Cambridge IGCSE · Chemistry 0620 · Notes

Identification of ions and gases

Read online at **pastopic.com/cambridge/chemistry-0620/notes/identification-of-ions-and-gases**

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Read first: **Acids, bases and oxides**, **Formulae and equations**

What you need to know

By the end of this topic you should be able to:

1. **Describe the tests for five anions** (negative ions):
   - **carbonate**, $\mathrm{CO_3^{2-}}$: add dilute acid, then check the gas given off for carbon dioxide;
   - **chloride**, $\mathrm{Cl^-}$, **bromide**, $\mathrm{Br^-}$, and **iodide**, $\mathrm{I^-}$: make the solution acidic with dilute nitric acid, then add aqueous silver nitrate;
   - **nitrate**, $\mathrm{NO_3^-}$: warm with aqueous sodium hydroxide and aluminium foil, which reduce the nitrate, then check the gas for ammonia;
   - **sulfate**, $\mathrm{SO_4^{2-}}$: make the solution acidic with dilute nitric acid, then add aqueous barium nitrate;
   - **sulfite**, $\mathrm{SO_3^{2-}}$: add acidified aqueous potassium manganate(VII).
2. **Describe how aqueous sodium hydroxide and aqueous ammonia identify eight cations** (positive ions) in solution: aluminium $\mathrm{Al^{3+}}$, ammonium $\mathrm{NH_4^+}$, calcium $\mathrm{Ca^{2+}}$, chromium(III) $\mathrm{Cr^{3+}}$, copper(II) $\mathrm{Cu^{2+}}$, iron(II) $\mathrm{Fe^{2+}}$, iron(III) $\mathrm{Fe^{3+}}$ and zinc $\mathrm{Zn^{2+}}$.
3. **Describe the tests for six gases**: ammonia (damp red litmus paper), carbon dioxide (limewater), chlorine (damp litmus paper), hydrogen (a lighted splint), oxygen (a glowing splint) and sulfur dioxide (acidified aqueous potassium manganate(VII)).
4. **Describe how a flame test identifies six cations**: lithium $\mathrm{Li^+}$, sodium $\mathrm{Na^+}$, potassium $\mathrm{K^+}$, calcium $\mathrm{Ca^{2+}}$, barium $\mathrm{Ba^{2+}}$ and copper(II) $\mathrm{Cu^{2+}}$.

Every outcome here is Core, so Core and Extended students learn the same tests. **Extended only:** Paper 4 also asks for the **ionic equation** of a test precipitate, using the skill taught in Formulae and equations.

Why ammonia turns red litmus blue is explained in Acids, bases and oxides, and why manganate(VII) loses its colour is in Redox. This note uses both results without repeating the reasons in full.

Understand it

What a chemical test is

A **test** is something you add or do (the **reagent** or method) plus something you can **see** (the **result**). A good test gives a result that only one substance, or one small group, can give. If nothing happens, the result is **negative**: that ion or gas is not there.

Many tests make a **precipitate**: an insoluble solid that appears when two solutions are mixed. The liquid turns cloudy and the solid slowly settles. Always use the word **precipitate** (or "ppt."), with its colour. "Goes cloudy" or "white solution" is not enough.

To name a salt, find its **cation** with one test and its **anion** with another, then put the names together, cation first: iron(II) + sulfate gives **iron(II) sulfate**; lithium + iodide gives **lithium iodide**.

Tests for gases

Gas	Test	Positive result	Why it works
hydrogen, $\mathrm{H_2}$	hold a **lighted** splint at the mouth of the tube	squeaky **pop**	hydrogen burns explosively with oxygen in the air
oxygen, $\mathrm{O_2}$	put a **glowing** splint into the gas	splint **relights**	oxygen helps things burn
carbon dioxide, $\mathrm{CO_2}$	bubble the gas through **limewater**	limewater turns **milky** (cloudy white)	$\mathrm{CO_2}$ reacts with the calcium hydroxide in limewater to make insoluble calcium carbonate
ammonia, $\mathrm{NH_3}$	hold **damp red litmus paper** in the gas	turns **blue**	ammonia is the common alkaline gas
chlorine, $\mathrm{Cl_2}$	hold **damp litmus paper** in the gas	**bleached** (turns white)	chlorine is a bleach; blue litmus may go red for a moment first
sulfur dioxide, $\mathrm{SO_2}$	bubble the gas through **acidified aqueous potassium manganate(VII)**	**purple to colourless**	$\mathrm{SO_2}$ is a reducing agent, so it removes the purple colour

