10 The s-Block Elements

LESSON AT A GLANCE

- s-Block elements constitute Group 1 and 11 elements.
- General electronic configuration of
  Group I = [Noble gas] ns^1
  Group II = [Noble gas] ns^2
- **Diagonal Relationship**

Group	**1**	**2**	**3**	**4**
Second period	Li	Be	B	C
Third period	Na	Mg	Al	Si

  The first three elements of second period (Li, Be, B) show diagonal similarity with the elements (Mg, Al, Si) of third period. Such similarities are termed as diagonal relationship.
- The alkali metals-silvery-white-solft-metals. They are highly reactive. Their aqueous solutions are strongly alkaline in nature. Their atomic and ionic sizes increase on moving down the group and ionization enthalpies decrease systematically down the group.
- **Alkaline earth metals.** They are much similar to alkali metals but due to small size some differences are there. Their oxides and hydroxides are less basic than the alkali metals.
- Sodium hydroxide (NaOH) is prepared by the electrolysis of aq.NaCl in Cather Kellenr's cell.
- Slaked lime $Ca(OH)_2$ is formed by the action of quick lime on water.
- Gypsum is $CaSO_4 \cdot 2\ H_2O$. On heating upto 390 K $CaSO_4$ 1/2 H_2O plaster of paris is formed.

TEXTBOOK QUESTIONS SOLVED

Q1. *What are the common physical and chemical features of alkali metals?*

Ans. **Physical properties of alkali metals**

(*i*) Alkali metals have low ionization enthalpies.

(*ii*) Alkali metals are highly electropositive in nature.

(*iii*) Alkali metals exhibit +1 oxidation states in their compounds.

(*iv*) Alkali metals impart characteristic colours to the flame.

Chemical properties of alkali metals:

(*i*) Alkali metals are highly reactive in nature.

(*ii*) Alkali metals hydroxides are highly basic in nature.

(*iii*) Alkali metals dissolve in liquid ammonia to form blue and conducting solution.

Q2. *Discuss the general characteristics and gradation in properties of alkaline earth metals.*

Ans. (*i*) Atomic size goes on increasing down the group.

(*ii*) Ionisation energy goes on decreasing down the group.

(*iii*) They are harder than alkali metals.

(*iv*) They are less electropositive than alkali metals.

Electropositive character increases on going down the group.

Q3. *Why are alkali metals not found in nature?*

Ans. Because of the high reactivity, alkali metals are not found in the free state in nature. This can be seen from the much lower $E^{\ominus}_{red}$ potential values of alkali metals, *e.g.*, for Li^+/Li it is –3.05 V and for Na^+/Na –2.71 V.

Q4. *Find out the oxidation state of sodium in Na_2O_2.*

Ans.

$$\overset{x}{Na_2}\overset{-2}{(O_2)}$$

$$2x - 2 = 0; x = 2 \div 2 = +1$$

Oxidation state of Na is +1.

Q5. *Explain why is sodium less reactive than potassium.*

Ans. Sodium is less reactive than potassium because $E^{\ominus}_{red}$ for K^+/K is more negative than the $E^{\ominus}_{red}$ for Na^+/Na (K^+/K = –2.92 V and Na^+/Na = –2.71 V), also the first ionisation enthalpy of Na is greater than that of K.

Q6. *Compare the alkali metals and alkaline earth metals with respect to (i) ionisation enthalpy (ii) basicity of oxides and (iii) solubility of hydroxides.*

Ans. (*i*) **Ionisation enthapy ($\Delta_{ie}H$):** First ionisation enthalpy of alkaline earth metals is higher than those of corresponding alkali metals, but reverse is true for the second ionisation enthalpies. Ionisation enthalpy depends on nuclear charge, atomic size and the electronic configuration, respectively. For the first ionisation enthalpy, the answer lies in the higher nuclear charge and smaller atomic radius that the alkaline earth metals possess when compared to alkali metals.

