Experiment 9
Titration of Acetic Acid in Vinegar

OUTCOMES

After completing this experiment, the student should be able to:

- perform a simple acid-base titration.
- calculate the concentration of an acid in solution.

DISCUSSION

A titration is a technique often used to find the concentration of a solute in a solution, though it may also be used in other analyses, such as determining the mass of a substance in a mixture of solids. During a titration, a solution of known concentration is added to a solution of unknown concentration until an endpoint is reached. This endpoint is often shown with some type of colored indicator. Using the moles of the known solution (from its concentration and volume) and the balanced chemical equation, the moles of solute in the unknown solution can be calculated via stoichiometry. The moles of unknown can then be used with the volume of the unknown solution to determine its concentration.

In this experiment, two different titrations will be done using NaOH. In the first, the concentration of the NaOH solution will be determined by titrating it against potassium hydrogen phthalate, ($KHC_8H_4O_4$, also known as "KHP").

molecular equation: $KHC_8H_4O_4(aq) + NaOH(aq) \rightarrow KNaC_8H_4O_4(aq) + H_2O(l)$

net ionic equation: $HC_8H_4O_4^-(aq) + OH^-(aq) \rightarrow C_8H_4O_4^{2-}(aq) + H_2O(l)$

KHP is often used as a standard for titrating the NaOH because it is a solid. Thus, one can measure out a precise amount of the acid on an analytical balance and know exactly how many moles of acid are being used in the titration. Upon reaching the equivalence point, where moles of acid equal moles of base, we therefore also know exactly how many moles of NaOH have been added (based on the stoichiometry with the KHP) along with the volume of NaOH used. These two pieces of information can be used to calculate the concentration of the NaOH solution. Equations used in these calculations can be found in the "Helpful Equations" link on the "Acid-Base Titration" website or in your textbook.

For the second set of titrations, the same NaOH solution will be used. This time it will be titrated against vinegar which contains acetic acid, among other things. It is the acetic acid which gives vinegar its characteristic smell. The reaction is as follows:

$$HC_2H_3O_2(aq) + NaOH(aq) \rightarrow NaC_2H_3O_2(aq) + H_2O(l)$$

In this titration, the solution with the known concentration is now the NaOH. The concentration of the acetic acid in the vinegar will be determined by reacting a known volume of the vinegar with the NaOH to determine the volume and, from the molarity calculated in the KHP reactions, moles of NaOH required to reach the endpoint. The moles of NaOH can then be combined with the stoichiometry from the balanced equation to calculate the moles of acetic acid in the vinegar itself.

Once the moles of acetic acid have been determined, they may be used to establish the concentration of the vinegar in two different ways. First, the moles of acetic acid and the volume of vinegar will be used to calculate the molarity of the acetic acid. In addition, you will be able to determine the mass of the acetic acid from the moles and molar mass of acetic acid. The mass of acetic acid can then be used with the mass of the vinegar to calculate the mass percentage of acetic acid in the vinegar and compare it with the manufacturer's claim on the label.

Phenolphthalein, an acid-base indicator, will be used in all of the titrations to detect the endpoint. Phenolphthalein is colorless in acidic and neutral solution, but pink in basic solution. Therefore, you will proceed with the titration until you see a pink color that remains for at least 30 seconds.

PROCEDURE

⚠ ***Wear safety glasses or goggles at all times for this experiment.***
⚠ ***Avoid skin contact with the NaOH in this experiment.***

Procedure 1: Standardizing the NaOH Solution

1. Using an analytical balance, measure between 0.08 g and 0.1 g of potassium hydrogen phthalate ($KHC_8H_4O_4$), abbreviated as KHP, into a clean 50 mL Erlenmeyer flask. Record the exact mass of KHP used. Add about 10 mL of deionized water, using a wash bottle to rinse down any chemicals that may have splashed onto the walls of the flask. Add 1 drop of phenolphthalein indicator to the flask. Swirl to dissolve the solid.

2. Set up a micro-titration apparatus as described by your instructor. Rinse and fill a clean 2 mL pipet (the microburet) with the NaOH solution. Record the initial microburet reading of the NaOH solution.

3. Slowly add the NaOH solution to the flask containing the KHP, swirling gently during the addition, Continue adding the NaOH until the endpoint is reached, which is the first sign of a pink color that remains after at least 30 seconds of swirling.

4. Record the final microburet reading. Calculate the volume of NaOH solution that was used in your titration.

5. Repeat steps 1 to 4 **twice** to obtain a total of 3 trials.

6. Calculate the molarity of the NaOH for each of the three trials from the volume of NaOH and the mass of KHP used. Compute and record the average molarity of the NaOH solution.

Note: If the three trials were not in good agreement, repeat the titration as many times as necessary to obtain three consistent trials.

Procedure 2: Titrating the Vinegar

1. Tare a clean 50 mL Erlenmeyer flask on an analytical balance. Using a micropipette, dispense exactly 500 µL (0.500 mL) of vinegar into the Erlenmeyer flask. Since the liquid may evaporate a fair amount, measure and record the mass of vinegar that was added.

2. Add about 10 mL of deionized water, using a wash bottle to rinse down any chemicals that may have splashed onto the walls of the flask. Add 1 drop of phenolphthalein indicator to the flask. Swirl to mix the solution.

3. Use the NaOH solution that you standardized in Procedure 1 to titrate the vinegar sample to the endpoint. Calculate and record the volume of NaOH used.

4. Repeat steps 1 to 3 **twice** to obtain a total of 3 trials.

5. Calculate and record the molarity of acetic acid in the vinegar for each of the three trials from the *volumes* of vinegar and standardized NaOH used and the molarity of NaOH. Compute the average molarity of the vinegar.

6. Calculate and record the mass percentage of acetic acid in the vinegar for each of the three trials from the mass of vinegar used, the volume of standardized NaOH used and the molarity of the NaOH. Compute the average mass percentage and compare it to the manufacturer's claim on the label. Tell which sample of vinegar was used, by sample number or brand name.

Note: If the three trials were not in good agreement, repeat the titration as many times as necessary to obtain three consistent trials.

⚠ ***Dispose of all chemicals in the proper waste container.***

POSTLAB ACTIVITY

You will be individually completing a postlab quiz on D2L. While taking the quiz, you will be given data to analyze. Before leaving lab today, your instructor should check your work to make sure that you correctly understand the necessary concepts and calculations before beginning the quiz.