

Reactivity trends in group 2 and the halogens

Chemistry grades 11-12 (A Level · IB · Class 11-12) · Lesson

Quick answer: Group 2 metals are reactive metals that lose two outer electrons to form 2+ ions, and their reactivity rises down the group. The halogens are reactive non-metals that gain one electron to form 1– ions, and their oxidising power falls down the group. Both groups show clear trends that you can test in the lab.

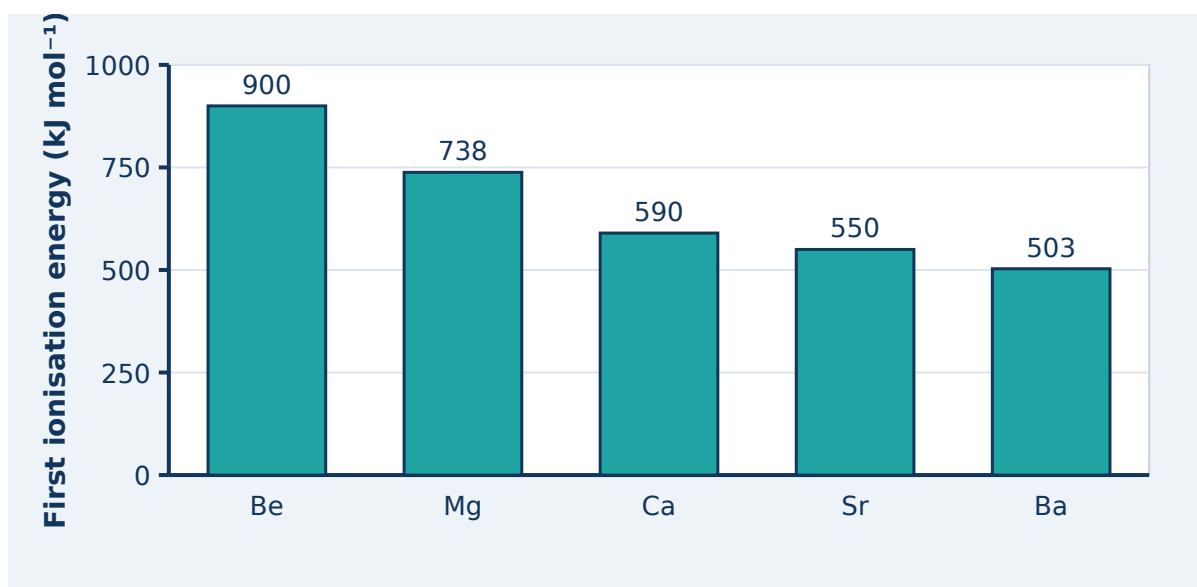
Level: Chemistry grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** A Level 3.2.2-3.2.3

How do the group 2 metals react?

The group 2 elements (beryllium, magnesium, calcium, strontium and barium) each have two electrons in their outer s subshell. They react by losing both: $M \rightarrow M^{2+} + 2e^{-}$. Reactivity increases down the group, because the atoms get larger, the outer electrons sit further from the nucleus and are shielded by more inner shells, so less energy is needed to remove them.

Definition

The **first ionisation energy** is the energy needed to remove one electron from each atom in one mole of gaseous atoms: $M(g) \rightarrow M^{+}(g) + e^{-}$. It is measured in kJ mol^{-1} .



First ionisation energy falls steadily down group 2, so the outer electrons are lost more easily.

With oxygen the metals burn to form oxides ($2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$). With dilute acids they give a salt and hydrogen ($\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$). With water, magnesium reacts very slowly when cold and rapidly with steam to give magnesium oxide and hydrogen, while calcium, strontium and barium react with cold water to form the hydroxide and hydrogen: $\text{Ca} + 2\text{H}_2\text{O} \rightarrow \text{Ca}(\text{OH})_2 + \text{H}_2$.

Worked example

Aarav in Pune drops 0.80 g of calcium into water. Calculate the volume of hydrogen at room temperature and pressure ($24.0 \text{ dm}^3 \text{ mol}^{-1}$, A_r of Ca = 40.1).

