Cambridge (CIE) IGCSE Chemistry

Your notes

Identification of Ions & Gases

Contents

Your notes

Identification of anions

- Negatively charged non-metal ions are known as **anions**
- You must be able to **describe** the tests for the following ions:
  - Carbonate ions, CO_3^{2-}
  - Halide ions, Cl^-, Br^-, I^-
  - Nitrate ions, NO_3^-
  - Sulfate ions, SO_4^{2-}
  - Sulfite ions, SO_3^{2-}

Test for carbonate ions

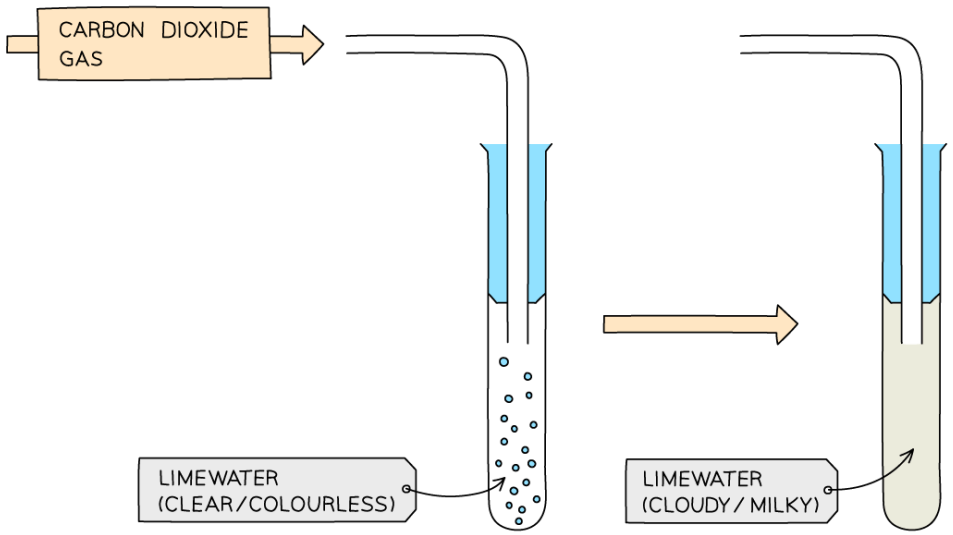
- Carbonate compounds contain the carbonate ion, CO_3^{2-}
- The test for the carbonate ion is:
  - Add **dilute acid**
  - Bubble the **gas** released through limewater
  - Limewater turns cloudy if the carbonate ion is present
- If a carbonate compound is present then fizzing / effervescence should be seen as CO_2 gas is produced, which forms a white precipitate of calcium carbonate when bubbled through limewater:

$$CO_3^{2-}(aq) + 2H^+(aq) \rightarrow CO_2(g) + H_2O(l)$$

$$CO_2(g) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + H_2O(l)$$

- The white precipitate turns limewater **cloudy**

Testing for carbonate ions



Limewater turns milky in the presence of carbon dioxide caused by the formation of insoluble calcium carbonate

Examiner Tips and Tricks

- If you are asked to describe the test for carbonate ions, make sure that you say:
  - Bubble the gas produced through limewater, which turns cloudy if the carbonate ion is present
- Just saying that limewater turns cloudy is not enough
  - This isn't describing the test, it is stating the result

Test for halide ions

- Halide ions are the negative ions / anions formed by the elements in Group 7
- The test for the halide ions is:
  - Acidify the sample with nitric acid
  - Add **silver nitrate solution,** $AgNO_3$,
  - A silver halide **precipitate** forms if a halide ion is present
    - The precipitate is indicated by the state symbol (s)
- The colour of the silver halide precipitate depends on the halide ion:
  - The chloride ion forms a **white** precipitate of silver chloride

