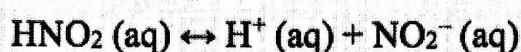


Buffers

A buffer is a mixture of a weak acid and its conjugate base, or a weak base and its conjugate acid. A buffer's function is to absorb acids (H^+ or H_3O^+ ions) or bases (OH^- ions) so that the pH of the system changes very, very little.

In many systems, buffers are critical. Blood plasma, a natural example in humans, is a bicarbonate buffer that keeps the pH of blood between 7.2 and 7.6.

By design, a buffer is an equilibrium system. For example, a buffer can be prepared with nitrous acid, HNO_2 . The weak acid establishes an aqueous equilibrium as shown below.



The equilibrium constant expression is shown below.

$$K_a = \frac{[\text{H}^+][\text{NO}_2^-]}{[\text{HNO}_2]}$$

To prepare a buffer system with nitrous acid, a conjugate base is added, such as sodium nitrite (NaNO_2). The resulting system is a mixture of HNO_2 and NO_2^- ions. The nitrous acid molecule will neutralize hydroxide ions and the nitrite ion from the conjugate will neutralize hydrogen ions.

A variation of the equilibrium expression above, called the Henderson-Hasselbalch equation, is the best reference in preparing a buffer solution. For our nitrous acid/sodium nitrite buffer example, the Henderson-Hasselbalch equation is shown below.

$$\text{pH} = \text{p}K_a + \log \frac{[\text{NO}_2^-]}{[\text{HNO}_2]}$$

The pH range in which a buffer solution is effective is generally considered to be ± 1 of the $\text{p}K_a$.

In this experiment, you will use the Henderson-Hasselbalch equation to determine the amount of acetic acid and sodium acetate needed to prepare two acidic buffer solutions. You will then prepare the buffers and test their buffer capacities by adding solutions of NaOH and HCl .

OBJECTIVES

In this experiment, you will

- Prepare and test two acid buffer solutions.
- Determine the buffer capacity of the prepared buffers.

MATERIALS

LabQuest
LabQuest App
Vernier pH Sensor
magnetic stirrer and stirring bar
three 250 mL beakers
100 mL graduated cylinder
25 mL graduated cylinder
balance
ring stand

0.5 M sodium hydroxide, NaOH, solution
two 50 mL burets and two buret clamps
0.5 M hydrochloric acid, HCl, solution
0.1 M acetic acid, $\text{HC}_2\text{H}_3\text{O}_2$, solution
1.0 M acetic acid, $\text{HC}_2\text{H}_3\text{O}_2$, solution
solid sodium acetate, $\text{NaC}_2\text{H}_3\text{O}_2$
utility clamp
distilled water

PRE-LAB EXERCISE

Use the Henderson-Hasselbalch equation to perform the following calculations. The K_a of acetic acid is 1.8×10^{-5} . Review your calculations with your instructor before preparing the buffer solutions.

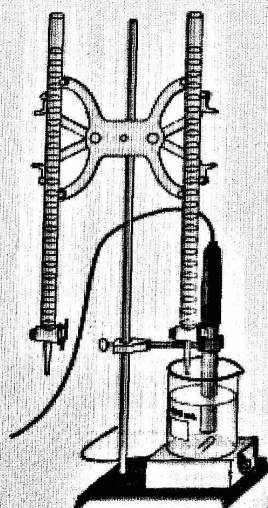
Buffer A: Calculate the mass of solid sodium acetate required to mix with 100.0 mL of 0.1 M acetic acid to prepare a pH 4 buffer. Record the mass in your data table.

Buffer B: Calculate the mass of solid sodium acetate required to mix with 100.0 mL of 1.0 M acetic acid to prepare a pH 4 buffer. Record the mass in your data table.

PROCEDURE

Part I Prepare and Test Buffer Solution A

1. Obtain and wear goggles.
2. Use your calculations from the Pre-Lab Exercise to prepare 100 mL of Buffer A. Weigh out the precise mass of sodium acetate and dissolve it in 100.0 mL of 0.1 M acetic acid solution.
3. Set up two burets, buret clamp, and ring stand (see Figure 1). Rinse and fill one buret with 0.5 M NaOH solution. Rinse and fill the second buret with 0.5 M HCl solution. **CAUTION:** *Sodium hydroxide solution is caustic. Avoid spilling it on your skin or clothing. Handle the hydrochloric acid with care. It can cause painful burns if it comes in contact with the skin.*