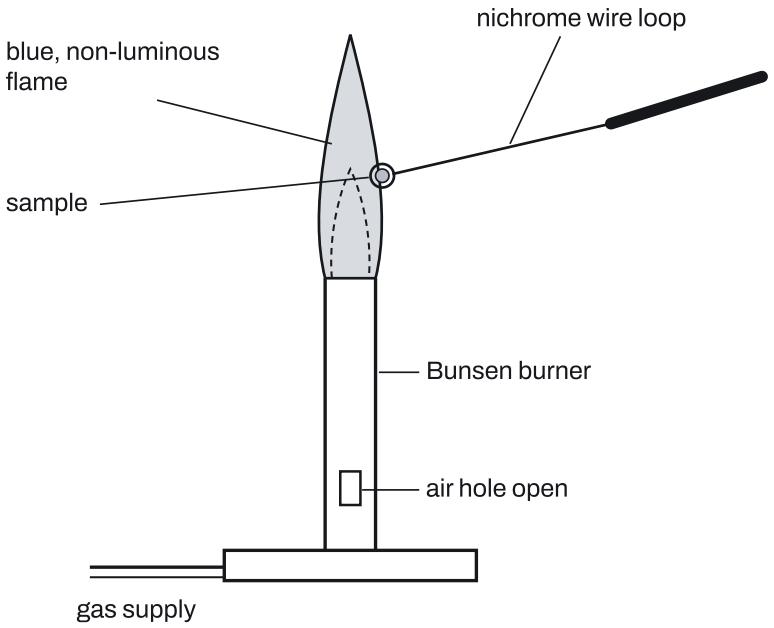
Litmus paper must be **damp**: a gas has to dissolve in water before it can change the dye. A **lighted** (burning) splint is for hydrogen; a **glowing** splint (lit, then blown out) is for oxygen. Mixing these two up is one of the commonest lost marks.

Flame tests

Some metal ions give out coloured light when they are heated strongly.

1. Take a clean nichrome (or platinum) wire loop, or a damp wooden splint.
2. Dip it into the solid (or its solution).

3. Hold it **in** the edge of a **blue, non-luminous** Bunsen flame (air hole open), not above it or beside it.
4. Note the colour of the flame.



Ion	Flame colour
lithium, Li^{+}	red
sodium, Na^{+}	yellow
potassium, K^{+}	lilac
calcium, Ca^{2+}	orange-red
barium, Ba^{2+}	light green
copper(II), Cu^{2+}	blue-green

A yellow (luminous) flame is useless: it is already yellow. Sodium's strong yellow can also hide another colour, so a sample containing sodium ions may not show the other ion's colour clearly. For copper, write **blue-green**; "blue" alone is not accepted.

Cations with aqueous sodium hydroxide and aqueous ammonia

Both reagents contain hydroxide ions, OH^{-}. Most metal hydroxides are insoluble, so a few drops make a **coloured precipitate** of the metal hydroxide. Then you keep adding the reagent **until it is in excess** and watch whether the precipitate **dissolves** (or stays). So every answer has two parts: what you see with a few drops, and what you see in excess.

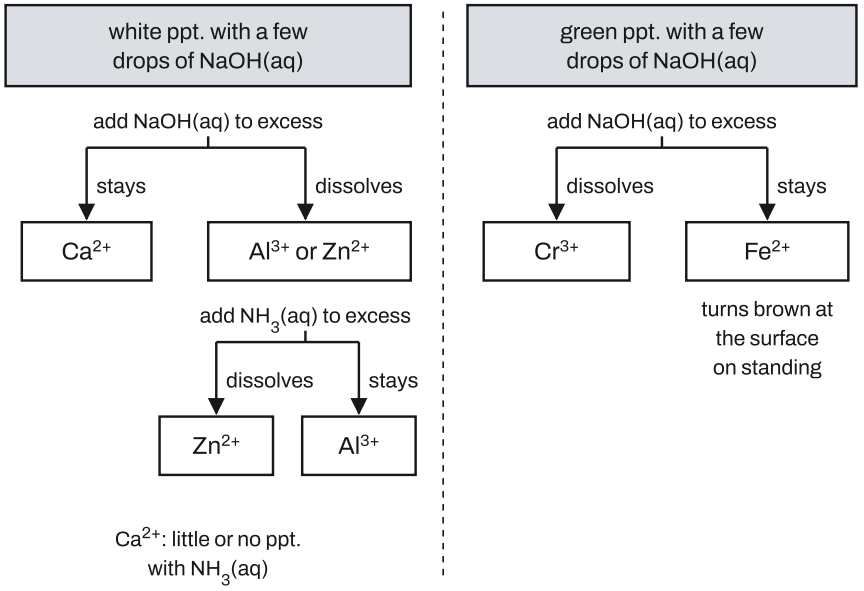
Cation	Aqueous sodium hydroxide	Aqueous ammonia
aluminium, Al^{3+}	white ppt., **dissolves** in excess (colourless solution)	white ppt., **does not dissolve** in excess

