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# **HYDROGEN & IT'S COMPOUND**

# POSITION OF HYDROGEN IN THE PERIODIC TABLE

Hydrogen is the first element in the periodic table. However, its placement in the periodic table has been a subject of discussion in the past. As you know by now that the elements in the periodic table are arranged according to their electronic configurations. Hydrogen has electronic configuration  $1s^1$ . On one hand, its electronic configuration is similar to the outer electronic configuration  $(ns^1)$  of alkali metals, which belong to the first group of the periodic table. On the other hand, like halogens (with  $ns^2np^5$  configuration belonging to the seventeenth group of the periodic table), it is short by one electron to the corresponding noble gas configuration, helium  $(1s^2)$ . Hydrogen, therefore, 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. Like alkali metals, hydrogen forms oxides, halides and sulphides. However, unlike alkali metals, it has a very high ionization enthalpy and does not possess metallic characteristics under normal conditions. In fact, in terms of ionization enthalpy, hydrogen resembles more with halogens,  $\Delta_i$ H of Li is 520 kJ mol<sup>-1</sup>, F is 1680 kJ mol<sup>-1</sup> and that of H is 1312 kJ mol<sup>-1</sup>. Like halogens, it forms a diatomic molecule, combines with elements to form hydrides and a large number of covalent compounds. However, in terms of reactivity, it is very low as compared to halogens.

Inspite of the fact that hydrogen, to a certain extent resembles both with alkali metals and halogens, it differs from them as well. Now the pertinent question arises as where should it be placed in the periodic table? Loss of the electron from hydrogen atom results in nucleus ( $H^+$ ) of ~1.510<sup>-3</sup> pm size. This is extremely small as compared to normal atomic and ionic sizes of 50 to 200pm. 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.

# □ DIHYDROGEN, H,

### Occurrence

Dihydrogen is the most abundant element in the universe (70% of the total mass of the universe) and is the principal element in the solar atmosphere. The giant planets Jupiter and Saturn consist mostly of hydrogen. However, due to its light nature, it is much less abundant (0.15% by mass) in the earth's atmosphere. Of course, in the combined form it constitutes 15.4% of the earth's crust and the oceans. In the combined form besides in water, it occurs in plant and animal tissues, carbohydrates, proteins, hydrides including hydrocarbons and many other compounds.

# Isotopes of Hydrogen

Hydrogen has three isotopes: **protium**, <sup>1</sup><sub>1</sub>H, **deuterium**, <sup>2</sup><sub>1</sub>H or D and **tritium**, <sup>3</sup><sub>1</sub>H or T. These isotopes differ from one another in respect of the presence of neutrons. Ordinary hydrogen, protium, has no neutrons, deuterium (also known as heavy hydrogen) has one and tritium has two neutrons in the nucleus. In the year 1934, an American scientist, Harold C. Urey, got Nobel Prize for separating hydrogen isotope of mass number 2 by physical methods.

The predominant form is protium. Terrestrial hydrogen contains 0.0156% of deuterium mostly in the form of HD. The tritium concentration is about one atom per 1018 atoms of protium. Of these isotopes, only tritium is radioactive and emits low energy  $\beta^-$  particles.

# **Atomic and Physical Properties of Hydrogen**

Property	Hydrogen	Deuterium	Tritium
Relative abundace (%)	99.985	0.0156	$10^{-15}$
Relative atomic mass (g mol <sup>-1</sup> )	1.008	2.014	3.016
Melting point / K	13.96	18.73	20.62
Boiling point /K	20.39	23.67	25.0
Density / gL <sup>-1</sup>	0.09	0.18	0.27
Enthalpy of fusion/KJ mol <sup>-1</sup>	0.117	0.197	_
Enthalpy of vaporization/kJ mol <sup>-1</sup>	0.904	1.226	_
Enthalpy of bond dissociation/kJ mol <sup>-1</sup> at 298.2K	435.88	443.35	-
Internuclear distance/pm	74.14	74.14	_
Ionization enthalpy/kJ mol <sup>-1</sup>	1312	_	_
Electron gain enthalpy/kJ mol <sup>-1</sup>	-73	_	_
Covalent radius/pm	37	-	_
Ionic radius(H <sup>-</sup> )/pm	208		

Since the isotopes have the same electronic configuration, they have almost the same chemical properties. The only difference is in their rates of reactions, mainly due to their different enthalpy of bond dissociation. However, in physical properties these isotopes differ considerably due to their large mass differences.

# • Different forms of Hydrogen:

### (a) Based on oxidation Number.

There are three types of hydrogen

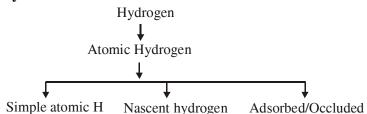
	H <sup>+</sup>	H-	Н
	Proton	Hydride	Atomic hydrogen
Number of electron	0	2	1
Oxidation number	+1	-1	0
Formation	$H \rightarrow H^+ + e^-$	$H + e^- \rightarrow H^-$	$H_2 \xrightarrow{\Delta} 2H$

**Note:** In the aqueous state proton (H<sup>+</sup>) exist as H<sup>+</sup> (H<sub>2</sub>O)<sub>n</sub>

Where n is a large number.

$$\begin{array}{cccc} \text{If} & \text{$n=1$} & \longrightarrow & \text{$H_3O^+$} \\ & \text{$n=2$} & \longrightarrow & \text{$H^+(H_2O)_2$} \end{array}$$

(b) Based on reactivity:



- Atomic hydrogen:
  - (i) Simple atomic hydrogen It is formed by simple dissociation of hydrogen.

Favourable condition – Favourable condition are high temp & low pressure.

(ii) Nascent hydrogen – Hydrogen at the moment of its birth it called nascent hydrogen means which forms at the instant is known as Nascent hydrogen.

It is formed only by some specific chemical reaction.

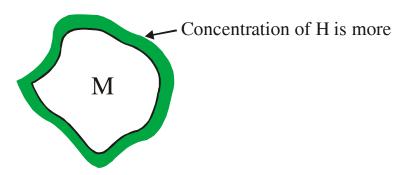
$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + 2H$$

$$2NaOH + Be \longrightarrow Na_2BeO_2 + 2H$$

(c) C<sub>2</sub>H<sub>5</sub>OH + Alkali metal

$$C_2H_5OH + Na \longrightarrow C_2H_5ONa + H$$

(iii) Adsorbed/Occluded hydrogens



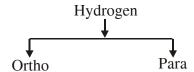
Adsorbed H is hydrogen present at the outer surface of metal.

• Occlusion: The property of metal to adsorb any gas is called occlusion.

Reactivity order

Atomic hydrogen > Nascent hydrogen > Molecular hydrogen

# (iii) Based on Nuclear spin (Nuclear isomers)



- (a) Ortho hydrogen: The molecular form of hydrogen having same spin of nucleus is called ortho hydrogen.
- **(b) Para hydrogen :** The molecular form of hydrogen having opposite spin of nucleus is called para hydrgen.

In ortho hydrogen spin of nucleus is same, so they will repel each other & because of this repulsion, internal energy of ortho hydrogen increases. So ortho hydrogen has more internal energy.

# Stability of ortho & Para hydrogen

Stability of ortho & para hydrogen depends upon temperature condition.

At low temp: para hydrogen is more stable than ortho hydrogen while at high temp ortho hydrogen is more stable than para hydrogen.

# • Imp. Note:

- (i) We can obtain 100% pure para hydrogen at low temp but can't ortho because at high temp parahydrogen will dissociate into atomic hydrogen.
- (ii) Ortho & Para hydrogen differs only in physical properties but have same chemical properites.

# $\hfill \square$ PREPARATION OF DIHYDROGEN, $\hfill H_2$

There are a number of methods for preparing dihydrogen from metals and metal hydrides.

# **+** Laboratory Preparation of

# Dihydrogen

(i) It is usually prepared by the reaction of granulated zinc with dilute hydrochloric acid.

$$Zn + 2H^+ \rightarrow Zn^{2+} + H_2$$

(ii) It can also be prepared by the reaction of zinc with aqueous alkali.

$$Zn + 2NaOH \rightarrow Na_2ZnO_2 + H_2$$

Sodium zincate

# Commercial Production of Dihydrogen

The commonly used processes are outlined below:

(i) Electrolysis of acidified water using platinum electrodes gives hydrogen.

$$2H_2O(\ell) \xrightarrow{\text{Electrolysis}} 2H_2(g) + O_2(g)$$

- (ii) High purity (>99.95%) dihydrogen is obtained by electrolysing warm aqueous barium hydroxide solution between nickel electrodes.
- (iii) It is obtained as a byproduct in the manufacture of sodium hydroxide and chlorine by the electrolysis of brine solution. During electrolysis, the reactions that take place are: at anode:

$$2Cl^{-}(aq) \rightarrow Cl_{2}(g) + 2e^{-}$$

at cathode: 
$$2H_2O(\ell) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$$

The overall reaction is

$$2Na^{+}(aq) + 2Cl^{-}(aq) + 2H_{2}O(\ell) \rightarrow Cl_{2}(g) + H_{2}(g) + 2Na^{+}(aq) + 2OH^{-}(aq)$$

(iv) Reaction of steam on hydrocarbons or coke at high temperatures in the presence of catalyst yields hydrogen.

$$C_n H_{2n-2} + nH_2 O \xrightarrow{1270 \text{ K}} nCO + (2n-1) H_2$$
  
e.g.,

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

The mixture of CO and  $H_2$  is called *water gas*. As this mixture of CO and  $H_2$  is used for the synthesis of methanol and a number of hydrocarbons, it is also called *synthesis gas or 'syngas'*. Nowadays 'syngas' is produced from sewage, saw-dust, scrap wood, newspapers etc. The process of producing 'syngas' from coal is called '*coal gasification*'.

$$\mathrm{C}(\mathrm{s}) + \mathrm{H}_2\mathrm{O}(\mathrm{g}) \xrightarrow{\phantom{a}1270\mathrm{K}\phantom{a}} \mathrm{CO}(\mathrm{g}) + \mathrm{H}_2(\mathrm{g})$$

The production of dihydrogen can be increased by reacting carbon monoxide of syngas mixtures with steam in the presence of iron chromate as catalyst (Fe<sub>2</sub>O<sub>3</sub> and Cr<sub>2</sub>O<sub>3</sub>).

$$\mathrm{CO}(g) + \mathrm{H_2O}(g) \xrightarrow{\phantom{-}673\mathrm{K}\phantom{+}\phantom{+}\phantom{+}} \mathrm{CO_2}(g) + \mathrm{H_2}(g)$$

This is called water-gas shift reaction /**Bosch process**. Carbon dioxide is removed by scrubbing with sodium arsenite solution. Presently ~77% of the industrial dihydrogen is produced from petro-chemicals, 18% from coal, 4% from electrolysis of aqueous solutions and 1% from other sources.

# **□** PROPERTIES OF DIHYDROGEN

# Physical Properties

Dihydrogen is a colourless, odourless, tasteless, combustible gas. It is lighter than air and insoluble in water. Its other physical properties along with those of deuterium are given in Table.

# Chemical Properties

The chemical behaviour of dihydrogen (and for that matter any molecule) is determined, to a large extent, by bond dissociation enthalpy. The H–H bond dissociation enthalpy is the highest for a single bond between two atoms of any element. What inferences would you draw from this fact? It is because of this factor that the dissociation of dihydrogen into its atoms is only ~0.081% around 2000K which increases to 95.5% at 5000K. Also, it is relatively inert at room temperature due to the high H–H bond enthalpy. Thus, the atomic hydrogen is produced at a high temperature in an electric arc or under ultraviolet radiations. Since its orbital is incomplete with 1s<sup>1</sup> electronic configuration, it does combine with almost all the elements. It accomplishes reactions by (i) loss of the only electron to give H<sup>+</sup>, (ii) gain of an electron to form H<sup>-</sup>, and (iii) sharing electrons to form a single covalent bond. The chemistry of dihydrogen can be illustrated by the following reactions:

• Reaction with halogens: It reacts with halogens, X<sub>2</sub> to give hydrogen halides HX,

$$H_2(g) + X_2(g) \rightarrow 2HX(g) (X = F, Cl, Br, I)$$

While the reaction with fluorine occurs even in the dark, with iodine it requires a catalyst.

• **Reaction with dioxygen:** It reacts with dioxygen to form water. The reaction is highly exothermic.

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

• *Reaction with dinitrogen:* With dinitrogen it forms ammonia.

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

This is the method for the manufacture of ammonia by the Haber process.

Reactions with metals: With many metals it combines at a high temperature to yield the corresponding hydrides.

$$H_2(g) + 2M(g) \rightarrow 2MH(s)$$
;

where M is an alkali metal

• Reactions with metal ions and metal oxides: It reduces some metal ions in aqueous solution and oxides of metals (less active than iron) into corresponding metals.

$$\operatorname{H}_2(g) + \operatorname{Pd}^{2+}\left(\operatorname{aq}\right) \to \operatorname{Pd}(\operatorname{s}) + 2\operatorname{H}^+\left(\operatorname{aq}\right)$$

$$yH_2(g) + M_xO_v(s) \rightarrow xM(s) + yH_2O(\ell)$$

- **Reactions with organic compounds:** It reacts with many organic compounds in the presence of catalysts to give useful hydrogenated products of commercial importance. For example:
  - (i) Hydrogenation of vegetable oils using nickel as catalyst gives edible fats (margarine and vanaspati ghee)
  - (ii) Hydroformylation of olefins yields aldehydes which further undergo reduction to give alcohols.

$$H_2 + CO + RCH = CH_2 \rightarrow RCH_2CH_2CHO$$

$$H_2 + RCH_2CH_2CHO \rightarrow RCH_2CH_2CH_2OH$$

# Problem-1

Comment on the reactions of dihydrogen with (i) chlorine, (ii) sodium, and (iii) copper(II) oxide.

### **Solution**

- (i) Dihydrogen reduces chlorine into chloride (Cl<sup>-</sup>) ion and itself gets oxidised to H<sup>+</sup> ion by chlorine to form hydrogen chloride. An electron pair is shared between H and Cl leading to the formation of a covalent molecule.
- (ii) Dihydrogen is reduced by sodium to form NaH. An electron is transferred from Na to H leading to the formation of an ionic compound, Na<sup>+</sup>H<sup>-</sup>.
- (iii) Dihydrogen reduces copper(II) oxide to copper in zero oxidation state and itself gets oxidised to  $H_2O$ , which is a covalent molecule.

# **Uses of Dihydrogen**

The largest single use of dihydrogen is in the synthesis of ammonia which is used in the manufacture of nitric acid and nitrogenous fertilizers.

• Dihydrogen is used in the manufacture of vanaspati fat by the hydrogenation of polyunsaturated vegetable oils like soyabean, cotton seeds etc. . It is used in the manufacture of bulk organic chemicals, particularly methanol.

$$CO(g) + 2H_2(g) \xrightarrow{cobalt} CH_3OH(\ell)$$

- It is widely used for the manufacture of metal hydrides.
- It is used for the preparation of hydrogen chloride, a highly useful chemical.
- In metallurgical processes, it is used to reduce heavy metal oxides to metals.
- Atomic hydrogen and oxy-hydrogen torches find use for cutting and welding purposes. Atomic hydrogen atoms (produced by dissociation of dihydrogen with the help of an electric arc) are allowed to recombine on the surface to be welded to generate the temperature of 4000 K.
- It is used as a rocket fuel in space research.
- Dihydrogen is used in fuel cells for generating electrical energy. It has many advantages over the conventional fossil fuels and electric power. It does not produce any pollution and releases greater energy per unit mass of fuel in comparison to gasoline and other fuels.

### **□** HYDRIDES

Dihydrogen, under certain reaction conditions, combines 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.,  $B_2H_6$ ).

