DAY TWENTY ONE

s-Block Elements

Learning & Revision for the Day

- Group 1 Elements (Alkali Metals)
- Compounds of Sodium
- Biological Significance of Na and K
- Group 2 Elements (Alkaline Earth Metals)
- Compounds of Calcium
- Biological Significance of Mg and Ca

Group 1 Elements (Alkali Metals)

- Lithium ($Z = 3$), sodium ($Z = 11$), potassium ($Z = 19$), rubidium ($Z = 37$), caesium ($Z = 55$) and francium ($Z = 87$) are the elements of IA (or 1) group of the periodic table. These elements because of the highly alkaline nature of their water soluble hydroxides are known as **alkali metals.**
- These elements are known as *s*-block elements as their last or valence electron enters in the *s*-orbitals. These all are soft metals.

Electronic Configuration All the alkali metals have one valence electron ns^1 outside the noble gas core. Their general electronic configuration is [noble gas] ns^1. They readily lose electron to give monovalent M^+ ions. Hence, they are never found in free state in nature.

General Trends in Physical Properties

- Alkali metals are most electropositive elements and on moving down the group the electropositive character increases. Therefore, they readily lose electron to give monovalent, M^+ ions.
- The alkali metal atoms have the largest size and on moving down the group, the size of atom increases. Low densities of alkali metals are due to their large size.
- Alkali metals give flame test. The colour of the flame depends upon the wavelength of radiation emitted. Caesium and potassium are used as electrodes in photoelectric cells due to their low ionisation enthalpy.
- Alkali metals are strong reducing agent and down the group, their reducing nature increases.
- Alkali metal compounds are most ionic in nature and down the group, ionic character increases.
- Alkali metal oxides are most basic in nature and down the group, basic character increases.

NOTE The ionisation enthalpies of alkali metals are considerably low and decreases down the group from Li to Cs.

- Hydration enthalpy of alkali metal ions decreases with increase in ionic sizes $Li^+ > Na^+ > K^+ > Rb^+ > Cs^+$. Therefore, Li^+ has maximum degree of hydration and due to this reason lithium salts are mostly hydrated, e.g. $LiCl \cdot 2H_2O$.
- Mobility of their cations in aqueous medium is directly proportional to the size of cation due to poor hydration enthalpy

$$\xrightarrow[\text{Mobility}]{Li^+ < Na^+ < K^+ < Rb^+ < Cs^+}$$

General Trends in Chemical Properties

The alkali metals are highly reactive due to their large size and low ionisation enthalpy. The reactivity of these metals increases down the group.

1. **Reactivity Towards Air**

$$4Li + O_2 \longrightarrow 2Li_2O \text{ (oxide)}$$
$$2\,Na + O_2 \longrightarrow Na_2O_2 \text{(peroxide)}$$
$$M + O_2 \longrightarrow MO_2 \text{ (superoxide) } (M = K, Rb, Cs)$$

- Metal peroxides are diamagnetic and sodium peroxide is widely used as an oxidising agent in inorganic chemistry.
- The superoxides are paramagnetic in nature because of the presence of three electron bonds with one unpaired electron.
- Normal oxides of Li and Na are colourless and diamagnetic, but K_2O is pale yellow, Pb_2O is bright yellow and Cs_2O is orange. Na_2O_2 is yellow due to the presence of small amount of superoxide because superoxide ion, O_2^- has three electron bonds with one unpaired electron.
- KO_2 is used in space capsules, sub-marines and breathing masks as it produces O_2 and removes CO_2 and CO.

2. **Solutions in Liquid Ammonia** The alkali metals dissolve in liquid ammonia giving deep blue solutions which are conducting in nature.

$$M + (x + y)NH_3 \longrightarrow [M(NH_3)_x]^+ + [e(NH_3)_y]^-$$

The blue colour of the solution is due to the ammoniated electrons. The solutions are paramagnetic and on standing, slowly liberate hydrogen resulting in the formation of amide.

$$M^+ + e^- + NH_3(l) \longrightarrow MNH_2 + \frac{1}{2}H_2(g)$$

3. **Reducing Nature** Reducing power of alkali metals in aqueous solution follows the trend: Li > Na > K > Rb > Cs. The standard electrode potential ($E°$) which measures the reducing power represents the overall change.

$M(s) \longrightarrow M(g)$ (sublimation energy)

$M(g) \longrightarrow M^+(g) + e^-$ (ionisation energy)

$H^+(g) + H_2O \longrightarrow M^+(aq)$ (hydration enthalpy)

4. **Carbonates** Alkali metals on exposure to air and moisture get converted into oxides, hydroxides and finally to carbonates,

$$4M + O_2 \longrightarrow 2M_2O \xrightarrow{H_2O} 2MOH \xrightarrow{CO_2} M_2CO_3$$

NOTE (i) Alkali metals are normally kept in kerosene oil because of their high reactivity towards air and water.

(ii) Carbonates of alkali metals are thermally stable except Li_2CO_3 which decomposes readily to evolve CO_2 on heating. Due to the strong polarising action of small cation, Li^+ on the large carbonate ion facilitates their decomposition.

$$Li_2CO_3 \longrightarrow Li_2O + CO_2$$

Anomalous Properties of Lithium

- The anomalous behaviour of Li is due to exceptionally small size (like Mg) and high polarising power (i.e. charge/radius ratio) (like Mg) that exhibits some properties which are different from those of the other members of first group but similar to that of magnesium (present diagonally in the following group, i.e. II group).
- The property of showing similarity in properties with the element present diagonally opposite in the periodic table is called **diagonal relationship**.

