

Metal Containing Complexes of Polyazole Based Ligands and Their Biological Activity

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Abstract. Objective. The aim of this study is to synthesize and investigate the physicochemical and biological properties of complex compounds of 3d metals with imidazole (**L**₁) and 1,2,4-triazole (**L**₂). **Methods.** The synthesized compounds were characterized by a set of physicochemical methods, including elemental analysis (CHN), thermogravimetric analysis (TGA), X-ray structural analysis (XRD), and infrared spectroscopy (IR). **Results.** Complexes of various compositions were synthesized by solution reactions between chlorides, sulfates, and nitrates of 3d metals with ligands **L**₁ and **L**₂. IR spectroscopy showed that **L**₁ coordinates through the nitrogen atom N(3) of the imidazole ring as a monodentate ligand. The coordination mode of **L**₂ depends on the composition: in complexes with a 1:4:2 ratio, it acts as a monodentate ligand, whereas in 1:2:2 complexes it behaves as a bidentate bridging ligand, forming polymeric chains. Thermal decomposition of all complexes proceeds in both endothermic and exothermic stages without melting, accompanied by the cleavage of azole rings.

X-ray diffraction analysis revealed that the complex CuL₁4Cl₂ (**I**) crystallizes in a monoclinic system (space group *P*2₁/*n*), where the Cu(II) atom forms a tetragonal pyramidal coordination polyhedron. The polymeric isostructural complexes [CoL₁6](NO₃)₂ (**II**) and [CdL₁6](NO₃)₂ (**III**) crystallize in a triclinic system (*R*-3), featuring slightly distorted octahedral coordination. In [ZnL₁2](NO₃)₂(H₂O)₂ (**IV**), ligand **L**₁ acts as a chelating-bridging ligand, forming zigzag polymeric chains.

Biological screening revealed three Cu(II) complexes — CuL₁4Cl₂ (**I**), CuSO₄·6L₁·(H₂O)₆ (**II**), and CuL₂4SO₄·2(H₂O) (**III**) — exhibiting high cestocidal activity (85–100%) against *Echinococcus granulosus* protoscoleces and low toxicity (LD₅₀ = 1040–2110 mg/kg).

Conclusions. New complexes of 3d metals with ligands **L**₁ and **L**₂ were synthesized, and their structures and biological activities were determined. The obtained compounds are low-toxic and highly effective anthelmintic agents with pronounced helminthicidal activity.

Novelty. For the first time, complexes of 3d metal salts with ligands **L**₁ and **L**₂ have been synthesized, and their structures and physicochemical properties determined by X-ray structural analysis.

Key words: imidazole, 1,2,4-triazole, 3d-metals, complexes, thermogravimetric and X-ray structural analysis, IR spectroscopy, bioactivity.

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I. INTRODUCTION

Azoles, which are five-membered heterocyclic compounds containing one or more nitrogen atoms, play pivotal roles in synthetic organic chemistry and serve as essential scaffolds in pharmaceuticals with potent biological activities—including anthelmintic (1), antimicrobial (2), antituberculosis (3), and anticancer effects (4). Furthermore, azole derivatives are key components in

chelating ligands that form coordination complexes with transition metals.

Azoles play a crucial role in coordination chemistry due to their ability to form metal–organic coordination polymers and supramolecular structures. Their diverse functionality enables the integration of imidazole and triazole fragments into various topological frameworks, leading to a wide geometric diversity in the resulting coordination compounds.

Azoles have long served as first-line antifungal agents (e.g., clotrimazole, fluconazole, itraconazole) and exhibit helminthocidal activity (e.g., albendazole, mebendazole, vermoz); however, the rise of resistant strains underscores the urgent need for new, more effective drugs.

Complexing azoles with essential metal ions such as Cu, Co, Zn, and Mn represents a promising strategy for developing next-generation biologically active compounds (5–7). Metal coordination not only merges multiple bioactive functionalities into a single entity but also often yields synergistic effects, broadens the spectrum of action, and can reduce toxicity (8–10). Consequently, investigating the complexation behavior of ligands containing imidazole and triazole cycles is highly relevant.

II. METHODS AND MATERIALS

Objectives of this investigation include:

- Systematically studying the reactions between 3d-metal salts and ligands L^1 (imidazole-based) and L^2 (triazole-based) in aqueous media at 25 °C to discover and isolate novel coordination compounds;
- Determining the composition ranges, solubility behaviors, and coordination stoichiometry of the resulting complexes;
- Studying their physicochemical and biological properties;
- Elucidating the nature of bonding, ligand coordination modes, and the structures of the resulting compounds, supported by schematic representations of the coordination units.

