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SYNTHESIS AND CHARACTERIZATION OF THIOPHENE CYCLIC SCHIFF BASE LIGAND AND METAL ION COMPLEXES

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Abstract: In this study, a new Schiff base ligand (L) containing a thiophene ring was synthesized via the reaction of thiophene-2,5-dicarbaldehyde with 5-amino-1,3,4-thiadiazole-2-thiol. The structure of the ligand was elucidated using elemental analysis, FT-IR, NMR, and UV-Vis spectroscopy. The ligand (L) reacted with metal acetate salts [$M(CH_3COO)_2$; M = Cu, Co, Ni] in a 1:1 molar ratio to form metal complexes with the general formula [$ML(CH_3COO)_2]\cdot nH_2O$ (n = 2, 3). Structural characterization of the metal complexes was performed using elemental analysis, FT-IR, UV-Vis, TGA/DTA, electrolytic conductivity, and magnetic susceptibility measurements. Based on the obtained data, it was proposed that the Cu(II), Co(II), and Ni(II) complexes adopt a tetrahedral geometry. Moreover, the molar conductivities of the complexes were found to be in the range of 1.5–2.9 $\mu S\cdot cm^{-1}$, indicating their non-electrolytic nature.

Keywords: Thiophene, Thiadiazole, Schiff base, Metal complex, Characterization

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1. Introduction

Schiff bases and their metal complexes represent one of the most important research areas in coordination chemistry. These ligands are easily synthesized thru the condensation of amines with carbonyl compounds (Abd-El-Aziz et al., 2025). Schiff bases coordinate metal ions by azomethine (C=N) functional groups. Bidentate, tridentate, and tetradentate ligands containing N, O, and sometimes S donor atoms are commonly found (Mirosław, 2020; Saritha and Metilda, 2021). Compared to free ligands, Schiff base metal complexes generally exhibit enhanced antioxidant, antimicrobial, antifungal, and anticancer activities (Abdel Aziz and Seda, 2017; Soroceanu and Bargan, 2022). Schiff bases are used in environmental applications, particularly for the detection and removal of heavy metal ions. Catalysis is also important in energy materials, supramolecular chemistry, magnetism, nanoscience, and biomedical studies (Miroslaw, 2020; Kumar et al., 2023; Dhanapal and Manju, 2024; Rajimon et al., 2024).

Schiff base ligands that incorporate sulfur atoms form a crucial subgroup of heterocyclic compounds and have shown considerable development due to their diverse applications in medicine, industry, electrochemistry, and polymer chemistry (Bingöl and Turan, 2020; Mishra et al., 2023). These ligands are often derived from sulfur-containing heterocycles such as thiophene, thiadiazole, and thiosemicarbazide (Chandra et al., 2015; Pandey et al., 2022). These ligands are attracting attention for their antimicrobial, antifungal, antituberculosis, and anticancer applications (Rezki et al., 2015; Süleymanoğlu et al., 2020; Radha and Prabakaran, 2022; Pervaiz et al., 2023). Especially metal complexes, which are more effective than free ligands, exhibit high biological activity against various diseases, fungal species, and cancer, and are therefore considered as potential new drug candidates. Additionally, Co(II) and Cu(II) complexes have antidiabetic potential as α-amylase inhibitors (Radha and Prabakaran, 2022).

These ligands can form protective films on carbon steel surfaces to effectively prevent corrosion and contribute to the photostabilization of polymers like PVC (Reeja et al., 2022). In addition, nonlinear optical applications such as laser technology, optical switching, and photonic devices are also available thanks to the high-order nonlinear optical options of these images (Soliman et al., 2025). All these features provide an advancement in expanding a wide range of applications, from biomedicine to technology and from science to catalysis, for Schiff bases and metal complexes derived from thiophene. Especially biological activity and sensor developments are increasing the potential for using these compounds.

In this study, a novel Schiff base ligand (L) containing thiadiazole and thiophene heteroaromatic rings, along with nitrogen and sulfur donor atoms, was synthesized.

The ligand was reacted with Cu(II), Co(II), and Ni(II) acetate salts to obtain corresponding metal ion complexes. The structural characterization of the ligand and its metal complexes was performed using various analytical and spectroscopic techniques. This research aims to contribute to the understanding of the structural and potential biological properties of sulfur-containing Schiff base complexes.

2. Materials and Methods

2.1. Equipment and Supplies

All the chemicals used in the study were obtained from Sigma-Aldrich and Merck companies. The UV-vis spectra of the synthesized compounds were scanned in the wavelength range of 190–800 nm using the PG Instruments T80+ UV/Vis spectrophotometer. Infrared (FT-IR) spectra were directly obtained from solid samples in the 4000–400 cm^{-1} range using a Perkin Elmer Spectrum 100 FT-IR spectrometer with an ATR accessory. For the Schiff base ligand (L), ^{1}H NMR and ^{13}C NMR spectra were recorded using a Bruker Avance 400 MHz NMR spectrometer in a d_6-DMSO solution containing approximately 10 mg of the sample, with tetramethylsilane (TMS) as the internal standard. The magnetic susceptibility measurements of the metal complexes were performed using a Sherwood Scientific brand device. To demonstrate the difference between the reaction products and the starting materials, the melting points of the ligands and complexes were determined using a Stuart SMP30 model device in the Chemical Research Laboratory of Gaziantep University.

