Laboratory Manual for Acid/Base Titration

Titration of Hydrochloric Acid with Sodium Hydroxide

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Introduction

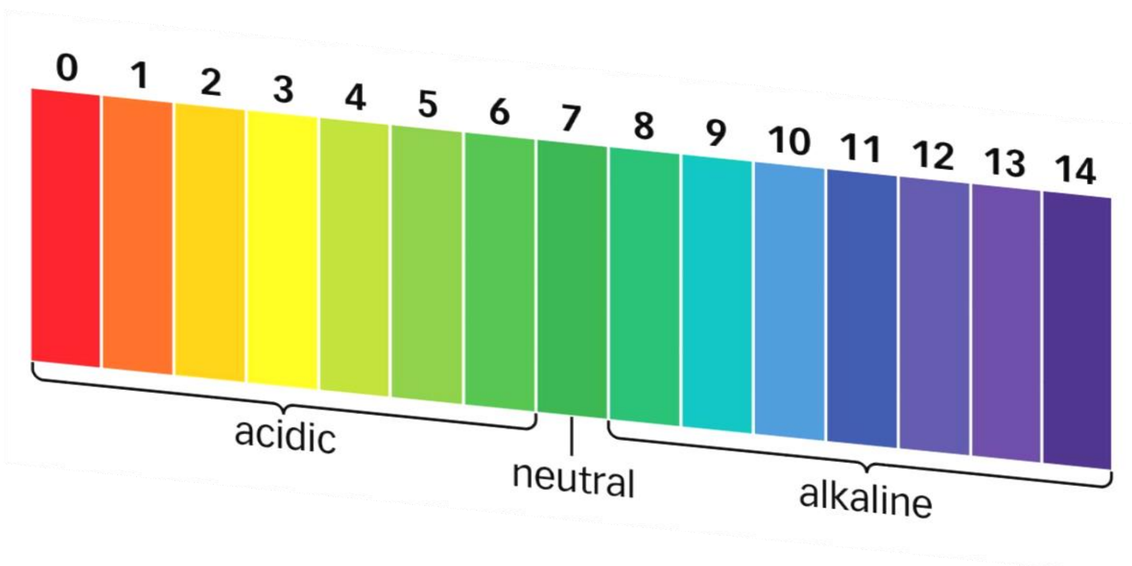
One of the most common forms of chemical laboratory testing used in high school chemistry courses is the acid base titration. This experimental scenario is used in a variety of testing. Titrations are key in the world of medicine, marine life, and even water purification. Unfortunately if these processes are carried out using rather high concentrations of either acids or bases they can be extremely dangerous to perform.

Acid base titrations are used to determine an unknown molarity or concentration) of a given substance. In this lab the chemical of unknown molarity will be Sodium Hydroxide or NaOH. This manual provides a brief summary to help you better understand exactly what acids and bases are as well as a detailed procedure on how to properly and safely carry out an acid base titration. In this lab we will use the base sodium hydroxide to titrate the hydrochloric acid. The end goal of this lab will be to properly calculate the molarity of the 3 of this manual.

This manual is arranged in a step-by-step procedure that makes it easy for even the most inexperienced chemistry student to properly carry out this titration and to properly calculate the unknown molarity.

This laboratory experiment uses chemicals that are quite dangerous if they come in contact with your skin.. This laboratory manual places your safety above all else, for this reason several precautions are placed throughout the lab to remind you of basic safety precautions that should be followed.

Chapter 1: Introduction to Acids, Bases and the Purpose of Titration



Chapter 1: Introduction to Acids, Bases, and the Purpose of Titration

What are Acids and Bases?

There are different qualifications that determine if a solution is an acid or a base. The different models we use to determine this are the Arrhenius, Bronsted-Lowry, and Lewis Theory.