The starting materials for the synthesis were salts of 3d-metals (Cu, Ni, Zn, Cd, Co, Mn), imidazole and 1,2,4-triazole of “chemically pure” grade (Chemical Line, Russia).

Synthesis: The study of the interaction of chloride, sulfates, nitrates of 3d-metals with L^1 and L^2 was carried out by the solubility method in a three-component water-saturated medium ($MeX_2 - L^{1,2} - H_2O$ at 25°C [11, 12], where Me = Cu, Ni, Zn, Cd, Co, Mn; X = Cl⁻, SO₄²⁻, NO₃⁻. As a result, the formation of complex compounds of the following composition was established:

($MeL^{1,2}Cl_2(H_2O)_2$), (Cu, Co, Ni, Zn);
 $MeL^1_4Cl_2$, (Cu, Ni, Zn); ($MeL^2Cl_2(H_2O)_2$), (Zn, Cd),
 $MeL^2_2Cl_2(H_2O)_2$, Me = Ni, Mn; $CuL^2_4Cl_2(H_2O)_2$;
 sulfates $MeL^2_2SO_4(H_2O)_2$, (Me = Cu, Cd),
 $MeL_6SO_4(H_2O)_6$, (Cu, Ni, Co), $MeL^2 \cdot SO_4(H_2O)$,
 Me = Cd, Zn; $MeL^2_2 \cdot SO_4(H_2O)_2$, Me = Ni, Mn,
 $CuL^2_4 \cdot SO_4(H_2O)_2$; nitrates $ZnL^{1,2}(NO_3)_2 \cdot (H_2O)_2$,
 $MeL^1_4(NO_3)_2(H_2O)_2$, (Zn, Co), $MeL^1_6(NO_3)_2(H_2O)_2$,
 (Cu, Ni).

The composition, properties and structure of (I) are characterized by thermogravimetric, X-ray structural analysis and IR spectroscopy. The IR spectrum of I was recorded on a Nicolette Avatar spectrophotometer in KBr tablets in the frequency range of 400–4000 cm⁻¹ with a resolution of 0.5 cm⁻¹.

Thermogravimetric analysis was performed on a Paulik-Paulik, Erdey derivatograph in an air atmosphere with heating from 20 to 1000°C at a

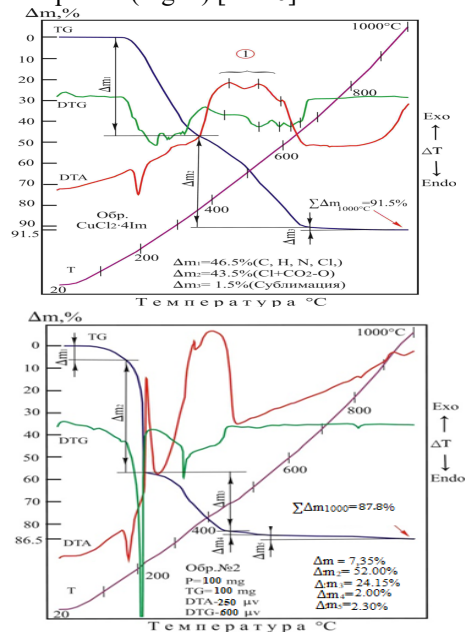
heating rate of 10 deg/min. Al₂O₃ served as a standard.

To perform X-ray diffraction analysis, the crystal of the complexes was selected under a layer of vaseline oil in a polarized Meiji Techno EMZ-8TRD microscope (Japan) and quickly transferred to a diffractometer, where they were cooled by a flow of dry gaseous nitrogen. X-ray diffraction data for the crystals were collected on a BRUKER SMART APEX II automatic diffractometer. Using (Mo K α -study, λ -0.7013 Å⁰, graphite monochromator). The structures were solved by the direct method and refined by the full-matrix anisotropic least squares method on F² for all non-hydrogen atoms (SHELIX Plus) [13].

III. RESULTS AND DISCUSSION

The compounds were isolated, analyzed, and their physicochemical properties were studied: solubility in organic solvents with different dielectric constants and relative densities.

