Riverside's Dilemma: Instructor Guide

Title:

Riverside's Dilemma

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Discipline:

Chemistry and Biochemistry

Target Audience

Introductory, nonmajors or majors

Keywords

Ka and Kb, acid-base chemistry, equilibrium, neutralization reactions, pH calculations, weak and strong acids and bases

Length of Time/Staging

One to two 50-minute classes for parts 1 and 2; part 3 is usually an out-of-class assignment

Abstract

A town council is faced with some decisions to make centering on allowable pH limits for anticipated waste streams going into a river. In dealing with the issue, students encounter

concepts in acid-base chemistry - e.g., weak and strong acids and bases, neutralization reactions, and related equilibrium calculations.

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Student Learning Objectives

Part 1

1. To recognize compounds as acids or bases, and as strong, or weak.
2. To describe the behavior of strong species in solution, and to calculate the resulting pH.
3. To formulate equilibrium expressions for a weak acid or base in solution, and to calculate the pH of that solution.
4. To describe the behavior of a polyprotic acid in solution, and to calculate its pH.

Part 2

1. To recognize and formulate neutralization reactions.
2. To understand the relationship between neutralization and acid-base dissociation reactions, and to derive an equilibrium constant for a neutralization from appropriate dissociation constants.
3. To recognize the stoichiometric and equilibrium components of pH calculations for this type of process, and to be able to carry those out correctly.
4. To identify which reactants could be combined in a neutralization reaction, and to estimate an equilibrium constant for the reaction.
5. To set up an equilibrium expression for each reaction, and use it to determine the ratio of reactants required to achieve the desired pH.
6. To decide which of the possible neutralization processes are the most reasonable, and to discuss factors that justify their choice.

Part 3

1. To deal effectively with more complex acid-base combinations, including recognizing the possibility of buffer formation.
2. To recognize factors other than pH that would have to be addressed in considering the environmental impact of the waste discharges.
3. To understand the purposes and limitations of making assumptions in defining a system.

Student Resources

Primary resource: a general chemistry textbook

Author's Teaching Notes

Background

This problem is used in the second semester of an Honors general chemistry course as a context for the development of concepts associated with aqueous acid-base chemistry. Part 1 is used to introduce the equilibrium behavior of strong and weak acids and bases in solution. Part 2 deals with the concept of neutralization and its relationship to dissociation equilibria. In Part 3, students encounter a more complex neutralization process, which requires them to pull together and apply the concepts developed in Parts 1 and 2 to a more open-ended situation.

Part 1

Students in this course have a wide range of past experiences with acid-base chemistry. This problem is introduced after the students have completed a quick quiz (first as individuals and then in groups) that asks them to identify or define a series of terms associated with acid-base chemistry. They report out and compare their answers, but there is no formal instruction concerning any of these topics at this time - the purpose of the exercise is to jog memories, and to highlight areas of little common knowledge. (Ideas associated with Ka and Kb invariably fall in the latter category.)

Part 2

Students have a tendency to think that a neutralization reaction results in a solution of pH 7. This problem prompts them to discover the relationship between neutralization and dissociation reactions; when they recognize that a neutralization is the reverse of a weak dissociation process, the need to treat the neutralization as a separate,strongly-favored step in the pH calculation process becomes clearer.

Part 3

The third part of this problem is more difficult and open-ended. It requires students to pull together the material they've dealt with in Parts 1 and 2 in thinking about a more complex situation. They must recognize the various combinations of waste streams that are possible; decide which constitute neutralization processes; and of these, which have equilibrium constants appropriate for the desired result. They must then work backwards to decide on ratios of reactants that would results in the desired pH at the end.