Crystal structures of bis-{N-[1-(pyridin-2-yl-κN)ethyldenedi]nicotinedihydrazone-κ²N⁵,O}cobalt(II) bis(perchlorate) dihydrate and bis-{N-[1-(pyridin-2-yl-κN)ethyldenedi]nicotinoyldihydrazone-κ²N⁵,O}copper(II) perchlorate

Moussa Faye 1, Mouhamadou Moustapha Sow 1, Papa Aly Gaye 2, Moussa Dieng 1 and Mohamed Gaye 2*

1 Department of Chemistry, UFR SATIC, University Alioune Diop, Bambey, 21400, Senegal
2 Corresponding author at: Department of Chemistry, University Cheikh Anta Diop, Dakar, 10700, Senegal
*e-mail: mohamedl.gaye@ucad.edu.sn (M. Gaye).

KEYWORDS
Cobalt(II), Copper(II), Perchlorate, 2-Acetyl pyridine, Nicotinic hydrazide, Single crystal structure

ABSTRACT
Complexes of Co(II), [Co(C₉H₇NO₂)₃]·(ClO₄)·(H₂O)·Co(II), [Cu(C₉H₇NO₂)₃]·(ClO₄)·Cu(II) have been synthesized. The prepared two compounds were characterized by elemental analysis, infrared and their structures were determined by single-crystal X-ray diffraction. The compound 1 crystallizes in the triclinic space group P-1 with the following unit cell parameters: a = 8.880 (5) Å, b = 10.529 (5) Å, c = 18.430 (5) Å, α = 99.407 (5)°, β = 102.174 (5)°, γ = 100.652 (2)°, V = 1618.2 (13) Å³, Z = 2, T = 293(2), μ(MoKα) = 0.77 mm⁻¹, Dcal = 1.582 g/cm³, 16135 reflections measured (5.05° ≤ θ ≤ 59.152°), 7648 unique, R₁ = 0.034 which were used in all calculations. The final R₁ was 0.066 (I ≥ 2σ(I)) and wR₂ = 0.22 (all data). The compound 2 crystallizes in the monoclinic space group P2₁/c with the following unit cell parameters: a = 11.652 (5) Å, b = 16.540 (5) Å, c = 14.512 (5) Å, β = 93.495 (5)°, V = 2791.6 (18) Å³, Z = 4, T = 293(2), μ(MoKα) = 1.05 mm⁻¹, Dcal = 1.768 g/cm³, 15592 reflections measured (5.624° ≤ θ ≤ 58.884°), 6630 unique, R₁ = 0.025 which were used in all calculations. The final R₁ was 0.050 (I ≥ 2σ(I)) and wR₂ = 0.144 (all data). In both complexes, the ligand acts in a tridentate fashion. In the structure of the mononuclear complex 1, the Co(II) cation is coordinated by two ligand molecules. The basal plane around the Co(II) cation is occupied by two pyridine nitrogen atoms and two carbonyl oxygen atoms. Two imino nitrogen atoms occupy the apical positions of the distorted square-pyramidal geometry. The mononuclear 2 consists of a Cu(II) coordinated by one ligand and one monodeprotonated ligand molecule. The metal center lies in a distorted square bipyramidal environment. The basal plane around the Cu(II) is occupied by two pyridine nitrogen atoms and two carbonyl oxygen atoms, the apical position being occupied by the two imino nitrogen atoms.

1. Introduction

The development of new molecules with drug activity and without dangerous side effects is one of the major challenges of science. The compounds having a hydrazone unit -Co-N-NR- are characterized by their use in the synthesis of compounds having therapeutic properties [1-4]. Compounds with antibacterial [5,6], antifungal [7], antiviral [8], and anticancer [9] properties are listed. These compounds having donor sites such as N, O or S atoms are widely used in coordination chemistry. Complexes with diverse structures have been synthesized in recent years [10,11].

