

Titrations

Mark Scheme



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1. Titration is a laboratory method used to find the exact concentration of a solution by reacting it with a solution of known concentration.

Circle the letter of the correct answer for each of the following questions.

- a) A student needs to accurately measure exactly 25.0 cm³ of sodium hydroxide solution to put into a conical flask. Which piece of apparatus should they use?

D – is the only correct answer.	1 mark
	Total: 1 mark

- b) During a titration of hydrochloric acid with sodium hydroxide, phenolphthalein is used as an indicator. The alkali (sodium hydroxide) is in the conical flask.

What is the correct colour change at the end-point?

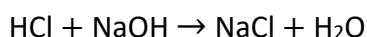
C – is the only correct answer.	1 mark
	Total: 1 mark

- c) Why is it important to repeat a titration until **concordant** results are obtained?

B – is the only correct answer.	1 mark
	Total: 1 mark

- d) A student titrates 25.0 cm³ of 0.20 mol/dm³ hydrochloric acid (HCl) against a solution of sodium hydroxide (NaOH) of unknown concentration.

The balanced equation for the reaction is:



The student finds that 18.50 cm³ of NaOH is needed to neutralise the acid.

What is the concentration of the sodium hydroxide solution?

B – is the only correct answer.	1 mark
	Total: 1 mark

(Total for Question 1 is 4 marks)

2. Titrations are a common procedure used to prepare pure salts from soluble reactants.

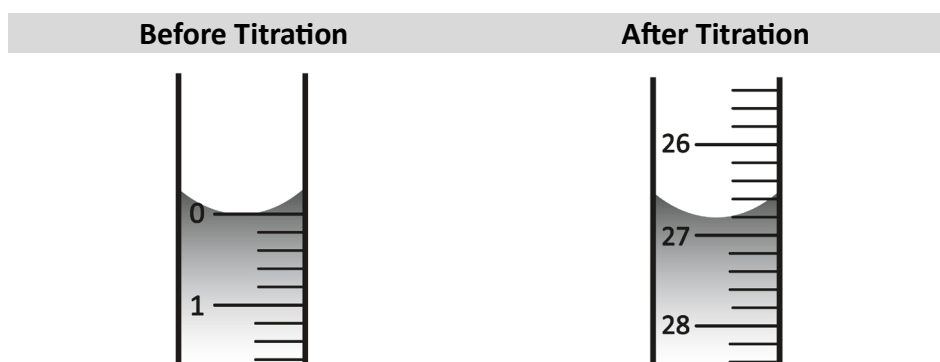
Sodium sulfate is a useful salt that can be made by a neutralisation reaction.

- a) State the **name** of the acid and the alkali that are neutralised to make sodium sulfate.

Sulfuric acid and sodium hydroxide.	2 mark s
1 mark for each correct reactant.	
	Total: 2 marks

- b) A student carries out a titration using the reactants from part (a) and records the burette readings at the start and the end of the experiment.

The figure below shows the readings on the burette before and after the titration.



Determine the volume of solution added from the burette into the conical flask.

Give your answer to 2 decimal places.

$50 \text{ cm}^3 - 26.8 \text{ cm}^3$	1 mark
$= 23.2 \text{ cm}^3$	1 mark
	Total: 2 marks

- c) The concentration of the sodium hydroxide solution used in the titration was **8.0 g/dm³**.

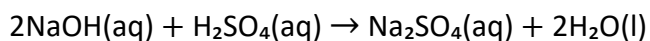
Calculate the concentration of this sodium hydroxide solution in **mol/dm³**.

Relative atomic masses: Na = 23, O = 16, H = 1

Step 1: Calculate the relative formula mass (Mr) of NaOH. $\text{Mr}(\text{NaOH}) = 23 + 16 + 1 = 40$	1 mark
Step 2: Use the formula to convert concentration. $\text{Conc}(\text{mol/dm}^3) = \text{Conc}(\text{g/dm}^3) \div \text{Mr}$ $\text{Conc}(\text{mol/dm}^3) = 8.0 \div 40$	1 mark
Step 3: Calculate the final answer. $\text{Conc} = 0.20 \text{ mol/dm}^3$	1 mark
	Total: 3 marks

- d) In a different titration, a student needs to find the volume of the 0.20 mol/dm³ sodium hydroxide solution needed to fully neutralise 25.0 cm³ of a different sulfuric acid solution with a concentration of 0.12 mol/dm³.

The balanced equation for the reaction is:



Calculate the volume of sodium hydroxide solution needed.

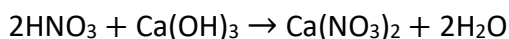
Give your answer in cm^3 .

