CHAPTER > 09

Hydrogen

KEY NOTES

- Hydrogen, the most abundant element in the universe and the third most abundant on the surface of the globe.
- Hydrogen is the **lightest element.**

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.

Dihydrogen, H_2

- **Occurrence** Dihydrogen (H_2) is the most abundant element in the universe (70% of total mass of universe) and is also the main element present in the solar atmosphere.
- **Isotopes** Hydrogen has three isotopes, namely **protium** (^1_1H), **deuterium** (D of ^2_1H) and **tritium** (T of ^3_1H). Tritium is radioactive in nature and emits low energy β-particles.

Name	Symbol	Atomic number	Relative atomic mass	Density	Relative abundance	Nature
Protium	^1_1H or H	1	1.0078	0.09	99.98%	Non-radioactive
Deuterium	^2_1H or D	1	2.0141	0.18	0.0156%	Non-radioactive
Tritium	^3_1H or T	1	3.016	0.27	10^{-15}%	Radioactive (emits β-rays, $t_{1/2}$ = 12.33 years)

Preparation of Dihydrogen

Laboratory Preparation

It is usually prepared by the reaction of granulated zinc with dilute hydrochloric acid or by the reaction of zinc with aqueous alkali .

$$Zn + 2H^+ \longrightarrow Zn^{2+} + H_2 \uparrow$$

$$Zn + 2NaOH \longrightarrow \underset{\text{Sodium zincate}}{Na_2ZnO_2} + H_2 \uparrow$$

Commercial Production

- It is produced by following methods :
  - **Electrolysis of acidified water** using platinum electrodes.

$$2H_2O(l) \xrightarrow[\text{Traces of acid/base}]{\text{Electrolysis}} 2H_2(g) + O_2(g)$$

  - High purity dihydrogen is obtained by electrolysing warm aqueous barium hydroxide $Ba(OH_2)$, solution between nickel electrodes.
  - **Reaction of steam on hydrocarbons** or coke at high temperature in the presence of catalyst yields hydrogen.

$$CH_4(g) + H_2O(g) \xrightarrow[Ni]{1270\ K} \underbrace{CO(g) + 3H_2(g)}_{\text{Water gas or } syn \text{ gas}}$$

  The mixture of CO and H_2 is also called synthesis gas or ***syn* gas.**

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

- **Coal Gasification** The mixture of CO and H_2 is also called *syn* gas, as it is used in synthesis of methanol and other hydrocarbons.

  The production of H_2 can be increased by water gas shift reaction by reacting carbon monoxide of *syn* gas mixture with steam in presence of iron chromate as catalyst.

$$CO\ (g) + H_2O\ (g) \xrightarrow[Fe_2CrO_3]{673\ K} CO_2(g) + H_2(g)$$

- It is also obtained as a by-product by the **electrolysis of brine**.

Properties of Dihydrogen

Physical Properties

- Dihydrogen is a colourless, odourless, tasteless and combustible gas.
- It is lighter than air and insoluble in water.
- It is neutral to litmus.

Chemical Properties

The important chemical reactions of dihydrogen are :

$$H_2(g) + X_2(g) \longrightarrow 2HX(g); \quad (X = F,\ Cl,\ Br \text{ and } I)$$

$$2H_2(g) + O_2(g) \xrightarrow{\Delta} 2H_2O(l)$$

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

$$H_2(g) + 2M(g) \longrightarrow 2MH(s); \quad (M = \text{alkali metal})$$

$$H_2(g) + Pd^{2+}(aq) \longrightarrow Pd(s) + 2H^+(aq)$$

$$yH_2(g) + M_xO_y(s) \longrightarrow xM(s) + yH_2O(l)$$

- Hydroformylation of olefins yields aldehydes which further undergo reduction to give alcohols.

$$H_2 + CO + RCH{=}CH_2 \longrightarrow RCH_2CH_2CHO \xrightarrow{H_2} RCH_2CH_2CH_2OH$$

Uses of Dihydrogen

- Dihydrogen is used in the synthesis of ammonia which is used in the manufacture of nitric acid and nitrogenous fertilisers.
- It is used in the manufacture of vanaspati ghee by the hydrogenation of polyunsaturated vegetable oils like soyabean, cotton, seeds, etc.
- It is used as a rocket fuel in space research.

Hydrides

- Dihydrogen combines with almost all the elements to form hydrides.
- Hydrides can be classified into three categories as follows :

Ionic or Saline Hydrides

- Ionic hydrides are formed by *s*-block elements.
- They are crystalline, non-volatile and non-conducting in solid state.

Covalent or Molecular Hydrides

- Covalent hydrides are formed by *p*-block elements.
- They are covalent, volatile and non-conductors.
- They are further classified as electron-deficient (group-13), electron-precise (group-14) and electron-rich (group 15-17) hydrides.

Metallic or Non-stoichiometric (or Interstitial) Hydrides

- Hydrides are formed by *d*-block or *f*-block elements.
- They conduct heat and electricity and are mostly non-stoichiometric (e.g. $LaH_{2.87}$, $YbH_{2.55}$).
- They are useful for ultrapurification of dihydrogen and as dihydrogen storage media.

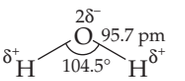
Note *The metals of group* 7, 8 *and* 9 *do not form hydride. Even from group* 6, *only chromium forms* CrH.

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.
- We can survive without food but survival in absence of water is almost impossible.
- It constitutes a major part of all the living organism, e.g. it forms about 65% of human body and almost 95% of some plants.

Physical Properties

- Water is a transparent colourless, tasteless and odourless substance.
- Its freezing point, boiling point, heat of vaporisation and heat of fusion is higher than hydrides of other group 16 elements.
- It has a high specific heat, thermal conductivity, surface tension, dipole moment and dielectric constant than many other liquids.
- Water molecule is highly polar in nature due to its bent structure. This property leads to hydrogen bonding which is maximum in ice and least in water vapours.



- Density of ice is less than that of water.

Structure of Ice

- Ice has a highly ordered three dimensional hydrogen bonded structure.
- Each oxygen atom is surrounded tetrahedrally by four other oxygen atoms.
- Hydrogen bonding gives ice a rather open type structure with wide holes which can hold small molecules interstitially.

Chemical Properties

- Water (H_2O) has the ability to act as an acid as well as a base, i.e. amphoteric substance.

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

$$\underset{\text{Acid}}{H_2O(l)} + \underset{\text{Base}}{NH_3(aq)} \rightleftharpoons \underset{\text{Acid}}{NH_4^+(aq)} + \underset{\text{Base}}{\bar{O}H(aq)}$$

The auto-protolysis of water takes place as follows :

$$\underset{\substack{\text{Acid-1}\\(\text{acid})}}{H_2O(l)} + \underset{\substack{\text{Base-2}\\(\text{base})}}{H_2O(l)} \rightleftharpoons \underset{\substack{\text{Acid-2}\\(\text{conjugate acid})}}{H_3O^+(aq)} + \underset{\substack{\text{Base-1}\\(\text{conjugate base})}}{OH^-(aq)}$$

- In redox reactions, water reacts with both metals and non-metals.

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

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

- 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.

Hard and Soft Water

Water forming lather with soap is called **soft water** and water that does not do so is called **hard water**.

The hardness of water may be of two types :

Temporary Hardness

- It is due to the presence of calcium and magnesium bicarbonates.
- Temporary hardness of water can be removed by **Clark's method** (by treating hard water with lime) or by **simply boiling** which converts $Mg(HCO_3)_2$ into insoluble $Mg(OH)_2$ and $Ca(HCO_3)_2$ changed to insoluble $CaCO_3$.

Permanent Hardness

- It is due to the presence of soluble salt of Ca and Mg in the form of chlorides and sulphates in water.
- Permanent hardness can be removed :
  - **By treatment with washing soda** $Na_2CO_3 \cdot 10H_2O$ which converts Ca^{2+} and Mg^{2+} bicarbonates into insoluble carbonates.
  - **By Calgon's method** (treatment with sodium hexametaphosphate, $Na_2[Na_4(PO_3)_6]$ that forms soluble complex).
  - **By ion-exchange method** in which $NaAlSiO_4$ (zeolite) is used which replaces Ca^{2+} / Mg^{2+} ions by Na^+.
  - **By synthetic raisin method** in which pure de-mineralised (de ionised) water free from all soluble mineral salts is obtained by passing water successively through a cation exchange (in the H^+ form) and an anion exchange (in the OH^- form) resins.

Degree of Hardness

Degree of hardness of water is measured in ppm by weight of $CaCO_3$ irrespective of its presence and is estimated by simple titration of EDTA solution.

Hydrogen Peroxide, H_2O_2

It is an important compound used in pollution control treatment of domestic and industrial effluents.

Preparation

- It can be manufactured by acidifying barium peroxide and removing excess water by evaporation under reduced pressure.

  $BaO_2 \cdot 8H_2O + H_2SO_4 \longrightarrow BaSO_4 + H_2O_2 + 8H_2O$
- The electrolysis of 50% H_2SO_4 or by the auto-oxidation of 2-alkyl anthraquinols.

  At anode :

  $$2HSO_4^- \longrightarrow HO_3SOOSO_3H + 2e^-$$

  $$\xrightarrow{\text{Hydrolysis}} H_2SO_4 + H_2O_2$$

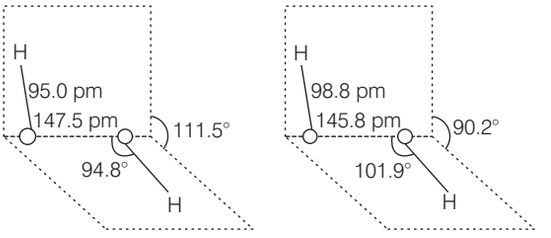
Physical Properties

H_2O_2 is a colourless liquid and miscible with water. **'20 volume H_2O_2'** means 2 mL of this solution on decomposition liberates 20 mL of oxygen at NTP.

Structure

H_2O_2 has a non-polar structure.

- In structure of H_2O_2, two O—H bonds are in different planes due to repulsion between bonding and antibonding orbitals.
- Bond angle H—O—O—H is 111.5° in gas phase and 90.2° in solid phase.



Structure of H_2O_2

(a) Gas phase (b) Solid phase

Chemical Properties

- **Oxidising agent** It acts as a strong oxidising agent in acidic as well as in basic medium.

  $$H_2O_2 + 2H^+ + 2e^- \longrightarrow 2H_2O$$

  $$H_2O_2 + OH^- + 2e^- \longrightarrow 3OH^-$$

- **Reducing agent**
  - In acidic medium,

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

    $$Cr_2O_7^{2-} + 8H^+ + 3H_2O_2 \longrightarrow 2Cr^{3+} + 7H_2O + 3O_2$$
  - In basic medium,

    $$2K_3[Fe(CN)_6] + 2KOH + H_2O_2 \longrightarrow 2K_4[Fe(CN)_6] + 2H_2O + O_2$$
  - **Bleaching properties** Its bleaching action is due to oxidation by atomic oxygen.

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

    dye + [O] ⟶ dye is oxidised and bleached

Storage

- H_2O_2 decomposes slowly on exposure to light.
- In the presence of metal surface or traces of alkali, its decomposition reaction is catalysed.

  Therefore, it is stored in a wax-lined glass or plastic vessel in dark.

KEY NOTES

Uses

- 30% solution of H_2O_2 is called **perhydrol** and is used as germicide and antiseptic. In daily life, it is used as a hair bleach.
- It is important chemical used in pollution control treatment of domestic and industrial effluents.
- It is used in manufacture chemicals like sodium perborate and per carbonate, in the industries as a bleaching agent for textiles, leather, etc.
- Now-a-days, it is also used in Environmental (Green) chemistry.

Heavy Water, D_2O

- Heavy water (D_2O) can be prepared by exhaustive electrolysis of water or as a by-product in some fertilizer industries.
- It is used for the preparation of other deuterium compounds

Dihydrogen As a Fuel

Dihydrogen reacts with oxygen releasing large amount heat energy and thus can be utilised as a fuel in rocket engines and fuel cells. Motor vehicle engines that can use hydrogen as fuel are also under development.

Hydrogen Economy

It is the use of liquid hydrogen as an alternate source of energy. Hydrogen fuel has many advantages over conventional fuels as it is non-polluting and liberates large amount of energy on combustion.

