10

The *s*-Block Elements

Multiple Choice Questions (MCQs)

Q. 1 The alkali metals are low melting. Which of the following alkali metal is expected to melt if the room temperature rises to 30°C?

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

Ans. *(d)* The energy binding the atoms in the crystal lattice of the alkali metals is low due to their large atomic radii and especially due to the presence of one valence electron per metal atom as compared to large number available vacant orbitals.

Hence, alkali metals have low melting and boiling points. The melting point of alkali metals decreases from Li to Cs as cohesive force decreases with increase in atomic size.

Melting point of Cs = 302 K *i.e.*, 29°C.

Q. 2 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

Ans. *(a)* Li has most negative standard reduction potential due to very high enthalpy of hydration. Thus, reaction of Li with water will be most exothermic, but surprisingly Li reacts with water gently, whereas Na and K vigorously.

The explanation is in kinetics and not in thermodynamics of the reaction. No doubt, maximum energy is evolved with Li but its fusion, vaporisation and ionisation consume more energy. As a result reaction proceeds slowly.

Na or K have low melting points and molten metal spreads over water exposing a larger surface to water, making the reaction vigorous.

Q. 3 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

Ans. *(c)* Standard reduction potential (E°_{RP}) is a measure of tendency of an element to lose electron in aqueous solution. Higher the negative E°_{RP} greater is the ability to lose electrons.

E°_{RP} *depends on*

(i) enthalpy of sublimation
(ii) ionisation enthalpy
(iii) enthalpy of hydration

Thus, in aqueous medium, order of reactivity of alkali metals is Na < K < Rb < Cs < Li.

E°_{RP} value of Li is least (–3.04 V) among all alkali metals.

The formation of $Li^+(aq)$ *from* Li *involves following steps*

(i) $Li(s) \xrightarrow{\text{Sublimation}} Li\,(g)$ ΔH_s = Enthalpy of sublimation

(ii) $Li(g) \longrightarrow Li^+(s)$ IE_1 = Ionisation enthalpy

(iii) $Li^+(g) \longrightarrow Li^+(aq)$ ΔH_n = Enthalpy of hydration

For alkali metals, enthalpies of sublimation are almost same. IE_1 value of Li is endothermic and highest and hydration is exothermic and maximum for Li^+.

The highly exothermic step (iii) for smallest Li^+ makes it strongest reducing agent.

Q. 4 **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) $BaCO_3$

Thinking Process

All the alkaline earth metals form carbonates having general formula MCO_3. *These carbonates decompose on heating to form metal oxide and carbon dioxide.*

$$MCO_3 \rightleftharpoons 1\ MO + CO_2 \qquad [M = \text{Be, Mg, Ca, Sr, Ba}]$$

Thermal stability of carbonates increases with increase in atomic number, i.e., on moving down the group

$$BeCO_3 < MgCO_3 < CaCO_3 < SrCO_3 < BaCO_3.$$

Ans. ***(d)*** $BaCO_3$ 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 (maximum in case of $BaCO_3$).

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

Q. 5 **Which of the carbonates given below is unstable in air and is kept in CO_2 atmosphere to avoid decomposition?**

(a) $BeCO_3$ (b) $MgCO_3$ (c) $CaCO_3$ (d) $BaCO_3$

Ans. ***(a)*** $BeCO_3$ is unstable to the extent that it is stable only in atmosphere of CO_2. $BeCO_3$ shows reversible reaction because stability of oxide formed is more than carbonates.

$$BeCO_3 \rightleftharpoons BeO + CO_2$$

$BeCO_3$ is unstable due to strong polarising effect of small Be^{2+} ion on the large polarisable carbonation. Moreover, an extrastability of the oxide achieved through lattice energy by packing small cation with small oxide ion.

Q. 6 **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) $Ba(OH)_2$

Ans. ***(a)*** All the alkaline earth metals form hydroxides. Solubility of hydroxides of alkaline earth metals increases from Be to Ba. $Be(OH)_2$ and $Mg(OH)_2$ are almost insoluble.

The basic nature of hydroxides of alkaline earth metal depends on the solubility of hydroxide in water. More the solubility more the basicity. Solubility of hydroxides depends on lattice energy and hydration energy.

$$\Delta H_{\text{solution}} = \Delta H_{\text{lattice energy}} + \Delta H_{\text{hydration energy}}$$

The magnitude of hydration energy remains almost same whereas lattice energy decreases down the group leading to more negative values for $\Delta H_{\text{solution}}$ down the group.

More negative $\Delta H_{\text{solution}}$ more is solubility of compounds.

Hence, $Be(OH)_2$ and $Mg(OH)_2$ have less negative values for $\Delta H_{\text{solution}}$ hence, least basic.

Q. 7 **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) $SrCl_2$

Ans. ***(a)*** Ethanol is an organic compound *i.e.*, of covalent character ‘‘Like dissolves like’’. 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.

