

THE S-BLOCK ELEMENTS

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Members of the s-Block Elements

IA	IIA
Li	Be
Na	Mg
K	Ca
Rb	Sr
Cs	Ba
Fr	Ra

IA Alkali metals

IIA Alkaline Earth metals

Chapter summary

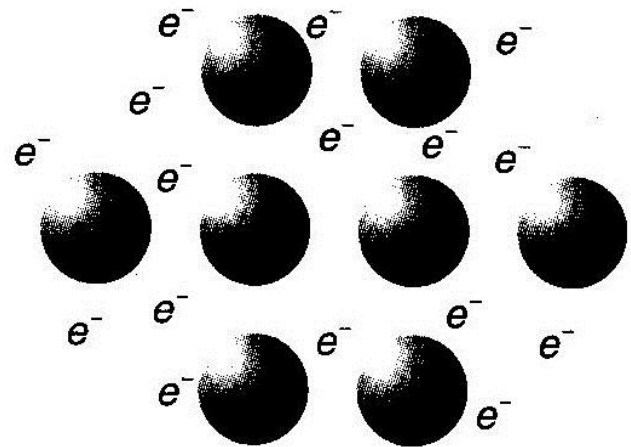
- Characteristic properties of the s-block elements
- Variation in properties of the s-block elements
- Variation in properties of the s-block compounds
- Uses of compounds of the s-block elements

Characteristic properties of s-block elements

- Metallic character
- Low electronegativity
- Basic oxides, hydroxides
- Ionic bond with fixed oxidation states
- Characteristic flame colours
- Weak tendency to form complex

Metallic character

- High tendency to lose e^- to form positive ions
- Metallic character increases down both groups



Electronegativity

- Low nuclear attraction for outer electrons
- Highly electropositive
- Small electronegativity

Group I		Group II	
Li	1.0	Be	1.5
Na	0.9	Mg	1.2
K	0.8	Ca	1.0
Rb	0.8	Sr	1.0
Cs	0.7	Ba	0.9
Fr	0.7	Ra	0.9

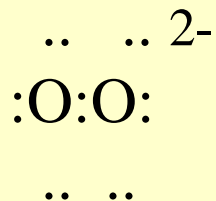
Basic oxides, hydroxides

Oxide	Hydroxides
Li_2O	LiOH
Na_2O , Na_2O_2	NaOH
K_2O_2 , KO_2	KOH
Rb_2O_2 , RbO_2	RbOH
Cs_2O_2 , CsO_2	CsOH

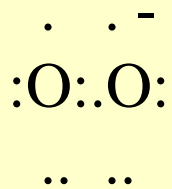
Oxide	Hydroxides
BeO	$\text{Be}(\text{OH})_2$
MgO	$\text{Mg}(\text{OH})_2$
CaO	$\text{Ca}(\text{OH})_2$
SrO	$\text{Sr}(\text{OH})_2$
BaO , Ba_2O_2	$\text{Ba}(\text{OH})_2$

Oxides, Peroxide, Superoxide

Reaction with water:



Peroxide ion



Super oxide

Li does not form
peroxide or super oxide
 $\text{Li}_2\text{O}_2 \rightarrow \text{Li}_2\text{O} + \frac{1}{2} \text{O}_2$

Hydroxides

Group I
hydroxides

Li Na K Rb Cs



All are soluble, base strength increase.

Group II
hydroxide

Be Mg Ca Sr Ba



Solubility increase, from Amphoteric to basic, base strength increase

Predominantly ionic with fixed oxidation state

Group I: Most electropositive metals.

Low first I.E. and extremely high second I.E.

Form predominantly ionic compounds with non-metals by losing one electron.

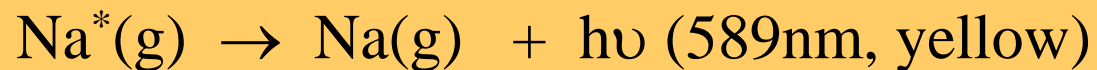
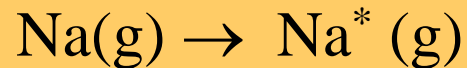
Fixed oxidation state of +1.

Group II: Electropositive metals.

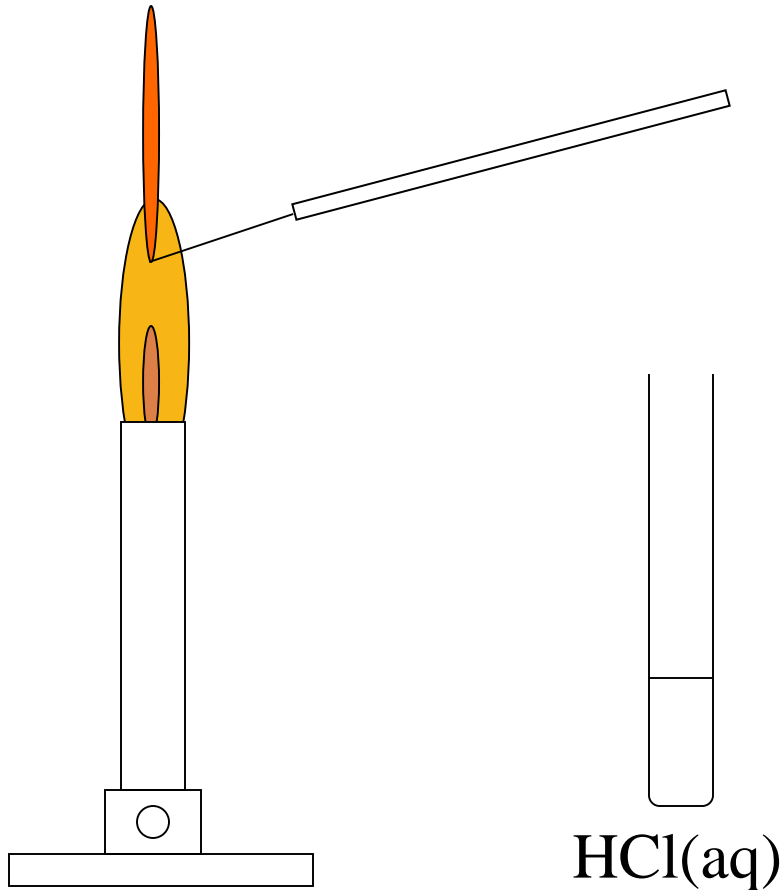
Low first and second I.E. but very high third I.E.. Have a fixed oxidation state of +2.