Mastering NCERT

MULTIPLE CHOICE QUESTIONS

TOPIC 1 ~ *Position of Hydrogen in the Periodic Table*

1 The number of proton and electron in atomic form of hydrogen respectively are
(a) 2 and 1 (b) 1 and 2
(c) 1 and 1 (d) 2 and 2

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 Hydrogen does not possess the metallic character under normal conditions because
(a) it has very low ionisation enthalpy
(b) it has very low electron gain enthalpy
(c) it has very high electron gain enthalpy
(d) it has very high ionisation enthalpy

4 Which of the following explanation justifies for not placing hydrogen in either the group of alkali metals or halogens?
(a) The ionisation energy of the hydrogen is too high for placing it in the group of alkali metals and too low for the halogens containing group
(b) Hydrogen atom does not contain any neutron
(c) Hydrogen is much lighter than the alkali metals or halogens
(d) Hydrogen can form compounds with almost all other elements

TOPIC 2 ~ *Dihydrogen (H_2) and its Preparation*

5 Hydrogen is much less abundant in the earth's atmosphere because of its
(a) low enthalpy of fusion
(b) low enthalpy of vaporisation
(c) light nature
(d) All of the above

6 The isotopes of hydrogen are ***JEE Main 2019***
(a) deuterium and tritium
(b) protium and deuterium
(c) protium, deuterium and tritium
(d) tritium and protium

7 Most common isotope of hydrogen (non-radioactive) is ***JIPMER 2019***

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

8 Hydrogen has three isotopes (A), (B) and (C). If the number of neutron(s) in (A), (B) and (C) respectively, are (x), (y) and (z), the sum of (x), (y) and (z) is ***JEE Main 2020***

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

9 Which of the following isotope of hydrogen is radioactive?

(a) Protium
(b) Deuterium
(c) Tritium
(d) *Ortho* and *para* hydrogens

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

(a) 2 (b) 1 (c) 3 (d) 0

11 The isotopes of hydrogen have the same electronic configurations and chemical properties. The only difference is in their rate of reaction. It is mainly due to their different

(a) enthalpy of fusion (b) enthalpy of vaporisation
(c) bond dissociation enthalpy (d) atomic mass

12 Which of the following metal and acid are used to prepare dihydrogen respectively?

(a) Crystalline zinc with dil. HCl
(b) Granulated zinc with dil. HCl
(c) Granulated zinc with conc. HCl
(d) Crystalline zinc with conc. HCl

13 Dihydrogen is prepared by the reaction of Zn with (aq) NaOH. Which of the following compounds is produced with dihydrogen during the course of reaction?

(a) Zinc oxide (b) Zinc hydroxide
(c) Sodium zincate (d) None of these

14 Dihydrogen is not obtained when zinc reacts with

(a) cold water (b) hot NaOH solution
(c) dil. H_2SO_4 (d) dil. HCl

15 Which of the following is the laboratory preparation of dihydrogen?

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

(b) $2Na + 2H_2O \longrightarrow 2NaOH + H_2$

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

(d) All of the above

16 Which of the following gas is/are obtained by electrolysis of acidified water using platinum electrodes?

(a) H_2 (b) O_2 (c) N_2 (d) H_2 and O_2

17 Which of the following methods is used to obtain high purity (> 99.95%) dihydrogen?

(a) Electrolysing (aq) barium hydroxide solution between nickel electrodes
(b) Electrolysing (aq) NaOH solution between nickel electrodes
(c) Electrolysing (aq) barium hydroxide solution between platinum electrodes
(d) Electrolysing (aq) NaOH solution between platinum electrodes

18 Dihydrogen is obtained as a byproduct in the manufacture of

(a) sodium hydroxide and bromine by electrolysis
(b) potassium hydroxide and bromine by electrolysis
(c) sodium hydroxide and chlorine by electrolysis
(d) potassium hydroxide and chlorine by electrolysis

19 The major components of water gas (or synthesis gas or *syn* gas) which is used for the synthesis of methanol and a number of hydrocarbons are

(a) $CO_2 + H_2$
(b) $CO + H_2$
(c) $CO + N_2$
(d) $CO + CO_2 + H_2$

20 The process of producing *syn* gas from coal is called

(a) water gas shift
(b) coal gasification
(c) synthesis gas shift
(d) carbonisation

21 Consider the reaction given below.

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

The above reaction is called

(a) water gas reaction
(b) water gas shift reaction
(c) gasoline reaction
(d) coal gasification reaction

22 In context with the industrial preparation of hydrogen from water gas

(a) CO and H_2 are fractionally separated using difference in their densities
(b) CO is removed by absorption in aq. Cu_2Cl_2 solution
(c) H_2 is removed through occlusion with Pd
(d) CO is oxidised to CO_2 with steam in the presence of a catalyst followed by absorption of CO_2 in alkali

23 The maximum percentage of the industrial dihydrogen is produced from

(a) petrochemicals
(b) coal
(c) electrolysis of aqueous solution of salts
(d) other sources except these

TOPIC 3 ~ *Properties of Dihydrogen*

24 The chemical behaviour and relative inertness of dihydrogen at room temperature depends upon
(a) H—H bond dissociation enthalpy
(b) ionisation enthalpy
(c) enthalpy of fusion
(d) enthalpy of vaporisation

25 Which of the following is a physical property of dihydrogen?
(a) Coloured (b) Sweet smelling
(c) Bitter taste (d) Combustible

26 The chemical reactions of dihydrogen is accomplished by the
(a) loss of an electron to give H^+
(b) gain of an electron to form H^-
(c) sharing electrons to form a single covalent bond
(d) All of the above

27 Consider the following reaction,

$$H_2(g) + X_2(g) \longrightarrow 2HX(g)$$

where, X = F, Cl, Br and I.

The order of reactivity of X_2 towards hydrogen is
(a) $F_2 > Cl_2 > Br_2 > I_2$ (b) $Cl_2 > Br_2 > F_2 > I_2$
(c) $I_2 > Br_2 > Cl_2 > F_2$ (d) $I_2 > Cl_2 > F_2 > Br_2$

28 Reaction of dihydrogen with dioxygen is an exothermic reaction. The product(s) formed in this reaction is/are
(a) $H_2O + O_2$ (b) H_2O_2 (c) H_2O (d) $H_2O + H_2$

29 Which of the following reactions represents Haber's process?
(a) $2H_2(g) + O_2(g) \xrightarrow{\text{Catalyst}} 2H_2O(l)$;
$\Delta H^\circ = -285.9\ \text{kJ mol}^{-1}$
(b) $3H_2(g) + N_2(g) \xrightarrow[\text{Fe}]{673\ \text{K}, 200\ \text{atm}} 2NH_3(g)$;
$\Delta H^\circ = -92.6\ \text{kJ mol}^{-1}$
(c) $H_2(g) + I_2(g) \longrightarrow 2HI(g)$
(d) $H_2(g) + Pd^{2+}(aq) \longrightarrow Pd(s) + 2H^+(aq)$

30 Which of the following reactions is correct for reduction of metal ions or metal oxides to their corresponding metal atoms?
(where, M = metals less reactive than Fe)
(a) $H_2(g) + Pd^{2+}(aq) \longrightarrow Pd(s) + 2H^+(aq)$
(b) $yH_2(g) + M_xO_y(s) \longrightarrow xM(s) + xH_2O(l)$
(c) $yH_2(g) + M_xO_y(s) \longrightarrow yM(s) + yH_2O(l)$
(d) $H_2(g) + Pd^{2+}(aq) \longrightarrow Pd^+(aq) + H^+ + \frac{1}{2}H_2$

31 Hydrogenation of vegetable oils using nickel as a catalyst gives edible fat which is
(a) coconut oil
(b) soyabean oil
(c) margarine and vanaspati ghee
(d) peanut oil

32 $H_2 + CO + R\text{CH}{=}{=}CH_2 \longrightarrow X \xrightarrow{H_2} Y$

What are X and Y in the above reaction?
(a) $R\text{CH}_2\text{CH}_2\text{CHO}$ and $R\text{CH}_2\,\text{CH}_2\,\text{CH}_2\text{OH}$
(b) $R\text{CH}_2\text{CH}_2\text{CHO}$ and $R\text{CH}_2\text{CH}_2\text{OH}$
(c) $R\text{CH}_2\text{CH}_2\text{CHO}$ and $R\text{CH}_2\text{CH}_2\text{COOH}$
(d) $R\text{CH}_2\text{CH}_2\text{OH}$ and $R\text{CH}_2\text{CH}_2\text{COOH}$

33 $CO(g) + H_2(g) \xrightarrow{\text{Cobalt catalyst}}$ product. Identify the product formed in the given reaction.
(a) CH_3COOH (b) CO_2
(c) H_2O (d) CH_3OH

34 The major component of rocket fuel used in the space research is
(a) dihydrogen (b) dioxygen
(c) dinitrogen (d) None of these

35 The gas used in the fuel cells for generating the electrical energy which has many advantages over the conventional fossil fuels and electric power is
(a) Cl_2 (b) He (c) N_2 (d) H_2

TOPIC 4 ~ *Hydrides*

36 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

37 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

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

39 Ionic hydrides react with water to give
(a) acidic solutions (b) hydride ions
(c) basic solutions (d) None of these

40 Which of the following is covalent and polymeric in structure?
(a) LiH (b) BeH_2
(c) MgH_2 (d) Both (b) and (c)

41 Which of the following reactions is incorrect?
(a) $8\,LiH + Al_2Cl_6 \longrightarrow 2\,LiAlH_4 + 6\,LiCl$
(b) $2\,LiH + B_2H_6 \longrightarrow 2\,LiBH_4$
(c) $2\,LiH + Al_2Cl_6 \longrightarrow LiCl + LiH + LiAlH_4$
(d) $NaH(s) + H_2O \longrightarrow NaOH(aq) + H_2(g)$

42 NaH is an example of ***JEE Main 2019***
(a) metallic hydride (b) electron-rich hydride
(c) saline hydride (d) molecular hydride

43 Which of the following groups form electron rich hydrides?
(a) Chalcogens (b) Alkali metals
(c) Noble gases (d) Alkaline earth metals

44 CH_4, NH_3, H_2O and HF are the examples of
(a) molecular hydrides (b) metallic hydrides
(c) ionic hydrides (d) Both (a) and (c)

45 Which of the following are formed by *d*-block elements?
(a) Ionic hydrides (b) Non-stoichiometric hydrides
(c) Molecular hydrides (d) Covalent hydrides

46 Which of the following is the example of interstitial or non-stoichiometric hydrides?
(a) $LaH_{2.87}$, $YbH_{2.55}$
(b) $TiH_{1.5-1.8}$, $ZrH_{1.3-1.75}$
(c) $VH_{0.56}$, $NiH_{0.6-0.7}$, $PdH_{0.6-0.8}$
(d) All of the above

47 Earlier, it was thought that in the non-stoichiometric hydrides, hydrogen occupies interstices in the metal lattice producing distortion without any change in its type. Consequently, they were termed as
(a) interstitial hydrides (b) molecular hydrides
(c) ionic hydrides (d) None of these

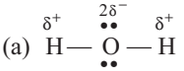
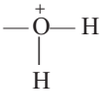
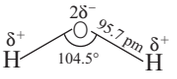
48 Recent studies show that the metallic hydrides have different lattice from that of the parent metal except
(a) Cu (b) Pt
(c) K (d) Ac

49 Some of the metals (e.g. Pd, Pt) can accommodate a very large volume of hydrogen and therefore, can be used as its storage media. This property has high potential for
(a) oxidation and hydrogenation reaction
(b) hydrogenation reaction and reduction
(c) hydrogen storage and source of energy
(d) source of energy and oxygen storage

50 Phosphorus(P) with outer electronic configuration $3s^2 3p^3$ does not form PH_5 because
(a) $\Delta_a H$ value of dihydrogen does not favour to exhibit the lower oxidation state of P
(b) $\Delta_{e_g} H$ value of hydrogen does not favour to exhibit the lower oxidation state of P
(c) P does not exhibit +3 and +5 oxidation states
(d) P is not very reactive

TOPIC 5 ~ *Water*

51 Temperature of maximum density of H_2O and D_2O is respectively
(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

52 Identify the structure of water in the gaseous phase.
(a) 
(b) 
(c) 

(d) None of these

53 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

54 The maximum number of hydrogen bonds formed by a water molecule in ice is
(a) 4 (b) 1
(c) 2 (d) 3

55 $\underset{\text{Acid-1 (Acid)}}{H_2O(l)} + \underset{\text{Base-2 (Base)}}{H_2O(l)} \longrightarrow \underset{\text{Acid-2 (Conjugate acid)}}{H_3O^+(aq)} + \underset{\text{Base-1 (Conjugate base)}}{OH^-(aq)}$

The above reaction is known as
(a) auto-protolysis of water
(b) self-ionisation of water
(c) hydration of water
(d) Both (a) and (b)

56 In which of the following reactions H_2O acts only as a Bronsted acid?

(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

57 Consider the reaction given below :

$$2F_2 + 2H_2O \longrightarrow 4H^+ + 4F^- + O_2$$

In the above reaction, water acts as a/an
(a) oxidising agent
(b) reducing agent
(c) oxidant
(d) None of the above

58 Which of the following is the incorrect reaction?

(a) $P_4O_{10}(s) + 6H_2O(l) \longrightarrow 4H_3PO_4(aq)$

(b) $SiCl_2(s) + 2H_2O(l) \longrightarrow SiO_2(s) + 4HCl(aq)$

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

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

59 How many coordinated water molecules are associated in $Cr(H_2O)_6Cl_3$?
(a) 6 (b) 5
(c) 4 (d) 0

60 What is reason of temporary hardness of water?
(a) Na_2SO_4 (b) $CaCl_2$ ***JEE Main 2019***
(c) NaCl (d) $Ca(HCO_3)_2$

61 The method used to remove temporary hardness of water is ***NEET (National) 2019***
(a) Clark's method (b) ion-exchange method
(c) synthetic resins method (d) Calgon's method

62 A water sample is said to contain permanent hardness if water contains
(a) sulphates and chlorides of calcium and magnesium
(b) carbonates of calcium and magnesium
(c) bicarbonates of calcium and magnesium
(d) sulphates and chlorides of sodium and potassium

63 Calgon is used as water softening agent because it
(a) forms soluble complexes with cationic species
(b) forms soluble complexes with anionic species
(c) forms soluble complexes with both cationic and anionic species
(d) forms precipitate with cationic species

64 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

65 In comparison to the Zeolite process for the removal of permanent hardness, the synthetic resins method is ***JEE Main 2020***
(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

66 In synthetic resin method, X resins contain large organic molecule with $—SO_3H$ group and are water insoluble. Ion exchange resin (RSO_3H) is changed to RNa by treating it with NaCl.