Q. 8 **The order of decreasing ionisation enthalpy in alkali metals is**

(a) Na > Li > K > Rb (b) Rb < Na < K < Li

(c) Li > Na > K > Rb (d) K < Li < Na < Rb

Thinking Process

Ionisation energies depend upon how strongly the valence electron is held by the nucleus. Ionisation energy value will be high if electron is tightly held and if interaction between electron and nucleus is poor then ionisation energy will be low.

Ans. ***(c)*** On moving down in the group (from Li to Cs), the ionisation energy value decreases from Li to Cs, size of the atom increases and so valence electron is less tightly held. Increased screening effect from Li to Cs also makes the removal of electron easier.

Q. 9 **The solubility of metal halides depends on their nature, lattice enthalpy and hydration enthalpy of the individual ions. Amongst fluorides of alkali metals, the lowest solubility of LiF in water is due to**

(a) ionic nature of lithium fluoride

(b) high lattice enthalpy

(c) high hydration enthalpy for lithium ion

(d) low ionisation enthalpy of lithium atom

Ans. ***(b)*** Solubilities of alkali metal halides in water can be explained in terms of lattice enthalpy and hydration enthalpy. Lower lattice enthalpies and higher hydration enthalpies favour dissolution.

Among fluorides, the order of solubility is LiF < NaF < KF < RbF < CsF. Low solubility of LiF is due to very high lattice energy. On moving down in the group LiF to CsF, solubility increases because lattice energy decreases.

Except LiF, other halides of lithium are highly soluble in water.

Q. 10 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) $Ba(OH)_2$

Ans. *(a)* The solubility of hydroxides of alkaline earth metals increases from Be to Ba, in water. $Be(OH)_2$ and $Mg(OH)_2$ are almost insoluble.

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

$Be(OH)_2$ is an amphoteric hydroxide. With acids, $Be(OH)_2$ is neutralised giving salts.

$$Be(OH)_2 + 2HCl \longrightarrow BeCl_2 + 2H_2O$$

$Be(OH)_2$ reacts with NaOH also forming beryllate.

$$Be(OH)_2 + 2NaOH \longrightarrow Na_2BeO_2 + 2H_2O$$

Q. 11 In the synthesis of sodium carbonate, the recovery of ammonia is done by treating NH_4Cl with $Ca(OH)_2$. The by-product obtained in this process is

(a) $CaCl_2$ (b) NaCl (c) NaOH (d) $NaHCO_3$

Ans. *(a)* Sodium carbonate is synthesised by Solvay ammonia soda process.

The reactions involved are

$$NH_3 + H_2O + CO_2 \longrightarrow \underset{\text{Ammonium bicarbonate}}{NH_4HCO_3}$$

$$NaCl + NH_4HCO_3 \longrightarrow \underset{\text{Sodium bicarbonate}}{NaHCO_3} \downarrow + NH_4Cl$$

$$2NaHCO_3 \xrightarrow{\Delta} \underset{\text{Sodium carbonate}}{Na_2CO_3} + H_2O + CO_2$$

NH_3 is recovered from NH_4HCO_3 and NH_4Cl formed during the reaction.

$$NH_4HCO_3 \xrightarrow{\text{Heat}} NH_3 + H_2O + CO_2$$

$$\underset{\text{Ammonium chloride}}{2NH_4Cl} + Ca(OH)_2 \longrightarrow \underset{\text{Ammonia}}{2NH_3} + \underset{\text{Calcium chloride}}{CaCl_2} + 2H_2O$$

Q. 12 When sodium is dissolved in liquid ammonia, a solution of deep blue colour is obtained. The colour of the solution is due to

(a) ammoniated electron (b) sodium ion

(c) sodium amide (d) ammoniated sodium ion

Ans. *(a)* All alkali metal dissolve in liquid NH_3 giving highly conducting deep blue solution.

$$Na + (x + y)\, NH_3 \longrightarrow \underset{\text{Ammoniated cation}}{[Na\,(NH_3)x]^+} + \underset{\text{Ammoniated electron}}{e(NH_3)_y^-}$$

When light fall on these solutions, the ammoniated electrons excite in higher energy level by absorbing red wavelengths and so transmitted light is blue.

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

Ans. *(b)* Raw materials for cement-limestone, clay, gypsum. Cement is a dirty greyish heavy powder containing calcium aluminates and silicates.

Gypsum ($CaSO_4 \cdot 5H_2O$) is added to the components to increase the setting time of cement so that it gets sufficiently hardened. Setting of cement is an exothermic process and involves hydration of calcium aluminates and silicates.

Q. 14 Dead burnt plaster is

(a) $CaSO_4$ (b) $CaSO_4 \cdot \frac{1}{2}H_2O$ (c) $CaSO_4 \cdot H_2O$ (d) $CaSO_4 \cdot 2H_2O$

Ans. *(a)* Plaster of Paris is prepared by heating gypsum at 120°C.

$$\underset{\text{Gypsum}}{2CaSO_4 \cdot 2H_2O} \longrightarrow \underset{\text{Plaster of Paris}}{(CaSO_4)_2 \cdot \frac{1}{2}H_2O} + 3H_2O$$

On heating plaster of Paris at 200°C, if forms anhydrous calcium sulphate *i.e.,* dead plaster which has no setting property as it absorbs water very slowly.

$$CaSO_4 \cdot \frac{1}{2}H_2O \xrightarrow{200^\circ C} \underset{\text{Anhydride}}{CaSO_4} \xrightarrow{1100^\circ C} CaO + SO_3$$

Q. 15 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

Ans. *(c)* Calcium hydroxide is prepared by adding water to quicklime (CaO).

$$\underset{\text{Quick lime}}{CaO(s)} + H_2O(l) \longrightarrow \underset{\text{Slaked lime}}{Ca(OH)_2(s)}$$

It is a white amorphous powder. It is sparingly soluble in water.

