



Buffer Capacity Performer's Version

Safety Hazards

- Personal Protective Equipment
 - Safety glasses/goggles
 - Nitrile gloves
 - Flame & chemical retardant lab coat
- Physical Hazards
 - Universal indicator is a highly flammable liquid and vapor.
 - Acetic acid is a highly flammable liquid and vapor.
- Chemical Hazards
 - Acetic acid causes severe skin burns and eye damage
 - Sodium hydroxide is highly corrosive; causes severe skin and eye damage.

Materials

- 2x 1L graduated cylinders
- 700 mL 1:1 Buffer mixture (1M Sodium acetate/1M Acetic acid buffer)
- 700 mL 10:1 Buffer mixture (0.1M Sodium acetate/0.01M Acetic acid buffer)
- 0.5M Sodium hydroxide solution
- 3M Sodium hydroxide solution
- Universal indicator
- 2x magnetic stir plates
- 2x magnetic stir bars
- Power strip
- Pipette
- Pipette tips

Safety Data Sheets

- [Universal Indicator](#)
- [Sodium Hydroxide](#)
- [Sodium acetate](#)
- [Acetic acid](#)

Procedure

1. Plug the power strip into the nearest outlet, and plug both stir plates into it.
2. Place both graduated cylinders on the stir plates, dropping the stir bars to the bottom.
3. Fill one graduated cylinder with the 1:1 buffer mixture and the other with the 10:1 buffer mixture.
4. Add 2 – 5 mL universal indicator to each cylinder, turning the stir plates on to gently stir both solutions. Allow the indicator to uniformly distribute throughout the solution and observe the color difference between the two due to the different pHs.
5. While stirring both mixtures, begin adding the 0.5M Sodium hydroxide solution one milliliter at a time.
6. Continue adding sodium hydroxide, using either the 0.5M or 3M solution (depending on your time constraint) until the weaker buffer is broken, but the stronger still resists pH change.
7. Continue adding sodium hydroxide until the stronger buffer is broken.
8. Turn off the stir plates and place the graduated cylinders onto the table.

Pedagogy & Supplemental Information

Acid-base reactions are fundamental to many chemical processes, and their principles can be effectively demonstrated in many ways. In this demonstration, students can witness this principle in action by observing the dramatic color change of a solution with universal indicator when a strong base is added to both a 1:1 and 1:10 buffer solution of acetic acid and sodium acetate.

Under the Brønsted-Lowry definition, an acid is a substance that donates protons (H^+ ions), while a base is a substance that accepts protons. In neutralization reactions, acids and bases combine to form water and a salt. This concept underscores the dynamic interplay between hydrogen ions (H^+) and hydroxide ions (OH^-) in aqueous solutions. Buffers, essential components of this chemistry, are solutions that resist changes in pH upon addition of acid or base. They consist of a weak acid and its conjugate base, or a weak base and its conjugate acid, which together maintain a stable pH.

What sets buffers apart is their remarkable pH resistance, a property crucial for maintaining the stability of various biological systems and industrial processes. A well-designed buffer system can withstand significant changes in hydrogen ion concentration, thereby preserving optimal conditions for biochemical reactions or chemical processes. The ideal buffer is typically a 1:1 ratio of weak acid to its conjugate base or weak base to its conjugate acid, as this ensures maximal buffering capacity.

In contrast, a 1:10 buffer, characterized by a higher concentration of weak acid or base relative to its conjugate, is notably weaker and more susceptible to pH shifts. This weakness stems from the imbalance in the buffering components, making it easier for added acid or base to disrupt the equilibrium and cause a significant change in pH.

The practical significance of buffer systems extends far beyond the classroom, finding application in diverse fields such as biochemistry, pharmaceuticals, and environmental science. Biological organisms rely on buffers to maintain physiological pH levels, ensuring proper functioning of enzymes and cellular processes. Similarly, in industrial processes such as fermentation or water treatment, buffers play a crucial role in optimizing reaction conditions and product yield. Understanding buffer capacities and their behavior provides valuable insights into the control and manipulation of chemical environments for practical purposes, underscoring their indispensable role in both scientific research and everyday life.