  These properties are:

  (i) Alkali metals do not react with nitrogen except Li.

$$6Li + N_2 \xrightarrow{\text{Heat}} \underset{\text{Lithium nitride}}{2Li_3N}$$

(Li metal is used as scavenger in metallurgy to remove O_2 and N_2 gases.)

$$3Mg + N_2 \longrightarrow \underset{\text{Magnesium nitride}}{Mg_3N_2}$$

(ii) Alkali metal carbonates, nitrates and hydroxides do not decompose on heating into their oxides except lithium.

$$NaOH \xrightarrow{\text{Heat}} \text{No reaction}$$
$$2LiOH \xrightarrow{\text{Heat}} Li_2O + H_2O$$
$$Mg(OH)_2 \xrightarrow{\text{Heat}} MgO + H_2O$$
$$Na_2CO_3 \xrightarrow{\text{Heat}} \text{No reaction}$$
$$Li_2CO_3 \xrightarrow{\text{Heat}} Li_2O + CO_2$$
$$MgCO_3 \xrightarrow{\text{Heat}} MgO + CO_2$$
$$4LiNO_3 \xrightarrow{\text{Heat}} 2Li_2O + 4NO_2 + O_2$$
$$2Mg(NO_3)_2 \xrightarrow{\text{Heat}} 2MgO + 4NO_2 + O_2$$
$$2NaNO_3 \longrightarrow 2NaNO_2 + O_2$$

(iii) $MgCl_2$ and LiCl are deliquescent and crystallises as their hydrates, $LiCl \cdot 2H_2O$ and $MgCl_2 \cdot 8H_2O$.

Compounds of Sodium

The compounds of sodium are industrially important therefore, some of them are discussed below:

1. Sodium Carbonate (Washing Soda, $Na_2CO_3 \cdot 10H_2O$)

Preparation

- Sodium carbonate is generally prepared by Solvay process.

$$2NH_3 + H_2O + CO_2 \longrightarrow (NH_4)_2CO_3$$
$$(NH_4)_2CO_3 + H_2O + CO_2 \longrightarrow 2NH_4HCO_3$$
$$NH_4HCO_3 + NaCl \longrightarrow NH_4Cl + NaHCO_3$$

- Sodium hydrogen carbonate crystals gets separated out. These are heated to obtain sodium carbonate.

$$2NaHCO_3 \xrightarrow{150^\circ C} Na_2CO_3 + CO_2\uparrow + H_2O$$

- In this process, NH_3 is recovered when the solution containing NH_4Cl is treated with $Ca(OH)_2$. Solvay process cannot be extended to the manufacture of potassium carbonate because potassium hydrogen carbonate is too soluble to be precipitated to a saturated solution of potassium chloride.

Properties

- Sodium carbonate is soluble in water with the evolution of considerable amount of heat. This solution is alkaline in nature due to hydrolysis.

$$Na_2CO_3 + 2H_2O \rightleftharpoons 2NaOH + H_2CO_3$$

- On passing CO_2 through the concentrated solution of sodium carbonate, sodium bicarbonate gets precipitated

$$Na_2CO_3 + H_2O + CO_2 \longrightarrow 2NaHCO_3$$

- When solution of sodium carbonate and slaked lime is heated, sodium hydroxide is obtained.

$$Na_2CO_3 + Ca(OH)_2 \longrightarrow 2NaOH + CaCO_3$$

2. Sodium Hydroxide (Caustic Soda, NaOH)

Preparation

- Sodium hydroxide is prepared commercially by the electrolysis of sodium chloride in **Castner-Kellner cell** (or mercury cathode cell).

At cathode $Na^+ + e^- \xrightarrow{Hg} Na\text{-}Hg$ (Amalgam)

At anode $Cl^- \longrightarrow \frac{1}{2}Cl_2 + e^-$ (By product)

- The amalgam is treated with water to give sodium hydroxide and hydrogen gas.

$$2Na\text{-}Hg + 2H_2O \longrightarrow 2NaOH + 2Hg + H_2$$

Properties

- Sodium hydroxide is called **caustic soda** because it breaks down proteins of skin to a pasty mass. On exposure to atmosphere it absorbs moisture and CO_2.

$$2\,NaOH + CO_2 \longrightarrow Na_2CO_3 + H_2O$$

- It is a strong alkali so reacts with acids, acidic oxides and amphoteric oxides to form their corresponding salts. Non-metals like halogens, phosphorus, sulphur, silicon, boron also get attacked by NaOH. It reacts with metals like Zn, Al, Sn and Pb and evolve H_2 gas e.g.

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

- It also reacts with metallic salts to form hydroxides. It is used in soap manufacture, purification of bauxite, manufacture of rayon etc.

3. Sodium Hydrogen Carbonate (Baking Soda, $NaHCO_3$)

Preparation

- Sodium hydrogen carbonate is prepared by saturating a solution of Na_2CO_3 (cold) with CO_2.

$$Na_2CO_3 + CO_2 + H_2O \longrightarrow \underset{\text{Sparingly soluble}}{2NaHCO_3}$$

Properties

- Its aqueous solution is alkaline in nature due to hydrolysis.

$$NaHCO_3 + H_2O \rightleftharpoons NaOH + H_2CO_3$$

- If heated, it decomposes to give Na_2CO_3 and CO_2 gas.

$$2NaHCO_3 \xrightarrow{Heat} Na_2CO_3 + H_2O + CO_2$$

- It is used as a medicine to neutralise acidity in stomach.
- It is used as a constituent of baking powder and in fire extinguisher.

Biological Significance of Na and K

- Na^+ ions are found mainly in extracellular region (outside the cell) and play an important role in the transmission of nerve signals. They also regulate the flow of water across cell membranes and in transport of sugars and amino acid into the cells.
- Prolonged sweating results in sodium ion loss in sweat thus, it is important that Na^+ ions are replaced through proper diet.
- Potassium ions are the most abundant cations within cell fluids where they activate many enzymes, which participate in oxidation of glucose to produce ATP (adenosine triphosphate).
- Potassium ions along with sodium ions are responsible for transmission of nerve signals.
  The functional features of nerve cells depend upon the sodium-potassium ion gradient that is established in the cell. Their ionic gradients are maintained by sodium-potassium pumps that operate across the cell membranes.

