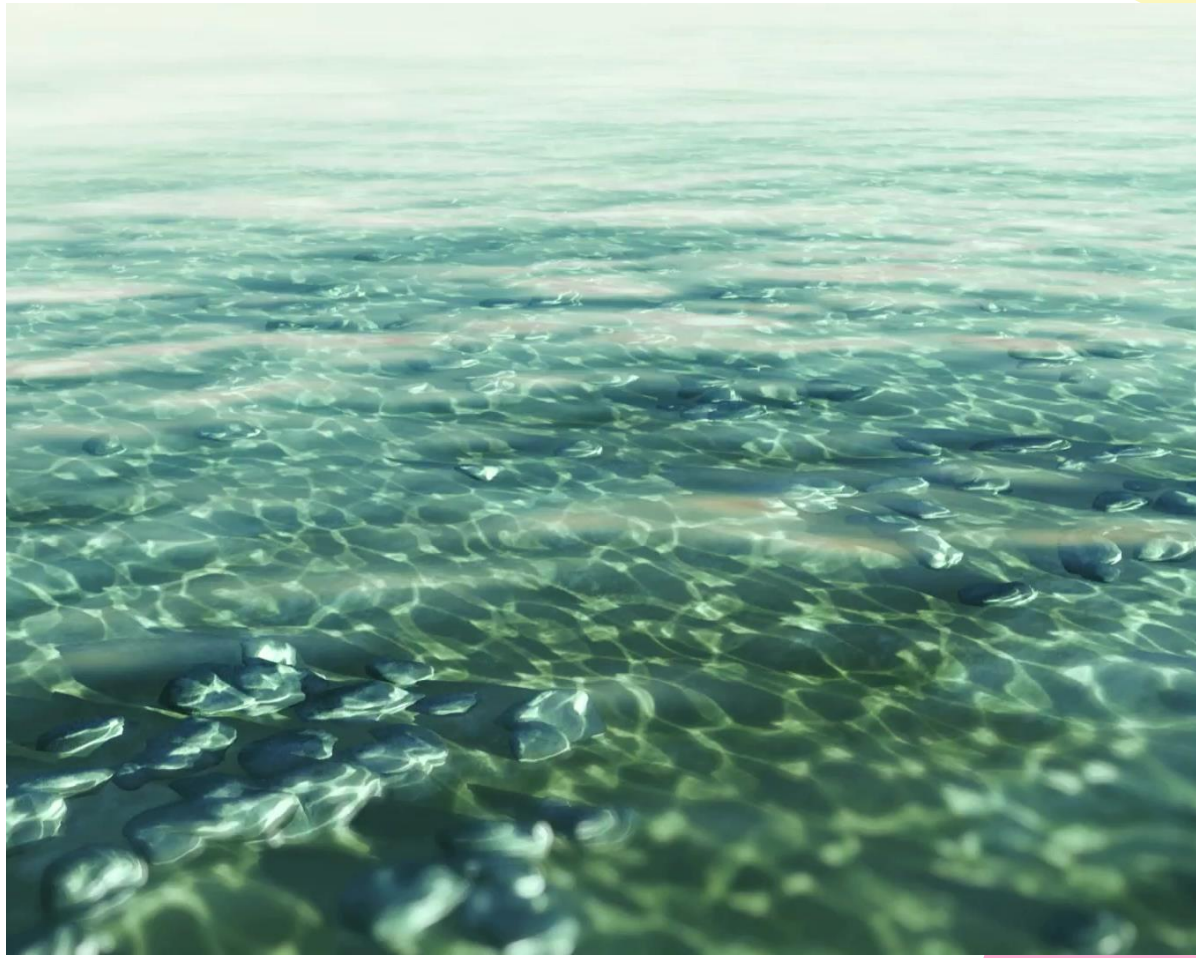
CHAPTER 9
SALTS

Chapter 9 Salts

- **9.1 What Are Salts?**
- 9.2 How Are Salts Prepared?

9.1 What Are Salts?

- **Learning Outcome(s)**
  - Describe the general rules of solubility for common salts in water.



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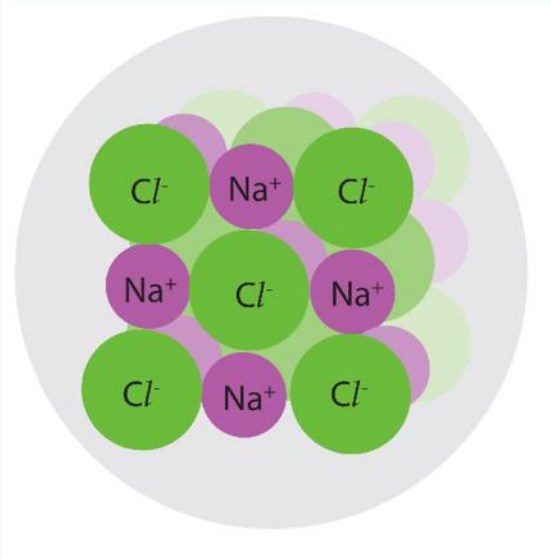
9.1 What Are Salts?

