Thinking Pathways Education

# 📝 O-Level Chemistry Notes: Preparation of Salts

### For Pure/Combined Chemistry Students

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# 🎯 Learning Outcomes

- **Use solubility rules** to predict whether a salt is soluble or insoluble in water.
- **Choose the correct preparation method** (precipitation, acid reactions, or titration) for a given salt.
- **Describe the experimental steps** clearly, including filtration, washing, crystallisation, and drying.
- **Write balanced word and chemical equations** (with state symbols) for salt preparation reactions.
- **Explain why a method is chosen** based on solubility and whether reactants are soluble/insoluble.

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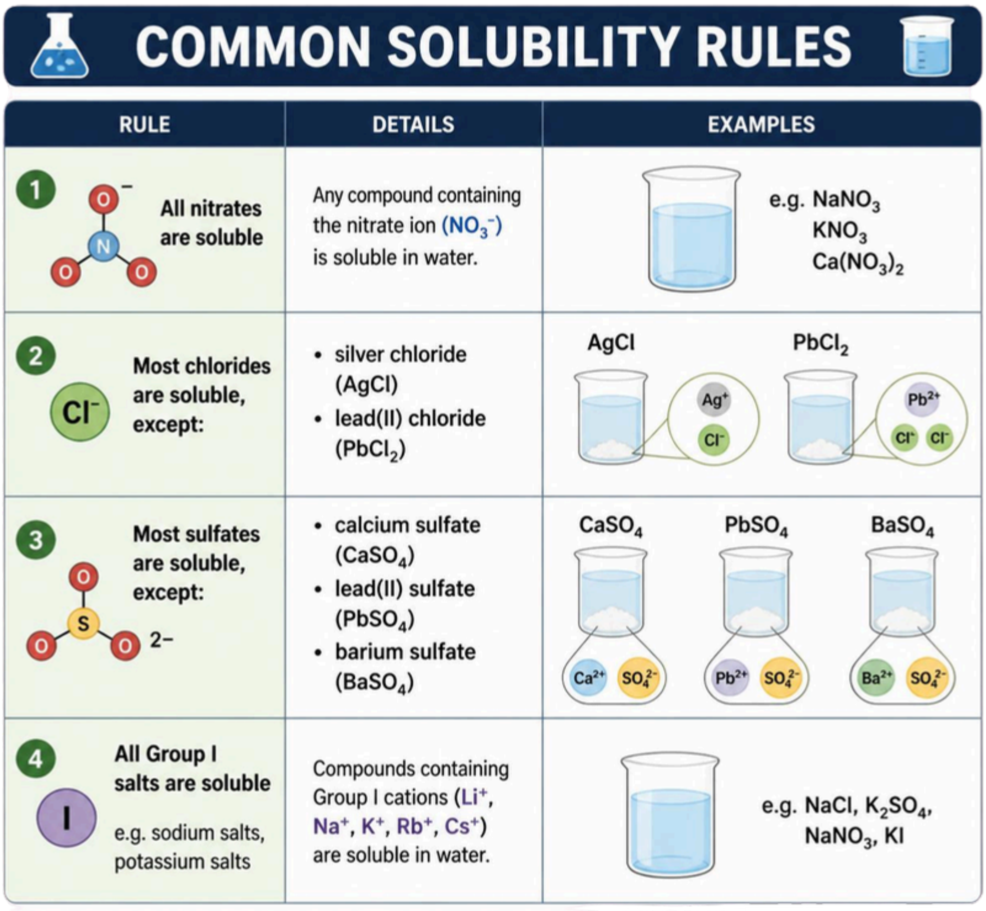
# 💡 The Big Idea: 3 Methods of Salt Preparation

The method you choose depends mainly on **whether the salt is soluble in water**. If the salt is insoluble, you form it as a precipitate. When preparing a soluble salt, the final salt must not be contaminated by excess acid or alkali. The methods are:

1. **Precipitation**
2. **Acid Reactions (Adding Excess Method)**
3. **Titration**

# 📋 Solubility Rules You Must Know

| Rule | Exceptions/Notes |
|---|---|
| All nitrates are soluble. | No common exceptions at O-Level. |
| Most chlorides are soluble. | Except **AgCl** and **$PbCl_2$** (insoluble). |
| Most sulfates are soluble. | Except **$CaSO_4$, $PbSO_4$, $BaSO_4$** (insoluble). |
| All Group I salts are soluble. | Group I: $Li^+$, $Na^+$, $K^+$ (and others). Their salts dissolve in water. |
| All ammonium salts are soluble. | Any salt containing **$NH_4^+$** is soluble. |



# 🤔 How to Choose the Correct Method

**Step 1: Is the salt soluble in water?**

If **No (insoluble)** → use **Method 1: Precipitation**.

