9

HYDROGEN AND s-BLOCK ELEMENTS

HYDROGEN AND IT'S COMPOUNDS

POSITION OF HYDROGEN IN PERIODIC TABLE

* Lightest element known having atomic number 1.

* It resembles both alkali metals and halogens and therefore, its position is anomalous.

* In modern periodic table it is located separately.

Resemblance of hydrogen with Alkali Metals (Group I-A):

(i) Like alkali metals hydrogen has one electron in its valency shell. H (Z = 1) : K^1 Li (Z = 3) : K^2, L^1
Na (Z = 11) : K^2, L^8, M^1

(ii) Valance shell electronic configuration of hydrogen and alkali metal is same. H (Z = 1): $1s^1$
Na (Z = 11) : $1s^2, 2s^2, 2p^6, 3s^1$

(iii) Both hydrogen an alkali metals are good reducing agents.

(iv) Like alkali metals hydrogen can also form halides.
Hydrogen: HCl, HI. ; I A : NaCl, KBr.

(v) Halides of alkali metals and hydrogen ionized in similar way in aqueous solution.

(vi) Like alkali metals hydrogen can also form compounds with non-metals.

Differences :

(i) Hydrogen is a non-metal where as elements of I-A are metals.

(ii) Hydrogen can form both covalent and ionic compounds. But alkali metals only form ionic compounds.

(iii) **Ionization energy and size of the ion :** Due to extremely small size of the hydrogen atom, it has an exceptionally high value of ionization energy whereas all alkali metals have relatively very low values of ionisation energy and can easily form M^+ ions. The values of the ionization energies are 1312, 529 and 495 kJ mol^{-1} for hydrogen, sodium and potassium respectively.

(iv) Hydrogen cannot lose its valence electron.

(v) **Nature of halides :**

(a) Alkali metals halides are completely ionic even in the solid state while hydrogen halides even in the gaseous state are covalent in characters. Of course they have a fairly polar character in polar solvents which further decreases in the following order :
HF > HCl > HBr > HI

(b) Pure hydrogen halides (HF, HCl, HBr, HI) are low boiling covalent compounds where as alkali metal halides are high melting solids.

(vi) Hydrogen is a gas at room temperature but alkali metals are solids.

(vii) Unlike Na^+ or K^+ hydrogen ion (H^+) is unstable in water.

(viii) **Nature of oxides :** Oxides of alkali metals Na_2O, K_2O are basic in nature, and form strong alkalies on reaction with water. But similar oxide of hydrogen, H_2O is neutral in the pure state.

Resemblance of Hydrogen with Carbon Family (IV-A) :

(i) Valance shell of hydrogen is half-filled like the elements of group IV-A.
H (Z=1) : Capacity of K-Shell =2 , no. of e^-= 1 , % = 50%
C (Z=6) : Capacity of L-Shell = 8 , no. of e^- = 4 , % = 50%

(ii) I.P. and E.A. of hydrogen and carbon are comparable.

(iii) E.N. of H and Carbon family are almost similar.
[H = 2.1, C = 2.5 , Si= 2.4]

Differences :

(i) Carbon is tetravalent but Hydrogen is a mono-valent.

(ii) Hydrogen is a gas at room temperature but elements of group IV-A are solids.

(iii) Boiling and melting points of hydrogen is very less than that of the elements of group IV-A.

Resemblance Of Hydrogen With Halogens

(i) Both Hydrogen and Halogens require one electron to complete their valence shell.

(ii) Both hydrogen and Halogens are non-metals
(Except iodine which has partial metallic character).

(iii) Both hydrogen and Halogens act as negative ions when combined with metals.

(iv) Their molecules are diatomic.

(v) Like Halogens, hydrogen can also form both ionic and covalent bond.

(vi) Both H and Halogens form compound with metals and non-metals. Hydrogen : H_2S [S = non-metal]
Halogens : HCl [H = non-metal]

Differences :

(i) Hydrogen has one electron in valence shell while Halogens has seven electrons.

(ii) Electronic configuration of H = $1s^1$
Valence shell electronic config. of Halogens = ns^2, ns^5

(iii) Unlike X^- ion, H^- ion is unstable in water.

(iv) Hydrogen is less electronegative than halogens.

(v) Oxides of halogens are acidic where as oxide of hydrogen is neutral i.e., H_2O (neutral) ; Cl_2O_7 (acidic)

Unique atomic structure of hydrogen : Hydrogen is the only element which has no neutron in its nucleus.

Conclusion : Due to above reasons it is clear that hydrogen cannot be placed in any one of the above mentioned groups.

DIHYDROGEN, (H_2) :

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 many other compounds.

Isotopes of Hydrogen :

Hydrogen has three isotopes: protium, (^1_1H) deuterium, $(^2_1H \text{ or } D)$ and tritium, $(^3_1H \text{ or } T)$. These isotopes differ from one another in respect of the presence of neutrons. Ordinary hydrogen, protium, has no neutron deuterium (also known as heavy hydrogen) has one and tritium has two neutrons in the nucleus.

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 10^{18} atoms of protium. Of these isotopes, only tritium is radioactive and emits low energy β^- particles ($t_{1/2}$, 12.33 years).

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.

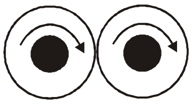
Isotopes of hydrogen :

Protium	Deuterium	Tritium
(a) $_1H^1$	$_1H^2$ or D	$_1H^3$ or T
(b) p = 1, e = 1, n = 0	p = 1, e = 1, n = 1	p = 1, e = 1, n = 2
(c) Abundance 99%	01%	10^{-15}%
(d) Ordinary hydrogen	Heavy hydrogen	Radioactive used as tracer to study Rx^n mechanism.

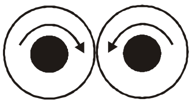
ORTHO AND PARA HYDROGEN

A molecule of dihydrogen contains two atoms, in which the nuclei of both the atoms are spinning.

Ortho hydrogen molecules are those in which the spins of both the nuclei are in the same direction. Molecules of hydrogen in which the spins of both the nuclei are in the opposite direction are called **para hydrogen**.



Ortho hydrogen



Para hydrogen

$$\text{Ortho hydrogen} \rightleftharpoons \text{Para hydrogen}$$

Ordinary dihydrogen is an equilibrium mixture of ortho and para hydrogen. The amount of ortho and para hydrogen varies with temperature as:

- * At 0K, hydrogen contains mainly para hydrogen which is more stable.
- * At the temperature of liquefaction of air, the ratio of ortho and para hydrogen is 1 : 1.
- * At the room temp., the ratio of ortho to para hydrogen is 3: 1.
- * Even at very high temperatures, the ratio of ortho to para hydrogen can never be more than 3 : 1.
- * Thus, it has been possible to get pure para hydrogen by cooling ordinary hydrogen gas to a very low temperature (close to 20K) but it is never possible to get a sample of hydrogen containing more than 75% of ortho hydrogen.

PREPARATION OF DIHYDROGEN, H_2

(i) Laboratory Preparation of Dihydrogen :

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

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

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

$$Zn(s) + 2NaOH\,(aq) \longrightarrow \underset{\text{Sodium zincate}}{Na_2ZnO_2\,(aq)} + H_2(g)$$

Methods for preparing H_2 in the laboratory

* Metal + Acid ⟶ Metal salt + H_2

$$Mg\,(s) + 2HCl\,(aq) \longrightarrow MgCl_2\,(aq) + H_2\,(g)$$

* Metal + H_2O or base → Metal hydroxide or oxide + H_2

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

$$2\,Fe\,(s) + 3H_2O\,(\ell) \longrightarrow Fe_2O_3\,(s) + 3H_2\,(g)$$

$$2\,Al\,(s) + 2\,KOH\,(aq) + 6H_2O\,(\ell) \longrightarrow 2K\,[Al(OH)_4]\,(aq) + 3H_2\,(g)$$

* Metal hydride + H_2O ⟶ Metal hydrodixe + H_2

$$CaH_2\,(s) + 2H_2O\,(\ell) \longrightarrow Ca(OH)_2\,(s) + 2H_2\,(g)$$

(ii) Commercial Production of Dihydrogen :

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

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

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

(c) It is obtained as a by-product in the manufacture of sodium hydroxide and chlorine by the electrolysis of brine solution. During electrolysis, the reactions are:

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

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

The overall reaction is

$$2Na^+(aq) + 2Cl^- + 2H_2O\,(\ell) \longrightarrow Cl_2(g) + H_2(g) + 2Na^+(aq) + 2OH^-(aq)$$

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

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

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

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**.

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

The production of dihydrogen can be increased by reacting carbon monoxide of syngas mixtures with steam in the presence of iron chromate as catalyst.

$$\underbrace{CO + H_2}_{\text{water gas}} + H_2O \xrightarrow[Fe_2O_3+Cr_2O_3]{\text{Catalyst}} CO_2 + 2H_2$$

(Bosch's process)

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

PROPERTIES OF DIHYDROGEN

(i) Physical Properties :

(a) Dihydrogen is a colourless, odourless, tasteless, combustible gas.

(b) It is lighter than air and insoluble in water.

(c) It is adsorbed (occluded) by certain metals like Fe, Au, Pt and Pd. Palladium in the powdered state can occlude nearly 1000 times its own volume of hydrogen.

(d) Since critical temperature of hydrogen is very low (36.1K) it can't be liquefied easily.

(ii) Chemical Properties :

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 $1s^1$ electronic configuration, it does combine with almost all the elements. It accomplishes reactions by

- loss of the only electron to give H^+
- gain of an electron to form H^-, and
- sharing electrons to form a single covalent bond.

The chemistry of dihydrogen can be illustrated by :

(a) Reaction with halogens : It reacts with halogens, X_2 to give hydrogen halides, HX,

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

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

Reactivity of halogen towards H_2 decreases as

$$F_2 > Cl_2 > Br_2 > I_2$$

(b) Reaction with dioxygen : It reacts with dioxygen to form water. The reaction is highly exothermic.

$$2H_2(g) + O_2(g) \xrightarrow{\text{catalyst or heating}} 2H_2O\,(\ell)$$

$$\Delta H^{\ominus} = -285.9 \text{ kJ mol}^{-1}.$$

(c) Reaction with carbon monoxide : Dihydrogen reacts with carbon monoxide at 700 K in presence of a catalyst ZnO/Cr_2O_3 to produce methyl alcohol.

$$CO(g) + 2H_2(g) \xrightarrow[\substack{ZnO,\, Cr_2O_3 \\ \text{High pressure}}]{700K} \underset{\text{Methyl alcohol}}{CH_3OH}$$

(d) Reaction with dinitrogen: With dinitrogen it forms ammonia.

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

$$\Delta H^{\ominus} = -92.6 \text{ kJ mol}^{-1}.$$

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

(e) Reactions with metals: With many metals it combines at high temperature to yield the corresponding hydrides

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

(f) 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.

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

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

(g) Reactions with organic compounds : It reacts with many organic compounds in the presence of catalysts to give useful hydrogenated products of commercial importance. **Example :**

- Hydrogenation of vegetable oils using nickel as catalyst gives edible fats (margarine & vanaspati ghee)
- Hydroformylation of olefins yields aldehydes which further undergo reduction to give alcohols.

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

$$H_2 + RCH_2CH_2CHO \rightarrow RCH_2CH_2CH_2OH$$

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

1. Ionic or saline or saltlike hydrides
2. Covalent or molecular hydrides
3. Metallic or non-stoichiometric hydrides

1. **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_2 and MgH_2. In fact BeH_2 and MgH_2 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^- ion.

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

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.,

$$8LiH + Al_2Cl_6 \rightarrow 2LiAlH_4 + 6\,LiCl$$
$$2LiH + B_2H_6 \rightarrow 2LiBH_4$$

2. **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.

Types of Molecular hydrides :

(i) Electron-deficient : 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. What do you expect from their behaviour?
They act as Lewis acids i.e., electron acceptors.

(ii) Electron-precise : 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_4) which are tetrahedral in geometry.

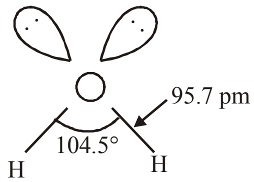
(iii) Electron-rich hydrides : Electron-rich hydrides have excess electrons which are present as lone pairs. Elements of group 15-17 form such compounds. (NH_3 has 1-lone pair, H_2O - 2 and HF -3 lone pairs). What do you expect from the behaviour of such compounds? They will behave as Lewis bases i.e., electron donors. The presence of lone pairs on highly electronegative atoms like N, O and Fin hydrides results in hydrogen bond formation between the molecules. This leads to the association of molecules.

3. **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 & therefore, can be used as its storage media. This property has high potential for hydrogen storage and as a source of energy.

WATER (H_2O) :

Structure of water :



- The shape of H_2O in gas phase is bent having 104.5° HOH bond angle and 95.7 pm H – O bond length. The oxygen of water is sp^3 hybridised.
  In liquid phase water molecules are held together by extensive inter molecular hydrogen bonding and the water moles held by hydrogen bond are in a dynamic equilibrium.
- Molecule is polar and possessed dipole moment (1.84 D).
- Due to open cage like structure, ice has a relatively larger volume for a given mass of liquid.

Properties of Water :

- Pure water is a very weak conductor of electricity.
- Water can act both as an acid and a base and it is amphoteric in nature.

(a) Water as an acid : Water acts as an acid in the presence of a base stronger than itself such as NH_3.

$$\underset{acid}{H_2O\,(l)} + \underset{base}{NH_3\,(aq)} \rightleftharpoons \underset{acid}{NH_4^+\,(aq)} + \underset{base}{OH^-\,(aq)}$$

(b) Water as a base : Water acts as a base in the presence of an acid stronger than itself such as HCl.

$$\underset{acid}{HCl\,(aq)} + \underset{base}{H_2O\,(l)} \rightleftharpoons \underset{acid}{H_3O^+\,(aq)} + \underset{base}{Cl^-\,(aq)}$$

- Water can act both as oxidising as well as reducing agent.

$$2Na(s) + \underset{oxidant}{2\,H_2O\,(l)} \rightarrow 2NaOH\,(aq) + H_2\,(g)$$

$$2F_2(g) + \underset{reductant}{2\,H_2O\,(l)} \rightarrow 2HF\,(aq) + O_2\,(g)$$

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 hydrogen carbonate, 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.

$$2\,C_{17}H_{35}COONa\,(aq) + M^{2+}\,(aq) \longrightarrow (C_{17}H_{35}COO)_2M\downarrow + 2Na^{+}(aq)\ (M = Ca, Mg)$$

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 :

1. **Temporary Hardness:** Temporary hardness is due to the presence of magnesium and calcium hydrogen carbonates. It can be removed by
   (i) **Boiling :** During boiling, the soluble $Mg(HCO_3)_2$ is converted into insoluble $Mg(OH)_2$ and $Ca\,(HCO_3)_2$ is changed to insoluble $CaCO_3$. It is because of high solubility product of $Mg(OH)_2$ as compared to that of $MgCO_3$, that $Mg(OH)_2$ is precipitated. These precipitates can be removed by filtration. Filtrate thus obtained will be soft water.

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

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

   (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.

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

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

2. **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 –
   (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.

$$MCl_2 + Na_2CO_3 \longrightarrow MCO_3\downarrow + 2NaCl\ (M = Mg, Ca)$$

$$MSO_4 + Na_2CO_3 \longrightarrow MCO_3\downarrow + Na_2SO_4$$

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

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

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

   The complex anion keeps the Mg^{2+} and Ca^{2+} ions in solution.

   (iii) **Ion-exchange method :** This method is also called zeolite/permutit process. Hydrated sodium aluminium silicate is zeolite/permutit. For the sake of simplicity, sodium aluminium silicate ($NaAlSiO_4$) can be written as NaZ. When this is added in hard water, exchange reactions take place.

$$2NaZ(s) + M^{2+}\,(aq) \rightarrow MZ_2(s) + 2Na^{+}(aq)\ \ (M = Mg, Ca)$$

   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.

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

   (iv) **Synthetic resins method :** Nowadays hard water is softened by using synthetic cation exchangers. This method is more efficient than zeolite process. Cation exchange resins contain large organic molecule with $-SO_3H$ group and are water insoluble. Ion exchange resin (RSO_3H) is changed to RNa by treating it with NaCl. The resin exchanges Na^{+} ions with Ca^{2+} and Mg^{2+} ions present in hard water to make the water soft. Here R is resin anion.

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

   The resin can be regenerated by adding aqueous NaCl solution. Pure de-mineralised (de-ionized) water free from all soluble mineral salts is obtained by passing water successively through a cation exchange (in the H^{+} form) and an anionexchange (in the OH^{-} form) resins: $2RH(s) + M^{2+}(aq) \rightleftharpoons MR_2(s) + 2H^{+}(aq)$

   In this cation exchange process, H^{+} exchanges for Na^{+}, Ca^{2+}, Mg^{2+} and other cations present in water. This process results in proton release and thus makes the water acidic, In the anion exchange process:

$$RNH_2\,(s) + H_2O(\ell) \rightleftharpoons RNH_3^{+}.OH^{-}\,(s)$$

$$RNH_3^{+}.OH(s) + X^{-}(aq) \rightleftharpoons RNH_3^{+}.X^{-}(s) + OH^{-}(aq)$$

   OH^{-} exchanges for anions like Cl^{-}, HCO_3^{-}, SO_4^{2-} etc. present in water. OH^{-} ions, thus, liberated neutralise the H^{+} ions set free in the cation exchange.

$$H^{+}(aq) + OH^{-}(aq) \rightarrow H_2O\,(\ell)$$

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

HYDROGEN PEROXIDE (H_2O_2)

Hydrogen peroxide is an important chemical used in pollution control treatment of domestic and industrial effluents.

Preparation:

(i) **Merck's method :** Na_2O_2 is gradually added to 20% ice cold H_2SO_4. $Na_2O_2 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O_2$
Most of $Na_2SO_4.10H_2O$ is crystallised out by cooling.

(ii) By the action of CO_2 on an ice cold paste of BaO_2

$$BaO_2 + H_2O + CO_2 \rightarrow BaCO_3\downarrow + H_2O_2$$

(iii) By the action of phosphoric acid on BaO_2

$$3BaO_2 + 2H_3PO_4 \rightarrow Ba_3\,(PO_4)_2\downarrow + 3H_2O_2$$

Impurities (metal ions) present in BaO_2 are removed as their phosphates.

Reaction of $BaO_2.8H_2SO_4$ with H_2SO_4 (ice cold) also gives H_2O_2 but the method is not used as the presence of H_2SO_4 & other metal ions (impurities of BaO_2) catalyse the decomposition of H_2O_2.

(iv) Electrolysis of equimolar mixture of H_2SO_4 & ammonium sulphate: $(NH_4)_2SO_4 + H_2SO_4 \rightarrow 2NH_4HSO_4$

$2NH_4HSO_4 \rightarrow 2H^+ + 2NH_4SO_4^-$

At cathode : $2H^+ + 2e^- \rightarrow H_2$

At anode : $2NH_4SO_4^- \rightarrow (NH_4)_2S_2O_8 + 2e^-$
(Amm. persulphate)

Ammonium persulphate is collected and distilled with water to produce H_2O_2.

$$(NH_4)_2S_2O_8 + 2H_2O \rightarrow 2NH_4HSO_4 + H_2O_2$$

(v) Industrially it is prepared by the autooxidation of 2-alklylanthraquinols.

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

In this case 1% H_2O_2 is formed. It is extracted with water and concentrated to ~ 30% (by mass) by distillation under reduced pressure. It can be further concentrated to ~85% by careful distillation under low pressure. The remaining water can be frozen out to obtain pure H_2O_2.

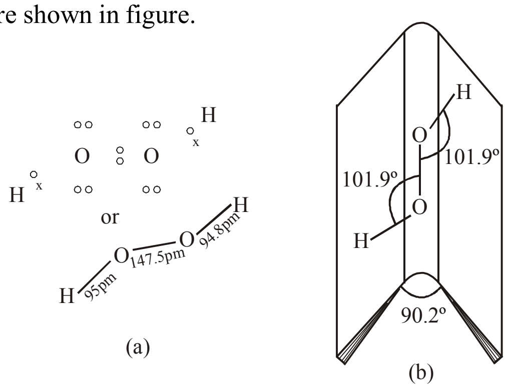
Physical Properties :

In the pure state H_2O_2 is an almost colourless (very pale blue) liquid. Its important physical properties are given in Table. H_2O_2 is miscible with water in all proportions and forms a hydrate $H_2O_2.H_2O$ (mp 221K).

A 30% solution of H_2O_2 is marketed as '100 volume' hydrogen peroxide. It means that one millilitre of 30% H_2O_2 solution will give 100 V of oxygen at STP. Commercially, it is marketed as 10V, which means it contains 3% H_2O_2.

Structure:

Hydrogen peroxide has a non-planar structure. The molecular dimensions in the gas phase and solid phase are shown in figure.



Structure of hydrogen peroxide in the (a) gas phase, (b) solid phase

(a) H_2O_2 structure in gas phase, dihedral angle is 101.9°.

(b) H_2O_2 structure in solid phase at 110 K, dihedral angle is 90.2°.

Storage of hydrogen peroxide : Hydrogen peroxide is an unstable compound and readily decomposes on keeping. However, its decomposition can be reduced, by storing in blue coloured glass bottles and by adding small amounts of acetanilide which acts as a negative catalyst or it is stored in wax coated polythene bottles.

Chemical Properties :

It acts as an oxidising as well as reducing agent in both acidic and alkaline media. Hydrogen peroxide is a powerful oxidising agent but a weak reducing agent.

(i) **Oxidising action in acidic medium :**

$2Fe^{2+}(aq) + 2H^+(aq) + H_2O(aq) \rightarrow 2Fe^{+3}(aq) + H_2O(\ell)$

$PbS(s) + 4H_2O_2(aq) \rightarrow PbSO_4(s) + 4H_2O(\ell)$

(ii) **Reducing action in acidic medium :**

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

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

(iii) **Oxidising action in basic medium :**

$2Fe^{2+} + H_2O_2 \rightarrow 2Fe^{+3} + 2OH^-$

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

(iv) **Reducing action in basic medium :**

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

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

(v) **Decomposition :** Pure hydrogen peroxide is an unstable liquid and decomposes into water and oxygen on long standing or heating.

$2H_2O_2 \rightarrow 2H_2O + O_2 ; \Delta H = -196.0 \text{ kJ}$

It is an example of auto-oxidation and auto-reduction.

(vi) **Acidic nature :** Pure hydrogen peroxide turns blue litmus red but its dilute solution is neutral to litmus. It behaves as a weak acid.

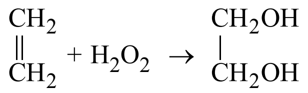
(vii) **Bleaching action :** The bleaching action of hydrogen peroxide is due to the nascent oxygen which it liberates on decomposition.

$H_2O_2 \rightarrow H_2O + [O]$

The nascent oxygen combines with colouring matter which, in turn, gets oxidised. It is used for the bleaching of delicate materials like ivory, feather, silk, wool, etc.

Colouring matter + [O] → Colourless matter

(viii) **Addition reactions :** Hydrogen peroxide reacts with alkenes to form glycols.



$$\begin{matrix} CH_2 \\ \| \\ CH_2 \end{matrix} + H_2O_2 \rightarrow \begin{matrix} CH_2OH \\ | \\ CH_2OH \end{matrix}$$

Ethylene Ethylene glycol

Tests of H_2O_2 :

(i) It liberates iodine from KI solution in the presence of ferrous sulphate.

(ii) It gives orange red colour with acidified titanium oxide due to formation of pertitanic acid.

$Ti(SO_4)_2 + H_2O_2 + 2H_2O \rightarrow H_2TiO_4 + 2H_2SO_4$

(iii) When brought in contact with H_2O_2 solution, a filter paper with black stain of PbS turns white.

(iv) It decolourises $KMnO_4$ solution.

Uses:

Its wide scale use has led to tremendous increase in the industrial production of H_2O_2.

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

(ii) It is used to manufacture chemicals like sodium perborate and per-carbonate, which are used in high quality detergents.

(iii) It is used in the synthesis of hydroquinone, tartaric acid and certain food products and pharmaceuticals (cephalosporin) etc.

(iv) It is employed in the industries as a bleaching agent for textiles, paper pulp, leather, oils, fats, etc.

(v) Nowadays it is also used in Environmental (Green) Chemistry. For example, in pollution control treatment of domestic and industrial effluents, oxidation of cyanides, restoration of aerobic conditions to sewage wastes, etc.

