Group 1 and Group 2

Trends in ionisation energy and reactivity, reactions of the alkali and alkaline earth metals and their compounds, solubility and thermal stability trends, flame colours, and tests for ions.

Trends in the s-block

Ionisation energy

The first ionisation energy **decreases down both groups**. The outer electron is in a shell further from the nucleus and is more shielded by inner shells, so less energy is needed to remove it.

Reactivity

Reactivity **increases** down Group 1 (Li to K) and Group 2 (Mg to Ba), because the outer electron or electrons are lost more easily. Group 2 elements have to lose two electrons, so they are less reactive than the Group 1 element in the same period.

Reactions of the elements

Reaction	Group 1 (M)	Group 2 (M)
With oxygen	$4M + O_2 \rightarrow 2M_2O$ (Li); Na and K also make peroxides and superoxides in excess	$2M + O_2 \rightarrow 2MO$
With chlorine	$2M + Cl_2 \rightarrow 2MCl$	$M + Cl_2 \rightarrow MCl_2$
With water	$2M + 2H_2O \rightarrow 2MOH + H_2$, vigorous and getting more so from Li to K	$M + 2H_2O \rightarrow M(OH)_2 + H_2$, slow for Mg and faster to Ba. (Mg reacts quickly with steam to give MgO.)

Observations with water: lithium fizzes steadily, sodium melts into a ball and moves, and potassium burns with a lilac flame. The resulting solutions are alkaline.

Oxides and hydroxides

- **Oxides** of Group 1 and 2 are basic. They react with water to form hydroxides: $Na_2O + H_2O \rightarrow 2NaOH$, $CaO + H_2O \rightarrow Ca(OH)_2$. They react with dilute acids to form a salt and water.
- **Hydroxides** react with dilute acids to form a salt and water (neutralisation).

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Trends in Group 2 compounds

Solubility

Compound	Trend down the group
Hydroxides	Solubility **increases** ($Mg(OH)_2$ is almost insoluble; $Ba(OH)_2$ is soluble)
Sulfates	Solubility **decreases** ($MgSO_4$ is soluble; $BaSO_4$ is insoluble)

The test for sulfate ions uses the insolubility of barium sulfate (see below).

Thermal stability of carbonates and nitrates

The carbonates and nitrates of Group 1 and 2 decompose on heating. Stability **increases down the group**.

Group 2 carbonates give the oxide and carbon dioxide: $MgCO_3 \rightarrow MgO + CO_2$.

Group 2 nitrates give the oxide, nitrogen dioxide and oxygen: $2Mg(NO_3)_2 \rightarrow 2MgO + 4NO_2 + O_2$.

Group 1 carbonates (except lithium) do not decompose in a Bunsen flame. Group 1 nitrates give the **nitrite** and oxygen: $2NaNO_3 \rightarrow 2NaNO_2 + O_2$. Lithium nitrate behaves like Group 2 and gives the oxide, NO_2 and O_2.

Explanation: a small, highly charged cation polarises the carbonate or nitrate anion, weakening a C–O or N–O bond so that the compound decomposes more easily. Down the group the cation radius increases, charge density falls, polarising power falls, and so the compounds are more stable. Group 2 ions are smaller and more highly charged than Group 1 ions, so their compounds are less stable.

Tests: **carbon dioxide** turns limewater milky. **Oxygen** relights a glowing splint. **Nitrogen dioxide** is a brown gas that turns damp blue litmus paper red.

Flame colours

When a compound is heated in a flame, electrons are excited to higher energy levels. When they fall back they emit energy as light of a specific colour.

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Ion	Flame colour
Li^+	Red (crimson)
Na^+	Yellow (orange)
K^+	Lilac
Ca^{2+}	Brick red
Sr^{2+}	Red
Ba^{2+}	Apple green (pale green)

Use a clean nichrome or platinum loop moistened with concentrated hydrochloric acid, which makes the chloride, and dip it in the solid.

Tests for ions

Ion	Test	Result and equation
Carbonate, CO_3^{2-}	Add dilute acid	Effervescence; gas turns limewater milky. $CO_3^{2-} + 2H^+ \rightarrow H_2O + CO_2$
Hydrogencarbonate, HCO_3^-	Add dilute acid	Same gas. $HCO_3^- + H^+ \rightarrow H_2O + CO_2$
Sulfate, SO_4^{2-}	Add acidified barium chloride solution	White precipitate. $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$
Ammonium, NH_4^+	Warm with sodium hydroxide	Ammonia gas turns damp red litmus blue; with HCl vapour makes white smoke. $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$

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NOTE

The barium chloride is acidified (with dilute hydrochloric acid) to remove carbonate ions, which would also give a white precipitate with Ba^{2+}. Do not use sulfuric acid, which would give false positives.

TRY IT

A white solid dissolves in water and gives no precipitate with acidified barium chloride. On warming with sodium hydroxide it gives off a gas that turns damp litmus paper blue. Which ions are present?

The gas is ammonia, so NH_4^+ is present. No precipitate means sulfate is absent.