

CHAPTER 11: Group II

- 11.1 Physical Properties of Group II Elements
- 11.2 Reactions of Group II Elements
- 11.3 Group II Oxides, Hydroxides and Carbonates
- 11.4 Thermal Decomposition
- 11.5 Uses of Group II Compounds

Learning outcomes:

- (a) describe the reactions of the elements with oxygen, water and dilute acids.
- (b) describe the behaviour of the oxides, hydroxides and carbonates with water and with dilute acids.
- (c) describe the thermal decomposition of the nitrates and carbonates.
- (d) interpret, and make predictions from, the trends in physical and chemical properties of the elements and their compounds.
- (e) explain the use of magnesium oxide as a refractory lining material
- (f) describe and explain the use of lime in agriculture.

11.1 Physical Properties of Group II Elements

Introduction to Group II elements

- 1) Group II elements(also called the 'alkaline earth metals') are s-block elements with a characteristic outer shell configuration ns^2 .

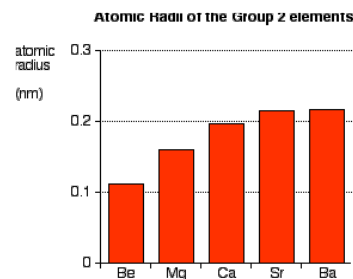
<u>Group II elements</u>	<u>Atomic no.</u>	<u>Electronic configuration</u>
beryllium Be	4	$1s^2 2s^2$
magnesium Mg	12	$1s^2 2s^2 2p^6 3s^2$
calcium Ca	20	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$
strontium Sr	38	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 5s^2$
barium Ba	56	$[Xe] 6s^2$

- 2) Group II elements are very reactive metals. They have low electronegativity and are readily oxidised, they **always** exhibit an oxidation state of +2 in their compounds. This is because the two outer s electrons are readily lost during a reaction to achieve a noble gas configuration.



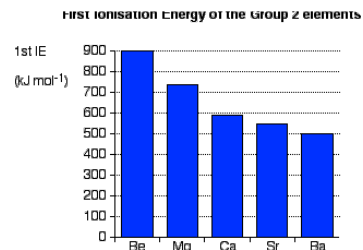
Variation in atomic radius

- 1) The atomic radius **increases** going down the Group. This is because going down the Group, each succeeding element has **one more shell of electrons**. The distance between nucleus and outer electrons are progressively further.



Variation in first ionisation energy

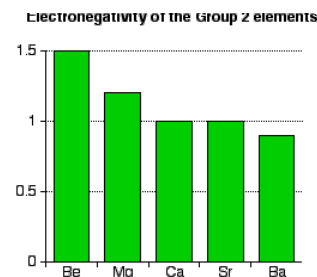
- 1) The first ionisation energy **decreases** down the Group. This is because the distance between nucleus and outer electrons increases, and the outer electrons are more shielded.



- 2) These two factors outweigh the increasing nuclear charge. So, the attractive force between nucleus and outer electrons decreases and less energy is required to remove the electron.

Variation in electronegativity

- 1) Electronegativity **decreases** down the Group. This is because the distance between the nucleus and the bonded pair of electrons increases down the Group. Therefore the electrons are held less strongly by the nucleus.

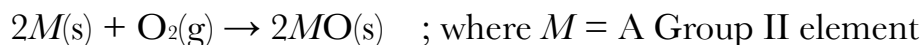


- 2) In other words, the reducing power (and reactivity) increases down the Group.

11.2 Reactions of Group II Elements

Reaction with oxygen gas, O₂

- 1) All Group II elements (except beryllium) burn in oxygen with a bright flame to form monoxides.