The hydrides are classified into three categories:

- (i) Ionic or saline or saltlike hydrides
- (ii) Covalent or molecular hydrides
- (iii) Metallic or non-stoichiometric hydrides

# • Ionic or Saline Hydrides

These are stoichiometric compounds of dihydrogen formed with most of the *s*-block elements which are highly electropositive in character. However, significant covalent character is found in the lighter metal hydrides such as LiH, BeH<sub>2</sub> and MgH<sub>2</sub>. In fact BeH<sub>2</sub> and MgH<sub>2</sub> are polymeric in structure. The ionic hydrides are crystalline, non-volatile and nonconducting in solid state. However, their melts conduct electricity and on electrolysis liberate dihydrogen gas at anode, which confirms the existence of H<sup>-</sup> ion.

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

Saline hydrides react violently with water producing dihydrogen gas.

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

Lithium hydride is rather unreactive at moderate temperatures with  $O_2$  or  $Cl_2$ . It is, therefore, used in the synthesis of other useful hydrides, e.g.,

$$8 \text{LiH} + \text{Al}_2 \text{Cl}_6 \rightarrow 2 \text{LiAlH}_4 + 6 \text{LiCl}$$
 
$$2 \text{LiH} + \text{B}_2 \text{H}_6 \rightarrow 2 \text{LiBH}_4$$

# Covalent or Molecular Hydride

Dihydrogen forms molecular compounds with most of the p-block elements. Most familiar examples are  $CH_4$ ,  $NH_3$ ,  $H_2O$  and HF. For convenience hydrogen compounds of nonmetals have also been considered as hydrides. Being covalent, they are volatile compounds. Molecular hydrides are further classified according to the relative numbers of electrons and bonds in their Lewis structure into:

# (i) electron-deficient, (ii) electron-precise, and (iii) electron-rich hydrides.

An electron-deficient hydride, as the name suggests, has too few electrons for writing its conventional Lewis structure. Diborane  $(B_2H_6)$  is an example. In fact all elements of group 13 will form electron-deficient compounds. They act as Lewis acids i.e., electron acceptors.

Electron-precise compounds have the required number of electrons to write their conventional Lewis structures. All elements of group 14 form such compounds (e.g., CH<sub>4</sub>) which are tetrahedral in geometry.

Electron-rich hydrides have excess electrons which are present as lone pairs. Elements of group 15-17 form such compounds. (NH $_3$  has 1- lone pair, H $_2$ O – 2 and HF –3 lone pairs). They will behave as Lewis bases i.e., electron donors. The presence of lone pairs on highly electronegative atoms like N, O and F in hydrides results in hydrogen bond formation between the molecules. This leads to the association of molecules.

Problem -2

### Wor

Would you expect the hydrides of N, O and F to have lower boiling points than the hydrides of their subsequent group members? Give reasons.

### **Solution**

On the basis of molecular masses of  $NH_3$ ,  $H_2O$  and HF, their boiling points are expected to be lower than those of the subsequent group member hydrides. However, due to higher electronegativity of N, O and F, the magnitude of hydrogen bonding in their hydrides will be quite appreciable. Hence, the boiling points  $NH_3$ ,  $H_2O$  and HF will be higher than the hydrides of their subsequent group members.

# Metallic or Non-stoichiometric (or Interstitial) Hydrides

These are formed by many d-block and f-block elements. However, the metals of group 7, 8 and 9 do not form hydride. Even from group 6, only chromium forms CrH. These hydrides conduct heat and electricity though not as efficiently as their parent metals do. Unlike saline hydrides, they are almost always nonstoichiometric, being deficient in hydrogen. For example,  $LaH_{2.87}$ ,  $YbH_{2.55}$ ,  $TiH_{1.5-1.8}$ ,  $ZrH_{1.3-1.75}$ ,  $VH_{0.56}$ ,  $NiH_{0.6-0.7}$ ,  $PdH_{0.6-0.8}$  etc. In such hydrides, the law of constant composition does not hold good.

Earlier it was thought that in these hydrides, hydrogen occupies interstices in the metal lattice producing distortion without any change in its type. Consequently, they were termed as interstitial hydrides. However, recent studies have shown that except for hydrides of Ni, Pd, Ce and Ac, other hydrides of this class have lattice different from that of the parent metal. The property of absorption of hydrogen on transition metals is widely used in catalytic reduction / hydrogenation reactions for the preparation of large number of compounds. 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**.

# **□** WATER

A major part of all living organisms is made up of water. Human body has about 65% and some plants have as much as 95% water. It is a crucial compound for the survival of all life forms. It is a solvent of great importance. The distribution of water over the earth's surface is not uniform. The estimated world water supply is given in Table.

# **Estimated World Water Supply**

Source	% of total
Oceans	97.33
Saline lakes and inland seas	0.008
Polar ice and glaciers	2.04
Ground water	0.61
Lakes	0.009
Soil moisture	0.005
Atomspheric water vapour	0.001
Rivers	0.001

# Physical Properties of Water

It is a colourless and tasteless liquid. Its physical properties are given in Table along with the physical properties of heavy water. The unusual properties of water in the condensed phase (liquid and solid states) are due to the presence of extensive hydrogen bonding between water molecules. This leads to high freezing point, high boiling point, high heat of vaporisation and high heat of fusion in comparison to  $H_2S$  and  $H_2Se$ . In comparison to other liquids, water has a higher specific heat, thermal conductivity, surface tension, dipole moment and dielectric constant, etc. These properties allow water to play a key role in the biosphere.

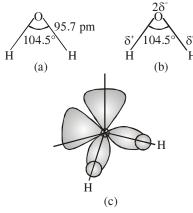
Physical Properties of H<sub>2</sub>O and D<sub>2</sub>O

Property	$\mathbf{H}_2\mathbf{O}$	$D_2O$
Molecular mass (g mol <sup>-1</sup> )	18.0151	20.0276
Melting point/K	273.0	276.8
Boiling point/K	373.0	374.4
Enthalpy of formation/kJ mol <sup>-1</sup>	-285.9	-294.6
Enthalpy of vaporisation (373K)/kJmol <sup>-1</sup>	40.66	41.61
Enthalpy of fusion/kJ mol <sup>-1</sup>	6.01	-
Temp of max. density/K	276.98	284.2
Density(298K)/g cm <sup>-3</sup>	1.0000	1.1059
Viscosity/centipoise	0.8903	1.107
Deielectric constant/C <sup>2</sup> /N.m <sup>2</sup>	78.39	78.06
Electrical conductivity (293K/ohm <sup>-1</sup> cm <sup>-1</sup> )	$5.7 \times 10^{-8}$	-

The high heat of vaporisation and heat capacity are responsible for moderation of the climate and body temperature of living beings. It is an excellent solvent for transportation of ions and molecules required for plant and animal metabolism. Due to hydrogen bonding with polar molecules, even covalent compounds like alcohol and carbohydrates dissolve in water.

**Structure of Water** 

In the gas phase water is a bent molecule with a bond angle of 104.5° and O-H bond length of 95.7 pm as shown in Fig (a).



H<sub>2</sub>O molecule

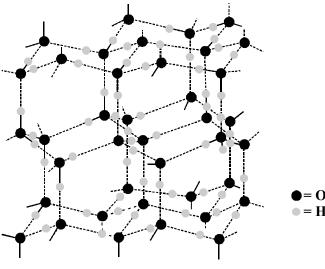
(a) The bent structure of water; (b) the water molecule as a dipole and (c) the orbital overlap picture in water molecule.

It is a highly polar molecule, (Fig (b)). Its orbital overlap picture is shown in Fig. (c). In the liquid phase water molecules are associated together by hydrogen bonds.

The crystalline form of water is ice. At atmospheric pressure ice crystallises in the hexagonal form, but at very low temperatures it condenses to cubic form. Density of ice is less than that of water. Therefore, an ice cube floats on water. 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.

# **Structure of Ice**

Ice has a highly ordered three dimensional hydrogen bonded structure as shown in Fig. Examination of ice crystals with X-rays shows that each oxygen atom is surrounded tetrahedrally by four other oxygen atoms at a distance of 276 pm. Hydrogen bonding gives ice a rather open type structure with wide holes. These holes can hold some other molecules of appropriate size interstitially.



The Structure of Ice

E

# Chemical Properties of Water

Water reacts with a large number of substances. Some of the important reactions are given below.

# (1) Amphoteric Nature:

It has the ability to act as an acid as well as a base i.e., it behaves as an amphoteric substance. In the Brönsted sense it acts as an acid with  $NH_3$  and a base with  $H_2S$ .

$$H_2O(\ell) + NH_3(aq) \rightarrow OH^-(aq) + NH_4^{+}(aq)$$

$$H_2O(\ell) + H_2O(aq) \rightarrow H_3O^+(aq) + HS^-(aq)$$

The auto-protolysis (self-ionization) of water takes place as follows:

$$H_2O(\ell) + H_2O(\ell) \to H_3O^+(aq) + OH^-(aq)$$

# (2) Redox Reactions Involving Water:

Water can be easily reduced to dihydrogen by highly electropositive metals.

$$2H_2O(\ell) + 2Na(s) \rightarrow 2NaOH(aq) + H_2(g)$$

Thus, it is a great source of dihydrogen.

Water is oxidised to O<sub>2</sub> during photosynthesis.

$$6\text{CO}_2(g) + 12\text{H}_2\text{O}(\ell) \rightarrow \text{C}_6\text{H}_{12}\text{O}_6(aq) + 6\text{H}_2\text{O}(\ell) + 6\text{O}_2(g)$$

With fluorine also it is oxidised to  $O_2$ .

$$2F_2(g) + 2H_2O(\ell) \to 4H^+\,(aq) + 4F^-(aq) + O_2(g)$$

# (3) Hydrolysis Reaction:

Due to high dielectric constant, it has a very strong hydrating tendency. It dissolves many ionic compounds. However, certain covalent and some ionic compounds are hydrolysed in water.

$$\mathrm{P_4O_{10}(s)} + 6\mathrm{H_2O}(\ell) \rightarrow 4\mathrm{H_3PO_4} \ (\mathrm{aq})$$

$$\mathrm{SiCl}_4(\ell) + 2\mathrm{H}_2\mathrm{O}(\ell) \to \mathrm{SiO}_2(s) + 4\mathrm{HCl}(aq)$$

$$N^{3-}(s) + 3H_2O(\ell) \rightarrow NH_3(g) + 3OH^{-}(aq)$$

# (4) Hydrates Formation:

From aqueous solutions many salts can be crystallised as hydrated salts. 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<sub>2</sub>.2H<sub>2</sub>O
- (iii) hydrogen-bonded water e.g.,

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

# **Problem -3**

The number of water molecule(s) directly bonded to the metal centre in CuSO<sub>4</sub>. 5H<sub>2</sub>O is - [JEE 2009]

Solution. 3,

$$\begin{bmatrix} H & H & 2+ & \Theta \\ H & Cu & H & O \\ H & O & H & O \end{bmatrix}$$

### Hard and Soft Water

Rain water is almost pure (may contain some dissolved gases from the atmosphere). Being a good solvent, when it flows on the surface of the earth, it dissolves many salts. Presence of calcium and magnesium salts in the form of hydrogencarbonate, chloride and sulphate in water makes water 'hard'. Hard water does not give lather with soap. Water free from soluble salts of calcium and magnesium is called **Soft water**. It gives lather with soap easily.

Hard water forms scum/precipitate with soap. Soap containing sodium stearate ( $C_{17}H_{35}COONa$ ) reacts with hard water to precipitate out Ca/Mg stearate.

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

It is, therefore, unsuitable for laundry. It is harmful for boilers as well, because of deposition of salts in the form of scale. This reduces the efficiency of the boiler. The hardness of water is of two types: (i) temporary hardness, and (ii) permanent hardness.

# Temporary Hardness:

Temporary hardness is due to the presence of magnesium and calcium hydrogencarbonates. It can be removed by :

(i) **Boiling**: During boiling, the soluble Mg(HCO<sub>3</sub>)<sub>2</sub> is converted into insoluble Mg(OH)<sub>2</sub> and Ca(HCO<sub>3</sub>)<sub>2</sub> is changed to insoluble CaCO<sub>3</sub>. It is because of high solubility product of Mg(OH)<sub>2</sub> as compared to that of MgCO<sub>3</sub>, that Mg(OH)<sub>2</sub> is precipitated. These precipitates can be removed by filtration. Filtrate thus obtained will be soft water.

$$\begin{array}{c} \text{Mg(HCO}_3)_2 & \xrightarrow{\text{Heating}} & \text{Mg(OH)}_2 \downarrow + 2\text{CO}_2 \uparrow \\ \\ \text{Ca(HCO}_3)_2 & \xrightarrow{\text{Heating}} & \text{CaCO}_3 \downarrow + \text{H}_2\text{O} + \text{CO}_2 \uparrow \end{array}$$

(ii) 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.

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

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

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# Permanent Hardness

It is due to the presence of soluble salts of magnesium and calcium in the form of chlorides and sulphates in water. Permanent hardness is not removed by boiling. It can be removed by the following methods:

(i) Treatment with washing soda (sodium carbonate): Washing soda reacts with soluble calcium and magnesium chlorides and sulphates in hard water to form insoluble carbonates.

$$MCl_2 + Na_2CO_3 \rightarrow MCO_3 \downarrow + 2NaCl (m + Mg, Ca)$$
  
 $MSO_4 + Na_2CO_3 \rightarrow MCO_3 \downarrow + Na_2SO_4$ 

(ii) Calgon's method: Sodium hexametaphosphate ( $Na_6P_6O_{18}$ ), commercially called 'calgon', when added to hard water, the following reactions take place.

$$Na_6P_6O_{18} \rightarrow 2Na^+ + Na_4P_6O_{18}^{2-}$$
 (M = Mg. Ca)

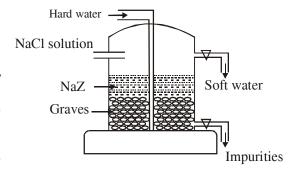
$$M^{2+} + Na_4P_6O_{18}^{2-} \rightarrow [Na_2MP_6O_{18}]^{2-} + 2Na^+$$

The complex anion keeps the Mg<sup>2+</sup> and Ca<sup>2+</sup> ions in solution.

(iii) Ion-exchange method (By Zeolite): This method is also called zeolite / permutit process.

$$\begin{split} &[\text{Na}_2\text{Al}_2\text{Si}_2\text{O}_8.\ x\text{H}_2\text{O}] \\ &[\text{Na}_2\text{O}.\text{Al}_2\text{O}_3.2\text{SiO}_2.\text{xH}_2\text{O}] \end{split}$$

Hydrated sodium aluminium silicate is zeolite/permutit. For the sake of simplicity, sodium aluminium silicate (NaAlSiO<sub>4</sub>) can be written as NaZ. When this is added in hard water, exchange reactions take place.



$$2\text{NaZ}(s) + \text{M}^{2+}(aq) \rightarrow \text{MZ}_2(s) + 2\text{Na}^+(aq) \text{ (M=Mg, Ca)}$$

Permutit/zeolite is said to be exhausted when all the sodium in it is used up. It is regenerated for further use by treating with an aqueous sodium chloride solution.

$$MZ_2(s) + 2NaCl(aq) \rightarrow 2NaZ(s) + MCl_2(aq)$$

(iv) Ion exchange method (By synthetic resins): Ion exchanges resins are the most popular water softener these days. This resins are synthetic substance. The cation exchanger consists of granular insoluble organic acid resins having giant molecules with –SO<sub>3</sub>H or –COOH groups (represented as RH) while the anion exchanger contains giant organic molecules with basic groups derived from amine (represented as ROH). Ion exchange resins remove all soluble mineral from water.