potassium chloride + silver nitrate → potassium nitrate + silver chloride

Your notes

$$KCl\,(aq) + AgNO_3\,(aq) \rightarrow KNO_3\,(aq) + AgCl\,(s)$$

- The bromide ion forms a **cream** precipitate of silver bromide

potassium bromide + silver nitrate → potassium nitrate + silver bromide

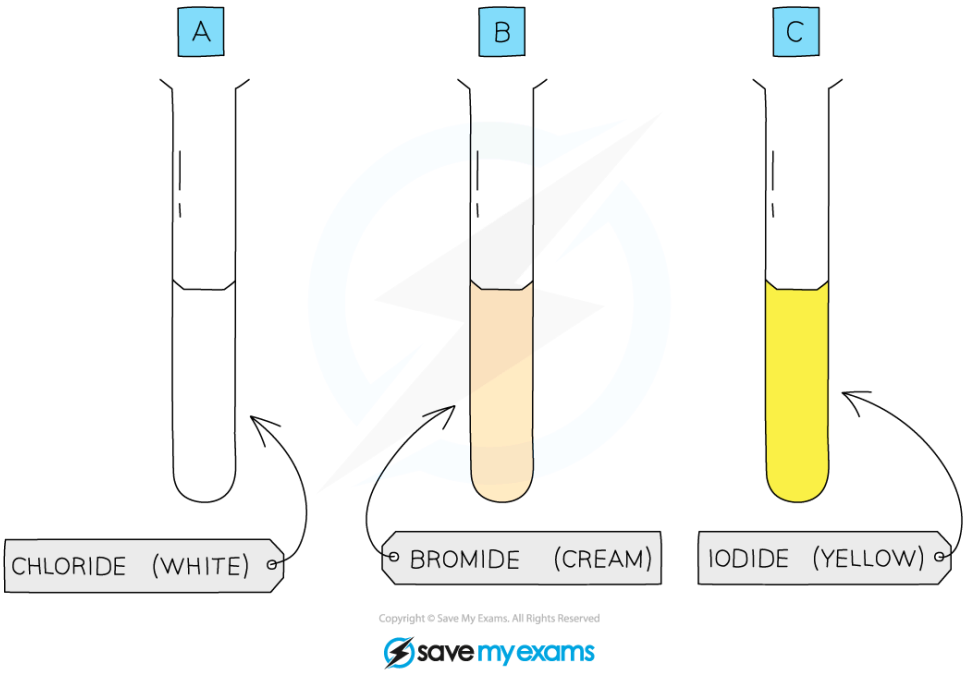
$$KBr\,(aq) + AgNO_3\,(aq) \rightarrow KNO_3\,(aq) + AgBr\,(s)$$

- The iodide ion forms a **yellow** precipitate of silver iodide

potassium iodide + silver nitrate → potassium nitrate + silver iodide

$$KI\,(aq) + AgNO_3\,(aq) \rightarrow KNO_3\,(aq) + AgI\,(s)$$

Testing for halide ions



Each silver halide produces a precipitate of a different colour

Examiner Tips and Tricks

The acidification step in the halide ion test must be done with nitric acid rather than hydrochloric acid.

HCl contains the chloride ion which would interfere with the results.

Test for nitrate ions

- Nitrate compounds contain the nitrate ion, NO_3^-
- The test for the nitrate ion is

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- Add **aqueous NaOH** and **aluminium foil**
- **Warm** gently and test the gas released
- The gas given off is ammonia, NH_3

- Ammonia is a gas with a characteristic sharp choking smell that turns damp **red** litmus paper **blue**

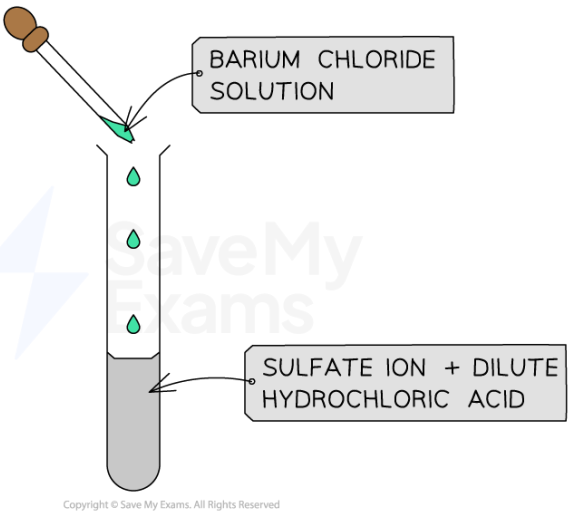
Test for sulfate ions

- Sulfate compounds contain the sulfate ion, SO_4^{2-}
- The test for the sulfate ion is:
  - Acidify the sample with **dilute nitric acid**
  - Add a few drops of **barium chloride solution**
  - A **white** precipitate of barium sulfate is formed, if the sulfate ion is present

