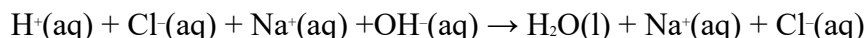


Acid-Base Titration

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:



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 pH Sensor 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.

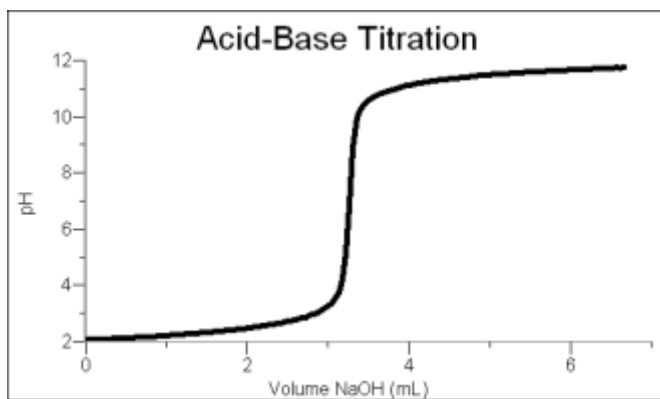


Figure 1

OBJECTIVES

- 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

Materials for both Method 1 (buret) and Method 2 (Drop Counter)

Chromebook, computer, or mobile device	HCl solution, unknown concentration
Graphical Analysis app	~0.1 M NaOH solution
Go Direct pH	pipet bulb or pump
Stir Station	250 mL beaker
magnetic stirring bar	wash bottle
(optional) Phenolphthalein	distilled water

Materials required only for Method 1 (buret)

Electrode Support	buret clamp or utility clamp
50 mL buret	2nd 250 mL beaker
10 mL pipet	

Measuring Volume Using a Buret

1. Obtain and wear goggles.
2. Use a pipet bulb (or pipet pump) to pipet 10 mL of the HCl solution into a 250 mL beaker. Add 50 mL of distilled water. **DANGER:** *Hydrochloric acid solution, HCl: Causes severe skin and eye damage. Do not breathe mist, vapors, or spray. May cause respiratory irritation. May be harmful if swallowed.*
3. Place the beaker on a Stir Station and add a stirring bar.
4. Launch Graphical Analysis. Connect the pH Sensor to your Chromebook, computer, or mobile device.
5. 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.
6. Use an Electrode Support to suspend a pH Sensor on a Stir Station (see Figure 2). 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 Stir Station, and adjust it to a medium stirring rate (with no splashing of solution). Check to see that the pH value is between 1.5 and 2.5.



Figure 2

7. Obtain a 50 mL buret and rinse the buret with a few mL of the ~0.1 M NaOH solution. Dispose of the rinse solution as directed by your teacher. **WARNING:** *Sodium hydroxide solution, NaOH: Causes skin and eye irritation.*

Use a buret clamp or a utility clamp to attach the buret to the Stir Station as shown in Figure 2. 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 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.

8. You are now ready to perform the titration. This process is faster if one person manipulates and reads the buret while another person enters volumes.
 - a. Click or tap Collect to start data collection.
 - b. Before you have added any drops of NaOH solution, click or tap Keep and enter **0** as the buret volume in mL. Click or tap Keep Point to store the first data pair for this experiment.
 - c. Add the next increment of NaOH titrant (enough to raise the pH about 0.15 units). When the pH stabilizes, click or tap Keep, enter the current buret reading (to the nearest 0.01 mL), and then click or tap Keep Point.
 - d. Continue adding NaOH solution in increments that raise the pH by about 0.15 units and enter the buret reading after each increment. 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.
 - e. 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.
 - f. Continue adding NaOH solution until the pH value remains constant.
9. Click or tap Stop to stop data collection.
10. Examine the data on the graph of pH vs. volume to find the *equivalence point*—that is the largest increase in pH upon the addition of 1 drop of NaOH solution. Move to the region of the graph with the largest increase in pH (you can adjust the Examine line by dragging the flag). Find the NaOH volume just *before* this jump. Record this value in the data table. Then record the NaOH volume *after* the drop producing the largest pH increase was added. **Note:** Another method for determining the equivalence-point volume is described in the Alternate Equivalence Point Method of this experiment.
11. (optional) Export, download, or print a copy of the graph of pH vs. volume.
12. Dispose of the beaker contents as directed by your teacher. Rinse the pH Sensor and return it to the pH storage solution.

DATA TABLE

Concentration of NaOH	M	M
NaOH volume added before largest pH increase	mL	mL
NaOH volume added after largest pH increase	mL	mL

Volume of NaOH added at equivalence point	mL	mL
Moles NaOH	mol	mol
Moles HCl	mol	mol
Concentration of HCl	mol/L	mol/L
Average [HCl]	M	