- A salt is an ionic compound that consists of a cation (positive ion) and an anion (negative ion).



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9.1 What Are Salts?

Solubility of Salts in Water

- **Solubility** refers to the **ability of a solute to dissolve in a solvent.**
- Different salts have different solubilities. Salts may be soluble or insoluble.
- The solubility of a salt must be determined before we decide on a method to prepare the salt.

9.1 What Are Salts?

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Solubility of Salts in Water

actually, it's all Group 1 salts!

Soluble Salts		Insoluble Salts	
all sodium salts all potassium salts all ammonium salts all nitrates		–	
all chlorides	except →	silver chloride, $AgCl$ lead(II) chloride, $PbCl_2$	**SLC**
all sulfates	except →	barium sulfate, $BaSO_4$ lead(II) sulfate, $PbSO_4$ calcium sulfate, $CaSO_4$ (sparingly soluble)	**B**io **P**hy **C**hem
sodium carbonate, Na_2CO_3 potassium carbonate, K_2CO_3 ammonium carbonate, $(NH_4)_2CO_3$	← except	all carbonates	

SPA(N)

9.1 What Are Salts?

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Solubility of Salts in Water

Soluble base	Insoluble base
sodium hydroxide, NaOH potassium hydroxide, KOH calcium hydroxide, $Ca(OH)_2$ *ammonium hydroxide (SPA salts)	all hydroxides
sodium oxide, Na_2O potassium oxide, K_2O calcium oxide, CaO	all oxides

Applications of Solubility Rules

Summary of Lesson

- Salts are **ionic** compounds.
- Not all salts are soluble in water.
- The **solubility** of a salt must be determined before we can choose a suitable method to prepare the salt.

Chapter 9 Salts

- 9.1 What Are Salts?
- **9.2 How Are Salts Prepared?**

9.2 How Are Salts Prepared?

Learning Outcome(s)

- Describe the techniques used in the preparation, separation and purification of salts.
- Suggest a method of preparing a salt from suitable starting materials.

9.2 How Are Salts Prepared?

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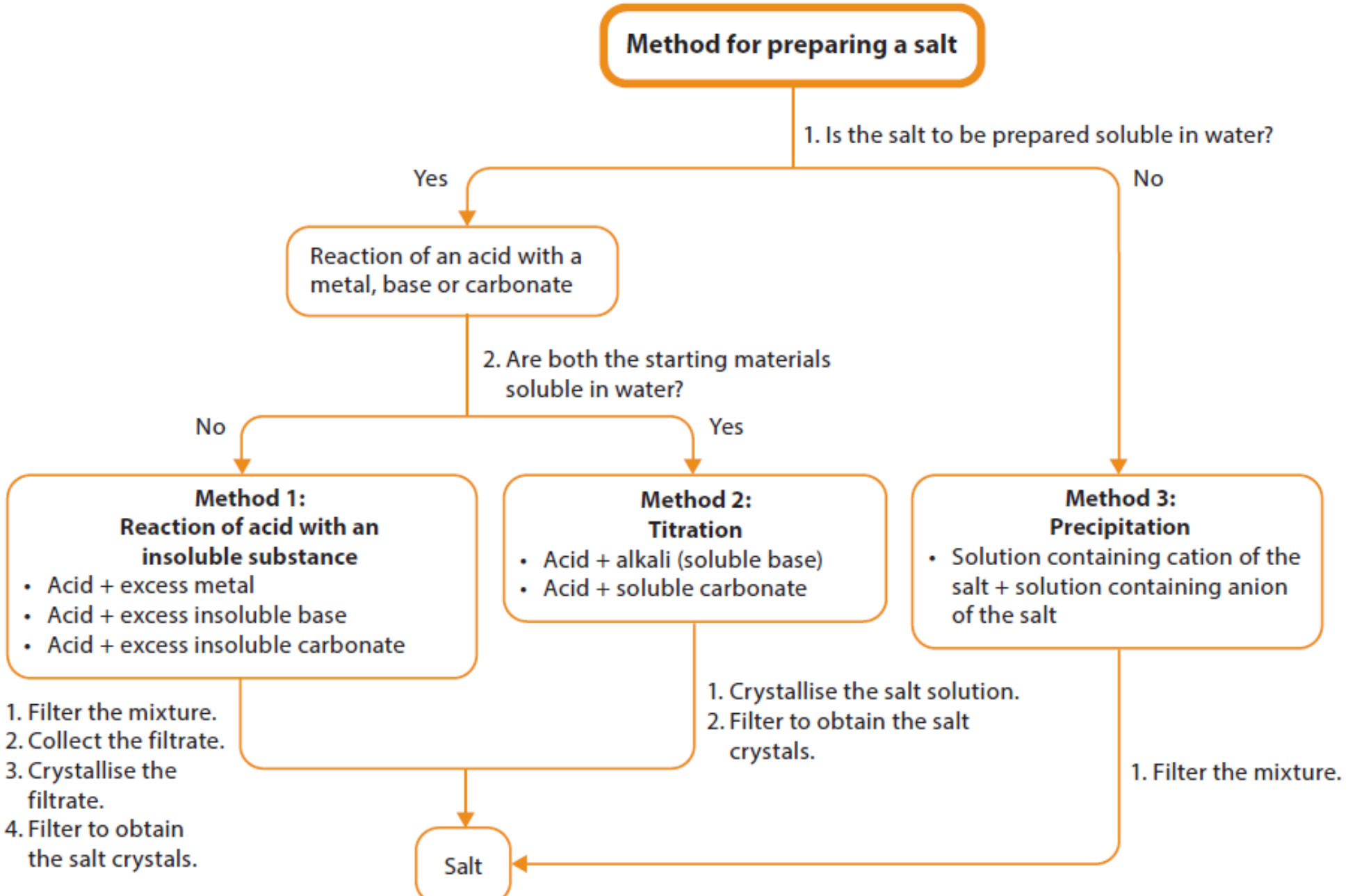
- There are several ways to prepare salts.
- Before deciding on how to prepare a salt, two factors must be considered:
    - The **solubility of the salt** in water
    - The **solubility of the starting materials** in water
- If a salt is **soluble** in water → prepared by **reactions of acids**
- If a salt is **insoluble** in water → prepared by **precipitation**


