

## Objectives

To prepare a standard solution of sodium carbonate.

To determine the strength of a given solution of hydrochloric acid by titrating it against standard sodium carbonate solution.

## The Theory

### What is Titration?

One of the important methods in Quantitative Analysis is Volumetric Analysis, a commonly used laboratory technique. It is used to determine the unknown concentration of a sample by measuring its volume. This process is also called titration. In a titration, a solution of unknown concentration is reacted with a solution of known concentration. The solution taken in the burette is called the titrant and the solution taken in the conical flask is called the analyte.

### What does the end point of a titration mean?

The endpoint of a titration is the point at which the reaction between the titrant and the analyte becomes complete. Generally the endpoint of a titration is determined using indicators.

### What is a standard solution?

A solution of known concentration is called the standard solution. A standard solution can be prepared by dissolving a known quantity of the substance in a definite volume of the solvent. The substance used to prepare the standard solution can be classified into two types.

#### 1. Primary standard

A primary standard has the following features.

It is highly pure and cheaply available.

It is highly soluble in water.

It is neither deliquescent nor hygroscopic.

It is highly stable.

Oxalic acid, Mohr's salt, potassium dichromate are some examples of primary standards.

## 2. Secondary standard

Substances whose standard solutions cannot be prepared directly are called secondary standards.

Some examples are sodium hydroxide and potassium permanganate.

How do we express the concentration of a solution?

The concentration of a solution can be expressed in the following ways.

Normality: It is defined as the number of gram equivalent of solute dissolved in one litre of the solution. It is denoted by the letter 'N'.

$$\text{Normality} = \frac{\text{Number of gram equivalent of solute}}{\text{Volume of solution in litre}}$$

$$\frac{m \times 1000}{M \times V}$$

Molarity: It is defined as the number of gram moles of solute dissolved in one litre of the solution. It is denoted by the letter 'M'.

$$M = \frac{m}{M \times V}$$

$$\frac{M}{m} \times \frac{V}{1000} = \frac{m}{M} \times \frac{V}{1000}$$

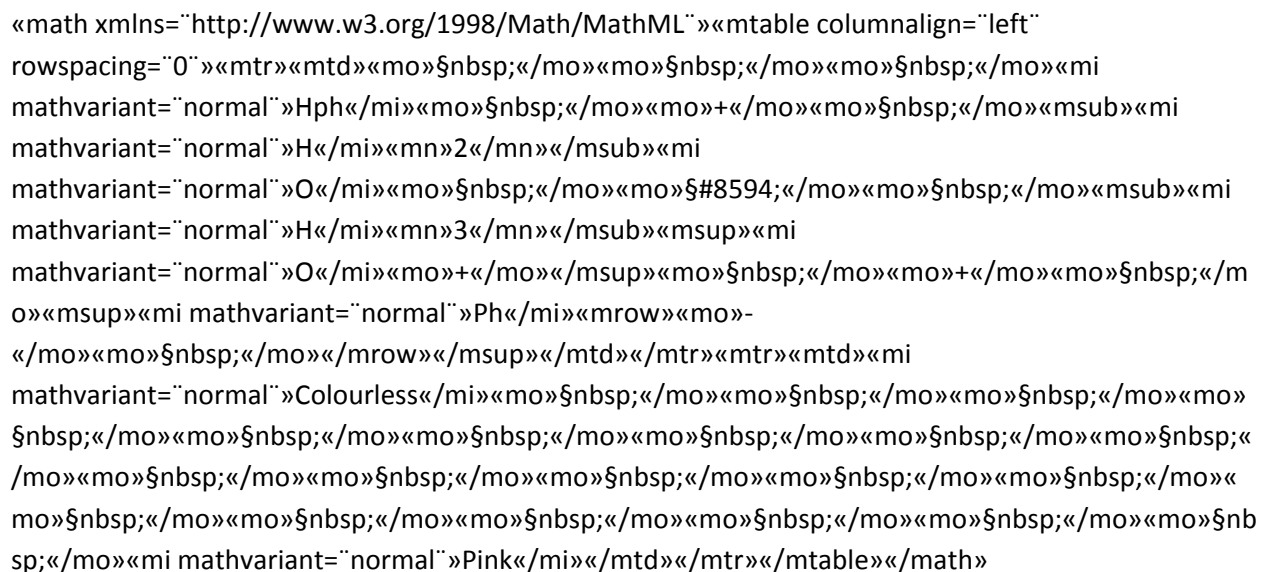
Molality: It is defined as the number of moles of the solute dissolved in 1Kg of the solvent. It is denoted by the letter 'm'.

$$\text{Molality} = \frac{N}{m} \times \frac{u}{M}$$



organic acids or weak organic bases. The colour change of an indicator depends on the pH of the medium. The un-ionized form of an indicator has one colour, but its ionized form has a different colour.

