16A. Equilibria with Weak Acids and Weak Bases

Introduction

Equilibria with weak acids and weak bases are subjects of considerable importance (Ebbing/Gammon, Chapter 16). Your study of these equilibria will begin with solutions containing a single solute. The solute will be either a weak acid or a weak base. Salts that hydrolyze will be included in this category. Next you will consider solutions with two solutes. The common-ion effect and buffer solutions will be included in this category.

Purpose

This experiment will allow you to examine the effect of dilution on the degree of ionization of a weak acid and a weak base, the pH of a solution containing a polyprotic acid, the common-ion effect, and buffer solutions.

Concept of the Experiment

Each part of this experiment and your interpretation of the results depend on your estimate or measurement of pH. You will use either pH paper or a pH meter. These methods, which may be familiar to you from the experiment "The Relative Strengths of Some Acids," are discussed in Appendix D.

Procedure

Getting Started

1. Your laboratory instructor may ask you to work with a partner.
2. If you are using a pH meter for the first time, obtain instructions.

Table 16A.1 Composition of Solutions

Solution	Composition
1	0.10 M $HC_2H_3O_2$
2	5 mL 0.10 M $HC_2H_3O_2$ + 5 mL H_2O
3	1 mL 0.10 M $HC_2H_3O_2$ + 99 mL H_2O
4	5 mL 0.10 M $HC_2H_3O_2$ + 5 mL 0.10 M HCl
5	0.10 M H_3PO_4
6	0.10 M NH_3
7	0.10 M NH_4NO_3
8	50 mL 0.10 M NH_3 + 50 mL 0.10 M NH_4NO_3
9	10 mL Solution 8 + 6 mL H_2O
10	10 mL Solution 8 + 5 mL H_2O + 1 mL 0.10 M HCl
11	10 mL Solution 8 + 6 mL 0.10 M HCl
12	10 mL Solution 8 + 5 mL H_2O + 1 mL 0.10 M NaOH
13	10 mL 0.10 M $HC_2H_3O_2$ + 5 mL 0.10 M NaOH
14	10 mL 0.10 M NH_4NO_3 + 5 mL 0.10 M NaOH

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Doing the Experiment

1. Prepare the solutions in Table 16A.1 one at a time in clean, dry glassware. Always use distilled water.
2. After you prepare each of the solutions, mix it thoroughly. If you use a stirring rod, make sure it is clean and dry. Estimate or measure the pH and record the result.
3. Rinse and dry the glassware before using it again.

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Equilibria with Weak Acids and Weak Bases

Prelaboratory Assignment

1. Define the following terms:

   a. Acid-ionization constant (K_a)

   b. Base-ionization constant (K_b)

   c. Degree of ionization

   d. Percent ionization

   e. Common-ion effect

   f. Buffer

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2. a. Which substances in this experiment are strong acids and strong bases?

b. Which are weak acids and weak bases?

c. Which solutions in Table 16A.1 should exhibit common-ion effects?

d. Which solutions are buffers?

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Results

Solution No.	pH	Solution No.	pH
1	______	8	______
2	______	9	______
3	______	10	______
4	______	11	______
5	______	12	______
6	______	13	______
7	______	14	______

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Questions

1. a. Calculate the degree of ionization of acetic acid in Solutions 1 through 3.

   b. How do your results compare with expected behavior?

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2. Calculate the expected pH of the following solutions (Ebbing/Gammon, Sections 16.1, 16.2, and 16.3). Compare the calculated values with your experimental results from Solutions 5, 6, and 7.

   a. 0.10 M H_3PO_4 with $K_{a1} = 6.9 \times 10^{-3}$:

   b. 0.10 M NH_3 with $K_b = 1.8 \times 10^{-5}$:

   c. 0.10 M NH_4NO_3:

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3. a. Compare Solutions 2 and 4. How does the common-ion effect influence the pH of Solution 4? Explain fully, and calculate the expected pH of each of these solutions.

b. How does the common-ion effect influence the pH of Solution 8? Explain fully. Compare the observed pH with the calculated value.

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4. a. How do Solutions 8, 10, 11, and 12 show the properties of a buffer?

b. Calculate the expected pH for each of these solutions.

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c. Should the pH of a buffer change when the buffer is diluted? Explain fully, using the Henderson–Hasselbalch equation as well as your results from Solutions 8 and 9.

5. What is responsible for the pH behavior of each of the following solutions? Include a chemical equation in your explanation. Show by calculation the pH you would expect from each solution.

a. Solution 13

b. Solution 14

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