09 Salts

1 Salts and Solubility

1.1 What a salt is

A **salt** is an ionic compound made of a _____ (positive ion) and an _____ (negative ion).

- A salt forms when the hydrogen ions of an acid are replaced by metal ions or ammonium ions, e.g. in the reactions of acids with metals, bases and carbonates.
- Sulfuric acid gives **sulfates**, nitric acid gives **nitrates** and hydrochloric acid gives **chlorides**.

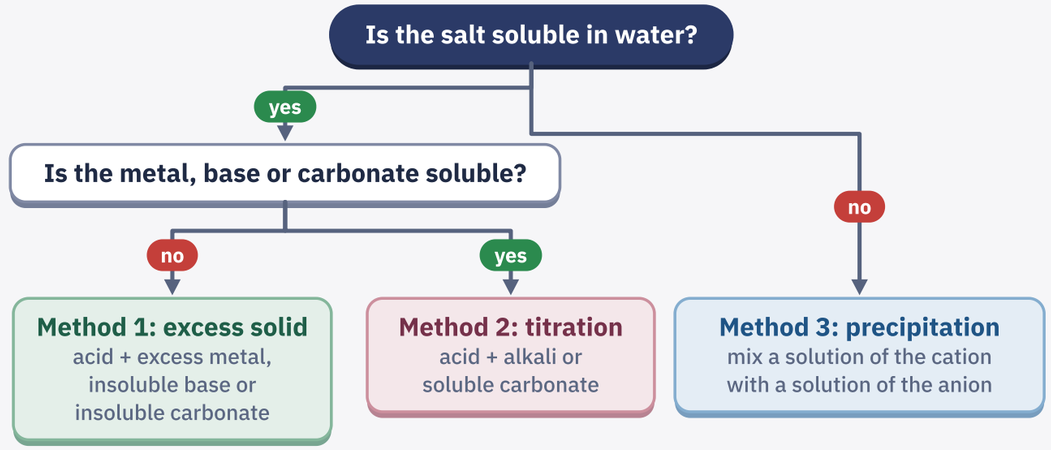
1.2 Solubility rules

Salts	Soluble in water	Insoluble in water
sodium, potassium and ammonium salts	_____	none
nitrates	all	none
chlorides	most	_____ AgCl and _____ $PbCl_2$
sulfates	most	_____ $BaSO_4$, _____ $PbSO_4$ and calcium sulfate $CaSO_4$ (sparingly soluble)
carbonates	sodium, potassium and ammonium carbonates only	_____, e.g. $CaCO_3$, $CuCO_3$, $ZnCO_3$
hydroxides	sodium, potassium and ammonium hydroxides (calcium hydroxide is slightly soluble)	all others, e.g. $Cu(OH)_2$, $Fe(OH)_3$

EXAM TIP Check the solubility of the salt **and** of each starting material before you choose a method to prepare a salt.

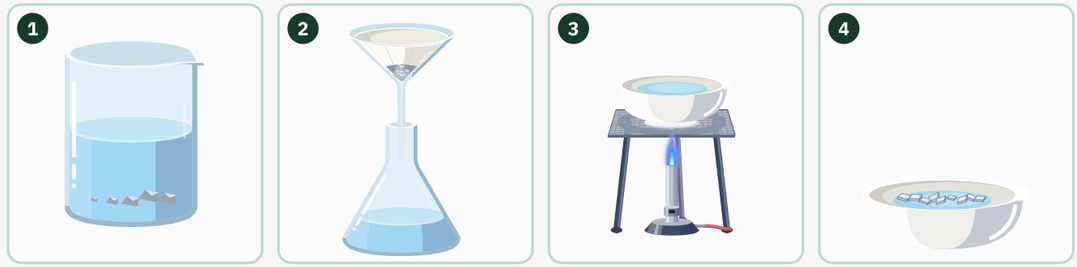
2 Preparing Salts

2.1 Choosing a method



2.2 Method 1: an acid and an excess insoluble substance

acid + metal → salt + hydrogen
acid + insoluble base → salt + water
acid + insoluble carbonate → salt + water + carbon dioxide



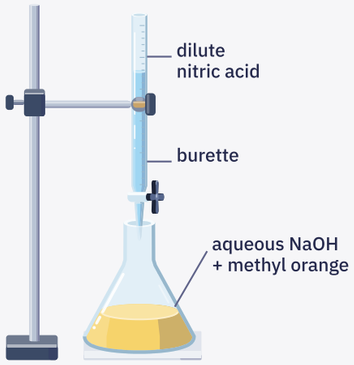
1. add excess zinc to the acid
2. filter off the excess zinc
3. heat the filtrate until saturated
4. cool to crystallise, then filter, wash and dry

- Add the solid in _____, so that all the acid is used up and the salt is not contaminated with acid. The excess solid is insoluble, so it is removed by **filtration**.
- Heat the filtrate until _____: a glass rod dipped in and removed shows small crystals forming as it cools.
- Do not use very reactive metals (they react violently) or unreactive metals such as copper (they do not react with dilute acids). Use the metal oxide or carbonate instead.

