Experiment

23

Titration Curves of Strong and Weak Acids and Bases

In this experiment you will react the following combinations of strong and weak acids and bases:

- Hydrochloric acid, HCl (strong acid), with sodium hydroxide, NaOH (strong base)
- Hydrochloric acid, HCl (strong acid), with ammonia, NH_3 (weak base)
- Acetic acid, $HC_2H_3O_2$ (weak acid), with sodium hydroxide, NaOH (strong base)
- Acetic acid, $HC_2H_3O_2$ (weak acid), with ammonia, NH_3 (weak base)

A computer-interfaced pH Sensor will be placed in one of the acid solutions. A solution of one of the bases will slowly drip from a buret into the acid solution at a constant rate. As base is added to the acid, you should see a gradual change in pH until the solution gets close to the equivalence point. At the equivalence point, equal numbers of moles of acid and base have been added. Near the equivalence point, a rapid change in pH occurs. Beyond the equivalence point, where more base has been added than acid, you should again observe more gradual changes in pH. A titration curve is normally a plot of pH versus *volume* of titrant. In this experiment, however, we will monitor and plot pH versus *time*, and assume that time is proportional to volume of base. The volume being delivered by the buret per unit time should be nearly constant.

One objective of this lab is to observe differences in shapes of titration curves when various strengths of acids and bases are combined. You will also learn about the function and selection of appropriate acid-base indicators in this experiment. In order to do several other experiments in this lab manual, you need to be able to interpret the shape of a titration curve.

OBJECTIVES

In this experiment, you will

- Observe differences in shapes of titration curves when various strengths of acids and bases are combined.
- Learn about the function and selection of appropriate acid-base indicators.
- Learn how to interpret the shape of a titration curve.

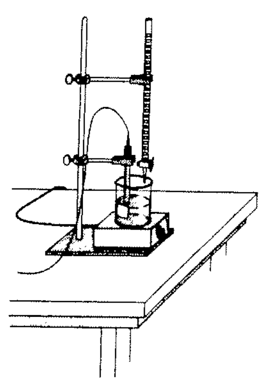

Figure 1

MATERIALS

computer
Vernier computer interface
Logger*Pro*
Vernier pH Sensor
magnetic stirrer (if available)
stirring bar
250 mL beaker
phenolphthalein indicator
wash bottle
0.10 M NaOH
0.10 M NH_3
0.10 M HCl
0.10 M $HC_2H_3O_2$
50 mL buret
ring stand
2 utility clamps
distilled water

PROCEDURE

1. Obtain and wear goggles.
2. Place 8 mL of 0.1 M HCl solution into a 250 mL beaker. Add about 100 mL of distilled water. Add 3 drops of phenolphthalein acid-base indicator. **CAUTION:** *Handle the hydrochloric acid with care. It can cause painful burns if it comes in contact with the skin.*
3. Place the beaker onto a magnetic stirrer and add a small stirring bar. Turn on the stirrer and adjust it to a slow stirring speed.
4. Use a utility clamp to suspend a pH Sensor on a ring stand as shown in Figure 1. Situate the pH Sensor in the HCl solution and adjust its position toward the side of the beaker so that it is not struck by the stirring bar.
5. Obtain a 50 mL buret and rinse the buret with a few mL of the 0.1 M NaOH solution. Fill the buret to about the 0 mL mark. **CAUTION:** *Sodium hydroxide solution is caustic. Avoid spilling it on your skin or clothing.*
6. Connect the pH Sensor to the computer interface. Prepare the computer for data collection by opening the file "23 Titration Curves" from the *Chemistry with Computers* folder. The pH reading should be between 2.0 and 3.0 for the HCl solution.
7. You are now ready to begin monitoring data. Click [Collect]. Carefully open the buret stopcock to provide a dripping rate of about 1 drop per second. Do not worry if the rate is somewhat faster or slower when you first start; initial additions of base will have very little effect on the pH.
8. Watch to see if the phenolphthalein changes color before, at the same time, or after the rapid change in pH at the equivalence point. **Note:** Time is being displayed in the table. If phenolphthalein is a suitable indicator for this reaction, it should change from clear to red at about the same time as the jump in pH occurs. In your data table, record the time when the phenolphthalein indicator changes color. When data collection has ended after 250 seconds, turn the buret stopcock to stop the flow of NaOH titrant.
9. Label the point on your graph where the indicator changes color.
   a. Choose Text Annotation from the Insert menu.
   b. Click in the text box and type "Color change".
   c. Click and drag the arrow head to the appropriate place on the graph.

   d. If you want, you can also move the text box. The cursor will become a hand when at the edge of the text box. At this point you can grab and move the box.

