### Chapter 11 Qualitative Analysis

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Chapter 11 Qualitative Analysis

# **11.1 Test for Cations** 11.2 Test for Anions

11.3 Test for Gases

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- Learning Outcome(s)
  - Describe the use of aqueous sodium hydroxide and/or aqueous ammonia to identify aqueous cations through the formation of precipitates and their subsequent solubility.

#### \_\_\_\_\_11.1 How Do We Test for Cations?

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• The Singapore Food Agency (SFA) constantly checks the amount of heavy metals in the food we eat in Singapore to make sure it's safe.

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- PReagents used to identify Cations:
  - Aqueous sodium hydroxide, NaOH(aq)
  - Aqueous ammonia, NH<sub>3</sub>(aq)
  - A cation can be identified by noting:
    - the colour of the precipitate produced, if any, when the reagent is added (add dropwise first);

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- whether the precipitate is soluble or insoluble in an excess of the reagent; and
- whether ammonia gas is evolved on the addition of aqueous sodium hydroxide solution <u>on warming</u>.

 $\bigcirc$  These are also the observations we note down when we add NaOH $\bigcirc$  and NH<sub>3</sub>.

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- Reagents used to identify Cations:
  - aqueous sodium hydroxide, NaOH(aq)
  - aqueous ammonia, NH<sub>3</sub>(aq)
- Most cations give precipitates with alkalis, NaOH(aq) and NH<sub>3</sub>(aq), except <u>Na<sup>+</sup>, K<sup>+</sup> and NH<sub>4</sub><sup>+</sup>.</u>

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When NaOH or NH<sub>3</sub> is added to a solution containing cations, the precipitate formed is the <u>hydroxide</u> of the metal ion.
 e.g. Cu<sup>2+</sup>(aq) + 2OH<sup>-</sup>(aq)→ Cu(OH)<sub>2</sub>(s)

 $\bigcirc$ Recall most hydroxides are insolubleexcept those of Na<sup>+</sup>, K<sup>+</sup> and $\bigcirc$  $\mathsf{NH}_4^+$ .

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- Reagents used to identify Cations:
  - aqueous sodium hydroxide, NaOH(aq)
  - aqueous ammonia, NH<sub>3</sub>(aq) —

How does NH<sub>3</sub> form hydroxides with metal ions? **Textbook** 

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■ Most cations give precipitates with alkalis, NaOH(aq) and NH<sub>3</sub>(aq), except Na<sup>+</sup>, K<sup>+</sup> and NH<sub>4</sub><sup>+</sup>. Aqueous ammonia partially ionises in water NH<sub>3</sub>(aq) + H<sub>2</sub>O(*l*)  $\rightleftharpoons$  NH<sub>4</sub><sup>+</sup> (aq) +OH<sup>-</sup>(aq)

When NaOH or NH<sub>3</sub> is added to a solution containing cations, the precipitate formed is the <u>hydroxide</u> of the metal ion.
 e.g. Cu<sup>2+</sup>(aq) + 2OH<sup>-</sup>(aq)→ Cu(OH)<sub>2</sub>(s)

 $\bigcirc$  Recall most hydroxides are <u>insoluble</u> except those of Na<sup>+</sup>, K<sup>+</sup> and  $\bigcirc$  NH<sub>4</sub><sup>+</sup>.

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Cation	Aqueous Sodium H	ydroxide, NaOH(aq)	Aqueous Amn	nonia, NH <sub>3</sub> (aq)
Cation	On Adding a Few Drops	On Adding Excess	On Adding a Few Drops	On Adding Excess
Aluminium ion, $A/^{3+}$ $Al^{3+}$ (aq) + 30H <sup>-</sup> (a $\rightarrow$ Al(OH) <sub>3</sub> (s)	White precipitate of aluminium hydroxide, A/(OH) <sub>3</sub>	Precipitate dissolves in excess → colourless solution	White precipitate of aluminium hydroxide, A/(OH) <sub>3</sub> Al <sup>3+</sup> (aq) + 3OH <sup>-</sup> (aq)→ Al(O	Precipitate is insoluble in excess. H) <sub>3</sub> (s)
Zinc ion, Zn <sup>2+</sup>	White precipitate of zinc hydroxide, Zn(OH) <sub>2</sub> $Zn(OH) \rightarrow Zn(OH)$	Precipitate dissolves in excess → colourless	White precipitate of zinc hydroxide, $Zn(OH)_2$ $Zn^{2+}(aq) + 2OH^{-}(aq) \rightarrow Zn(C)$	Precipitate dissolves in excess → colourless
Lead ion, Pb <sup>2+</sup> Pb <sup>2+</sup> (aq) + 2OH <sup>-</sup> (a $\rightarrow$ Pb(OH) <sub>2</sub> (s)	White precipitate of lead(II) hydroxide, Pb(OH) <sub>2</sub>	Precipitate dissolves in excess → colourless solution	White precipitate of lead(II) hydroxide, Pb(OH) <sub>2</sub> Pb <sup>2+</sup> (aq) + 2OH <sup>−</sup> (aq) → Pb(	Precipitate insoluble in excess OH) <sub>2</sub> (s)