2.2. Synthesis of the Ligand 5,5'-(((1E,1'E)-Thiofen-2,5-Diylbis (methanilidene)) Bis (azanilidene)) Bis (1,3,4-thiadiazol-2-thiol) (L)

0.140 g (1 mmol) thiophene-2,5-dicarboxaldehyde was dissolved in 15 mL of acetonitrile and transferred to the reaction flask. In a separate container, 0.266 g (2 mmol) of 5-amino-1,3,4-thiadiazol-2-thiol was prepared in 15 mL of acetonitrile, and this solution was added dropwise to the previous solution. After the mixture was stirred and left to stand for 1 hour, a catalytic amount of p-toluenesulfonic acid was added. The reaction medium turned dark red, and the formation of a solid product was observed. The progress of the reaction was monitored by thin-layer chromatography (TLC), and the process was terminated after 4 hours. The resulting solid product was collected by filtration, then washed with ethanol and diethyl ether for purification (Figure 1).

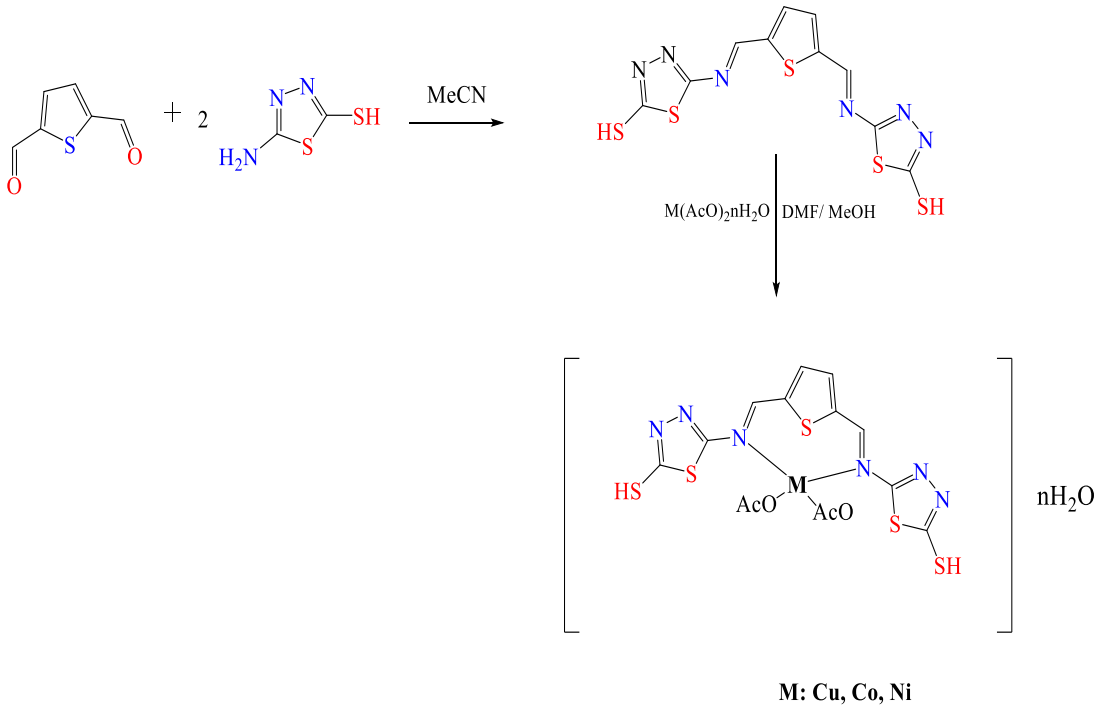

Figure 1. Synthesis scheme of ligand and metal complexes.

Color: Brick red. Yield: 65%, Melting point: 271–275 °C. Molecular formula: $C_{10}H_6N_6S_5$. Molar mass: 370.50 $g{\cdot}mol^{-1}$. FT-IR (ATR, cm^{-1}): 3100–2938 (C–H), 2722 (S–H), 1585 (C=N), 1514 (S–C=N), 1501 (C=C), 1350 (C–S–C), 1263 (C=N–C), 1120 (N–N), 816 (C–S), ^{1}H NMR (400 MHz, DMSO-d_6, δ ppm): 13.80 (s, 1H, SH), 9.18 (s, 1H, CH=N), 8.08-7.14 (d, 2H, CH). ^{13}C NMR (DMSO-d_6, δ ppm): 186.93 (C–SH), 163.41 C=N(thiazole), 161.51 C=N (ımine), 146.88 C-S (thiophene), 138.56 aromatic (Thiophene). UV-Vis (λmax, nm, Abs.): 270 (0.703), 325.44 (0.945), 370 (1.196), 455 (1.374), 580 (1.285). Elemental analysis (C, H, N, S): Theoretical: C 32.42%; H 1.63%; N 22.68%; S 43.27% Found: C 32.32%; H 1.40%; N 22.49%; S 42.72%.

2.3. Synthesis of Metal Complexes

Ligand (0.33 mmol) was taken in a flask and dissolved in a hot mixture of 20 mL DMF. In a beaker, 0.33 mmol $M(AcO)_2{\cdot}nH_2O$ [M=Cu(II), Ni(II), Co(II)] were dissolved in

5 mL of methanol at elevated temperature, and then this solution was slowly added. The reaction was refluxed under a water bath for approximately 24 hours. The solid residue left after the solvent was removed from the evaporator was washed with water, methanol, and ether, and then dried in a desiccator (Figure 1).

$[CuL(AcO)_2]\cdot 3H_2O$ Complex: A brown-colored copper complex was obtained. The closed formula is $C_{14}H_{18}CuN_6O_7S_5$, with a molar mass of 606.18 g·mol^{-1}. The yield was calculated to be 32%. The melting point (decomposition temperature) is above 300 °C. FT-IR (ATR, cm^{-1}): 1255 (C=N–C), 819 (C–S–C), 1665 (C=N), 3068 (aromatic C–H), 3286–3500 (H_2O), 1488 (C=C), 550 (Cu–N), 1488/1374 (Cu–OAc, asymmetric/symmetric). UV-Vis (λmax, nm / Abs.): 280 (0.572), 290.44 (0.874), 325 (0.866), 545 (0.023). Elemental Analysis (C, H, N, S): Theoretical: C 27.74%; H 2.99%; N 13.86%; S 26.44%. Found: C 26.96%; H 2.17%; N 13.99%; S 25.59%. Magnetic susceptibility (μeff): 2.3 BM. Molar conductivity (ΛM, DMF, 10^{-3} M): 2.9 μS·cm^{-1}.