HEAVY WATER (D_2O)

It is extensively used as a moderator in nuclear reactors and in exchange reactions for the study of reaction mechanisms. It can be prepared by exhaustive electrolysis of water or as a by-product in some fertilizer industries. It is used for the preparation of other deuterium compounds, for example:

$CaC_2 + 2D_2O \rightarrow C_2C_2 + Ca(OD)_2$
$SO_3 + D_2O \rightarrow D_2SO_4$
$Al_4C_3 + 12D_2O \rightarrow 3CD_4 + 4Al(OD)_3$

DIHYDROGEN AS A FUEL

Dihydrogen releases large quantities of heat on combustion.

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.

Example 1 :

Hydrogen gas will not reduce–

(A) heated cupric oxide (B) heated ferric oxide
(C) heated stannic oxide (D) heated aluminium oxide

Sol. **(D).** Hydrogen gas will not reduce heated aluminium oxide because ΔG for this reaction is positive.

Example 2 :

Which of the pair will not produce dihydrogen gas–

(A) Cu + HCl (dil) (B) $Fe + H_2SO_4$
(C) Mg + steam (D) Na + alcohol

Sol. **(A).** The less active metals which lie below hydrogen in electrochemical series can't displaced hydrogen gas from dilute mineral acid.

Example 3 :

Find the volume strength of 3.57 N H_2O_2 solution.

Sol. We have, Strength = Normality × Eq. wt.

∴ Strength of 3.57 N H_2O_2 solution = 3.57 × 17 g/litre.

Eq. wt. of H_2O_2 = 17

Now, 68 g. of H_2O_2 gives 22400ml of O_2 at NTP

∴ 3.57 × 17g. of H_2O_2 will give

$$\frac{68}{22400} \times 3.57 \times 17 \text{ml of } O_2 \text{ at NTP}$$

But 3.57 × 17g. of H_2O_2 is contained in 1000ml of H_2O_2 solution. Hence, 1000ml of H_2O_2 solution gives

$$\frac{22400}{68} \times 3.57 \times 17 \text{ml of } O_2 \text{ at NTP}$$

∴ 1ml. of H_2O_2 will give

$$\frac{22400}{68} \times 3.57 \times 17 \times \frac{1}{1000} = 19.99 \text{ ml of } O_2 \text{ at NTP}$$

Hence, volume strength of 3.57 N H_2O_2 solution
= 19.99 volume = 20 vol.

Example 4 :

Which one of the following reactions depicts the reduction action of hydrogen peroxide?

(A) $C_6H_6 + H_2O_2 \rightarrow C_6H_5OH + H_2O$
(B) $O_3 + H_2O_2 \rightarrow 2O_2 + H_2O$
(C) $2Fe^{2+} + 2H^+ + H_2O_2 \rightarrow 2Fe^{3+} + 2H_2O$
(D) $2I^- + 2H^+ + H_2O_2 \rightarrow I_2 + H_2O$

Sol. **(B).** O_3 is better oxidising agent then H_2O_2 so in the reaction B it shows reducing behaviour.

TRY IT YOURSELF-1

Q.1 What is the effect of pure hydrogen perioxide on litmus?

Q.2 When H_2O_2 is added to mixture of conc. H_2SO_4 & $K_2Cr_2O_7$, which colour is observed and why ?

Q.3 Syn gas or water gas is represented as –
(A) $C + H_2O$ (B) $CO + H_2O$
(C) $CO + H_2$ (D) $CO_2 + H_2$

Q.4 Electronegativity and ionisation energy of hydrogen is similar to –
(A) Group 1 (B) Group 17
(C) Both Group. 1 and 17 (D) Nieither Group 1 nor 17

Q.5 Heavy water is used in nuclear reactor as –
(A) Fuel (B) Coolant
(C) Neutron moderator (D) Both (B) and (C)

Q.6 In ion-exchange method, exhausted permutit is regenerated by adding
(A) HCl (B) NaOH
(C) NaCl (D) H_2O

Q.7 Which is true regarding the structure and hybridisation of hydrogen peroxide ?
(A) Planar structure, sp^2 (B) Planar structure, sp^3
(C) Non-planar structure, sp^3 (D) non-planar structure, sp^2

Q.8 Hydrogen peroxide solution can be concentrated by –
(A) Cooling
(B) Evaporation on water baths
(C) Dehydration in vacuum desicator
(D) All of these

Q.9 If 10 volume solution of hydrogen peroxide is given, then find its strength is gm/L ?

Q.10 30% solution of H_2O_2 is equal to –
(A) 30 volume H_2O_2 (B) 100 volume H_2O_2
(C) 3 volume H_2O_2 (D) 300 volume H_2O_2

Q.11 Among the following which is/are interstitial hydride ?
(A) LaH_3 (B) CaH_2
(C) Both (A) & (B) (D) HF

ANSWERS

(1) It turns blue litmus red
(2) Blue colour appears due to CrO_5.

(3) (C)	**(4)** (B)	**(5)** (D)
(6) (C)	**(7)** (C)	**(8)** (D)
(9) 30.36 gm/L	**(10)** (B)	**(11)** (A)

s-BLOCK ELEMENTS

INTRODUCTION

Elements of IA and IIA group of the periodic table are called s-block elements. IA [ns^1] group elements are called alkali metals and IIA [ns^2] group elements are called alkaline earth metals. Alkali word is derived from the Arabic word '*alquis*' meaning plant ashes which are rich in the carbonates of sodium and potassium.

GENERAL CHARACTERISTIC

* They are good conductors of heat and electricity.
* Exhibit valency of 1 and 2 for IA and IIA groups respectively.
* They form colourless compounds except chromates, dichromates etc.
* Their cations are diamagnetic.
* They form ionic compounds (except Li and Be).
* Their solutions in liquid ammonia are good conductors of electricity and are good reductants
* Oxides are basic in nature.

ALKALI METALS

Table : Atomic and Physical Properties of the Alkali Metals

	Ionization enthalpy (kJ mol^{-1})	Ionic radius (pm)	M.P. (K)	Standard potential
Li (3)	520	76	454	–3.04
Na (11)	496	102	371	–2.714
K (19)	419	138	336	–2.925
Rb (37)	403	152	312	–2.930
Cs (55)	376	167	302	–2.927
Fr (87)	~375	180	–	–

PHYSICAL PROPERTIES

1. **Atomic Size :** These elements are largest in size in the period and the atomic size increase in going downwards in the group.
Order of size: Li < Na < K < Rb < Cs

2. **Oxidation state :** These metals exhibit +1 oxidation state, difference of their first and second ionisation potentials is more than 16eV. Their +1 oxidation state is more stable.

3. **Density :** Atomic weight increase from Li to Cs in the group and volume also increase, but increase in atomic weight is more when compared to volume. Therefore, density increases from Li to Cs.
Exception : Density of Na is more than that of K.
Density : Li < K < Na < Rb < Cs

4. **Tendency of forming ionic Bond :** One electron is present in the outermost shell of these metals. They form cation by the loss this electron, i.e., they form ionic bond in their compounds.

5. **Reducing character :** All the alkali metals are good reudcing agents due to their low ionization energies.
Reducing character order : Na < K < Rb < Cs < Li
The reducing character of any metal is best measured in terms of its electrode potential.

6. **Standard Electrode potential :** The measure of the tendency of donating electrons of a metal in water is called its electrode potential. If concentration of metal ions is unity, then it is called standard electrode potential.
Lithium has highest electrode potential which is due to its highest hydration energy.

7. **Colourless and Diamagnetic ions :** The property of an ion as being colourless or coloured, depends on the number of unpaired electrons present in the ion. If unpaired electrons are present in an ion, then these electrons get excited by the energy from light and show colour on coming back to the ground state. The ion which have unpaired electrons, show magnetic properties. Whereas, the ions having paired electrons nullify the magnetic fields of each other. Such ions are called diamagnetic ions.
Magnetic behaviour : The compounds of alkali metals are diamagnetic. Superoxides of alkali metals are, however, paramagnetic.

8. **Flame Test :** Alkali metals have large size. When they are heated in the flame of Bunsen burner, the electrons present in the valence shell move from lower energy level to higher energy level by absorption of heat from the flame (ns^1 n^0p). When they come back to the ground state, they emit the extra energy in the form of visible light to provide colour to the flame. Elements and their respective colours imported to the flame are give below.

Element	Li	Na	K	Rb	Cs
Colour	Crimson red	Yellow	Violet	Red violet	Blue

9. **Photoelectric effect :** Size of Cs is large and one electron is present in its outermost shell due to this, electron of outermost shell is emitted by absorption of visible light. Therefore, Cs shows photoelectric effect. This is the reason that it is used in the cells.

10. **Solubility in Liquefied Ammonia :** Ionisation potential is low due to large size of these metals, i.e., they readily dissolve in liquefied ammonia to form blue coloured solution, which is a good conductor of electricity and strong reducing agent.

11. **Hydration Energy :**
    - * Hydration energy decreases on going downwards in the group, due to increase in the size of metal ion.
      $Li > Na > K > Rb > Cs$
    - * Lithium gets more hydrated due to high hydration energy of Li^+ and the charge present on its gets protected. Thus, with the increase of hydration, size of ion increases and electric conductance decreases.
    - * Salts of lithium such as LiF, Li_2CO_3, Li_3PO_4 are insoluble in water.
    - * Ionic Mobility $\propto \dfrac{1}{\text{Size of hydrated ion}}$
      Order of ionic mobility:
      $Li^+(aq) < Na^+(aq) < K^+(aq) < Rb^+(aq) < Cs^+(aq)$

12. **Ionization energy :**
    (a)The I^{st} I.E. of alkali metals< I^{st} I.E. of alkaline earth metal.
    (b)The II^{nd} I.E. of alkali metals > II^{nd} I.E. of alkaline earth metal.
    (c) The alkali metals have lowest I.E. followed by alkaline earth metal.

13. **Reactivity :** Due to large size of these metals, the electron of the outermost shell is weakly attracted towards the nucleus.
    - * Na is very reactive and is kept in kerosene, so that air does not come directly in contact with sodium.
    - * Li hardly reacts with steam, whereas, Cs reacts even with cold water.
    - * Li forms only one of oxide (Li_2O), because ionisation potential of Li is high.
    - *

	Li	Na	K	Rb	Cs
I.P.	5.4	5.1	4.3	4.2	3.9

$\xrightarrow{\hspace{4cm}}$ Decreasing

Metallic nature/ Reactivity $\xrightarrow{\hspace{4cm}}$ Increasing

14. **Crystal Structure:** All the Alkali metals have their body centre cubic (BCC) structure with coordination number 8.

15. **Lustrous Surface :** Lustre is due to mobile electrons in the metallic lattice. Valence electrons generate vibration in the electrical field of the light waves. The vibrating electrons emit electromagnetic energy in the form of light, and thus the surface of these metals starts shining.

16. **Tendency of Forming Complex compounds :**
    These metals have weak tendency of forming complex compound due to large size, low charge density.

17. **Melting Point and Boiling Point :** Their melting and boiling points are low due to weak metallic bonds. Strength of metallic bond decreases in the group from Li to Cs, due to which hardness from Li to Cs. $Li > Na > K > Rb > Cs$
    Thus, melting and boiling points decrease down the group.

CHEMICAL PROPERTIES

* The alkali metals are highly reactive elements. The reactivity of alkali metals is due to low value of ionization energy; and low heat of atomisation.

* The reactivity of alkali metals increases from Li to Cs.

1. **Reaction with Air :**
    - * Li is stable in air, surface of Na become non-lustrous, Rb and Cs spontaneously burn in air.
    - * These metals form alkaline carbonates in moist air, because these metals react with air to form metal oxides, which further reacts with moisture and CO_2 to form metal carbonates. $4Na + O_2 \rightarrow 2Na_2O$
      $Na_2O + H_2O\,(\text{moisture}) \rightarrow 2NaOH$
      $2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$

2. **Reaction with oxygen :**
    - * Li forms one type of oxide (M_2O) and Na forms two type of oxide (M_2O, M_2O_2) and K, Rb and Cs form three type of oxide (M_2O, M_2O_2 and MO_2).
      $4\,Li + O_2 \rightarrow 2Li_2O$ (Oxide)
      $2\,Na + O_2 \rightarrow Na_2O_2$ (Peroxide)
    - * Basic nature of these oxides increases from Li to Cs, due to increase in the size of cation, because the species that gives electron is a base. Therefore, the tendency of donating electrons increases from Li to Cs.
    - * Size of cation increases from Li to cs. Therefore, according of Fajans Rule, ionic character of these oxides increases from Li to Cs, due to which melting and boiling points increase.
    - * Solubility in water increases from Li to Cs oxides, due to increase in ionic character of these metal oxides,
    - * Due to increase in atomic size from Li to Cs, reactivity of these metal oxides increases.

3. **Hydroxides :**
    - * The alkali metals react with water to form corresponding hydrodixes and evolve hydrogen (dihydrogen)
      $2M + 2H_2O \rightarrow 2M^+ + 2OH^- + H_2\uparrow$
    - * Except lithium, other alkali metals react explosively with water.
    - * Hydroxides are of MOH type ($M = Li, Na, K, Rb, Cs$)
    - * Basic nature of these hydroxides increases from Li to Cs. $LiOH < NaOH < KOH < RbOH < CsOH$
    - * Ionic character, melting point, boiling point, reactivity thermal stability and solubility in water increase from Li to Cs.

4. **Halides / Chlorides :**
    - * Alkali metals directly combine with halogen to form halides (MX), which are ionic compounds.
      The reactivity of alkali metal towards a particular halogen increases in the order : $Li < Na < K < Cs$.
    - * Hydrolysis of Halides : The ionic compounds get dissolved in water, while the covalent compounds get Hydrolysed. Ionic character increases from LiCl to CsCl. The amount of hydrolysis of decreases from LiCl to CsCl.

LiCl gets hydrolysed due to its covalent nature. Decreasing order of these halides in undergoing hydrolysis is : $LiCl > NaCl > KCl > RbCl > CsCl$.

5. **Metal carbonates**
   - * All these metals from M_2CO_3 type carbonates. (Li_2CO_3, Na_2CO_3, K_2CO_3, Rb_2CO_3, Cs_2CO_3)
   - * Li_2CO_3 is least stable out of all these carbonates, because it is covalent and decomposes to Li_2O and CO_2 at low temperature. Order of their stability is as :

     $Li_2CO_3 < Na_2CO_3 < K_2CO_3 < Rb_2CO_3 < Cs_2CO_3$
   - * Stability of carbonates of IA group metals > stability of carbonates of IIA group metals.

6. **Nitrides :**
   - * Among all alkali metals, only lithium directly combines with nitrogen to form nitride. Other alkali metals combine indirectly with nitrogen, because Li_3N is covalent and as the metallic character increases, the tendency of donating electron and forming ionic bond increases. Due to which strength of metal nitrogen bond decreases.
   - * Li_3N, is ionic ($3Li^+$ and N^{3-}), and is ruby red.
   - * First, on heating to a high temperature it decomposes to the elements, and second, it reacts with water, giving ammonia. $2Li_3N \xrightarrow{\text{Heat}} 6Li + N_2$

     $Li_3N + 3H_2O \rightarrow 3LiOH + NH_3$

7. **Sulphates :**
   - * Except Li_2SO_4 other alkali metal sulphate salts do not decompose even at high temperature

$$Li_2SO_4 \xrightarrow{\Delta} Li_2O + SO_3 \xrightarrow{\text{High temp.}} SO_2 + \tfrac{1}{2}O_2\uparrow$$

   - * Order of solubility :

     $Li_2SO_4 < Na_2SO_4 < K_2SO_4 < Rb_2SO_4 < Cs_2SO_4$

8. **Nitrates :** $LiNO_3$ decomposes to Li_2O at low temperature, whereas $NaNO_3$ gets decomposed to $NaNO_2$

9. **Hydrides :**
   - * Lithium reacts with hydrogen.
   - * Thermal stability of LiH is high.

     $LiH > NaH > KH > RbH > CsH$
   - * They are ionic hydrides and their stability depends on lattice energy.
   - * The hydrides of alkali metals react with water to form corresponding hydroxides and hydrogen gas

     $LiH + H_2O \rightarrow LiOH + H_2$

     $NaH + H_2O \rightarrow NaOH + H_2$

10. **Reaction with dilute acids :** Due to alkaline nature, these metals react rapidly with dilute acids and the rate of reaction increases from Li to Cs, because of increase in basic character.

11. **Bicarbonates :** These metals from $MHCO_3$ type bicarbonates thermal stability of these bicarbonates increase from Li to Cs.

12. **Formation of Amalgams :** Alkali metals form amalgams with mercury and alloys with other metals.

LITHIUM V/S OTHER ALKALI METALS

Due to small size of Li, it has high tendency of polarization and due to high density of electrical charge. It shows difference with other alkali metals.

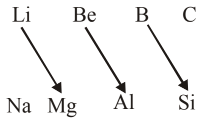
- * Li is hard, due to which its melting and boiling points are higher as compared to other metals.
- * LiOH is weak base compared to other hydroxides.
- * Li forms single type of oxide (Li_2O), whereas, Na(M_2O and M_2O_2), K, Rb and Cs (M_2O, M_2O_2 and MO_2) form more type of oxides.
- * Lithium nitrate when heated gives lithium monoxide, Li_2O. The other alkali metal nitrates decompose to give the corresponding nitrites. $4LiNO_3 \rightarrow 2Li_2O + 4NO_2 + O_2$

  $2NaNO_3 \rightarrow 2NaNO_2 + O_2$
- * Lithium carbonate decomposes on heating to evolve CO_2 where as other alkali metal carbonates do not.

  $Li_2CO_3 \xrightarrow{\Delta} Li_2O + CO_2\uparrow$
- * LiCl is insoluble in water, whereas, other chlorides are soluble, LiCl gets dissolved in benzene, petrol and ether.
- * Due to small size of Li^{+1}, its hydration energy is high.
- * Li does not get affected easily by moist air. Therefore, it can be kept open in the air, whereas, other metals form oxides.
- * Due to high hydration energy of Li, its conductivity is low.
- * Li directly combines with N_2 to form Li_3N whereas, other metals do not form nitrides.
- * Lithium combines with ammonia to form lithium imide (Li_2NH) while other alkali metals form amides of the general formula MNH_2, (where M = Na, K, Rb, Cs).

  $2Na + 2NH_3 \xrightarrow{Fe(NO_3)_3} 2NaNH_2 + H_2$
- * Phosphate, oxalate, chloride, fluoride, sulphate and carbonate of Li are insoluble in water, whereas the above compounds of other alkali metals are soluble.
- * Due to small size of Li, its ionisation potential electronegativity and electron affinity are higher than those of the other alkali metals.
- * Due to covalent nature of LiCl, their melting and boiling points are lower than those of other alkali metal halides.

DIAGONAL RELATIONSHIP B/W LITHIUM & MAGNESIUM



Due to this relationship, there will be similarities in the following properties.

- * Li and Mg both are hard metals due to the presence of strong metallic bonds in them.
- * Li and Mg both are hard, therefore, their melting and boiling points are high.
- * LiOH and $Mg(OH)_2$ both are weak bases.
- * LiCl and $MgCl_2$ are insoluble in water due to their covalent nature, but soluble in organic solvents.
- * LiCl and $MgCl_2$ get hydrolysed due to their covalent nature.

- Li and Mg directly combine with O_2 to form normal oxides (Li_2O and MgO).
- Li_2SO_4 and $MgSO_4$ show isomorphism.
- Li and Mg directly combine with N_2 to form Li_3N and Mg_3N_2
- Carbonates and nitrates of Li and Mg are unstable and readily decompose to form oxides.
- Hydration energies of Li^{+1} and Mg^{+2} ions are higher due to small size.
- Chlorides of Li and Mg remain in the form of $LiCl.\ 2H_2O$ and $MgCl_2.6H_2O$.
- Both ions are unreactive and colourless.
- Li and Mg form complex compounds due to their small size.

COMPOUNDS OF ALKALI METALS

1. SODIUM HYDROXIDE (CAUSTIC SODA), NaOH

Preparation:

Sodium hydroxide is commonly called caustic soda therefore used for air purify and it is prepared by electrolytic process.

(i) Castner Kellner cell:

A brine solution is electrolysed using mercury cathode and carbon (graphite rod) anode. Sodium metal, discharged at the cathode, combines with mercury to form sodium amalgam.

$$NaCl\,(aq) \rightarrow Na^+ + Cl^-$$

At cathode (mercury) : $2Na^+ + 2e^- \rightarrow 2Na$

$$Na + Hg \rightarrow NaHg \text{ (Sodium amalgam)}$$

At anode (graphite): $2Cl^- \rightarrow Cl_2 + 2e^-$

Sodium amalgam is removed from the cell. It is then decomposed in a separate cell by water giving NaOH, hydrogen and mercury. Mercury is recirculated to the cell.

(ii) Nelson cell (or Diaphragm cell) :

$$NaCl\,(aq) \rightarrow Na^+ + Cl^-$$

$$H_2O \rightarrow H^+ + OH^-$$

At cathode (perforated steel) : $2H^+ + 2e^- \rightarrow H_2$

At anode (carbon rod) : $2Cl^- \rightarrow Cl_2 + 2e^-$

Note: This cell is used for the industrial production of Cl_2. As well as this cell can be used for production of Na_2CO_3, for which CO_2 is mixed with steam.

Properties:

(i) Sodium hydroxide is a white, translucent solid.

(ii) NaOH is stable towards heat but is reduced to metal when heated with carbon

$$2NaOH + 2C \rightarrow 2Na + 2CO + H_2$$

(iii) It is readily soluble in water and forms a strong alkaline solution.

Uses :

(i) In purification of bauxite.

(ii) In the manufacturing of soap, paper, artifical silk.

(iii) Used in the textile industries for mercerizing cotton fabrics.

2. SODIUM CARBONATE (WASHING SODA) (Na_2CO_3)

It exists in various forms, namely anhydrous sodium carbonate Na_2CO_3 (soda-ash); monohydrate, $Na_2CO_3.H_2O$ (crystal carbonate); heptahydrate, $Na_2CO_3.\ 7H_2O$ and decahydrate, $Na_2CO_3 .\ 10H_2O$ (washing soda). It occurs in the form of reh and sajji matti in U.P. and Bihar.

Manufacture : (Solvay or ammonia soda process) :

In this process, brine (NaCl), ammonia and carbon dioxide are the raw materials. The chemical reactions involved are

$$NH_3 + CO_2 + H_2O \rightarrow NH_4HCO_3$$

$$NH_4HCO_3 + NaCl \xrightarrow{30°C} \underset{\text{Sod. bicarbonate}}{NaHCO_3 \downarrow} + NH_4Cl$$

$$\underset{\text{Sod. bicarbonate}}{2NaHCO_3} \xrightarrow{250°C} Na_2CO_3 + H_2O + \underset{\text{(used again)}}{CO_2}$$

$$\underset{\text{Amm. chloride}}{2NH_4Cl} + \underset{\text{Slaked lime}}{Ca(OH)_2} \longrightarrow CaCl_2 + 2H_2O + \underset{\text{(used again)}}{2NH_3}$$

Note : Solvay process can not be used for the production of K_2CO_3, since $KHCO_3$ has much greater solubility than $NaHCO_3$. So, $KHCO_3$ cannot be precipitated.

Properties:

(i) Sodium carbonate crystallizes from water as decahydrate. It is a white solid which efflorescence on exposure to dry air forming the monohydrate.

$$Na_2CO_3 \cdot 10H_2O \xrightarrow{\text{dry air}} Na_2CO_3 \cdot H_2O + 9H_2O$$

On heating, the monohydrate changes to anhydrous salt (m.p. 853°C) which does not decompose on further heating even to redness.

(ii) It is soluble in water with considerable evolution of heat. The resulting solution is alkaline due to hydrolysis.

$$\underset{\text{Sod. carbonate}}{Na_2CO_3} + 2H_2O \rightarrow \underset{\text{(weak acid)}}{H_2CO_3} + \underset{\text{(Strong alkali)}}{2\,NaOH}$$

(iii) It is readily decomposed by acids with the evolution of CO_2 gas.

(iv) It reacts with metal salts to form insoluble normal or basic carbonate.

$$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 \downarrow + 2\,NaCl$$

$$2MgCl_2 + 2Na_2CO_3 + H_2O \rightarrow MgCO_3 .\ Mg(OH)_2 \downarrow + 4\,NaCl + CO_2$$

Carbonates of metals like Al, Fe, Sn, etc. When formed are immediately hydrolysed to hydroxides.

$$Fe_2(SO_4)_3 + 3\,Na_2CO_3 \rightarrow Fe_2(CO_3)_3 \xrightarrow{3H_2O} 2Fe(OH)_3 + 3CO_2$$

(v) When CO_2 gas is passed through aqueous solution of sodium carbonate, sodium bicarbonate is formed.

$$Na_2CO_3 + H_2O + CO_2 \rightarrow \underset{\text{Sod. bicarbonate}}{2NaHCO_3}$$

Uses :

(i) In the manufacturing of glass, soap, borax and caustic soda.