Step 1: Calculate moles of sulfuric acid (H_2SO_4). $\text{Moles} = \text{Conc} \times \text{Vol}$ $\text{Moles} = 0.12 \times (25.0 \div 1000)$ $\text{Moles } \text{H}_2\text{SO}_4 = 0.003 \text{ mol}$	1 mark
Step 2: Use molar ratio to find moles of sodium hydroxide (NaOH). $\text{Ratio } \text{NaOH} : \text{H}_2\text{SO}_4 \text{ is } 2 : 1$ $\text{Moles } \text{NaOH} = 2 \times 0.003 = 0.006 \text{ mol}$	1 mark
Step 3: Calculate volume of NaOH. $\text{Volume} = \text{Moles} \div \text{Conc}$ $\text{Volume} = 0.006 \div 0.20$ $\text{Volume} = 0.03 \text{ dm}^3$	1 mark
Step 4: Convert volume to cm^3 $\text{Volume in } \text{cm}^3 = 0.03 \times 1000 = 30.0 \text{ cm}^3$	1 mark
	Total: 4 marks

(Total for Question 2 is 11 marks)

3. In a titration experiment, a student found that 21.50 cm³ of 0.200 mol/dm³ nitric acid (HNO₃) completely reacted with 25.0 cm³ of calcium hydroxide solution, Ca(OH)₂.

The equation for the reaction is:



Calculate the concentration of the calcium hydroxide solution in **mol/dm³** and in **g/dm³**.

Relative atomic masses (Ar): H = 1, O = 16, Ca = 40

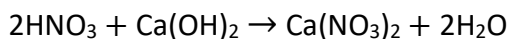
Step 1: Calculate moles of nitric acid (HNO₃). Moles = Conc × Vol Moles = 0.200 × (21.50 ÷ 1000) Moles = 0.00430 mol	1 mark
Step 2: Use molar ratio to find moles of calcium hydroxide (Ca(OH)₂). Ratio HNO ₃ : Ca(OH) ₂ is 2 : 1 Moles Ca(OH) ₂ = 0.00430 ÷ 2 Moles Ca(OH) ₂ = 0.00215 mol	1 mark
Step 3: Calculate concentration of Ca(OH)₂ in mol/dm³. Conc = Moles ÷ Vol = 0.00215 Conc = (25.0 ÷ 1000) Conc = 0.0860 mol/dm ³	1 mark
Step 4: Calculate the relative formula mass (Mr) of Ca(OH)₂. Mr = 40 + (16 + 1) × 2 Mr = 74	1 mark
Step 5: Convert concentration to g/dm³. Conc (g/dm ³) = Conc (mol/dm ³) × Mr Conc (g/dm ³) = 0.0860 × 74	1 mark
Step 6: Final answer for concentration in g/dm³ = 6.36 g/dm³	1 mark
	Total: 6 marks

(Total for Question 3 is 6 marks)

4. A student titrated 25.0 cm³ portions of dilute nitric acid with a 0.080 mol/dm³ calcium hydroxide solution. The table below shows the student's results.

	Titration 1	Titration 2	Titration 3	Titration 4	Titration 5
Volume of calcium hydroxide solution (cm ³)	25.50	22.80	22.90	23.50	22.85

The equation for the reaction is:



- a) Calculate the concentration of the nitric acid in mol/dm³.

Use only the student's concordant results. Concordant results are those within 0.10 cm³ of each other.

Concordant results are 22.80, 22.90, 22.85	
Mean = $(22.80 + 22.90 + 22.85) \div 3 = 22.85 \text{ cm}^3$	1 mark
Moles = $0.080 \times (22.85 \div 1000) = 0.001828 \text{ mol}$	1 mark
Ratio HNO ₃ : Ca(OH) ₂ is 2 : 1 Moles HNO ₃ = $0.001828 \times 2 = 0.003656 \text{ mol}$	1 mark
Concentration = $0.003656 \div (25.0 \div 1000) = 0.14624$	1 mark
	Total: 4 marks

- b) Calculate the mass of calcium hydroxide in 50.0 cm³ of a 0.080 mol/dm³ solution.

Relative atomic masses: H = 1, O = 16, Ca = 40

Mr of Ca(OH) ₂ = $40 + (16 + 1) \times 2 = 74$ Moles = $0.080 \times (50.0 \div 1000) = 0.004 \text{ mol}$ Mass = $0.004 \times 74 = 0.296 \text{ g}$	1 mark
	Total: 1 mark

- c) Explain why the student should use a pipette to measure the dilute nitric acid and a burette to measure the calcium hydroxide solution.