Group 2 Elements

(Alkaline Earth Metals)

Be, Mg, Ca, Sr, Ba and Ra are also belong to *s*-block and are called alkaline earth metals. These are called 'alkaline earth metals' (except Be) due to the following facts:

(i) Their hydroxides form alkaline aqueous solutions.

(ii) Their oxides are earthen, i.e. their oxides are found in earth crust.

Electronic Configuration

These elements have two electrons in the *s*-orbital of the valence shell. Their general electronic configuration is represented as [noble gas]ns^2.

General Trends in Physical Properties

- These are less metallic as compared to alkali metals. Radium is the radioactive element of this group.
- The alkaline earth metals also have low ionisation enthalpies but these are higher than that of alkali metals.
- The melting and boiling points of these metals are higher than the corresponding alkali metals due to smaller size.
- Except Be and Mg (due to their small size and high IE), all other alkaline earth metals give flame test like calcium, strontium and barium and impart characteristic brick red, crimson and apple green colours, respectively to the flame.

NOTE Like alkali metal ions, the hydration enthalpies of alkaline metal ions decrease with increase in ionic size on moving down the group.

$$Be^{2+} > Mg^{2+} > Ca^{2+} > Sr^{2+} > Ba^{2+}$$

The hydration enthalpies of alkaline earth metal ions are larger than those of alkali metal ions.

General Trends in Chemical Properties

Alkaline earth metals give all the usual reactions of alkali metals. However, these are less reactive as compared to alkali metals in their chemical reactions.

1. **Reaction with Water and Acid** Except Be and Mg, all other alkaline earth metals give hydroxide with cold water while Be forms hydroxide with steam and Mg with hot water.

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

- Except Mg, other members of the group do not give H_2 with HNO_3.

$$Mg + 2HNO_3\ (5\%) \longrightarrow Mg(NO_3)_2 + H_2$$

- With HNO_3, Be becomes passive due to the formation of oxide layer.
- Alkaline earth metal chlorides, nitrates and hydroxides exhibit an increase in their solubilities on moving down the group.

$$\begin{array}{c} MgCl_2 < CaCl_2 < SrCl_2 < BaCl_2 \\ \xrightarrow{\hspace{8cm}} \\ Mg(OH)_2 < Ca(OH)_2 < Sr(OH)_2 < Ba(OH)_2 \end{array}$$

2. **Carbonates** Carbonates of alkaline earth metals are insoluble in water. The solubility of carbonates in water decreases as the atomic number of metal ion increases.

- Beryllium carbonate is unstable and can be kept only in the atmosphere of CO_2. The thermal stability increases with increase in cationic size.
- Bicarbonates of alkali metals are found in solid state whereas, bicarbonates of alkaline earth metals exist only in solution state.

3. **Sulphates** The sulphates of alkaline earth metals are all white solids and stable to heat. $BeSO_4$ and $MgSO_4$ are readily soluble in water. The solubility decreases from $CaSO_4$ to $BaSO_4$.

The insolubility of $BaSO_4$ is used for detecting obstruction in the digestive system by the technique commonly known as barium meal.

4. **Nitrides** All the alkaline earth metals form nitrides, however among the alkali metals, only Li forms nitrides.

$$3Ca + N_2 \longrightarrow Ca_3N_2$$

5. **Halides** Halides of Be are essentially covalent, hygroscopic and fumes in air while halides of other alkaline earth metals are ionic and ionic character increases down the group.

In solid state $BeCl_2$ exists in polymeric chain while in vapour state it tends to form a chloro-bridged dimer which dissociates into the linear monomer at high temperature (1200 K).

6. **Reducing Nature** Reducing character or reactivity of alkaline earth metals increases from Be to Ba, i.e. $Be < Mg < Ca < Sr < Ba$.

- $Mg(ClO_4)_2$ is used as drying agent under the name anhydrone. It is a strong oxidising agent. So, it is not used with organic material.

Anomalous Behaviour of Beryllium

Beryllium due to its exceptionally small size (like Al) and high polarising power (like Al) shows similarities with aluminium, in its properties.

These properties are:

- BeO, like Al_2O_3, is amphoteric and covalent while oxides of other alkaline earth elements are ionic and basic in nature.
- Both $BeCl_2$ and $AlCl_3$ are soluble in organic solvents because of covalent nature and both have a bridged polymeric structure.
- Beryllium hydroxide dissolves in excess of alkali to give a beryllate ion, $[Be(OH)_4]^{2-}$ just as aluminium hydroxide gives aluminate ion, $[Al(OH)_4]^{-}$.

- Beryllium and aluminium ions have strong tendency to form complexes, BeF_4^{2-}, AlF_6^{3-}.
- Carbides of Be are covalent and react with water to produce methane gas whereas carbides of other members are ionic and produce acetylene with water.

Compounds of Calcium

All the alkaline earth metals form several compounds. Some industrially important compounds of calcium are given below:

1. Lime (Quicklime), CaO

Preparation

$$\underset{\text{Limestone}}{CaCO_3} \xrightleftharpoons[1000^\circ C]{\Delta} CaO + CO_2$$

Uses

- It is used in the manufacture of $CaOCl_2$, $Ca(OH)_2$, CaC_2, glass and cement etc.
- It is used as basic lining in the furnaces.
- It is used in the purification of sugar and in water softening.

2. Limestone, $CaCO_3$

Preparation

$$\underset{\text{Slaked lime}}{Ca(OH)_2} + CO_2 \longrightarrow \underset{\text{Milky}}{CaCO_3} + H_2O$$

Uses

- It is used in the manufacture of quick lime, slaked lime, cement, glass and washing soda etc.
- It is used as a flux in smelting of iron and lead ores.

