Titration and Acid-Base Neutralization

LEARNING OBJECTIVES

11.2.2.7 understand the purpose of, be able to carry out, and be able to carry out calculations involving, titration

The Titration

- One of the most important lab procedures involving acids and bases is the titration.
- A titration is an analytical procedure that allows for the measurement of the amount of one solution that is required to exactly react with the contents of another solution.
- In acid-base terms, you add one solution to the other until the **equivalence point** is reached.
- The use of a pH meter will produce a pH curve (titration curve), so you can specifically calculate at what pH your solutions have been neutralized.

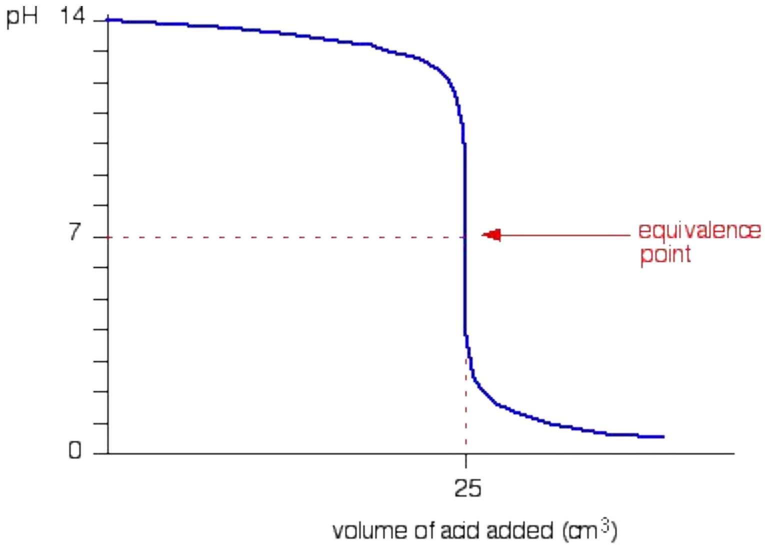
Acid-Base Titration Terms to Know

- Titrant: the standard solution of known molarity in the buret that is being added to the solution in the flask. This is more often the acid than the base.
- Analyte: the solution in the flask of unknown concentration. Usually the base.
- Indicator: a compound that is added in small amounts (a few drops) in acid-base titrations. It changes color over a certain pH range, and indicates the end of the titration. This range should be matched with pH at which you expect your solutions to reach the equivalence point.
- Endpoint: the point at which the titration is stopped, when the indicator permanently changes color. Traditionally, this is the point when the titration is stopped, where the number of moles of titrant is equal to the number of moles of analyte, or some multiple thereof (as in di- or tri- protic acids)
- Equivalence point (a.k.a. neutralization or endpoint): the point (in mL of solution added) at which the number of moles of acid equal the number of moles of base.

Types of Acid-Base Titrations

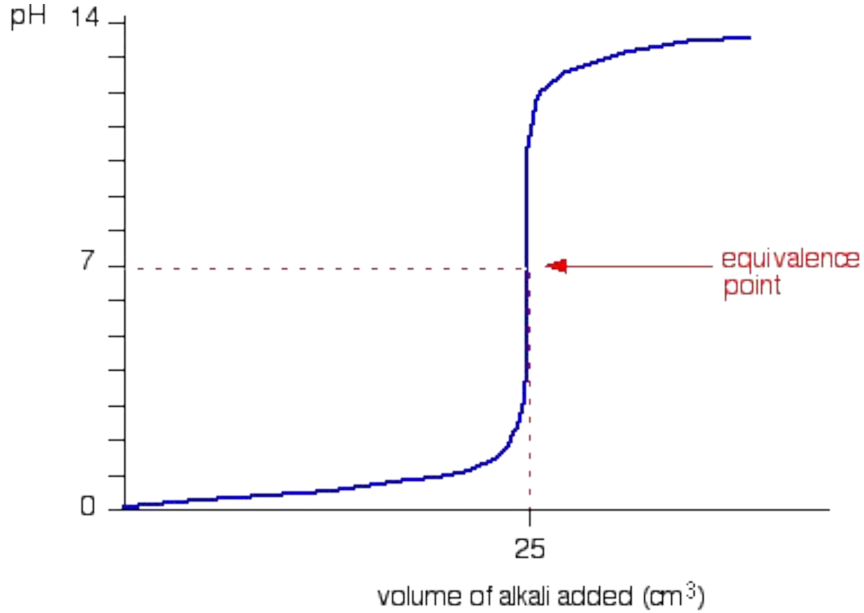
- The quality of the titration depends on the strength of the acids and bases you use. This, in turn, will affect the resulting pH curve.
- Let’s look at a few examples of pH curves.

