

Identifying substances with chemical tests

Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Lesson

Quick answer: Chemical analysis identifies what a sample contains. Pure substances have sharp melting points, chromatography separates mixtures and gives $R_f = \text{distance moved by spot} \div \text{distance moved by solvent}$, flame tests and sodium hydroxide precipitates identify metal ions, and simple tests identify gases, carbonates, sulfates and halides.

Level: Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** GCSE C8

How can you tell if a substance is pure?

Definition

In chemistry a **pure substance** is a single element or compound with nothing else mixed in. It is not the same as "natural" or "unprocessed" in everyday language.

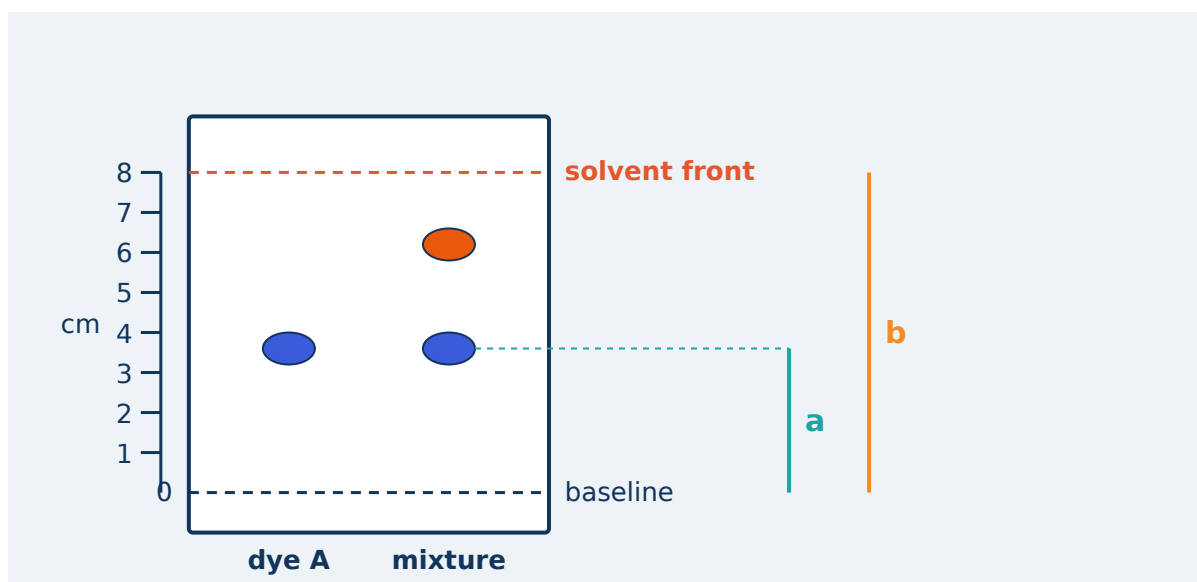
A pure substance melts and boils at one sharp, fixed temperature. A mixture melts over a range of temperatures, and impurities usually lower the melting point. A **formulation** is a mixture designed on purpose, with exact amounts of each component, to give useful properties. Paints, fuels, medicines, fertilisers and alloys are formulations.

How does chromatography separate a mixture?

In paper chromatography a solvent (the **mobile phase**) moves up a sheet of paper (the **stationary phase**). Each substance in the sample spends time dissolved in the solvent and time held by the paper. Substances that dissolve well and cling little travel far; others stay near the start. Draw the baseline in pencil, because pencil lead is insoluble and does not run, and keep the starting line above the solvent level.

Formula

$R_f = \text{distance moved by the substance} \div \text{distance moved by the solvent front}$. Both distances are in cm, so R_f has no unit and lies between 0 and 1.