3. Plaster of Paris, $CaSO_4 \cdot \frac{1}{2} H_2O$

Preparation

$$\underset{\substack{\text{Calcium sulphate}\\ \text{dihydrate or gypsum}}}{CaSO_4 \cdot 2H_2O} \xrightarrow[393K]{\Delta} \underset{\substack{\text{Calcium sulphate}\\ \text{hemihydrate or}\\ \text{plaster of Paris}}}{CaSO_4 \cdot \frac{1}{2} H_2O} + 1\frac{1}{2} H_2O$$

Above 393K, no water of crystallisation is left and $CaSO_4$ (anhydrous) is formed.This is called 'dead burnt plaster'.

Uses

- It is used in making toys, decorative materials and casts of statues.
- It is used in medical applications for setting fractured bones in the right position and in dentistry.

Cement

Preparation

- Cement is an important building material. It is obtained by combining a material such as clay which contains silica, SiO_2 along with the oxides of aluminium, iron and magnesium.
- The raw materials for the manufacture of clement are limestone and clay.

Uses

- It is used in plostering and in the construction of bridges, dams and buildings.
- It is used for making concrete and reinforced concrete.

NOTE The average composition of portland cement is 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%.

Biological Significance of Mg and Ca

- Mg^{2+} ions are present inside the animal cells while Ca^{2+} ions are in the body fluids, i.e. in the extracellular region, the same way as K^+ ions are inside the cell and Na^+ ions outside the cell. All enzymes that utilise ATP in phosphate transfer require Mg^{2+} as cofactor. In green plants, magnesium is present in chlorophyll.
- Ca^{2+} and Mg^{2+} are also essential for the transmission of impulses along nerve fibres.
- In bones and teeth, Ca is present as apatite, $Ca_3(PO_4)_2$ and in enamel on teeth as fluorapatite, $2Ca_3(PO_4)_2 . CaF_2$. Ca^{2+} ions play an important role in blood clotting and are required to trigger the contraction of muscles.
- Ca^{2+} ions also regulate the heart beats.

Comparison between the Properties of Alkaline Earth Metals and Alkali Metals

Unlike the members of group I A, the chemistry of II A group elements is not completely dominated by the chemistry of cations.

When compared with alkali metals, it is found that :

- They are less reactive than alkali metals.
- They are less electropositive, i.e. less metallic than alkali metals.
- Their reducing power is much less than those of alkali metals.
- They are less basic than alkali metals.
- The gradation in properties of these elements is not as regular as in the case of alkali metals, because of different structures of their crystal lattices.

The difference in properties with alkali metals is due to:

(i) Smaller size of atoms and ions.

(ii) Stronger metallic bonds (resulting to more density and hardness).

(iii) Higher melting and boiling points.

DAY PRACTICE SESSION 1

FOUNDATION QUESTIONS EXERCISE

1 The electronic configuration of metal M is $1s^2, 2s^2 2p^6, 3s^1$. The formula of its oxide would be

(a) MO (b) M_2O (c) M_2O_3 (d) MO_2

2 The characteristic not related to alkali metal is

(a) high ionisation energy
(b) their ions are isoelectronic with noble gases
(c) low melting point
(d) low electronegativity

3 Which of the following reacts with water at a high rate?

(a) Li (b) K (c) Na (d) Rb

4 Among Na^+, Na, Mg and Mg^{2+} the largest particle is

(a) Mg^{2+} (b) Mg (c) Na (d) Na^+

5 The ionic conductance of following cation in a given concentration are in the order

(a) $Li^+ < Na^+ < K^+ < Rb^+$ (b) $Li^+ > Na^+ > K^+ > Rb^+$
(c) $Li^+ < Na^+ > K^+ > Rb^+$ (d) $Li^+ = Na^+ < K^+ < Rb^+$

6 The reducing power of a metal depends on various factors. Suggest the factor which makes Li, the strongest reducing agent in aqueous solution.

(a) Sublimation enthalpy (b) Ionisation enthalpy
(c) Hydration enthalpy (d) Electron gain enthalpy

7 The stability of the following alkali metal chlorides follows the order

(a) LiCl > KCl > NaCl > CsCl
(b) CsCl > KCl > NaCl > LiCl
(c) NaCl > KCl > LiCl > CsCl
(d) KCl > CsCl > NaCl > LiCl

8 The main oxides formed on combustion of Li, Na and K in excess of air respectively are ➜ 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

9 The metallic sodium dissolves in liquid ammonia to form a deep blue coloured solution. The deep blue colour is due to the formation of

(a) solvated electron, $e^-(NH_3)_x$
(b) solvated atomic sodium, $Na(NH_3)_4$
(c) $(Na^+ + Na^-)$
(d) $NaNH_2 + H_2$

10 The solubilities of carbonates decrease down the group due to a decrease in

(a) lattice energies of solid
(b) hydration energies of cations
(c) interionic attraction
(d) entropy of solution formation

11 Consider the following abbreviations for hydrated alkali ions.

$X = [Li(H_2O)_n]^+$; $Y = [K(H_2O)_n]^+$; $Z = [Cs(H_2O)_n]^+$

What is the correct order of size of these hydrated alkali ions?

(a) $X > Y > Z$ (b) $Z > Y > X$
(c) $X = Y = Z$ (d) $Z > X > Y$

12 The gas evolved on heating Na_2CO_3 is

(a) CO_2 (b) water vapour
(c) CO (d) No gas is evolved

13 Sodium is heated in air at 350°C to form A. Compound A when reacts with carbon dioxide forms sodium carbonate and Y. Here, Y is

(a) hydrogen peroxide (b) hydrogen
(c) ozone (d) oxygen

14 When CO is passed over solid NaOH heated to 200°C, it forms

(a) Na_2CO_3 (b) H_2CO_3
(c) HCOONa (d) All of these

15 Which one of the following is true?

(a) NaOH is used in the concentration of bauxite ore
(b) NaOH is a primary standard in volumetric analysis
(c) Managanous hydroxide is soluble in excess of NaOH solution
(d) NaOH solution does not react with Cl

