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. $[H^+] \approx K_a[HA]/[A^-]$.

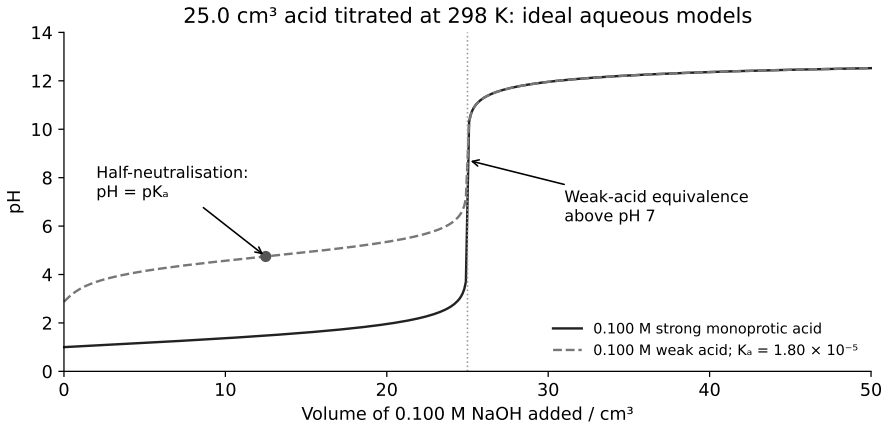
Worked method

0.0100 mol HA reacts with 0.00400 mol OH^-. HA + OH^- → 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 = pKa. 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 Ka = 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. Ka = 1.00×10^{-5}. Calculate the resulting buffer pH and explain the error in using initial moles of HA. [4]

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

3.3 Prepare 100.0 cm^3 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. Ka = 1.80×10^{-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 $CH_3COO^- + H^+ \rightarrow CH_3COOH$; $CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2O$.

2.2 $[H^+] = 2.00 \times 10^{-5}(0.100/0.200) = 1.00 \times 10^{-5}$ mol dm^{-3}; 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 HA = 0.0150 mol and A^- = 0.00500 mol. $[H^+] = 10^{-5}(0.0150/0.00500) = 3.00 \times 10^{-5}$ mol dm^{-3}; 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. $[OH^-] = 0.000500/0.0550 = 0.00909$ mol dm^{-3}. pOH = 2.04, pH = 11.96. HA is exhausted; an HA/A^- buffer no longer exists.

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