

**15.3 - Buffering Capacity**

Picture Here

**Buffering Capacity**

You've seen how buffered solutions minimize the pH-altering effects that the addition of a strong acid or base elicits.

Depending on how much chemical is involved, buffers can resist changes more or less.

The buffering capacity of a solution represents the amounts of  $H^+$  or  $OH^-$  ions the buffer can absorb without a significant change in pH.

A buffer with a large capacity contains large concentrations of buffering components and so can absorb a relatively large amount of  $H^+$  or  $OH^-$  ions and show little change.

**Adding Strong Acid Example**

Calculate the change in pH that occurs when 0.010 mole of gaseous HCl is added to 1.0 L of the following acetic acid buffers:

- 5.00 M  $CH_3COOH$  and 5.00 M  $NaCH_3COO$
- 0.050 M  $CH_3COOH$  and 0.050 M  $NaCH_3COO$

$K_a$  for acetic acid is  $1.8 \times 10^{-5}$ .

Note 1: Since the HCl is gaseous, volume change is negligible.

Note 2: Since 0.010 mol HCl is added to a 1.0 L solution, the molarity change will be 0.010 M (for both acetic acid and the acetate ion).

**Adding Acid Answer (Slide 1)**

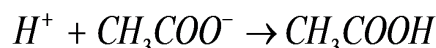
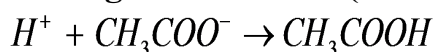
First, calculate the pH of the original buffers.

Note: in the H & H equation since it is the log of the ratio of base to acid that matters, in this problem both of the buffers have the same ratio of 1 part base to 1 part acid.

Thus, pH:  $pH = pK_a + \log\left(\frac{[CH_3COO^-]}{[CH_3COOH]}\right)$

$$pH = -\log 1.8 \times 10^{-5} + \log(1) = \boxed{4.74}$$

Next, the chemical reaction. The hydrogen ion of HCl will bind with the free acetate ion:

**1. Adding Acid Answer (Slide 2)**

Use Stoichiometry to calculate amount reacted:

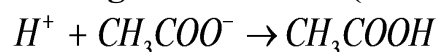
Acetic acid:  $5.00 \text{ M } CH_3COOH + 0.010 \text{ M} = 5.01 \text{ M}$ :

Acetate ion:  $5.00 \text{ M } CH_3COO^- - 0.010 \text{ M} = 4.99 \text{ M}$ .

New pH Calc:  $pH = pK_a + \log\left(\frac{[CH_3COO^-]}{[CH_3COOH]}\right)$

$$pH = -\log 1.8 \times 10^{-5} + \log\left(\frac{4.99}{5.01}\right) = \boxed{4.74}$$

Note: there is a pH change, but insignificant.

**2. Adding Acid Answer (Slide 3)**

Use Stoichiometry to calculate amount reacted:

Acetic acid:  $0.050 \text{ M } CH_3COOH + 0.010 \text{ M} = 0.060 \text{ M}$

Acetate ion:  $0.050 \text{ M } CH_3COO^- - 0.010 \text{ M} = 0.040 \text{ M}$ .

pH Calc:  $pH = pK_a + \log\left(\frac{[CH_3COO^-]}{[CH_3COOH]}\right)$

$$pH = -\log 1.8 \times 10^{-5} + \log\left(\frac{0.040}{0.060}\right) = \boxed{4.56}$$

The acid affects this dilute buffer much more.

### Preparing Buffer Solutions

Chemists sometimes have to determine how to prepare buffer solutions that will work in particular pH ranges.

With so many chemicals to choose from, a method exists for determining the best one.

First: know that buffers work best when the ratio of acid to conjugate base (or base/conj. acid) is 1:1 (smaller pH swings vs. acid or base addition).

Second: with the ratio of 1 : 1, the  $pK_a$  of the acid should be as close to the desired pH as possible.

### Build Your Own Buffer Example

A chemist has four choices of acids and their sodium salts for making a buffer of pH 4.30:

- A. chloroacetic acid ( $K_a = 1.35 \text{ E } -3$ )
- B. propanoic acid ( $K_a = 1.30 \text{ E } -5$ )
- C. benzoic acid ( $K_a = 6.40 \text{ E } -5$ )
- D. hypochlorous acid ( $K_a = 3.50 \text{ E } -8$ )

3. If a solution is made by making 1.0 M solutions of the acid and its sodium salt in the same flask, which acid should the chemist select?

4. How could the chemist alter the amounts, to produce a closer value to the pH = 4.30 target?

### Build Your Own Buffer Answer

3. The  $pK_a$  of the acid should be as close to the desired pH, (assuming that the ratio of acid to conjugate base is 1 : 1):

$$pH = pK_a + \log\left(\frac{A^-}{HA}\right) = pK_a + \log(1) = pK_a$$

So:

- chloroacetic acid  $pK_a = -\log 1.35 \text{ E } -3 = 2.87$
- propanoic acid  $pK_a = -\log 1.30 \text{ E } -5 = 4.89$
- benzoic acid  $pK_a = -\log 6.40 \text{ E } -5 = 4.19$
- hypochlorous acid  $pK_a = -\log 3.50 \text{ E } -8 = 7.46$

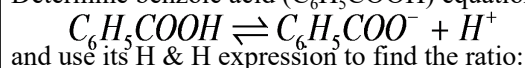
The closest acid/conjugate base pair is benzoic acid.

### Build Your Own Buffer Answer

4. What ratio will of acid to conjugate base will produce the desired pH of 4.30?

Calculate  $[H^+]$ :  $[H^+] = 10^{-4.30} = 5.01 \text{ E } -5$

Determine benzoic acid ( $C_6H_5COOH$ ) equation:



and use its H & H expression to find the ratio:

$$pH = pK_a + \log\left(\frac{[C_6H_5COO^-]}{[C_6H_5COOH]}\right)$$

$$pH - pK_a = \log\left(\frac{[C_6H_5COO^-]}{[C_6H_5COOH]}\right)$$

$$10^{pH - pK_a} = 10^{4.30 - 4.19} = \boxed{1.29} = \left(\frac{[C_6H_5COO^-]}{[C_6H_5COOH]}\right)$$

The chemist would have to use 1.29 times as much sodium benzoate as benzoic acid.

### Homework

Preview 12.3

12.1-.2 Problems in your Booklet  
Due: Next Class