The structural features of the coordination polyhedron of the obtained compounds were determined using methods of elemental (CNH), IR spectroscopy, X-ray structural analysis and thermogravimetry. Thermogravimetric analysis has established thermal destruction of complexes with L^1 and L^2 occurs stepwise, reflecting the structural rearrangement that occurs during heating. It is shown that the stage-by-stage nature of thermolysis of compounds depends on the nature of the acidoligands, the central ion, and the structure of the complexes (Fig. 1) [14–16].



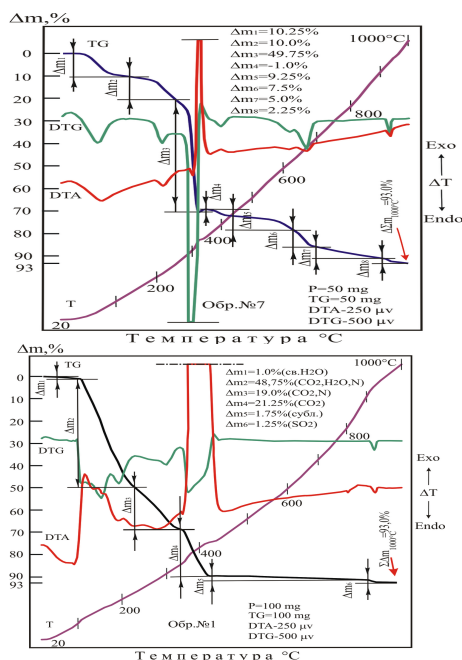


Figure 1. TG and DTA/DTG curves: a) CuL_4Cl_2 ; b) $\text{CuSO}_4 \cdot 6\text{C}_3\text{H}_4\text{N}_2 \cdot 6\text{H}_2\text{O}$; c) $\text{CuSO}_4 \cdot 4\text{C}_2\text{H}_3\text{N}_3 \cdot 2\text{H}_2\text{O}$; d) $[\text{CoL}_6](\text{NO}_3)_2$

The IR method established that imidazole behaves as a monodentate ligand, coordinating through its pyridine N-atom. The configuration of the obtained compounds and the schematic representation of the coordination units of the complexes were established.

IR spectroscopy for halide complexes of Cu(II), Ni(II) of 1:2:2 composition and Zn(II) of 1:2 composition established that the imidazole molecule is coordinated monodentately through the nitrogen heteroatom, and the chlorine atoms are bridging, with one chlorine atom forming a bridge between metal atoms of the Me-Cl-Me type, and the other forming a terminal Me-Cl bond.

Thus, two configurations of the complexes are established: in the first case, a monomeric-tetrahedral structure, where monodentately coordinated pyridine nitrogen atoms participate, and the chlorine ions form terminal bonds, located in the trans position around the cation; in the second case - polymer-octahedral, with the presence of two bridging chlorine atoms and monodentate coordination of the imidazole molecule. Therefore, for chloride complexes of 1:2:2 and 1:2 composition, the coordination polyhedron is complemented to an octahedron by four chlorine atoms, which create a bridging bond, thereby forming infinite polymer chains [17].

In the spectra of sulfate complexes, a shift to the higher frequencies is also observed for the stretching vibrations of cyclic C=N, C=C and C=N bonds by 10-35 cm^{-1} , 20-35 cm^{-1} and approximately 20 cm^{-1} , respectively – and for the out-of-plane vibrations of the imidazole ring by 15-20 cm^{-1} , which confirms the coordination of imidazole with metals through the pyridine N-atom. In the IR spectra of Cu(II), Ni(II), Mn(II), Zn(II) and Cd(II) complexes with stoichiometries of 1:4:2 and 1:6:2, absorption bands corresponding to crystallization water are

observed: ν_{OH} 3450 cm^{-1} , δ_{HOH} bending at 1650-1630 cm^{-1} , $\rho(\text{H}_2\text{O})$ at 540-510 cm^{-1} , indicating that water is present as crystallohydrate molecules.

The shape and nature of these absorption bands also suggest that the sulfate ion remains in its ionic form and resides in the outer coordination sphere of the complexes. This is supported by the presence of absorption bands in the ranges 1020-1145 cm^{-1} (for SO_4^{2-} stretching vibrations) and 545-622 cm^{-1} (for deformation mode) characteristic of the free sulfate ion.