So, it forms a suspension of slaked lime in water which is called milk of lime and the clear solution obtained after the suspension settles is known as lime water.

Q. 16 Which of the following elements does not form hydride by direct heating with dihydrogen?

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

Ans. *(a)* Except Be, all alkaline earth metals form hydrides (MH_2) on directly heating with H_2.

BeH_2 can't be prepared by direct action of H_2 on Be. It is prepared by the action of $Li\,AlH_4$ on $BeCl_2$.

$$2BeCl_2 + LiAlH_4 \longrightarrow 2BeH_2 + LiCl + AlCl_3$$

Q. 17 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

Ans. *(d)* On heating washing soda, it loses its water of crystallisation. Above 373 K, it becomes completely anhydrous white powder called soda ash.

$$\underset{\text{Washing soda}}{Na_2CO_3 \cdot 10H_2O} \xrightarrow{>373\text{ K}} \underset{\text{Soda ash}}{Na_2CO_3 \cdot 10\,H_2O}$$

Q. 18 A substance which gives brick red flame and breaks down on heating to give oxygen and a brown gas is

(a) magnesium nitrate (b) calcium nitrate

(c) barium nitrate (d) strontium nitrate

Ans. *(b)* Calcium gives brick red coloured flame. Hence, calcium nitrate on heating decomposes into calcium oxide, with evolution of a mixture of NO_2 and O_2.

$$2\,Ca(NO_3)_2 \longrightarrow 2CaO + NO_2 + O_2$$

NO_2 is brown coloured gas.

Q. 19 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

Ans. ***(a)*** Calcium hydroxide is used in the manufacture of bleaching powder.

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

Q. 20 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) $CaCO_3$

Ans. ***(c)*** To recover NH_3 in Solvay ammonia soda process $Ca(OH)_2$ is used.

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

On passing CO_2 through $Ca(OH)_2$, it turns milky due to the formation of $CaCO_3$.

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

$Ca(OH)_2$ is used for white washing.

Q. 21 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 is correct about these halides?

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

Ans. ***(d)*** 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.,* $MgCl_2 \cdot 6H_2O$, $CaCl_2 \cdot 6H_2O$, $BaCl_2 \cdot 2H_2O$, $SrCl_2 \cdot 2H_2O$

Multiple Choice Questions (More Than One Options)

Q. 22 **Metallic elements are described by their standard electrode potential, fusion enthalpy, atomic size, etc. The alkali metals are characterised by which of the following properties?**

(a) High boiling point
(b) High negative standard electrode potential
(c) High density
(d) Large atomic size

Ans. ***(b, d)***

Alkali metals are the first members in a period. Alkali metals have largest atomic radii in their period due to least effective nuclear charge.

They have low density because size is large and mass is least in a period. Alkali metals are soft metals to cut with a knife *i.e.,* low boiling point.

Due to *ns* electronic configuration, they lose electron easily and have high negative standard electrode potential.

Q. 23 **Several sodium compounds find use in industries. Which of the following compounds are used for textile industry?**

(a) Na_2CO_3 (b) $NaHCO_3$ (c) NaOH (d) NaCl

Ans. ***(a, c)***

NaOH is used in manufacture of rayon.
Na_2CO_3 is used in manufacture of soap powders, in laundry for washing.

Q. 24 **Which of the following compounds are readily soluble in water?**

(a) $BeSO_4$ (b) $MgSO_4$ (c) $BaSO_4$ (d) $SrSO_4$

Ans. ***(a, b)***

Solubility of sulphates of alkaline earth metals in water decreases from Be to Ba $\cdot BeSO_4$ are fairly soluble while $BaSO_4$ is almost completely insoluble.

The decreasing solubility of $BeSO_4$ to $BaSO_4$ can be explained on the basis of decreasing hydration energy from Be^{2+} to Ba^{2+} (as size increases). For $BeSO_4$ and $MgSO_4$, hydration energy is more than lattice energy and so they are readily soluble.

Q. 25 **When zeolite, which is hydrated sodium aluminium silicate is treated with hard water, the sodium ions are exchanged with which of the following ion(s)?**

(a) H^+ ions (b) Mg^{2+} ions
(c) Ca^{2+} ions (d) SO_4^{2-} ions

Ans. ***(b, c)***

To make hard water soft, zeolite method is used. Sodium zeolite or sodium alumino silicate $(Na_2Al_2SiO_3 \cdot xH_2O)$ is used. It has a unique property of exchanging cations such as Ca^{2+} and Mg^{2+} in hard water for sodium ion.

