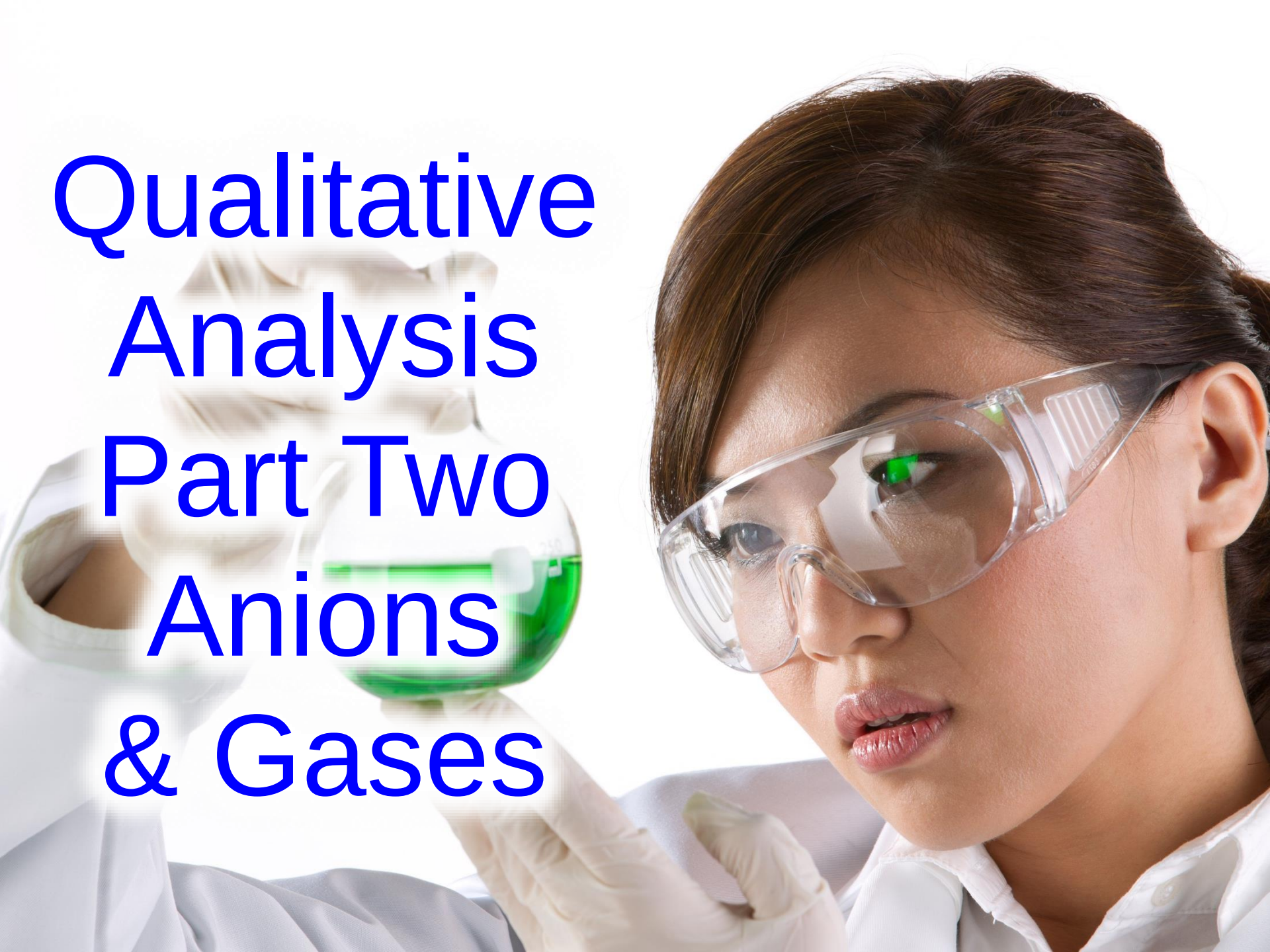
Qualitative Analysis Part Two Anions & Gases



Qualitative Analysis

Qualitative Analysis

Which anions must I know the tests for?

Qualitative Analysis

Describe tests to identify the following anions:

- Carbonate – CO_3^{2-} (by the addition of dilute acid and subsequent use of limewater).
- Chloride – Cl^- (by reaction of an aqueous solution with nitric acid and aqueous silver nitrate).
- Iodide – I^- (by reaction of an aqueous solution with nitric acid and aqueous silver nitrate).
- Nitrate – NO_3^- (by reduction with aluminium and aqueous sodium hydroxide to ammonia and subsequent use of litmus paper).
- Sulfate – SO_4^{2-} (by reaction of an aqueous solution with nitric acid and either aqueous barium chloride or aqueous barium nitrate).

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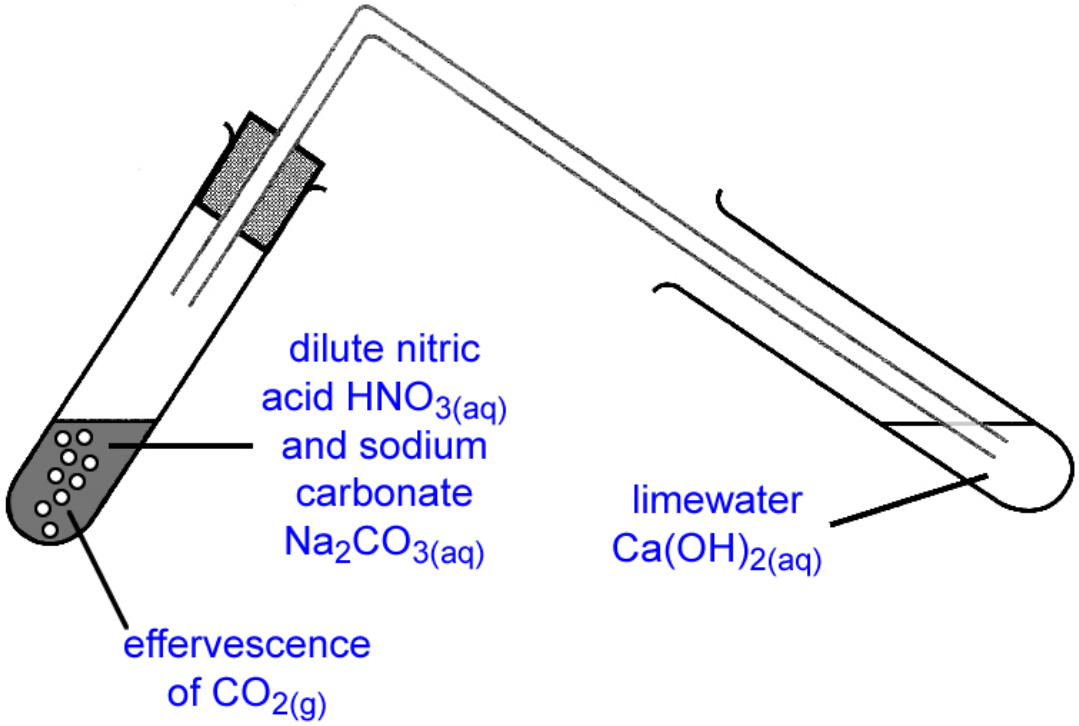
Qualitative Analysis

Test for Carbonate, $CO_3^{2-}(aq)$: Addition of $HNO_3(aq)$, Use of $Ca(OH)_2(aq)$



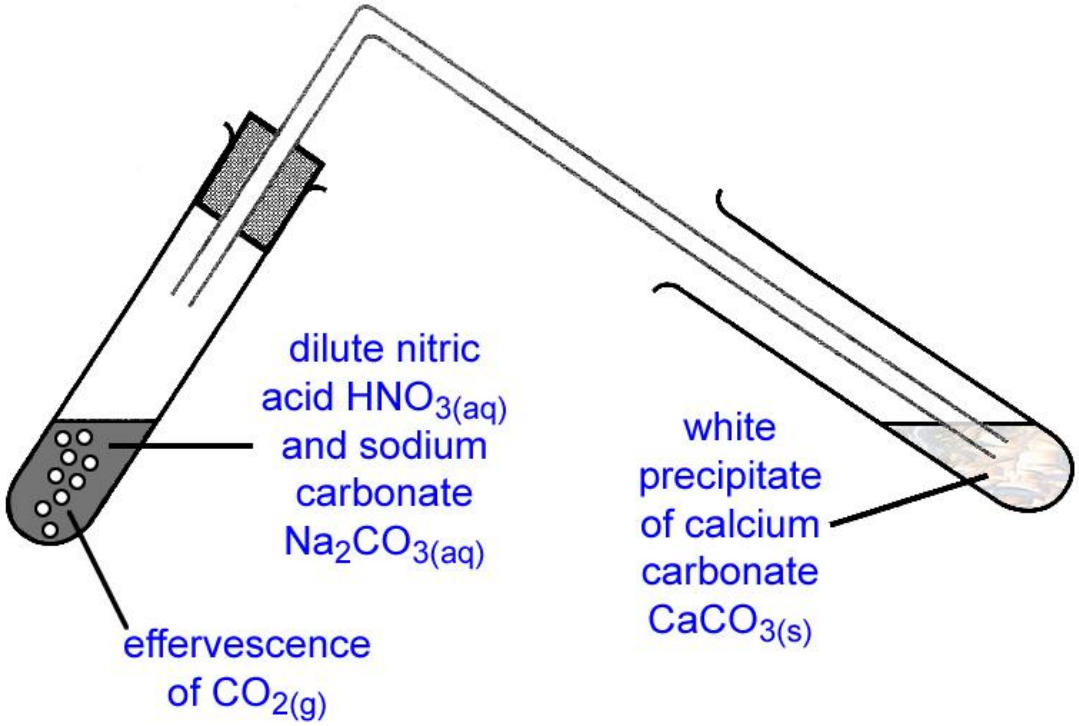
Sodium Carbonate + Nitric Acid → Sodium Nitrate + Water + Carbon Dioxide

$$Na_2CO_3(aq) + 2HNO_3(aq) \rightarrow 2NaNO_3(aq) + H_2O(l) + CO_2(g)$$

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

Qualitative Analysis

Test for Carbonate, $CO_3^{2-}(aq)$: Addition of $HNO_3(aq)$, Use of $Ca(OH)_2(aq)$



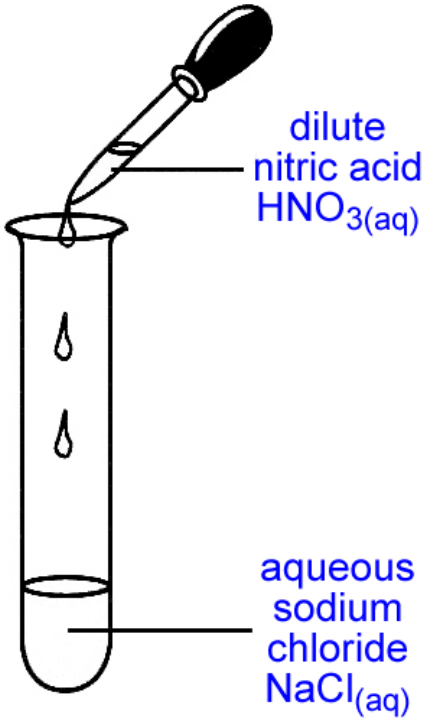
Calcium Hydroxide + Carbon Dioxide → Calcium Carbonate + Water

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

$$Ca^{2+}(aq) + 2OH^-(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$$

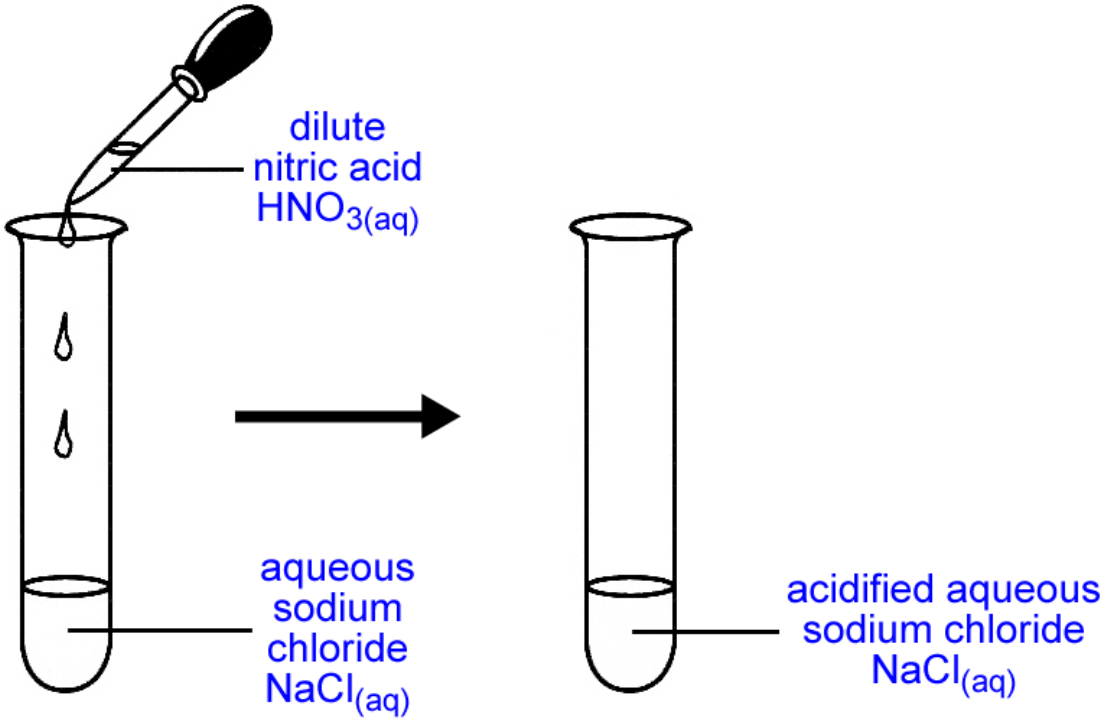
Qualitative Analysis

Test for Chloride, $Cl^-(aq)$: Addition of $HNO_3(aq)$ and $AgNO_3(aq)$



Qualitative Analysis

Test for Chloride, $Cl^-(aq)$: Addition of $HNO_3(aq)$ and $AgNO_3(aq)$



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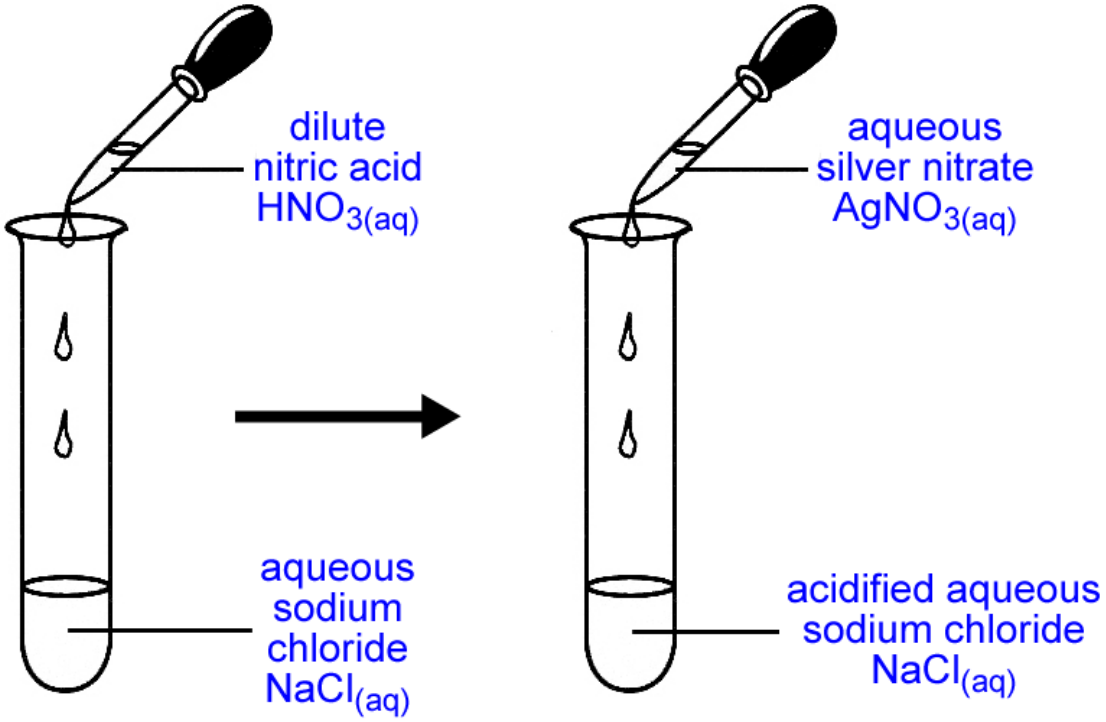