Cation	Aqueous sodium hydroxide	Aqueous ammonia
zinc, Zn^{2+}	white ppt., **dissolves** in excess (colourless solution)	white ppt., **dissolves** in excess (colourless solution)
calcium, Ca^{2+}	white ppt., does not dissolve in excess	no ppt., or only a very slight white ppt.
chromium(III), Cr^{3+}	green ppt., **dissolves** in excess (dark green solution)	green ppt., does not dissolve in excess
iron(II), Fe^{2+}	green ppt., does not dissolve; turns brown at the surface if left to stand	the same as with sodium hydroxide
iron(III), Fe^{3+}	red-brown ppt., does not dissolve in excess	red-brown ppt., does not dissolve in excess
copper(II), Cu^{2+}	light blue ppt., does not dissolve in excess	light blue ppt., **dissolves** in excess to give a **dark blue solution**
ammonium, NH_4^+	no ppt.; on **warming**, ammonia gas is given off (damp red litmus turns blue)	(not used)

Three pairs are easy to confuse, and exam options are built on them:

- **Three white precipitates** (Al^{3+}, Zn^{2+}, Ca^{2+}). With excess sodium hydroxide, calcium's stays; aluminium's and zinc's dissolve. Aqueous ammonia then separates aluminium from zinc: only zinc's precipitate dissolves.
- **Two green precipitates** (Cr^{3+}, Fe^{2+}). Chromium(III) hydroxide dissolves in excess sodium hydroxide; iron(II) hydroxide does not.
- **Copper(II)** is the only light blue precipitate, and the only one that turns into a dark blue solution with excess ammonia.

Sodium, potassium and lithium ions give **no precipitate** at all (their hydroxides dissolve), so identify them with a flame test instead.



Tests for anions

Carbonate. Add dilute acid (hydrochloric or nitric). There is **effervescence** (fizzing), and the gas turns **limewater milky**, so it is carbon dioxide. You need both parts: fizzing alone could be another gas.

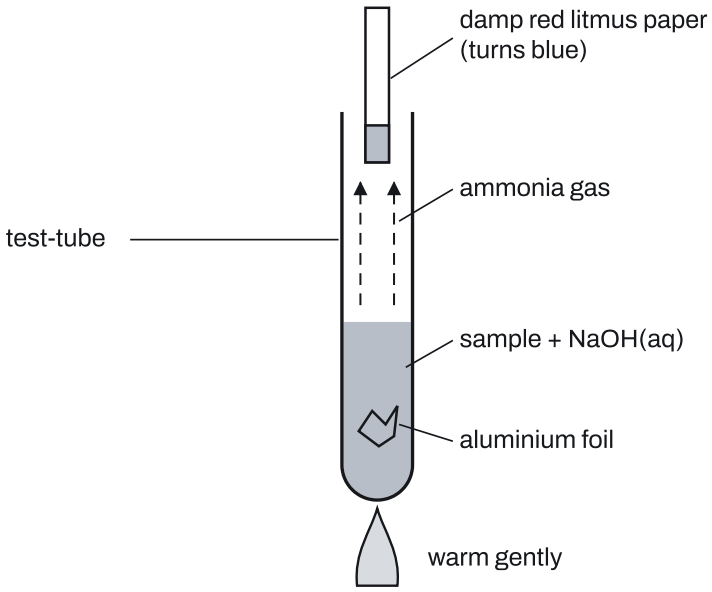
Halides (chloride, bromide, iodide). Add **dilute nitric acid**, then **aqueous silver nitrate**. The silver halide precipitates:

Halide	Precipitate with acidified silver nitrate
chloride, Cl^-	**white**
bromide, Br^-	**cream**
iodide, I^-	**yellow**

Sulfate. Add **dilute nitric acid**, then **aqueous barium nitrate**: a **white** precipitate of barium sulfate.

Why the acid, and why nitric? The acid first removes any carbonate ions, which would also give a white precipitate with silver or barium ions. The acid must not bring in the ion you are testing for: **hydrochloric acid** adds chloride ions, so the silver nitrate would give a white precipitate whatever the sample was, and **sulfuric acid** adds sulfate ions, which ruins the sulfate test. Nitric acid adds only nitrate ions, which give no precipitate with either reagent.

Nitrate. Add **aqueous sodium hydroxide** and **aluminium foil**, then **warm** gently. The aluminium reduces the nitrate ions to **ammonia**, which turns **damp red litmus paper blue**.



Ammonium ions give ammonia with sodium hydroxide **without** aluminium. So if the solution gives ammonia **before** the foil is added, ammonium ions are present; ammonia that appears **only after** adding aluminium comes from nitrate. (A salt such as ammonium nitrate would give ammonia in both steps.)

Sulfite. Add a little **acidified aqueous potassium manganate(VII)**: it changes from **purple to colourless**. Sulfate ions do not do this, which is how you tell sulfite from sulfate. It is the same colour change as the sulfur dioxide test.

Putting tests together

Identifying a compound usually takes one cation test and one anion test. Work through one result at a time and cross out every option it rules out. A **negative** result matters as much as a positive one: no precipitate with barium nitrate means there is **no sulfate**; no ammonia on warming with sodium hydroxide alone means **no ammonium ions**.

Key facts and formulas

None of these results are printed on Papers 1 to 4, so every one is "Learn it". (The practical papers print them in their Notes for use in qualitative analysis.)

