

4.4.2 Buffers, neutralisation and indicator choice

Name: _____ Class: _____ Date: _____

Total: 21 marks

KEY WORDS buffer solution

Objective

React the moles first, then choose a valid pH expression or indicator. Questions and marking guidance are original.

1 Key knowledge and worked examples

A weak-acid buffer contains appreciable HA and A[−]. Added H⁺ reacts with A[−]; added OH[−] reacts with HA. The capacity is finite. $[H^+] \approx K_a[HA]/[A^-]$.

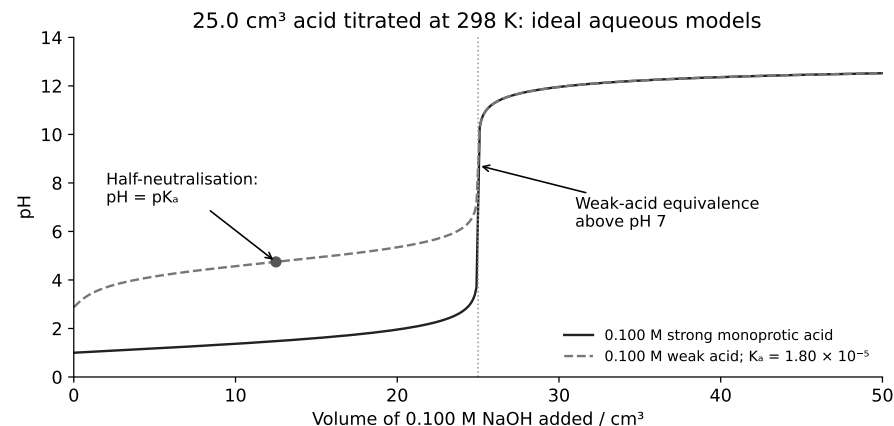
■ Worked method

0.0100 mol HA reacts with 0.00400 mol OH[−]. $HA + OH^- \rightarrow A^- + H_2O$ leaves 0.00600 mol HA and makes 0.00400 mol A[−]. For $K_a = 1.80 \times 10^{-5}$:

$$[H^+] = 1.80 \times 10^{-5} \times \frac{0.00600}{0.00400} = 2.70 \times 10^{-5} \text{ mol dm}^{-3}$$

$$pH = -\log_{10}(2.70 \times 10^{-5}) = 4.57$$

Common final volume cancels in this ratio. At half-neutralisation pH = pK_a. Beyond equivalence use excess strong reagent, not the buffer expression. Choose an indicator interval entirely within the steep part of the supplied titration curve. Weak-acid/strong-base equivalence is above pH 7 at 298 K; equivalence and neutral pH are different ideas.



2 Practice

2.1 Write equations showing how an ethanoic acid/ethanoate buffer consumes added H⁺ and OH[−]. [2]

2.2 For K_a = 2.00 × 10^{−5}, [HA] = 0.100 and [A[−]] = 0.200 mol dm^{−3}, calculate buffer pH. [3]

2.3 A titration has a steep region from pH 8.0 to 10.5. Indicator X changes at 3.1–4.4 and Y at 8.2–10.0. Select and justify. [2]

3 Exam-style questions

3.1 0.0200 mol HA is mixed with 0.00500 mol NaOH. $K_a = 1.00 \times 10^{-5}$. Calculate the resulting buffer pH and explain the error in using initial moles of HA. [4]

3.2 25.0 cm³ of 0.100 mol dm⁻³ monoprotic HA receives 30.0 cm³ of 0.100 mol dm⁻³ NaOH at 298 K. Calculate pH using $K_w = 10^{-14}$. Explain why the buffer expression fails. [5]

3.3 Prepare 100.0 cm³ of a buffer with pH 5.00 using only 0.200 mol dm⁻³ HA and 0.200 mol dm⁻³ sodium A stock solutions. $K_a = 1.80 \times 10^{-5}$ mol dm⁻³. Assuming additive volumes and the usual buffer approximation, calculate each stock volume and explain why their ratio is the concentration ratio in the final mixture. [5]

Solutions

Original marking guidance: M1 method, A1 accuracy, B1 explanation.

2.1 $\text{CH}_3\text{COO}^- + \text{H}^+ \rightarrow \text{CH}_3\text{COOH}$; $\text{CH}_3\text{COOH} + \text{OH}^- \rightarrow \text{CH}_3\text{COO}^- + \text{H}_2\text{O}$.

2.2 $[\text{H}^+] = 2.00 \times 10^{-5}(0.100/0.200) = 1.00 \times 10^{-5} \text{ mol dm}^{-3}$; $\text{pH} = 5.00$.

2.3 Y; its transition lies within the steep region so a small titrant addition produces the endpoint colour change.

3.1 After reaction $\text{HA} = 0.0150 \text{ mol}$ and $\text{A}^- = 0.00500 \text{ mol}$. $[\text{H}^+] = 10^{-5}(0.0150/0.00500) = 3.00 \times 10^{-5} \text{ mol dm}^{-3}$; $\text{pH} = 4.52$. OH^- has consumed HA and formed A^- , so initial acid moles are no longer the buffer numerator.

3.2 Acid 0.00250 mol , OH^- added 0.00300 mol ; excess 0.000500 mol . $[\text{OH}^-] = 0.000500/0.0550 = 0.00909 \text{ mol dm}^{-3}$. $\text{pOH} = 2.04$, $\text{pH} = 11.96$. HA is exhausted; an HA/ A^- buffer no longer exists.

3.3 $[\text{H}^+] = 10^{-5.00} = 1.00 \times 10^{-5} \text{ mol dm}^{-3}$. $[\text{A}^-]/[\text{HA}] = K_a/[\text{H}^+] = 1.80$. Equal stock concentrations make this the volume ratio; common final volume cancels. $V_{\text{HA}} + V_{\text{A}^-} = 100.0$ and $V_{\text{A}^-} = 1.80V_{\text{HA}}$ give $V_{\text{HA}} = 35.7 \text{ cm}^3$ and $V_{\text{A}^-} = 64.3 \text{ cm}^3$.