

Acid-Base Titration

Key ideas

Neutralization: acid + base → salt + water. · $n = c \times V$ (V in litres)

Method: moles of titrant → mole ratio from the balanced equation → moles of analyte → concentration.

Burette: read from the top down, at the bottom of the meniscus, to ± 0.05 mL. Use the average of concordant titres (within 0.10 mL of each other); ignore the rough trial.

A Titration vocabulary

3 marks

Write the letter of the matching description ($\frac{1}{2}$ mark each).

- | | |
|----------------------------|---|
| 1. _____ Titrant | a. The point where moles of acid and base have reacted exactly, according to the equation |
| 2. _____ Analyte | b. A solution whose concentration is known accurately |
| 3. _____ Burette | c. The solution of known concentration added from the burette |
| 4. _____ Equivalence point | d. The point where the indicator changes colour |
| 5. _____ End point | e. The solution of unknown concentration in the flask |
| 6. _____ Standard solution | f. A long graduated tube with a tap, used to add solution drop by drop |

B Neutralization equations

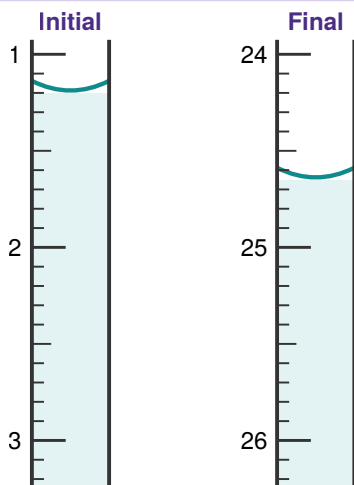
3 marks

7. Complete and balance: $\text{HCl} + \text{NaOH} \rightarrow$ _____
8. Complete and balance: $\text{H}_2\text{SO}_4 + \text{KOH} \rightarrow$ _____
9. Complete and balance: $\text{HNO}_3 + \text{Ca}(\text{OH})_2 \rightarrow$ _____

C Reading a burette

3 marks

Titration	Rough	Trial 1	Trial 2	Trial 3
Volume of NaOH (mL)	24.10		23.40	23.45



10. Read both burettes. What volume of NaOH was added in Trial 1? Record it in the table.

11. Why is the rough trial left out of the average?

12. Calculate the average volume of the concordant trials.

D Titration calculations

7 marks

13. 25.00 mL of HCl is neutralized by 18.40 mL of 0.150 mol/L NaOH. Find the concentration of the HCl. (2 marks)

14. 20.00 mL of H_2SO_4 is neutralized by 32.50 mL of 0.100 mol/L NaOH. Find $[\text{H}_2\text{SO}_4]$. ($\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$) (2 marks)

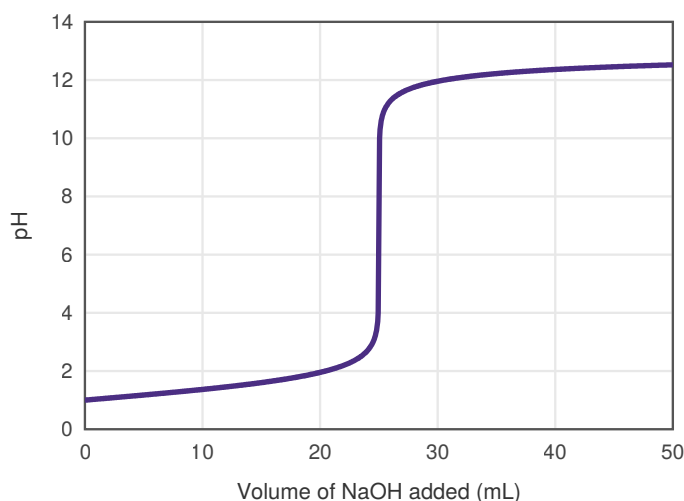
15. What volume of 0.250 mol/L HCl is needed to neutralize 15.0 mL of 0.400 mol/L NaOH?