**Reaction at Cation exchanger** 

$$\mathrm{Ca^{2+}} + \mathrm{RH} {\longrightarrow} \mathrm{R_2Ca} + 2\mathrm{H}^{\scriptscriptstyle \oplus}$$

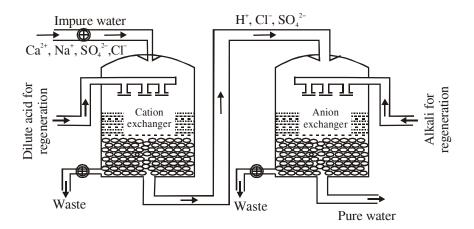
$$Mg^{2+} + RH \longrightarrow R_2^2 Mg + 2H^{\oplus}$$

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$$ROH + Cl^{-} \longrightarrow RCl + OH^{-}$$

$$2ROH + SO_{4}^{2-} \longrightarrow R_{2}SO_{4} + 2OH^{-}$$

The water coming from cation exchanger is acidic due to  $H^{\oplus}$ . This water is then passed through another bed containing anion exchanger. This exchanger removes anion like  $Cl^-$ ,  $SO_4^{2-}$ ,  $NO_3^-$  by exchanging with  $OH^-$  ions.



$$\mathrm{H}^+(\mathrm{aq}) + \mathrm{OH}^-(\mathrm{aq}) \to \mathrm{H}_2\mathrm{O}(\ell)$$

This water is free from impurities & can be used for drinking purpose.

After some times when both resin gets exhausted process is stopped.

### **Regenration of resin:**

(i) Cation exchange resin: We use dil acid.

$$2HCl + R_2Ca \longrightarrow RH + CaCl_2$$

(ii) Anion exchange resin : We use dil NaOH solution

# $\Box$ HYDROGEN PEROXIDE (H<sub>2</sub>O<sub>2</sub>)

This article has been taken in p-block chapter.

# $\Box$ HEAVY WATER, D<sub>2</sub>O:

It can be prepared by exhaustive electrolysis of water or as a by-product in some fertilizer industries.

# Physical properties :

(a) Heavy water is a colourles, odourless and tasteless mobile liquid, (b) Nearly all the physical constants are higher than the corresponding values of ordinary water.

It is used for the preparation of other deuterium compounds, for example:

$$CaC_2 + 2D_2O \rightarrow C_2D_2 + Ca(OD)_2$$
  
 $SO_3 + D_2O \rightarrow D_2SO_4$   
 $Al_4C_3 + 12D_2O \rightarrow 3CD_4 + 4Al(OD)_3$ 

• Uses: It is extensively used as a moderator & coolant in nuclear reactors and in exchange reactions for the study of reaction mechanisms. As a neutron moderator: Fission in uranium-235 is brought by slow speed neutrons. The substances which are used for slowing down the speed of neutrons are called moderators. Heavy water is used for this purpose in nuclear reactors.

# **□** DIHYDROGEN AS A FUEL

Dihydrogen releases large quantities of heat on combustion. The data on energy released by combustion of fuels like dihydrogen, methane, LPG etc. are compared in terms of the same amounts in mole, mass and volume, are shown in Table.

From this table it is clear that on a mass for mass basis dihydrogen can release more energy than petrol (about three times). Moreover, pollutants in combustion of dihydrogen will be less than petrol. The only pollutants will be the oxides of dinitrogen (due to the presence of dinitrogen as impurity with dihydrogen).

This, of course, 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. However, the mass of the containers in which dihydrogen will be kept must be taken into consideration. A cylinder of compressed dihydrogen weighs about 30 times as much as a tank of petrol containing the same amount of energy. Also, dihydrogen gas is converted into liquid state by cooling to 20K. This would require expensive insulated tanks. Tanks of metal alloy like NaNi<sub>5</sub>, Ti–TiH<sub>2</sub>, Mg–MgH<sub>2</sub> etc. are in use for storage of dihydrogen in small quantities. These limitations have prompted researchers to search for alternative techniques to use dihydrogen in an efficient way.

In this view Hydrogen Economy is an alternative. The basic principle of hydrogen economy is the transportation and storage of energy in the form of liquid or gaseous dihydrogen. Advantage of hydrogen economy is that energy is transmitted in the form of dihydrogen and not as electric power. It is for the first time in the history of India that a pilot project using dihydrogen as fuel was launched in October 2005 for running automobiles. Initially 5% dihydrogen has been mixed in CNG for use in four-wheeler vehicles. The percentage of dihydrogen would be gradually increased to reach the optimum level.

Nowadays, it is also used in fuel cells for generation of electric power. It is expected that economically viable and safe sources of dihydrogen will be identified in the years to come, for its usage as a common source of energy.

The Energy Released by Combustion of Various Fuels in Moles, Mass and Volume

Energy released on Combustion in kJ state)	Dihydrogen in gaseous state)	Dihydrogen (in liuqid)	LPG	CH <sub>4</sub> gas	Octance (in liuquid state)
per mole	286	285	2220	880	5511
per gram	143	142	50	53	47
per litre	12	9968	25590	35	34005

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# DIHYDROGEN

1.	The sum number of neutrons and protons in one of the isotopes of hydrogen is:-					
	(A) 3	(B) 4	(C) 5	(D) 6		
					HY0001	
2.	The catalyst use	ed in Bosch process of manu	facture of H <sub>2</sub> is :-			
	(A) Finely divid	ded Ni (B) V <sub>2</sub> O <sub>5</sub>	(C) Pb	(D) $\operatorname{Fe_2O_3} + \operatorname{Cr_2O_3}$		
					HY0002	
3.	The most abunc	lant isotope of hydrogen is:	_			
	(A) Tritium	(B) Deuterium	(C) Protium	(D) Para hydrogen		
					HY0003	
4.	The n/p ratio fo	•				
	(A) 1	(B) 2	(C) 3	(D) Zero		
					HY0004	
5.	Ordinary hydro	gen at high temperature is a	mixture of :-			
	•	lrogen + 25% p-Hydrogen	(B) 25% o-Hydrogen + 75% p-Hydrogen			
	(C) 50% o-Hyd	rogen + 50% p-Hydrogen	(D) 1% o-Hydro	ogen + 99% p-Hydrogen		
					HY0005	
6.	Hydrogen is be					
	(A) Electroposis					
	(B) Electronega					
		opositive as well as elecctro-	_			
	(D) Neither elec	etropositive nor electronegat	ive			
_					HY0006	
7.		ature Para hydrogen is :-				
		than ortho hydrogen				
	(B) More stable than ortho hydrogen					
		s ortho hydrogen				
	(D) None of the	ese				
0	<b>117</b> 7				HY0007	
8.	When the same amount of zinc is treated separately with excess of sulphuric acid and excess of sodium hydroxide, the ratio of volumes of hydrogen evolved is:-					
	•					
	(A) 1:1	(B) 1:2	(C) 2:1	(D) 9:4		

(B) Sodium meta-aluminate

(D) Hydrated sodium aluminium silicate

(A) Normal sodium phosphate

(C) Sodium hexametaphosphate

E

19.	Permutit is:-						
	(A) Hydrated sodium	aluminium silicate	(B) Sodium hexamet	aphosphate			
	(C) Sodium silicate		(D) Sodium meta-alu	minate			
					HY0019		
20.	Heavy water has four	nd application in atomi	c reactor as :-				
	(A) Coolant		(B) Moderator				
	(C) Both coolant and	moderator	(D) Neither coolant r	or moderator			
21.	Calgon (a water softe	ener) is :-					
	(A) Na2[Na4(PO3)6]	$(B) \operatorname{Na}_{4}[\operatorname{Na}_{2}(\operatorname{PO}_{3})]_{6}$	$(C) \operatorname{Na}_{2}[\operatorname{Na}_{4}(\operatorname{PO}_{4})]_{6}$	(D) $Na_4[Na_2(PO_4)]$	6]		
					HY0021		
22.	The hardness of water	er is due tometal	ions				
	(A) Ca <sup>2+</sup> and Na <sup>+</sup>	(B) $Mg^{2+}$ and $K^+$	(C) $Ca^{2+}$ and $Mg^{2+}$	(D) $Zn^{2+}$ and $Ba^{2+}$			
					HY0022		
23.	The formula of heav	y water is :-					
	(A) $H_2O^{18}$	(B) $D_2O$	(C) $T_2O$	(D) $H_2O^{17}$			
					HY0023		
24.		Pure de-mineralised water can be obtained by -					
	<ul><li>(A) Na<sup>+</sup> cation excha</li><li>(B) H<sup>+</sup> cation excha</li></ul>	nger and Cl <sup>-</sup> anion excl	nanger				
		ger and OH <sup>-</sup> anion exch	anger				
	(D) Na <sup>+</sup> cation excha	=	S				
					HY0024		
			EROXIDE (H <sub>2</sub> O <sub>2</sub> )				
25.		rties of H <sub>2</sub> O <sub>2</sub> are due to					
	(A) Reducing proper	ties	(B) Oxidising properties				
	(C) Unstable nature		(D) Acidic nature		11370025		
26.	Hydrogen peroxide l	200 0 .			HY0025		
20.	(A) Linear structure	ilas a	(R) Pyramidal structu	ıre			
	(C) Closed book type structure		<ul><li>(B) Pyramidal structure</li><li>(D) Half open book type structure</li></ul>				
	(e) closed book type	o structure	(B) Han open book t	y pe structure	HY0026		
27.	Hydrogen peroxide i	is a :-			1110020		
	(A) Liquid	(B) Gas	(C) Solid	(D) Semi-solid			
	• •				HV0027		

- 28. Which of the following is a true structure of H<sub>2</sub>O<sub>2</sub>

  - $(A) H \xrightarrow{180^{\circ}} O H \qquad (B) H \xrightarrow{94.8^{\circ}} O \searrow_{IJ} \qquad (C) H \searrow_{IJ} O O \qquad (D) H \searrow_{IJ} O = O$

HY0028

29. Decomposition of H<sub>2</sub>O<sub>2</sub> is retarded by :-

 $2\text{H}_2\text{O}_2(\ell) \rightarrow 2\text{H}_2\text{O}(\ell) + \text{O}_2(g)$ 

(A) Acetanilide

(B) MnO,

(C) Zinc

(D) Finely divided metals

HY0029

- **30.**  $H_2O_2$  is :-
  - (A) An oxiding agent

(B) Both oxidising and reducing agent

(C) Reducing agent

(D) None of the above

HY0030

- **31.** H<sub>2</sub>O<sub>2</sub> is always stored in black bottles because :-
  - (A) It is highly unstable
  - (B) Its enthalpy of decomposition is high
  - (C) It undergoes auto-oxidation on prolonged standing
  - (D) None of these

HY0031

- Acidified solution of K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> on treatment with H<sub>2</sub>O<sub>2</sub> yields:-**32.** 
  - $(A) CrO_3 + H_2O + O_3$

(B)  $Cr_{,}O_{,} + H_{,}O + O_{,}$ 

(C) CrO<sub>5</sub> + H<sub>2</sub>O + K<sub>2</sub>SO<sub>4</sub>

(D)  $H_2Cr_2O_7 + H_2O + O_3$ 

HY0032

- 33. H<sub>2</sub>O<sub>2</sub> restores the colour of old lead paintings, blackened by the action of H<sub>2</sub>S gas by:-
  - (A) Converting PbO<sub>2</sub> to Pb
- (B) By oxidising PbS to PbSO<sub>4</sub>
- (C) Converting PbCO<sub>3</sub> to Pb
- (D) Oxidising PbSO<sub>3</sub> to PbSO<sub>4</sub>

HY0033

- The reaction,  $H_2S + H_2O_2 \longrightarrow S + 2H_2O$  manifests: 34.
  - (A) Acidic nature of H<sub>2</sub>O<sub>2</sub>

- (B) Alkaline nature of H<sub>2</sub>O<sub>2</sub>
- (C) Oxidising nature of H<sub>2</sub>O<sub>2</sub>
- (D) Reducing nature of H<sub>2</sub>O<sub>2</sub>

HY0034

- **35.** Hydrogen peroxide is now generally prepared on industrial scale by the :-
  - (A) Action of H<sub>2</sub>SO<sub>4</sub> on barium peroxide
- (B) Action of H<sub>2</sub>SO<sub>4</sub> on sodium peroxide
- (C) auto-oxidation of 2-alklylanthraquinols
- (D) Burning hydrogen in excess of oxygen

# EXERCISE # 0-2

1.	(A) In the number of protons							
	(B) In the molecular	•						
	<ul><li>(C) In the nature of spins of nucleus</li><li>(D) In the nature of spins of electrons</li></ul>							
	(D) In the nature or	spins of electrons			11370027			
2	In Dosahla meagass	which cooks NOT util	ised for the production	of by drogon.	HY0036			
2.	-	_	ised for the production					
	(A) Producer gas	(B) Water gas	(C) Coal gas	(D) Natural gas	11370025			
3.	The goodes) used in	the hydrogenetics of	ails in prosonae of piel	ral as a patalyst is Land	HY0037			
3.	(A) Methane	(B) Ethane	oils in presence of nicl (C) Ozone	•	;			
	(A) Methane	(B) Ethane	(C) Ozolie	(D) Hydrogen	HY0038			
4.	Water softening by	Clarizaia proposa dosa	NOT was a		H 1 0038			
4.	(A) Calcium bicarb	Clarke's process does		(B) Sodium bicarbonate				
	(C) Potash alum		` '	(D) Calcium hydroxide				
					HY0039			
5.	Which of the following produces hydrolith with dihydrogen:-							
J.	(A) Mg	(B) Al	(C) Cu	(D) Ca				
	(11) 111g	( <b>D</b> ) / <b>H</b>	(C) Cu	(D) Cu	HY0040			
6.	Which process is/ar	Which process is/are used to remove permanent hardness:-						
0.	(A) Boiling	e asea to remove perm	(B) Clark's metho	d				
	` ,	(C) On reaction with with NaOH						
	(e) on reaction with with reacti		(D) Permutit proc		HY0041			
7.	Ionic hydrides is/ard	e usually :-			2220012			
	•	•	olid (B) Easily reduce	d				
	(C) Good reducing agents		(D) Liquid at roor					
	_			-	HY0042			
8.	Which of the follow	Which of the following will produce hydrogen gas:-						
	(A) Reaction between Fe and dil. HCl							
	(B) Reaction between Zn and conc. H <sub>2</sub> SO <sub>4</sub>							
	(C) Reaction between Zn and NaOH							
		NaCl (aq.) in Nelson'	s cell					
	, , <b>,</b>	<b>\ 1</b> /			HY0043			

Ε

9.	Ortho-hydrogen and para-hydrogen resembles in which of the following property:-					
	(A) Thermal conduct	ivity	(B) Magnetic propert	ties		
	(C) Chemical propert	ries	(D) Heat capacity			
					HY0044	
10.	Which of the following	ng statements concerni	ng protium, deuterium	and tritium is / are tr	ue:-	
	(A) They are isotopes of each other					
	(B) They have simila	r electronic configurati	ons			
	(C) They exist in the	nature in the ratio of 1	:2:3			
	(D) Their mass numb	pers are in the ratio of 1	:2:3			
					HY0045	
11.	Ionic hydrides are for	rmed by :-				
	(A) Transition metals	3				
	(B) Elements of very high electropositivity					
	(C) Elements of very low electropositivity					
	(D) Metalloids					
					HY0046	
12.	Which of the following	ng statements is/are cor	rect:			
	(A) Atomic hydrogen is obtained by passing hydrogen gas through an electric arc					
	(B) 30% (w/v) or 100V $H_2O_2$ solution is not called per hydrol.					
	(C) Finely divided palladium absorbs large volume of hydrogen gas.					
	(D) Ortho and para hydrogen have same physical properties.					
	(D) Ortilo and para in	ydrogen nave same pn	ysicai properties.		HY0047	
13.	Which hydride is/are an ionic hydride :-					
	(A) NH <sub>3</sub>	(B) H <sub>2</sub> S	(C) TiH <sub>1.73</sub>	(D) NaH		
	J	2	1.75		HY0048	
14.		ing hydride is/are "elec		(D) DU		
	(A) HF	(B) H <sub>2</sub> O	(C) SiH <sub>4</sub>	(D) $PH_3$	HY0049	
15.	Hydrogen peroxide o	can act as a :-			111004)	
	(A) A reducing agen		(B) An oxidising age	ent		
	(C) A dehydrating ag		(D) A bleaching age			
					HY0050	

# **EXERCISE # S-1**

# **Integer Type**

Find out the sum of protons, electrons and neutrons in the heaviest isotope of hydrogen.