Formula	Status
$\mathrm{H_2}$: lighted splint, pops · $\mathrm{O_2}$: glowing splint, relights	Learn it
$\mathrm{CO_2}$: limewater turns milky · $\mathrm{NH_3}$: damp red litmus turns blue	Learn it
$\mathrm{Cl_2}$: damp litmus bleached · $\mathrm{SO_2}$: acidified $\mathrm{KMnO_4}$(aq) purple to colourless	Learn it
Flame colours: $\mathrm{Li^+}$ red, $\mathrm{Na^+}$ yellow, $\mathrm{K^+}$ lilac, $\mathrm{Ca^{2+}}$ orange-red, $\mathrm{Ba^{2+}}$ light green, $\mathrm{Cu^{2+}}$ blue-green	Learn it
With NaOH(aq): $\mathrm{Al^{3+}}$, $\mathrm{Zn^{2+}}$ white ppt. dissolving in excess; $\mathrm{Ca^{2+}}$ white ppt. staying; $\mathrm{Cr^{3+}}$ green ppt. dissolving; $\mathrm{Fe^{2+}}$ green ppt. staying; $\mathrm{Fe^{3+}}$ red-brown ppt.; $\mathrm{Cu^{2+}}$ light blue ppt.	Learn it
With $\mathrm{NH_3}$(aq): only $\mathrm{Zn^{2+}}$ and $\mathrm{Cu^{2+}}$ precipitates dissolve in excess ($\mathrm{Cu^{2+}}$ gives a dark blue solution); $\mathrm{Ca^{2+}}$ gives little or no ppt.	Learn it
$\mathrm{NH_4^+}$: warm with NaOH(aq), ammonia given off	Learn it
$\mathrm{CO_3^{2-}}$: dilute acid, effervescence, gas turns limewater milky	Learn it
$\mathrm{Cl^-}$ / $\mathrm{Br^-}$ / $\mathrm{I^-}$: dilute $\mathrm{HNO_3}$ then $\mathrm{AgNO_3}$(aq), white / cream / yellow ppt.	Learn it
$\mathrm{SO_4^{2-}}$: dilute $\mathrm{HNO_3}$ then $\mathrm{Ba(NO_3)_2}$(aq), white ppt.	Learn it
$\mathrm{NO_3^-}$: NaOH(aq) and aluminium foil, warm, ammonia given off	Learn it

Formula	Status
SO_3^{2-}: acidified $KMnO_4$(aq) purple to colourless	Learn it
Extended: $Ag^+(aq) + X^-(aq) \rightarrow AgX(s)$ for $X = Cl, Br, I$	Learn it
Extended: $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$	Learn it
Extended: $M^{n+}(aq) + nOH^-(aq) \rightarrow M(OH)_n(s)$, such as $Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$	Learn it

How to do it

In the questions we have tagged for this topic (125 questions, 2021–2025; many multiple-choice questions appear on several paper variants, so there are 114 different ones), the types came up this often. 5 of the 125 questions mix two or three types, so the counts add up to 131.

Question type	Questions
Identify a compound, or predict its results, from two or more tests	25
Describe an anion test	23
Pick the substance from a list that gives a stated test result	21
Recall the result of a named cation or anion test	18
Describe a cation test	15
Describe a gas test	13
Identify a gas from its test result	10
Write the ionic equation for a test precipitate	4
Explain how a test is carried out	2

1. Identify a compound, or predict its results, from two or more tests (25 questions)

Multiple choice. You are given a table of results and four compounds, or a named compound and four rows of results.

1. **Take the cation result** (flame colour, or the precipitate with sodium hydroxide or ammonia) and name the cation. Cross out every option with a different cation.
2. **Take the anion result** (the silver nitrate colour, a white precipitate with barium nitrate, fizzing with acid, ammonia only after adding aluminium) and name the anion. Cross out the rest.
3. Check that the one option left fits **every** result, including the negative ones.

For example: a red flame, and a cream precipitate with acidified silver nitrate, means lithium ions and bromide ions: **lithium bromide**.

Variations you will meet:

- **"Which row shows the results for [named compound]?"** Work forwards: write down what its cation and its anion should each give, then find the row where **every** column matches, including "no visible change" for reagents that test for ions it does not have. Sodium chloride, for instance, gives **no** precipitate with sodium hydroxide (sodium hydroxide is soluble) and a **white** one with acidified silver nitrate.
- **Chromium(III) or iron(II)?** Both give green precipitates. Look at excess sodium hydroxide: dissolves means chromium(III). A question may add aqueous ammonia too: chromium(III) hydroxide does **not** dissolve in excess ammonia.
- **Ammonium or nitrate?** Ammonia on warming with sodium hydroxide **alone** means ammonium; ammonia only after adding aluminium means nitrate. Fizzing with acid plus ammonia from sodium hydroxide means **ammonium carbonate**.
- **Three tests stacked** (Paper 2): a white precipitate with barium nitrate plus a white precipitate with both sodium hydroxide and ammonia that dissolves in excess of each means **zinc sulfate** (aluminium's would stay in excess ammonia).
- **Other reagents in a row**, such as dilute sulfuric acid: its sulfate ions give a white precipitate with barium ions (barium sulfate is insoluble), but none with sodium or copper(II) ions. Settle the row with the columns you know best, the flame colour and the hydroxide precipitate.
- **Products of burning**: a substance whose products turn limewater milky and also give water contains carbon and hydrogen, such as ethanol.