Based on the IR spectral data and the analysis of the coordination environment, it can be concluded that in the spatial models of 1:6:2 Cu(II), Co(II), and Ni(II) complexes, the imidazole molecule coordinates through six nitrogen atoms of the pyridine ring to the metal cations. The coordination polyhedron adopts an octahedral configuration. In the spectra of sulfate complexes $\text{CuL}_2\text{SO}_4(\text{H}_2\text{O})_2$ (I) and $\text{CdL}_2\text{SO}_4(\text{H}_2\text{O})_2$ (II), broad, intense, split absorption bands are observed at approximately 660 and 1065–1165 cm^{-1} (I) and 613, 640, and 995–1150 cm^{-1} (II). These bands correspond to the asymmetric stretching vibration (ν_3) of the sulfate ion (SO_4^{2-}). The splitting of the ν_3 band indicates a reduction in symmetry from Td (tetrahedral) to C_{2v} , resulting from coordination to the metal center. Such splitting of the ν_3 band is characteristic of a bridging bidentate coordination mode of the sulfate ion. This significant splitting suggests that the sulfate ion is coordinated within the inner coordination sphere of the complexes.

It has been established that in the complexes $\text{CuL}_2\text{SO}_4(\text{H}_2\text{O})_2$ and $\text{CdL}_2\text{SO}_4(\text{H}_2\text{O})_2$, the coordination polyhedron of Cu^{2+} and Cd^{2+} is an octahedron consisting of two monodentately coordinated nitrogen atoms from the imidazole ring and four oxygen atoms from bidentately coordinated sulfate ions. In the $\text{CdL}_2\text{SO}_4(\text{H}_2\text{O})_2$ complex, the sulfate ions exhibit bidentate-chelating properties [18].

IR spectra of imidazole complexes with metal nitrates $[\text{MeL}_4](\text{NO}_3)_2 \cdot (\text{H}_2\text{O})_2$, where Me = Co(II), Zn(II), Mg(II), Ca(II) show a significant shift of the stretching bands $\nu(\text{C}=\text{N})$ from 1490–1587 cm^{-1} , and deformation vibrations of the heterocycle $\nu(\text{C}=\text{N})$ at 750 cm^{-1} toward higher frequencies by 15–25 cm^{-1} and 20–30 cm^{-1} , respectively. The shift of the stretching vibrations of the heterocycle to higher frequencies, along with changes in the intensity of the deformation vibration bands, suggests that metal coordination to the ligand occurs through the pyridine nitrogen atom of the heterocycle, which acts as a monodentate ligand. Additionally, a new absorption band appears in the range of 425–447 cm^{-1} , which is absent in the free ligand and corresponds to the stretching vibration of the Me–N bond, indicating complex formation via the heterocyclic nitrogen atom. Results show that the coordination polyhedron of the metals is a slightly distorted tetrahedron, in which the metal ions are surrounded by four monodentately coordinated nitrogen atoms from the heterocycle, while the nitrate ion and water molecules reside in the outer coordination sphere.

In the spectra of nitrate anhydrous $[\text{CoL}_6](\text{NO}_3)_2$, $[\text{CdL}_6](\text{NO}_3)_2$ and hydrated complexes $[\text{CuL}_6](\text{NO}_3)_2 \cdot (\text{H}_2\text{O})_2$ and $[\text{NiL}_6](\text{NO}_3)_2 \cdot (\text{H}_2\text{O})_2$ imidazole, a shift to the short-wave region of vibrations of cyclic $\nu(\text{C}=\text{N})$ and $\delta(\text{C}-\text{N})$ bonds by 15–20 cm^{-1} is observed, as well as out-of-plane vibrations of the imidazole ring $\tau_{\text{cycl}}(\text{C}-\text{N})$ by 20–25 cm^{-1} . New absorption bands of the $\text{Me} \leftarrow \text{N}$ stretching vibration appear at 470–450 cm^{-1} , confirming the coordination of the heterocycle with metals via the nitrogen atom (N3).

In the Cu(II) and Ni(II) compounds with 1:6:2 composition, there are uncoordinated absorption bands of crystallization water: $\nu(\text{OH})$ at about 3450 cm^{-1} , $\delta(\text{OH})$ at 1597–1625 cm^{-1} , $\rho\text{H}_2\text{O}$ at 510–540 cm^{-1} . In the given complexes, the NO_3^- anion is not coordinated with the central atoms, being located in the outer sphere. This is supported by the absence of $\text{Me} \leftarrow \text{O}$ absorption bands for copper and nickel nitrate complexes, which should be expected in the 750–650 cm^{-1} region.