HY0051

- 2. Find out the number of following orders which are correct against the mentioned properties:
  - (i)  $H_2 < D_2 < T_2$ (Number of protons)
  - (ii)  $H_2 < D_2$ (Bond energy)
  - (iii)  $H_2 < D_2 < T_2$ (Boiling point)
  - (iv)  $H_2 < D_2 < T_2$ (No. of neutrons)

HY0052

- **3.** Find out the number of following orders which are **NOT** correct against the mentioned properties :
  - (i)  $CaH_2 < BeH_2$

(Electrical conductance in molten condition)

(ii) LiH < NaH < CsH

(Ionic character)

(iii)  $H_{2} < D_{2} < F_{2}$ 

(Bond dissociation enthalpy)

(iv) NaH < MgH<sub>2</sub>< H<sub>2</sub>O

(Reducing property)

HY0053

4. What is the oxidation state of oxygen of  $H_2O_2$  in the final product when it reacts with  $ClO_3^-$ .

HY0054

Find out the value of 'x' in ion  $[H_vO_4]^+$ : **5.** 

# **EXERCISE # S-2**

# **Matrix Match Type**

1. Match List I with List II and select the correct answer using the codes given below the lists:-

List – I

P. Heavy water

Q. Temporary hard

R. Soft water

S. Permanent hard

List II

1. Bicarbonates of Mg and Ca in water

2. No foreign ions in water

3. D<sub>2</sub>O

4. Sulphates and chlorides of Mg and Ca in water

Code:

P

R

S

(A) 3

1

Q

2

4

(B) 3

4

2

3

(C) 3 (D) 2

3

1

4

HY0056

2. Match List I with List II and select the correct answer using the codes given below the lists:-

List - I

P. Calgon

Q. Non-stoichiometric compound

R. Covalent hydride

S. Salt-like hydride

List II

1. Metallic hydride

2. Polymetaphosphate of sodium

3. Hydrolith

4. Hydrogen compounds of non-metals

Code:

P

Q

R

 $\mathbf{S}$ 

(A) 2

1

3

4

(B)3

4

2

3

(C) 2

1

4

3

(D) 2

3

1

4

# **Comprehenstion Type:**

# Passage for Q.3 to Q.5

Hydrogen accounts for approximately 75% of the mass of the universe. Hydrogen serves as the nuclear fuel of our Sun and other stars, and these are mainly composed of hydrogen.

Hydrogen has three isotopes: hydrogen or protium (<sup>1</sup><sub>1</sub>H), deuterium or heavy hydrogen (D or <sup>2</sup><sub>1</sub>H), tritium (T or <sup>3</sup>, H).

- **3.** Which of the following is radioactive in nature?
  - (A) hydrogen only

(B) deuterium only

(C) tritium only

(D) deuterium and tritium

HY0058

- 4. Hydrogen, H<sub>2</sub>, is very less abundant in the atmosphere due to -
  - (A) inflammable nature of H,
  - (B) weak earth's gravity which is not able to hold light  $H_2$  molecules
  - (C) diatomic nature of hydrogen
  - (D) very rapid reaction between hydrogen and atmospheric oxygen

HY0058

- **5.** Liquid H<sub>2</sub> has been used as rocket fuel as
  - (A) its reaction with oxygen is highly exothermic
  - (B) it occupies small space
  - (C) it has high thrust
  - (D) all of the above

HY0058

# MATCHING LIST TYPE 1 × 3 Q. (THREE LIST TYPE Q.)

Column - I Name	Column - II] Formula	Column - III Specification
(1) Calogen	$(P) Na_6P_6O_{18}$	(i) Used to Remove temporary Hardness
(2) Permutit	(Q) Na <sub>2</sub> Al <sub>2</sub> Si <sub>2</sub> O <sub>8</sub> .xH <sub>2</sub> O	(ii) Used to remove permanent hardness
(3) Perhydrol	(R) '100 V' H <sub>2</sub> O <sub>2</sub>	(iii) Used in Rockect propelent
(4) Washing Soda	(S) Na <sub>2</sub> CO <sub>3</sub> .10H <sub>2</sub> O	(iv) Also named as zeolite

- Which combination is **NOT** related to removal of Ca<sup>+2</sup>/Mg<sup>+2</sup> form the sample of water **6.** 
  - (A)(1)-(P)-(i)(ii)
- (B) (2)-(Q)-(i)(ii)(iv) (C) (3)-(R)-(i)(ii)
- (D) (4)-(S)-(i)(ii)

HY0059

nodeJ6\B0B0-BA\Kato\JEFJAdvanced}\Enfluse\Gremishy\Shee\Hydrogen &If's comp.,f-Block &Environmental Chem\(i) Hydrogen &Its comp\Eng p6S

- 7. Which of the following is **INCORRECT** between column I & II
  - (A) 1-P
- (B) 2-Q
- (C) 3-R
- (D) 2-S

HY0059

- **8.** Which of the following is **INCORRECT** matching between column III & column II
  - (A)(iii) R
- (B)(iv) Q
- (C) (iv) P
- (D) none of these

HY0059

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[AIEEE 2003]

1.

# **EXERCISE # JEE-MAIN**

Which one of the following processes will produce hard water:-

(1) Saturation of water with CaSO<sub>4</sub> (2) Addition of Na<sub>2</sub>SO<sub>4</sub> to water (3) Saturation of water with CaCO<sub>3</sub> (4) Saturation of water with MgCO<sub>3</sub> HY0060 2. Very pure hydrogen (99.9%) can be made by which of the following processes?[AIEEE 2012] (1) Reaction of salt like hydrides with water (2) Reaction of methane with steam (3) Mixing natural hydrocarbons of high molecular weight (4) Electrolysis of water **HY0061 3.** [**JEE(Main)** 2014] In which of the following reaction  $H_2O_2$  acts as a reducing agent? (a)  $H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$ (b)  $H_2O_2 - 2e^- \rightarrow O_2 + 2H^+$ (c)  $H_2O_2 + 2e^- \rightarrow 2OH^-$ (d)  $H_2O_2 + 2OH^- - 2e^- \rightarrow O_2 + 2H_2O$ (1)(a),(c)(2)(b),(d)(3)(a),(b)(4)(c),(d)HY0062 4. Which of the following statements about  $Na_2O_2$  is **not** correct? [**JEE(Main)** 2014] (1) Na<sub>2</sub>O<sub>2</sub> oxidises Cr<sup>3+</sup> to CrO<sub>4</sub><sup>2-</sup> in acid medium (2) It is diamagnetic in nature (3) It is the super oxide of sodium (4) It is a derivative of H<sub>2</sub>O<sub>2</sub> HY0063 **5.** Hydrogen peroxide acts both as an oxidising and as a reducing agent depending upon the nature of the reacting species. In which of the following cases  $H_2O_2$  acts as a reducing agent in acid medium ? :-JEE(Main)Online-2014]  $(2) SO_3^{2-}$ (1)  $MnO_{\Delta}^{-}$ (4)  $Cr_2O_7^{2-}$ (3) KI HY0064 Permanent hardness in water cannot be cured by: JEE(Main)Online-2015] 6. (1) Treatment with washing soda (2) Calgon's method (3) Boiling (4) Ion exchange method **HY0065** 7. From the following statements regarding H<sub>2</sub>O<sub>2</sub>, choose the incorrect statement : (1) It has to be stored in plastic or wax lined glass bottles in dark **JEE(Main)Online-2015**] (2) It has to be kept away from dust (3) It can act only as an oxidizing agent (4) It decomposes on exposure to light HY0066

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28 JEE-Chemistry ALLEN

8.	In which of the follo	wing reaction, h	vdrogen peroxide act	s as an oxidizing agent?
•	III WILLOW OF CITE TOTAL	" III S TOUGHOII, II	janoson peromiae aet	e as an emaising agent.

(1)  $I_2 + H_2O_2 + 2OH^- \rightarrow 2I^- + 2H_2O + O_2$ 

**JEE(Main)-2017**]

- (2)  $HOC1 + H_2O_2 \rightarrow H_3O^+ + Cl^- + O_2$
- (3) PbS +  $4H_2O_2 \rightarrow PbSO_4 + 4H_2O$
- (4)  $2MnO_4^- + 3H_2O_2 \rightarrow 2MnO_2 + 3O_2 + 2H_2O + 2OH^-$

HY0067

- 9. Hydrogen peroxide oxidises  $[Fe(CN)_6]^{4-}$  to  $[Fe(CN)_6]^{3-}$  in acidic medium but reduces  $[Fe(CN)_6]^{3-}$  to  $[Fe(CN)_6]^{4-}$  in alkaline medium. The other products formed are, respectively :
  - $(1) (H_2O + O_2)$  and  $(H_2O + OH^-)$

**JEE(Main) -2018**]

- (2)  $H_2O$  and  $(H_2O + O_2)$
- (3)  $H_2O$  and  $(H_2O + OH^-)$
- $(4) (H_2O + O_2)$  and  $H_2O$

HY0068

**10.** The chemical nature of hydrogen preoxide is :-

**JEE(Main) -2019**]

- (1) Oxidising and reducing agent in acidic medium, but not in basic medium.
- (2) Oxidising and reducing agent in both acidic and basic medium
- (3) Reducing agent in basic medium, but not in acidic medium
- (4) Oxidising agent in acidic medium, but not in basic medium.

HY0069

- 11. The total number of isotopes of hydrogen and number of radioactive isotopes among them, respectively, are:

  JEE(Main) -2019]
  - (1) 2 and 0
- (2) 3 and 2
- (3) 3 and 1
- (4) 2 and 1

HY0070

- 12. Th correct statements among (a) to (d) regarding H<sub>2</sub> as a fuel are: **JEE(Main) -2019**]
  - (a) It produces less pollutant than petrol
  - (b) A cylinder of compressed dihydrogen weighs ~ 30 times more than a petrol tank producing the same amount of energy
  - (c) Dihydrogen is stored in tanks of metal alloys like NaNi<sub>5</sub>
  - (d) On combustion, values of energy released per gram of liquid dihydrogen and LPG are 50 and 142 kJ, respectively
  - (1) b and d only
- (2) a, b and c only
- (3) b, c and d only
- (4) a and c only

HY0071

**13.** The correct statements among (a) to (b) are:

**JEE(Main) -2019]** 

- (a) saline hydrides produce  $H_2$  gas when reacted with  $H_2O$ .
- (b) reaction of LiAH<sub>4</sub> with BF<sub>3</sub> leads to B<sub>2</sub>H<sub>6</sub>.
- (c) PH<sub>3</sub> and CH<sub>4</sub> are electron rich and electron-precise hydrides, respectively.
- (d) HF and CH<sub>4</sub> are called as molecular hydrides.
- (1) (c) and (d) only

(2) (a), (b) and (c) only

(3) (a), (b), (c) and (d)

(4) (a), (c) and (d) only

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- **14.** In comparison to the zeolite process for the removal of permanent hardness, the synthetic resins method is:

  JEE(Main) -2020]
  - (1) less efficient as it exchanges only anions
  - (2) more efficient as it can exchange only cations
  - (3) less efficient as the resins cannot be regenerated
  - (4) more efficient as it can exchange both cations as well as anions

HY0073

- **15.** 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) an (z) is:

  JEE(Main) -2020]
  - (1)4

- (2) 3
- (3) 2
- (4) 1

HY0074

**16.** Among the statements (a) - (d), the correct ones are -

**JEE(Main) -2020]** 

- (a) Decomposition of hydrogen peroxide gives dioxygen
- (b) Like hydrogen peroxide, compounds, such as KClO<sub>3</sub>, Pb(NO<sub>3</sub>)<sub>2</sub> and NaNO<sub>3</sub>when heated liberated dioxygen
- (c) 2-Ethylanthraquinone is useful for the industrial preparation of hydrogen peroxide.
- (d) Hydrogen peroxide is used for the manufacture of sodium perborate
- (1) (a), (b) and (c) only

(2) (a) and (c) only

(3) (a), (b), (c) and (d)

(4) (a), (c) and (d) only

		EXERCISE #	JEE ADVANC	ED			
1.	When zeolite (hydrated sodium aluminium silicate) is treated with hard water, the sodium ions are exchanged						
	with:-				[IIT 1990]		
	(A) H <sup>+</sup> ions	(B) Ca <sup>2+</sup> ions	(C) $SO_4^{2-}$ ions	(D) OH ions			
					HY0076		
2.	Which of the foll	owing statement is corre	ect:-				
	(A) Hydrogen ha	s same ionisation potent	tial as sodium				
	(B) H has same e	lectronegativity as halog	gens				

**HY0077** 

- **3.** Polyphosphates are used as water softening agent because they:-[IIT 2002]
  - (A) Form soluble complexes with anionic species
  - (B) Precipitate anionic species

(C) It will not be liberated at anode

(D) H has oxidation state +1, zero and -1

- (C) Form soluble complexes with cationic species
- (D) Precipitate cationic species.

HY0078

4. Hydrogen peroxide in its reaction with KlO<sub>4</sub> and NH<sub>2</sub>OH respectively, is acting as a

[JEE Adv. 2014]

- (A) reducing agent, oxidising agent
- (B) reducing agent, reducing agent
- (C) oxidising agent, oxidising agent
- (D) oxidising agent, reducing agent

HY0079

**5.** Which of the following combination will produce H, gas? [JEE Adv. 2017]

- (A) Zn metal and NaOH(aq.)
- (B) Au metal and NaCN(aq.) in the presence of air
- (C) Cu metal and conc. HNO<sub>3</sub>
- (D) Fe metal and conc. HNO<sub>3</sub>

# **ANSWERS KEY**

# **EXERCISE: 0-1**

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	A	D	С	D	A	C	A	A	D	В	В	С	A	A	В
Que.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ans.	D	В	С	A	С	A	С	В	С	В	D	A	В	A	В
Que.	31	32	33	34	35										
Ans.	С	C	В	C	С										

# **EXERCISE: 0-2**

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	A,B,D	A,C,D	D	A,B,C	D	D	C	A,C,D	C	A,B,D
Que.	11	12	13	14	15					
Ans.	В	A,C	D	С	A,B,D					

# **EXERCISE: S-1**

Que.	1	2	3	4	5
Ans.	4	3	3	0	9

# **EXERCISE: S-2**

Q	ue.	1	2	3	4	5	6	7	8
A	ns.	A	C	С	В	D	С	D	С

# **EXERCISE: JEE-MAINS**

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	1	4	2	3	1	3	3	3	2	2
Que.	11	12	13	14	15	16				
Ans.	3	2	3	4	2	3				

# **EXERCISE: JEE-ADVANCED**

	Que.	1	2	3	4	5
ĺ	Ans.	В	D	С	A	A

# **Inner Transition Elements:**

The elements in which the additional electron enters in (n-2)f orbitals are called inner **transition** elements or f-block elements.

# Position in the periodic table:

The lanthanides resemble with Yttrium in most of their properties. So it became necessary to accommodate all the fifteen elements together at one place. This has been done by placing the first element, lanthanum below yttrium and placing the remaining fourteen elements separately in the lower part of the periodic table.

Lanthanide series (Z = 58 - 71) (Ce - Lu)Actinide series (Z = 90 - 103) (Th - Lr)

# LANTHANIDES (RARE EARTHS OR LANTHANONES)

- (i) Lanthanides are reactive elements so do not found in free state in nature.
- (ii) Most important minerals for lighter Lanthanides are Monazite, cerites and for heavier lanthanides Gadolinite and Xenotime

# **Electronic configuration:**

(i) The general configuration of lanthanides may be given as  $4f^{1-14}5s^25p^65d^{0-1}6s^2$ .