These hydrazone compounds have the ability to exhibit keto-enol tautomeric forms which can coordinate in a tridentate fashion. These tautomeric forms offer these molecules the possibility of coordinating in the neutral mode [12], in monoaconionic mode [13], or diamionic mode [10,14]. These complexes often exhibit important properties for industries such as magnetism [15], luminescence [16], catalysis [17], and optics [18]. These metal transition coordination compounds obtained with hydrazone ligands are also studied because of their broad profile in the pharmacological field, with anticancer [19], antimicrobial [20,21] and anti-tuberculosis [22] potential. It has been shown that hydrazone ligands with biological properties can see their activity increased after complexation with metal ions. Cindric et al. demonstrated that free benzohydrazole having cytotoxic activity against a THP-1 and HepG2 cell line saw its activity significantly increased after complexation with copper [23]. It is in this context that we have prepared transition metal and lanthanide complexes from ligands having hydrazine units [24-29].

Cite this: Eur. J. Chem. 2021, 12(2), 159-164
Journal website: www.eurjchem.com
In this work, we describe the synthesis and characterization of two complexes of cobalt(II) and copper (II) ions obtained from the N’-(1-(pyridin-2-yl)ethylidene)nicotinohydrazide (HL) ligand, which are characterized by elemental analysis, FT-IR, $^1$H NMR, and $^{13}$C NMR. The crystal structures of these two complexes have been elucidated by X-ray diffraction studies.

2. Experimental

2.1. Materials and instrumentation

Nicotinic hydrazide, 2-acetyl pyridine, cobalt perchlorate hexahydrate, and copper perchlorate hexahydrate were purchased from Sigma-Aldrich and used as received without further purification. All solvents used were of reagent grade. The ligand, N’-(1-(pyridin-2-yl)ethylidene)nicotinohydrazide (HL) was synthesized following the reported procedure [30]. Melting points were determined on a Büchi 570 melting-point apparatus and were uncorrected. Elemental analyses of C, H and N were recorded on a VxRio EL Instrument. Infrared spectra were obtained on an FTIR Spectrum Two of Perkin Elmer spectrometer in the 4000-400 cm$^{-1}$ region. The molar conductance of 1×10$^{-3}$ M in DMSO solution of the metal complexes was measured at 25°C using a WTW LF-330 conductivity meter with a WTW conductivity cell. Room temperature magnetic susceptibilities of the powdered samples were measured using a Johnson Matthey scientific magnetic susceptibility balance (Calibrant: Hg[Co(SCN)$_4$]).

2.2. Synthesis and characterization of N’-(1-(pyridin-2-yl)ethylidene)nicotinohydrazide (HL)

The ligand HL was synthesized following the procedure reported in the literature [30]. To a solution of 2-acetyl pyridine (0.6627 g, 5.5 mmol) in 10 mL of methanol was added a solution of nicotinic hydrazide (0.7566 g, 5.5 mmol) in 30 mL of methanol. The mixture was heated under reflux for two hours. The solvent was evaporated to dryness and the solid was collected and recrystallized from ethanol solution. After one week, the white powder was collected (Scheme 1).

**Scheme 1.** Synthetic scheme for HL and complex preparation.

$^{N’}$-(1-(pyridin-2-yl)ethylidene)nicotinohydrazide (HL): Color: White. M.p.: 171-172°C. Yield: 66%. FT-IR (ATR, ν, cm$^{-1}$): ν(NH) 3201, ν(C=O) 1663, ν(C=N) 1622, 1581, ν(N-N) 1150. $^1$H NMR (500 MHz, DMSO-d$_6$, δ, ppm): 2.52 (s, 3H, CH$_3$), 7.50-9.07 (m, 8H, Ar-H), 11.29 (s, 1H, NH). $^{13}$C NMR (125 MHz, DMSO-d$_6$, δ, ppm): 13.52 (CH$_3$), 120.92 (H-C2), 120.96 (H-C4’), 123.89 (H-C4), 123.92 (C1’), 130.20 (H-C3), 136.36 (H-C5’), 137.16 (H-C3’), 149.18 (H-C5), 152.63 (H-C2’), 152.84 (C1), 155.48 (C=N), 163.37 (C=O). Anal. calcd. for C$_{13}$H$_{12}$ON$_4$: C, 64.99; H, 5.03; N, 23.32. Found: C, 64.96; H, 5.01; N, 23.30%.