$[CoL(AcO)_2]\cdot 3H_2O$ Complex: A brown-colored cobalt complex was obtained. The closed formula is $C_{14}H_{18}CoN_6O_7S_5$, and its molar mass is 601.57 g·mol^{-1}. The yield is 30%. The melting point (decomposition temperature) is above 300 °C. FT-IR (ATR, cm^{-1}): 1315 (C=N–C), 816 (C–S–C), 1654 (C=N), 3068 (aromatic C–H), 3265–3500 (H_2O), 1488 (C=C), 514 (Co–N), 1491/1383 (Co–OAc, asymmetric/symmetric). UV-Vis (λmax, nm / Abs.): 280 (2.062), 335 (0.744), 550 (0.254). Elemental Analysis (C, H, N, S): Theoretical: C 27.95%; H 3.02%; N 13.97%; S 26.65%. Found: C 26.89%; H 3.17%; N 12.99%; S 25.95%. Magnetic susceptibility (μeff): 3.8 BM. Molar conductivity (ΛM, DMF, 10^{-3} M): 1.5 μS·cm^{-1}.

$[NiL(AcO)_2]\cdot 4H_2O$ Complex: A black-colored nickel complex was obtained. The closed formula is $C_{14}H_{20}NiN_6O_8S_5$, and its molar mass is 619.34 g·mol^{-1}. The yield is 30%. The melting point (decomposition temperature) is above 300 °C.

FT-IR (ATR, cm^{-1}): 1310 (C=N–C), 813 (C–S-C), 1664 (C=N), 3068 (aromatic C–H), 3296–3500 (H_2O), 1488 (C=C), 501 (Ni–N), 1455/1380 (Ni–OAc, asymmetric/symmetric). UV-Vis (λmax, nm / Abs.): 270 (2.278), 330 (1.404), 525 (0.458). Elemental Analysis (C, H, N, S): Theoretical: C 27.15%; H 3.26%; N 13.57%; S 25.88%. Found: C 26.35%; H 2.81%; N 13.40%; S 24.47%. Magnetic susceptibility (μeff): 2.8 BM. Molar conductivity (ΛM, DMF, 10^{-3} M): 2.1 μS·cm^{-1}.

3. Results and Discussion

The new Schiff base ligand (L) was synthesized from the reaction of 5-amino-1,3,4-thiadiazole-2-thiol with thiophene-2,5-dicarboxaldehyde in a 2:1 ratio in an acetonitrile medium. The progress of the reaction was monitored by thin-layer chromatography (TLC). The obtained red-colored ligand is well soluble in solvents such as DMSO and DMF. The structure of the Schiff base ligand (L) was elucidated using elemental analysis, FT-IR, NMR, and UV-vis methods. The thiophene ring Schiff base ligand (L) was studied in a 1:1 stoichiometric ratio with $Cu(AcO)_2$.H2O, $Co(AcO)_2.4H_2O$ and $Ni(AcO)_2.4H_2O$ Metal ion complexes were obtained from the reaction of salts with a methanol/DMF (4/1) solvent mixture. The structure of the metal ion complexes was determined using elemental analysis, molar conductivity, magnetic susceptibility, IR, UV-vis, and TGA/DTA methods. The obtained spectroscopic and analytical findings showed that in the formation of the complex, the thiophene-ringed Schiff base ligand (L) coordinates to the metal ion through the nitrogen atoms in the imine group.

3.1. NMR Analysis of the Thiophene Ring SCHIFF Base Ligand (L)

In the ^{1}H NMR spectrum of the Schiff base ligand (L), the SH proton appears as a singlet at 13.80 ppm (Kumar et al., 2023). The SH proton in the 1,3,4-Thiadiazole ring exhibits acidic properties; after the proton is removed, the electron pair remaining on the S atom is delocalized over the ring. This is thought to increase the stability of the formed anion (Beytur et al., 2019; Shalinee and Kumar, 2024). The peaks of the HC=N imine protons appear as a singlet at 9.18 ppm, while the CH protons in the thiophene ring appear as a doublet at 8.08-7.14 ppm (Figure 2) (Capan et al., 2018; Begum et al., 2022). In the ^{13C} NMR spectrum of Schiff base ligand (L), the peak observed at 161.41 ppm corresponds to the signals of the C=N carbon in the thiophene ring (Shalinee and Kumar, 2024). Additionally, the carbons of the thiophene ring are observed at 146.88 and 138.56 ppm, respectively. The signals corresponding to the carbons of 5-amino-1,3,4-thiadiazol-2-thiol were observed at 186.93 and 163.41 ppm, respectively (Figure 3) (Suganya et al., 2014; Warad et al., 2019). The reason the carbons in the thiadiazole ring appear at such low fields is due to the presence of electronegative S and N atoms in the structure The carbon signals observed in the ^{13}C-NMR spectrum support the proposed structure (Babu et al., 2020; Süleymanoğlu et al., 2020; Begum et al., 2022; Kumar et al., 2023; Mishra et al., 2023).

