

## CHAPTER EIGHT

### Buffer Solutions

**8.128** What is a buffer solution? What constitutes a buffer solution?

**8.129** Define  $pK_a$  for a weak acid. What is the relationship between the value of the  $pK_a$  and the strength of the acid? Do the same for a weak base.

**8.130** The  $pK_a$ s of two monoprotic acids HA and HB are 5.9 and 8.1, respectively. Which of the two is the stronger acid?

**8.131** Identify the buffer systems below:

- (a) KCl/HCl
- (b)  $\text{NH}_3/\text{NH}_4\text{NO}_3$
- (c)  $\text{Na}_2\text{HPO}_4/\text{NaH}_2\text{PO}_4$
- (d)  $\text{KNO}_2/\text{HNO}_2$
- (e)  $\text{KHSO}_4/\text{H}_2\text{SO}_4$
- (f)  $\text{HCOOK}/\text{HCOOH}$

**8.132** Calculate the pH of the buffer system made up of 0.15 M  $\text{NH}_3$ /0.35 M  $\text{NH}_4\text{Cl}$ .

**8.133** Calculate the pH of the following two buffer solutions: (a) 2.0 M  $\text{CH}_3\text{COONa}$ /2.0 M  $\text{CH}_3\text{COOH}$ , (b) 0.20 M  $\text{CH}_3\text{COONa}$ /0.20 M  $\text{CH}_3\text{COOH}$ . Which is the more effective buffer? Why?

**8.134** The pH of a bicarbonate-carbonic acid buffer is 8.00. Calculate the ratio of the concentration of carbonic acid ( $\text{H}_2\text{CO}_3$ ) to that of the bicarbonate ion ( $\text{HCO}_3^-$ ).

**8.135** What is the pH of the buffer 0.10 M  $\text{Na}_2\text{HPO}_4$ /0.15 M  $\text{KH}_2\text{PO}_4$ ?

**8.136** The pH of a sodium acetate-acetic acid buffer is 4.50. Calculate the ratio  $[\text{CH}_3\text{COO}^-]/[\text{CH}_3\text{COOH}]$ .

**8.137** The pH of blood plasma is 7.40. Assuming the principal buffer system is  $\text{HCO}_3^-/\text{H}_2\text{CO}_3$ , calculate the ratio  $[\text{HCO}_3^-]/[\text{H}_2\text{CO}_3]$ . Is this buffer more effective against an added acid or an added base?

**8.138** Calculate the pH of the 0.20 M  $\text{NH}_3$ /0.20 M  $\text{NH}_4\text{Cl}$  buffer. What is the pH of the buffer after the addition of 10.0 mL of 0.10 M HCl to 65.0 mL of the buffer?

**8.139** Calculate the pH of 1.00 L of the buffer 1.00 M  $\text{CH}_3\text{COONa}$ /1.00 M  $\text{CH}_3\text{COOH}$  before and after the addition of (a) 0.080 mol NaOH, (b) 0.12 mol HCl. (Assume that there is no change in volume.)

**8.140** A diprotic acid,  $\text{H}_2\text{A}$ , has the following ionization constants:  $K_{a1} = 1.1 \times 10^{-3}$  and  $K_{a2} = 2.5 \times 10^{-6}$ . In order to make up a buffer solution of pH 5.80, which combination would you choose?

$\text{NaHA}/\text{H}_2\text{A}$  or  $\text{Na}_2\text{A}/\text{NaHA}$ .

**8.141** A student is asked to prepare a buffer solution at pH  $\approx$  8.60, using one of the following weak acids:

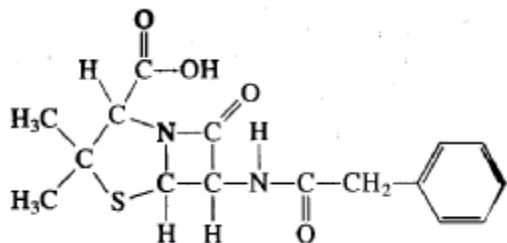
HA ( $K_a = 2.7 \times 10^{-3}$ ), HB ( $K_a = 4.4 \times 10^{-6}$ ), HC ( $K_a = 2.6 \times 10^{-9}$ ). Which acid should she choose? Why?

**8.142** The buffer range is defined by the equation  $\text{pH} = pK_a \pm 1$ . Calculate the range of the ratio  $[\text{conjugate base}]/[\text{acid}]$  that corresponds to this equation.

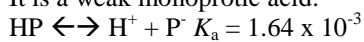
**8.143** Describe how you would prepare a 1-L 0.20 M  $\text{CH}_3\text{COONa}$ /0.20 M  $\text{CH}_3\text{COOH}$  buffer system by (a) mixing a solution of  $\text{CH}_3\text{COOH}$  with a solution of  $\text{CH}_3\text{COONa}$ , (b) reacting a solution of  $\text{CH}_3\text{COOH}$  with a solution of NaOH, and (c) reacting a solution of  $\text{CH}_3\text{COONa}$  with a solution of HCl.

**8.144** Phenolphthalein is the common indicator for the titration of a strong acid with a strong base. (a) If the  $pK_a$  of phenolphthalein is 9.10, what is the ratio of the nonionized form of the indicator (colorless) to the ionized form (reddish pink) at pH 8.00? (b) If 2 drops of 0.060 M phenolphthalein are used in a titration involving a 50.0-mL volume, what is the concentration of the ionized form at pH 8.00? (Assume that 1 drop = 0.050 mL.)

**8.145** One of the most common antibiotics is penicillin G (benzylpenicillanic acid), which has the following structure:



It is a weak monoprotic acid:



where HP denotes the parent acid and P<sup>-</sup> the conjugate base. Penicillin G is produced by growing molds in fermentation tanks at 25°C and a pH range of 4.5 to 5.0. The crude form of this antibiotic is obtained by extracting the fermentation broth with an organic solvent in which the acid is soluble. (a) Identify the acidic hydrogen atom. (b) In one stage of purification, the organic extract of the crude penicillin G is treated with a buffer solution at pH = 6.50. What is the ratio of the conjugate base of penicillin G to the acid at this pH? Would you expect the conjugate base to be more soluble in water than acid? (c) Penicillin G is not suitable for oral administration, but the sodium salt (NaP) is because it is soluble. Calculate the pH of a 0.12 M NaP solution formed when a tablet containing the salt is dissolved in a glass of water.