Arrhenius Theory

According to the Arrhenius Theory acids are defined as substances that increase the hydrogen ion concentration when in solution and bases are substances that increase the hydroxide ion concentration when placed in solution. The Arrhenius theory is the simplest theory to describe acids and bases but has several limitations. For this reason others models to describe acids and bases exist.

$$HCl + NaOH \rightarrow NaCl + H_2O$$

In the equation above hydrochloric acid increases the H+ concentration and sodium hydroxide increases the OH- concentration. According to the Lewis theory HCl is an acid and NaOH is a base.

Bronsted-Lowry Theory

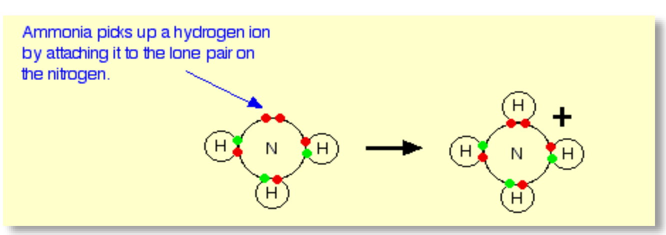
According to the Bronsted-Lowry theory acids are defined as proton donors while acids are defined as proton acceptors. The Bronsted Lowry definition of acids and bases does not counteract the Lewis definition of acids and bases it only adds to it.

$$H_2O + HCl \rightarrow H_3O^+ + Cl^-$$

In the reaction above hydrochloric acid donates a proton to the hydronium ion. Because HCl donated a proton and H30+ accepted it, HCl is an acid and H_3O^+ is base according to the Bronsted Lowry theory of acids and bases. Although the Bronsted-Lowry offers a more complete description it still has several limitations.

Lewis Theory

The Lewis theory offers the most complete definition of acids and bases but is also most difficult to comprehend. Under the Lewis theory acids are defined electron pair Acceptors and bases are defined as electron pair donors. It is easier to understand this theory when the Lewis structures of molecules are drawn out.



$$NH_3 + H^+ \rightarrow NH_4^+$$

From the reaction above, it is clear that the NH_3 molecule donates an electron pair to the H+ in order to form the ammonium molecule. In this case NH_3^+ is considered a base and H+ is considered an acid under the Lewis Theory of acids and bases.

What is the Purpose of Acid/Base Titration?

In short the purpose of acid base titration is to determine the unknown concentration of a substance. When titrating the solution of known concentration is known as the titrate, and the solution of unknown concentration is known as the analyte. In order to determine the concentration of the analyte we must first determine the point at which:

Moles of acid (in this case the titrate) = Moles of base (in this case the analyte)

(In this case we will be using the acid HCl and the base NaOH.)

> *Note: The number of moles of a certain substance can be broken down into:
> Molarity x Volume

Thus,

$$M_{HCl} \times V_{HCl} = M_{NaOH} \times V_{NaOH}$$

The point at which these two values are equal is known as the equivalence point. We will be able to determine one this point has been reached through the use of an indicator.