(ii) In water softening in laundry.

3. SODIUM HYYDROGEN CARBONATE (BAKING SODA) ($NaHCO_3$)

Prepration :

- Made by saturating a solution of sodium carbonate with carbon dioxide. The white crystalline powder of sodium hydrogen carbonate, being less soluble, gets separated out. $Na_2CO_3 + H_2O + CO_2 \rightarrow 2NaHCO_3$

Properties :

- Aqueous solution gives no colour with phenolphthalein but yellow colour with Methyl orange and hence is weakly basic.
- On heating : $2NaHCO_3 \xrightarrow{\Delta} Na_2CO_3 + CO_2 + H_2O$
- Salts which give basic carbonates with washing soda give normal salts with the bicarbonate.
  $ZnSO_4 + 2NaHCO_3 \rightarrow ZnCO_3 + Na_2SO_4 + H_2O + 2CO_2$

Uses :

- It is used to neutralise stomach acidity.
- Sodium/Potassium salt of tartaric acid and $NaHCO_3$ mixture is used as Baking Soda.
- Used in Fire extinguisher.

BIOLOGICAL SIGNIFICANCE OF SODIUM AND POTASSIUM

(i) **Sodium (Na) :** Sodium ions are found primarily in the blood plasma. They are also found in the interstitial fluids surrounding the cells.
  - **(a)** Sodium ions help in the transmission of nerve signals.
  - **(b)** They help in regulating the flow of water across the cell membranes.
  - **(c)** They also help in transporting sugars and amino acids into the cells.

(ii) **Potassium (K):** Potassium ions are found in the highest quantity within the cell fluids.
  - **(a)** K ions help in activating many enzymes.
  - **(b)** They also participate in oxidising glucose to produce ATP.
  - **(c)** They also help in transmitting nerve signals.

Example 5 :

Considering greater polarization in LiCl compared to that in NaCl, which of the following statements you would expect to be wrong?
(A) LiCl has lower melting point than that of NaCl.
(B) LiCl dissolves more in organic solvents.
(C) LiCl will ionize in water more than NaCl.
(D) Fused LiCl would be less conducting than fused NaCl.

Sol. **(C).** According to Fajan's rules, higher the polarization, higher is the covalent character. Thus, LiCl is covalent while NaCl is ionic. As a result, LiCl will not ionize in water more than NaCl.

Example 6 :

Based on lattice energy and other considerations which one of the following alkali metal chlorides is expected to have the highest melting point –
(A) LiCl (B) NaCl
(C) KCl (D) RbCl

Sol. **(B).** Although lattice energy of LiCl higher than NaCl but LiCl is covalent in nature and NaCl ionic there, after, the melting point decreases as we move NaCl because the lattice energy decreases as a size of alkali metal atom increases (lattice energy $\propto$ melting point of alkali metal halide).

TRY IT YOURSELF-2

Q.1 Arrange group 1 elements in order of density.

Q.2 The colour imparted by Li and Ba are respectively –
(A) Crimson red, Crimson red
(B) Crimson red, green
(C) Yellow, green
(D) No colour, Crimson red

Q.3 The incorrect order of ionization enthalpy is given by –
(A) I^{st} IE Na < I^{st} IE Mg (B) I^{st} IE Na < II^{nd} IE Na
(C) I^{st} IE Mg > II^{nd} IE Mg (D) I^{st} IE K > I^{st} IE Rb

Q.4 Which is the strongest reducing agent in group 1 and why?

Q.5 Among the chlorides of alkali metals, what is the decreasing order of hydration ?
(A) NaCl > KCl > RbCl > LiCl > CsCl
(B) LiCl > CsCl > KCl > RbCl > NaCl
(C) LiCl > NaCl > KCl > RbCl > CsCl
(D) All are equally hydrated as halide is same.

Q.6 Among the alkali metal halides which of the alkali metal halide is the most covalent?
(A) LiCl (B) NaI
(C) KI (D) LiI

Q.7 Sodium carbonate is prepared by –
(A) Solvay process (B) Castner process
(C) Castner-Kellner process (D) Contact process

Q.8 Sodium and potassium react with water much more vigorously than lithium because:
(A) Sodium and potassium have high values of hydration energy as compared to that of lithium.
(B) Sodium and potassium have higher melting point than that of lithium.
(C) Sodium and potassium have lower melting point than that of lithium.
(D) Sodium and potassium have lower hydration energy than that of lithium.

For Q.9.-Q.10

Q.9 **Statement-1 :** Solubilities of alkali metal fluorides and carbonates increase down the group.
Statement-2: Hydration energies of alkali metal halides decrease down the group with increase in size of cations.
(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1.
(C) Statement-1 is True, Statement-2 is False.
(D) Statement-1 is False, Statement-2 is True.

Q.10 **Statement-1 :** Lithium is the most powerful reducing agent and sodium is the least powerful reducing agent amongst the alkali metals in aqueous solutions.

Statement-2 : Lithium has the highest hydration enthalpy and the sodium the least value.

Q.11 The melting point of lithium (180°C) is almost double the melting point of sodium (97°C) because:
(A) down the group, the hydration energy decreases.
(B) down the group, the ionization energy decreases.
(C) down the group, the cohesive energy decreases.
(D) none of these

Q.12 Which of the following statements is incorrrect ?
(A) The superoxide ion (i.e. O_2^-) is stable only in presence of larger cations such as K^+, Rb^+, Cs^+.
(B) Alkali metals are normally kept in kerosene oil.
(C) All the alkali metal hydrides are ionic solids with high melting points.
(D) The concentrated solution of alkali metals in liquid ammonia is paramagnetic in nature.

ANSWERS

(1) Li < K < Na < Rb < Cs **(2)** (C) **(3)** (C)
(4) Lithium **(5)** (C) **(6)** (D)
(7) (A) **(8)** (C) **(9)** (B)
(10) (C) **(11)** (C) **(12)** (D)

ALKALINE EARTH METALS

Table : Atomic and Physical Properties of the Alkaline Earth Metals

	Ionization enthalpy (I)/kJ mol^{-1}	Ionization enthalpy (II)/kJ mol^{-1}	Ionic radius (pm)	M.P. (K)	Standard potential
Be (4)	899	1757	31	1560	–1.97
Mg (12)	737	1450	72	924	–2.36
Ca (20)	590	1145	100	1124	–2.84
Sr (38)	549	1064	118	1062	–2.89
Ba (56)	503	965	135	1002	–2.92
Ra (88)	509	979	148	973	–2.92

PHYSICAL PROPERTIES

1. **Atomic Size :** Size of these elements are small as compared to alkali metals and it increases on going downwards in the group. Order of size : Be < Mg < Ca < Sr < Ba

2. **Oxidation State :** These metals exhibit + 2 oxidation state, difference of their second and first ionisation potentials is 11eV. Therefore, the +2 oxidation state of these metals is more stable.

3. **Density :** Atomic weight increase from Be to Ba in a group and volume also increases, but increase in atomic weight is more as compared to volume. Therefore, density increases from Be to Ba.
Exception : Density of Mg is more as compared to Ca
Density : Ca < Mg < Be < Sr < Ba

4. **Tendency of forming ionic Bond :** There are two electrons in the outermost shell of these metal, which are donated to form ionic compounds for example, $BaCl_2$, $CaCl_2$, etc. Due to small size of cations of Be and Mg, their compounds have covalent character.

5. **Standard Electrode potential or Standard Oxidation potential:**
Size of these metals is less than that of alkali metals. Therefore, their ionisation potential will be higher than those of alkali metals, i.e. they have low tendency of donating electron as compared to alkali metals. Their standard electrode potentials (oxidation potentials) are lower than those of alkali metals and increases in the group with increases in atomic size from Be to Ba.
Be < Mg < Ca < Sr < Ba

6. **Colourless and Diamagnetic ions :** These metals form dipositive ions (M^{+2}). These dipositive ions have noble gas configuration and their compounds are colourless, because all the electrons are paired. Their ions are diamagnetic due to presence of paired electrons. For example, $BeCl_2$, $CaCl_2$, $CaCO_3$, $BaSO_4$ etc. are colourless compounds.

7. **Flame Test :** Size of Be and Mg is very small and their electrons are strongly bonded to the nucleus. These electrons cannot be excited to higher energy level by the flame of the burner. Thus, Be and Mg do not impart any colour to the flame. Elements and their respective colour imparted to the flame are given below :

Element	Be	Mg	Ca	Sr	Ba
Flame	–	–	Brick red	Crimson red	Apple green

8. **Photoelectric effect :** Due to small size of these metals as compared to alkali metals, their ionisation potential is high. Thus, electrons can be released only by high energy radiations.

9. **Solubility in Liquefied Ammonia :** Due to small size of Be and Mg. Their ionisation potential is high. Therefore, they do not dissolve in liquefied ammonia. Ca, Sr & Ba give ammoniated electron by getting dissolved in liquefied ammonia due to large size due to which the solution turns blue.
$Ca + nH_3 \rightarrow Ca^{+2} + 2e^- (NH_3)_n$
The solution is a good conductor of electricity and a strong reducing agent.

10. **Hydration Energy :** Hydration energy of the metal ions (M^{+2}) is higher than that of the elements of IA group, because the size of these cations is small and charge is high. Hydration energy decreases on going downwards in the group, due to increase in the size of cations.
$Be^{2+} > Mg^{2+} > Ca^{2+} > Sr^{2+} > Ba^{2+}$

11. **Reactivity :** Due to small size of these metals as compared to alkali metals, the alkaline earth metals are less reactive than the alkali metals. Their reactivity increases from Be to Ba with increase in the size of the metal.
* Beryllium does not react with hot water, Mg reacts with hot water, whereas Ca, Sr and Ba react even with cold water.
* All these metals react with oxygen to form MO type oxides (M = Be, Mg, Ca, Sr and Ba), but due to low ionisation potential and high reactivity, Ca, Sr and Ba form peroxides also at low temperature.

* Be and Mg are less reactive due to their high ionisation potential and they form normal oxides because of breaking of O=O bond.

12. **Lustrous Surface :** Luster is due to mobile electron in the metallic lattice. Valence electrons generate vibration in the electrical field of the light waves. The vibrating electrons emit electromagnetic energy in the form of light, and thus the surface of these metals starts shining.

13. **Tendency of Forming Complex compounds :** These metals have weak tendency of forming complex compounds due to large size, low charge density . But these metals have higher tendency of forming complex compounds as compared to alkali metals, due to their relatively smaller size. This tendency decreases from Be to Ba.

14. **Melting Point and Boiling Point :** Melting and boiling points of these metals are low, but these metals are harder as compared to metals of IA group. Thus, their melting and boiling points are higher as compared to metals of IA group.
Hardness decreases from Be to Ba, due to which melting and boiling points decrease. $Be > Ca > Sr > Ba > Mg$

CHEMICAL PROPERTIES

1. **Reaction with Air :** Beryllium is stable due to its low reactivity. The surface of Mg becomes gloomy in air, Sr and Ba burn spontaneously in air.

2. **Reaction with oxygen :** Be and Mg form normal MO type oxides, whereas, Ca, Sr and Ba form normal oxides (MO) as well as peroxides MO_2 . Their peroxides are coloured due to crystal defect.
Basic nature ($BeO < MgO < CaO < SrO < BaO$), ionic character, melting point, boiling point, thermal stability reactivity and solubility in water of these oxides increases from Be to Ba, BeO shows amphoteric nature and therefore, react with acids as well as bases. MgO is a weak base, while CaO, SrO and BaO are strongly basic.

$$BeO + 2HCl \rightarrow BeCl_2 + H_2O$$

$$BeO + 2NaOH \rightarrow Na_2BeO_2 \text{ (Sodium berallyte)} + H_2O$$

3. **Reaction with water :**
Ca, Sr and Ba react with cold water, liberating hydrogen gas

$$Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$$

$$Sr + 2H_2O \rightarrow Sr(OH)_2 + H_2$$

Magnesium decomposes hot water

$$Mg + H_2O \rightarrow MgO + H_2$$

or $Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2$

Beryllium does not react with water. Mg reacts with boiling water while Ca, Sr, Ba react vigorously even with cold water.
Order of reactivity : $Ba > Sr > Ca > Mg$

4. **Hydroxides :** Ionic character, melting point, boiling point, reactivity, thermal stability and solubility in water increases from Be to Ba. Increasing order of basic character of these hydroxides is as follows :
$Be(OH)_2 < Mg(OH)_2 < Ca(OH)_2 < Sr(OH)_2 < Ba(OH)_2$
$Be(OH)_2$ reacts with acids as well as base, due to their amphoteric nature. Other hydroxides react with acids only.

5. **Halides / Chlorides :**
* All these metals react with halogens at elevated temperature to form MX_2 type halides ($BeCl_2$, $MgCl_2$, $CaCl_2$, $SrCl_2$, $BaCl_2$)
* Ba turns on coming on contact with chlorine.
* Covalent character of these halides decreases from $BeCl_2$ to $BaCl_2$. Therefore, the amount of hydrolysis also decreases from $BeCl_2$ to $BaCl_2$. Only $BeCl_2$ and $MgCl_2$ get hydrolysed due to their covalent nature .Other halides do not get hydrolysed. Hydrolysis is as : $BeCl_2 > MgCl_2 > CaCl_2 > SrCl_2 > BaCl_2$
* Beryllium chloride is prepared indirectly, from its oxide as : $BeO + C + Cl_2 \xrightleftharpoons{600\text{-}800K} BeCl_2 + CO$

6. **Metal carbonates :**
* All these metals form MCO_3 type carbonates ($BeCO_3$, $MgCO_3$, $CaCO_3$, $SrCO_3$, $BaCO_3$)
* $BeCO_3$ is least stable out of all these carbonates because it is covalent and decomposes to BeO and CO_2 at low temperature. Order of their stability is as follows.
$BeCO_3 < MgCO_3 < CaCO_3 < SrCO_3 < BaCO_3$
* Stability of Carbonates of IA group metals > stability of carbonates of IIA group metals.
* All the carbonates decompose on heating to give carbon dioxide and metal oxide.

$$MCO_3 \xrightarrow{\Delta} MO + CO_2$$

7. **Nitrides :** Only Be and Mg (and to some extent Ca) burn in N_2 to form nitrides (M_3N_2), which decomposes to give NH_3.

$$3Mg + N_2 \rightarrow Mg_3N_2$$

$$Mg_3N_2 + 6H_2O \rightarrow 3Mg(OH)_2 + 2NH_3$$

8. **Sulphates :**
Solubility of Sulphates : Their hydration energy is high due to small size of Be^{+2} and Mg^{+2} and it overcomes the lattice energy. This is the reason why
$BeSO_4 > MgSO_4 > CaSO_4 > SrSO_4 > BaSO_4$
Increasing order of thermal stability
$BeSO_4 < MgSO_4 < CaSO_4 < SrSO_4 < BaSO_4$
* All sulphates of alkaline earth metals decompose on heating. $MgSO_4 \xrightarrow{\Delta} MgO + SO_3$
* **Lithopone:** Mixture of $BaSO_4$ & ZnS is known as lithopone.

9. **Nitrates :** These metals also form $M(NO_3)_2$ and all nitrates give oxides on decomposition.

10. **Carbides :** BeO when heated with C at about 2000°C, Be_2C is formed. The metals Mg, Ca, Sr and Ba form carbides of the formula MC_2. These carbides are formed when the metal or the metal oxide is heated with carbon in an electric furnace.
These carbides are ionic in nature.
Be_2C yields methane on hydrolysis whereas carbides of other metals yield acetylene

$$Be_2C + 4H_2O \rightarrow 2Be(OH)_2 + CH_4$$

$$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$$

11. **Hydrides :** These metals (except Be) combine with hydrogen to form MH_2 type hydrides. Thermal stability of these hydrides is as follows.
$BeH_2 < MgH_2 > CaH_2 > SrH_2 > BaH_2$
BeH_2 and MgH_2 get polymerized.
Thermal stability of BeH_2 is high due to low electropositive character of Be, which decreases from BeH_2 to BaH_2.

12. **Reaction with dilute acids :** Beryllium is amphoteric, so it reacts slowly with dilute acids. Other metals are alkaline and therefore react rapidly with dilute acids.

13. **Bicarbonates :** These metals form $M(HCO_3)_2$ type bicarbonates. The thermal stability of bicarbonates increases from Be to Ba.

14. **Formation of Amalgams :** These metals form alloys with other metals and amalgams with mercury. Tendency of formation of amalgam is less than alkali metal.

Example 7:

The ion having highest mobility in aqueous solution is –

(A) Be^{2+} (B) Mg^{2+}
(C) Ca^{2+} (D) Ba^{2+}

Sol. **(D).** Though Ba^{2+} is the heaviest ion but it is least hydrated. As a result, its size becomes lesser than any other hydrated alkaline earth metal cation and hence has the highest ionic mobility.

Example 8 :

Which of the following elements will form a compound with oxygen in which one atom of the element is combined with one atom of oxygen to form an oxide of formula MO?

(A) Be (B) Ne
(C) Al (D) Cl

Sol. **(A).** Be forms BeO, Al forms Al_2O_3, Cl forms Cl_2O_7, Cl_2O, ClO_2 etc. while Ne does not react.

Example 9 :

A metal M readily forms water soluble sulphate MSO_4, water insoluble hydroxide $M(OH)_2$ and oxide MO which becomes inert on heating. The hydroxide is soluble in NaOH. M is –

(A) Be (B) Mg
(C) Ca (D) Sr

Sol. **(A).** $Be(OH)_2$ is amphoteric in nature so it is soluble in NaOH.

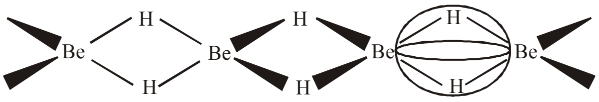
ANOMALOUS PROPERTIES OF BERYLLIUM

Beryllium exhibits different behaviour due to small size as compared to other elements of its group.

* Ionisation potential and electronegativity of Be are higher than those of other metals.
* $BeCl_2$ is insoluble in water, due to its covalent nature, but soluble in organic solvents. Other chlorides ($CaCl_2$, $SrCl_2$ and $BaCl_2$) get dissolved in water.
* $BeCl_2$ gets hydrolysed due to its covalent nature. Chlorides of Ca, Sr and Ba get dissociated.
* BeO and $Be(OH)_2$ are amphoteric in nature. Therefore they react with acids as well as bases. Other oxides react only with acids due to their alkaline nature.

$$BeO + 2NaOH \rightarrow Na_2BeO_2 \text{ (Sodium berylate)} + H_2O$$
$$BeO + 2HCl \rightarrow BeCl_2 + H_2O$$

* Beryllium forms single type of oxide (MO), Ca Sr and Ba form peroxides also.
* Beryllium does not give flame test, Ca, Sr and Ba impart characteristic colours to the flame.
* Due to small size, Be forms complex compounds.
* Hydrides and halides of Be get polymerized.



Polymerized BeH_2 in which tricentric forces are present.

* Beryllium does not react with water even at high temperatures. Others (Ca, Sr and Ba) react even with cold water.

DIAGONAL RELATIONSHIP BETWEEN Be AND Al

Beryllium shows difference from IIA group elements, but it shows similarity with Al.

* Be and Al both are hard due to strong metallic bonds. Therefore, their melting and boiling points are high.
* $BeCl_2$ and $AlCl_3$ both are covalent compounds. Therefore, they are insoluble in water and soluble in organic solvents.
* Both get hydrolysed due to their covalent tendency.
* Melting points of $BeCl_2$ and $AlCl_3$ are low due to their covalent tendency.
* Be and Al both have tendency of forming complex BeF_4^{2-}, AlF_6^{3-} due to small size.
* Be and Aluminium form similar type of normal oxides (BeO and Al_2O_3)
* $Be(OH)_2.Al(OH)_3$,, BeO and Al_2O_3 are amphoteric in nature.

$$BeO + 2HCl \rightarrow BeCl_2 + H_2O$$
$$Al_2O_3 + 2HCl \rightarrow 2AlCl_3 + 3H_2O$$
$$Al_2O_3 + NaOH \rightarrow 2NaAlO_2 \text{ (Sod. metaaluminate)} + H_2O$$
$$BeO + 2NaOH \rightarrow Na_2BeO_2 \text{ (Sodium berylate)} + H_2O$$

* $BeCl_2$ and $AlCl_3$ from dimers, because both are electron deficient compounds.
* Be and Al both become inert in conc. HNO_3, because both form a protective layer of oxides.
* Be and Al both react directly with C to form Be_2C and Al_4C_3, respectively, which give methane on reaction with water.

$$Be_2C + 2H_2O \rightarrow CH_4 + 2BeO$$
$$Al_4C_3 + 12H_2O \rightarrow 3CH_4 + 4Al(OH)_3$$

COMPOUNDS OF CALCIUM

1. Calcium oxide (Quick lime) (CaO) :

Preparation :

It is prepared by heating lime stone ($CaCO_3$) at 800°C

$$CaCO_3 \rightleftharpoons CaO + CO_2 \quad ; \Delta H = 179.9 \text{ KJ}$$

Condition for Good Yield:

(i) Since the reaction is reversible, therefore the carbon dioxide formed must be removed as soon as it is formed so that the reaction remain in the forward direction.

(ii) Temperature should not be allowed to rise above 1270K otherwise silica (SiO_2) present as impurity in limestone will react with CaO to form $CaSiO_3$.

Properties :

(i) Action of water :

$CaO + H_2O \rightarrow Ca(OH)_2 + 15000$ Caloric

(Quick lime) (Slaked lime)

Paste of lime in water is called milk of lime, while its hydrate is known as lime water.

(ii) Quick lime is a basic oxide and hence reacts with acids, SO_2 etc. on heating with ammonium salt it gives ammonia.

$$CaO + 2NH_4Cl \xrightarrow{\Delta} CaCl_2 + 2NH_3 + H_2O$$

(iii) With moist chlorine :

$CaO + Cl_2 \rightarrow CaOCl_2$ (Bleaching powder)

(iv) When heated with carbon, it forms calcium carbide.

$$CaO + 3C \xrightarrow{2000°C} CaC_2 + CO$$

Uses :

(i) It is used in steel industry to remove phosphates and silicates as slag.

(ii) It is used to make cement by mixing it with silica, alumina or clay.

(iii) It is used in making glass.

(iv) It is used in lime soda process for the conversion of Na_2CO_3 to NaOH & vice versa.

(v) It is used for softening water, for making slaked lime $Ca(OH)_2$ by treatment with water and calcium carbide

2. Calcium hydroxide (Slaked lime) $Ca(OH)_2$:

Preparation :

By the action of water on quick lime.

$CaO + H_2O \rightarrow Ca(OH)_2 + Heat$

means it is an exothermic reaction.

Properties :

(i) Sparingly soluble in water and its solubility decreases with increases in temperature.

(ii) Action of CO_2 : Lime water turns milky on passing CO_2 gas.

$Ca(OH)_2 + CO_2 \rightarrow CaCO_3$ (Milkiness) $+ H_2O$

(iii) Action of chlorine:

(a) Cold Condition: $2Ca(OH)_2 + 2Cl_2 \xrightarrow{Cold}$

$CaCl_2 + Ca(OCl)_2$ (Cal. Hypochlorite)$+ 2H_2O$

(b) Below 35°C :

$$3Ca(OH)_2 + 2Cl_2 \xrightarrow[35°C]{below} CaOCl_2 + H_2O$$

(c) On gentle Heating:

$6Ca(OH)_2 + 6Cl_2$

$$\xrightarrow{Heat} 5CaCl_2 + Ca(ClO_3)_2 + 6H_2O$$

(d) On Red Hot :

$$2Ca(OH)_2 + 2Cl_2 \xrightarrow{Red\ Heat} 2CaCl_2 + 2H_2O + O_2$$

(iv) Action of Ammonia:

$Ca(OH)_2 + 2NH_4Cl \rightarrow CaCl_2 + 2NH_3 + 2H_2O$

Uses :

(i) Slaked lime is used as a building material in form of mortar. It is prepared by mixing 3-4 times its weight of sand and by gradual addition of water. Its sets into a hard mass by loss of H_2O and gradual absorption of CO_2 from air.

(ii) In manufacture of bleaching powder by passing Cl_2 gas.

(iii) In making glass and in the purification of sugar.

(iv) It is used in softening of hard water.

3. Calcium Carbonate, ($CaCO_3$):

Calcium carbonate is found in nature as limestone, marble, coral, ice land spar, calcite, chalk, dolomite, etc.

Preparation:

It is prepared as a white powder known as precipitated chalk by dissolving marble or limestone in hydrochloric acid followed by precipitation with sodium or ammonium carbonate.

