InkChemistry

ANSWER BOOK

Buffer solutions and buffer calculations

Acids and bases · Unit C11

AQA 3.1.12.6 · OCR A 5.1.3

14 questions · 48 marks

NAVY EDITION

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SECTION B · Standard, 3 to 5 marks

B1 BS-Q16

B1 Ksp = $[Pb^{2+}][I^-]^2$, for $PbI_2(s) \rightleftharpoons Pb^{2+}(aq) + 2I^-(aq)$. **B1** the units are $mol^3\ dm^{-9}$. **M1** if the solubility is s, $[Pb^{2+}] = s$ and $[I^-] = 2s$. **M1** Ksp = $s \times (2s)^2 = 4s^3 = 9.80 \times 10^{-9}$, so $s^3 = 2.45 \times 10^{-9}$. **A1** $s = 1.35 \times 10^{-3}$ mol dm^{-3}, to three significant figures. [5]

B2 BS-Q7

B1 the solution contains large amounts of NH_3 and NH_4^+, the NH_4^+ coming from the fully dissociated salt. **B1** added acid is removed by ammonia: $NH_3 + H^+ \rightarrow NH_4^+$. **B1** added alkali is removed by ammonium ions: $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$. **B1** both reservoirs are large, so the ratio of NH_3 to NH_4^+, and the pH, change very little. [4]

B3 BS-Q1

B1 a buffer is a solution that resists changes in pH when small amounts of acid or base are added; reject 'keeps the pH constant'. **B1** mix ethanoic acid with sodium ethanoate, a salt of the weak acid. **B1** add sodium hydroxide to an excess of ethanoic acid, so that only part of the acid is neutralised. [3]

B4 BS-Q3

B1 mixture B, ammonia with ammonium chloride, is the buffer. **B1** it contains a weak base and its conjugate acid in large amounts, to remove added H^+ and added OH^-. **B1** in mixture A, Cl^- is too weak a base to remove added H^+, and there are no HCl molecules to react with added OH^-. [3]

B5 BS-Q4

B1 when $[HA] = [A^-]$ the pH equals the pKa, 4.76. **M1** $[H^+]$ = 10^(-4.50) = 3.16×10^{-5} mol dm^{-3}, and the ratio = Ka ÷ $[H^+]$. **A1** $[CH_3COO^-]/[CH_3COOH] = 1.74 \times 10^{-5} \div 3.16 \times 10^{-5} = 0.550$, to three significant figures. [3]

B6 BS-Q8

B1 dilution lowers [HA] and $[A^-]$ by the same factor. **B1** the ratio $[HA]/[A^-]$ is unchanged, so $[H^+] = Ka \times [HA]/[A^-]$ and the pH are almost unchanged. **B1** there is less HA and A^- in each cubic decimetre, so a smaller addition of acid or alkali uses up a reservoir. [3]

B7 BS-Q9

M1 $[H^+] = Ka \times [HA] / [A^-]$, with $[A^-]$ taken from the salt. **M1** $[H^+] = 1.35 \times 10^{-5} \times 0.200 \div 0.100 = 2.70 \times 10^{-5}$ mol dm^{-3}. **A1** pH = 4.57, to two decimal places. [3]

B8 BS-Q13

B1 H^+ from the lactic acid reacts with hydrogencarbonate ions: $HCO_3^- + H^+ \rightarrow H_2CO_3$. **B1** the large reservoir of HCO_3^- means $[H^+]$ rises only slightly. **B1** the H_2CO_3 breaks down to CO_2 and H_2O, and the CO_2 is removed by breathing it out, faster during exercise. [3]

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B9 BS-Q14 **B1** the amount of ethanoate available to take up H^+ is far smaller than the amount of H^+ released. **B1** the ethanoate is used up, after which the extra H^+ is not removed and the pH falls sharply, as it would in water. **B1** use the same ratio at much higher concentrations, well above 0.0100 mol dm^{-3} of each, so the pH is unchanged but the reservoirs are large. [3]

B10 BS-Q15 **B1** a buffer resists a change in pH, but the pH still changes a little with each addition. **B1** it works only for small additions, compared with the amounts of weak acid and conjugate base present. **B1** once the added acid or base exceeds the reservoir of A^- or HA, the buffer is used up and the pH changes sharply, so the statement is incorrect. [3]

B11 BS-Q17 **M1** mixing equal volumes halves each concentration, so $[Ag^+] = [Cl^-] = 1.0 \times 10^{-4}$ mol dm^{-3}. **M1** the ionic product $[Ag^+][Cl^-] = 1.0 \times 10^{-8}$ mol^2 dm^{-6}. **B1** 1.0×10^{-8} is greater than Ksp, so silver chloride precipitates until the product falls to 1.80×10^{-10}. [3]

B12 BS-Q18 **B1** a saturated solution has $AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$ at equilibrium, with $Ksp = [Ag^+][Cl^-]$ constant at a given temperature. **B1** sodium chloride supplies a high concentration of Cl^-, the common ion, which shifts the equilibrium to the left. **B1** with $[Cl^-]$ fixed near 0.100 mol dm^{-3}, $[Ag^+]$ can reach only Ksp ÷ 0.100, so far less silver chloride dissolves. [3]

B13 BS-Q19 **B1** in saturated barium sulfate $[Ba^{2+}] = \sqrt{(1.1 \times 10^{-10})} = 1.0 \times 10^{-5}$ mol dm^{-3}, so very little toxic Ba^{2+} is in solution. **B1** sodium sulfate raises $[SO_4^{2-}]$, the common ion, shifting $BaSO_4(s) \rightleftharpoons Ba^{2+}(aq) + SO_4^{2-}(aq)$ to the left. **B1** since $[Ba^{2+}][SO_4^{2-}]$ must stay equal to Ksp, $[Ba^{2+}]$ falls further. [3]

SECTION C · Long, 6 marks or more

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C1 BS-Q2 **Indicative content** [6]

B1 the buffer contains large amounts of both CH_3CH_2COOH and $CH_3CH_2COO^-$, the propanoate coming from the fully dissociated salt. **B1** added H^+ reacts with propanoate ions, $CH_3CH_2COO^-(aq) + H^+(aq) \rightarrow CH_3CH_2COOH(aq)$, so most of it is removed. **B1** added OH^- reacts with propanoic acid molecules, $CH_3CH_2COOH(aq) + OH^-(aq) \rightarrow CH_3CH_2COO^-(aq) + H_2O(l)$. **B1** both reservoirs are large compared with the amount added, so the ratio $[HA]/[A^-]$ changes very little. **B1** $[H^+] = Ka \times [HA]/[A^-]$, so with the ratio almost unchanged $[H^+]$ and the pH change only slightly. **B1** once the added acid or alkali exceeds the propanoate or the propanoic acid present, that reservoir is used up and the pH changes sharply.

Levels

Level 3 (5–6 marks) both reservoirs are identified with the salt as the source of propanoate, both equations are correct and matched to added acid and added alkali, the small change in the $[HA]/[A^-]$ ratio is linked to $[H^+]$ through Ka, and the limit is explained as a reservoir being used up.

Level 2 (3–4 marks) both equations are given and the removal of added H^+ and OH^- is explained; the answer does not get from the $[HA]/[A^-]$ ratio to $[H^+]$ through Ka, or does not say why a large addition overwhelms the buffer.

Level 1 (1–2 marks) the buffer is said to contain a weak acid and its salt, usually with the claim that its pH cannot change at all; one equation at most, and nothing on large additions.

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