Method for preparing a salt
1. Is the salt to be prepared soluble in water?
Yes
No
Reaction of an acid with a metal, base or carbonate
2. Are both the starting materials soluble in water?
No
Yes
Method 1: Reaction of acid with an insoluble substance
• Acid + excess metal
• Acid + excess insoluble base
• Acid + excess insoluble carbonate
Method 2: Titration
• Acid + alkali (soluble base)
• Acid + soluble carbonate
Method 3: Precipitation
• Solution containing cation of the salt + solution containing anion of the salt
1. Filter the mixture.
2. Collect the filtrate.
3. Crystallise the filtrate.
4. Filter to obtain the salt crystals.
1. Crystallise the salt solution.
2. Filter to obtain the salt crystals.
1. Filter the mixture.
Salt

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Method 1: Reaction of Acid With an Insoluble Substance

- This method is used to prepare **salts** that are **soluble** in water.
- However, this is **NOT** used to prepare **SPA** (**S**odium, **P**otassium and **A**mmonium) salts.
- General equations for this method:
  - acid + excess metal(s) → salt + hydrogen
  - acid + excess insoluble base(s) → salt + water
  - acid + excess insoluble carbonate(s) → salt + water + carbon dioxide
- The excess starting materials are removed by **filtration**.

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Method 1: Reaction of Acid With an Insoluble Substance

- General equations for this method:
  - acid + excess metal(s) → salt + hydrogen
  - acid + excess insoluble base(s) → salt + water
  - acid + excess insoluble carbonate(s) → salt + water + carbon dioxide

Note!
The metal, base or carbonate must be added **in excess** so that all the acid is used up. This prevents the salt formed from being contaminated by the remaining acid.

- The excess starting materials are removed by **filtration**.

Method 1: Reaction of Acid With an Insoluble Substance

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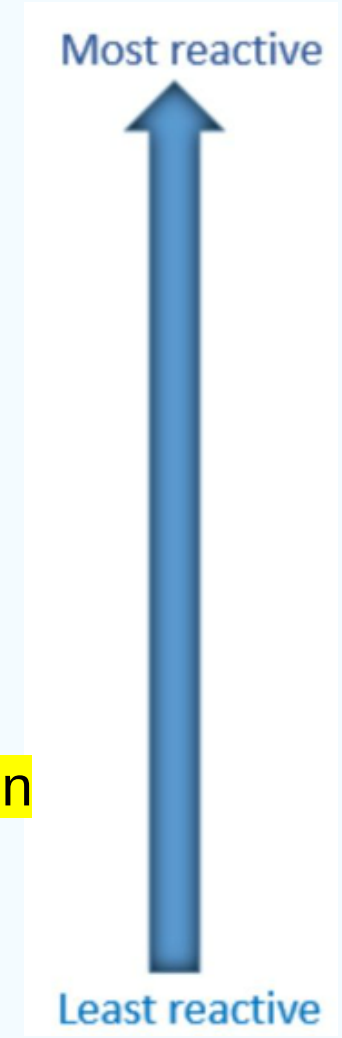
Step 1	Determine if the salt is soluble in water.	Zinc sulfate is soluble in water.
Step 2	Identify the starting materials.	Zn^{2+} can come from either Zn, ZnO or $ZnCO_3$. — $ZnSO_4$ — SO_4^{2-} comes from H_2SO_4. • Possible starting materials: Sulfuric acid with zinc metal, zinc oxide or zinc carbonate • Consider the **reactivity of the metal** when choosing starting materials.