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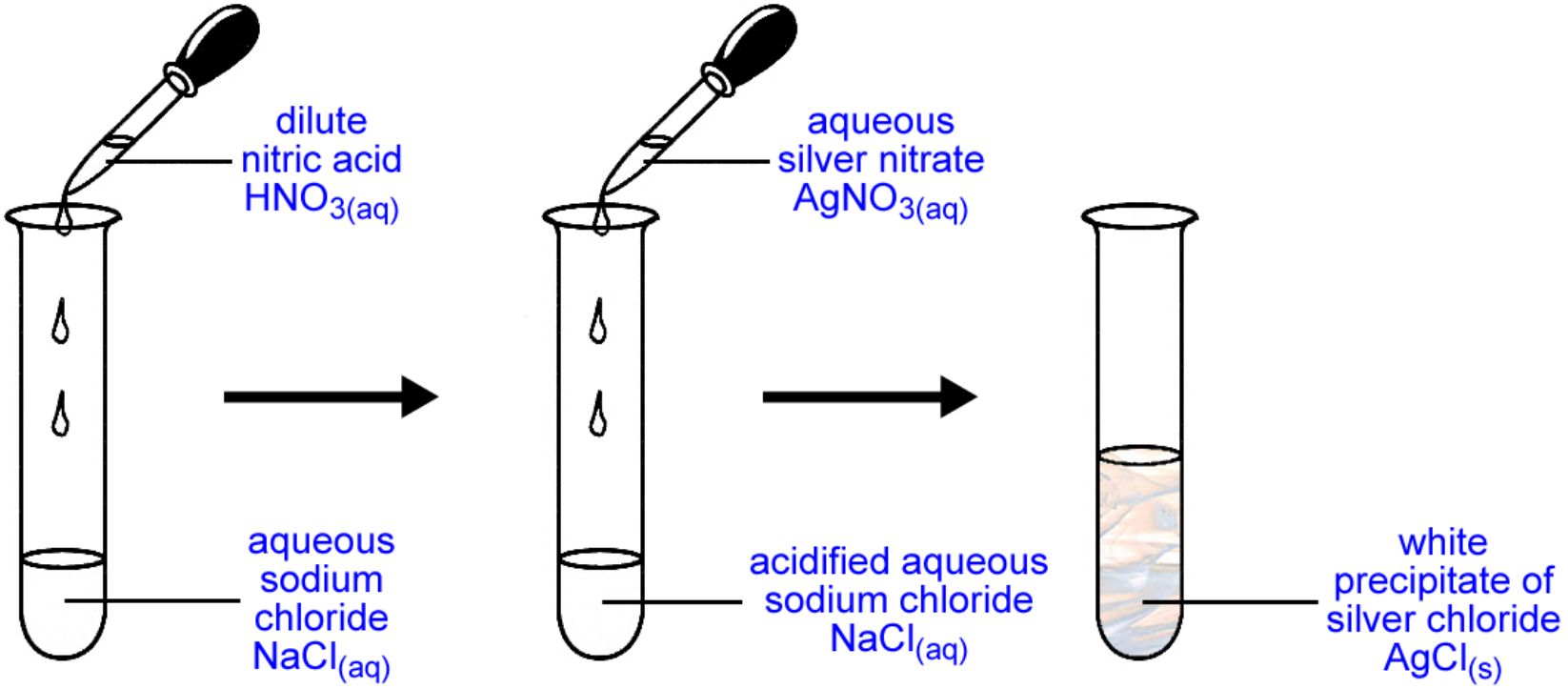
Test for Chloride, $Cl^-(aq)$: Addition of $HNO_3(aq)$ and $AgNO_3(aq)$



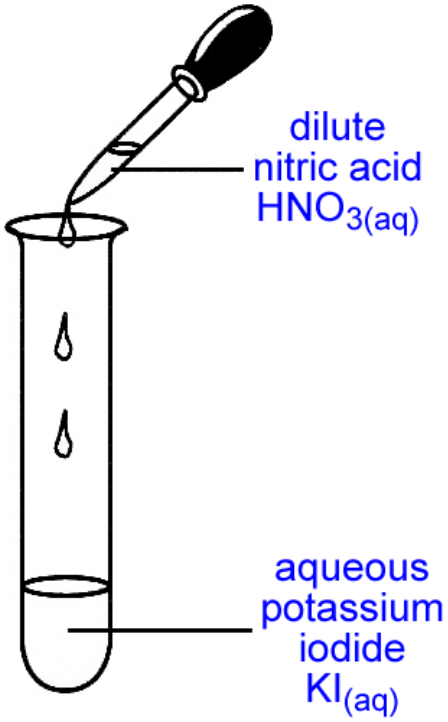
Silver Nitrate + Sodium Chloride → Silver Chloride + Sodium Nitrate

$$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$$

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

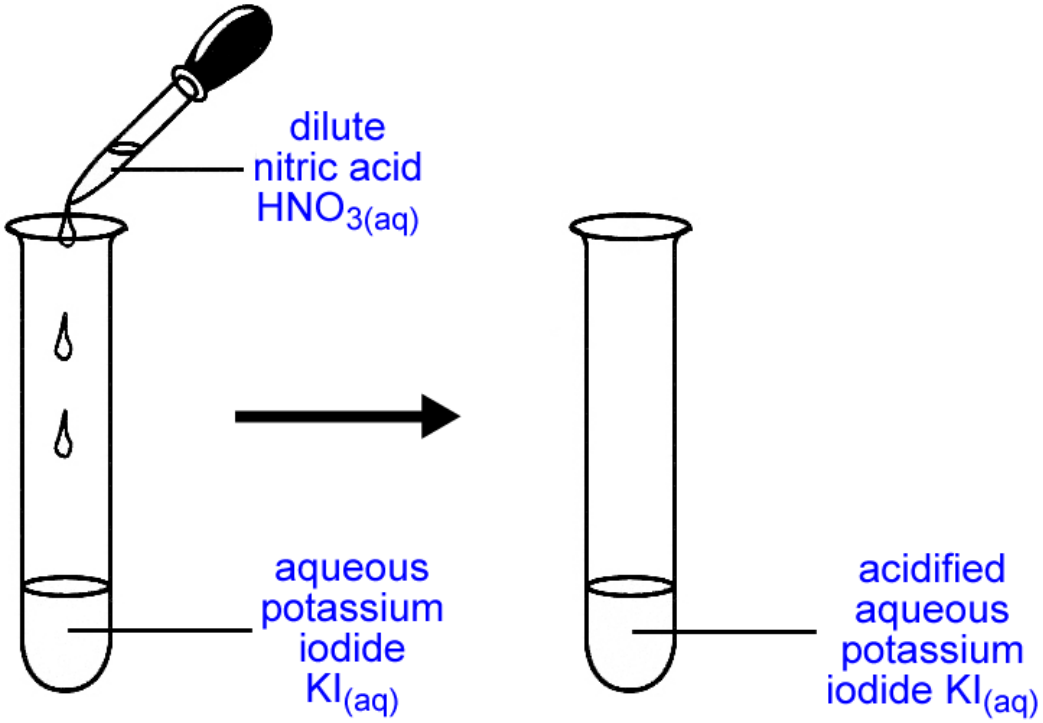
Qualitative Analysis

Test for Iodide, $I^-(aq)$: Addition of $HNO_3(aq)$ and $Pb(NO_3)_2(aq)$



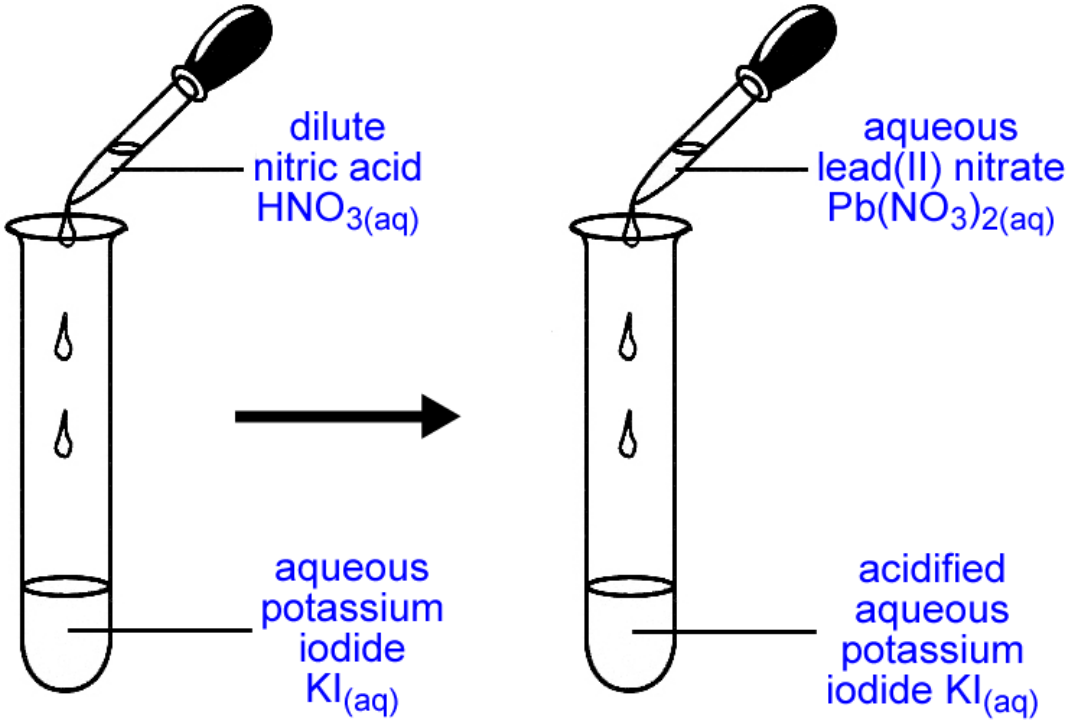
Qualitative Analysis

Test for Iodide, $I^-(aq)$: Addition of $HNO_3(aq)$ and $Pb(NO_3)_2(aq)$



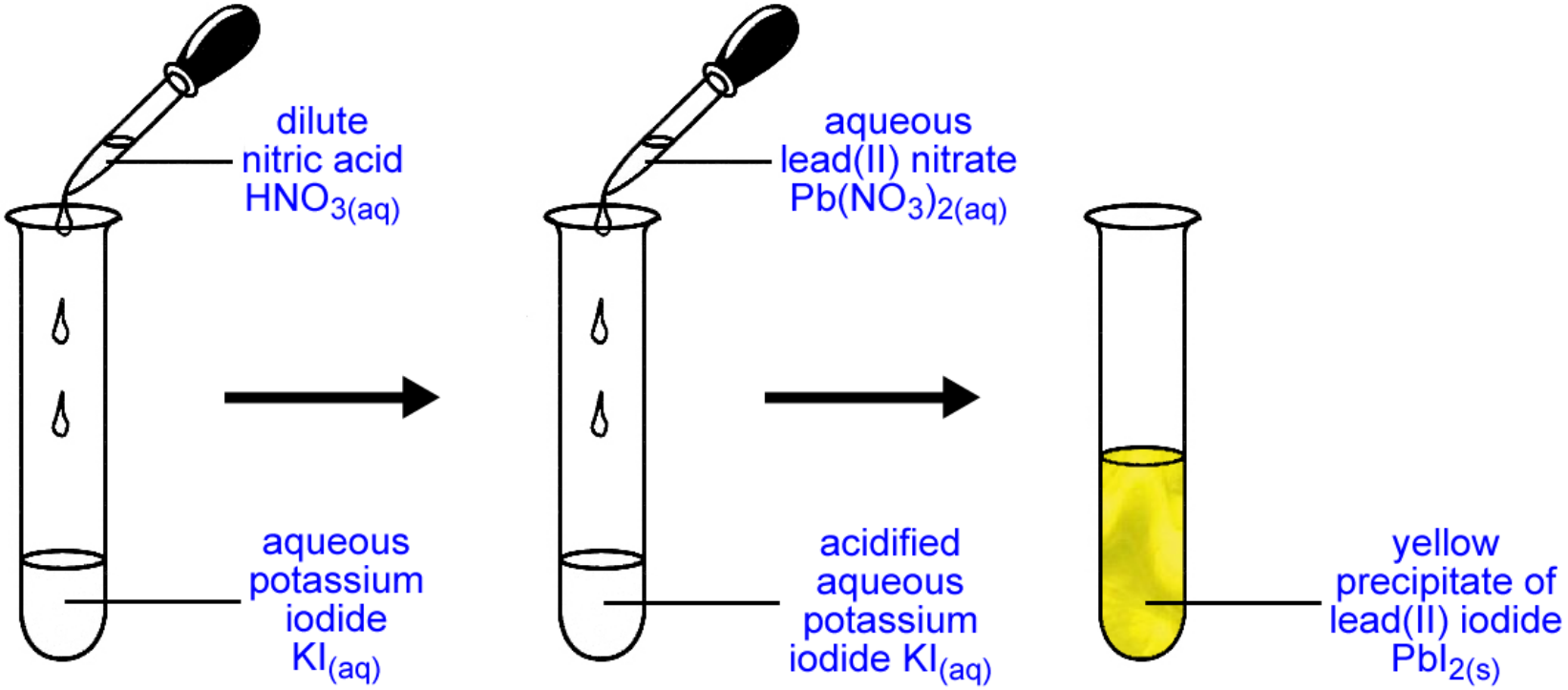
Qualitative Analysis

Test for Iodide, $I^-(aq)$: Addition of $HNO_3(aq)$ and $Pb(NO_3)_2(aq)$



Qualitative Analysis

Test for Iodide, $I^-(aq)$: Addition of $HNO_3(aq)$ and $Pb(NO_3)_2(aq)$



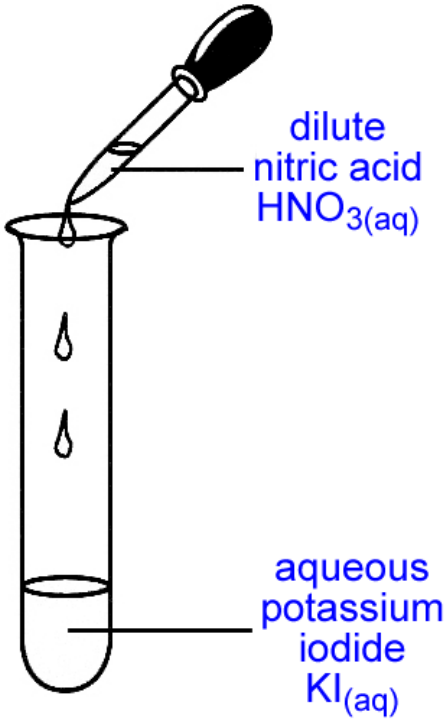
Lead(II) Nitrate + Potassium Iodide → Lead(II) Iodide + Potassium Nitrate

$$Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$$

$$Pb^{2+}(aq) + 2I^-(aq) \rightarrow PbI_2(s)$$

Qualitative Analysis

Test for Iodide, $I^-(aq)$: Addition of $HNO_3(aq)$ and $AgNO_3(aq)$ (2014)



Qualitative Analysis

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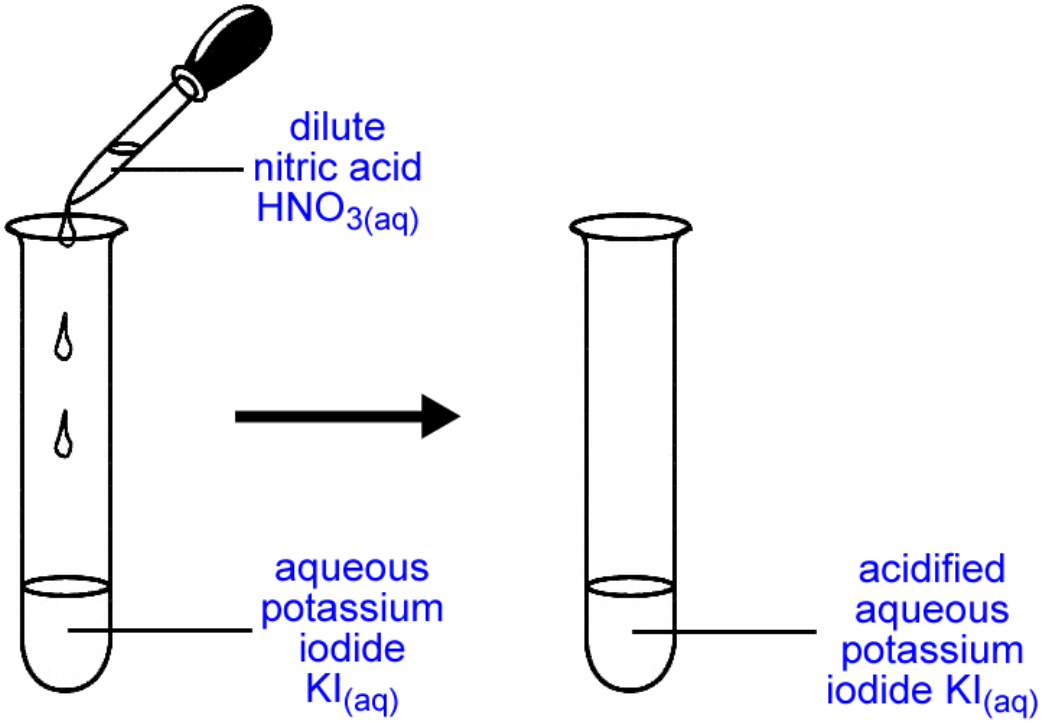

