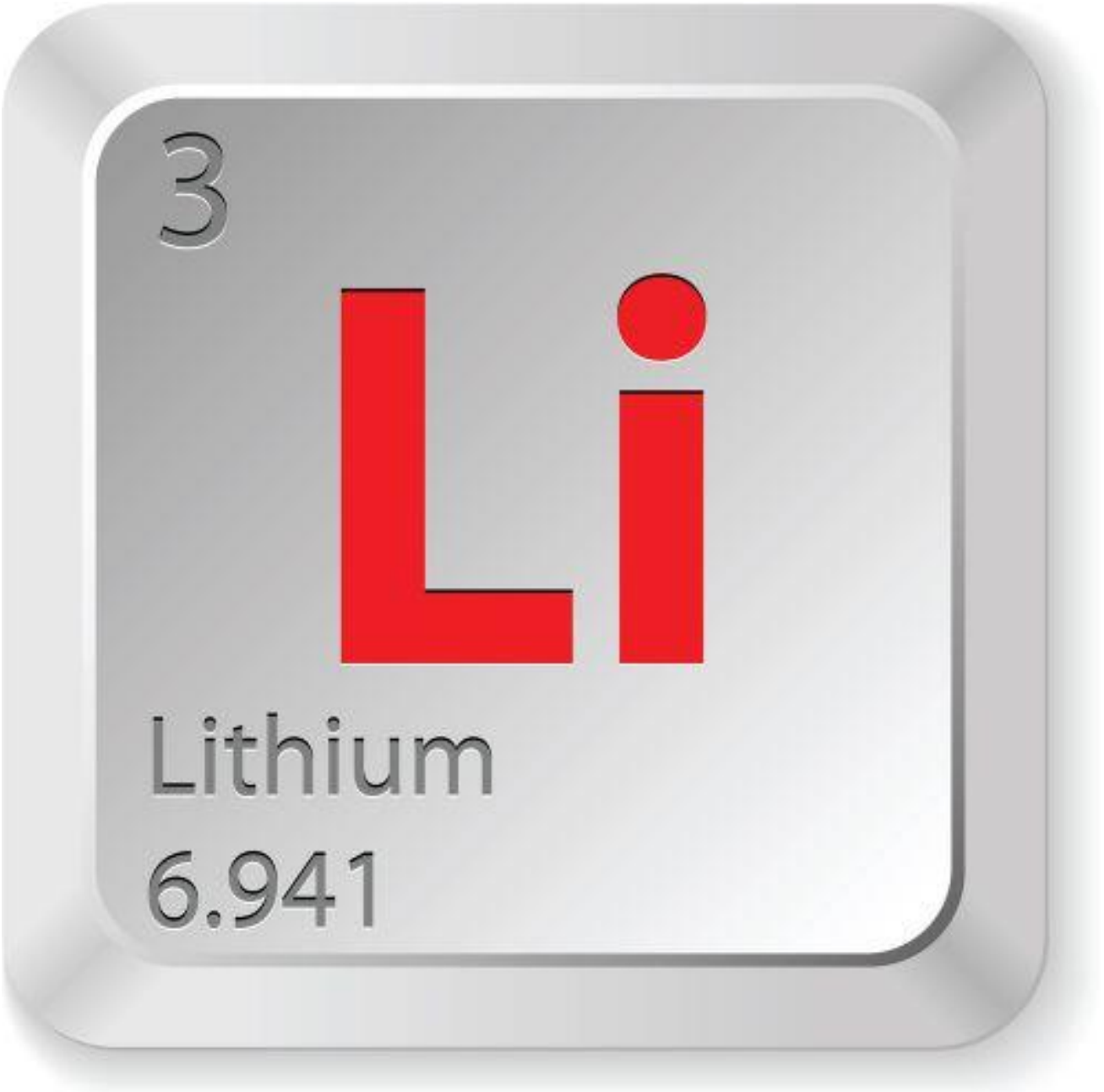
The s Block Elements



DESIGNED

By

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The elements in which the last electron enters the outermost s-orbital are called s-block elements. s-block has two groups (1 and 2).

- Group 1 elements are called alkali metals. They form hydroxides by reacting with water that is strongly alkaline in nature and hence are regarded as alkali metals.
- Whereas Group 2 elements are called alkaline earth metals. The oxides and hydroxides of these metals are alkaline in nature and exist in earth crust and hence are regarded as alkaline earth metals.

Group 1 Elements: Alkali Metals

Electronic configuration: The alkali metals have one valence electron ns^1.

- They easily lose the loosely held electron and give M^+ ions thereby are the most electropositive metals.