Common Acid–Base Indicators

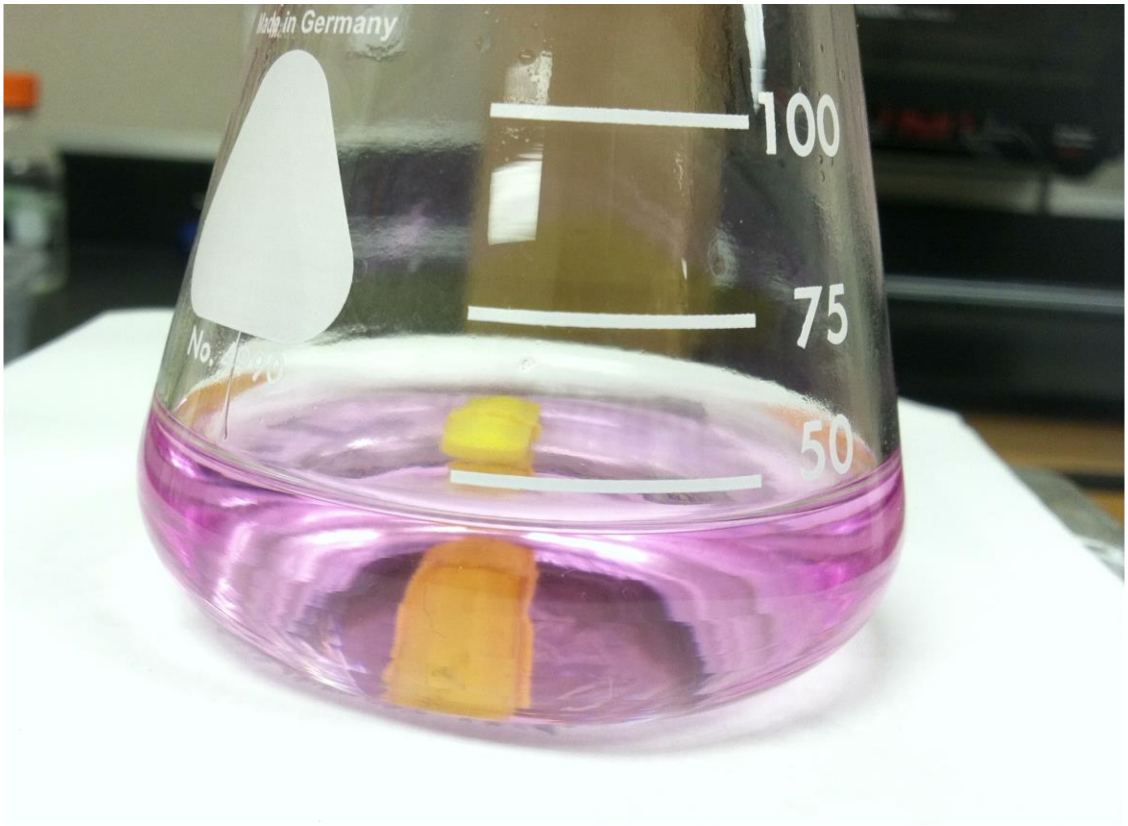
Indicator	Approximate pH Range for Color Change	Color Change
methyl orange	3.2–4.4	red to yellow
bromthymol blue	6.0–7.6	yellow to blue
phenolphthalein	8.2–10	colorless to pink
litmus	5.5–8.2	red to blue
bromcresol green	3.8–5.4	yellow to blue
thymol blue	8.0–9.6	yellow to blue

In this experiment we will be using the indicator Phenolphthalein. When the equivalence point is reached there will be a color change from clear to pink. From this point we will be able calculate the concentration of the unknown.

What is pH?

pH measure the concentration of hydrogen ions in a given solution. This reading tells us if a solution is either acidic or basic. The pH scale ranges from 0-14, acid have a pH of below 7 while bases have a pH above seven. A solution with a pH of seven is said to be neutral such as water.

Chapter 2: Acid/Base Titration Procedure



Chapter 2: Acid/ Base Titration Procedure

Equipment Needed

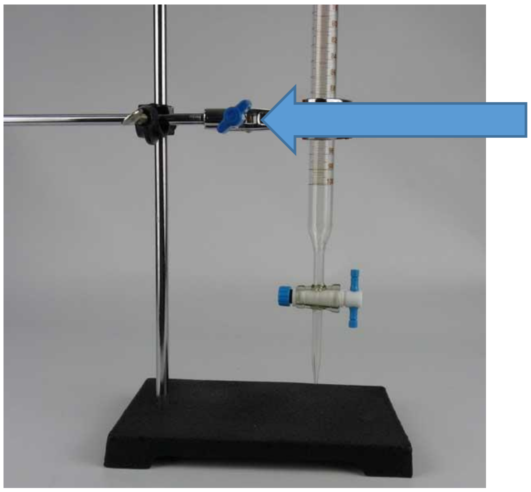
For this experiment the following safety equipment is needed.
Goggles Gloves Lab coat