For the second ionisation enthalpy variation, the noble gas electronic configuration of M^+ ions formed by alkali metals make their ionisation enthalpy values much higher than the corresponding alkali metals. [See Art. 10.10(*e*)]

(*ii*) **Basicity of oxides:** Both the alkali and alkaline earth metals' oxides dissolve in water giving basic solutions. However, the alkali metals' oxides are more basic than the corresponding alkaline earth metals because the alkali metals are more electropositive than alkaline earth metals. Alkali metals hydroxide can easily ionise to furnish OH^- ions.

(*iii*) **Solubility of hydroxides:** Alkali metal hydroxides are more soluble in water than the corresponding hydroxides of alkaline earth metals. This is due to the smaller size and higher ionic charge of alkaline earth metal atoms. Thus, the lattice enthalpy of alkaline earth metals becomes higher than those of alkali metals. However, the solubility of hydroxides of both the alkali and alkaline earth metals increase down their respective groups due to a much larger decrease in their lattice enthalpies as compared to their hydration enthalpies.

Q7. *In what ways lithium shows similarities to magnesium in its chemical behaviour?*

Ans. (*i*) Both react with nitrogen to form nitrides.

(*ii*) Both react with O_2 to form monoxides.

(*iii*) Both the elements have the tendency to form covalent compounds.

(*iv*) Both can form complex compounds.

Q8. *Explain why can alkali and alkaline earth metals not be obtained by chemical reduction methods?*

Ans. Alkali and alkaline earth metals themselves are very strong reducing agents, hence, cannot be obtained by chemical reduction method. They are obtained by electrolytic reduction methods using their appropriate anhydrous salt, *e.g.*, NaCl for Na and $MgCl_2$ for Mg, etc.

Q9. *Why are potassium and caesium, rather than lithium used in photoelectric cells?*

Ans. Potassium and caesium have much lower ionisation enthalpies than lithium and so can emit electrons easily when light falls on them while lithium remains inactive. For this reason, potassium and caesium are used in photoelectric cells.

Q10. *When an alkali metal dissolves in liquid ammonia the solution can acquire different colours. Explain the reasons for this type of colour change.*

Ans. Alkali metals dissolve in liquid ammonia and give deep blue solutions which are conducting in nature because ammoniated electrons absorb energy in the visible region of light and impart blue colour.

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

Q11. *Beryllium and magnesium do not give colour to flame whereas other alkaline earth metals do so. Why?*

Ans. Due to small size the ionization enthalpies of Be and Mg are much higher than those of other alkaline earth metals. Therefore, a large amount of energy is needed to excite their valence electron and that's why they do not impart colour to the flame.

Q12. *Discuss the various reactions that occur in the Solvay process.*

Ans.

$$CaCO_3\,(s) \xrightarrow{\text{heat}} CaO + CO_2$$

$$NH_3 + H_2O \longrightarrow NH_4^+ + OH^-$$

$$NaCl + NH_4OH + CO_2 \longrightarrow NaHCO_3 + NH_4Cl$$

$$2\,NaHCO_3 \xrightarrow{heat} Na_2CO_3 + CO_2 + H_2O$$
$$Na_2CO_3 + 10\,H_2O \longrightarrow Na_2CO_3 \cdot 10\,H_2O$$

Q13. *Potassium carbonate cannot be prepared by Solvay process. Why?*

Ans. K_2CO_3 cannot be obtained by a method similar to Solvay method for Na_2CO_3 because of the very high solubility of $KHCO_3$ in water in contrast to the much lower solubility of $NaHCO_3$.

Q14. *Why is Li_2CO_3 decomposed at a lower temperature whereas Na_2CO_3 at higher temperature?*

Ans. The polarizing power of Li^+ is much more than Na^+ because of the smaller size and high charge density. Consequently, Li_2CO_3 shows covalent character while Na_2CO_3 is almost ionic, hence Li_2CO_3 decomposes at a lower temperature than Na_2CO_3 because of its covalent character.

