11 Qualitative Analysis

1 Testing for Cations

1.1 How the tests work

Qualitative analysis identifies the _____ in a substance, and the _____ it gives off, from what is observed when reagents are added.

- Cations are identified with **aqueous sodium hydroxide** and **aqueous ammonia**. Add a few drops, then add the reagent _____.
- Note the _____ of any precipitate, whether it _____, and whether _____ is given off on warming.
- The precipitate is the **metal hydroxide**, which is insoluble in water. Sodium, potassium and ammonium ions give no precipitate.

$Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$

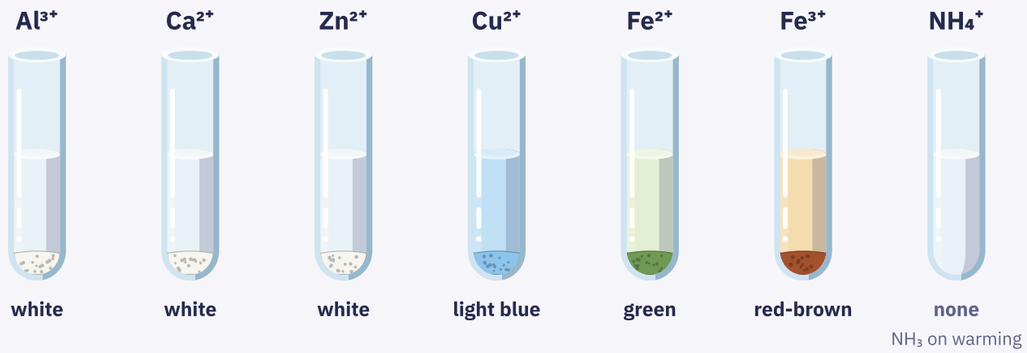
$Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$

1.2 Results for each cation

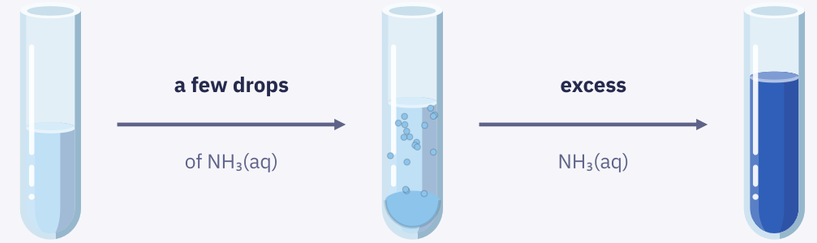
Cation	Aqueous sodium hydroxide	Aqueous ammonia
aluminium, Al^{3+}	white precipitate, _____ in excess giving a colourless solution	white precipitate, _____ in excess
ammonium, NH_4^+	ammonia produced on warming	no change
calcium, Ca^{2+}	white precipitate, insoluble in excess	_____
copper(II), Cu^{2+}	_____ precipitate, insoluble in excess	light blue precipitate, soluble in excess giving a _____
iron(II), Fe^{2+}	_____ precipitate, insoluble in excess	green precipitate, insoluble in excess
iron(III), Fe^{3+}	_____ precipitate, insoluble in excess	red-brown precipitate, insoluble in excess
zinc, Zn^{2+}	white precipitate, soluble in excess giving a colourless solution	white precipitate, _____ in excess giving a colourless solution

1 Testing for Cations (continued)

1.3 The colours of the precipitates



- The green precipitate of iron(II) hydroxide turns _____ on standing.
- In excess aqueous sodium hydroxide, the white precipitates of aluminium and zinc hydroxide _____ to give colourless solutions. Calcium hydroxide does not.
- Only copper(II) hydroxide dissolves in excess aqueous ammonia to give a **dark blue** solution.



1 Testing for Cations (continued)

1.4 Identifying a cation: the complete flowcharts

Add aqueous sodium hydroxide: a few drops, then in excess

Is there a precipitate?

- **no** → **NH_4^+** warm it: ammonia turns damp red litmus blue
- **yes** → **What colour is the precipitate?**

coloured: the colour tells you the ion directly

- **light blue** → **Cu^{2+}** insoluble in excess
- **green** → **Fe^{2+}** insoluble in excess
- **red-brown** → **Fe^{3+}** insoluble in excess

white: test further

- **white** → **Dissolves in excess?**
  - **yes** → **Al^{3+} or Zn^{2+}** test with $NH_3(aq)$
  - **no** → **Ca^{2+}** insoluble in excess

Add aqueous ammonia: a few drops, then in excess

Is there a precipitate?

- **no** → **Ca^{2+}** no precipitate
- **yes** → **What colour is the precipitate?**

coloured: the colour tells you the ion directly

- **light blue** → **Cu^{2+}** dissolves in excess: dark blue solution
- **green** → **Fe^{2+}** insoluble in excess
- **red-brown** → **Fe^{3+}** insoluble in excess

white: test further

- **white** → **Dissolves in excess?**
  - **yes** → **Zn^{2+}** colourless solution
  - **no** → **Al^{3+}** insoluble in excess

EXAM TIP Describe a result in full: the **colour** of the precipitate and what happens **in excess**, e.g. "white precipitate, soluble in excess giving a colourless solution". Aluminium and zinc give the same result with aqueous sodium hydroxide, so aqueous ammonia is needed to tell them apart.