16. What volume of 0.200 mol/L HCl is needed to neutralize 0.500 g of $\text{Ca}(\text{OH})_2$? ($2\text{HCl} + \text{Ca}(\text{OH})_2 \rightarrow \text{CaCl}_2 + 2\text{H}_2\text{O}$; $M = 74.10 \text{ g/mol}$) (2 marks)

E The titration curve

4 marks

25.0 mL of 0.100 mol/L HCl is titrated with 0.100 mol/L NaOH.



17. What volume of NaOH is needed to reach the equivalence point?

18. What is the pH at the equivalence point? Why?

19. What is the pH before any NaOH is added?

20. Which indicator in the table is the best choice for this titration? Explain.

Indicator	pH range	Colour change
Methyl orange	3.1–4.4	red → yellow
Bromothymol blue	6.0–7.6	yellow → blue
Phenolphthalein	8.2–10.0	colourless → pink

F Spot the mistake

2 marks

21. A student says: "At the end point, the volume of acid always equals the volume of base." Explain the error and correct it.

22. A student rinses the burette with distilled water and then fills it with NaOH. Explain the error and correct it.

Acid-Base Titration **ANSWER KEY****Key ideas****Neutralization:** acid + base → salt + water. · $n = c \times V$ (V in litres)**Method:** moles of titrant → mole ratio from the balanced equation → moles of analyte → concentration.**Burette:** read from the top down, at the bottom of the meniscus, to ± 0.05 mL. Use the average of concordant titres (within 0.10 mL of each other); ignore the rough trial.**A Titration vocabulary**

3 marks

Write the letter of the matching description ($\frac{1}{2}$ mark each).

- | | |
|-------------------------------|---|
| 1. <u>c</u> Titrant | a. The point where moles of acid and base have reacted exactly, according to the equation |
| 2. <u>e</u> Analyte | b. A solution whose concentration is known accurately |
| 3. <u>f</u> Burette | c. The solution of known concentration added from the burette |
| 4. <u>a</u> Equivalence point | d. The point where the indicator changes colour |
| 5. <u>d</u> End point | e. The solution of unknown concentration in the flask |
| 6. <u>b</u> Standard solution | f. A long graduated tube with a tap, used to add solution drop by drop |

B Neutralization equations

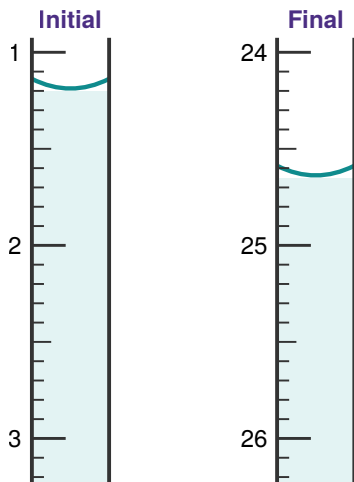
3 marks

7. Complete and balance: $\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$
8. Complete and balance: $\text{H}_2\text{SO}_4 + 2\text{KOH} \rightarrow \text{K}_2\text{SO}_4 + 2\text{H}_2\text{O}$
9. Complete and balance: $2\text{HNO}_3 + \text{Ca(OH)}_2 \rightarrow \text{Ca(NO}_3)_2 + 2\text{H}_2\text{O}$

C Reading a burette

3 marks

Titration	Rough	Trial 1	Trial 2	Trial 3
Volume of NaOH (mL)	24.10	23.45	23.40	23.45



10. Read both burettes. What volume of NaOH was added in Trial 1? Record it in the table.

Initial 1.20 mL, final 24.65 mL; volume = 23.45 mL (accept ± 0.05)

11. Why is the rough trial left out of the average?

It is done quickly to find the approximate end point, so it overshoots.