Q. 26 Identify the correct formula of halides of alkaline earth metals from the following.

(a) $BaCl_2 \cdot 2H_2O$ (b) $BaCl_2 \cdot 4H_2O$ (c) $CaCl_2 \cdot 6H_2O$ (d) $SrCl_2 \cdot 4H_2O$

Ans. ***(a, c)***

All the chlorides of alkaline earth metals are hydrated to different extent and extent of hydration decreases from Mg to Ba *e.g.,* $MgCl_2 \cdot 6H_2O, CaCl_2 \cdot 6H_2O, BaCl_2 \cdot 2H_2O, SrCl_2 \cdot 2H_2O$.

Q. 27 Choose the correct statements from the following.

(a) Beryllium is not readily attacked by acids because of the presence of an oxide film on the surface of the metal

(b) Beryllium sulphate is readily soluble in water as the greater hydration enthalpy of Be^{2+} overcomes the lattice enthalpy factor

(c) Beryllium exhibits coordination number more than four

(d) Beryllium oxide is purely acidic in nature

Ans. ***(a, b)***

Due to diagonal relationship, beryllium is similar to aluminium. It also forms an oxide film which is very stable on the surface of the metal.

Beryllium sulphate is soluble in water due to high hydration energy. Beryllium does not exhibit coordination number more than four. Like Al_2O_3, BeO is amphoteric in nature.

Note *The anomalous behaviour of* Be *is mainly due to its very small size and partly due to its high electronegativity. These two factors increase the polarising power of* Be^{2+} *ions to such extent that it becomes significantly equal to the polarising power of* Al^{3+} *ions. Therefore, these two elements,* Be *and* Al *resemble (diagonal relationship) very much.*

$$\text{Polarising power} = \frac{\text{Ionic chgarge}}{(\text{Ionic radii})^2}$$

Q. 28 Which of the following are the correct reasons for anomalous behaviour of lithium?

(a) Exceptionally small size of its atom

(b) Its high polarising power

(c) It has high degree of hydration

(d) Exceptionally low ionisation enthalpy

Ans. ***(a, b)***

Although Li exhibits, the characteristic properties of alkali metals but it dffers at same time in many of its properties from alkali metals.

The anomalous behaviour of lithium is due to extremely small size of lithium and its cation.

On account of small size and high nuclear charge, lithium exerts the greatest polarising effect out of all alkali metals on negative ions.

Short Answer Type Questions

Q. 29 How do you account for the strong reducing power of lithium in aqueous solution?

Ans. Strong reducing power of lithium in aqueous solution can be understood in terms of electrode potential. Electrode potential is a measure of the tendency of an element to lose electrons in the aqueous solution. It mainly depends upon the following three factors *i.e.,*

(i) $\text{Li}\,(s) \xrightarrow[\text{Enthalpy}]{\text{Sublimation}} \text{Li}\,(g)$

(ii) $\text{Li}\,(g) \xrightarrow[\text{Enthalpy}]{\text{Ionisation}} \text{Li}^+(g) + e^-$

(iii) $\text{Li}^+\ (g) + aq \longrightarrow \text{Li}^+\ (aq) + \text{enthalpy of hydration}$

With the small size of its ion, lithium has the highest hydration enthalpy. However, ionisation enthalpy of Li is highest among alkali metals but hydration enthalpy predominates over ionisation enthalpy.

Therefore, lithium is the strongest reducing agent in aqueous solution mainly because of its high enthalpy of hydration.

Q. 30 When heated in air, the alkali metals form various oxides. Mention the oxides formed by Li, Na and K.

Ans. The reactivity of alkali metals towards oxygen increases on moving down the group with the increase in atomic size. Thus, Li forms only lithium oxide (Li_2O), sodium forms mainly sodium peroxide Na_2O_2 along with a small amount of sodium oxide while potassium forms only potassium superoxide (KO_2).

$$4\text{Li} + \text{O}_2 \xrightarrow{\Delta} 2\text{Li}_2\text{O}$$

$$6\text{Na} + 2\text{O}_2 \xrightarrow{\Delta} \underset{\substack{\text{Sodium peroxide}\\ \text{(major)}}}{\text{Na}_2\text{O}_2} + \underset{\substack{\text{Monoxide}\\ \text{(minor)}}}{2\text{Na}_2\text{O}}$$

$$\text{K} + \text{O}_2 \xrightarrow{\Delta} \underset{\substack{\text{Potassium}\\ \text{super oxides}}}{\text{KO}_2} + \underset{\text{Peroxide}}{\text{K}_2\,\text{O}_2} + \underset{\text{Monoxide}}{\text{K}_2\,(\text{O})}$$

The superoxide, O_2^- ion is stable only in presence of large cations such as K, Rb etc.