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- (		Aqueous Sodium NaOH(a	Hydroxide, q)	Aqueous Ammonia, NH <sub>3</sub> (aq)		
	Cation	On Adding a Few Drops	On Adding Excess	On Adding a Few Drops	On Adding Excess	
	Calcium ion, Ca <sup>2+</sup>	White precipitate of	Precipitate is	No precipitate.	No change is	
	Ca <sup>2+</sup> (aq) + 2OH <sup>−</sup> (aq) → Ca(OH) <sub>2</sub> (s)	calcium hydroxide, Ca(OH) <sub>2</sub>	excess.		observed.	
	Ammonium ion, NH <sub>4</sub> +	No precipitate. On heating,	No change is observed.	_	_	
	$NH_4^+ (aq) + OH^-(aq)$ $\rightarrow NH_3(g) + H_2O(I)$	ammonia gas is given off.				
	Copper(II) ion, Cu <sup>2+</sup>	Light blue precipitate of copper(II) hydroxide, Cu(OH) <sub>2</sub>	Precipitate is insoluble in excess.	Light blue precipitate of copper(II) hydroxide, Cu(OH) <sub>2</sub>	Precipitate dissolves in excess → dark blue solution	
	Cu	$1^{2+}$ (aq) + 2OH <sup>-</sup> (aq) $\rightarrow$ Cu(OH) <sub>2</sub>	<u>(</u> s)	$Cu^{2+}$ (aq) + 2OH <sup>-</sup> (aq) $\rightarrow$ Cu(C	)H) <sub>2</sub> (s)	



	st for Cations		Page 191	
Cation	Aqueous Sodiu NaOl	um Hydroxide, H(aq)	Aqueous Amn	nonia, NH <sub>3</sub> (aq)
	On Adding a Few Drops	On Adding Excess	On Adding a Few Drops	On Adding Excess
lron(II) ion, Fe <sup>2+</sup>	Green precipitate of iron(II) hydroxide, Fe(OH) <sub>2</sub>	Precipitate is insoluble in excess. (Precipitate turns brown on standing.)	Green precipitate of iron(II) hydroxide, Fe(OH) <sub>2</sub>	Precipitate is insoluble in excess. (Precipitate turns brown on standing.)
Fe <sup>2+</sup>	(aq) + 2OH⁻(aq)→ Fe(OH	) <sub>2</sub> (s) F	$e^{2+}$ (aq) + 2OH <sup>-</sup> (aq) $\rightarrow$ Fe	(OH) <sub>2</sub> (s)
lron(III) ion, Fe <sup>3+</sup>	Red-brown precipitate of iron(III) hydroxide, Fe(OH) <sub>3</sub>	Precipitate is insoluble in excess.	Red-brown precipitate of iron(III) hydroxide, Fe(OH) <sub>3</sub>	Precipitate is insoluble in excess.
Fe <sup>3+</sup>	<sup>+</sup> (aq) + 3OH <sup>−</sup> (aq) $\rightarrow$ Fe(O	H) <sub>3</sub> (s)	$\mathrm{e}^{3+}$ (aq) + 3OH $^-$ (aq) $ ightarrow$ Fe	e(OH) <sub>3</sub> (s)

#### Textbook How to differentiate Al<sup>3+</sup> and Pb<sup>2+</sup> Page 191 Aqueous Ammonia, NH<sub>3</sub>(ag) Aqueous Sodium Hydroxide, NaOH(ag) Cation On Adding a Few On Adding Excess On Adding a Few On Adding Excess Drops Drops Aluminium ion, White precipitate Precipitate White precipitate Precipitate is A/3+ of aluminium dissolves in excess of aluminium insoluble in excess. hydroxide, $\rightarrow$ colourless hydroxide, A/(OH)<sub>3</sub> A/(OH)<sub>3</sub> solution Lead ion, Pb<sup>2+</sup> Precipitate White precipitate White precipitate Precipitate insoluble of lead(II) dissolves in excess of lead(II) in excess hydroxide, $\rightarrow$ colourless hydroxide, Pb(OH)<sub>2</sub> Pb(OH)<sub>2</sub> solution The observations with NaOH(aq) and NH<sub>3</sub>(aq) are the same for A $l^{3+}$ and Pb<sup>2+</sup> ions! $\bigcirc$ How to differentiate these two ions??