How to remember the Reactivity Series

Please	Potassium
Stop	Sodium
Calling	Calcium
Me	Magnesium
A	Aluminium
Careless	Carbon
Zebra	Zinc
Huh	Hydrogen
Instead	Iron
Try	Tin
Learning	Lead
How	Hydrogen ion
Cupid	Copper
Shoots	Silver
Gold	Gold



15.1 What Is the Order of Reactivity of Metals?

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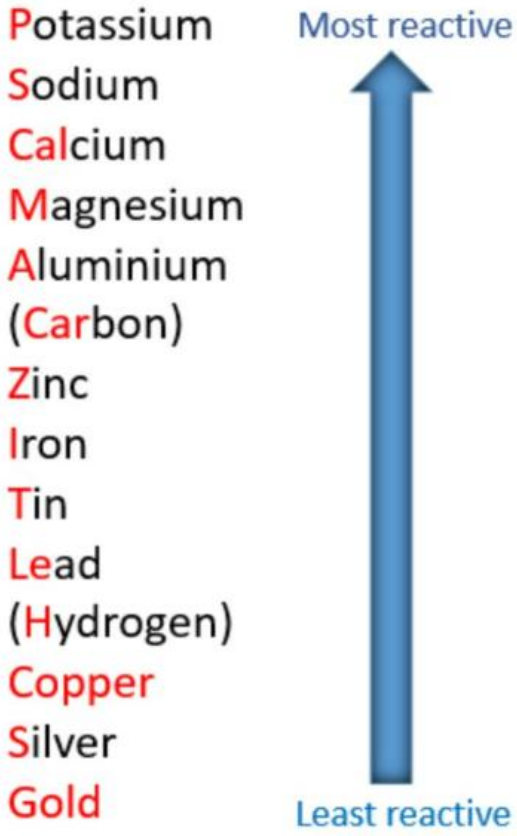
- Metals above hydrogen in the reactivity series react with hydrochloric acid.

Table 15.2 Reactions of some metals with dilute hydrochloric acid

Metal	Observation and Equation for Reaction with Dilute Hydrochloric Acid	Equation
potassium	React explosively. These reactions should not be carried out in the school laboratory.	$2K(s) + 2HCl(aq) \longrightarrow 2KCl(aq) + H_2(g)$
sodium		$2Na(s) + 2HCl(aq) \longrightarrow 2NaCl(aq) + H_2(g)$
calcium	Reacts violently to give hydrogen gas.	$Ca(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2(g)$
magnesium	Reacts rapidly to give hydrogen gas.	$Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$
zinc	Reacts moderately fast to give hydrogen gas.	$Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$
iron	Reacts slowly to give hydrogen gas.	$Fe(s) + 2HCl(aq) \longrightarrow FeCl_2(aq) + H_2(g)$
*lead copper silver	No reaction occurs.	



Method 1: Reaction of Acid With an Insoluble Substance

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Step 3	Determine if the starting materials are soluble in water.	• Zinc sulfate is soluble in water. • Zinc metal, zinc oxide and zinc carbonate are insoluble in water. • **Method 1** can be used.
Step 4	Select the starting materials.	• Sulfuric acid with zinc metal: dilute sulfuric acid + zinc ⟶ zinc sulfate + hydrogen