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$

- The test can also be carried out with barium nitrate solution

Testing for sulfate ions



A white precipitate of barium sulfate is a positive result for the presence of sulfate ions

Examiner Tips and Tricks

Nitric is added first to remove any **carbonates** which may be present which would also produce a precipitate and interfere with the results.

Test for sulfite ions

- Sulfite compounds contain the sulfite ion, SO_3^{2-}

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- The test for the sulfite ion is:
  - Add **dilute acid**
  - Warm the mixture gently
  - Bubble the **gas** released through potassium manganate(VII) solution
  - The potassium manganate(VII) solution changes from purple to colourless if the sulfite ion is present

Examiner Tips and Tricks

For qualitative inorganic analysis, there will be one test for the metal **cation** and another test for the non-metal **anion**.

If you are an extended level student you may be asked to write balanced ionic equations for cation and anions tests, so make sure you know the formulae of all the ions and precipitates formed.

Your notes

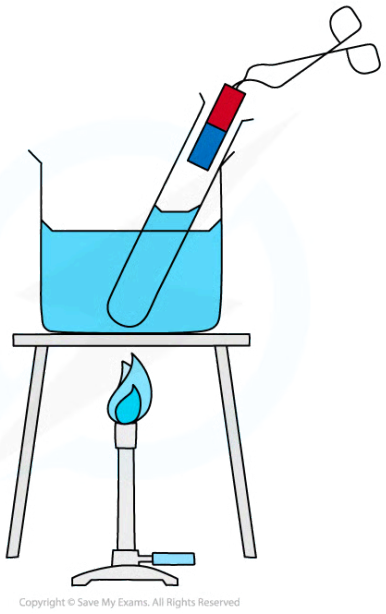
Your notes

Identification of cations

Test for ammonium ions

- Ammonium ions, NH_4^+, can be identified by gently warming a solution containing the ions with sodium hydroxide solution
  - The sodium hydroxide solution is a source of hydroxide ions, OH^-, for the test
- This releases ammonia gas which turns damp red litmus paper blue

Testing for ammonium ions



Heating ammonium ions with sodium hydroxide solution releases ammonia gas which turns damp red litmus blue

- Metal cations in aqueous solution can be identified by the **colour** of the precipitate they form on addition of sodium hydroxide and ammonia
  - Most transition metals produce hydroxides with distinctive colours

Test for metal ions with sodium hydroxide solution

- If a small amount of sodium hydroxide solution is used, the resulting **metal hydroxide** normally precipitates out of solution
- If **excess** sodium hydroxide solution is used, some of the precipitates may re-dissolve
  - For this reason, just a few drops of sodium hydroxide solution are added at first and **very slowly**

- The sodium hydroxide test for the metal ion is:
  - Add a few drops of sodium hydroxide solution
  - Record any colour changes or precipitates formed
  - Add excess sodium hydroxide solution
  - Record any colour changes or changes to precipitates

Your notes

Test with sodium hydroxide summary

Metal Ion	Effect of aqueous NaOH	Effect of excess aqueous NaOH
aluminium, Al^{3+}	white precipitate	soluble in excess giving a colourless solution
ammonium, NH_4^+	ammonia produced on warming	-
calcium, Ca^{2+}	white precipitate	insoluble in excess
chromium(III), Cr^{3+}	green precipitate	soluble in excess
copper, Cu^{2+}	light blue precipitate	insoluble in excess
iron, Fe^{2+}	green precipitate	insoluble in excess, but the surface of the precipitate turns brown on standing
iron, Fe^{3+}	red-brown precipitate	insoluble in excess
zinc, Zn^{2+}	white precipitate	soluble in excess giving a colourless solution

