GROUP II ELEMENTS

Beryllium to Barium

Introduction

Elements in Group I *(alkali metals)* and Group II *(alkaline earths)* are known as **s-block elements** because their valence (bonding) electrons are in s orbitals.

	Be	*Mg*	*Ca*	*Sr*	*Ba*
Atomic Number	4	12	20	38	56
Electronic configuration	$1s^2 2s^2$	[Ne] $3s^2$	[Ar] $4s^2$	[Kr] $5s^2$	[Xe] $6s^2$

PHYSICAL PROPERTIES

Atomic Radius

Increases down each group electrons are in shells further from the nucleus

	Be	*Mg*	*Ca*	*Sr*	*Ba*
Atomic radius / nm	0.106	0.140	0.174	0.191	0.198

Ionic Size

Increases down the group

The size of positive ions is less than the original atom because the nuclear charge exceeds the electronic charge.

	Be^{2+}	*Mg^{2+}*	*Ca^{2+}*	*Sr^{2+}*	*Ba^{2+}*
Ionic radius / nm	0.030	0.064	0.094	0.110	0.134

Melting Points

Decrease down each group metallic bonding gets weaker due to increased size

Each atom contributes two electrons to the delocalised cloud. Melting points tend not to give a decent trend as different crystalline structures affect the melting point.

	Be	*Mg*	*Ca*	*Sr*	*Ba*
Melting point / °C	1283	650	850	770	710

Ionisation Energy

Decreases down the group atomic size increases

Values are low because the electron has just gone into a new level and is shielded by filled inner levels. This makes them reactive.

	Be	*Mg*	*Ca*	*Sr*	*Ba*
Ist I.E. / kJ mol $^{-1}$	899	738	590	550	500
2nd I.E. / kJ mol $^{-1}$	1800	1500	1100	1100	100
3rd I.E. / kJ mol $^{-1}$	14849	7733	4912		

There is a **large increase for the 3rd I.E.** as the electron is now being removed from a **shell nearer the nucleus** and there is **less shielding**.

Electronegativity **Decreases down the group**

Increased shielding makes the shared pair less strongly attracted to the nucleus

	Be	*Mg*	*Ca*	*Sr*	*Ba*
Electronegativity (Pauling)	1.5	1.2	1.0	0.95	0.89

Hydration Enthalpy **Decreases** *(gets less negative)* **down each group**

Charge density of the ions decreases thus reducing the attraction for water

	Be^{2+}	Mg^{2+}	Ca^{2+}	Sr^{2+}	Ba^{2+}
Hydration Enthalpy / kJ mol $^{-1}$		-1891	-1562	-1413	-1273

CHEMICAL PROPERTIES

Water

- **react with increasing vigour down the group**

Be — does not react with water or steam

Mg — reacts slowly with cold water and quickly with steam

$$\mathbf{Mg_{(s)} + H_2O_{(g)} \longrightarrow MgO_{(s)} + H_{2(g)}}$$

Ca, Sr, Ba — react with cold water with increasing vigour

e.g. $$\mathbf{Ca_{(s)} + 2H_2O_{(l)} \longrightarrow Ca(OH)_{2(aq)} + H_{2(g)}}$$

COMPOUNDS

Hydroxides

- white crystalline solids
- solubility in water increases down the Group

$Be(OH)_2$ *insoluble*
$Mg(OH)_2$ *sparingly soluble*
$Ca(OH)_2$ *slightly soluble* - an aqueous solution is known as 'lime water'
$Sr(OH)_2$ *quite soluble*
$Ba(OH)_2$ *very soluble*

- **basic strength also increases down group**
- the **metal ions get larger** so charge density decreases
- there is a lower attraction between the OH^- ions and larger unipositive ions
- the ions will split away from each other more easily
- there will be a greater concentration of OH^- ions in water

$$M\mathbf{(OH)_{2(s)}} + \text{water} \longrightarrow \mathbf{M^{2+}_{(s)} + 2OH^-_{(aq)}}$$

'*The greater the concentration of OH^- ions in water the greater the alkalinity*'

Sulphates

- white crystalline solids
- solubility in water decreases down the Group

Salt	*Ionic radius (M^{2+}) / nm*	*Hydration Enthalpy (M^{2+}) / kJ mol $^{-1}$*	*Solubility moles/100g*
$MgSO_4$	0.064	-1891	3600×10^{-4}
$CaSO_4$	0.094	-1562	11×10^{-4}
$SrSO_4$	0.110	-1413	0.62×10^{-4}
$BaSO_4$	0.134	-1273	0.009×10^{-4}

- reasons for solubility decreasing down the group ...
  - there is little change in the lattice enthalpy BUT
  - as the **cation gets larger** the **hydration enthalpy gets much smaller**
  - a **larger cation** has a **lower charge density** and so is **less attracted to water**

Testing for sulphates

- barium sulphate's insolubility is used as a test for sulphates

Method
- make up a solution of the compound to be tested
- acidify it with dilute hydrochloric (or nitric) acid *
- add a few drops of barium chloride solution
- white precipitate of barium sulphate conforms the presence of a sulphate

$$Ba^{2+}_{(aq)} + SO_4^{2-}_{(aq)} \longrightarrow BaSO_{4(s)}$$

** adding acid prevents the precipitation of other insoluble ions such as carbonate*

THE ATYPICAL NATURE OF BERYLLIUM

Theory Beryllium differs from the other Group II elements; it has properties closer to that of aluminium - THE DIAGONAL RELATIONSHIP. Being the **head element** of a Group...

it has
- a much **smaller ionic size** (a **greater charge/size ratio** - **highly polarising**)
- a much **larger ionisation energies** than those elements below it

so
- is less likely to form ions
- compounds ($BeCl_2$) show covalent character
  - often soluble in organic solvents
  - have lower melting points
  - often hydrolysed by water
- maximum co-ordination number of 4 - due to small size
- beryllium hydroxide is AMPHOTERIC - dissolves in both acids and bases

$$Be(OH)_{2(s)} + 2H^+_{(aq)} + 2H_2O_{(l)} \longrightarrow [Be(H_2O)_4]^{2+}_{(aq)}$$

$$Be(OH)_{2(s)} + 2OH^-_{(aq)} \longrightarrow [Be(OH)_4]^{2-}_{(aq)}$$