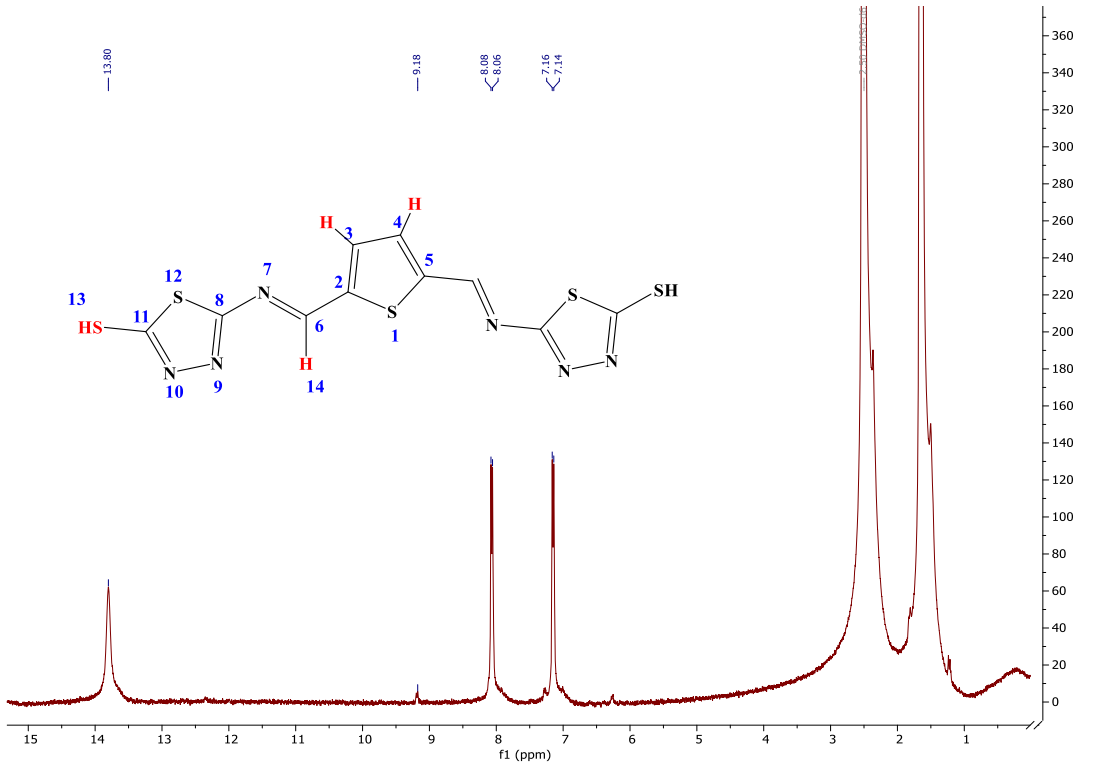

Figure 2. ^{1}H NMR spectrum of thiophene ring Schiff base ligand (L).

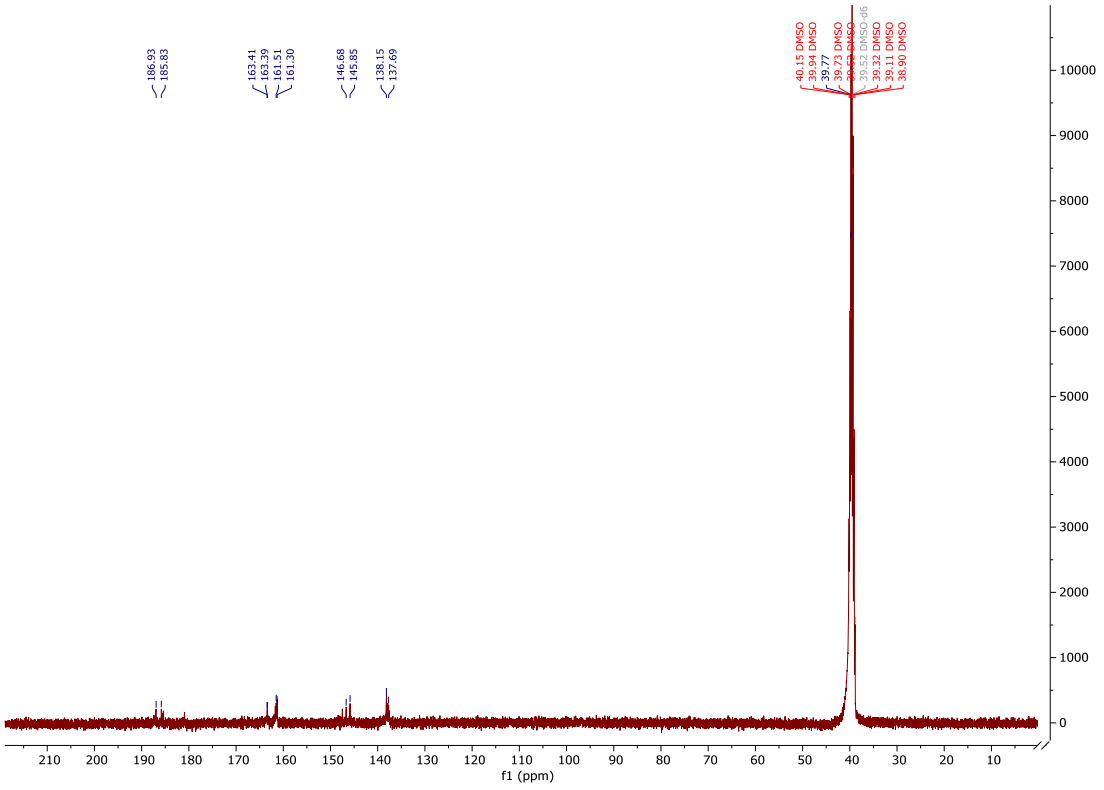

Figure 3. ^{13}C NMR spectrum of thiophene ring Schiff base ligand (L).