Test for metal ions with ammonia solution

- If a small amount of ammonia solution is used, the resulting **metal hydroxide** normally precipitates out of solution
- If **excess** ammonia solution is used, some of the precipitates may re-dissolve
  - For this reason, just a few drops of ammonia solution are added at first and **very slowly**
- The ammonia test for the metal ion is:
  - Add a few drops of ammonia solution
  - Record any colour changes or precipitates formed

- Add excess ammonia solution
- Record any colour changes or changes to precipitates

Your notes

Test with ammonia summary

Metal Ion	Addition of 2-3 drops of ammonia	Addition of excess ammonia
aluminium, Al^{3+}	white precipitate	insoluble in excess
calcium, Ca^{2+}	no precipitate or very slight white precipitate	no change
chromium(III), Cr^{3+}	green precipitate	insoluble in excess
copper, Cu^{2+}	light blue precipitate	soluble in excess giving a dark blue solution
iron, Fe^{2+}	green precipitate	insoluble in excess, but the surface of the precipitate turns brown on standing
iron, Fe^{3+}	red-brown precipitate	insoluble in excess
zinc, Zn^{2+}	white precipitate	soluble in excess giving a colourless solution

Analysing results

- The tables above contain the results for all **metal cations** included in the syllabus
- For example, zinc chloride:

$$ZnCl_2(aq) + 2NaOH(aq) \rightarrow Zn(OH)_2(s) + 2NaCl(aq)$$

- There are 3 metal ions that all form white precipitates:
  - Aluminium ions, Al^{3+}
  - Calcium ions, Ca^{2+}
  - Zinc ions, Zn^{2+}
- Calcium ions, Ca^{2+}, can be easily distinguished from Zn^{2+} and Al^{3+}
  - The white precipitate of calcium hydroxide **does not dissolve** in excess sodium hydroxide solution
  - The white precipitates of zinc hydroxide and aluminium hydroxide **dissolve** in excess sodium hydroxide solution

- Zinc ions, Zn^{2+}, can then be distinguished from Al^{3+} ions as
  - The white precipitate of zinc hydroxide **dissolves** in excess ammonia solution
  - The white precipitate of aluminium hydroxide **does not dissolve** in excess ammonia solution

Examiner Tips and Tricks

The ammonia or sodium hydroxide solution must be added very slowly. If it is added too quickly and the precipitate is soluble in excess, then you run the risk of missing the formation of the initial precipitate, which dissolves as quickly as it forms if excess solution is added.

Be sure to distinguish between the term "**colourless**" and "**clear**". A solution that loses its colour has become colourless. A clear solution is one that you can see through such as water. Solutions can be clear **and** have colour eg. dilute copper sulphate.

Flame tests for metal ions

- The **flame test** is used to identify the metal cations by the colour of the flame they produce
  - Ions from **different** metals produce **different colours**
- Dip the loop of an **unreactive** metal wire such as nichrome or platinum in concentrated acid and then hold it in the blue flame of a Bunsen burner until there is no colour change
  - This is an important step as the test will only work if there is just **one type** of ion present
    - Two or more ions means the colours will mix, making identification erroneous
    - This cleans the wire loop and avoids **contamination**
- A small sample of the compound is placed on an **unreactive** metal wire loop such as nichrome or platinum
- Dip the loop into the solid sample / solution and place it in the edge of the **blue** Bunsen flame
  - Avoid letting the wire get so hot that it glows red otherwise this can be confused with a flame colour