2.3. Synthesis and characterization of complexes 1 and 2

To a solution of 2-acetyl pyridine (0.6627 g, 5.5 mmol) in 10 mL of ethanol was added a solution of nicotinic hydrazide (0.7566 g, 5.5 mmol) in 30 mL of ethanol. The mixture was heated under reflux for two hours. After cooling, the volume is completed to 50 mL. To 25 mL of the above solution was added a solution of Co(ClO$_4$)$_2$·6H$_2$O (0.0915 g, 2.5 mmol) or Cu(ClO$_4$)$_2$·6H$_2$O (0.0926 g, 2.5 mmol) in 5 mL of methanol. The mixture was stirred at room temperature for two hours. The precipitate was discarded, and the filtrates were left for slow evaporation. On standing for five days, crystals suitable for X-ray single crystal diffraction analysis were formed, brown prisms of complex 1 and light-yellow prisms of complex 2 were collected (Scheme 1).

**Scheme 1.** Synthetic scheme for HL and complex preparation.

$^{N’}$-(1-(pyridin-2-yl)ethylidene)nicotinohydrazide (HL): Color: White. M.p.: 171-172°C. Yield: 66%. FT-IR (ATR, ν, cm$^{-1}$): ν(NH) 3201, ν(C=O) 1663, ν(C=N) 1622, 1581, ν(N-N) 1150. $^1$H NMR (500 MHz, DMSO-d$_6$, δ, ppm): 2.52 (s, 3H, CH$_3$), 7.50-9.07 (m, 8H, Ar-H), 11.29 (s, 1H, NH). $^{13}$C NMR (125 MHz, DMSO-d$_6$, δ, ppm): 13.52 (CH$_3$), 120.92 (H-C2), 120.96 (H-C4’), 123.89 (H-C4), 123.92 (C1’), 130.20 (H-C3), 136.36 (H-C5’), 137.16 (H-C3’), 149.18 (H-C5), 152.63 (H-C2’), 152.84 (C1), 155.48 (C=N), 163.37 (C=O). Anal. calcd. for C$_{13}$H$_{12}$ON$_4$: C, 64.99; H, 5.03; N, 23.32. Found: C, 64.96; H, 5.01; N, 23.30%.

Bis-$^{N’}$-(1-(pyridin-2-yl)ethylidene)nicotinohydrazide (HL): Color: Brown. Yield: 53%. FT-IR (ν, cm$^{-1}$): 3100, 1602, 1583, 1502, 1462, 1409, 1373, 1161, 1070, 1028, 912, 823, 780, 620. Λ$_{M}$ (S.cm$^2$.mol$^{-1}$): 154.4. Anal. calcd. for Co$_{13}$H$_{12}$N$_8$Cl$_2$O$_{12}$: C, 40.33; H, 3.64; N, 14.47. Found: C, 40.31; H, 3.62; N, 14.44%.
FT-IR (υ, cm⁻¹): 3092, 1612, 1588, 1504, 1463, 1380, 1113, 1097, 1041, 920, 838, 788, 616. μ (µB): 1.77. Λ (eV): 1.77. Λ (µB) for complex 1 and 1.80 for complex 2.

3. Results and discussion

3.1. Synthesis

The IR spectrum of the ligand shows main bands at 3194, 1656, and 1605 cm⁻¹, attributable, respectively, to v(N-H), v(C=O) and v(N=O) vibration modes. Additional bands due to the aromatic ring are located in the range 1428-1582 cm⁻¹. Comparison of the infrared data of the ligand and those of the complexes described above shows that no iminolization undergoes during the synthesis of the complexes. In fact, the ν(C=O) vibration bands appear at 1656, 1605, 1583, and 1588 cm⁻¹ in the complexes. The broad band centered in the range 3090-3110 cm⁻¹ is probably due to the stretching of H–N [36]. The bands located at ca. 1070 cm⁻¹ (v=O) and 620 cm⁻¹ (δ=O) on the spectrum of complex 1 and 1097 cm⁻¹ (v=O) and 616 cm⁻¹ (δ=O) for complex 2 are indicative of the presence of free tetrahedral perchlorate anions [37].