It is understood that the integral ratios observed in the 1H NMR spectrum and the chemical environment of the carbon observed in the ^{13}C NMR spectrum of the thiophene ring Schiff base ligand (L) confirm the proposed structure for the ligand

3.2. FT-IR Analysis of the Thiophene Ring Schiff Base Ligand (L) and Metal Complexes

The FT-IR analysis of the thiophene ring Schiff base ligand (L) and metal ion complexes was conducted in the range of 4000-400 cm-1 using the ATR method, examining the functional groups.

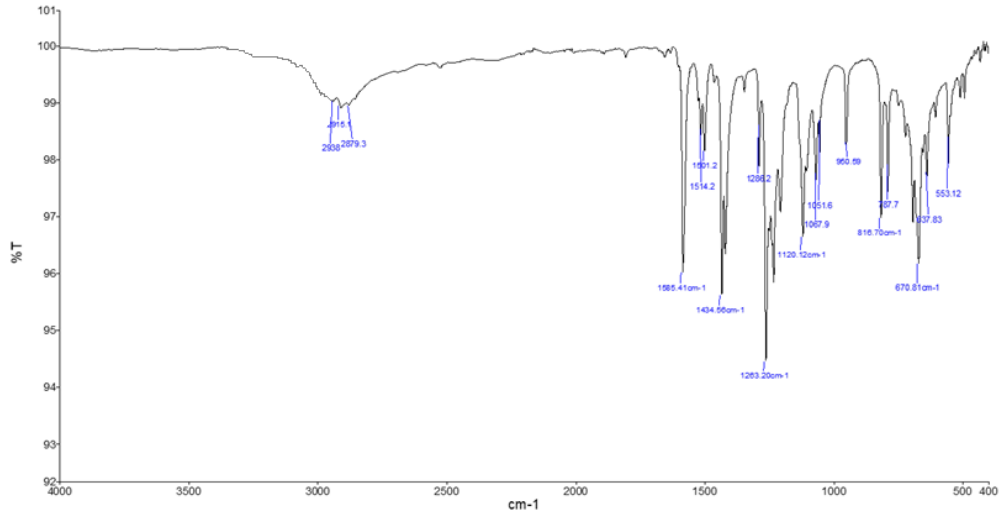

Figure 4. FT-IR spectrum of thiophene ring Schiff base ligand (L).

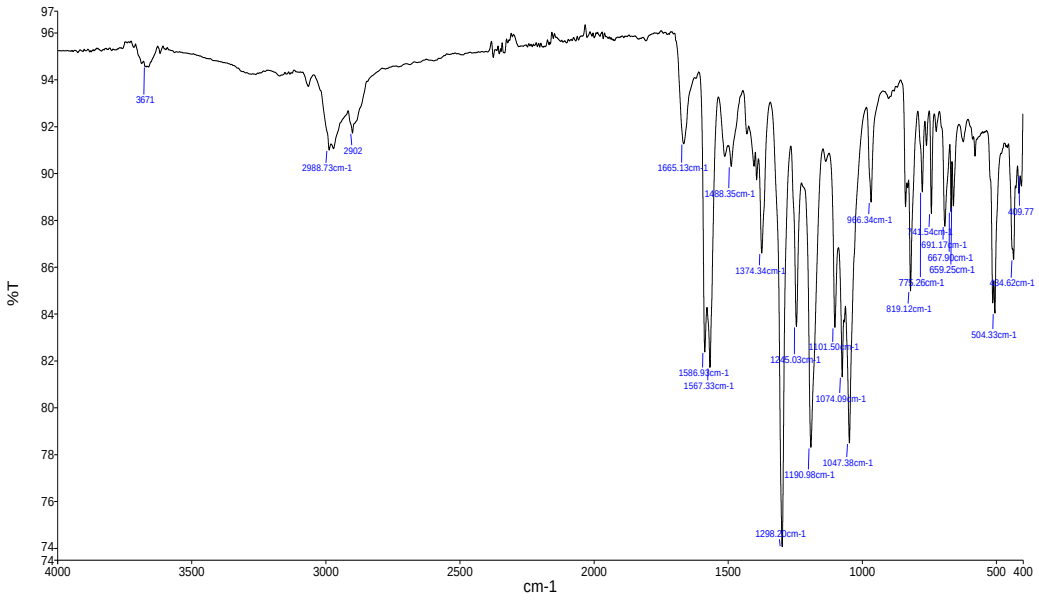

Figure 5. FT-IR spectrum of Cu (II) metal complex of thiophene ring Schiff base ligand (L).

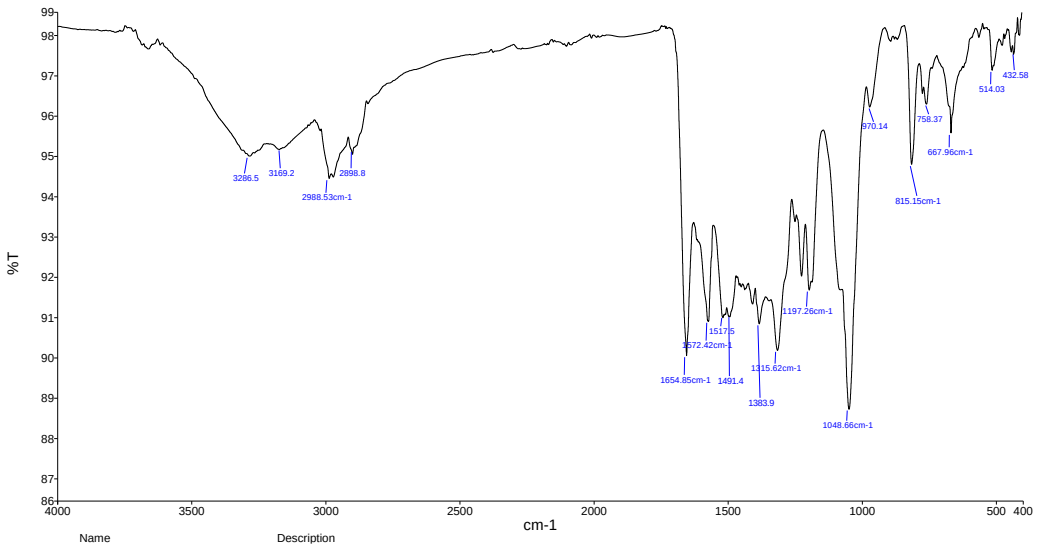

Figure 6. FT-IR spectrum of Co (II) metal complex of thiophene ring Schiff base ligand (L).

