

Synthesis Involving Asymmetric Pyrazine-Schiff Base with Co^{2+} , Ni^{2+} and Cu^{2+} ions: Spectral and Magnetic Characterization; and Antibacterial studies

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Abstract:- New-fangled Co^{2+} , Ni^{2+} and Cu^{2+} complexes with novel pyrazine-Schiff base, $(\text{C}_2\text{H}_2\text{NC}_2\text{HN})\text{C}(\text{O})\text{:N}=\text{CH}(\text{C}_4\text{H}_3\text{S})$ derived from thiophene-2-carbaldehyde and pyrazine-2-carboxamide in ethyl-alcohol have been successfully synthesized. The metallic compounds and their Schiff base ligand were characterized via analytical (complexometric, molar conductivity, magnetic susceptibility and melting point); and spectral (CHNS, FT-IR, UV-Vis ^1H and ^{13}C NMR; and ESI-MS) methods. The spectral results corroborates tridentate chelating nature for the Schiff base ligand forming a six coordinate octahedral geometry in 2L:1M mole ratio with Co^{2+} , Ni^{2+} and Cu^{2+} ions separately. The metallic compounds assumed monomeric assemblage with assigned geometry validated by magnetic susceptibility values. The molar conductivity data confirms that all the pyrazine-Schiff base complexes are electrolytes of 2:1 mole ratio in dimethylsulphoxide. The metallic compounds demonstrated better anti-bacterial activities compared to the Schiff base, but the Cu^{2+} complex had the best in vitro activity against all the screened microbes, validating its possibility of exhibiting broad spectrum antibacterial activity.

Keywords: Pyrazine, Schiff base, electrolytes, magnetic susceptibility and metallic complexes.

I. INTRODUCTION

The chemistry of $-\text{C}=\text{N}-$ moiety bearing chelators and their metallic compounds have been an interesting aspects of bioinorganic chemistry¹ in the last two decades, owing to their vast applications. The former which are termed Schiff bases, bind and stabilize different metallic ions at several oxidation states² making them a special class of chelators. However, Schiff bases bearing heterocyclic arrangements own greater degree of binding affinity to biological structures with pronounced therapeutic, analytical, and industrial uses. Broad spectrum biological activities as documented are associated to heterocyclic nitrogenous compounds including pyrazine derivatives³. Metallic compounds of heterocyclic Schiff bases have found applications as probable drugs, owing to the existence of various characteristic moieties^{4,5}. Pyrazine is recognized to universally occur in wildlife as vital component of fused oil, cocoa bean, green peas, molds resembling

Aspergillus flavus, *A. oryzae*, etc and have been engaged as synthetic forerunner of bioactive compounds. An extensive range of therapeutic active compounds of pyrazine, and its applications in antibiotics is becoming progressively vast mostly with the functionalized derivatives⁶. Pyrazine derivatives are documented to display a wide range of pharmacological activities consisting of anticancer, antitubercular, diuretic, antidiabetic, insecticide and nematocide⁷⁻⁹. Also, drugs bearing pyrazine structure have remained famous chemotherapeutic agents and are applied as inhibitors against various tumor enzyme targets. For instance, the pyrazine moiety containing drug, oltipraz has been documented for cancer-growth inhibition¹⁰. Similarly, zibotentan has been practically used as a proficient cancer drug-candidate¹¹. However, imidazole[1,2-*a*]pyrazine and 5,7-disubstituted-6-amino-5*H*-pyrrolo[3,2-*b*]pyrazine-2,3-dicarbonitrile have gained relevance as core prospective aurora kinase and protein kinase inhibitors with the latter exhibiting excellent antiproliferative activity^{12,13}. Also, the active pyrazine derivative 3-alkoxyamino-5-(pyridine-2-ylamino)pyrazine-2-carbonitrile is a potent and multi-targeted cancer inhibitors' drug and reported orally active as well as highly selective Chk1 inhibitor with IC₅₀ 7.7 nM¹⁴. Reportedly, pyrazine moiety serves as building blocks for biologically significant compounds including the antimycobacterial agent containing N'-[(E)-(mono substituted benzylidene)]-2-pyrazinecarbohydrazides found sensitive against Mtb ATCC 27294¹⁵ and antithrombotic candidate comprising 6-(difluoromethoxy)-2,5-dimethylpyridin-3-amino assembly¹⁶. Similarly, functionalized pyrazine derivatives found applications in development of drug utilized for the management and cure of diabetics¹⁷, Hepatitis C¹⁸, tuberculosis¹⁹, smoking addiction²⁰ and oxidative allergies²¹. Various pharmacological activities documented for pyrazine bearing drugs/agents might be ascribed to their exhibited low toxicity and structural resemblance to biological systems⁶. Following all observations; and as a measure of continuing our research with the coordination study of heterocyclic Schiff base ligands²²⁻²⁴, We here report the synthesis and

characterization of M^{2+} ($M=Cu, Co$ and Ni) compounds of a new pyrazine Schiff base chelator, $(C_2H_2NC_2HN)C(O):N=CH(C_4H_3S)$. The divalent metallic compounds were examined experimentally for several analytical, spectroscopic, magnetic interactions (i.e. ferromagnetism, anti-ferromagnetism and ferrimagnetism) and geometric properties.