Thus, based on the results of IR and DTG, it was established that the complexes are surrounded by six monodentate-coordinated nitrogen atoms (N3) of imidazole, forming an octahedral polyhedron and creating six-membered metallocycles (Fig. 2) [19].

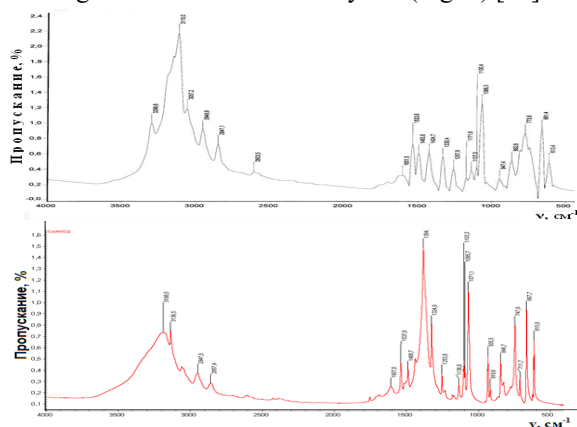


Figure 2. IR spectra of complexes: a) CuL_4Cl_2 ; b) $\text{CuSO}_4 \cdot 6\text{C}_3\text{H}_4\text{N}_2 \cdot 6\text{H}_2\text{O}$; c) $[\text{CoL}_6](\text{NO}_3)_2$

Thermogravimetric analysis of copper (II) complexes with L_2 namely $\text{CuL}_24\text{Cl}_2 \cdot (\text{H}_2\text{O})_2$ I and $\text{CuSO}_4 \cdot 4\text{L}_2 \cdot 2\text{H}_2\text{O}$ II revealed endothermic effects associated with dehydration occurring at 140–220°C for I and 160–200°C for II. The decomposition of the organic part of complex I takes place in the temperature range of 220–360°C with a theoretical mass loss ($\Delta m_{\text{theor.}}$) of 62.3%, and an experimental mass loss ($\Delta m_{\text{exp.}}$) of 61.75%. For complex II, the corresponding values are $\Delta m_{\text{theor.}} = 68.00\%$; and $\Delta m_{\text{exp.}} = 69.00\%$. The final product of thermolysis is CuO , which is characteristic of copper (II) chloride and sulfate complexes of (Fig. 3) [20].

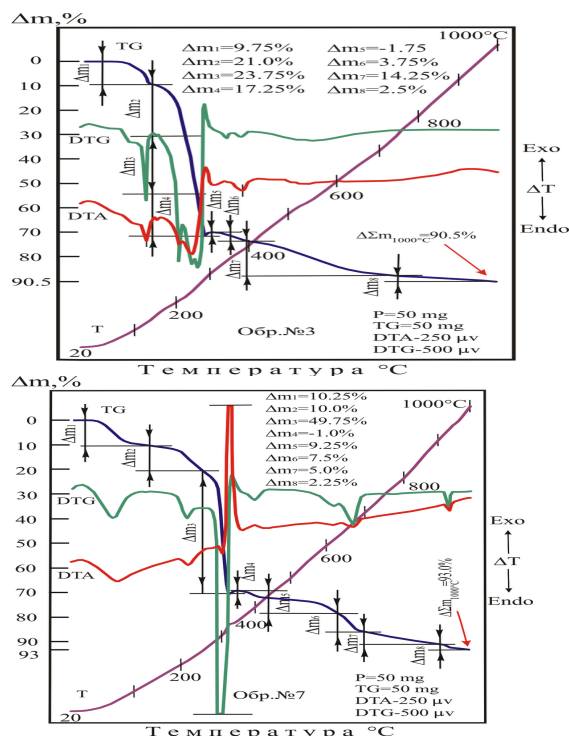


Figure 3. TG, DTA/DTG curves of complexes a) $[\text{CuL}_4]\text{Cl}_2 \cdot (\text{H}_2\text{O})_2$ and b) $[\text{CuL}_4]\text{SO}_4 \cdot (\text{H}_2\text{O})_2$