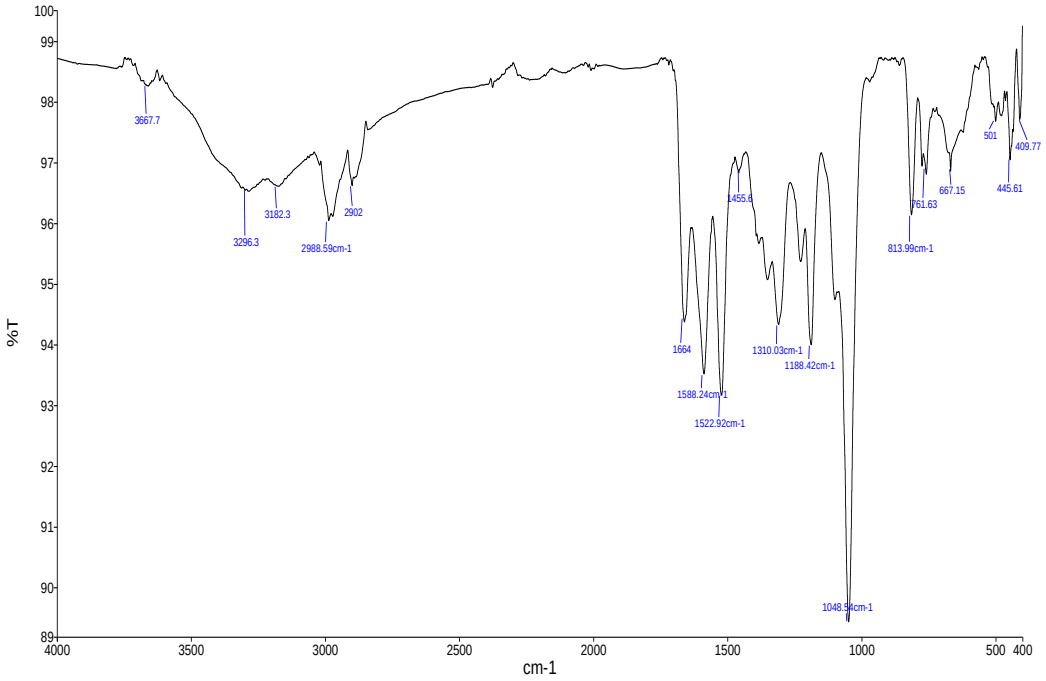

Figure 7. FT-IR spectrum of Ni (II) metal complex of thiophene ring Schiff base ligand (L).

In the FT-IR spectrum of ligand (L), stretching vibrations for the S-H bond associated with the 5-amino-1,3,4-thiadiazole ring are observed at 2722 cm^{-1} ν(S-H). From the FT-IR spectrum of ligand (L), bending bands at 1263 cm^{-1} (C=N-C) and 1120 cm-1 (N-N) and stretching bands at 1350 cm^{-1} (C-S-C) and 816 cm^{-1} (C-S) belonging to the thiophene ring can be observed (Babu et al., 2020; Bingöl and Turan, 2020; Süleymanoğlu et al., 2020; Mishra et al., 2023). Additionally, bending bands at 1514 cm^{-1} (S-C=N) and a strong stretching vibration band at 1585 cm^{-1} corresponding to the azomethine bond (C=N) are observed (Shaalan et al., 2022). On the other hand, stretching vibrations of ν(C=C) at 1434 cm^{-1} and stretching vibrations of ν(C-H) belonging to the thiophene ring in the range of 2938-2879 cm^{-1} are observed (Figure 4) (Abdel Aziz and Seda, 2017; Soliman et al., 2025). It was observed that the vibrational frequencies seen in the FT-IR spectrum of the thiophene ring Schiff base ligand (L) support the ligand structure and are consistent with the vibrational frequencies in the literature (Zhang et al., 2009; Pandey et al., 2012; Chandra et al., 2015; Babu et al., 2020; Bingöl and Turan, 2020; Süleymanoğlu et al., 2020).

When examining the FT-IR spectra of the $[CuL(AcO)_2]\cdot 3H_2O$, $[CoL(AcO)_2]\cdot 3H_2O$, and $[NiL(AcO)_2]\cdot 4H_2O$ complexes, it provides important information about the coordination of the ligand with metals and the formation of the complexes. In all complexes, bending bands at approximately 1290–1315 cm^{-1} (C=N–C), stretching bands at 813–819 cm^{-1} (C–S–C), aromatic stretching bands at around 2898 cm^{-1} (C–H), and broad bands belonging to water molecules in the range of 3300–3500 cm^{-1} are observed. Additionally, in the spectrum of each complex, stretching vibrations (C=C) are observed in the range of 1455–1491 cm^{-1}. The ν(C=N) vibration frequency of the azomethine group is located at 1585 cm^{-1} for ligand L. In the complexes, this frequency is observed at a higher wavenumber of 1665 cm^{-1} for Cu(II), 1655 cm^{-1} for Co(II), and 1664 cm^{-1} for Ni(II), indicating that the ligand (L) coordinates with metal ions through the nitrogen atom in the imine group (Figure 5-7) (Pandey et al., 2012; Chandra et al., 2015; Abd-El-Aziz et al., 2025).