$n(\text{Ca}) = 0.80 \div 40.1 = 0.01995 \text{ mol}$. The equation shows 1 mol Ca gives 1 mol H_2 , so $n(\text{H}_2) = 0.01995 \text{ mol}$. $V = 0.01995 \times 24.0 = 0.479 \text{ dm}^3$, which is **479 cm³**.

How do the hydroxides and sulfates change down group 2?

Hydroxides become more soluble down the group, so the solutions are more strongly alkaline. Sulfates show the opposite trend and become less soluble. This gives a standard test for sulfate ions: add dilute hydrochloric acid, then barium chloride solution. A white precipitate of barium sulfate forms: $\text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s})$.

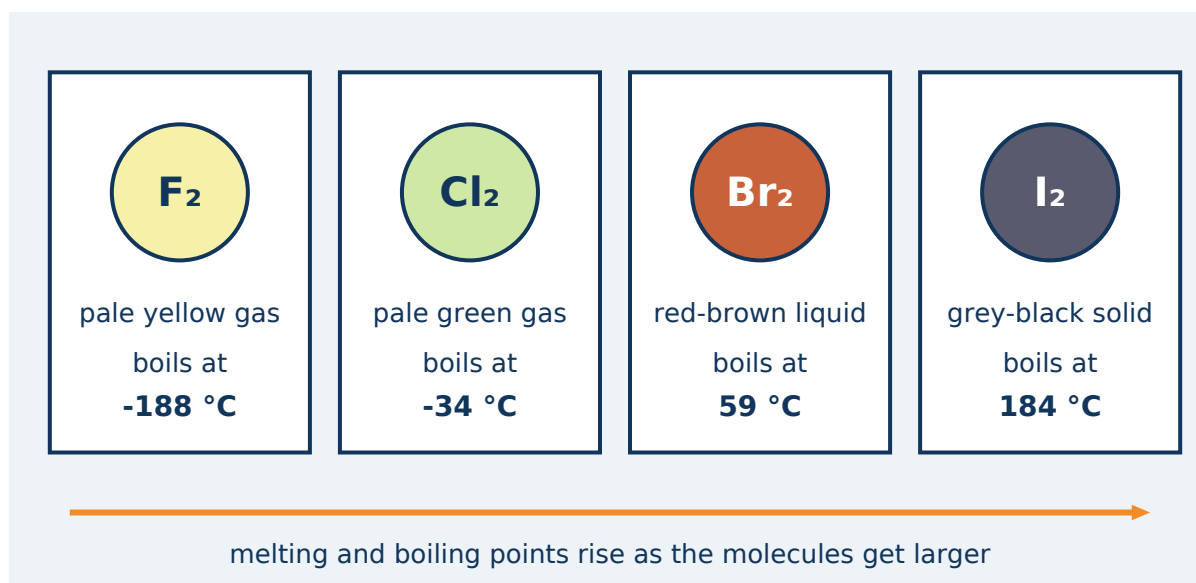
Compound	Mg	Ca	Sr	Ba
Hydroxide $\text{M}(\text{OH})_2$	almost insoluble	slightly soluble	soluble	fairly soluble
Sulfate MSO_4	soluble	slightly soluble	almost insoluble	insoluble

Key law

Down group 2: reactivity with water increases, hydroxide solubility increases, sulfate solubility decreases, and the hydroxide solutions become more alkaline.

What are the halogens like?

The halogens (fluorine, chlorine, bromine, iodine) exist as diatomic molecules, X_2 , held together by London forces. These forces grow with the number of electrons, so melting and boiling points rise down the group and the colour darkens.



The halogens change from gases to a solid down the group because London forces grow with molecular size.

How do halogens displace each other?

A halogen atom gains one electron to become a halide ion, so the halogens are oxidising agents. Oxidising power falls down the group, because the incoming electron is added further from the nucleus and is more shielded. A more reactive halogen therefore displaces a less reactive halide from solution: $\text{Cl}_2(\text{aq}) + 2\text{Br}^-(\text{aq}) \rightarrow 2\text{Cl}^-(\text{aq}) + \text{Br}_2(\text{aq})$. In this reaction chlorine is reduced ($0 \rightarrow -1$) and bromide is oxidised ($-1 \rightarrow 0$).

