

Finding concentration by titration

Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Lesson

Quick answer: A titration finds an unknown concentration by measuring the exact volume of one solution that reacts with a known volume of another. A burette adds the acid, an indicator marks the end point, and the concentration follows from $n = c \times V$ and the mole ratio in the balanced equation.

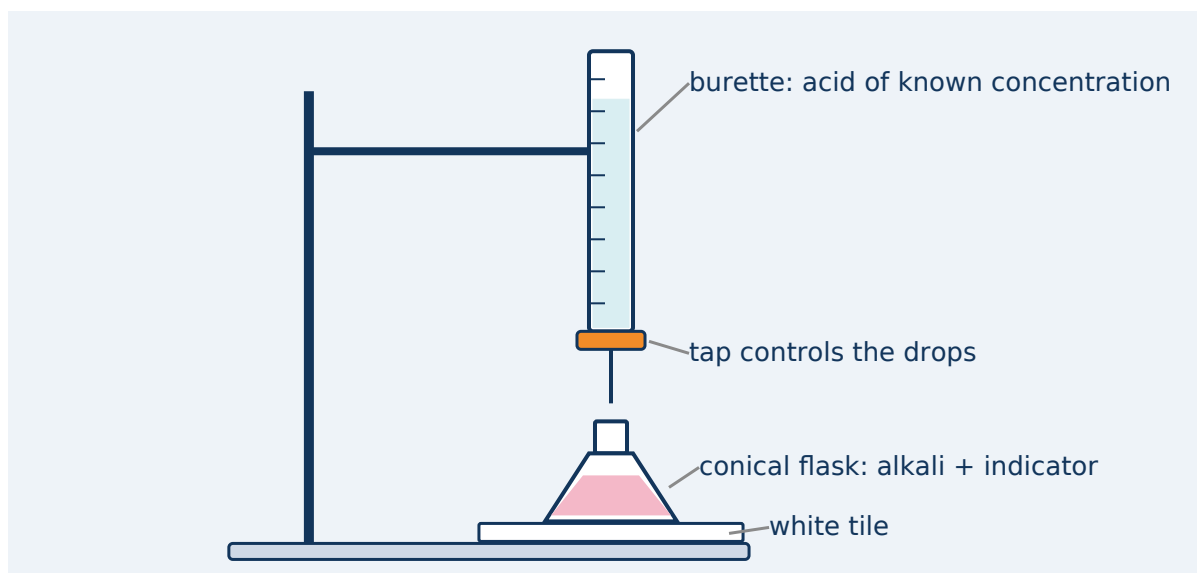
Level: Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** GCSE C4 RP

What is a titration?

Definition

A **titration** is a method that finds the concentration of a solution by measuring the exact volume of it that reacts with a known volume of another solution of known concentration.

In an acid-alkali titration, a **burette** delivers the acid drop by drop into a conical flask. A **pipette** has already measured exactly 25.0 cm^3 of alkali into the flask, together with a few drops of indicator. The **end point** is the moment the indicator changes colour, showing that the acid and alkali have reacted in exactly the proportions of the equation.



Titration set-up: acid from the burette is run into the alkali in the flask.

How do you carry out a titration accurately?

Good technique decides whether the results are reliable. The steps below give consistent titres, which are the volumes of acid used.

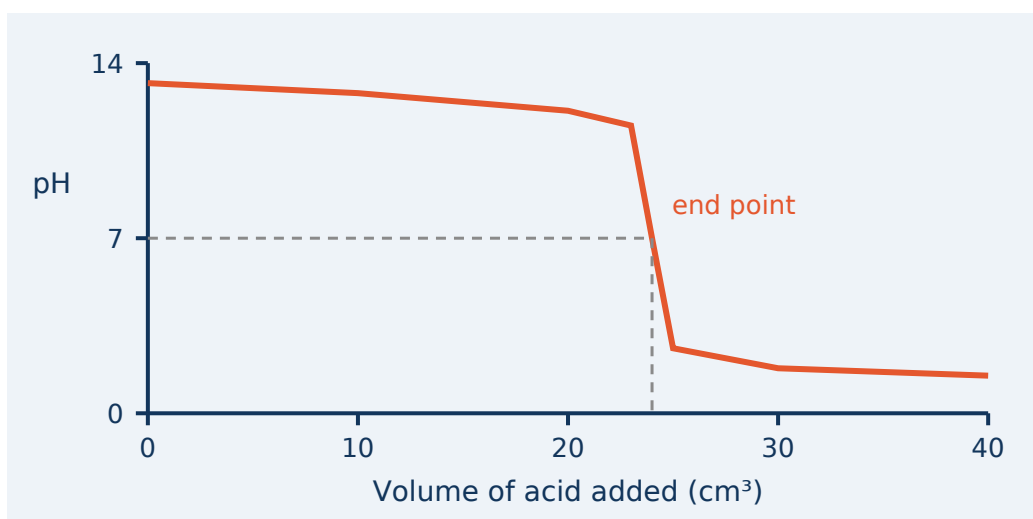
1. Rinse the burette with a little of the acid, then fill it and open the tap briefly to remove air from the tip.

2. Use a pipette filler to transfer 25.0 cm³ of alkali into a clean conical flask and add two or three drops of indicator.
3. Record the starting reading, with your eye level with the bottom of the meniscus.
4. Run in the acid quickly for a rough titration, swirling all the time.
5. Repeat accurately, adding acid drop by drop near the end point, until one drop changes the colour permanently.
6. Repeat until you have two or three **concordant** titres, results within 0.10 cm³ of each other, and take their mean.