In the FT-IR spectra of the $[CuL(AcO)_2]\cdot 3H_2O$, $[CoL(AcO)_2]\cdot 3H_2O$, and $[NiL(AcO)_2]\cdot 4H_2O$ complexes, stretching vibrations corresponding to Cu–N at 550 cm^{-1}, Co–N at 514 cm^{-1}, and Ni–N at 501 cm^{-1} are observed. Additionally, the appearance of asymmetric and symmetric stretching vibrations corresponding to Cu-OAc at 1488/1374 cm^{-1}, Co-OAc at 1491/1383 cm^{-1}, and Co-OAc at 1455/1380 cm^{-1} in the spectra of each complex indicates the formation of M(II) complexes (Zhang et al., 2009; Süleymanoğlu et al., 2020; Babu et al., 2020; Saritha and Metilda, 2021; Pandey et al., 2022; Soroceanu and Bargan, 2022).

3.3. UV/vis Analysis of the Thiophene Ring Schiff Base Ligand (L) and Metal Complexes

The absorption band observed at 270 nm in the UV-vis spectrum of the thiophene-ringed Schiff base ligand ligand (L) corresponds to the π-π* transitions of the thiophene ring. Additionally, the absorption bands at wavelengths of 325, 370, 455, and 580 nm correspond to the π-π* and n-π* transitions of the thiadiazole ring (Zhang et al., 2009; Warad et al., 2019; Kumar et al., 2023; Soliman et al., 2025).

The absorption bands observed at wavelengths of 280 and 545 nm in the UV-vis spectrum of the Cu(II) complex are due to π-π* and weak d-d transitions associated with

the thiol ring (Zhang et al., 2009). Similarly, the bands observed in the 270-280 and 550-525 nm wavelength range for Co(II) and Ni(II) complexes correspond to the π-π* and weak d-d transitions of the thiol ring (Figure 8) (Warad et al., 2019; Kumar et al., 2023; Soliman et al., 2025).

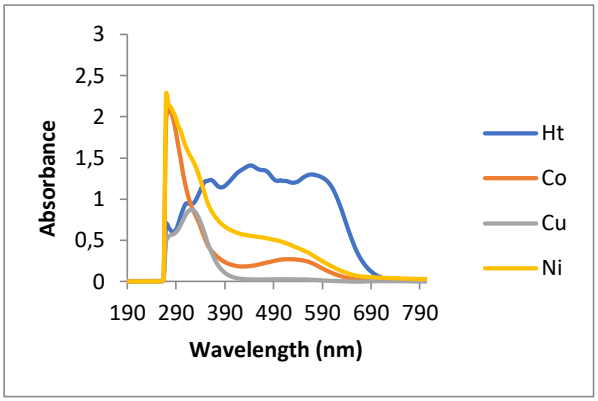

Figure 8. UV-vis spectrum of thiophene ring Schiff base ligand (L) and metal ion complexes.

3.4. Magnetic Susceptibility and Electronic Conductivities Analysis of the Metal Complexes

Magnetic susceptibility has found applications in various fields such as materials science, geophysics, medicine, and archaeology. The magnetic susceptibility value of a complex varies depending on the geometry and electron configuration of that complex. The magnetic susceptibility measurements of the synthesized metal ion complexes and the standard material were conducted at 25 °C for each sample, and the magnetic moment value was calculated in Bohr magnetons (BM). The CBAL value was obtained from the magnetic susceptibility measurements of the standard material. The magnetic moment values of the Cu(II), Co(II), and Ni(II) complexes were determined to be 2.3, 3.8, and 2.8 BM, respectively. It was observed that the magnetic moment values found for the synthesized metal ion complexes are consistent with the magnetic moment values observed for tetrahedrally coordinated Cu(II), Co(II), and Ni(II) complexes in the literature (Zhang et al., 2009; Bandi et al., 2014; Babu et al., 2020). It was understood that the electrolytic conductivity of the metal ion complexes was between 1.5-2.9 $\mu S.cm^{-1}$ [Cu(II) complex: 2.9, Co(II) complex: 1.5 and Ni(II) complex: 2.1 $\mu S.cm^{-1}$] and therefore, the complexes did not have electrolytic conductivity.

3.5. TGA/TDA Analysis of the Metal Complexes

TGA/DTA analyses were conducted to determine the thermal stability of Cu(II), Co(II), and Ni(II) metal ion complexes of some thiophene ring Schiff ligands (L) and the type of H_2O molecules in the complex structures (ligand or hydrate). For this purpose, the thermal properties of the metal ion complexes were examined by measuring them in a dry air environment within the temperature range of 25-1000 °C, with a temperature increase of 10 °C every 60 seconds. $[CuL(AcO)_2].3H_2O$, $[CoL(AcO)_2].3H_2O$ and $[NiL(AcO)_2]\ 4H_2O$. From the TGA curve of the $2H_2O$ complexes, it is understood that the complexes degrade in three steps (Figure 9, 10 and 11). $[CuL(AcO)_2]$. In the first step for the $3H_2O$ complex, dehydration of 3 moles of water (H_2O) is observed in the temperature range of 0-200 °C. In the second step, the decrease observed in the TG curve in the temperature range of 200-400 °C indicates the separation of organic compounds [acetate groups (CH_3COO-) and partially thiazole rings] from the structure. In the third stage, a sharp mass loss in the temperature range of 400-800 °C indicates that the organic structures completely degrade and burn, converting into metal oxide (CuO) (Chandra et al., 2015; Xiong et al., 2015; Begum et al., 2022). [CoL(AcO)2]. In the first step for the $3H_2O$ complex, a loss of 3 moles of water (H2O) occurs around 200 °C. In the second step, the thermal decomposition of organic compounds [acetate groups (CH3COO-) and thiazole rings] is observed in the temperature range of 400-600°C. In the third stage, the formation of CoO is observed at 800°C and beyond, with no further mass loss detected (Chandra et al., 2015; Xiong et al., 2015; Begum et al., 2022).