An explanation to include:	
A pipette is used to measure the nitric acid because it measures a fixed volume very accurately/precisely.	1 mark
A burette is used to measure the calcium hydroxide because it can deliver a variable volume and it measures the volume added accurately/precisely.	1 mark
	Total: 2 marks

(Total for Question 4 is 7 marks)

5. A student wants to find the exact concentration of a sulfuric acid solution. They are given a standard solution of potassium hydroxide with a known concentration.

Describe a method the student could use with the apparatus and solutions in the figure below to accurately determine the concentration of the sulfuric acid solution.

Marking guidance		
Level	Marks	Descriptor
Level 1	1 - 2	A simple or incomplete method is described. Key apparatus or steps are missing. The method is unlikely to produce a valid result.
Level 2	3 - 4	The main steps of the method are described but may lack detail or be in a less logical order. The method is workable but may not be fully accurate or reliable.
Level 3	5 - 6	A detailed and logically sequenced method is described. The use of apparatus to ensure accuracy is clear. Most key steps for obtaining a reliable result are included, using appropriate specialist terms.

Indicative Content	
Preparation & Measurement: - Rinse pipette with sulfuric acid solution. - Use pipette (and filler) to transfer a fixed volume (e.g., 25.0 cm³) of sulfuric acid into a conical flask. - Rinse burette with potassium hydroxide solution. - Fill burette with potassium hydroxide solution and ensure the jet is full. Titration Procedure: - Add a few drops of indicator to the conical flask. - Place the flask on a white tile. - Add potassium hydroxide from the burette, swirling the flask. - Add dropwise near the end-point. - Stop when the indicator gives a permanent colour change. Recording and Reliability: - Record the initial and final burette readings. - Repeat the titration until concordant results are obtained (titres within 0.10 cm³ of each other). - Calculate a mean volume from the concordant results	
	Total: 6 marks

(Total for Question 5 is 6 marks)

6. A student used a solution of phosphoric acid to determine the concentration of a solution of potassium hydroxide by titration.

- a) The student made 250 cm³ of a solution of phosphoric acid of concentration 0.100 mol/dm³. Calculate the **mass** of phosphoric acid (H₃PO₄) required.

Relative atomic masses (Ar): H = 1 P = 31 O = 16

Calculate Mr of H₃PO₄. (3 × 1) + 31 + (4 × 16) = 98	1 mark
Calculate moles of H₃PO₄. Moles = 0.100 × (250 ÷ 1000) = 0.025 mol	1 mark
Mass = 0.025 × 98 = 2.45 g	1 mark
	Total: 3 marks

This is part of the method the student used for the titration.

Measure 25.0 cm³ of the potassium hydroxide solution into a conical flask using a pipette.

Add a few drops of indicator to the flask. Fill a burette with phosphoric acid solution.

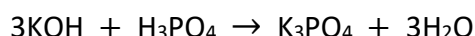
- b) Describe how the student would complete the titration.

A description to include the following:	
Read initial burette volume.	1 mark
Add acid from burette (swirling) until a permanent colour change.	1 mark
Read final burette volume and calculate titre (volume added).	1 mark
	Total: 3 marks

- c) Give **two** reasons why a burette is used for the phosphoric acid solution.

It can deliver a variable volume.	1 mark
Accept 'different amounts'	
It measures volume accurately / precisely.	1 mark
Accept mention of fine control using the tap.	
	Total: 2 marks

- d) 18.50 cm³ of 0.100 mol/dm³ phosphoric acid solution was needed to neutralise 25.0 cm³ of potassium hydroxide solution. The equation for the reaction is:



Calculate the concentration of the potassium hydroxide solution in mol/dm³.

Moles = 0.100 × (18.50 ÷ 1000) = 0.00185 mol	1 mark
Ratio KOH : H ₃ PO ₄ is 3 : 1. Moles = 3 × 0.00185 Moles = 0.00555 mol	1 mark
Concentration = 0.00555 ÷ (25.0 ÷ 1000) Concentration = 0.222 mol/dm ³	1 mark
	Total: 3 marks

- e) After the titration described in part (d), the student heated the resulting solution to evaporate the water and crystallise the potassium phosphate (K_3PO_4) salt.

Calculate the maximum theoretical mass of potassium phosphate that could be produced in this reaction.

Relative atomic masses: $\text{K} = 39$, $\text{P} = 31$, $\text{O} = 16$

Ratio $\text{H}_3\text{PO}_4 : \text{K}_3\text{PO}_4$ is 1 : 1.	
Moles = 0.00185 mol	1 mark
$(3 \times 39) + 31 + (4 \times 16) = 212$	1 mark
Mass = $0.00185 \times 212 = 0.3922 \text{ g}$	1 mark
	Total: 3 marks

(Total for Question 6 is 14 marks)