Properties of Buffers

Introduction

Buffers resist changes in pH when acids or bases are added to them. An effective buffer system contains significant quantities of a specific weak acid and its conjugate base. There are two common methods used to prepared a buffer. One method is to combine approximately equal quantities of an acid and its conjugate base. The other method is to convert about half of the weak acid in a solution or half of the weak base in a solution to its conjugate form by adding a strong base or strong acid respectively. This process is called **partial neutralization**. The $[H^+]$ is calculated from equation (1) where HA is a weak acid and A^- is the conjugate base.

$$[H^+] = K_a\,[HA]/[A^-] \qquad \textbf{(1)}$$

pH may be calculated from the **Henderson–Hasselbalch equation**. This is the logarithmic form of equation (1). Two equivalent forms of the equation are:

$$\mathrm{pH} = \mathrm{pK}_a + \log\left(\frac{[\mathrm{A}^-]}{[\mathrm{HA}]}\right) \qquad \textbf{(2)}$$

$$\mathrm{pH} = \mathrm{pK}_a - \log\left(\frac{[\mathrm{HA}]}{[\mathrm{A}^-]}\right).$$

In this experiment you will prepare a buffer and measure its pH with a pH-meter. The weak acid of the buffer will be acetic acid ($HC_2H_3O_2$) and its conjugate base, the acetate ion($C_2H_3O_2^-$). The buffer solution will be prepared using both methods described above.

You will measure the pH as a strong acid and base are added to the buffer solution, and compare the results with measurements made when a strong acid and base are added to plain water and to dilute buffer solutions.

Note: The symbol HOAc is often used to represent acetic acid and OAc^- to represent the acetate ion.

Procedure:

Special equipment:

pH-meter
magnetic stirrer and small stirring bar
two 50-mL burets

Note: If performing this experiment in the studio classroom use 25-mL burets.

A. Buffer Solution Preparations

1. All glassware must be clean. If the graduated cylinders and burets to be used are not totally dry, rinse them first with three small portions of the solution to be used. Drain out the rinsing solution each time as completely as you can. Then fill them with the required solution.

2. Set up the burets with about 30mL of 0.100 M HCl in one and 30 mL of 0.100 M NaOH in the other.

3. Prepare your first buffer by mixing 50.0 mL of 0.100 M NaOAc and 45.0 mL of 0.100 M HOAc. Use graduated cylinders for these volume measurements. Mix well. Label this **Buffer ONE**

4. Prepare your second buffer by mixing 50.0 mL of 0.100 M NaOH and 95.0 mL of 0.100 M HOAc . Use graduated cylinders for these volume measurements. Mix well. Label this **Buffer TWO.**

5. Measure and record the pH values of the two buffer solutions prepared.

B. Addition of Acid and Base to the Buffers

1. Place 30.0 mL of **Buffer ONE** into a clean dry 50-mL beaker. Add the magnetic stirring bar and put the beaker on the magnetic stirrer. Turn the stirrer on and adjust it so that it is stirring but not splashing. Add five drops of bromocresol green indicator to the buffer. Insert the pH-meter probe so that the stirring bar does not hit it. Record the color of the buffer, record its pH.

2. Arrange the buret so that you can add the 0.100 M HCl solution to the buffer and measure the pH while the solution is continuously stirred.

3. The suggested volumes of HCl to be added are: 0.50, 1.00, 1.50, 2.25, 3.00, 3.50, 3.50, 2.00 mL. (*8 additions of HCl for a total volume of 19.25 mL*) The volume increments which you actually add may differ from these values by up to 0.20 mL, but you must have a record of the exact volumes which you added. Read the buret at the beginning and after each addition. Obtain exact values by subtraction.

4. Record the color, pH value, and the ***total volume*** of HCl after each addition in your laboratory notebook.

5. When you've completed your measurements you may discard the solution in the sink. **Don't lose the magnetic stirring bar!**

6. Repeat Steps1 to 4 using 0.100 M NaOH solution instead of the 0.100 M HCl solution.

C. Addition of Acid and Base to Deionized water

1. Pour 30.0 mL deionized water into a clean dry 50-mL beaker. Add five drops of bromocresol green indicator. Measure the pH and note the color. Add the following volume increments of 0.100 M HCl solution to the water with continual magnetic stirring: 0.25 mL then three of 0.50 mL each, then three of 1.00mL each.

2. Record the color, pH value, and the ***total volume*** of HCl after each addition.

3. Discard the solution in the sink. **Don't lose the magnetic stirring bar!**

4. Repeat Steps1 to 3 using 0.100 M NaOH solution instead of the 0.100 M HCl solution.

D. Addition of Acid and Base to Diluted Buffer

1. Pour 15.0 mL of **Buffer TWO** into a clean dry 50-mL beaker. Add five drops of bromocresol green. Add 15.0 mL deionized water. Set the beaker on the magnetic stirrer, stir, and measure the pH. Note the color.

2. Add the following increments of 0.100 M HCl solution with continuous stirring. Record the pH values, color, and the total volume added after each increment. The suggested increments are: 0.50 mL, then 6 portions 1.00 mL each, then 3 portions 1.50 mL each.

3. Discard the solution from the beaker in the sink. **Don't lose the magnetic stirring bar!**

4. Repeat Steps1 to 3 using 0.100 M NaOH solution instead of 0.100 M HCl solution.

Clean-up:

1. Discard all solutions in the sink. **Don't lose the magnetic stirring bar!**

2. Rinse the burets and pipets with deionized water before returning them.

3. Return the pH meters to their appropriate containers.

Sample Data Charts

Data must be recorded in your laboratory notebook.

Buffer and Their Properties

Table 1: Addition of acid, HCl, to Buffer ONE

Color	pH_{obs}	Total volume HCl added (mL)	mmols H^+ added	[H+]	pH_{calc}

Table 2: Addition of base, NaOH, to Buffer ONE

Color	pH_{obs}	Total volume NaOH added (mL)	mmols OH^- added	[H+]	pH_{calc}

Table 3: Addition of acid, HCl, to deionized water

Color	pH $_{obs}$	Total volume HCl added (mL)	mmols H^+ added	$[H^+]$	pH $_{calc}$

Table 4: Addition of base, NaOH, to deionized water

Color	pH $_{obs}$	Total volume NaOH added (mL)	mmols OH^- added	$[H^+]$	pH $_{calc}$

Table 5: Addition of acid, HCl, to Diluted Buffer TWO

Color	pH $_{obs}$	Total volume HCl added (mL)	mmols H^+ added	[H+]	pH $_{calc}$

Table 6: Addition of base, NaOH, to Diluted Buffer TWO

Color	pH $_{obs}$	Total volume NaOH added (mL)	mmols OH^- added	[H+]	pH $_{calc}$

Preparation Instructions for Properties of Buffers

4 sets of the following:

500mL bottle of 0.1 M acetic acid
500mL bottle of 0.1 M sodium acetate
200mL bottle 0.1 M HCl
200mL bottle 0.1 M NaOH

dropper bottle bromocresol green indicator

pH-meter (in studio classroom)
magnetic stirrer and small stirring bar (in studio classroom)
eight 25-mL burets (use short burets if doing this experiment in the studio classroom)