16 A sodium salt on treatment with $MgCl_2$ gives white precipitate only on heating. The anion of sodium salt is

(a) HCO_3^- (b) CO_3^{2-}
(c) NO_3^- (d) SO_4^{2-}

17 Solubility of the alkaline earth's metal sulphates in water decreases in the sequence ➜ CBSE-AIPMT 2015

(a) Mg > Ca > Sr > Ba (b) Ca > Sr > Ba > Mg
(c) Sr > Ca > Mg > Ba (d) Ca > Mg > Sr > Ca

18 Solubility of alkaline earth metal sulphates decreases down the group 2 because

(a) they become more ionic
(b) lattice energy of sulphates does not vary significantly
(c) hydration energy decreases rapidly from Be^{2+} to Ba^{2+}
(d) lattice energy plays more predominant role than hydration energy

19 The correct order of increasing ionic character is

(a) $BeCl_2 < MgCl_2 < CaCl_2 < BaCl_2$
(b) $BeCl_2 < MgCl_2 < BaCl_2 < CaCl_2$
(c) $BeCl_2 < BaCl_2 < MgCl_2 < CaCl_2$
(d) $BaCl_2 < CaCl_2 < MgCl_2 < BaCl_2$

20 Which pair of the following chlorides does not impart colour to the flame?

(a) $BeCl_2$ and $SrCl_2$
(b) $BeCl_2$ and $MgCl_2$
(c) $CaCl_2$ and $BaCl_2$
(d) $BaCl_2$ and $SrCl_2$

21 In context with beryllium, which one of the following statements is incorrect?

(a) It is rendered passive by nitric acid
(b) It forms Be_2C
(c) Its salts are rarely hydrolysed
(d) It hydride is electron-deficient and polymeric

22 Beryllium and aluminium exhibit many properties which are similar but the two elements differ in

(a) exhibiting maximum covalency in compounds
(b) forming polymeric hydrides
(c) tendency of forming chelate type complexes.
(d) exhibiting amphoteric nature in their oxides

23 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) $BaCO_3$

24 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) $Ba(OH)_2$

25 Which of the following statements are 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

26 The solubilities of carbonates decreases down the magnesium group due to decrease in

(a) lattice energies of solids
(b) hydration energies of cations
(c) interionic attraction
(d) entropy of solution formation

27 Which one of the following alkaline earth metal sulphates has its hydration enthalpy greater than its lattice enthalpy? → JEE Main 2015

(a) $CaSO_4$ (b) $BeSO_4$
(c) $BaSO_4$ (d) $SrSO_4$

28 Among the following, which is insoluble in water?

(a) Sodium fluoride (b) Potassium fluoride
(c) Beryllium fluoride (d) Magnesium fluoride

29 Which of the following on thermal decomposition yields a basic as well as acidic oxide? → AIEEE 2012

(a) $NaNO_3$ (b) $KClO_3$
(c) $CaCO_3$ (d) NH_4NO_3

30 Match the following and choose the correct option.

	Column I		Column II
A.	Li	1.	Insoluble oxalate
B.	Na	2.	Strongest monoacidic base
C.	Ca	3.	Most negative $E^{\ominus}$ value among alkali metals
D.	Ba	4.	$6s^2$ outer electronic configuration

Codes

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

31 Which of the following statements(s) is/are correct?

(a) Group 2 metals are denser and harder than group 1 metals
(b) Group 1 metals are less electropositive than group 2 metals
(c) The first ionisation energy of group 1 metals is more than that of group 2 metals
(d) All of the above statements are incorrect

Direction (Q. Nos. 32-35) *In the following questions Assertion* (A) *followed by reason* (R) *is given. Choose the correct option out of the choices given bleow*:

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

32 **Assertion** (A) The carbonate of lithium decomposes easily on heating to form lithium oxide and CO_2.

Reason (R) Lithium being very small in size polarises large carbonate ion leading to the formation of more stable Li_2O and CO_2.

33 **Assertion** (A) Beryllium carbonate is kept in the atmosphere of carbon dioxide.

Reason (R) Beryllium carbonate is unstable and decomposes to give beryllium oxide and carbon dioxide.

34 **Assertion** (A) Among the alkali metals, lithium salts exhibit the least electrical conductance in aqueous solutions.

Reason (R) Smaller the radius of the hydrated cation, lower is the electrical conductance in aqueous solutions.

35 **Assertion** (A) $BaCO_3$ is more soluble in HNO_3 than in water.

Reason (R) Carbonate is a weak base and reacts with H^+ from the strong acid, causing the barium salt to dissociate.

DAY PRACTICE SESSION 2

PROGRESSIVE QUESTIONS EXERCISE

1 A mixture contains two moles of Na_2CO_3 and 1 mole of Li_2CO_3. What will be the volume of CO_2 formed on heating this mixture and the data is converted to STP?

(a) 22.4 L (b) 44.8 L (c) 50.2 L (d) 11.2 L

2 A metal *M* readily forms water soluble MSO_4. It also forms oxide *MO* which becomes inert on heating. Hydroxide $M(OH)_2$ is insoluble in water but soluble in NaOH solution. What is *M*?

(a) Mg (b) Ba (c) Ca (d) Be

3 Mg has favourbale standard reduction electrode potential ($E^\circ_{Mg^{2+}/Mg} = -2.37$ V) but it does not react readily. It is because of

(a) its resemblance to Li
(b) formation of protective oxide layer
(c) its oxidising nature
(d) its reaction with acids

4 In group 2, the electrons are more firmly held to the nucleus and hence

(a) ionisation energy of group 2 is greater than group 1
(b) atoms of group 2 are bigger than group 1
(c) reactivity of group 2 is greater than group 1
(d) group 2 metals are less abundant in nature

5 Element *A* burns in nitrogen to give an ionic compound *B*. Compound *B* reacts with water to give *C* and *D*. The solution of *C* becomes milky on bubbling carbon dioxide. The element *A* is

(a) Li (b) Mg
(c) Ca (d) Be

6 On dissolving moderate amount of sodium metal in liquid NH_3 at low temperature, which one of the following does not occur ?