4. Use a graduated cylinder to measure out 10.0 mL of the Buffer A solution into a 250 mL beaker and add 15 mL of distilled water. Place the beaker on a magnetic stirrer, beneath the buret of NaOH, and add a stirring bar. If no magnetic stirrer is available, you will stir with a stirring rod during the testing.
5. Connect the pH Sensor to LabQuest and choose New from the File menu. If you have an older sensor that does not auto-ID, manually set up the sensor. Suspend the pH Sensor in the pH 4 buffer solution, as shown in Figure 1. Make sure that the sensor is not struck by the stirring bar.
6. On the Meter screen, tap Mode. Change the data-collection mode to Events with Entry. Enter the Name (Volume) and Units (mL). Select OK.
7. Collect data. You will slowly and carefully add 0.50 M NaOH solution to the sample of Buffer A.
 - a. Start data collection.
 - b. Take an initial pH reading of the buffer solution. Allow the pH readings to stabilize and then tap Keep. Enter 0 as the buret volume in mL. Select OK to save the first data pair. Record the initial pH value in your data table.
 - c. Add a small amount of the NaOH solution, up to 0.50 mL. When the pH stabilizes, tap Keep. Enter the current buret reading, and then select OK to save the second data pair.
 - d. Continue adding the NaOH solution in small increments that raise the pH consistently and enter the buret reading after each increment. Your goal is to raise the pH of the buffer by precisely 2 pH units.
 - e. When the pH of the buffer solution is precisely 2 units greater than the initial reading, continue to add the NaOH solution in small increments until you have reached, and passed, the equivalence point of the titration.
 - f. Stop data collection to view the graph.
8. Examine your titration curve.
 - a. To examine the data pairs on the displayed graph, select any data point. As you tap each point, the pH and volume values of each data point are displayed to the right of the graph.
 - b. Identify the point at which the pH increased by 2 units and record the volume of NaOH in your data table.
 - c. Store the data from the first trial by tapping the File Cabinet icon.
9. Dispose of the reaction mixture as directed. Rinse the pH Sensor with distilled water in preparation for the second trial.
10. Repeat Steps 7–9, using a fresh 10.0 mL sample of the Buffer A solution. For this second trial, titrate the buffer with 0.5 M HCl solution. Carefully add HCl in small increments until the pH of the solution has been lowered by precisely 2 units. Record, in your data table, the volume of HCl that was used. You may save the data if you wish.

Part II Prepare and Test Buffer Solution B

11. Use your calculations from the Pre-Lab Exercise to prepare 100 mL of Buffer B. Weigh out the precise mass of sodium acetate and dissolve it in 100.0 mL of 1.0 M acetic acid solution. If necessary, refill the burets of NaOH and HCl solution.

Experiment 10

12. Use a graduated cylinder to measure out 10.0 mL of the Buffer B solution and add 15 mL of distilled water. Repeat the necessary steps to test Buffer B in a manner similar to the Part I trials. Determine the volumes of NaOH and HCl that were used to change the pH of Buffer B by 2 units and record the values in your data table. Remember to save the data from the titration with NaOH solution.
13. Print the two graphs for the titrations of Buffer A and Buffer B with 0.5 M NaOH. Print the graphs directly from LabQuest, or transfer the data to a computer and Logger Pro software to prepare and print the graphs.

DATA TABLE

	Buffer A	Buffer B
Mass of $\text{NaC}_2\text{H}_3\text{O}_2$ used to prepare buffer (g)		
Volume of buffer prepared (mL)	100.0	100.0
Molar concentration of $\text{HC}_2\text{H}_3\text{O}_2$ in buffer (M)	0.1	1.0
Initial pH of buffer		
Volume of 0.5 M NaOH to raise pH by 2 units (mL)		
Volume of 0.5 M HCl to lower pH by 2 units (mL)		
Volume of 0.5 M NaOH at equivalence point (mL)		

DATA ANALYSIS

1. Write reaction equations to explain how your acetic acid-acetate buffer reacts with an acid and reacts with a base.
2. Buffer capacity has a rather loose definition, yet it is an important property of buffers. A commonly seen definition of buffer capacity is: "The amount of H^+ or OH^- that can be neutralized before the pH changes to a significant degree." Use your data to determine the buffer capacity of Buffer A and Buffer B.
3. Say, for example, that you had prepared a Buffer C, in which you mixed 8.203 g of sodium acetate, $\text{NaC}_2\text{H}_3\text{O}_2$, with 100.0 mL of 1.0 M acetic acid.
 - a. What would be the initial pH of Buffer C?
 - b. If you add 5.0 mL of 0.5 M NaOH solution to 20.0 mL each of Buffer B and Buffer C, which buffer's pH would change less? Explain.