Q. 31 Complete the following reactions

(i) $O_2^{2-} + H_2O \longrightarrow$ (ii) $O_2^- + H_2O \longrightarrow$

Ans. O_2^{2-} represents a peroxide ion
O_2^- represents a superoxide ion

(i) Peroxide ion react with water to form H_2O_2

$$\text{O}_2^{2-} + 2\text{H}_2\text{O} \longrightarrow 2\text{OH}^- + \underset{\substack{\text{Hydrogen}\\ \text{peroxide}}}{\text{H}_2\text{O}_2}$$

(ii) Superoxide ion react with water to form H_2O_2 and O_2

$$2\text{O}_2^- + 2\text{H}_2\text{O} \longrightarrow 2\text{OH}^- + \underset{\substack{\text{Hydrogen}\\ \text{peroxide}}}{\text{H}_2\text{O}_2} + \text{O}_2$$

Q. 32 Lithium resembles magnesium in some of its properties. Mention two such properties and give reasons for this resemblance.

Ans. Lithium resembles with magnesium as its charge size ratio is closer to Mg. Its resemblance with Mg is known as diagonal relationship.

Generally, the periodic properties show either increasing or decreasing trend along the group and *vice-versa* along the period which brought the diagonally situated elements to closer value.

Period	Group I	Group II
2	Li ↘	Be
3	Na	Mg

Following characteristics can be noted

(i) Due to covalent nature, chlorides of Li and Mg are deliquescent and soluble in alcohol and pyridine.

(ii) Carbonates of Li and Mg decompose on heating and liberate CO_2

$$Li_2CO_3 \longrightarrow Li_2O + CO_2$$
$$MgCO_3 \longrightarrow MgO + CO_2$$

Q. 33 Name an element from group 2 which forms an amphoteric oxide and a water soluble sulphate.

Ans. An element from group 2 which forms an amphoteric oxide and a water soluble sulphate is beryllium.

Beryllium forms oxides of formula BeO. All other alkaline earth metal oxides are basic in nature. BeO is amphoteric in nature *i.e.,* it reacts with acids and bases both.

$$Al_2O_3 + 2NaOH \longrightarrow 2NaAlO_2 + H_2O$$
$$Al_2O_3 + 6HCl \longrightarrow 2AlCl_3 + 3H_2O$$

Sulphate of beryllium is a white solid which crystallises as hydrated salts ($BeSO_4 \cdot 4H_2O$).

$BeSO_4$ is fairly soluble in water due to highest hydration energy in the group (small size).

For $BeSO_4$, hydration energy is more than lattice energy and so, they are readily soluble.

Q. 34 Discuss the trend of the following

(i) Thermal stability of carbonates of Group 2 elements.

(ii) The solubility and the nature of oxides of Group 2 elements.

Ans. (i) All the alkaline earth melals form carbonates (MCO_3). All these carbonates decompose on heating to give CO_2 and metal oxide. The thermal stability of these carbonates increases down the group *i.e.,* from Be to Ba.

$$BeCO_3 < MgCO_3 < CaCO_3 < SCO_3 < BaCO_3$$

$BeCO_3$ is unstable to the extent that it is stable only in atmosphere of CO_2. These carbonates however show reversible decomposition in closed container.

$$BeCO_3 \rightleftharpoons BeO + CO_2$$

Hence, more is the stability of oxide formed, less will be stability of carbonates. Stability of oxides decreases down the group is beryllium oxide *i.e.,* high stable making $BeCO_3$ unstable.

(ii) All the alkaline earth metals form oxides of formula *M*O. The oxides are very stable due to high lattice energy and are used as refractory material.

Except BeO (predominantly covalent) all other oxides are ionic and their lattice energy decreases as the size of cation increases.

The oxides are basic and basic nature increases from BeO to BaO (due to increasing ionic nature).

$$\underbrace{BeO <}_{\text{Amphoteric}} \underbrace{MgO <}_{\text{Weak basic}} \underbrace{CaO < SrO < BaO}_{\text{Strong basic}}$$

BeO dissolves both in acid and alkalies to give salts and is amphoteric

The oxides of the alkaline earth metals (except BeO and MgO) dissolve in water to form basic hydroxides and evolve a large amount of heat. BeO and MgO possess high lattice energy and thus insoluble in water.

Q. 35 Why are $BeSO_4$ and $MgSO_4$ readily soluble in water while $CaSO_4$, $SrSO_4$ and $BaSO_4$ are insoluble?

Ans. The lattice energy of alkaline earth metal sulphates is almost constant due to large size of sulphate ion. Thus, their solubility is decided by hydration energy which decreases on moving down the group.

The greater hydration enthalpies of Be^{2+} and Mg^{2+} ions overcome the lattice enthalpy factor and therefore, their sulphates are soluble in water.

However, hydration enthalpy is low for Ca^{2+}, Sr^{2+} ions and cannot overcome the lattice energy factor. Hence, these are insoluble.

Q. 36 All compounds of alkali metals are easily soluble in water but lithium compounds are more soluble in organic solvents. Explain.

Ans. Smallest size of Li^+ ion among all alkali metals and its high polarising power are the two factors which develop covalent character in the lithium compounds (Fajan's rule). Compounds of other alkali metals are ionic in nature. So, they are soluble in water.

Since lithium compounds being relatively covalent are soluble in alcohol and other organic solvents in accordance with ''like dissolve like''.

