

### Lab 6: Making a buffer solution

**Objective:** Plan and make 50.00 mL of a given pH acetic acid/sodium acetate trihydrate buffer solution, and demonstrate its buffering characteristics.

**Skills:**

- Making solutions both from powder and from stock solutions
- Using a pH meter to make acid/base measurements

Buffers are extremely useful solutions because of their ability to resist rapid pH changes as other solutions are added. In this lab, you will be making a buffer out of solid sodium acetate trihydrate ( $\text{NaC}_2\text{H}_3\text{O}_2 \cdot 3\text{H}_2\text{O}$ , molar mass = 136.08 g/mol) and a stock 6.00 M solution of acetic acid ( $\text{HC}_2\text{H}_3\text{O}_2$ , sometimes written  $\text{CH}_3\text{COOH}$ , molar mass = 60.05 g/mol).

**Prelab 6:** For Thursday, March 5, **prepare a recipe** for the buffer pH that you are assigned; see the paragraphs below for the recipe format. Note: this will also help you prepare for the exam; there will be a question directly related to the preparation and action of a buffer.

Read section 10.8 in the text.

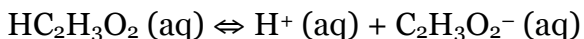
In order to make this lab possible, I want the final concentration of acetic acid in your buffer to be 1.00 M. Please see the paragraphs below for instructions on how to write the recipe for your buffer.

#### Introduction: How to make a buffer

All buffers rely on having two components: a substance that will neutralize with excess acidity and a substance that will neutralize excess alkalinity (basicity). Thus a weak acid and its conjugate base are typically the two substances used in buffers.

The basic equation governing buffers is called the **Henderson-Hasselbalch equation**, after the two scientists who independently published it in the early 20<sup>th</sup> century. This equation is derived from the expression for the equilibrium constant of a weak acid.

For instance, if the weak acid is acetic acid, you can write the ionization of **acetic acid** into **hydrogen ions** and **acetate ions**:



which becomes the equilibrium constant ( $K_a$ ) expression:

$$K_a = \frac{[H^+][C_2H_3O_2^-]}{[HC_2H_3O_2]}$$

The  $K_a$  can be looked up any reference; the text gives the  $K_a$  of acetic acid to be  $1.8 \times 10^{-5}$  (page 376). The Henderson-Hasselbalch equation is given in the text (page 399) in a slightly different form; you can use that one or the one given below to derive the various concentrations needed for your recipe.

I'll define the "p $K_a$ " in a manner analogous to pH:

$$pK_a = -\log_{10} K_a$$

Thus, the p $K_a$  of acetic acid is  $= -\log_{10} (1.8 \times 10^{-5}) = 4.74$ .

So to make a buffer of a certain pH, the general Henderson-Hasselbalch equation is:

$$pH = pK_a + \log_{10} \left( \frac{[base]}{[acid]} \right)$$

For the specific case of a buffer system using acetic acid and sodium acetate trihydrate, to get the buffer to be a certain pH:

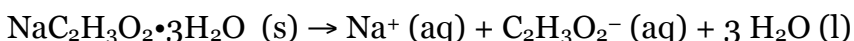
$$pH = 4.74 + \log_{10} \left( \frac{[C_2H_3O_2^-]}{[HC_2H_3O_2]} \right)$$

Thus, in order to write your recipe, you need to know what the concentration of acid  $[HC_2H_3O_2]$  is (earlier, I told you that this concentration must be 1.00 M), and what the concentration of the base  $[C_2H_3O_2^-]$  is (notice you can solve for this concentration in the equation above, since this is the only unknown).

**Before anything further, solve the equation above for  $[C_2H_3O_2^-]$ .**

Once you know what  $[C_2H_3O_2^-]$  you need, you should calculate how many grams of  $NaC_2H_3O_2 \cdot 3H_2O$  (sodium acetate trihydrate) you will need to get that concentration.

Recall that sodium acetate trihydrate ionizes in this fashion:



So that one mole of sodium acetate trihydrate yields one mole of acetate ions.

Since you are making 50.00 mL ( $= 0.05000$  L) of solution, first calculate the number of moles of acetate ions you will need, using the  $[C_2H_3O_2^-]$  you need:

$$(\text{number of moles of acetate ions needed}) = [\text{C}_2\text{H}_3\text{O}_2^-] (0.05000 \text{ L})$$

Then, since the number of moles of sodium acetate trihydrate you will need is going to be the same as the number of moles of acetate ion you will need:

$$(\# \text{ of moles of sodium acetate trihydrate needed}) = (\# \text{ of moles of acetate ions needed})$$

Use the molar mass of sodium acetate trihydrate (136.08 g/mol) to calculate the number of grams of sodium acetate trihydrate you need.

Since the  $[\text{HC}_2\text{H}_3\text{O}_2] = 1.00 \text{ M}$  and since you're starting off with stock 6.00 M acetic acid solution, use the dilution formula (section 10.10) to determine the number of milliliters of the stock solution you will need:

$$(\text{conc. of stock acid}) (\text{volume of stock acid}) = (\text{conc. of dilute acid}) (\text{volume of dilute acid})$$

where you are solving for the volume of the stock acid solution (you know all the other numbers).

### **The recipe format:**

Fill in the blanks:

“To make 50.00 mL of pH \_\_\_\_\_ acetic acid/sodium acetate trihydrate buffer:

In a 50.00 mL volumetric flask, add about 30 mL of distilled water. To this add \_\_\_\_\_ mL of stock 6.00 M acetic acid solution and \_\_\_\_\_ g sodium acetate trihydrate, and stir until dissolved. Bring the solution up to 50.00 mL by adding distilled water in a squirt bottle, and mix thoroughly.”

### **Materials provided:**

- solid sodium acetate trihydrate
- 50 mL volumetric flask
- concentrated hydrochloric acid
- various other glassware as needed
- stock 6.0 M solution of acetic acid
- digital pH meter
- concentrated NaOH solution

**Safety issues:** There will be acids and bases in this lab; please wear goggles and tie back long hair. In addition, there will be plenty of glassware so be aware of your surroundings while you are working and while you are transporting glassware.

### **Procedure:**

1. (It will save a great deal of time if you do this in advance) **Write a recipe** for making 50.00 mL of a buffer at the pH you have been assigned using sodium acetate trihydrate

and acetic acid. The recipe should include the mass of sodium acetate trihydrate you will use and the volume of the stock solution of acetic acid you will use, along with a few procedure steps to explain how you will make the buffer. The printed copy of the *correct* recipe is worth 10 points for both you and your partner (so only one copy for the both of you is due) — this is the prelab assignment.

2. Prepare 50.00 mL of your buffer, using the glassware and chemicals in the lab. Use the digital pH meter to get within 0.1 pH unit of your assigned value (use the concentrated HCl or concentrated NaOH to adjust the final pH).

3. After your buffer has reached the required pH, call me over and demonstrate, by adding a few drops of concentrated HCl or concentrated NaOH, that the pH of the buffer does not change by more than 0.2 pH unit. Also show me how much the pH of water changes by adding the same number of drops of concentrated HCl or concentrated NaOH. My witnessing this demonstration of buffering capacity is worth 10 points to you and your partner.

**Waste:** Please pour all solutions into the waste container provided; Metro requires that any solution poured into the drains be between pH 5.5 and pH 12. I will check after lab that we meet this requirement.