The resin exchanges Y ions with Ca^{2+} and Mg^{2+} ions present in the hard water to make the water soft. Here, X and Y respectively are

	X	Y
(a)	anion exchange resin	Na^+
(b)	cation exchange resin	Na^+
(c)	cation exchange resin	Cl^-
(d)	anion exchange resin	Cl^-

67 Which of the following reaction represents anion exchange process?

(a) $2RNa(s) + M^{2+}(aq) \longrightarrow R_2M(s) + 2Na^+(aq)$

(b) $Ca(HCO_3)_2 \longrightarrow CaCO_3\downarrow + H_2O + CO_2\uparrow$

(c) $MSO_4 + Na_2CO_3 \longrightarrow MCO_3\downarrow + Na_2SO_4$ $(M = Mg, Ca)$

(d) $RNH_2(s) + H_2O(l) \longrightarrow RNH_3^+OH^-(s)$
$\downarrow X^-(aq)$
$RNH_3^+ \cdot X^-(s) + OH^-(aq)$

TOPIC 6 ~ *Hydrogen Peroxide (H_2O_2)*

68 Which of the following is the industrial method of preparation of H_2O_2?

(a) $BaO_2 \cdot 8H_2O(s) + H_2SO_4(aq) \longrightarrow BaSO_4(s) + H_2O_2(aq) + 8H_2O(l)$

(b) $2HSO_4^-(aq) \xrightarrow{\text{Electrolysis}} HO_3SOOSO_3H(aq) \xrightarrow{\text{Hydrolysis}} 2HSO_4^-(aq) + 2H^+(aq) + H_2O_2(aq)$

(c) $K_2S_2O_8(s) + 2H_2O(l) \longrightarrow 2KHSO_4(aq) + H_2O_2(l)$

(d) 2-ethyl anthraquinol $\underset{H_2/Pd}{\overset{O_2\ (air)}{\rightleftharpoons}} H_2O_2$ + (oxidised product)

69 Which of the following is true for the electrolytic preparation of H_2O_2

(a) lead is used as anode
(b) 80% H_2SO_4 is used
(c) hydrogen is liberated at anode
(d) sulphuric acid undergoes oxidation

70 H_2O_2 is obtained by which of the following? ***AIIMS 2019***

(a) BaO_2 (b) MnO_2
(c) SeO_2 (d) TeO_2

71 Which of the following is almost colourless (very pale blue) liquid in its pure state?

(a) D_2O (b) H_2O_2
(c) H_2O (d) H_3O^+

72 30% solution of H_2O_2 is marketed as X volume hydrogen peroxide. It means that one millilitre of 30% H_2O_2 solution will give Y volume of oxygen at STP. Here, X and Y respectively are

(a) 10 V and 100 mL
(b) 100 mL and 10 V
(c) 100 V and 100 mL
(d) 10 V and 50 mL

73 The strength of 10 volume solution of hydrogen peroxide is

(a) 3.036 g L^{-1} (b) 30.36 g L^{-1}
(c) 300.36 g L^{-1} (d) 33.36 g L^{-1}

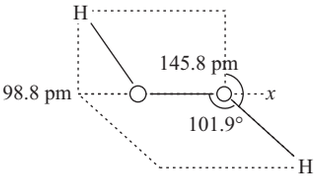
74 What is the volume of oxygen liberated at NTP from 15 mL of 20 volume H_2O_2?

(a) 350 mL (b) 300 mL (c) 250 mL (d) 200 mL

75 Which of the following is true for 6 volumes sample of H_2O_2?

(a) It gives 6 volumes of oxygen per unit volume of H_2O_2 sample at STP
(b) It contains 6% V/V of H_2O_2
(c) It contains 6% w/V of H_2O_2
(d) It gives 6 volumes of oxygen per unit mass of H_2O_2 sample at STP

76 Consider the figure given below :



The value of x in the above figure is

(a) 90.2° (b) 111.5° (c) 80.6° (d) 120°

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

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

78 Moist hydrogen peroxide cannot be dried over conc. H_2SO_4 because

(a) it can catch fire
(b) it is reduced by H_2SO_4
(c) it is oxidised by H_2SO_4
(d) it is decomposed by H_2SO_4

79 I. $H_2O_2 + O_3 \longrightarrow H_2O + 2O_2$

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

What is the role of hydrogen peroxide in the above reactions? ***CBSE AIPMT 2014***

(a) Oxidising in I and reducing in II
(b) Reducing in I and oxidising in II
(c) Reducing in I and II
(d) Oxidising in I and II

80 Which of the following reactions will show the reducing action of H_2O_2 in basic medium?

(a) $2Fe^{2+} + H_2O_2 \longrightarrow 2Fe^{3+} + 2OH^-$

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

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

(d) All of the above

81 H_2O_2 decomposes slowly on exposure to light

$$2H_2O_2(l) \xrightarrow{\text{Catalyst}} 2H_2O(l) + O_2(g)$$

The catalyst in the above reaction is

(a) metal surfaces or traces of alkali
(b) sodium, zinc, platinum
(c) Pt, Pd, Na and K
(d) None of the above

82 Which of the following acts as a stabiliser for the storage of H_2O_2?
(a) Urea (b) Ammonia
(c) Potassium permanganate (d) Water

83 Hydrogen peroxide (H_2O_2) is kept away from dust because
(a) dust can impure the compound
(b) dust can induce explosive decomposition of the compound
(c) dust can reduce explosive decomposition of the compound
(d) All of the above

84 H_2O_2 is sold in market as an antiseptic. The name of this antiseptic is
(a) hydrol
(b) perhydrol
(c) hydrogen peroxide
(d) All of the above

85 Which of the following is not a use of H_2O_2 ?
(a) In treatment of domestic effluents
(b) Restoration of aerobic conditions to sewage wastes
(c) Oxidation of cyanide
(d) In the synthesis of hydroquinone

TOPIC 7 ~ *Heavy Water (D_2O) and Dihydrogen as a Fuel*

86 Heavy water is obtained as a by-product in some fertiliser industries. It is also obtained from water by
(a) exhaustive electrolysis
(b) reduction
(c) oxidation
(d) hydrolysis

87 What is the correct representation of heavy water?
(a) $H_2^{18}O$ (b) D_2O
(c) DO_2 (d) H_2O at 4°C

88 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

89 $X + 12\ D_2O \longrightarrow Y + 4Al(OD)_3$
Here, X refers to
(a) AlC_4 (b) Al_2C
(c) AlC_2 (d) Al_4C_3

90 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

91 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

92 The pollutants present in the combustion of dihydrogen will be the oxides of dinitrogen. This can be minimised by
(a) injecting a small amount of water into the cylinder to lower the temperature
(b) injecting a small amount of hydrogen peroxide into the cylinder to lower the temperature
(c) injecting a small amount of water into the cylinder to increase the temperature
(d) injecting a small amount of hydrogen peroxide into the cylinder to decrease the temperature

93 On the mass basis, dihydrogen can release more energy than petrol. As compared to petrol, pollutant in the combustion of dihydrogen will be
(a) more (b) less
(c) equal (d) moderate

94 The metal alloy of tank which is used for the storage of dihydrogen contains which of the following compounds in small quantities ?
(a) NaH and B_2H_6
(b) $NaNi_5$ and TiH_2
(c) LiH, NaH and CH_4
(d) $NaNi_5$, Ti-TiH_2 and Mg-MgH_2

95 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

96 Which of the following fuel is used for running the automobiles first time in the history of India during October 2005?
(a) D_2O (b) H_2O_2
(c) D_2 (d) H_2

SPECIAL TYPES QUESTIONS

I. Statement Based Questions

97 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

98 Which of the following is/are correct statement(s) regarding characteristic of hydrogen?
I. Hydrogen resembles alkali metals due to the similar outer electronic configuration.
II. Hydrogen resembles halogens due to the similar outer electronic configuration.
III. Hydrogen is short by one electron to the corresponding noble gas configuration, helium.

Choose the correct option.
(a) Only I (b) Both I and III
(c) Both II and III (d) I, II and III

99 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

100 Hydrogen shows resemblance with alkali metals, as like alkali metals,
I. it forms oxides and oxyacids.
II. it forms halides and interhalides.
III. it forms oxides, halides and sulphides.

Select the correct statement(s) among the above.
(a) Both I and II (b) Only III
(c) Only I (d) Both II and III

101 Which of the following statements about hydrogen is incorrect? ***NEET 2016***
(a) Hydrogen never acts as a cation in ionic hydrides
(b) Hydronium ion, $H_3\overset{+}{O}$ exists freely in solution
(c) Dihydrogen acts as a reducing agent
(d) Hydrogen has three isotopes of which tritium is the most common

102 Which of the following statements regarding protium, deuterium and tritium is incorrect?
(a) They are isotopes of hydrogen
(b) They have similar electronic configurations
(c) They exist in the nature in the ratio of 1 : 2 : 3
(d) Their atomic masses are in the ratio of 1 : 2 : 3

103 Which of the following statement is incorrect method of commercial production of dihydrogen?
(a) Electrolysis of acidified water using platinum electrodes, gives dihydrogen
(b) High purity (>99.95%) dihydrogen is obtained by electrolysis of warm aqueous barium hydroxide solution between the nickel electrodes
(c) Dihydrogen is obtained as a by-product in the manufacture of sodium hydroxide and chlorine by the electrolysis of brine solution
(d) Reaction of cold water with hydrocarbons or coke in the presence of catalyst yields dihydrogen

104 Which of the following properties of dihydrogen is incorrect?
(a) It is colourless, odourless, tasteless
(b) It is combustible gas
(c) It is lighter than air
(d) It is soluble in water

105 Which of the following statement of hydrogen is correct ?
(a) H — H bond dissociation enthalpy is the highest for a single bond between two atoms of any element
(b) At around 2000K dissociation of H_2 into its atoms is 95.5%
(c) At around 5000K dissociation of H_2 into its atoms is 0.081%
(d) All of the above

106 Consider the following reactions :
I. $H_2(g) + X_2(g) \longrightarrow 2HX(g)\ (X = F, Cl, Br, I)$
II. $2H_2(g) + O_2(g) \xrightarrow[\text{heating}]{\text{Catalyst or}} 2H_2O(l)$
III. $3H_2(g) + N_2(g) \xrightarrow[Fe]{673\ K,\ 200\ atm} 2NH_3(g)$
IV. $H_2(g) + 2M(g) \longrightarrow 2MH(s)$ $(M = \text{alkali metal})$

The correct reactions are
(a) II, III and IV
(b) III and IV
(c) I, II and IV
(d) All of the above

107 Dihydrogen has many uses in synthesis of many compounds as,
I. It is used in manufacture of nitric acid and nitrogenous fertilisers.
II. It is used in manufacture of vanaspati fat.
III. It is used in manufacture of methanol.
IV. It is used in preparation of hydrogen chloride.

