7—Investigation of Buffer Systems

Name: _____

Date: _____

Section: _____

Objectives
- Reinforce concepts of buffer, buffer range and buffer capacity
- Learn how to prepare acid-base buffers
- Learn how to calculate the pH of a buffer solution by using Henderson-Hasselbalch Equation
- Learn how to use pH meters
- Learn how to plot acid-base titration curves
- Learn the effect of adding small amount of strong acids and bases to buffers
- Learn how to estimate the buffer capacity for the addition of a strong acid and a strong base

Pre-Laboratory Requirements
- Read Chapter 19.1 in Silberberg
- Pre-Lab Questions (if required by your instructor)
- Laboratory Notebook—prepared before lab (if require by your instructor)

Safety Notes
- Eye protection must be worn at all times
- If get acid or base in eyes, immediately wash with large volumes of running water

Discussion
An acid-base buffer is a solution whose pH does not change significantly when small amounts of a strong base or acid are added. The resistance of change in pH of a buffer is caused by the presence of a conjugate acid-base pair, either a weak acid and its conjugate base (an anion) or a weak base and its conjugate acid (a cation). The base component in the buffer will consume added H_3O^+ from a strong acid or the acid component reacts with added OH^- from a strong base, and further to keep pH of the buffer solution relatively constant. Consider a sodium-acetic acid buffer system consisting of acetic acid (CH_3COOH) and its conjugate base, acetate anion (CH_3COO^-).

(1) When a strong acid is added to the buffer, the acetate ion acts as a base to neutralize the H_3O^+ generated from the strong acid.

$$H_3O^+ \, (aq) + CH_3COO^- \, (aq) \leftrightarrow H_2O \, (l) + CH_3COOH \, (aq)$$
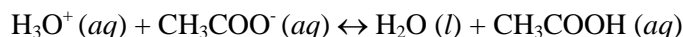
(2) In like fashion, the acetic acid reacts with the OH^- generated from the strong base added.

$$OH^- \, (aq) + CH_3COOH \, (aq) \leftrightarrow H_2O \, (l) + CH_3COO^- \, (aq)$$
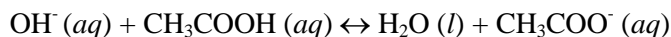
Since both OH^- and H_3O^+ are removed by reaction with the components of the buffer, the pH of the solution will be relatively constant.

However, a buffer will cease to retard the change of pH when all the reacting component is consumed by the OH⁻ or H_3O^+ added. Further addition of strong acid or base will cause a rapid change in pH. Buffer capacity is a quantitative measure of the resistance of a buffer solution to change in pH on addition of strong acid or base. Normally it can be defined as the millimoles of strong acid or base required to change the pH of 1 liter of buffer by ±1.0 unit. Buffer capacity is related to the concentrations of base and acid components. Higher concentration of base component in a buffer can consume more H_3O^+ added resulting in a higher buffer capacity for the addition of a strong acid. In a same fashion, a buffer consisting of higher concentration of acid component has a higher buffer capacity for the addition of a strong base.

The pH of a buffer solution can be calculated by using Henderson-Hasselbalch equation

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

where K_a is the acid ionization constant, [HA] is the concentration of acid component and [A⁻] is the concentration of base component

Procedure

Part I-A: Preparing Buffers
1. Transfer 0.100 M CH_3COOH with a graduated cylinder into a 100 mL-beaker.
2. To the same beaker, add 0.100 M NaOH and DI water.
3. Stir well.
4. The amount of solutions transferred for buffers are listed in the following table

Solution	Volume transferred, mL	
	Buffer *a*	Buffer *b*
0.100 M CH₃COOH	40.0	40.0
0.100 M NaOH	20.0	30.0
DI water	20.0	10.0

Part I-B: Calculating pH of Buffers (K_a CH₃COOH = 1.8 x 10⁻⁵)

	Buffer *a*	Buffer *b*
pH		

Calculations

Part II-A: Measuring pH for the addition of Strong acid

1. Measure 25.0 mL of buffer *a* with a graduated cylinder into a 200 mL-beaker, measure the pH with a pH meter, and record the data.
2. Add a certain amount of 0.10 *M* HCl solution in mL from a buret to buffer *a*. Measure the pH and record it. Stir constantly while the strong acid is being added
3. Continue to add HCl solution. The total volumes of HCl solution being added are listed in the following table. Stir well and record the pH at each point
4. Repeat steps 1 through 3 with 25.0 mL of buffer *b.*
5. Repeat steps 1 through 3 with 25.0 mL of DI water. The total amount of HCl solution being added is in drops

| Total volume HCl added	pH (Buffer *a*)	Total volume HCl added	pH (Buffer *b*)	Total volume HCl added	pH (DI water)
0 mL		0 mL		0 drop	
2.00 mL		2.00 mL		1 drop	
4.00 mL		4.00 mL		2 drops	
4.50 mL		6.00 mL		5 drops	
5.00 mL		7.00 mL			
5.50 mL		8.00 mL			
6.00 mL		8.50 mL			
6.50 mL		9.00 mL			

Part II-B: Measuring pH for the addition of Strong base

1. Measure 25.0 mL of the remainder of buffer *a* with a graduated cylinder into a 200 mL-beaker
2. Add a certain amount of 0.10 *M* NaOH solution in mL from another buret to buffer *a*. Measure the pH and record it. Stir constantly while the strong acid is being added
3. Continue to add NaOH solution. The total volumes of NaOH solution being added are listed in the following table. Stir well and record the pH at each point
4. Repeat steps 1 through 3 with 25.0 mL of the remainder of buffer *b.*
5. Repeat steps 1 through 3 with 25.0 mL of DI water. The total amount of NaOH solution being added is in drops