Method 1: Reaction of Acid With an Insoluble Substance

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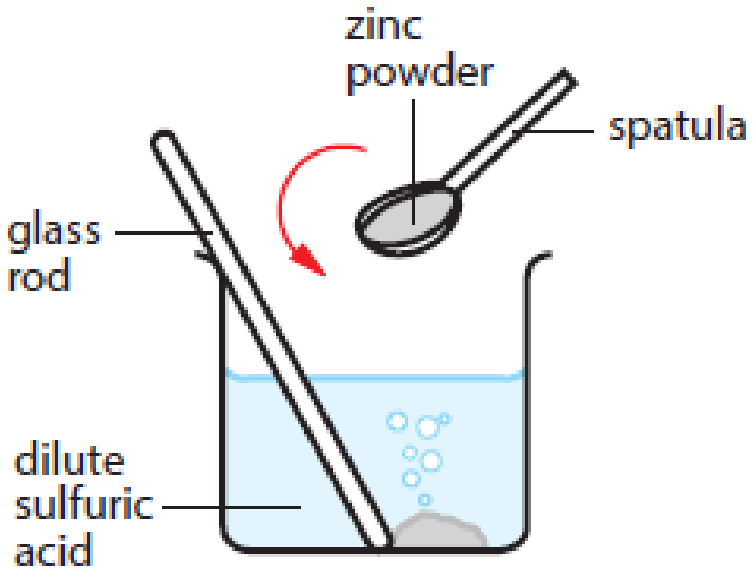
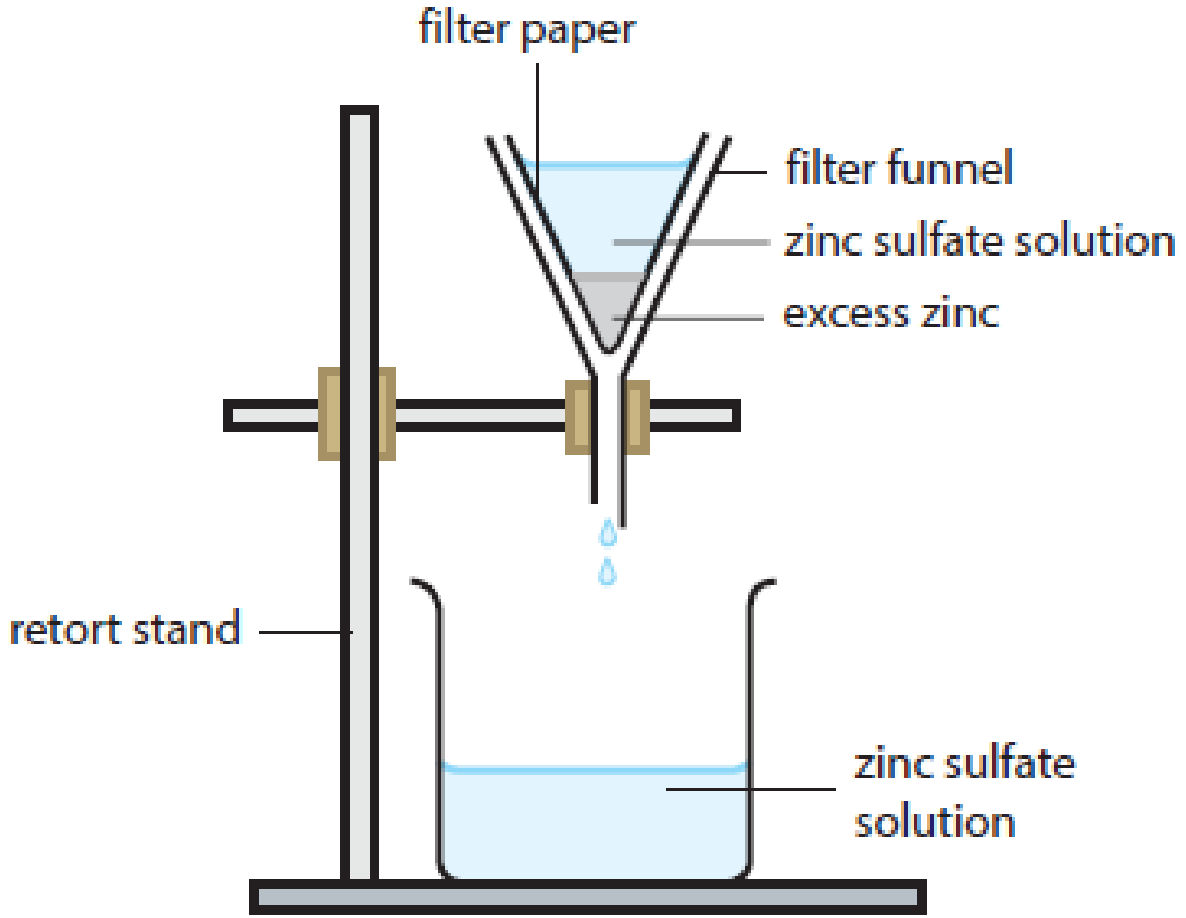
① Fill half a beaker with dilute sulfuric acid. With constant stirring, add zinc powder until no more zinc will dissolve in the acid or no more **effervescence** is observed.



② Filter to remove the excess (unreacted) zinc powder. Collect the filtrate. This is the zinc sulfate solution.



