DETERMINATION OF THE K_A OF A WEAK ACID

Introduction:

Acids and bases are often described as being "weak" or "strong". While this classification seems somewhat arbitrary, other more quantitative descriptors exist. For acids, Ka values are commonly used. The ionization of an acid can be shown by the following equation:

$$HA_{(aq)} \leftrightarrow \quad H^{+}_{(aq)} \; + \quad A^{-}_{(aq)} \qquad \text{(Eq. 1)}$$

Since an equilibrium exists, an equilibrium constant, Ka, can be written:

$$K_a = \frac{[H^+][A^-]}{[HA]} \qquad \text{(Eq. 2)}$$

The K_a value is an indication of acid strength. The larger the value of the Ka, the stronger the acid. This value is characteristic of the acid and can be used to help identify an unknown acid. A similar system exists for bases (K_b).

Two methods may be used to determine the K_a value. Both methods require the use of a pH meter. In the first method, a sample of acid is titrated with base. The pH values are plotted vs. the volume of base added. The equivalence point is determined from the graph. Next, the volume of base halfway to the equivalence point is found, and the pH at this volume is noted. The $[H^+]$ corresponding to this pH is equal to the K_a for the acid. At a point halfway to the equivalence point, $[H^+] = [HA]$ $[A^-]$ for a monoprotic acid. Canceling out $[A^-]$ and $[HA]$ in Equation 2 gives $K_a = [H^+]$.

The second method for determining K_a values involves a "half volume" method. A solution of the acid is prepared and divided in half as accurately as possible. One portion is titrated to its endpoint with phenolphthalein. The two portions are then recombined, and the pH of the resulting solution is measured. Since half of the acid has been titrated, $[H^+] = [HA]$ $[A^-]$. Again, if $[A^-]$ and $[HA]$ are canceled in Equation 2, K_a $[H^+]$. The pH value of the combined solutions can be converted to $[H^+]$ to give a K_a value.

Purpose:

The purpose of this experiment is to determine the K_a value for a weak acid by two methods: potentiometric titration and "half volume" methods.

Equipment/Materials:

pH meter	acid sample
buret	standard base solution (0.10 M NaOH)
buffer solutions	beakers
distilled water	phenolphthalein
Erlenmeyer flask	graduated cylinder

Safety:

- An apron and goggles should be worn at all times in the lab.

Procedure:

Part I: Potentiometric Titration

Note: The procedure for standardizing pH meters varies from model to model. For this reason, specific instructions for that step have not been included. Follow your instructor's directions for this step or refer to the manual for the instrument.

1. Rinse a buret with tap water and then with distilled water. If the buret drains without leaving drops of water behind, it is clean. If not, wash the buret with a dilute detergent solution. Rinse the buret several times with tap water and then with distilled water.

2. Pour some of the sodium hydroxide solution into a beaker. Pour a small amount of this into the buret and let it drain through into a "waste" beaker. Fill the buret with the sodium hydroxide solution. Make sure that the tip of the buret has been completely filled. Drain the sodium hydroxide solution to the 0.00 mL line or below.

3. Place half of the unknown acid in a beaker and add enough water so that the end of the pH electrode will be covered. Usually a titration is done in a flask. In this experiment, room for the pH electrode is needed.

4. Note the initial reading of the sodium hydroxide in the buret. Record the value.

5. Rinse the pH electrode and place it in the beaker with the acid. Adjust your set-up so that the buret containing the sodium hydroxide is over the beaker. If you are using a magnetic stirrer and a stirring bar, make sure that the pH electrode is above the stirring bar. The tips of the electrodes are fragile and break easily.

6. Begin adding small portions of the sodium hydroxide to the acid sample. After each addition, record the total volume of sodium hydroxide added and the pH of the solution.

7. When the pH begins to rise rapidly, add smaller portions of the sodium hydroxide. Rinse the sides of the beaker occasionally with distilled water from the wash bottle. Continue to add the sodium hydroxide until the pH is in the basic region AND has leveled off.

8. Discard the titrated acid sample in the beaker, and repeat the titration.

9. For each trial, plot pH (y-axis) as a function of volume of base added (x-axis). Determine the equivalence point on each graph. Find the volume of base that corresponds to the equivalence point. Divide this value by two to determine the amount of base needed to reach half way to the equivalence point. The pH at this volume of base is converted to $[H^+]$ to give the K_a of the acid.

Part II: "Half Volume" Method

1. It is assumed that the pH meter and buret are ready for use. If not, refer to Steps 1 and 2 from Part I.

2. Obtain a sample of the unknown acid. Measure out 100 mL of distilled water with a graduated cylinder and pour into a 250 mL Erlenmeyer flask. Dissolve the sample of acid in the water, and stir to mix thoroughly.

3. Divide the solution you have prepared into two equal portions. Use a graduated cylinder, and do so as accurately as possible. The portion in the flask should be titrated to a phenolphthalein endpoint with sodium hydroxide solution. Add the sodium hydroxide slowly while swirling the flask. As the endpoint approaches, add the sodium hydroxide solution drop by drop until the solution has a permanent pink color.

4. Mix the titrated solution with the other half of the acid solution and determine the pH of the resulting solution. Again, since half of the acid has been titrated, $[H^+]$ $[HA]$ $[A^-]$. Using Equation 2 and canceling out the values for $[HA]$ and $[A^-]$, the K_a value is once again determined from the $[H^+]$ value. From the observed pH, calculate the K_a of the unknown acid.

Determination of the K_A of a Weak Acid

Data:

Part I: Potentiometric Titration

Trial 1		Trial 2	
Initial Buret Reading:		Initial Buret Reading:	
mL Base Added	pH	mL Base Added	pH

Part II: Half Volume Method

Trial 1 pH of combined solutions

Trial 2 pH of combined solutions

Calculations:

Part I: Potentiometric Titration

	Trial 1	Trial 2
mL of base at equivalence point		
base volume ½ distance to equivalence point		
pH at ½ distance to equivalence point		
K_a of acid		

Part II: Half Volume Method

	Trial 1	Trial 2
K_a (pH converted to $[H^+]$		

Questions:

1. What are some sources of error in each of the methods used in this experiment?

2. What is the accepted value for the K_a of the acid you used?

3. Which method gave better results?

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Teacher Notes

Lab Time: Either method could require 80 minutes to complete. The instructor might decide to have the class use only one of the methods. The half volume method works well if the number of pH meters is limited.

Preparation:

Time: 30 minutes Samples of the unknown acids should be placed in vials. Formic and acetic acids work well for this lab. Any weak monoprotic acid could be used.

0.10 M NaOH Solution Add 4.0 grams of the solid to a volumetric flask, and add water to the line.

T: Provide a set of materials to each lab group.

V: Any materials, especially pH meters and buffer solutions, can be provided by the van.

Answers to Questions:

1. What are some sources of error in each of the methods used in this experiment?

Errors may result if the equivalence point is not determined correctly in Part I. In Part II, error will result if the sample is not evenly divided or if the sample is over titrated.

2. What is the accepted value for the K_a of the acid you used?

Acetic Acid K_a 1.8×10^{-5} *Formic Acid* K_a $= 1.8 \times 10^{-4}$

3. Which method gave better results? *Student answers*