- 2) i. $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$; burns with brilliant white flame
ii. $2Ca(s) + O_2(g) \rightarrow 2CaO(s)$; burns with brick red flame
iii. $2Sr(s) + O_2(g) \rightarrow 2SrO(s)$; burns with crimson red flame
iv. $2Ba(s) + O_2(g) \rightarrow 2BaO(s)$; burns with apple green flame



Magnesium burning



Calcium burning



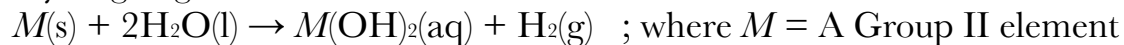
Strontium burning



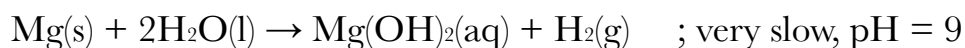
Barium burning

Reaction with water, H₂O

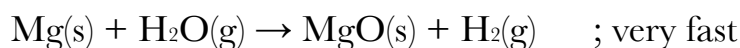
- 1) All Group II elements(except beryllium) reacts with water to form hydroxides and hydrogen gas.



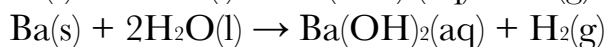
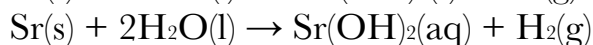
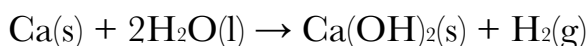
- 2) i. **Beryllium** has no reaction with cold water or steam even at red heat due to the formation of protective oxide layer on its surface.
ii. **Magnesium** reacts very slowly with cold water, taking several days to collect a test tube of hydrogen gas and a weakly alkaline magnesium hydroxide solution.



However, it reacts rapidly with steam to produce magnesium oxide and hydrogen gas. This is because the hydroxide formed thermally decompose into an oxide.



- iii. **Calcium, strontium** and **barium** reacts vigorously with cold water to give hydroxides.



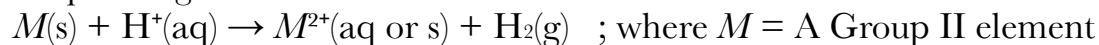
Note:

- i. Ca(OH)₂ appears as white precipitate. It is sparingly soluble therefore a weakly alkaline solution will also be formed.

- 3) The reactivity of the elements with water **increases** down the Group. In other words, they become **more soluble** going down the Group.

Reaction with acids

- 1) All Group II elements react with acid to give hydrogen gas and the corresponding salt.



- 2) i. Beryllium reacts slowly with acids and has no reaction at room temperature.
ii. The rest of Group II metals react with **increasing vigorous** going down the Group.

11.3 Group II Oxides, Hydroxides and Carbonates

Group II oxides

	BeO	MgO	CaO	SrO	BaO
<i>Nature of oxide</i>	<i>amphoteric</i> (reacts with both acids and bases) $\text{BeO} + 2\text{H}^+ \rightarrow \text{Be}^{2+} + \text{H}_2\text{O}$ $\text{BeO} + 2\text{OH}^- + \text{H}_2\text{O} \rightarrow \text{Be}(\text{OH})_4^{2-}$ beryllate	<i>basic</i> (reacts with acids to give salts and water) $\text{MgO} + 2\text{H}^+ \rightarrow \text{Mg}^{2+} + \text{H}_2\text{O}$ $\text{CaO} + 2\text{H}^+ \rightarrow \text{Ca}^{2+} + \text{H}_2\text{O}$ $\text{SrO} + 2\text{H}^+ \rightarrow \text{Sr}^{2+} + \text{H}_2\text{O}$ $\text{BaO} + 2\text{H}^+ \rightarrow \text{Ba}^{2+} + \text{H}_2\text{O}$			
<i>Reaction with water</i>	<i>insoluble in water</i> (high lattice energy making solution difficult)	<i>slightly soluble in water</i> (pH \approx 9)	<i>dissolve in water to give an alkaline solution</i> (pH 10 – 13) * $\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca}(\text{OH})_2$ $\text{SrO} + \text{H}_2\text{O} \rightarrow \text{Sr}(\text{OH})_2$ $\text{BaO} + \text{H}_2\text{O} \rightarrow \text{Ba}(\text{OH})_2$		

- 1) All Group II oxides(except beryllium oxide) reacts with water, at least to some extent to give the corresponding hydroxides.
- 2)
 - i. Beryllium oxide is insoluble because Be^{2+} ion is a very small and highly charged ion, thus making the lattice energy of BeO exceptionally high.
 - ii. Magnesium oxide is only slightly soluble in water, producing a weakly alkaline solution.
 - iii. Addition of calcium oxide with water is a very vigorous and exothermic reaction.
- 3) All Group II oxides(except beryllium oxide) are **basic**. They react with acids to give the corresponding salt and water.
- 4) Beryllium oxide, on the other hand, is amphoteric. It reacts with both acid and base.