Be and Mg compounds possess some degree of covalent character.

Characteristic flame colours



Flame test

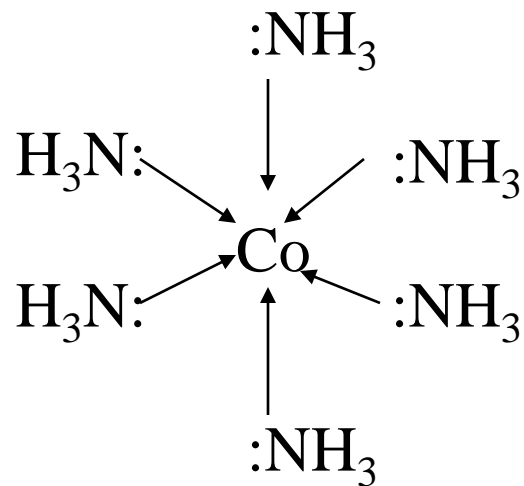


Li	deep red	Ca	brick red
Na	yellow	Sr	blood red
K	lilac	Ba	apple green
Rb	bluish red		
Cs	blue		

Weak tendency to form complex

Complex formation is a common feature of d-block element. e.g. $\text{Co}(\text{NH}_3)_6^{3+}$

s-block metal ions have no low energy vacant orbital available for bonding with lone pairs of surrounding ligands, they rarely form complexes.

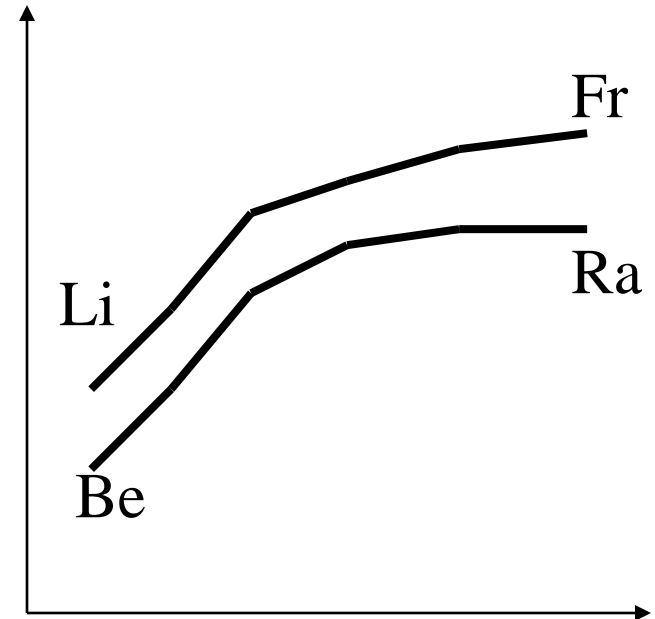


Variation in properties of elements

- Atomic radii
- Ionization enthalpies
- Hydration enthalpies
- Melting points
- Reactions with oxygen, water, hydrogen and chlorine

Atomic radii (nm)

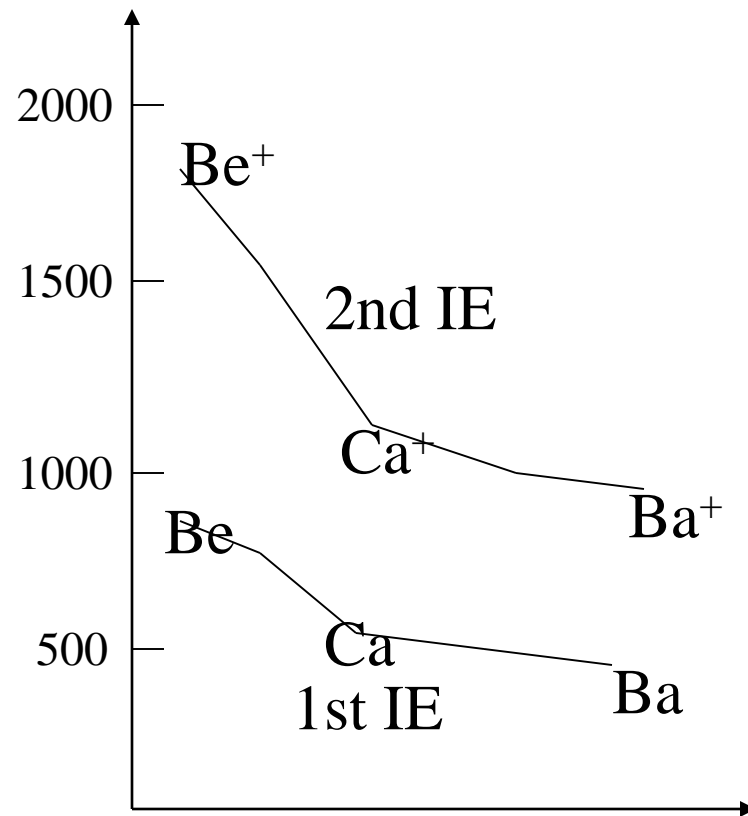
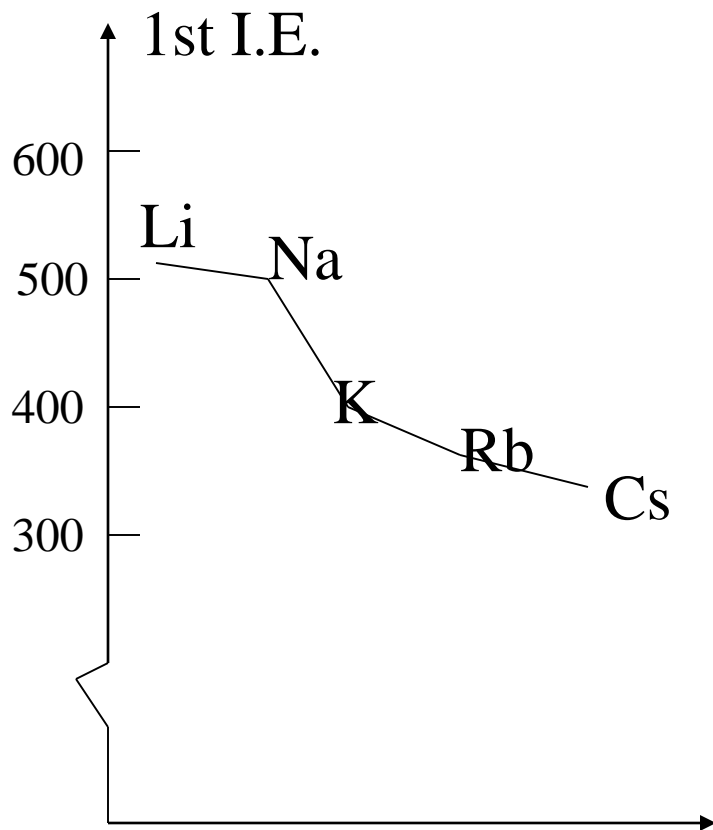
Li	0.152	Be	0.112
Na	0.186	Mg	0.160
K	0.231	Ca	0.197
Rb	0.244	Sr	0.215
Cs	0.262	Ba	0.217
Fr	0.270	Ra	0.220