10. To print a graph of pH *vs.* time:

   a. Click on the graph. In the title edit box that appears, type the trial and acid and base strength. Click OK.

   b. Print copies of the graph.

11. You can read pH and time values along the pH curve by clicking the Examine button, . As you move the mouse cursor across the graph, pH and time data points are displayed in the examine box on the graph. Determine the approximate time for the equivalence point; that is, for the biggest jump in pH in the steep vertical region of the curve. Record this time in the data table. Rinse the pH Sensor and return it to the sensor storage solution. Dispose of the beaker contents as directed by your teacher. Clean and dry the 250 mL beaker for the next trial. **Note:** You do not need to save or store your data for any of the four trials.

12. Repeat the procedure using NaOH titrant and acetic acid solution, $HC_2H_3O_2$. **CAUTION:** *Handle the solutions with care.* You do not need to refill the buret. Add 8 mL of 0.10 M $HC_2H_3O_2$ solution to the 250 mL beaker. Add about 100 mL of distilled water and 3 drops of phenolphthalein to the beaker. Rinse the tip of the sensor and position it in the acid solution as you did in Step 4. Repeat Steps 7-11 of the procedure.

13. Repeat the procedure using NH_3 titrant and HCl solution. **CAUTION:** *Handle the solutions with care.* Drain the remaining NaOH from the buret and dispose of it as directed by your teacher. Rinse the 50 mL buret with a few mL of the 0.1 M NH_3 solution. Fill the buret with NH_3 to about the 0 mL mark. Add 8 mL of 0.10 M HCl solution to the 250 mL beaker. Add about 100 mL of distilled water and 3 drops of phenolphthalein to the beaker. Rinse the sensor and position it in the acid solution as you did in Step 4. Repeat Steps 7-11 of the procedure.

14. Repeat the procedure using NH_3 titrant and $HC_2H_3O_2$ solution. **CAUTION:** *Handle the solutions with care.* You do not need to refill the buret. Add 8 mL of 0.10 M $HC_2H_3O_2$ solution to the 250 mL beaker. Add about 100 mL of distilled water and 3 drops of phenolphthalein to the beaker. Rinse the sensor and position it in the acid solution as you did in Step 4. Repeat Steps 7-11 of the procedure.

PROCESSING THE DATA

1. Examine the time data for each of the Trials 1-4. In which trial(s) did the indicator change color at about the same time as the large increase in pH occurred at the equivalence point? In which trial(s) was there a significant difference in these two times?

2. Phenolphthalein changes from clear to red at a pH value of about 9. According to your results, with which combination(s) of strong or weak acids and bases can phenolphthalein be used to determine the equivalence point?

3. On each of the four printed graphs, draw a horizontal line from a pH value of 9 on the vertical axis to its intersection with the titration curve. In which trial(s) does this line intersect the nearly vertical region of the curve? In which trial(s) does this line miss the nearly vertical region of the curve?

4. Compare your answers to Questions 1 and 3. By examining a titration curve, how can you decide which acid-base indicator to use to find the equivalence point?

5. Methyl red is an acid-base indicator that changes color at a pH value of about 5. From what you learned in this lab, methyl red could be used to determine the equivalence point of what combination of strong or weak acids and bases?

6. Of the four titration curves, which combination of strong or weak acids and bases had the longest vertical region of the equivalence point? The shortest?

7. The acid-base reaction between HCl and NaOH produces a solution with a pH of 7 at the equivalence point ($NaCl + H_2O$). Why does an acid-base indicator that changes color at pH 5 or 9 work just as well for this reaction as one that changes color at pH 7?

8. In general, how does the shape of a curve with a weak specie (NH_3 or $HC_2H_3O_2$) differ from the shape of a curve with a strong specie (NaOH or HCl)?

9. Complete each of the equations in the table.

DATA TABLE

Trial	Equation for acid-base reaction	Time of indicator color change	Time at equivalence point
1	$NaOH + HCl \longrightarrow$	s	s
2	$NaOH + HC_2H_3O_2 \longrightarrow$	s	s
3	$NH_3 + HCl \longrightarrow$	s	s
4	$NH_3 + HC_2H_3O_2 \longrightarrow$	s	s