Make it Visible

Prelab Assignment:

Read the entire experiment. Submit your completed prelab questions on Labflow before you begin the lab, according to the deadline set in the syllabus.

Experimental Overview

This experiment is divided up into three activities that guide your exploration of the relationship between strength of acids and bases and concentration of solutions. In your report you will combine the information you have gathered into one coherent idea.

You will first investigate the relationship between various methods of determining acid-base characteristics. Then you will investigate pH changes with concentration and with the addition of a salt.

The measurement of the acid-base content of a substance can be accomplished in a number of ways: litmus paper, pH paper, indicators, or with a pH meter.

The most common definition of an acid or base refers to its pH in solution. An acid solution has a pH below 7, while a basic solution has a pH above 7, and a neutral solution has a pH of 7. The pH of a solution is related to the concentration of hydrogen ions in solution, according to Equation 1.

$$pH = -\log [H^+] \qquad (1)$$

Application

In order to find and measure tumors or foreign objects in the body, medical professionals have many techniques they can use. Some, such as x-rays, make measurements of solid objects simple. Others allow us to detect and locate growths that occur in soft tissues that do not show clearly on an x-ray.[1] Magnetic resonance images (MRIs) allow more detailed images of soft tissues and avoid additional radiation exposure. To further enhance an MRI, patients can be given substances that give off radioactivity or light. One example, ^{18}F-labeled deoxyglucose is taken up by actively metabolizing cells and produces a much brighter spot in an image.[2] Fluorescent dyes have also been covalently attached to proteins that can locate and stick to foreign bodies, such as cancerous growths.[3] When the dyes are used, it is important to use the correct concentration of dye, so only the site that is wanted will be labeled with the dye. At the correct concentration, a greater number of dye molecules will localize where the target is located. If the concentration is too high, there will be more dye molecules left in solution and the image will be too bright with background fluorescence.

Many fluorescent dye molecules are weak acids, such as cypate, Figure 1. Reactions with weak acids can be influenced by changing the pH of the solution, causing the acidic hydrogen to associate or dissociate from the dye molecule.

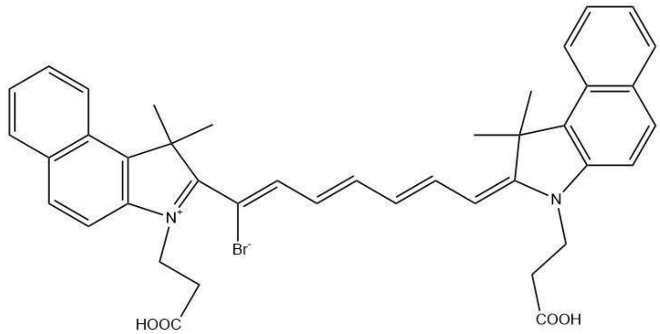

Figure 1 - Cypate.[4] A fluorescent dye that has been used to covalently bond to protein chains.

References:

1. X-ray, CT and MRI. Center for Diagnostic Imaging https://www.mycdi.com/ knowledge_center/difference_between_mri_ct_and_x-ray/ (accessed 09/22/2016)
2. Goldenberg, D, Sharkey, R, Barbet, J, Chatal, J. Radioactive antibodies: selective targeting and treatment of cancer and other diseases, Appl. Rad. (2007) 36 (4) 10-22.
3. Pu, Y.; Wang, W.B.; Achilefu, S.; Alfano, R. R. "Study of rotational dynamics of receptor-targeted contrast agents in cancerous and normal prostate tissues using time-resolved picosecond emission spectroscopy," Appl. Opt. (2011) 50, 1312-1322.
4. Pu, Y.; Achilefu, S.; Alfano, R. R.Cancer Detection/Fluorescence Imaging: 'Smart beacons' target cancer tumors (2013) http://www.biiopticsworld.com/articles/print/volume-6/issue-4/ features/ cancer-detection-fluorescence-imaging-smart-beacons-target-cancer-tumors.html (accessed 09/22/2016)

Safety Note

- Wear safety goggles at all times in the laboratory.
- Be aware of the solutions you are using and any hot equipment.

<u>Part I- Categorizing: Acids and Bases</u>

1. Obtain a well plate and dropper bottles of 0.1 M solutions of HCl, HNO_3, NaOH, KHP, $H_2C_2O_4$, $HC_2H_3O_2$, KOH, distilled water, $Ba(OH)_2$, and H_2SO_4.

2. Place the well plate on a sheet of paper. You can make notes about the contents of each well on this sheet. Fill one spot about half-full of the first solution.

3. Test the spot of each solution with a small portion of a strip of red litmus paper. Repeat with blue litmus paper. Add a drop of phenolphthalein indicator to the solution in the spot. Record all results.

4. Calibrate the pH meter assigned to you using the buffer solutions provided. For this, follow the instructions provided for the pH meter in your laboratory.

5. Measure the pH of each solution in a test tube. Use only the required volume (about 4 mL)

for each solution. Then add 1 drop of bromothymol blue indicator solution to the solution in the test tube. Record both of your results.

6. Repeat steps 2 through 5 with each of the remaining solutions. Empty and clean your test tubes as needed. Use a 600 mL beaker for waste.

7. When you have finished this Part, clean the well plate and your waste beaker as directed. Rinse the plate and invert it. Clean any beakers or test tubes you may have used.

