Acid-Base Titration

Titration is a very important laboratory technique which is used to determine the concentration of a wide variety of chemical substances. A standard solution (one of known molarity) is titrated against (reacted with) another solution in such a manner that the concentration of the second solution may be calculated from the results. The second solution is added to a known volume of the first solution by means of a buret, which allows the volume of solution delivered to the reaction vessel to be accurately determined. A chemical indicator is used to show when the reaction is complete.

Acid-base titrations involve a net reaction in which aqueous hydrogen ions and hydroxide ions react with one another to form neutral water molecules:

$$H^+(aq) + OH^-(aq) \rightleftharpoons H_2O(l)$$

This net process is called *neutralization*.

The indicator phenolphthalein will be used to show when the reaction is complete, at which point the number of moles of acid consumed equals the number of moles of base added. This point is called the *equivalence point*.

A titration is one of the most common analytical procedures performed by the chemist. We all depend upon chemical analysis and it is with this branch of chemistry that the average citizen is most likely to come into contact. Decisions involving large sums of money, or even life and death, depend upon the accuracy and speed of chemical analysis, whether in hospital lab testing, environmental pollution monitoring, or crime detection.

OBJECTIVES

1. to titrate a hydrochloric acid solution of unknown concentration with standardized 0.5*M* sodium hydroxide
2. to titrate an acetic acid solution (vinegar) with standardized 0.5*M* sodium hydroxide
3. to utilize the titration results to calculate the molarity of the hydrochloric acid and the molarity and percent composition of the vinegar

SUPPLIES

Equipment
suction bulb
volumetric pipet (10 mL)
buret (50 mL)
buret stand and clamp
Erlenmeyer flask (250 mL)
lab apron
safety goggles

Chemical Reagents
standardized NaOH solution
(approx. 0.5*M*, known exactly)
unknown HCl solution
white vinegar (acetic acid solution, CH_3COOH)
phenolphthalein solution

PROCEDURE

Part I: Determining the Molarity of a Hydrochloric Acid Solution

1. Put on your lab apron and safety goggles.
2. Obtain about 50 mL of the hydrochloric acid solution of unknown concentration and about 100 mL of the standardized NaOH solution. Your instructor will provide you with the exact molarity of the NaOH. Record this value in your copy of Table 1 in your notebook.

CAUTION

The hydrochloric acid and sodium hydroxide solutions are corrosive to skin, eyes, and clothing. Wash any spills and splashes with plenty of water. Call your instructor.

3. Using a suction bulb, pipet 10.00 mL of the HCl solution into a 250 mL Erlenmeyer flask, after rinsing the pipet with a small amount of HCl first.
4. Add 3 drops of phenolphthalein solution.
5. Rinse a clean buret with approximately 15 mL of the standardized NaOH solution. Drain the buret and refill with standardized NaOH solution. Flush a small amount through the tip to remove any possible air bubbles. Clamp it into position with the buret clamp and stand. (See Figure 13C-1.) Record the initial reading of the buret in Table 1.

CAUTION

The phenolphthalein indicator used in this experiment is toxic and flammable. Make sure there are no open flames in the vicinity.

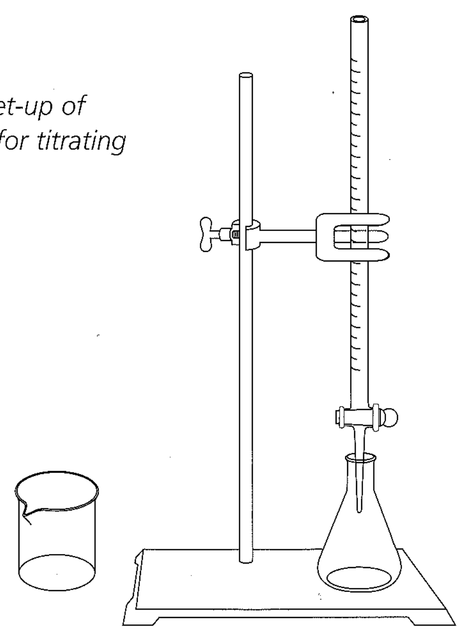

Figure 13C-1 *Set-up of buret and flask for titrating*

6. Gradually dispense some of the standardized NaOH solution into the flask, swirling constantly. Continue adding NaOH solution, watching the contents of the flask carefully for changes.
7. As the equivalence point approaches, a pinkish color is evident, which initially disappears with swirling. At this point, place a piece of white paper under the flask so that the pink color is more easily observed. When this color starts to take a little longer to dissipate, add the NaOH solution drop by drop. Stop the titration and take the reading on the buret when the solution remains pale pink for approximately 30 s. The most accurate end point to the titration is where the solution remains the faintest possible pink.
8. Repeat Steps 3 to 7 using a second 10.00 mL sample of the HCl. Knowing the volume required in your first titration enables you to be extra careful with the remaining ones. When you are within 1 mL of the previous value, add the NaOH a drop at a time, swirling after each drop. This lessens the likelihood of your overshooting the mark.
9. If the two values differ widely, it would be a good idea to do one more titration if you have time.