The molar conductivity values of the freshly DMF (1×10⁻³ M) complex solution and fifteen days later are, respectively, 154.4 (S.cm⁻².mol⁻¹) and 158.2 (S.cm⁻².mol⁻¹) for complex 1 and 75.1 (S.cm⁻².mol⁻¹) and 76.2 (S.cm⁻².mol⁻¹) for complex 2. These values are in accordance with those reported for related complexes [38]. The molar conductivity values fifteen days later showed that the complexes are stable in DMF.

The values of the magnetic moment at room temperature for the diamagnetic complexes are indicative of the presence of one metal atom per molecule. The magnetic moment value of 4.17 µB for complex 1 is in accordance with three unpaired electrons by d⁷ configuration. The magnetic moment value of 1.77 µB for complex 2 is in accordance with one unpaired electron in d⁵ configuration [39].

3.2. Single crystal structure

3.2.1. Complex 1

In the crystal structure of the coordination compound [Co(C6H4N8O2)·(H2O)2·(ClO4)2], the Co(II) center is hexacoordinated by two pyridine nitrogen atoms, two imino nitrogen atoms and two carbonyl oxygen atoms of the neutral molecule ligand. The coordination environment can be best described as severely distorted square bipyramidal (Figure 1). The basal plane around the Co(II) cation is occupied by the pyridine nitrogen atoms N4 and N8 with Co–N distances of 1.887(3) and 1.905(3) Å (Table 2). The apical positions are occupied by the imino nitrogen atoms N3 and N7 with distances 1.920(3) and 1.915(3) Å and the carbonyl oxygen atoms O1 and O2 with Co–O distances of 1.887(3) and 1.905(3) Å (Table 2).

The bond lengths are slightly shorter than the values reported for related complexes [40]. The apical positions are occupied by the imino nitrogen atoms N3 and N7 with distances of Co–N of 1.853(3) and 1.856(3) Å. These values are shorter than the reported values for a similar complex [41].

