Titrations

4.4.2.5 · Chemical changes · revision notes

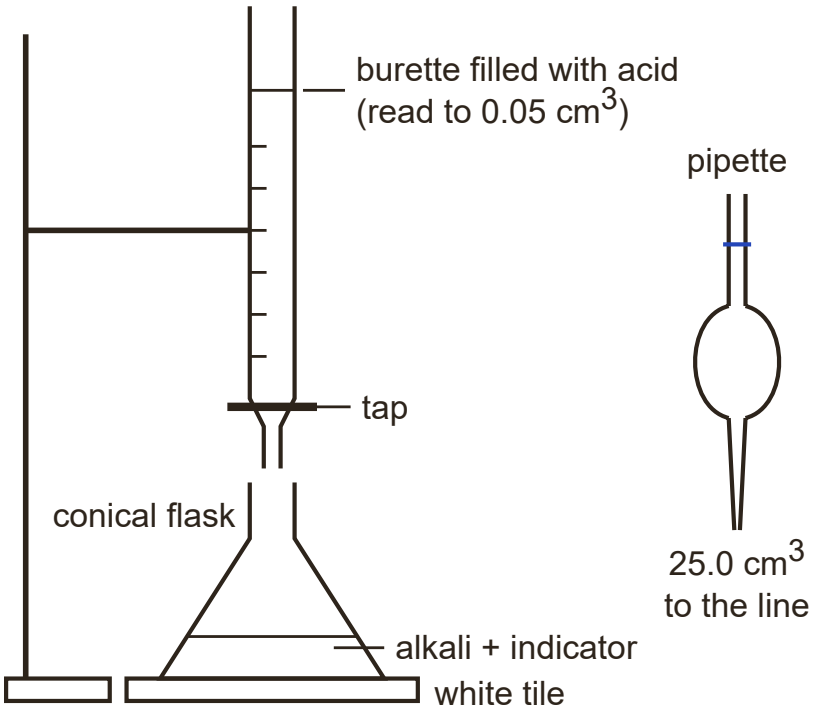
GCSE Chemistry only (not in Combined Science). How to carry out a titration to find the exact volumes of a strong acid and a strong alkali that react (required practical 2), and at Higher tier how to use the results to calculate a concentration in mol/dm^3 and g/dm^3.

Key facts

- Titre = final burette reading − initial burette reading
- $cm^3 \div 1000 = dm^3$
- concentration (mol/dm^3) = moles ÷ volume (dm^3)
- $HCl + NaOH \rightarrow NaCl + H_2O$ (1 : 1)
- Concordant titres: within 0.10 cm^3 of each other
- moles = concentration (mol/dm^3) × volume (dm^3)
- g/dm^3 = mol/dm^3 × M_r
- $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$ (1 : 2)

Method (required practical 2)

- A titration finds the exact volumes of acid and alkali that react with each other.
- 1. Use a **pipette** and pipette filler to put exactly 25.0 cm^3 of alkali (e.g. sodium hydroxide solution) into a **conical flask**.
- 2. Add a few drops of **indicator** (e.g. phenolphthalein or methyl orange) and stand the flask on a white tile.
- 3. Fill a **burette** with the acid and record the starting reading.
- 4. Add the acid while swirling the flask. Near the end point, add it **drop by drop** until the indicator **just** changes colour.
- 5. Record the final reading. Titre = final reading − initial reading.
- 6. Do a rough titration first, then repeat until you have **concordant** results (within 0.10 cm^3 of each other).



Pipette the alkali into the flask; run the acid in from the burette until the indicator just changes colour.

Getting accurate results

- Read the burette at eye level, at the bottom of the meniscus, to the nearest 0.05 cm^3.
- Use an indicator with a sharp colour change. Universal indicator is not used because its colour changes gradually.
- The white tile makes the colour change easier to see.
- Calculate the mean titre from the concordant results only, not the rough titre.

Calculations (Higher tier) Grade 7+ only

- Convert volumes to dm^3: divide cm^3 by 1000.
- moles = concentration (mol/dm^3) × volume (dm^3)
- Step 1: moles of the solution whose concentration you know. Step 2: use the balanced equation to find the moles of the other substance. Step 3: concentration = moles ÷ volume in dm^3.
- Concentration in g/dm^3 = concentration in mol/dm^3 × M_r.
- Example: 25.0 cm^3 of NaOH reacts with 20.00 cm^3 of 0.100 mol/dm^3 HCl. Moles HCl = 0.100 × 0.02000 = 0.00200 mol. The ratio is 1 : 1, so moles NaOH = 0.00200 mol. Concentration = 0.00200 ÷ 0.0250 = 0.0800 mol/dm^3, which is 0.0800 × 40 = 3.20 g/dm^3.

How to answer each type of question

6-mark: describe how to carry out a titration 4 to 6 marks **Grade 5**

1. Measure a fixed volume of alkali with a pipette into a conical flask and add indicator.
2. Fill the burette with acid and record the initial reading.
3. Add acid while swirling, dropwise near the end point, until the colour just changes.
4. Record the final reading, repeat to get concordant results and calculate the mean.