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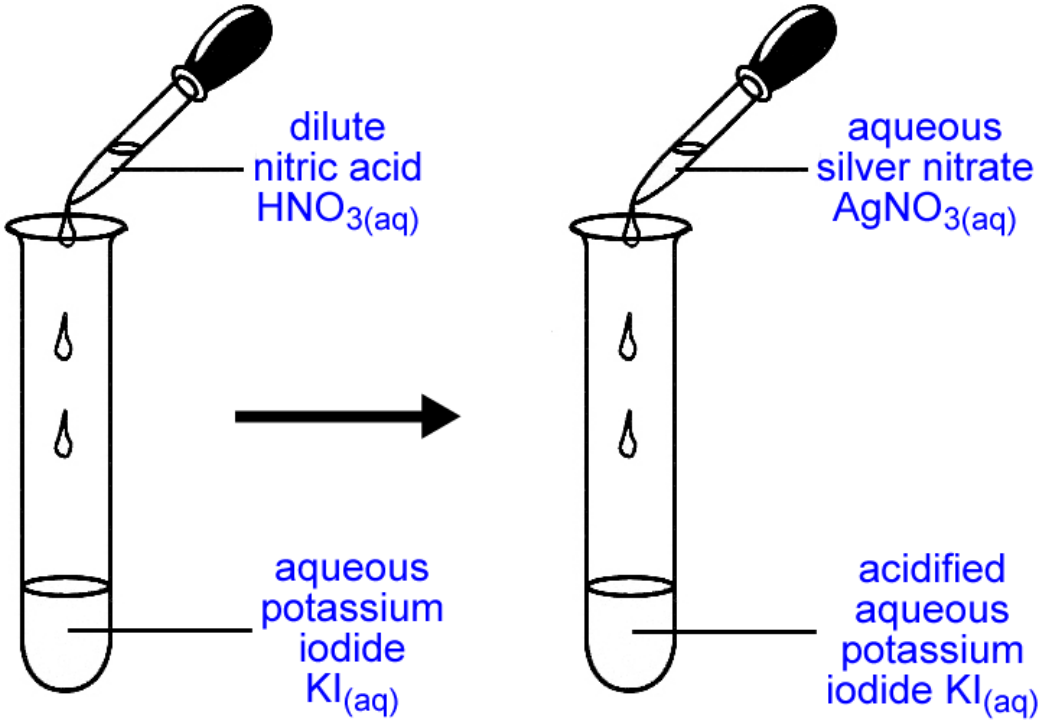

Qualitative Analysis

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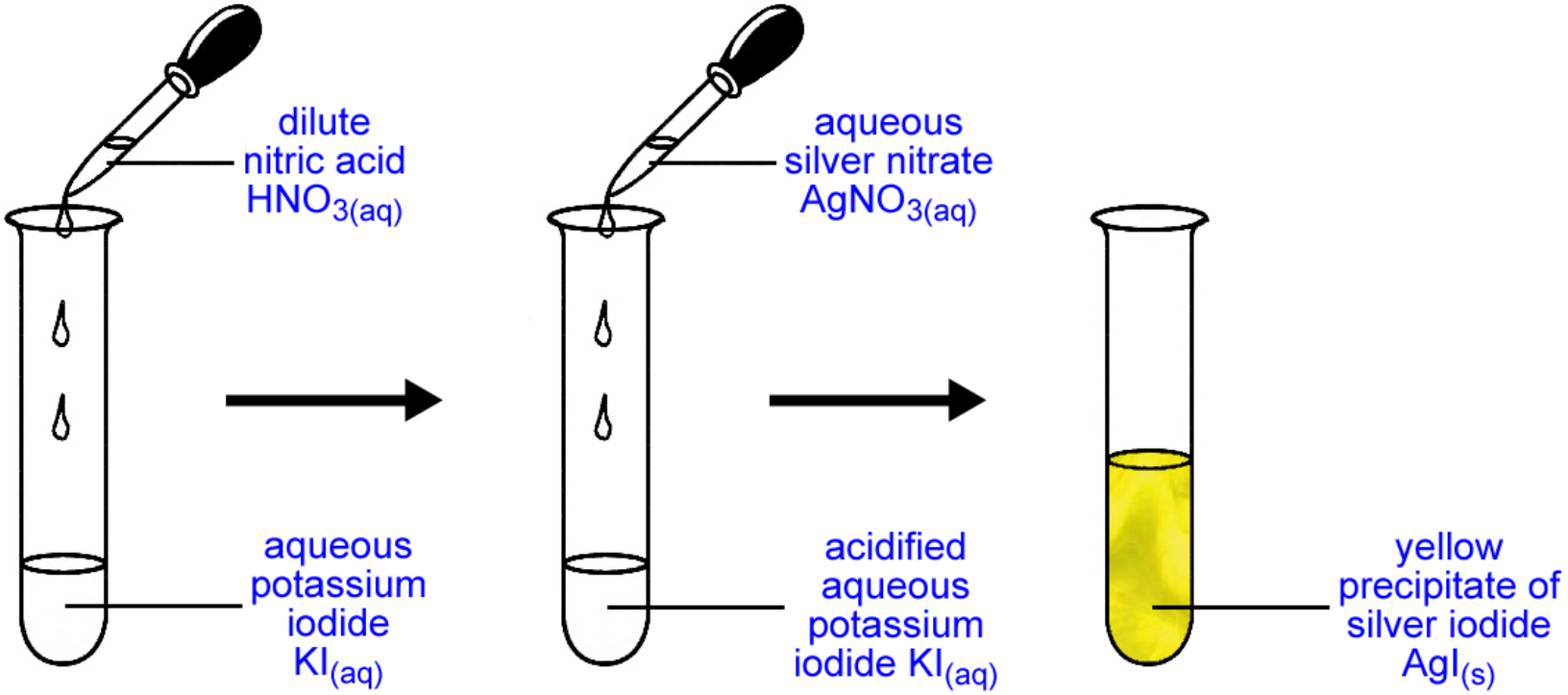


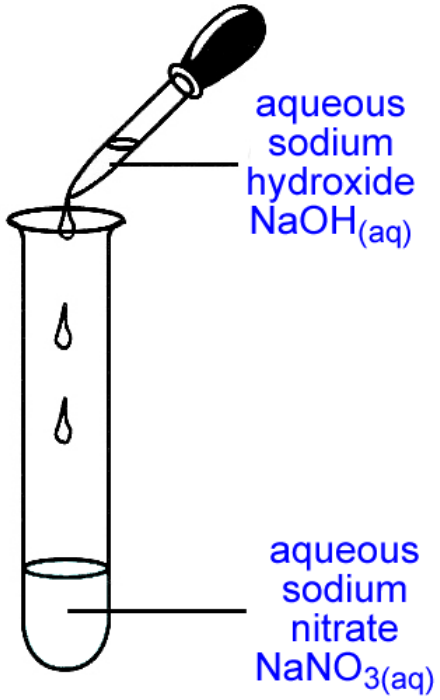
Silver Nitrate + Potassium Iodide → Silver Iodide + Potassium Nitrate

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

$$Ag^+(aq) + I^-(aq) \rightarrow AgI(s)$$

Qualitative Analysis

Test for Nitrate, $NO_3^-(aq)$: Addition of NaOH(aq) and A*l*(s) or Zn(s)



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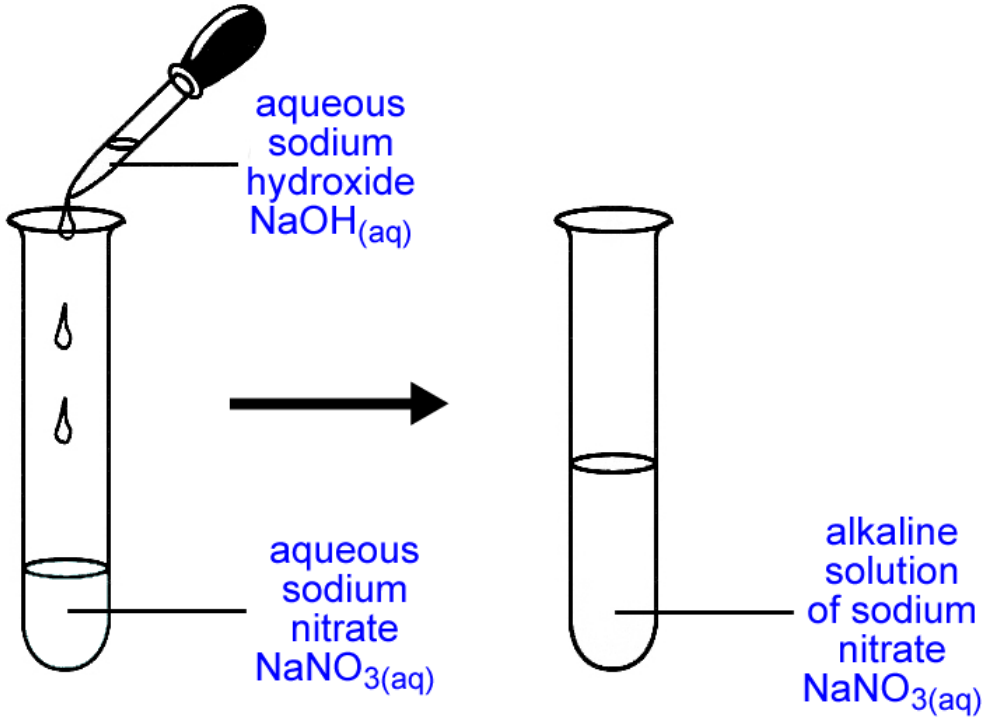
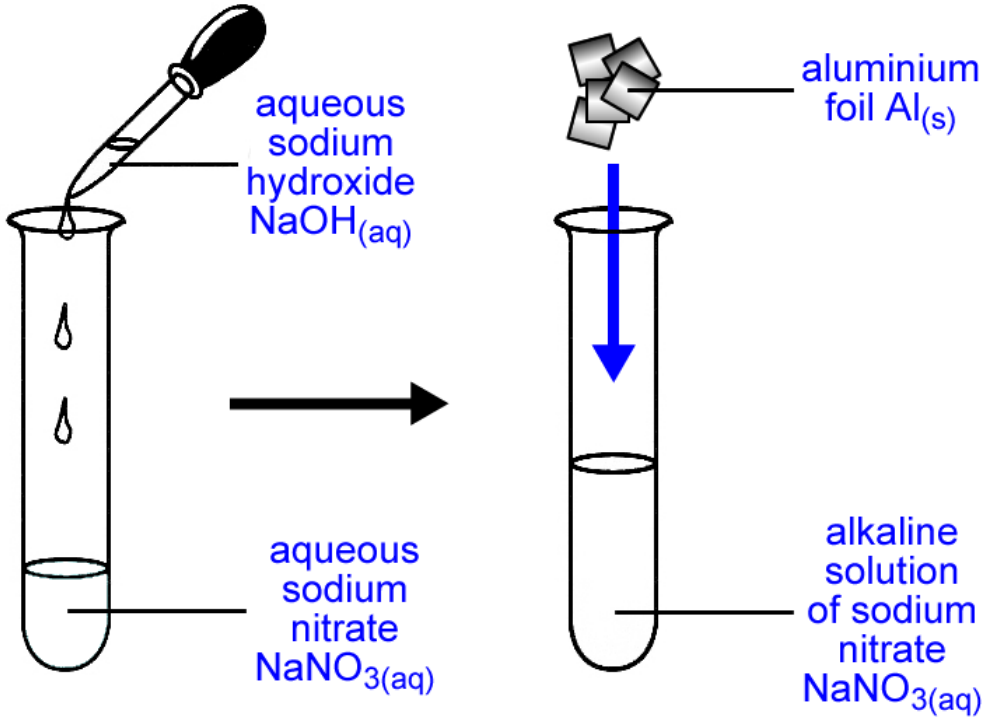


Qualitative Analysis

Test for Nitrate, $NO_3^-(aq)$: Addition of NaOH(aq) and Al(s) or Zn(s)



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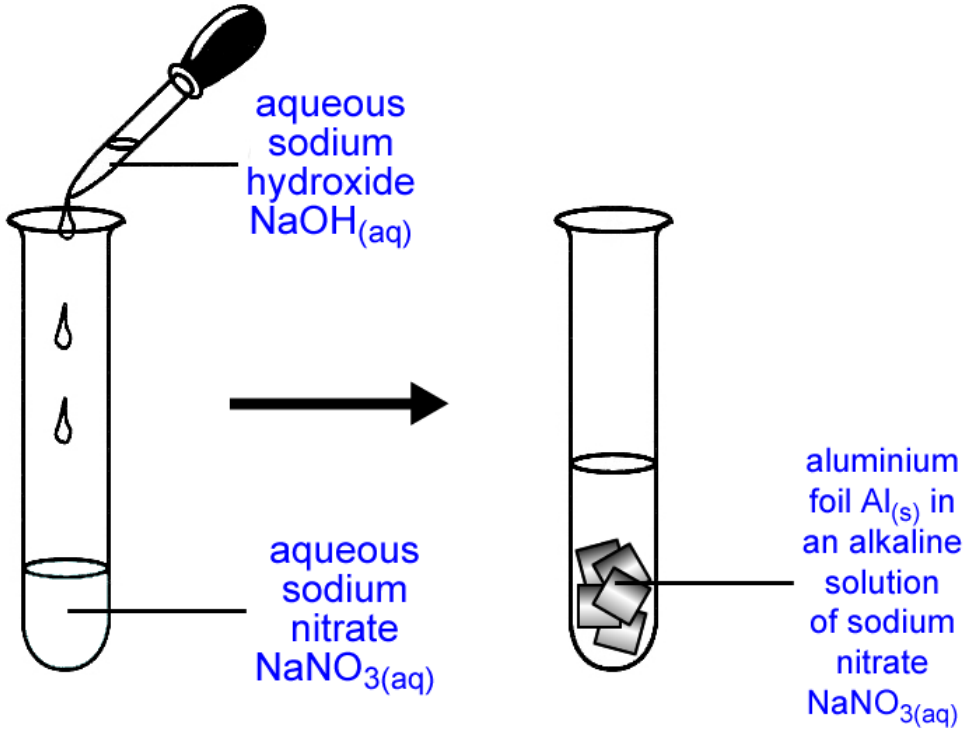

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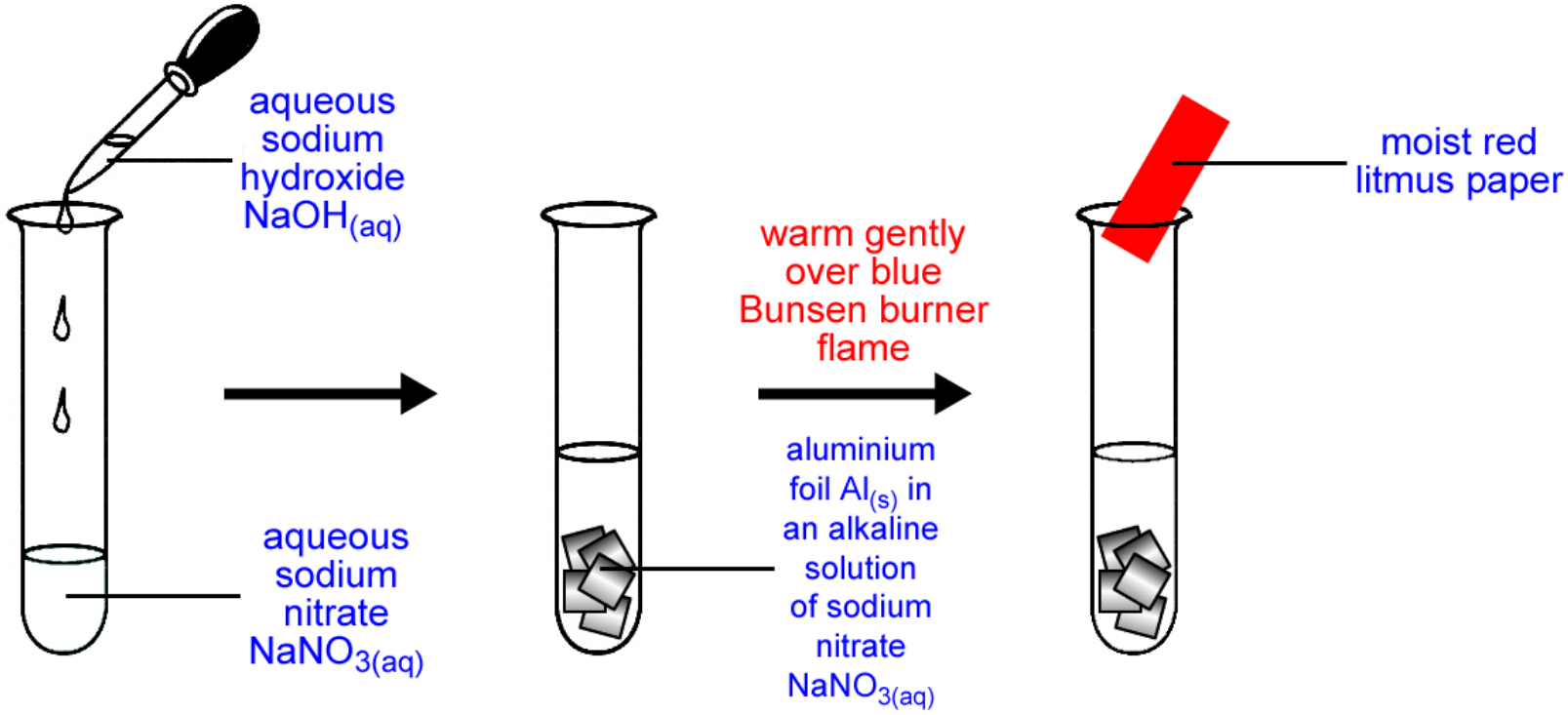