If **Yes (soluble)** → go to Step 2.

**Step 2: Is the salt a Group I salt or an ammonium salt?**

If **Yes** → use **Method 3: Titration**.

If **No** → use **Method 2: Acid Reactions (Adding Excess Method)**.

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# ⚗️ Method 1: Precipitation

**Used for:** preparing **insoluble salts**.

**Main Concept:** Mix **two soluble solutions** so that an **insoluble salt** forms as a precipitate.

> **Pattern:** S + S → I

**Examples (insoluble salts):**

- silver chloride ($AgCl$)
- calcium sulfate ($CaSO_4$)
- lead(II) sulfate ($PbSO_4$)
- barium sulfate ($BaSO_4$)

**Steps:**

1. Prepare two **soluble salt solutions** containing the required ions.
2. Mix the two solutions in a beaker.
3. Stir thoroughly to ensure precipitation is complete.
4. Filter the mixture to collect the precipitate as the **residue**.
5. Wash the residue with **distilled water**.

6. Dry the residue between filter papers.

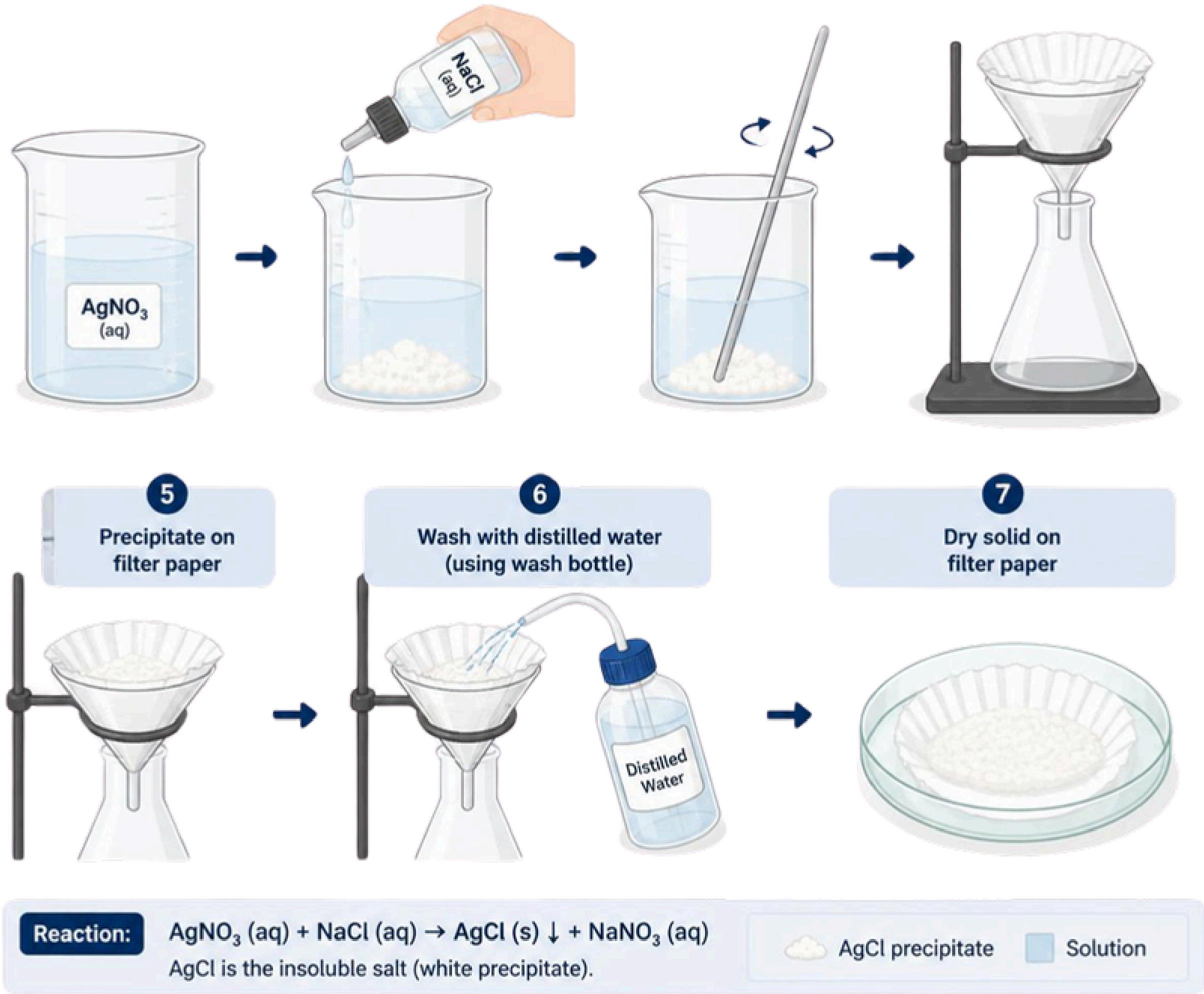
**Worked Example: Preparation of silver chloride (AgCl)**