Ionization Enthalpy

Group I	1st I.E.	2nd I.E.	Group I	1st I.E.	2nd I.E.	3 rd I.E.
Li	519	738	Be	900	1760	14800
Na	494	456	Mg	736	1450	7740
K	418	312	Ca	590	1150	4940
Rb	402	263	Sr	548	1060	4120
Cs	376	234	Ba	502	966	3390

Ionization Enthalpy



Ionization Enthalpy

Group I

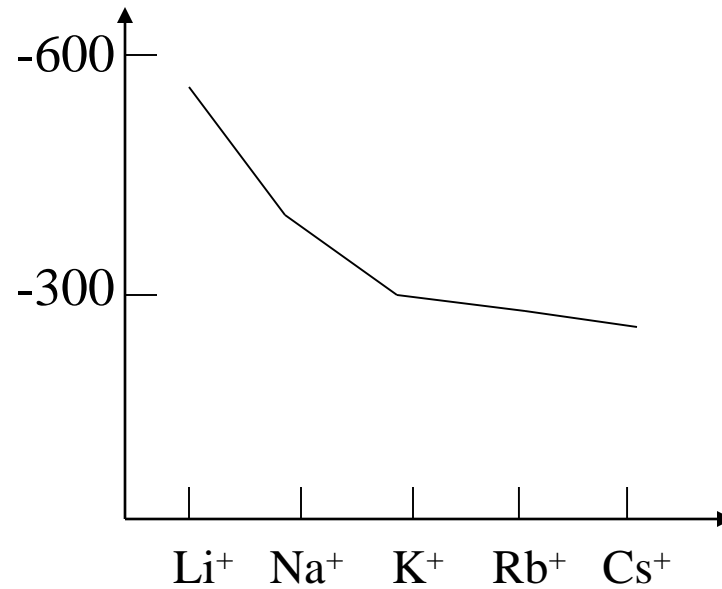
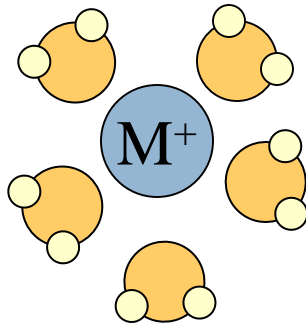
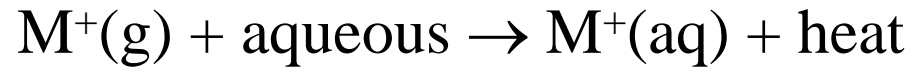
1. Have generally low 1st I.E. as it is well shielded from the nucleus by inner shells.
2. Removal of a 2nd electron is much more difficult because it involves the removal of inner shell electron.
3. I.E. decreases as the group is descended.
As atomic radius increases, the outer e is further away from the well-shielded nucleus.

Ionization Enthalpy

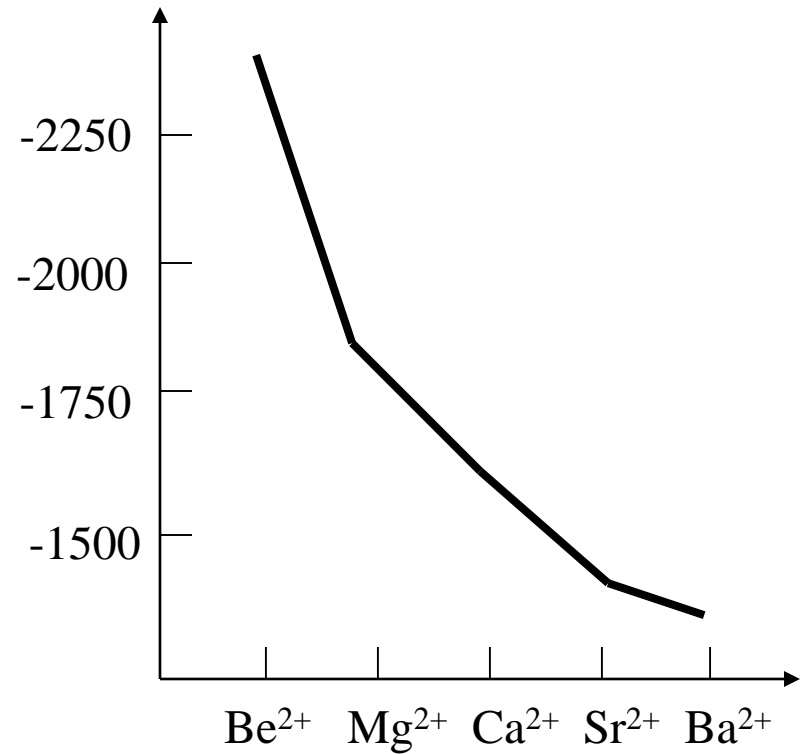
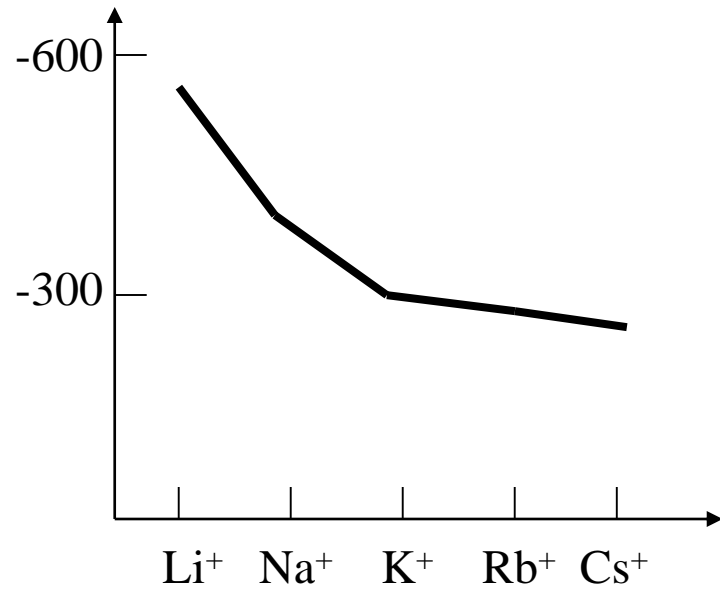
Group II