Q. 37 In the Solvay process, can we obtain sodium carbonate directly by treating the solution containing $(NH_4)_2CO_3$ with sodium chloride? Explain.

Ans. No, $(NH_4)_2CO_3$ reacts with NaCl as

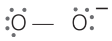
$$(NH_4)_2CO_3 + 2NaCl \rightleftharpoons Na_2CO_3 + 2NH_4Cl$$

Because the products obtained Na_2CO_3 and NH_4Cl are highly soluble and the equilibrium will not shift in forward direction.

That's why in the Solvay process, we cannot obtain sodium carbonate directly by treating the solution containing $(NH_4)_2CO_3$ with sodium chloride.

Q. 38 Write Lewis structure of O_2^- ion and find out oxidation state of each oxygen atom? What is the average oxidation state of oxygen in this ion?

Ans. The Lewis structure of O_2^- is



Oxygen atom carrying no charge has six electrons, so its oxidation number is zero. But oxygen atom carrying – 1 charge has 7 electrons, so its oxidation number is – 1.

Average oxidation number of each oxygen atom = $\frac{1}{2}$

$$O_2^- = 2x = -1$$

$$x = -\frac{1}{2}$$

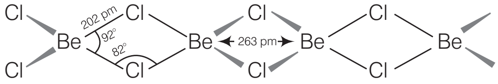
Q. 39 Why do beryllium and magnesium not impart colour to the flame in the flame test?

Ans. All alkaline earth metals (except Be and Mg) impart a characteristic colour to the Bunsen flame. The different colours arise due to different energies required for electronic excitation and de-excitation.

Be and Mg atoms due to their small size, bind their electrons more strongly (because of higher effective nuclear charge). Hence, require high excitation energy and are not excited by the energy of the flame with the result that no flame colour is shown by them.

Q. 40 What is the structure of $BeCl_2$ molecule in gaseous and solid state?

Ans. Beryllium chloride has different structures in solid and vapour state. In solid state, it exists in the form of polymeric chain structure in which each Be-atom is surrounded by four chlorine atoms having two of the chlorine atoms covalently bonded while the other two by coordinate bonds. The resulting bridge structure contains infinite chains.

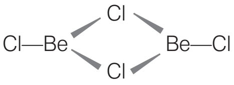


Structure of $BeCl_2$ in solid state

In vapour state, above 1200 K, it exists as a monomer having linear structure and zero dipole moment. But below 1200 K, it exists as dimer structure even in vapour state.

Cl—Be—Cl

Above 1200 K
Monomer



Below 1200 K
Dimer

Matching The Columns

Q. 41 Match the elements given in Column I with the properties mentioned in Column II.

Column I	Column II
A. Li	1. Insoluble sulphate
B. Na	2. Strongest monoacidic base
C. Ca	3. Most negative $E^{\ominus}$ value among alkali metals
D. Ba	4. Insoluble oxalate
	5. $6s^2$ outer electronic configuration

Ans. **A.** → (3) **B.** → (2) **C.** → (4) **D.** → (5)

A. Li—Most negative E^- among alkali metals

[Due to very high hydration energy the resulting $E^{\ominus}$ is most negative].

B. Na—Strongest monoacidic base

[Alkalies are more acidic than alkaline earth metals. LiOH has covalent character].

C. Ca—insoluble oxalate

[Calciuim oxalate is insoluble in water]

D. Ba—Insoluble sulphate
[Hydration energy decreases as size of cation increases].
$6s^2$ outer electronic configuration
$_{56}Ba = 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{10}, 4s^2, 4p^6, 4d^{10}, 5s^2, 5p^6, 6s^2$]

Q. 42 Match the compounds given in Column I with their uses mentioned in Column II.

Column I	Column II
A. $CaCO_3$	1. Dentistry, ornamental work
B. $Ca(OH)_2$	2. Manufacture of sodium carbonate from caustic soda
C. CaO	3. Manufacture of high quality paper
D. $CaSO_4$	4. Used in white washing

Ans. **A.** → (3) **B.** → (4) **C.** → (2) **D.** → 1

A. $CaCO_3$ — Manufacture of high quality paper
B. $Ca(OH)_2$ — Used in white washing
C. CaO — Manufacture of sodium carbonate from caustic soda
D. $CaSO_4$ — Dentistry, ornamental work

Q. 43 Match the elements given in Column I with the colour they impart to the flame given in Column II.

Column I	Column II
A. Cs	1. Apple green
B. Na	2. Violet
C. K	3. Brick red
D. Ca	4. Yellow
E. Sr	5. Crimson red
F. Ba	6. Blue

Ans. **A.** → (6) **B.** → (4) **C.** → (2) **D.** → (3) **E.** → (5) **F.** → 1

Elements with the characteristic flame colour are as follows

A. Cs – Blue
B. Na – Yellow
C. K – Violet
D. Ca – Brick red
E. Sr – Crimson red
F. Ba – Apple green

Flame colours are produced from the movement of the electrons in the metal ions present in the compounds. These movement of electrons (electronic excitation-de-excitation) requires energy.