Atomic	Element	Symbol	Outer electronic co	nfiguration
Number			Atomic	+3 ion
58	Cerium	Ce	4f <sup>1</sup> 5d <sup>1</sup> 6s <sup>2</sup>	$4f^1$
59	Praseodymium	Pr	$4f^3 6s^2$	$4f^2$
60	Neodymium	Nd	$4f^4 6s^2$	$4f^3$
61	Promethium	Pm	$4f^5 6s^2$	$4f^4$
62	Samarium	Sm	$4f^6 6s^2$	$4f^5$
63	Europium	Eu	$4f^7 6s^2$	$4f^6$
64	Gadolinium	Gd	$4f^7 5d^1 6s^2$	$4f^7$
65	Terbium	Tb	4f <sup>9</sup> 6s <sup>2</sup>	4f <sup>8</sup>
66	Dysprosium	Dy	$4f^{10} 6s^2$	$4f^9$
67	Holmium	Но	$4f^{11} 6s^2$	$4f^{10}$
68	Erbium	Er	$4f^{12} 6s^2$	$4f^{11}$
69	Thulium	Tm	$4f^{13} 6s^2$	$4f^{12}$
70	Ytterbium	Yb	$4f^{14} 6s^2$	$4f^{13}$
71	Lutetium	Lu	4f <sup>14</sup> 5d <sup>1</sup> 6s <sup>2</sup>	$4f^{14}$

- (ii) It is to be noted that filling of 4f orbitals in the atoms is not regular. A 5d electron appears in gadolinium (Z = 64) with an outer electronic configuration of  $4f^75d^16s^2$  (and not  $4f^86s^2$ ). This is because the 4f and 5d electrons are at about the same potential energy and that the atoms have a tendency to retain stable half filled configuration.
- (iii) On the other hand, the filling of f-orbitals is regular in tripositive ions.
- (iv) After losing outer electrons, the f-orbitals shrink in size and became more stable.
- (v) **Pm** is the only synthetic radioactive lanthanide.

# **Oxidation states:**

Lanthanides	Oxidation	Actinides	Oxidation state
Ce <sub>58</sub>	+3, +4	$Th_{90}$	+4
Pr <sub>59</sub>	+3, (+4)	Pa <sub>91</sub>	(+4), +5
Nd <sub>60</sub>	+3	$\mathrm{U_{92}}$	(+3), (+4), (+5), +6
Pm <sub>61</sub>	+3	$Np_{93}$	(+3), (+4), +5, (+6), (+7)
Sm <sub>62</sub>	(+2), +3	$Pu_{94}$	(+3), +4, (+5), (+6), (+7)
Eu <sub>63</sub>	+2, +3	$Am_{95}$	+2,(+3),(+4),(+5),(+6)
Gd <sub>64</sub>	+3	$Cm_{96}$	+3, (+4)
Tb <sub>65</sub>	+3, +4	$\mathrm{Bk}_{97}$	+3, (+4)
Dy <sub>66</sub>	+3, (+4)	$\mathrm{Cf}_{98}$	+3
Ho <sub>67</sub>	+3	$\mathrm{Es}_{99}$	+3
Er <sub>68</sub>	(+2), +3	$Fm_{_{100}}$	+3
Tm <sub>69</sub>	(+2), +3	$\mathrm{Md}_{101}$	+3
Yb <sub>70</sub>	+2, +3	$\mathrm{No}_{_{102}}$	+3
Lu <sub>71</sub>	+3	Lr <sub>103</sub>	+3

# (Oxidation states in brackets are unstable states)

- (i) The lanthanides contains two  $\mathbf{s}$  electrons in the outermost shell, they are therefore expected to exhibit a characteristic oxidation state of +2. But for the lanthanides, the +3 oxidation is common.
- (ii) This corresponds to the use of two outermost electrons (6s²) alongwith one inner electron. The inner electron used is a 5d electron (in La, Gd and Lu), or one of the 4f electron if no 5d electrons present.
- (iii) All the lanthanides attains +3 oxidation state and only **Cerium, Praseodymium,** and **Terbium** exhibit **higher oxidation state** (+4). **Eu and Yb** exhibit +2 oxidation state.
- (iv) Oxidation states +2 and +4 occur particularly when they lead to -
  - (a) A noble gas configuration  $\mathbf{Ex.}$   $\mathbf{Ce^{4+}}$  (f  $^0$ ). The formation of  $\mathbf{Ce^{IV}}$  is favoured by its noble gas configuration, but it is a strong oxidant reverting to the common +3 state. The  $\mathbf{E^o}$  value for  $\mathbf{Ce^{4+}}$   $\mathbf{Ce^{3+}}$  is + 1.74 V which suggests that it can oxidise water. However, the reaction rate is very slow and hence  $\mathbf{Ce}(\mathbf{IV})$  is a good analytical reagent.
  - (b) A half filled 'f' orbital **Ex.** Eu<sup>2+</sup>, (f<sup>7</sup>), Pr, Nd, Tb and Dy also exhibit +4 state but only in oxides,  $MO_2$ . Eu<sup>2+</sup> is formed by losing the two s electrons and its  $f^7$  configuration accounts for the formation of this ion. However, Eu<sup>2+</sup> is a strong reducing agent changing to the common +3 state. Similarly Yb<sup>2+</sup> which has  $f^{14}$  configuration is a reductant.
  - (c) A completely filled 'f' orbital **Ex.** Yb<sup>2+</sup> (f <sup>14</sup>)
- (v) Therefore, in higher oxidation state, they act as oxidising while in lower state as reducing agents.

# **Magnetic properties:**

- (i) In tripositive lanthanide ions the number of unpaired electrons regularly increases from lanthanum to Gadolinium (0 to 7) and then continuously decreases upto lutecium (7 to 0).
- (ii) lanthanum and lutecium ions are diamagnetic, while all other tripositive lanthanide ions are paramagnetic. (Exception Neodyomium is the most paramagnetic lanthanide).
- (iii) Ce<sup>+4</sup> and Yb<sup>+2</sup> are also diamagnetic ions.

### **Colour:**

- (i) The lanthanide ions have unpaired electrons in their 4f orbitals. Thus these ions absorbs visible region of light and undergo f–f transition and hence exhibit colour.
- (ii) The colour exhibited depends on the number of unpaired electrons in the 4f orbitals.
- (iii) The ions often with 4f<sup>n</sup> configuration have similar colour to those ions having 4f<sup>14-n</sup> configuration.
- (iv) Lanthanide ions having 4f <sup>0</sup>, 4f <sup>14</sup> are colourless.

# **Other Properties:**

- All the lanthanoids are silvery white soft metals and tarnish rapidly in air.
- The hardness increases with increasing atomic number, samarium being steel hard. Their melting points range between 1000 to 1200 K but samarium melts at 1623 K.
- They have typical metallic structure and are good conductors of heat and electricity.
- Highly dense metals with high m.pts. do not show any regular trend.
- **Ionisation Energies :** Lanthanides have fairly low ionisation energies comparable to alkaline earth metals.
- **Electro positive character:** High due to low I.P.
- Complex formation: Do not have much tendency to form complexes due to low charge density because of their large size. Lu<sup>+3</sup> is smallest in size can only form complex.
- **Reducing Agent:** They readily lose electrons so are good reducing agent.
- **Alloy:** Alloys of lanthanides with Fe are called Misch **metals**, which consists of a lanthanoid metal (~95%) and iron (~5%) and traces of S, C, Ca and Al.
- **Basic Nature :** La(OH)<sub>3</sub> is most basic in nature while Lu(OH)<sub>3</sub> least basic.
- Carbide: Lanthanides form MC, type carbide with carbon, which on hydrolysis gives C<sub>2</sub>H<sub>2</sub>.
- The lanthanide elements Eu and Yb dissolve directly in very high concentration in liquid ammonia.

### **Lanthanide contraction:**

- (i) In the lanthanide series with increasing atomic number, there is a progressive decrease in the size from lanthanum to lutetium or from La<sup>+3</sup> to Lu<sup>+3</sup>. This contraction in size is known as lanthanide contraction.
- (ii) The general electronic configuration of these elements is  $4f^{1-14}5s^2p^6d^{0-1}6s^2$ . In these elements the added electron enters the deep seated f-orbitals and therefore experiences considerable pull by the nucleus.
- (iii) Due to very poor shielding effect of (n-2)f electrons, they exert very little screening effect on the outermost 6s<sup>2</sup> electrons.
  - Hence, with increasing atomic number, the enhanced nuclear charge leads to contraction in the size of atoms and ions.
- (iv) The atomic volumes of Europium and Ytterbium are unexceptely large. The large atomic size of Eu and Yb suggest weaker bonding in the solid elements. Both these elements have only two electrons extra than the stable configurations (half filled, f<sup>7</sup>, and completely filled, f<sup>14</sup>), hence they utilise two electrons in metallic bonding as in the case with barium.

### **Effects of Lanthanide Contraction:**

Close resemblance of Lanthanides: The general decrease in the sizes of the lanthanides with an increase in their nuclear charges result in a small increase in their ionisation energies. Hence their basic and ionic nature gradually decreases from La to Lu. This also explains the variations in properties such as increased tendency for hydrolysis and formation of complex salts and decreased thermal stability, solubility of their salts.

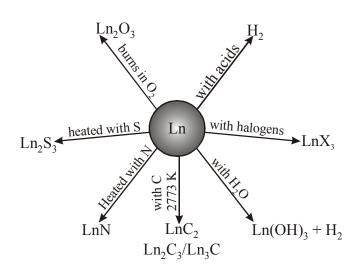
**Similarity of Yttrium with lanthanides:** The properties of Yttrium are so similar to the lanthanides that it is considered more a member of the lanthanide series than a congener of scandium.

**Anomalous behaviour of post-lanthanides :** The following anomalies may be observed in the behaviour of post-lanthanide elements.

- (a) Atomic size: The ionic radii of Zr<sup>+4</sup> is about 9% more than Ti<sup>+4</sup>. Similar trend is not maintained on passing from the second to third transition series. The ionic radius of Hf<sup>+4</sup>, instead of increasing (because of inclusion of one more electronic shell), decreases (or is virtually equal to Zr<sup>+4</sup>) as a consequence of the lanthanide contraction. This explains the close similarities between the members of the second and third transition series than between the elements of the first and second series.
- **(b) Ionisation potential and electronegativity :** The effect of lanthanide contraction is also seen in the increase in the ionisation potential values and electronegativities of the elements of the third transition series, contrary to the general trend. Because of the lanthanide contraction, the post-lanthanide elements have stronger positive field and thus the electrons are held more tightly.

The greater effective nuclear charge of the former make them more electronegative than the latter.

- **(c) High density:** Because of lanthanide contraction, the atomic sizes of the post lanthanide elements become very small. Consequently, the packing of atoms in their metallic crystals become so much compact that their densities are very high. The densities of the third transition series elements are almost double to those of the second series elements.
- (d) Chemical reactions of the lanthanoids.



# **Application of lanthanides:**

Cerium is most useful element in the lanthanides –

- Ceramic application CeO<sub>2</sub>, La<sub>2</sub>O<sub>3</sub>, Nd<sub>2</sub>O<sub>3</sub> and Pr<sub>2</sub>O<sub>3</sub> are used as decolourizing agents for glasses.
- CeS (m.p. 2000°C) is used in the manufacture of a special type of crucibles and refractories.
- Lanthanide compounds like cerium molybdate, cerium tungstate are used as paints and dyes.
- In textile and leather industries (Ce salts).
- Mish metal is pyropheric and is used in cigarette & gas lighter.

### **ACTINIDES (5f - BLOCK ELEMENTS)**

- (i) The elements in which the extra electron enters 5f-orbitals of (n-2)th main shell are known as actinides.
- (ii) The man-made eleven elements  $Np_{93} Lr_{103}$  are placed beyond uranium in the periodic table and are collectively called trans-uranium elements.
- (iii) Th, Pa and U first three actinides are natural elements.

# **Electronic configuration:**

The general configuration of actinides may be given as 5f <sup>1-14</sup> 6d<sup>0-1</sup>,7s<sup>2</sup>.

Atomic No.	Elements	Symbol	Electronic Configuration
90	Thorium	Th	5f <sup>0</sup> 6d <sup>2</sup> 7s <sup>2</sup>
91	Protactinium	Pa	$5f^26d^17s^2$
92	Uranium	U	$5f^36d^17s^2$
93	Neptunium	Np	$\mathbf{5f^46d^17s^2}$
94	Plutonium	Pu	$5f^66d^07s^2$
95	Americium	Am	$5f^{7}6d^{0}7s^{2}$
96	Curium	Cm	$5f^76d^17s^2$
97	Berkelium	Bk	$5f^96d^07s^2$
98	Californium	Cf	$5f^{10}6d^{0}7s^{2}$
99	Einstenium	Es	$5f^{11}6d^{0}7s^{2}$
100	Fermium	Fm	$5f^{12}6d^{0}7s^{2}$
101	101 Mandelevium		$5f^{13}6d^{0}7s^{2}$
102	Nobelium	No	$5f^{14}6d^{0}7s^{2}$
103	Lawrencium	Lr	$5f^{14}6d^{1}7s^{2}$

# **Oxidation states:**

- (i) In lanthanides and actinides +3 oxidation is the most common for both of the series of elements.
- (ii) This oxidation state becomes increasingly more stable as the atomic number increases in the actinide series.
- (iii) Highest oxidation states in the actinides is +7 exhibited by  $Np_{03}$  &  $Pu_{04}$ , it is unstable.
- (iv) Highest stable oxidation state is +6 shown by  $U_{92}$ .

### **Other Properties:**

- **Physical appearance :** Acitinides are silvery white metals. They get tarnished when exposed to the attack of alkalies.
- **Density**: All the actinides except **thorium** and **americium** have high densities.
- **Colour :** Actinide ions are generally coloured. The colour of actinide ions depends upon the number of 5f-electrons. The ions containing no unpaired 5f-electrons (exactly full filled f-subshell) are colourless, as expected.
- **Ionisation energies :** Ionisation energies values of actinides are low.
- **Electropositive character:** All the known actinide metals are **highly electropositive**. They resemble lanthanide series in this respect.
- **Melting Boiling properties:** They have **high melting and boiling points.** They do not follow regular gradation of melting or boiling points with increase in atomic number.
- **Magnetic properties :** The actinide elements are paramagnetic due to the presence of unpaired electrons.
- **Radioactive nature :** All the actinides are radiaoactive in nature.
- **Actinide contraction :** The size of atom/cation decrease regularly along the actinides series. The steady decrease in ionic radii with increase in atomic number is referred to as **actinide contraction.** This is due to poor shielding of 5f-electrons.

### **Comparision of lanthanides and Actinides**

### **Points of Resemblance:**

- (i) Both lanthanides and actinides show a dominant oxidation state of +3.
- (ii) Both are electropositive and act as strong reducing agents.
- (iii) Cations with unpaired electrons in both of them are paramagnetic.
- (iv) Most of the cations of lanthanides and actinides are coloured.
- (v) Both of them show a steady decrease in their ionic radii along the series. Thus, lanthanides show **lanthanide contraction** and actinides show **actinide contraction**.

### Difference between lanthanides & Actinides:

	33		
	Lathanides		Actinides
1.	Besides the most common oxidation state of +3	1.	Besides the most common oxidation state of +3,
	lanthanides show +2 and +4 oxidation states in		actinides show +4, +5 and +6 oxidation states
	case of certain elements.		in case of certain elements.
2.	Lanthanides have less tendency towards	2.	Actinides have a stronger tendency towards
	complex formation.		complex formation.
3.	Except promethium, they are non radioactive.	3.	All the actinides are radioactive.
4.	Oxides and hydroxide of lanthanides are	4.	Oxides and hydroxides of actinides are
	less basic.		more basic

### Some important uses of actinides are as follows –

**Thorium:** Thorium is used in atomic reactors as fuel rods and in the treatment of cancer.

**Uranium :** Uranium is used as nuclear fuel. Its salts are used in glass industry (for imparting green colour). textile industry and also in medicines.