$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$

$CaCl_2 + (NH_4)_2CO_3 \rightarrow CaCO_3 + 2NH_4Cl$

In the laboratory, it is prepared by passing CO_2 through lime-water or by adding sodium or ammonium carbonate solution to $CaCl_2$.

$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 \downarrow + H_2O$

$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl$

Properties:

(i) It is a white fluffy powder and exists in two crystalline forms: calcite and aragonite.

(ii) When $CaCO_3$ is heated to 1200 K, it decomposes to evolve CO_2.

$$CaCO_3 \xrightarrow{1200\ K} CaO + CO_2 \uparrow$$

(iii) It is insoluble in water but dissolves in the presence of CO_2 due to the formation of calcium bicarbonate.

$CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$

(iv) It reacts with dilute acid to liberate carbon dioxide.

$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2 \uparrow$

Uses :

(i) It is used as building material in form of marble.

(ii) In manufacture of quick lime.

(iii) It is used as a raw material for the manufacture of Na_2CO_3 in solvay – ammonia process.

(iv) Commercial limestone contains iron oxide, alumina, magnesia, silica & sulphur with a CaO content of 22- 56%, MgO content upto 21%. It is used as such as a fertilizer.

4. Calcium Bicarbonate, ($Ca(HCO_3)_2$):

It does not exist in solid state. However, its solution can be prepared by passing CO_2 gas through a suspension of calcium carbonate in water. On warming, it decomposes to calcium carbonate along with the evolution of carbon dioxide gas.

5. Calcium Sulphate, ($CaSO_4$):

It occurs in nature as anhydride ($CaSO_4$)) and gypsum ($CaSO_4.2H_2O$).

Preparation:

It may be prepared by adding dilute sulphuric acid or soluble sulphate (e.g. Na_2SO_4) to the solution of a calcium salt.

$$CaCl_2 + H_2SO_4 \rightarrow CaSO_4 + 2HCl$$

Properties :

(i) It is a white crystalline solid. Like slaked lime, it is sparingly soluble in cold water and its solubility decreases further with the increase in temperature.

(ii) It dissolves much more readily in dilute acids, even in acetic acid than in water. It dissolves also in ammonium sulphate solution forming $CaSO_4.(NH_4)SO_4.H_2O$.

(iii) Monoclinic crystals of gypsum when heated, first changes into orthorhombic form without any loss of water. On further heating to 120°C, It loses three-fourth of its water of crystallization and forms the hemihydrate, $(2CaSO_4)\cdot H_2O$ or $CaSO_4.\frac{1}{2}H_2O$ which is commonly known as Plaster of Paris.

$$CaSO_4.2H_2O \xrightarrow{120°C} CaSO_4.\tfrac{1}{2}H_2O + 1\tfrac{1}{2}H_2O$$

Plaster of Paris is a white powder which when mixed with water takes up the water of clystallization again, thus converted back into the dehydrate and sets to a hard mass with slight expansion. Setting takes about 10-15 minutes and may be catalysed by the addition of common salt or delayed by the use of alum or borax.

$$\underset{\text{Plaster of Paris}}{CaSO_4.\tfrac{1}{2}H_2O} \xrightarrow[\text{setting}]{H_2O} \underset{\text{Orthorhomic}}{CaSO_4.2H_2O}$$

$$\xrightarrow{\text{Hardening}} \underset{\text{Monoclinic (gypsum)}}{CaSO_4.2H_2O}$$

Plaster of paris or gypsum when heated to about 200°C is converted into anhydrous calcium sulphate. The anhydrous form (anhydrite) is known as dead burnt because it does not set like Plaster of Paris when moistened with water.

Uses of Plaster of paris

(i) Plaster of paris is used for producing moulds for pottery and ceramics & casts of statues & busts.

(ii) It is used in surgical bandages used for plastering broken or fractured bones.

(iii) It is also used in dentistry.

Example 10 :

Setting of plaster of paris is –

(A) Oxidation with atmospheric CO_2

(B) Combination with atmospheric CO_2

(C) Dehydration

(D) Hydration to yield another hydrate

Sol. **(D).** Setting of plaster of paris is

$$CaSO_4.\tfrac{1}{2}H_2O \xrightarrow{H_2O} CaSO_4.2H_2O \text{ (Orthorhomic)}$$

$$\xrightarrow{\text{Hardening}} CaSO_4.2H_2O \text{ (Mono orthorhombic Gypsum)}$$

The setting is due to formation of another hydrate.

CEMENT

- * J. Aspdin introduced cement for the first time in England.
- * It resembles with the famous Portland rock in England hence the name Portland cement was given.
- * Composition of Portland cement Lime, CaO = 50– 60%, Silica, SiO_2 = 20–25%, Alumina, Al_2O_3 = 5 – 10%, Ferric oxide, Fe_2O_3 = 1–2%, Sulphur trioxide, SO_3 = 1 – 2%, Magnesia MgO = 2–3% Sodium oxide Na_2O = 1%, Potassium oxide K_2O = 1%
- * For a good quality cement the ratio of the oxide should be maintained as : $[\%\ SiO_2] : [\%Al_2O_3] = 2.5 - 4.0$
  $[\%CaO] : [\%SiO_2 + \%Al_2O_3 + \%Fe_2O_3] = 1.9 - 2.1$
- * **Raw materials :**
  - **(i)** Lime stone $[CaCO_3] \rightarrow$ it supplies CaO
  - **(ii)** Clay $[Al_2O_3.\ SiO_3.\ Fe_2O_3.\ 2H_2O] \rightarrow$ it supplies SiO_2, Al_2O_3.
  - **(iii)** Gypsum, $[CaSO_4.\ 2H_2O] \rightarrow$ it decreases the setting time of cement.

Mixing of cement clinker with gypsum :

Clinker is powdered and 2 – 3% gypsum ($CaSO_4.\ 2H_2O$) is added to slow down the setting of cement. It assumes the form : $3CaO.\ Al_2O_3.\ 3CaSO_4.\ 2H_2O$ calcium sulphoaluminate.

Mortar : A mixture of Cement, sand [1 : 3] in water, used in binding bricks and plastering.

BIOLOGICAL SIGNIFICANCE OF MAGNESIUM & CALCIUM

Magnesium and calcium are referred to as macro-minerals. This term indicates their higher abundance in the human body system.

(a) Mg helps in relaxing nerves and muscles.

(b) Mg helps in building and strengthening bones.

(c) Mg maintains normal blood circulation in the human body system.

(d) Ca helps in the coagulation of blood.

(e) Ca also helps in maintaining homeostasis.

TRY IT YOURSELF-3

Q.1 Arrange group 2 hydroxide in order of solubility. Give reason.

Q.2 Suspension of slaked lime in water is known as

(A) lime water (B) quick lime

(C) milk of lime (D) aqueous solution of slaked lime

Q.3 Among alkaline earth metal, the element rarest of all ?

(A) Be (B) Sr

(C) Ra (D) Both (A) and (C)

Q.4 By adding gypsum to cement
(A) setting time of cement becomes less.
(B) setting time of cement increases.
(C) colour of cement becomes light.
(D) shining surface is obtained.

Q.5 Beryllium shows diagonal relationship with –
(A) Li (B) Mg
(C) Na (D) Al

Q.6 The following compounds have been arranged in order of their increasing thermal stabilities. Identify the correct order. K_2CO_3 (I), $MgCO_3$ (II), $CaCO_3$ (III), $BeCO_3$ (IV)
(A) I < II < III < IV (B) IV < II < III < I
(C) IV < II < I < III (D) II < IV < III < I

Q.7 Choose the correct statement (s) for the solutions of alkali metals and alkaline earth metals in ammonia (*l*) ?
(A) Concentrated solutions of alkali metals in ammonia are copper - bronzed coloured and have a metallic lusture.
(B) Dilute solutions of alkaline earth metals are deep bule-black in colour due to the spectrum from the solvated electron.
(C) Concentrated solutions of the alkaline earth metals in ammonia are bronze coloured.
(D) Evaporation of the ammonia from solutions of alkali metals yields the metal, but with alkaline earth metals evaporation of ammonia gives hexammoniates of the metals.

Q.8 Property of the alkaline earth metals that increases with their atomic number is :
(A) Ionisation energy
(B) solubility of their hydroxides
(C) solubility of their sulphates
(D) Electronegativity

Q.9 Metal carbonates decompose on heating to give metal oxide and carbon dioxide. Which of the metal carbonates is most stable thermally?
(A) $MgCO_3$ (B) $CaCO_3$
(C) $SrCO_3$ (D) $BaCO_3$

Q.10 Some of the Group 2 metal halides are covalent and soluble in organic solvents. Among the following metal halides, the one which is soluble in ethanol is
(A) $BeCl_2$ (B) $MgCl_2$
(C) $CaCl_2$ (D) $SrCl_2$

Q.11 Amphoteric hydroxides react with both alkalies and acids. Which of the following Group 2 metal hydroxides is soluble in sodium hydroxide?
(A) $Be(OH)_2$ (B) $Mg(OH)_2$
(C) $Ca(OH)_2$ (D) $Ba(OH)_2$

ANSWERS

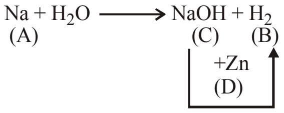
(1) $Be(OH)_2 < Mg(OH)_2 < Ca(OH)_2 < Sr(OH)_2 < Ba(OH)_2$
(2) (C) **(3)** (C) **(4)** (B)
(5) (D) **(6)** (B) **(7)** (ABCD)
(8) (B) **(9)** (D) **(10)** (A)
(11) (A)

ADDITIONAL EXAMPLES

Example 1 :

When a substance A reacts with water it produces a combustible gas B and a solution of a substance C in water. When another substance D reacts with this solution of C, it also produces the same gas B on warming, but D can produce B on reaction with dilute sulphuric acid at room temperature. A imparts a deep golden yellow colour to a smokeless flame of Bunsen burner. A, B, C and D respectively are –
(1) Na, H_2, NaOH and Zn
(2) K, H_2, KOH and Al
(3) Ca, H_2, $Ca(OH)_2$ and Sn
(4) CaC_2,C_2H_2,$Ca(OH)_2$ &Sn

Sol. **(1).**



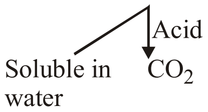
$\underset{(A)}{Na} + H_2O \longrightarrow \underset{(C)}{NaOH} + \underset{(B)}{H_2}$

$Zn\,(D) + H_2SO_4 \longrightarrow ZnSO_4 + H_2$

Example 2 :

A colourless solid (X) on heating evolved CO_2 and also gave a white residue, soluble in water. Residue also gave CO_2 when treated with dilute acid (X) is –
(1) Na_2CO_3 (2) $CaCO_3$
(3) $NaHCO_3$ (4) $Ca(HCO_3)_2$

Sol. **(1).** $2NaHCO_3 \longrightarrow Na_2CO_3 + H_2O + CO_2$



Example 3 :

CO_2 gas along with solid (Y) is obtained when sodium salt (X) is heated. (X) is again obtained when CO_2 gas is passed (X) and (Y) are –
(1) Na_2CO_3, Na_2O (2) Na_2CO_3, NaOH
(3) $NaHCO_3$, Na_2CO_3 (4) Na_2CO_3, $NaHCO_3$

Sol. **(3).** $\underset{(X)}{2NaHCO_3} \xrightarrow{Heat} \underset{(Y)}{Na_2CO_3} + H_2O + CO_2$;

$\underset{(Y)}{Na_2CO_3} + H_2O + CO_2 \longrightarrow \underset{(X)}{2NaHCO_3}$

Example 4 :

Identify the correct statement –
(1) The percentage of calcium is lower in gypsum in comparison to plaster of Paris.
(2) Gypsum is not a natural product. It is obtained by heating of plaster of Paris
(3) Plaster of Paris is obtained by hydration of gypsum.
(4) Plaster of Paris is formed by oxidation of gypsum.

Sol. **(1).** The formulae of gypsum and plaster of Paris are $CaSO_4.2H_2O$ and $CaSO_4.½H_2O$ respectively. Hence, molecular mass of gypsum is higher than molecular mass of plaster of Paris. Therefore, the percentage of calcium is lower in gypsum in comparison to plaster of Paris.

Example 5 :

Commercial common salt becomes slightly damp on keeping. This is due to the fact that :

(1) Common salt is hygroscopic

(2) Common salt contains some impurity which is hygroscopic

(3) Salt is efflorescent

(4) Salt is crystalline

Sol. **(2).** Commercial common salt commonly becomes slightly damp on keeping because common salt contains some impurity $MgCl_2$ and $CaCl_2$ which is hygroscopic in nature and absorbs moisture from the atmosphere.

Example 6 :

H_2O_2 and heavy water was discovered by respectively :

(1) Thenard, Urey (2) Urey, Rutherford

(3) Aston, Urey (4) Aston, Chadwick

Sol. **(1).** H_2O_2 was discovered by Thenard and Urey discovered heavy water.

Example 7 :

The highest melting point of alkali metal is :

(1) Li (2) Na

(3) K (4) Rb

Sol. **(1).** Li has highest melting point among alkali metals. All alkali metals have low M.P. The M.P. decrease down the group. The low M.P. are attributed to their larger atomic size due to which the binding energies of their atoms in the crystal lattice are low.

Example 8 :

Li has the maximum value of ionisation potential among alkali metals i.e. lithium has the minimum tendency to ionise to give Li^+ ion. Thus, lithium is –

(1) Strongest reducing agent

(2) Poorest reducing agent

(3) Strongest oxidising agent

(4) Poorest oxidising agent

Sol. **(1).** The ionisation potential value of Lithium is maximum among alkali metals i.e. its tendency to ionise to give Li^+ ions should be the minimum i.e. Li should be the poorest reducing agent. But, lithium is the strongest reducing agent. This is due to the largest value of hydration energy of Li^+ ions.

Example 9 :

Which compound decomposes at highest temperature :

(1) $SrCO_3$ (2) $BaCO_3$

(3) $CaCO_3$ (4) $MgCO_3$

Sol. **(2).** $BaCO_3$ decomposes at highest temp. All the carbonates decompose on heating to give CO_2 and metal oxide. $MCO_3 \xrightarrow{\Delta} MO + CO_2$

The stability of carbonate towards heat depends upon the stability of the resulting metal oxide. More is the stability of the resulting metal oxide lesser is the stability of the carbonate towards heat and vice versa.

Example 10 :

$$4\,D_2O + 3Fe \xrightarrow{\text{red-hot}} Fe_3O_4 + \text{gas.}$$

The gas produced in the above reaction is –

(1) O_2 (2) H_2

(3) D_2 (4) None

Sol. **(3).** The gas produced in the reaction is deuterium.

Example 11 :

Which of the following compound affects mercury

(1) D_2O (2) H_2O

(3) O_3 (4) dil. HCl

Sol. **(3).** Ozone wipes out meniscus of mercury due to the formation of Hg_2O as a result of $[O_3 - Hg]$ reaction.

Example 12 :

An inorganic substance liberates oxygen on heating and turns an acidic solution of KI brown and reduces acidified $KMnO_4$ solution. The substance is –

(1) HgO (2) H_2O_2

(3) KNO_3 (4) $Pb(NO_3)_2$

Sol. **(2).** $2H_2O_2 \xrightarrow{\text{Heat}} 2H_2O + O_2$

$$2KI + H_2O_2 \xrightarrow{\text{Acidic}} 2KOH + \underset{\text{Brown}}{I_2}$$

Acidified $KMnO_4$ acts as an oxidising agent when it is decolourised, $H_2O_2 + O \longrightarrow H_2O + O_2$

Example 13 :

In which of the following reactions does hydrogen act as an oxidising agent :

(1) $H_2 + F_2 \longrightarrow$ (2) $H_2 + SiCl_4 \longrightarrow$

(3) $Na + H_2 \longrightarrow$ (4) $CuO + H_2 \longrightarrow$

Sol. (3). The reaction in which hydrogen accepts the electron or its oxidation number changes from 0 to –1, it acts as an oxidising agent. $2Na + H_2 \longrightarrow 2Na + H^-$

Example 14 :

When H_2O_2 is added to ice cold solution of acidified potassium dichromate in ether and the contents are shaken and allowed to stand :

(1) A blue colour is obtained in ether due to formation of $Cr_2(SO_4)_3$.

(2) A blue colour is obtained in ether due to formation of CrO_5.

(3) A blue colour is obtained in ether due to formation of CrO_3.

(4) Chromyl chloride is formed

Sol. **(2).** $Cr_2O_7^{2-} + 2H^+ + 4H_2O_2 \longrightarrow \underset{\text{Blue colour in ether}}{2CrO_5} + 5H_2O$

Example 15 :

Ba^{2+} ion is poisonous;yet $BaSO_4$ is given to patient prior to taking stomach X-ray.

Sol. $BaSO_4$ is extremely insoluble and doesn't pass from digestive system into circulatory system. It is X-ray opaque also.

QUESTION BANK

CHAPTER 9 : HYDROGEN AND S-BLOCK ELEMENTS

EXERCISE - 1 [LEVEL-1]

Choose one correct response for each question.

PART - 1 : POSITION OF HYDROGEN IN PERIODIC TABLE

Q.1 Electronegativity and ionisation energy of hydrogen is similar to –

(A) Group 1 (B) Group 17
(C) Both Group 1 and 17 (D) Neither Group 1 nor 17

Q.2 Which of the following properties of hydrogen is incorrect?

(A) Like halogens, hydrogen exists as a diatomic gas.
(B) Like halogens, hydrogen exhibits –1 oxidation state in its compounds with metals.
(C) Like halogens, hydrogen is liberated at cathode.
(D) The ionisation energy of hydrogen is quite close to halogens.

Q.3 Hydrogen resembles –

(A) Alkali metals only
(B) Halogen only
(C) Both alkali metals and halogens
(D) Neither alkali metals nor halogens

Q.4 Hydrogen accepts an electron to form inert gas configuration. In this it resembles

(A) Halogen (B) Alkali metals
(C) Chalcogens (D) Alkaline earth metals

PART - 2 : OCCURRENCE AND ISOTOPES OF HYDROGEN

Q.5 Which of the following is not an isotope of hydrogen?

(A) Protium (B) Deuterium
(C) Tritium (D) Ortho- para hydrogen

Q.6 A deuterium is –

(A) an electron with a positive charge.
(B) a nucleus having two protons.
(C) a nucleus containing a neutron and two protons.
(D) a nucleus containing a neutron and a proton.

PART - 3 : PREPARATION OF DIHYDROGEN

Q.7 Syngas is a mixture of

(A) $CO_2 + H_2$ (B) $CO + H_2$
(C) $CO + CO_2$ (D) $CO + O_2$

Q.8 Which of the following reactions increases production of dihydrogen from synthesis gas?

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

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

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

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

Q.9 Which of the following metals does not liberate hydrogen from acids?

(A) Fe (B) Cu
(C) Mg (D) Zn

Q.10 Which of the following is laboratory preparation of dihydrogen?

(A) $3Fe + 4H_2O\,(steam) \rightarrow Fe_3O_4 + 4H_2$
(B) $2Na + 2H_2O \rightarrow 2NaOH + H_2$
(C) $CaH_2 + 2H_2O \rightarrow Ca(OH)_2 + 2H_2$
(D) $Zn + H_2SO_4\,(dil.) \rightarrow ZnSO_4 + H_2$

PART - 4 : PROPERTIES AND USES OF DIHYDROGEN

Q.11 Alkenes combine with carbon monoxide and hydrogen in presence of octacarbonyldicobalt as catalyst under high temperature and pressure to form –

(A) aldehydes which can be further reduced to alcohols by hydrogen.
(B) alkanes which are formed by addition of hydrogen.
(C) alcohols formed by reaction of CO and hydrogen.
(D) ketones which can be further reduced to aldehydes by hydrogen.

Q.12 Which of the following metals directly combine with hydrogen gas to give a hydride?

(A) Au (B) Ni
(C) Ca (D) Cu

Q.13 Which of the following reactions of hydrogen with non-metals represents Haber's process?

(A) $2H_2 + O_2 \xrightarrow{Heat} 2H_2O; \Delta H = -285.9\ kJ\ mol^{-1}$

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

(C) $H_2 + Cl_2 \xrightarrow{hv} 2HCl$

(D) $2H_2 + C \xrightarrow{1100°C} CH_4$

PART - 5 : HYDRIDES

Q.14 Which of the following statements regarding hydrides is not correct?

(A) Ionic hydrides are crystalline, non–volatile and non-conducting if solid state.
(B) Electron-deficient hydrides act as Lewis acids or electron acceptors.
(C) Elements of group-13 form electron deficient hydrides.
(D) Elements of group 15-17 form electron-precise hydrides.

Q.15 Which of the following hydrides is electron-precise hydride?
(A) B_2H_6 (B) NH_3
(C) H_2O (D) CH_4

Q.16 Among the which is/are interstitial hydride ?
(A) LaH_3 (B) CaH_2
(C) Both (A) & (B) (D) HF

Q.17 Given below are the elements and the type of hydrides formed by them. Mark the incorrect match.
(A) Phosphorus–Molecular hydride
(B) Potassium–Ionic hydride
(C) Vanadium–Interstitial hydride
(D) Nitrogen–Electron–deficient covalent hydride

Q.18 Phosphorus cannot form PH_5 with its outer electronic configuration as $3s^2 . 3p^3$ because –
(A) Phosphorus cannot show +5 oxidation state
(B) PH_5 is not a stable compound.
(C) Δ_aH value of dihydrogen and $\Delta_{eg}H$ value of hydrogen do not favour higher oxidation state of phosphorus.
(D) Phosphorus is not very reactive hence does not form PH_5.

Q.19 Carbon hydrides of the type, C_nH_{2n+2} do not act as Lewis acid or Lewis base. They behave as normal covalent hydrides because
(A) carbon hydrides are electron-rich hydrides
(B) carbon hydrides are electron-deficient hydrides.
(C) carbon hydrides are electron-precise hydrides.
(D) carbon hydrides are non-stoichiometric hydrides.

PART - 6 : WATER

Q.20 Temporary hardness of water can be removed by
(A) Addition of potassium permagenate
(B) Boiling
(C) Filtration
(D) Addition of chlorine

Q.21 The formula for permutit or zeolite which is used as softener in ion-exchange method is –
(A) $NaAlSiO_4$ (B) $NaAlO_2$
(C) $Ca_3(PO_4)_2$ (D) Na_2SO_4

Q.22 The density of water is less in its solid state because –
(A) in solid state (ice), water molecules are arranged in highly ordered open cage like structure.
(B) more extensive hydrogen bonding is present in solid state ice.
(C) the water molecules are closest in solid state of water.
(D) water is a rigid crystalline, closely packed structure in its solid state.

Q.23 Liquid water is denser than ice due to
(A) higher surface tension (B) hydrogen bonding
(C) van der Waals forces (D) covalent bonding.

Q.24 When two ice cubes are pressed over each other, they unite to form one cube. Which of the following forces is responsible to hold them together
(A) Hydrogen bond formation (B) Van der Waals forces
(C) Covalent attraction (D) Ionic interaction

Q.25 A water sample is said to contain permanent hardness if water contains –
(A) sulphates and chlorides of Ca and Mg.
(B) carbonates of Ca and Mg.
(C) bicarbonates of Ca and Mg.
(D) sulphates and chlorides of Na and K.