| Parameters | Complex 1 | Complex 2 |
|------------|-----------|-----------|
| Formula    | CoC6H4C6H4N8O2·2H2O·ClO4 | CoC6H4C6H4N8O2·2H2O·ClO4 |
| PW         | 774.39    | 742.97    |
| Crystal shape / color | Block, brown | Block, yellow-light |
| Crystal size (mm) | 0.10 × 0.10 × 0.05 | 0.30 × 0.10 × 0.09 |
| Crystal system | Triclinic | Monoclinic |
| Space group | P-1/c | P-2/c |
| a (Å)      | 8.800 (5) | 11.652 (5) |
| b (Å)      | 10.529 (5) | 16.540 (5) |
| c (Å)      | 18.430 (5) | 14.512 (5) |
| α (°)      | 99.407 (5) | 90.000 |
| β (°)      | 102.174 (5) | 93.495 (5) |
| γ (°)      | 100.652 (5) | 90.000 |
| V (Å³)     | 1618.2 (13) | 2791.6 (18) |
| Z          | 2         | 4         |
| Dm (g/cm³) | 1.582     | 1.768     |
| λ (MoKα)   | 0.71073   | 0.71073   |
| T (K)      | 293(2)    | 293(2)    |
| μ (mm⁻¹)   | 0.77      | 1.05      |
| Index ranges | -1 ≤ h ≤ 14, 1 ≤ k ≤ 14, -24 ≤ l ≤ 22 | -15 ≤ h ≤ 12, 2 ≤ k ≤ 18, 16 ≤ l ≤ 19 |
| F(000)     | 730       | 1516      |
| θ range (°) | 2.925-29.576 | 2.812-29.402 |
| No. of measured reflections | 16135 | 15597 |
| No. of independent reflections | 7648 | 6630 |
| No. of observed reflections | 5762 | 4967 |
| R(F) | 0.034 | 0.025 |
| wR(F) | 0.22 | 0.144 |
| Goodness-of-fit (Gof) on F² | 1.08 | 1.02 |
| No. of parameters | 509 | 381 |
| No. of restraints | 0 | 0 |
| Δρmax, Δρmin (e Å⁻³) | 0.97, -0.64 | 0.63, -0.75 |
respectively. The angles imposed by the five-membered rings two membered rings share one nitrogen atom N3 and N7, respectively. The angles O2–Co1–N8 and O1– Co1–N4 are, plane, the transoid smaller than those reported by Cocu et al. [41]. In the basal square bipyramid (82.56(11) are severely deviated from the ideal angles of 90° for a regular angles subtended by the donor atoms of Co(II) in the equatorial angles are in the range [87.59(13)-82.50 (13)°, 101.36(12)°] while the (II) center: N–C–C–N–Co and O–C–N–N–Co. For each ligand, the act as a tridentate, formed two five-membered rings with the Co Upon coordination, each of the two ligand molecules, which fact as a tridentate, formed two five-membered rings with the Co (II) center: N–C–C–N–Co and O–C–N–N–Co. For each ligand, the two membered rings share one nitrogen atom N3 and N7, respectively. The angles imposed by the five-membered rings are severely deviated from the ideal angles of 90° for a regular square bipyramid (82.56(11)-101.36(12)°). These angles are smaller than those reported by Gou et al. [41]. In the basal plane, the transoid angles O2–Co1–N8 and O1–Co1–N4 are, respectively, 165.37(12)° and 165.34(13)° while the cissoid angles are in the range [87.59(13)-93.98(14)°]. The sum of the angles subtended by the donor atoms of Co(II) in the equatorial plane [O1–O2–N4–N8] is 363.65°, indicating approximate coplanarity for these atoms as shown by the rms value of 0.0422 Å. The angle value of 175.12(13)° is defined by the atoms in the apical position: N3 –Co1–N7. A geometrical analysis has been performed on π–π stacking in the cobalt complex. Considering the crystal structure of the cobalt complex as shown in Figure 2, there are two types of π–π stacking interactions between the 2-substituted pyridyl rings (N4- C9-C13 and N8- C22-C26) and those between the 3-substituted pyridyl rings (N1- C1-C5 and N6- C14-C18) with Cg–Cg distances of 3.881 and 3.824 Å, respectively. The π–π stacking interactions link the molecules into a ribbon along the c-axis, Figure 2.

### Table 2. Selected bond lengths and bond angles for complexes 1 and 2.

| Atom-Atom | Bond lengths (Å) | Atom-Atom | Bond lengths (Å) |
|-----------|-----------------|-----------|-----------------|
| Co1-N7    | 1.856 (3)       | Co1-N6    | 2.050 (2)       |
| Co1-O2    | 1.905 (3)       | Co1-N2    | 2.058 (3)       |
| Co1-O1    | 1.807 (3)       | Co1-O1    | 2.099 (2)       |
| Co1-N3    | 1.853 (3)       | Co1-O2    | 2.130 (2)       |
| Co1-N4    | 1.920 (3)       | Co1-N1    | 2.220 (3)       |
| Co1-N8    | 1.915 (3)       | Co1-N5    | 2.277 (3)       |

**Figure 1.** The crystal structure of complex 1. Displacement ellipsoids are drawn at the 30% probability level and H atoms are shown as a small sphere.