1. Have low 1st and 2nd IE.
2. Removal of the 3rd electron is much more difficult as it involves the loss of an inner shell electron.
3. IE decrease as the group is descended.
4. IE of the group II is generally higher than group I.

Hydration Enthalpy



Hydration Enthalpy



Hydration Enthalpy

General trends:

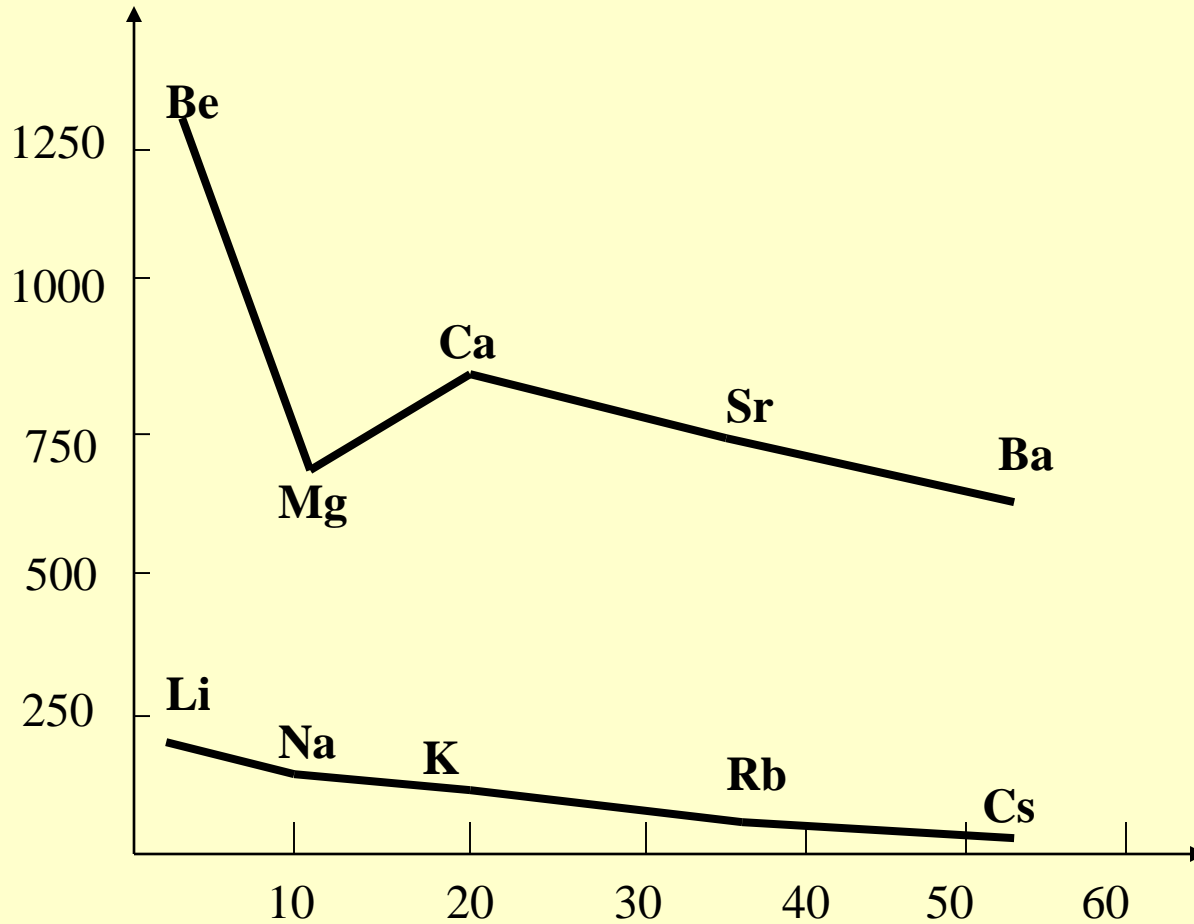
1. On going down both groups, hydration enthalpy decreases.

(As the ions get larger, the charge density of the ions decreases, the electrostatic attraction between ions and water molecules gets smaller.)

2. Group 2 ions have hydration enthalpies higher than group 1.

(Group 2 cations are doubly charged and have smaller sizes)

Variation in Melting Points



Variation in Melting Points

Strength of metallic bond depends on:

1. Ionic radius
2. Number of e^- contributed to the electron sea per atom
3. Crystal lattice structure

Note: The exceptionally high m.p. of calcium is due to contribution of d-orbital participation of metallic bonding.

Variation in Melting Points

Group I	Structure	Group II	Structure
Li	B.C.C.	Be	H.C.P.
Na	B.C.C.	Mg	H.C.P.
K	B.C.C.	Ca	C.C.P.
Rb	B.C.C.	Sr	C.C.P.
Cs	B.C.C.	Ba	B.C.C.