Choose the correct statements among the above.
(a) I, II and IV (b) II, III and IV
(c) I, II and III (d) I, II, III and IV

108 Which of the following statements regarding hydrides is incorrect?

(a) Ionic hydrides are crystalline, non-volatile and non-conducting in solid state
(b) Electron-deficient hydrides act as Lewis acids or electron acceptors
(c) Elements of group-13 form electron-deficient hydrides
(d) Elements of group 15-17 form electron-precise hydrides

109 Which of the following statements is incorrect?

(a) Ionic hydrides are also known as saline or salt like hydrides
(b) Covalent hydrides are also known as molecular hydrides
(c) Metallic hydrides are also known as stoichiometric hydrides
(d) None of the above

110 Which of the following statements is incorrect?

(a) Ionic hydrides are stoichiometric compounds of dihydrogen formed with most of the s-block elements
(b) A significant covalent character is found in the lighter metal hydrides
(c) BeH_2 and MgH_2 are monomeric in structure
(d) The ionic hydrides are crystalline in solid state

111 Which of the following statements is incorrect about covalent hydrides?

(a) Electron deficient hydride has too few electrons for writing its conventional Lewis structure
(b) Electron precise compounds have the required number of electrons to write their conventional Lewis structure
(c) Electron rich hydrides have excess electrons which are present as lone pairs
(d) All of the above statements are true

112 Which of the following statements is correct about the boiling points of hydrides of N, O and F?

(a) The boiling point of NH_3, H_2O and HF, are lower than those of subsequent group member hydrides
(b) Boiling point of NH_3, H_2O and HF is higher than those of subsequent group member hydrides
(c) The boiling points of hydrides of N, O and F do not follow any regular trend
(d) None of the above

113 Which of the following statements is correct?

(a) Boiling point of H_2O, NH_3, HF are maximum in their respective group due to intermolecular H-bonding
(b) Boiling point of CH_4 out of CH_4, SiH_4, GeH_4, SnH_4 is the least
(c) Formic acid forms dimer by H-bonding
(d) All of the above

114 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

115 Which of the following statement 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

116 Which one of the following statements about water 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 $CuSO_4$

117 Consider the following statements about intermolecular and intramolecular hydrogen bonding.

I. Both types of H-bonds are temperature dependent.
II. $BaCl_2 \cdot 2H_2O$ contains interstitial water.
III. Water exhibits amphoteric nature.
IV. 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, II and IV (b) Both III and IV
(c) I, III and IV (d) All of these

118 Consider the following statements regarding water.

I. There is extensive hydrogen bonding between water molecules.
II. Water has high freezing and boiling point in comparsion 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) Both I and III (d) All of these

119 Pure de-mineralised water is obtained by passing water successively through a cation exchange and an anion exchange resins.

I. In cation exchange process, H^+ exchanges for Na^+, Ca^{2+}, Mg^{2+} and other cations present in water.
II. In anion exchange process, OH^- exchanges anions like Cl^-, HCO_3^-, SO_4^{2-} present in water.
III. The exhausted cation and anion exchange resin beds cannot be regenerated.

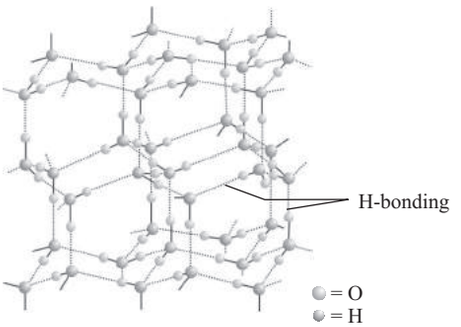
Choose the correct statements.

(a) Only I (b) Only II
(c) Both I and II (d) I, II and III

120 The correct statement about the structure of water is
(a) 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

121 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

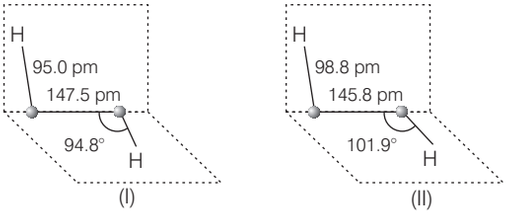
122



Choose the correct option for the above figure.
(a) Hydrogen bonding gives ice an open type structure with wide holes, which hold some other molecules of appropriate size interstitially
(b) Hydrogen bonding gives ice a closed type structure with small holes. These holes can hold some other molecules of appropriate size interstitially
(c) Hydrogen bonding gives ice a closed type structure with wide holes which cannot hold other molecules
(d) Hydrogen bonding gives ice a closed type structure with both small and wide holes which cannot hold other molecules

123 Which of the following statements is incorrect?
(a) Calgon is sodium hexametaphosphate
(b) Permutit is potassium aluminium silicate which is used as softener in ion-exchange method
(c) Synthetic resin method is more efficient than zeolite method
(d) Permutit is also known as zeolite

124 Which of the following statements in reference to the given figure is/are correct?



(a) Hydrogen peroxide has a non-planar structure
(b) I is the structure of H_2O_2 in gaseous phase (dihedral angle is 111.5°)
(c) II is the structure of H_2O_2 in solid phase (dihedral angle is 90.2°)
(d) All of the above

125 From the following statements regarding H_2O_2, Choose the incorrect statement.
(a) It can act only as an oxidising agent
(b) It decomposed on exposure to light
(c) It has to be stored in plastic or wax lined glass bottles in dark
(d) It has to be kept away from dust

126 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

127 H_2O_2 has following uses :
I. It is used as perhydrol.
II. It is used in the manufacturing of chemicals like sodium perborate and percarbonate.
III. It is used in the synthesis of hydroquinone.
IV. It is used in the environmental (green) chemistry and in pollution control treatment.

Choose the correct option.
(a) I, II and IV
(b) I, III and IV
(c) I, II and III
(d) All the four statements are correct

128 Which of the following statements are correct regarding D_2O and H_2O ?
I. D_2O reacts with Al_4C_3 at a faster rate than does with H_2O.
II. The freezing point of D_2O is higher than that of H_2O.
III. NaCl is more soluble in D_2O than in H_2O.
IV. Ionic product of D_2O is smaller than that of H_2O.

Select the correct answer using the codes given below.
(a) Both I and II (b) Both I and III
(c) Both II and III (d) Both II and IV

129 Which of the following statements is correct for basic principle of hydrogen economy?
(a) It is the transportation and storage of energy in the form of liquid dihydrogen
(b) It is the transportation and storage of energy in the form of gaseous dihydrogen
(c) It is the transportation and storage of energy in the form of liquid or gaseous dihydrogen
(d) It is only the transportation of energy in the form of liquid or gaseous dihydrogen

130 The correct statements among (a) to (d) regarding H_2 as a fuel are : ***JEE Main 2019***

I. It produces less pollutants than petrol.

II. A cylinder of compressed dihydrogen weights ~30 times more than a petrol tank producing the same amount of energy.

III. Dihydrogen is stored in tanks of metal alloys like $NaNi_5$.

IV. On combustion, values of energy released per gram of liquid dihydrogen and LPG are 50 and 142 kJ, respectively.

(a) I, II and III only (b) II, III and IV only
(c) II and IV only (d) I and III only

II. Assertion and Reason

■ **Directions** (Q. Nos. 131-150) *In the following questions, a statement of Assertion* (A) *is followed by a corresponding statement of Reason* (R). *Of the following statements, choose the correct one.*

(a) Both A and R are correct; R is the correct explanation of A.
(b) Both A and R are correct; R is not the correct explanation of A.
(c) A is correct; R is incorrect.
(d) A is incorrect; R is correct.

131 **Assertion** (A) Hydrogen is the first element in the periodic table.
Reason (R) It has electronic configuration $1s^1$.

132 **Assertion** (A) Hydrogen is placed separately in the periodic table.
Reason (R) Hydrogen is extremely small in size as compared to the normal atomic and ionic sizes of 50 to 200 pm.

133 **Assertion** (A) Lithium hydride is used in the synthesis of other useful hydrides.
Reason (R) Lithium hydride is unreactive at moderate temperature with O_2 or Cl_2.

134 **Assertion** (A) Reducing power of dihydrogen is less than that atomic hydrogen.
Reason (R) Bond energy of H_2 is minimum.

135 **Assertion** (A) Oxy-hydrogen flame produces lower temperature while atomic hydrogen flame produces higher temperature.
Reason (R) The heat generated during burning of these gases in oxygen is used to boil substances.

136 **Assertion** (A) In space crafts, H_2 gas is used in fuel cells for generating electrical energy and for providing clean drinking water to the astronauts.
Reason (R) A fuel cell may have an alkaline or acidic electrolyte.

137 **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.

138 **Assertion** (A) Hydrogen is discharged at anode when sodium hydride is electrolysed in fused state.
Reason (R) In sodium hydride, hydrogen is present as cation.

139 **Assertion** (A) Water plays a key role in the biosphere.
Reason (R) In comparison to other liquids, water has lower specific heat capacity, thermal conductivity and surface tension.

140 **Assertion** (A) The crystalline form of water is ice.
Reason (R) At atmospheric pressure, ice crystallises in the hexagonal form but at very low temperature, it condenses into the cubic form.

141 **Assertion** (A) An ice cube floats on water.
Reason (R) Density of ice is less than that of water.

142 **Assertion** (A) In winter season, ice formed on the surface of a lake provides thermal insulation.
Reason (R) It ensures the death of the aquatic life and this fact is of great ecological significance.

143 **Assertion** (A) H_2O_2 is miscible with water in all proportions.
Reason (R) It forms a hydrate $H_2O_2 \cdot H_2O$ with melting point 221 K.

144 **Assertion** (A) Consider the following reaction,

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

Reason (R) H_2O_2 acts as a reducing agent in the acidic medium.

145 **Assertion** (A) Consider the following reaction,

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

Reason (R) H_2O_2 acts as an oxidising agent in the acidic medium.

146 **Assertion** (A) Consider the following reaction,

$$2MnO_4^- + 3H_2O_2 \longrightarrow 2MnO_2 + 3O_2 + 2H_2O + 2OH^-$$

Reason (R) H_2O_2 acts as a reducing agent in the basic medium.

147 **Assertion** (A) Hard water does not lather with soap.
Reason (R) Hard water contains calcium and magnesium salts in the form of hydrogen carbonate, chloride and sulphate.

148 **Assertion** (A) Soft water is free from the soluble salts of calcium and magnesium.
Reason (R) It does not lather with soap easily.

149 **Assertion** (A) Hard water forms scum/precipitate with soap.
Reason (R) Formation of scum occurs as
$2C_{17}H_{35}COONa(aq) + M^{2+}(aq) \longrightarrow (C_{17}H_{35}COO)_2 M \downarrow + 2Na^+(aq)$; M is Ca/Mg

150 **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.

III. Matching Type Questions

151 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	B	C
(a)	1	3	2	(b)	2	1	3
(c)	3	2	1	(d)	1	2	3

152 Match Column I with Column II. Choose the correct matching codes from the choices given below.

	Column I (Hydride)		**Column II** (Nature)
A.	BeH_2	1.	Complex
B.	AsH_3	2.	Lewis acid
C.	B_2H_6	3.	Interstitial
D.	LaH_3	4.	Covalent
E.	$LiAlH_4$	5.	Polymeric

Codes

	A	B	C	D	E		A	B	C	D	E
(a)	3	2	4	5	1	(b)	5	2	4	3	1
(c)	1	4	2	3	5	(d)	5	4	2	3	1

153 Match the items given in Column I with the molecular formula given in Column II. Select the correct option from the codes given below.

