Chemistry | Inorganic Chemistry

Test for Nickel (II) Radical

General Aim

Detection of the presence of nickel ions as base radicals in inorganic salts such as nickel chloride.

Method

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

Learning Objectives (ILOs)

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

Theoretical Background/Context

Nickel had been widely used for centuries before being discovered or isolated. Around 3500 BC, trace amounts of nickel were among the Syrian bronzes. In 235 BC, China coins contained small amounts of nickel. Nickel was thought to be useless when it was first discovered. However, afterwards, it was discovered that nickel is a valuable element in alloys owing to its hardness, strength and resistance to corrosion.

Abundance of Nickel in Nature

Nickel is the 22nd most abundant element in the earth crust. It is also counted to be the earth's 7th most abundant transition metal. It possesses a silver white crystalline appearance. It is naturally abundant in meteors or ores with other elements. They are commonly found in two types of ores which are:

a. oxides or silicates such as garnierite whose chemical formula is (Ni,Mg)6Si4O10OH)8.
b. Sulfides such as pentlandite that contains around 1.5%, nickel combined with other metals that include copper, cobalt, etc.

Properties and Uses of Nickel

- Nickel is silver crystalline white metal. It is characterized by being ductile, malleable, strong and corrosion resistible. It could conduct electricity and heat. In addition, it exhibits magnetic properties under the temperature of 345°C. Nickel is abundant in five known isotopes.
- Nickel is chemically stable in its metallic form. It is insoluble in cold and hot water, ammonia and concentrated nitric acid and alkalis. However, it is observed that it is soluble in dilute nitric acid while sparingly soluble in dilute hydrochloric and sulfuric acids.
- Nickel has been widely used in alloying. For instance, it has been used in alloys such as stainless steel that is used in the manufacture of kitchen sinks, utensils, etc. In addition, nickel has been used with copper to form alloys used in the manufacture of tubes used during the desalination process of seawater.

Furthermore, nickel is used in electroplating of other metals owing to its robustness and resistance to corrosion. Nickel is also used in catalyzing hydrogenation reactions of vegetable oils. Finally, due to its colored compounds, nickel is used as a coloring agent to glass.

Nickel Compounds

Nickel is found in an oxidation state between -1 to +4 within its chemical compounds. However, the most abundant oxidation state is +2. Therefore, nickel oxides, hydroxides, carbonates, nitrates and chlorides are commonly known. Nickel containing compounds are characterized by having blue and green colors. Some of these compounds change their color upon being exposed to certain temperatures.

Preparation of Nickel Chloride

Nickel chloride could be prepared through extracting nickel using hydrochloric acid as shown in the below equation:

$$Ni + HCl \rightarrow NiCl2 + H2 \uparrow$$

The hydrated form of nickel chloride possesses green color. It can be dehydrated using thionyl chloride leading to changing its color from the green to yellow as shown below.

$$NiCl2.6H2O + 6\ SOCl2 \rightarrow NiCl2 + 6\ SO2 + 12\ HCl$$

In addition, pure nickel chloride could be obtained from nickel extracted using ammonia through continuous heating of hexaamminenickel as shown below:

$$[Ni(NH3)6]Cl2 \rightarrow NiCl2 + 6NH3$$

Properties and Uses of Nickel Chloride

- Nickel chloride is a green powdered salt when it is dehydrated. Its color turns into yellow upon its hydration, where it attaches to six water molecules to possess a chemical formula of NiCl2.6H2O.
- Nickel chloride has been reported for its carcinogenic activity towards lungs and nasal pathways in case of long term inhalation.
- Nickel chloride has been used as the nickel source in many organic reactions.
- Nickel chloride has been used as a mild Lewis acid in many organic synthesis procedures.
- Due to its color change according to humidity, it is used as an analytical reagent.
- It has been used in various applications such as electroplating, dyeing, etc.

Principle of Work

- In this experiment, nickel ion in nickel chloride is detected through some identification and confirmatory tests. The nickel radical is among the fourth group of basic radicals in which ammonium sulfide along with ammonium hydroxide and ammonium chloride are used as group reagents.
- During the experiment, salt solubility in water will be tested. Then the behavior of the salt will be tested with ammonium sulfide followed by confirmatory tests which will be performed using sodium hydroxide, ammonia, and potassium cyanide tests to confirm the presence of nickel radical in the salt. Finally, dimethylglyoxime test is carried out as a specific test for the presence of nickel radical.

First: Physical Appearance Test

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

Second: Solubility Test

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

Third: Ammonium Sulfide Test

It depends on the fact that sulfide anions can displace chloride ions in nickel chloride salt forming insoluble nickel sulfide as a black precipitate as the following reactions:

$$(NH_4)_2S + NiCl_2 \rightarrow 2\,NH_4Cl + NiS \downarrow \text{(Black ppt.)}$$

Fourth: Sodium Hydroxide Test

Sodium Hydroxide solution is added to aqueous nickel chloride leading to the precipitation of nickel hydroxide as a green precipitate due to its low solubility product.

$$NiCl_2 + 2NaOH \rightarrow 2NaCl + Ni(OH)_2 \downarrow \text{(Green ppt.)}$$

Fifth: Ammonia Test

Ammonia solution is added to aqueous nickel chloride leading to the precipitation of the nickel hydroxide as a green precipitate due to its low solubility product. Then, upon adding excess ammonia, the precipitate dissolves again due to the formation of the soluble nickel amine hydroxide complex:

$$NiCl_2 + 2NH_4OH \rightarrow NH_4Cl + Ni(OH)_2 \downarrow \text{(Green ppt.)}$$

$$6\,NH_3 + Ni(OH)_2 \rightarrow [Ni(NH_3)_6]^{2+} + 2OH^-$$

Sixth: Potassium Cyanide Test

Potassium cyanide solution is added to nickel chloride aqueous solution resulting in precipitation of nickel cyanide as a green precipitate which is soluble in excess reagent.

$$NiCl_2 + 2KCN \rightarrow 2KCl + Ni(CN)_2 \downarrow \text{(Green ppt.)}$$

Seventh: Dimethylglyoxime Test

Dimethylglyoxime alcoholic solution is added to nickel chloride aqueous solution resulting in precipitation of nickel dimethylglyoxime abbreviated as Ni(dmg)2 as a red ppt as shown in the reaction below.

$$[Ni(NH_3)_6]^{2+}(aq) + 2\,(CH_3CNOH)_2\,(alc) \rightarrow$$

$$2NH_4^+(aq) + 4NH_3(aq) + Ni[ONC(CH_3)C(CH_3)NOH]_2 \downarrow \text{(Red precipitate)}$$