Each atom has particular energy gap between ground and excited energy level therefore each of these movements involves a specific amount of energy emitted as light energy, and each corresponds to a particular colour. As we know energy gap between ground and excited state energy level increases wavelength of decreases and complemently colouer is observed as a result.

Assertion and Reason

In the following questions a statement of Assertion (A) *followed by a statement of Reason* (R) *is given. Choose the correct option out of the choices given below in each question.*

Q. 44 **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.

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

Ans. *(a)* 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.

Q. 45 **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.

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

Ans. *(a)* 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.

$$BeCO_3 \rightleftharpoons BeO + CO_2$$

Long Answer Type Questions

Q. 46 The *s*-block elements are characterised by their larger atomic sizes, lower ionisation enthalpies, invariable $+1$ oxidation state and solubilities of their oxosalts. In the light of these features describe the nature of their oxides, halides and oxosalts.

Ans. Due to low ionisation energy and large atomic size, alkali metals form cation readily and so their compounds are ionic.

Oxides

Due to $+1$ oxidation state, alkali metals form normal oxides of general formula M_2O.

Only Li forms normal oxide Li_2O when heated in air. Other form peroxide and superoxide.

Oxides of alkali metals are strongly basic and are soluble in water.

The basic character of oxide increases gradually from Li_2O to Cs_2O due to increased ionic character.

Halides

Except lithium halides all other alkali metal halides are ionic. Due to high polarising power of Li^+. Lithium halide is covalent in nature. Due to + 1 oxidation states alkali metal halides have general formula *MX*. Low ionisation enthalpy allows formation of ionic halides.

Oxo salts

All alkali metals form solid carbonates of general formula M_2CO_3. Carbonates are stable except Li_2CO_3 due to high polarising capacity of Li^+ which is unstable and decomposes.

All the alkali metals (except Li) form solid bicarbonates $MHCO_3$. All alkali metals form nitrates having formula MNO_3. They are colourless, water soluble, electrovalent compounds.

Q. 47 Present a comparative account of the alkali and alkaline earth metals with respect to the following characteristics.

(a) Tendency to form ionic/covalent compounds
(b) Nature of oxides and their solubility in water
(c) Formation of oxosalts
(d) Solubility of oxosalts
(e) Thermal stability of oxosalts

Ans. **(a)** Alkaline earth metals form compounds which are predominantly ionic but less ionic than the corresponding compounds of alkali metals due to increased nuclear charge and small size.

(b) Oxides of alkaline earth metals are less basic than corresponding oxides of alkali metals.

The oxides dissolve in water to form basic hydroxides and evolve a large amount of heat. The alkaline earth metal hydroxides, are however less basic and less stable than alkali metal hydroxides.

(c) Alkaline earth metals form oxoacids as alkali metals. The formation of alkali metal oxoacids is much more faster and stronger than their corresponding alkaline earth metals due to increased nuclear charge and small size.

(d) Solubility of alkaline oxoacids is more than alkali oxoacids because alkaline earth metals have small size of cation and higher hydration energy. Salts like $CaCO_3$ are insoluble in water.

(e) Oxosalts of alkali metals are thermally more stable than those of alkaline earth metals. As the electropositive character increases down the group, the stability of carbonate and hydrogen carbonates of alkali metal increases.

Whereas for alkaline earth metals, carbonate decomposes on heating to give carbon dioxide and oxygen.

Q. 48 When a metal of group 1 was dissolved in liquid ammonia, the following observations were obtained

(a) Blue solution was obtained initially.
(b) On concentrating the solution, blue colour changed to bronze colour.
How do you account for the blue colour of the solution? Give the name of the product formed on keeping the solution for some time.

Ans. **(a)** The reaction that takes place when alkali metal is dissolved in liquid ammonia is

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

The blue colour of the solution is due to the presence of ammoniated electron which absorb energy in the visible region of light and thus impart blue colour to the solution.

(b) In concentrated solution, the blue colour changes to bronze colour due to the formation of metal ion clusters. The blue solution on keeping for some time liberate hydrogen slowly with the formation of amide.

$$\underset{\text{Ammoniacal}}{M^+ + e^-} + NH_3 \longrightarrow \underset{\text{Amide}}{MNH_2} + \frac{1}{2}H_2$$

Q. 49 The stability of peroxide and superoxide of alkali metals increase as we go down to group. Explain giving reason.

Ans. The stability of peroxide or superoxide increases as the size of metal ion increases *i.e.,*

$$KO_2 < RbO_2 < CsO_2$$

The reactivity of alkali metals toward oxygen to form different oxides is due to strong positive field around each alkali metal cation. Li^+ is the smallest, it does not allow O^{2-} ion to react with O_2 further. Na^+ is larger than Li, its positive field is weaker than Li^+. It cannot prevent the conversion of O^{2-} into O_2^{2-}.

The largest K^+, Rb^+ and Cs^+ ions permit O_2^{2-} ion to react with O_2 forming superoxide ion O_2^-.

$$\underset{\text{Oxide}}{O_2^{2-}} \xrightarrow{\frac{1}{2}O_2} \underset{\text{Peroxide}}{O^{2-}} \xrightarrow{O_2} \underset{\text{Superoxide}}{2O_2^-}$$

Futhermore, increased stability of the peroxide or superoxide with increase in the size of metal ion is due to the stabilisation of large anions by larger cations through lattice energy effect.