	Column I		Column II
A.	Coordinated water	1.	$[Cu(H_2O)_4]^{2+} SO_4^{2-} \cdot H_2O$
B.	Interstitial water	2.	$BaCl_2 \cdot 2H_2O$
C.	Hydrogen-bonded water	3.	$[Cr(H_2O)_6]^{3+} 3Cl^-$

Codes

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

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

155 Match the Column I with Column II. Select the correct option from the codes given below.

	Column I		Column II
A.	10 vol of H_2O_2	1.	Perhydrol
B.	20 vol of H_2O_2	2.	5.358 N
C.	30 vol of H_2O_2	3.	1.785 M
D.	100 vol of H_2O_2	4.	3.03% H_2O_2

Codes

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

156 Match the Column I with Column II. Select the correct option from the codes given below.

	Column I		Column II
A.	Heavy water	1.	Bicarbonates of Mg and Ca in water
B.	Temporary hard water	2.	No foreign ions in water
C.	Soft water	3.	D_2O
D.	Permanent hard water	4.	Sulphates and chlorides of Mg and Ca in water

Codes

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

NCERT & NCERT Exemplar

MULTIPLE CHOICE QUESTIONS

NCERT

157 The hydrogen occur in diatomic form rather than in a monoatomic form under normal conditions because
(a) it has a tendency to achieve the halogen configuration
(b) it has a tendency to achieve the nearest inert gas configuration
(c) it is highly reactive
(d) None of the above

158 Consider the following reactions,

(i) $xH_2(g) + M_xO_y(s) \xrightarrow{\Delta} A$

(ii) $CO(g) + H_2(g) \xrightarrow[\text{Catalyst}]{\Delta} B$

(iii) $C_3H_8(g) + 3H_2O(g) \xrightarrow{\text{Ni, 1270 K}} C$

The products A, B and C are respectively

	A	B	C
(a)	mM	CH_3OH	CO
(b)	mM	C_2H_5OH	CO_2
(c)	M	CH_3OH	CO_2
(d)	mM	C_2H_5OH	CO

159 The order of increasing bond dissociation enthalpy of H — H, D — D and F — F is
(a) H — H < D — D < F — F
(b) F — F < H — H < D — D
(c) H — H < F — F < D — D
(d) F — F < D — D < H — H

160 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

161 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

162 The nature of hydrides if formed by elements of atomic numbers 15, 19, 23 and 44 with dry dihydrogen will be respectively :
(a) $Z = 15$ covalent hydride, $Z = 19$ ionic hydride, $Z = 23$ do not form hydride and $Z = 44$ non-stoichiometric hydride
(b) $Z = 15$ covalent hydride, $Z = 19$ ionic hydride, $Z = 23$ non-stoichiometric hydride and $Z = 44$ do not form hydride
(c) $Z = 15$ ionic hydride, $Z = 19$ covalent hydride, $Z = 23$ non-stoichiometric hydride and $Z = 44$ do not form hydride
(d) $Z = 15$ non-stoichiometric hydride, $Z = 19$ ionic hydride, $Z = 23$ covalent hydride and $Z = 44$ do not form hydride

163 The order of increasing electrical conductance of CaH_2, BeH_2 and TiH_2 is
(a) $BeH_2 < CaH_2 < TiH_2$ (b) $CaH_2 < TiH_2 < BeH_2$
(c) $TiH_2 < CaH_2 < BeH_2$ (d) $BeH_2 < TiH_2 < CaH_2$

164 The difference between the terms 'hydrolysis' and 'hydration' is
(a) hydrolysis yields the original acid and base while hydration forms hydrated salts or ions
(b) hydrolysis forms hydrated salts or ions while hydration yields the original acid and base
(c) hydrolysis yields only the original acid while hydration yields the original base
(d) hydrolysis yields only the original base while hydration yields the original acid

165 In the reaction of water with F_2
(a) water is oxidised and fluorine gets reduced
(b) fluorine is oxidised and water gets reduced
(c) water is oxidised as well as reduced
(d) fluorine is oxidised as well as reduced

166 D_2O cannot be used for drinking purposes because
(a) rate of biochemical reactions increases in heavy water
(b) rate of biochemical reactions decreases in heavy water
(c) rate of biochemical reactions remains same in heavy water
(d) None of the above

NCERT Exemplar

167 Radioactive elements emit α, β and γ-rays and are characterised by their half-lives. The radioactive isotope of hydrogen is
(a) protium (b) deuterium (c) tritium (d) hydronium

168 Hydrogen resembles halogens in many respects for which several factors are responsible. Of the following factors which one is the most important in this respect?
(a) Its tendency to lose an electron to form a cation
(b) Its tendency to gain a single electron in its valence shell to attain stable electronic configuration
(c) Its low negative electron enthalpy value
(d) Its small size

169 Why does H^+ ion always get associated with other atoms or molecules?

(a) Ionisation enthalpy of hydrogen resembles with that of alkali metals

(b) Its reactivity is similar to halogens

(c) It resembles both with alkali metals and halogens

(d) Loss of an electron from hydrogen atom results in a nucleus of very small size

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

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

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

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

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

171 Elements of which of the following groups of periodic table do/does not form hydride?

(a) Groups 7, 8, 9 (b) Group 13

(c) Groups 15, 16, 17 (d) Group 14

172 Which of the following hydrides is electron-precise hydride?

(a) B_2H_6 (b) NH_3 (c) H_2O (d) CH_4

173 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

174 Which of the following reaction 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) $CO(g) + 2H_2(s) \xrightarrow[Catalyst]{Cobalt} CH_3OH(l)$

175 Hydrogen peroxide is obtained by the electrolysis of

(a) water

(b) sulphuric acid

(c) hydrochloric acid

(d) fused sodium peroxide

176 When sodium peroxide is treated with dilute sulphuric acid, we get .

(a) sodium sulphate and water

(b) sodium sulphate and oxygen

(c) sodium sulphate, hydrogen and oxygen

(d) sodium sulphate and hydrogen peroxide

177 The oxide that gives H_2O_2 on treatment with dilute H_2SO_4 is

(a) PbO_2 (b) hydrated BaO_2 (c) MnO_2 (d) TiO_2

178 Consider the reactions :

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

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

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

(a) an oxidising agent in both I and II

(b) an oxidising agent in I and reducing agent in II

(c) a reducing agent in I and oxidising agent in II

(d) a reducing agent in both I and II

179 Which of the following equations depicts 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) $KIO_4 + H_2O_2 \longrightarrow KIO_3 + H_2O + O_2$

180 Which of the following equation depicts reducing nature of H_2O_2?

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

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

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

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

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

(a) Ca^{2+} (b) Na^+ (c) Cl^- (d) K^+

182 Which of the following compounds is used for water softening?

(a) $Ca_3(PO_4)_2$ (b) Na_3PO_4 (c) $Na_6P_6O_{18}$ (d) Na_2HPO_4

183 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
A.	Synthesis gas	1.	$Na_2[Na_4(PO_3)_6]$
B.	Dihydrogen	2.	Oxidising agent
C.	Heavy water	3.	Softening of water
D.	Calgon	4.	Reducing agent
E.	Hydrogen peroxide	5.	Stoichiometric compounds of *s*-block elements
F.	Salt like hydrides	6.	Prolonged electrolysis of water
		7.	Zn + NaOH
		8.	Zn + dil. H_2SO_4
		9.	Synthesis of methanol
		10.	Mixture of CO and H_2

Codes

	A	B	C	D	E	F
(a)	(9, 10)	(4, 5, 7, 8, 9)	(6)	(1, 3)	(2, 4)	(5)
(b)	(1, 2, 3)	(4, 5)	(7)	(8, 9)	(10)	(6)
(c)	(6, 7)	(1)	(2, 3, 4)	(8)	(5)	(9, 10)
(d)	(4)	(3)	(1, 2, 7)	(5)	(9, 10)	(6, 8)

184 Match Column I with Column II for the given properties/application mentioned there in.

	Column I		Column II
A.	H	1.	used in the name of perhydrol.
B.	H_2	2.	can be reduced to dihydrogen by NaH.
C.	H_2O	3.	can be used in hydroformylation of olefin
D.	H_2O_2	4.	can be used in cutting and welding.

Codes

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

185 Match the items in Column I with the relevant items in Column II.

	Column I		Column II
A.	Electrolysis of water produces	1.	atomic reactor
B.	Lithium aluminium hydride is used is	2.	polar molecule
C.	Hydrogen chloride is a	3.	recombines on metal surface to generate high temperature
D.	Heavy water is used in	4.	reducing agent
E.	Atomic hydrogen	5.	hydrogen and oxygen

Codes

	A	B	C	D	E
(a)	1	2	4	3	5
(b)	2	3	1	5	4
(c)	3	5	4	2	1
(d)	5	4	2	1	3

186 Match the items in Column I with the relevant item 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	B	C
(a)	(2, 4)	(3)	(1, 3)	(b)	1	3	2
(c)	(2, 1)	(4)	(3)	(d)	3	(1, 2)	4

Answers

› *Mastering NCERT with MCQs*

1 (c)	*2* (a)	*3* (d)	*4* (a)	*5* (c)	*6* (a)	*7* (a)	*8* (c)	*9* (c)	*10* (c)
11 (c)	*12* (b)	*13* (c)	*14* (a)	*15* (a)	*16* (d)	*17* (a)	*18* (c)	*19* (b)	*20* (b)
21 (b)	*22* (d)	*23* (a)	*24* (a)	*25* (d)	*26* (d)	*27* (a)	*28* (c)	*29* (b)	*30* (a)
31 (c)	*32* (a)	*33* (d)	*34* (a)	*35* (d)	*36* (b)	*37* (d)	*38* (a)	*39* (c)	*40* (d)
41 (c)	*42* (c)	*43* (a)	*44* (a)	*45* (b)	*46* (d)	*47* (a)	*48* (d)	*49* (c)	*50* (a)
51 (a)	*52* (c)	*53* (a)	*54* (a)	*55* (d)	*56* (a)	*57* (b)	*58* (b)	*59* (a)	*60* (d)
61 (a)	*62* (a)	*63* (a)	*64* (a)	*65* (d)	*66* (b)	*67* (d)	*68* (d)	*69* (d)	*70* (a)
71 (b)	*72* (c)	*73* (b)	*74* (b)	*75* (a)	*76* (a)	*77* (d)	*78* (d)	*79* (a)	*80* (b)
81 (a)	*82* (a)	*83* (b)	*84* (b)	*85* (d)	*86* (a)	*87* (b)	*88* (d)	*89* (d)	*90* (d)
91 (d)	*92* (a)	*93* (b)	*94* (d)	*95* (c)	*96* (d)				

› *Special Types Questions*

97 (d)	*98* (b)	*99* (d)	*100* (b)	*101* (d)	*102* (d)	*103* (d)	*104* (d)	*105* (a)	*106* (d)
107 (d)	*108* (d)	*109* (c)	*110* (c)	*111* (d)	*112* (b)	*113* (d)	*114* (d)	*115* (b)	*116* (b)
117 (d)	*118* (c)	*119* (c)	*120* (b)	*121* (b)	*122* (a)	*123* (b)	*124* (d)	*125* (a)	*126* (a)
127 (d)	*128* (d)	*129* (c)	*130* (a)	*131* (a)	*132* (a)	*133* (a)	*134* (c)	*135* (b)	*136* (b)
137 (a)	*138* (c)	*139* (c)	*140* (b)	*141* (a)	*142* (c)	*143* (b)	*144* (a)	*145* (a)	*146* (c)
147 (a)	*148* (c)	*149* (a)	*150* (a)	*151* (b)	*152* (d)	*153* (d)	*154* (a)	*155* (a)	*156* (d)

› *NCERT & NCERT Exemplar Questions*

157 (b)	*158* (a)	*159* (b)	*160* (c)	*161* (a)	*162* (b)	*163* (a)	*164* (a)	*165* (a)	*166* (b)
167 (c)	*168* (b)	*169* (d)	*170* (c)	*171* (a)	*172* (d)	*173* (b)	*174* (d)	*175* (b)	*176* (d)
177 (b)	*178* (b)	*179* (c)	*180* (b)	*181* (a)	*182* (c)	*183* (a)	*184* (c)	*185* (d)	*186* (a)

Hints & Explanations

2 (*a*) 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 (*d*) Hydrogen has a very high ionisation enthalpy, i.e. a large amount of energy is required to remove electron. That's why, it does not possess metallic character under normal conditions.

4 (*a*) The ionisation energy value of hydrogen is too high as compared to that of alkali metals and too low as compared to that of halogens and, thus it cannot be placed in any of these two groups.

5 (*c*) Hydrogen, due to its light nature is much less abundant (0.15% by mass) in the earth's atmosphere.

6 (*c*) Hydrogen has three isotopes-protium (^1_1H), deuterium (^2_1H or D) and tritium (^3_1H or T).

These isotopes differ from one another in respect of the number of neutrons.

7 (*a*) 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%).

8 (*b*) Number of neutrons in protium (^1_1H) is zero (x).

Number of neutrons in deuterium

$$(^2_1H \text{ or } ^2_1D) \text{ is } 1\ (y)$$

Number of neutrons in tritium

$$(^3_1H \text{ or } ^3_1T) \text{ is } 2\ (z)$$

So, the sum of x, y and z is $x + y + z = 3$

9 (*c*) Tritium is the radioactive isotope of hydrogen which emits low energy β^--particles whose half-life period ($t_{1/2}$) is 12.33 years.

10 (*c*) The radioactive isotope of hydrogen is tritium ($_1H^3$) and mass number of tritium is 3.

11 (*c*) The difference in the rate of reaction of isotopes of hydrogen is mainly due to their different bond dissociation enthalpies.

12 (*b*) Hydrogen is prepared by the reaction of granulated zinc with dil.HCl as shown below :

$$Zn + HCl \longrightarrow ZnCl_2 + H_2\uparrow$$

13 (*c*) The reaction between Zn and NaOH is shown below :

$$Zn + 2NaOH(aq) \longrightarrow \underset{\text{Sodium zincate}}{Na_2ZnO_2} + \underset{\text{Dihydrogen}}{H_2}\uparrow$$

Thus, sodium zincate is produced in the reaction.

