Melting point and boiling point of halides of a particular alkali metal follow the order :

Fluorides > Chlorides > Bromides > Iodides.

- **Solubility in liquid ammonia :** All alkali metals dissolve and form blue solution in liquid ammonia. Solubility of alkali metals in liquid ammonia may be as high as 5M. When alkali metals are dissolved in liquid ammonia, there is a considerable expansion in total volume hence such solutions are called **expanded metals**. The blue solution of an alkali metal in ammonia shows certain characteristic properties which are explained on the basis of formation of ammoniated (solvated) metal cations and ammoniated electrons in the metal ammonia solution in the following way :

$$M \longrightarrow M^+ + \text{electron}$$

$$M^+ + xNH_3 \longrightarrow [M(NH_3)_x]^+$$

$$\text{electron} + yNH_3 \longrightarrow [e(NH_3)_y]^-$$

$$\text{Thus } M + (x+y)NH_3 \longrightarrow \underset{\text{Ammoniated metal cation}}{[M(NH_3)_x]^+} + \underset{\text{Ammoniated electron}}{[e(NH_3)_y]^-}$$

The blue solution is paramagnetic and has high electrical conductivity due to the presence of unpaired electron in the cavities in ammoniacal solution and ammoniated cations and electrons respectively.

- **Anomalous properties of lithium**
  - Hardest and has high m.pt. and b.pt.
  - Li is deliquescent and crystallizes as a hydrate $LiCl{\cdot}2H_2O$.
  - Salts of lithium have lower ionic characters as compared to other group-I metals.
  - Readily reacts with N_2 to form Li_3N (lithium nitride), other group metals do not react.
  - Lithium hydroxides and carbonates are unstable and decompose on heating.

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

    $Na_2CO_3 \xrightarrow{\Delta}$ No effect

    $2LiOH \xrightarrow{\Delta} Li_2O + H_2O$

    $NaOH/KOH \xrightarrow{\Delta}$ No effect (thermally stable)
  - Li^+ ion is more heavily hydrated.
  - LiI is covalent in nature, because smaller size of Li^+ cause higher polarization.

PREPARATION AND PROPERTIES OF SOME IMPORTANT COMPOUNDS

1. Sodium Carbonate, Na_2CO_3

- Sodium carbonate exists in various forms such as :

Na_2CO_3	-	Soda ash or light ash
$Na_2CO_3.H_2O$	-	Monohydrate, widely used in glass manufacturing
$Na_2CO_3.7H_2O$	-	Hepta hydrate
$Na_2CO_3.10H_2O$	-	Washing soda or Sal soda (used in soaps and detergents)

- **Solvay process**

$$NH_3 + CO_2 + H_2O \longrightarrow NH_4HCO_3$$

$$NH_4HCO_3 + NaCl \longrightarrow NaHCO_3 + NH_4Cl$$

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

- **Chemical reaction**

$Na_2CO_3 \xrightarrow{H_2O} H_2CO_3 + NaOH$

$Na_2CO_3 \xrightarrow{H_2SO_4} Na_2SO_4 + H_2CO_3$

$Na_2CO_3 \xrightarrow{H_2O + CO_2} NaHCO_3$

$Na_2CO_3 \xrightarrow{H^+} CO_2$

$Na_2CO_3 \xrightarrow{CaCl_2} CaCO_3 + 2NaCl$

$Na_2CO_3 \xrightarrow{Ca(OH)_2} 2NaOH + CaCO_3$

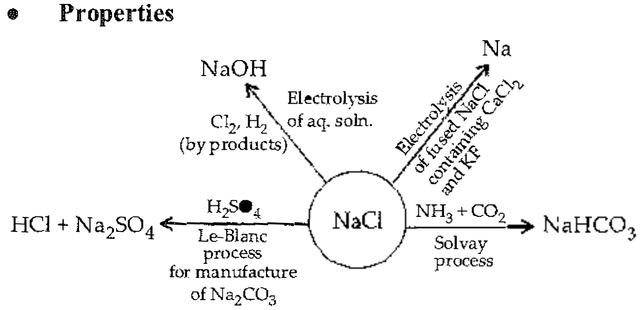
- **Uses**
  - Na_2CO_3 used to remove hardness of water.
  - Na_2CO_3 is used to manufacture glass, caustic soda, etc.
  - Na_2CO_3 is used in laundries as washing soda.