**Figure 2.** Intermolecular π–π stacking between the pyridyl rings in the title complex 1.
3.2.2. Complex 2

In complex 2, the Cu (II) lies in an octahedral environment (Figure 3). One neutral ligand molecule coordinates the Cu (II) center through its pyridine nitrogen atom, its imine nitrogen atom, and its carbonyl oxygen atom. Additionally, a monodeprotonated ligand molecule coordinates the Cu (II) center through its pyridine nitrogen atom, its imine nitrogen atom and its iminolate oxygen atom. In each case two five-membered rings N-C-C-N-Cu and O-C-N-N-Cu are formed. The result is a severely distorted square bipyramid environment as shown by the transoid angles (149.64(9)° and 165.60(10)°) and the cissoid angles (90.06(9)-97.37(8)°) (Table 2). Two imino nitrogen atoms, one iminolate oxygen atom and one pyridine nitrogen atom occupy the basal plane, while one pyridine nitrogen atom and one carbonyl oxygen atom occupy the apical positions. The Cu–N distances are in the range 2.050(2)-2.277(3) Å and agree with the values reported by Santiago et al. [42]. The Cu1–O1 and Cu1–O2 are, respectively, 2.099(2) and 2.130(2) Å showing the negative charge difference of these two oxygen atoms. In fact, the iminolate oxygen atom O1 is more negatively charged than the carbonyl oxygen atom O2 and the link O2 to Cu1 is stronger, resulting in a shorter distance as observed for similar complexes [42]. Additionally, the C–O bonds in the two ligand molecules are slightly different. The C21–O2 (1.271 (3) Å) bond is longer than the C8–O1 (1.264 (3) Å) bond which has a double bond character. The sum of the angles subtended by the donor atoms at the Cu (II) in the equatorial plane [N2 O2 N6 N5] is 359.95°, indicating approximate coplanarity for these atoms as shown by the rms value of 0.078 Å. The crystal structure of the copper complex illustrated in Figure 4 shows two types of π–π stacking interactions between the 2-substituted pyridyl ring and the 3-substituted pyridine ring with Cg–Cg distances of 3.845 and 3.940 Å respectively. The π–π stacking interaction link the molecules into sheet parallel to the bc plane (Figure 4).

4. Conclusion

The acetylpyridinenicotinohydrazone ligand well known in the literature is used to synthesize two new complexes from perchlorate salts of cobalt or copper. Magnetic measurements, spectroscopic studies, and X-ray diffraction indicated the formation of a dicanionic mononuclear complex in the case of cobalt (1) and a monocanionic mononuclear complex in the case of copper (2). In complex 1, two ligand molecules act in a tridentate fashion in a neutral form, while in complex 2 one ligand molecule acts in a tridentate manner in a neutral form while a second monodeprotonated ligand molecule acts in tridentate fashion. In both structures, we have a hexacoordinate environment with a distorted octahedral geometry for the two complexes.

Acknowledgement

The authors thank Professor Dominique Luneau at LMI, University Claude Bernard, Lyon, France, for technical assistance.

Supporting information

CCDC-2054420 and 2054421 contain the supplementary crystallographic data for compounds 1 and 2, respectively. These data can be obtained free of charge via
Disclosures statement

Conflict of interests: The authors declare that they have no conflict of interest.

Author contributions: All authors contributed equally to this work.

Ethical approval: All ethical guidelines have been adhered.

Conflict of interests: The authors declare that they have no conflict of interest.

Disclosure statement

1EZ, UK; fax: +44(0)1223 124 880.

References

[1]. Koivusalo, L.; Karvinen, J.; Sorra, E.; Jonkkäri, I.; Väliaho, J.; Kallio, P.; Ilmarinen, T.; Miettinen, S.; Skottman, H.; Kellomäki, M. Mater. Sci. Eng. C Mater. Biol. Appl. 2018, 85, 60–70.

[2]. Uppal, G.; Bala, S.; Kamboj, S.; Saini, M. Pharma Chem. 2011, 3, 250–268.

[3]. Cakirman, D. S.; Pinheiro, A. B.; Castilheira-Filho, S. L. P.; da Silva, A. S. P.; Fiott, M. C.; De Falco, A.; de P. Ribeiro, T.; Diouf, O.; Gaye, M.; Sall, A. S. Polyhedron 2012, 43, 97–103.

[4]. Sanford, A. G.; Shatze, T. T.; Poturi, L. P.; Watson, G. F.; Darner, E. B.; Zach, S. J.; Hemsley, R. M.; Wallick, A. I.; Warner, R. C.; Charman, S. A.; Retailleau, P. Eur. J. Med. Chem. 2013, 69 (2), m108.

