GROUP 2 ELEMENTS - Beryllium to Barium

Introduction Group I *(alkali metals)* and Group 2 *(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] $6s^2$

TRENDS IN PHYSICAL PROPERTIES

Atomic Radius **Increases down each group** electrons 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** nuclear charge exceeds the electronic charge

The size of a positive ions is always 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 and lower charge density

Each atom contributes two electrons to the delocalised cloud. Melting points tend not to give a decent trend as crystalline structure affects melting points.

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

TRENDS IN CHEMICAL PROPERTIES

Overall
- undergo redox reactions involving the 'loss' of electrons to form 2+ ions
- **reactivity increases down the Group** due to the ease of cation formation

Reason
- **ionisation energies (I.E.) decrease down the group**

REMINDER

1st I.E. *The energy required to remove one mole of electrons (to infinity) from one mole of gaseous atoms to form one mole of gaseous positive ions.*

e.g. $Mg(g) \longrightarrow Mg^{+}(g) + e^{-}$

2nd I.E. *e.g.* $Mg^{+}(g) \longrightarrow Mg^{2+}(g) + e^{-}$

Ionisation Energy **Decreases down the group** atomic size increases

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

Group 2 values are higher than their Group I equivalents due to the increased nuclear charge.

	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	1000
3rd I.E. / kJ mol $^{-1}$	14849	7733	4912	4120	3390

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

CHEMICAL PROPERTIES OF THE ELEMENTS

Oxygen • **react with increasing vigour down the group**

Mg burns readily with a bright white flame

0 0 +2 -2

2Mg(s) + **O_2**(g) ——> **2MgO**(s)

Ba burns readily with an apple-green flame

2Ba(s) + **O_2**(g) ——> **2BaO**(s)

In both cases **metal is oxidised** Oxidation No. increases from 0 to +2
oxygen is reduced Oxidation No. decreases from 0 to -2

Mg ——> Mg^{2+} + $2e^-$

O + $2e^-$ ——> O^{2-}

Water • **react with increasing vigour down the group**

Mg reacts very slowly with cold water

Mg(s) + **$2H_2O$**(l) ——> **$Mg(OH)_2$**(aq) + **H_2**(g)

but reacts quickly with steam

Mg(s) + **H_2O**(g) ——> **MgO**(s) + **H_2**(g)

Ba react with vigourously with cold water

Ba(s) + **$2H_2O$**(l) ——> **$Ba(OH)_2$**(aq) + **H_2**(g)

Dilute acid

- **react with increasing vigour down the group to produce hydrogen + a salt**
- reactions are more vigorous than with water

e.g. **Mg**(s) + **H_2SO_4**(aq) ——> **$MgSO_4$**(aq) + **H_2**(g)

Mg(s) + **2HC*l*** (aq) ——> **MgC_{l2}**(aq) + **H_2**(g)

ionically **Mg(s)** + **$2H^+$**(aq) ——> **Mg^{2+}**(aq) + **H_2**(g)

OXIDES OF GROUP 2 ELEMENTS

Properties

- ionic solids; EXC. beryllium oxide which has covalent character

- **BeO** *beryllium oxide* **MgO** *magnesium oxide*
  CaO *calcium oxide* **SrO** *strontium oxide*
  BaO *barium oxide*

Reaction with water

Most Group 2 oxides react with water to produce the hydroxide

e.g. **CaO**(s) + **H_2O**(l) ——> **$Ca(OH)_2$**(s)

	BeO	MgO	CaO	SrO	BaO
Reactivity with water	NONE	reacts	reacts	reacts	reacts
Solubility of hydroxide g/100cm^3 of water	insoluble	sparingly	slightly	quite	very
approx. *pH of 0.1M solution*	-	10.4	12.5	13.0	13.1

Hydroxides

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

Uses

$Ca(OH)_2$

- used in agriculture to neutralise acid soils

$Ca(OH)_2$(s) + **$2H^+$** (aq) ——> **Ca^{2+}**(aq) + **$2H_2O$**(l)

$Mg(OH)_2$

- used in toothpaste and indigestion tablets as an antacid

$Mg(OH)_2$(s) + **$2H^+$** (aq) ——> **Mg^{2+}**(aq) + **$2H_2O$**(l)

- *both the above are weak alkalis and not as caustic as sodium hydroxide*

CARBONATES OF GROUP 2 ELEMENTS

Properties

- insoluble in water
- undergo thermal decomposition to oxide and carbon dioxide

  e.g. $MgCO_3(s) \longrightarrow MgO(s) + CO_2(g)$

- ease of decomposition decreases down the group

	$MgCO_3$	$CaCO_3$	$SrCO_3$	$BaCO_3$
Solubility (g/100cm^3 of water)	1.5×10^{-4}	1.3×10^{-5}	7.4×10^{-6}	9.1×10^{-6}
Decomposition temperature / °C	400	980	1280	1360

SULFATES OF GROUP 2 ELEMENTS

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}

- 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** so is **less attracted to water**

AQA

Test for sulfates

- **barium sulfate's high insolubility** is the basis for a laboratory **test for sulfates**

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 sulfate** conforms presence of sulfate ion

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$$

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

Q.1 *How is the high insolubility of barium sulfate made use of in hospitals?*