Q.26 Triple point of water is
(A) 273 K (B) 373 K
(C) 203 K (D) 193 K

Q.27 The H – O – H angle in water molecule is about
(A) 90° (B) 180°
(C) 102° (D) 105°

Q.28 Which of the following represents calgon?
(A) $Na_2Al_2Si_2O_8$ (B) $Mg_3(PO_4)_2$
(C) $Na_2[Na_4(PO_3)_6]$ (D) $Na_2[Mg_2(PO_3)_6]$

Q.29 During hydrate formation from aqueous solution, water can be associated in different forms. Indicate the correct combination.
(A) Coordinated water – $[Cr(H_2O)_6]^{3+} 3Cl^-$
(B) Interstitial water – $BaCl_2 \cdot 2H_2O$
(C) Hydrogen bonded water$[Cu(H_2O)_4]^{2+}SO_4^{2-}. H_2O$
(D) All of these

PART - 7 : HYDROGEN PEROXIDE

Q.30 Which is true regarding the structure and hybridisation of hydrogen peroxide ?
(A) Planar structure, sp^2
(B) Planar structure, sp^3
(C) Non-planar structure, sp^3
(D) Non-planar structure, sp^2

Q.31 Which of the following act as a stabiliser for the storage of H_2O_2?
(A) Alkali (B) Dust
(C) Urea (D) None of these

Q.32 Hydrogen peroxide solution can be concentrated by –
(A) Cooling
(B) Evaporation on water baths
(C) Dehydration in vacuum desicator
(D) All of these

Q.33 The oxide that gives H_2O_2 on treatment with dilute H_2SO_4 is
(A) PbO_2 (B) $BaO_2.8H_2O$
(C) MnO_2 (D) TiO_2

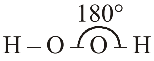
Q.34 30% solution of H_2O_2 is equal to –
(A) 30 volume H_2O_2 (B) 100 volume H_2O_2
(C) 3 volume H_2O_2 (D) 300 volume H_2O_2

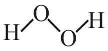
Q.35 Which the following represents the chemical equation involved in the preparation of H_2O_2 from barium peroxide?
(A) $BaO_2 \cdot 8H_2O + H_2SO_4 \rightarrow BaSO_4 + H_2O_2 + 8H_2O$
(B) $CH_3CHOHCH_3 + O_2 \rightarrow CH_3COCH_3 + H_2O_2$
(C) $BaO_2 + CO_2 + H_2O \rightarrow BaCO_3 + H_2O_2$
(D) $Ba_3(PO_4)_2 + 3H_2SO_4 \rightarrow 3BaSO_4 + 2H_3PO_4$

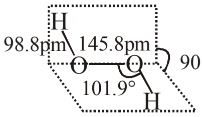
Q.36 HCl is added to the following oxides which one would give H_2O_2
(A) MnO_2 (B) PbO_2
(C) BaO_2 (D) None

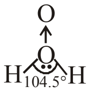
Q.37 The oxide that gives hydrogen peroxide (H_2O_2) on the treatment with a dilute acid (H_2SO_4) is
(A) MnO_2 (B) PbO_2
(C) Na_2O_2 (D) TiO_2

Q.38 Which of the following is a true structure of H_2O_2 in solid phase?

(A) 

(B) 

(C) 

(D) 

Q.39 In lab H_2O_2 is prepared by –
(A) Cold H_2SO_4 and BaO_2 (B) HCl and BaO_2
(C) Conc. H_2SO_4 and Na_2O_2 (D) $H_2 + O_2$

Q.40 H_2O_2 is
(A) Poor polar solvent than water.
(B) Better polar solvent than H_2O.
(C) Both have equal polarity.
(D) Better polar solvent but its strong auto oxidising ability limits its use as such.

Q.41 H_2O_2 used in rockets has the concentration
(A) 50% (B) 70%
(C) 30% (D) 90%

Q.42 Which of the following easily catalyse the decomposition of H_2O_2 when stored?
(i) Rough surface (ii) Sunlight
(iii) Dust particles (iv) Metals
(A) (i) and (ii) (B) (i), (ii) and (iii)
(C) (ii) and (iii) (D) All of these

Q.43 H_2O_2 is a
(A) Weak acid (B) Weak base
(C) Neutral (D) None of these

Q.44 Which of the following cannot be used as a test for H_2O_2?
(A) A paper dipped in PbS (black) turns white when brought in contact with H_2O_2.
(B) It liberates iodine from KI solution which gives blue colour with starch solution.
(C) It gives blue colour with $K_4[Fe(CN)_6]$.
(D) It decolourises acidified $KMnO_4$ solution.

PART - 8 : HEAVY WATER

Q.45 Heavy water is used in nuclear reactor as –
(A) Fuel (B) Coolant
(C) Neutron moderator (D) Both (B) and (C)

Q.46 What is heavy water?
(A) H_2O^{18} (B) D_2O
(C) H_2O^{17} (D) H_2O

Q.47 Heavy water freezes at
(A) 0°C (B) 3.8°C
(C) 38°C (D) – 0.38°C

Q.48 Molecular weight of heavy water is
(A) 19 (B) 18
(C) 17 (D) 20

Q.49 Which of the following reactions is not used in preparation of deuterium compounds using heavy water
(A) $CaC_2 + 2D_2O \rightarrow C_2D_2 + Ca(OD)_2$
(B) $SO_3 + D_2O \rightarrow D_2SO_4$
(C) $2AlN + 3D_2O \rightarrow Al_2O_3 + 2ND$
(D) $Al_4C_3 + 12D_2O \rightarrow 3CD_4 + 4Al(OD)_3$

PART - 9 : ALKALI METALS

Q.50 Which of the following statement is correct regarding alkali metals –
(A) Cation is less stable than the atom
(B) Cation is smaller than the atom
(C) Size of cation and atom is the same
(D) Cation is greater in size than the atom

Q.51 Valency electrons in alkali metals are
(A) 1 (B) 7
(C) 4 (D) 2

Q.52 Arrange the following elements in the order of the increasing electropositive character.
Li, Na, K, Rb, Cs
(A) Li > Na > K> Rb > Cs (B) Li < Na < K < Rb < Cs
(C) Li > Na < K < Rb < Cs (D) Na> Li > K< Rb < Cs

Q.53 The word 'alkali' is used for alkali metals indicates
(A) Ash of the plants (B) Metallic nature
(C) Silvery lusture (D) Active metal

Q.54 Which of the properties is not true for an alkali metal –
(A) Low atomic volume (B) Low ionization energy
(C) Low density (D) Low electronegativity

Q.55 Which of the following alkali metal ions has lowest ionic mobility in aqueous solution
(A) Rb^+ (B) Cs^+
(C) Li^+ (D) Na^+

Q.56 The metal which reacts with water at room temperature is
(A) Copper (B) Iron
(C) Magnesium (D) Sodium

Q.57 Potassium is kept in
(A) Alcohol (B) Water
(C) Kerosene (D) Liquid ammonia

Q.58 Which of the following alkali metals when burnt in air forms a mixture of oxide as well as nitride?
(A) K (B) Na
(C) Li (D) Cs

Q.59 Which of the following reacts with water with high rate
(A) Li (B) K
(C) Na (D) Rb

Q.60 When sodium is dropped in small amount of water it catches fire. Which one of the following burns in the process?
(A) Na (B) H_2O
(C) H_2 (D) NaOH

Q.61 The reaction of water with sodium and potassium is –
(A) Exothermic
(B) Endothermic
(C) Reversible
(D) Irreversible & endothermic

PART - 10 : COMPOUNDS OF ALKALI METAL

Q.62 Which is most basic in character
(A) RbOH (B) KOH
(C) NaOH (D) LiOH

Q.63 Which of the following has lowest thermal stability?
(A) Li_2CO_3 (B) Na_2CO_3
(C) K_2CO_3 (D) Rb_2CO_3

Q.64 Choose the correct statement –
(A) The alkali metal halides are all high melting, colourless crystalline solids.
(B) The alkali metals form salts with oxo-acids.
(C) Both (A) and (B)
(D) None of these

Q.65 If Na is heated in presence of air, it forms –
(A) Na_2CO_3 (B) Na_2O_2
(C) Na_2O (D) Both (B) and (C)

Q.66 Which of the following statements is not true about alkali metals?
(A) All alkali metals form oxo salts such as carbonates, sulphates and nitrates.
(B) The basic character of oxides increases down the group.
(C) Carbonates and sulphates of lithium are stable and their stability decreases down the group.
(D) Solubility of carbonates and sulphates increases down the group.

Q.67 Choose the correct statement –
(A) On combustion in excess of air potassium forms the superoxides.
(B) The oxides and the peroxides of alkali metals are colourless when pure, but the superoxides are yellow or orange in colour.
(C) Both (A) and (B)
(D) None of these

Q.68 Choose the correct statement about halides of alkali metal.
(A) Halides are soluble in water.
(B) The melting and boiling points follow the order : fluoride>chloride>bromide > iodide.
(C) Halides of lithium are soluble in ethanol, acetone and ethylacetate; LiCl is soluble in pyridine.
(D) All of these

PART - 11 : ANOMALOUS PROPERTIES OF LITHIUM

Q.69 As compared to lithium, sodium reacts quickly with water because –
(A) Its molecular weight is less
(B) It is stronger electronegative
(C) It is stronger electropositive
(D) It is a metal

Q.70 The properties of lithium are similar to those of Mg. This is because
(A) both have nearly the same size.
(B) the ratio of their charge to size is nearly the same.
(C) both have similar electronic configurations.
(D) both are found together in nature.

Q.71 In certain matters lithium differs from other alkali metals, the main reason for this is
(A) Small size of Li atom and Li^+ ion
(B) Extremely high electropositivity of Li
(C) Greater hardness of Li
(D) Hydration of Li^+ ion

Q.72 Choose the correct statement.
(A) Lithium is least reactive but the strongest reducing agent among all the alkali metals.
(B) LiCl is deliquescent and crystallises as a hydrate.
(C) Lithium unlike other alkali metals forms no ethynide on reaction with ethyne.
(D) All of these

Q.73 Choose the INCORRECT statement.
(A) LiCl and $MgCl_2$ are soluble in ethanol.
(B) Lithium and magnesium react fastly with water.
(C) The carbonates of lithium and magnesium decompose easily on heating
(D) All of these

PART - 12 : COMPOUNDS OF SODIUM

Q.74 Baking soda is
(A) $NaHCO_3$ (B) $NaHCO_3{\cdot}6H_2O$
(C) Na_2CO_3 (D) $Na_2CO_3{\cdot}10H_2O$

Q.75 What are the raw materials used in Solvay's process?
(A) NaCl, NH_3, $CaCO_3$
(B) NaOH, CO_2
(C) NaCl, $CaCO_3$, C, H_2SO_4
(D) NH_3, H_2O, NaCl

Q.76 The formula of soda ash is
(A) $Na_2CO_3{\cdot}10H_2O$ (B) $Na_2CO_3{\cdot}2H_2O$
(C) $Na_2CO_3{\cdot}H_2O$ (D) Na_2CO_3

Q.77 When washing soda is heated
(A) CO is released
(B) CO + CO_2 is released
(C) CO_2 is released
(D) water vapour is released.

Q.78 Which of the following statements is not correct regarding preparation of NaOH?
(A) NaOH is prepared by electrolysis of sodium chloride in Castner-Kellner cell.
(B) Sodium metal discharged at cathode combines with mercury to form sodium amalgam.
(C) Chlorine is evolved at anode.
(D) Amalgam is heated to separate Na and Hg.

PART - 13 : BIOLOGICAL IMPORTANCE OF SODIUM AND POTASSIUM

Q.79 What is the biological importance of Na^+ and K^+ ions in cell fluids like blood plasma?
(A) They participate in transmission of nerve signals.
(B) They regulate the number of red and white blood corpuscles in the cell.
(C) They can be present in any amount in the blood since they are absorbed by the cells.
(D) They regulate the viscosity and colour of the blood.

Q.80 Choose the correct statement for human beings
(A) Quantity of Na is more than K.
(B) Quantity of K is more than Na.
(C) Sodium ions participate in the transport of sugars and amino acids into cells.
(D) Both (B) and (C)

Q.81 Choose the correct statement –
(A) Potassium ions are the most abundant cations within cell fluids, where they activate many enzymes, participate in the oxidation of glucose to produce ATP
(B) Sodium ions are found primarily on the outside of cells.
(C) Both (A) and (B)
(D) None of these

PART - 14 : ALKALINE EARTH METALS

Q.82 Which of the following alkaline earth metals shows some properties similar to aluminium
(A) Be (B) Ca
(C) Sr (D) Ba

Q.83 Which among the following is kinetically inert towards water?
(A) Na (B) Be
(C) Ca (D) K

Q.84 In the Alkaline earth metals, the element forming predominantly covalent compound is
(A) Be (B) Mg
(C) Sr (D) Ca

Q.85 When alkaline earth metals dissolve in ammonia, they form coloured solution like alkali metals. Which of the following observations regarding the reaction are correct?
(i) Dilute solutions are bright blue in colour due to solvated electrons.
(ii) These solutions decompose to form amides and hydrogen.
(iii) From this solution the ammoniates $[M(NH_3)_6]^{2+}$ can be recovered by evaporation.
(A) (i) and (ii) (B) (i), (ii) and (iii)
(C) (ii) and (iii) (D) Only (i)

PART - 15 : COMPOUNDS OF ALKALINE EARTH METALS

Q.86 The right order of the solubility of sulphates of alkaline earth metals in water is
(A) Be > Ca > Mg > Ba > Sr (B) Mg > Be > Ba > Ca > Sr
(C) Be > Mg > Ca > Sr > Ba (D) Mg > Ca > Ba > Be > Sr

Q.87 Some of the Group 2 metal halides are covalent and soluble in organic solvents. Among the following metal halides, the one which is soluble in ethanol is –
(A) $BeCl_2$ (B) $MgCl_2$
(C) $CaCl_2$ (D) $SrCl_2$

Q.88 Choose the correct statement –
(A) The alkaline earth metal hydroxides are less basic and less stable than alkali metal hydroxides.
(B) The fluorides are relatively less soluble than the chlorides.
(C) Both (A) and (B)
(D) None of these

Q.89 The increasing order of basic character of oxides MgO, SrO, K_2O, and Cs_2O is –
(A) $MgO < SrO < K_2O < Cs_2O$
(B) $SrO < MgO < Cs_2O < K_2O$
(C) $Cs_2O < K_2O < SrO < MgO$
(D) $K_2O < Cs_2O < SrO < MgO$

Q.90 Which of the following hydroxide is insoluble in water
(A) $Be(OH)_2$ (B) $Mg(OH)_2$
(C) $Ca(OH)_2$ (D) $Ba(OH)_2$

Q.91 Which of the following compounds are not arranged in correct order as indicated?
(A) $SrCl_2 < CaCl_2 < MgCl_2 < BeCl_2$ (increasing order of hydrolysis)
(B) $SrCl_2 < CaCl_2 < MgCl_2 < BeCl_2$ (increasing lattice energy)
(C) $CaSO_4 < MgSO_4 < BeSO_4$ (increasing stability)
(D) $Be(OH)_2 < Mg(OH)_2 < Ca(OH)_2$ (increasing solubility)

Q.92 Metals form basic hydroxides. Which of the following metal hydroxide is the least basic?
(A) $Mg(OH)_2$ (B) $Ca(OH)_2$
(C) $Sr(OH)_2$ (D) $Ba(OH)_2$

Q.93 $Be(OH)_2$ is insoluble in water while $Ba(OH)_2$ is highly soluble due to
(A) Bond order (B) Lattice energy difference
(C) Common ion effect (D) Hard acid

Q.94 Sulphates of Be and Mg are readily soluble in water but sulphates of Ca, Sr and Ba are insoluble. This is due to the fact
(A) the greater hydration enthalpies of Be^{2+} and Mg^{2+} overcome the lattice enthalpy.
(B) high lattice enthalpy of Be^{2+} and Mg^{2+} makes them soluble in water.
(C) solubility decreases from $BeSO_4$ to $BaSO_4$ due to increase in ionic size.
(D) $BeSO_4$ and $MgSO_4$ are ionic in nature while other sulphates are covalent.

PART - 16 : ANOMALOUS BEHAVIOUR OF BERYLLIUM

Q.95 Beryllium differs from rest of the members of its family (Group-2) in many ways. The reason for this is its
(A) Small size and higher electronegativity
(B) Small size and lower electronegativity
(C) Large size and lower ionisation energy
(D) Large size and largest ionic radius

Q.96 Beryllium shows diagonal relationship with aluminium. Which of the following similarity is incorrect?
(A) Be_2C like Al_4C_3 yields methane on hydrolysis.
(B) Be like Al is rendered passive by HNO_3.
(C) $Be(OH)_2$ like $Al(OH)_3$ is basic.
(D) Be forms beryllates and Al forms aluminates.

Q.97 Choose the correct statement –
(A) Beryllium forms compounds which are largely covalent and get easily hydrolysed.
(B) The oxide and hydroxide of beryllium are amphoteric in nature.
(C) Both (A) and (B)
(D) None of these

PART - 17 : COMPOUNDS OF CALCIUM

Q.98 Setting of plaster of paris is
(A) Oxidation with atmospheric oxygen
(B) Combination with atmospheric CO_2
(C) Dehydration
(D) Hydration to yield another hydrate

Q.99 The average composition of portland cement is
(A) CaO : 40-50%, SiO_2 : 30-40%, Al_2O_3, Fe_2O_3 : 10-20%
(B) CaO : 50-60%, SiO_2 : 20-25%, Al_2O_3 : 5-10%, MgO : 2-3%, Fe_2O_3 : 1-2% and SO_3 : 1-2%
(C) SiO_2 : 40-50%, CaO : 30-40%, Al_2O_3 : 10-20%
(D) CaO : 50%, SiO_2 : 50%

Q.100 Bleaching powder is obtained by the interaction of chlorine and –
(A) Conc. solution of $Ca(OH)_2$
(B) Dil. solution of $Ca(OH)_2$
(C) Dry calcium oxide
(D) Dry slaked lime

Q.101 Plaster of paris hardens by
(A) Giving off CO_2 (B) Changing into $CaCO_3$
(C) Uniting with water (D) Giving out water

Q.102 Which of the following statements is true about $Ca(OH)_2$?
(A) It is used in the preparation of bleaching powder.
(B) It is a light blue solid.
(C) It does not possess disinfectant property.
(D) It is used in the manufacture of cement.

Q.103 When plaster of Paris comes in contact with water it sets into a hard mass. The composition of the hard mass is –
(A) $CaSO_4 \cdot H_2O$ (B) $CaSO_4 \cdot Ca(OH)_2$
(C) $CaSO_4 \cdot 2H_2O$ (D) $CaSO_4 \cdot 2Ca(OH)_2$

Q.104 Plaster of paris is used –
(A) In surgery and dentistry
(B) As a white wash
(C) As a constituent of tooth paste
(D) For the preparation of RCC

Q.105 Which is quick lime
(A) $Ca(OH)_2$ (B) CaO
(C) $CaCO_3$ (D) $Ca(OH)_2 + H_2O$

PART - 18 : BIOLOGICAL IMPORTANCE OF MAGNESIUM AND CALCIUM

Q.106 Which of the following metals is required as cofactor all enzymes utilising ATP in phosphate transfer?
(A) K (B) Ca
(C) Na (D) Mg

Q.107 Choose the correct statement –
(A) An adult body contains more Ca as compared to Mg.
(B) Chlorophyll contains magnesium
(C) 99 % of body calcium is present in bones and teeth.
(D) All of these

Q.108 Choose the correct statement –
(A) Magnesium plays important roles in neuromuscular function, interneuronal transmission, cell membrane integrity and blood coagulation.
(B) The calcium concentration in plasma is regulated by calcitonin and parathyroid hormones.
(C) Both (A) and (B)
(D) None of these

EXERCISE - 2 [LEVEL-2]

Choose one correct response for each question.

PART - A [HYDROGEN]

Q.1 Hydrogen molecule differs from chlorine molecule in the following respect
(A) Hydrogen molecule is non-polar but chlorine molecule is polar.
(B) Hydrogen molecule is polar while chlorine molecule is non-polar.
(C) Hydrogen molecule can form intermolecular hydrogen bonds but chlorine molecule does not.
(D) Hydrogen molecule cannot participate in coordination bond formation but chlorine molecule can.

Q.2 Tritium undergoes radioactive decay giving –
(A) α-particles (B) β-particles
(C) Neutrons (D) γ-rays

Q.3 The gas used in the hydrogenation of vegetable oils in the presence of nickel as catalyst is –
(A) Methane (B) Ethane
(C) Ozone (D) Hydrogen

Q.4 Triatomic hydrogen is called –
(A) Deuterium (B) Hyzone
(C) Ortho form (D) Hydronium ion

Q.5 Which is the lightest gas
(A) Nitrogen (B) Helium
(C) Oxygen (D) Hydrogen

Q.6 Which of the following will not displace hydrogen
(A) Ba (B) Pb
(C) Hg (D) Sn

Q.7 Which of the following gas is insoluble in water
(A) SO_2 (B) NH_3
(C) H_2 (D) CO_2

Q.8 Which of the following pair of ions makes the water hard
(A) Na^+, SO_4^{2-} (B) K^+, HCO_3^-
(C) Ca^{2+}, NO_3^- (D) NH_4^+, Cl^-

Q.9 The pH of D_2O and H_2O at 298 K is
(A) 7.0, 7.0 (B) 7.35, 7.0
(C) 7.0, 6.85 (D) 6.85, 7.35

Q.10 Which of the following will cause softening of hard water
(A) Passing it through cation exchange resin
(B) Passing it through anion exchange resin
(C) Passing it through sand
(D) Passing it through alumina

Q.11 The alum used for purifying water is –
(A) Ferric alum (B) Chrome alum
(C) Potash alum (D) Ammonium alum

Q.12 What is the product of the reaction of H_2O_2 with Cl_2
(A) $O_2 + HCl$ (B) $HCl + O_2$
(C) $H_2O + HCl$ (D) $HCl + H_2$

Q.13 The volume strength of 1.5 N H_2O_2 solution is
(A) 8.4 litres (B) 4.2 litres
(C) 16.8 litres (D) 5.2 litres

Q.14 From group 6 only one metal forms hydride. This metal is –
(A) Mo (B) W
(C) Cr (D) Co

Q.15 Why does H^+ ion always get associated with other atoms or molecules?
(A) Ionisation enthalpy of hydrogen resembles that of alkali metals.
(B) Its reactivity is similar to halogens.
(C) It resembles both alkali metals and halogens.
(D) Loss of an electron from hydrogen atom results in a nucleus of very small size as compared to other atoms or ions. Due to small size it cannot exist free.

Q.16 In which of the following reactions H_2O acts as a Bronsted acid?
(A) $H_2O(\ell) + NH_3(aq) \rightleftharpoons OH^-(aq) + NH_4^+(aq)$
(B) $H_2O(\ell) + H_2S(aq) \rightleftharpoons H_3O^+(aq) + HS^-(aq)$
(C) $H_2O(\ell) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$
(D) $H^+(aq) + OH^-(aq) \rightleftharpoons H_2O(\ell)$

Q.17 When CO_2 is bubbled through a solution of barium peroxide in water –
(A) carbonic acid is formed.
(B) H_2O_2 is formed
(C) H_2O is formed
(D) barium hydroxide is formed.

Q.18 In what respect electronic configuration of hydrogen and halogens are similar?
(A) Hydrogen and halogens have one electron in their outermost shell.
(B) Hydrogen and halogens have one electron less than the noble gas configuration.
(C) Hydrogen and halogens can lose one electron to form positive ions.
(D) Hydrogen & halogens show noble gas configuration.

Q.19 Heavy water is obtained by
(A) boiling water
(B) heating H_2O_2
(C) prolonged electrolysis of H_2O
(D) All of these.

Q.20 Hydrogen peroxide is –
(A) an oxidising agent
(B) a reducing agent
(C) both an oxidising and a reducing agent
(D) neither oxidising nor reducing agent

Q.21 Water plays a key role in the biosphere. It is due to certain properties of H_2O as compared to other liquids. These are except
(A) higher specific heat
(B) lesser thermal conductivity
(C) high dielectric constant
(D) high surface tension.

Q.22 Given below are two reactions of water with sodium and carbon dioxide. What is the nature of water in these reactions?
(i) $2Na + 2H_2O \rightarrow 2NaOH + H_2$
(ii) $6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$
(A) In (ii) water acts as an oxidising agent and in (i) it acts as a reducing agent.
(B) In (i) water acts as an oxidising agent–while in (ii) it acts as a reducing agent.
(C) In both, (i) and (ii) hydrogen acts as a reducing agent.
(D) In both, (i) and (ii) hydrogen acts as an oxidising agent.

Q.23 When sodium peroxide is treated with dilute sulphuric acid, we get –
(A) sodium sulphate and water
(B) sodium sulphate and oxygen
(C) sodium sulphate, hydrogen and oxygen
(D) sodium sulphate and hydrogen peroxide

Q.24 What will be the strength of 20 vol of H_2O_2 in terms of gram per litre?
(A) 60.71 g L^{-1} (B) 5.6 g L^{-1}
(C) 30.62 g L^{-1} (D) 17 g L^{-1}

PART - B [s-BLOCK ELEMENTS]

Q.1 Which of the statement about LiCl and NaCl is correct
(A) LiCl has higher melting point than NaCl.
(B) LiCl dissolves in water whereas NaCl does not.
(C) LiCl would ionize in water more than NaCl
(D) Fused LiCl would be less conducting than fused NaCl.

Q.2 In the Castner's process for the extraction of sodium, the anode is made of.......metal.
(A) Copper (B) Iron
(C) Sodium (D) Nickel

Q.3 A substance X is a compound of an element of group 1 the substance X gives a violet colour in flame test, X is
(A) LiCl (B) NaCl
(C) KCl (D) None

Q.4 Which of the following is a false statement
(A) Fluorine is more electronegative than chlorine.
(B) Nitrogen has greater IE_1 than oxygen.
(C) Lithium is amphoteric.
(D) Chlorine is an oxidising agent.

