Experiment
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# 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 HCl solution is given and you will determine the unknown concentration of the NaOH. 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:

$$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow H_2O_{(l)} + NaCl_{(aq)}$$

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 HCl titrant used at the equivalence point will be used to determine the molarity of the NaOH.

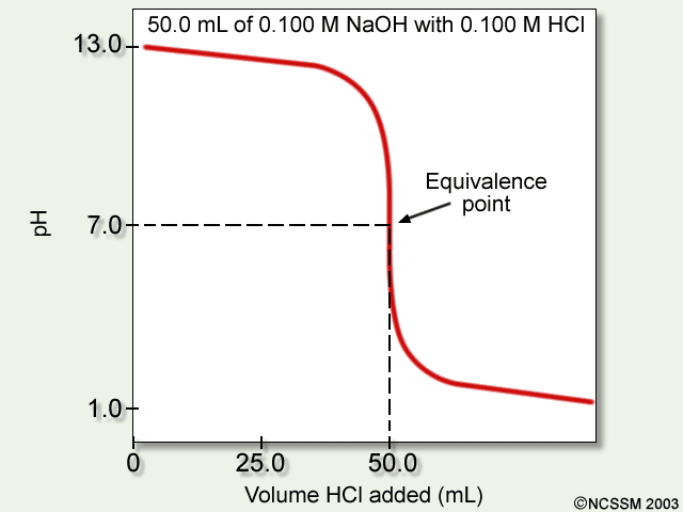


*Figure 1*

## MATERIALS

Power Macintosh or Windows PC
Vernier computer interface
Logger*Pro*
Vernier pH Sensor
NaOH solution, unknown concentration
0.100 M HCl solution
distilled water
Wash bottle
50-mL buret
Burette clamp
utility clamps
10-mL graduated cylinder
Pipet bulb or pump
250-mL beaker

## PROCEDURE

1. Obtain and wear goggles.

2. Use a graduated cylinder and a pipet place 5.0 mL of one of the 4 NaOH solutions into a 250-mL beaker. Write down the letter of this unknown immediately. Add 50 mL of distilled water.

3. Stir with a stirring rod during the titration.

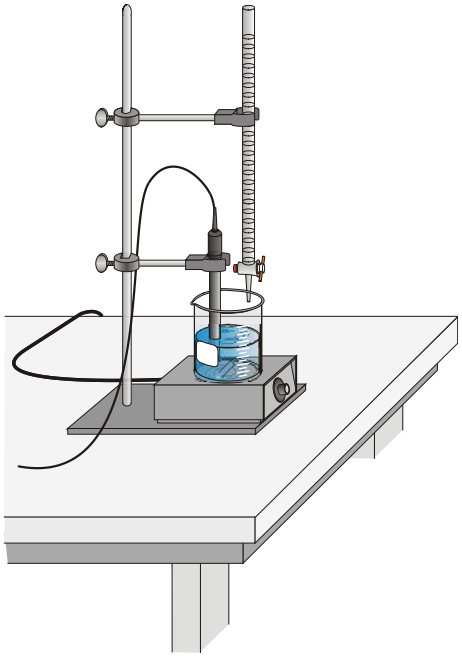

*Figure 2*

4. Check to make sure there is liquid in the container on the pH sensor. Do not refill this container with water if you spill it. Remove the container and use a utility clamp to suspend a pH Sensor on a ring stand as shown in Figure 2.

5. Obtain a 50 mL buret, and use a buret clamp to attach the buret to the ring stand as shown in Figure 2. Fill the buret a little above the 0.00-mL level of the buret with 0.10 M HCl solution. Drain a small amount of HCl solution so it fills the buret tip *and* leaves the HCl at the 0.00-mL level of the buret.

6. Launch Graphical Analysis. Connect the pH Sensor to your Chromebook, computer, or mobile device. Set up the data-collection mode.

   a. Click or tap Mode to open Data Collection Settings. Change Mode to Event Based.

   b. Enter **Volume** as the Event Name and **mL** as the Units. Click or tap Done.

7. Before adding HCl, 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 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. Before you begin. **Never attempt to catch a drop and prevent it from entering the solution**. Do **NOT hit keep unless the reading is stable!** If it is rapidly decreasing you have to see what it falls to.
   b. Add a small amount of HCl (enough to lower the pH about 0.25 units, you want drops coming out of the buret, not a steady stream). When the pH stabilizes, again click keep. In the edit box, type the current buret reading, to the nearest 0.01 mL. Press ENTER. You have now saved the second data pair for the experiment.
   c. Continue adding HCl solution in increments that lower the pH by about 0.25 units and enter the buret reading after each increment.
   d. **When a pH value of approximately 11 is reached, change to a one-drop increment**. For each drop check the pH value, if it went down by more than .25, click keep, and record the volume. If it did not decrease by .25 add another drop.
   e. After a pH value of approximately 3.5 is reached, add larger amounts of HCl to lower the pH by about 0.25 pH units, and enter the buret volume after each increment.
   f. Continue adding HCl solution until the pH value remains constant. Your graph will start to flatten out.
9. When you have finished collecting data, click Stop. Dispose of the beaker contents as directed by your teacher. Save the file.
10. Complete a 2nd trial using the same unknown.
11. Print a copy of your two best titrations.
12. Print a copy of the Graph window and the table. Enter your name(s) and the number of copies of the graph.

## PROCESSING THE DATA

1. Use your graph and data table to determine the volume of HCl titrant used in each trial. Examine the data to find the point where the pH values began to drop drastically when HCl was added. Record this as HCl volume just *before* the large drop. The large drop is not in between two points, but the whole region where it is going almost straight down.
2. Find and record the HCl volume *after* the drop producing the large pH drop was added.
3. Determine the volume of HCl added at the equivalence point. To do this, add the two HCl values determined in steps 1 and 2 and divide by two.
4. Calculate the number of moles of HCl used at the equivalence point using your volume from step 3 and the concentration of the solution.
5. See the balanced equation for the neutralization reaction given in the introduction. Determine the number of moles of NaOH used, using the ratios between HCl and NaOH.
6. Recall that you pipeted out 5.0 mL of the unknown NaOH solution for each titration. Calculate the NaOH concentration.
7. Repeat this lab a 2nd time with the same unknown acid.

8. Determine the average [NaOH] in mol/L.

9. Calculate the $[H_3O^+]$ and $[OH^-]$ at the following points

## DATA TABLE

UNKNOWN LETTER _____

| | | |
|---|---|---|
| Concentration of HCl | 0.10 M | 0.10 M |
| HCl volume added *before* the large pH drop | mL | mL |
| HCl volume added *after* the large pH drop | mL | mL |

| | | |
|---|---|---|
| Volume of HCl added at equivalence point | mL | mL |
| Moles HCl | mol | mol |
| Moles NaOH | mol | mol |
| Concentration of NaOH | mol/L | mol/L |
| Average [NaOH] | | M |
| $[H_3O^+]$ and $[OH^-]$ at pH = 3.50 and pH=10.00 | pH= 3.50 | pH = 10.00 |