**Word equation:** silver nitrate + sodium chloride → silver chloride + sodium nitrate

**Chemical equation:** $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

**Observation:** A **white precipitate** forms.

**Why washing is important:** Washing removes **soluble impurities** (e.g. $NaNO_3(aq)$) that stick to the precipitate, so the final salt is purer.



# 🧪 Method 2: Acid Reactions (Adding Excess Method)

**Used for:** preparing **soluble salts** that are **NOT** Group I salts and **NOT** ammonium salts.

**Main Concept:** React an acid with an **insoluble solid** (metal / base / carbonate) added in **excess**, then crystallise the salt from the filtrate.

- **acid + metal** → salt + hydrogen ($H_2$)
- **acid + insoluble base** → salt + water ($H_2O$)
- **acid + insoluble carbonate** → salt + water ($H_2O$) + carbon dioxide ($CO_2$)

> **Pattern:** S + I → S

**Why add solid in excess?**

Adding the solid in excess ensures **all the acid is completely used up**. Any extra solid is **insoluble**, so it can be removed easily by filtration, leaving a salt solution without leftover acid.

**General Steps:**

1. Warm the acid gently in a beaker (speeds up reaction).
2. Add the insoluble solid a little at a time while stirring.
3. Continue adding until **excess solid remains** and no more reacts.
4. Filter to remove the excess solid (residue).
5. Collect the **filtrate** (salt solution).
6. Heat the filtrate to **near saturation** (do not boil to dryness).
7. Allow the hot saturated solution to cool to form crystals.
8. Filter to collect the crystals.
9. Dry the crystals between filter papers.

> **Worked Example 1: Copper(II) sulfate from copper(II) oxide (CuO)**
> **Word equation:** sulfuric acid + copper(II) oxide → copper(II) sulfate + water
> **Chemical equation:** $H_2SO_4(aq) + CuO(s) \rightarrow CuSO_4(aq) + H_2O(l)$
> **Explanation:** CuO is an **insoluble base**, so it can be added in excess and filtered off.

**Worked Example 2: Calcium nitrate from calcium carbonate ($CaCO_3$)**
**Word equation:** nitric acid + calcium carbonate → calcium nitrate + water + carbon dioxide
**Chemical equation:** $2HNO_3(aq) + CaCO_3(s) \rightarrow Ca(NO_3)_2(aq) + H_2O(l) + CO_2(g)$
**Explanation:** $CaCO_3$ is an **insoluble carbonate**; excess solid removes leftover acid.

**Worked Example 3: Magnesium sulfate from magnesium oxide (MgO)**
**Word equation:** sulfuric acid + magnesium oxide → magnesium sulfate + water
**Chemical equation:** $H_2SO_4(aq) + MgO(s) \rightarrow MgSO_4(aq) + H_2O(l)$
**Explanation:** Add excess MgO so all acid is used up, then filter off unreacted MgO.

# 🔬 Method 3: Titration

**Used for:** preparing **soluble salts** of **Group I metals** or **ammonium** ($NH_4^+$).
**Examples:**

- sodium chloride ($NaCl$)
- potassium nitrate ($KNO_3$)
- ammonium sulfate ($(NH_4)_2SO_4$)

**Why titration is needed:** Both reactants are **soluble**, so you cannot add one in excess and filter it off. You must use **exact volumes** so there is no leftover acid or alkali.
**Main Concept:** Use a titration to find the **exact neutralisation volumes**, then repeat without indicator to obtain a pure salt solution for crystallisation.