2. Describe an anion test (23 questions)

Usually 2 marks: 1 for the reagent, 1 for the result.

1. **Name the reagents in order**, with "aqueous" and "dilute": for a halide, "add dilute nitric acid, then aqueous silver nitrate"; for sulfate, "add dilute nitric acid, then aqueous barium nitrate".
2. **Give the result as a precipitate with its colour**: white (chloride), cream (bromide), yellow (iodide), white (sulfate).
3. For **nitrate**: "warm with aqueous sodium hydroxide and aluminium foil; ammonia is given off, which turns damp red litmus paper blue".
4. For **carbonate**: "add dilute acid; effervescence; the gas turns limewater milky".

Variations you will meet:

- **A table of ions in a water sample** (Paper 3) with "Describe a test for the chloride ions" in one part. The rest of the question is on other topics; this part is the standard 2 marks.
- **Fill in the words** (Core): "Add aqueous sodium ____, then ____. Warm. The gas is ____." → hydroxide, aluminium, ammonia. Or "name the aqueous solution and the metal": sodium hydroxide and aluminium.

- **What is seen for a stated mixture** (Paper 4): aqueous silver nitrate added to aqueous sodium iodide gives a **yellow precipitate**; an acidic solution of barium ions added to a solution containing sulfate ions gives a **white precipitate**. Here only the observation earns the mark.
- Mark schemes put the nitric acid in brackets, so "silver nitrate" alone often earns the reagent mark. For sulfate, one mark scheme also accepted barium chloride. Write the full method anyway: adding **hydrochloric** or **sulfuric** acid is marked wrong.

3. Pick the substance from a list that gives a stated test result (21 questions)

One mark each, in the opening Paper 3 question ("Each substance may be used once, more than once or not at all"), and occasionally on Paper 4.

1. **Turn the result into the ion or gas**: "a gas identified using limewater" → carbon dioxide; "identified using damp red litmus paper" → ammonia; "tested for using acidified aqueous potassium manganate(VII)" → sulfur dioxide; "bleaches damp litmus" → chlorine; "the gas made in the nitrate test" → ammonia.
2. For ions: flame colour → the metal (red Li, yellow Na, lilac K, orange-red Ca, blue-green Cu); red-brown precipitate → Fe (iron(III)); green precipitate with a few drops → Cr or Fe (iron(II)); white precipitate that stays in excess sodium hydroxide → Ca; cream precipitate with silver nitrate → bromide; white → chloride.
3. **Answer in the form asked**: a symbol ("Give the symbol of the element": Fe), a formula from the list ($\mathrm{Na^+}$), or a name ("Give the name of the substance": sodium bromide). The substance must be **in the list**.

Variations you will meet:

- **"Name the element which has aqueous ions that form a white precipitate with aqueous silver ions"**: chlorine (its ion is chloride).
- **"...forms a blue hydroxide which dissolves in aqueous ammonia"**: copper.
- **A green precipitate where both Cr and Fe are on the list**: read the extra words. "Dissolves in excess sodium hydroxide" points to Cr; "insoluble in excess" fits Fe. If only one of them is on the list, that is the answer.

4. Recall the result of a named cation or anion test (18 questions)

Multiple choice with one result and one ion. Learn the three tables in "Understand it" and use the traps list:

1. **White precipitates**: $\mathrm{Ca^{2+}}$ stays in excess sodium hydroxide; $\mathrm{Al^{3+}}$ and $\mathrm{Zn^{2+}}$ dissolve; only $\mathrm{Zn^{2+}}$ also dissolves in excess ammonia. So "dissolves in excess of **both** reagents" is zinc.
2. **Green precipitates**: $\mathrm{Cr^{3+}}$ dissolves in excess sodium hydroxide (grey-green precipitate, dark green solution); $\mathrm{Fe^{2+}}$ does not.
3. **Blue**: only $\mathrm{Cu^{2+}}$. It dissolves in excess **ammonia** (dark blue solution), not in excess sodium hydroxide.
4. **Flame colours**: check each one in an option row. Yellow is sodium, lilac is potassium (options often swap these two), red is lithium, light green is barium.