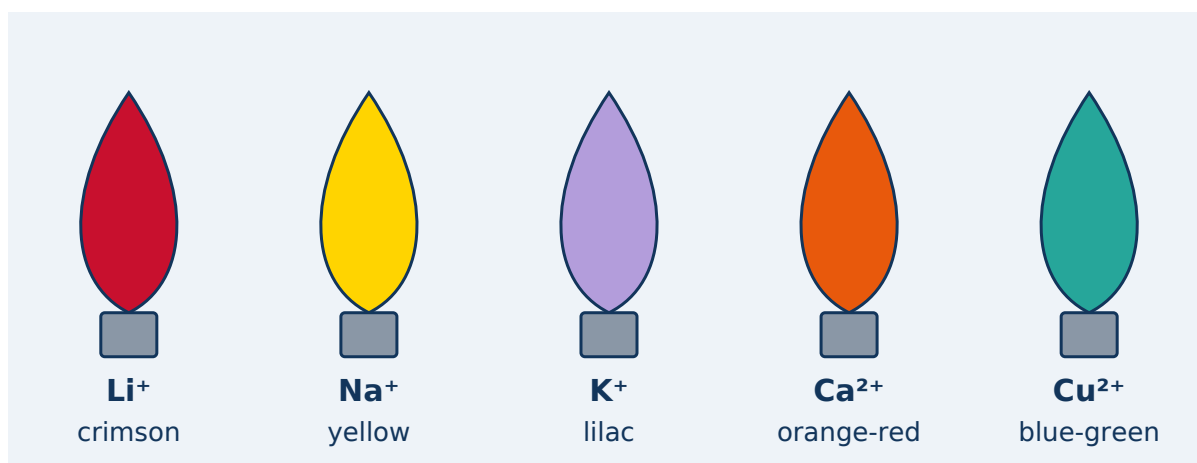
A chromatogram: *a* is the distance moved by the spot and *b* is the distance moved by the solvent front.

Worked example

A spot moves 3.6 cm while the solvent front moves 8.0 cm. $R_f = 3.6 \div 8.0 = \mathbf{0.45}$. In the same solvent, a spot with $R_f = 0.30$ and a front at 9.5 cm travels $0.30 \times 9.5 = \mathbf{2.85 \text{ cm}}$.

How do flame tests identify metal ions?

Dip a clean nichrome wire loop in dilute hydrochloric acid, then in the sample, and hold it in a blue Bunsen flame. Metal ions give light of characteristic colours.



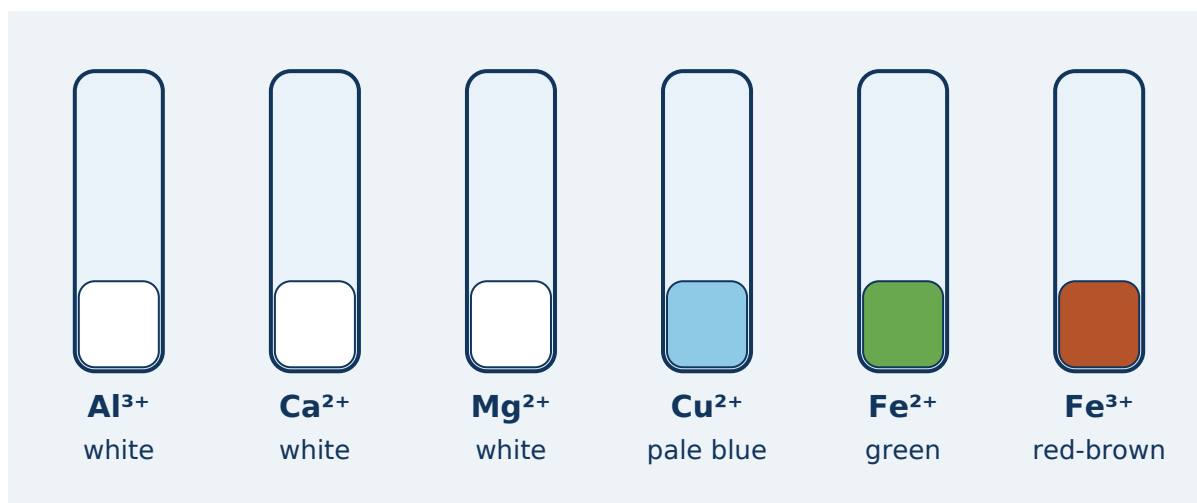
Flame test colours of five metal ions.

How does sodium hydroxide identify metal ions?

