Pass the Buffer-in: Instructor Guide

Title:

Pass the Buffer-in

Author:

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Discipline:

Chemistry and Biochemistry

Target Audience

Introductory, majors and nonmajors

Keywords

Buffers, neutralization

Length of Time/Staging

Two 50-minute class periods for working on problem and reporting out

Abstract

A student needing to prepare a pH 7.5 buffer must decide whether an unlabeled recipe will do the job.

Date Submitted

9/18/2001

Date Published

10/22/2001

Format of Delivery

Students work on the problem in groups of four, and submit a written analysis as well as reporting out orally on their results.

Student Learning Objectives

1. To learn the characteristic features of a buffer system.
2. To recognize the role of neutralization reactions in the preparation of buffer solutions.
3. To recognize how relative Ka values lead to stepwise neutralization reactions.
4. To determine the major components of a solution at equilibrium.
5. To learn how to calculate the pH of a buffer solution, and how to prepare a buffer that will have a certain pH.

Student Resources

Standard general chemistry textbook

Author's Teaching Notes

This problem follows an analysis of acid-base titration curves, with no prior discussion of buffer systems. Students must first recognize the combination of phosphoric acid and KOH as a highly favored neutralization reaction; a decision must be made as to whether that proceeds in a stepwise fashion, with each phosphoric acid molecule losing a proton first, or statistically. They must recognize that the neutralization process will continue until all of the strong base is depleted, at which point the pH may be calculated.

The first reaction to the question about using NaOH *vs.* KOH is usually that it will make no difference, since both are strong bases; there are always a number of students, though, who soon realize that the different molecular weights will influence the position of equilibrium and thus change the final pH.

Two points discussed in review:

Reviewer: *I quickly pulled out my calculator and determined the pH to be 7.54. Since the buffer called for a 7.50 buffer, I judged the protocol to be slightly incorrect. I then looked at the 35 mL on the "slip of paper." My question is: Was the protocol correct based on two significant figures or incorrect based upon the 7.50? I don't know whether this is minor point or not. What would you do if half the groups said it was a good protocol and that most cells wouldn't care about the 0.04 pH, and the other half was a picky bunch of "sig fig"* *nerds?*

Author: The pH does, in fact, come out to be 7.54 instead of 7.50. I use this as an opportunity to, first, point out that solutions rarely have exactly the pH you calculate for them anyway; most protocols for preparing a buffer will suggest adjusting the solution at the end to the exact pH required by adding small amounts of strong acid or base and monitoring via a pH meter. I also use the difference in pH to ask them whether it really matters:in a practical sense, with the answer being that it depends on what kind of pH control you need!), and in a sig-fig sense. I also ask: if they wanted to get to pH 7.50 from 7.54, how would the ratio of [HA]/{A-] have to change? - and we work through that calculation. The last provides a lead-in to showing the Henderson-Hasselbach equation, and pointing out the control that [HA]/{A-] ratio has over the pH.

So, I think coming out to a slightly-off answer is actually useful as a springboard for other discussions. One could certainly adjust the numbers to get the "right" answer and avoid that, though.

Reviewer: *Is it proper to use the word neutralization with a weak acid reacting with a strong base? Perhaps this could be replaced with "acid-base reactions."*

Author: Regarding neutralization: most definitions I've seen for this term describe it as the reaction between a stoichiometric amount of acid and base to produce a salt and water; the resulting solution is not required to be neutral. I am aware that a few texts indicate that a neutral solution is produced, which would limit the use of the term to strong acid-base reactions. Since I use (and subscribe) to the first description, I do refer to this as a neutralization reaction. We will have done another problem before this ("Riverside"), in which students encountered strong + (weak or strong) acid-base reactions, all described as neutralizations - with the point having been made that the resulting solutions are not always neutral. So....the term neutralization fits with my understanding of the reaction in the Buffer-in problem as that between a stoichiometric amount of acid and base producing a salt and water. I would keep this terminology, but can understand how others using an alternate definition of "neutralization" might choose to replace it.

Assessment Strategies

Students give both written and oral reports of their work, Exam questions probe the student's ability to recognize neutralization reactions, to identify the major components at equilibrium in multi-component mixtures, as well as to design the synthesis of buffers with characteristic pH and buffer capacity.