Your notes

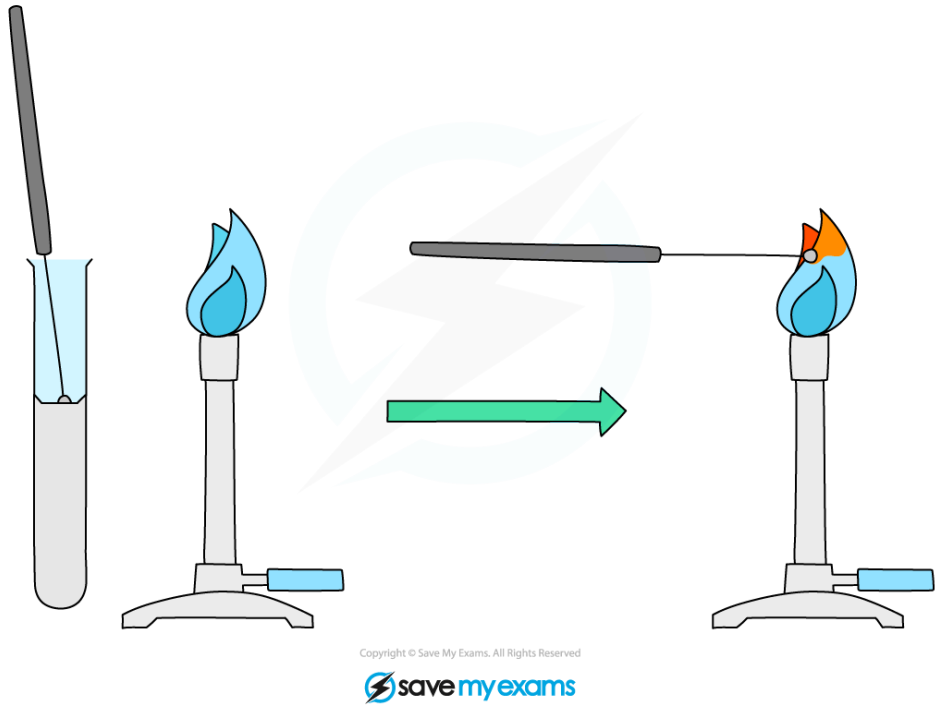
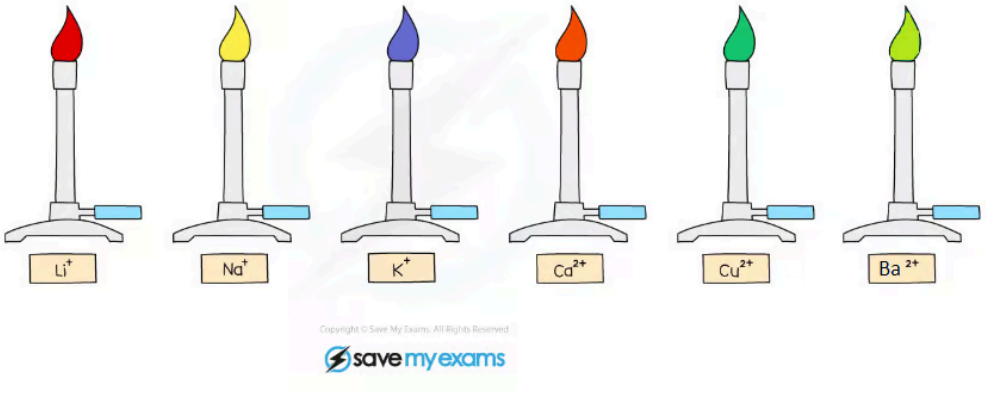


Diagram showing the technique for carrying out a flame test

- The colour of the flame is observed and used to identify the metal ion present:

Cation	Flame Colour
Li^+	Red
Na^+	Yellow
K^+	Lilac
Ca^{2+}	Orange-red
Ba^{2+}	Light-green
Cu^{2+}	Blue-green

Your notes



Metal ions form distinctive coloured flames

Your notes

Examiner Tips and Tricks

The sample needs to be heated strongly, so the Bunsen burner flame should be on a blue flame.