2 Testing for Anions

2.1 Tests for anions

Anion	Test	Result
carbonate, CO_3^{2-}	add dilute acid, and bubble the gas into limewater	_____: the gas is carbon dioxide, which gives a white precipitate with limewater
chloride, Cl^-	acidify with dilute nitric acid, then add aqueous **silver nitrate**	_____ precipitate of silver chloride
iodide, I^-	acidify with dilute nitric acid, then add aqueous **silver nitrate**	_____ precipitate of silver iodide
sulfate, SO_4^{2-}	acidify with dilute nitric acid, then add aqueous **barium nitrate**	_____ precipitate of barium sulfate
nitrate, NO_3^-	add aqueous sodium hydroxide, then **aluminium** foil, and warm carefully	_____ is produced: it turns damp red litmus paper blue

1. **add dilute acid, then bubble** any gas through limewater → **CO_3^{2-}** fizzes; limewater turns milky — $CO_3^{2-}(aq) + 2H^+(aq) \rightarrow CO_2(g) + H_2O(l)$
2. **acidify with dilute nitric acid,** then add aqueous silver nitrate → **Cl^-** white precipitate — $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$
   → **I^-** yellow precipitate — $Ag^+(aq) + I^-(aq) \rightarrow AgI(s)$
3. **acidify with dilute nitric acid,** then add aqueous barium nitrate → **SO_4^{2-}** white precipitate — $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$
4. **add aqueous sodium hydroxide** and aluminium foil, then warm → **NO_3^-** ammonia: damp red litmus blue — the nitrate is reduced to ammonia

2.2 Why dilute nitric acid is added first

- The acid removes any _____ (and hydroxide) ions, which would also form a precipitate with silver or barium ions and give a false result.
- Nitric acid is used because all nitrates are soluble, so it adds no ions that form a precipitate.

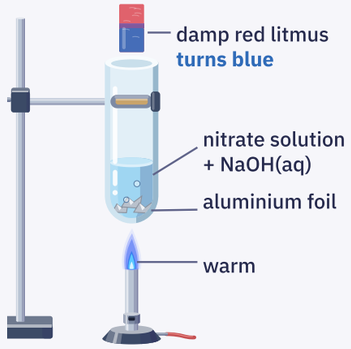
EXAM TIP Do not acidify with hydrochloric acid in the chloride test, or with sulfuric acid in the sulfate test. They add the very ions being tested for.

WORKED EXAMPLE An unknown solution contains either sodium chloride or sodium iodide. Describe how you would find out which anion is present.

1. Acidify a sample with dilute **nitric acid**, then add aqueous **silver nitrate**.
2. A **white** precipitate shows chloride ions. A **yellow** precipitate shows iodide ions.

2 Testing for Anions (continued)

2.3 The nitrate test



- Aluminium _____ the nitrate ions to ammonia, which turns damp red litmus paper blue.
- Ammonium ions also give ammonia when warmed with aqueous sodium hydroxide, even without aluminium. Test for them first.
- Hold the litmus paper at the mouth of the tube. It must not touch the alkali in the tube.

3 Testing for Gases

3.1 Tests for gases



oxygen
glowing splint relights

hydrogen
lighted splint: pop

carbon dioxide
limewater turns milky

ammonia
red litmus turns blue

chlorine
blue litmus bleached

sulfur dioxide
purple to colourless

Gas	Test	Result
oxygen, O_2	insert a **glowing** splint	the splint _____
hydrogen, H_2	hold a **lighted** splint at the mouth	the splint is extinguished with a _____
carbon dioxide, CO_2	bubble the gas into limewater	_____, which dissolves with excess carbon dioxide
ammonia, NH_3	hold damp **red** litmus paper at the mouth	it turns _____
chlorine, Cl_2	hold damp **blue** litmus paper at the mouth	it turns red, then is _____ white
sulfur dioxide, SO_2	bubble into, or hold filter paper soaked in, acidified potassium manganate(VII)	it turns from _____

- Oxygen, hydrogen and carbon dioxide are colourless and odourless. Ammonia, chlorine and sulfur dioxide have a **pungent** smell, and chlorine is **greenish-yellow**.

3 Testing for Gases (continued)

3.2 Putting the tests together

WORKED EXAMPLE A solution of compound K gives these results.
(1) Warmed with aqueous sodium hydroxide: a light blue precipitate, and a gas that turns damp red litmus paper blue.
(2) With aqueous ammonia: a light blue precipitate, soluble in excess to give a dark blue solution.
(3) Acidified with dilute nitric acid, then aqueous barium nitrate added: a white precipitate.
Identify the ions in K.

The gas is ammonia, so K contains **ammonium** ions, NH_4^+.

The light blue precipitate that dissolves in excess ammonia to a dark blue solution shows **copper(II)** ions, Cu^{2+}.

The white precipitate with barium nitrate shows **sulfate** ions, SO_4^{2-}.

EXAM TIP When a gas is given off, name it and give its test and result. The tables in this topic are printed in the practical paper (Paper 3) only, so learn them for Papers 1 and 2.