14 (*a*) Zinc does not react with cold water. It reacts with steam to produce H_2 gas as shown below :

$$Zn + \underset{\text{Steam}}{H_2O} \longrightarrow ZnO + H_2\uparrow$$

The reaction of Zn with other reagents are shown below :

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

$$Zn + 2HCl(\text{dil.}) \longrightarrow ZnCl_2 + H_2\uparrow$$

$$Zn + H_2SO_4(\text{dil.}) \longrightarrow ZnSO_4 + H_2\uparrow$$

15 (*a*) The reaction for the laboratory preparation of H_2 is shown below :

$$Zn + 2NaOH \longrightarrow \underset{\text{Sodium zincate}}{Na_2ZnO_2} + H_2\uparrow$$

16 (*d*) Electrolysis of acidified water using platinum electrodes gives dihydrogen alongwith oxygen.

17 (*a*) High purity (> 99.95%) dihydrogen is obtained by electrolysing (*aq*) barium hydroxide solution between nickel electrodes reaction.

18 (*c*) Dihydrogen is obtained as a byproduct in the manufacture of sodium hydroxide and chlorine by electrolysis of brine solution.

During electrolysis, the reactions that take place are as follows :

At anode $2Cl^-(aq) \longrightarrow Cl_2(g) + 2e^-$

At cathode $2H_2O(l) + 2e^- \longrightarrow H_2(g) + 2OH^-(aq)$

The overall reaction is :

$$2Na^+(aq) + 2Cl^-(aq) + 2H_2O(l)$$

$$\downarrow$$

$$Cl_2(g) + H_2(g) + 2Na^+(aq) + 2OH^-(aq)$$

19 (*b*) The mixture of CO and H_2 is called **water gas**.

It is used for the synthesis of methanol and a number of hydrocarbons. It is also called synthesis gas or **'*syn* gas'.**

20 (*b*) The process of producing '*syn* gas' from coal is called coal gasification.

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

21 (*b*) The production of dihydrogen can be increased by reacting carbon monoxide (CO) of *syn* gas mixtures with steam in the presence of iron chromate as catalyst.

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

This is called water gas shift reaction.

22 (*d*) In the industrial preparation of hydrogen from water gas, CO is oxidised to CO_2 with steam in the presence of a catalyst followed by absorption of CO_2 in alkali.

$$CO + H_2 + H_2O \xrightarrow[\text{catalyst}]{\text{Steam}} CO_2 + 2H_2$$
$$\downarrow \text{KOH}$$
$$K_2CO_3$$

23 (*a*) ~ 77% of the industrial dihydrogen is produced from petrochemicals, 18% from coal, 4% from electrolysis of aqueous solution of salts and 1% from other sources.

24 (*a*) The chemical behaviour of dihydrogen is determined to a large extent by H—H bond dissociation enthalpy. The H—H bond dissociation enthalpy is the highest for a single bond between two atoms of any other element.

25 (*d*) Dihydrogen is a colourless, odourless, tasteless and combustible gas.

27 (*a*) Reaction of hydrogen with fluorine occurs even in the dark, with iodine it requires a catalyst.

Thus, the order of reactivity of X_2 is

$$F_2 > Cl_2 > Br_2 > I_2.$$

28 (*c*) Dihydrogen reacts with dioxygen to form water. The reaction is highly exothermic as shown below :

$$2H_2(g) + O_2(g) \xrightarrow{\text{Catalyst or heating}} 2H_2O(l)\ ;$$
$$\Delta H^\circ = -285.9\ \text{kJ mol}^{-1}$$

29 (*b*) The reaction which represents Haber's process is given below :

$$3H_2(g) + N_2(g) \xrightarrow[\text{Fe}]{\text{673K, 200 atm}} 2NH_3(g);$$
$$\Delta H^\circ = -92.6\ \text{kJ mol}^{-1}$$

This is the method for the manufacture of ammonia.

30 (*a*) Dihydrogen reduces some metal ions in aqueous solution and oxides of metals (less active than iron) into corresponding metals.

$$H_2(g) + Pd^{2+}(aq) \longrightarrow Pd(s) + 2H^+(aq)$$
$$yH_2(g) + M_xO_y(s) \longrightarrow xM(s) + yH_2O(l)$$

31 (*c*) Hydrogenation of vegetable oils using nickel as a catalyst gives edible fats like margarine and vanaspati ghee.

32 (*a*) Hydroformylation of olefins yield aldehydes which further undergo reduction to give alcohols as shown below :

$$H_2 + CO + RCH{=}CH_2 \longrightarrow RCH_2CH_2CHO(X)$$
$$H_2 + RCH_2CH_2CHO \longrightarrow RCH_2CH_2CH_2OH(Y)$$

33 (*d*) The complete reaction is given below :

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

This reaction is used for the manufacture of methanol.

35 (*d*) Dihydrogen (H_2) is used in the fuel cells for generating electrical energy. It does not produce any pollution and releases greater energy per unit mass of fuel in comparison to gasoline and other fuels.

36 (*b*) Noble gases do not react with dihydrogen even at higher temperature to yield the corresponding hydrides.

37 (*d*) 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).

38 (*a*) Ionic hydrides in their molten state can conduct electricity and on electrolysis liberate dihydrogen gas at anode, which confirms the existence of H^- ion as shown below :

$$2H^-(\text{melt}) \xrightarrow{\text{Anode}} H_2(g) + 2e^-$$

39 (*c*) Ionic hydrides give basic solutions when they react with water,

$$\text{e.g. } LiH + H_2O \longrightarrow LiOH + H_2\uparrow$$

40 (*d*) 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.

41 (*c*) The incorrect reaction given in the option (c) can be corrected as follows :

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

42 (*c*) NaH is an example of ionic or saline hydride. These hydrides are formed when hydrogen combines with metals having less electronegativity and more electropositive character with respect to hydrogen. Except Be and Mg, all *s*-block metals form saline hydrides.

Hydrides of *p*-block elements are covalent in nature, *viz*, electron deficient hydrides (by group-13 elements), electron-precise hydrides (by group-14 elements), and electron-rich hydrides (by group 15-17 elements). Hydrides of *d*, *f*-block metals are called interstitial or metallic hydrides.

43 (*a*) Elements of groups 15-17 form electron rich hydrides. The group 16 elements are also known as chalcogens.

44 (*a*) Dihydrogen forms molecular hydrides with most of the *p*-block elements. Most familiar examples are CH_4, NH_3, H_2O and HF.

46 (*d*) In non-stoichiometric hydrides, hydrogen occupies interstices in the metal lattice. These hydrides are also termed as interstitial hydrides. These include examples given in the options.

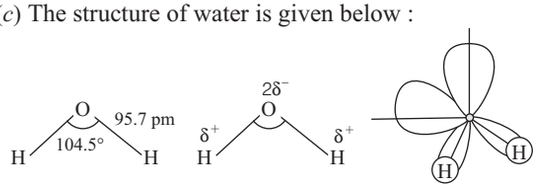
48 (*d*) Except Ni, Pd, Ce and Ac, other metallic hydrides have different lattice from that of the parent metal.

49 (*c*) Some of the metals (e.g. Pd, Pt) can accommodate a very large volume of hydrogen and, therefore can be used as its storage media. This property has high potential for hydrogen storage and as a source of energy.

50 (*a*) Although, phosphorus exhibits +3 and +5 oxidation states but it cannot form PH_5. High $\Delta_a H$ value of dihydrogen and $\Delta_{eg} H$ value of hydrogen do not favour to exhibit the highest oxidation state of P and consequently the formation of PH_5.

51 (*a*) H_2O and D_2O have maximum density at 4°C and 11.6°C respectively.

52 (*c*) The structure of water is given below :



(I) (II) (III)

In gaseous phase, water being a bent molecule behaves as a dipole.

53 (*a*) 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.

55 (*d*) The auto-protolysis (self-ionisation) of water takes place as follows :

$$\underset{\text{Acid-1 (Acid)}}{H_2O(l)} + \underset{\text{Base-2 (Base)}}{H_2O(l)} \rightleftharpoons \underset{\text{Acid-2 (Conjugate acid)}}{H_3O^+(aq)} + \underset{\text{Base-1 (Conjugate base)}}{OH^-(aq)}$$

56 (*a*) 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) $H_2O(l) + H_2S(aq) \rightleftharpoons H_3O^+(aq) + HS^-(aq)$

57 (*b*) On reaction with fluorine, water is oxidised to O_2. Hence, water acts as a reducing agent.

58 (*b*) Water can easily be reduced to dihydrogen by highly electropositive metals.

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

Water is oxidised to O_2 during photosynthesis.

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

Due to high dielectric constant, water has a very strong hydration tendency. It dissolves many ionic compounds.

However, certain covalent and some ionic compounds are hydrolysed in water.

$$P_4O_{10}(s) + 6H_2O(l) \longrightarrow 4H_3PO_4(aq)$$

$$SiCl_4(l) + 2H_2O(l) \longrightarrow SiO_2(s) + 4HCl(aq)$$

$SiCl_4$ is a liquid, not a solid.

59 (*a*) The given compound is

$$[Cr(H_2O)_6]^{3+}\,3Cl^-$$

No water molecule is present outside the square bracket (coordination sphere) to form hydrogen bond.

Thus, all six H_2O molecules are coordinated and are present as ligands.

61 (*a*) 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.

62 (*a*) Permanent hardness is due to the presence of soluble salts of magnesium and calcium in the form of chlorides and sulphates in water.

63 (*a*) When calgon ($Na_6P_6O_{18}$) is added to water, the following reactions take place,

$$Na_6P_6O_{18} \longrightarrow 2Na^+ + Na_4P_6O_{18}^{2-}$$

$$M^{2+} + Na_4P_6O_{18}^{2-} \longrightarrow [Na_2MP_6O_{18}]^{2-} + 2Na^+$$

[M = Mg and Ca]

The complex ions formed above are soluble in water. As a result, the Mg^{2+} and Ca^{2+} remain entrapped in the complex ions and water becomes softner.

64 (*a*) 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.

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

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

65 (*d*) *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.

66 (*b*) In synthetic resin method, cation exchange resins (X) contain large organic molecule with —SO_3H group and are water insoluble. Ion exchange resin (RSO_3H) is changed to RNa by treating it with NaCl. The resin exchanges Na^+ (Y) ions with Ca^{2+} and Mg^{2+} ions present in hard water to make the water soft.

67 (*d*) In anion exchange process, following reaction takes place.

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

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

68 (*d*) Industrially, hydrogen peroxide (H_2O_2) is prepared by the auto-oxidation of 2-alkylanthraquinols.

$$\text{2-ethyl anthraquinol} \underset{H_2/Pd}{\overset{O_2(air)}{\rightleftharpoons}} H_2O_2 + (\text{oxidised product})$$

69 (*d*) H_2O_2 can be prepared by electrolysis of 50% solution of H_2SO_4. In this method, hydrogen is liberated at cathode.

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

At anode $2HSO_4^- \longrightarrow H_2S_2O_8 + 2e^-$

$$H_2S_2O_8 + 2H_2O \longrightarrow 2H_2SO_4 + H_2O_2$$

At cathode $2H^+ + 2e^- \longrightarrow H_2\uparrow$

70 (*a*) H_2O_2 can be obtained from $BaO_2 \cdot 8H_2O$ as follows :

$$\underset{\text{Barium peroxide}}{BaO_2 \cdot 8H_2O(s)} + H_2SO_4(aq) \longrightarrow BaSO_4(s) + \underset{\text{Hydrogen peroxide}}{H_2O_2(aq)} + 8H_2O(l)$$

Anhydrous barium oxide (BaO_2) is not used here because the precipitate $BaSO_4$ forms a protective layer on the unreacted barium peroxide and this prevents its further participation in the reaction.

72 (*c*) 30% solution of H_2O_2 is marketed as '100 V' hydrogen peroxide. It means that, one millilitre 1 mL of 30% H_2O_2 solution will give 100 mL of oxygen at STP.

73 (*b*) '10 volume H_2O_2' means 1L of its solution on decomposition at NTP, gives 10 L oxygen gas.

$$\underset{2 \times 34\ g}{\underset{2\ mol}{2H_2O_2}} \longrightarrow 2H_2O + \underset{22.4\ L}{\underset{1\ mol}{O_2}}$$

$\because$ 22.4 L of O_2 is formed at NTP by decomposition of 68 g H_2O_2.

$\therefore$ 1 L of O_2 is formed at NTP from $\frac{68}{22.4}$ g of H_2O_2.

$\therefore$ 10L of O_2 will be formed at NTP from

$$\frac{68 \times 10}{22.4}\ g\ H_2O_2 = 30.36\ g\ H_2O_2$$

So, strength of "10 volume H_2O_2" = 30.36 g L^{-1}

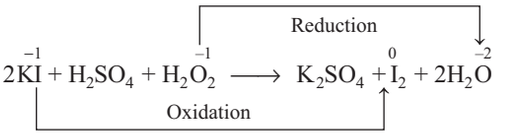
74 (*b*) '20 volume' H_2O_2 means 1 mL H_2O_2 gives 20 mL O_2 at NTP

Thus, 15 mL H_2O_2 will give $15 \times 20 = 300$ mL O_2 at NTP.

