_4 with Pb stops after some time due to the formation of insoluble $PbSO_4 \cdot Fe$ with dil. H_2SO_4, gives H_2.

$$Fe + H_2SO_4 \longrightarrow FeSO_4 + H_2 \uparrow$$

6 The metals, present below hydrogen in the electrochemical series, cannot liberate hydrogen from the dilute acids.

Among the given metals, only Ag is present below hydrogen in electrochemical series, so it does not evolve hydrogen with dil. HCl.

$$Ag + \text{dil. } HCl \longrightarrow \text{No reaction}$$

7 Hydrides are instant source of hydrogen of higher purity.

They react with H_2O forming H_2 gas.

$CaH_2 + 2H_2O \longrightarrow Ca(OH)_2 + 2H_2$

8 Occlusion is the phenomenon of adsorption of hydrogen by metal.

9 Hydrogen, due to having only one electron in its orbit, can donate or accept one electron to achieve a stable state hence, it resembles with both alkali metals and halogens in its properties.

10 Elements of group 7,8 and 9 do not form hydrides and are known as hydride gap in the periodic table.

11 $M^+H^- \longrightarrow M^+ + H^-$ (hydride ion)

$$H^- \longrightarrow \frac{1}{2} H_2 + e^- \text{ (at anode)}$$

12 $Ca + H_2 \longrightarrow CaH_2$

$$CaH_2 \xrightarrow{2H_2O} Ca(OH)_2 + 2H_2$$

13 Metals being more electropositive than hydrogen, acquire positive oxidation state (+1, + 2 etc.) in a metal hydride. Consequently, hydrogen acquire an oxidation state of –1.

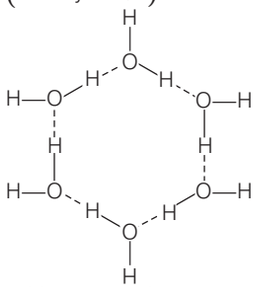
14 Metal hydrides are stronger reducing agents than non-metal hydrides. Thus, H_2O is a weaker reducing agent and NaH due to more electropositive nature of Na is strongest reducing agent among the given. Thus, the correct order is

$$H_2O < MgH_2 < NaH$$

15 Water is a polar covalent compound. Polarity in water arises due to the presence of highly electronegative oxygen atom and fairly less electronegative hydrogen atoms.

16 Critical temperature of water is more than O_2 due to its dipole moment (dipole moment of water = 1.84 D; dipole moment of O_2 = 0 D)

17 In ice molecules of H_2O are not packed so closely as in liquid water. There exists vacant spaces in the crystal lattice. This results in larger volume and lower density (density = m/V)



Hexagonal honey comb structure of ice

18 Presence of Ca^{2+} and HCO_3^- ions is the main reason of temporary hardness of water. Presence of sulphates (SO_4^{2-}) and chlorides (Cl^-) of calcium and magnesium causes permanent hardness.

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

20 Both (A) and (R) are false.

Hard water has limited use in daily life. Though it is potable (provided it is free from any harmful contamination) but it can not be used for washing clothes where it results is wastage of soap. It should also be avoided from being used is boiler as it forms a layer of insoluble salt inside the boiler and affect the efficiency of the boiler.

21 Due to having slightly heavier mass than normal water, the heavy water freezes at a higher freezing point (3.8°C).

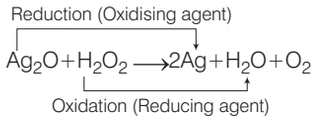
22 In a nuclear reactor, heavy water can be used as both moderator (by trapping neutrons) and coolant (by trapping heat).

23 30.3% by volume (also called 100 volume) hydrogen peroxide is known as perhydrol. It is used as an antiseptic agent.

24 Hydrogen peroxide can be reduced by lead sulphide as per the following reaction

$$\underset{\text{O.S of O}=-1}{4H_2O_2} + PbS \rightarrow PbSO_4 + \underset{\text{O.S of O}=-2}{4H_2O}$$

25

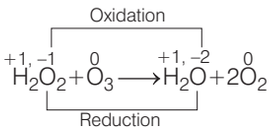


It means H_2O_2 is acting as reducing agent and Ag_2O is acting as oxidising agent.