> **Pattern:** S + S → S

**General Steps:**

1. Pipette a measured volume of acid into a conical flask.
2. Add 2–3 drops of a suitable indicator.
3. Fill the burette with alkali (or the other solution).
4. Add the alkali slowly while swirling the flask.
5. Stop at the **end-point** (indicator just changes colour).
6. Record the titre (volume used).
7. Repeat the titration to obtain consistent titres.
8. Repeat the reaction again using the **same exact volumes** but **WITHOUT indicator**.
9. Heat the solution to near saturation, then cool to crystallise.
10. Filter off the crystals and dry them between filter papers.

> **Important Note:** The experiment is repeated **without indicator** because indicators are impurities. If indicator is present, it contaminates the crystals and affects purity/colour.

**Why universal indicator is not used:** Universal indicator changes colour over a **range** of pH values, so there is **no sharp end-point**. A suitable indicator such as phenolphthalein or methyl orange may be used, depending on the acid and alkali involved.

**Worked Example 1: Sodium chloride (NaCl)**

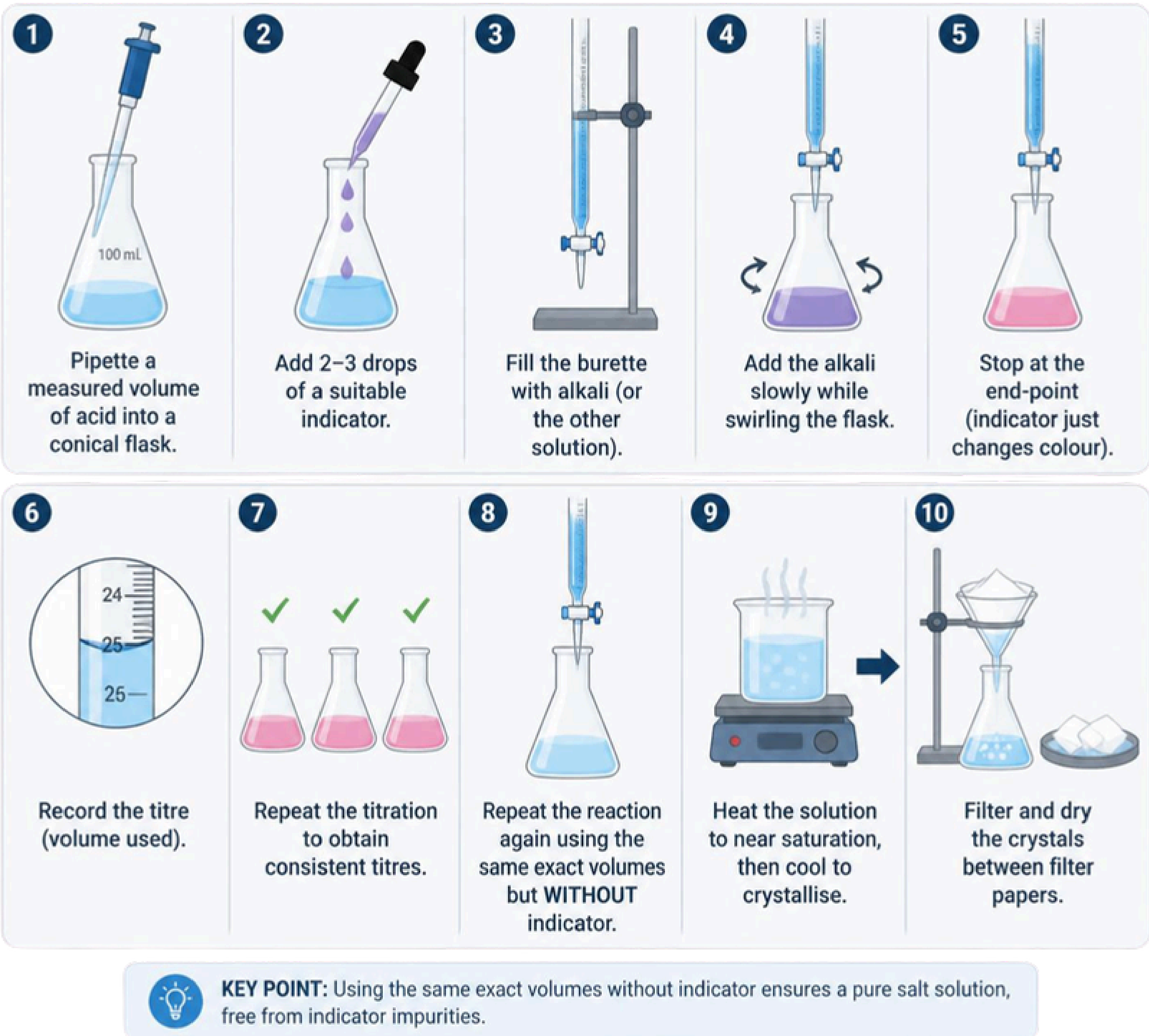
**Word equation:** hydrochloric acid + sodium hydroxide → sodium chloride + water

