Salts and Titration

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Salts and Titration

A salt is the ionic product of an acid-base reaction. Knowing which salts are soluble, which preparation method to apply, and how to perform a volumetric calculation are among the most tested skills in CSEC Chemistry.

Salts: Types and Basicity

A **salt** is the ionic compound formed when the replaceable hydrogen of an acid is fully or partially replaced by a metal ion or ammonium ion.

A **normal salt** is formed when all replaceable hydrogen atoms are replaced:

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$$

An **acid salt** is formed when only some of the replaceable hydrogen is replaced — the salt still contains ionisable hydrogen:

$$H_2SO_4 + NaOH \rightarrow NaHSO_4 + H_2O$$

The **basicity** of an acid is the number of replaceable hydrogen atoms per molecule:

- HCl — monobasic (one replaceable H)
- H_2SO_4 — dibasic (two replaceable H)
- H_3PO_4 — tribasic (three replaceable H)

Solubility Rules

The preparation method depends on whether the target salt is soluble or not, so check solubility first.

Knowing which salts dissolve in water determines which preparation method to use:

Salt type	Solubility	Exceptions

Nitrates	All soluble	None
Chlorides	Most soluble	AgCl, PbCl, Hg_2Cl_2 (all insoluble)
Sulfates	Most soluble	$BaSO_4$, $PbSO_4$, $SrSO_4$ (insoluble); $CaSO_4$ (slightly soluble)
Carbonates	Most insoluble	Na_2CO_3, K_2CO_3, $(NH_4)_2CO_3$ (soluble)
Hydroxides	Most insoluble	NaOH, KOH, $Ba(OH)_2$ (soluble); $Ca(OH)_2$, $Sr(OH)_2$ (slightly soluble)
Sodium, potassium, ammonium salts	All soluble	None

💡 **Tip**

Memorising the solubility rules

Use two mnemonics:

- **NAG** — **N**itrates, **A**mmonium salts, and **G**roup I (sodium, potassium) salts are **all soluble**, no exceptions.
- **SAG** — **S**ulfates, most **A**nions (chlorides), and most others are **generally soluble** — but each has exceptions to learn separately (AgCl, PbCl, $BaSO_4$, $PbSO_4$).

For the insoluble side: **Carbonates and Hydroxides are mostly insoluble** — except those covered by NAG (Na^+, K^+, NH_4^+ versions are always soluble).

Quick check: if the salt contains Na^+, K^+, NH_4^+, or NO_3^- → always soluble. If it's a carbonate or hydroxide of anything else → almost certainly insoluble.

Methods of Salt Preparation

There are three preparation methods. Which one applies depends on whether the salt is soluble or insoluble, and whether the base used to make it is soluble or not.

Soluble Salts — Using Excess Insoluble Base

Used when the base (metal oxide, hydroxide, or carbonate) is insoluble.

- 1. Add excess base to the acid until no more dissolves and the solid remains.
- 2. Filter off the excess base.
- 3. Evaporate the filtrate to concentrate it.
- 4. Allow to crystallise; filter and dry the crystals.

Excess base ensures all the acid reacts. It can be filtered off because it is insoluble and the salt is in solution.

Soluble Sodium, Potassium, or Ammonium Salts — By Titration

Used when the base is NaOH, KOH, or NH_3(aq) — all soluble, so they cannot be filtered off.

- 1. Use an indicator to find the exact volume of acid that neutralises a known volume of alkali.
- 2. Repeat the titration using the same volumes but without the indicator (the indicator would contaminate the product).
- 3. Evaporate and crystallise the pure salt.

Insoluble Salts — By Precipitation

- 1. Mix solutions of two soluble salts, each containing one of the required ions.
- 2. The insoluble salt precipitates immediately.
- 3. Filter, wash with distilled water, and dry.

$$\mathrm{Pb(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow PbSO_4(s) \downarrow + 2NaNO_3(aq)}$$

Uses and Dangers of Salts

Salts are not only laboratory products. Many are everyday substances in food, medicine, and construction, though some carry health risks at high doses.

Salt	Use
NaCl (sodium chloride)	Food seasoning, preservation, de-icing roads
$NaHCO_3$ (baking powder)	Leavening agent in baking, antacid
$CaCO_3$ (calcium carbonate)	Cement and concrete manufacture
$CaSO_4$·½H_2O (plaster of Paris)	Casts, moulds, wall plaster
$MgSO_4$·7H_2O (Epsom salts)	Laxative, bath soaks
$NaNO_3$ (sodium nitrate)	Fertiliser, food preservative
$NaNO_2$ (sodium nitrite)	Cured meat preservation

Dangers: sodium nitrate and nitrite, when consumed in excess, are potentially carcinogenic and have been implicated in brain damage in infants. Their use in food preservation is regulated.

Neutralisation and Titration

Making a salt by titration requires knowing exactly when neutralisation is complete, and calculating concentrations from the volumes used. That is what volumetric analysis covers.

Neutralisation is always exothermic — the formation of water from H^+ and OH^- releases heat. This can be used in a **thermometric titration**: the temperature peaks at the equivalence point. Plotting temperature against volume gives two straight lines whose intersection marks the end point.

In standard titrations, an **indicator** signals the end point by colour change:

- **Phenolphthalein:** colourless (acid) to pink (alkali)
- **Methyl orange:** red (acid) to yellow (alkali)

Volumetric Analysis Calculations

$$n = c \times V \quad (V \text{ in dm}^3,\ 1 \text{ dm}^3 = 1000 \text{ cm}^3)$$

📋 **Example**

25.0 cm^3 of 0.10 mol dm^{-3} NaOH was titrated with HCl. 20.0 cm^3 of acid was required. Find the concentration of the HCl.

Equation: $HCl + NaOH \rightarrow NaCl + H_2O$ (1 : 1 ratio)

Moles NaOH = 0.10 × 0.025 = 0.0025 mol
Moles HCl = 0.0025 mol (1 : 1 ratio)
Concentration HCl = 0.0025 / 0.020 = **0.125 mol dm^{-3}**

📋 **Example**

20.0 cm^3 of H_2SO_4 was neutralised by 30.0 cm^3 of 0.20 mol dm^{-3} NaOH. Find the concentration of the H_2SO_4.

Equation: $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$ (1 : 2 ratio)

Moles NaOH = 0.20 × 0.030 = 0.006 mol
Moles H_2SO_4 = 0.006 / 2 = 0.003 mol (1 : 2 ratio)
Concentration H_2SO_4 = 0.003 / 0.020 = **0.15 mol dm^{-3}**