(a) Blue coloured solution is obtained
(b) Na^+ ions are formed in the solution
(c) Liquid NH_3 solution becomes good conductor of electricity
(d) Liquid NH_3 solution remains diamagnetic

7 The atomic radius for Li and Li^+ are 1.23 Å and 0.76 Å respectively. Assuming that the difference in ionic radii relates to the space occupied by 2*s*-electrons. What will be the % of volume of Li atom occupied by single valence electron?

(a) 70.0% (b) 30.0% (c) 24.75% (d) 76.34%

8 A chemical *A* is used for the preparation of washing soda to recover ammonia. When CO_2 is bubbled through an aqueous solution of *A*, the solution turns milky. It is used in white washing due to disinfectant nature. What is the chemical formula of *A*?

(a) $Ca(HCO_3)_2$ (b) CaO (c) $Ca(OH)_2$ (d) $CaCO_3$

9 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) $SrCl_2$

10 A binary salt of potassium '*A*' gives compound '*B*' when heated with S. Compound '*B*' forms white precipitate '*C*' with barium chloride which is insoluble in conc.HCl. 7.1 g of '*A*' gave 11.15 g of white precipitate '*C*'. The compound '*A*' is

(a) KO_2 (b) K_2SO_4 (c) KOH (d) K_2CO_3

11 Select the correct statements(s).

(a) $CaCO_3$ is more soluble in a solution of CO_2 than in H_2O
(b) Na_2CO_3 is converted to Na_2O and CO_2 on heating
(c) Li_2CO_3 is thermally stable
(d) Presence of $CaCl_2$ or $CaSO_4$ in water causes temporary hardness

12 The charge/size ratio of a cation determines its polarising power. Which one of the following sequences represents the increasing order of the polarising power of cationic species; K^+, Ca^{2+}, Mg^{2+}, Be^{2+}?

(a) $Mg^{2+} < Be^{2+} < K^+ < Ca^{2+}$ (b) $Be^{2+} < K^+ < Ca^{2+} < Mg^{2+}$
(c) $K^+ < Ca^{2+} < Mg^{2+} < Be^{2+}$ (d) $Ca^{2+} < Mg^{2+} < Be^{2+} < K^+$

13 0.2 g of magnesium ribbon was placed in a crucible and heated with a lid on until the magnesium began to burn rapidly. At the end of the experiment there was 0.3 g of a white powder left. This result does not agree with the equation; $2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$. It can be due, to

(a) some MgO may have escaped as vapours
(b) some Mg may not have reacted
(c) some Mg_3N_2 can be formed
(d) All of the above

14 Choose the incorrect statement.

(a) $BeCO_3$ is kept in the atmosphere of CO_2 since, it is least thermally stable
(b) Be dissolves in alkali forming $[Be(OH)_4]^{2-}$
(c) BeF_2 forms complex ion with NaF in which Be goes with cation
(d) BeF_2 forms complex ion with NaF in which Be goes with anion

15 Dehydration of hydrates of halides of calcium, barium and strontium, i.e. $CaCl_2 \cdot 6H_2O$, $BaCl_2 \cdot 2H_2O$, $SrCl_2 \cdot 2H_2O$, can be achieved by heating.
These become wet on keeping in air. Which of the following statements are correct about these halides?

(a) Act as dehydrating agent
(b) Can absorb moisture from air
(c) Tendency to form hydrate decreases from to barium
(d) All of the above

ANSWERS

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

Hints and Explanations

SESSION 1

1 Electronic configuration indicates that the metal is univalent (alkali metal). Its oxide will be M_2O.

2 Alkali metals have low ionisation energy. They possess minimum value of ionisation energy in their period due to their large sizes.

3 Rb being most electropositive has the highest reactivity towards water.

4 Atomic radii of alkali metals are largest in the corresponding period. Moreover, size of monovalent alkali metal ion is always smaller than its parent atom. Thus, Na is the largest particle among the given metals.

5 Conductance of cation in aqueous solution is dependent upon its hydrates size as ionic conductance $\propto \frac{1}{\text{ionic size of hydrate ion}}$. Thus, ionic conductance in aqueous solution increases in the order $Li^+ < Na^+ < K^+ < Rb^+$. This is because the size of hydrated ion is minimum for Rb^+ among given hydrates alkali metal ions.

6 Hydration enthalpy of Li^+ is highest among all other alkali metal due to its smaller size. Therefore, Li^+ acts as a strong reducing agent.

7 Stability of a compound depends upon its enthalpy of formation ΔH_f. The more negative value of ΔH_f shows more stability of a compound.

ΔH_f for LiCl $= -408.8\ \text{kJ mol}^{-1}$,

ΔH_f for NaCl $= -412.5\ \text{kJ mol}^{-1}$

ΔH_f for CsCl $= -433\ \text{kJ mol}^{-1}$,

ΔH_f for KCl $= -436\ \text{kJ mol}^{-1}$

Thus, KCl is more stable and LiCl is least stable.

Hence, (d) option is correct.

8 $2Li + \underset{\text{(Excess)}}{\frac{1}{2}O_2(g)} \longrightarrow Li_2O$

$$2Na + \underset{\text{(Excess)}}{O_2(g)} \longrightarrow Na_2O_2$$

$$K + \underset{\text{(Excess)}}{O_2(g)} \longrightarrow KO_2$$

9 $Na \rightleftharpoons Na^+ \text{ (in liq. } NH_3) + e^-$

$$e^- + xNH_3 \longrightarrow \underset{\substack{\text{Ammonia solvated}\\ \text{electron}}}{e(NH_3)_x^-}$$

10 Solubilities of carbonates decrease down the group because lattice energy decrease is almost constant while decrease in hydration energy happens sharply.

Finally difference of hydration energy and lattice energy decreases, thus solubility decreases.

11 All alkali metal salts are soluble in water. The degree of hydration depends upon the size of the cation. Smaller the size of cation, greater is its charge density and hence, greater is its tendency to withdraw electrons from molecules which are thus polarised. Li^+ ion being smallest in size among alkali metal ions is the most extensively hydrated while Cs^+ ion being the largest alkali metal ion is the least hydrated. The size of hydrated alkali ions is as

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

Hence, the correct order is $X > Y > Z$.

