**General Aim**

To determine concentration of acetic acid in a commercial vinegar sample of vinegar by titrating it with a standard solution of NaOH.

**Method**

Determination of acetic acid by acid-base titration.

**Learning Objectives (ILOs)**

- Identify the difference between acid and base.
- Define the meaning of a standard solution.
- Predict how a certain sample could be analyzed.
- Determine accurately the concentration of acetic acid in vinegar via volumetric analysis, making use of the reaction of acetic acid with a strong base, sodium hydroxide.
- Acquire the correct techniques of titration.

**Theoretical Background/Context**

- Quantitative analysis deals with the determination of the quantity of the substance to be analyzed. Methods of quantitative analysis may be classified into:
  1. **Gravimetric analysis**: It depends on isolating and weighing of the final product with known pure, stable and definite form.
  2. **Instrumental analysis**: It depends on measuring some physical properties which change quantitatively with changing concentration of sample.
  3. **Volumetric analysis (Titration)**: It depends on measuring volume of standard solution (titrant) used for complete reaction with the sample.

- Titration is the capacity of the sample to combine with the suitable standard quantitatively through quantitative reaction. A quantitative reaction is the reaction that proceeds forward to produce stable product(s) such as weakly ionizable compounds, e.g. H2O, weak acids & base, sparingly soluble salts (precipitate), complex ion, etc. The types of quantitative Reactions can be:
  1. Neutralization Reactions
     a. H2O formation
     b. Displacement: Formation of weak acid or weak base
  2. Complexometric reactions
  3. Redox reactions (Electron transfer)
  4. Precipitometric reactions
Theoretical Background/Context

- Any sample is a solution of unknown concentration and a Standard is a solution of exactly known concentration. The requirements of titrimetric reactions are:
  - The reaction must be simple and expressed by a chemical equation
  - A single reaction must occur between the sample and titrant
  - The reaction must be instantaneous (rapid).
  - Suitable standard solutions must be available.
  - The end point should be easily detected.

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<tr>
<th>Oxidation is loss of electrons and increase in valency number, gain of oxygen or loss of hydrogen</th>
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<td>Fe²⁺ → Fe³⁺ + e⁻¹</td>
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<th>Reduction is gain of electrons and reduction in valency number, loss of oxygen or gain of hydrogen</th>
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<td>Fe³⁺ + e⁻¹ → Fe²⁺, Fe²⁺ + 2e⁻¹ → Fe⁰</td>
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<th>Oxidizing agent or oxidant is the substance that gain electrons</th>
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<td>Ex: KMnO₄, K₂Cr₂O₇, Ce(SO₄)₂</td>
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<th>Reducing agent or reductant is the substance that donate (lose) electrons</th>
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<td>FeSO₄, Na₂S₂O₃, H₂C₂O₄</td>
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Principle of Work

- Vinegar is a common household item containing acetic acid as well as some other chemicals. This experiment is designed to determine the molar concentration of acetic acid in a sample of vinegar by titrating it with a standard solution of NaOH.

  \[
  \text{CH}_3\text{COOH(aq)} + \text{NaOH(aq)} \rightarrow \text{CH}_3\text{COONa(aq)} + \text{H}_2\text{O}
  \]

- By adding the sodium hydroxide, which is a basic solution, to the acetic acid, which is an acidic solution, a neutralization reaction occurs. An indicator known as phenolphthalein, is also added to the vinegar. This indicator turns the solution to a dark pink when excess NaOH is added to make the solution more basic.