Chemistry | Inorganic Chemistry

Test for Cadmium Radical

General Aim

Detection of the presence of cadmium ion as a base radical in inorganic salts such as cadmium sulfate.

Method

Detection of the presence of cadmium as a base radical using specific chemical reagents.

Learning Objectives (ILOs)

- Define and differentiate between members of the second group cations and those of other cation groups.
- Classify inorganic salts according to their base radicals.
- Compare between cadmium containing salts and other members of the same group in terms of chemical structures, properties and reactions.
- Identify cadmium radicals containing salts experimentally.
- Select the appropriate reagents to detect the presence of cadmium radical.
- Balance the chemical equations of chemical reactions.

Theoretical Background/Context

Cadmium (Cd) is one of the transition metals that are located in the d-block of the periodic table. Cadmium is located in the fifth period and twelfth group of the periodic table. Cd possesses an atomic number of 48 and an atomic mass of 112.411g. It was first discovered by the German scientist, Friedrich Strohmeyer in 1817 in Germany. At that time, cadmium was commonly used to protect iron and steel from corrosion as it was inserted as a sacrificial anode. Additionally, it was used in the manufacture of nickel-cadmium batteries. Cadmium is a highly toxic element so it has to be handled with great caution.

Abundance of Cadmium in Nature

Cadmium cannot be easily found in its elemental form naturally. It has been detected in the Earth's Crust in very minute amounts that do not exceed 0.1 to 0.2 ppm. However, it usually occurs in the form of compounds accompanied with other elements. The most common naturally occurring compounds of cadmium include cadmium sulfide, cadmium carbonate, carbon oxide, etc. Carbon sulfide, commonly known as the mineral Greenockite, is considered a common source of cadmium. Most of the extracted pure cadmium are obtained as products of the zinc refinement process.

Properties and Uses of Cadmium

Cadmium is a silvery grey and soft malleable metal especially when it is abundant in its pure form. It is widely used as a corrosion resistant during steel and iron electroplating. Due to their brilliant colors, cadmium containing compounds have also been used in oil paints such as cadmium yellow. Cadmium is also used as an electricity conductor. Like zinc and tin, cadmium metal cries when it is bent rapidly i.e. emits a high pitched sound.

Cadmium Salts

Cadmium sulfate refers to a series of hydrated forms of cadmium sulfate salts with the chemical formula of $CdSO_4 \cdot xH_2O$, where x represents the number of water molecules. All of them are white crystalline salts that are highly soluble in water. The most common of them is the monohydrate form that possesses a chemical formula of $CdSO_4 \cdot H_2O$. Then come the next two commons salts that possess the chemical formulas of $CdSO_4 \cdot 8/3H_2O$ and the anhydrous salt ($CdSO_4$).

Theoretical Background/Context (Cont')

Preparation of Cadmium Sulfate

Cadmium sulfate can be prepared through the reaction of cadmium metal, cadmium oxide or cadmium hydroxide dilute sulfuric acid as shown in the following reactions:

$$Cd + H_2SO_4 \rightarrow CdSO_4 + H_2$$

$$CdO + H_2SO_4 \rightarrow CdSO_4 + H_2O$$

$$Cd(OH)_2 + H_2SO_4 \rightarrow CdSO_4 + 2\,H_2O$$

Properties and Uses of Cadmium Sulfate

- Cadmium sulfate is a white crystalline salt that possesses the chemical formula of $CdSO_4.xH_2O$ when it is hydrated, while $CdSO_4$ when it is dehydrated.
- When used in high amounts, cadmium sulfate can cause throat dryness, cough, chest constrictions and headache.
- Cadmium sulfate is used as a pigment in fluorescein screens.
- Cadmium sulfate has some medicinal properties. For example, it is used as an antiseptic. In addition, it is used in the treatment of venereal diseases and rheumatism.
- Cadmium sulfate has been used as an indicator for the presence of hydrogen sulfide gas.

Principle of Work

- In this experiment, cadmium ion in cadmium sulfate is detected through some identification and confirmatory tests. The cadmium radical is among the second group of basic radical in which hydrogen sulfide is used as a group reagent.
- During the experiment, salt solubility in water will be tested. Then the behavior of the salt will be tested with hydrogen sulfide followed by confirmatory tests which will be performed using sodium hydroxide and ammonia to confirm the presence of cadmium radical in the salt.

First: Physical Appearance Test

In this test, a sample of the cadmium salt is tested for its color, odor, texture, etc.

Second: Solubility Test

In this test, a sample of the cadmium salt is tested for its solubility in water.

Third: Hydrogen Sulfide Test

It depends on the fact that sulfide anions can displace sulfate ions in cadmium sulfate salt forming insoluble cadmium sulfide as a yellow precipitate which is soluble in hot dilute nitric acid as the following reactions:

$$H_2S + CdSO_4 \rightarrow H_2SO_4 + CdS\downarrow \text{ (Yellow ppt.)}$$

$$3CdS + 8HNO_3 \rightarrow 3Cd(NO_3)_2 + 4H_2O + 2NO + 3S$$

Fourth: Sodium Hydroxide Test

Sodium Hydroxide solution is added to aqueous cadmium sulfate leading to the precipitation of cadmium hydroxide as a white precipitate which is not soluble in excess reagent.

$$CdSO_4 + 2NaOH \rightarrow Na_2SO_4 + Cd(OH)_2\downarrow \text{ (White ppt.)}$$

Fifth: Ammonia Test

Ammonia solution is added to aqueous cadmium sulfate leading to the precipitation of cadmium hydroxide as a white precipitate which dissolves again in excess reagent due to the formation of the soluble tetra-amine cadmium sulfate complex:

$$CdSO_4 + 2NH_4OH \rightarrow (NH_4)_2SO_4 + Cd(OH)_2\downarrow \text{ (White ppt.)}$$

$$NH_4OH + Cd(OH)_2 \rightarrow [Cd(NH_4)_2]^{2+} + 2OH^-$$