Experiment 10: Buffers

Reading: Sections 16.1-16.2 in Olmstead and Williams, *General Chemistry*, 5th Ed.

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

Introduction

First, you will use the model system of acetic acid and its conjugate base acetate ion to investigate some of the factors that affect a buffer solution. The useful buffering range of the acetic acid-acetate buffer will be determined using buffers with mole ratios of 10:1 and 1:10. The changes in the pH upon a ten-fold dilution of the buffer, upon addition strong acid, and upon addition of strong base will be determined. Next you will produce a good buffer from your weak acid and the standardized NaOH solution that you used in the previous lab. Finally, a pH 5 or pH 9 buffer will be prepared using solid sodium acetate or ammonium chloride with added strong acid or strong base. Please use the assigned reading to review pH calculations and the preparation of buffers.

Part 1: Using a pH Meter (work together as a pair)

The first goal for today is to calibrate a typical laboratory pH meter. The procedure for operating every pH meter is slightly different. The ones we have in lab are fairly self-explanatory so we would like you to independently figure out how to calibrate the lab pH meters. However, before you begin, it is universally true that for a pH electrode to work correctly, **the filling hole near the top of the electrode must be open**. Since the filling hole should be kept closed when the meter is not in use to prevent evaporation of the solution inside the electrode, the first thing you should always do when operating a pH meter is to open the filling hole. The last thing you should do is to close the filling hole. Note that if you can't SEE a hole, then the hole is not open. The hole is opened by turning the dial at the top of the probe in the "open" direction.

After you have opened the filling hole, use standard pH buffers of 4.0 (usually pink), 7.0 (usually yellow), and 10.0 (usually green or blue) to calibrate the meter. Make sure that the electrode is completely immersed in solution when you are measuring pH. The reference junction is a small porous glass circle on the side of the electrode. The reference junction must be completely submerged. Adjust the level of the probe by using the lever arm - you should never directly handle the probe itself (unless you are opening or closing the filling hole). Avoid touching the surface of the pH glass membrane, which will change the calibration.

Following successful calibration of the meter, obtain a solution of **unknown pH** from your instructor. Measure the pH of the unknown and confirm this value with your instructor. Upon confirmation of your measurement, you will be assured that you are correctly using a pH meter. Rinse the electrode with distilled water, and proceed to your buffer investigations.

Part 2: Factors that Affect Buffers (work together as a pair)

A. pH of Different Ratios of Weak Acid/Conjugate Base: Determine the Buffer Range

1. Prepare about 50 mL of 3 different solutions with the following ratios of 0.50 M sodium acetate to 0.50 M acetic acid: 10/1; 1/1; 1/10. **Keep the 1:1 solution until you are completely finished with this experiment- you will use it multiple times.**
2. Standardize a pH meter and measure the pH of each of these solutions in a 50-mL beaker. (You do not have to use all 50 mL of your solution; make sure you don't overflow the beaker.)

B. Effect of Dilution

1. Take 2 mL of the 1/1 solution. Dilute this solution by a factor of 10 by mixing it with 18 mL of deionized water. Measure its pH (in a 30-mL beaker).
2. Measure the pH of a sample of the stock 0.50 M acetic acid. Dilute it by a factor of 10, and measure the pH of this dilution.
3. Repeat step 2 with the stock 0.50 M sodium acetate solution.

C. Effect of Addition of Strong Acid or Base

1. Measure the pH of approximately 0.001 M NaCl in water. If a 0.001 M solution is not available, add just a small amount of solid NaCl on the end of a scoopla to about 100 mL of water. Note that an approximate pH is fine.
2. To 20 mL of 0.001 M NaCl, add 10 mL of 0.10 M HCl. Record the pH. Again, an approximate pH reading is fine.
3. To 20 mL of 0.001 M NaCl, add 10 mL of your 0.10 M NaOH. Record the pH.
4. To 20 mL of the 1/1 solution of sodium acetate/acetic acid (the original solution- not the dilution), add 10 mL of the 0.10 M HCl. Record the pH.
5. To 20 mL of **FRESH** 1/1 solution of sodium acetate/acetic acid, add 10 mL of ~0.10 M NaOH. Record the pH.

D. Analysis of Results

- For your Part A data, calculate the expected pH of each solution you tested. How well do your measured values agree with the expected values?
- From your Part B data, calculate the expected pH of each solution you tested. What is unique about a mixture of a weak acid/conjugate base relative to the weak acid or conjugate base alone?
- From your Part C data, calculate the expected pH of each solution you tested. How does a mixture of a weak acid/conjugate base respond to added acid or base relative to 0.001 M NaCl?

Part 3: Creation of Buffers (work <u>individually</u> for Part 3)

A. Using your Weak Acid

You determined both the identity and pK_a of a weak acid in the previous week. The pK_a dictates the pH at which a weak acid can act as a good buffer, assuming an equal amount of its conjugate base is also present. Use your weak acids to create buffers as follows:

1. Based on the concentration of the weak acid, determine the volume of standardized NaOH (~0.10 M) to add to 50 mL of the weak acid to achieve a 1:1 ratio of weak acid: conjugate base. Make up two beakers containing such a solution.
2. Record the pH of these two solutions (**Thought question for your notebook**: what do you expect this pH to be - how close are you?).
3. *In the presence of your instructor*, add a pipette full of 0.1 M HCl to one of the beakers and record the pH. **Notebook:** Does this change in pH meet your expectations for a good buffer?
4. Repeat step 3 with ~0.1 M NaOH.

B. Using Other Reagents

The following reagents will be available in the laboratory:

Solids	Solutions
sodium acetate ·trihydrate; MM 136.08 g/mol (pK_b= 9.25)	NaOH (from previous week)
ammonium chloride; MM 53.5 g/mol (pK_a=9.25)	0.10 M HCl

Prepare a buffer that will buffer against pH changes at pH 5 or pH 9 (one partner from Part 1 does one pH, another does the other):

Possible helpful information:

- A 0.100 M solution has sufficient buffering capacity for the exercise.
- 100 mL volumetric flasks will be available.
- If you have a weak acid, you can conveniently obtain its conjugate base by adding strong base.
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- The pH you chose for your buffer should correspond to the pK_a of the reagent you are also choosing to use.

After you have created a buffer solution that you believe will act as a good buffer at either pH 5 or pH 9, set up two ~50 mL aliquots in separate beakers. Record the pH of each aliquot, then ask your instructor to add acid and base to your buffer and record the new pH values. If you constructed an effective buffer, then the pH change should be small in each case.

Lab report: Use the report form. To help save time, the Introduction, Theory, and Procedure sections are written for you. Additional comments in the Introduction, Theory, and Procedure sections are not necessary.

Questions to address in your discussion:

- Chemically speaking, what constitutes a *buffer*?
- How well do the experimental values compare to the predicted values? Explain possible causes for the differences.
- When choosing and making an appropriate buffer solution, what is the importance of the buffer pK_a?
- What factors influence the buffering *range*. We did not determine the buffer *capacity*; however, what factors influence the buffer *capacity*?