Q15. *Compare the solubility and thermal stability of the following compounds of the alkali metals with those of the alkaline earth metals.* (*a*) *Nitrates* (*b*) *Carbonates* (*c*) *Sulphates.*

Ans. (*a*) Nitrates of both group 1 and group 2 elements are soluble in water because hydration energy is more than the lattice energy.

Nitrates of both group 1 and group 2 elements are thermally unstable but they decompose differently except $LiNO_3$ *e.g.*

$$2NaNO_3 \xrightarrow{heat} 2NaNO_2 + O_2$$
$$2KNO_3 \xrightarrow{\Delta} 2KNO_2 + O_2$$
$$4LiNO_3 \xrightarrow{\Delta} 2Li_2O + 4\,NO_2 + O_2$$
$$2Mg(NO_3)_2 \xrightarrow{\Delta} 2MgO + 4\,NO_2 + O_2$$

(*b*) Carbonates of group 1 elements are soluble in water except Li_2CO_3.

They are also thermally stable except Li_2CO_3.

$$Li_2CO_3 \xrightarrow{heat} Li_2O + CO_2$$

Group 2 carbonates are insoluble in water because their Lattice energy are higher than hydration energy.

Thermal stability of carbonates of group 2 increases down the group because Lattice energy goes no increasing due to increase in ionic character.

(*c*) Sulphates of group 1 are soluble in water except Li_2SO_4. They are thermally stable.

Solubility of sulphates of group 2 decreases down the group because Lattice energy dominates over hydration energy.

Sulphates of group 2 elements are thermally stable and increasing down the group due to increases in Lattice energy.

Q16. *Starting with sodium chloride how would you proceed to prepare* (*i*) *sodium metal* (*ii*) *sodium hydroxide* (*iii*) *sodium peroxide* (*iv*) *sodium carbonate?*

Ans. (*i*) **Sodium metal from NaCl:** Sodium metal is obtained by using Down's cell where a fused mixture of anhydrous NaCl (40%) and $CaCl_2$ (60%) is electrolysed using iron cathode and graphite cathode. The operating temperature is 873 K. $CaCl_2$ acts as flux and lowers the fusion temperature. Ca^{2+} ions are not discharged at the working potential at the cathode. Electrode reactions are:

Cathode: $Na^+ + e^- \longrightarrow Na$

Anode: $2Cl^- \longrightarrow Cl_2 + 2e^-$

(*ii*) **Sodium hydroxide:** Sodium hydroxide is manufactured by electrolysis of an aqueous solution NaCl (brine) in Catner-Kelner cell.

Cathode:

$$Na^+ + e^- \longrightarrow \underset{\text{Sodium}}{Na}$$

$$2Na + Hg \longrightarrow Na - Hg$$

$$2Na - Hg + 2H_2O \longrightarrow 2NaOH + H_2 + Hg$$

At anode:

$$Cl^- - e^- \longrightarrow Cl$$

$$Cl + Cl \longrightarrow Cl_2$$

(*iii*) **Sodium peroxide:** Sodium peroxide, (Na_2O_2) is formed when sodium is heated in excess of air:

$$4Na\,(s) + O_2\,(g) \longrightarrow 2Na_2O\,(s)$$

$$2Na_2O\,(s) + O_2\,(g) \longrightarrow 2Na_2O_2\,(s)$$

(*iv*) **Sodium carbonate:** Sodium carbonate is obtained by solvay ammonia process.

$$NaCl + NH_3 + CO_2 + H_2O \longrightarrow NaHCO_3\downarrow + NH_4Cl$$

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

Q17. *What happens when (i) magnesium is burnt in air (ii) quick lime is heated with silica (iii) chlorine reacts with slaked lime (iv) calcium nitrate is heated?*

