Qualitative Analysis

Matthew Williams • Chemistry • May 15, 2026

Qualitative Analysis

Qualitative analysis is the branch of chemistry concerned with identifying what substances are present in a sample. Unlike quantitative analysis, which measures how much, qualitative analysis gives a yes or no: does this ion exist here? Each test relies on a characteristic, reproducible observation — a colour change, a precipitate, a gas that reacts with a reagent — that is specific enough to distinguish one ion from another.

Flame Tests

When a metal salt is held in a flame, the metal cation absorbs energy and its electrons jump to higher energy levels. When they fall back, they emit light at characteristic wavelengths visible as a coloured flame. The test is carried out using a clean nichrome or platinum wire loop dipped in the sample and held in the hottest part of a Bunsen burner flame.

Ion	Flame colour
Sodium (Na^+)	Persistent yellow-orange
Potassium (K^+)	Lilac (pale violet)
Calcium (Ca^{2+})	Brick red
Copper (Cu^{2+})	Blue-green (verdigris)
Barium (Ba^{2+})	Apple green
Lithium (Li^+)	Crimson red

> 📝 **Exam Tip**
> The wire must be cleaned between tests by dipping in concentrated hydrochloric acid and re-holding in the flame until no colour is imparted. A dirty wire carrying traces of sodium will give a yellow flame that masks every other colour — in particular it makes the pale lilac of potassium almost invisible.

Gas Tests

A gas produced in a reaction can be identified by directing it at a reagent or applying a simple test. Each has a specific, named reagent and a specific, observable result.

Gas	Test	Positive result
Hydrogen (H)	Apply a burning splint	Burns with a squeaky pop
Oxygen (O)	Apply a glowing splint	Splint relights
Carbon dioxide (CO)	Bubble through limewater	Limewater turns milky (white precipitate of CaCO)
Ammonia (NH)	Hold damp red litmus paper near	Paper turns blue
Chlorine (Cl)	Hold damp litmus paper near	Paper is bleached to white
Sulfur dioxide (SO)	Pass through acidified potassium dichromate(VI)	Orange dichromate turns green

Equations for selected reactions:

$$\mathrm{Ca(OH)_2 + CO_2 \rightarrow CaCO_3 \downarrow + H_2O} \quad (\mathrm{CO_2\ test})$$

$$\mathrm{Cr_2O_7^{2-} + 3SO_2 + 2H^+ \rightarrow 2Cr^{3+} + 3SO_4^{2-} + H_2O} \quad (\mathrm{SO_2\ test;\ orange \rightarrow green})$$

> **Remember**
> Both ammonia and chlorine affect litmus — but in opposite directions and for different reasons. Ammonia is alkaline so it turns red litmus blue. Chlorine is an oxidising agent that destroys the dye and bleaches (decolourises) litmus entirely. The distinction is important.

Testing for Cations

Using Sodium Hydroxide Solution (NaOH)

Adding sodium hydroxide solution precipitates metal hydroxides. The colour and solubility of the precipitate in excess NaOH are diagnostic.

Ion	Observation with NaOH (drop by drop)	Observation with excess NaOH

Copper (Cu^{2+})	Light blue precipitate	Precipitate remains (insoluble)
Iron(II) (Fe^{2+})	Green precipitate (turns brown/rust at surface on standing in air)	Precipitate remains
Iron(III) (Fe^{3+})	Reddish-brown precipitate	Precipitate remains
Zinc (Zn^{2+})	White precipitate	Dissolves in excess (amphoteric — forms zincate ion)
Aluminium (Al^{3+})	White precipitate	Dissolves in excess (amphoteric — forms aluminate ion)
Calcium (Ca^{2+})	Slight white precipitate	Precipitate remains (slightly soluble)
Ammonium (NH_4^+)	No precipitate; ammonia gas evolved on warming	Smell of ammonia; turns damp red litmus blue

Key equations:

$$Cu^{2+} + 2OH^- \rightarrow Cu(OH)_2 \downarrow \quad \text{(light blue)}$$

$$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2 \downarrow \quad \text{(green)}$$

$$Fe^{3+} + 3OH^- \rightarrow Fe(OH)_3 \downarrow \quad \text{(reddish-brown)}$$

$$Zn^{2+} + 2OH^- \rightarrow Zn(OH)_2 \downarrow \quad \text{; then } Zn(OH)_2 + 2OH^- \rightarrow [Zn(OH)_4]^{2-} \quad \text{(dissolves)}$$

$$Al^{3+} + 3OH^- \rightarrow Al(OH)_3 \downarrow \quad \text{; then } Al(OH)_3 + OH^- \rightarrow [Al(OH)_4]^- \quad \text{(dissolves)}$$

$$NH_4^+ + OH^- \xrightarrow{\Delta} NH_3 \uparrow + H_2O$$

Using Dilute Ammonia Solution ($NH_3(aq)$)

Ammonia solution can also precipitate metal hydroxides, but the results differ for ions that form soluble ammonia complexes.