Strong Acid-Strong Base



- This diagram shows the change in pH as a solution of strong acid is slowly added to a solution of strong base.
- **Strong acid-strong base titrations usually have an equivalence point around 7**.
- This is due to the fact that in solution, strong acids and strong bases will both completely dissociate, so there is an approximate 1:1 ratio of moles of acid to moles of base at the equivalence point.

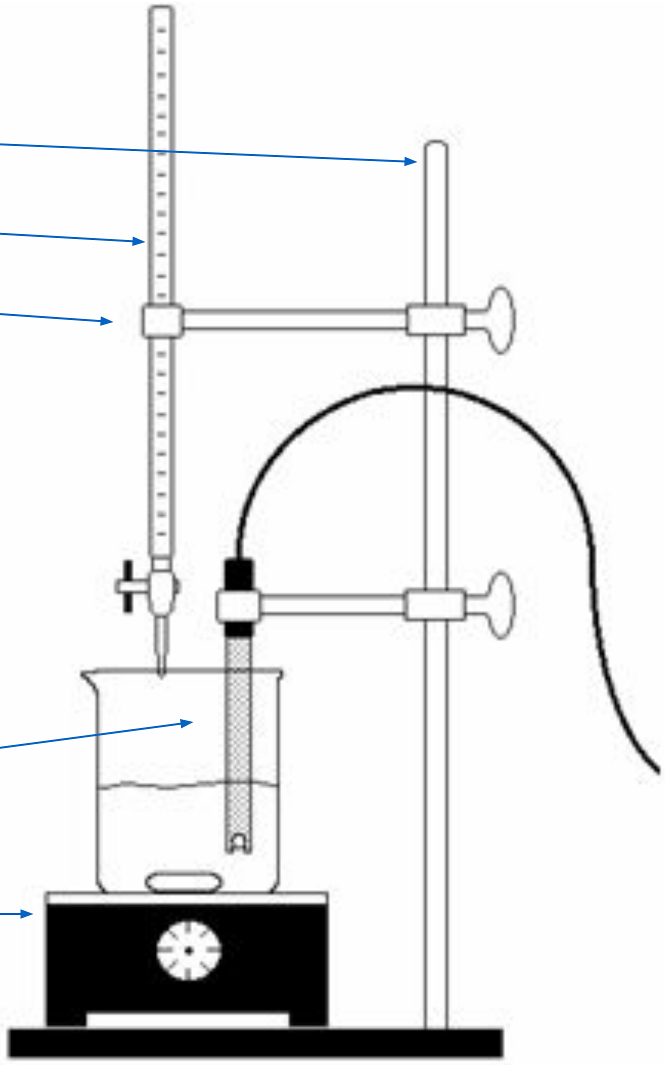
Strong Base-Strong Acid



- Strong base-strong acid titrations are just like the strong acid-strong base titrations: the pH at the equivalence point is around 7
- Note that in both types, there is relatively little change in pH until it jumps steeply at the equivalence point.

Titration Equipment

- Stand
- Buret
- Buret clamp
- Erlenmeyer Flask (diagram shows a beaker)
- Analyte (unknown molarity)
- Titrant (standard solution of known molarity)
- Indicator
- pH meter (optional, but highly recommended)
- Stirrer (optional, recommended)



Preparing the Titration

- Make sure your equipment is clean!
- Take care when preparing the buret. Run distilled water through it to make sure it is clean. Then, rinse it with some of the **titrant** solution, letting it run through to stopcock as well. This will ensure that there is no water left, so that the concentration of the titrant is not unexpectedly diluted when you actually perform the titration.
- Measure out the volume of the analyte that you add to the flask, and record it. Add a few drops of an appropriate indicator. Set the flask on the stirrer and the magnet inside in flask.
- Fill the buret with an appropriate amount of titrant, and record this initial amount. Secure the buret to the stand over the flask with a clamp.
- Put the pH meter in the flask, and secure it with a clamp.