Element	Symbol	Electronic configuration
Lithium	Li	$1s^2 2s^1$
Sodium	Na	$1s^2 2s^2 2p^6 3s^1$
Potassium	K	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
Rubidium	Rb	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 5s^1$
Caesium	Cs	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^6 6s^1$ or [Xe] $6s^1$
Francium	Fr	[Rn]$7s^1$

Atomic and Ionic Radii: In Group 1 the atomic and ionic radii increases down the group.

- Increase in atomic number increases the size of the atom of the elements.

Li < Na < K < Rb < Cs < Fr

Ionization Enthalpy: Ionization energy is the quantity of energy required to remove loosely bound electron from an atom.

- Down the group ionization enthalpies of alkali metals decreases.

Li > Na > K > Rb > Cs < Fr

Hydration Enthalpy: The energy released as a result of the formation of new bonds between ions and water molecules is called hydration enthalpy.

- In alkali metals the hydration enthalpies decreases with the increase in ionic sizes.

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

Physical Properties: Alkali metals appears silvery white, soft and light metals.

- They have low density due to their large size which goes on increasing down the group.
- The melting and boiling point of the alkali metals are low.
- This shows that they have weak metallic bonding.
- These metals impart colour when exposed to oxidizing flame due to the excitation of the outermost electron to a higher energy level and then return to their ground state by emitting radiation.

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

Chemical Properties

(i) Reactivity towards air: Alkali metals get tarnished in the presence of dry air due to the formation of their respective oxides.

$$4Li + O_2 \rightarrow 2Li_2O \text{ (Oxide)}$$

(ii) Reactivity towards water: The alkali metals react with water and forms hydroxide and dihydrogen.

$$2M + 2H_2O \rightarrow 2M^+ + 2OH^- + H_2$$
(M = an alkali metal)

- Lithium due to its small size and very high hydration energy does not react with water vigorously even though it has most negative E^0 value.
- But on the other hand sodium do reacts with water vigorously even though it has least negative E^0 value.

(iii) Reactivity towards dihydrogen: The alkali metals react with dihydrogen at about 673K (lithium at 1073K) and form hydrides.

$$2M + H_2 \rightarrow 2M^+H^-$$

(iv) Reactivity towards halogens: Alkali metals react vigorously with halogens and form ionic halides, M^+X^-

(v) Reducing nature: The alkali metals are strong reducing agents.

- Lithium is the most powerful and sodium is the least powerful.

$M(s) \rightarrow M(g)$ sublimation enthalpy
$M(g) \rightarrow M^+(g) + e^-$ ionization enthalpy
$M^+(g) + H_2O \rightarrow M^+(aq)$ hydration enthalpy

(vi) Solutions in liquid ammonia: The alkali metals dissolve in liquid ammonia and impart a deep blue colour to the solutions.

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

The solutions are paramagnetic and liberate hydrogen on standing which in turn results in the formation of amide.

$$M^+_{(am)} + e^- + NH_3(l) \rightarrow MNH_{2(am)} + \tfrac{1}{2}H_2(g)$$
(where 'am' denotes solution in ammonia.)

Anomalous properties of lithium: It refers to the deviation of the properties and behaviour of an element from its usual or normal behaviour.

It is due to the following reasons:

(i) Exceptionally small size of its atom and ion

(ii) High polarizing power

The anomalous behaviour of lithium is as follows:

- Lithium is harder than other metals of the respective group.
- It has higher Melting and boiling point than other metals

- It is least reactive.
- It is strongest reducing agent.
- Unlike other metals LiCl is deliquescent and exist as $LiCl.2H_2$
- Lithium does not form ethynide on reacting with Ethyne.
- Heating lithium nitrate results in the production of lithium oxide, Li_2

$$4LiNO_3 \rightarrow 2Li_2O + 4NO_2 + O_2$$

- Heating nitrates of other alkali metal results in the decomposition of the nitrate leading to the production of their corresponding nitrite.

$$2NaNO_3 \rightarrow 2NaNO_2 + O_2$$

Similarity of lithium with magnesium

- Both the elements are harder and lighter than the other elements.
- Both of them react slowly with water.
- The oxides and hydroxides of both the elements are less soluble.
- The hydroxides of both the elements decompose on heating.
- Both the elements form nitrides by combining directly with nitrogen.

$$6\ Li + N_2\ (g) = 2\ Li_3N$$

$$3\ Mg(s) + N_2\ (g) = Mg_3N_2(s)$$

Some important compound of Sodium

1. **Washing Soda**: The chemical name of washing soda is Sodium Carbonate ($Na_2CO_310H_2O$).
   - It is a white crystalline solid existing as dehydrate ($Na_2CO_310H_2O$).
   - It is used for softening of water, laundering, cleaning, manufacture of glass,soap, borax, paper, paints and textile
   - It is also extensively used as laboratory reagent.