[5]. Seck, T. M.; Faye, A.; Diouf, O.; Barry, A. H.; Gaye, M.; Sall, A. S. Polyhedron 2010, 76, 660–663.

[6]. Sy, A.; Dieng, M.; Thiam, I. E.; Orton, J.; Coles, S.; Gaye, M. Acta Crystallogr. B Crystallogr. Commun. 2020, 75 (4), 625–626.

[7]. Sylla-Gueye, R.; Thiam, I. E.; Orton, J.; Coles, S.; Gaye, M. Acta Crystallogr. B Crystallogr. Commun. 2021, 75 (6), 660–663.

[8]. Sarah, K.; Kamar, M.; Alsaleh, H.; Shehata, M. M.; El-Deglawy, A. J. Phys. Chem. Solids 2021, 151 (109817).

[9]. Alagesan, M.; Bhuvanes, N. S. P.; Dharmaraj, N. Dalton Trans. 2013, 42 (19), 7210–7223.

[10]. Cao, W.; Liu, Y.; Zhang, T.; Jia, J. Polyhedron 2018, 147, 62–68.

[11]. Bhatkar, R. S.; Ladole, C. A.; Salunkhe, N. G.; Barade, J. M.; Akwar, A. S. Arab. J. Chem. 2020, 13 (8), 6559–6567.

[12]. Joshi, N.; Gore, V.; Tekale, S.; Rajani, D.; Bembalkar, S.; Pawar, R. Lett. Appl. Nanosci 2021, 10, 2056–2062.

[13]. Cindrie, M.; Bjelopetrovic, A.; Pavlovic, G.; Damjanovic, V.; Lovric, J.; Matkovic-Calogovic, D.; Vrdoljak, V. New J Chem. 2017, 41 (6), 2425–2435.

[14]. Sysy, M. L.; Aragon, M.; Goban, Z.; Gil-Valle, A.; Segura-Carretero, A.; Segura-Carretero, A.; Díaz-Rodriguez, A.; Saura-Carmona, S. J. Toxicol. Environ. Health, Part A 2017, 80, 416–424.

[15]. Sheldrick, G. M. SHELXTL Version 5.10. Bruker AXS Inc: Madison, Wisconsin, USA, 1997.

[16]. Sheldrick, G. M. Acta Crystallogr. A Fund. Adv. 2015, 71 (1), 3–8.

[17]. Sheldrick, G. M. Acta Crystallogr. C Struct. Chem. 2015, 71 (1), 3–8.

[18]. Furrugia, L. J. J. Appl. Crystallogr. 2012, 45 (4), 849–854.

[19]. Seck, T. M.; Sy, A.; Lo, D.; Gaye, P. A.; Sall, M. L.; Diouf, O.; Gaye, M. Sci. Open J. Appl. Chem. 2019, 09 (04), 35–32.

[20]. Singh, A. K.; Pardey, O. P.; Sengupta, S. K. Spectrochem. Acta A Mol. Bioanal. Spectrosc. 2013, 218, 253–259.

[21]. Roy, T. G.; Hazari, S. K.; Miah, H. A.; Gupta, S. K. D.; Roy, P. G.; Behrens, U.; Rebber, D. Inorg. Chim. Acta 2014, 415, 124–131.

[22]. Geary, W. J.; Coord. Chem. Rev. 1975, 17 (1), 81–122.

[23]. Jothi, N.; Ganji, N.; Daravath, S.; Shivaraj, J. Mol. Catal. 2020, 1207 (127799), 127799.

[24]. Roztoka, K.; Matoga, D.; Niter, W. Inorg. Chim. Acta 2014, 449, 86–92.

[25]. Cucu, M.; Bulbuc, I.; Coropceanu, E.; Melnic, E.; Shova, S.; Ciobanica, O.; Gutium, V.; Bourouch, P. J. Mol. Catal. 2014, 1063, 274–282.

[26]. Santiago, P. H. O.; Santiago, M. B.; Martins, C. H. G.; Gatto, C. C. Inorg. Chim. Acta 2020, 508 (119632), 119632.