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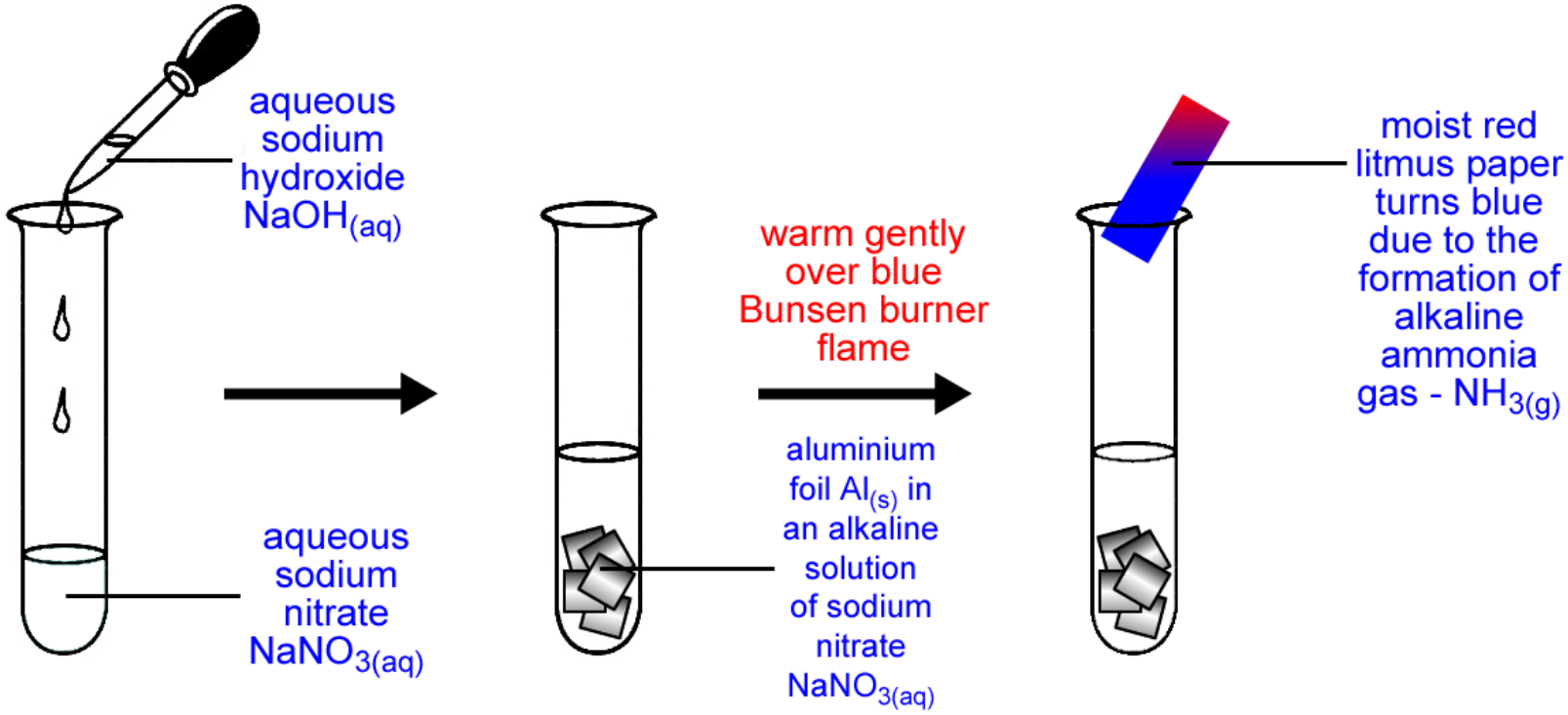
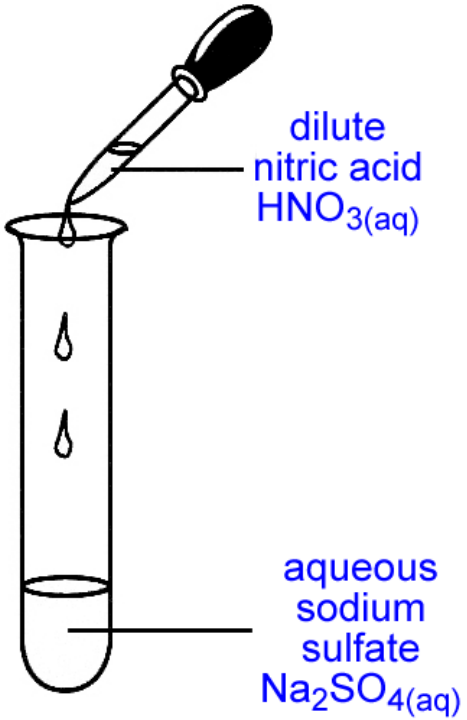


$$3NO_3^-(aq) + 8Al(s) + 5OH^-(aq) + 18H_2O(l) \rightarrow 3NH_3(g) + 8[Al(OH)_4]^-(aq)$$

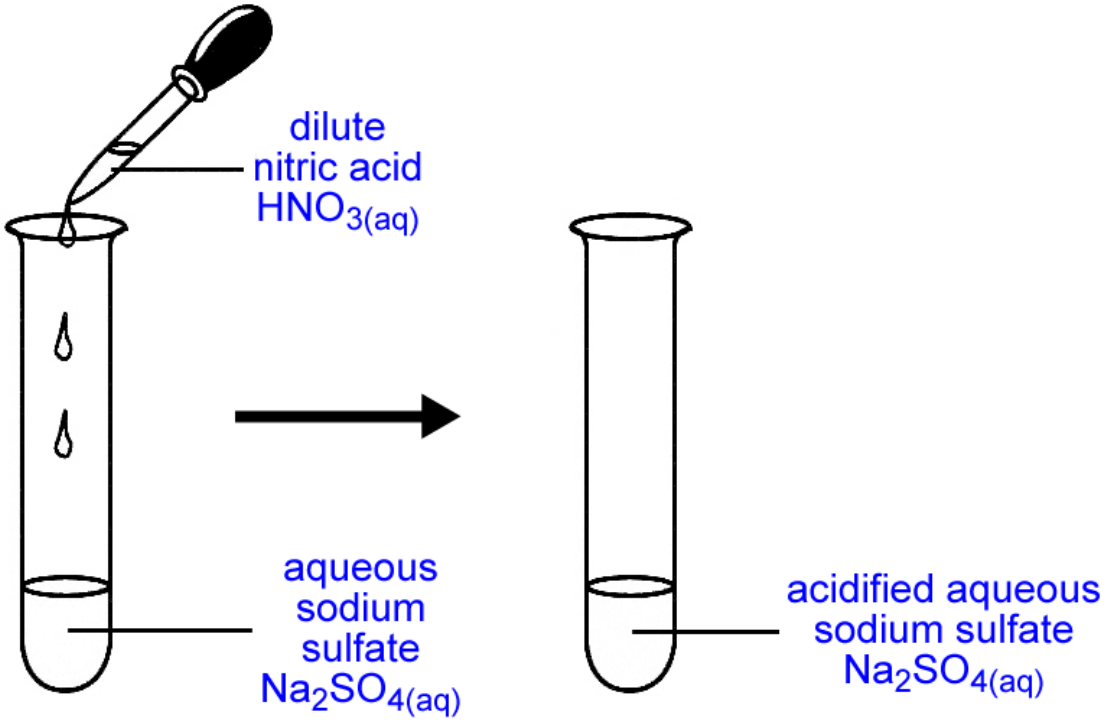
Qualitative Analysis

Test for Sulfate, $SO_4^{2-}(aq)$: Addition of $HNO_3(aq)$ and $BaCl_2(aq)$ or $Ba(NO_3)_2(aq)$



Qualitative Analysis

Test for Sulfate, $SO_4^{2-}(aq)$: Addition of $HNO_3(aq)$ and $BaCl_2(aq)$ or $Ba(NO_3)_2(aq)$



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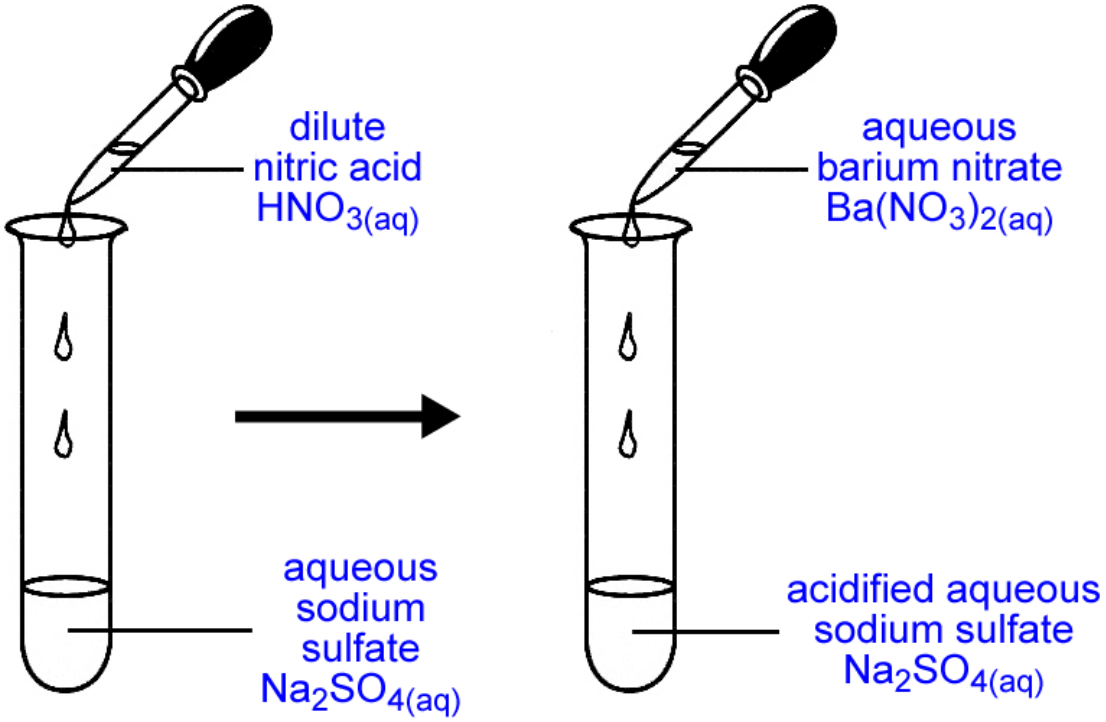

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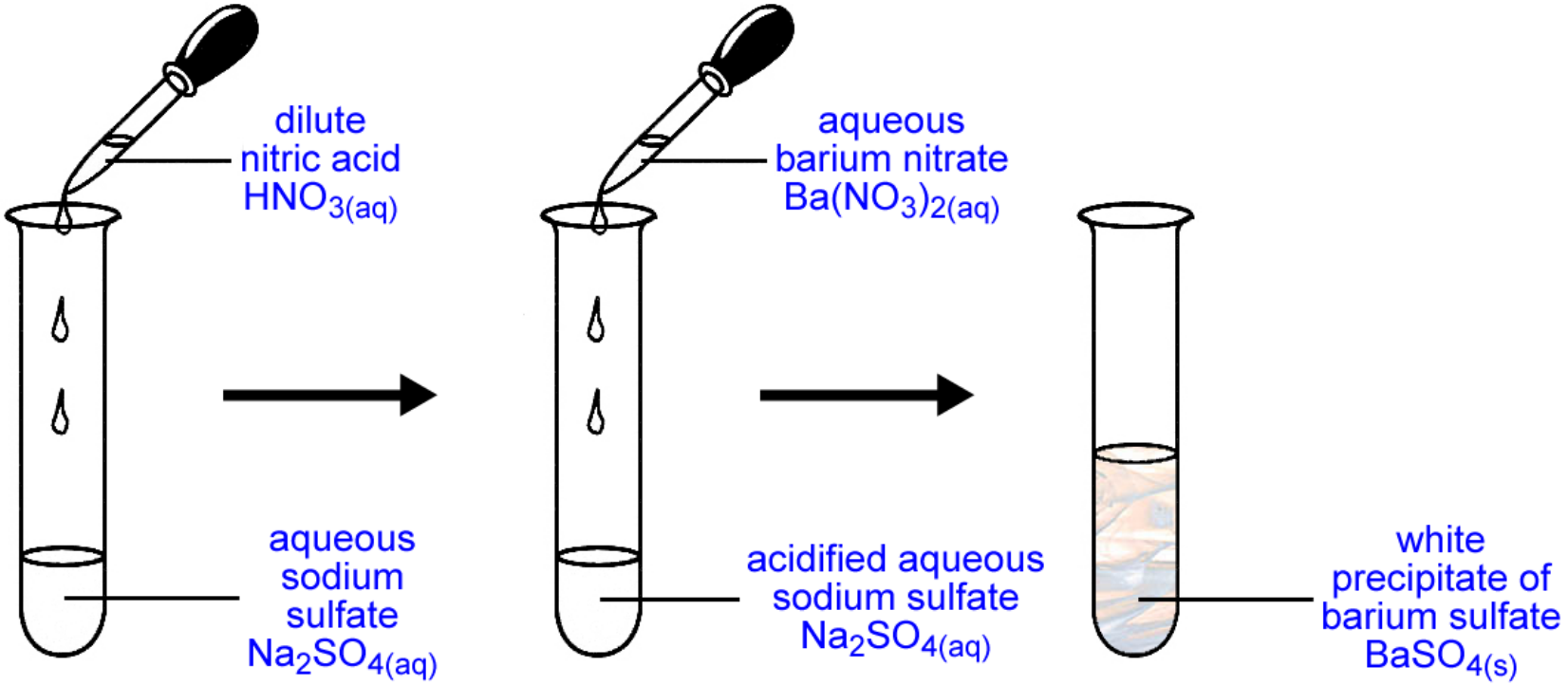

Barium Chloride + Sodium Sulfate → Barium Sulfate + Sodium Chloride

$$BaCl_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaCl(aq)$$

Barium Nitrate + Sodium Sulfate → Barium Sulfate + Sodium Nitrate

$$Ba(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaNO_3(aq)$$

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

Qualitative Analysis

Why must the solutions be *acidified*?

Qualitative Analysis

- Imagine that a solution of aqueous silver nitrate were added to an aqueous solution of sodium carbonate. What would be observed?

The precipitation of silver carbonate:

Silver Nitrate + Sodium Carbonate $\rightarrow$ Silver Carbonate + Sodium Nitrate

$2AgNO_3(aq) + Na_2CO_3(aq) \rightarrow Ag_2CO_3(s) + 2NaNO_3(aq)$

- What erroneous conclusion might you draw from these observations?

The precipitate of silver carbonate could be mistaken for the precipitate of silver chloride.

- How does the addition of nitric acid avoid this erroneous conclusion?

The silver carbonate would react with the nitric acid to form a solution of silver nitrate:

Silver Carbonate + Nitric Acid $\rightarrow$ Silver Nitrate + Water + Carbon Dioxide

$Ag_2CO_3(s) + 2HNO_3(aq) \rightarrow 2AgNO_3(aq) + H_2O(l) + CO_2(g)$

Therefore, a precipitate would only be observed if a chloride ion were present, and not a carbonate ion.

Qualitative Analysis

- Imagine that a solution of aqueous barium nitrate were added to an aqueous solution of sodium carbonate. What would be observed?

The precipitation of barium carbonate:

Barium Nitrate + Sodium Carbonate → Barium Carbonate + Sodium Nitrate

$Ba(NO_3)_2(aq) + Na_2CO_3(aq) \rightarrow BaCO_3(s) + 2NaNO_3(aq)$

- What erroneous conclusion might you draw from these observations?

The precipitate of barium carbonate could be mistaken for the precipitate of barium sulfate.

- How does the addition of nitric acid avoid this erroneous conclusion?

The barium carbonate would react with the nitric acid to form a solution of barium nitrate:

Barium Carbonate + Nitric Acid → Barium Nitrate + Water + Carbon Dioxide

$BaCO_3(s) + 2HNO_3(aq) \rightarrow Ba(NO_3)_2(aq) + H_2O(l) + CO_2(g)$

Therefore, a precipitate would only be observed if a sulfate ion were present, and not a carbonate ion.

Qualitative Analysis

Why is *nitric acid* used to acidify the solution?

Qualitative Analysis

- When nitric acid reacts with another chemical, the resulting salt will be a *nitrate*, and *all nitrates are soluble in water*. Consequently, the formation of misleading, erroneous precipitates will be avoided.

- Alternatively, imagine using hydrochloric acid to acidify a reagent before adding silver nitrate. The precipitate of silver chloride is bound to appear, regardless of whether or not the unknown chemical that is being tested contains chloride ions:

$$AgNO_3(aq) + HCl(aq) \rightarrow AgCl(s) + HNO_3(aq)$$

- Alternatively, imagine using sulfuric acid to acidify a reagent before adding barium nitrate. The precipitate of barium sulfate is bound to appear, regardless of whether or not the unknown chemical that is being tested contains sulfate ions:

$$Ba(NO_3)_2(aq) + H_2SO_4(aq) \rightarrow BaSO_4(s) + 2HNO_3(aq)$$

Qualitative Analysis

Can I please have a summary?

Qualitative Analysis

Summary – Test for Anions

Anion	Test	Test Result
Carbonate – CO_3^{2-} (solid or aqueous)	Add dilute acid.	Effervescence observed, carbon dioxide produced (produces white ppt. with limewater).
Chloride – Cl^- (in aqueous solution)	Acidify with dilute nitric acid, then add aqueous silver nitrate.	White ppt.
Iodide – I^- (in aqueous solution)	Acidify with dilute nitric acid, then add either aqueous lead(II) nitrate or aqueous silver nitrate.	Yellow ppt.
Nitrate – NO_3^- (in aqueous solution)	Add aqueous sodium hydroxide, then aluminium foil, warm carefully.	Ammonia produced (turns moist red litmus paper blue).
Sulfate – SO_4^{2-} (in aqueous solution)	Acidify with dilute nitric acid, then add either aqueous barium chloride or aqueous barium nitrate.	White ppt.