Your notes

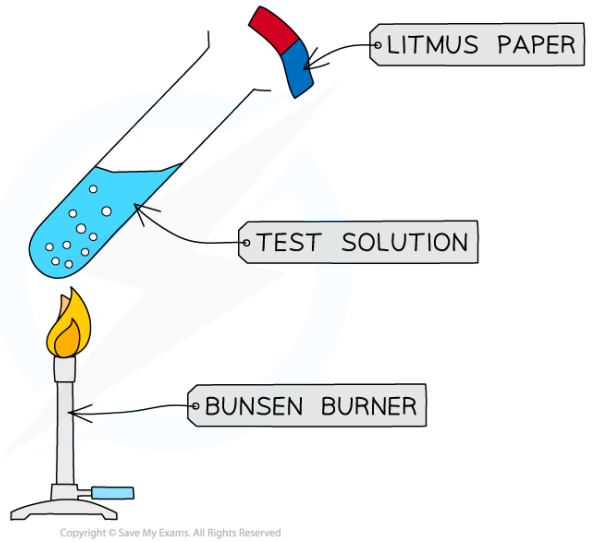
Identification of gases

- Several tests for anions and cations produce **gases** which then need to be tested
- The gases included in the syllabus are:
  - Ammonia
  - Carbon dioxide
  - Chlorine
  - Hydrogen
  - Oxygen
  - Sulfur dioxide

Test for ammonia

- Ammonia is a gas with a characteristic sharp choking smell that turns damp **red** litmus paper **blue**
- Hold the litmus paper near the mouth of the test tube, but be careful to avoid touching the sides of the test tube
- If you are testing for ammonia produced from ammonium ions and sodium hydroxide, avoiding touching the sides to prevent traces of sodium hydroxide from also turning the red litmus paper blue

Testing for ammonia gas



Damp red litmus paper turns blue in the presence of ammonia

Your notes

Examiner Tips and Tricks

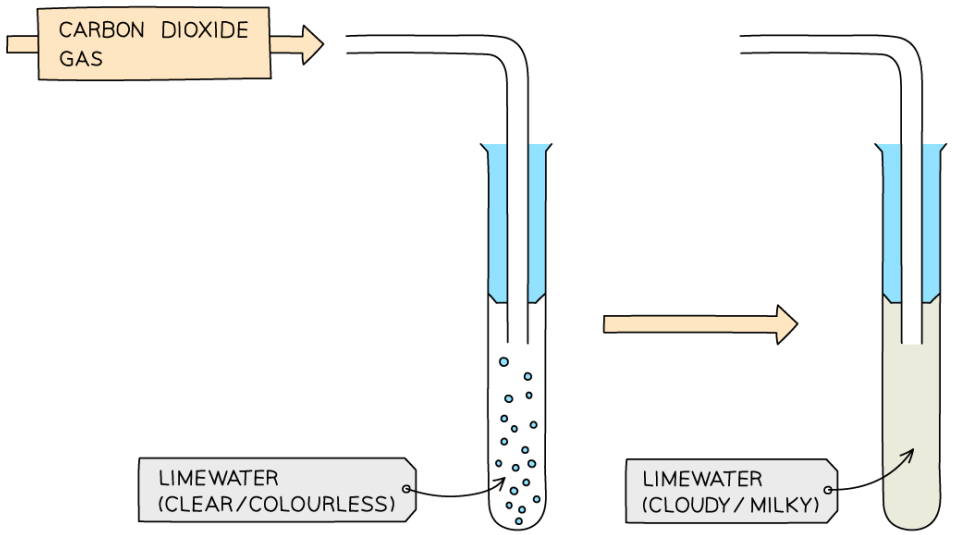
Make sure you understand the difference between ammonium and ammonia.

- Ammonium refers to the aqueous cation, NH_4^+
- Ammonia refers to the gas, NH_3.

Test for carbon dioxide

- The test for carbon dioxide involves bubbling the gas through an aqueous solution of **limewater** (calcium hydroxide)
- If the gas is carbon dioxide, the limewater turns **cloudy white**

Testing for carbon dioxide gas



Limewater turns cloudy white in the presence of carbon dioxide

Examiner Tips and Tricks

Sometimes students think that extinguishing a burning splint indicates carbon dioxide gas.

However, while it is a property of carbon dioxide, other gases, such as nitrogen, will also do this.