For this experiment the following lab equipment is needed
Burette 100 ml beaker Erlenmeyer flask 10 ml of .2 M solution of Hydrochloric Acid HCl 10ml of unknown concentration of Sodium Hydroxide Phenolphthalein Plain sheet of white paper or white tile

Procedure

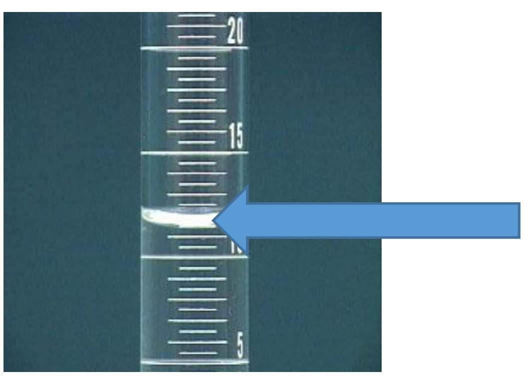
Be sure all proper safety equipment is worn when handling harmful chemicals

1.)Clamp the burette to its stand as below.



Be sure that this clamp is not too tight as it may damage the glass burette.

2.) Collect 10 mL of .2 M Hydrochloric Acid in a graduated cylinder. Be sure to measure at the meniscus!



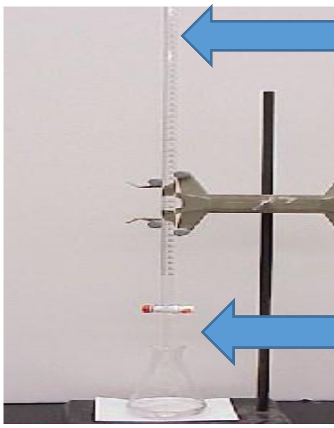
Be sure that you are wearing all proper lab equipment when handling chemicals!

3.) Transfer the contents to an Erlenmeyer flask

4.) Fill the burette up to the 0.0 ml mark using a funnel with the unknown concentration of sodium hydroxide.

BE SURE THE BURETTE VALVE IS CLOSED!

5.) Place the Erlenmeyer flask of Hydrochloric acid under the tip of the burette.



Burette filled with NaOH

Erlenmeyer flask filled with HCl

Note* You may want to add a white tile or piece of paper under the flask in order to more easily see the color change.

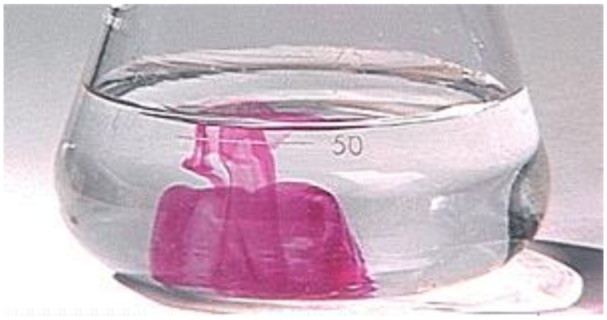
6.) Add 3-4 drops of phenolphthalein to the solution of HCl in the Erlenmeyer flask.

7.) Begin to slowly allow the sodium hydroxide in the burette to fall into the HCl by opening the burette valve.

Open this valve so only single drops escape at once

⚠ Do not completely open the valve! For best results allow only 1-2 drops to enter the flask at a time!

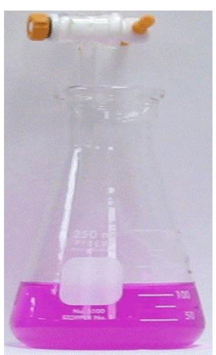
8.)After a few drops gave entered the flask close the valve and swirl the solution around until the pink color goes away.



The solution may appear pink but after it is swirled this color will go away

9.) Repeat step 8 until the pink color does not go away after swirling. You have reached the equivalence point!