**Plutonium:** Plutonium is used as fuel for atomic reactors as well as in atomic bombs.

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### EXERCISE # 0-1

- 1. 5f-subshell is filled by electron(s) -
  - (A) In actinides

- (B) After filling of 7s-subshell
- (C) Before filling of electron in 6d series
- (D) All are correct

FB0001

- Ln (Lanthanide)  $\xrightarrow{\text{With}}$  (X) 2.
  - Ln (Lanthanide)  $\xrightarrow{\text{Burn With}}$  (Y)
  - Ln (Lanthanide)  $\xrightarrow{\text{Heated with}}$  (Z)
  - X, Y & Z are respectively -
  - (A)  $LnX_3$ ,  $Ln_2O_3$ ,  $Ln_3N$

(B)  $LnX_3$ ,  $Ln_2O_3$ , LnN

(C) LnX2, LnO, LnN

(D) LnX<sub>2</sub>, Ln<sub>2</sub>O<sub>3</sub>, Ln<sub>3</sub>N

FB0002

- 3. Last element of lanthanide series is -
  - (A) Lawrencium
- (B) Lutetium
- (C) Thulium
- (D) Hafnium

FB0003

- 4. Which is consequence of lanthanide contraction -
  - (A) Size of Zr >> Hf (B) Size of Zr << Hf (C) Size of Zr  $\approx$  Hf (D) Size of Zr > Zr<sup>4+</sup>

FB0004

- 5. Select the ion which is larger than Ce<sup>3+</sup>
  - (A)  $Lu^{3+}$
- (B) Eu<sup>3+</sup>
- (C)  $Ce^{4+}$
- (D)  $La^{3+}$

FB0005

- 6. Select the reducing agent out of given options-
  - (A) Ce<sup>4+</sup>
- (B)  $Eu^{2+}$
- (C) La<sup>3+</sup>
- (D) Na<sup>+</sup>

FB0006

- The correct order of ionic radii of Y<sup>3+</sup>, La<sup>3+</sup>, Eu<sup>3+</sup> and Lu<sup>3+</sup> is :-7.
  - (A)  $Y^{3+} < La^{3+} < Eu^{3+} < Lu^{3+}$
- (B)  $Y^{3+} < Lu^{3+} < Eu^{3+} < La^{3+}$
- (C)  $Lu^{3+} < Eu^{3+} < La^{3+} < Y^{3+}$
- (D)  $La^{3+} < Eu^{3+} < Lu^{3+} < Y^{3+}$

FB0007

- 8. Which of the following statement is **NOT CORRECT**?
  - (A) La(OH)<sub>3</sub>, is less basic than Lu(OH)<sub>3</sub>
  - (B) In lanthanide series, ionic radius of Ln<sup>3+</sup> ions decreases
  - (C) La is actually an element of transition series rather than lanthanide series
  - (D) Atomic radii of Zr and Hf are same because of lanthanide contraction.

FB0008

- 9. In the lanthanide series, the basicity of the lanthanide hydroxides
  - (A) Increases

- (B) Decreases
- (C) First increase and then decrease
- (D) First decrease and then increases

- The reason for the stability of Gd<sup>3+</sup> ion is **10.** 
  - (A) 4f subshell half filled
  - (B) 4f subshell completely filled
  - (C) Possesses the general electronic configuration of noble gases
  - (D) 4f subshell empty

FB0010

- Which of the following pairs has the same size? 11.
  - (A)  $Zn^{2+}$ ,  $Hf^{4+}$
- (B)  $Fe^{2+}$ ,  $Ni^{2+}$
- (C)  $Zr^{4+}$ ,  $Ti^{4+}$
- (D)  $Zr^{4+}$ ,  $Hf^{4+}$

FB0011

- Which of the following ions will exhibit colour in aqueous solutions? **12.** 
  - (A)  $Sc^{3+}$  (Z = 21) (B)  $La^{3+}$  (Z = 57) (C)  $Ti^{3+}$  (Z = 22)
- (D)  $Lu^{3+}$  (Z = 71)

FB0012

- **13.** Which of the following exhibits only +3 oxidation state?
  - (A) Ac
- (B) Pa
- (C) U
- (D) Th

- 1. Arrange Ce<sup>3+</sup>, La<sup>3+</sup>, Pm<sup>3+</sup> and Yb<sup>3+</sup> in increasing order of their ionic radius [AIEEE-2002]
  - (1)  $Yb^{3+} < Pm^{3+} < Ce^{3+} < La^{3+}$
- (2)  $Ce^{3+} > Yb^{3+} < Pm^{3+} < La^{3+}$
- (3)  $Yb^{3+} > Pm^{3+} < La^{3+} < Ce^{3+}$
- (4)  $Pm^{3+} < La^{3+} < Ce^{3+} > Yb^{3+}$

FB0014

**2.** Most common oxidation states shown by cerium are :

[AIEEE-2002]

- (1) +2, +4
- (2) +3, +4
- (3) +3, +5
- (4) +2, +3

FB0015

- 3. A reduction in atomic size with increase in atomic number is a characteristic of elements of :
  - (1) f-Block

(2) Radioactive series

[AIEEE-2003]

(3) High atomic masses

(4) d-Block

FB0016

- 4. The radius of La<sup>3+</sup> is 1.06Å, which of the following given values will be closest to the radius of Lu<sup>3+</sup> (At no. of Lu = 71, La = 57)
  [AIEEE-2003]
  - (1) 1.6 Å
- (2) 1.4 Å
- (3) 1.06 Å
- (4) 0.85 Å

FB0017

- 5. Cerium (Z = 58) is an important member of the lanthanoids. Which of the following statements about cerium is **INCORRECT** [AIEEE-2004]
  - (1) Cerium (IV) acts as an oxidising agent
  - (2) The +3 oxidation state of cerium is more stable than the +4 oxidation state
  - (3) The +4 oxidation state of cerium is not known in solutions
  - (4) The common oxidation states of cerium are +3 and +4

FB0018

**6.** The lanthanoid contraction is responsible for the fact that -

[AIEEE-2005]

- (1) Zr and Y have about the same radius
- (2) Zr and Nb have similar oxidation state
- (3) Zr and Hf have about the same radius
- (4) Zr and Zn have similar oxidation state

FB0019

7. Lanthanoid contraction is caused due to

[AIEEE-2006]

- (1) the same effective nuclear charge from Ce to Lu
- (2) the imperfect shielding on outer electrons by 4f electrons from the nuclear charge
- (3) the appreciable shielding on outer electrons by 4f electrons from the nuclear charge
- (4) the appreciable shielding on outer electrons by 5d electrons from the nuclear charge

FB0020

- **8.** Identify the **INCORRECT** statement among the following-
- [AIEEE-2007]
- (1) d-block elements show irregular and erratic chemical properties among themselves
- (2) La and Lu have partially filled d-orbitals and no other partially filled orbitals
- (3) The chemistry of various lanthanoids is very similar
- (4) 4f and 5f-orbitals are equally shielded

- 9. The actinoids exhibits more number of oxidation states in general than the lanthanoids. This is because [AIEEE-2007]
  - (1) The 5*f*-orbitals are more buried than the 4*f*-orbitals
  - (2) There is a similarly between 4f-and-5f in the their angular part of the wave function
  - (3) The actinoids are more reactive than the lanthanoids
  - (4) The 5*f*-orbitals extend further from the nucleus than the 4*f*-orbitals

FB0022

- 10. Larger number of oxidation states are exhibited by the actinoids than those by the lanthanoids, the main reason being [AIEEE-2008]
  - (1) 4f orbitals more diffused than the 5f orbitals
  - (2) lesser energy difference between 5f and 6d than between 4f and 5d orbitals
  - (3) more energy difference between 5f and 6d than between 4f and 5d orbitals
  - (4) more reactive nature of the actinides than the lanthanides

FB0023

- 11. Knowing that the chemistry of lanthanoids (Ln) is dominated by its +3 oxidation state, which of the following statements is **INCORRECT**? [AIEEE-2009]
  - (1) Ln(III) compounds are generally colourless
  - (2) Ln(III) hydroxides are mainly basic in character
  - (3) Because of the large size of the Ln(III) ions the bonding in its compounds is predominently ionic in character
  - (4) The ionic sizes of Ln(III) decrease in general with increasing atomic number

FB0024

- 12. In context of the lanthanoids, which of the following statements is **NOT CORRECT**?

  [AIEEE-2011]
  - (1) Because of similar properties the separation of lanthanoids is not easy
  - (2) Availability of 4f electrons results in the formation of compounds in +4 state for all the members of the series
  - (3) There is a gradual decrease in the radii of the members with increasing atomic number in the series
  - (4) All the members exhibit +3 oxidation state

FB0025

**13.** Which of the following forms stable +4 oxidation state?

[Jee-Main 2012, Online]

- (1) La(Z = 57)
- (2) Eu(Z = 63)
- (3) Gd(Z = 64)
- (4) Ce(Z = 58)

FB0026

- 14. The number of unpaired electrons in Gadolinium [Z = 64] is :- [Jee-Main 2012, Online]
  - (1) 2
- (2)6
- (3) 8
- (4) 3

**15.** The lanthanide ion that would show colour is-

[Jee-Main 2019, Online]

- $(1) \text{ Sm}^{3+}$
- $(2) La^{3+}$
- (3)  $Lu^{3+}$
- $(4) \text{ Gd}^{3+}$

FB0028

16. The highest possible oxidation states of uranium and plutonium, respectively, are:-

(1) 6 and 4

(2) 7 and 6

[Jee-Main 2019, Online]

(3) 4 and 6

(4) 6 and 7

FB0029

17. The correct order of atomic radii is:

[Jee-Main 2019, Online]

(1) Ce > Eu > Ho > N

(2) N > Ce > Eu > Ho

(3) Eu > Ce > Ho > N

(4) Ho > N > Eu > Ce

FB0030

18. The maximum number of possible oxidation states of actinoides are shown by [Jee-Main 2020, Online]

- (1) berkelium (Bk) and californium (Cf)
- (2) nobelium (No) and lawrencium (Lr)
- (3) actinium (Ac) and thorium (Th)
- (4) neptunium (Np) and plutonium (Pu)

FB0031

19. The electronic configurations of bivalent europium and trivalent cerium are

(atomic number : Xe = 54, Ce = 58, Eu = 63)

[Jee-Main 2020, Online]

(1) [Xe] 4f<sup>4</sup> and [Xe] 4f<sup>9</sup>

- (2) [Xe]  $4f^7$  and [Xe]  $4f^1$
- (3) [Xe]  $4f^7 6s^2$  and [Xe]  $4f^2 6s^2$
- (4) [Xe]  $4f^2$  and [Xe]  $4f^7$

FB0032

# **ANSWERS KEY**

### **EXERCISE # 0-1**

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13
Ans	D	В	В	С	D	В	В	A	В	A	D	C	Α

### **EXERCISE # JEE-MAIN**

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	1	2	1	4	3	3	2	4	4	2
Que.	11	12	13	14	15	16	17	18	19	
Ans.	1	2	4	3	1	4	3	4	2	

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# **ENVIRONMENTAL CHEMISTRY**

### 1. ENVIRONMENTAL POLLUTION

A substance, which causes pollution, is known as pollutant. Pollutants can be solid, liquid or gaseous substances present in greater concentration than in natural abundance and are produced due to human activities or due to natural happenings.

### 2. ATMOSPHERIC POLLUTION

The lowest region of atmosphere in which the human beings along with other organisms live is called **troposphere.** It extends up to the height of  $\sim 10$  km from sea level.

Above the troposphere, between 10 and 50 km above sea level lies **stratosphere**. The stratosphere contains dinitrogen, dioxygen, ozone and little water vapour.

The presence of ozone in the stratosphere prevents about 99.5 per cent of the sun's harmful ultraviolet (UV) radiations from reaching the earth's surface

### 2.1 Tropospheric Pollution

Tropospheric pollution occurs due to the presence of undesirable solid or gaseous particles in the air.

- **1. Gaseous air pollutants:** These are oxides of sulphur, nitrogen and carbon, hydrogen sulphide, hydrocarbons, ozone and other oxidants.
- **2. Particulate pollutants:** These are dust, mist, fumes, smoke, smog etc.

### 1. Gaseous air pollutants

- (a) Oxides of Sulphur: Oxides of sulphur are produced when sulphur containing fossil fuel is burnt.
  - Sulphur dioxide is a gas that is poisonous to both animals and plants. It causes respiratory diseases e.g., asthma, bronchitis, emphysema in human beings. Sulphur dioxide causes irritation to the eyes, resulting in tears and redness.
  - High concentration of SO<sub>2</sub> leads to stiffness of flower buds which eventually fall off from plants.
  - Uncatalysed oxidation of sulphur dioxide is slow. However, the presence of particulate matter in polluted air catalyses the oxidation of sulphur dioxide to sulphur trioxide.

$$2SO_{2}(g) + O_{2}(g) \rightarrow 2SO_{3}(g)$$

The reaction can also be promoted by ozone and hydrogen peroxide.

$$\mathrm{SO}_2(\mathsf{g}) + \mathrm{O}_3(\mathsf{g}) \to \mathrm{SO}_3(\mathsf{g}) + \mathrm{O}_2(\mathsf{g})$$

ALLEN

$$SO_2(g) + H_2O_2(1) \rightarrow H_2SO_4(aq)$$

- **(b)** Oxides of Nitrogen: Dinitrogen and dioxygen do not react with each other at a normal temperature. At high altitudes when lightning strikes, they combine to form oxides of nitrogen.
  - $NO_2$  is oxidised to nitrate ion,  $NO_3^-$  which is washed into soil, where it serves as a fertilizer.
  - In an automobile engine (at high temperature), when fossil fuel is burnt, dinitrogen and dioxygen combine to yield significant quantities of nitric oxide (NO) and nitrogen dioxide (NO<sub>2</sub>) as given below:

$$N_2(g) + O_2(g) \xrightarrow{1483 \text{ K}} 2NO(g)$$

NO reacts instantly with oxygen to give NO<sub>2</sub>

2NO (g) + 
$$O_2$$
 (g)  $\rightarrow$  2NO<sub>2</sub> (g)

Rate of production of  $NO_2$  is faster when nitric oxide reacts with ozone in the stratosphere.

$$NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g)$$

The irritant red haze in the traffic and congested places is due to oxides of nitrogen. Higher concentrations of  $NO_2$  damage the leaves of plants and retard the rate of photosynthesis. It is also a lung irritant.

- **(c) Hydrocarbons :** Hydrocarbons are formed by incomplete combustion of fuel used in automobiles and are carcinogenic.
- (d) Oxides of Carbon:
  - (i) Carbon monoxide: It blocks the delivery of oxygen to the organs and tissues. It is produced as a result of incomplete combustion of carbon.
    - It binds to haemoglobin to form carboxyhaemoglobin, which is about 300 times more stable than the oxygen-haemoglobin complex. In blood, when the concentration of carboxyhaemoglobin reaches about 3 4 per cent, the oxygen carrying capacity of blood is greatly reduced.
  - (ii) Carbon dioxide: Carbon dioxide (CO<sub>2</sub>) is released into the atmosphere by respiration, burning of fossil fuels for energy, and by decomposition of limestone during the manufacture of cement.
    - It forms about 0.03 per cent by volume of the atmosphere.

• The increased amount of CO<sub>2</sub> in the air is mainly responsible for global warming.

### Global Warming and Greenhouse Effect

- About 75 % of the solar energy reaching the earth is absorbed by the earth's surface, which increases its temperature. The rest of the heat radiates back to the atmosphere. Some of the heat is trapped by gases such as carbon dioxide, methane, ozone, chlorofluorocarbon compounds (CFCs) and water vapour in the atmosphere. Thus, they add to the heating of the atmosphere. This causes global warming.
- The atmosphere has kept the temperature on earth constant. As the glass in a greenhouse holds the sun's warmth inside, atmosphere traps the sun's heat near the earth's surface and keeps it warm. This is called natural greenhouse effect.