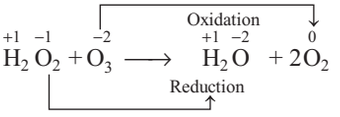
75 (*a*) 6 volume sample of H_2O_2 means 6 volume of oxygen is given out per unit volume of H_2O_2 sample at STP.

76 (*a*) The given figure shows the solid phase of H_2O_2. In the solid phase, the bond angle is equal to 90.2°.

77 (*d*) The reaction in which H_2O_2 is reduced, while the other reactant is oxidised, represents the oxidising property of H_2O_2 as shown below :

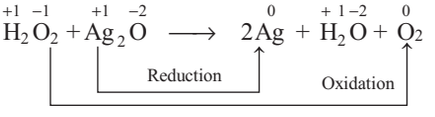


79 (*a*) Consider the reaction is given below :



Since, H_2O_2 oxidises O_3 into O_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.

80 (*b*) The equation for the reducing action of H_2O_2 in basic medium is as follows :

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

81 (*a*) In the presence of metal surface or traces of alkali (present in glass containers), the decomposition of H_2O_2 is catalysed.

84 (*b*) In daily life, H_2O_2 is used as a hair bleach and as a mild disinfectant. As an antiseptic it is sold in the market as perhydrol.

85 (*d*) H_2O_2 is used in pollution control by the treatment of domestic effluents. It is also used in restoration of aerobic conditions to sewage wastes and in oxidation of cyanide. H_2O_2 has no role in synthesis of hydroquinone.

Thus, the option (d) is not use of H_2O_2 in the evironmental chemistry.

86 (*a*) Heavy water (D_2O) is prepared by exhaustive electrolysis of water or as a by-product in some fertiliser industries.

88 (*d*) D_2O is used for the preparation of deuterium containing compounds. The reaction is similar to H_2O.

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

89 (*d*) The complete reaction is shown below :

$$\underset{\text{Aluminium carbide } (X)}{Al_4C_3} + 12D_2O \longrightarrow \underset{\text{Tetradeutero methane } (Y)}{3CD_4} + 4Al(OD)_3$$

91 (*d*) Ordinary water stops the nuclear fission by absorbing the fast moving neutrons.

92 (*a*) The only pollutants in combustion of dihydrogen will be the oxides of dinitrogen (due to the presence of dinitrogen as impurity with dihydrogen). This can be minimised by injecting a small amount of water into the cylinder to lower the temperature, so that the reaction between dinitrogen and dioxygen may not take place.

94 (*d*) Alloy with compounds like $NaNi_5$, Ti-TiH_2 and Mg -MgH_2, in trace amount, is impervious to dihydrogen gas and, hence is used to make the storage tank for hydrogen.

97 (*d*) Statement (d) is incorrect.

It's correct form is as follows :

In physical properties, isotopes of hydrogen differ considerably due to their large mass differences.

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

Rest other statements are correct.

98 (*b*) Statements I and III both are correct but II is incorrect. It's correct form is as follows :

Hydrogen does not resemble halogens because its outer electronic configuration (ns^1) is different from the outer electronic configuration of halogens (ns^2np^5).

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

Because it is very low as compared to halogens.

Rest other statements are correct.

100 (*b*) Statement III is correct, while the statements I and II are incorrect.

Corrected form are as follows :

Like alkali metals, hydrogen forms oxides, halides and sulphides such as H_2O, HCl, H_2S etc. but does not form oxyacid and interhalides.

101 (*d*) Statement (d) is incorrect.

It's correct form is as follows :

Hydrogen has three isotopes :

Protium (^1_1H), deuterium (^2_1H), tritium (^3_1H),

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

Rest other statements are correct.

102 (*d*) Statement (d) is incorrect.

It's correct form is as follows :

The atomic masses of isotopes of hydrogen are not in the ratio of 1:2:3 as abundance of D and T is very less as compared to H.

Rest other statements are correct.

103 (*d*) Statement (d) is incorrect.

It's correct form is as follows :

Reaction of steam with hydrocarbons or coke at high temperatures in the presence of catalyst yields dihydrogen. This is not a commercial method for its preparation.

The equation is shown below :

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

Rest other statements are correct.

104 (*d*) Statement (d) is incorrect.

It's correct form is as follows :

Dihydrogen is insoluble in water (because of its non-polar nature.)

Rest other statements are correct.

105 (a) Statement (a) is correct, while the other statements are incorrect.

Corrected form are as follows :

Dissociation of dihydrogen into its atoms is only ~0.081% around 2000 K which increases to 95.5% at 5000K.

108 (*d*) Statement (d) is incorrect.

It's correct form is as follows :

Elements of group 15 to 17 form electron rich hydrides.

Rest other statements are correct.

109 (*c*) Statement (c) is incorrect.

It's correct form is as follows :

Metallic hydrides are also known as non-stoichiometric or interstitial hydrides.

Rest other statements are correct.

110 (*c*) Statement (c) is incorrect.

It's correct form is as follows :

BeH_2 and MgH_2 are polymeric in structure.

Rest other statements are correct.

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

Corrected form are as follows :

Due to small size and higher electronegativity of N, O and F, the magnitude of hydrogen bonding in their hydrides will be quite appreciable than those of subsequent hydrides and hence, their hydrides have higher boiling point than the hydrides of subsequent group members.

114 (*d*) Statement (d) is incorrect.

It's correct form is as follows :

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

Rest other statements are correct.

115 (*b*) 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.

116 (*b*) 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.

119 (*c*) Statements I and II are correct, while the statement III is incorrect. It's correct form is as follows :

The exhausted cation and anion exchange resin beds are regenerated by treatment with dilute acid and alkali solutions respectively.

120 (*b*) 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.

121 (*b*) 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.

123 (*b*) Statement (b) is incorrect.

It's correct form is as follows :

Chemically, permutit or zeolite is sodium aluminium silicate ($NaAlSiO_4$).

Rest other statements are correct.

125 (*a*) Statement (a) is incorrect.

It's correct form is as follows :

H_2O_2 acts as an oxidising as well as reducing agent, because oxidation number of oxygen in H_2O_2 is -1. So, it can be oxidised to oxidation state 0 or reduced to oxidation state -2.

Rest other statements are correct.

126 (*a*) 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.

128 (*d*) Statements II and IV are correct, while I and III are incorrect.

Corrected form are as follows :

I. Being heavier in mass D_2O reacts with Al_4C_3 slower than H_2O.

III. NaCl is less soluble in D_2O as compared to H_2O.

130 (*a*) (I) H_2 is a 100% pollution free fuel. So, option (I) is correct.

(II) Molecular weight of H_2(2u).

$= \frac{1}{29} \times$ molecular weight of butane,

C_4H_{10} (LPG) [58u].

So, compressed H_2 weighs ~30 times more than a petrol tank and option (b) is correct.

(III) $NaNi_5$, T-TiH_2 etc. are used for storage of H_2 in small quantities. Thus, option (c) is correct.

(IV) On combustion values of energy released per gram of liquid dihydrogen (H_2) : 142 kJ g^{-1}, and for LPG : 50 kJ g^{-1}.
So, option (d) is incorrect.

131 (*a*) Hydrogen is the first element in the periodic table as it has the electronic configuration of $1s^1$.

Thus, both A and R are correct and R is the correct explanation of A.

132 (*a*) Hydrogen is extremely small in size as compared to normal atomic and ionic sizes of 50 to 200 pm. As a consequence, H^+ does not exist freely and is always associated with other atoms or molecules. Thus, it is unique in behaviour and is therefore, best placed separately in the periodic table.

Thus, both A and R are correct and R is the correct explanation of A.

133 (*a*) 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 A and R are correct and R is the correct explanation of A.

134 (*c*) Atomic hydrogen is more powerful reducing agent than dihydrogen because bond energy of H_2 is maximum for a single bond between two atoms.

Thus, A is correct but R is incorrect.

135 (*b*) Atomic hydrogen flame produces a temperature of 4000 K but oxy-hydrogen flame produces a temperature of 2000 K.

Thus, both A and R are correct and R is not the correct explanation of A.

136 (*b*) Hydrogen gas is used in fuel cells for generating electrical energy because it provides lot of energy without causing pollution.

The electrolyte used in fuel cells may be acidic or alkaline.

Thus, both A and R are correct and R is not the correct explanation of A.

137 (*a*) Metals like platinum and palladium can absorb the large volumes of hydrogen so they are used as the storage media for hydrogen.

Thus, both A and R are correct and R is the correct explanation of A.

138 (*c*) Sodium hydride is an electrovalent compound in which hydrogen is present as an anion, H^- which is discharged as H_2 at anode on electrolysis.

Thus, A is correct but R is incorrect.

139 (*c*) In comparison to other liquids, water has a higher specific heat capacity, thermal conductivity and surface tension.

These properties allow water to play a key role in the biosphere.

Thus, A is correct but R is incorrect.

140 (*b*) The crystalline form of water is ice. At atmospheric pressure, ice crystallises in the hexagonal form, but at very low temperature, it condenses into the cubic form.

Thus, both A and R are correct and R is not the correct explanation of A.

141 (*a*) Density of ice is less than that of water because of it has open cage like structures which consists of air filled voids.

Therefore, an ice cube floats on water.

Thus, both A and R are correct and R is the correct explanation of A.

142 (*c*) 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, A is correct but R is incorrect.

143 (*b*) H_2O_2 is miscible with water in all proportions and forms a hydrate $H_2O_2 \cdot H_2O$ (m.p. 221 K).

Thus, both A and R are correct and R is not the correct explanation of A.

144 (*a*) H_2O_2 shows reducing action in the acidic medium as shown below :

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

Thus, both A and R are correct and R is the correct explanation of A.

145 (*a*) H_2O_2 shows an oxidising action in the acidic medium as shown in the following reaction :

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

Thus, both A and R are correct and R is the correct explanation of A.

146 (*a*) H_2O_2 shows reducing action in the basic medium.

e.g.

$2MnO_4^- + 3H_2O_2 \longrightarrow 2MnO_2 + 3O_2 + 2H_2O + 2OH^-$

Thus, both A and R are correct and R is the correct explanation of A.

147 (*a*) 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 A and R are correct and R is the correct explanation of A.

148 (*c*) Soft water gives lather with soap easily as it is free from soluble salts of calcium and magnesium.

Thus, A is correct but R is incorrect.

149 (*a*) Hard water forms scum/precipitate with soap.

Soap containing sodium stearate ($C_{17}H_{35}\overset{-}{C}O\overset{+}{O}Na$) reacts with hard water to precipitate out Ca/Mg stearate.

$2C_{17}H_{35}COONa(aq) + M^{2+}(ag) \longrightarrow (C_{17}H_{35}COO)_2M\downarrow + 2Na^+(aq)$; ($M$ is Ca/Mg.)

Thus, both A and R are correct and R is the correct explanation of A.

150 (*a*) Permanent hardness of water is removed by treatment with washing soda because washing soda reacts with soluble magnesium and calcium sulphate to form insoluble carbonates.

Thus, both A and R are correct and R is the correct explanation of A.

152 (*d*) The correct match is :

A → 5, B → 4, C → 2, D → 3, E → 1.

- Complex compounds do not give all their constituent ions when dissolved in water. In them, individual identity of ions are lost, e.g. $LiAlH_4$.

- Lewis acids are electron deficient species which gain electrons while forming a bond with Lewis bases. e.g. B_2H_6.
- Interstitial hydrides are formed by elements of *d* and *f*-block, e.g. LaH_3.
- AsH_3 is covalent, while BeH_2 is polymeric.

153 (*d*) The correct match is :

$$A \rightarrow 3, B \rightarrow 2, \rightarrow C \rightarrow 1.$$

Many salts can be crystallised as hydrated salts from an aqueous solution. Such an association of water is of different types *viz.*

(i) coordinated water, e.g. $[Cr(H_2O)_6]^{3+}3Cl^-$

(ii) interstitial water, e.g. $BaCl_2 \cdot 2H_2O$

(iii) hydrogen-bonded water,

e.g. $[Cu(H_2O)_4]^{2+}SO_4^{2-} \cdot H_2O$ in $CuSO_4 \cdot 5H_2O$

154 (*a*) The correct match is :

$$A \rightarrow 3, B \rightarrow 1, C \rightarrow 2, D \rightarrow 4$$

The different methods for the removal of hardness of water are given below :

Boiling

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

Clark's method

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

Calgon's method

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

$$M^{2+} + Na_4P_6O_{18}^{2-} \longrightarrow [Na_2MP_6O_{18}]^{2-} + 2Na^+ ; \quad (M = \text{Mg, Ca})$$

Ion-exchange method / Zeolite permutit process

$$2NaZ(s) + M^{2+}(aq) \longrightarrow MZ_2(s) + 2Na^+(aq) ; \quad (M = \text{Mg, Ca})$$

$NaAlSiO_4$ can be written as Na*Z*.