   Preparation

   - Carbon dioxide reacts with the dissolved ammonia to form ammonium carbonate followed by ammonium hydrogen carbonate.

$$2NH_3 + H_2O + CO_2 \rightarrow (NH_4)_2CO_3$$

$$(NH_4)_2CO_3 + H_2O + CO_2 \rightarrow NH_4HCO_3$$

$$NH_4HCO_3 + NaCl \rightarrow NH_4Cl + NaHCO_3$$

Sodium hydrogen carbonate crystal separates. These are heated to give sodium carbonate.

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

2. **Sodium chloride**: Chemical formula of sodium chloride is NaCl.
   - Preparation of sodium chloride: Sodium chloride is derived by mining the deposits and crystallization of brine solution.
   - It melts at 1081K.
   - It is used as a common or table salt.
   - It is also used for the preparation of Na_2O_2, NaOH and Na_2CO_3.
3. **Caustic Soda**: The chemical name of caustic soda is Sodium Hydroxide (NaOH).
   - It is a white, translucent solid that melts at 591 K.
   - It readily dissolves in water and gives a strong alkaline solution.
   - The crystals of sodium hydroxide are deliquescent.
   - It reacts with CO_2 in the atmosphere to form Na_2CO_3.

     $$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$$
   - It is used in manufacturing of soap, paper, pure fats and oils and artificial silk.
   - It is also used in the refining of petroleum and purification of bauxite.
   - It is also used to manufacture laboratory reagent

   Preparation: It is commercially prepared by electrolysis of sodium chloride in Castner-Kellner cell.

   $$\text{Anode}: Cl^- \rightarrow \frac{1}{2}Cl_2 + e^-$$

   $$\text{Cathode}: Na^+ + e^- \xrightarrow{Hg} Na - \text{amalgam}$$
   - The amalgam then reacts with water and produces sodium hydroxide and hydrogen gas.

     $$2Na\text{-amalgam} + 2H_2O \rightarrow 2NaOH + 2Hg + H_2$$
4. **Baking Soda**: The chemical name of baking soda is Sodium Hydrogencarbonate ($NaHCO_3$).
   - It exists as a white crystalline powder.
   - It is used in baking industry.
   - It is also used as a mild antiseptic to treat skin infections.
   - It is also used in fire extinguishers
   - It is prepared by saturating with passing CO_2 into the liquid.

     $$Na_2CO_3 + H_2O + CO_2 \rightarrow NaHCO_3$$

Group 2 Elements: Alkaline Earth Metals

Electronic Configuration: The general electron configuration of all alkaline earth metals is ns^2.

These elements have two valence electrons in the outermost s sublevel.

Element	Symbol	Electronic configuration
Beryllium	Be	$1s^2 2s^2$
Magnesium	Mg	$1s^2 2s^2 2p^6 3s^2$
Calcium	Ca	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$
Strontium	Sr	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 5s^2$
Barium	Ba	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^6 6s^2$ or $[Xe]6s^2$
Radium	Ra	$[Rn]7s^2$

Atomic and Ionic Radii: The atomic and ionic radii of the alkaline earth metals are smaller than alkali metals due to the increased nuclear charge in these elements.

- The atomic and ionic radii increase with increase in atomic number within a group.

  Be < Mg < Ca < Sr < Ba < Ra

Ionization Enthalpy: Ionization energy is the quantity of energy required to remove loosely bound electron from an atom.

- They have low ionization enthalpies due to fairly large size of the atoms.
- Ionization enthalpy decreases with the increase in atomic size down the group.

  Be > Mg > Ca > Sr > Ba > Ra

- The first ionization enthalpy of these metals is higher than corresponding alkali metals due to the small size of these elements compared to the corresponding alkali metals.
- The second ionization enthalpy of these metals is lower than corresponding alkali metals.

Hydration Enthalpy: The energy released as a result of the formation of new bonds between ions and water molecules is called hydration enthalpy.

- Hydration enthalpies of alkaline earth metal ions decrease with the increasing ionic size down the group.
- Hydration enthalpies of alkaline earth metal ions are larger than those of alkali metal
- $MgCl_2$ and $CaCl_2$ exist as hydrates in the form of $MgCl_2.6H_2O$ and $CaCl_2\ 6H_2O$.

Physical Properties: The alkaline earth metals are silvery white, soft and lustrous.

- But they are some harder than alkali metals.
- Beryllium and magnesium are greyish in colour.
- Melting and boiling points of these metal sare higher than corresponding alkali metal.
- They have low ionization enthalpy which makes them strongly electropositive that increases down the group from Be to Ba.

- When exposed to flame calcium, strontium and barium imparts brick red, crimson and apple green colours.
- They impart characteristic colour due to excitation of electrons to higher energy levels and then dropping back to the ground state.
- But Beryllium and magnesium do not impart colour due to their very small size.
- The elements emit this energy in the form of visible light.
- They have high electrical and thermal conductivities.

