Qualitative Analysis: Tests for Ions – GCSE Chemistry

CONTENTS:

1. Introduction

- Qualitative analysis is used in chemistry to identify unknown ions by observing their specific colours, reactions, or precipitates.
- Each ion must have a unique test because if two ions gave the same result, it would be impossible to know which one is present.
- In this blog, we are going to study different tests, which are useful in water testing, environmental studies, medical labs, and industry.

2. What is a Flame Test?

- This is a simple method used in chemistry to identify metal ions based on the colour they produce when heated in a flame.
- When metal ions are heated, their electrons absorb energy and move to higher energy levels.
- As the electrons return to their original levels, they release energy in the form of visible light.
- The colour of the flame depends on the type of metal ion present.

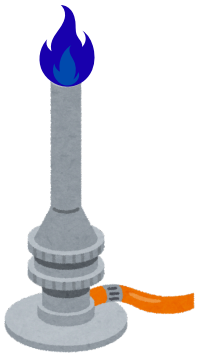
Qualitative Analysis: Tests for Ions – GCSE Chemistry

How it is done:

- A clean wire loop made of platinum or nichrome is dipped into the sample solution.
- It is then held in the blue part of a Bunsen burner flame.
- The flame colour is then carefully observed to see which metal ion is present.

Common flame colours:

- Lithium (Li^+): Crimson red
- Sodium (Na^+): Bright yellow
- Potassium (K^+): Lilac
- Calcium (Ca^{2+}): Orange-red
- Copper (Cu^{2+}): Green



Lithium

Sodium

Potassium

Calcium

Copper

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3. How do we test for Cations?

- Compounds that contain transition metals often have distinct colours.
- When two chemicals are reacted together and a new solid form that does not dissolve in the solution, this is called a **precipitation reaction.**
- In solutions, compounds can dissociate into ions, and the positive ions are called **cation**s.

How it is done:

- A dilute solution of sodium hydroxide (NaOH) can be used to test for certain metal ions.
- It can also help identify ammonium ions by producing characteristic reactions when added to the solution.

Common results:

Cation	Reaction with NaOH	Observation
Copper (Cu^{2+})	Blue precipitate	Copper(II) hydroxide forms
Iron (II) (Fe^{2+})	Green precipitate	Iron(II) hydroxide forms
Iron (III) (Fe^{3+})	Brown precipitate	Iron(III) hydroxide forms
Aluminium (Al^{3+})	White precipitate (dissolves in excess NaOH)	Aluminium hydroxide
Calcium (Ca^{2+})	White precipitate (doesn't dissolve in excess NaOH)	Calcium hydroxide

Qualitative Analysis: Tests for Ions – GCSE Chemistry

4. How do we test for Anions?

- Anions are negatively charged ions, such as carbonates (CO_3^{2-}), sulfates (SO_4^{2-}), and halides (Cl^-, Br^-, I^-).
- Each has a specific chemical test:

1. Carbonate Ions (CO_3^{2-}):

- To test for carbonate ions, add a few drops of dilute acid such as hydrochloric acid to the sample.
- If effervescence is seen, it shows that carbon dioxide gas is being released.
- To confirm this, the gas is passed through limewater, which turns cloudy or milky, proving the gas is carbon dioxide and confirming the presence of carbonate ions.

2. Sulfate Ions (SO_4^{2-}):

- To test for sulfate ions, add dilute hydrochloric acid followed by a few drops of **barium chloride solution ($BaCl_2$)**.
- If sulfate ions are present, a white insoluble precipitate of **barium sulfate ($BaSO_4$)** will form.
- The acid is added first to remove any carbonate ions that could give a false white precipitate.
- The formation of this white solid confirms that sulfate ions are present in the solution.

3. Halide Ions (Cl^-, Br^-, I^-):

- To test for halide ions, first add dilute nitric acid to the sample, then add a few drops of silver nitrate solution ($AgNO_3$).
- Depending on the halide present, different coloured insoluble precipitates will form: white for chloride (AgCl), cream for bromide (AgBr), and yellow for iodide (AgI).

Qualitative Analysis: Tests for Ions – GCSE Chemistry

- The nitric acid helps remove carbonate ions that might interfere with the result, and the colour of the precipitate confirms which halide ion is present.