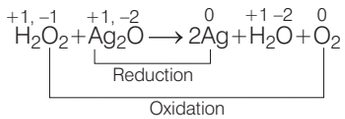
26 Both assertion and reason are correct and the reason is the correct explanation for the assertion.

$$\underset{\text{O·S of O}=-1}{H_2O_2} \xrightarrow{\Delta} \underset{\text{O·S of O}=-2}{H_2O} + \underset{\text{O·S of O}=0}{O_2}$$

27 In the reaction,

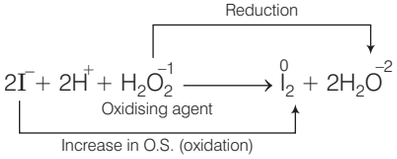


Since, H_2O_2 reduce to H_2O, i.e. from (–) 1 to (–) 2, thus, it behaves as an oxidising agent. Further, in the reaction,

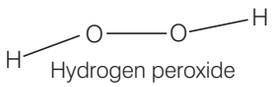


Here, H_2O_2 reduces Ag_2O into metallic silver [Ag] (as oxidation number is reducing from +1 to 0). Thus, H_2O_2 behaves as a reducing agent.

28 The reaction in which H_2O_2 is reduced, i.e. oxidation state of oxygen decreases from –1 to –2 depicts the oxidising nature of H_2O_2, e.g.

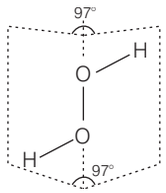


29 (c) In the structure of H_2O_2, the two O—H bonds are in different planes due to the repulsion between different bonding and antibonding orbitals.



Hydrogen peroxide

30 (b) The structure of H_2O_2 molecule resembles to an open book where the O—O bond is at the spine of the book, while the two H-atoms are on different (opposite) sides of the spine



The angle between the two pages (or planes) of the book is 97°.

SESSION 2

1 Isotopic properties of hydrogen depends on molar mass of the elements i.e.,

Molar mass $\propto$ B· P

$\propto$ B· E

$\propto$ Order of reactivity

(i) Molar mass of P_2 (i.e. protium) is one, because has one proton only.

(ii) Molar mass of D_2 (i.e. Deutirium) is 2 [$\because$ has one proton + one neutron]

(iii) Molar mass of T_3 (i.e. Tritium) is three ($\because$ has one proton and two neutron)

Therefore, correct order is

$$T_2 > D_2 > P_2$$

Since, bond length (B.L.) does not depends on number of neutron in the nucleus

$$\therefore \quad T_2 = D_2 = P_2$$

Hence, (b) is the correct option.

2 The mixture of CO and H_2 is called water gas as this mixture of CO and H_2 is used for the synthesis of methanol and a number of hydrocarbons, it is also called synthesis gas or 'syn' gas.

3 Negative ions which are capable to donate lone pair of electron are called bases.

(a) H^- is stronger base due to its smaller size than of OH^- thus its conjugate is a weak acid i.e.

$$H^- + H_2O \longrightarrow OH^- + H_2(g)$$

Hence, option (c) is the correct option.

4 Among the given reactions, in reaction (d) H_2O_2 act as an reducing agent because it oxidises Cl_2 (O.N = 0) to Cl^- [O.N = –1]

While oxygen of H_2O_2 it self oxidised from – to zero.

5 Ionic character increases with the size of the cation as we move down the group.

6 Sodium zeolite removes Ca^{2+} and Mg^{2+} ion from from hard water.

$$Na_2Z + M^{2+} \longrightarrow MZ + 2Na^+$$

(M = Cr, Mg)

where, $Z = Al_2Si_2O_8H_2O$

7 H_2SO_4 acts as a catalyst for decomposition of H_2O_2. Therefore, some weaker acids such as H_3PO_4. H_2CO_3 is preferred over H_2SO_4 for prepairing H_2O_2 from peroxides.

$$3BaO_2 + 2H_3PO_4 \longrightarrow \underset{\text{Insoluble}}{Ba_3(PO_4)_2} + 3H_2O_2$$

8 From the given option (d) shows oxidising property of H_2O_2.

$$2KI + H_2SO_4 + H_2O_2 \longrightarrow K_2SO_4 + I_2 + 2H_2O$$

In this reaction oxidation of Iodide into Iodine takes place.

9 Hydrogen can be produced by the reaction of calicum hydride and calcium with water.

$$CaH_2 + 2H_2O \longrightarrow Ca(OH)_2 + 2H_2\uparrow$$

$$Ca + 2H_2O \longrightarrow Ca(OH)_2 + H_2\uparrow$$

10 CO is oxidised to CO_2 with steam in the presence of a catalyst followed by the absorption of CO_2 in alkali.

$$CO + H_2 \xrightarrow[\text{Cetalyst}]{\text{Steam}} CO_2 + 2H_2$$

$$\downarrow \text{KOH}$$

$$K_2CO_3$$

11
- For ionic salts, hydrogen never behaves as cation, but behaves as anion ((H^-).
- H_3O^+ exists freely in solution.
- Dihydrogen acts as a reducing agent.
- Hydrogen has three isotopes.

Protium ($_1^1H$) Deuterium ($_1^2H$)

Tritium ($_1^3H$)

Protium is the most common isotopes of hydrogen with an abundance of 99.98%.