Ion	With dilute ammonia (drop by drop)	With excess ammonia
Copper (Cu^{2+})	Light blue precipitate	Precipitate dissolves to give a deep blue solution (tetraamminecopper(II) complex)
Zinc (Zn^{2+})	White precipitate	Precipitate dissolves (forms colourless zincammine complex)
Iron(II) (Fe^{2+})	Green precipitate	Precipitate does not dissolve
Iron(III) (Fe^{3+})	Reddish-brown precipitate	Precipitate does not dissolve

The deep blue formed from Cu^{2+} with excess ammonia is the most striking and recognisable result:

$$\mathrm{Cu^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4]^{2+} \quad (deep\ blue)}$$

This reaction distinguishes Cu^{2+} from all other common ions and is itself a confirmatory test.

Testing for Anions

Carbonate Ion (CO_3^{2-})

Add dilute hydrochloric acid (or dilute H_2SO_4). A carbonate effervesces, releasing a colourless gas. The gas is then bubbled through limewater to confirm it is CO_2.

$$\mathrm{CO_3^{2-} + 2H^+ \rightarrow H_2O + CO_2 \uparrow}$$

$$\mathrm{Ca(OH)_2 + CO_2 \rightarrow CaCO_3 \downarrow \quad (limewater\ turns\ milky)}$$

Sulfate Ion (SO_4^{2-})

Acidify the solution with dilute nitric acid (to dissolve any sulfite or carbonate that might give a false positive), then add barium chloride solution. A white precipitate of barium sulfate forms immediately:

$$\mathrm{Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4 \downarrow \quad (white,\ insoluble\ in\ excess\ acid)}$$

The precipitate is insoluble in dilute nitric acid — this distinguishes it from barium sulfite (which would dissolve).

Halide Ions (Cl⁻, Br⁻, I⁻)

Acidify with dilute nitric acid (to destroy carbonate and sulfite ions that would give false positives), then add silver nitrate solution. The colour of the precipitate identifies the halide:

Ion	Precipitate colour	Solubility in dilute ammonia
Chloride (Cl^-)	White (AgCl)	Dissolves readily
Bromide (Br^-)	Cream (AgBr)	Dissolves in concentrated ammonia only
Iodide (I^-)	Yellow (AgI)	Insoluble — does not dissolve in ammonia

$$Ag^+ + Cl^- \rightarrow AgCl\downarrow \quad (\text{white})$$

$$Ag^+ + Br^- \rightarrow AgBr\downarrow \quad (\text{cream})$$

$$Ag^+ + I^- \rightarrow AgI\downarrow \quad (\text{yellow})$$

> 📝 **Exam Tip**
> Always acidify with dilute nitric acid before adding silver nitrate — never hydrochloric acid (which would add Cl^- and give a false positive for chloride) or sulfuric acid (which would give a $BaSO_4$ precipitate if Ba^{2+} were used later).

Testing for Water

The presence of water (or any aqueous solution) is shown by two tests:

Test	Observation indicating water
Add anhydrous copper(II) sulfate (white powder)	Turns blue — water of crystallisation absorbed to form $CuSO_4 \cdot 5H_2O$
Use cobalt(II) chloride paper (blue when dry)	Paper turns pink — $CoCl_2$ absorbs water to form the hydrated pink complex

These tests detect the presence of water, but do not prove it is pure water. To confirm purity, measure the boiling point (100 °C at 1 atm) or the freezing point (0 °C).

Summary: Quick-Reference Table

What you observe	Likely ion or substance
Yellow-orange flame	Naz
Lilac flame	Kz
Brick-red flame	Ca^{2}z
Blue-green flame	Cu^{2}z
Squeaky pop with lit splint	H,gas
Relights glowing splint	O,gas
Turns limewater milky	CO,gas
Turns damp red litmus blue	NHfgas
Bleaches damp litmus	Cl,gas
Orange dichromate turns green	SO,gas
Light blue precipitate with NaOH, deep blue with excess NHf	Cu^{2}z
Green precipitate with NaOH	Fe^{2}z
Reddish-brown precipitate with NaOH	Fe^{3}z
White precipitate, dissolves in excess NaOH or NHf	Zn^{2}z(or Al^{3}z— Al^{3}zdoes not dissolve in NHf
Effervescence with acid, CO,confirmed by limewater	CO^{2}f{
White precipitate with acidified Ba^{2}zinsoluble in acid	SO^{2}„{
White precipitate with acidified Agz	Cl{
Cream precipitate with acidified Agz	Br{
Yellow precipitate with acidified Agz	I{
Anhydrous CuSO„turns blue	Water present
Cobalt chloride paper turns pink	Water present