Variations you will meet:

- **"Which statement about aqueous sodium hydroxide is correct?"** Test each against the table. Sodium hydroxide gives **no** precipitate with sulfate ions, and the ammonia from ammonium salts turns **red litmus blue**, not blue litmus red.
- **"Which row shows the observation when a few drops of P are added to Q?"** Work out each pair: sodium hydroxide into zinc chloride gives a white precipitate; acidified manganate(VII) into a sulfite is decolourised (so a "purple solution" is wrong).
- **One cation, two tests** (flame test and sodium hydroxide): only copper(II) fits blue-green with a light blue precipitate. Check both halves of every row.

5. Describe a cation test (15 questions)

1. **Group I ions and calcium:** flame test. Mark 1: the method ("flame test", or "put the compound in a blue, non-luminous flame"). Mark 2: the colour.
2. **Other metal ions:** "add aqueous sodium hydroxide (or aqueous ammonia)" for mark 1; the precipitate colour for mark 2. For iron(II): "green precipitate". For iron(III): "red-brown precipitate". For copper(II): "light blue precipitate".
3. When the question asks for **a few drops and then excess**, give two observations: for calcium with sodium hydroxide, "white precipitate", then "white precipitate remains (insoluble in excess)"; for zinc with ammonia, "white precipitate", then "precipitate dissolves, giving a colourless solution".

Variations you will meet:

- **Calcium**: either test earns the marks. Sodium hydroxide gives a white precipitate that **does not** dissolve in excess; ammonia gives no precipitate or only a very slight one. Saying calcium's precipitate dissolves loses the mark.
- **Paper 4 mixtures**: "aqueous copper(II) sulfate is added to aqueous sodium hydroxide" → light blue precipitate. "A flame test on a solution containing K^{+} ions" → lilac.

6. Describe a gas test (13 questions)

Usually 2 marks: the test, then the result. Write both, even when the question gives one line.

1. Hydrogen: **lighted** splint → **pops**. (One mark scheme gave a single mark for both together.)
2. Oxygen: **glowing** splint → **relights**.
3. Carbon dioxide: **limewater** → **turns milky** (or cloudy).
4. Ammonia: **damp red litmus** → **turns blue**.
5. Chlorine: **damp litmus** → **bleached** (turns white).
6. Sulfur dioxide: **acidified aqueous potassium manganate(VII)** → from **purple to colourless**.

Variations you will meet:

- **The gas comes from another reaction** in the question (heating a nitrate gives oxygen, heating iron(II) sulfate gives sulfur dioxide, a metal with acid gives hydrogen, electrolysis gives chlorine). Name the gas first if you need to, then give its test.

- **"Name the acidified solution used to test for sulfur dioxide and state the observations"**: potassium manganate(VII); it turns colourless.

7. Identify a gas from its test result (10 questions)

Multiple choice.

1. Read the result and name the gas using the gas table: pops → hydrogen; relights → oxygen; milky limewater → carbon dioxide; red litmus to blue → ammonia; litmus to white → chlorine; manganate(VII) to colourless → sulfur dioxide.
2. Check the option also gets the details right: **lighted** versus **glowing** splint, **purple to colourless** (not colourless to purple).

Variations you will meet:

- **Three gases in a table**, each with several tests: find the one positive result in each column; the others say "no change".
- **"Which reagent tests for chlorine?"** → damp litmus paper.
- **An element burns to an acidic gas that decolourises manganate(VII)**: the gas is sulfur dioxide, so the element is **sulfur**.
- **A burning fuel containing sulfur compounds** is pulled through a solution: acidified potassium manganate(VII), turning colourless.

8. Write the ionic equation for a test precipitate (4 questions)

Extended only. Three marks: the precipitate as the only product, the right ions as the only reactants, and state symbols.

1. Write the **insoluble product** on the right with **(s)**: $\mathrm{AgCl(s)}$, $\mathrm{AgI(s)}$, $\mathrm{BaSO_4(s)}$, $\mathrm{Cu(OH)_2(s)}$.
2. Write **only the ions that form it** on the left, each with **(aq)**. Leave out spectator ions (sodium, nitrate, potassium).
3. Balance charges: $\mathrm{Cu^{2+}}$ needs **two** $\mathrm{OH^-}$.

$$\mathrm{Ag^+(aq) + I^-(aq) \rightarrow AgI(s)} \qquad \mathrm{Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)}$$

9. Explain how a test is carried out (2 questions)

- **Why not hydrochloric acid in the halide test?** It contains **chloride ions**, which would give a white precipitate with silver nitrate even if the sample had no halide. Name **nitric acid** as the acid to use.
- **How is a flame test done?** A clean wire is dipped into the substance and held **in a blue (non-luminous)** Bunsen flame. Options with a yellow flame, or with a lit or glowing splint above a tube (those are gas tests), are wrong.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **B1** mark for a correct result on its own, with no method needed.

Example 1

A technician finds three jars of white solid whose labels have come off. The solids are known to be lithium carbonate, potassium sulfate and ammonium chloride.