Ans. (*i*) $2Mg\,(s) + O_2\,(g) \xrightarrow{\Delta} 2MgO\,(s)$

A small amount of Mg_3N_2 is also formed as air contains N_2 gas:

$$6Mg\,(s) + 2N_2\,(g) \longrightarrow 2Mg_3N_2\,(s)$$

(Air) (Magnesium nitride)

(*ii*) $CaO\,(s) + SiO_2\,(s) \longrightarrow CaSiO_3\,(s)$

Quick lime Silica Calcium silicate

(*iii*) $2Ca(OH)_2 + 2Cl_2\,(g) \longrightarrow$

Slaked lime $CaCl_2\,(s) + Ca\,(OCl)_2\,(s) + 2H_2O\,(l)$

Bleaching powder

(*iv*) $2Ca(NO_3)_2\,(s) \xrightarrow{\Delta} 2CaO\,(s) + 4NO_2\,(g) + O_2\,(g)$

Q18. *Describe two important uses of each of the following: (i) caustic soda (ii) sodium carbonate (iii) quicklime.*

Ans. (*i*) **Caustic soda**

- It is used in the manufacturing of soap paper, artificial silk etc.
- It is used in textile industries.

(*ii*) **Sodium carbonate**

- It is used in the softening of water, for laundry and cleaning purposes.
- It is used in glass manufacturing.

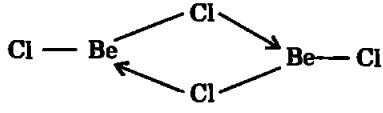
(*iii*) **Quick lime**

- It is used in the preparation of bleaching powder.
- It is used in the purification of sugar and in the manufacturing of cement.

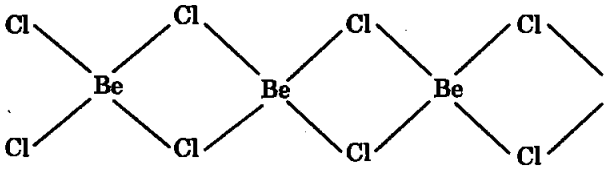
Q19. *Draw the structure of (i) $BeCl_2$ (vapour) (ii) $BeCl_2$ (solid).*

Ans. $BeCl_2$ (vapour)

In the vapour state, it exists as a chlorobridged dimer.



In solid state



Q20. *The hydroxides and carbonates of sodium and potassium are easily soluble in water while the corresponding salts of magnesium and calcium are sparingly soluble in water. Explain.*

Ans. Solubility of salts in water depends on their lattice enthalpies and hydration enthalpies. These two enthalpy terms, in turn, depend on size and charge of ions.

Na^+ and K^+ ions are larger in size as compared to Mg^{2+} and Ca^{2+} ions, respectively. Smaller ions have larger lattice enthalpies and higher hydration enthalpies. Thus,

(*i*) For carbonates and hydroxides of alkali metals (Na or K), the hydration enthalpies are greater than the lattice enthalpies and so, these compounds are soluble in water.

(*ii*) Carbonates and hydroxides of Mg and Ca are sparingly soluble in water because the lattice enthalpies of these compounds are smaller than the hydration enthalpies.

Q21. *Describe the importance of the following:*
(*i*) *limestone* (*ii*) *cement* (*iii*) *plaster of Paris.*

Ans. (*i*) **Limestone:**

- Extensively used in the manufacturing of high quality paper.
- Used as mild abrasive in toothpaste.
- As a filler in cosmetics.
- Used as an antacid.

(*ii*) **Cement:** It is an important building material. It is used extensively in construction industry in various fields such as buildings, dams, bridges and many others.

(*iii*) **Plaster of Paris: $(CaSO_4)_2.H_2O$.** It is used in making plaster casts, as a surface for walls and in surgery to keep an injured limb rigid.

Q22. *Why are lithium salts commonly hydrated and those of the other alkali ions usually anhydrous?*

Ans. Since Li^+ is the smallest ion in the alkali metals' group (Group 1), it forms hydrated salts more easily than other metals. It is due to the higher polarization power of Li^+ ions because of the smaller size. These ions polarize the water molecules more easily. The water molecules are thus get attached to lithium salts as water of crystallisation, *e.g.*, $LiCl.2H_2O$.