Method 1: Reaction of Acid With an Insoluble Substance

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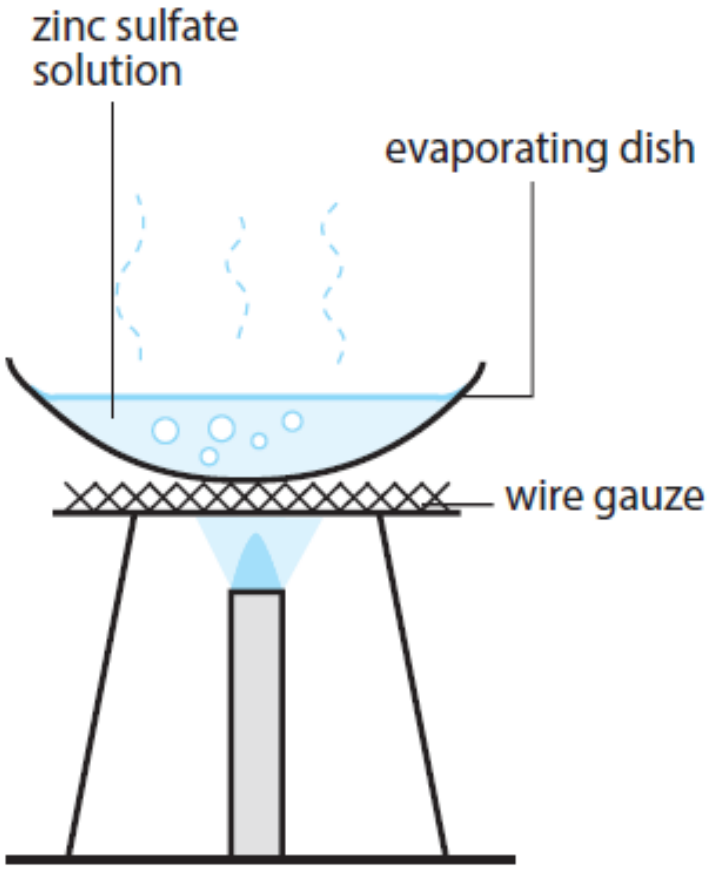
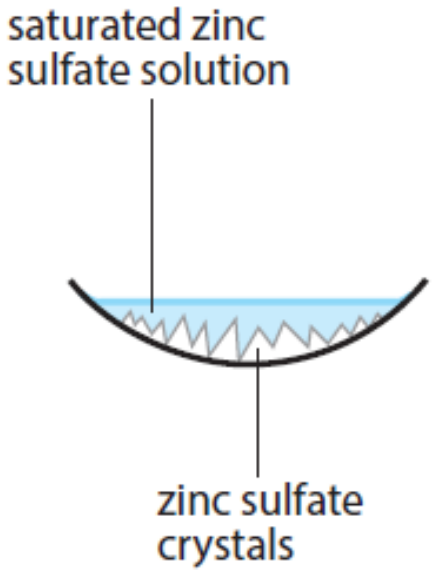
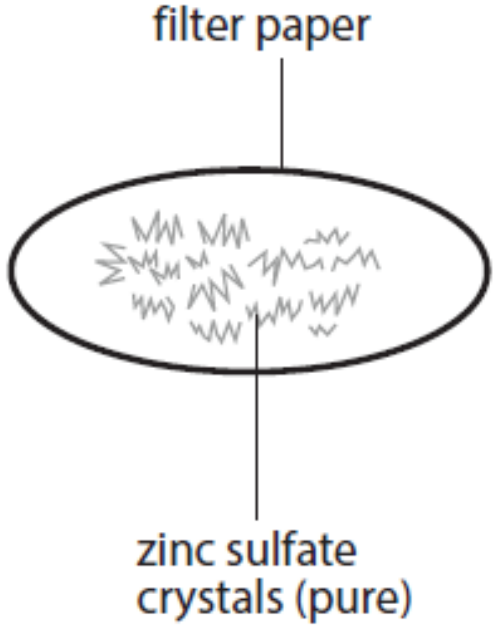
③ Heat the filtrate until it is saturated.



④ Allow the saturated solution to cool so that the salt can crystallise.



⑤ Filter to collect the crystals. Then, wash the crystals with a little cold distilled water to remove impurities. Dry the crystals between a few sheets of filter paper.



Note!
The method is not suitable for **very reactive** or **unreactive metals**.

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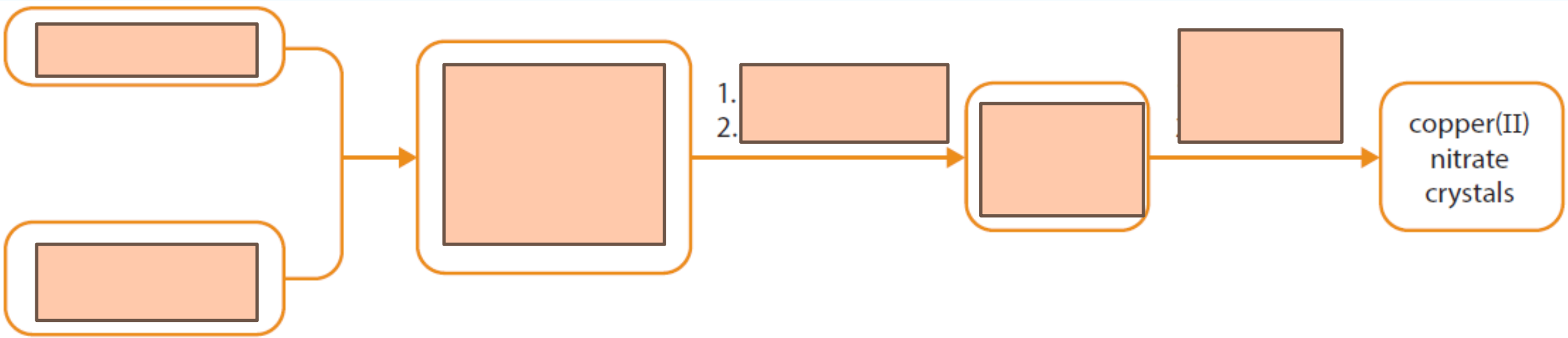
Method 1: Reaction of Acid With an Insoluble Substance