For example, consider the indicator phenolphthalein, whose ionization can be written as,



Some common examples of acid-base indicators

Indicators	pH Range	Acid	Base
Phenolphthalein	8.0 - 10.0	Colourless	Pink
Methyl Orange	3.1 - 4.4	Red	Orange
Methyl Red	4.4 - 6.2	Red	Yellow
Phenol Red	6.4 - 8.0	Yellow	Red
Thymol Blue	1.2 - 2.8	Red	Yellow
Thymol Blue	8.0 - 9.6	Yellow	Blue
Methyl Yellow	2.9 - 4.0	Red	Yellow

What are the different types of Acid-Base titrations?

Acid-base titration can be classified into the following types.

**Strong acid-Strong base titration:** In this type, a strong acid is titrated against a strong base. Both the acid and base are of equal strength, so at the endpoint, the pH will be neutral. The indicators used are phenolphthalein and methyl orange.

Example: Titration of HCl Vs NaOH

**Strong acid-weak base titration:** In this type, strong acid reacts with a weak base to form an acidic solution. So the pH of the solution is  $<7$ . Methyl orange is the indicator used to determine the endpoint.

Example: Titration of HCl Vs  $\text{NH}_4\text{OH}$

**Strong base-weak acid titration:** Here a strong base reacts with a weak acid to form a basic solution. So the pH of the solution is  $>7$ . In this type phenolphthalein is a suitable indicator for the determination of the end point.

Example: Titration of  $\text{CH}_3\text{COOH}$  Vs NaOH

**Weak acid-weak base titration:** This type of titration is not very practical. Here both the acid and base are very weak so they do not ionize completely. So, it is difficult to determine the pH range around the end point and it is difficult to choose a suitable indicator for this type of titration.

Example: Titration of  $\text{CH}_3\text{COOH}$  Vs  $\text{NH}_4\text{OH}$

How do we determine the strength of a given acid or base?

Determination of the strength is based on the Law of Equivalents. According to this law, the number of equivalence of the substance to be titrated is equal to the number of equivalence of the titrant used.

Consider an acid-alkali titration.  $V_1$  cm<sup>3</sup> is that of an acid solution of normality  $N_1$  required to neutralize  $V_2$  cm<sup>3</sup> of a base of normality  $N_2$ .

We know that 1000 cm<sup>3</sup> of 1N acid solution contains acid = 1 gram equivalent

$V_1$  cm<sup>3</sup> of 1N acid solution contains acid =  $V_1/1000$  gram equivalents

Thus number of gram equivalents of acid in V1 cm<sup>3</sup> of N1 acid solution is; 
$$\frac{V_1 \times N_1}{1000}$$

Similarly, number of gram equivalents of base in V2 cm<sup>3</sup> of N2 basic solution is; 
$$\frac{V_2 \times N_2}{1000}$$

By the law of equivalents, at the end point, 
$$\frac{V_1 \times N_1}{1000} = \frac{V_2 \times N_2}{1000}$$

i.e, 
$$V_1 \times N_1 = V_2 \times N_2$$

This is called the Normality Equation.

Similarly, Molarity equation can be written as,

$$\frac{M_1 \times V_1}{1000} = \frac{M_2 \times V_2}{1000}$$







$$\frac{M_1 V_1 + M_2 V_2}{M_3 V_3} = \frac{M_4 V_4}{M_5 V_5}$$

### Learning outcomes

Students understand the terms: quantitative estimation, acid-base titrations, end point, standard solutions, molarity, molality, normality and indicators..

Students can calculate the strength of a given acid or base using molarity or normality equations.

Students acquire the skill to prepare the standard solution and to determine the end point.

Students acquire the skill to select the indicators based on the nature of the solution.

Students are familiar with the apparatus used for titration.

Students acquire the skill to perform the titration using sodium carbonate and hydrochloric acid in the real lab once they visualize the different steps.