(a) Describe a flame test to pick out the lithium carbonate, and state the result. **[2]**

(b) Describe a test to show that potassium sulfate contains sulfate ions. **[2]**

(c) Describe how the ammonium ions in ammonium chloride can be detected. **[3]**

(d) Describe what is seen when dilute hydrochloric acid is added to lithium carbonate, and how the gas is identified. **[2]**

(a) Dip a clean nichrome wire into the solid and hold it in a blue (non-luminous) Bunsen flame. **B1** The lithium compound gives a **red** flame. **B1**

(b) Dissolve the solid in water, add dilute nitric acid, then aqueous barium nitrate. **B1** A **white precipitate** forms. **B1**

(c) Warm the solid with aqueous sodium hydroxide. **B1** Hold damp red litmus paper at the mouth of the tube. **B1** It turns **blue**, because ammonia is given off. **B1**

(d) Effervescence (fizzing). **B1** Bubble the gas through limewater: it turns **milky**, so the gas is carbon dioxide. **B1**

Example 2

An aqueous solution of compound Y contains one cation and one anion. The results of three tests are shown.

Test	Few drops	Excess
1: aqueous sodium hydroxide	white precipitate	precipitate dissolves, colourless solution
2: aqueous ammonia	white precipitate	precipitate dissolves, colourless solution
3: dilute nitric acid, then aqueous silver nitrate	cream precipitate	

(a) Identify the cation in Y. Explain how test 2 rules out one other cation. **[2]**

(b) Identify the anion and name Y. **[2]**

(c) Predict what is seen when dilute nitric acid and then aqueous barium nitrate are added to a solution of Y. **[1]**

(d) Write the ionic equation, with state symbols, for the reaction in test 3. **[3]**

(a) Zinc, Zn^{2+}. **B1** Aluminium ions also give a white precipitate that dissolves in excess sodium hydroxide, but aluminium's precipitate does **not** dissolve in excess ammonia; this one does. **B1**

(b) A cream precipitate means bromide, Br^{-}. **B1** Y is **zinc bromide**. **B1**

(c) No visible change (no precipitate), because Y contains no sulfate ions. **B1**

(d) $\mathrm{Ag}^{+}(\mathrm{aq}) + \mathrm{Br}^{-}(\mathrm{aq}) \rightarrow \mathrm{AgBr}(\mathrm{s})$. **B1** for AgBr as the only product, **B1** for Ag^{+} and Br^{-} as the only reactants, **B1** for the state symbols. (This part is Extended.)

Example 3

A student collects a gas from each of three experiments:

- A: magnesium ribbon added to dilute ethanoic acid;
- B: hydrogen peroxide solution with a manganese(IV) oxide catalyst;
- C: the positive electrode during the electrolysis of concentrated aqueous sodium chloride.

(a) For each gas, give its name and describe a test for it, with the result. **[6]**

(b) A fourth gas, D, turns acidified aqueous potassium manganate(VII) from purple to colourless. Name gas D. **[1]**

(c) Explain why the litmus paper used in gas tests must be damp. **[1]**

(a) A is **hydrogen** (a metal with an acid). **B1** A lighted splint gives a squeaky **pop**. **B1**

B is **oxygen**. **B1** A glowing splint **relights**. **B1**

C is **chlorine**. **B1** Damp litmus paper is **bleached** (turns white). **B1**

(b) Sulfur dioxide. **B1**

(c) The gas must dissolve in water on the paper before it can change the colour of the litmus. **B1**

Example 4

Solution R contains one cation and one anion. The table shows the results of three tests on R.

Test	Result
1: aqueous sodium hydroxide, a few drops then excess	green precipitate, which dissolves in excess to give a dark green solution
2: dilute nitric acid, then aqueous barium nitrate	white precipitate

Test	Result
3: warmed with aqueous sodium hydroxide and aluminium foil, damp red litmus held at the mouth of the tube	litmus stays red

(a) Identify R. **[2]**

(b) A student wants to use dilute sulfuric acid instead of dilute nitric acid in test 2. Explain why this is wrong. **[1]**

(c) Write the ionic equation, with state symbols, for the formation of the white precipitate in test 2. **[3]**

(d) Predict what is seen when aqueous ammonia is added to R, a few drops and then in excess. **[2]**

(a) A green precipitate that dissolves in excess sodium hydroxide is chromium(III), Cr^{3+} (iron(II) would stay). Test 2 shows sulfate, and test 3 shows there is no nitrate. R is **chromium(III) sulfate**. **B1** for chromium(III), **B1** for sulfate.

(b) Sulfuric acid contains sulfate ions, so a white precipitate would form with barium nitrate even if R had no sulfate. **B1**

(c) $\mathrm{Ba}^{2+}(\mathrm{aq}) + \mathrm{SO}_4^{2-}(\mathrm{aq}) \rightarrow \mathrm{BaSO}_4(\mathrm{s})$. **B1** for BaSO_4 as the only product, **B1** for the two ions as the only reactants, **B1** for the state symbols.