Chemical Properties

(i) Reactivity towards air and water

- Beryllium and magnesium are kinetically inert to oxygen and water due to an oxide film on their surface.
- Powdered beryllium burns brilliantly on ignition in air to give BeO and Be3N2.
- Magnesium is more electropositive and burns with dazzling brilliance in air to give MgO and Mg3N2.
- Calcium, strontium and barium react with water and air.

(ii) Reactivity towards the halogens: They combine with halogen to form halides.

$$M + X_2 \rightarrow MX_2$$

(iii) Reactivity towards hydrogen: Alkaline earth metals elements except beryllium combine with hydrogen upon heating to form their hydrides.

But BeH_2 can be prepared by following process too.

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

(iv) Reactivity towards acids: They readily react with acids liberating dihydrogen.

$$M + 2HCl \rightarrow MCl_2 + H_2$$

(vi) Solutions in liquid ammonia: Dissolve in liquid ammonia to give deep blue black solutions forming ammoniated ions.

$$M + (x+y)\,NH_3 \rightarrow [M(NH_3)_x]^{2+} + 2[e(NH_3)_y]^-$$

Anomalous behaviour of beryllium: Anomalous behaviour of an element refers to the deviation of the properties and behaviour of an element from its usual or normal behaviour.

- Beryllium has small atomic and ionic size.
- The high ionization enthalpy and small size of alkaline earth metals results in the formation of covalent compounds that are easy to hydrolyze.
- The coordination number of beryllium is not greater than 4 due to the presence of four electrons in the valence shell.

- The oxide and hydroxide of beryllium are amphoteric in nature.

Some important compound of Calcium

1) **Quick Lime**: The chemical name of Quick Lime is Calcium Oxide (CaO).

- It is a white amorphous solid.
- The melting point of CaO is 2870 K.
- It absorbs moisture and carbon dioxide when exposed to atmosphere.
- It is used in manufacturing industry to manufacture cement, dye stuffs and sodium carbonate.
- It is also used for the purification of sugar.
- It is prepared by heating limestone ($CaCO_3$) in a kiln at a temperature of 1070-1270 K.

$$CaCO_3 \text{ <---> } CaO + CO_2$$

- Addition of water to CaO results in slaking of lime.
- Slaking of Quick lime with soda results solid soda lime.
- CaO being a basic oxide combines with acidic oxides at high

$$CaO + SiO_2 \rightarrow CaSiO_3$$

$$6CaO + P_4O_{10} \rightarrow 2Ca_3(PO_4)_2$$

2) **Slaked lime**: The chemical name of slaked lime is Calcium Hydroxide $Ca(OH)_2$.

- It is a white amorphous powder sparingly soluble in water.
- Passing carbon dioxide through aqueous solution of $Ca(OH)_2$ lime water it turns milky due to the formation of calcium carbonate.

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

- Passing excess of carbon dioxide dissolves the precipitate to form calcium

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

$Ca(OH)_2$ is extensively used in the preparation of mortar, for white wash, glass making and also in tanning industry.

3) **Calcium Carbonate ($CaCO_3$)**: It is a white fluffy powder that is insoluble in water and gets decomposed followed by the release of carbon-dioxide on heating to 1200 K.

$$CaCO_3 + 1200k \rightarrow CaO + CO_2$$

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

$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2O + CO_2$$

- It is prepared by passing carbon dioxide through slaked lime.

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

- It can also be prepared by the addition ofsodium carbonate to calcium chloride.

$$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + NaCl$$

- It is sued to manufacture of quick lime.
- It is used as a flux in combination with magnesium carbonate in the extraction of metals such as iron.
- It is also used as an ant acid, mild abrasive in tooth paste and chewing gum.

4) **Plaster of Paris**: The chemical name of Plaster of Paris is Calcium Sulphate ($CaSO_4 \cdot \frac{1}{2} H_2O$).

- It is obtained by heating the gypsum, $CaSO_4 \cdot 2H_2O$, to 393 K.

$$2(CaSO_4 \cdot 2H_2O) \rightarrow 2(CaSO_4).H_2O + 3H_2O$$

- It forms a plastic mass on addition of water which further gets hardened within 5-15 minutes.
- It is extensively used in manufacturing decorating pieces, in repairing fractured bones or sprains.

5) **Cement**: Combination of CaO with clay containing silica, SiO_2 along with the oxides of aluminium, iron and magnesium leads to the formation of cement.

Composition of Portland cement: CaO = 50-60%; SiO_2 = 20-25%; Al_2O_3 = 5-10%; MgO = 2-3%; Fe_2O_3 = 1-2%; SO_3 = 1-2%.

- **Important ingredients of Cement**:

Dicalcium silicate (Ca_2SiO_4) = 26%,

Tricalcium silicate (Ca_3SiO_5) = 51%

Tricalcium aluminate ($Ca_3Al_2O_6$) = 11%

KHATAM