# Acid-Base Titration

A titration is a process used to determine the volume of a solution needed to react with a given amount of another substance. In this experiment, you will titrate hydrochloric acid solution, HCl, with a basic sodium hydroxide solution, NaOH. The concentration of the NaOH solution is given and you will determine the unknown concentration of the HCl. Hydrogen ions from the HCl react with hydroxide ions from the NaOH in a one-to-one ratio to produce water in the overall reaction:

$$H^+(aq) + Cl^-(aq) + Na^+(aq) + OH^-(aq) \longrightarrow H_2O(l) + Na^+(aq) + Cl^-(aq)$$
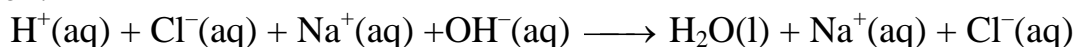
When an HCl solution is titrated with an NaOH solution, the pH of the acidic solution is initially low. As base is added, the change in pH is quite gradual until close to the equivalence point, when equimolar amounts of acid and base have been mixed. Near the equivalence point, the pH increases very rapidly, as shown in Figure 1. The change in pH then becomes more gradual again, before leveling off with the addition of excess base.

In this experiment, you will use a computer to monitor pH as you titrate. The region of most rapid pH change will then be used to determine the equivalence point. The volume of NaOH titrant used at the equivalence point will be used to determine the molarity of the HCl.
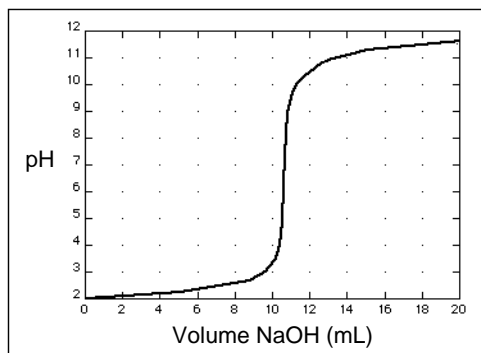


*Figure 1*

## OBJECTIVES

In this experiment, you will

- Use a pH Sensor to monitor changes in pH as sodium hydroxide solution is added to a hydrochloric acid solution.
- Plot a graph of pH *vs*. volume of sodium hydroxide solution added.
- Use the graph to determine the equivalence point of the titration.
- Use the results to calculate the concentration of the hydrochloric acid solution.

## MATERIALS

| | |
|---|---|
| computer | magnetic stirrer |
| Vernier computer interface | stirring bar or Microstirrer |
| Logger *Pro* | wash bottle |
| Vernier pH Sensor | distilled water |
| HCl solution, unknown concentration | ring stand |
| ~0.1 M NaOH solution | 1 utility clamp |
| pipet bulb or pump | 250 mL beaker |
| 50 mL buret | 2nd utility clamp |
| 10 mL pipet | 2nd 250 mL beaker |

## Procedure

1. Obtain and wear goggles.

2. Add 50 mL of distilled water to a 250 mL beaker. Use a pipet bulb (or pipet pump) to pipet 10.0 mL of the HCl solution into the distilled water in the 250 mL beaker. **CAUTION:** *Handle the hydrochloric acid with care. It can cause painful burns if it comes in contact with the skin.*

3. Place the beaker on a magnetic stirrer and add a stirring bar. If no magnetic stirrer is available, you need to stir with a stirring rod during the titration.

4. Use a utility clamp to suspend a pH Sensor on a ring stand as shown here. Position the pH Sensor in the HCl solution and adjust its position so it will not be struck by the stirring bar. Turn on the magnetic stirrer, and adjust it to a medium stirring rate (with no splashing of solution).
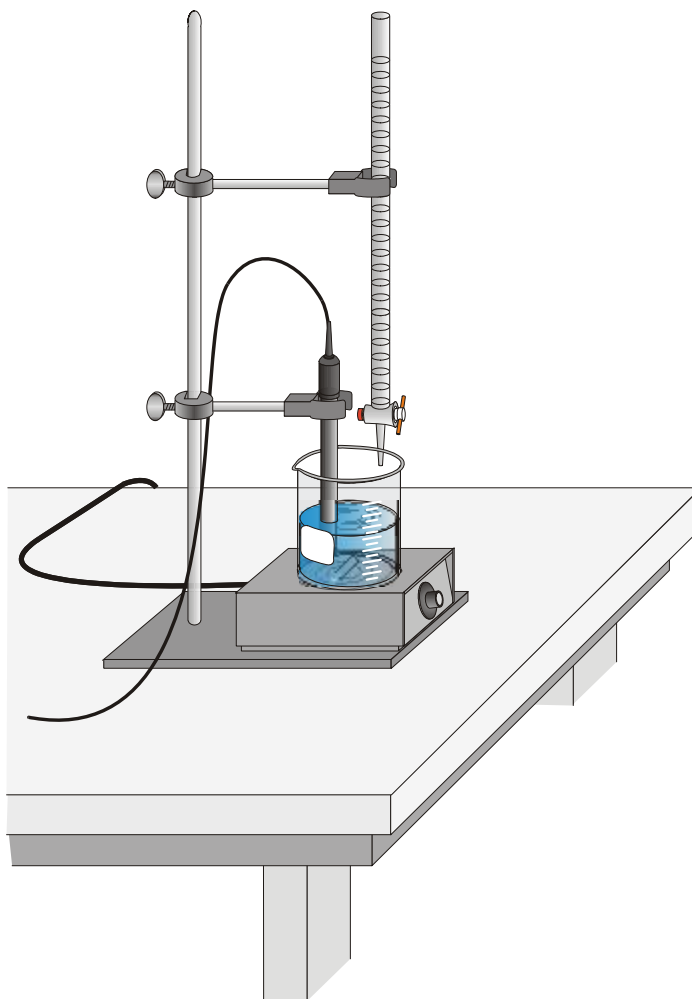
5.  Obtain approximately 60 mL of ~0.1 M NaOH solution in a 250 mL beaker. Obtain a 50 mL buret and rinse the buret with a few mL of the ~0.1 M NaOH solution. Use a utility clamp to attach the buret to the ring stand as shown here. Fill the buret a little above the 0.00 mL level of the buret with ~0.1 M NaOH solution. Drain a small amount of NaOH solution into the beaker so it fills the buret tip *and* leaves the NaOH at the 0.00 mL level of the buret. Record the precise concentration of the NaOH solution in your data table. Dispose of the waste solution from this step as directed by your teacher. **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 "24a Acid-Base Titration" from the *Chemistry with Computers* folder. Check to see that the pH value is between 2 and 3.

