Solving Buffer Problems

- Calculating the pH of a given buffer
- How to prepare a buffer at a particular pH: Calculating the $[A^-]/[HA]$ ratio needed

Equations for Calculations

HA represents a weak acid; A^- represents a weak base

$$HA \leftrightarrow H^+ + A^-$$

$$K_a = \frac{[H^+] \times [A^-]}{[HA]}$$

$$\frac{K_a}{[H+]} = \frac{[A^-]}{[HA]}$$

"Handy Equation"

$$pH = pK_a + \log \frac{[A^-]}{[HA]}$$

Henderson-Hasselbach Equation

Calculation shortcut

[ ] = concentration in moles/L

$[A^-]/[HA] = (A^-$ in mol/L) / (HA in mol/L)

The value of L is the same for A^- and HA, so

$[A^-]/[HA] = (\text{mol of } A^-)/(\text{mol of HA})$

Calculating the pH of a given buffer

Sample Problem: Calculate the pH of a buffer containing 0.100 M CH_3COOH and 0.150 M $NaCH_3COO$.
The $K_a(CH_3COOH) = 1.76 \times 10^{-5}$; $pK_a = 4.75$.

$$pH = pK_a + \log \frac{[A^-]}{[HA]} = 4.75 + \log(0.150/0.100);$$

$$pH = 4.75 + 0.18 = 4.93$$

$$\frac{K_a}{[H^+]} = \frac{[A^-]}{[HA]} \qquad \frac{1.76 \times 10^{-5}}{[H^+]} = \frac{0.150}{0.100}$$

$[H^+] = (1.76 \times 10^{-5})/1.50$ $\quad$ $[H^+] = 1.17 \times 10^{-5}$; $pH = 4.93$

How to make a buffer

A buffer is a mixture of HA and A^-

1. Mix solutions of HA and A^-.

2. Start with a solution of HA. Add OH^- to convert some of the HA to A^-.

$$HA + OH^- \rightarrow A^- + H_2O$$

3. Start with a solution of A^-. Add H^+ to convert some of the A^- to HA.

$$H^+ + A^- \rightarrow HA$$

Calculate how to make a buffer

Sample Problem: Calculate how to use CH_3COOH and $NaCH_3COO$ to make a buffer with a pH of 5.0
The $K_a(CH_3COOH) = 1.76 \times 10^{-5}$; $pK_a = 4.75$.

Use the Handy Equation to calculate the $[A^-]/[HA]$ needed.

$$\frac{K_a}{[H^+]} = \frac{[A^-]}{[HA]} = \frac{1.76 \times 10^{-5}}{1.00 \times 10^{-5}} \qquad \frac{[A^-]}{[HA]} = \frac{1.76}{1.00}$$

So make a mixture where the ratio of $NaCH_3COO$ to CH_3COOH is 1.76:1.00

How to make a buffer

How to make a mixture where the ratio of $NaCH_3COO$ to CH_3COOH is 1.76 : 1.00

1. Mix 176 mL of 1.00 M $NaCH_3COO$ with 100 ml of 1.00 M CH_3COOH (0.176 mol $NaCH_3COO$ + 0.100 mol CH_3COOH).

2. Mix 276 mL of 1.00 M CH_3COOH with 176 ml of 1.00 M NaOH (0.276 mol CH_3COOH + 0.176 mol OH^-).
   (0.100 mol CH_3COOH remain; 0.176 mol $NaCH_3COO$ formed.)

How to make a buffer

3. Mix 276 mL of 1.00 M $NaCH_3COO$ with 100 ml of 1.00 M HCl (0.276 mol $NaCH_3COO$ + 0.100 mol H^+). (0.176 mol $NaCH_3COO$ remain; 0.100 mol CH_3COOH formed.)

Summary

Calculate the pH of a buffer, given the concentrations of HA and A^-, use either the Henderson-Hasselbach equation or the Handy Equation.

To make a buffer at a given pH, first calculate the ratio of moles of A^- to moles of HA.

This video is posted on my website: chemistrysky.com