Add a few drops of sodium hydroxide solution to the sample solution. Many metal ions form an insoluble metal hydroxide, a precipitate. The colour, and whether it dissolves in excess alkali, identifies the ion.

Ion	Precipitate	In excess sodium hydroxide
Al^{3+}	white	dissolves, colourless solution

Ion	Precipitate	In excess sodium hydroxide
Ca^{2+}	white	no change
Mg^{2+}	white	no change
Cu^{2+}	pale blue	no change
Fe^{2+}	green	no change
Fe^{3+}	red-brown	no change



Precipitates formed when sodium hydroxide is added to solutions of metal ions.

The ionic equation for copper(II) ions is $\text{Cu}^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq}) \rightarrow \text{Cu}(\text{OH})_2(\text{s})$. The charges balance: $+2 - 2 = 0$.

How do you test for gases and negative ions?

Gas	Test and result
Hydrogen	lit splint: squeaky pop
Oxygen	glowing splint relights
Carbon dioxide	limewater turns cloudy
Chlorine	damp litmus paper is bleached white

Ion	Test	Result
Carbonate CO_3^{2-}	add dilute acid	fizzing, CO_2 made
Sulfate SO_4^{2-}	add dilute HCl, then barium chloride	white precipitate of BaSO_4
Chloride Cl^{-}	add dilute HNO_3 , then silver nitrate	white precipitate
Bromide Br^{-}	as chloride	cream precipitate
Iodide I^{-}	as chloride	yellow precipitate

For sulfate, $\text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s})$. For chloride, $\text{Ag}^{+}(\text{aq}) + \text{Cl}^{-}(\text{aq}) \rightarrow \text{AgCl}(\text{s})$.

Worked example

A white solid gives a white precipitate with sodium hydroxide that dissolves in excess, no flame colour, and a white precipitate with acidified barium chloride. The precipitate behaviour shows Al^{3+} , and the barium result shows **sulfate**. The compound is **aluminium sulfate**, $\text{Al}_2(\text{SO}_4)_3$.

Common mistake

Do not add barium chloride or silver nitrate before acidifying. Carbonates also give white precipitates with both reagents, so the acid removes carbonate first. Also remember that an Al^{3+} precipitate dissolves in excess alkali, but a Ca^{2+} or Mg^{2+} precipitate does not.

Lina's tip

Use two tests for each unknown metal ion. Flame colour separates calcium from magnesium, which both give a white precipitate that stays in excess alkali.

Key points to remember

- Pure substances melt at one sharp temperature; mixtures melt over a range, lower than the pure value.
- R_f = distance moved by spot ÷ distance moved by solvent front; it has no unit and is always less than 1.
- Flame colours: Li^+ crimson, Na^+ yellow, K^+ lilac, Ca^{2+} orange-red, Cu^{2+} blue-green.
- Gas tests: H_2 squeaky pop, O_2 relights a glowing splint, CO_2 clouds limewater, Cl_2 bleaches damp litmus.
- Sulfate: acidified barium chloride, white ppt; chloride, bromide, iodide: acidified silver nitrate, white, cream, yellow.

Identifying substances with chemical tests: frequently asked questions

Why is the chromatography baseline drawn in pencil?

Pencil lead is insoluble in the solvent, so the line stays put and does not add extra spots. Ink from a pen would dissolve and travel up the paper with the sample.

Can an R_f value be greater than 1?

No. The solvent front always travels at least as far as any substance, so the distance moved by a spot is at most the distance moved by the front. R_f is between 0 and 1.

How can you tell calcium from magnesium?

Both give a white precipitate with sodium hydroxide that does not dissolve in excess. A flame test separates them: calcium gives an orange-red flame, while magnesium gives no flame colour.

Why is the sample acidified before testing for sulfate?

Carbonate ions would also give a white precipitate with barium ions. Adding dilute hydrochloric acid first destroys carbonate, so a white precipitate is then due to sulfate alone.

How can a melting point show that a substance is pure?

A pure substance melts sharply at a fixed temperature that can be compared with a data book value. A sample with impurities melts below that value and over a range of temperatures.