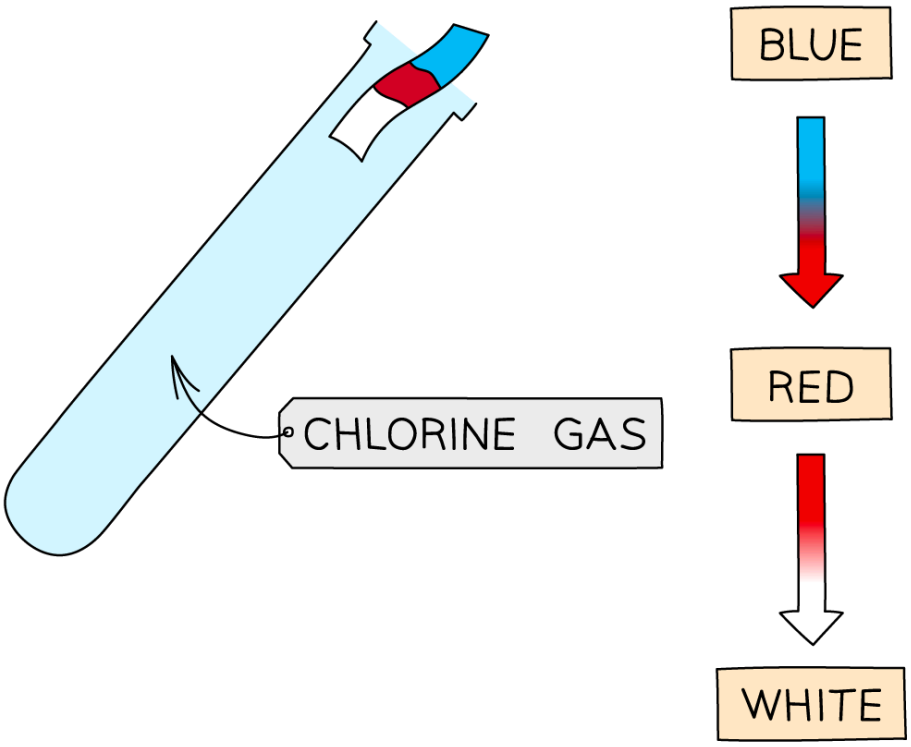
So, the test is not definitive and should not be given as an exam answer.

Test for chlorine gas

Your notes

- The test for chlorine makes use of **litmus paper**
- If chlorine gas is present, damp blue litmus paper will turn red and then be **bleached white**
  - It turns red initially as acids are produced when chlorine comes into contact with water
- Chlorine also has a characteristic sharp, choking smell
- Chlorine should always be handled in a fume cupboard due to its toxicity

Testing for chlorine gas



Chlorine bleaches damp blue litmus paper white

Examiner Tips and Tricks

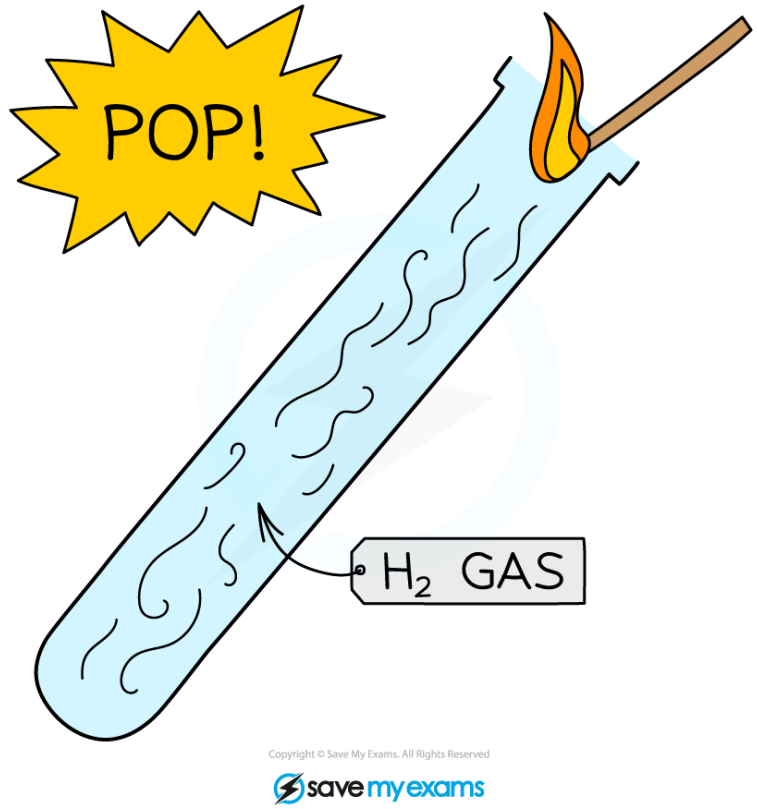
You should distinguish between properties of gases and tests for gases. Chlorine 'smells like swimming pools' is a characteristic, but it is not an acceptable means of identification.