IR spectra of I and II complexes show, that in the region of fundamental functional group vibrations, practically identical changes are observed. The bands of stretching and deformation vibrations of the ring at 1470–1520 cm^{-1} shift by 15–20 cm^{-1} toward higher frequencies, which is characteristic to complexes of this class and indicates coordination of the nitrogen atoms of the ring to the metal. The possible coordination mode of 1, 2, 4-triazole with copper(II) can be inferred by analyzing the torsional vibration region of the triazole ring, where absorption bands appear in the frequency range of 600–700 cm^{-1} . Monodentate coordination leads to a disruption of the local C_{2v} symmetry of the triazole ring, resulting in increased IR activity of the torsional vibrations, located near 690 cm^{-1} . The bands of stretching vibrations $\nu(\text{N}-\text{N})$ are shifted to a lesser extent or are even shifted toward lower frequencies rather than higher ones. This indicates that in complexes I and II, the ligand behaves as monodentate, since the least polarization of the triazole ring occurs precisely with monodentate coordination. In the region of 2600–3400 cm^{-1} , structured bands are also present, attributed to $\nu(\text{C}-\text{H})$ vibrations of the triazole ring. The spectra of complexes I and II contain uncoordinated absorption bands of crystalline water: $\nu(\text{OH})$ at 3450 cm^{-1} , $\delta(\text{H}_2\text{O})$ at 1590–1620 cm^{-1} , and $\rho(\text{H}_2\text{O})$ at 510–240 cm^{-1} , as well as $\nu(\text{SO}_4^{2-})$ at 1020–1145 cm^{-1} and $\delta(\text{SO}_4^{2-})$ at 545–622 cm^{-1} . Additionally, a new absorption band, absent in the free ligand, appears in the range of 420–450 cm^{-1} , corresponding to the stretching vibration of the $\text{M} \leftarrow \text{N}$ bond, which supports complex formation through the nitrogen atom of the heterocycle (see Fig. 4).

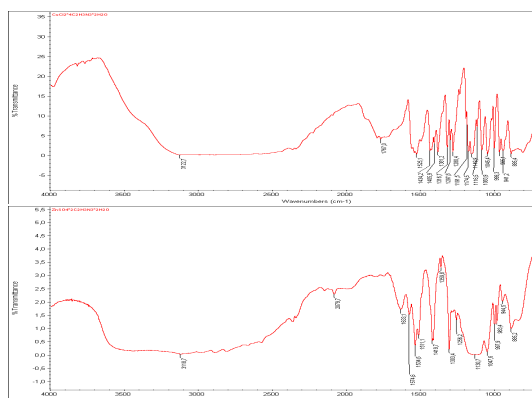


Figure 4. IR spectra of absorption of the complexes a) $[\text{CuL}_4]\text{Cl}_2 \cdot (\text{H}_2\text{O})_2$ and b) $[\text{CuL}_4]\text{SO}_4 \cdot (\text{H}_2\text{O})_2$

Thus, based on the IR spectra of complexes I and II (stretching and deformation vibrations, torsional vibrations of the ring, $\nu(\text{OH})$ at 3450 cm^{-1} , $\delta(\text{H}_2\text{O})$ at $1590\text{--}1620\text{ cm}^{-1}$, $\nu(\text{SO}_4^{2-})$ at $1020\text{--}1145\text{ cm}^{-1}$, $\delta(\text{SO}_4^{2-})$ at 545 and 622 cm^{-1} , and the stretching vibrations of the $\text{M}\leftarrow\text{N}$ bond—along with literature data [21], it can be concluded that in complexes I and II, 1,2,4-triazole acts as a monodentate ligand, coordinating to the metal through four nitrogen atoms at the 4-position, forming a square planar configuration with a coordination unit of CuL_4 . The coordination mode of L_2 to metal ions in complexes with composition $\text{MeL}_{22}\text{X}_2(\text{H}_2\text{O})_2$, where $\text{Me} = \text{Cu(II)}, \text{Ni(II)}, \text{Zn(II)}, \text{Cd(II)}, \text{Mn(II)}$ and $\text{X} = \text{Cl}^-, \text{SO}_4^{2-}$, differs from that of the 1:4:2 complexes.

Complexes with composition 1:2:2 have a polymeric chain structure, where the triazole ligand acts as a bridging ligand. The coordination unit is formed by four nitrogen atoms at positions (N1) and (N2) of two bidentate bridging ligand molecules and two oxygen atoms from water molecules. The coordination polyhedron is a distorted octahedron [22].