**Chemical equation:** $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

**Worked Example 2: Potassium nitrate ($KNO_3$)**

**Word equation:** nitric acid + potassium hydroxide → potassium nitrate + water

**Chemical equation:** $HNO_3(aq) + KOH(aq) \rightarrow KNO_3(aq) + H_2O(l)$



# 💎 Crystallisation Process

1. Heat the salt solution in an evaporating basin to **near saturation** (some water evaporates).
2. Test for near saturation: a drop placed on a cold tile forms crystals quickly, or crystals start forming at the edge of the basin.
3. Stop heating and allow the solution to cool slowly so larger crystals form.
4. Filter to collect crystals and dry between filter papers.

**Why not heat to dryness?** Heating to dryness may **decompose** some salts, produce **very small crystals**, and cause **spitting** (loss of product and safety hazard).

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# 📊 Summary: The 3 Methods at a Glance

| Method | Type of Salt Prepared | Type of Reactants | Key Idea |
|---|---|---|---|
| **1. Precipitation** | Insoluble salts (precipitates) | Two **soluble** salt solutions | Mix solutions to form an insoluble salt; filter, wash, dry. |
| **2. Acid Reactions (Excess)** | Soluble salts (not Group I / not $NH_4^+$) | Acid + solid reactant (metal/insoluble base/insoluble carbonate) | Add solid in excess to use up acid; filter; crystallise from filtrate. |
| **3. Titration** | Soluble Group I or ammonium salts | Acid + alkali (both **soluble**) | Use exact volumes (no excess); repeat without indicator; crystallise. |

# 🔍 How to Identify Reactants from Salt Name

To plan a salt preparation, identify the **positive ion (cation)** and **negative ion (anion)** in the salt name. The anion often tells you which acid to use, while the cation helps you choose a suitable base/metal/carbonate (or whether titration is needed).

| Acid | Produces |
|---|---|
| Hydrochloric acid ($HCl$) | Chlorides ($Cl^-$) |
| Nitric acid ($HNO_3$) | Nitrates ($NO_3^-$) |
| Sulfuric acid ($H_2SO_4$) | Sulfates ($SO_4^{2-}$) |

**Worked examples:**

1. **Magnesium nitrate, $Mg(NO_3)_2$:** Use **nitric acid** + an insoluble magnesium compound (e.g. $MgCO_3$) using the **adding excess method**.
2. **Ammonium sulfate, $(NH_4)_2SO_4$:** Contains $NH_4^+$, so use **titration** (e.g. $H_2SO_4$ + aqueous ammonia).
3. **Silver chloride, AgCl:** Insoluble chloride, so use **precipitation** (e.g. $AgNO_3(aq)$ + $NaCl(aq)$).

# ✍️ Common Exam Examples

**A. Sodium chloride (NaCl)**
**Method:** Titration
**Reactants:** HCl(aq) and NaOH(aq)
**Equation:** $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

**B. Copper(II) sulfate ($CuSO_4$)**
**Method:** Acid reactions (adding excess)

**Reactants:** $H_2SO_4(aq)$ and $CuO(s)$
**Equation:** $H_2SO_4(aq) + CuO(s) \rightarrow CuSO_4(aq) + H_2O(l)$

**C. Silver chloride (AgCl)**
**Method:** Precipitation
**Reactants:** $AgNO_3(aq)$ and $NaCl(aq)$
**Equation:** $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

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# ⚠️ Common Mistakes to Avoid

- **Choosing the wrong method:** Always check solubility first, then check if the salt is Group I or ammonium.
- **Using titration for non-Group I/non-ammonium salts:** Many can be made more simply by adding excess insoluble solid and filtering.
- **Forgetting state symbols:** Precipitates must be (s); solutions are (aq); water is (l); gases are (g).
- **Not adding the solid in excess (Method 2):** If acid remains, the salt solution is contaminated and crystals are impure.
- **Not washing the precipitate (Method 1):** Soluble salts (e.g. $NaNO_3$) remain on the residue and reduce purity.
- **Heating to dryness:** Can decompose salts, cause spitting, and give poor crystals.
- **Crystallising without near saturation:** If the solution is too dilute, few/no crystals form.
- **Not repeating titration without indicator:** Indicator contaminates crystals and may affect colour/purity.