12 On heating Na_2CO_3, no gas is evolved.

13 $2Na + O_2 \xrightarrow{350°C} \underset{A}{Na_2O_2}$

$$2Na_2O_2 + 2CO_2 \longrightarrow 2Na_2CO_3 + \underset{Y}{O_2}$$

14 $\underset{\text{Solid}}{NaOH} + CO \xrightarrow{200°C} \underset{\text{Sodium formate}}{HCOONa}$

15 NaOH is used in concentration of bauxite ore. Impure bauxite is treated with NaOH with which it forms water soluble sodium meta aluminate complex.

$$Al_2O_3 \cdot 2H_2O + 2NaOH \xrightarrow{420\text{-}425\,K} \underset{\substack{\text{Sodium meta}\\ \text{aluminate}}}{2NaAlO_2} + 3H_2O$$

Impurities such as Fe_2O_3, TiO_2 and silica are left behind.

Pure alumina is recovered from solution.

$$NaAlO_2 + 2H_2O \longrightarrow Al(OH)_3 + NaOH$$

$$2Al(OH)_3 \xrightarrow{\Delta} Al_2O_3 + 2H_2O$$

16 $2NaHCO_3 + MgCl_2 \xrightarrow{\Delta} \underset{\text{White ppt.}}{(Mg(HCO_3)_2} + 2NaCl$

17 $Mg > Ca > Sr > Ba$

This is because down the group the hydration energies of cations decreases.

18 Due to very large size of sulphate ions, the magnitude of lattice energy of alkaline earth metal sulphates remains almost constant. While the hydration energy decreases rapidly down the group. Thus, their solubility is governed by only hydration energy which decreases from Be^{2+} to Ba^{2+}.

19 Larger the size of the cation, smaller the polarising power and thus larger the ionic nature.

Size (cation) $Be^{2+} < Mg^{2+} < Ca^{+} < Ba^{2+}$

Ionic nature

$$BeCl_2 < MgCl_2 < CaCl_2 < BaCl_2$$

20 Among the alkaline earth metals, the size of beryllium and magnesium metals is very small. Therefore, the electrons in these metals are bounded more strongly and are not excited by the energy of flame to higher energy states.

Hence, these metals or their salts do not impart any colour to the flame.

21 Due to small size and high hydration energy of Be^{2+} ions, its salts are easily hydrolysed.

22 Be ($Z = 4$) has maximum covalency of four while Al ($Z = 13$) has maximum covalency of 6.

23 $BaCO_3$ is thermally most stable because of the small size of resulting oxide ion. With the increase in atomic number, the size of the metal ion, the stability of the metal ion decreases and, hence that of carbonate increases, i.e. from Be to Ba.

Therefore, the increasing size of cation destabilises the oxides and hence, does not favour the decomposition of heavier alkaline earth metal carbonates like $BaCO_3$.

24 The solubility of hydroxides of alkaline earth metals increases from Be to Ba, in water.

Due to high hydration enthalpy and high lattice energy, $Be(OH)_2$ is not soluble in water.

25 Calcium hydroxide is used in the manufacturing of bleaching powder.

$$\underset{\text{Slaked lime}}{2Ca(OH)_2} + 2Cl_2 \longrightarrow CaCl_2 + \underset{\text{Bleaching powder}}{Ca(OCl)_2} + 2H_2O$$

26 The solubilities of carbonates decreases down the magnesium group due to decrease in hydration energy because hydration energy inversely proportional to ionic size. As the size increases, hydration enthalpy of metal ions decreases from Mg^{2+} to Ba^{2+}.

27 As we move down the group, size of metal increases. Be has lower size while SO_4^{2-} has bigger size, that's why $BeSO_4$ breaks easily and lattice energy becomes smaller but due to smaller size of Be, water molecules are gathered around and hence, hydration energy increases. On the other hand, rest of the metals, i.e. Ca, Ba, Sr have bigger size and that's why lattice energy is greater than hydration energy.

28 The fluorides of alkaline earth metals except beryllium fluoride are insoluble in water because of high hydration energy of small Be^{2+} ion. Hence, magnesium fluoride is insoluble in water.

29 (a) $2NaNO_3 \xrightarrow{\Delta} 2NaNO_2 + O_2$

(b) $2KClO_3 \xrightarrow{\Delta} 2KCl + 3O_2$

(c) $CaCO_3 \xrightarrow{\Delta} \underset{\text{Basic}}{CaO} + \underset{\text{Acidic}}{CO_2}$

(d) $NH_4NO_3 \xrightarrow{\Delta} \underset{\text{Neutral}}{N_2O} + \underset{\text{Neutral}}{H_2O}$

30 A → 3, B → 2, C → 1, D → 4

31 (a) Group 2 metals are denser and harder than group 1 metals. Thus statement is correct.

(b) Group 1 metals are more electropositive than group 2 metals. Thus statement is incorrect.

(c) The first ionisation energy of group 2 metals is more than that of group 1 metals. Thus, statement is incorrect.

32 The thermal stability of carbonates increases down the group. Hence, Li_2CO_3 is least stable.

Due to small size of Li^{+}, strong polarising power distorts the electron cloud of CO_3^{2-} ion. High lattice energy of Li_2O than Li_2CO_3 also favours the decomposition of Li_2CO_3.

33 BeO is more stable than $BeCO_3$ due to small size and high polarising power of Be^{2+}.

As $BeCO_3$ is unstable and BeO is more stable thus, when $BeCO_3$ is kept in an atmosphere of CO_2, a reversible process takes place and stability of $BeCO_3$ increases.

$$BeCO_3 \rightleftharpoons BeO + CO_2$$

34 Li^{+} ion being largest in size becomes highly hydrated, hence moves slowly under the influence of electric field (poorest conductor).