For establishment of the crystal structure, an X-ray structural analysis of a single crystal of the copper (II) tetramidazole chloride complex was performed as given in Fig. 5.

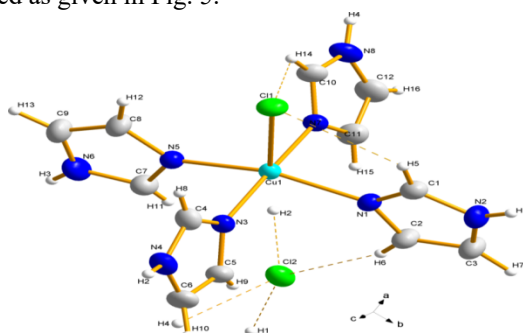


Figure 5. Structure of coordination compound $[\text{Cu}(\text{L})_4\text{Cl}]\text{Cl}$

As a result, it was established that the CuL_4Cl_2 compound crystallizes in the monoclinic syngony and has a tetragonal-pyramidal configuration due to the N-monodentate coordination of four imidazole molecules with an additional remote vertex of the chlorine ion $[(4+1)+1]$. The second chlorine ion is located in the outer sphere and

is localized in the framework planes. The structural units of the single crystal of the coordination compound $[\text{Cu}(\text{L})_4\text{Cl}]\text{Cl}$ I are the complex $[\text{Cu}(\text{L})_4\text{Cl}]^+$ cation and the Cl^- anion [23].

The results of X-ray structural analysis show that the coordination compounds $[\text{CoL}_6](\text{NO}_3)_2$ and $[\text{CdL}_6](\text{NO}_3)_2$ crystallize in the triclinic syngony with space group R3 with the unit cell parameters presented in the Table 1 [19].

It has been established that compounds II and III are iso-structural and have a similar structure, so we will consider them in more detail using the Co(II) complex example. The structure of complex II consists of discrete $[(\text{Co}(\text{L}_6))]^{2+}$ cations and NO_3^- anions. The Co^{2+} ion has a center-symmetric octahedral configuration with the coordination unit CoN_6 . The heterocycle is coordinated monodentately through the pyridine nitrogen atom (N3) to the Co^{2+} ion, the average length of the $\text{Co}\text{--}\text{N}$ bond is $2.1590\text{ \AA}$. The molecules in the coordination polymer II are additionally linked to each other by strong intermolecular hydrogen bonds through the proton of the pyrrole group of imidazole and the oxygen of the nitrate group to form the $\text{N}\text{--}\text{H}\cdots\text{O}$ chain. Polymer chains are linked in layers along the (001) plane [24, 25] (Fig. 6).

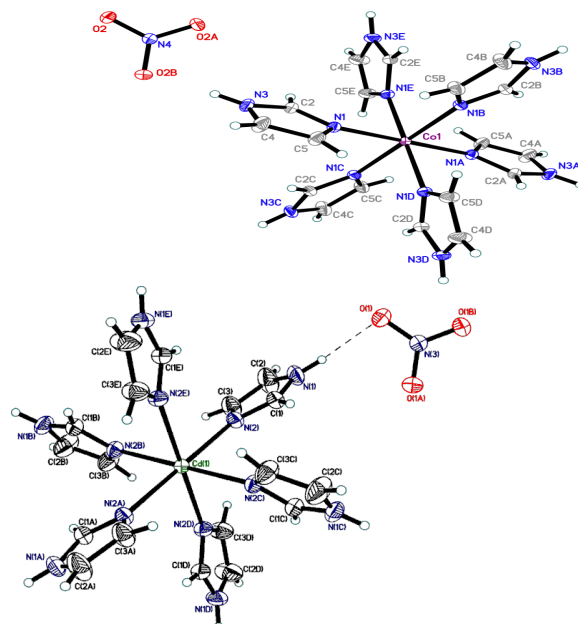


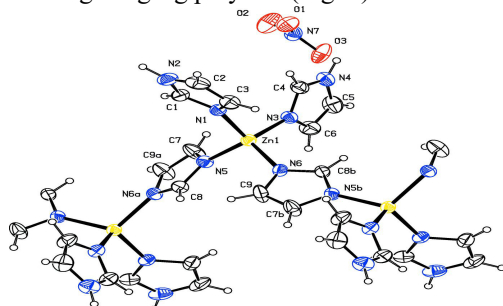
Figure 6. Structure of coordination polyhedron of the complexes $[\text{CoL}_6](\text{NO}_3)_2$ and $[\text{CdL}_6](\text{NO}_3)_2$