### Acid rain:

Normally rain water has a pH of 5.6 due to the presence of H<sup>+</sup> ions formed by the reaction of rain water with carbon dioxide present in the atmosphere.

$$\begin{aligned} &H_2O\left(l\right) + CO_2\left(g\right) \rightarrow H_2CO_3(aq) \\ &H_2CO_3\left(aq\right) \rightarrow H^+\left(aq\right) + HCO_3^-\left(aq\right) \end{aligned}$$

When the pH of the rain water drops below 5.6, it is called acid rain.

Burning of fossil fuels (which contain sulphur and nitrogenous matter) such as coal and oil in power stations and furnaces or petrol and diesel in motor engines produce sulphur dioxide and nitrogen oxides. SO<sub>2</sub> and NO<sub>2</sub> after oxidation and reaction with water are major contributors to acid rain.

$$\begin{split} 2\mathrm{SO}_2\left(\mathrm{g}\right) + \mathrm{O}_2\left(\mathrm{g}\right) + 2\mathrm{H}_2\mathrm{O}\left(\mathrm{l}\right) &\rightarrow 2\mathrm{H}_2\mathrm{SO}_4\left(\mathrm{aq}\right) \\ 4\mathrm{NO}_2\left(\mathrm{g}\right) + \mathrm{O}_2\left(\mathrm{g}\right) + 2\mathrm{H}_2\mathrm{O}\left(\mathrm{l}\right) &\rightarrow 4\mathrm{HNO}_3\left(\mathrm{aq}\right) \end{split}$$

- Acid rain is harmful for agriculture, trees and plants as it dissolves and washes away nutrients needed for their growth.
- □ The Taj Mahal in India has been affected by acid rain.

### 2. Particulate Pollutants:

- Particulates pollutants are the minute solid particles present in vehicle emissions, smoke particles from fires, dust particles and ash from industries.
- Non-viable particulates may be classified as follows:
  - (a) Smoke
  - (b) Dust
  - (c) Mists
  - (d) Fumes
- Lead used to be a major air pollutant emitted by vehicles.

### Smog:

- The word smog is derived from smoke and fog. There are two types of smog:
  - (a) Classical smog is a mixture of smoke, fog and sulphur dioxide. Chemically it is a reducing mixture and so it is also called as reducing smog.
  - **(b)** Photochemical smog: The main components of the photochemical smog result from the action of sunlight on unsaturated hydrocarbons and nitrogen oxides produced by

automobiles and factories. Photochemical smog has high concentration of oxidising agents and is, therefore, called as oxidising smog.

### Formation of photochemical smog:

Two pollutants, hydrocarbons (unburnt fuels) and nitric oxide (NO) when build up to sufficiently high levels, a chain reaction occurs from their interaction with sunlight in which NO is converted into nitrogen dioxide ( $NO_2$ ). This  $NO_2$  in turn absorbs energy from sunlight and breaks up into nitric oxide and free oxygen atom.

$$NO_2(g) \xrightarrow{hv} NO(g) + O(g)$$
 (i)

Oxygen atoms are very reactive and combine with the  $O_2$  in air to produce ozone.

$$O(g) + O_{\gamma}(g) \to O_{\gamma}(g) \tag{ii}$$

The ozone formed in the above reaction (ii) reacts rapidly with the NO(g) formed in the reaction (i) to regenerate  $NO_2$ .  $NO_2$  is a brown gas and at sufficiently high levels can contribute to haze.

$$NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g)$$
 (iii)

Ozone is a toxic gas and both  $NO_2$  and  $O_3$  are strong oxidising agents and can react with the unburnt hydrocarbons in the polluted air to produce chemicals such as formaldehyde, acrolein and peroxyacetyl nitrate (PAN).

$$3CH_4 + 2O_3 \rightarrow 3CH_2 = O + 3H_2O$$
Formaldehyde

 $CH_2 = CHCH = O$ 
Acrolein

 $O$ 

Peroxyacetyl nitrate [PAN]

Both ozone and PAN act as powerful eye irritants. Ozone and nitric oxide irritate the nose and throat and their high concentration causes headache, chest pain, dryness of the throat, cough and difficulty in breathing.

### 2.2 Stratospheric Pollution Formation and Breakdown of Ozone:

- The upper stratosphere consists of considerable amount of ozone  $(O_3)$ , which protects us from the harmful ultraviolet (UV) radiations ( $\lambda$  255 nm) coming from the sun. These radiations cause skin cancer (melanoma) in humans.
- Ozone in the stratosphere is a product of UV radiations acting on dioxygen  $(O_2)$  molecules. The UV radiations split apart molecular oxygen into free oxygen (O) atoms. These oxygen atoms combine with the molecular oxygen to form ozone.

$$O_2(g) \xrightarrow{UV} O(g) + O(g)$$

$$O(g) + O_2(g) \xrightarrow{UV} O_3(g)$$

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- Ozone is thermodynamically unstable and decomposes to molecular oxygen. Thus, a dynamic equilibrium exists between the production and decomposition of ozone molecules. The main reason of ozone layer depletion the release of chlorofluorocarbon.
- Compounds (CFCs), also known as freens. These compounds are nonreactive, non flammable, non toxic organic molecules. Once CFCs are released in the atmosphere, they get broken down by powerful UV radiations, releasing chlorine free radical.

$$CF_2Cl_2(g) \xrightarrow{UV} \dot{C}l(g) + \dot{C}F_2Cl(g)$$
 (i)

The chlorine radical then react with stratospheric ozone to form chlorine monoxide radicals and molecular oxygen.

$$\overset{\bullet}{\text{Cl}}(g) + O_3(g) \rightarrow \overset{\bullet}{\text{Cl}}O(g) + O_2(g)$$
 (ii)

Reaction of chlorine monoxide radical with atomic oxygen produces more chlorine radicals.

$$\dot{\text{Cl}} \text{ O}(g) + \text{O}(g) \rightarrow \dot{\text{Cl}}(g) + \text{O}_2(g)$$
 (iii)

The chlorine radicals are continuously regenerated and cause the breakdown of ozone.

### The Ozone Hole

- In summer season, nitrogen dioxide and methane react with chlorine monoxide (reaction iv) and chlorine atoms (reaction v) forming chlorine sinks, preventing much ozone depletion, whereas in winter, special type of clouds called polar stratospheric clouds provide surface on which chlorine nitrate formed (reaction iv) gets hydrolysed to form hypochlorous acid (reaction (vi)).
- It also reacts with hydrogen chloride produced as per reaction (v) to give molecular chlorine.

$$\begin{split} &\dot{\text{C1}}\,\text{O(g)} + \text{NO}_2\,(\text{g}) \rightarrow \text{C1ONO}_2(\text{g}) \\ &\dot{\text{C1}}\,(\text{g}) + \text{CH}_4\,(\text{g}) \rightarrow \dot{\text{C}}\,\text{H}_3(\text{g}) + \text{HCl}(\text{g}) \\ &\text{C1ONO}_2(\text{g}) + \text{H}_2\text{O}\,(\text{g}) \rightarrow \text{HOCl}\,(\text{g}) + \text{HNO}_3\,(\text{g}) \\ &\text{C1ONO}_2(\text{g}) + \text{HCl}\,(\text{g}) \rightarrow \text{Cl}_2\,(\text{g}) + \text{HNO}_3\,(\text{g}) \\ \end{split} \tag{vi}$$

When sunlight returns to the Antarctica in the spring, the sun's warmth breaks up the clouds and HOCl and  $Cl_2$  are photolysed by sunlight, as given in reactions (viii) and (ix).

$$\begin{array}{ccc} \text{HOCl}\left(g\right) & \xrightarrow{\text{hv}} & \dot{O} \text{ H}\left(g\right) + \dot{C} \text{ l}\left(g\right) \\ \text{Cl}_{2}(g) & \xrightarrow{\text{hv}} & 2 \dot{C} \text{ l}\left(g\right) \end{array} \tag{ix)} \end{array}$$

The chlorine radicals thus formed, initiate the chain reaction for ozone depletion.

### 3. WATER POLLUTION

Pollution of water originates from human activities.

### 3.1 Causes of Water Pollution

- (i) Pathogens: The most serious water pollutants are the disease causing agents called pathogens.
- (ii) Organic wastes: Organic matter such as leaves, grass, trash etc. pollute water as a consequence of run off.

The large population of bacteria decomposes organic matter present in water. They

consume oxygen dissolved in water. In cold water, dissolved oxygen (DO) can reach a concentration up to 10 ppm (parts per million).

- The concentration of dissolved oxygen in water is very important for aquatic life. If the concentration of dissolved oxygen of water is below 6 ppm, the growth of fish gets inhibited.
- The amount of oxygen required by bacteria to break down the organic matter present in a certain volume of a sample of water, is called Biochemical **Oxygen Demand (BOD).** Clean water would have BOD value of less than 5 ppm where as highly polluted water could have a BOD value of 17 ppm or more.
- (iii) Chemical Pollutants: Water soluble inorganic chemicals that include heavy metals such as cadmium, mercury, nickel etc constitute an important class of pollutants. The process in which nutrient enriched water bodies support a dense plant population, which kills animal life by depriving it of oxygen and results in subsequent loss of biodiversity is known as Eutrophication.

### 3.2. International Standards for Drinking Water

**Fluoride :** Fluoride ion concentration deficiency in drinking water causes diseases such as tooth decay etc. Soluble fluoride is often added to drinking water to bring its concentration upto 1 ppm or 1 mg dm<sup>-3</sup>.

• However, F<sup>-</sup> ion concentration above 2 ppm causes brown mottling of teeth. At the same time, excess fluoride (over 10 ppm) causes harmful effect to bones and teeth. The F<sup>-</sup> ions make the enamel on teeth much harder by converting hydroxyapatite, [3(Ca<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub>.Ca(OH)<sub>2</sub>], the enamel on the surface of the teeth, into much harder fluorapatite, [3(Ca<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub>.CaF<sub>2</sub>].

**Lead:** The prescribed upper limit concentration of lead in drinking water is about 50 ppb. Lead can damage kidney, liver, reproductive system etc.

**Sulphate:** Excessive sulphate (>500 ppm) in drinking water causes laxative effect, otherwise at moderate levels it is harmless.

**Nitrate:** The maximum limit of nitrate in drinking water is 50 ppm. Excess nitrate in drinking water can cause disease such as methemoglobinemia ('blue baby' syndrome).

Table: Maximum Prescribed Concentration of Some Metals in Drinking Water.

Metal	Maximum concentration (ppm or mg dm <sup>-3</sup> )
Fe	0.2
Mn	0.05
Al	0.2
Cu	3.0
Zn	5.0
Cd	0.005

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### 4. SOIL POLLUTION

### 4.1 Pesticides:

Pesticides are basically synthetic toxic chemicals with ecological repercussions.

### 5. INDUSTRIAL WASTE

- Industrial solid wastes are also sorted out as biodegradable and non-degradable wastes. Biodegradable wastes are generated by cotton mills, food processing units, paper mills, and textile factories.
- Non-biodegradable wastes are generated by thermal power plants which produce fly ash; integrated iron and steel plants which produce blast furnace slag and steel melting slag. Nowadays, fly ash and slag from the steel industry are utilised by the cement industry.

### 6. STRATEGIES TO CONTROL ENVIRONMENTAL POLLUTION

### 6.1 Waste Management :

The improper disposal of wastes is one of the major causes of environmental degradation. Therefore, the management of wastes is of utmost importance.

### Collection and Disposal:

Domestic wastes are collected in small bins, which are then transferred to community bins by private or municipal workers.

### 7. GREEN CHEMISTRY:

### 7.1 Introduction:

- Green chemistry is a production process that would bring about minimum pollution or deterioration to the environment.
- The byproducts generated during a process, if not used gainfully, add to the environmental pollution.
- Such processes are not only environmental unfriendly but also cost-ineffective. The waste generation and its disposal both are economically unsound.
- Utilisation of existing knowledge base for reducing the chemical hazards along with the developmental activities is the foundation of green chemistry.

### 7.2 Green Chemistry in day-to-day Life

### (i) Dry Cleaning of Clothes

Tetra chlroroethene ( $\operatorname{Cl_2C=CCl_2}$ ) was earlier used as solvent for dry cleaning. The compound contaminates the ground water and is also a suspected carcinogen. Replacement of halogenated solvent by liquid  $\operatorname{CO_2}$  will result in less harm to ground water.

### (ii) Bleaching of Paper

Chlorine gas was used earlier for bleaching paper. These days, hydrogen peroxide  $(H_2O_2)$  with suitable catalyst.

### (iii) Synthesis of Chemicals

Ethanal (CH<sub>3</sub>CHO) is now commercially prepared by one step oxidation of ethene in the presence of ionic catalyst in aqueous medium with a yield of 90%.

$$CH_2 = CH_2 + O_2 \xrightarrow{\text{Catalyst}} CH_3 CHO (90\%)$$

# **EXERCISE # I**

1.	Which one is not the or Pollutions means:	correct statement ?						
	(A) The presence of a	nything in the environ	nment in excess of the r	required limit				
			ch was not there in its n					
	(C) direct or indirect changes in one or more components of the ecosystem which are not harmful to living organisms							
		ase of any chemical su	bstance in the environ	ment with harmful	leffects			
		•			EN0001			
2.	Which is the main air	nollutant ?			2110001			
<b>4</b> •	(A) CO <sub>2</sub>	(B) CO	(C) N <sub>2</sub>		(D) S			
	$(11) CO_2$	(B) CO	(0) 1,2		• •			
2	Th				EN0002			
3.	The acid rain possess		(C) aulahurana aai	(D) a	11 of these			
	(A) Sulphuric acid	(B) nitric acid	(C) sulphurous aci	(D) a	ll of these			
					EN0003			
4.	Carbon monoxide (C							
	(A) It competes with	<del>-</del>	, ,	s carbolic acid				
	(C) It generates exces	ss CO <sub>2</sub>	(D) It is carcinoger	nic				
					EN0004			
<b>5.</b>	Lung diseases are fou	r times more in urban	areas than rural areas.	This is due to the	presence of :-			
	(A) SO <sub>2</sub>	(B) $CO_2$	$(C) N_2$	(D) Water-va	pour			
					EN0005			
6.	Which one is not corr	rect?						
	Greenhouse effect:							
	(A) is due to high con	centration of CO <sub>2</sub> in a	atmosphere					
			and chlorofluorocarbo	ons				
	(C) would result in th	e warming up of the e	earth					
	(D) would result in lo	wering the level of oc	ceans due to high evapo	oration				
					EN0006			
7.	Which is not a green	house gas -						
	(A) CFC's	(B) Methane	(C) H,	(D) CO <sub>2</sub>				
			2	2	EN0007			
8.	Green house effect is	related to -						
	(A) Cultivation of gre		(C) Global wannir	าg				
	(B) Cultivation of veg	•	(D) Global green a	•				
			. ,	C	EN0008			
9.	Acid rains are produc	ed by			E110000			
7.	(A) Excess productio	•	and coal gas					
		-	incomplete combustior	1				
			n and animal respiration					
	(D) Excess NO, and S	<del>-</del>		·				
		2, 110111 0011111115 01	100011 10010					

