

Buffers

Name: _____

Date: _____

Partner: _____

Introduction: The buffering ability and properties under dilution of acetic acid - sodium acetate buffers was determined. A buffer using the weak acid from the previous titration laboratory was prepared. A pH 5 or pH 9 buffer was be prepared using solid sodium acetate or ammonium chloride.

Theory: The pH of a buffer solution, neglecting dissociation, is determined by rearranging the K_a equilibrium expression and using nominal concentrations for the acid and its conjugate base:

$$[H^+] = K_a \frac{[HA]}{[A^-]} \cong K_a \frac{C_A}{C_B} \quad (1) \quad \text{or equivalently} \quad pH = pK_a + \log \frac{C_B}{C_A} \quad (2)$$

Procedure: The buffering range was determined using buffer ratios 10:1 and 1:10. The pH response was determined after dilution or stresses from added strong acid or strong base.¹ The identity of the weak acid for Part 3 and its concentration were determined by titration against standardized 0.10 M NaOH.²

Results: (*Provide the results in the following tables.*) The results of the experiments are summarized in Tables 1-5.

Table 1: Buffering Range of 0.5 M Acetic Acid- 0.5 M Acetate Buffers (Part 2A).

Ratio Acetic Acid-Acetate	10:1	1:1	1:10
Measured pH			
Theoretical pH			

Table 2: Effect of Dilution of Acetic Acid – Acetate Buffer, Acetic Acid, and Sodium Acetate.

Solution	Measured pH before	Measured pH after	Theoretical pH before	Theoretical pH after
1:1 Buffer				
0.50 M Acetic Acid				
0.50 M Acetate				

Table 3: Effect of Addition of Strong Acid or Strong Base (Part 2C).

Solution	Measured pH before	Measured pH after	Theoretical pH before	Theoretical pH after
To 0.001 M NaCl				
add HCl			--	--
add NaOH			--	--
To 1:1 Buffer				
add HCl				
add NaOH				

(-- Theoretical values for the 0.001 M NaCl additions are not necessary)

Table 4: Preparation of a 1:1 Buffer from Weak Acid: name of your weak acid (Part 3A).

Concentration Weak Acid (M)	Volume of Weak acid (mL)	Concentration NaOH (M)	Volume NaOH (mL)	Starting pH	pH after acid addition	pH after base addition

Table 5: Preparation of pH 5 or 9 Buffer from Sodium Acetate or Ammonium Chloride and NaOH or HCl (Part 3B).

Mass <u>sodium acetate or ammonium chloride</u> (g)	Concentration of <u>NaOH or HCl</u> (m)	Volume of <u>NaOH or HCl</u> (mL)	Starting pH	pH after acid addition	pH after base addition

Discussion:

The action of buffers was characterized. The reaction that determines the pH for the acetic acid-acetate buffers is (Part 2A, 2B, and 2C):

Write the acetic acid-acetate reaction that you are studying.

- Part 2A: State the buffer range. Explicitly reference the corresponding table. In a sentence or two, at most, explain why the range is determined by the 10:1 and 1:10 buffer ratios. How well do the measured values agree with the theoretical values. Explicitly reference Eq. 1 or Eq. 2 in discussing your theoretical predictions.*
- Part 2B: In a sentence or two, explain the different results for the 1:1 buffer as opposed to pure acetic acid or pure sodium acetate. Explicitly reference the corresponding table. How well do the measured values agree with the theoretical values.*
- Part 2C: In a sentence or two, explain how the 1:1 buffer responds to the addition of strong acid or strong base as opposed to a dilute NaCl solution. Give the chemical reactions that result from the addition of strong acid and from the addition of strong base. Explicitly reference the corresponding table. How well do the measured values agree with the theoretical values.*
- Part 3A: Give the identity and pK_a of your unknown acid. Give the measured pH of your buffer and the theoretical pH of your buffer. Did your buffer solution act as a buffer? Explicitly reference the corresponding table. How well does the measured pH agree with the theoretical value for the buffer, before addition of strong acid or strong base. When choosing appropriate buffer components, what is the importance of the pK_a of the acid?*
- Part 3B: List the components that you used to prepare the buffer in Part 3B. If you made a buffer using ammonium acetate, give the chemical reaction that determines the pH. Give the measured pH of your buffer and the theoretical pH of your buffer. Did your buffer solution act as a buffer? Explicitly reference the corresponding table. How well does the measured pH agree with the theoretical value for the buffer, before addition of strong acid or strong base.*

- (f). Consider the effect of random and systematic errors.
- (i). Use the number of significant figures in the concentrations and the literature pK_a values to predict the expected number of significant figures in the buffer pH results. Remember the approximate rule that the number of significant figure in the concentration gives the number of significant figures after the decimal point in the pH. For example $[H^+] = 2.31 \times 10^{-4} M$ gives $pH = 3.636$, but $[H^+] = 2.3 \times 10^{-4} M$ gives $pH = 3.64$. Compare this expected number of significant figures to the observed differences between the measured pH and theoretical predictions. There are two possibilities for this comparison (choose one):
- (1). If the expected number of significant figures, as predicted from the uncertainty in the concentrations and the literature pK_a , is consistent with the observed differences, then draw a conclusion about the predominant source of random error.
 - (2). If the expected number of significant figures is not consistent with the observed measured versus theoretical differences, give a likely additional source of random error.
- (ii). Suggest a source of systematic error. Remember that student mistakes are neither random nor systematic errors; student mistakes are just student mistakes. What effect does the source of systematic error have on the final results? (For example, does the systematic error cause the measured pH to increase or decrease?)
- (g). To summarize the experiment answer the following questions:
- (i). In a buffer, what are the predominant species in solution?
 - (ii). In forming a buffer, why must the acid-conjugate base pair be weak?
 - (iii). What is the position of equilibrium that gives the best ability to resist changes in pH from additions of both strong acid and strong base? What is the position of equilibrium for a 1:1 buffer?
 - (iv). When choosing appropriate buffer components, what is the importance of the pK_a of the acid, compared to the target pH of the buffer?

Literature Cited:

1. J. T. Millard, K. P. Rice, T. W. Shattuck, "Experiment 10: Buffers," Honors General Chemistry Laboratory Manual, Colby College Department of Chemistry, 2014.
<http://www.colby.edu/chemistry/CH145/lab/CH145Exp10Buffers.pdf> Last accessed 11/12.2014.
2. Give your initials and last name, "Experiment 9: Weak Acid Titration," Lab report for Honors General Chemistry, Department of Chemistry, Colby College, Waterville, ME, 2014. (Copies available from the author upon request).

Attach your data tables if they are not included in the bulk of the Report.

Checklist:

- Use complete sentences and provide the proper number of significant figures and units.*
- All Figures and Tables must have captions.*
- Refer by number to each figure and table in the body of the text or your report.*
- Acknowledge any data that were not taken by you or your partner.*
- Captions start with Figure # or Table # and then a concise description of the contents.*
- You can write the captions by hand in black pen on attached sheets.*
- Answer all the questions in the Discussion section of the write-up.*
- Remove all the italicized prompts in your final report. The report should then read smoothly.*