(d) A **green precipitate** with a few drops **B1**, which **does not dissolve** in excess ammonia. **B1**

Common mistakes

- **Using the wrong acid in the halide or sulfate test.** Hydrochloric acid brings chloride ions and sulfuric acid brings sulfate ions, so either gives a precipitate every time. Use dilute **nitric** acid. Examiner reports have criticised this more than once, for both the bromide and the chloride test.
- **Getting the halide colours wrong**, especially calling the bromide precipitate white. Learn: chloride white, bromide cream, iodide yellow.
- **Leaving out the word "precipitate".** "Goes white" or "cloudy" loses the mark; "white precipitate" earns it. The same goes for a "white solution".
- **Confusing chlorine with chloride.** Chlorine is a gas (damp litmus bleached); chloride is an ion in solution (white precipitate with acidified silver nitrate).
- **Swapping the splints.** Lighted splint pops for hydrogen; glowing splint relights for oxygen. "Burning splint relights" and "splint test" earn nothing.
- **Giving the name of the gas as the result.** "Carbon dioxide is produced" is not what you see in the carbonate test; "effervescence, and the gas turns limewater milky" is. Likewise "a pungent smell" is not a test for ammonia.
- **Describing a flame test badly**: holding the sample "over" or "near" the flame, using tongs, or not saying the flame is blue (non-luminous). Hold it **in** a blue flame on a wire or splint.
- **Reporting impossible results for a flame test**, such as a precipitate or fizzing. A flame test only ever gives a colour.

- **Saying calcium's white precipitate dissolves in excess sodium hydroxide.** It stays; that is how you tell calcium from zinc and aluminium.
- **Suggesting a flame test, or silver nitrate, for the wrong ion.** Examiners see flame tests offered for chloride, sulfate and iron(III) ions. Flame tests are for the six metal ions only; iron(III) needs sodium hydroxide (red-brown precipitate).
- **Writing "blue" for copper's flame.** It is **blue-green**.
- **Mixing up the nitrate and ammonium tests.** Aluminium is only needed for nitrate. Ammonia from sodium hydroxide alone means ammonium ions.
- **Ignoring negative results.** If manganate(VII) stays purple, there is **no** sulfite. If barium nitrate gives no precipitate, there is **no** sulfate.

How to get the marks

- **"Describe a test"** means the reagents **and** the result, even if only one line is printed. For a gas test, both are needed for the 2 marks.
- **Name reagents fully**: "aqueous silver nitrate", "acidified aqueous potassium manganate(VII)", "damp red litmus paper". "Potassium manganate" without "acidified" may be accepted as the reagent, but saying acidified is safer.
- **Observations are what you see**: colours, precipitates, fizzing, a splint relighting. Not the names of products.
- **Give both colours for a colour change, in order**: "purple to colourless".
- **Few drops then excess** questions have one mark for each stage. Say what happens to the precipitate in excess: "remains" or "dissolves".
- **Answer in the form asked**: a symbol, a formula from the list, or a name. Use only substances in the list when the question says so.
- **Multiple choice**: check every column of the row you choose, including "no reaction" entries.
- **Ionic equations (Extended)**: only the ions that form the precipitate, the precipitate as the only product, and **(aq)** and **(s)** state symbols.

Quick check

1. Describe a test to show that aqueous magnesium chloride contains chloride ions, and give the result.
2. A few drops of aqueous ammonia added to a solution give a light blue precipitate, which dissolves in excess ammonia to give a dark blue solution. Name the cation, and state the flame test colour of this cation.
3. A gas turns damp blue litmus paper red and then white. Name the gas.
4. A white solid W gives a red flame test. When W is warmed with aqueous sodium hydroxide alone, no gas is given off. When aluminium foil is added and the mixture is warmed again, a gas is given off which turns damp red litmus paper blue. Name W.

5. Extended. Aqueous sodium hydroxide is added to aqueous iron(III) chloride. State what is seen, and write the ionic equation, with state symbols, for the reaction.

Answers

1. Add dilute nitric acid, then aqueous silver nitrate. A **white precipitate** forms.
2. Copper(II), Cu^{2+}. Its flame test colour is **blue-green**.
3. **Chlorine** (it is acidic, then it bleaches the litmus).
4. A red flame means lithium ions. No gas with sodium hydroxide alone means no ammonium ions; ammonia only after adding aluminium means nitrate ions. W is **lithium nitrate**.
5. A **red-brown precipitate**. $\mathrm{Fe}^{3+}(\mathrm{aq}) + 3\mathrm{OH}^{-}(\mathrm{aq}) \rightarrow \mathrm{Fe(OH)}_3(\mathrm{s})$.

Past questions to try

- **0620/12/F/M/25 Q36**: two iron salts told apart by their cation and anion tests.
- **0620/23/O/N/23 Q40**: three tests, with chromium(III) and iron(II) halides as the options.
- **0620/43/O/N/22 Q5**: predicting the flame test and barium ion results for a solution, then the ionic equation.
- **0620/41/O/N/21 Q2**: copper(II) ions with sodium hydroxide, and the ionic equation.