

Buffers, titration curves and indicators

AP Chemistry · Test answers (mark scheme)

Each model answer is followed by a marking guide. Follow-through marks apply where a later step correctly uses an earlier wrong value.

Level: AP Chemistry · **Curriculum:** AP Chem Unit 8

Question 1 Defining a buffer (2 marks)

A buffer resists changes in pH when small amounts of acid or base are added. It consists of a weak acid and its conjugate base, for example **CH₃COOH and CH₃COONa**.

Marking: 1 mark for the definition, 1 mark for a correct pair.

Question 2 Buffer pH (3 marks)

$\text{pH} = \text{pK}_a + \log_{10}([\text{F}^-]/[\text{HF}]) = 3.17 + \log_{10}(0.25/0.15) = 3.17 + 0.22 = \mathbf{3.39}$.

Marking: 1 mark for the equation, 1 for substitution, 1 for the answer.

Question 3 Adding acid (3 marks)

HCl reacts with NH₃: $\text{NH}_3 = 0.15 - 0.020 = 0.13 \text{ mol}$; $\text{NH}_4^+ = 0.20 + 0.020 = 0.22 \text{ mol}$. $\text{pH} = 9.25 + \log_{10}(0.13/0.22) = \mathbf{9.02}$.

Marking: 1 mark for the stoichiometry, 1 for the new amounts, 1 for the pH.

Question 4 Effective range (2 marks)

The ratio $[\text{A}^-]/[\text{HA}]$ is between 0.1 and 10 in this range, so both components remain in comparable amounts. Each can neutralise added base or acid, giving **high buffer capacity**.

Marking: 1 mark for the ratio, 1 for the capacity argument.

Question 5 Reading a titration curve (3 marks)

- The steep rise is at **20 cm³**.
- At half-equivalence, 10 cm³, $\text{pH} = 4.8$, so **pK_a = 4.8**.
- Phenolphthalein**, whose range includes the equivalence pH of about 8.7.

Marking: 1 mark for each part.

Question 6 Strong acid titration (2 marks)

$n(\text{HCl}) = 0.0200 \times 0.150 = 3.00 \times 10^{-3} \text{ mol}$. $V = 3.00 \times 10^{-3} / 0.100 = 0.0300 \text{ dm}^3 = \mathbf{30.0 \text{ cm}^3}$.

Marking: 1 mark for the amount, 1 for the volume.

Question 7 Equivalence pH of HCN (3 marks)

Equivalence at 25.0 cm^3 : $[\text{CN}^-] = 5.00 \times 10^{-3} \text{ mol} / 0.0500 \text{ dm}^3 = 0.100 \text{ mol/dm}^3$. $K_b = 1.0 \times 10^{-14} / 4.9 \times 10^{-10} = 2.04 \times 10^{-5}$. $[\text{OH}^-] = \sqrt{(2.04 \times 10^{-5} \times 0.100)} = 1.429 \times 10^{-3} \text{ mol/dm}^3$; $\text{pOH} = 2.85$; $\text{pH} = \mathbf{11.15}$. CN^- is a weak base, so it makes the solution basic.

Marking: 1 mark for $[\text{CN}^-]$, 1 for the pH, 1 for the explanation.

Question 8 Not a buffer (2 marks)

HCl is a strong acid and Cl^- is a negligible base, so there is no basic species to neutralise added acid. A buffer needs a **weak acid and its conjugate base**.

Marking: 1 mark for the point about a strong acid, 1 for the missing conjugate pair.