Q.5 Sodium when heated in a current of dry ammonia gives
(A) Sodium nitrite (B) Sodium hydride
(C) Sodium amide (D) Sodium azide

Q.6 Soda lime is
(A) NaOH (B) CaO
(C) NaOH & CaO (D) Na_2CO_3

Q.7 Alkali metals are-
(A) Diamagnetic and coloured.
(B) Diamagnetic and colourless.
(C) Paramagnetic and coloured.
(D) Paramagnetic and colourless

Q.8 Which one of the following salts gives aqueous solution which is weakly basic
(A) $NaHCO_3$ (B) $NaHSO_4$
(C) NaCl (D) NH_4HCO_3

Q.9 The compounds of Ca are-
(A) Paramagnetic and colourless.
(B) Paramagnetic and coloured.
(C) Diamagnetic and coloured, provided their anions are also coloured.
(D) Diamagnetic and colourless, provided their anions are also colourless.

Q.10 Calcium is obtained by
(A) Roasting of lime stone
(B) Reduction of $CaCl_2$ with carbon
(C) Electrolysis of a solution of $CaCl_2$ in water
(D) Electrolysis of molten $CaCl_2$

Q.11 In the lime (kiln), the reaction
$CaCO_3\ (s) \rightarrow CO_2\ (g)$ goes to completion because
(A) Of high temperature
(B) CaO is more stable than $CaCO_3$
(C) CO_2 escapes simultaneously
(D) CaO is not dissociated

Q.12 Among alkaline earth metal, the element rarest of all ?
(A) Be (B) Sr
(C) Ra (D) Both (A) and (C)

Q.13 By adding gypsum to cement
(A) setting time of cement becomes less.
(B) setting time of cement increases.
(C) colour of cement becomes light.
(D) shining surface is obtained.

Q.14 Beryllium shows diagonal relationship with –
(A) Li (B) Mg
(C) Na (D) Al

Q.15 The following compounds have been arranged in order of their increasing thermal stabilities. Identify the correct order. K_2CO_3 (I), $MgCO_3$ (II), $CaCO_3$ (III), $BeCO_3$ (IV)
(A) I < II < III < IV (B) IV < II < III < I
(C) IV < II < I < III (D) II < IV < III < I

Q.16 Choose the correct statement (s) for the solutions of alkali metals and alkaline earth metals in ammonia (l) ?
(A) Concentrated solutions of alkali metals in ammonia are copper-bronzed coloured and have a metallic lusture.
(B) Dilute solutions of alkaline earth metals are deep bule-black in colour due to the spectrum from the solvated electron.
(C) Concentrated solutions of the alkaline earth metals in ammonia are bronze coloured.
(D) All of these

Q.17 The reason for the lower basicity of alkaline earth metals than alkali metals is.
(A) Alkali metals form ionic compounds
(B) The bond of oxygen is more for alkali metals
(C) The electropositivity of alkali metals is more than alkaline earth metals
(D) The electropositivity of alkali metals is less than alkaline earth metals

Q.18 Select the correct statements :
(I) Cs^+ is more highly hydrated than the other alkali metal ions
(II) Among the alkali metals Li, Na, K and Rb, lithium has the highest melting point
(III) Among the alkali metals only lithium forms a stable nitride by direct combination with nitrogen.
(A) I, II and III (B) I and II
(C) I and III (D) II and III

Q.19 Some of the Group 2 metal halides are covalent and soluble in organic solvents. Among the following metal halides, the one which is soluble in ethanol is
(A) $BeCl_2$ (B) $MgCl_2$
(C) $CaCl_2$ (D) $SrCl_2$

Q.20 Amphoteric hydroxides react with both alkalies and acids. Which of the following Group 2 metal hydroxides is soluble in sodium hydroxide?
(A) $Be(OH)_2$ (B) $Mg(OH)_2$
(C) $Ca(OH)_2$ (D) $Ba(OH)_2$

Q.21 The solubility of alkali metal salts in water is due to the fact that the cations get hydrated by water molecules. The degree of hydration depends upon the size of the cation. If the trend of relative ionic radii is

$Cs^+ > Rb^+ > K^+ > Na^+ > Li^+$.

What is the relative degree of hydration?

(A) $Cs^+ (aq) > Rb^+ (aq) > K^+ (aq) > Na^+ (aq) > Li^+ (aq)$
(B) $Li^+ (aq) > Na^+ (aq) > K^+ (aq) > Rb^+ (aq) > Cs^+ (aq)$
(C) $Na^+ (aq) > K^+ (aq) > Rb^+ (aq) > Cs^+ (aq) > Li^+ (aq)$
(D) $Cs^+ (aq) > Na^+ (aq) > Li^+ (aq) > K^+ (aq) > Rb^+ (aq)$

Q.22 Which of the following materials conducts electricity?
(A) Crystalline potassium chloride
(B) Fused sulphates
(C) Molten sodium chloride
(D) Diamond

Q.23 Alkali metals react with water vigorously to form hydroxides and dihydrogen. Which of the following alkali metals reacts with water least vigorously?
(A) Li (B) Na
(C) K (D) Cs

Q.24 The right order of the solubility of sulphates of alkaline earth metals in water is
(A) $Be > Ca > Mg > Ba > Sr$
(B) $Mg > Be > Ba > Ca > Sr$
(C) $Be > Mg > Ca > Sr > Ba$
(D) $Mg > Ca > Ba > Be > Sr$

Q.25 What happens when H_2 is passed over lithium at 1073K?
(A) Covalent lithium hydride is formed.
(B) Coloured complex is formed.
(C) Ionic lithium hydride is formed.
(D) No reaction takes place.

EXERCISE - 3 (NUMERICAL VALUE BASED QUESTIONS)

NOTE : The answer to each question is a NUMERICAL VALUE.

Q.1 In 100 ml sample of hard water, 100 ml of (N/50) Na_2CO_3 was added and the mixture was boiled and filtered. The filtrate was neutralized with 60 ml of (N/50) HCl. Calculate the permanent hardness of water (in ppm).
(sp. gr. of hard water = 1).

Q.2 Number of crystal water in Gypsum, Plaster of Paris and Epsom salt respectively are X, Y, Z. Find the value of (X + 2Y + Z).

Q.3 If α, β and γ in the following equation are X, Y, Z.

$\alpha K_4 [Fe(CN)_6] + \beta K_2CO_3 + \gamma S \xrightarrow{heat}$ Products.

The products are Fe, CO_2, KCNO and KSCN. Find the value of (X + Y + Z).

Q.4 Strength of a sample of 10 volume of hydrogen peroxide solution is X%. Find the nearest integer value of X.

Q.5 The volume strength of 1.5N H_2O_2 solution is X litres. Find the value of (10X).

Q.6 The strength in volumes of a solution containing 30.36 g/litres of H_2O_2 is –

Q.7 The total number of dirpotic acids among the following is : H_3PO_4 H_2SO_4 H_3PO_3 H_2CO_3 $H_2S_2O_7$ H_3BO_3 H_3PO_2 H_2CrO_4 H_2SO_3

Q.8 Number of correct order in the given statements :
(i) Order of increasing electrical conductance :
$BeH_2 < CaH_2 < TiH_2$
(ii) Order of increasing ionic character :
$NaH < LiH < CsH$
(iii) Order of increasing bond dissociation enthalpy :
$F-F < H-H < D-D$
(iv) Order of increasing reducing property :
$NaH < MgH_2 < H_2O$

Q.9 Find the oxidation state of sodium in Na_2O_2.

Q.10 Number of correct statements are –
(i) BeO is insoluble but $BeSO_4$ is soluble in water.
(ii) BaO is insoluble but $BaSO_4$ is soluble in water.
(iii) LiI is more soluble than KI
(iv) $NaHCO_3$ is known in solid state but $Ca(HCO_3)_2$ is not isolated in solid state.

EXERCISE - 4 [PREVIOUS YEARS AIEEE / JEE MAIN QUESTIONS]

Q.1 A metal M readily forms its sulphate MSO_4 which is water soluble. It forms oxide MO which becomes inert on heating. It forms insoluble hydroxide which is soluble in NaOH. The metal M is - **[AIEEE 2002]**

(A) Mg (B) Ba
(C) Ca (D) Be

Q.2 KO_2 is used in space and submarines because it -

(A) Absorbs CO_2 and increase O_2 concentration
(B) Absorbs moisture **[AIEEE 2002]**
(C) Absorbs CO_2
(D) Produces ozone

Q.3 In current cement plasters, water is sprinkled from time to time. This helps in - **[AIEEE 2003]**

(A) Hydrating sand and gravel mixed with cement
(B) Converting sand into silicate
(C) Developing interlocking needle like crystals of hydrated silicates. (D) Keeping it cool

Q.4 The solubilities of carbonates decreases down the magnesium group due to decrease in - **[AIEEE 2003]**

(A) Inter-ionic attraction
(B) Entropy of solution formation
(C) Lattice energy of solids
(D) Hydration energy of cations

Q.5 The substance not likely to contain $CaCO_3$ is **[AIEEE-2003]**

(A) Sea shells (B) Dolomite
(C) A marble statue (D) Calcined gypsum

Q.6 Which of the following process will produce hard water

(A) Saturation of water with $CaCO_3$ **[AIEEE-2003]**
(B) Saturation of water with $MgCO_3$
(C) Saturation of water with $CaSO_4$
(D) Addition of Na_2CO_3 water

Q.7 The reagent commonly used to determine hardness of water titrimetrically is - **[AIEEE-2003]**

(A) Oxalic acid (B) Disodium salt of EDTA
(C) Sodium citrate (D) Sodium thiosulphate.

Q.8 One mole of magnesium nitride on reaction with excess of water gives - **[AIEEE-2004]**

(A) Two mole of HNO_3 (B) Two mole of NH_3
(C) 1 mole of NH_3 (D) 1 mole of HNO_3

Q.9 Beryllium and aluminium exhibit many properties which are similar. But the two elements differ in **[AIEEE-2004]**

(A) Exhibiting maximum covalency in compounds
(B) Forming polymeric hydrides
(C) Forming covalent halides
(D) Exhibiting amphoteric nature in their oxides

Q.10 The ionic mobility of alkali metal ions in aqueous solution is maximum for - **[AIEEE-2006]**

(A) Rb^+ (B) Li^+
(C) Na^+ (D) K^+

Q.11 Which one of the following is the correct statement ? **[AIEEE-2008]**

(A) Beryllium exhibits coordination number of six.
(B) Chlorides of both beryllium and aluminium have bridged chloride structures in solid phase.
(C) $B_2H_6.2NH_3$ is known as inorganic benzene.
(D) Boric acid is a protonic acid.

Q.12 In context with the industrial preparation of hydrogen from water gas ($CO+H_2$), which of the following is the correct statement? **[AIEEE-2008]**

(A) CO is removed by absorption in aqueous Cu_2Cl_2 solution.
(B) H_2 is removed through occlusion with Pd.
(C) CO is oxidized to CO_2 with steam in the presence of a catalyst followed by absorption of CO_2 in alkali.
(D) CO & H_2 are fractionally separated using differences in their densities.

Q.13 Three reactions involving $H_2PO_4^-$ are given below :

(i) $H_3PO_4 + H_2O \rightarrow H_3O^+ + H_2PO_4^-$
(ii) $H_2PO_4^- + H_2O \rightarrow HPO_4^{2-} + H_3O^+$
(iii) $H_2PO_4^- + OH^- \rightarrow H_3PO_4 + O^{2-}$

In which of the above does $H_2PO_4^-$ act as an acid ? **[AIEEE 2010]**

(A) (ii) only (B) (i) and (ii)
(C) (iii) only (D) (i) only

Q.14 Which of the following on thermal decomposition yields a basic as well as acidic oxide ? **[AIEEE 2012]**

(A) $NaNO_3$ (2) $KClO_3$
(C) $CaCO_3$ (4) NH_4NO_3

Q.15 Very pure hydrogen (99.9) can be made by which of the following processes ? **[AIEEE 2012]**

(A) Reaction of methane with steam.
(B) Mixing natural hydrocarbons of highmolecular weight.
(C) Electrolysis of water.
(D) Reaction of salts like hydrides with water.

Q.16 The metal that cannot be obtained by electrolysis of an aqueous solution of its salts is – **[JEE MAIN 2014]**

(A) Cu (B) Cr
(C) Ag (D) Ca

Q.17 From the following statement regarding H_2O_2, choose the incorrect statement **[JEE MAIN 2015]**

(A) It decomposes on exposure to light
(B) It has to be stored in plastic or wax lined glass bottles in dark.
(C) It has to be kept away from dust
(D) It can act only as an oxidizing agent

Q.18 Which one of the following alkaline earth metal sulphates has its hydration enthalpy greater than its lattice enthalpy? **[JEE MAIN 2015]**

(A) $BeSO_4$ (B) $BaSO_4$
(C) $SrSO_4$ (D) $CaSO_4$

Q.19 The molecular formula of a commercial resin used for exchanging ions in water softening is $C_8H_7SO_3Na$ (mol. wt. 206). What would be the maximum uptake of Ca^{2+} ions by the resin when expressed in mole per gram resin? **[JEE MAIN 2015]**

(A) 1/206 (B) 2/309
(C) 1/412 (D) 1/103

Q.20 Which one of the following statements about water is FALSE? **[JEE MAIN 2016]**

(A) Water can act both as an acid and as a base.
(B) There is extensive intramolecular hydrogen bonding in the condensed phase.
(C) Ice formed by heavy water sinks in normal water.
(D) Water is oxidized to oxygen during photosynthesis.

Q.21 The main oxides formed on combustion of Li, Na and K in excess of air are, respectively: **[JEE MAIN 2016]**

(A) LiO_2, Na_2O_2 and K_2O (B) Li_2O_2, Na_2O_2 and KO_2
(C) Li_2O, Na_2O_2 and KO_2 (D) Li_2O,Na_2O and KO_2

Q.22 Both lithium and magnesium display several similar properties due to the diagonal relationship; however, the one which is incorrect, is: **[JEE MAIN 2017]**

(A) nitrates of both Li & Mg yield NO_2 & O_2 on heating.
(B) both form basic carbonates.
(C) both form soluble bicarbonates.
(D) both form nitrides.

Q.23 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: **[JEE MAIN 2018]**

(A) H_2O and $(H_2O + O_2)$
(B) H_2O and $(H_2O + OH^-)$
(C) $(H_2O + O_2)$ and H_2O
(D) $(H_2O + O_2)$ and $(H_2O + OH^-)$

Q.24 The alkaline earth metal nitrate that does not crystallise with water molecules, is : **[JEE MAIN 2019 (JAN)]**

(A) $Sr(NO_3)_2$ (B) $Mg(NO_3)_2$
(C) $Ca(NO_3)_2$ (D) $Ba(NO_3)_2$

Q.25 The isotopes of hydrogen are **[JEE MAIN 2019 (JAN)]**

(A) Tritium and protium only.
(B) Deuterium and tritium only.
(C) Protium and deuterum only.
(D) Protium, deuterium and tritium.

Q.26 The correct order of hydration enthalpies of alkali metal ions is - **[JEE MAIN 2019 (APRIL)]**

(A) $Li^+ > Na^+ > K^+ > Rb^+ > Cs^+$
(B) $Li^+ > Na^+ > K^+ > Cs^+ > Rb^+$
(C) $Na^+ > Li^+ > K^+ > Rb^+ > Cs^+$
(D) $Na^+ > Li^+ > K^+ > Cs^+ > Rb^+$

Q.27 100 mL of a water sample contains 0.81 g of calcium bicarbonate and 0.73 of magnesium bicarbonate. The hardness of this water sample expressed in terms of equivalents of $CaCO_3$ is: **[JEE MAIN 2019 (APRIL)]**
(Molar mass of calcium bicarbonate is 162gmol^{-1} and magnesium bicarbonate is 146 gmol^{-1})

(A) 1,000 ppm (B) 10,000 ppm
(C) 100 ppm (D) 5,000 ppm

Q.28 The covalent alkaline earth metal halide (X = Cl, Br, I) is **[JEE MAIN 2019 (APRIL)]**

(A) CaX_2 (B) SrX_2
(C) BeX_2 (D) MgX_2

Q.29 C_{60}, an allotrope of carbon contains : **[JEE MAIN 2019 (APRIL)]**

(A) 20 hexagons and 12 pentagons.
(B) 12 hexagons and 20 pentagons.
(C) 18 hexagons and 14 pentagons.
(D) 16 hexagons and 16 pentagons.

Q.30 The alloy used in the construction of aircrafts is : **[JEE MAIN 2019 (APRIL)]**

(A) Mg – Sn (B) Mg – Mn
(C) Mg – Al (D) Mg – Zn

Q.31 Which of the following statements are correct ? **[JEE MAIN 2020 (JAN)]**

(I) On decomposition of H_2O_2, O_2 gas is released.
(II) 2-ethylanthraquinol is used in preparation of H_2O_2.
(III) On heating $KClO_3$, $Pb(NO_3)_2$, $NaNO_3$, O_2 gas is released.
(IV) In the preparation of sodium peroxoborate, H_2O_2 is treated with sodium metaborate.

(A) I, II, IV (B) II, III, IV
(C) I, II, III, IV (D) I, II, III

Q.32 Gypsum on heating at 393K produces **[JEE MAIN 2020 (JAN)]**

(A) dead burnt plaster (B) Anhydrous $CaSO_4$
(C) $CaSO_4 \cdot \frac{1}{2} H_2O$ (D) $CaSO_4 .5H_2O$

Q.33 Determine total number of neutrons in three isotopes of hydrogen. **[JEE MAIN 2020 (JAN)]**

(A) 1 (B) 2
(C) 3 (D) 4

Q.34 The hardness of a water sample containing 10^{-3} M $MgSO_4$ expressed as $CaCO_3$ equivalents (in ppm) is ______.
(Molar mass of $MgSO_4$ is 120.37 g/mol) **[JEE MAIN 2020 (JAN)]**

Q.35 Among the statements (a)-(d) the correct ones are: **[JEE MAIN 2020 (JAN)]**

(a) Lithium has the highest hydration enthalpy among the alkali metals.
(b) Lithium chloride is insoluble in pyridine.
(c) Lithium cannot form ethynide upon its reaction with ethyne.
(d) Both lithium and magnesium react slowly with H_2O.

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

EXERCISE - 5 (PREVIOUS YEARS AIPMT/NEET EXAM QUESTIONS)

Q.1 The correct order of the mobility of the alkaline metal ions in aqueous solution is **[AIPMT 2006]**
(A) $Na^+ > K^+ > Rb^+ > Li^+$ (B) $K^+ > Rb^+ > Na^+ > Li^+$
(C) $Rb^+ > K^+ > Na^+ > Li^+$ (D) $Li^+ > Na^+ > K^+ > Rb^+$

Q.2 The correct order of increasing thermal stability of K_2CO_3, $MgCO_3$, $CaCO_3$ and $BeCO_3$ is – **[AIPMT 2007]**
(A) $BeCO_3 < MgCO_3 < CaCO_3 < K_2CO_3$
(B) $MgCO_3 < BeCO_3 < CaCO_3 < K_2CO_3$
(C) $K_2CO_3 < MgCO_3 < CaCO_3 < BeCO_3$
(D) $BeCO_3 < MgCO_3 < K_2CO_3 < CaCO_3$

Q.3 In which of the following the hydration energy is higher than the lattice energy – **[AIPMT 2007]**
(A) $MgSO_4$ (B) $RaSO_4$
(C) $SrSO_4$ (D) $BaSO_4$

Q.4 The sequence of ionic mobility in aqueous solution is: **[AIPMT 2008]**
(A) $Na^+ > K^+ > Rb^+ > Cs^+$ (B) $K^+ > Na^+ > Rb^+ > Cs^+$
(C) $Cs^+ > Rb^+ > K^+ > Na^+$ (D) $Rb^+ > K^+ > Cs^+ > Na^+$

Q.5 Equimolar solutions of the following were prepared in water separately. Which one of the solutions will record the highest pH? **[AIPMT 2008]**
(A) $CaCl_2$ (B) $SrCl_2$
(C) $BaCl_2$ (D) $MgCl_2$

Q.6 The alkali metals form salt-like hydrides by the direct synthesis at elevated temperature. The thermal stability of these hydrides decreases in which of the following orders? **[AIPMT 2008]**
(A) LiH > NaH > KH > RbH > CsH
(B) CsH > RbH > KH > NaH > LiH
(C) KH > NaH > LiH > CsH > RbH
(D) NaH > LiH > KH > RbH > CsH

Q.7 In the case of alkali metals, the covalent character decreases in the order: **[AIPMT 2009]**
(A) MF > MCl > MBr > MI (B) MF > MCl > MI > MBr
(C) MI > MBr > MCl > MF (D) MCl > MI > MBr > MF

Q.8 Oxides not expected to react with sodium hydroxide?
(A) CaO (B) SiO_2 **[AIPMT 2009]**
(C) BeO (D) B_2O_3

Q.9 Which of the following alkaline earth metal sulphates has hydration enthalpy higher than the lattice enthalpy?
(A) $CaSO_4$ (B) $BeSO_4$ **[AIPMT (PRE) 2010]**
(C) $BaSO_4$ (D) $SrSO_4$

Q.10 Property of the alkaline earth metals that increases with their atomic number: **[AIPMT (PRE) 2010]**
(A) Solubility of their hydroxides in water
(B) Solubility of their sulphates in water
(C) Ionization energy
(D) Electronegativity

Q.11 Which one of the following compounds is a peroxide ? **[AIPMT (PRE) 2010]**
(A) KO_2 (B) BaO_2
(C) MnO_2 (D) NO_2

Q.12 Some statements about heavy water are given :
(i)Heavy water is used as a moderator in nuclear reactors.
(ii) Heavy water is more associated than ordinary water.
(iii)Heavy water is more effective solvent than ordinary water. **[AIPMT (MAINS) 2010]**
Which of the above statements are correct?
(A) (i) and (ii) (B) (i), (ii) and (iii)
(C) (ii) and (iii) (D) (i) & (iii)

Q.13 The compound A on heating gives a colourless gas and a residue that is dissolved in water to obtain B. Excess of CO_2 is bubbled through aqueous solution of B, C is formed which is recovered in the solid form. Solid C on gentle heating gives back A. The compound A is : **[AIPMT (MAINS) 2010]**
(A) $CaCO_3$ (B) Na_2CO_3
(C) K_2CO_3 (D) $CaSO_4.2H_2O$

Q.14 Which of the following compounds has the lowest melting point? **[AIPMT (PRE) 2011]**
(A) CaF_2 (B) $CaCl_2$
(C) $CaBr_2$ (D) CaI_2

Q.15 Which one of the following is present as an active ingredient in bleaching powder for bleaching action? **[AIPMT (PRE) 2011]**
(A) $CaCl_2$ (B) $CaOCl_2$
(C) $Ca(OCl)_2$ (D) CaO_2Cl

Q.16 Match List-I with List - II **[AIPMT (MAINS) 2011]**

List-I - Substances	**List-II - Composition**
(a) Plaster of paris	(i) $CaSO_4.2H_2O$
(b) Epsomite	(ii) $CaSO_4.½\,H_2O$
(c) Kieserite	(iii) $MaSO_4.7H_2O$
(d) Gypsum	(iv) $MgSO_4.\,H_2O$
Code :	(v) $CaSO_4$

(A) (a) (iii), (b) (iv), (c) (i), (d) (ii)
(B) (a) (ii), (b) (iii), (c) (iv), (d) (i)
(C) (a) (i), (b) (ii), (c) (iii), (d) (v)
(D) (a) (iv), (b) (iii), (c) (ii), (d) (i)

Q.17 Which one of the alkali metals, forms only, the normal oxide, M_2O on heating in air ? **[AIPMT (PRE) 2012]**
(A) Rb (B) K
(C) Li (D) Na

Q.18 The ease of adsorption of the hydrated alkali metal ions on an ion-exchange resins follows the order : **[AIPMT (PRE) 2012]**
(A) $Li^+ < K^+ < Na^+ < Rb^+$ (B) $Rb^+ < K^+ < Na^+ < Li^+$
(C) $K^+ < Na^+ < Rb^+ < Li^+$ (D) $Na^+ < Li^+ < K^+ < Rb^+$

Q.19 Solubility of the alkaline earth's metal sulphates in water decreases in the sequence **[AIPMT 2015]**
(A) Ca > Sr > Ba > Mg (B) Sr>Ca > Mg > Ba
(C) Ba > Mg > Sr > Ca (D) Mg>Ca > Sr > Ba

Q.20 The function of "Sodium pump" is a biological process operating in each and every cell of all animals. Which ion is also a constituent of this pump ? **[AIPMT 2015]**
(A) Mg^{2+} (B) K^+
(C) Fe^{2+} (D) Ca^{2+}

Q.21 Which on heating releases CO_2 most easily? **[RE-AIPMT 2015]**
(A) $MgCO_3$ (B) $CaCO_3$
(C) K_2CO_3 (D) Na_2CO_3

Q.22 Which of the following statements is false? **[NEET 2016 PHASE 1]**

(A) Mg^{2+} ions form a complex with ATP.