Example. Describe how you would use a titration to find the volume of dilute hydrochloric acid that reacts exactly with 25.0 cm^3 of potassium hydroxide solution. [6 marks]

Model answer.

Marked in levels. A top-level answer is a complete method in a logical order, such as:

Use a pipette (and filler) to measure 25.0 cm^3 of potassium hydroxide solution into a conical flask (1)

Add a few drops of indicator, e.g. phenolphthalein, and stand the flask on a white tile (1)

Fill a burette with hydrochloric acid and record the reading (1)

Add the acid while swirling, drop by drop near the end point (1)

Stop when the indicator changes colour (pink to colourless) and record the final reading (1)

Repeat until results are concordant (within 0.10 cm^3) and calculate the mean (1)

Calculate a mean titre

2 marks **Grade 5**

1. Pick the concordant titres (within 0.10 cm^3 of each other).
2. Leave out the rough titre and any result that is not concordant.
3. Add the concordant titres and divide by how many there are; give 2 decimal places.

Example. A student recorded these titres.

Titration	Rough	1	2	3	4
Titre in cm^3	24.60	23.95	24.30	24.00	23.90

Calculate the mean titre using only the concordant results.

Model answer.

Concordant titres are 23.95, 24.00 and 23.90 cm^3 (1)

Mean = (23.95 + 24.00 + 23.90) ÷ 3 = 71.85 ÷ 3 = 23.95 cm^3 (1)

Explain a step in the method

1 mark each **Grade 5**

1. Link the step to accuracy: mixing, not overshooting the end point, seeing the colour change.
2. Give one clear reason for each step.

Example. (a) Why is the conical flask swirled during a titration?
(b) Why is the acid added drop by drop near the end point?
(c) Why is universal indicator not used?

Model answer.

(a) To mix the acid and alkali so they react completely (1)

(b) So the end point is not overshot / to find the exact volume needed (1)

(c) Its colour changes gradually, so the end point is not sharp (1)

Calculate a concentration in mol/dm^3 and g/dm^3

3 to 5 marks | Grade 8

1. Moles of the solution with known concentration = concentration × volume in dm^3.
2. Use the mole ratio from the balanced equation.
3. Concentration = moles ÷ volume in dm^3.
4. For g/dm^3, multiply by M_r.

Example. 25.0 cm^3 of sodium hydroxide solution was neutralised by 22.50 cm^3 of 0.100 mol/dm^3 sulfuric acid.

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

(a) Calculate the concentration of the sodium hydroxide solution in mol/dm^3.

(b) Calculate its concentration in g/dm^3. (M_r of NaOH = 40)

Model answer.

(a) Moles H_2SO_4 = 0.100 × 22.50 ÷ 1000 = 0.00225 mol (1)

Moles NaOH = 2 × 0.00225 = 0.00450 mol (1)

Concentration = 0.00450 ÷ (25.0 ÷ 1000) = 0.180 mol/dm^3 (1)

(b) 0.180 × 40 = 7.20 g/dm^3 (1)

Don't lose marks

- Using cm^3 instead of dm^3 in moles = concentration × volume (the answer comes out 1000 times too big).
- Including the rough titre in the mean.
- Forgetting the 1 : 2 ratio when sulfuric acid reacts with sodium hydroxide.
- Reading the burette from the top of the meniscus, or not at eye level.
- Writing burette readings to 1 decimal place, e.g. 23.5 instead of 23.50.

More tips

Memory tricks

- n = c × V, with V in dm^3. Rearrange for whichever one you need: c = n ÷ V, V = n ÷ c.
- Sense check the ratio: with sulfuric acid, you need twice as many moles of sodium hydroxide as moles of acid.
- Burette readings are written to 2 decimal places, ending in 0 or 5, e.g. 23.45 cm^3.

Exam technique

- Show every step of a calculation with units: you can still get marks for correct working if the final answer is wrong.
- Give answers to a sensible number of significant figures, usually the same as the data (often 3).
- Use the technical words: pipette, burette, conical flask, end point, titre, concordant.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 4

Name the equipment used in a titration

Burette, pipette with pipette filler, conical flask, indicator and white tile.

Grade 5

Describe how to carry out a titration

Add acid from a burette to a measured volume of alkali with indicator until the colour just changes.

Grade 5

Choose concordant results and find the mean

Use titres within 0.10 cm^3 of each other and leave out the rough titre.

Grade 5

Explain how to find the end point accurately

Swirl, add dropwise near the end point, use a white tile and read the burette at eye level.

Grade 7

Calculate a concentration in mol/dm^3

moles = concentration × volume in dm^3, use the mole ratio, then concentration = moles ÷ volume.

Grade 7

Convert between mol/dm^3 and g/dm^3

Concentration in g/dm^3 = concentration in mol/dm^3 × M_r.

Grade 8

Solve titrations with a 1 : 2 ratio

For example, sulfuric acid reacts with sodium hydroxide in a 1 : 2 ratio, so double the moles of acid.

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