Qualitative Analysis

Qualitative Analysis

Which chemical reactions produce gaseous products?

Qualitative Analysis

- Ammonia – NH_3

$$\text{ammonium salt} + \text{base} \xrightarrow{\text{heat}} \text{salt} + \text{water} + \text{ammonia}$$

$$NH_4Cl(aq) + NaOH(aq) \xrightarrow{\text{heat}} NaCl(aq) + H_2O(l) + NH_3(g)$$

- If an unknown chemical reacts with a base, and ammonia gas is produced, then the unknown chemical maybe an ammonium salt.

$$\text{nitrate} + \text{base} + \text{aluminium (or zinc)} + \text{water}$$
$$\downarrow \text{heat}$$
$$\text{sodium tetrahydroxyaluminate} + \text{ammonia}$$

$$3NaNO_3(aq) + 5NaOH(aq) + 8Al(s) + 18H_2O(l)$$
$$\downarrow \text{heat}$$
$$8Na[Al(OH)_4](aq) + 3NH_3(g)$$

- If an unknown chemical reacts with a base in the presence of aluminium or zinc powder, and ammonia gas is produced, then the unknown chemical maybe a nitrate.

Qualitative Analysis

- Carbon dioxide – CO_2

acid + carbonate → salt + water + carbon dioxide

$$2HNO_3(aq) + Na_2CO_3 \rightarrow 2NaNO_3(aq) + H_2O(l) + CO_2(g)$$

- If an acid is added to an unknown chemical, and carbon dioxide gas is produced, then the unknown chemical maybe a carbonate.

thermal decomposition of a carbonate

$$CaCO_3(s) \xrightarrow{\text{heat}} CaO(s) + CO_2(g)$$

- If an unknown chemical decomposes on heating, and carbon dioxide gas is produced, then the unknown chemical maybe a carbonate.

Qualitative Analysis

- Chlorine – Cl_2

manganese(IV) oxide + hydrochloric acid

↓

manganese(II) chloride + water + chlorine

$$MnO_2(s) + 4HCl(aq) \rightarrow MnCl_2(aq) + 2H_2O(l) + Cl_2(g)$$

sodium hypochlorite + hydrochloric acid

↓

sodium chloride + water + chlorine

$$NaClO(s) + 2HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + Cl_2(g)$$

- Chlorine gas is produced when chloride ions are oxidised. In these reactions, oxidation is defined as the loss of electrons:

$$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$$

Qualitative Analysis

- Hydrogen – H_2

acid + reactive metal $\rightarrow$ salt + hydrogen

$$H_2SO_4(aq) + Zn \rightarrow ZnSO_4(aq) + H_2(g)$$

- If an acid is added to an unknown chemical, and hydrogen gas is produced, then the unknown chemical maybe a reactive metal.

More Reactive $\rightarrow$

Potassium
Sodium
Calcium
Magnesium
Aluminium
Zinc
Iron
Lead
$\rightarrow$ Hydrogen $\leftarrow$
Copper
Silver

Less Reactive $\rightarrow$

The Reactivity Series of Metals

Metals that are *above hydrogen* in the reactivity series *react* with acids to produce a salt and hydrogen gas. The more reactive the metal, the faster the reaction. Metals *below hydrogen do not react* with acids.

Qualitative Analysis

- Oxygen – O_2

catalytic decomposition of hydrogen peroxide into water and oxygen

$$2H_2O_2(aq) \xrightarrow{\text{catalyst}} 2H_2O(l) + O_2(g)$$

thermal decomposition of a nitrate

$$2Pb(NO_3)_2(s) \xrightarrow{\text{heat}} 2PbO(s) + 4NO_2(g) + O_2(g)$$

- If an unknown chemical decomposes on heating, and oxygen gas is produced, then the unknown chemical maybe a nitrate. **Note**: Some, but not all, nitrates decompose on heating to produce oxygen gas and nitrogen dioxide gas – which is reddish-brown in colour.

Qualitative Analysis

- Sulfur dioxide – SO_2

acid + sulphite $\rightarrow$ salt + water + sulfur dioxide

$$2HCl(aq) + K_2SO_3(aq) \xrightarrow{\text{heat}} 2KCl(aq) + H_2O(l) + SO_2(g)$$

- If an acid is added to an unknown chemical and heated, and sulfur dioxide gas is produced, then the unknown chemical maybe a sulphite.

Qualitative Analysis

Qualitative Analysis

Describe tests to identify the following gases:

- Ammonia – $NH_3(g)$ (using damp red litmus paper).
- Carbon dioxide – $CO_2(g)$ (using limewater).
- Chlorine – $Cl_2(g)$ (using damp litmus paper).
- Hydrogen – $H_2(g)$ (using a burning splint).
- Oxygen – $O_2(g)$ (using a glowing splint).
- Sulfur dioxide – $SO_2(g)$ (using acidified $KMnO_4(aq)$).
- Water vapour – $H_2O(g)$ (using anhydrous $CuSO_4(s)$ or $CoCl_2(s)$).

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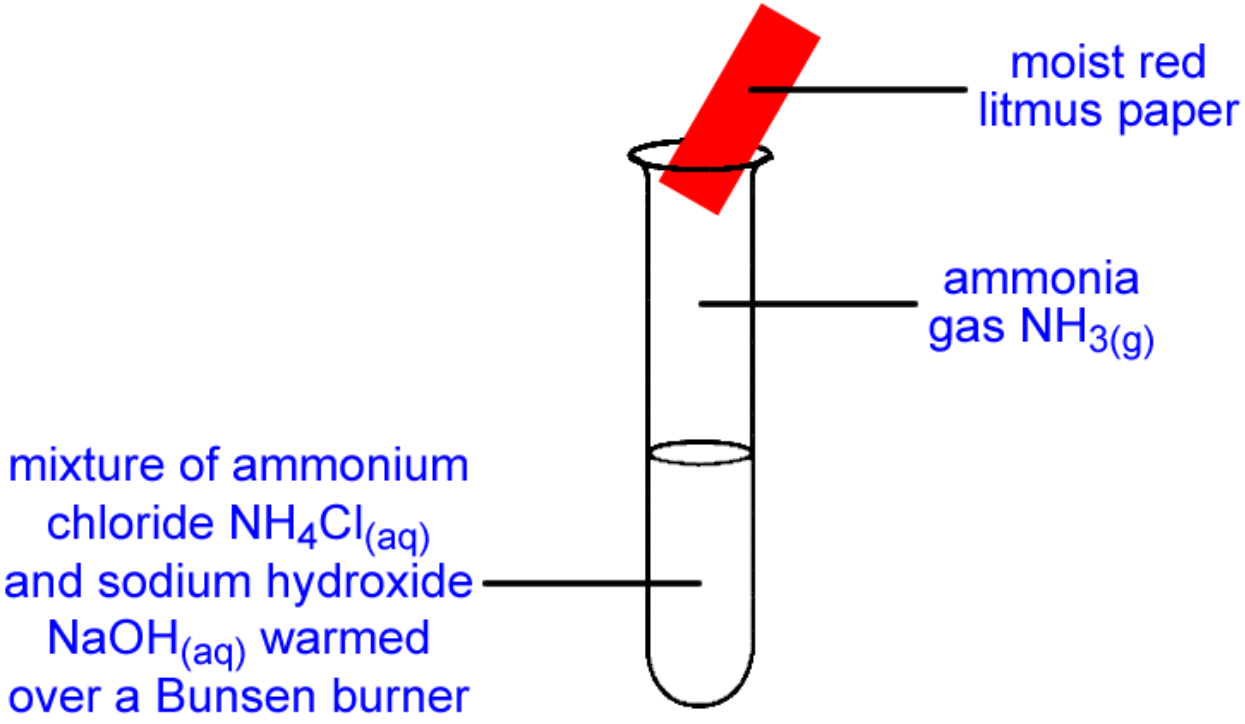
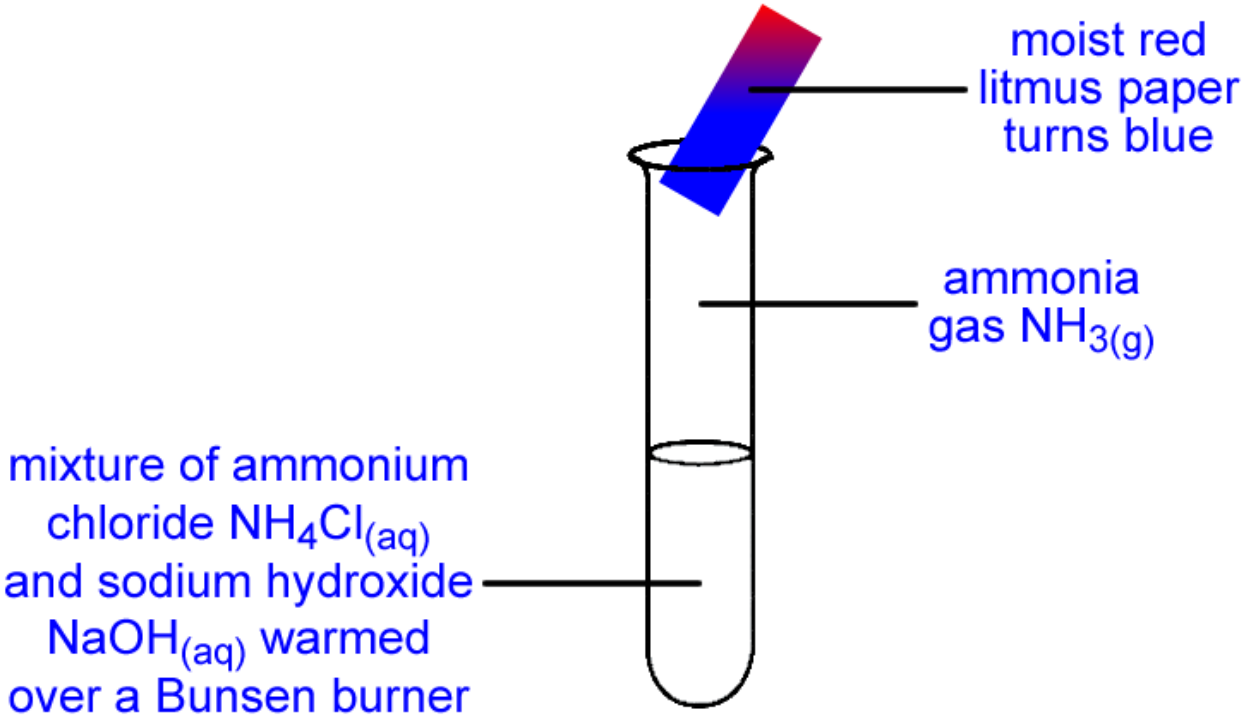
Qualitative Analysis

Test for $NH_3(g)$



Qualitative Analysis

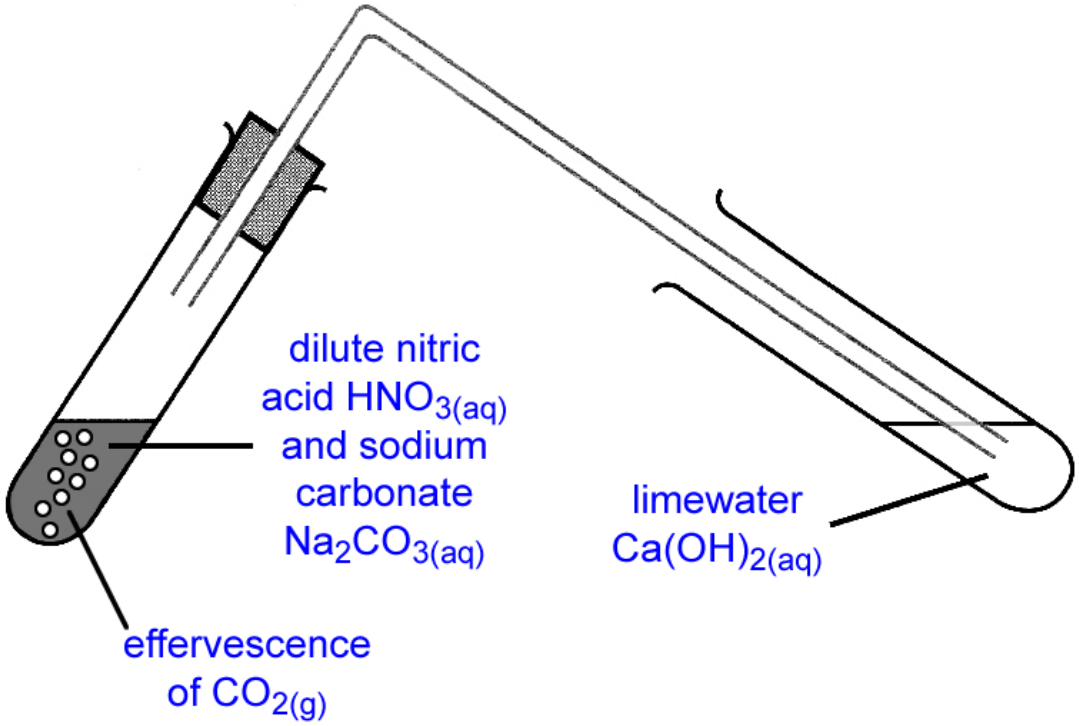
Test for $NH_3(g)$



Ammonia is an alkaline gas which will turn moist **red** litmus paper **blue**.

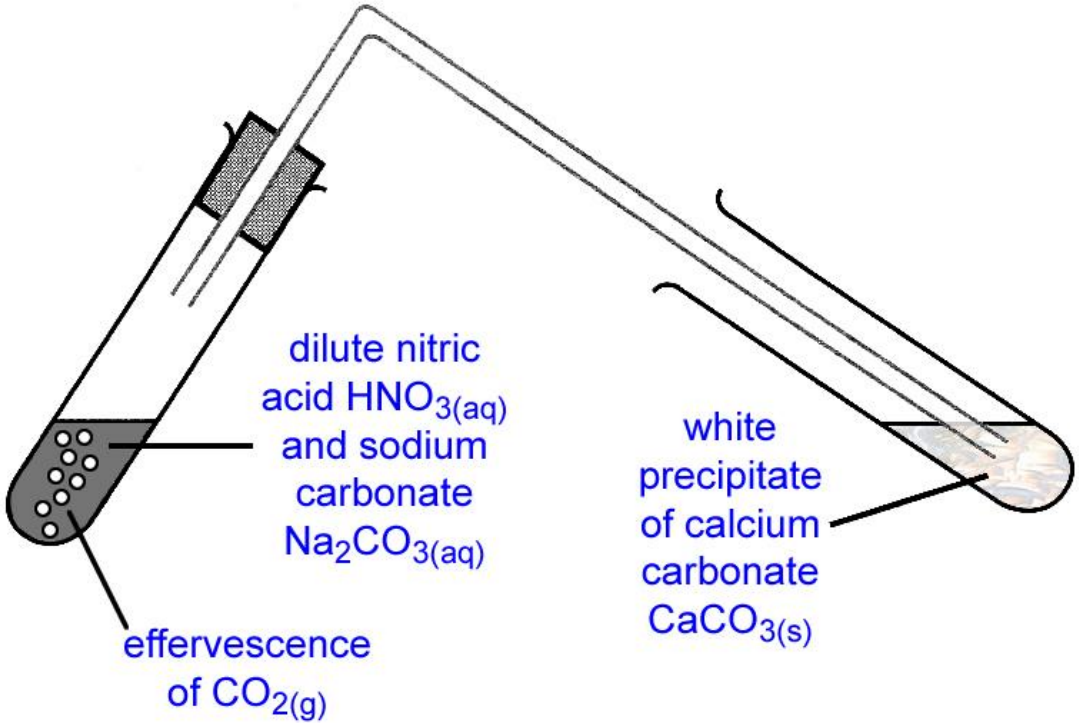
Qualitative Analysis

Test for $CO_2(g)$



Qualitative Analysis

Test for $CO_2(g)$



Calcium Hydroxide + Carbon Dioxide → Calcium Carbonate + Water

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

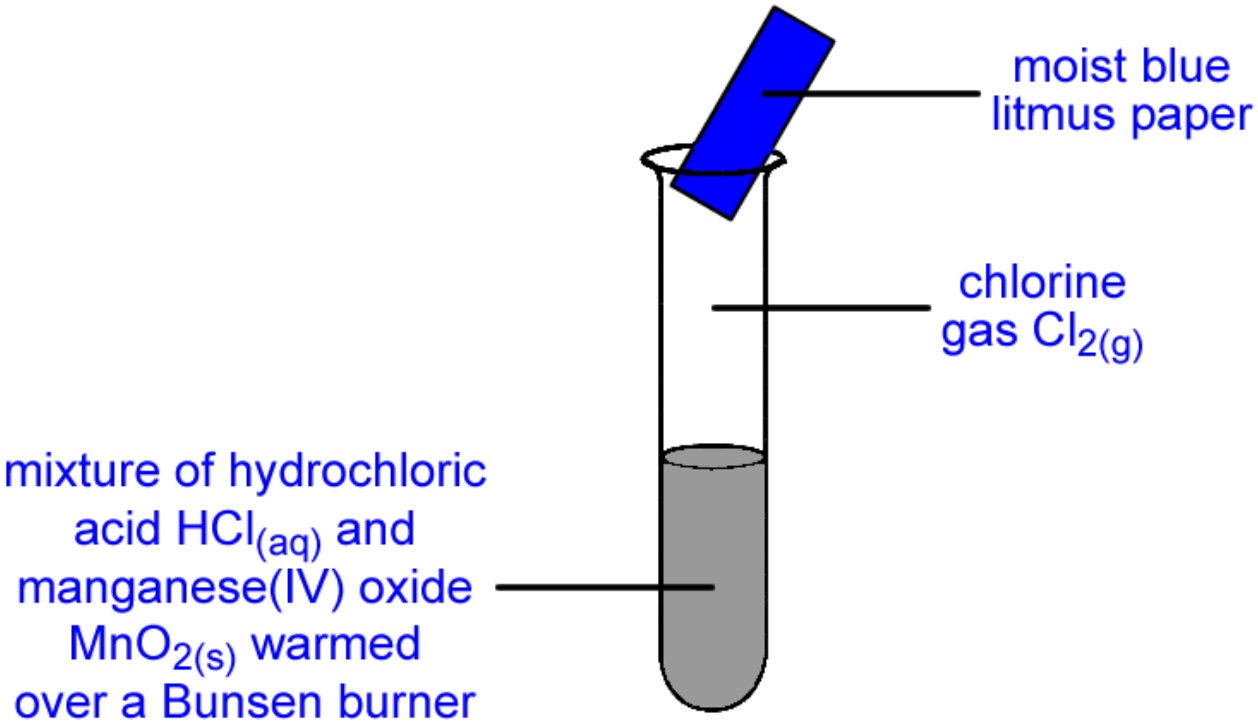
$$Ca^{2+}(aq) + 2OH^-(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$$