	1	How to differentiate Al <sup>3+</sup> and Pb <sup>2+</sup> TextboolPage 192				
<b>H</b>	Cation	Aqueous Sodium H	ydroxide, NaOH(aq)	Aqueous Ammonia, NH <sub>3</sub> (aq)		
	Cation	On Adding a Few Drops	On Adding Excess	On Adding a Few Drops	On Adding Excess	
	Aluminium ion, Al <sup>3+</sup>	White precipitate of <u>aluminium</u> hydroxide, A/(OH) <sub>3</sub>	Precipitate dissolves in excess → colourless solution	White precipitate of <u>aluminium</u> hydroxide, A/(OH) <sub>3</sub>	Precipitate is insoluble in excess.	Ŷ
	Lead ion, Pb <sup>2+</sup>	White precipitate of lead(II) hydroxide, Pb(OH) <sub>2</sub>	Precipitate dissolves in excess → colourless solution	White precipitate of lead(II) hydroxide, Pb(OH) <sub>2</sub>	Precipitate insoluble in excess	
Œ	The observat	ions with NaOH How to	(aq) and NH <sub>3</sub> (aq) differentiate thes	are the same for se two ions??	Al <sup>3+</sup> and Pb <sup>2+</sup> ions!	
0	Add <b>potassium iodide, KI</b> , to both solutions. A <u>yellow precipitate of PbI<sub>2</sub> will</u> form with the solution containing Pb <sup>2+</sup> but <u>no precipitate</u> will be observed with the A <i>l</i> <sup>3+</sup> solution.					

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- **Reagents used to identify cations:** 
  - aqueous sodium hydroxide, NaOH(aq)
  - aqueous ammonia, NH<sub>3</sub>(aq)
- In excess NaOH(aq), the hydroxides of Zn<sup>2+</sup>, Al<sup>3+</sup> and Pb<sup>2+</sup> (ZAP) will dissolve.
- In excess NH<sub>3</sub>(aq), the hydroxides of Cu<sup>2+</sup> and Zn<sup>2+</sup> (CuZ) will dissolve.



### Summary of Lesson

- Aqueous sodium hydroxide, NaOH(aq) and aqueous ammonia, NH<sub>3</sub>(aq) are used to identify cations.
- A cation can be identified by noting:

- the colour of the precipitate produced, if any, when the reagent is added;
- whether the precipitate is soluble or insoluble in an excess of the reagent; and
- whether ammonia gas is evolved on the addition of aqueous sodium hydroxide solution.

Chapter 11 Qualitative Analysis

### 11.1 Test for Cations

### **11.2 Test for Anions**

### 11.3 Test for Gases

### 11.2 Test for Anions

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#### Learning Outcome(s)

• Describe tests to identify aqueous anions.

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### 11.2 Test for Anions

Anion	est Add dilute acid. Bubble the gas given off into limewater.		Observations for Positive Test and Inference	
Carbonate ion, CO <sub>3</sub> <sup>2-</sup>			Effervescence is observed. Gas given off forms a white precipitate (calcium carbonate, $CaCO_3$ ) with limewater.	
		CO <sub>2</sub> (g) -	$(g) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + H_2O(I)$	
			Carbon dioxide gas is produced.	
Chloride ion, C <i>l</i> <sup>-</sup>	Add dilute nitric acid, then add aqueous silver nitrate.		A white precipitate (silver chloride, AgCl) is formed. $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$	
Iodide ion, I <sup>-</sup> Add dilute nitric acid, then add aqueous silver		<mark>cid</mark> , silver	A yellow precipitate (silver iodide, AgI) is formed.	
	nitrate.		$Ag^+(aq) + I^-(aq) \rightarrow AgI(s)$	

11	.2 Test for Anions	Textbook Page 193
Anion	Test	Observations for Positive Test and Inference
Sulfate ion, SO <sub>4</sub> <sup>2-</sup>	Add dilute nitric acid, then add aqueous barium nitrate.	A white precipitate (barium sulfate, BaSO <sub>4</sub> ) is formed. Ba <sup>2+</sup> (aq) + SO <sub>4</sub> <sup>2-</sup> (aq) $\rightarrow$ BaSO <sub>4</sub> (s)
Nitrate ion, NO <sub>3</sub> -	Add aqueous sodium hydroxide, then add a piece of aluminium. Warm the mixture carefully. Test the gas given off with a piece of damp red litmus paper.	Effervescence is observed. The gas given off turns damp red litmus paper blue. Ammonia gas is produced.