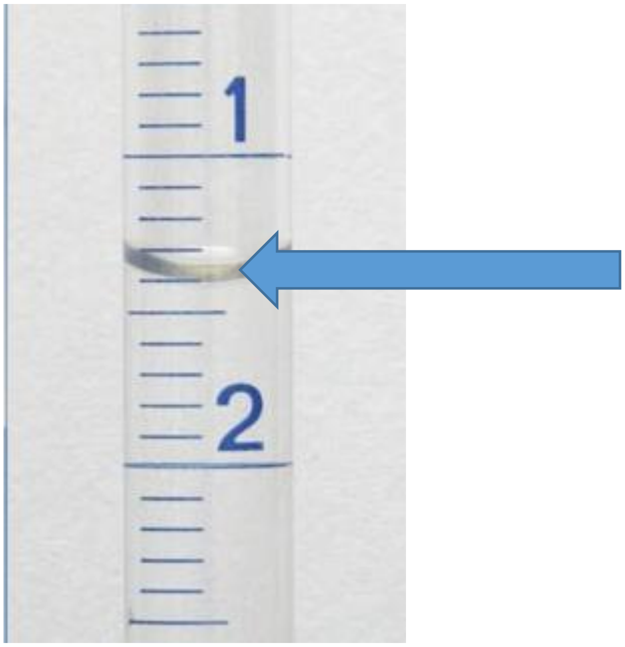
The solution at the equivalence point should appear slightly pink



If the solution appears dark pink you have overshot the endpoint and have added too much Sodium Hydroxide

Note* if your solution is dark pink the value calculated for NaOH concentration will be falsely elevated

10.) After the equivalence point is reached document the amount of Sodium Hydroxide that was used by reading the amount on the burette.



For example in this case 1.4 ml of solution was used

11.) After all data has been recorded be sure to dispose of all waste and thoroughly clean up your lab station.

Ask your instructor how and where they would like you to dispose of the acids and bases

Chapter 3: Determining the Concentration of Sodium Hydroxide

Chapter 3: Determining the concentration of Sodium Hydroxide

1.) Set the number of moles at the equivalence point equal to one another.

$$M_{HCl} \times V_{HCl} = M_{NaOH} \times V_{NaOH}$$

2.) Document all the known variables in the equation.

M_{HCl}: .2 M

V_{HCl}: 10ml

V_{NaOH}:_______ ← For this value substitute the amount of sodium hydroxide that was used (this is the reading you took from the burette)

3.) Algebraically solve for M_{NaOH}:

Divide by V_{NaOH} on each side of the equation

$$\frac{(M_{HCl})(V_{HCl})}{V_{NaOH}} = \frac{(M_{NaOH})\cancel{(V_{NaOH})}}{\cancel{V_{NaOH}}}$$

Therefore,

$$M_{NaOH} = \frac{(M_{HCl})(V_{HCl})}{V_{NaOH}}$$

This is the final equation to determine the concentration of the sodium hydroxide

4.) Substitute the values from step one and solve for concentration of sodium hydroxide (For this calculation 1.4 mL of NaOH will be used only to provide an example)

$$M_{NaOH} = \frac{(.2M)(10mL)}{1.4mL} \approx 1.42\ M$$

Note* Be sure to use the experimental value you observed for V_{NaOH}.

Glossary

Acids
A solution with a pH below the neutral point (pH 7)

Arrhenius Theory
Defines acids as substances that increase the hydrogen ion concentration, and bases as substances that increase hydroxide ion concentration.

Bases
A solution with a pH above the neutral point (pH 7)

Bronsted-Lowry Theory
Defines acids as proton donors, and bases as proton acceptors.

Equivalence Point
The point at which

Moles of acid = Moles of base

Indicator
A chemical that changes appearance in the presence of different pH levels

Lewis Theory
Defines acids as electron pair acceptors and bases as electron pair donors.

Molarity
Measures the concentration of a given substance, molarity can be written as

$$\frac{moles\ of\ substance}{Liters\ of\ solution}$$

Titration
Adding on substance to another in hopes of finding the point at which moles of the two substances are equal in order to determine an unknown concentration

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