# Buffer Action and Calculations

## Cautions

Acetic acid and hydrochloric acid are toxic, irritants and corrosive. Ionic salts may be irritants and toxic.

Avoid skin contact from all chemicals and rinse thoroughly with running water if contact occurs.

## Purpose

To compare calculated and measured pH values of a buffer solution and investigate buffer action.

## Introduction

Buffers are solutions that resist large changes in pH when small quantities of strong acid or strong base are added to them. These solutions contain a weak acid and its conjugate base in nearly equal quantities. When small amounts of strong acid are added, it reacts with the conjugate base present to produce weak acid; small additions of strong base react with weak acid to form conjugate base. Changes in pH of buffer solutions can be determined using the Henderson-Hasselbalch equation:

$$pH = pK_a + \log \frac{[A^-]}{[HA]} \qquad (1)$$

where pKa is $-\log(K_a)$, $[A^-]$ is the concentration of conjugate base and [HA] is the concentration of weak acid present in the buffer. Human blood is a buffer solution, with a normal pH range of 7.35 – 7.45. Variations in blood pH ± 0.1 can cause serious health problems.

## Procedure

***NOTE**: Distilled water (not deionized) will be used for all experimental procedures.*

### *A. Acetic Acid-Acetate Buffer*

| Buffer | Acetic Acid (mL) | Sodium Acetate (mL) |
|---|---|---|
| ***A*** | 25.0 | 25.0 |
| ***B*** | 5.0 | 45.0 |
| ***C*** | 45.0 | 5.0 |

C1. In a clean beaker, mix together 25.0 mL of acetic acid solution and 25 mL of sodium acetate solution provided to make Buffer Solution ***A***

C2. Use the pH meter to measure the pH of the solution

C3. Using the same acetic acid and sodium acetate solutions, prepare Buffer Solutions ***B*** and ***C*** using the volumes of acid and conjugate base indicated in the table above.

C4. Measure the pH of each solution, making sure to rinse the electrode with distilled water between measurements.

### *B. Observing pH Change in a Buffer*

B1. Label 4 clean, dry 50 mL beakers "**1**," "**2**," "**3**," and "**4**."

B2. Add 25 mL of buffer solution ***A*** from part ***A*** into beakers **1** and **3**.

B3. Add 25 mL distilled water to beakers **2** and **4**.

B4. Measure the pH of the four solutions in beakers **1-4**.

B5. Transfer 1.0 mL 1 M HCl to beakers **1** and **2**. **Thoroughly mix** each solution with a clean glass stirring rod.

B6. Transfer 1.0 mL 1 M NaOH to beakers **3** and **4**. **Thoroughly mix** each solution with a clean glass stirring rod.

B7. Measure the **new** pH of the four solutions in beakers **1-4**.

# Buffer Action and Calculations

## Disposal

Dispose of all solutions into the appropriate waste containers.

## Clean-Up

Wash all glassware with soap then rinse 3 times with tap water, and once with distilled water.

Clean your work area with water and dry with paper towels. Wash your hands before leaving the laboratory.

## Calculations and Helpful Hints

*Perform the following calculations, record the results on the Data Sheets, and **show all work CLEARLY on extra paper**.*

**A. Acetic Acid/ Acetate Buffer Solution and pH**

- Calculate the concentration of acetic acid in the buffers by dilution (see equation above)
- Calculate the concentration of sodium acetate in the buffers by dilution
- Calculate the theoretical pH of each acetic acid–acetate buffer solution.

**B. *Observing pH Change in a Buffer***

- Determine the number of moles of acid and conjugate base present in the buffer
- Calculate the number of moles of strong acid or strong base added to the buffer and use this value to determine its effect on the buffer components
- Use the Henderson-Hasselbach equation to calculate the theoretical pH of the buffer solution after addition of strong acid or strong base
- Calculate the change in pH ($\Delta$pH) for the buffer solution a) when strong acid was added; b) when strong base was added. Use the pH of the pure buffer solution (beakers **1** and **3**) as the initial pH and the pH of the mixture of strong acid or strong base with buffer as the final pH.
- Calculate the change in pH ($\Delta$pH) for the distilled water a) when strong acid was added; b) when strong base was added. Use the pH of pure water (beakers **2** and **4**) for the initial pH and the pH of the mixture of strong acid or strong base with water as the final pH.

# Buffer Action and Calculations

## Data Sheet

**Name:** ______________________________________ **Lab Partner**________________________________

***Show all calculations on a separate piece of paper.***

### *A. Acetic Acid – Acetate Buffer Solution and pH*

| | Molarity |
|---|---|
| **Acetic Acid** | |
| **Sodium Acetate** | |

| Buffer Solution | Volume Acid (mL) | Volume Base (mL) | [Acid] | [Base] | Measured pH | Theoretical pH |
|---|---|---|---|---|---|---|
| A | 25.0 | 25.0 | | | | |
| B | 5.0 | 45.0 | | | | |
| C | 45.0 | 5.0 | | | | |

### *B.* Observing pH Change in Buffer Solution A

| Beaker | Solution | Measured pH (without HCl or NaOH) | Measured pH (with HCl or NaOH) | Theoretical pH (with HCl or NaOH) | ΔpH |
|---|---|---|---|---|---|
| **1** | Buffer A + HCl | | | | |
| **2** | Water + HCl | | | | |
| **3** | Buffer A + NaOH | | | | |
| **4** | Water + NaOH | | | | |

## Buffer Action and Calculations

### Post-lab Assignment

**Name:** ______________________________________

1. A different pH change was observed when 3 M HCl was added to the buffer compared to the same amount of 3 M HCl added to the distilled water. Why? Use reactions to explain your answer.

2. Provide some reasons why the measured pH of the buffer doesn't match the pH calculated using concentrations and the Henderson-Hasselbalch equation.

# Buffer Action and Calculations

## Pre-lab Assignment

**Name:** ________________________________________

1. Which of the following conjugate acid/base pairs can be used to prepare a buffer?

   NaOH/HCl $NH_4^+/NH_3$ $HNO_3/NaNO_3$

2. A biochemist is working with bacteria that require a culture medium at a pH of 3.6. Which of the following conjugate acid/base pairs is the best choice for this buffer? Explain your reasoning.

   | | |
   |---|---|
   | $H_2CO_3/NaHCO_3$ | $K_{a1} = 4.27 \times 10^{-7}$ |
   | $KH_2PO_4/K_2HPO_4$ | $K_{a2} = 6.17 \times 10^{-8}$ |
   | $HC_2H_3O_2/NaC_2H_3O_2$ | $K_a = 1.78 \times 10^{-5}$ |
   | $HCO_2H/KCO_2H$ | $K_a = 1.82 \times 10^{-4}$ |

3. A buffered solution contains 0.45 M acetic acid ($K_a = 1.80 \times 10^{-5}$) and 0.60 M sodium acetate. Calculate the pH of this solution.