EN0019

10.	(A) Less than the pre	in the earth's atmosphere esent	, the temperature of ea	rth's surface would be	<del>2</del> -				
	<ul><li>(B) The same</li><li>(C) Dependent on the amount of oxygen in the atmosphere</li></ul>								
	<del>-</del>	· -	e atmosphere						
	(D) Higher than the p	present			ENIO010				
11	The pH of said main	votania .			EN0010				
11.	The pH of acid rain v (A) 1.2	(B) 3.1	(C) 5	(D) 6					
	(A) 1.2	( <b>D</b> ) 3.1	(C) 3	(D) 0	ENI0011				
12	Which ois pollytopt i	a mat malageed by societion	and ages 9		EN0011				
12.	(A) SO <sub>2</sub>	s not released by scooter (B) Fly ash	(C) Hydrocarbons	(D) CO					
	$(A) SO_2$	(D) Try asii	(C) Trydrocarbons	(D) CO	EN0012				
12	CECL is responsible	for the decomposition of	forana to form ovvicas	. Which of the follow					
13.	with ozone to form o	for the decomposition of	ozone to form oxyger	i. Which of the follow	ving reacts				
	with ozone to form o	oxygen:							
	(A) Cl <sub>2</sub>	(B) Cl <sup>-</sup>	(C) F	(D) C1					
	2				EN0013				
14.	Pick up the correct st	atement			21,0020				
	•	or pollutant resulting fror	n the combustion of fu	els in automobiles pla	ıvs a maior				
	role in photochen	•			.g =				
	-	as an oxidizing character	while the photochemic	cal smog is reducing in	n character				
	· ·	nog occurs in day time wl	-						
		n of smog the level of oz		= -	υ				
	· / ·	C	1		EN0014				
15.	Air pollutants that pr	oduce photochemical sm	0g <b>-</b>		21,002.				
	(A) Ozone, chlorine	•	(B) Oxygen, chlorin	e and nitric acid					
	(C) Nitrous oxide, P.	•	(D) CO <sub>2</sub> , CO and S						
	(0)1(101000)11100,11	TI ( WIIW WOI DIVIN	$(2)$ $20_2$ , $20$ and $2$	2	EN0015				
16.	P.A.N, stands for-				12110013				
10.	(A) Peroxy acetyl nit	rite	(B) Peroxy acetyl ni	trate					
	(C) peroxy acetyl nitr		(D) Pyridine aceto-n						
	(C) peroxy accept mu	THE	(D) I yridine accto-ii	nunc	EN0016				
17.	The photochemical of	mag ann ha gunnragad b	X .		EMOUTO				
1/.	<u>=</u>	smog can be suppressed by	•	(D) formaldahyda					
	(A) nitrogen oxides	(B) hydrocarbons	(C) radical traps	(D) formaldehyde	ENIO015				
40	TT 1: 0 11				EN0017				
18.	-	which are responsible for	-						
	$(A) SO_2$		(B) CO <sub>2</sub>						
	(C) CO		(D) Oxides of nitrog	gen and chlorofluoroc					
					EN0018				
19.	Taj mahal is threaten								
	(A) Chlorine	(B) Sulphur dioxide	(C) Oxygen	(D) Hydrogen					

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48 **IEE-Chemistry** 20. Ozone hole refers to :-(A) Increased concentration of ozone (B) Reduction in the thickness of ozone layer in troposphere (C) Reduction in the thickness of ozone layer in stratosphere (D) Hole in ozone layer EN0020 21. One of the pollutants that is generally helping in the early degradation of the ozone layer is:-(B) DDT (A) SO<sub>2</sub> (C) CO, (D) Freons EN0021 22. In coming years, skin related disorders will become more common due to -(A) Airpollution (B) Excessive use of detergents (C) Depletion of ozone layer (D) Water pollution EN0022 23. Often in water bodies subjected to sewage pollution, fishes die because of the-(A) Foul smell (B) Reduction in dissolved oxygen caused by microbial activity (C) Clogging of their gills by solid substances (D) Pathogens released by the sewage EN0023 24. Which one is not a water pollutant? (A) Automobile exhaust (B) Plant nutrients (C) Oxygen demanding wastes (D) Disease causing agents EN0024 If BOD of river is high, it means that the river is :-25. (A) Not polluted (B) Very much polluted with inorganic chemicals (C) Very much polluted with organic chemicals which are decomposed by micro-organisms (D) Polluted with pesticides EN0025 **26.** When huge amount of sewage is dumped in a river, the BOD will:-(A) Increase (B) Remain unchanged (C) Decrease (D) Increase or decrease EN0026 27. By what method the quantity of organic pollutants in water can be determined (A) By measuring BOD (B) By pH Measurement

A dental disease characterised by mottling of teeth is due to presence of a certain chemical element in

(C) Boron

(C) By transparency measurements

drinking water. Which is the element -

(B) Mercury

28.

(A) Fluorine

EN0028

(D) By measuring the change of colour/CFC

(D) Chlorine

<b>29.</b>	Excess of nitrate in dr	inking water causes:	-		
	(A) itai-itai syndrome		(B) Rickets s	yndrome	
	(C) Laxative effect		(D) Methemo	oglobinemia ('blue baby' sy	(ndrome)
					EN0029
30.	Eutrophication is cau	sed by			
	(A) Increase nutrient	•	(B) Petrocher	mical and fertilizer plant ef	fluents
	(C) $NO_3^{-1}$ and $SO_4^{-2}$		(D) Mine effl	-	
	3 4 1	L	,		EN0030
31.	Continuous sewage fl	low into a stream wou	ıld lead to-		21,0000
01.	(A) Increase in tempe		(B) Algal blo	oom	
	(C) Eutrophication		(D) Depletion		
	(e) zuwepineuren		(E) E opiono	01 0.1, 8011	EN0031
32.	Indiscriminate use of	DDT is undesirable b	2001102		ENUOSI
34.	(A) It is harmful	DD1 is undestrable b	(B) It is degra	adahla	
	(C) It causes mutation		, ,	mulated in food chain	
	(C) It causes illutation	I	(D) It is accu	inulated in 1000 chain	ENIOGA
					EN0032
33.	Fluorosis, a bone dise		•		
	(A) Pesticides in water		(B) Fluorides		
	(C) Carbon monoxide	e in air	(D) Sulphur	dioxide in air	
					EN0033
34.	Major source of meth	ane in India is :			
	(A) fruit orchards		(B) sugar can	ne plantatton	
	(C) rice fields		(D) wheat fie	elds	
					EN0034
<b>35.</b>	Green chemistry mea	ns such reactions whi	ch:		
	(A) are related to the	depletion of ozone lay	/er		
	(B) produce colour du	iring reactions			
	(C) study the reaction	s in plants			
	(D) reduce the use and	d production of hazar	dous chemicals		
					EN0035
36.	Among the following	the one that is is not	a green house ga	s is :-	
	(A) Nitrous oxide	(B) Methane	(C) Ozone	(D) Sulphur dioxide	
	` '	. ,	, ,	. , 1	EN0036
37.	Which oxide of nitrog	en is not a common no	allutant introduced	l into the atmosphere both o	
07.	and human activity?	en is not a common pe		into the unitosphere both	ace to maturar
	(A) NO <sub>2</sub>	(B) N <sub>2</sub> O	(C) $N_2O_5$	(D) NO	
	$(11)$ $110_2$	( <b>b</b> ) 11 <sub>2</sub> 0	(C) 11 <sub>2</sub> O <sub>5</sub>	(D) 110	ENI0027
20	Wali 1 C.1 C.11 .				EN0037
38.	Which of the following	ng is a sink for CO?	(D) M'		
	(A) Haemoglobin			ganisms present in the soil	
	(C) Oceans		(D) Plants		
					EN0038

ALLEN

# **EXERCISE # JEE-MAINS**

1. When rain is accompanied by a thunderstorm, the collected rain water will have a pH val							
	(1) slightly higher than that when the thu	nderstorm is not there	[AIEEE-2003]				
	(2) uninfluenced by occurence of thunde	(2) uninfluenced by occurence of thunderstorm					
	(3) which depends on the amount of dus	t in air					
	(4) slightly lower than that of rain water	without thunderstorm					
			EN0039				
2.	The smog is essentially caused by the pr	esence of:	[AIEEE-2004]				
	(1) O2 and $O3$	$(2) O_3$ and $N_2$					
	(3) Oxides of sulphur and nitrogen	(4) $O_2$ and $N_2$					
			EN0040				
3.	Regular use of which of the following fe	rtilizers increases the acidity of soil?	[AIEEE-2007]				
	(1) potassium nitrate	(2) Urea					
	(3) Superphosphate of lime	(4) Ammonium sulphate					
			EN0041				
4.	Identify the wrong statements in the follo	owing:	[AIEEE-2008]				
	(1) Chlorofluorocarbons are responsible for ozone layer depletion						
	(2) Greenhouse effect is responsible for global warming						
	(3) Ozone layer does not permit infrared radiation from the sun to reach the earth						
	(4) Acid rains is mostly because of oxide	es of nitrogen and sulphur					
			EN0042				
<b>5.</b>	What is DDT among the following:		[JEE-MAINS-2012]				
	(1) Greenhouse gas	(2) A fertilizer	:				
	(3) Biodegradable pollutant	(4) Non-biodegradable polluta	nt				
			EN0043				
6.	The gas leaked from a storage tank of th	e Union Carbide plant in Bhopal gas t	ragedy was :				
	(1) Methylisocyanate	(2) Methylamine	[JEE-MAINS-2013]				
	(3) Ammonia	(4) Phosgene					
_			EN0044				
7.	<b>Assertion:</b> Nitrogen and Oxygen are the	_					
	to form oxides of nitrogen. [JEE-MAINS-2015]  Reason: The reaction between nitrogen and oxygen requires high temperature.						
	(1) Both assertion and reason are correct, and the reason is the correct explanation for the assertion						
	(2) Both assertion and reason are correct,	<u>*</u>	1				
	(3) The assertion is incorrect, but the reason is correct						
	(4) Both the assertion and reason are inco	orrect					
			EN0045				

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The concentration of fluoride, lead, nitrate and iron in a water sample from an underground lake was 8. found to be 1000 ppb, 40 ppb, 100 ppm and 0.2 ppm, respectively. This water is unsuitable for drinking due to high concentration of:

### [JEE-MAINS-2016]

- (1) Fluoride
- (2) Lead
- (3) Nitrate
- (4) Iron

EN0046

A water sample has ppm level concentration of following anions  $F^- = 10$ ;  $SO_4^{2-} = 100$ ;  $NO_3^- = 50$ 9. the anion/anions that make / makes the water sample unsuitable for drinking is / are :

(1) only  $NO_3^-$ 

(2) both  $SO_4^{2-}$  and  $NO_3^{-}$ 

[**JEE-MAINS-2017**]

(3) only F-

(4) only  $SO_4^{2-}$ 

EN0047

Identify the pollutant gases largely responsible for the discoloured and lustreless nature of marble of 10. the Taj Mahal [**JEE-MAINS-2017**]

- $(1) O_3$  and  $CO_2$

- (2)  $CO_2$  and  $NO_2$  (3)  $SO_2$  and  $O_3$  (4)  $SO_2$  and  $NO_2$

**EN0048** 

11. Which of the following is a set of green house gases? [JEE-MAINS-2017]

(1) O<sub>3</sub>, N<sub>2</sub>, CO<sub>2</sub>, NO<sub>2</sub>

(2)  $CH_4$ ,  $O_3$ ,  $N_2$ ,  $SO_2$ 

 $(3) CO_2, CH_4, N_2O, O_3$ 

(4) O<sub>3</sub>, NO<sub>2</sub>, SO<sub>2</sub>, Cl<sub>2</sub>

EN0049

- **12.** Biochemical Oxygen Demand (BOD) value can be a measure of water pollution caused by the organic matter. Which of the following statements is correct -[JEE-MAINS ONLINE-2018]
  - (1) Anaerobic bacteria increase the BOD value
  - (2) Aerobic bacteria decrease the BOD value
  - (3) Polluted water has BOD value higher than 10 ppm
  - (4) Clean water has BOD value higher than 10 ppm

EN0050

The recommended concentration of fluoride ion in drinking water is up to 1 ppm as fluoride ion is **13.** required to make teeth enamel harder by converting [3Ca<sub>3</sub> (PO<sub>4</sub>)<sub>2</sub>·Ca(OH)<sub>2</sub>] to:

(1)  $[3(CaF_2)\cdot Ca(OH)_2]$ 

[**JEE-MAINS-2018**]

- (2)  $[3(Ca_3(PO_4)_2 \cdot CaF_2]$
- (3)  $[3(Ca(OH)_2] \cdot CaF_2]$
- (4)  $[CaF_2]$

EN0051

- (1) Zn
- (2) Fe
- (3) Mn
- (4) Cu

EN0052

**15.** Which of the following conditions in drinking water causes methemoglobinemia?

(1) > 50ppm of load

- (2) > 100 ppm of sulphate
- [JEE-MAINS-2019]

(3) > 50 ppm of chloride

(4) > 50 ppm of nitrate

EN0053

**16.** The reaction that is NOT involved in the ozone layer depletion mechanism is the stratosphere is:

(1)  $HOCl(g) \xrightarrow{h\upsilon} OH(g) + Cl(g)$ 

[JEE-MAINS-2019]

- (2)  $CF_2Cl_2(g) \xrightarrow{uv} Cl(g) + CF_2Cl(g)$
- (3)  $CH_4 + 2O_3 \rightarrow 3CH_2 = O + 3H_2OP$
- (4)  $ClO(g) + O(g) \rightarrow Cl(g) + O_2(g)$

EN0054

**17.** The compound that is NOT a common component of photochemical smog is :[JEE-MAINS-2019]

 $(1) O_3$ 

(2) CH<sub>2</sub>=CHCHO

(3) CF<sub>2</sub>Cl<sub>2</sub>

(4)  $H_3C-C-OONO_2$ 

EN0055

18. The upper stratosphere consisting of the ozone layer protects us from the sun's radiation that falls in the wavelength region of: [JEE-MAINS-2019]

- (1) 600-750 nm
- (2) 0.8-1.5 nm
- (3) 400-550 nm
- (4) 200-315 nm

EN0056

19. Biochemical Oxygen Demand (BOD) is the amount of oxygen required (in ppm):

- (1) by anaerobic bacteria to breakdown inorganic waste present in a water body.
- (2) for the photochemical breakdown of waste present in 1 m<sup>3</sup> volume of a water body.
- (3) by bacteria to break-down organic waste in a certain volume of a water sample.
- (4) for sustaining life in a water body.

[JEE-MAINS-2020]

EN0057

20. Among the gases (a) - (e), the gases that cause greenhouse effect are :

[JEE-MAINS-2020]

- (a) CO<sub>2</sub>
- (b)  $H_2O$
- (c) CFCs (d)  $O_2$
- (e)  $O_3$

(1) (a), (b), (c) and (d)

(2) (a), (c), (d) and (e)

(3) (a) and (d)

(4) (a), (b), (c) and (e)

EN0058

# **ANSWER KEY**

		EXERCISE #	I	
1. Ans. (C)	2. Ans. (B)	3. Ans. (D)	4. Ans. (A)	5. Ans. (A)
6. Ans. (D)	7. Ans. (C)	8. Ans. (C)	9. Ans. (D)	10. Ans. (A)
11. Ans. (C)	12. Ans. (B)	13. Ans. (D)	<b>14.</b> Ans. (C)	15. Ans. (C)
16. Ans. (B)	17. Ans. (C)	18. Ans. (D)	19. Ans. (B)	<b>20.</b> Ans. (C)
21. Ans. (D)	22. Ans. (C)	23. Ans. (B)	24. Ans. (A)	25. Ans. (C)
26. Ans. (A)	27. Ans. (A)	28. Ans. (A)	29. Ans. (D)	30. Ans. (A)
31. Ans. (D)	32. Ans. (D)	33. Ans. (B)	34. Ans. (C)	35. Ans. (D)
<b>36.</b> Ans.(D)	37. Ans.(C)	38. Ans.(B)		
	EXEF	RCISE # JEE-N	MAINS	
1. Ans. (4)	2. Ans. (3)	3. Ans. (4)	4. Ans. (3)	5. Ans. (4)
6. Ans. (1)	7. Ans. (1)	8. Ans. (3)	9. Ans. (3)	10. Ans.(4)
11. Ans.(3)	12. Ans.(2)	13. Ans.(2)	14. Ans.(3)	15. Ans.(4)
16. Ans.(3)	17. Ans.(3)	18. Ans.(4)	19. Ans.(3)	20. Ans.(4)

54 JEE-Chemistry ALLEN

Important Notes				

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