Preparation of Copper(II) Nitrate

→ $Cu(NO_3)_2$ + _



9.2 How Are Salts Prepared?

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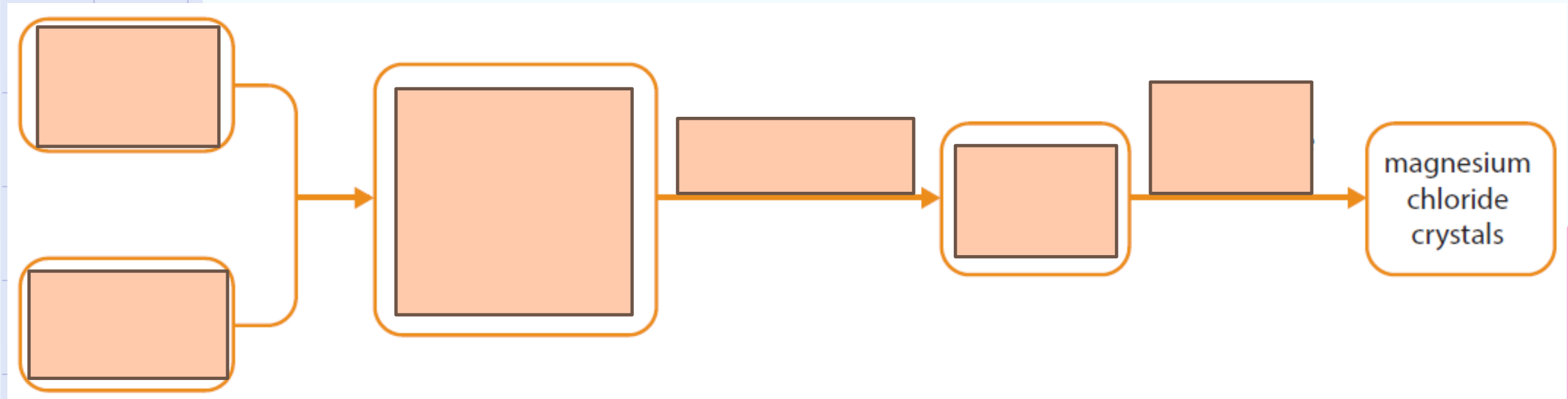
Method 1: Reaction of Acid With an Insoluble Substance

Preparation of Magnesium Chloride

- [redacted] $\rightarrow MgCl_2$ [redacted] + [redacted]



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Think!

Lead(II) sulfate cannot be prepared using the reaction between lead metal with a solution of dilute sulfuric acid. Suggest why this is so.

$$Pb(s) + H_2SO_4(aq) \rightarrow PbSO_4(s) + H_2(g)$$

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Lead(II) sulfate cannot be prepared by the reaction of an acid with lead metal. This is because an insoluble layer will form around the metal, preventing the lead metal from reacting further with the acid.

$$Pb(s) + H_2SO_4(aq) \rightarrow PbSO_4\mathbf{(s)} + H_2(g)$$

What other salts cannot similarly be formed by reacting a metal with sulfuric acid??

Calcium and barium metals (chem, bio, phy)

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Method 2: Titration

- This method is used to prepare “SPA” [sodium, potassium (Group 1) and ammonium] salts.

- General equations for this method:
  - acid + alkali (soluble base) ⟶ SPA salt + water
  - acid + soluble carbonate ⟶ SPA salt + water + carbon dioxide

- In titration, both reactants are soluble. **Exact volumes** of the starting materials must be used to get the pure salt.

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Method 2: Titration

Preparation of Sodium Nitrate

Step 1	Determine if the salt is soluble in water.	Sodium nitrate is soluble in water. Na^+ can come from Na, NaOH or Na_2CO_3. — $NaNO_3$ — NO_3^- comes from HNO_3.
Step 2	Identify the starting materials.	• Possible starting materials: Nitric acid and sodium hydroxide or sodium carbonate • Sodium metal is highly reactive and should not be used.

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Method 2: Titration
Preparation of Sodium Nitrate

Step 3	Determine if the starting materials are soluble in water.	• Sodium nitrate, nitric acid, sodium hydroxide and sodium carbonate are soluble in water. • Method 2 can be used.
Step 4	Select the starting materials.	• Dilute nitric acid with aqueous sodium hydroxide:

dilute nitric acid + aqueous sodium hydroxide ⟶ sodium nitrate + water

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Method 2: Titration

1. Titrate the acid with the alkali, with a suitable indicator, to determine the exact volumes of the two solutions.
2. Repeat the titration, without the indicator, to form the required salt.
3. Heat the solution until it is saturated.
4. Leave the solution to cool for crystallisation to occur.
5. Filter and wash the crystals with a little cold water.
6. Dry crystal with filter paper.

