Deacon's Challenge

No 186 - Answer

Two solutions (A and B) have the following compositions:

A: 6 g anhydrous sodium dihydrogen orthophosphate in 500 mL water

B: 7.1 g anhydrous disodium hydrogen orthophosphate in 500 mL water

a) 50 mL of A is mixed with 50 mL B and the measured pH is 6.82. Calculate the pKa_2.

b) 60 mL of A is mixed with 40 mL B. Calculate the expected pH.

First calculate the molar concentrations of phosphate in each of solutions A and B:

$$\text{Concentration (mol/L)} = \frac{\text{Concentration (g/L)}}{\text{MW}}$$

For A: MW NaH_2PO_4 = 23 + (2 x 1) + 31 + (4 x 16) = 23 + 2 + 31 + 64 = 120

$$\text{Concentration (mol/L)} = \frac{2 \times 6}{120} = 0.1 \text{ mol/L}$$

For B: MW Na_2HPO_4 = (2 x 23) + 1 + 31 + (4 x 16) = 46 + 1 + 31 + 64 = 142

$$\text{Concentration (mol/L)} = \frac{2 \times 7.1}{142} = 0.1 \text{ mol/L}$$

a) If solutions A and B are mixed in equal proportions then the concentration of each phosphate species will become 0.05 mol/L. Therefore the pKa_2 will be equal to the pH:

The dissociation to be considered is:

$$H_2PO_4^- \leftrightarrow HPO_4^{2-} + H^+$$

and the Henderson-Hasselbalch equation is:

$$pH = pKa_2 + \log_{10} \frac{[Na_2HPO_4]}{[NaH_2PO_4]}$$

Which can be re-arranged to:

$$pKa_2 = pH - \log_{10} \frac{[Na_2HPO_4]}{[NaH_2PO_4]}$$

Substitute for pH and both phosphate concentrations and solve for pKa_2:

$$pKa_2 = 6.82 - \log_{10} \frac{0.05}{0.05} = 6.82 - \log_{10} 1 = 6.82 - 0 = \mathbf{6.82}$$

b) Calculate the final concentrations for each phosphate species when 60 mL of A is mixed with 40 mL of B:

$$[NaH_2PO_4] = 0.1 \times \frac{60}{100} = 0.06 \text{ mol/L}$$

$$[Na_2HPO_4] = 0.1 \times \frac{40}{100} = 0.04 \text{ mol/L}$$

Substitute these values into the Henderson-Hasselbalch equation and solve for pH:

$$pH = 6.82 + \log_{10} \frac{0.04}{0.06}$$

$$pH = 6.82 + \log_{10} 0.6667$$

$$pH = 6.82 + (-0.18)$$

$$pH = \mathbf{6.64}$$

Question 187

A solution contains 250 mg NADH disodium salt (formula $C_{21}H_{27}N_7O_{14}P_2Na_2$) per litre. A 1 in 5 dilution transmits 36% of incident light at 340 nm (versus an appropriate blank) in a cell with 1 cm path length.

a) Calculate the molar absorptivity of NADH.

b) How much of the original solution will be needed to prepare 1 L of a solution with an absorbance at 340 nm of 0.5 when measured in a cell with a path length of 0.5 cm?