Reactions with oxygen

S-block elements are strong reducing agents. Their reducing power increases down both groups. (As the atomic size increases, it becomes easier to remove the outermost electron)

S-block elements reacts readily with oxygen. Except Be and Mg, they have to be stored under liquid paraffin to prevent contact with the atmosphere.

Reactions with oxygen

	Normal Oxide	Peroxide	Superoxide
Structure	$\begin{array}{c} \cdot\cdot \text{ 2-} \\ \text{:O:} \\ \cdot\cdot \end{array}$	$\begin{array}{c} \cdot\cdot \cdot\cdot \text{ 2-} \\ \text{:O-O:} \\ \cdot\cdot \cdot\cdot \end{array}$	$\begin{array}{c} \cdot \quad \cdot \text{ -} \\ \text{:O::O:} \\ \cdot\cdot \quad \cdot\cdot \end{array}$
Formed by	Li and Group II	Na and Ba	K, Rb, Cs

Reaction with water



Li -3.05 volt

Na -2.71

K -2.93

Rb -2.99

Cs -3.20

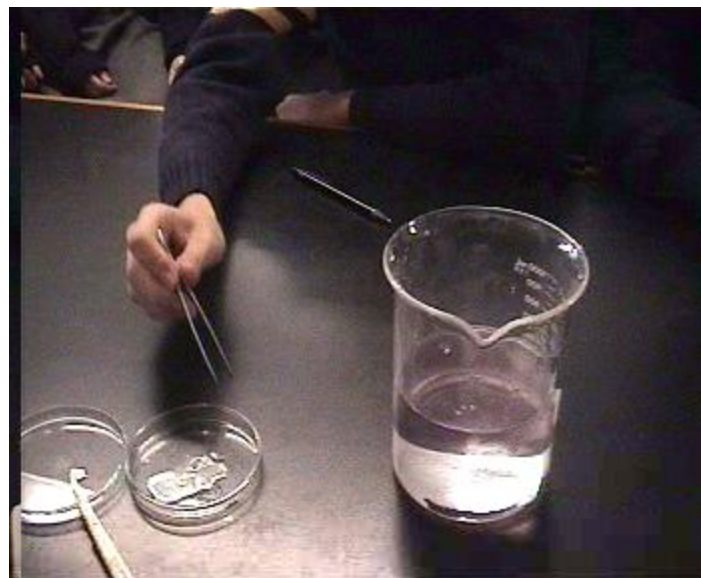
Be -1.85 volt

Mg -2.38

Ca -2.87

Sr -2.89

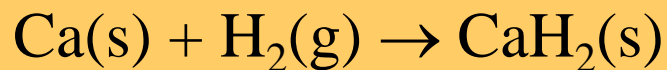
Ba -2.90



Energetic vs. Kinetic Factor

Reaction with hydrogen

All the s-block elements except Be react directly with hydrogen.



The reactivity increases down the group.

Only BeH_2 and MgH_2 are covalent, others are ionic.

Reaction with chlorine

All the s-block metals react directly with chlorine to produce chloride.

All group I chlorides are ionic.

BeCl_2 is essentially covalent, with comparatively low m.p.

The lower members in group II form essentially ionic chlorides, with Mg having intermediate properties.

Although lithium has highly negative E° , it only reacts slowly with water. This illustrates the importance of the role of kinetic factors in determining the rate of a chemical reaction.

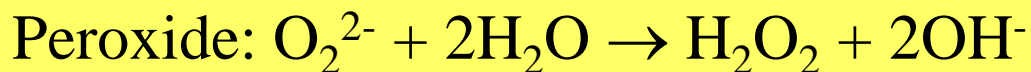
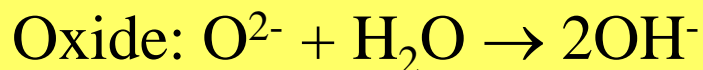
Lithium has a higher m.p., this increases the activation energy required for dissolution in aqueous solution. It does not melt during the reaction as Na and K do, and thus it has a smaller area of contact with water.

Variation in properties of the compounds

- Reactions of oxides and hydroxides
- Reactions of chlorides
- Reactions of hydrides
- Relative thermal stability of carbonates and hydroxides
- Relative solubility of sulphate(VI) and hydroxide

Reactions of oxides and hydroxides

1. All group I oxides reacts with water to form hydroxides



2. All group I oxides/hydroxides are basic and the basicity increases down the group.

Reactions of oxides and hydroxides

3. Group II oxides/hydroxides are generally less basic than Group I. Beryllium oxide/hydroxide are amphoteric.

Reactions of chlorides

1. All group I chlorides are ionic and readily soluble in water. No hydrolysis occurs.

2. Group II chlorides show some degree of covalent character.

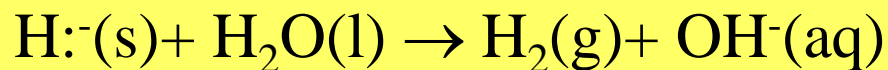
Beryllium chloride is covalent and hydrolysis to form $\text{Be}(\text{OH})_2(\text{s})$ and $\text{HCl}(\text{aq})$.

Magnesium chloride is intermediate, it dissolves and hydrolysis slightly.

Other group II chlorides just dissolve without hydrolysis.

Reactions of hydrides

They all react readily with water to give the metal hydroxide and hydrogen due to the strong basic property of the hydride ion, H^-



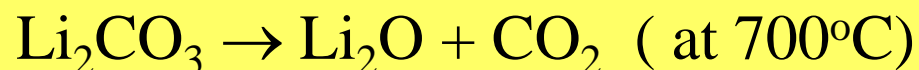
Hydride ions are also good reducing agent. They can be used to prepare complex hydrides such as LiAlH_4 and NaBH_4 which are used to reduce $\text{C}=\text{O}$ in organic chemistry.

Thermal Stability

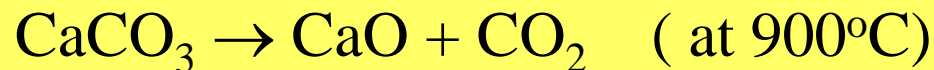
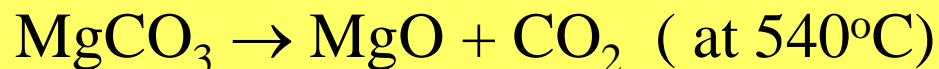
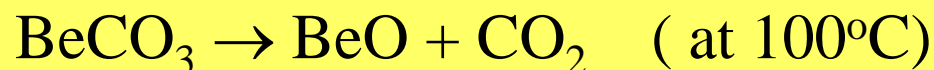


Thermal stability refers to decomposition of the compound on heating. Increased thermal stability means a higher temperature is needed to decompose the compound.