Starting the Titration

- Turn the stirrer onto a low setting.
- Add a few milliliters of titrant to the analyte at a time by switching the stopcock between the open and closed positions, and record the pH every few milliliters added.
- As the titrant is dropped into the analyte, the indicator will briefly change color, and then disappear.
- The initial changes in pH will be very small, since all of the added titrant will be reacted by the excess analyte

Around the Endpoint

- You have reached the endpoint when the indicator first **permanently** changes color.
- There will be a very large jump in pH as all of the analyte is reacted, and there is now excess titrant.

Example of a solution using phenolphthalein as a indicator. The reaction has just reached the equivalence point, because the solution has just permanently turned pale pink.

Acid Base Neutralization Reaction

- Acid + Base Water + Salt
- Ex: **HCl + NaOH H_2O + NaCl**

Example: Stomach antacids

Titration:

- A laboratory method for determining the concentration of an unknown acid or base using a neutralization reaction.

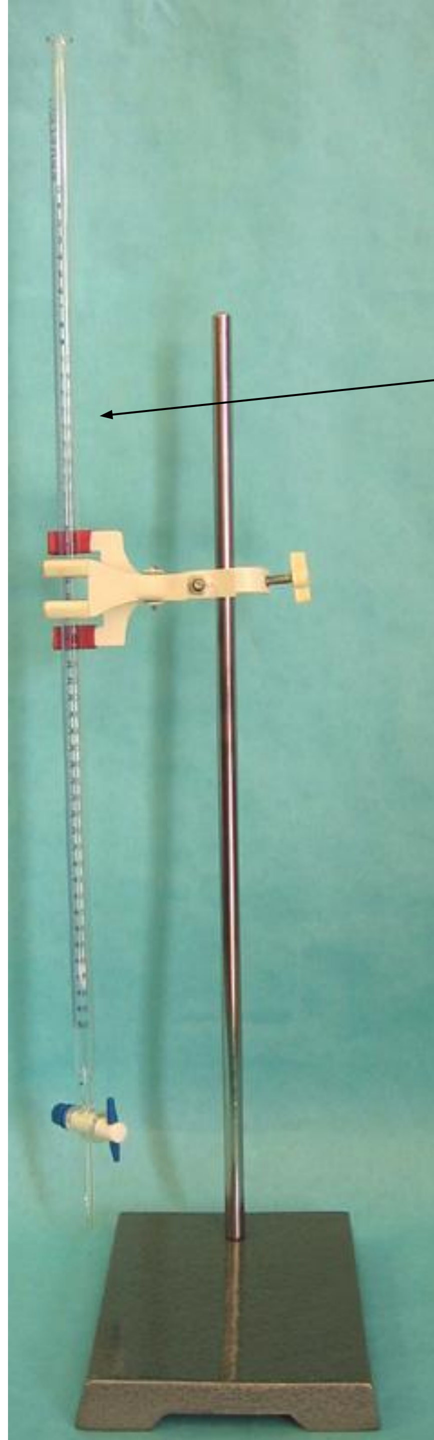
- A *standard solution*,(a solution of known concentration), is used.

Equivalence Point

- The point at which there are stoichiometrically equivalent amounts of acid and base.

