Qualitative Analysis in Chemistry

Identifying Anions and Cations

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Qualitative analysis is used to identify and separate cations and anions in a sample substance. Unlike quantitative analysis, which seeks to determine the quantity or amount of sample, qualitative analysis is a descriptive form of analysis. In an educational setting, the concentrations of the ions to be identified are approximately 0.01 M in an aqueous solution. The "semimicro" level of qualitative analysis employs methods used to detect 1-2 mg of an ion in 5 mL of solution.

While there are qualitative analysis methods used to identify covalent molecules, most covalent compounds can be identified and distinguished from each other using physical properties, such as refractive index and melting point.

Lab Techniques for Semi-Micro Qualitative Analysis

It's easy to contaminate the sample through poor laboratory technique, so it's important to adhere to certain rules:

- Do not use tap water. Rather, use distilled water or deionized water.
- Glassware must be clean prior to use. It's not essential that it be dried.
- Don't put a reagent dropper tip into the mouth of a test tube. Dispense reagent from above the test tube lip to avoid contamination.
- Mix solutions by flicking the test tube. Never cover the test tube with a finger and shake the tube. Avoid exposing yourself to the sample.

Steps of Qualitative Analysis

- If the sample is presented as a solid (salt), it's important to note the shape and color of any crystals.
- Reagents are used to separate cations into groups of related elements.

Ions in a group are separated from each other. After each separation stage, a test is performed to confirm certain ions truly were removed. The test is not performed on the original sample!

Separations rely on different characteristics of ions. These may involve redox reactions to change oxidation state, differential solubility in an acid, base, or water, or precipitating certain ions.

Sample Qualitative Analysis Protocol

First, ions are removed in groups from the initial aqueous solution. After each group has been separated, then testing is conducted for the individual ions in each group. Here is a common grouping of cations:

Group I: Ag^{+}, Hg_2^{2+}, Pb^{2+}
Precipitated in 1 M HCl

Group II: Bi^{3+}, Cd^{2+}, Cu^{2+}, Hg^{2+}, (Pb^{2+}), Sb^{3+} and Sb^{5+}, Sn^{2+} and Sn^{4+}
Precipitated in 0.1 M H_2S solution at pH 0.5

Group III: Al^{3+}, (Cd^{2+}), Co^{2+}, Cr^{3+}, Fe^{2+} and Fe^{3+}, Mn^{2+}, Ni^{2+}, Zn^{2+}
Precipitated in 0.1 M H_2S solution at pH 9

Group IV: Ba^{2+}, Ca^{2+}, K^{+}, Mg^{2+}, Na^{+}, NH_4^{+}

Ba^{2+}, Ca^{2+}, and Mg^{2+} are precipitated in 0.2 M $(NH_4)_2CO_3$ solution at pH 10; the other ions are soluble

Many reagents are used in the qualitative analysis, but only a few are involved in nearly every group procedure. The four most commonly used reagents are 6M HCl, 6M HNO_3, 6M NaOH, 6M NH_3. Understanding the uses of the reagents is helpful when planning an analysis.

Common Qualitative Analysis Reagents

Reagent	Effects
6M HCl	Increases $[H^{+}]$ Increases $[Cl^{-}]$ Decreases $[OH^{-}]$ Dissolves insoluble carbonates, chromates, hydroxides, some sulfates Destroys hydroxo and NH_3 complexes Precipitates insoluble chlorides

6M HNO_3	Increases $[H^+]$ Decreases $[OH^-]$ Dissolves insoluble carbonates, chromates, and hydroxides Dissolves insoluble sulfides by oxidizing sulfide ion Destroys hydroxo and ammonia complexes Good oxidizing agent when hot
6 M NaOH	Increases $[OH^-]$ Decreases $[H^+]$ Forms hydroxo complexes Precipitates insoluble hydroxides
6M NH_3	Increases $[NH_3]$ Increases $[OH^-]$ Decreases $[H^+]$ Precipitates insoluble hydroxides Forms NH_3 complexes Forms a basic buffer with NH_4^+

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