Thermal Stability of carbonates

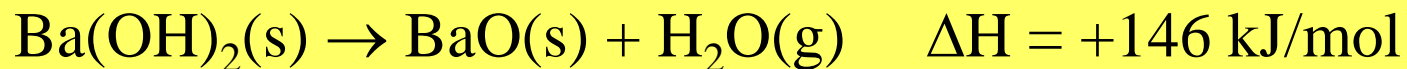
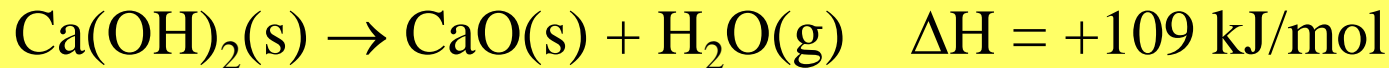
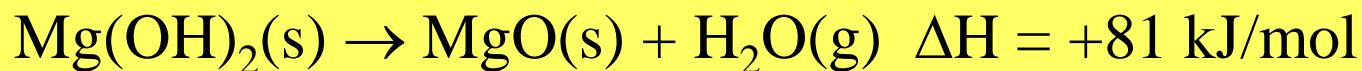


All other group I carbonates are stable at $\sim 800^\circ\text{C}$



Thermal Stability of hydroxides

All group I hydroxides are stable except LiOH at Bunsen temperature.



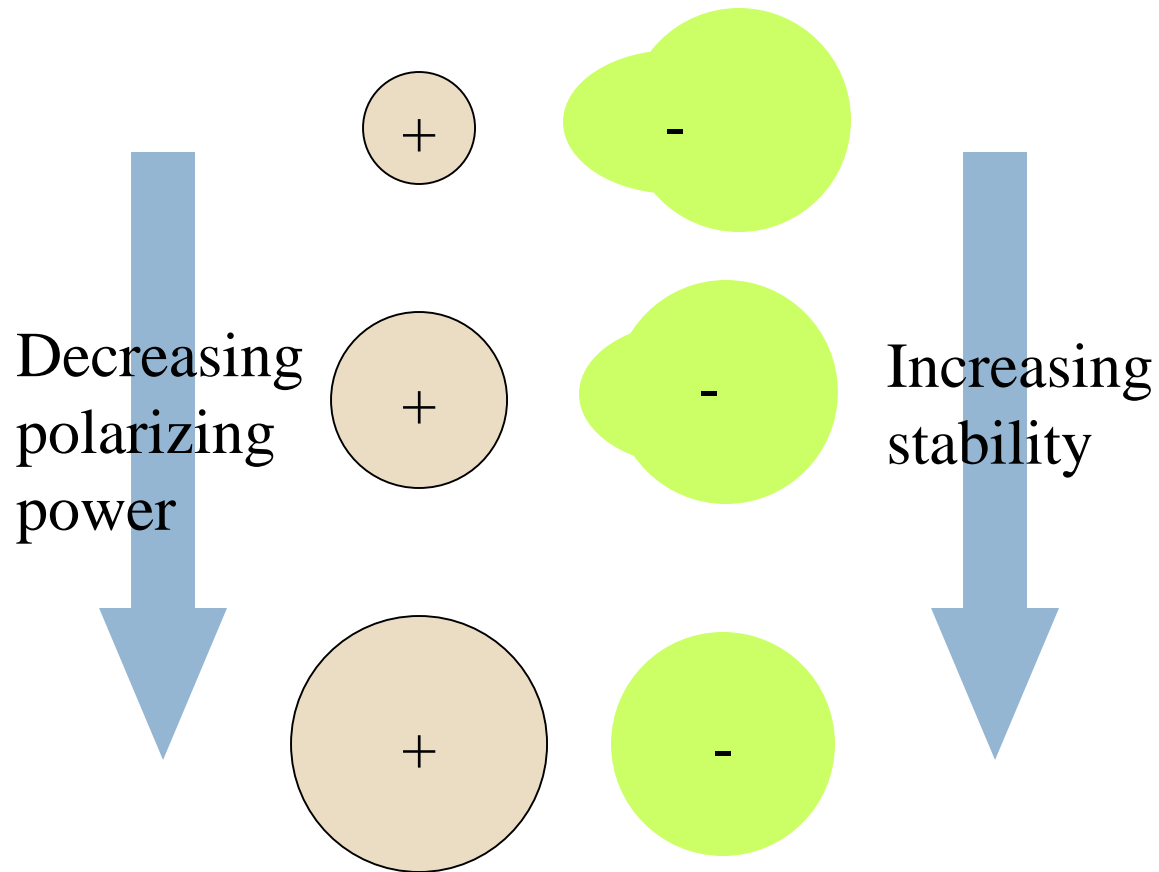
Thermal stability

1. Carbonates and hydroxides of Group I metals are as a whole more stable than those of Group II.
2. Thermal stability increases on descending the group.
3. Lithium often follow the pattern of Group II rather than Group I.
This is an example of the *diagonal relationship*.

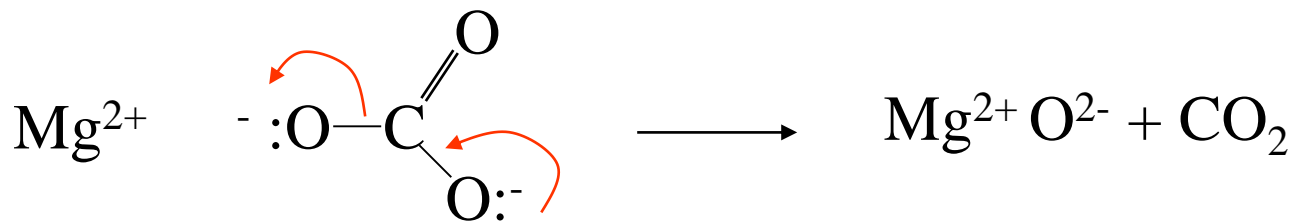
Explanation of Thermal Stability

1. Charge of the ions
2. Size of the ions
3. Compounds are more stable if the charge increases and size decreases.
4. For compounds with large polarizable anions, thermal stability is affected by the polarizing power of the cations.