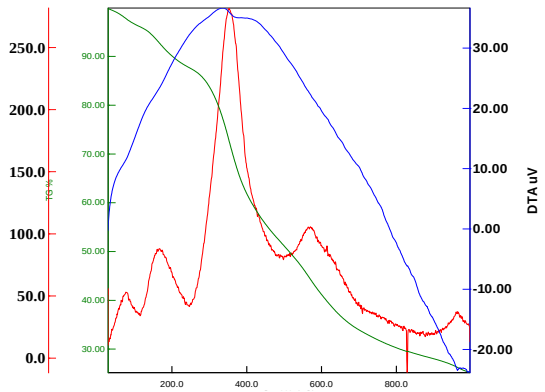

Figure 9. TGA/DTA thermogram of the complex $[CuL(AcO)_2].3H_2O$.

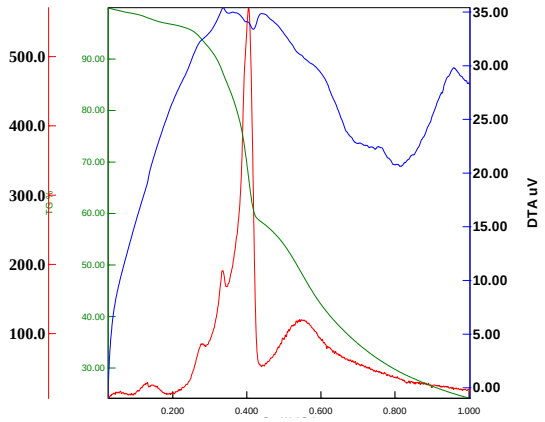

Figure 10. TGA/DTA thermogram of the $[CoL(AcO)_2].3H_2O$ complex.

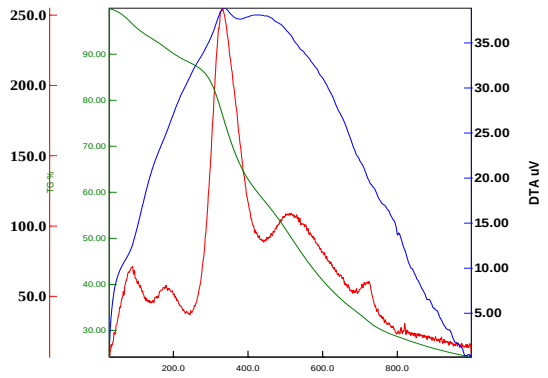

Figure 11. TGA/DTA thermogram of the complex $NiL(AcO)_2].4H_2O$.

[NiL(AcO)2]. In the first step for the 4H2O complex, dehydration of 4 moles of water (H2O) is observed in the temperature range of 100-200 °C. In the second step, the thermal decomposition of organic compounds [acetate groups (CH3COO-) and thiazole rings] is observed in the temperature range of 200-400 °C. In the third stage, it is observed that the mass loss slows down and reaches a balance above 400 °C. At this stage, the organic residues decompose and convert into metal oxide (NiO) (Chandra et al., 2015; Xiong et al., 2015; Begum et al., 2022).

In conclusion, the proposed structures of the thiophene-ringed Schiff base ligand (L) for metal ion complexes are consistent with the mass losses and thermal decomposition processes observed in the TGA curves. In the first step, the loss of water from the complex structures, in the second step, the separation of organic compounds, and in the final step, the amount of final residue, are consistent with theoretical calculations. The TGA values and the calculated values are also consistent with the literature. From the TGA curves, it is understood that the thermal stabilities of the metal ion complexes increase in the order of Co(II)>Cu(II)>Ni(II). Results and Discussion can be combined if the editor accepted.

4. Conclusion

In recent years, heterocyclic compounds such as pyridine, thiophene, and thiadiazole ringed ligands and their metal complexes have drawn significant attention due to their biological activities. In this study, a novel thiophene-ringed Schiff base ligand (L) and its Co(II), Cu(II), and Ni(II) metal complexes were synthesized and characterized. The structure of the ligand was elucidated by elemental analysis, FT-IR, ^{13}C-NMR, ^{1}H-NMR, and UV-Vis spectroscopic techniques. The metal complexes were analyzed using elemental analysis, FT-IR, magnetic susceptibility, molar conductivity, and TGA/DTA techniques. Results indicated a 1:1 ligand-to-metal ion stoichiometry, and the metal complexes were proposed to adopt a four-coordinate tetrahedral geometry.

In recent years, studies on Schiff bases containing thiophene rings and biologically active metal complexes have been highlighted, emphasizing their significant potential in various fields. Thiophene-derived Schiff bases and their metal complexes are attracting attention not only for their biological activities but also for their wide application potential in diverse fields such as biomedicine, sensor technology, materials science, and catalysis. Specifically, advancements in biological activity and sensor-based growth further enhance the potential for use in this configuration. The synthesized Schiff base and its metal complexes' potential biological activities, such as antimicrobial and antioxidant properties, lay the groundwork for future studies.

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	A.Ç.	A.E.H.	M.S.
C	40	20	40
D	40	20	40
S	40	20	40
DCP	40	30	30
DAI	40	30	30
L	40	20	40
W	50	30	20
CR	50	30	20
SR	40	30	30
PM	40	30	30

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study since there was no study on animals or humans.

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