Problem 8-13 Buffers

0.096 mol of sodium acetate was dissolved in v 800 cm^3 of acetic acid solution of concentration 0.1 mol dm^{-3}.

(a) What is pH of this buffer solution?

(b) What change in pH will cause an addition of 2 cm^3 HCl solution of concentration 4 mol dm^{-3} (neglect the mixing change in volume)?

(c) What change in pH will occur if you dissolve 8 mmol of NaOH in this buffer solution?

[(a) pH = 4.838 ; (b) ΔpH = 0.078 ; (c) ΔpH = –0.046]

Solution:

(a) $HAc = H^+ + Ac^-$ conversion x $K_{HAc} = \frac{c_{H^+} \cdot c_{Ac^-}}{c_{HAc}}$

$NaAc = Na^+ + Ac^-$ complete dissociation

$c_{HAc} = 0.1$ mol dm^{-3}

$c_{NaAc} = c_{Ac^-} = \frac{0.098}{800 \cdot 10^{-3}} = 0.1225$ mol dm^{-3}

(c_{Ac^-} which is formed by dissociation of the acid is negligible due to very small value of the dissociation constant)

$c_{H^+} = K_{HAc} \cdot \frac{c_{HAc}}{c_{Ac^-}} = 1,78 \cdot 10^{-5} \cdot \frac{0,1}{0,1225} = 1.453_{06} \cdot 10^{-5}$ mol dm^{-3}

pH = –log $(1.453_{06} \cdot 10^{-5})$ = 4.8377

(b) $V_{HCl} = 2$ cm^3, $(c_{HCl})_0 = 4$ mol dm^{-3}

$V_{solution} = 800$ cm^3

$c_{HCl,solution} = \frac{(c_{HCl})_0 \cdot V_{HCl}}{V_{solution}} = \frac{4 \cdot 2}{800} = 0.01$ mol dm^{-3}

On addition of the strong acid a reaction

NaAc + HCl = NaCl + HAc

will occur and 0.01 mol dm^{-3} of acetate converts to 0.01 mol dm^{-3} of acid HAc

New balance:

$c_{HAc} = 0.1 + 0.01 = 0.11$ mol dm^{-3}

$c_{Ac^-} = 0.1225 - 0.01 = 0.1125$

$c_{H^+} = K_{HAc} \cdot \frac{c_{HAc}}{c_{Ac^-}} = 1.78 \cdot 10^{-5} \cdot \frac{0.11}{0.1125} = 1.7404 \cdot 10^{-5}$ mol dm^{-3}

pH = –log $(1.7404 \cdot 10^{-5})$ = 4.7593

The change in pH: ΔpH = 4.8377 – 4.759 = 0.0784

(c) $n_{NaOH} = 8 \cdot 10^{-3}$ mol NaOH , $V_{solution} = 800$ cm^3

$c_{NaOH} = \frac{8 \cdot 10^{-3}}{800 \cdot 10^{-3}} = 0.01$ mol dm^{-3}

On addition of the strong base a reaction

HAc + NaOH = NaAc + H_2O

will occur and 0.01 mol dm^{-3} of acid HAc converts to 0.01 mol dm^{-3} of salt NaAc

New balance:

$c_{HAc} = 0.1 - 0.01 = 0.09$ mol dm^{-3}

$c_{Ac^-} = 0.1225 + 0.01 = 0.1225$

$c_{H^+} = K_{HAc} \cdot \frac{c_{HAc}}{c_{Ac^-}} = 1.78 \cdot 10^{-5} \cdot \frac{0.09}{0.1225} = 1.3077 \cdot 10^{-5}$ mol dm^{-3}

pH = –log $(1.3077 \cdot 10^{-5})$ = 4.8835

The change in pH: ΔpH = 4.838 – 4.8835 = –0.0458