Ion	Reagent Added	Positive Result	Conclusion
Carbonate (CO_3^{2-})	Dilute acid → gas through limewater	Effervescence; limewater turns milky	CO_2 released → Carbonate present
Sulfate (SO_4^{2-})	Dilute HCl + $BaCl_2$	White precipitate	Sulfate present
Halides (Cl^-, Br^-, I^-)	Dilute HNO_3 + $AgNO_3$	White (Cl^-), Cream (Br^-), Yellow (I^-) ppt	Halide identified

Qualitative Analysis: Tests for Ions – GCSE Chemistry

5. How does a Flame photometer work?

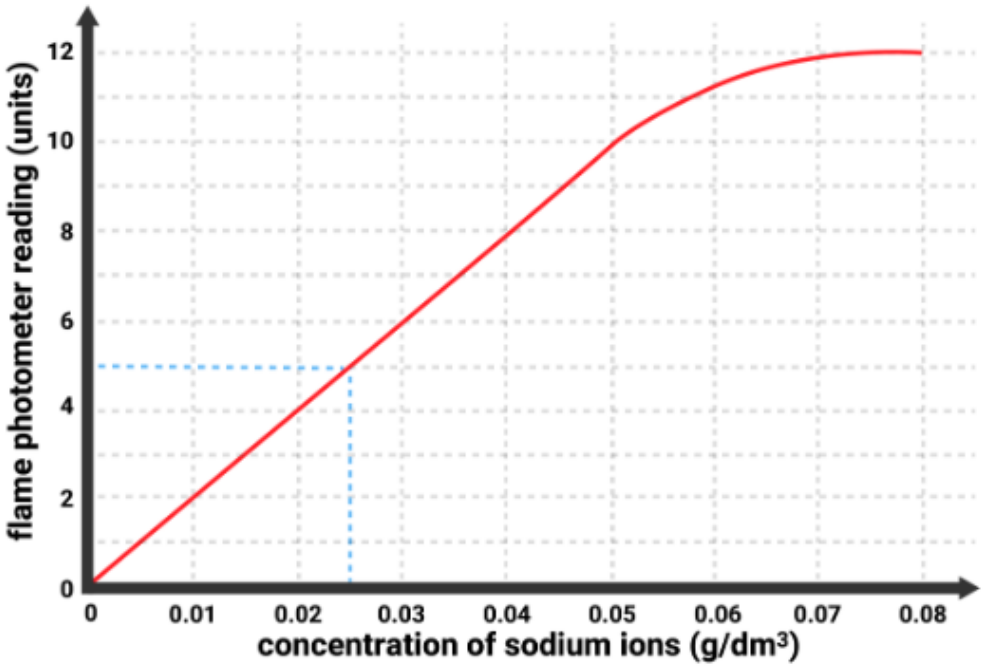
- A Flame photometer is an instrumental method used to identify and measure metal ions in a solution.

How it is worked:

- A sample is heated in a flame, and the light it emits is passed through a spectroscope, producing a spectrum — a pattern of coloured lines.
- Each element gives off light at specific wavelengths, creating a unique spectrum like a fingerprint.
- This helps scientists identify metal ions accurately, even in mixtures where one metal's colour might hide another in a normal flame test.

Determining Concentrations:

- A Flame photometer can measure the light intensity for solutions with different known concentrations of a metal ion.
- These readings are used to create a **calibration curve**.



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- Once the curve is made, scientists can easily determine the concentration of an unknown sample by comparing its reading to the graph.
- **Example:** If a solution of sodium ions gave a reading of 5 units on the flame photometer, then the calibration curve allows us to read off that the sample had a concentration of 0.025 g/dm^3.

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6. FAQs

1. What is a flame test?

A flame test is a method used to identify metal ions by the colour they produce in a flame.

2. Why do different metal ions give different flame colours?

Because electrons in metal ions absorb energy, move to a higher level, and release energy as light when they return — each metal emits specific wavelengths.

3. Which metal ions can be identified using a flame test?

Common ones include lithium (red), sodium (yellow), potassium (lilac), calcium (orange-red), and copper (green).

4. How do we test for cations?

Cations (positively charged ions) are tested using sodium hydroxide (NaOH) or ammonia (NH_3) to form coloured precipitates.

5. Can you give an example of a cation test?

Yes — Cu^{2+} + NaOH → blue precipitate (copper hydroxide) or Fe^{3+} + NaOH → brown precipitate (iron hydroxide).

6. How do we test for anions?

Anions (negatively charged ions) are tested using specific chemical reactions:

- Carbonates → fizz with acid
- Sulfates → white precipitate with barium chloride
- Halides → coloured precipitate with silver nitrate

Qualitative Analysis: Tests for Ions – GCSE Chemistry

7. Why do we use instrumental methods of analysis?

Because they are fast, accurate, and can detect small amounts of substances better than simple chemical tests.

8. What are examples of instrumental methods?

Examples include flame photometry, spectroscopy, chromatography, and mass spectrometry.

9. How does a flame photometer work?

A sample is sprayed into a flame, emitting light. The light is split into a spectrum, and the intensity shows the concentration of metal ions.

10. Why is a flame photometer better than a normal flame test?

Because it can measure the amount of metal ions, separate colours in a mixture, and give a unique spectrum for each element — even in mixtures.