2. Sodium Chloride, NaCl

- Sodium chloride is found in abundance in sea water with an average concentration of 3%. It naturally occurs as rock salt or halide deposits.

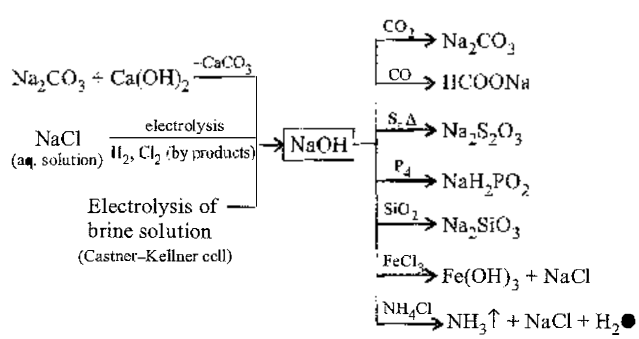
  Pure NaCl can be prepared by passing HCl gas into saturated solution of commercial salt. Pure salt gets precipitated due to common ion effect.

- **Properties**



- **Uses**
  - NaCl is used as table salt.
  - NaCl is used in preparation of number of compounds such as Na_2CO_3, NaOH, Na_2O_2, etc.

3. Sodium Hydroxide, NaOH



- **Uses**
  - It is used in the manufacture of soap, paper, rayon, etc.
  - It is used in textile industry for mercerising cotton fabrics.
  - It is used in the manufacture of dyes and many other chemicals.
  - It is used as a laboratory reagent.

4. Sodium Hydrogen Carbonate, $NaHCO_3$

- **Preparation :** Sodium bicarbonate or sodium hydrogen carbonate is obtained as intermediate compound in Solvay process.
  - It can also be prepared by passing CO_2 through solution of sodium carbonate.

    $Na_2CO_3 + CO_2 + H_2O \longrightarrow 2NaHCO_3$
- **Properties :** $NaHCO_3$ on heating decomposes to produce bubbles of CO_2 which make the cakes and pastries fluffy.

  $$2NaHCO_3 \xrightarrow{\Delta,\ 100°C} Na_2CO_3 + H_2O - CO_2$$
- **Uses**
  - $NaHCO_3$ is used in the preparation of baking powder.

    [Baking powder = $NaHCO_3$(30%) + $Ca(H_2PO_4)_2$ (10%) + Starch (40%) + $NaAl(SO_4)_2$]
  - It is used in fire extinguisher.

    $NaHCO_3 + HCl \longrightarrow NaCl + CO_2 + H_2O$
  - Such kind of fire extinguishers are known as soda-fire extinguisher.
  - It is used as antacid and mild antiseptic.
- **Biological significance of sodium and potassium**

  Na^+ and K^+ are essential for proper functioning of human body.
  - Different ratio of Na^+ to K^+ inside and outside cells produce an electrical potential across the cell membrane which is essential for functioning of nerve and muscle cells.
  - These ions activate many enzymes.
  - These ions primarily help in transmission of nerve signals, in regulating the flow of water across cell membrane, transport of sugars and amino acids into the cells, etc.

GROUP-2 ELEMENTS (ALKALINE EARTH METALS)

Occurrence and Abundance

- Like alkali metals, alkaline earth metals are also highly reactive and occur mostly in combined state as silicates, carbonates, sulphates and phosphates.