(B) Ca^{2+} ions are important in blood clotting.

(C) Ca^{2+} ions are not important in maintaining the regular beating of the heart.

(D) Mg^{2+} ions are important in the green parts of plants.

Q.23 Which of the following statements about hydrogen is incorrect? **[NEET 2016 PHASE 1]**

(A) Hydrogen has three isotopes of which tritium is the most common.

(B) Hydrogen never acts as cation in ionic salts.

(C) Hydronium ion, H_3O^+ exists freely in solution.

(D) Dihydrogen acts as a reducing agent.

Q.24 The suspension of slaked lime in water is known as – **[NEET 2016 PHASE 2]**

(A) Limewater

(B) Quicklime

(C) Milk of lime

(D) Aqueous solution of slaked lime

Q.25 In context with beryllium, which one of the following statements is incorrect? **[NEET 2016 PHASE 2]**

(A) It is rendered passive by nitric acid

(B) It forms Be_2C

(C) Its salts rarely hydrolyze

(D) Its hydride is electron-deficient and polymeric

Q.26 Ionic mobility of which of the following alkali metal ions is lowest when aqueous solution of their salts are put under an electric field ? **[NEET 2017]**

(A) K (B) Rb

(C) Li (D) Na

Q.27 Which of the following oxides is most acidic in nature? **[NEET 2018]**

(A) BaO (B) BeO

(C) MgO (D) CaO

Q.28 Among CaH_2, BeH_2, BaH_2, the order of ionic character is **[NEET 2018]**

(A) $BeH_2 < BaH_2 < CaH_2$ (B) $CaH_2 < BeH_2 < BaH_2$

(C) $BeH_2 < CaH_2 < BaH_2$ (D) $BaH_2 < BeH_2 < CaH_2$

Q.29 Enzymes that utilize ATP in phosphate transfer require an alkaline earth metal (M) as the cofactor. M is : **[NEET 2019]**

(A) Be (B) Mg

(C) Ca (D) Sr

Q.30 Which of the following is an amphoteric hydroxide? **[NEET 2019]**

(A) $Sr(OH)_2$ (B) $Ca(OH)_2$

(C) $Mg(OH)_2$ (D) $Be(OH)_2$

Q.31 The method used to remove temporary hardness of water is : **[NEET 2019]**

(A) Calgon's method

(B) Clark's method

(C) Ion-exchange method

(D) Synthetic resins method

ANSWER KEY

EXERCISE - 1

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	B	C	C	A	D	D	B	C	B	D	A	C	B	D	D	A	D	C	C	B	A	A	B	A	A
Q	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
A	A	D	C	D	C	C	D	B	B	A	C	C	C	A	D	D	D	A	C	D	B	B	D	C	B
Q	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
A	A	B	A	A	C	D	C	C	D	C	A	A	A	C	D	C	C	D	C	B	A	D	B	A	A
Q	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
A	D	D	D	A	D	C	A	B	A	B	C	A	C	A	A	C	A	B	A	A	C	C	D	B	D
Q	101	102	103	104	105	106	107	108																	
A	C	A	C	A	B	D	D	C																	

EXERCISE - 2 [Section-A]

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
A	D	B	D	B	D	C	C	B	B	A	C	B	A	C	D	A	B	B	C	C	B	B	D	A

EXERCISE - 2 [Section-B]

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	D	C	C	C	C	C	B	A	D	D	C	C	B	D	B	D	C	D	A	A	B	C	A	C	C

EXERCISE - 3

Q	1	2	3	4	5	6	7	8	9	10
A	400	10	7	3	84	10	6	2	1	3

EXERCISE - 4

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	D	A	C	D	D	C	B	B	A	A	B	C	A	C	D	D	D	A	C	B	C	B	A	D	D
Q	26	27	28	29	30	31	32	33	34	35															
A	A	B	C	A	C	C	C	C	100	C															

EXERCISE - 5

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	C	A	A	C	C	A	C	A	B	A	B	A	A	D	C	B	C	B	D	B	A	C	A	C	C
Q	26	27	28	29	30	31																			
A	C	B	C	B	D	B																			

SOLUTIONS

HYDROGEN AND s-BLOCK

TRY IT YOURSELF-1

(1) It turns blue litmus red, being acidic in nature.
(2) Blue colour appears due to CrO_5.
(3) (C)
(4) (B)
(5) (D)
(6) (C)
(7) (C)
(8) (D)
(9) $2H_2O_2\,(l) \rightarrow O_2\,(g) + H_2O\,(l)$

22.4 L of O_2 at STP is produced from $H_2O_2 = 68$gm

10 L of O_2 at STP is produced from $H_2O_2 = \frac{68}{22.4} \times 10 = 30.36$

Strength = 30.36 gm/L

(10) (B)
(11) (A)

TRY IT YOURSELF-2

(1) $Li < K < Na < Rb < Cs$
(2) (B)
(3) (C)
(4) Lithium is strongest reducing agent, as it has greatest E° value (–3.05 volt). E° value depends upon factors i.e., sublimation, hydration and ionization enthalpy.
(5) (C)
(6) (D)
(7) (A)
(8) **(C).** When sodium and potassium react with water, the heat evolved causes them to melt, giving a larger area of contact with water, lithium on the other hand, does not melt under these condition and thus reacts more slowly.

	Li	Na	k
Melting point (°C)	180	98	64

(9) **(B).** Both statements are correct but S2 is not correct explanation of S1 .

Statement -1 : The reason for this is that their lattice energies change is more than the hydration energies on descending the group.

Statement -2: HyDratron energy $\propto \frac{1}{\text{size of cation}}$

(10) **(C).** (i) $E^\circ\ Li^+/Li = -3.04$; $Na^+/Na = -2.71$ which is least among the alkali metals.

(ii) Hydration enthalpy / $KJ\ mol^{-1}$
$Li = -506$; $Na = -406$
Cs has the least $\Delta H_{hyd} = -276$

(11) **(C).** The atom becomes larger on descending the group, so the bonds are weaker (metallic bond), the cohesive force/energy decreases and accordingly melting point also decreases.

(12) **(D).**
(A) Bigger anion is stabilised by bigger cation through lattice energy effect.
(B) Because of their high reactivity towards air and water.
(C) True Statement
(D) In concentrated solution, unpaired electrons with opposite spins paired up-forming the solution diamagnetic.

TRY IT YOURSELF-3

(1) $Be(OH)_2 < Mg(OH)_2 < Ca(OH)_2 < Sr(OH)_2 < Ba(OH)_2$.
The decrease in lattice energy is more than the decrease in hydration enthalpy. Hence solubility increases.
(2) (C)
(3) (C)
(4) (B)
(5) (D)
(6) **(B).** As the size of cation decreases, the extent of polarisation increases so covalent character ↑ and stability ↓
(7) **(ABCD).**
(A) Due to the formation of metal ion clusters.
(B) $M + (x+y)\,NH_3 \rightarrow M^+(NH_3)_x + e^-\,(NH_3)_y$
(C) due to the formation of metal clusters.
(D) $M\,(NH_3)_6 \rightarrow$ true statement
(8) **(B).** Solubility of alkaline earth metal hydroxide increases as the solubility product increases.

$Be(OH)_2$ <------< $Ba(OH)_2$
K_{sp} 1.6×10^{-26} 5.4×10^{-3}

(9) (D)
(10) (A)
(11) (A)

CHAPTER-9 : HYDROGEN & s-BLOCK

EXERCISE-1

(1) **(B).** Electronegativity and ionisation energy of hydrogen is similar to group 17.

(2) **(C).** Like halogens, hydrogen is liberated at anode, e.g.
$2NaH \rightarrow 2Na + H_2$ (at anode)
$2NaCl \rightarrow 2Na + Cl_2$ (at anode)

(3) **(C).** Hydrogen resembles both alkali metals and halogens.

(4) **(A).** $H\,(1s^1) + e^- \rightarrow H^-\,(1s^2 \text{ or } [He]^2)$

$$\underset{[He]^2 2s^2 2p^5}{F + e^-} \rightarrow \underset{[He]^2 2s^2 2p^6 \text{ or } [Ne]^{10}}{F^-}$$

(5) **(D).** Ortho-para hydrogen are spin isomers of hydrogen. Hydrogen has 3 isotopes:

Protium $({}^1_1H)$, Deuterium $({}^2_1D)$, Tritium $({}^3_1T)$.

(6) **(D).** Deuterium is ${}^2_1H$.

(7) **(B).** Syngas also known as synthetic gas, is the name given to a mixture of CO and H_2.

(8) **(C).** The production of dihydrogen can be increased by reacting carbon monoxide of syngas mixtures with steam in the presence of iron chromate as catalyst.

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

This is called water-gas shift reaction.

(9) **(B).** Copper being less reactive than hydrogen cannot displace hydrogen from acids.

(10) **(D).** In laboratory, hydrogen gas is prepared by action of dilute H_2SO_4 on granulated zinc.
$Zn + H_2SO_4\,(\text{dil.}) \rightarrow ZnSO_4 + H_2$

(11) **(A).** $R-CH=CH_2 + H_2 + CO$
$\rightarrow RCH_2CH_2CHO$ (aldehyde)

$$\xrightarrow{H_2} RCH_2CH_2CH_2OH$$

(12) **(C).** Hydrogen directly combines with highly reactive metals to give hydrides. $Ca + H_2 \rightarrow CaH_2$

(13) **(B).** Formation of NH_3 by reaction of hydrogen and nitrogen is known as Haber's process.

(14) **(D).** Elements of group 15-17 form electron-rich hydrides. Group 14 elements form electron-precise hydrides.

(15) **(D).** Elements of group 14 form electron-precise (having required number of electrons to write the Lewis structure) hydrides.

(16) **(A).** LaH_3 is interstitial hydride.

(17) **(D).** Nitrogen forms electron-rich covalent or molecular hydrides.

(18) **(C).** Since higher oxidation state of P is not favoured by high Δ_aH of dihydrogen and $\Delta_{eg}H$ of hydrogen, P does not form PH_5 though it exhibits +3 and +5 oxidation states.

(19) **(C).** Carbon hydrides with general formula C_nH_{2n+2} are electron-precise hydrides like CH_4. They have a complete octet hence they do not behave as Lewis acid or Lewis base.

(20) **(B).** By boiling temporary hardness of water can be removed.

$$Ca(HCO_3)_2 \xrightarrow{\text{Boil}} \underset{\text{(insoluble)}}{CaCO_3} + H_2O + CO_2$$

(21) **(A).** Zeolite/permutit is hydrated sodium aluminium silicate which is also written as NaZ.

(22) **(A).** The water has maximum density at 4°C when it is converted to ice, an open cage three dimensional structure is formed.

(23) **(B).** Due to extensive H-bonding water is denser than ice. Some of the H-bonding breaks when ice is formed.

(24) **(A).** Two ice cubes when pressed over each other unite due to hydrogen bond formation.

(25) **(A).** Permanent hardness of water is due to sulphates and chlorides of calcium and magnesium.

(26) **(A).** The triple point of any substance is that temperature and pressure at which the material can exist in all three phases (Solid, liquid and gas) in equilibrium specifically the triple point of water is 273.16 K at 611.2Pa.

(27) **(D).** H – O – H angle in water is slightly less than the typical tetrahedral angle. It is 104.5°.

(28) **(C).** The complex salt of metaphosphoric acid, sodium hexametaphosphate $(NaPO_3)_6$ is known as calgon. It is represented as $Na_2[Na_4(PO_3)_6]$.

(29) **(D).** All combinations are correct.

(30) **(C).** Hydrogen peroxide : Structure - Non-planar structure, Hybridisation : sp^3

(31) **(C).** H_2O_2 decomposes slowly on exposure to light. $2H_2O_2\,(\ell) \rightarrow 2H_2O\,(\ell) + O_2\,(g)$
In the presence of metal surfaces or traces of alkali (present in glass containers), the above reaction is catalysed. It is, therefore, stored in wax-lined glass or plastic vessels in dark. Urea can be added as a stabiliser. It is kept away from dust because dust can induce explosive decomposition of the compound.

(32) **(D).** Hydrogen peroxide solution can be concentrated by cooling, evaporation on water baths and dehydration in vacuum desicator.

(33) **(B).** $BaO_2\,.\,8H_2O(s) + H_2SO_4(aq)$
$\rightarrow BaSO_4(s) + H_2O_2(aq) + 8H_2O\,(\ell)$

(34) **(B).** 30% solution of H_2O_2 is equal to 100volume H_2O_2

(35) **(A).** $BaO_2 \cdot 8H_2O\,(s) + H_2SO_4\,(aq)$
$\rightarrow BaSO_4\,(s) + H_2O_2\,(aq) + 8H_2O\,(\ell)$

(36) **(C).** $BaO_2 + 2HCl \rightarrow BaCl_2 + H_2O_2$

(37) **(C).** $Na_2O_2 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O_2$

(38) **(C).** H_2O_2 has an open book structure with H – O – O bond angle equal to 101.9° in solid phase.

(39) **(A).** $H_2SO_4 + BaO_2 \rightarrow BaSO_4 + H_2O_2$

(40) **(D).** Although H_2O_2 is a better polar solvent than H_2O. However it cannot be used as such because of the strong auto-oxidation ability.

(41) **(D).** H_2O_2 is used as an oxidant for rocket fuel and has 90% concentration to be used in rockets.

(42) **(D).** Decomposition of H_2O_2 is catalyzed by metals, rough surfaces, sunlight, dust particles, glass and alkalis.

(43) **(A).** $\underset{\text{weak acid}}{H_2O_2} \rightarrow H_2O + [O]$

(44) **(C).** It does not give blue colour with $K_4[Fe(CN)_6]$.

(45) **(D).** Heavy water is used as a moderator to slow down the speed of fast moving neutrons and as well as a coolant.

(46) **(B).** D_2O is known as heavy water.

(47) **(B).** Freezing point of heavy water is 3.8°C.

(48) **(D).** $H_2O\ (H = {}_1H^2)$; $16 + 2 \times 2 = 20$ amu

(49) **(C).** $2AlN + 3D_2O \rightarrow Al(OD)_3 + ND_3$

(50) **(B).** After removal of an electron the effective nuclear charge per electron increases hence the size decreases.

(51) **(A).** Alkali metals valence shell configuration = ns^1

(52) **(B).** As ionisation energy decreases from Li to Cs, electropositive character increases from Li to Cs.

(53) **(A).** In alkali metal group elements alkali means plant ash.

(54) **(A).** They possess highest atomic volume in their respective periods.

(55) **(C).** Mobility decreases from top to bottom because of the atomic size increases. But Li^+ shows lowest ionic mobility due to very high hydration energy.

(56) **(D).** $2Na + 2H_2O \rightarrow 2NaOH + H_2$

(57) **(C).** Alkali metals are highly reactive metals.

They react with

Alcohol – $2C_2H_5OH + 2K \rightarrow 2C_2H_5OK + H_2$

Water – $2K + 2H_2O \rightarrow 2KOH + H_2$

Ammonia – $K + (x + y)NH_3 \rightarrow$

$$\underset{\text{Ammoniated cation}}{[K(NH_3)_x]^+} + \underset{\text{Ammoniated electron}}{[e(NH_3)_y]^-}$$

But they do not react with kerosene.

(58) **(C).** Lithium when burnt in air forms a mixture of oxide as well as nitride.

$4Li + O_2 \xrightarrow{\Delta} 2Li_2O$, $6Li + N_2 \xrightarrow{\Delta} 2Li_3N$

(59) **(D).** $2Rb + 2H_2O \rightarrow 2RbOH + H_2$

$\xrightarrow{Li < Na < K < Rb < Cs}$

As we go down the group reactivity with H_2O increases.

(60) **(C).** H_2 gas produced during the reaction burns.

$2Na + 2H_2O \rightarrow 2NaOH + H_2$

(61) **(A).** $2Na + 2HOH \rightarrow 2NaOH + H_2\uparrow$

$2K + 2HOH \rightarrow 2KOH + H_2\uparrow$

(62) **(A).** $\underrightarrow{LiOH < NaOH < KOH < RbOH}$

Down the group basic character increases

(63) **(A).** Li_2CO_3 is least stable and decomposes on heating unlike other alkali metal carbonates.

$Li_2CO_3 \rightarrow Li_2O + CO_2$

(64) **(C).** The alkali metal halides are all high melting, colourless crystalline solids.

The alkali metals form salts with oxo-acids.

(65) **(D).** When Na is heated in presence of air or oxygen, Na burns to form sodium oxide and sodium peroxide.

(66) **(C).** Carbonates and sulphates of lithium decompose on heating while the stability of carbonates and sulphates of other metals increases down the group.

(67) **(C).** On combustion in excess of air potassium forms the superoxides.

The oxides and the peroxides of alkali metals are colourless when pure, but the superoxides are yellow or orange in colour.

(68) **(D).**

(i) Halides are soluble in water.

(ii) The melting and boiling points follow the order : fluoride > chloride > bromide > iodide.

(iii) Halides of lithium are soluble in ethanol, acetone and ethylacetate; LiCl is soluble in pyridine.

(69) **(C).** On moving down the group electropositive character increases.

(70) **(B).** Lithium shows diagonal relationship with magnesium since they have almost the same polarizing power i.e. charge/size ratio.

(71) **(A).** Small atomic and ionic size leads to high electronegativity and hydration energy. Small atomic and ionic size leads to high electronegativity and hydration energy.

(72) **(D).** Lithium is least reactive but the strongest reducing agent among all the alkali metals.

LiCl is deliquescent and crystallises as a hydrate. Lithium unlike other alkali metals forms no ethynide on reaction with ethyne.

(73) **(B).** Li and magnesium react slowly with water.

(74) **(A).** $NaHCO_3$ is known as baking soda.

(75) **(A).** $CaCO_3 \rightarrow CaO + CO_2$

$2NH_3 + CO_2 + H_2O \rightarrow (NH_4)_2CO_3$

$(NH_4)_2CO_3 + H_2O + CO_2 \rightarrow 2NH_4HCO_3$

$NH_4HCO_3 + NaCl \rightarrow NaHCO_3 + NH_4Cl$

(76) **(D).** Anhydrous Na_2CO_3 is called 'soda ash' while sodium carbonate decahydrate, $Na_2CO_3 \cdot 10H_2O$ is called 'washing soda'.

(77) **(D).** $Na_2CO_3.10H_2O \xrightarrow[-9H_2O]{\Delta} Na_2CO_3.H_2O$

$\xrightarrow[-H_2O]{\Delta} Na_2CO_3$

(78) **(D).** Amalgam is treated with water to give sodium hydroxide and hydrogen gas.

$2Na\text{-amalgam} + 2H_2O \rightarrow 2NaOH + 2Hg + H_2$

(79) **(A).** Na^+ and K^+ ions participate in the transmission of nerve signals, in regulating the flow of water across cell membrane.

(80) **(D).** A typical 70 kg man contains about 90 g of Na and 170 g of K.

(81) **(C).** Potassium ions are the most abundant cations within cell fluids, where they activate many enzymes, participate in the oxidation of glucose to produce ATP and, with sodium, are responsible for the transmission of nerve signals. Sodium ions are found primarily on the outside of cells.

(82) **(A).** Be due to diagonal relationship.

(83) **(B).** Na, K and Ca decompose water by evolving hydrogen gas. However Be does not react with water even when red hot. Its protective oxide layer survives even at high temperature.

(84) **(A).** Be to Ba ionic character increasing.

(85) **(B).** All the observations are correct.

$M \to M^{2+} + 2e^-$; $2NH_3 + 2e^- \to 2NH_2^- + H_2$

$M^{2+} + 2NH_2^- \to M(NH_2)_2 \xrightarrow{\text{evaporation}} [M(NH_3)_6]^{2+}$

$[M(NH_3)_6]^{2+} \to M(NH_2)_2 + 4NH_3 + H_2$

(86) **(C).** On moving down the group lattice energy remains almost constant as the sulphate is so big that small increase in the size of the cations from Be to Ba does not make any difference. However the hydration energy decreases from Be^{+2} to Ba^{+2}. This causes decrease in the solubility of the sulphates as the ionic size increases.

(87) **(A).** Beryllium halides are essentially covalent and soluble in organic solvents like ethanol.

(88) **(C).** The alkaline earth metal hydroxides are less basic and less stable than alkali metal hydroxides. The fluorides are relatively less soluble than the chlorides owing to their high lattice energies.

(89) **(A).** Basic character of oxides increases down the group while decreases in a period.

(90) **(A).** The solubility of hydroxides of alkaline earth metals in water increases on moving down the group.

(91) **(C).** Iincreasing stability :

$BeSO_4 < MgSO_4 < CaSO_4$

Temp. of decomposition: 773 K 1168 K 1422 K

(92) **(A).** The basic character of metal hydroxides increases down the group from $Mg(OH)_2$ to $Ba(OH)_2$ due to increase in size, ionization enthalpy decreases and the M–O bond becomes weaker.

(93) **(B).** On moving down the group; Lattice energy decreases with increase in size of cation.

(94) **(A).** Due to smaller size their lattice enthalpies are high but their greater hydration enthalpies overcome the lattice enthalpies and they become soluble in water. Ca, Sr and Ba sulphates are insoluble is water due to lower hydration enthalpies.

(95) **(A).** (i) Small atomic size. (ii) High electronegativity (iii) Absence of d orbitals

(96) **(C).** Both $Be(OH)_2$ & $Al(OH)_3$ are amphoteric in nature.

(97) **(C).** Beryllium has exceptionally small atomic and ionic sizes and thus does not compare well with other members of the group.

Because of high ionisation enthalpy and small size it forms compounds which are largely covalent and get easily hydrolysed.

The oxide and hydroxide of beryllium are amphoteric in nature.

(98) **(D).** Setting of plaster of paris is exothermic process

$$CaSO_4.\frac{1}{2}H_2O \xrightarrow{H_2O} \underset{\text{Orthorhombic}}{CaSO_4.2H_2O} \xrightarrow{\text{Hardening}} \underset{\text{Mono orthorhombic Gypsum}}{CaSO_4.2H_2O}$$

(99) **(B).** CaO : 50 - 60%, SiO_2 : 20 - 25%,
Al_2O_3 : 5 - 10%,
MgO : 2 - 3%, Fe_2O_3 : 1 - 2% and
SO_3 : 1 - 2%

(100) **(D).** $\underset{\text{Slaked lime}}{Ca(OH)_2} + Cl_2 \to \underset{\text{Bleaching powder}}{CaOCl_2} + H_2O$

(101) **(C).** $\underset{\text{Plaster of paris}}{CaSO_4.\frac{1}{2}H_2O} + \frac{1}{2}H_2O \to \underset{\text{Hard mass}}{CaSO_4.2H_2O}$

(102) **(A).** $Ca(OH)_2$ is used in the preparation of bleaching powder.

(103) **(C).** $2CaSO_4 \cdot \frac{1}{2}H_2O$ (Plaster of Paris) + $3H_2O$

$\to 2CaSO_4 \cdot 2H_2O$

Gypsum (Hard mass)

(104) **(A).** Plaster of paris $[(CaSO_4)_2H_2O]$ is used in surgery for setting of bones, dentistry and manufacturing of statues. It is prepared as follows,

$$2CaSO_4.2H_2O \xrightarrow{125°C} \underset{\text{Plaster of paris}}{(CaSO_4)_2.H_2O} + 3H_2O$$

(105) **(B).** CaO – (quick lime)
$Ca(OH)_2$ – (slaked lime)
$Ca(OH)_2 + H_2O$ – an aqueous suspension of $Ca(OH)_2$ in water is called lime water.
$CaCO_3$ (lime stone).

(106) **(D).** Mg binds to phosphate group in ATP thus making a complex that catalyses phosphate transfer.

(107) **(D).** An adult body contains about 25 g of Mg and 1200 g of Ca.

The main pigment for the absorption of light in plants is chlorophyll which contains magnesium. About 99 % of body calcium is present in bones and teeth.

(108) **(C).** Magnesium plays important roles in neuromuscular function, interneuronal transmission, cell membrane integrity and blood coagulation. The calcium concentration in plasma is regulated by calcitonin & parathyroid hormones.

EXERCISE-2

SECTION - A [HYDROGEN]

(1) **(D).** Chlorine has lone pair which it can donate to form co-ordinate bond while hydrogen cannot.