Qualitative Analysis

Test for $CO_2(g)$

Qualitative Analysis

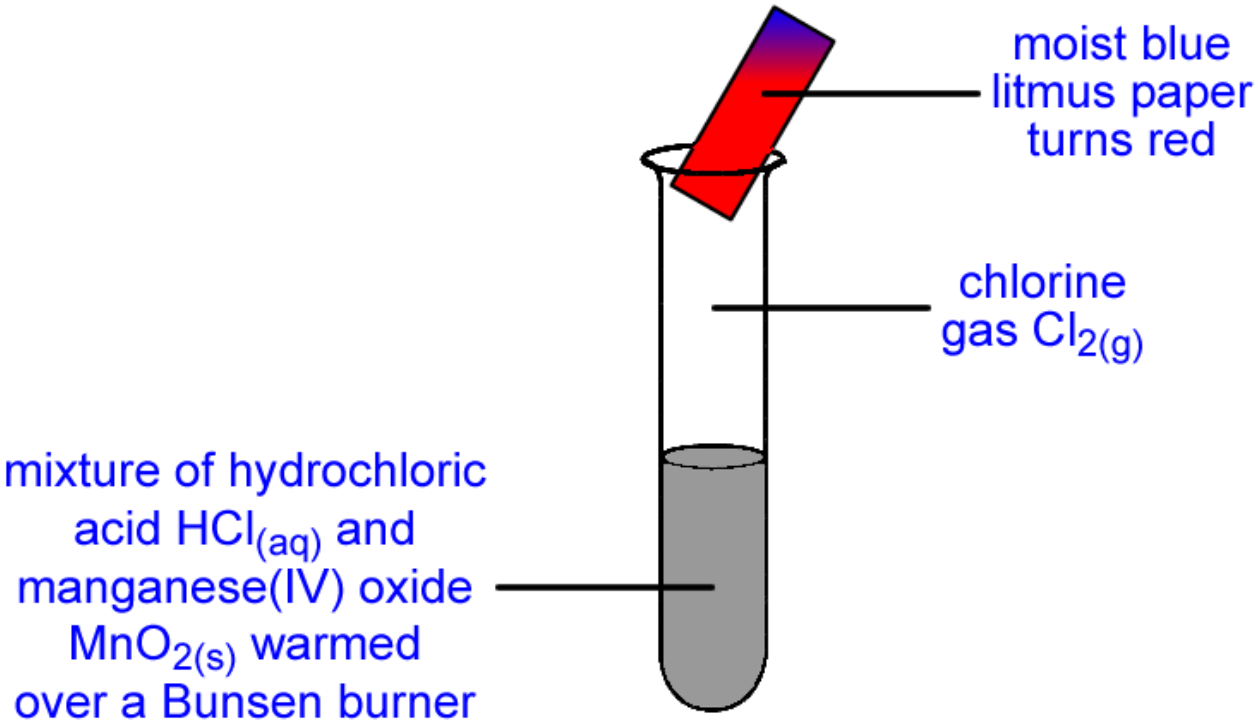
Test for $Cl_2(g)$



Chlorine is a **greenish-yellow** gas.

Qualitative Analysis

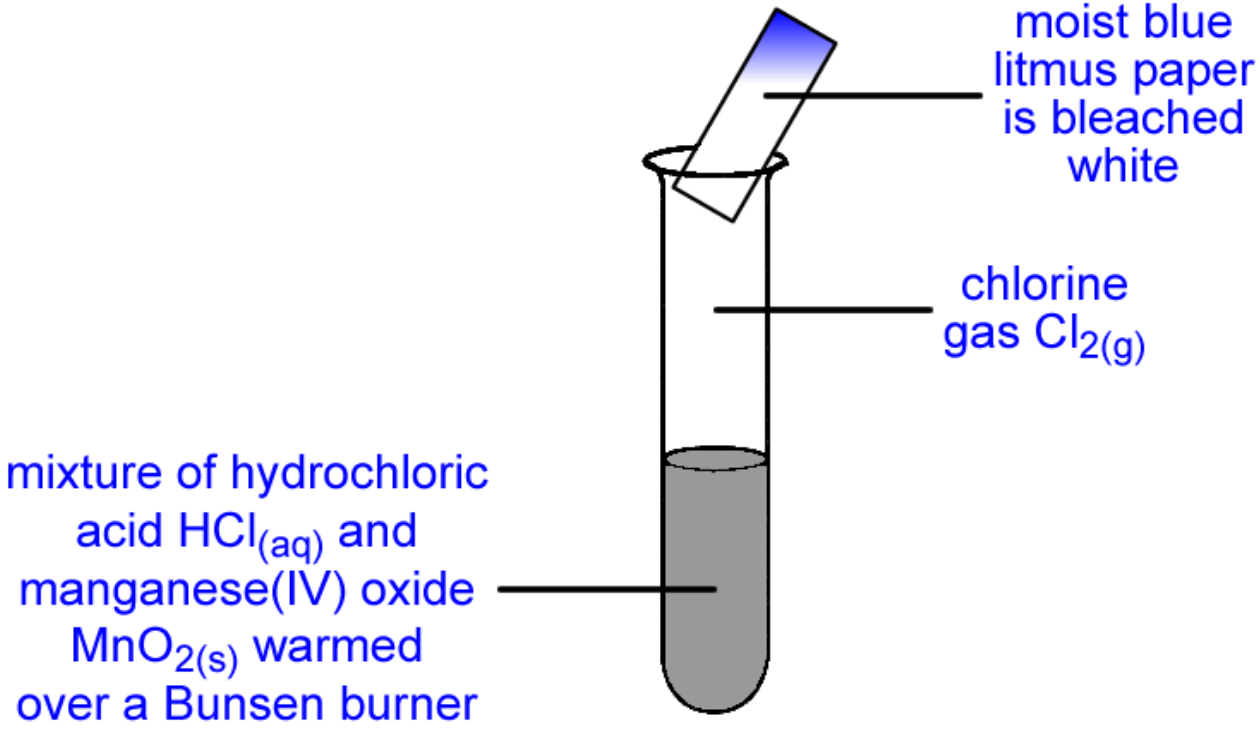
Test for $Cl_2(g)$



Chlorine is an acidic gas which will turn moist **blue** litmus paper **red**…

Qualitative Analysis

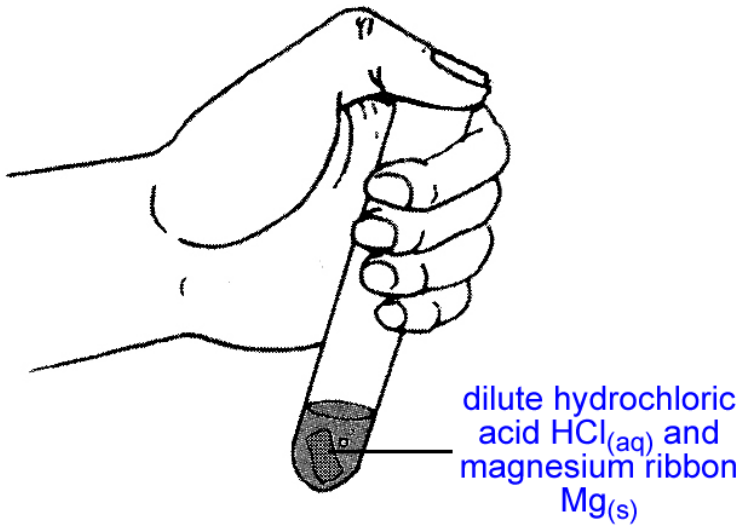
Test for $Cl_2(g)$



…before finally bleaching it **white**.

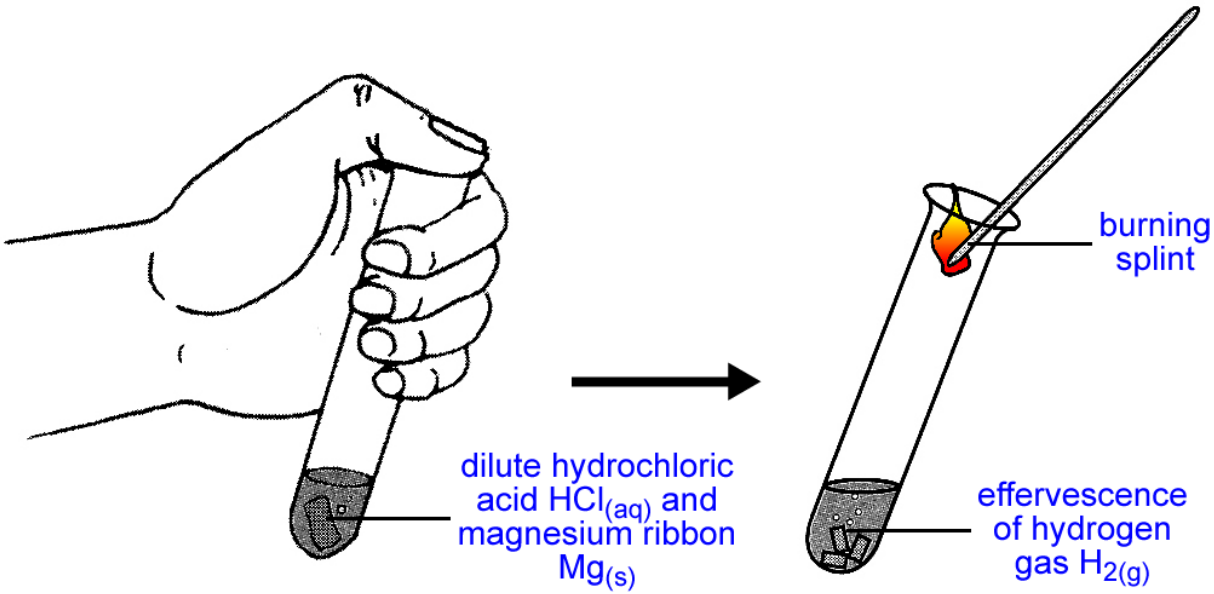
Qualitative Analysis

Test for $H_2(g)$



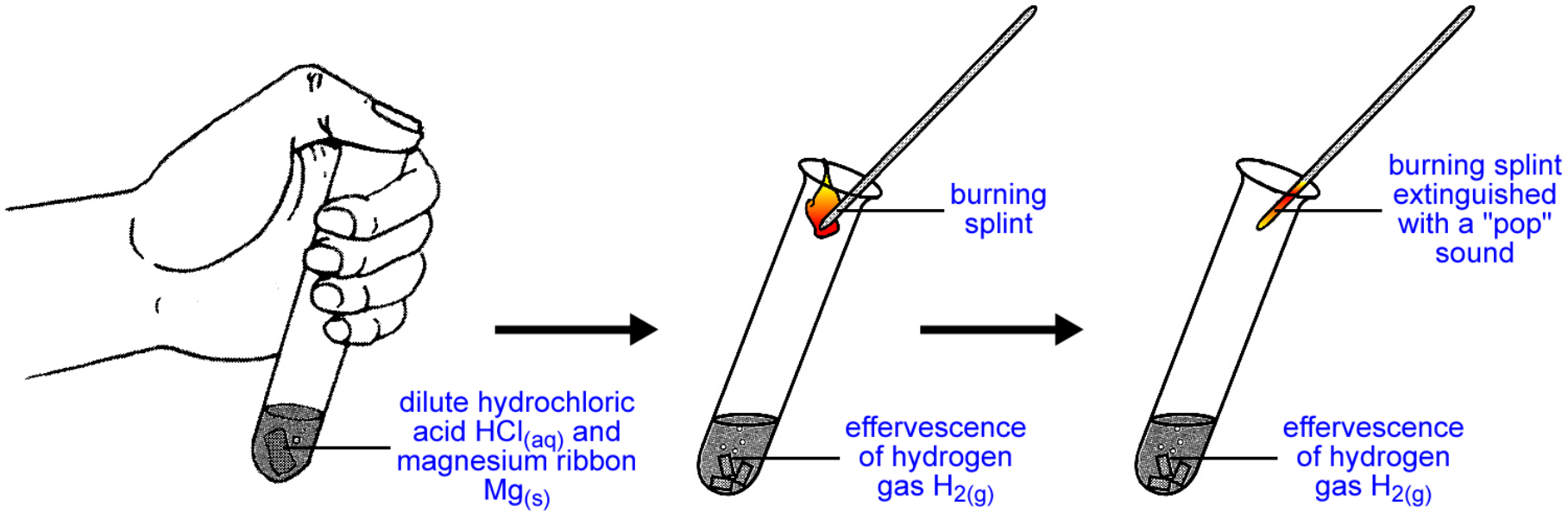
Qualitative Analysis

Test for $H_2(g)$



Qualitative Analysis

Test for $H_2(g)$



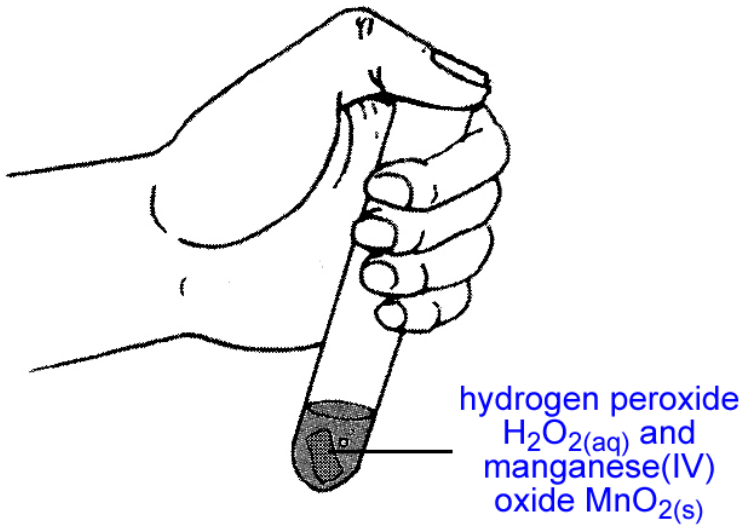
Hydrogen gas will **extinguish** a **burning** splint with a squeaky “pop” sound.