Element	Abundance (ppm) in earth crust	Ore
Be	2.0	$Be_3Al_2Si_6O_{18}$ – Beryl, Be_2SiO_4 – Phenacite
Mg	27640, 6th most abundant element	$MgCO_3{\cdot}CaCO_3$ – Dolomite, $MgSO_4{\cdot}7H_2O$ – Epsomite, $MgSO_4{\cdot}H_2O$ – Kieserite, $KCl{\cdot}MgCl_2{\cdot}6H_2O$ – Carnallite, $[CaMg_3(SiO_3)_4]$ – Asbestos
Ca	46600, 5th most abundant element	$CaCO_3$ – Limestone, $[3(Ca_3(PO_4)_2){\cdot}CaF_2]$ – Fluropatite, $CaSO_4{\cdot}2H_2O$ – Gypsum
Sr	384	$SrSO_4$ – Celestite, $SrCO_3$ – Strontianite
Ba	390	$BaSO_4$ – Barytes, $BaCO_3$ – Witherite
Ra	1.3×10^{-6}	Pitchblende

Physical Properties

- **Size of atoms and ions**
  - The atomic radii of alkaline earth metals are fairly large though smaller than the corresponding alkali metals since the extra nuclear charge of these atoms tend to pull the orbital electrons inwards *i.e.*, towards nucleus.
  - Both atomic and ionic radii increase down the group from Be to Ra due to the gradual addition of extra shells and also because of screening effect.
- **Melting and boiling points**
  - These elements have low melting and boiling points. However, their melting and boiling points are higher than those of alkali metals because of the presence of two bonding electrons, compared with one electron for group 1 metals.
  - The melting and boiling points do not vary regularly due to different crystal structures adopted by metals.
- **Ionization energy**
  - The alkaline earth metals have fairly low ionization energies although greater than those of the corresponding elements of group 1,
  - On moving down the group, ionization energy values go on decreasing because of the increase in atomic size due to addition of new shells and screening effect.

$$\underset{[\text{Noble gas}]ns^2}{M} \xrightarrow{IE_1} \underset{[\text{Noble gas}]ns^1}{M^+} \xrightarrow{IE_2} \underset{[\text{Noble gas}]}{M^{2+}} : IE_2 > IE_1$$

- **Hydration energy**
  - The hydration energies of the group 2 ions (M^{2+}) are four or five times greater than for group 1 ions (M^+). This is because of their smaller size and increased charge. $\Delta H_{\text{hydration}}$ decreases down the group as the size of the ions increases. High

hydration energy of Be is because of very strong complex $[Be(H_2O)_4]^{2+}$ formation.

Element	Be^{2+}	Mg^{2+}	Ca^{2+}	Sr^{2+}	Ba^{2+}
Hydration Energy (kJ/mol)	–2494	–1921	–1577	–1443	–1305

- **Reducing character**
  - Alkaline earth metals are stronger reducing agents since they have great tendency to release two electrons to form dipositive ions. But these are weaker reducing agents than alkali metals due to comparatively higher ionization energy and less negative electrode potential (E°_{red}).
  - Reducing character of alkaline earth metals increases down the group because ionization energy decreases and electrode potential becomes more negative from Be to Ba.

Element	Be	Mg	Ca	Sr	Ba	Ra
$E^\circ_{M^{2+}/M}$	–1.90	–2.37	–2.84	–2.89	–2.92	–2.90

Alkaline earth metals are highly reactive due to their low ionization energy and high negative value of standard electrode potential.

$$\xrightarrow[\text{Ionization energy decreases, reactivity increases}]{\text{Be Mg Ca Sr Ba}}$$

They are less reactive than alkali metals.

Chemical Properties

- **Action of air (Formation of oxides and peroxides)**
  - Alkaline earth metals react slowly with oxygen and form the corresponding oxides.
    The reactivity with oxygen increases as we move down the group since their electropositive character increases.

$$2BaO + O_2 \xrightarrow{773\ K} 2BaO_2$$

  - Oxides of group 2 elements are basic in nature. Their basic strength increases down the group.