7.  Before adding NaOH titrant, click | ▣ **Collect** | and monitor pH for 5-10 seconds. Once the displayed pH reading has stabilized, click | **Keep** |. In the edit box, type "0" (for 0 mL added). Press the ENTER key or click | **OK** | to store the first data pair for this experiment.

8. You are now ready to begin the titration. This process goes faster if one person manipulates and reads the buret while another person operates the computer and enters volumes.

    a.  Add the next increment of NaOH titrant (enough to raise the pH about 0.15 units). When the pH stabilizes, again click | **Keep** |. In the edit box, type the current buret reading, to the **nearest 0.01 mL**. Press ENTER or click | **OK** |. You have now saved the second data pair for the experiment.

    b.  Continue adding NaOH solution in increments that raise the pH by about 0.15 units and enter the buret reading after each increment. Proceed in this manner until the pH is 3.5.

c. When a pH value of approximately 3.5 is reached, change to a one-drop increment. Enter a new buret reading after each increment. Note: It is important that all increment volumes in this part of the titration be equal; that is, one-drop increments.

d. After a pH value of approximately 10 is reached, again add larger increments that raise the pH by about 0.15 pH units, and enter the buret level after each increment.

e. Continue adding NaOH solution until the pH value remains constant.

9. When you have finished collecting data, click ▪ **Stop** . Dispose of the beaker contents by flushing them down the drain with approximately 10x their volume of water.

10. Print copies of the table and the graph for each group member.

11. Repeat the procedure as many times as your teacher directs or as time permits.

# Report sheet

Name_____Date_____Period_____

**PROCESSING THE DATA**

**ATTACH YOUR GRAPHS TO THIS REPORT**

1. Use your graph and data table to determine the volume of NaOH titrant used in each trial. Examine the data to find the largest increase in pH values upon the addition of 1 drop of NaOH solution. Find and record (data table below) the NaOH volume just *before* this jump.
2. Find and record (data table below) the NaOH volume *after* the drop producing the largest pH increase was added.
3. Determine the volume of NaOH added at the equivalence point. To do this, add the two NaOH values determined above and divide by two.
4. Calculate the number of moles of NaOH used.
5. Using the equation for the neutralization reaction given in the introduction, determine the number of moles of HCl used.
6. Calculate the HCl concentration using the volume of unknown HCl you pipeted out for each titration.
7. If you did more than one titration, determine the average [HCl] in mol/L.

| Concentration of NaOH | M | M |
|---|---|---|
| NaOH volume added *before* the largest pH increase | mL | mL |
| NaOH volume added *after* the largest pH increase | mL | mL |

| | | |
|---|---|---|
| Volume of NaOH added at equivalence point<br><br>(SHOW WORK HERE) | mL | mL |
| Moles NaOH<br><br>(SHOW WORK HERE) | mol | mol |
| Moles HCl<br><br>(SHOW WORK HERE) | mol | mol |
| Concentration of HCl<br><br>(SHOW WORK HERE) | mol/L | mol/L |
| Average [HCl]<br><br>(SHOW WORK HERE) | | M |

# EXTRA CREDIT

## EQUIVALENCE POINT DETERMINATION:  An Alternate Method

An alternate way of determining the precise equivalence point of the titration is to take the first and second derivatives of the pH-volume data. The equivalence point volume corresponds to the *peak* (maximum) value of the first derivative plot, and to the volume where the second derivative equals *zero* on the second derivative plot.

1. In Method 1, view the first-derivative graph ($\Delta$pH/$\Delta$vol) by clicking the on the vertical-axis label (pH), and choose First Derivative. You may need to autoscale the new graph by clicking the Autoscale button, [A].

   In Method 2, you can also view the first derivative graph (pH/$\Delta$vol) on Page 2 of the experiment file by clicking on the Next Page button, [→]. On Page 2 you will see a plot of first derivative *vs.* volume.

2. In Method 1, view the second-derivative graph ($\Delta^2$pH/$\Delta$vol$^2$) by clicking on the vertical-axis label, and choosing Second Derivative. In Method 2, view the second-derivative on Page 3 by clicking on the Next Page button, [→].


**ATTACH YOUR GRAPH TO YOUR REPORT**