### 11.2 Test for Anions

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Test	Observations for Positive Test and Inference				
Add dilute nitric acid, then add aqueous barium nitrate.	A white precipitate of barium sulfate, $BaSO_4$ , is formed.				
Add dilute nitric acid, then add aqueous silver nitrate.	A white precipitate (silver chloride, AgCl) is formed.				
Add dilute nitric acid, then add aqueous silver nitrate.	A yellow precipitate (silver iodide, AgI) is formed.				
For sulfates, chlorides and iodide, why is there a need to add dilute nitric acid first before adding the test reagent ??					
To remove carbonates and hydroxide ions! If dilute nitric acid is not added, precipitates of $BaCO_3$ , $Ag_2CO_3$ and $AgOH$ will form when barium nitrate / silver nitrate is added, which will interfere with the results.					
	Test Add dilute nitric acid, then add aqueous barium nitrate. Add dilute nitric acid, then add aqueous silver nitrate. Add dilute nitric acid, then add aqueous silver nitrate. Chlorides and iodide, why is acid first before adding the test nates and hydroxide ions! If on CO <sub>3</sub> , Ag <sub>2</sub> CO <sub>3</sub> and AgOH will ded, which will interfere with				

Chapter 11 Qualitative Analysis

### 11.1 Test for Cations

### 11.2 Test for Anions

### **11.3 Test for Gases**

# 11.3 Test for gases

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## Learning Outcome(s)Describe tests to identify gases.

### 11.3 Test for Gases

#### https://www.youtube.com/watch?v=nXk7XauQefA

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### Tests for <u>odourless</u> gases

	Gas	Colour and Odour	Test	Observations
	Hydrogen, H <sub>2</sub>	Colourless and odourless	Place a <b>lighted splint</b> at the mouth of the test tube.	The lighted splint is extinguished with a "pop" sound.
) ()	Oxygen, O <sub>2</sub>	Colourless and odourless	Insert a <b>glowing splint</b> into the test tube.	The glowing splint is rekindled (i.e. catches fire again).
	Carbon dioxide, $CO_2$	Colourless and odourless	Bubble the gas through limewater.	A white precipitate is formed. The precipitate dissolves upon further bubbling.

### 11.3 Test for Gases

### Tests for <u>odourless</u> gases

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What is happening in the limewater test

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Limewater, Ca(OH)<sub>2</sub>(aq), reacts with CO<sub>2</sub>(g) the white precipitate <u>CaCO<sub>3</sub>(s)</u>.

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

\* The precipitate will further react with  $CO_2(g)$  to form  $Ca(HCO_3)_2$ , which is a soluble salt.

 $CaCO_3(s) + CO_2(g) + H_2O(I) \rightarrow Ca(HCO_3)_2(aq)$ 

### 11.3 Test for Gases

### Tests for <u>pungent</u> gases



Gas	Colour and Odour	Test	Observations
Chlorine, C <i>I</i> <sub>2</sub>	Yellow-green gas with a pungent smell	Place a piece of damp blue litmus paper at the mouth of the test tube.	The damp blue litmus paper turns red and is then bleached.
Sulfur dioxide, SO <sub>2</sub>	Colourless gas with a pungent smell	Place a piece of filter paper soaked with acidified potassium manganate(VII) (KMnO <sub>4</sub> ) at the mouth of the test tube.	The purple acidified potassium manganate(VII) turns colourless.
<sup>®</sup> Ammonia, NH <sub>3</sub>	Colourless gas with a pungent smell	Place a piece of damp red litmus paper at the mouth of the test tube.	The damp red litmus paper turns blue.

### **Tests for Presence of Water**

Water is given off when hydrated salts are heated. e.g.  $CuSO_4.5H_2O \rightarrow CuSO_4 + 5H_2O$ 

Presence (not purity!) of water can be tested by using 1. anhydrous cobalt(II) chloride paper & cobalt(II) chloride paper turns from blue to pink

anhydrous copper(II) sulfate

 anhydrous copper(II) sulfate changes from white to blue





#### Test for cations using NaOH(aq)



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#### Test for cations using NH<sub>3</sub>(aq)



#### **Test for anions**



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#### **Test for gases**