Group II hydroxides

- 1) Group II hydroxides are not very soluble, and they do not react with water. However, the solubility **increases** down the Group.
- 2)
 - i. Magnesium hydroxide is only slightly soluble in water, with a pH of about 9.
 - ii. Calcium hydroxide(slaked lime) is moderately soluble to give a solution called "lime water".

- 3) Group II hydroxides behave as a base and react with acids to give the corresponding salt and water.

Group II carbonates

- 1) Group II carbonates are mainly insoluble, and they do not react with water. The solubility **decreases** down the Group.
- 2) Group II carbonates react with acid to form salt, carbon dioxide and water.
 $MCO_3(s) + H^+ \rightarrow M^{2+}(aq \text{ or } s) + CO_2(g) + H_2O(l)$; where $M =$ A Group II element

11.4 Thermal Decomposition

Thermal decomposition of Group II salts

- 1) In general, compounds with **high charge density cation** and **large anion size** tend to decompose more easily (less stable on heat) due to the **greater polarisation of anion by the cation**.
- 2) Thermal decomposition of Group II salts **decreases** down the Group. In other words, the thermal stability of Group II salts **increases** down the Group.
- 3) This is because going down the Group, the cation size increases while the anion size remains unchanged. Therefore the charge density and polarising power of cation decreases and the anion cloud is less polarised. The compound is more stable on heating.
- 4) Group II salts are less stable compared to Group I salts due to the higher charge density of M^{2+} ion.

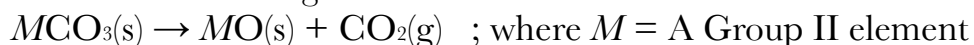
Thermal decomposition of Group II nitrates

- 1) All Group II nitrates decompose on heating to give the corresponding metal oxide, brown nitrogen monoxide gas and oxygen gas.
 $2M(NO_3)_2(s) \rightarrow 2MO(s) + 4NO_2(g) + O_2(g)$; where $M =$ A Group II element

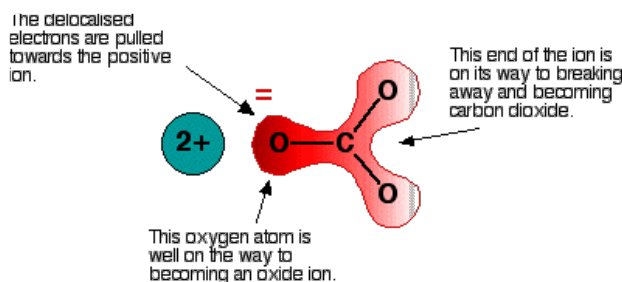
- 2) Thermal stability of Group II nitrates **increases** down the Group. This is because the cation size increases down the Group, this reduces the charge density and polarising power of cation. The nitrate ion is less polarised and the compound is more stable.

Thermal decomposition of Group II carbonates

- 1) All Group II carbonates decompose on heating to give the corresponding metal oxide and carbon dioxide gas.



- 2) Thermal stability of Group II carbonates **increases** down the Group. This is because the cation size increases down the Group, this reduces the charge density and polarising power of cation. The carbonate ion is less polarised and the compound is more stable.



11.5 Uses of Group II Compounds

- 1) Some ceramics contain magnesium oxide, MgO and they can be used as:
- electrical insulators in industrial electrical cables.
 - a refractory in furnace linings because it has a high melting point. (However, it cannot be used in furnaces where acid is present due to its basic nature)
 - in fire-resistant wall boards.
- 2) Calcium compounds have many uses, this includes:
- calcium carbonate (limestone) to make cement.
 - It is roasted in a lime kiln so that it decomposes into calcium oxide, CaO (quicklime). The cement made is mixed with rocks to make concrete.
 - using calcium hydroxide/oxide/carbonate to treat acidic soil as they react with acids.