155 (*a*) The correct match is A → 4, B → 3, C → 2, D → 1

A. 10 volume H_2O_2 means 1 L of H_2O_2 will give 10 L of oxygen at STP.

$$\underset{2\times34=68\text{ g}}{2H_2O_2(l)} \longrightarrow \underset{\substack{22.4\text{ L}\\ \text{at STP.}}}{O_2(g)} + H_2O(l)$$

$\because$ 22.4 L O_2 (at STP) is obtained from 68 g H_2O_2.

$\therefore$ 10 L O_2 (at STP) will be produced from H_2O_2

$$= \frac{68\times10}{22.4} = 30.36\text{ g}$$

This amount of H_2O_2 is present in 1 L (1000 mL)

$\therefore$ 100 mL of H_2O_2 contains

$$= \frac{30.36\times100}{1000}$$

$$= 3.03\%\ H_2O_2$$

Similarly,

B. 20 volume of $H_2O_2 = 60.6$ g/L

$$= \frac{60.6}{34}\text{ mol/L} = 1.785\text{ M}$$

C. 30 volume of $H_2O_2 = 90.9$ g/L

$$= \frac{90.9}{17}\text{ g equi/L} = 5.35\text{ N}$$

D. 100 volume of H_2O_2 is 30.3% H_2O_2 and is commonly called perhydrol.

156 (*d*) The correct match is A → 3, B → 1, C → 2, D → 4

Heavy water is D_2O. Temporary hardness of water is due to the presence of bicarbonates of Mg and Ca in water. Soft water does not contain any foreign ions and permanent hardness of water is due to the presence of sulphates and chlorides of Mg and Ca in water.

157 (*b*) Hydrogen atom has only one electron in its 1*s* orbital. So, to achieve stable nearest inert gas configuration, i.e. of helium, it exists as diatomic molecule and is called dihydrogen.

158 (*a*) The complete reactions are given below :

(i) $yH_2(g) + M_xO_y(s) \xrightarrow{\Delta} \underset{(A)}{xM(s)} + yH_2O(l)$

(ii) $CO(g) + 2H_2(g) \xrightarrow[\text{Catalyst}]{\Delta} \underset{\substack{\text{Methanol}\\ (B)}}{CH_3OH(l)}$

(iii) $C_3H_8(g) + 3H_2O(g) \xrightarrow{\text{Ni, 1270 K}} \underset{(C)}{3CO(g) + 7H_2(g)}$

Hence, *A* is *mM*, *B* is CH_3OH and *C* is CO.

159 (*b*) Shorter the bond length, higher is the bond dissociation energy. Hence, the correct order is given below :

$$F\text{—}F < H\text{—}H < D\text{—}D$$

160 (*c*) 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.

$$NaH + CO_2 \longrightarrow \overset{-}{H}COO\overset{+}{Na}$$

161 (*a*) 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.

162 (*b*) (i) Element with $Z = 15$, belongs to *p*-block. It forms covalent hydride, e.g. PH_3.

(ii) Element with $Z = 19$ belongs to *s*-block. It forms ionic or saline hydride, e.g. KH.

(iii) Element with $Z = 23$ belongs to *d*-block and Vth group elements. It forms interstitial hydride, e.g. $VH_{1.6}$. It is also called non-stoichiometric hydride.

(iv) Element with $Z = 44$ belongs to *d*-block and 8th group element. It is ruthenium. It does not form any hydride because metals of group 7, 8 and 9 do not form hydride (hydride gap).

163 (*a*) More the ionic character, higher is the electrical conductance.

The correct order is given below

$$\underset{\text{(Covalent)}}{BeH_2} < \underset{\text{(Ionic)}}{CaH_2} < \underset{\text{(Metallic)}}{TiH_2}$$

164 (*a*) Interaction of H^+ and OH^- ions of H_2O with the anion and the cation of a salt respectively to yield the original acid and the original base is called hydrolysis.

$$\text{e.g. } \underset{\text{Salt}}{Na_2CO_3} + 2H_2O \longrightarrow \underset{\text{Base}}{2NaOH} + \underset{\text{Acid}}{H_2CO_3}$$

Hydration, on the other hand, means addition of H_2O to ions or molecules to form hydrated ions or hydrated salts.

$$\text{e.g. } \underset{\text{Salt}}{KCl(s)} + H_2O(l) \longrightarrow K^+(aq) + Cl^-(aq)$$

$$\underset{\text{Colourless}}{CuSO_4(s)} + 5H_2O(l) \longrightarrow \underset{\text{Blue}}{CuSO_4 \cdot 5H_2O(s)}$$

165 (*a*) The reaction between F and H_2O is given below :

$$\underset{\text{Oxidant}}{2F_2(g)} + \underset{\text{Reductant}}{2H_2O(l)} \longrightarrow O_2(g) + 4H^+(aq) + 4F^-(aq)$$

In this reaction, water acts as a reducing agent and hence, itself gets oxidised to oxygen. Fluorine acts as an oxidising agent and, hence itself gets reduced to F^- ion.

166 (*b*) Heavy water (D_2O) is injurious to human beings because rate of biochemical reactions decreases in heavy water.

167 (*c*) The radioactive isotope of hydrogen is tritium. For tritium ($n = 2,\ p = 1$), therefore *n/p* ratio is 2.

168 (*b*) Hydrogen resembles halogen in many respects for which several factors are responsible. The most important is that hydrogen, like halogens accept an electron readily to achieve nearest inert gas configuration.

169 (*d*) H^+ always get associated with other atoms or molecules. The reason is that, loss of an electron from hydrogen atom results in a nucleus of very small size as compared to other atoms or ions. Due to small size, it cannot exist free.

170 (*c*) The process of producing *syn* gas or synthesis gas from coal is called 'coal gasification'.

$$\underset{\text{Coal}}{C(s)} + \underset{\text{Steam}}{H_2O(g)} \xrightarrow[\text{Ni}]{1270\ K} \underbrace{CO(g) + H_2(g)}_{\textit{Syn}\text{ gas}}$$

The production of hydrogen can be increased by reacting carbon monoxide of the *syn* gas with steam in the presence of iron chromate as a catalyst at 673 K.

$$CO(g) + H_2O(g) \xrightarrow{Fe_2(CrO_4)_3} CO_2(g) + H_2(g)$$

CO_2 is removed by scrubbing with a solution of sodium arsenite.

171 (*a*) Dihydrogen forms molecular compounds with most of the *p*-block elements (group 13 to 17). Most familiar examples are CH_4, NH_3, H_2O and HF. For convenience, hydrogen compounds of non-metals have also been considered as hydrides.

However, elements of group 7, 8, 9 do not form hydrides. This is known as hydride gap.

172 (*d*) Electron-precise hydrides contain exact number of electrons to form normal covalent bonds, e.g. CH_4.

173 (*b*) 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,

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

174 (*d*) The water gas is the combination of carbon monoxide and hydrogen. In the presence of cobalt (Co) as catalyst, it gives methanol.

$$CO(g) + 2H_2(g) \xrightarrow{\text{Cobalt}} CH_3OH(l)$$

175 (*b*) Peroxodisulphate, obtained by electrolytic oxidation of acidified sulphate solutions (sulphuric acid) at high current density, on hydrolysis yields hydrogen peroxide.

$$2HSO_4^-(aq) \xrightarrow{\text{Electrolysis}} HO_3SOOSO_3H(aq)$$

$$\xrightarrow{\text{Hydrolysis}} 2HSO_4^-(aq) + 2H^+(aq) + H_2O_2(aq)$$

176 (*d*) When sodium peroxide is treated with dilute sulphuric acid, we get sodium sulphate and hydrogen peroxide as shown below :

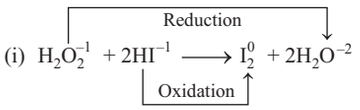
$$Na_2O_2 + \text{Dil. } H_2SO_4 \longrightarrow Na_2SO_4 + H_2O_2$$

177 (*b*) Oxides such as BaO_2, Na_2O_2 etc., which contain peroxide linkage (i.e. —O—O or O_2^{1-}) on treatment with dil. H_2SO_4 give H_2O_2 but dioxides (O═*M*═O, where, *M* is the metal atom) such as PbO_2, MnO_2, TiO_2 do not give H_2O_2 on treatment with dil. H_2SO_4.

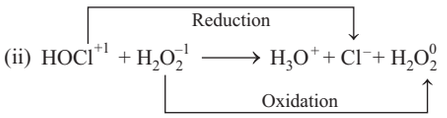
The reaction is shown below :

$$\underset{\substack{\text{Hydrated barium}\\\text{peroxide}}}{BaO_2 \cdot 8H_2O(s)} + H_2SO_4(aq) \longrightarrow BaSO_4(s) + \underset{\substack{\text{Hydrogen}\\\text{peroxide}}}{H_2O_2(aq)} + 8H_2O(l)$$

178 (*b*) The reactions are given below :

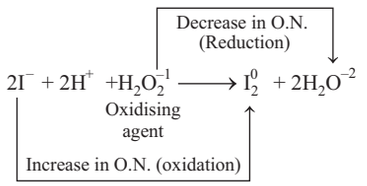


Thus, here H_2O_2 oxidises HI into I_2 hence, it behaves as oxidising agent.



Here, H_2O_2 reduces HOCl to Cl^{-1}, thus it acts as a reducing agent.

179 (*c*) The reaction in which H_2O_2 is reduced, i.e. oxidation state of oxygen decreases, shows the oxidising nature of H_2O_2. e.g.



180 (*b*) H_2O_2 acts as an oxidising as well as reducing agents in alkaline medium. The given reaction shows its reducing action in basic medium.

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

181 (*a*) Bicarbonates, chlorides and sulphates of Ca and Mg are responsible for the hardness of water.

182 (*c*) For water softening, sodium hexametaphosphate is used. Its chemical formula is $Na_2[Na_4(PO_3)_6]$ $= Na_6P_6O_{18}$. Its trade name is Calgon.

$$\underset{\text{(From hard water)}}{2CaCl_2} + \underset{\text{Sodium hexametaphosphate}}{Na_2[Na_4(PO_3)_6]} \longrightarrow \underset{\text{Complex salt (soluble)}}{Na_2[Ca_2(PO_3)_6]} + 4NaCl$$

183 (*a*) The correct match is :

A. $\rightarrow$ (9, 10); B. $\rightarrow$ (4, 5, 7, 8, 9); C. $\rightarrow$ (6);
D. $\rightarrow$ (1, 3); E. $\rightarrow$ (2, 4); F. $\rightarrow$ (5)

A. Synthesis gas – Synthesis of methanol
– Mixture of CO and H_2

B. Dihydrogen – Reducing agent
– Stoichiometric compounds of *s*-block elements
– Zn + NaOH
– Zn + dil. H_2SO_4
– Synthesis of methanol

C. Heavy water – Prolonged electrolysis of water

D. Calgon – $Na_2[Na_4(PO_3)_6]$
– Softening of water

E. Hydrogen peroxide – Oxidising agent
– Reducing agent

F. Salt like hydrides – Stoichiometric compounds of *s*-block elements.

184 (*c*) The correct match is :

A. $\rightarrow$ (4); B. $\rightarrow$ (3); C. $\rightarrow$ (2); D. $\rightarrow$ (1)

A. Atomic hydrogen (H) can be used in cutting and welding.
B. Dihydrogen (H_2) can be used in hydroformylation of olefin.
C. Water (H_2O) can be reduced to dihydrogen by NaH.
D. Hydrogen peroxide (H_2O_2) used in the name of perhydrol.

185 (*d*) The correct match is :

A. $\rightarrow$ (5); B. $\rightarrow$ (4); C. $\rightarrow$ (2); D. $\rightarrow$ (1); E. $\rightarrow$ (3)

A. Electrolysis of water produce hydrogen and oxygen.
B. Lithium aluminium hydride is used as reducing agent.
C. Hydrogen chloride is a polar molecule.
D. Heavy water is used in atomic reactor as moderator.
E. Atomic hydrogen recombines on metal surface to generate high temperature.

186 (*a*) The correct match is :

A. $\rightarrow$ (2, 4); B. $\rightarrow$ (3); C. $\rightarrow$ (1, 3)

A. Hydrogen peroxide is used as a perhydrol and propellant.
B. Sodium hexametaphosphate is used in Calgon method.
C. Permanent hardness of hard water is removed by zeolite and sodium hexametaphosphate.