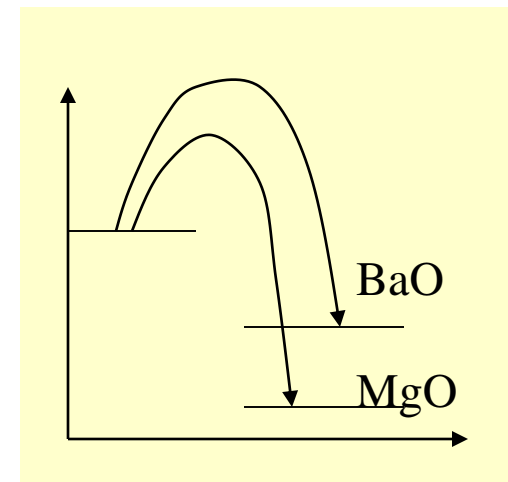
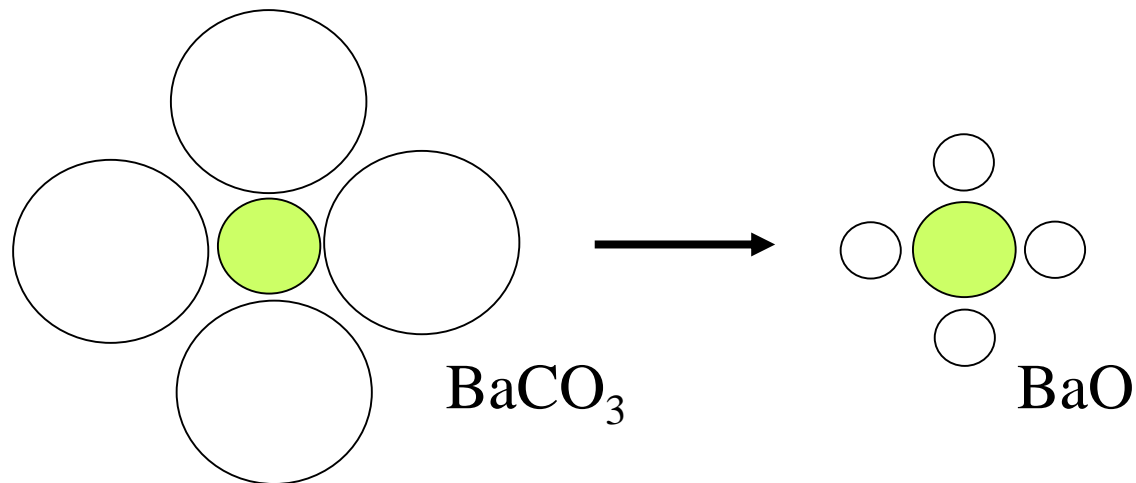
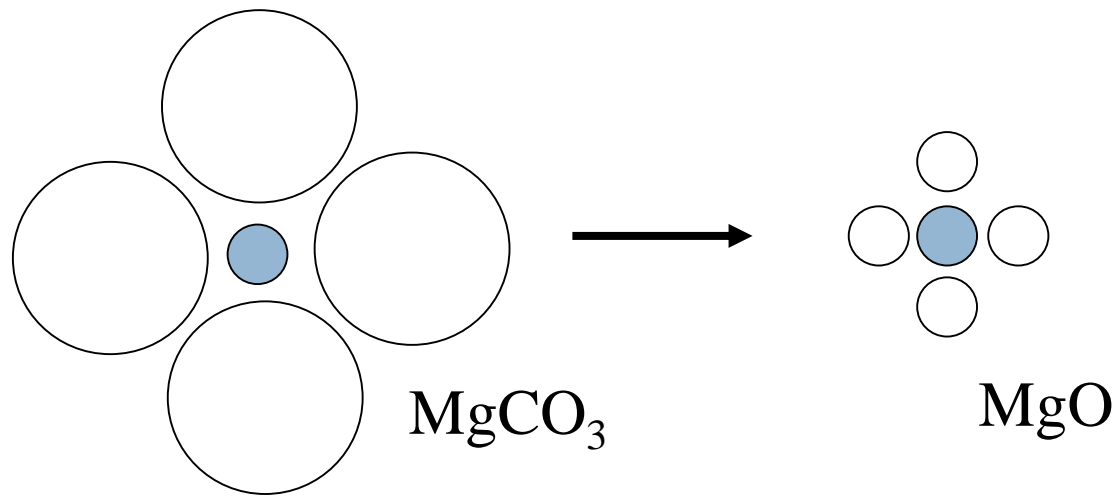
Explanation of Thermal Stability



Explanation of Thermal Stability



Explanation of Thermal Stability



Relative solubility of Group II hydroxides

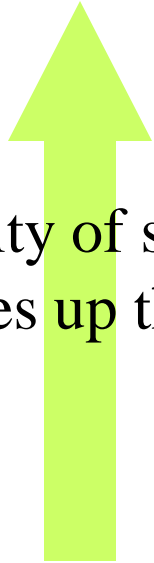
Compound	Solubility / mol per 100g water
Mg(OH) ₂	0.020 x 10 ⁻³
Ca(OH) ₂	1.5 x 10 ⁻³
Sr(OH) ₂	3.4 x 10 ⁻³
Ba(OH) ₂	15 x 10 ⁻³

Solubility of hydroxides increases down the group.



