AQA Chemistry GCSE Teacher required practical 2

C4.7

Carrying out a titration

Specification references:

- C4.2.5
- WS 2.4, 2.6, MS 1a, 1c, 2a
- AT 1, 8
- **Required practical activity 2:** Determination of the reacting volumes of solutions of a strong acid and a strong alkali by titration

Aims

In this required practical, students will be introduced to the titration technique for finding the concentration of an alkali (sodium hydroxide) using a known concentration of an acid (hydrochloric acid). The indicator used is phenolphthalein.

The equation for the reaction is:

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

Higher-tier students will also calculate the concentration of sodium hydroxide in mol/dm^3 and g/dm^3 from the reacting volumes and the known concentration of the hydrochloric acid.

Learning outcomes

After completing this activity, students should be able to:

- accurately read the volume on a burette to 1 decimal place
- identify concordant results
- calculate a titre
- describe how an indicator can be used to determine the end point
- explain how accuracy can be improved in a titration
- carry out a titration between hydrochloric acid and sodium hydroxide
- recall the main steps involved in the practical procedure
- justify the use of a pipette and burette for a titration, evaluating the errors involved in reading these instruments
- explain how precise results are obtained in a titration
- justify the use of an indicator in an acid–base titration
- calculate the concentration of sodium hydroxide in mol/dm^3 and in g/dm^3 (H)

Teacher notes

1 It is important that the teacher demonstrates the method first and explains the purpose of each piece of apparatus. Both methyl orange and phenolphthalein indicators should be demonstrated. The term ***end point*** (the point where the indicator changes colour) should be used during the introduction.

2 The practical activity is appropriate for all students.

Three student sheets are provided, with questions targeted at students aiming for grades 4, 6, and 8. The questions for Aiming for grades 6 and 8 involve calculating the concentration of sodium hydroxide (H), with the Aiming for grade 6 questions being more structured than the Aiming for grade 8 questions.

3 All students will need time to practise using a burette (for drop-wise delivery) and pipette (for using the pipette filler correctly) with water before starting on the practical. A useful video from the RSC is: carrying out a titration.

4 One approach for Aiming for grade 4 students would be for the teacher to carry out each step alongside the students, so everyone fills the burette with acid together, then everyone pipettes the alkali, and so on. The teacher would need to show students how to read the burette and how to complete the results table

5 Higher Tier students will need to have completed a worked example of the calculation before carrying out this activity. One approach would be for the teacher to demonstrate the titration technique and then use the burette readings to show students how to complete the results table and how to use the mean titre to calculate the concentration of one of the solutions. Two sessions will be required for this.

6 A discussion on accuracy, repeatability, and reliability should be included at some point during this session.

Sample results

	Rough	Accurate		
		1	2	3
final burette reading in cm^3	20.4	20.2	21.1	20.7
initial burette reading in cm^3	0.0	0.0	0.0	0.0
volume of HCl added in cm^3	20.4	20.2*	20.1*	20.2*

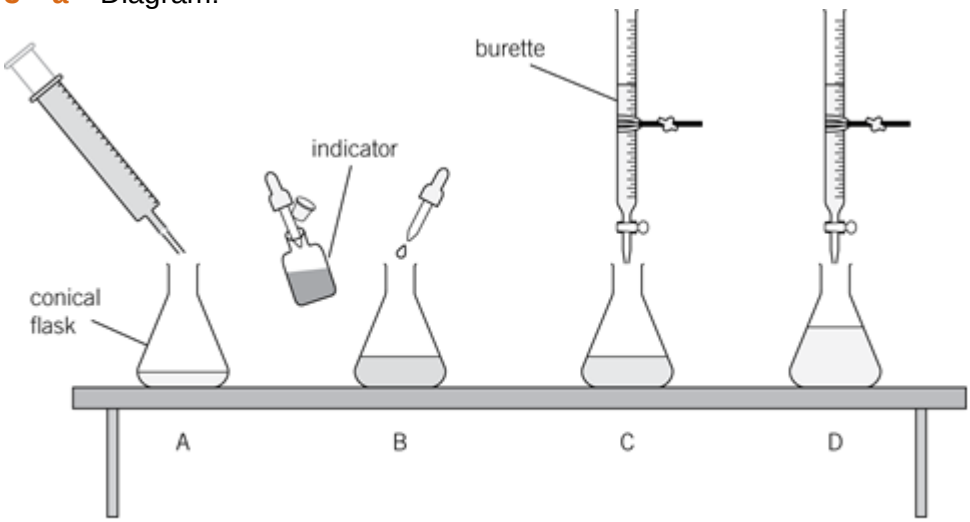
Answers

Aiming for grade 4 *(based on sample results)*

1 average volume of HCl added $= \frac{20.2 + 20.1 + 20.2}{3} = 20.17\,cm^3$ (*2 marks*)

2 25.0 cm^3 of sodium hydroxide was neutralised by **20.17** cm^3 of 0.100 mol dm^{-3} hydrochloric acid. (*1 mark*)

3 a Diagram:



(*3 marks*)

Students should label NaOH in the syringe or conical flask, HCl in the burette, phenolphthalein indicator. (*3 marks*)

b The end point is the point when the indicator changes colour. (*1 mark*)

c Methyl orange would change from yellow to red. (*1 mark*)

d Universal indicator is not a suitable indicator to use for a titration because it changes colour gradually, so the end point cannot be found accurately. Phenolphthalein and methyl orange change colour sharply at the end point. (*2 marks*)

e To ensure accuracy, any two reasonable answers, for example: (*2 marks*)

- the burette and pipette are washed with deionised water followed by the appropriate solution before use
- the burette is read where the bottom of the meniscus is on the mark
- the pipette is filled so that the bottom of the meniscus is in the mark
- the conical flask is swirled during the titration
- the acid is added dropwise near the end point
- the titration is repeated until concordant results are obtained
- only the concordant results are used to calculate the mean titre.