Q. 50 When water is added to compound (*A*) of calcium, solution of compound (*B*) is formed. When carbon dioxide is passed into the solution, it turns milky due to the formation of compound (*C*). If excess of carbon dioxide is passed into the solution milkiness disappears due to the formation of compound (*D*). Identify the compounds *A*, *B*, *C* and *D*. Explain why the milkiness disappears in the last step.

Ans. Appearance of milkiness on passing CO_2 in the solution of compound *B* indicates that compound *B* is lime water and compound *C* is $CaCO_3$. Since, compound *B* is obtained by adding H_2O to compound *A*, therefore, compound *A* is quicklime, CaO.

The reactions are as follows

(i) $$\underset{\substack{\text{Calcium}\\ \text{oxide}\\ (A)}}{CaO} + H_2O \longrightarrow \underset{\substack{\text{Lime water}\\ (B)}}{Ca(OH)_2}$$

(ii) $$\underset{(B)}{Ca(OH)_2} + CO_2 \longrightarrow \underset{\substack{\text{Calcium carbonate}\\ \text{(Milkiness)}}}{CaCO_3} + \underset{(C)}{H_2O}$$

(iii) When excess of CO_2 is passed, milkiness disappears due to the formation of soluble calcium bicarbonate (*D*).

$$\underset{\substack{\text{Milkiness}\\ (C)}}{CaCO_3} + CO_2 + H_2O \longrightarrow \underset{\substack{\text{Calcium bicarbonate}\\ \text{(Soluble in } H_2O)\\ (D)}}{Ca(HCO_3)_2}$$

Q. 51 Lithium hydride can be used to prepare other useful hydrides. Beryllium hydride is one of them. Suggest a route for the preparation of beryllium hydride starting from lithium hydride. Write chemical equations involved in the process.

Ans. BeH_2 can be prepared from the corresponding halides by the reduction with complex alkali metal hydrides such as lithium aluminium hydride $LiAlH_4$.

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

$$2BeCl_2 + LiAlH_4 \longrightarrow 2BeH_2 + LiCl + AlCl_3$$

Q. 52 **An element of group 2 forms covalent oxide which is amphoteric in nature and dissolves in water to give an amphoteric hydroxide. Identify the element and write chemical reactions of the hydroxide of the element with an alkali and an acid.**

Ans. The alkaline earth metals burn in oxygen to form monoxide *MO*. BeO is essentially covalent in nature, other being ionic in nature.

BeO is amphoteric while other oxides are basic in nature and react with water to form sparingly soluble hydroxides.

BeO dissolves both in acid and alkalis to give salt and is amphoteric.

$$\mathrm{BeO} + \mathrm{H_2O} \longrightarrow \underset{\text{Beryllium hydroxide}}{\mathrm{Be(OH)_2}}$$

$Be(OH)_2$ is an amphoteric hydroxide, dissolving in both acids and alkalies.

With alkalies it dissolves to form the tetrahydroxidoberyllate (Z^-) anion with sodium hydroxide solution.

$$2\,\mathrm{NaOH}\,(aq) + \mathrm{Be(OH)_2}(s) \longrightarrow \underset{\text{Sodium tetra hydroxidoberyllate}}{\mathrm{Na_2Be(OH)_4}(aq)}$$

With acids, it forms beryllium salts.

$$\mathrm{Be(OH)_2} + \underset{\text{Sulphuric acid}}{\mathrm{H_2SO_4}} \longrightarrow \underset{\text{Beryllium sulphate}}{\mathrm{BeSO_4}} + 2\mathrm{H_2O}$$

Q. 53 **Ions of an element of group 1 participate in the transmission of nerve signals and transport of sugars and aminoacids into cells. This element imparts yellow colour to the flame in flame test and forms an oxide and a peroxide with oxygen. Identify the element and write chemical reaction to show the formation of its peroxide. Why does the element impart colour to the flame?**

Ans. Yellow colour flame in flame test indicates that the alkali metal must be sodium. It reacts with O_2 to form a mixture of sodium peroxide, Na_2O_2 and sodium oxide Na_2O.

$$4\mathrm{Na} + \mathrm{O_2} \xrightarrow{\Delta} 2\mathrm{Na_2O}\ \text{(Minor)}$$

$$2\mathrm{Na_2O} + \mathrm{O_2} \xrightarrow{\Delta} 2\,\mathrm{Na_2O_2}\ \text{(Major)}$$

$$2\mathrm{Na} + \mathrm{O_2} \xrightarrow{\Delta} \mathrm{Na_2O_2}$$

Ionisation enthalpy of sodium is low. When sodium metal or its salt is heated in Bunsen flame, the flame energy causes an excitation of the outermost electron which on reverting back to its initial position gives out the absorbed energy as visible light and complementary colour of absorbed colour from the light radiation is seen.

That's why sodium imparts yellow colour to the flame.