

pH Properties of Buffer Solutions

Inquiry Guidance and AP* Chemistry Curriculum Alignment



Introduction

The physiological role of buffers within cells and in consumer products highlights the ability of buffers to resist changes in pH. Buffers provide an essential acid–base balancing act—in foods and drugs, consumer products, lakes and streams, and even living cells. All biological cells depend on the properties of buffers, as does the essential function of the respiratory system, breathing, which must be regulated within a very narrow pH range. What are buffers made of and how do they work?

Opportunities for Inquiry

Buffers represent an integrated concept bridging many big ideas. Understanding buffers requires students to synthesize knowledge and apply reasoning skills from chemical reactions, stoichiometry, and acid–base equilibrium. The myriad applications of buffers offer many interesting opportunities to study the composition and mechanism of action of buffers.

- Promote inquiry into buffers using a colorful demonstration. Dissolve Alka-Seltzer® tablets in water, add universal indicator, and observe the color and pH changes when 1 M HCl and 1 M NaOH are added. Ask students to design similar experiments to identify the potential buffering characteristics of other consumer products, including antacids, shampoos and conditioners, mouthwashes, beverages, contact lens solution, etc.
- Acetate buffers provide a convenient introductory activity to study how the pH of a buffer depends on the relative amounts of a weak acid and its conjugate base. Extend the baseline activity by asking students to select weak acid–conjugate base combinations that will be effective at different pH values across typical physiological or aqueous chemistry. Make it a challenge! Identify the ratios and concentrations at each pH that will have the highest capacity with respect to added acid or added base. *Hint:* They are not the same!
- Challenge students to prepare a set of buffer standards for an indicator color series that can be used for narrow-range pH analysis (± 0.2 pH units). An example is a series of phosphate buffers containing various ratios of NaH_2PO_4 and Na_2HPO_4 solutions with bromthymol blue ($\text{pH} = 6.0\text{--}7.6$).
- Forensic analysis of DNA by electrophoresis requires a buffer that will keep the charge on the DNA molecules relatively constant so that their migration in an electric field will depend only on their size. Research, prepare and study the pH profiles of electrophoresis buffers.
- Most enzymes have an optimum pH value for maximum activity. How are buffer solutions used to determine the optimum pH for a common enzyme such as amylase, catalase or pectinase?

Alignment with AP Chemistry Curriculum Framework—Big Ideas 3 and 6

Enduring Understandings and Essential Knowledge

Chemical changes are represented by a balanced chemical equation that identifies the ratios with which reactants react and products form. (Enduring Understanding 3A)

3A2: Quantitative information can be derived from stoichiometric calculations that utilize the mole ratios from the balanced chemical equations. The role of stoichiometry in real-world applications is important to note, so that it does not seem to simply be an exercise done only by chemists.

Chemical reactions can be classified by considering what the reactant are, what the product are, or how they change from one into the other. Classes of chemical reactions include synthesis, decomposition, acid–base, and oxidation–reduction reactions. (Enduring Understanding 3B)

3B2: In a neutralization reaction, protons are transferred from an acid to a base.

Chemical equilibrium plays an important role in acid base chemistry and in solubility. (Enduring Understanding 6C)

6C1: Chemical equilibrium reasoning can be used to describe the proton transfer reactions of acid–base chemistry.

6C2: The pH is an important characteristic of aqueous solutions that can be controlled with buffers. Comparing pH to $\text{p}K_a$ allows one to determine the protonation state of a molecule with a labile proton.

Learning Objectives

- 3.7 The student is able to identify compounds as Brønsted-Lowry acids, bases, and/or conjugate acid–base pairs, using proton-transfer reactions to justify the identification.
- 6.12 The student can reason about the distinction between strong and weak acids solutions with similar values of pH, including the percent ionization of acids, the concentrations needed to achieve the same pH, and the amount of base needed to reach the equivalence point in a titration.
- 6.16 The student can identify a given solution as being the solution of a monoprotic weak acid or base, including salts in which one ion is a weak acid or base), calculate the pH and concentration of all species in solution, and/or infer the relative strengths of the weak acids or bases from given equilibrium concentrations.
- 6.18 The student can design a buffer solution with a target pH and buffer capacity by selecting an appropriate conjugate acid–base pair and estimating the concentrations needed to achieve the desired capacity.
- 6.19 The student can relate the predominant form of a chemical species involving a labile proton (i.e., protonated/deprotonated form of a weak acid) to the pH of a solution and the pK_a associated with the labile proton.
- 6.20 The student can identify a solution as being a buffer solution and explain the buffer mechanism in terms of the reactions that would occur on addition of acid or base.

Science Practices

- 2.2 The student can apply mathematical routines to quantities that describe natural phenomena.
- 2.3 The student can estimate numerically quantities that describe natural phenomena.
- 4.2 The student can design a plan for collecting data to answer a particular scientific question.
- 5.1 The student can analyze data to identify patterns or relationships.
- 6.1 The student can justify claims with evidence.
- 6.4 The student can make claims or predictions about natural phenomena based on scientific theories and models.
- 7.2 The student can connect concepts in and across domains to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

The *pH Properties of Buffer Solutions*—AP Chemistry Classic Laboratory Kit is available from Flinn Scientific, Inc.

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AP6445	pH Properties of Buffer Solutions—AP Chemistry Classic Laboratory Kit

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