Aiming for grades 6 and 8 *(based on sample results)*

1 average volume of HCl added $= \frac{20.20 + 20.10 + 20.20}{3} = 20.17\,cm^3$ (*2 marks*)

2 25.0 cm^3 of sodium hydroxide was neutralised by **20.17** cm^3 of 0.100 mol/dm^3 hydrochloric acid. (*1 mark*)

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3 • number of moles HCl $= \frac{0.1 \times 20.17}{1000} = 0.002017$ (*1 mark*)

• 1:1 molar ratio, so number moles NaOH = 0.002 017 (*1 mark*)

• concentration of NaOH $= \frac{0.002017 \times 1000}{25} = 0.08068 = 0.0807$ mol/dm^3 (*1 mark*)

• M_r NaOH = 23 + 16 + 1 = 40 (*1 mark*)

• concentration of NaOH in g/dm^3 = 0.0807 × 40 = 3.23 g/dm^3 (*1 mark*)

4 a Flow chart: (*3 marks*)

Please see the answer to **Question 3a Aiming for grade 4.**

Students should label NaOH in the pipette or conical flask, HCl in the burette, phenolphthalein indicator. (*3 marks*)

b The end point is the point when the indicator changes colour. (*1 mark*)

c Methyl orange would change from yellow to red. (*1 mark*)

d Universal indicator is not a suitable indicator to use for a titration because it changes colour gradually, so the end point cannot be found accurately. Phenolphthalein and methyl orange change colour sharply at the end point. (*2 marks*)

e To improve accuracy: (*3 marks for Aiming grade for 6; 4 marks for Aiming grade for 8*)

Any 3 reasonable answers for Aiming for grade 6; any 4 reasonable answers for Aiming for grade 8. For example:

- the burette and pipette are washed with deionised water followed by the appropriate solution before use
- the burette is read where the bottom of the meniscus is on the mark
- the pipette is filled so that the bottom of the meniscus is in the mark
- the conical flask is swirled during the titration
- the acid is added dropwise near the end point
- the titration is repeated until concordant results are obtained
- only the concordant results are used to calculate the mean titre.

Student follow-up answers

Aiming for grade 4

1 a • Add **named indicator** (e.g., phenolpthalein or methyl orange) to the sodium hydroxide (in the conical flask).

• Add the acid from a **burette.**

• With swirling or dropwise towards the **end point** or until the indicator just **changes colour.**

• Until the indicator changes from **pink to colourless** (for phenolphthalein) or **yellow to red** (for methyl orange). (*4 marks*)

b Mean volume of acid $= \frac{27.75 + 27.65}{2} = 27.7$ cm^3 (*1 mark*)

Aiming for grades 6 and 8

1 a
- Add **named indicator** (e.g., phenolphthalein or methyl orange) to the sodium hydroxide (in the conical flask).
- Add the acid from a **burette.**
- With swirling or dropwise towards the **end point** or until the indicator just **changes colour.**
- Until the indicator changes from **pink to colourless** (for phenolphthalein) or **yellow to red** (for methyl orange). (*4 marks*)

b Mean volume of acid $= \frac{27.75 + 27.65}{2} = 27.7\ cm^3$ (*1 mark*)

c
- number of moles of NaOH $= \frac{0.1 \times 25}{1000} = 0.00250$
- number of moles of $H_2SO_4 = \frac{0.0025}{2} = 0.001250$
- concentration of $H_2SO_4 (mol/dm^3) = \frac{0.00125 \times 1000}{(27.7)}$

$= 0.0451\ mol/dm^3$ (3 sf) (*3 marks*)

d M_r of $H_2SO_4 = (2 \times 1) + 32 + (4 \times 16) = 98$

Concentration of sulfuric acid $(g/dm^3) = 0.045 \times 98 = 4.42\ g/dm^3$ (*2 marks*)

Support guidance

Students can be given further practice at performing titrations using a different strong acid (e.g. nitric acid) or a different concentration of sodium hydroxide and/or a different indicator. Aiming for grade 8 students could be asked to plan an experiment to find the concentration of acid in a solution.

Higher tier students will be given the opportunity to use a pH meter to measure the change in pH during a titration in a later practical.

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Technician notes

Safety

- Eye protection
- 0.100 mol/dm^3 hydrochloric acid: IRRITANT- CLEAPSS Hazcard 47A
- 0.080 mol/dm^3 sodium hydroxide: IRRITANT- CLEAPSS Hazcard 91A
- Indicator solutions CLEAPSS Hazcard 32

Equipment

- 50 cm^3 burette plus stand stand and burette holder
- 2 × 250 cm^3 beaker
- 250 cm^3 conical flask
- 25 cm^3 bulb pipette plus pipette filler
- white tile
- funnel
- methyl orange indicator
- phenolphthalein indicator
- 0.100 mol/dm^3 hydrochloric acid
- 0.080 mol/dm^3 sodium hydroxide (labelled NaOH of unknown concentration)
- wash bottle of distilled water