BaO	> SrO	> CaO	> MgO	> BeO
Strongly basic	Strongly basic	Basic	Weakly basic	Amphoteric

(Relative basic strength)

- **Action of water (Formation of hydroxides)**
  - Alkaline earth metals are less reactive with water as compared to alkali metals. Their reactivity with water increases down the group. Be does not react with water at all, magnesium reacts only with hot water while other metals Ca, Sr and Ba react with cold water.
  - Order of the reactivity with water : Ba > Sr > Ca > Mg
  - $Be(OH)_2$ is amphoteric, but the hydroxides of Mg, Ca, Sr and Ba are basic. The basic strength increases from Mg to Ba.

$Be(OH)_2$	$Mg(OH)_2$	$Ca(OH)_2$	$Sr(OH)_2$	$Ba(OH)_2$
Amphoteric	Weakly basic	Basic	Strongly basic	Strongly basic

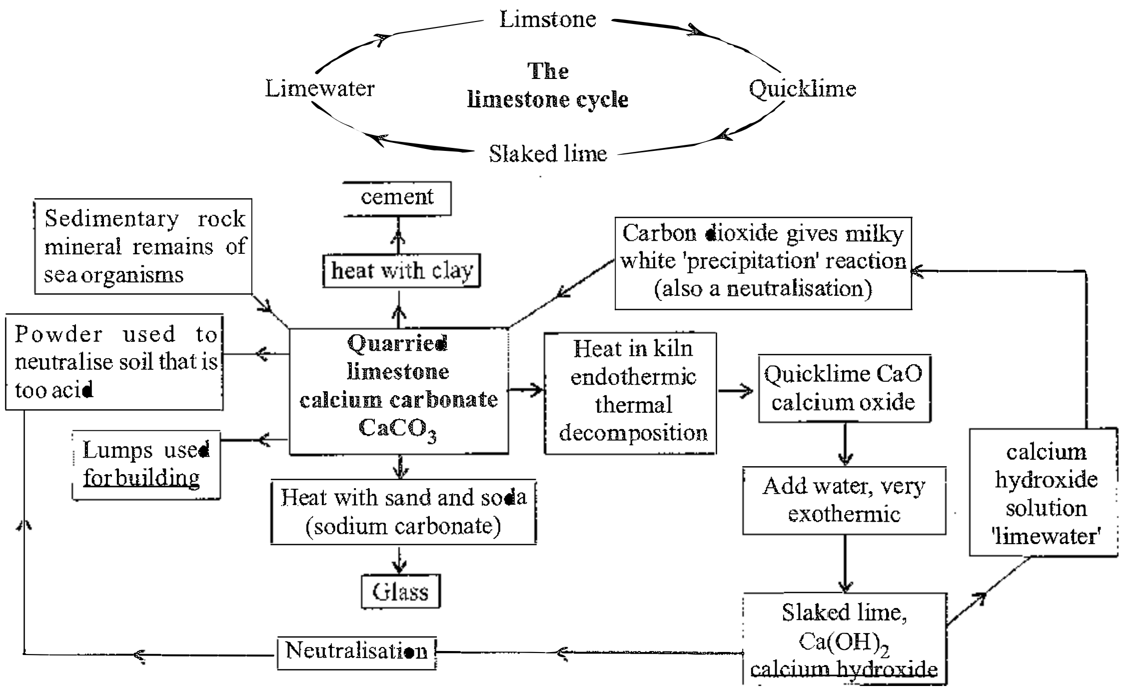
- **Action of hydrogen (Formation of hydrides)**
  - All alkaline earth metals except Be combine with hydrogen directly on heating to form hydride MH_2.