What patterns do you see in the data? What substances react in a similar manner? List the substances that react the same to litmus, to phenolphthalein and to bromothymol blue.

Based on the pH, which substances are acids and which are bases?

Explain how acids react with litmus, phenolphthalein and bromothymol blue. Do likewise for bases. Acids:

Bases:

Determine the hydrogen ion content of each of the acids based on the pH. Show your calculations.

Each acid was 0.10 M. Compare the hydrogen ion content of each. Are they constant or do they vary? Give an explanation for your findings.

Part II - pH and Concentration of an Acid

8. Obtain a small beaker with about 20 mL of 0.100 M acetic acid. Measure the pH of this solution (with your pH meter). Since this solution was prepared for you, the beaker can be shared by a number of groups.

9. Obtain a small beaker and two droppers. You will use one dropper for water and one dropper for acetic acid; remember to rinse it thoroughly when changing molarities.

10. Prepare 0.010 M, 0.0010 M and 0.00010 M solutions of acetic acid. You can make these solutions by using serial dilution.

Each dilution is performed by taking 1.0 mL of a more concentrated solution and adding 9.0 mL deionized water. For example, the 0.010 M solution is made by obtaining 1.0 mL of 0.10 M acetic acid in a 10.0 mL volumetric flask. It is important that you carefully adjust the amount with a dropper so that the meniscus reads exactly 1.0 mL. Then add distilled water to yield a total volume of 10.00 mL in the volumetric flask. Pour the contents of the volumetric flask into the small beaker.

Make sure to rinse your volumetric flask several times between making each solution.

11. Measure and record the pH of each of your acetic acid solutions. Rinse the volumetric flask several times with distilled water, then empty and allow to dry.

Write the chemical equation for the ionization of acetic acid.

From the pH, calculate the concentration of hydrogen ions. Next, find the concentration of the acetate ion. How would the concentration of hydrogen ion be related to the acetate ion? (Hint: look at the formula for acetic acid.) Considering that acetic acid is the source of hydrogen and acetate ions in this sample, determine the actual concentration of acetic acid that is in the solution at the time when you measured the pH. Show a set of sample calculations.

You might develop a table like this one:

Concentration of acetic acid	pH	$[H^+]$	$[C_2H_3O_2^-]$	$[HC_2H_3O_2]$
0.10 M				
0.010 M				
0.0010 M				
0.0001 M				

Is the ionization of acetic acid a relatively complete reaction, or is it a partial one that represents an equilibrium?

What general pattern do you observe in the concentration of acetic acid versus pH?

Compare the relationship among the three values ($[H^+]$, $[C_2H_3O_2^-]$, $[HC_2H_3O_2]$) for each initial concentration of acetic acid. Try different mathematical operations to see if you can find a (numerical) pattern to explain your observations (multiply, divide, etc.). You can try multiplying all three or a combination of multiplying and dividing (i.e., dividing one by the product of the other two, etc.).

Do these data give a constant or numbers having the same or nearly the same exponential values?

Part III – Effects of Adding a Salt

12. Obtain a clean, dry, 50 mL beaker, 10 mL graduated cylinder, and a dropper. Put exactly 5.0 mL of 0.10 M acetic acid into the beaker. Measure and record the pH.
13. Obtain two samples of sodium acetate, one about 0.050 g and the other about 0.150 g. Record the masses exactly.
14. Add the sample of sodium acetate that is about 0.050 g to the beaker with 0.10 M acetic acid. Stir with a stir rod. Measure and record the pH of the resulting solution.
15. Add the second sample of sodium acetate to the same beaker. Stir with a stir rod. Measure and record the pH of the resulting solution. Record the total mass of sodium acetate used.

Calculate the number of moles of sodium acetate added. Then calculate the hydrogen ion concentration from the pH. What are the possible sources of acetate ion? Are sodium salts soluble? Calculate the concentration of acetate ion from all sources in the solution. Finally, calculate the concentration of acetic acid in the solution after mixing in the sodium acetate. All these solutions contained 0.10 M acetic acid initially. Show your calculations.

A suggested table might look like this:

Amount of sodium acetate	pH	$[H^+]$	$[C_2H_3O_2^-]$	$[HC_2H_3O_2]$
0.00 mol				
mol				
mol				

What is the relationship between acetic acid and sodium acetate? How are their formulas related? What general pattern(s) do you see in the data?

Compare the relationship among the three concentrations. You can try multiplying all three or a combination of multiplying and dividing. Do the three sets of data give a constant or numbers that are similar? Is it similar to the relationship you found in Part II?

Questions to guide your discussion:

- Compare the merits of the various methods for determining the acid-base nature of a substance.
- Explain why the pH of every 0.1 M acid is not 1.0.
- What is meant by "weak acid"?
- What is K_a? Does this have any relationship to this laboratory?
- What conclusion can be drawn about the effect of adding a conjugate salt on the pH of the solution?
- Predict what should happen to the pH of an acetic acid solution if a salt that did not contain acetate ions were added.
- Explain what determines the pH of a weak acid.

Title:

Introduction:

Methods:

Results:

Discussion and Conclusion:

Literature Cited:

Refer to the posted **Mini-Report** guidelines as you write your report. The questions throughout the lab are intended to guide you in developing your report. Include molecular-level explanations where appropriate. References are required for all reports.

This report will be turned in via Labflow.