$H_2SO_4(aq) + Zn(s) \rightarrow ZnSO_4(aq) + H_2(g)$
$2HNO_3(aq) + CuO(s) \rightarrow Cu(NO_3)_2(aq) + H_2O(l)$
$2HCl(aq) + MgCO_3(s) \rightarrow MgCl_2(aq) + CO_2(g) + H_2O(l)$

2 Preparing Salts (continued)

2.3 Method 2: titration



acid + alkali → salt + water

acid + soluble carbonate → salt + water + carbon dioxide

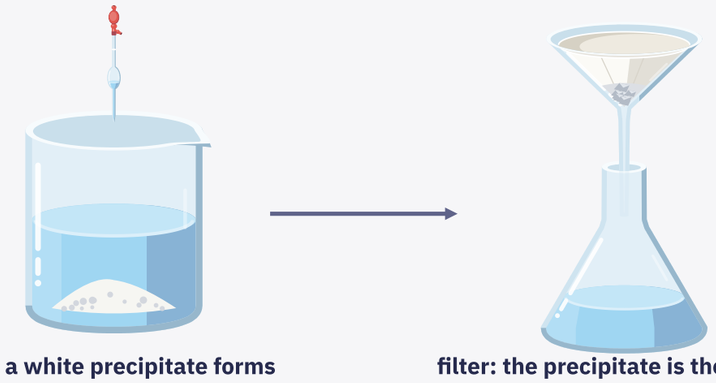
- Used for **sodium, potassium and ammonium** salts, where all the starting materials are soluble.
- An excess of either reactant cannot be filtered off, so the volumes must be _____.

1. Pipette 25.0 cm^3 of the alkali into a conical flask and add a few drops of indicator, e.g. methyl orange.
2. Add the acid from a burette until the indicator just changes colour (the **end-point**). Record the volume of acid used.
3. Repeat with the same volumes but _____, which would make the salt impure.
4. Heat the solution until saturated, cool to crystallise, then filter, wash with a little cold distilled water and dry the crystals.

$HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(l)$

2.4 Method 3: precipitation

An **insoluble** salt is made by mixing two solutions: one contains its _____ and the other contains its _____. The salt forms as a precipitate.



mix: a white precipitate forms **filter: the precipitate is the residue**

1. Mix the two solutions and stir until no more precipitate forms.
2. Filter to collect the precipitate as the residue.
3. Wash it with _____ to remove soluble impurities, then dry it between sheets of filter paper.

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

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

2 Preparing Salts (continued)

2.5 Planning a preparation

Salt	Soluble?	Method	Starting materials
zinc sulfate	yes	excess insoluble substance	dilute sulfuric acid + excess zinc, zinc oxide or zinc carbonate
copper(II) nitrate	yes	excess insoluble substance	dilute nitric acid + excess copper(II) oxide or carbonate (not copper)
sodium nitrate	yes	titration	dilute nitric acid + aqueous sodium hydroxide or sodium carbonate (not sodium)
barium sulfate	_____	precipitation	aqueous barium nitrate + dilute sulfuric acid or any soluble sulfate

WORKED EXAMPLE Describe how you would prepare lead(II) chloride from lead(II) carbonate, dilute nitric acid and aqueous potassium chloride.

Lead(II) chloride is insoluble, so it is made by **precipitation**. Lead(II) carbonate is also insoluble, so first turn it into a soluble lead(II) salt.

Add **excess** lead(II) carbonate to dilute nitric acid: $PbCO_3(s) + 2HNO_3(aq) \rightarrow Pb(NO_3)_2(aq) + CO_2(g) + H_2O(l)$.

Filter off the unreacted lead(II) carbonate. The filtrate is aqueous lead(II) nitrate.

Add excess aqueous potassium chloride to the filtrate: $Pb(NO_3)_2(aq) + 2KCl(aq) \rightarrow PbCl_2(s) + 2KNO_3(aq)$.

Filter to collect the lead(II) chloride, wash it with distilled water and dry it between sheets of filter paper.

EXAM TIP In a description, name the reagents, say which one is in excess and why, and give every step: filter, heat to saturation, cool, filter, wash and dry.

2.6 Common mistakes

Mistake	Why it is wrong
Using sodium or potassium metal with an acid	Very reactive metals react _____ with acids.
Using copper or silver with a dilute acid	Unreactive metals do _____ with dilute acids.
Not adding the solid in excess (method 1)	Some acid is left, so the salt is _____ with acid.
Leaving the indicator in (method 2)	The indicator makes the salt _____.
Using method 1 for a sodium salt	Sodium compounds are soluble, so an excess cannot be _____ off.
Washing crystals with a lot of water	Use a little **cold** distilled water, or the crystals dissolve.