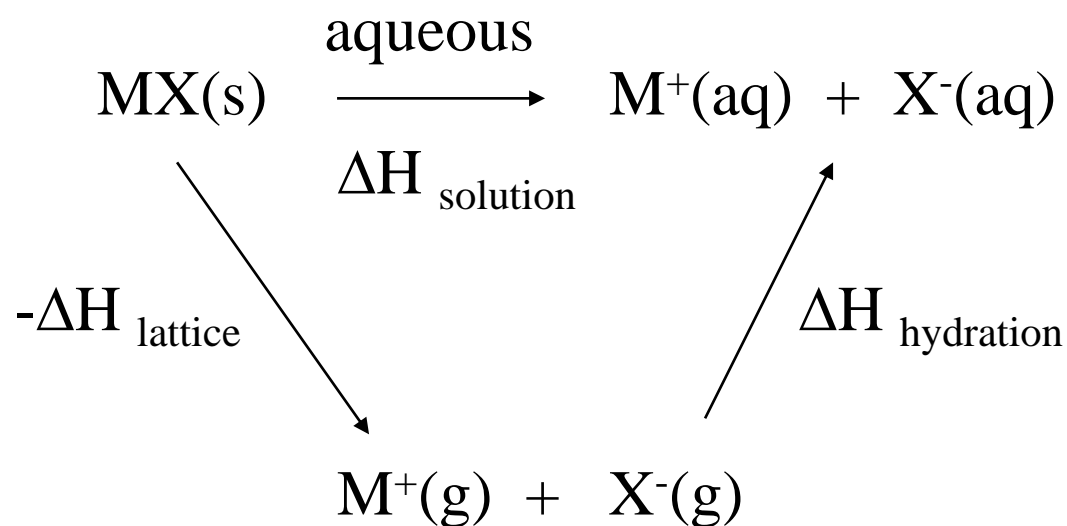
Solubility of Group II sulphates

Compound	Solubility / mol per 100g water
MgSO ₄	3600 x 10 ⁻⁴
CaSO ₄	11 x 10 ⁻⁴
SrSO ₄	0.62 x 10 ⁻⁴
BaSO ₄	0.009 x 10 ⁻⁴



Solubility of sulphates increases up the group.

Explanation of solubility



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

Explanation of solubility

1. Group I compounds are more soluble than Group II because the metal ions have smaller charges and larger sizes. $\Delta H_{\text{lattice}}$ is smaller, and $\Delta H_{\text{solution}}$ is more exothermic.

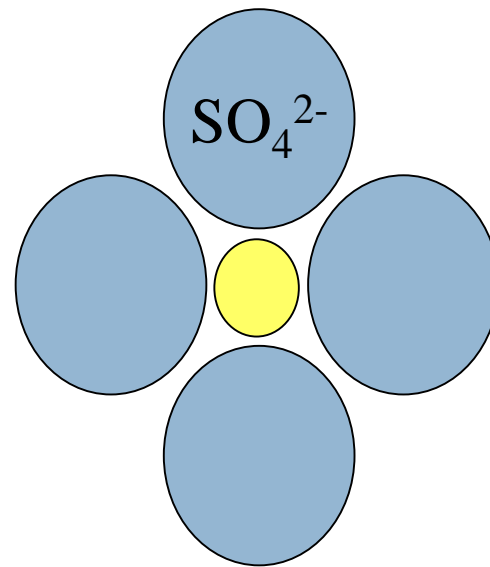
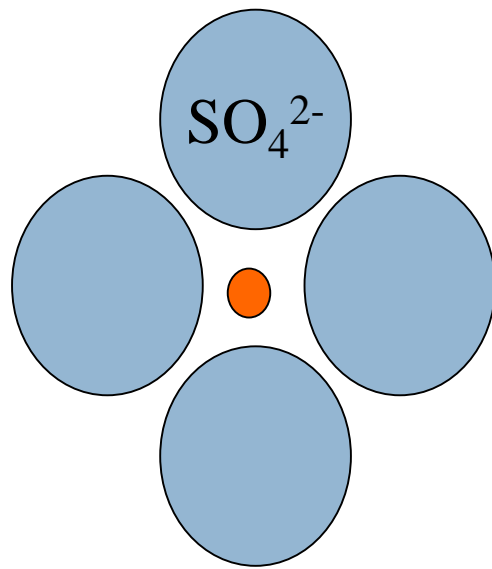
$$\Delta H_{\text{solution}} = -\Delta H_{\text{lattice}} + \Delta H_{\text{hydration}}$$

Explanation of solubility

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

2. For Group II sulphates, the cations are much smaller than the anions. The changing in size of cations does not cause a significant change in $\Delta H_{\text{lattice}}$ (proportional to $1/(r_+ + r_-)$).

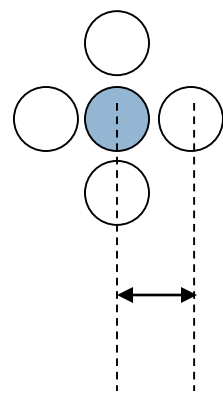
However, the changing in size of cations does cause $\Delta H_{\text{hydration}}$ (proportional to $1/r_+$ and $1/r_-$) to become less exothermic, and the solubility decreases when descending the Group.



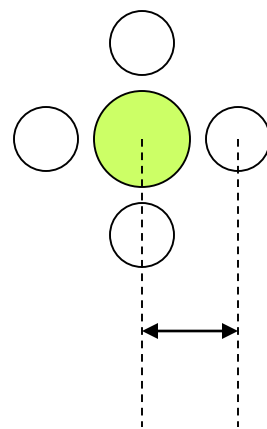
Explanation of solubility

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

3. For the smaller size anions, OH^- .
Down the Group, less enthalpy is required to break the lattice as the size of cation increases. However the change in $\Delta H_{\text{solution}}$ is comparatively smaller due to the large value of $1/r_-$.
As a result, $\Delta H_{\text{solution}}$ becomes more exothermic and the solubility increases down the Group.



$\text{Mg}(\text{OH})_2$



$\text{Sr}(\text{OH})_2$

Uses of s-block compounds

- Sodium carbonate
 - Manufacture of glass
 - Water softening
 - Paper industry
- Sodium hydrocarbonate
 - Baking powder
 - Soft drink

Uses of s-block compounds

- Sodium hydroxide
 - Manufacture of soaps, dyes, paper and drugs
 - To make rayon and important chemicals
- Magnesium hydroxide
 - Milk of magnesia, an antacid
- Calcium hydroxide
 - To neutralize acids in waste water treatment
- Strontium compound
 - Fireworks, persistent intense red flame



Thank You