Test for hydrogen gas

Your notes

- The test for hydrogen consists of holding a **burning splint** at the open end of a test tube of gas
- If the gas is hydrogen it burns with a loud "**squeaky pop**" which is the result of the rapid combustion of hydrogen with oxygen to produce water
- Be sure not to insert the splint right into the tube, just at the mouth, as the gas needs air to burn

Testing for hydrogen gas



A burning splint gives a 'squeaky pop' sound

Examiner Tips and Tricks

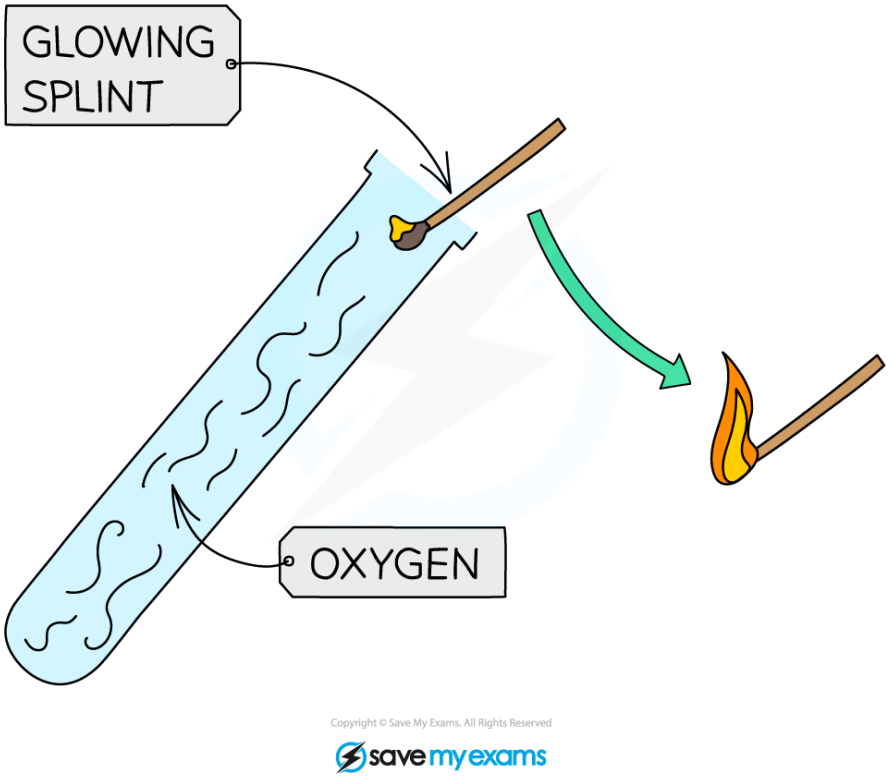
It is easy to confuse the tests for hydrogen and oxygen.

Try to remember that a lig**H**ted splint has an **H** for Hydrogen, while a gl**O**wing splint has an **O** for Oxygen.

Test for oxygen

- The test for oxygen consists of placing a **glowing splint** inside a test tube of gas
- If the gas is oxygen, the splint will **relight**

Testing for oxygen gas



A glowing splint will relight in the presence of oxygen

Examiner Tips and Tricks

Sometimes the splint does not relight, but it glows very brightly, which is also a positive result. In an exam, however, it is best to state it relights the glowing splint.

Test for sulfur dioxide

- Sulfur dioxide is a gas with a characteristic sharp choking smell
- The test for sulfur dioxide involves bubbling the gas through an acidified solution of **potassium manganate(VII)**
- If the gas is sulfur dioxide, the potassium manganate(VII) changes from purple to colourless

Your notes

- This is similar to the test for the sulfite ion

Your notes