Halogen added	Chloride	Bromide	Iodide
Chlorine water	no reaction	orange solution	brown solution
Bromine water	no reaction	no reaction	brown solution
Iodine solution	no reaction	no reaction	no reaction

Chlorine also reacts with water and with alkali. In water, $\text{Cl}_2 + \text{H}_2\text{O} \rightleftharpoons \text{HCl} + \text{HClO}$, and the chloric(I) acid kills bacteria. With cold dilute sodium hydroxide, $\text{Cl}_2 + 2\text{NaOH} \rightarrow \text{NaCl} + \text{NaClO} + \text{H}_2\text{O}$, making bleach. Here chlorine is both oxidised ($0 \rightarrow +1$) and reduced ($0 \rightarrow -1$), which is called disproportionation.

How do you test for halide ions?

Acidify the sample with dilute nitric acid, which removes carbonate and hydroxide ions that would also give precipitates, then add silver nitrate solution.

Cl⁻
white AgCl

Br⁻
cream AgBr

I⁻
yellow AgI

add dilute nitric acid, then silver nitrate solution

The silver nitrate test: the colour of the precipitate identifies the halide ion.

Halide	Precipitate	Dilute NH_3	Concentrated NH_3
Chloride	white	dissolves	dissolves
Bromide	cream	stays	dissolves
Iodide	yellow	stays	stays

Worked example

Wanjiru adds excess silver nitrate to 30.0 cm³ of 0.100 mol dm⁻³ sodium chloride. Calculate the mass of silver chloride ($M_r = 143.4$).

$n(\text{Cl}^-) = 0.0300 \text{ dm}^3 \times 0.100 \text{ mol dm}^{-3} = 0.00300 \text{ mol}$. $\text{Ag}^+ + \text{Cl}^- \rightarrow \text{AgCl}$ is 1 : 1, so $n(\text{AgCl}) = 0.00300 \text{ mol}$. Mass = $0.00300 \times 143.4 = \mathbf{0.430 \text{ g}}$.

Common mistake

Never acidify with hydrochloric acid or sulfuric acid before the silver nitrate test. Hydrochloric acid adds chloride ions, giving a false white precipitate, and sulfuric acid gives slightly soluble silver sulfate.

Lina's tip

Remember the halide precipitates as white, cream, yellow: the colour deepens as the halide ion gets bigger. Down the group the oxidising power of the halogen falls but the reducing power of the halide rises.

Key points to remember

- Group 2: $\text{M} \rightarrow \text{M}^{2+} + 2\text{e}^-$; first ionisation energy falls from Be (900) to Ba (503 kJ mol⁻¹)
- Down group 2: hydroxide solubility rises, sulfate solubility falls
- Halogens X₂ get darker and boil at higher temperatures down group 7 (London forces)
- A more reactive halogen displaces a less reactive halide: $\text{Cl}_2 + 2\text{Br}^- \rightarrow 2\text{Cl}^- + \text{Br}_2$
- Silver nitrate test: AgCl white, AgBr cream, AgI yellow

Reactivity trends in group 2 and the halogens: frequently asked questions

Why is barium more reactive than magnesium?

Barium atoms are larger and their outer electrons are more shielded, so the first and second ionisation energies are lower. Less energy is needed to form Ba²⁺, so it reacts faster.

Why does chlorine displace bromine from bromide solution?

Chlorine is a stronger oxidising agent than bromine because its smaller atom attracts an incoming electron more strongly. It takes electrons from bromide ions, forming chloride ions and bromine.

Why is nitric acid added before silver nitrate in the halide test?

Nitric acid removes carbonate and hydroxide ions, which would give a false precipitate with silver ions. Nitrate ions do not interfere because all nitrates are soluble.

Why is barium sulfate safe in a barium meal when barium ions are toxic?

Barium sulfate is so insoluble that almost no Ba²⁺ ions enter the body. It passes through the

gut and shows up on X-rays.

What is disproportionation?

It is a reaction in which the same element is both oxidised and reduced. Chlorine in cold sodium hydroxide goes from 0 to +1 in NaClO and from 0 to -1 in NaCl.