Experiment 5: QUALITATIVE ANALYSIS OF CATIONS

Introduction: Qualitative analysis is the process of identifying what is present in a chemical mixture. In this experiment, you will gain experience with various equipment and methods in the chemical laboratory that allow you to isolate and identify inorganic cations in both a known and unknown mixture. Specifically, the known contains silver (I), manganese (II), aluminum (III), strontium, and potassium ions. Your unknown will contain between one and three of the five cations in your known sample.

Qualitative Analysis Scheme: The qualitative analysis scheme in this experiment is based on categorizing metal cations into five groups, four of which will be covered in this experiment. These groups are based on the solubility differences of compounds containing these cations. Although the solubility rules will be covered more completely in Experiment 6, it is still important to appreciate the ability of metal cations to form chemical compounds with unique solubility characteristics. The five groups are:

Group A: All cations in this group form insoluble chlorides. In our scheme, we have only one cation from this group, silver (I).

$Ag^+ (aq) + Cl^- (aq) \rightarrow AgCl (s)$ (white precipitate)

Group B: All cations in this group form insoluble hydroxides and oxides. In our scheme, we have two cations from this group, manganese (II) and aluminum (III). When ammonia is added to water, it hydrolyzes (splits) water to a small degree in the following manner:

$NH_3 (aq) + H_2O (l) \rightarrow NH_4^+ (aq) + OH^- (aq)$

The basic conditions formed by the addition of ammonia results in the following Group B reactions:

$Mn^{2+} (aq) + 2\ OH^- (aq) \rightarrow Mn(OH)_2 (s)$ (pale pink precipitate)

$Al^{3+} (aq) + 3\ OH^- (aq) \rightarrow Al(OH)_3 (s)$ (white gelatinous precipitate)

These two cations can be further separated because they belong to two subgroups: B1 and B2

Group B1: Hydroxides/oxides insoluble in Ammonia and Oxidizing NaOH Solution – Manganese (II) hydroxide can be oxidized with hydrogen peroxide under strongly basic conditions to form a different insoluble solid.

$Mn(OH)_2 (s) + H_2O_2 (aq) \rightarrow 2\ H_2O (l) + MnO_2 (s)$ (brown-black precipitate)

Group B2: Hydroxides/oxides insoluble in Ammonia but Soluble in Oxidizing NaOH Solution – Aluminum hydroxide under a large excess of hydroxide will form a **complex ion**, which is soluble.

$Al(OH)_3 (s) + OH^- (aq) \rightarrow Al(OH)_4^- (aq)$ (soluble colorless tetrahydroxoaluminate (III) ion)

Group C: All cations in this group form insoluble carbonates in ammonia. In our scheme, we have only one cation from this group, strontium (II).

$Sr^{2+} (aq) + CO_3^{2-} (aq) \rightarrow SrCO_3 (s)$ (white precipitate)

Group D: Hydroxides/oxides soluble in ammonia but insoluble in NaOH. In our scheme, no cations are included.

Group E: Soluble Cations. These are the alkali metal ions and ammonium ion. In our scheme, we have only one cation from this group, potassium (I), which is determined by a flame test.