$$M + H_2 \xrightarrow{\text{Heat}} MH_2$$

  - Beryllium hydride is difficult to prepare, and less stable than the others.
    $2BeCl_2 + LiAlH_4 \longrightarrow 2BeH_2 + LiCl + AlCl_3$
    $Ca + H_2 \longrightarrow CaH_2$
  - CaH_2 is called hydrolith and is used for production of H_2 by action of water on it.
- **Action of halogens**
  - All elements of group IIA can form halides of MX_2 type either by the action of halogen acids (HX) on metals, metal oxides, hydroxides and carbonates, or directly heating metal with halogen.
    $M + 2HX \longrightarrow MX_2 + H_2$
    $MO + 2HX \longrightarrow MX_2 + H_2O$
    $M(OH)_2 + 2HX \longrightarrow MX_2 + 2H_2O$
    $MCO_3 + 2HX \longrightarrow MX_2 + CO_2 + H_2O$
    $M + X_2 \xrightarrow{\Delta} MX_2$
  - The halides of all other alkaline earth metals except Be are ionic. Their ionic character, however, increases as the size of the metal ion increases.
- **Anomalous properties of beryllium**
  - Hardest and have high b.pt. and m.pt.
  - Does not react with water even on boiling.
  - Beryllium forms covalent compound while other group-II metals forms ionic compounds.
  - Be form volatile Be_3N_2 and other metals form non-volatile nitrides.
  - Beryllium does not exhibit co-ordination number more than four.
  - BeO is insoluble in water and amphoteric.
  - $BeCO_3$ decomposes at low temperature.
    $BeCO_3 \longrightarrow BeO + CO_2$
    So usually placed in atmosphere of CO_2.
- **Diagonal relationship**
  - The similarity in properties of elements present diagonally is called diagonal relationship.

	Group 1	Group 2	Group 13	Group 14
Second period	Li ↘	Be ↘	B ↘	C
Third period	Na	Mg	Al	Si

  - The similarity in properties like electronegativity, ionisation energy, size of ion cause diagonal relation. Thus, Li shows similar properties as Mg and Be shows properties similar to Al.
- **Industrial applications of limestone**
  - Limestone is quarried for roadbeds, buildings and landscape construction and cement manufacture.
  - It is used as facade on some skyscrapers but only in thin sheets rather than solid blocks.



- **Industrial applications of lime**
  - Lime is directly or indirectly used in manufacture of virtually every consumer or industrial product.
  - Chemical and industrial processes require lime for purifying metals, neutralisation, causticization, coagulation, precipitation, hydrolysis, dehydration, high temperature processes, exothermic reactions, dissolution, gas absorption and saponification.
- **Lime is used in**
  - 35% metallurgy
  - 4% pulp and paper : Lime is traditionally used to reconstitute caustic soda from Na_2CO_3 left over from the pulp making process.
  - 3% sugar refining : Used to purify sugar from other sources such as maple or sorghum.
  - 13% construction and building material
  - 1% glass products
  - 3% chemicals.
- **Biological application of Mg^{2+}**
  - Mg^{2+} is the fourth most abundant metal ion in cells (in moles) and the most abundant free divalent cation – as a result it is deeply and intrinsically woven into cellular metabolism.
  - In nucleotides, the triple phosphate moiety of the compound is invariably stabilized by association with Mg^{2+} in all enzymic processes.
  - In photosynthetic organisms Mg^{2+} has the additional vital role of being the coordinating ion in the chlorophyll molecule.
  - Nucleic acids : The binding of Mg^{2+} to DNA and RNA stabilises structure.
  - ATP (adenosine triphosphate) must be bound to Mg^{2+} in order to be biologically active.
  - Mg^{2+} is essential for many enzymes and proteins.
- **Biological application of Ca^{2+}**
  - Ca^{2+} are concentrated in the body fluids outside the cell.
  - Ca^{2+} is present in bones and teeth as apatite $Ca_3(PO_4)_2$, and the enamel on teeth as fluoroapatite $[3(Ca_3(PO_4)_2) \cdot CaF_2]$, Ca^{2+} ions are important in blood clotting, and are required to trigger the contraction of muscles and to maintain the regular beating of the heart.