Qualitative Analysis

Test for $H_2(g)$

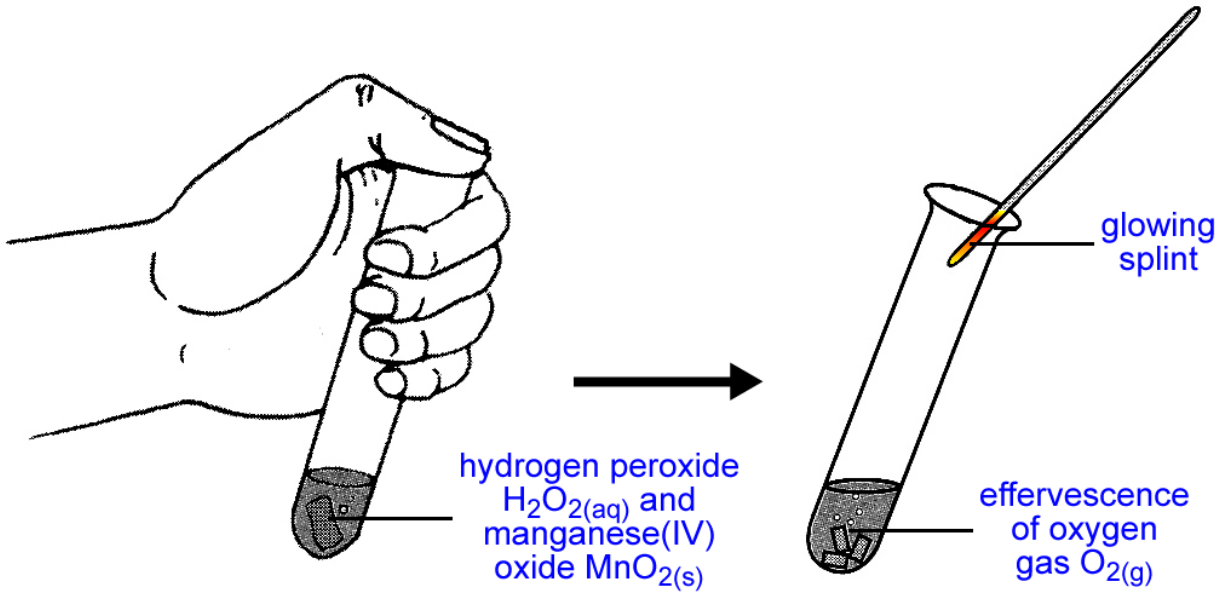
Qualitative Analysis

Test for $O_2(g)$



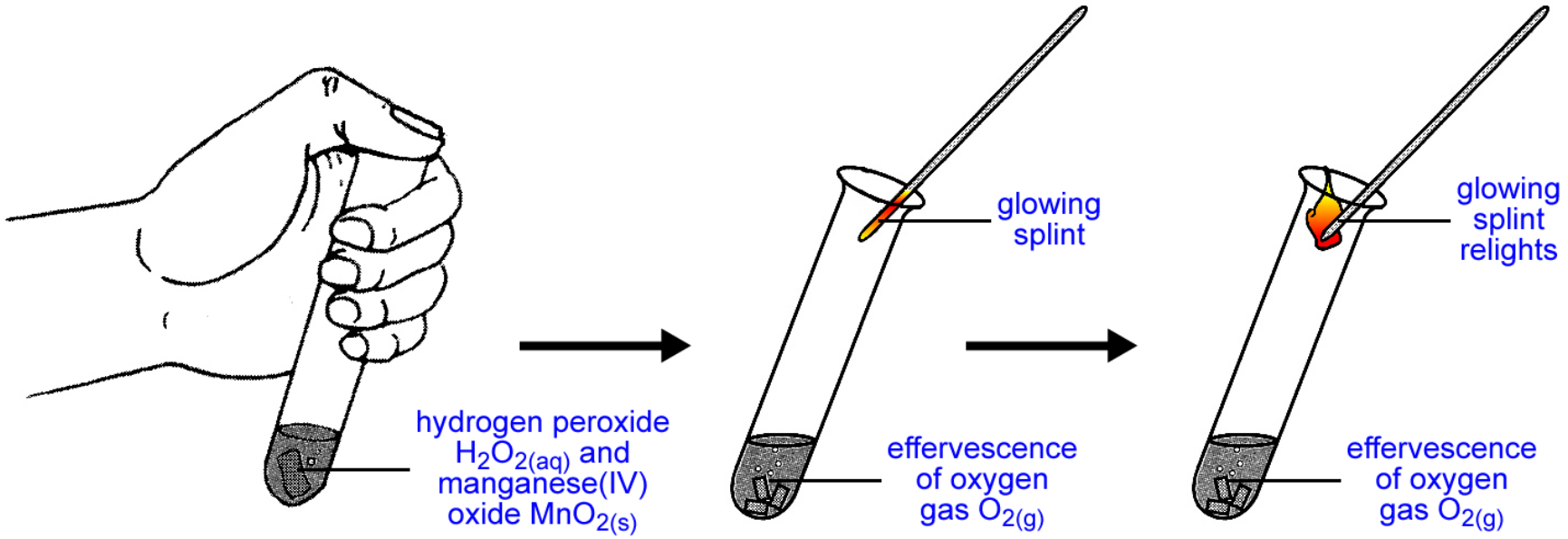
Qualitative Analysis

Test for $O_2(g)$



Qualitative Analysis

Test for $O_2(g)$



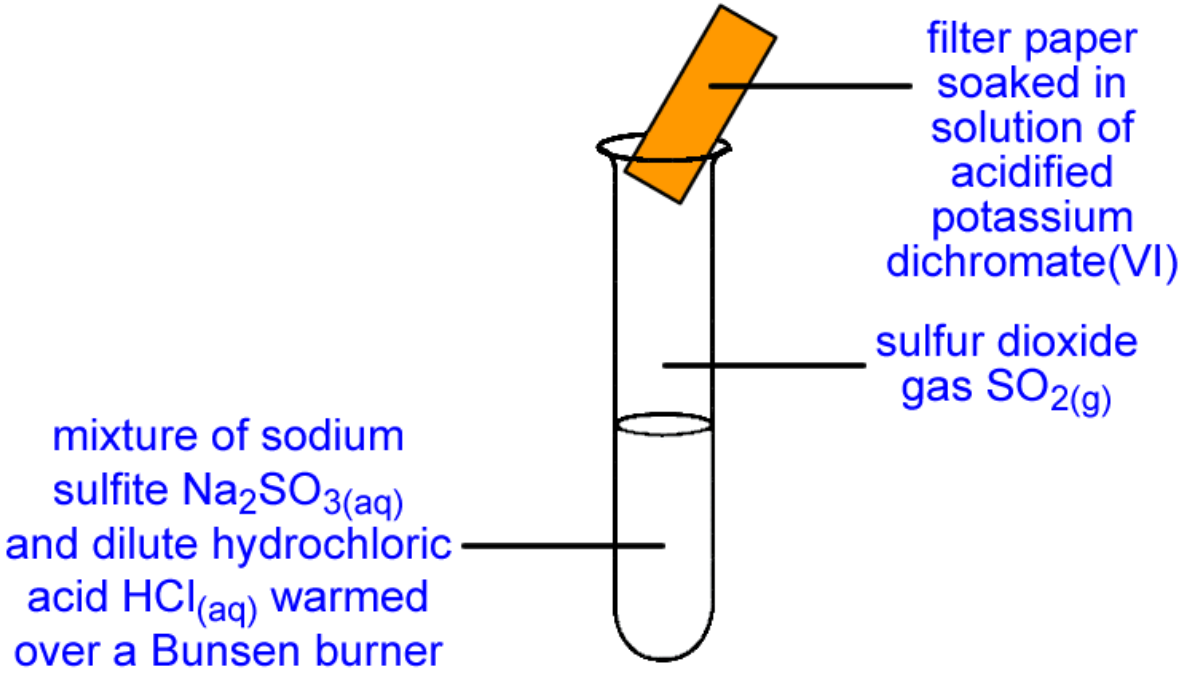
Oxygen gas will **relight** a **glowing** splint.

Qualitative Analysis

Test for $O_2(g)$

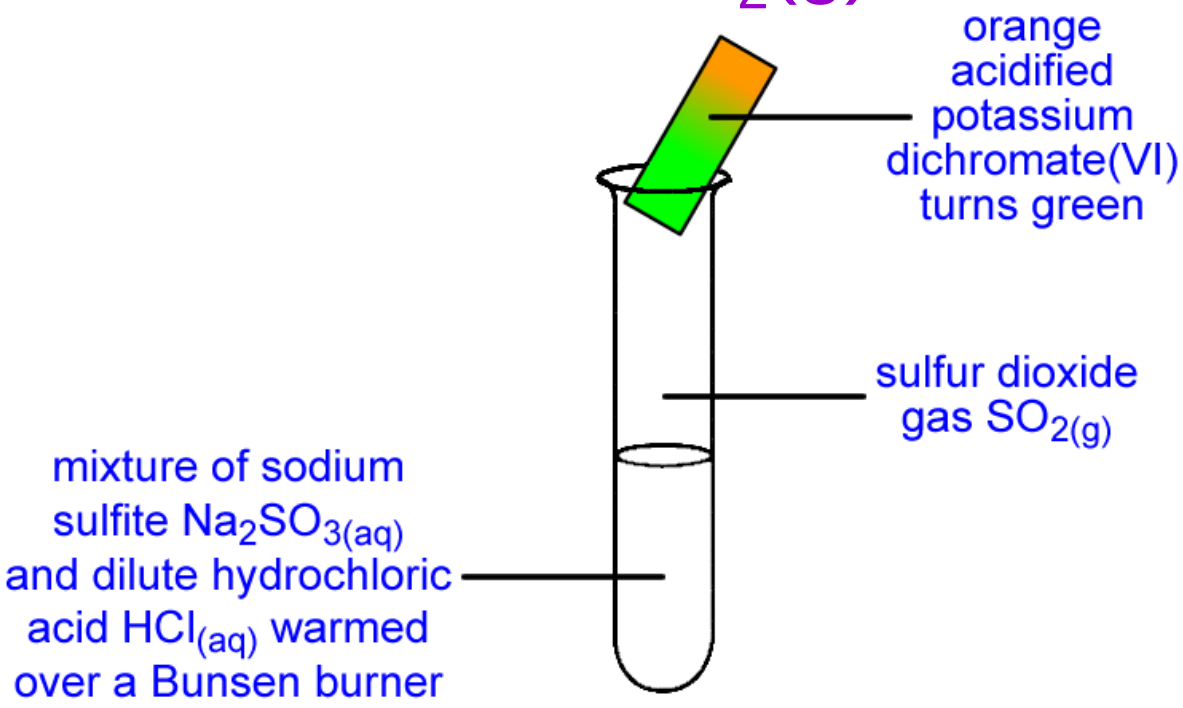
Qualitative Analysis

Test for $SO_2(g)$



Qualitative Analysis

Test for $SO_2(g)$

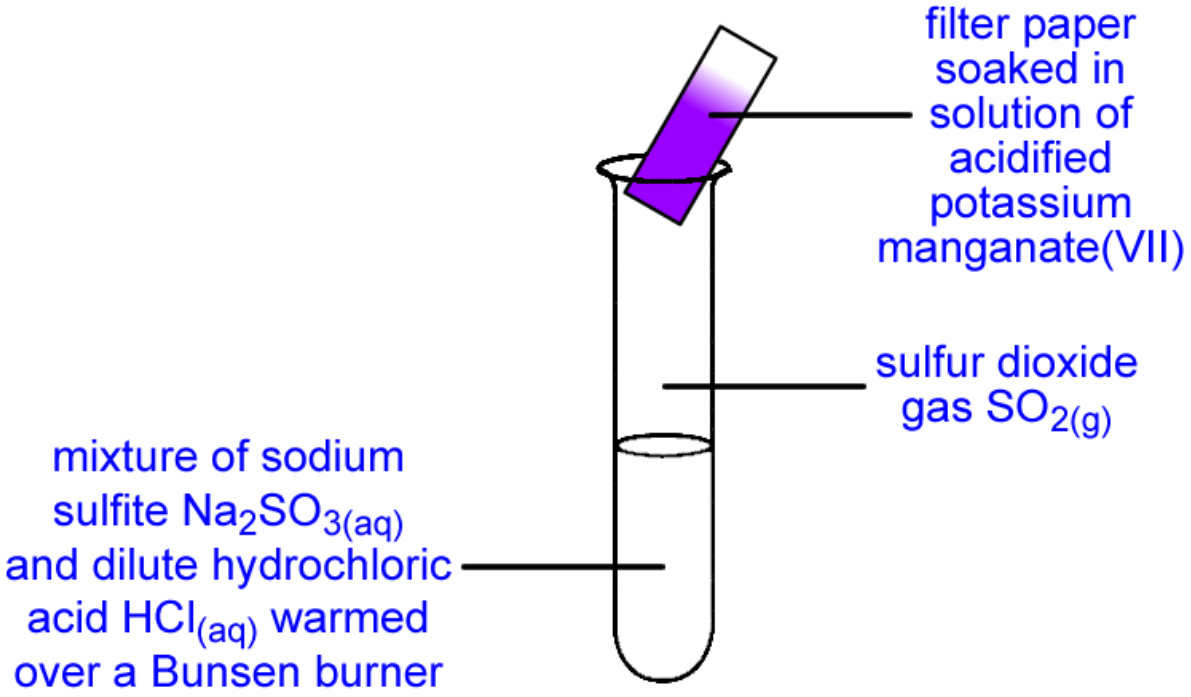


Sulfur dioxide gas will turn acidified potassium dichromate(VI) from **orange** to **green**.

$$K_2Cr_2O_7(aq) + 3SO_2(g) + H_2SO_4(aq) \rightarrow Cr_2(SO_4)_3(aq) + K_2SO_4(aq) + H_2O(l)$$

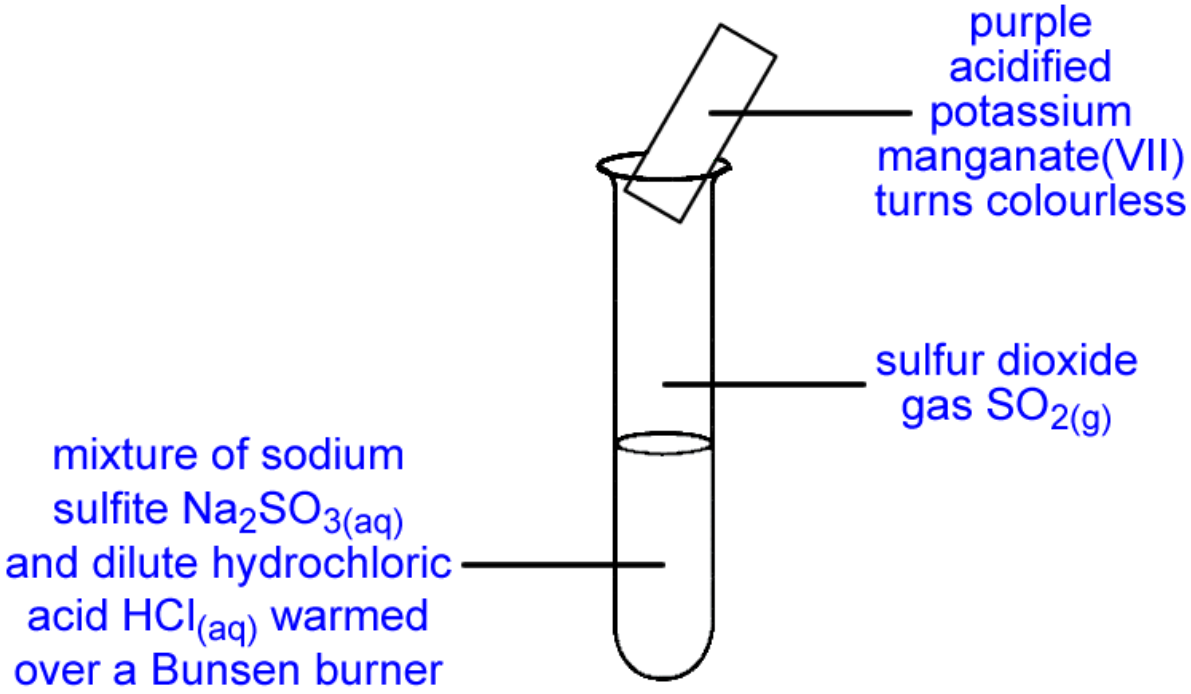
Qualitative Analysis

Test for $SO_2(g)$ (2014)



Qualitative Analysis

Test for $SO_2(g)$ (2014)

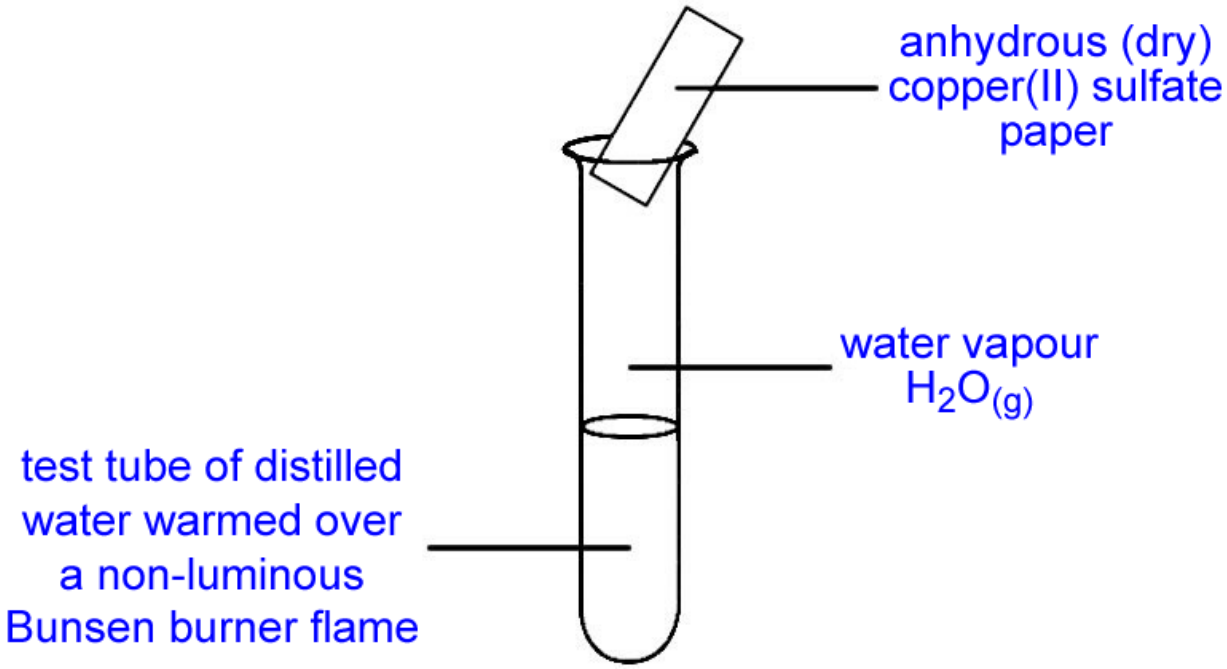


Sulfur dioxide gas will turn acidified potassium manganate(VII) from **purple** to **colourless**.

$$2KMnO_4(aq) + 5SO_2(g) + 2H_2O(l) \rightarrow K_2SO_4(aq) + 2MnSO_4(aq) + 2H_2SO_4(aq)$$