Q23. *Why is LiF almost insoluble in water whereas LiCl soluble not only in water but also in acetone?*

Ans. LiF is almost insoluble in water whereas LiCl is soluble because lattice enthalpy of LiF is higher than that of LiCl. Also LiCl is more covalent because of the bigger size of Cl^- ion which is quite polarizable (Fajans' Rules). That is, LiCl is less polar so less soluble in water. Since LiCl shows covalent character, it is also soluble in acetone.

Q24. *Explain the significance of sodium, potassium, magnesium and calcium in biological fluids.*

Ans. (*i*) Na^+ ions participate in the transmission of nerve signals, in regulating the flow of water across cell membranes.

(*ii*) In the transport of sugars and amino acids into cell.

Potassium ions:

(*i*) They activate many enzymes.

(*ii*) Participate in the oxidation of glucose to produce ATP.

Magnesium ions:

(*i*) All enzymes that utilise ATP in phosphate transfer require magnesium as a cofactor.

(*ii*) Mg is the main pigment for the absorption of light in plants.

Calcium:

(*i*) Ca^{2+} ions are present in bones.

(*ii*) plays important roles in neuromuscular function.

Q25. *What happens when*

(*i*) *sodium metal is dropped in water?*

(*ii*) *sodium metal is heated in free supply of air?*

(*iii*) *sodium peroxide dissolves in water?*

Ans. (*i*) Hydrogen gas is evolved when sodium is dropped in water which catches fire due to the exothermic nature of the reaction:

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

(*ii*) Na_2O and Na_2O_2 are formed depending on the amount of air:

$$4Na\,(s) + O_2\,(g) \longrightarrow 2Na_2O\,(s)$$

$$2Na\,(s) + \underset{\text{excess}}{O_2\,(g)} \longrightarrow Na_2O_2\,(s)$$

(*iii*) H_2O_2 is formed:

$$Na_2O_2\,(s) + 2H_2O\,(l) \longrightarrow 2NaOH\,(aq) + H_2O_2\,(aq)$$

Q26. *Comment on each of the following observations:*

(*a*) *The mobilities of the alkali metal ions in aqueous solution are* $Li^+ < Na^+ < K^+ < Rb^+ < Cs^+$.

(*b*) *Lithium is the only alkali metal to form a nitride directly.*

(*c*) E^0 *for* $M^{2+}\,(aq) + 2e^- \longrightarrow M(s)$

(*where* $M = Ca, Sr$ *or* Ba) *is nearly constant.*

Ans. (*a*) Smaller the size of the ion, more highly it is hydrated and hence greater is the mass of the hydrated ion and thus the ionic mobility become lesser. The extent of hydration decreases in the order.

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

Thus the mobility of Cs^+ will be the highest.

(*b*) Because the lattice enthalpy of ionic Li_3N more than compensates the other energy requirements for the formation of Li_3N.

$$6Li\,(s) + N_2\,(g) \xrightarrow{\Delta} 2Li_3N\,(s)$$

(*c*) It is because reduction potential depends upon sublimation energy, ionisation energy and hydration energy. Their resultant is almost constant for these ions.

Q27. *State as to why:*

(*a*) *a solution of* Na_2CO_3 *is alkaline?*

(*b*) *alkali metals are prepared by electrolysis of their fused chlorides?*

(*c*) *sodium is found to be more useful than potassium?*

Ans. (*a*) Hydrolysis of Na_2CO_3 gives a strong base, NaOH and a weak acid, H_2CO_3, and so its aqueous solution is alkaline. Also see that Na_2CO_3 is a salt of strong base (NaOH) and weak acid (H_2CO_3).

$$Na_2CO_3\,(s) + H_2O\,(l) \longrightarrow NaOH\,(aq) + H_2CO_3\,(aq)$$

(*b*) It is because of the two reasons:

(*i*) The melting points of anhydrous chloride is reasonably low to carry out the electrolytic reduction;

(*ii*) If the electrolytic reduction is done in an aqueous medium, water is reduced and hydrogen gas is evolved instead of getting the alkali metal because the discharge potential of hydrogen is lower than that of alkali metals.