Common mistake

Do not include the rough titration, or any result that is not concordant, in the mean. The rough run only tells you where to slow down.

Indicator	Colour in acid	Colour in alkali	Best for
Methyl orange	Red	Yellow	Strong acid with weak alkali, such as HCl and NH ₃
Phenolphthalein	Colourless	Pink	Strong alkali with weak acid, such as NaOH and CH ₃ COOH
Litmus	Red	Blue	Not used: colour change is too gradual



pH curve for acid added to alkali: the steep drop shows the end point.

The graph shows why a sharp indicator works: just before the end point the pH drops from about 12 to about 2 with only a few drops of acid, so the colour change is sudden.

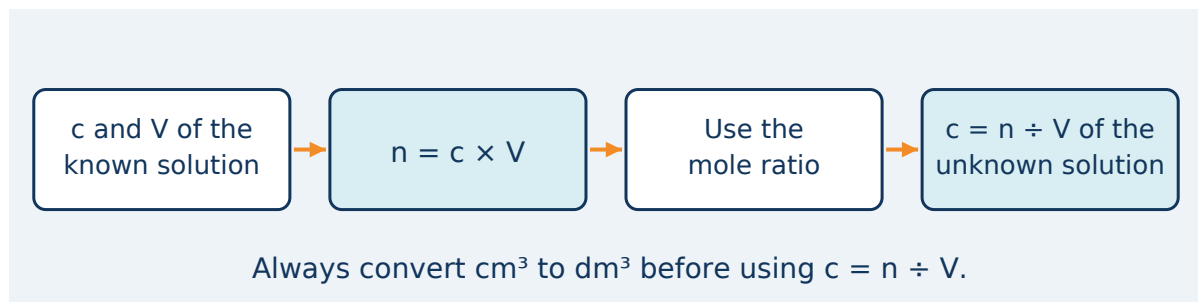
How do you calculate the concentration from a titration?

Always work in moles. Find the moles of the solution you know, use the balanced equation to find the moles of the other, then divide by its volume.

Formula

$$n = c \times V \text{ and } c = n \div V$$

n = amount (mol), c = concentration (mol/dm³), V = volume in dm³ (cm³ ÷ 1000). To convert to a mass concentration, multiply by the molar mass (g/mol).



The calculation route for every titration.

Worked example

Aarav in Pune titrates 25.0 cm³ of sodium hydroxide of unknown concentration with 0.100 mol/dm³ hydrochloric acid. The concordant titres are 22.40, 22.50 and 22.50 cm³. NaOH + HCl → NaCl + H₂O.

Mean titre = (22.40 + 22.50 + 22.50) ÷ 3 = 22.47 cm³. $n(\text{HCl}) = 0.100 \times 0.02247 = 0.002247$ mol. The ratio is 1 : 1, so $n(\text{NaOH}) = 0.002247$ mol and $c = 0.002247 \div 0.0250 = \mathbf{0.0899 \text{ mol/dm}^3}$.

Worked example

A 20.0 cm³ sample of sulfuric acid needs 24.0 cm³ of 0.100 mol/dm³ sodium hydroxide: H₂SO₄ + 2NaOH → Na₂SO₄ + 2H₂O (Ar: H = 1, S = 32, O = 16).

$n(\text{NaOH}) = 0.100 \times 0.0240 = 0.00240$ mol. The ratio acid : alkali is 1 : 2, so $n(\text{H}_2\text{SO}_4) = 0.00120$ mol. $c = 0.00120 \div 0.0200 = \mathbf{0.0600 \text{ mol/dm}^3}$, which is $0.0600 \times 98 = 5.88$ g/dm³.

Lina's tip

Put a white tile under the flask and stand over the swirl. Near the end point, stop and wash the inside of the flask with a little water from a wash bottle: it adds no moles, so it does not change the answer.

Key points to remember

- Burette adds the titrant; pipette measures a fixed volume
- End point: permanent indicator colour change
- Concordant titres agree within 0.10 cm³; use their mean
- $n = c \times V$ and $c = n \div V$, with volumes in dm³
- Use the mole ratio, then multiply by M for g/dm³

Finding concentration by titration: frequently asked questions

What is the end point of a titration?

The end point is the moment the indicator changes colour permanently, showing that the acid and alkali have reacted exactly in the ratio of the equation. It is found by adding the last few drops very slowly.

Why are concordant titres needed?

Concordant titres are within 0.10 cm^3 of each other. Getting two or three results that agree shows the technique is repeatable, and the mean of them is more reliable than a single value.

Why do we do a rough titration first?

The rough titration is a quick trial that shows roughly how much acid is needed. In the accurate runs you can add the acid fast until just before that volume and then go drop by drop.

Why is a pipette used for the alkali?

A pipette delivers one fixed volume, such as 25.0 cm^3 , with very small uncertainty. Using a measuring cylinder would add a much larger error to every calculation.

How do I convert titration results into g/dm^3 ?

First calculate the concentration in mol/dm^3 , then multiply by the molar mass in g/mol . For example, 0.0600 mol/dm^3 of H_2SO_4 is $0.0600 \times 98 = 5.88 \text{ g/dm}^3$.