Acid-Base Titration

Learning Outcomes:

Students will be able to:

1. define the term titration;
2. explain acid-base titration;
3. explain neutralization reactions;
4. complete and balance neutralization reactions.

Introduction:

Titration is a process or method to determine the concentration of a substance in a solution, in which a known reagent is added to a solution of unknown concentration.

Titration technique can be used to achieve different purposes and this shows its importance in different fields of our daily life. *For example*

- Pharmacists use titration to achieve a desired mix of compound drugs. Titration is also used to monitor blood glucose levels in patients with diabetes.
- Titration can be used in the manufacture of oils, fats and similar substances. Specific titration procedures exist to test free fatty acid content.

- Titration can be employed in biology labs, where it is used to determine the proper concentration of chemicals to make the animals faint.
- Titration is used in the production of biodiesel to determine the acidity of waste vegetable oil.
- Titration is used to test the underwater environment in fresh water and marine aquariums to ensure the survival of marine life being kept in the aquarium.
- Titration is important in environmental chemistry, where scientists can use it to analyze acid rain.

The chemical analysis to determine the amount of each susbtance during a chemical change is called *quantitative analysis*.

A quantitative analysis which is based upon the measurement of the volumes of reacting substances is called *volumetric analysis*.

Titration is an important method implied for volumetric analysis. *"It is the process of determinig the exact volume of one solution which reacts completely with a definite volume of another solution."*

Types of volumetric analysis:

There are various types of volumetric analysis, some of the most common types are given below:

1. Acid-Base Titration.
2. Redox Titration.
3. Complexometric Titration.
4. Precipitation Titration.

Acid-Base Titration:

Animation

Quantitative analysis of acid-base neutralization reactions are most conveniently carried out using a procedure known as ***Titration***.

In a titration experiment,

"a solution of accurately known concentration, called a ***standard solution,*** *is added gradually to another solution of unknown concentration, until the chemical reaction between the two solutions is complete".*

If we know the volumes of standard and unknown solutions used in the titration, along with the concentration of the standard solution, we can calculate the concentration of unknown solution.

Acid-base titration begins with a conical flask or Erlynmeyer flask containing a precise volume of the acid or a base and a small amount of *indicator*, placed underneath a burette containing the acid or a base. keep adding the acid or base slowly it is possible to detect the point at which the *indicator changes color*, which is known to be the *'equivalence point'*. This should be the point where the acid and base neutralize each other, and, by reading the scale on the burette, the volume of acid or base can be measured.

For example, one of the simplest types of neutralization reaction is the titration between NaOH and HCl. The reaction is represented by

$$NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O$$

In acid-base titrations, indicators are substances that have distinctly different colours in acidic and basic media. The most commonly used indicators are phenolphthalein and methyl orange.

Animation

NEUTRALIZATION:

Animation

Acids are compounds that dissolve in water to produce solutions containing hydronium ions, H_3O^+ (aq), and bases dissolve in water to produce hydroxide ions, HO^- (aq). When an acidic solution and a basic solution are mixed, hydroxide ions react with hydronium ions to produce water molecules:

$$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$$

OR

$$H3O^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$$

"This chemical process in which acid reacts with a base to form salt and water is called neutralization".

Let's look at the reaction between hydrochloric acid and sodium hydroxide:

$$HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$$
$$NaOH_{(aq)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$$
$$H^+_{(aq)} + Cl^-_{(aq)} + Na^+_{(aq)} + OH^-_{(aq} \rightarrow Na^+_{(aq)} + Cl^- + H_2O$$
$$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O$$
$$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O$$

If we are supposed to evaporate water from the solution after this neutralization reaction, sodium chloride will be left which is commonly known as table salt. In general, the term ***salt*** refers to any ionic compound that could be produced by a neutralization reaction.

Balancing equations of neutralization reactions:

To be useful, a chemical equation must be balanced, i.e. for each element there must be the same number of atoms on both sides of the equation. This is because the law of conservation of mass requires that atoms are neither created nor destroyed during a chemical reaction.
One way to balance the equation for a neutralization reaction is to remember that the underlying chemical process is the reaction of hydrogen ions and hydroxide ions in a one to one ratio.

We balance the overall equation by adding coefficients so that the numbers of hydrogen ions and hydroxide ions are equal.

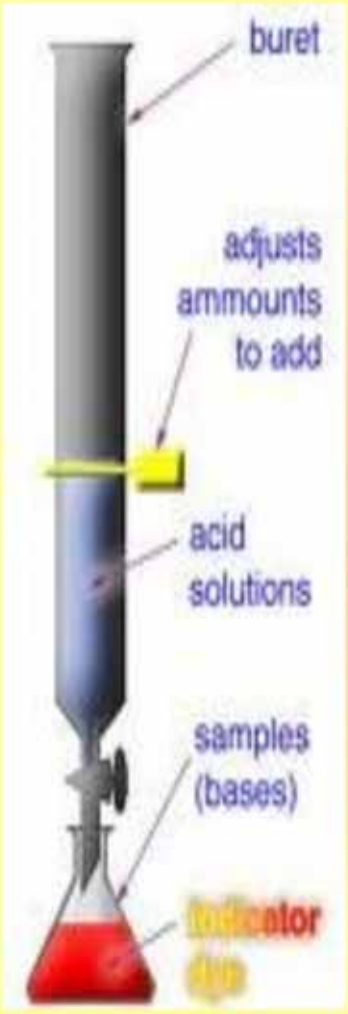
Consider as an example the reaction of hydrogen bromide with calcium hydroxide. Hydrogen ions from the acid will react with hydroxide ions from the base, and calcium and bromide ions will be left in solution. The ionic compound made up of calcium ions and bromide ions is calcium bromide, which has the formula $CaBr_2$ (remember that calcium is a group IIA metal and forms Ca^{2+} cations). We first write an overall equation for the process using the correct formulas for all of the compounds involved:

$HBr_{(aq)} + Ca(OH)_{2(aq)} \rightarrow CaBr_{2(aq)} + H_2O$ **(unbalanced)**

We can then quickly balance the equation by recognizing that we have 2 moles of hydroxide ions from 1 mole of calcium hydroxide, so we need 2 moles of hydrogen bromide and will get 2 moles of water:

$2HBr_{(aq)} + Ca(OH)_{2(aq)} \rightarrow CaBr_{2(aq)} + 2H_2O$ **(balanced)**

Inspection shows us that the other elements, calcium and bromine are also balanced. When balancing an equation, start with the correct formula for each compound and change the coefficients *NOT* the formulas.



Multiple Choice Questions

1. Which of the following 0.10 M salt solution is neutral?

A. $NaCl$
B. NH_4Cl
C. Na_2CO_3
D. NH_4NO_3

2. Which of the following equation is the best representation of a neutralization reaction?

A. $H_2O_{(l)} + CO_{2(g)} \rightarrow H_2CO_{3(aq)}$

B. $2HNO_{3(aq)} + Ba(OH)_{2(aq)} \rightarrow Ba(NO_3)_{2(aq)} + 2H_2O$

C. $2HBr_{(g)} + Cl_{2(g)} \rightarrow HCl_{(g)} + Br_{2(g)}$

D. $4Na_{(s)} + O_{2(g)} \rightarrow 2Na_2O_{(s)}$

3. Select from following that balance the given equation:

$$aAl(OH)_3 + bH_2SO_4 \rightarrow cAl_2(SO_4)_3 + dH_2O$$

A. a=1, b=1, c=1, d=1
B. a=2, b=3, c=2, d=6
C. a=2, b=2, c=2, d=3
D. a=2, b=3, c=1, d=6