## 🔑 Essential Exam Keywords

precipitate
filtrate
residue
saturated solution
crystallisation
add in excess
filter
wash with distilled water
dry between filter papers
exact volume
end-point
indicator contamination

## 📝 Model Answer Templates for Exam Questions

**Template 1: Preparing an insoluble salt (precipitation)**
1. Mix two suitable soluble salt solutions containing the required ions.
2. Stir to form a precipitate.
3. Filter to collect the precipitate as residue.
4. Wash residue with distilled water to remove soluble impurities.
5. Dry the residue between filter papers.

**Template 2: Preparing a soluble salt from an insoluble base/carbonate (adding excess)**
1. Warm dilute acid in a beaker.
2. Add insoluble base/carbonate in excess until no more reacts and excess solid remains.

3. Filter to remove excess solid.
4. Heat filtrate to near saturation.
5. Cool to crystallise, then filter and dry crystals.

**Template 3: Explaining why titration is used**
Titration is used because **both reactants are soluble**, so any excess reactant cannot be removed by filtration. Therefore, **exact volumes** are needed to ensure complete neutralisation with no leftover acid/alkali, producing a pure salt solution for crystallisation.

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# ✅ Quick Revision Checklist

- Insoluble salt → **precipitation** (S + S → I).
- Soluble salt (not Group I / not $NH_4^+$) → **adding excess** (S + I → S).
- Group I or $NH_4^+$ soluble salt → **titration** (S + S → S).
- Always include: **filter, wash (if precipitate), crystallise, dry**.
- Do not heat to dryness; heat to **near saturation**.
- Titration: repeat without indicator to avoid contamination.

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# 📚 Practice Questions

**Q1. Method selection (show reasoning)**

State the method to prepare each salt and explain why:

a) $BaSO_4$

b) $Na_2SO_4$

c) $Cu(NO_3)_2$

**Q2. Identify reactants**

For each salt, name a suitable acid and a suitable second reactant (metal/base/carbonate/alkali), then write the balanced chemical equation with state symbols:

a) $MgCl_2$

b) $KNO_3$

c) $PbSO_4$

**Q3. Explain key steps**

a) Why is the precipitate washed with distilled water in precipitation?

b) Why must the solid be added in excess in Method 2?

c) Why is the titration repeated without indicator before crystallisation?

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# ✔️ Answers to Practice Questions

**Answer 1:** Methods

a) **$BaSO_4$: Precipitation** because $BaSO_4$ is insoluble (sulfate exception). Mix two soluble solutions such as $BaCl_2$(aq) and $Na_2SO_4$(aq).

b) **$Na_2SO_4$: Titration** because sodium salts (Group I) are soluble and both reactants are soluble (e.g. $H_2SO_4$(aq) and NaOH(aq)).

c) **$Cu(NO_3)_2$: Acid reactions (adding excess)** because nitrates are soluble and $Cu^{2+}$ is not Group I or $NH_4^+$. Use $HNO_3$(aq) with an insoluble copper compound such as CuO(s) added in excess.

**Answer 2:** Reactants and equations

a) **$MgCl_2$:** Use HCl(aq) + $MgCO_3$(s) (adding excess method).
Chemical equation: 2HCl(aq) + $MgCO_3$(s) → $MgCl_2$(aq) + $H_2O$(l) + $CO_2$(g)

b) **$KNO_3$:** Use $HNO_3$(aq) + KOH(aq) (titration method).
Chemical equation: $HNO_3$(aq) + KOH(aq) → $KNO_3$(aq) + $H_2O$(l)

c) **$PbSO_4$:** Use precipitation because $PbSO_4$ is insoluble (sulfate exception).
Example reactants: $Pb(NO_3)_2$(aq) + $Na_2SO_4$(aq).
Chemical equation: $Pb(NO_3)_2$(aq) + $Na_2SO_4$(aq) → $PbSO_4$(s) + 2$NaNO_3$(aq)

**Answer 3:** Explanations

a) Washing removes **soluble impurities**, such as dissolved soluble salts sticking to the precipitate, improving the **purity** of the final salt.

b) Adding excess solid ensures **all acid is used up**. Any extra solid is insoluble and can be filtered off, leaving a pure salt solution.

c) Indicators are **impurities**. Repeating without indicator prevents contamination of crystals and gives a purer salt.

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