(*c*) Despite the close similarity of chemical properties between Na and K, their biological functions are very different. Sodium ions, Na^+, are found primarily on the outside of cells because Na^+ ions are actively expelled from cells, whereas K^+ ions are not. This ion transport is also called sodium-potassium pump which involves the expulsion of Na^+ ions and take-up of K^+ ions.

The different ratio of Na^+ to K^+ inside and outside cells produces an electrical potential across the cell membrane which is essential for the functioning of nerve and muscle cells. The movement of glucose into cells is associated with Na^+ ions; they enter the cell together. The movement of amino acids is similar to glucose. However, Na^+ ions entering the cells must be expelled. K^+ ions inside the cell are essential for the metabolism of glucose, the synthesis of proteins, and the activation of some enzymes. Both Na^+ and K^+ are important, however, Na^+ ions participate to a larger context biologically and are thus more useful.

Q28. *Write balanced equations for reactions between*

(*a*) *Na_2O_2 and water* (*b*) *KO_2 and water*

(*c*) *Na_2O and CO_2.*

Ans. (*a*) $Na_2O_2\,(s) + 2H_2O\,(l) \longrightarrow 2NaOH\,(aq) + H_2O_2\,(aq)$

(*b*) $2KO_2\,(s) + 2H_2O\,(l) \longrightarrow 2KOH\,(aq) + H_2O_2\,(aq) + O_2\,(g)$

(*c*) $Na_2O\,(s) + CO_2\,(g) \longrightarrow Na_2CO_3\,(s)$

Q29. *How would you explain the following observations?*

(*i*) *BeO is almost insoluble but $BeSO_4$ is soluble in water.*

(*ii*) *BaO is soluble but $BaSO_4$ is insoluble in water.*

(*iii*) *LiI is more soluble than KI in ethanol.*

Ans. (*i*) Lattice energy of BeO is compartively higher than the hydration energy. Therefore, it is almost insoluble in

water. Whereas $BeSO_4$ is ionic in nature and its hydration energy dominates the lattice energy.

(*ii*) Both BaO and $BaSO_4$ are ionic compounds but the hydration energy of BaO is higher than the lattice energy therefore it is soluble in water.

(*iii*) Since the size of Li^+ ion is very small in comparison to K^+ ion, it polarises the electron cloud of I^- ion to a great extent. Thus LiI dissolves in ethanol move easily than the KI.

Q30. *Which of the alkali metal is having least melting point?*

(*a*) *Na* (*b*) *K*

(*c*) *Rb* (*d*) *Cs*

Ans. (*d*) Cs

This is due to the bigger size of Cs atoms which are responsible for the weaker metallic bonds.

Q31. *Which one of the following alkali metals gives hydrated salts?*

(*a*) *Li* (*b*) *Na*

(*c*) *K* (*d*) *Cs*

Ans. (*a*) Li

This is due to the small size and high charge density of Li^+ ion which polarizes the water molecules to a greater extent. Hence lithium salts are hydrated.

Q32. *Which one of the alkaline earth metal carbonates is thermally the most stable?*

(*a*) $MgCO_3$ (*b*) $CaCO_3$

(*c*) $SrCO_3$ (*d*) $BaCO_3$

Ans. (*d*) $BaCO_3$

The thermal stability increases with the increase in cationic size.

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Chapter 2

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Chapter 4

Chapter 5

Chapter 6

Chapter 7

Chapter 8

Chapter 9

Chapter 10

Chapter 11

Chapter 12

Chapter 13

Chapter 14

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Maths 11

Biology 11

NCERT 12

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