Chemistry | Analytical Chemistry

Determination of Concentration of Citric Acid in Soda by Titration

General Aim

To determine the concentration of citric acid in a sample of lemon soda beverage using a standard solution of sodium hydroxide.

Method

Determination of citric 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.
- Understanding the concept of acid base titration.
- Understanding the neutralization reactions.
- Determination of amount of citric acid in soda beverages available in the market.

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.
- 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 ions, 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.Preciptimetric reactions

Theoretical Background/Context (Cont')

- 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.

Oxidation is loss of electrons and increase in valency number, gain of oxygen or loss of hydrogen

$$Fe^{2+} \rightarrow Fe^{3+} + e^{-1}$$

Reduction is gain of electrons and reduction in valency number, loss of oxygen or gain of hydrogen

$$Fe^{3+} + e^{-1} \rightarrow Fe^{2+} , Fe^{2+} + 2e^{-1} \rightarrow Fe^{0}$$

Oxidizing agent or oxidant is the substance that gain electrons

Ex: $KMnO_4$, $K_2Cr_2O_7$, $Ce(SO_4)_2$

Reducing agent or reductant is the substance that donate (lose) electrons

$FeSO_4$, $Na_2S_2O_3$, $H_2C_2O_4$

Principle of Work

- Food, snacks and beverages contain varying amounts of different acids which contribute to their tastes significantly. Acids are found among the ingredients of soda drinks giving them their pungent acidic taste. For instance, coca-flavored drinks possess carbonic and phosphoric acids. On the other hand, lemon-flavored soda such as Sprite, 7 up and Mist contains citric acid.
- Acids can be classified, according to the number of ionizable hydrogen atoms they possess, into:

a) Aprotic Acids: Acids that lose one H atom during their neutralization reactions with a base (e.g. NaOH) such as hydrochloric acid (HCl) and nitric acid (HNO3).

$$HCl + NaOH \rightarrow NaCl + H_2O$$

$$HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$$

b) Polyprotic Acids: Acids that lose more than H atom during their neutralization reactions with a base (e.g. NaOH). They can be sub-classified into:

- Diprotic: such as sulphuric acid (H2SO4).

$$H_2SO_4 + 2\ NaOH \rightarrow Na_2SO4 + 2\ H_2O$$

- Triprotic: such as phosphoric acid (H3PO4) and citric acid C3H5O(COOH)3.

$$H_3PO_4 + 3\ NaOH \rightarrow Na_3PO_4 + 3\ H_2O$$

$$C_3H_5O(COOH)_3 + 3\ NaOH \rightarrow Na_3C_3H_5O(COO)_3$$

- Concentration of citric acid in a sample of soda drink could be estimated through titration of the sample with a standard solution of sodium hydroxide (NaOH) of known concentration. Complete neutralization reaction occurs when a certain volume of the titrant (NaOH) is sufficient to neutralize the entire amount of citric acid in the sample converting it to sodium citrate salt.
- Phenolphthalein is used as an indicator in this experiment to determine the end point where complete neutralization occurs. Phenolphthalein changes according to the pH of the medium. It is colorless in acidic medium, while pink-colored in basic medium. Phenolphthalein is added in a few drops into the flask containing the sample containing citric acid. Then the titrant (NaOH) is withdrawn from the burette while shaking the flask.
- The sample will remain colorless till complete neutralization occurs.Near the end point, a pale pink color will appear in the sample flask then disappear immediately with shaking. After complete neutralization, the first excess drop of NaOH will turn the phenolphthalein into its pink-colored form. The volume of the titrant is recorded at the appearance of the first persistent pale pink color.

Note: If excess volume of NaOH was withdrawn from the burette beyond the end point, the color of the sample in the flask will turn into intense pink color due to the high basicity..