- $[H^+] = [OH^-]$

Valve

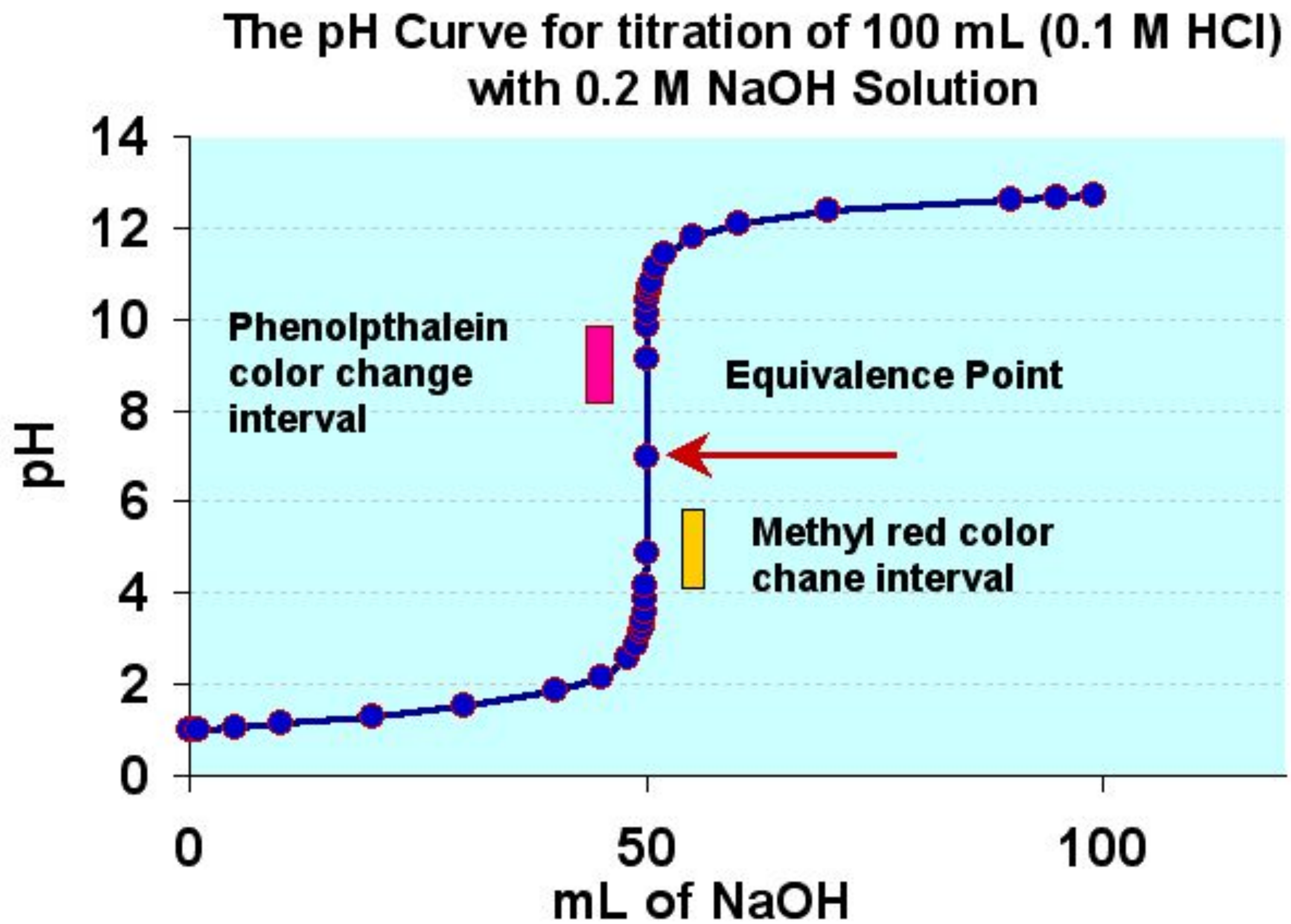


Buret

Titration

Acid with Phenolpthalein

End-Point


The pH Curve for titration of 100 mL (0.1 M HCl)
with 0.2 M NaOH Solution
14
12
10
8
6
4
2
0
pH
Phenolpthalein
color change
interval
Equivalence Point
Methyl red color
chane interval
0
50
100
mL of NaOH

Indicators

- Indicators are chosen, such that they change colors at the range of the pH of interest.

- The solution itself at the end-point may be:
  - **Basic,** if the reaction involves a strong base and a weak acid.
  - **Neutral,** if the reaction involves a strong acid and a strong base.
  - **Acidic,** if the reaction involves a strong acid and a weak base.

Methods of Solving Titration Problems:

a) using stoichiometry

b) using the titration formula $aM_aV_a = bM_bV_b$.

Ex. 1

What is the concentration of HCl if 30.0 mL of 0.10 M NaOH neutralizes 50.0mL HCl?

$NaOH + HCl \longrightarrow H_2O + NaCl$

Hint: Use $aM_aV_a=bM_bV_b$

$M_a=$

How many moles of HCl were used?

Hint: #moles= M_aV_a, but convert the volume to L(50mL=0.05L).

Ex. 2

A 20.0 mL solution of $Sr(OH)_2$ is neutralized after 25.0 mL of standard 0.05 M HCl is added. What is the concentration of $Sr(OH)_2$?

$$2\,HCl + Sr(OH)_2 \rightarrow 2\,H_2O + SrCl_2$$

Ex. 3

- How many mL of 0.20 M H_3PO_4 are needed to neutralize 55.0 mL of a 0.10 M solution of NaOH?

Ex. 4

- What volume of 0.20M $Ca(OH)_2$ will neutralize 45.0 mL of a 1M solution of HCl?
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