

# Group 2 — The Alkaline Earth Metals

## 01 · THE GROUP

Be, Mg, Ca, Sr, Ba — all end in **ns<sup>2</sup>** and form 2+ ions by losing both outer electrons.

Silvery reactive metals, always found combined in nature. Reactivity **increases down the group**.

## 02 · WHY REACTIVITY RISES DOWN THE GROUP

Atomic radius increases and shielding increases, so the outer electrons are held less strongly and the **first and second ionisation energies fall**.

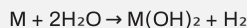
The metal is therefore a stronger reducing agent further down, and forms its 2+ ion more readily.

## 03 · REACTION WITH OXYGEN

$2M + O_2 \rightarrow 2MO$ . All burn vigorously to a white ionic oxide.

Flame colours: Mg brilliant white, Ca brick red, Sr crimson, Ba apple green.

## 04 · REACTION WITH WATER



**Mg** very slow in cold water, but  $Mg + H_2O(g) \rightarrow MgO + H_2$  with steam

**Ca** steady fizzing, cloudy suspension

**Sr, Ba** increasingly vigorous

The resulting solution is alkaline and gets more so down the group as the hydroxides become more soluble.

## 05 · REACTION WITH DILUTE ACID

$M + 2HCl \rightarrow MCl_2 + H_2$ , increasingly vigorous down the group.

With  $H_2SO_4$  the reaction slows or stops for Ca, Sr and Ba: the insoluble sulfate coats the metal and blocks further attack.

## 06 · SOLUBILITY TRENDS

| Compound   | Down the group              |
|------------|-----------------------------|
| hydroxides | solubility <b>increases</b> |
| sulfates   | solubility <b>decreases</b> |

$Mg(OH)_2$  is nearly insoluble (milk of magnesia);  $Ba(OH)_2$  dissolves freely.  $BaSO_4$  is so insoluble it is safe to swallow as a barium meal, and is the white precipitate in the sulfate test.

## 07 · THERMAL STABILITY OF CARBONATES



**Stability increases down the group**, so the decomposition temperature rises:  $MgCO_3$  decomposes easily,  $BaCO_3$  needs very strong heating.

Reason: the cation gets larger and less polarising, so it distorts the carbonate ion less. Nitrates follow the same trend:  $2M(NO_3)_2 \rightarrow 2MO + 4NO_2 + O_2$ .

## 08 · POLARISING POWER EXPLAINED

A small, highly charged cation pulls electron density from the large anion, weakening a C–O bond within  $CO_3^{2-}$  and making decomposition easier.

**Charge density** falls down the group as the ionic radius grows, so polarisation falls and stability rises. The same argument explains why Group 1 carbonates are more stable than Group 2 ones.

## 09 · THE OXIDES AND HYDROXIDES

$MO + H_2O \rightarrow M(OH)_2$  — all basic, and increasingly so down the group.

All react with acids:  $MO + 2HCl \rightarrow MCl_2 + H_2O$  and  $M(OH)_2 + H_2SO_4 \rightarrow MSO_4 + 2H_2O$ .

## 10 · USES

**Ca(OH)<sub>2</sub> / CaO** — neutralising acidic soil and acidic industrial gases; CaO in the blast furnace removes silica as slag.

**Mg(OH)<sub>2</sub> and CaCO<sub>3</sub>** — antacids: they neutralise excess stomach acid without being corrosive.

**BaSO<sub>4</sub>** — X-ray contrast medium; **Mg** — lightweight alloys and sacrificial protection.

## 11 · WORKED EXAMPLE — IDENTIFY THE METAL

A metal reacts steadily with cold water, gives a cloudy alkaline suspension and a brick-red flame colour. Its carbonate decomposes at a moderate temperature. Which is it?

Cold-water reaction rules out Mg  
Brick-red flame → **calcium**  
 $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$   
Cloudiness is the sparingly soluble  $Ca(OH)_2$ .

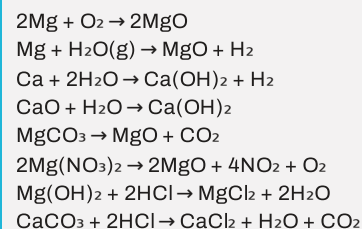
## 12 · WORKED EXAMPLE — THERMAL DECOMPOSITION

5.00 g of  $CaCO_3$  is heated until no further change. What mass of CaO remains?

$$\begin{aligned} n(CaCO_3) &= 5.00 \div 100.1 = 0.0500 \text{ mol} \\ 1 : 1 \rightarrow n(CaO) &= 0.0500 \text{ mol} \\ m &= 0.0500 \times 56.1 = \mathbf{2.80 \text{ g}} \end{aligned}$$

The 2.20 g lost is  $CO_2$ , which at r.t.p. occupies 1.20 dm<sup>3</sup>.

## 13 · EQUATIONS TO KNOW



## 14 · TESTS AND OBSERVATIONS

| Test               | Observation                        |
|--------------------|------------------------------------|
| flame test         | Ca brick red, Sr crimson, Ba green |
| + $BaCl_2 / HCl$   | white ppt confirms sulfate         |
| limewater + $CO_2$ | milky, then clears in excess       |
| carbonate + acid   | fizzing, gas turns limewater milky |

Limewater clears because the carbonate converts to soluble hydrogencarbonate:  $CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$  — the origin of temporary hardness in water.

## TRENDS IN ONE LINE

**Down Group 2:** radius ↑, ionisation energy ↓, reactivity ↑, hydroxide solubility ↑, sulfate solubility ↓, carbonate stability ↑.

Every one of these follows from the growing ionic radius and the falling charge density.

## MARKS LOST HERE

— Giving the hydroxide and sulfate solubility trends the same way round; they are opposite.

— Writing  $MgO + H_2$  for magnesium with **cold water**; that is the steam reaction.

— Explaining carbonate stability by "bigger atoms" rather than lower charge density and less polarisation.

— Forgetting that Group 2 nitrates give  $NO_2$  and  $O_2$ , not just the oxide.