Total volume NaOH added	pH (Buffer *a*)	Total volume NaOH added	pH (Buffer *b*)	Total volume NaOH added	pH (DI water)
1.00 mL		0.50 mL		1 drop	
2.00 mL		1.00 mL		2 drops	
3.00 mL		1.50 mL		5 drops	
4.00 mL		2.00 mL			
4.50 mL		2.20 mL			
5.00 mL		2.40 mL			
5.50 mL		2.60 mL			

Part II-C: Reporting Data and Determining Buffer Capacity

- For each buffer, make a plot of pH versus volume of HCl and NaOH added. All three plots should be done on the same graph.
- Use different symbols or different colors for data points.
- Plot the pH of each buffer at a volume of zero midway on the x-axis. The volumes of NaOH added are positive and the volume of HCl added are negative
- The scale for the y-axis will range from the lowest pH value measured to the highest pH measured for the three buffers.
- The scale for the x-axis will range from the largest amount of acid and base added.
- Make your graph large enough so that the three plots are not crowded.

pH

← Vol. of HCl added, mL   ↑ 0 mL   → Vol.of NaOH added, mL
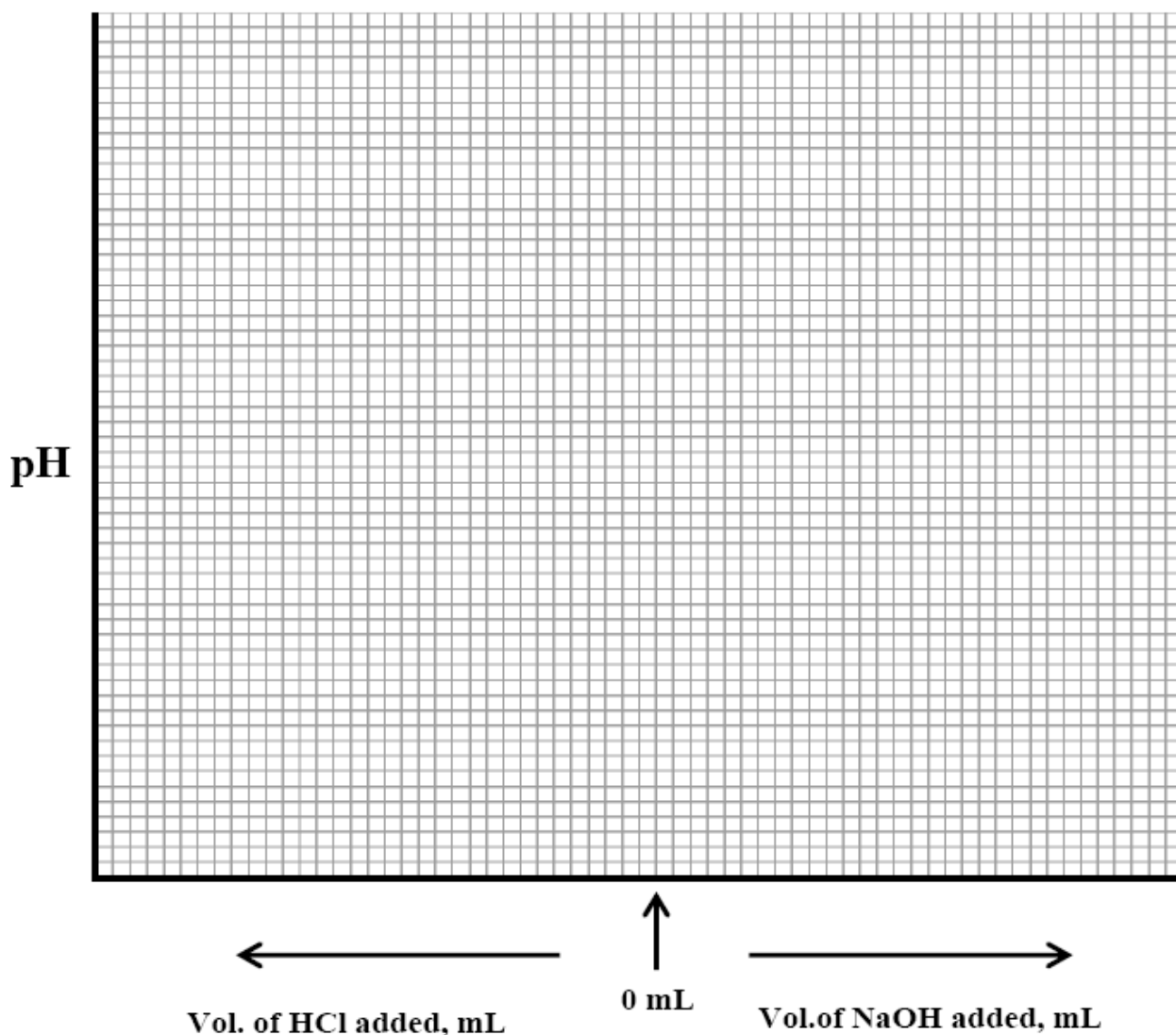
Final Report

Your final report should compare the buffer capacity of the three buffer solutions used in this experiment. Answer the questions: Which of the three solutions had the highest buffer capacity for the addition of a strong acid? Which of the three solutions had the highest buffer capacity for the addition of a strong base? Which of the three solutions had the smallest buffer capacity for the addition of both acid and base? What experimental evidence do you have to support the result?