(2) **(B).** ${}^3_1H \to {}^3_2He + {}^0_{-1}e$

(3) **(D).** Vegetable oil $+ H_2 \xrightarrow[\Delta]{Ni}$ Fat

(4) **(B).** H_3 is also called Hyzone

(5) **(D).** Hydrogen is the lightest gas.

(6) **(C).** Mercury (Hg) will not displace hydrogen.

(7) **(C).** Hydrogen is the lightest gas. It is insoluble in water.

(8) **(B).** HCO_3^- is main reason of temporary hardness of water.

(9) **(B).** Heavy water freezes at a slightly higher temperature than water.

(10) **(A).** In cation exchange resin Mg^{+2} and Ca^{+2} (cations) are replaced by Na^+ ions.

(11) **(C).** $K_2SO_4.Al_2(SO_4)_3.24H_2O$

Potash alum is generally used for purifying water.

(12) **(B).** $H_2O_2 + Cl_2 \rightarrow 2HCl + O_2$

(13) **(A).** Volume strength $= 5.6 \times$ Normality

$= 5.6 \times 1.5 = 8.4$ litre

(14) **(C).** Only chromium from group 6 forms CrH.

(15) **(D).** Loss of an electron from H atom results in H^+ ion having extremely small size ($\sim 1.5 \times 10^{-3}$ pm) as compared to normal atomic and ionic sizes of 50-200 pm. As a consequence, H^+ does not exist freely and is always associated with other atoms or molecules.

(16) **(A).** H_2O acts as a Bronsted acid and gives a proton to react with a base.

$H_2O + NH_3 \rightleftharpoons OH^- + NH_4^+$

acid base

In $H_2O + H_2S \rightarrow H_3O^+ + HS^-$,

base acid

H_2O acts as a base with H_2S.

(17) **(B).** When CO_2 is bubbled through a cold solution of barium peroxide in water, H_2O_2 is obtained.

$BaO_2 + CO_2 + H_2O \rightarrow BaCO_3\downarrow + H_2O_2$

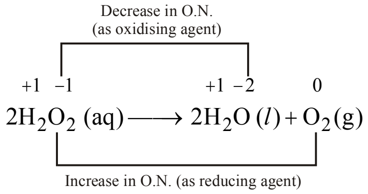
(18) **(B).** H - $1s^1$; He - $1s^2$

X - $ns^2\ np^5$; Ne - $1s^22s^22p^6$

Both have one electron less than the nearest noble gas configuration.

(19) **(C).** D_2O is prepared by repeated electrolysis of ordinary water which contains a small amount of alkali.

(20) **(C).**



$$\overset{+1\ -1}{2H_2O_2}\,(aq) \longrightarrow \overset{+1\ -2}{2H_2O}\,(l) + \overset{0}{O_2}(g)$$

(21) **(B).** Water has higher thermal conductivity, specific heat, dielectric constant and surface tension in comparison to other liquids.

(22) **(B).** With sodium metal water acts as an oxidising agent and gets reduced to H_2, with CO_2 water acts as a reducing agent and is oxidised to oxygen.

(23) **(D).** $\underset{\text{Sodium peroxide}}{Na_2O_2} + H_2SO_4(\text{dil.}) \rightarrow \underset{\text{Sodium sulphate}}{Na_2SO_4} + H_2O_2$

(24) **(A).** 20 volume of H_2O_2 means:

1 L of this H_2O_2 will give 20 L of oxygen at STP.

$2H_2O_2 \rightarrow O_2 + H_2O$

2×34 22.4 L at STP

22.4 L of O_2 is produced from 68g of H_2O_2

20 L of O_2 is produced frorn

$$= \frac{68\times20}{22.4} = 60.71\ g\ L^{-1} \text{ of } H_2O_2$$

SECTION - B [s-BLOCK ELEMENTS]

(1) **(D).** Generally ionic character decreasing from LiCl to NaCl.

(2) **(C).** In castner process Na metal is made of anode.

(3) **(C).** Potassium react with halogens (chlorine) to gives violet colour flame.

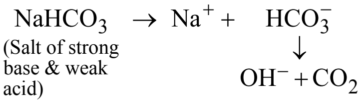
(4) **(C).** Lithium is basic in nature and hence it is not amphoteric.

(5) **(C).** $2Na + 2NH_3 \rightarrow 2NaNH_2 + H_2$

(6) **(C).** NaOH + CaO is called soda lime 3 : 1.

(7) **(B).** Since the electronic configurations of M^+ ions are similar to those of noble gases (s^2 or $s^2\ p^6$), these ions have no unpaired electrons and consequently are diamagnetic and colourless.

(8) **(A).**



$$\underset{\text{(Salt of strong base \& weak acid)}}{NaHCO_3} \rightarrow Na^+ + \underset{\substack{\downarrow \\ OH^- + CO_2}}{HCO_3^-}$$

(9) **(D).** The divalent Ca^{2+} ion has no unpaired electron, hence, its compounds are diamagnetic and colourless, provided their anions are also colourless.

(10) **(D).** $CaCl_2 \rightarrow \underset{\text{Cathode}}{Ca^{+2}} + \underset{\text{Anode}}{2Cl^-}$

Cathode : $Ca^{+2} + 2e^- \rightarrow Ca$

Anode : $2Cl^- \rightarrow 2e^- + Cl_2$

(11) **(C).** CO_2 escapes simultaneously.

(12) **(C).** Occurrence in lithosphere

Be : 2ppm ; Sr : 384ppm ; Ra : 10^{-6}ppm

(13) **(B).** By adding gypsum to cement setting time of cement increases.

(14) **(D).** Beryllium shows diagonal relationship with Al.

(15) **(B).** As the size of cation decreases, the extent of polarisation increases so covalent character ↑ and stability ↓

(16) **(D).**

(A) Due to the formation of metal ion clusters.

(B) $M + (x + y)\ NH_3 \rightarrow M^+(NH_3)_x + e^-\ (NH_3)_y$

(C) Due to the formation of metal clusters.

(17) **(C).** Because alkali metals are more electropositive than alkaline earth metals.

(18) **(D).** Metallic bonding is strongest in Li and weakest in Rb. Lithium shows a diagonal relation with magnesium and hence forms nitride.

(19) **(A).** Some of the Group 2 metal halides are covalent and soluble in organic solvents. $BeCl_2$ is soluble in ethanol is

(20) **(A).** Beryllium hydroxide, $Be(OH)_2$ is amphoteric in nature, as it reacts with acid and alkali both.

$Be(OH)_2 + 2HCl \rightarrow BeCl_2 + 2H_2O$

$Be(OH)_2 + 2NaOH \rightarrow Na_2BeO_2 + 2H_2O$

(21) **(B).** Smaller the size of cation, greater is its charge density and greater is its hydration.

(22) **(C).** Only molten or aqueous solution of ionic crystals conduct electricity.

(23) **(A).** Li reacts with water least vigorously due to small size and very high hydration energy.

(24) **(C).** Solubility of sulphates of alkaline earth metals decreases down the group.

(25) **(C).** Lithium forms ionic hydride having high melting point.

EXERCISE-3

(1) Equivalents of Na_2CO_3 used $= (100 - 60) \times 10^{-3} \times \frac{1}{50}$

Equivalent of Na_2CO_3 used = equivalent of Ca^{2+} or Mg^{2+} present in 100 ml of hard water = equivalent of Ca^{2+} or Mg^{2+}
present in 100 ml of hard water.
The amount of $CaCO_3$ in 10^3 gm of hard water

$$= \frac{40 \times 10^{-3} \times 10 \times 1 \times 50}{50} = 400 \times 10^{-3} \text{ gm}$$

$\therefore$ The amount of $CaCO_3$ in 10^6 gm of hard water = 400 gm.

$\therefore$ Permanent hardness of water = 400 ppm.

(2) **10.** The formulae of Gypsum, Plaster of Paris and Epsom salt are : $CaSO_4.2H_2O$, $CaSO_4.0.5H_2O$ and $MgSO_4.7H_2O$

(3) **7.** $K_4[Fe(CN)_6] + K_2CO_3 + 5S$
$\rightarrow Fe + CO_2 + KCNO + 5\,KCNS$

(4) **3.** $[H_2O_2 \rightarrow H_2O + \frac{1}{2}O_2] \times 2$

$\underset{68g}{2H_2O_2} \rightarrow 2H_2O + O_2$; 22.4 litre at N.T.P.

$\because$ 22.4 litre O_2 at N.T.P. obtained by 68gm. of H_2O_2

$\therefore$ 10 litre O_2 at N.T.P. obtained by

$$\frac{68}{22.4} \times 10 = 30.35 \text{ gm / litre}$$

$\therefore$ 1000 ml O_2 at N.T.P. obtained by = 30.35gm.

$\therefore$ 100ml O_2 at N.T.P. obtained by

$$= \frac{30.35}{1000} \times 100 = 3.035\%$$

(5) **84.** Volume strength = 5.6 × Normality = 5.6 × 1.5 = 8.4 litre

(6) **10.** E.W. of $H_2O_2 = 17$; $N = \frac{30.36}{17} = 1.78N$

Volume strength = 56.6 × Normality = 56.6 × 1.78 = 10 litre.

(7) **6.** H_2SO_4, H_3PO_3, H_2CO_3, $H_2S_2O_7$, H_2CrO_4, H_2SO_3
All are diprotic acids.

(8) **2.**

(i) Order of increasing electrical conductance :
$BeH_2 < CaH_2 < TiH_2$

(ii) Order of increasing ionic character :
$LiH < NaH < CsH$

(iii) Order of increasing bond dissociation enthalpy :
$F-F < H-H < D-D$

(iv) Order of increasing reducing property :
$H_2O < MgH_2 < NaH$

(9) **1.** The oxidation state of sodium in Na_2O_2 is +1.

(10) **3.**

(i) BeO is essentially covalent. Therefore, it does not dissolve in water. $BeSO_4$ in soluble in water due to its very high hydration enthalpy.

(ii) Barium oxide (BaO) reacts with water to form $Ba(OH)_2$. So BaO dissolve in water due to the reaction,

$$BaO + H_2O \longrightarrow Ba(OH)_2(aq)$$

$BaSO_4$ is almost insoluble in water due to its lower hydration enthalpy.

(iii) This is because the hydration enthalpy of Li^+ is much greater than that of K^+.

(iv) The bicarbonates of alkaline earth metals such as, $Ca(HCO_3)_2$ are stable only in solution. When water evaporates, soluble $Ca(HCO_3)_2$ decomposes into $CaCO_3$ by losing CO_2 and water. This can be attributed to strong polarising effect of small Ca^{2+} ion on large and more polarisable HCO_3^- ions.

EXERCISE-4

(1) **(D).** $Be(OH)_2 + NaOH \longrightarrow \underset{\text{soluble}}{Na_2BeO_2} + H_2O$

(2) **(A).** $KO_2 + \underset{\text{absorb}}{CO_2} \longrightarrow K_2CO_3 + \underset{\text{increase conc.}}{O_2 \uparrow}$

(3) **(C).** In current cement plasters, water is sprinkled from time to time. This helps in developing interlocking needle like crystals of hydrated silicates.

(4) **(D).** ↓ Hydration energy of cation
Solubility of carbonate

$BeCO_3 > MgCO_3 > CaCO_3 > SrCO_3 > BaCO_3$
$\xrightarrow{\qquad\qquad\qquad\qquad}$
↓ order of solubility

(5) **(D).** The substance not likely to contain $CaCO_3$ is calcined gypsum.

(6) **(C).** Hardening of water is due to SO_4^{2-}, HCO_3^-, Cl^-, NO_3^- salt of Ca and Mg.

(7) **(B).** The reagent commonly used to determine hardness of water titrimetrically is disodium salt of EDTA.

(8) **(B).** $Mg_3N_2 + H_2O \longrightarrow Mg(OH)_2 + 2NH_3$

(9) **(A).** Be show covalency = + 4
Al show covalency = + 6

(10) **(A).** Ionic mobility $\propto \dfrac{1}{\text{Hydration}}$
Hydration of $Rb^+ \downarrow$, mobility $\uparrow$

(11) **(B).** Chlorides of both beryllium and aluminium have bridged chloride structures in solid phase.

(12) **(C).** $CO + H_2 + H_2O \xrightarrow[773K]{Fe_2O_3/Cr_2O_3} CO_2 + 2H_2$
water gas (Bosch's process)

(13) **(A).** (i) $H_3PO_4 + H_2O \rightarrow H_3O^+ + H_2PO_4^-$
acid conjugate base
(ii) $H_2PO_4^- + H_2O \rightarrow HPO_4^{2-} + H_3O^+$
acid conjugate base
(iii) $H_2PO_4^- + OH^- \rightarrow H_3PO_4 + O^{2-}$
acid acid conjugate acid

(14) **(C).** $CaCO_3 \xrightarrow{\Delta} \underset{\text{Basic oxide}}{CaO} + \underset{\text{Acidic oxide}}{CO_2 \uparrow}$

(15) **(D).** $NaH + H_2O \rightarrow NaOH + H_2$
(very pure Hydrogen)

(16) **(D).** During the electrolysis of aqueous solution of s-block elements, H_2 gas is obtained at cathode.

(17) **(D).** H_2O_2 can be reduced or oxidised. Hence, it can act as reducing as well as oxidising agent.

(18) **(A).** $BeSO_4$ has hydration energy greater than its lattice energy.

(19) **(C).** $Ca^{+2} + 2C_8H_7SO_3^-Na^+ \rightarrow Ca(C_8H_7SO_3^-)_2 + 2Na^+$
1mol 2 mol

The maximum uptake $= \dfrac{1}{206 \times 2} = \dfrac{1}{412}$ mol / g

(20) **(B).** Water shows only intermolecular H-bond in the condensed phase.

(21) **(C).** Li mainly forms Li_2O ; Na mainly forms Na_2O_2
K mainly forms KO_2

(22) **(B).** Mg can form basic carbonate like
$5Mg^{+2} + 6CO_3^{2-} + 7H_2O$
$\rightarrow 4MgCO_3 . Mg(OH)_2 . 5H_2O \downarrow + 2HCO_3^-$
While Li can form only carbonate (Li_2CO_3) not basic carbonate.

(23) **(A).** During reduction $H_2O_2 \rightarrow H_2O$
During oxidation $H_2O_2 \rightarrow O_2$

(24) **(D).** Smaller in size of center atoms more water molecules will crystallize hence $Ba(NO_3)_2$ is answer due to its largest size of '+ve' ion.

(25) **(D).** Isotopes of hydrogen is :
Protium, deuterium and tritium.

(26) **(A).** Hydration enthalpy depends upon ionic potential (charge / size). As ionic potential increases hydration enthalpy increases.

(27) **(B).** $n_{eq}CaCO_3 = n_{eq}Ca(HCO_3)_2 + n_{eq}Mg(HCO_3)_2$

or $\dfrac{W}{100} \times 2 = \dfrac{0.81}{162} \times 2 + \dfrac{0.73}{146} \times 2 \quad \therefore \; W = 1.0$

$\therefore$ Hardness $= \dfrac{1.0}{100} \times 10^6 = 10000$ ppm

(28) **(C).** All halides of Be are predominantly covalent in nature.

(29) **(A).** In C_{60} molecule there are 20 hexagons and 12 pentagons.

(30) **(C).** Mg–Al alloy is used for construction of aircrafts.

(31) **(C).** (a) $H_2O_2 \rightarrow 2H_2O + O_2$

(b) 2-ethylanthraquinol $\underset{H_2/Pd}{\overset{O_2(air)}{\rightleftharpoons}}$
2-ethylanthraquinone + H_2O_2

(c) $KClO_3 \xrightarrow[MnO_2]{\Delta} KCl + \dfrac{3}{2}O_2$

$Pb(NO_3)_2 \xrightarrow{\Delta} PbO + 2NO_2 + \dfrac{1}{2}O_2$

$NaNO_3 \xrightarrow{\Delta} NaNO_2 + \dfrac{1}{2}O_2$

(d) $2H_3BO_3 + 2NaOH + 2H_2O_2$
$\rightarrow Na_2[B_2(O_2)(OH)_4] + 4H_2O$

All statements are correct.

(32) **(C).** $\underset{\text{Gypsum}}{CaSO_4.2H_2O} \xrightarrow{393\,K} \underset{\text{Plaster of paris}}{CaSO_4.\dfrac{1}{2}H_2O} + \dfrac{3}{2}H_2O$

(33) **(C).** ^1_1H $^2_1H(D)$ $^3_1H(T)$
Number of neutrons $0 + 1 + 2 = 3$

(34) **100.**
1 Litre has 10^{-3} moles $MgSO_4$
So, 1000 litre has 1 mole $MgSO_4$ = 1 mole $CaCO_3$ = 100 ppm

(35) **(C).** Lithium has highest hydration enthalpy among alkali metals due to its small size.
LiCl is soluble in pyridine because LiCl have more covalent character.
Li does not form ethynide with ethyne.
Both Li and Mg reacts slowly with H_2O.

EXERCISE-5

(1) **(C).** Ionic radii of alkali metals in water follows the order
$Li^+ > Na^+ > K^+ > Rb^+ > Cs^+$
Thus in aqueous solution due to larger ionic radius Li^+ has lowest mobility and hence the correct order of ionic mobility is $Li^+ < Na^+ < K^+ < Rb^+$

(2) **(A).** As the basicity of metal hydroxides increases down the group from Be to Ba, the thermal stability of their carbonates also increases in the same order. Further group 1 compounds are more thermally stable than group 2 because their hydroxide are much basic than group 2 hydroxides therefore, the order of thermal stability is $BeCO_3 < MgCO_3 < CaCO_3 < K_2CO_3$

(3) **(A).** The solubility of sulphates of alkaline earth metals decreases as we move down the group from Be to Ba due to the reason that ionic size increases down the group.
The lattice energy remains constant because sulphate ion is so large, so that small change in cationic sizes do not make any difference.
$BeSO_4 > MgSO_4 > CaSO_4 > SrSO_4 > BaSO_4$

(4) **(C).** Ionic mobility increases down the group as the hydrated ionic radii decreases down the group.

(5) **(C).** On going down the group basic strength increases thus pH increases.

(6) **(A).** Since electropositive character increases from Li to Cs, reactivity of hydrides increases from Li to Cs while thermal stability decreases from Li to Cs.

(7) **(C).** Alkali metals are highly electropositive and halogens are electronegative. Thus for the halides of a given alkali metal, the covalent character decreases with increase in electronegativity of halogens.
Order of covalent character of halides is :
$MI > MBr > MCl > MF.$

(8) **(A).** Sodium hydroxide, NaOH, being a strong alkali, never react with a basic oxide (compound). Among the given options, B_2O_3 and BeO are amphoteric oxides, SiO_2 is an acidic oxide and CaO is a basic oxide. Therefore, NaOH does not react with CaO.

(9) **(B).** Hydration energy varies inversely with size and in sulphates of alkaline earth metals lattice energy remains almost constant. The order of size of alkaline earth metals is $Be^{2+} < Ca^{2+} < Sr^{2+} < Ba^{2+}$
Thus, the order of hydration energy is
$Be^{2+} > Ca^{2+} > Sr^{2+} > Ba^{2+}$
Hence, $BeSO_4$ has the hydration enthalpy higher than the lattice enthalpy.

(10) **(A).** The hydroxides and sulphates of alkaline earth metals are ionic solids and the solubility of ionic solids and the solubility of ionic solids is governed by two factors, viz, lattice energy and hydration energy. For solubility, hydration energy > lattice energy.
Hydration energy varies inversely with size, i.e., decreases with increase in size. However, lattice energy in case of sulphates, remains almost same with increase in the atomic number of alkaline earth metals, due to large size of sulphate ion.

Hence, hydration energy only governs the solubility in this case. Thus, solubility of alkaline earth metal sulphates decreases on moving downward the group 2. In case of hydroxides, the lattice energies are different because of medium size of hydroxide ions, and decreases on moving from Be to Ba.
This tends to increase the solubility and to overcome the counter-effect produced by the decrease in hydration energy. Hence, the solubility of alkaline earth metal hydroxides increases with increase in the atomic number of alkaline earth metals.
Electronegativity as well as ionisation energy both usually decrease on moving downward a group with increase in atomic number.

(11) **(B).** In peroxides, the oxidation state of O is –1 and they give H_2O_2, with dilute acids, and have peroxide linkage. In KO_2, $+1 + (x \times 2) = 0$; $x = -1/2$
Thus, it is a superoxide, not a peroxide.
In BaO_2, $+2 + (x \times 2) = 0$; $x = -1$
Thus, it is a peroxide. Only it gives H_2O_2 when reacts with dilute acids and has peroxide linkage as $Ba^{2+}\,[O-O]^{2-}$
In MnO_2 and NO_2, Mn and N exhibit variable oxidation states, thus, the oxidation state of O in these is –2. Hence, these are not peroxides.

(12) **(A).** Heavy water is used for slowing down the speed of neutrons in nuclear reactors, hence used as moderators.
Boiling point of heavy water is greater (374.42 K) than that of ordinary water (373 K), hence heaver water is more associated. Dielectric constant of ordinary water is greater than that of heavy water, hence ordinary water is a better solvent.

(13) **(A).** $\underset{(A)}{CaCO_3} \xrightarrow{\Delta} \underset{\text{Colourless gas}}{CO_2} + \underset{\text{residue}}{CaO}$

$CaO + H_2O \longrightarrow \underset{(B)}{Ca(OH)_2}$

$\xrightarrow[\text{(excess)}]{CO_2} \underset{(C)}{Ca\,(HCO_3)_2} \xrightarrow{\Delta} \underset{(A)}{CaCO_3}$

(14) **(D).** CaI_2 has lowest melting point. As covalent character increases, melting point decreases.

(15) **(C).** $Ca\,(OCl)_2$, calcium hypochlorite is the active ingredient in bleaching powder which releases chlorine.

(16) **(B).** (a) Plaster of paris = $CaSO_4.½\,H_2O$
(b) Epsomite = $MgSO_4.7H_2O$
(c) Kieserite = $MgSO_4.H_2O$
(d) Gypsum = $CaSO_4.2H_2O$

(17) **(C).** $2Li + ½\,O_2 \rightarrow Li_2O$

(18) **(B).** Ease of adsorption of the hydrated alkali metal ions on an ion-exchange resins decreases as the size of alkali metal ions increases. Since the order of size of alkali metal ions: $Li^+ < Na^+ < K^+ < Rb^+$
Thus, the ease of adsorption follows the order :
$Rb^+ < K^+ < Na^+ < Li^+$

(19) **(D).** Solubility of alkaline earth metal sulphates decreases down the group $MgSO_4 > CaSO_4 > SrSO_4 > BaSO_4$

(20) **(B).** K^+ ion involved in "Sodium pump".
The K^+ ion are the most abundant cation within the cell fluid.

(21) **(A).** Thermal stability order
$K_2CO_3 > Na_2CO_3 > CaCO_3 > MgCO_3$
Therefore $MgCO_3$ releases CO_2 most easily

$MgCO_3 \xrightarrow{\Delta} MgO + CO_2$

(22) **(C).** Ca^{+2} are important in blood clotting and are also important in maintaining the regular beating of the heart.

(23) **(A).** Hydrogen has three isotopes of which protium $({}_1H^1)$ is the most common.

(24) **(C).** Suspension of slaked lime is called milk of lime.

(25) **(C).** Salts of beryllium is readily hydrolysed due to presence of vacant p-orbital.

(26) **(C).** Ionic mobility $\propto \dfrac{1}{\text{Size of hydrated ion}}$

Smaller size hydrated ion in aq. sol^n - $Rb^+(aq)$
Larger size hydrated ion in aq. sol^n - $Li^+(aq)$
Lowest ionic mobility in aq. $sol^n \rightarrow Li^+(aq)$ due to high hydration.

(27) **(B).** $BeO < MgO < CaO < BaO$

$\xrightarrow{\hspace{6cm}}$

Basic character increases. So, the most acidic should be BeO. In fact, BeO is amphoteric oxide while other given oxides are basic.

(28) **(C).** For 2nd group hydrides, on moving down the group metallic character of metals increases so ionic character of metal hydride increases. Hence the option (C) should be correct option.

(29) **(B).** All enzymes that utilize ATP in phosphate transfer require magnesium (Mg) as the co-factor.

(30) **(D).** $Be(OH)_2$ amphoteric in nature, since it can react both with acid and base.

$Be(OH)_2 + 2HCl \rightarrow BeCl_2 + 2H_2O$
$Be(OH)_2 + 2NaOH \rightarrow Na_2[Be(OH)_4]$

(31) **(B).** Clark's method is used to remove temporary hardness of water, in which bicarbonates of calcium and magnesium are reacted with slaked lime $Ca(OH)_2$.

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