Part II: Determining the Percentage Composition of Vinegar

1. Obtain approximately 30 mL of white vinegar (acetic acid solution).
2. Using the same buret of NaOH as was used in Part I, do more titrations, but this time use 10.00 mL portions of vinegar instead of HCl. Follow exactly the same procedures as in Part I (Steps 3 to 9). Refill the buret as required. Record your observations in your copy of Table 2.
3. Wash your hands thoroughly with soap and water before leaving the laboratory.

CAUTION

The vinegar solution is mildly corrosive. Wash any spills and splashes with plenty of water.

REAGENT DISPOSAL

Mix any leftover acids and bases together to neutralize them and pour them down the sink with plenty of water. Do not return any solutions to their original containers.

POST LAB CONSIDERATIONS

During the HCl titration, the hydroxide ions liberated from the standardized NaOH solution reacted in a 1:1 ratio with the hydrogen ions from the HCl to form neutral water molecules. When the number of moles of both species were the same, the equivalence point was reached. Since we have the volume of a solution of known molarity, the number of moles of NaOH can be calculated as follows:

$$\text{Volume}_{NaOH}\text{ (L)} \times \text{Molarity}_{NaOH} = \text{Reactant Moles}_{NaOH}$$

From the balanced equation for the reaction:

$$\text{Reactant Moles}_{NaOH} = \text{Reactant Moles}_{HCl}$$

Knowing the volume of HCl used originally, the molarity of the HCl can be calculated from the formula:

$$\text{Molarity}_{HCl} = \frac{\text{Moles}_{HCl}}{\text{Volume}_{HCl}\text{ (L)}}$$

In Part II, calculate the molarity of the acetic acid in vinegar in the same manner as shown for the HCl. In addition, calculate the percentage composition of the vinegar. This is given by:

$$\text{Percentage composition} = \frac{\text{mass solute}}{\text{mass solution}} \times 100\%$$

The mass of the acetic acid (CH_3COOH) is obtained from the number of moles times the molar mass. The mass of the solution is obtained from the measured volume of the solution times its density. For this experiment you may assume that the density of vinegar is 1.00 g/mL.

In both parts of this experiment, the acid and the base were in a 1:1 mole ratio. However, later you may encounter situations where this is not the case. For these the equivalence point is defined as the point at which the acid and base are in the mole ratio given by the coefficients in the balanced equation for the reaction.

EXPERIMENTAL RESULTS

Part I: Determining the Molarity of a Hydrochloric Acid Solution

Table 1 Volume of NaOH Needed to Neutralize 10.00 mL of Unknown HCl Solution

Molarity of NaOH = *M*	Trial 1	Trial 2	Trial 3 (if necessary)
Initial reading of buret (mL)			
Final reading of buret (mL)			
Volume of NaOH used (mL)			
Average volume of NaOH (mL)			

COMPLETE IN YOUR NOTEBOOK

Part II: Determining the Percentage Composition of Vinegar

Table 2 Volume of NaOH Needed to Neutralize 10.00 mL of Vinegar

Molarity of NaOH = *M*	Trial 1	Trial 2	Trial 3 (if necessary)
Initial reading of buret (mL)			
Final reading of buret (mL)			
Volume of NaOH used (mL)			
Average volume of NaOH (mL)			

COMPLETE IN YOUR NOTEBOOK

ANALYSIS OF RESULTS

Part I: Determining the Molarity of a Hydrochloric Acid Solution

1. Write out the balanced formula equation for the titration reaction of HCl(aq) with NaOH(aq).
2. Calculate moles of NaOH from the average volume used in Part I and the given molarity.
3. Calculate moles of HCl present originally.
4. Calculate the molarity of the HCl solution.

Part II: Determining the Percentage Composition of Vinegar

1. Write out the balanced formula equation for the titration reaction of CH_3COOH(aq) with NaOH(aq).
2. Calculate moles of NaOH from the average volume used in Part II and the given molarity.
3. Calculate moles of acetic acid present originally.
4. Calculate the molarity of the acetic acid solution.
5. Calculate the mass of acetic acid in 1.00 L of solution.
6. Calculate the percentage of acetic acid in the vinegar.

FOLLOW-UP QUESTIONS

1. While doing a titration, it is permissible to use a wash bottle to wash down any material that may have splashed higher up in the flask. This would appear to increase the volume of acid in the flask. Why will it have no effect on the results?
2. What was the reason for rinsing out the buret with NaOH solution before starting the titrations?
3. By law, vinegar must be not less than 4% by mass acetic acid. Did your sample meet this specification?

CONCLUSION

State the results of Objective 3.