Qualitative Analysis

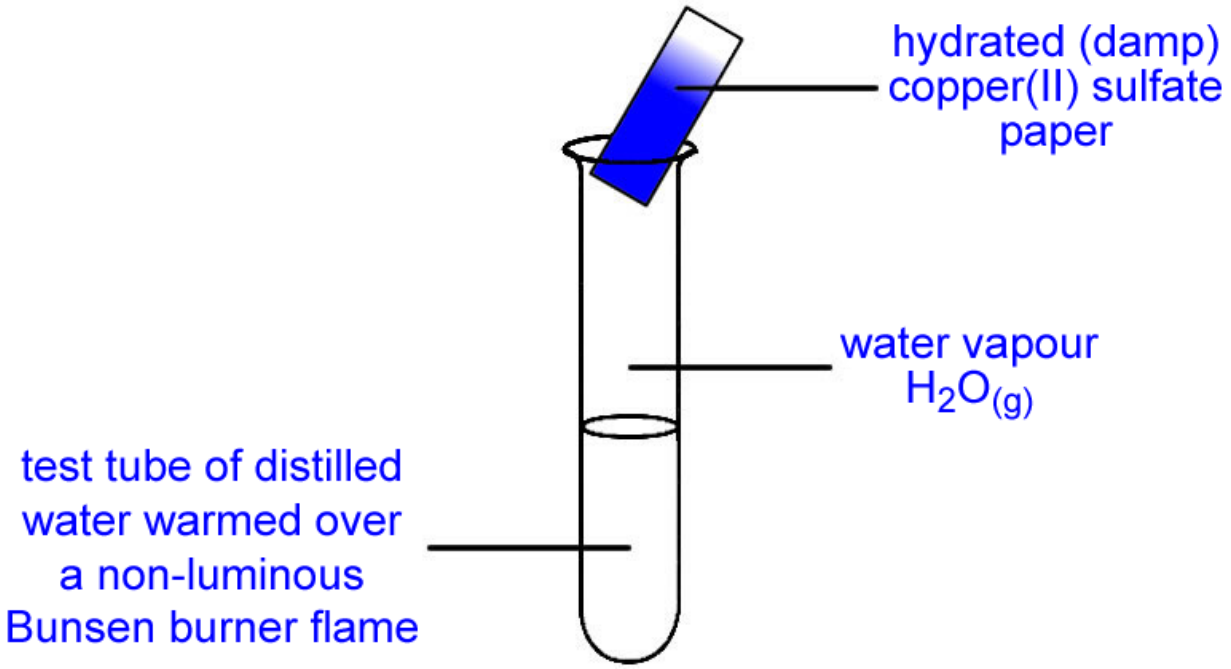
Test for $H_2O(g)$ – anhydrous copper(II) sulfate



Water vapour will change the colour of anhydrous copper(II) sulfate from **white** to **blue**.

Qualitative Analysis

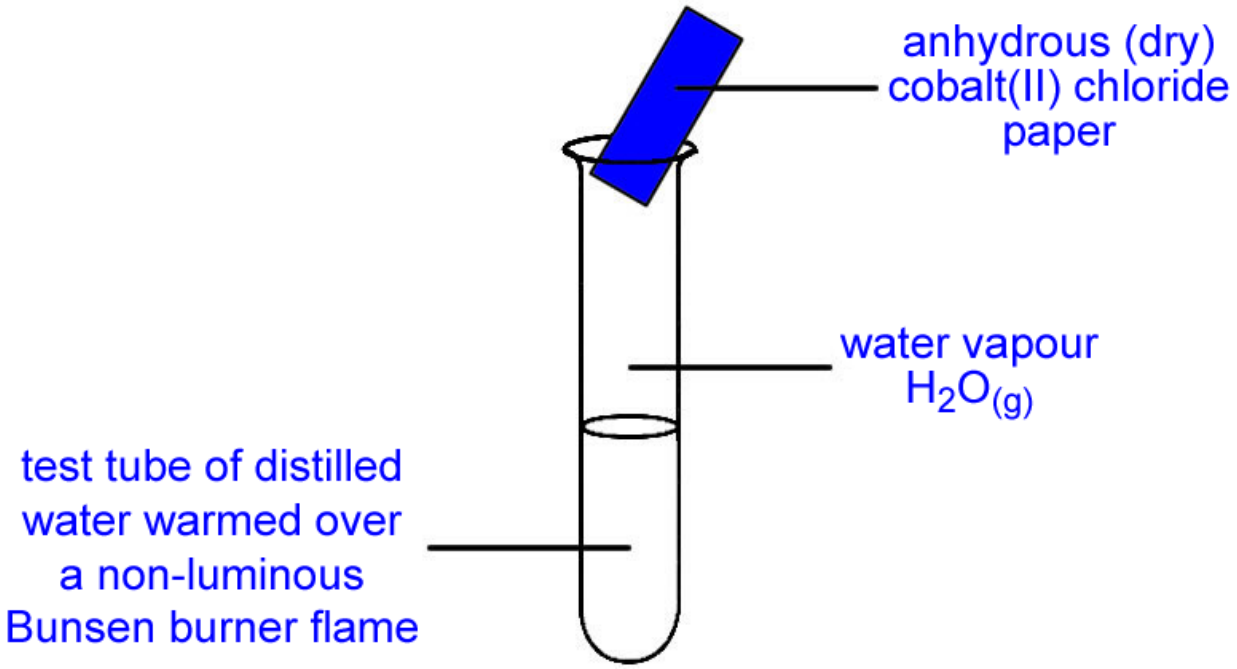
Test for $H_2O(g)$ – anhydrous copper(II) sulfate



Water vapour will change the colour of anhydrous copper(II) sulfate from **white** to **blue**.

Qualitative Analysis

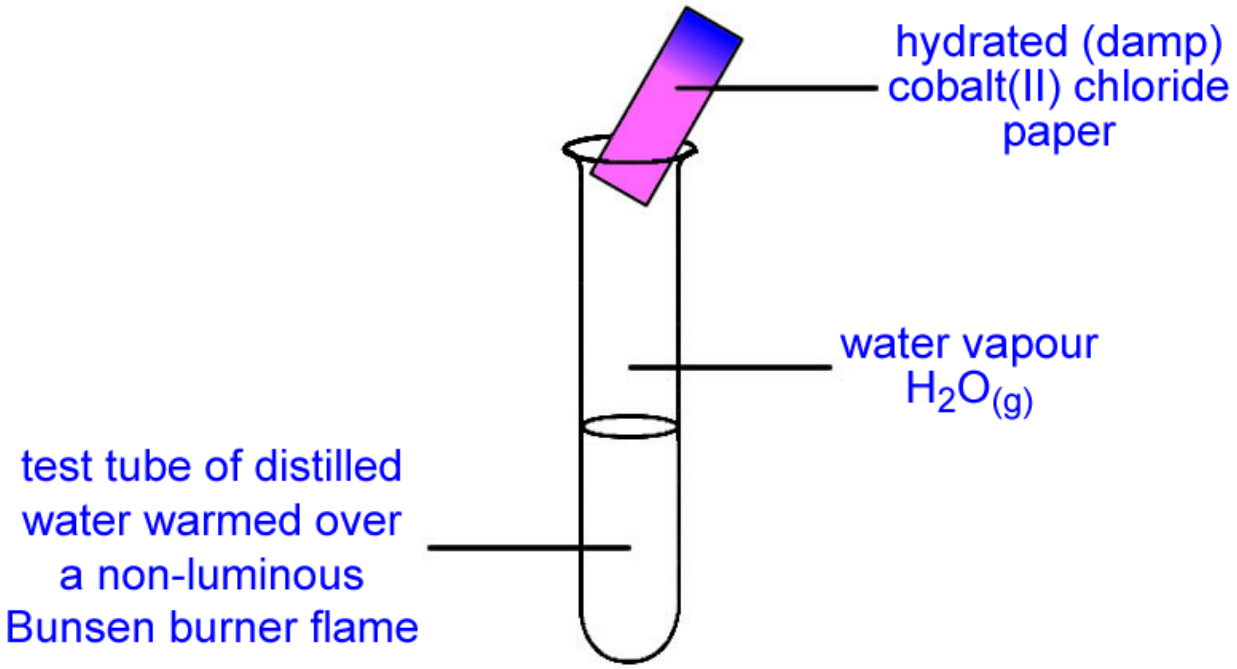
Test for $H_2O(g)$ – anhydrous cobalt(II) chloride



Water vapour will change the colour of anhydrous cobalt(II) chloride from **blue** to **pink**.

Qualitative Analysis

Test for $H_2O(g)$ – anhydrous cobalt(II) chloride



Water vapour will change the colour of anhydrous cobalt(II) chloride from **blue** to **pink**.

Qualitative Analysis

Can I please have a summary?

Qualitative Analysis

Summary – Test for Gases

Gas	Test
Ammonia – $NH_3(g)$	Turns damp red litmus paper blue.
Carbon dioxide – $CO_2(g)$	Gives white ppt. with limewater (ppt. dissolves with excess CO_2).
Chlorine – $Cl_2(g)$	Bleaches damp litmus paper.
Hydrogen – $H_2(g)$	Produces “pop” sound with a lighted splint.
Oxygen – $O_2(g)$	Relights a glowing splint.
Sulfur dioxide – $SO_2(g)$	Turns aqueous acidified potassium dichromate(VI) from orange to green. Turns aqueous acidified potassium manganite(VII) from purple to colourless.
Water vapour – $H_2O(g)$	Turns anhydrous copper(II) sulfate from white to blue. Turns anhydrous cobalt(II) chloride from blue to pink.

Qualitative Analysis

Summary – Properties of Gases

Colours	
Coloured	Colourless
Cl_2 greenish-yellow	CO_2
	H_2
	H_2O
	NH_3
	O_2
	SO_2

Odours	
Pungent	Odourless
Cl_2	CO_2
NH_3	H_2
SO_2	H_2O
	O_2

Qualitative Analysis

Summary – Properties of Gases

Flammability	
Flammable	Non-flammable
H_2	Cl_2
	CO_2
	H_2O
	NH_3
	O_2
	SO_2

Qualitative Analysis

Summary – Properties of Gases

Acid-Base Nature		
Acidic	Alkaline	Neutral
Cl_2	NH_3	H_2
CO_2		H_2O
SO_2		O_2

Qualitative Analysis

Summary – Properties of Gases

Redox		
Oxidising	Reducing	Neither
Cl_2	H_2	H_2O
CO_2	NH_3	
O_2	SO_2	

Qualitative Analysis

Are gases only produced by reactions between two chemicals?

- Gases can also be produced when a solid is heated to a high temperature and undergoes *thermal decomposition*.

Qualitative Analysis

- Carbonates can decompose on heating to produce a *metal oxide* and *carbon dioxide*.

$$CaCO_3(s) \xrightarrow{heat} CaO(s) + CO_2(g)$$

$$CuCO_3(s) \xrightarrow{heat} CuO(s) + CO_2(g)$$

green solid — black solid

Qualitative Analysis

- In general, the *lower* the metal is in the reactivity series of metals, the *lower* the temperature at which it will undergo thermal decomposition.

more reactive — less reactive

K ↔ Na ↔ Ca ↔ Mg ↔ Al ↔ Zn ↔ Fe ↔ Pb ↔ Cu ↔ Ag

- The carbonates of relatively unreactive metals can decompose completely to produce the *elemental metal*, *carbon dioxide* and *oxygen*.

$$2Ag_2CO_3(s) \xrightarrow{\text{heat}} 4Ag(s) + 2CO_2(g) + O_2(g)$$

Qualitative Analysis

- The products that are formed when a nitrate decomposes depend upon the reactivity of the metal.
- Nitrates of Group I metals decompose to produce the *metal nitrite* and *oxygen*.

$$2NaNO_3(s) \xrightarrow{heat} 2NaNO_2(s) + O_2(g)$$

- The nitrates of less reactive metals decompose at *lower temperatures*, and also decompose *more completely*.

$$2Pb(NO_3)_2(s) \xrightarrow{heat} 2PbO(s) + 4NO_2(g) + O_2(g)$$

reddish-brown gas

$$2AgNO_3(s) \xrightarrow{heat} 2Ag(s) + 2NO_2(g) + O_2(g)$$

reddish-brown gas

Qualitative Analysis

A dead body has been found on grassland. The autopsy report states that a large quantity of a clear and colourless solution was found in the victim's lungs. The coroner has reported that there are no visible signs of physical trauma to the victim's body. This evidence has lead to the initial conclusion that the victim was murdered by drowning. The victim's body was found within 2.7 km of five different water sources:

- **Sea water**

→ solution of NaC*l*(aq) and KI(aq)

- **Slightly polluted river water**

→ solution of Na_2SO_4(aq) and K_2SO_4(aq)

- **Swimming pool water**

→ solution of Cl_2(aq)

- **Natural spring water**

→ solution of Na_2CO_3(aq)

- **Pool of agricultural waste**

→ solution of KNO_3(aq) and NH_4NO_3(aq)

You are the senior forensic scientist assigned to the murder investigation. As part of the investigation, you are required to identify the clear and colourless solution that was found in the victim's lungs. Based on your knowledge of analytical chemistry, suggest a unique qualitative test(s) to identify each water source.

Qualitative Analysis

- **Possible test for sea water** (aqueous solution of sodium chloride – Na*Cl*(aq)):

Add an aqueous solution of silver nitrate to a sample of the seawater. A white precipitate of silver chloride will be observed. This confirms the presence of chloride ions in aqueous solution (all chlorides are soluble *except* silver chloride and lead(II) chloride):

$$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$$
$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

Note: A small amount of dilute nitric acid should be added to the white precipitate to ensure that it is *not silver carbonate*. Silver carbonate would react with the nitric acid to produce effervescence and the soluble salt silver nitrate:

$$2HNO_3(aq) + Ag_2CO_3(s) \rightarrow 2AgNO_3(aq) + H_2O(l) + CO_2(g)$$

Note: Silver ions can be used to test for chloride ions and chloride ions can be used to test for silver ions.

Qualitative Analysis

- **Possible test for slightly polluted river water**

(aqueous solution of sodium sulphate – $Na_2SO_4(aq)$ and potassium sulphate – $K_2SO_4(aq)$):

Add an aqueous solution of barium nitrate to a sample of the polluted river water. A white precipitate of barium sulphate will be observed. This confirms the presence of sulphate ions in aqueous solution (all sulphates are soluble *except* barium sulphate, calcium sulphate, lead(II) sulphate and silver sulphate):

$$Ba(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaNO_3(aq)$$

$$Ba(NO_3)_2(aq) + K_2SO_4(aq) \rightarrow BaSO_4(s) + 2KNO_3(aq)$$

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

Note: A small amount of dilute nitric acid should be added to the white precipitate to ensure that it is *not barium carbonate*. Barium carbonate would react with the nitric acid to produce effervescence and the soluble salt barium nitrate:

$$2HNO_3(aq) + BaCO_3(s) \rightarrow Ba(NO_3)_2(aq) + H_2O(l) + CO_2(g)$$

There would be no observed reaction if the white precipitate was barium sulphate.

Note: Barium ions can be used to test for sulphate ions and sulphate ions can be used to test for barium ions.

Qualitative Analysis

- **Possible test for swimming pool water** (aqueous solution of chlorine – $Cl_2(aq)$):

An aqueous solution of chlorine will turn blue litmus paper red, and then bleach it white.

Add an aqueous solution of potassium iodide to a sample of the swimming pool water. The clear and colourless (maybe very pale green/yellow) solution will change into an orange/brown solution of iodine:

$$2KI(aq) + Cl_2(aq) \rightarrow 2KCl(aq) + I_2(aq)$$
$$2I^-(aq) + Cl_2(aq) \rightarrow 2Cl^-(aq) + I_2(aq)$$

The presence of iodine in solution can be confirmed by adding an aqueous suspension of starch to the mixture. The formation of a blue / black complex will be observed.

Note: Iodide ions can be used to test for chlorine and chlorine can be used to test for iodide ions.

Qualitative Analysis

- **Possible test for natural spring water** (aqueous solution of sodium carbonate – $Na_2CO_3(aq)$):

Add dilute nitric acid to a sample of the spring water. Effervescence will be observed as carbon dioxide gas is produced:

$$2HCl(aq) + Na_2CO_3(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$
$$2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g)$$

The presence of carbon dioxide should be confirmed by bubbling the gas through limewater. A white precipitate of calcium carbonate will be observed:

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

Note: Acids can be used to test for carbonates and hydrogencarbonates. Carbonates and hydrogencarbonates can be used to test for acids.

Qualitative Analysis

• **Possible test for pool of agricultural waste**
(aqueous solution of potassium nitrate – $KNO_3(aq)$ and ammonium nitrate – $NH_4NO_3(aq)$):

Add dilute aqueous sodium hydroxide to a sample of the agricultural waste. Gently warm the mixture over a Bunsen burner. The ammonium ions will react with the hydroxide ions to produce ammonia gas and water:

$$NH_4NO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + NH_3(g) + H_2O(l)$$
$$NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l)$$

The presence of ammonia gas can be confirmed by holding a strip of moist red litmus paper in the mouth of the test tube. The alkaline ammonia gas will turn the moist red litmus paper blue.

• Why is it not possible to test for the nitrate ion, NO_3^-, in the presence of the ammonium ion, NH_4^+? **Hint:** Think about the observations that are made when testing for each ion.

Qualitative Analysis

Presentation on
Qualitative Analysis
Part Two: Anions and Gases

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