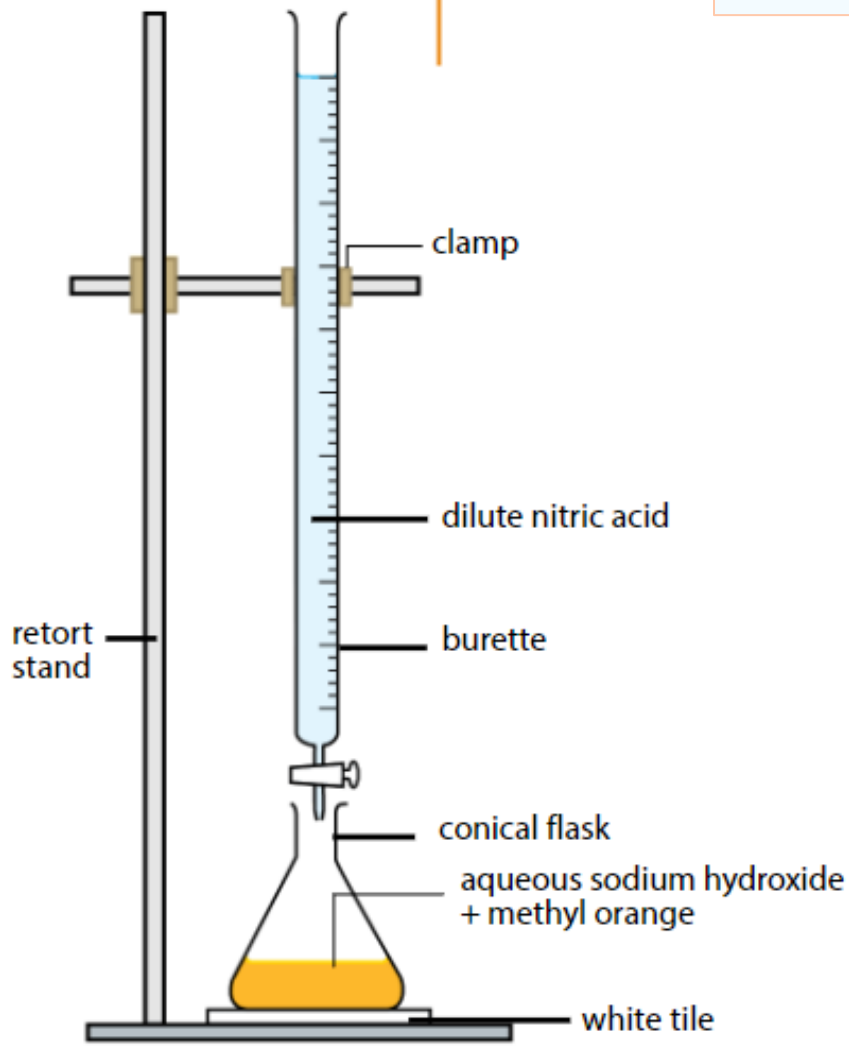

Figure 9.8 Titration of aqueous sodium hydroxide with dilute nitric acid

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Method 3: Precipitation

- This method is used to prepare an insoluble salt by mixing **two solutions.**
- General equation:

aqueous solution **AB** + aqueous solution **XY** → insoluble salt **AY** + aqueous solution **XB**

- Solution **A**B contains the cation
- Solution X**Y** contains the anion

- The salt can be separated from the starting materials by filtration.

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Method 3: Precipitation

Preparation of Barium Sulfate

Step 1	Determine if the salt is soluble in water.	Barium sulfate is insoluble in water. Ba^{2+} can come from $Ba(NO_3)_2$. — $BaSO_4$ — SO_4^{2-} can come from H_2SO_4 or any soluble sulfate.
Step 2	Identify the suitable method and starting materials.	• Method 3 can be used. • Possible starting materials: Barium nitrate and sulfuric acid or another soluble sulfate barium nitrate + sodium sulfate ⟶ barium sulfate + sodium nitrate
Step 3	Select the starting materials.	• Barium nitrate and aqueous sodium sulfate

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Think!

When a student tried to make the salt, $BaSO_4$ using $BaCO_3$ and a solution of dilute sulfuric acid, he noticed bubbles of CO_2 formed initially but the reaction soon stops. Why is this so?

Why cannot use Method 1 to make insoluble salts?

$$BaCO_3(s) + H_2SO_4(aq) \rightarrow BaSO_4(s) + H_2O(g) + CO_2(g)$$

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The insoluble barium sulfate formed will cover the solid barium carbonate and prevent the barium carbonate from reacting further with the acid.

$$BaCO_3(s) + H_2SO_4(aq) \rightarrow BaSO_4(s) + H_2O(g) + CO_2(g)$$

What other salts cannot similarly be formed by reacting a metal carbonate with sulfuric acid??

Calcium sulfate and lead sulfate (chem, bio, phy)

Let's Map It

Salts

can be classified as

Soluble salts

- All sodium, potassium and ammonium salts
- All nitrates
- All chlorides except $PbCl_2$ and $AgCl$
- All sulfates except $BaSO_4$, $CaSO_4$ and $PbSO_4$

can be prepared by

if the starting materials are insoluble in water

Reactions of acids with metals, insoluble bases or insoluble carbonates

if the starting materials are soluble in water

Titration

Insoluble salts

- $PbCl_2$ and $AgCl$
- $BaSO_4$, $CaSO_4$ and $PbSO_4$
- All carbonates except Na_2CO_3, K_2CO_3 and $(NH_4)_2CO_3$

can be prepared by

Precipitation

Summary of Lesson

- Before deciding on the method to prepare a salt, we must consider the following:
  - The solubility of the salt in water
  - The solubility of the starting materials in water
- Soluble salts are prepared from reactions of acids:
  - Reaction of an acid with an insoluble base/carbonates & metals
  - Reaction of an acid with a soluble base or carbonate (titration)
  - Insoluble salts are prepared by the precipitation method.