35 Both Assertion and Reason are correct and Reason is the correct explanation of the Assertion. $BaCO_3$ is more soluble in HNO_3 than in water as CO_3^{2-} reacts with H^{+} to form HCO_3^{-} that causes $BaCO_3$ to dissociate more than it would do in water.

SESSION 2

1 Decomposition of Li_2CO_3

$$\underset{\text{1 mol}}{Li_2CO_3} \xrightarrow{\Delta} Li_2O + \underset{\text{22.4 L}}{CO_2}$$

Na_2CO_3 is thermally stable, i.e. it doesn't give CO_2 gas on heating.

Hence, volume of CO_2 formed on heating the mixture at STP is 22.4 L.

2 On moving down, water solubility of alkaline earth metal decreases. Oxides of Be is amphoteric hence soluble in NaOH.

$$BeO \xrightarrow{H_2O} \underset{\text{Insoluble}}{Be(OH)_2} \xrightarrow{NaOH} \underset{\text{Soluble}}{Na_2[Be(OH)_4]}$$

3 It is because of protective oxide (MgO) layer, which makes it unreactive.

4 Since the electrons are more tightly held to the nucleus, because of its small size, thus it is difficult to remove the electrons and hence more energy is required.

5 Carbon dioxide turns only lime water milky. Thus, the compound C must be $Ca(OH)_2$ and the element A must be Ca. The reactions are as follows:

$$\underset{A}{3Ca} + N_2 \longrightarrow \underset{B}{Ca_3N_2}$$

$$\underset{B}{Ca_3N_2} + 6H_2O \longrightarrow \underset{C}{3Ca(OH)_2} + \underset{D}{2NH_3}$$

$$\underset{C}{Ca(OH)_2} + CO_2 \longrightarrow \underset{\text{Milky}}{CaCO_3} + H_2O$$

6 The alkali metals dissolve in liquid ammonia giving deep blue solution which are conducting in nature.

$$M + (x + 2y)\,NH_3 \longrightarrow \underset{\text{(Deep blue)}}{[M(NH_3)_x]^{2+}} + 2\,[e^{-}(NH_3)_y]^{-}$$

7 Volume occupied by Li^+

$$= \frac{4}{3}\pi \times (0.76 \times 10^{-8})^3$$

Volume occupied by Li

$$= \frac{4}{3}\pi \times (1.23 \times 10^{-8})^3$$

$\therefore$ Volume occupied by 2*s*-electron

$$= \frac{4}{3}\pi \times [(1.23)^3 - (0.76)^3] \times (10^{-8})^3$$

$\therefore$ % volume occupied by 2*s*-electron of Li- atom

$$= \frac{\frac{4}{3}\pi \times [\{(1.23)^3\} - (0.76)^3\} \times (10^{-8})]^3}{\frac{4}{3}\pi \times [1.23 \times 10^{-8}]^3} \times 100$$

$$= \frac{1.42}{(1.23)^3} \times 100 = 76.34\%$$

8 For the recovery of ammonia, $Ca(OH)_2$ is used during the preparation of washing soda.

$$\underset{A}{Ca(OH)_2} + CO_2 \longrightarrow \underset{\text{Milky}}{CaCO_3} + H_2O$$

9 Ethanol is an organic compound, i.e. of covalent character. As we know ''like dissolves like''. So, to dissolve in ethanol the compound should have more covalent character. Beryllium halides have covalent character due to small size and high effective nuclear charge. Hence, $BeCl_2$ is most covalent among all other chlorides.

10 $$\underset{\underset{A}{142\text{ g}}}{2KO_2} + S \xrightarrow{\Delta} \underset{B}{K_2SO_4},\ \underset{B}{K_2SO_4} + BaCl_2 \longrightarrow \underset{\underset{C}{223\text{ g}}}{BaSO_4}\downarrow + 2KCl$$

$\because$ 142 g KO_2 gives = 223 g $BaSO_4$

$\therefore$ 7.1 g KO_2 will give $= \frac{223}{142} \times 7.1 = 11.15$ g $BaSO_4$

11 (a) $CaCO_3 + H_2O + CO_2 \longrightarrow \underset{\text{Soluble}}{Ca(HCO_3)_2}$

(b) $Na_2CO_3 \xrightarrow{\Delta}$ No effect

(c) $Li_2CO_3 \xrightarrow{\Delta} Li_2O + CO_2$ (even at room temperature)

(d) Temporary hardness is due to soluble carbonates and bicarbonates.

12 Smaller the size of cations, larger the charge, larger the polarising power of the cations.

	Be^{2+}	Mg^{2+}	Ca^{2+}	K^+
Z (atomic number)	4	12	20	19
Charge	+2	+2	+2	+1
Size	$Be^{2+} <$	$Mg^{2+} <$	$Ca^{2+} <$	K^+
Polarising power	$Be^{2+} >$	$Mg^{2+} >$	$Ca^{2+} >$	K^+

13 $$\underset{2 \times 24\text{ g}}{2Mg(s)} + O_2(g) \longrightarrow \underset{2 \times 40\text{ g}}{2MgO}$$

48 g of Mg gives = 80 g of MgO

0.2 g of Mg gives $= \frac{80}{48} \times 0.2 = 0.33$ g of MgO

But residue left = 0.30. It is due to all of the given options.

14 $$BeF_2 + 2NaF \longrightarrow \underbrace{2Na^+}_{\text{Cation}} + \underbrace{BeF_4^{2-}}_{\text{Anion}}$$

Thus, (c) is incorrect (Be goes with anion).

15 Chlorides of alkaline earth metals are hydrated salts. Due to their hygroscopic nature, they can be used as a dehydrating agent, to absorb moisture from air.

Extent of hydration decreases from Mg to Ba, i.e.

$MgCl_2 \cdot 6H_2O$, $CaCl_2 \cdot 6H_2O$, $SrCl_2 \cdot 2H_2O$, $BaCl_2 \cdot 2H_2O$