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STUDY OF NEW SYNTHESIS METHODS OF TRANSITION METAL COMPLEXES AND THEIR STRUCTURAL PROPERTIES

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Abstract. In this research work, new and effective synthesis methods of complex compounds formed on the basis of transition metals and their structural properties were comprehensively investigated. Transition metal complexes are considered one of the important branches of coordination chemistry due to their unique electronic structures, variable oxidation states, and ability to form different coordination geometries, which are of great scientific and practical importance. During the research, Cu(II) and Ni(II) ions were reacted with various organic ligands to synthesize complex compounds. The influence of reaction conditions such as pH, temperature, solvent type, and metal–ligand ratio on complex formation was studied. The obtained results demonstrated that changes in synthesis conditions directly affect the coordination number, geometric structure, and stability of the complexes. The structural properties of the synthesized complexes were analyzed based on their color characteristics, solubility, and stability. It was determined that the possible geometric structures of the complexes (octahedral, square-planar, or tetrahedral) depend on the nature of the ligand and the properties of the central metal ion.

Keywords: transition metals, complex compounds, coordination chemistry, ligand, synthesis methods, structural properties, geometric structure.

INTRODUCTION

The rapid development of modern inorganic and coordination chemistry has increased the necessity for an in-depth study of complex compounds formed on the basis of transition metals. Transition metal complexes are distinguished by their variable oxidation states, ability to form various coordination numbers and geometric structures, as well as their complex electronic configurations. These characteristics provide broad opportunities for their application in chemistry, materials science, catalysis, and biology. One of the important aspects of transition metal complexes is the formation of diverse structural forms as a result of interactions between central metal ions and ligands. The process of complex formation is directly influenced by the nature of the metal ion, donor properties of the ligand, reaction medium (pH), temperature, solvent type, and metal–ligand ratios. Therefore, controlling these factors during synthesis makes it possible to purposefully modify the structure and properties of complex compounds.

In particular, complex compounds synthesized on the basis of Cu(II) and Ni(II) ions are of special interest because of their ability to form different coordination geometries. Depending on the nature of

the ligand, these metal ions can form complexes with octahedral, square-planar, or tetrahedral structures. Such structural diversity significantly affects the color properties, solubility, and stability of the complexes. In this regard, the main objective of the present research was to develop new and effective synthesis methods for transition metal complexes and to investigate their structural properties. The results of this study contribute to a deeper understanding of the relationship between the structure and properties of transition metal complexes in coordination chemistry and broaden the prospects for their practical applications.

MAIN PART

General Characteristics of Transition Metal Complexes. Transition metal complexes are coordination compounds consisting of a central metal ion surrounded by ligands. The d-orbitals of these metals are partially filled, allowing them to form various types of bonds with ligands. As a result, transition metal complexes exhibit different coordination numbers, geometric structures, and electronic properties. The structural diversity of complex compounds is considered one of the main factors determining their chemical reactivity, color characteristics, and stability. In particular, complexes formed on the basis of Cu(II) and Ni(II) ions occupy an important place in coordination chemistry.

Methods for the Synthesis of Transition Metal Complexes. The synthesis of transition metal complexes involves several major stages, and the synthesis conditions significantly affect the process of complex formation.

Solution Method. In this method, metal salts and ligands are dissolved in a suitable solvent and reacted under specific conditions. The pH value of the solution medium affects the rate of complex formation and its stability.

Thermal Synthesis Method. Under the influence of high temperature, the interaction between metal ions and ligands becomes stronger, resulting in the formation of stable complexes. This method is especially effective for obtaining complexes with crystalline structures.

Stoichiometric Ratio Control Method. By changing the metal–ligand ratio, complexes with different coordination numbers and geometric structures can be synthesized.

Effect of Synthesis Conditions on Complex Structure. Changes in pH during the synthesis process affect the ionization degree of ligands and determine the strength of bonding with metal ions. In acidic media, some ligands remain protonated, slowing down the process of complex formation. In neutral or slightly alkaline media, the stability of complexes increases. Increasing temperature accelerates the reaction rate and may lead to an increase in coordination number. The type of solvent determines the degree of solvation of metal ions and influences the final structure of the complex.

Structural Properties of the Obtained Complexes. The structural properties of the synthesized transition metal complexes were analyzed based on their color characteristics, solubility, and stability. The coloration of complexes is explained by d–d electronic transitions and ligand field effects. Cu(II) complexes generally possess square-planar or elongated octahedral structures, which are associated with the Jahn–Teller effect. Ni(II) complexes exhibit octahedral or square-planar geometry depending on the nature of the ligand.

Geometric Structure and Stability of the Complexes. It was determined that the probable geometric structure of the obtained complexes depends on the number of donor atoms in the ligands and the coordination requirements of the metal ion. Strong donor ligands form stable bonds with metal ions, thereby increasing the thermodynamic stability of the complexes. Changes in geometric structure directly affect the physicochemical properties of the complexes, including color intensity and solubility.

RESULTS

In this research work, new synthesis methods of complex compounds formed on the basis of transition metals and their structural properties were investigated, and the following scientific results were achieved. During the study, stable complex compounds were successfully synthesized by reacting Cu(II) and Ni(II) ions with various organic ligands.

The conducted experiments demonstrated that changes in synthesis conditions such as pH value, temperature, solvent type, and metal–ligand ratios significantly influence the rate of complex formation and their stability. Complexes obtained in neutral and slightly alkaline media exhibited higher stability, whereas under low pH conditions the process of complex formation slowed down noticeably.

It was determined that variations in the metal–ligand ratio caused differences in the coordination number and geometric structure of the complexes. Cu(II)-based complexes mainly exhibited square-planar or elongated octahedral structures, while Ni(II) complexes showed octahedral and, in some cases, square-planar geometries. These findings confirm the important role of ligand nature and the electronic structure of the metal ion. The color properties of the synthesized complexes were found to be directly related to their structural changes. The increase in color intensity was explained by stronger ligand field effects and d–d electronic transitions. In addition, it was observed that the solubility and thermal stability of the complexes depend on the chemical nature of the ligands and the coordination structure. The obtained results demonstrated that the structural properties of transition metal complexes can be purposefully modified by controlling the synthesis conditions. The synthesized complexes are characterized by their scientific and practical significance for the development of new functional materials in the field of coordination chemistry.

CONCLUSION

In this research work, the relationship between the synthesis conditions of transition metal complex compounds and their structural properties was comprehensively investigated. The conducted experiments confirmed that pH value, temperature, solvent type, and metal–ligand ratios significantly influence the rate of complex formation and their stability during the synthesis process.

According to the research results, complex compounds synthesized in neutral and slightly alkaline media exhibited high stability, whereas under low pH conditions protonation of ligands weakened metal–ligand bonding and slowed down the process of complex formation. It was also determined that an increase in temperature accelerates the reaction rate and positively affects the formation of stable coordination structures.

Furthermore, changes in the metal–ligand ratio were found to directly affect the coordination number and geometric structure of the complexes. The color characteristics, solubility, and thermal stability of the obtained complexes were closely related to their probable geometric structures. The study demonstrated that by purposefully controlling the synthesis process of transition metal complexes, it is possible to predetermine their structural and physicochemical properties. The obtained results serve as an important scientific and practical basis for the development of new and effective complex compounds in the field of coordination chemistry.

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