CHAPTER – 3 Redox Titration

3.1 INTRODUCTION

Redox titration refers to a laboratory method to determine the analyte concentration by carrying out a redox reaction between the analyte and the titrant. The redox titration often needs a redox indicator or a potentiometer.

Redox titration depends on an oxidation-reduction reaction that occurs between the analyte and the titrant. It is also one of the most common methods for identifying the concentration of the analytes that are unknown. For evaluating the redox titrations, it is essential to obtain the shape of the titration curve that corresponds. In redox titration, it is much more convenient for monitoring the concentration of the reaction potential instead of that of the reacting species.

3.2 Principle of Redox Titration

Redox reactions consist of both oxidation and reduction reactions. The primary features of these reactions are as follows:

Oxidation reaction: A substance undergoes oxidation in the following ways:

- Addition of oxygen
- Removal of hydrogen
- Loss or donation of electrons
- An overall increase in the oxidation state of the substance

Reduction reaction: A substance undergoes a reduction in the following ways:

- Addition of hydrogen atom
- Removal of the oxygen atom
- Accepting electrons
- Reduction in the oxidation state of the substance

Hence, we can say that redox titrations consist of a transfer of electrons between the titrant and the analyte. An example of this type of redox reaction is reacting the iodine solution with a reducing agent. A starch indicator is used to determine the endpoint of this redox titration. Here, the diatomic iodine gets reduced to the iodine ions and the blue coloured iodine solution loses its colour. This reaction is known as iodometric titration.

Oxidizing agent: Oxidizing agent are defined as substances containing an atom/ion, which accept an electron during the reaction and result in either decrease in their positive valency or increase in their negative valency.

Reducing agent: Reducing agent are defined as substances containing an atom/ion, which lose an electron during the reaction and result in either increase of their positive valency or decrease of their negative valency.

3.3 Theory on redox titration

Reduction potential is a measure of how thermodynamically favourable it is for a compound to gain electrons. A high positive value for a reduction potential indicates that a compound is readily reduced and consequently is a strong oxidizing agent that is it removes electrons from substances with lower reduction potential. The oxidized and reduced forms of a substance are known as a redox pair.

Redox reaction: $MnO_4^- + I^- \rightarrow Mn_2^+ + I_2$

3.4 Redox Titration Examples

The titration of potassium permanganate against oxalic acid is a great example of redox titration. The reaction is explained below.

Example - Titration of Potassium Permanganate Against Oxalic Acid

1. Firstly, prepare a standard oxalic acid solution, roughly 250 ml.
2. The molecular weight of oxalic acid can be calculated when the atomic weight of all the atoms is added. Doing so, we get the molecular mass of oxalic acid, which is,

$$H_2C_2O_4.2H_2O = 126$$

3. As the weight of the required oxalic acid for making 1000 ml of 1M solution is found to be 126g, the weight of the same for making 250ml of 0.1M solution is,

$$= (126/1000) \times 250 \times 0.1 = 3.15g$$

3.5 Determining the Strength of $KMnO_4$ using Standard Oxalic Acid Solution

In this titration, the analyte is oxalic acid and the titrant is potassium permanganate. The oxalic acid acts as a reducing agent, and the $KMnO_4$ acts as an oxidizing agent. Since the reaction takes place in an acidic medium, the oxidizing power of the permanganate ion is increased. This acidic medium is created by the addition of dilute sulfuric acid.

$KMnO_4$ acts as an indicator of where the permanganate ions are a deep purple colour. In this redox titration, MnO_4^- is reduced to colourless manganous ions (Mn_2^+) in the acidic medium. The last drop of permanganate gives a light pink colour on reaching the endpoint. The following chemical equation can represent the reaction that occurs.

Molecular equation

$2KMnO_4 + 3H_2SO_4 \rightarrow K_2SO_4 + 2MnSO_4 + 3H_2O + 5[O]$

$H_2C_2O_4.2H_2O + [O] \rightarrow 2CO_2 + 3[H_2O] \times 5$

Complete Reaction

$2KMnO_4 + 3H_2SO_4 + 5H_2C_2O_4.2H_2O \rightarrow K_2SO_4 + 2MnSO_4 + 18H_2O + 10CO_2$

Ionic equation

$MnO_4^{-} + 8H^{+} + 5e^{-} \rightarrow Mn^{2+} + 4H_2O] \times 2$
$C_2O_4^{2-} \rightarrow 2CO_2 + 2e^{-}] \times 5$