12. Calculate the average volume of the concordant trials.

$(23.45 + 23.40 + 23.45) \div 3 = 23.43$ mL

D Titration calculations

7 marks

13. 25.00 mL of HCl is neutralized by 18.40 mL of 0.150 mol/L NaOH. Find the concentration of the HCl. (2 marks)

$n(\text{NaOH}) = 0.150 \times 0.01840 = 0.002760$ mol = $n(\text{HCl})$ (1 : 1); $c = 0.002760 \div 0.02500$ L = 0.110 mol/L

14. 20.00 mL of H_2SO_4 is neutralized by 32.50 mL of 0.100 mol/L NaOH. Find $[\text{H}_2\text{SO}_4]$. ($\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$) (2 marks)

$n(\text{NaOH}) = 0.003250$ mol; $n(\text{H}_2\text{SO}_4) = \frac{1}{2} \times 0.003250 = 0.001625$ mol; $c = 0.001625 \div 0.02000$ L = 0.0813 mol/L

15. What volume of 0.250 mol/L HCl is needed to neutralize 15.0 mL of 0.400 mol/L NaOH?

$$n = 0.400 \times 0.0150 = 0.00600 \text{ mol}; V = 0.00600 \div 0.250 = 0.0240 \text{ L} = 24.0 \text{ mL}$$

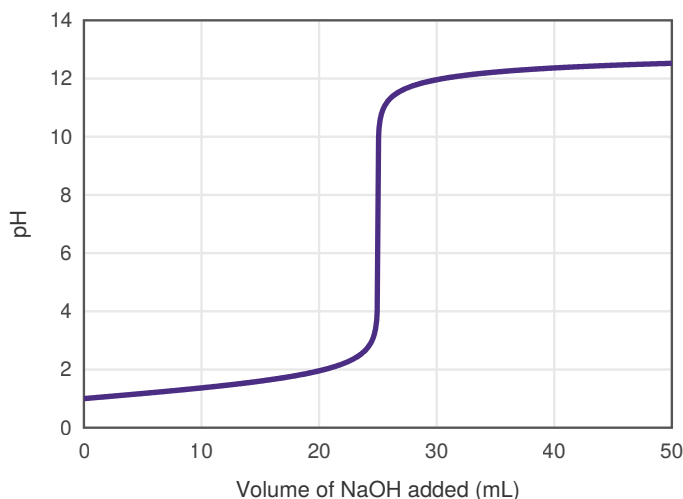
16. What volume of 0.200 mol/L HCl is needed to neutralize 0.500 g of Ca(OH)_2 ? ($2\text{HCl} + \text{Ca(OH)}_2 \rightarrow \text{CaCl}_2 + 2\text{H}_2\text{O}$; $M = 74.10 \text{ g/mol}$) (2 marks)

$$n(\text{Ca(OH)}_2) = 0.500 \div 74.10 = 0.006748 \text{ mol}; n(\text{HCl}) = 2 \times \text{that} = 0.01350 \text{ mol}; V = 0.01350 \div 0.200 = 67.5 \text{ mL}$$

E The titration curve

4 marks

25.0 mL of 0.100 mol/L HCl is titrated with 0.100 mol/L NaOH.



17. What volume of NaOH is needed to reach the equivalence point?

25.0 mL (where the curve rises steeply)

18. What is the pH at the equivalence point? Why?

pH 7: a strong acid and strong base make a neutral salt (NaCl) and water.

19. What is the pH before any NaOH is added?

pH 1.00 (0.100 mol/L HCl, so $[\text{H}^+] = 0.100$)

20. Which indicator in the table is the best choice for this titration? Explain.

Bromothymol blue: its colour change (pH 6.0–7.6) includes the equivalence point at pH 7.

Indicator	pH range	Colour change
Methyl orange	3.1–4.4	red → yellow
Bromothymol blue	6.0–7.6	yellow → blue
Phenolphthalein	8.2–10.0	colourless → pink

F Spot the mistake

2 marks

21. A student says: "At the end point, the volume of acid always equals the volume of base." Explain the error and correct it.

Only moles are related, and by the mole ratio in the equation. Volumes are equal only if the concentrations and ratio make them so (e.g. H_2SO_4 needs twice the moles of NaOH).

22. A student rinses the burette with distilled water and then fills it with NaOH. Explain the error and correct it.

The leftover water dilutes the NaOH, so more is needed and the calculated concentration is too high. Rinse with the NaOH solution.