The XRD results of the Zn(II) complex showed the following: the complex crystallizes in orthorhombic syngony with the unit cell parameters: $a = 12.1812(10)$, $b = 10.0713(7)$, $c = 11.3628(10)\text{ \AA}$; $\alpha = \beta = 90^\circ$; $\gamma = 120^\circ$; $V = 1914.78(5)\text{ \AA}^3$; space group - R3. In the Zn(II) complex, a new type of imidazole coordination was established, when it is simultaneously a monodentate and bridging ligand.

The composition of the ZnN_4 complex coordination unit, formed by four nitrogen atoms, two monodentately coordinated nitrogen atoms (chelate function) and two nitrogen atoms coordinated in a bridge-like manner. The structure

consists of chains of bis(imidazole zinc units) linked by imidazole anions, forming a zigzag polymer – $[\mu\text{-Zn}(\text{C}_3\text{H}_4\text{N}_2)(\text{C}_3\text{H}_4\text{N}_2)_2](\text{NO}_3)_2(\text{H}_2\text{O})_2$ (Table 1).

The zinc atom has a normal tetrahedral configuration. The average length of the Zn-N bond is 2.251(2) Å. Two units of bridged imidazole are linked by a screw axis and connect the zinc atoms, forming a zigzag polymer (Fig. 7).



						class (GHS)
1	$\text{CuL}^1_4\text{Cl}_2$	Mo use	Orally	21 10	Mg/kg	4
2	$\text{CuSO}_4 \cdot 6\text{L}^1_4 \cdot 6\text{H}_2\text{O}$	Mo use	Orally	15 80	Mg/kg	3
3	$\text{CuSO}_4 \cdot 4\text{L}^2_4 \cdot 2\text{H}_2\text{O}$	Mo use	Orally	10 40	Mg/kg	3
*, L^1 imidazole ($\text{C}_3\text{H}_4\text{N}_2$); L^2 -1,2,4-triazole ($\text{C}_2\text{H}_3\text{N}_3$)						

The results of the studies on the pharmacotoxicological and anthelmintic properties of the complex in animal helminthiasis allowed the development of a method for treating moniezia in sheep, and exhibit high cestocidal activity on echinococcal protoscoleces, the effectiveness of which is 85-100%. The Kyrgyz Republic for (No. 2280, 2368, 1954) patents the development of the drugs, presented in here.

IV. CONCLUSIONS

Based on the combination of DTA, XRD and IR data, it was established that in the $\text{MeL}_6\text{Cl}_2(\text{H}_2\text{O})$ (Me-Co, Mn. X-1,2,4-triazole) complexes, water molecules are in the outer coordination sphere, forming octahedral coordination. In the complexes $\text{MeL}_2\text{Cl}_2(\text{H}_2\text{O})_2$ (Me = Cu, Ni, Zn, Cd), the chlorine atoms are bridging and the complexes have a polymer-octahedral structure. The MeL_4Cl_2 complexes (Me = Cu, Zn, Ni) form five-coordinated compounds with a tetragonal-pyramidal configuration, whereas Cu and Cd in the $\text{MeL}_2\text{SO}_4(\text{H}_2\text{O})_2$ complexes form six-coordinated complexes with a bidentate-bridging function of the sulfate ion.

In nitrate complexes, it has been shown that, depending on the nature of the metal, acido- and heterocyclic ligand, distorted octahedral – $[\text{MeL}_6](\text{NO}_3)_2$, (Me = Co, Cd, Cu, Ni); $[\text{MeL}_4(\text{H}_2\text{O})_2]\text{Cl}_2$, (Me = Ca, Mg) tetrahedral – $[\text{MeL}_4](\text{NO}_3)_2(\text{H}_2\text{O})_2$, (Me = Co, Zn, Ca, Mg); orthorhombic – $[\text{ZnL}_2](\text{NO}_3)_2 \cdot (\text{H}_2\text{O})_2$ complexes are formed.

The results of studies on pharmacotoxicological anthelmintic properties of individual complexes in animal helminthiasis allowed developing a method for treating echinococcal protoscoleces (*Echinococcus granulosus*) in sheep. The invention was registered at Kyrgyz Republic Patent (No. 2280, 2368, 1954).

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