II. MATERIALS AND METHODS

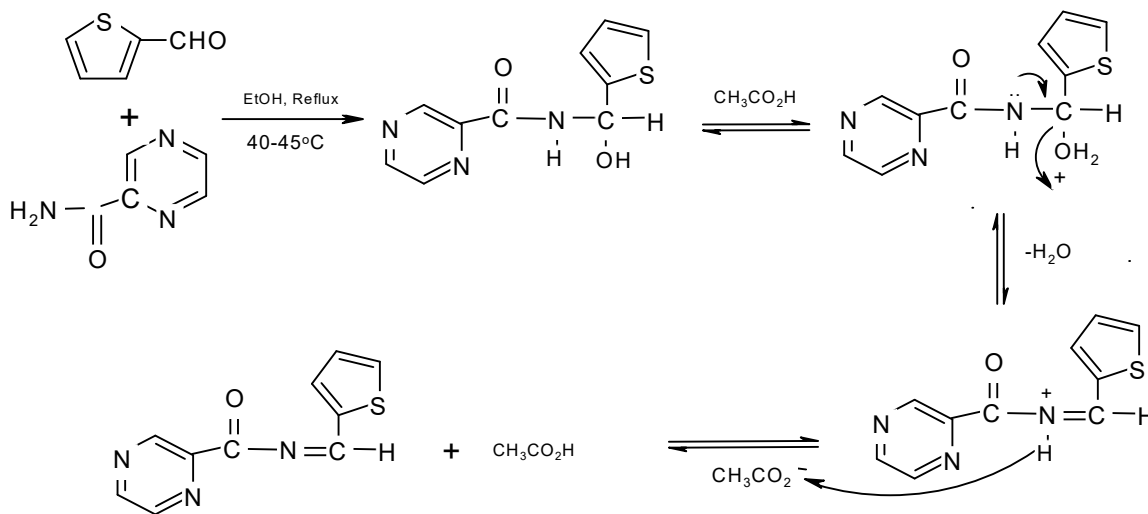
Entirely, the reagents; thiophene-2-carbaldehyde, pyrazine-2-carboxamide, $Ni(OAc)_2 \cdot 4H_2O$, $Co(OAc)_2 \cdot 4H_2O$ and $Cu(OAc)_2 \cdot 2H_2O$, CH_3CHO_2H , $(C_2H_5)_3N$ and EDTA, were of AnalaR rating acquired from Sigma-Aldrich Limited and used without additional distillation. The solvents; CH_3OH , CH_3CH_2OH were acquired as container standards and distilled using traditional methods²⁵. Uncorrected melting / decomposition points for the synthesised compounds were obtained on an Electro thermal melting point apparatus model-AZ6512. The ligand with its metallic complexes were assessed for solubility in polar and non-polar solvents. The elemental (CHNS) analysis for all synthesized compounds was evaluated using a Fison EA 1108 analyzer. Vibrational spectra (FT-IR) values were acquired by means of KBr disc method on SHIMADZU-8400, FTIR spectrophotometer as triplet shots at the range $4000-350\text{ cm}^{-1}$, whereas the electronic (UV-Vis) data recorded as solid reflectance scan on Lambda 25 UV/visible spectrophotometer within 190-900 nm range. Bruker DRX-400 MHz spectrophotometer was adopted to record the proton as well as carbon-13 NMR spectra for the ligand in d_6 -dimethylsulphoxide, while Tetramethylsilane (TMS) served as reference to the chemical shifts. Electrospray ionization type mass spectra (ESI-MS) disintegration form for the Schiff base was acquired using micrOTOF-Q II 10390 spectrometer. The HANNA HI 991300 conductivity cell

meter containing dip-type cell standardized in KCl solution was used to obtain molar conductivity values for the complexes. Magnetic susceptibility evaluation of the metallic compounds was acquired at 29°C on Johnson Mathey magnetic susceptibility balance. Pascal's constants were adopted for the diamagnetic corrections. The metallic ions' proportion contents in all complexes were achieved complexometrically with 0.01Methylenediaaminetetraacetic acid (EDTA) solution.

III. EXPERIMENTAL

Synthesis of $(C_2H_2NC_2HN)C(O):N=CH(C_4H_3S)$ Ligand

Ethyl-alcohol solution (30 mL) of pyrazine-2-carboxamide (0.00045 mmol, 5400 mg) and thiophene-2-carbaldehyde (0.00045 mmol, 5000 mg) were refluxed in the presence of glacial CH_3COOH for 300 mins on a magnetic-stirrer hotplate. The resulting precipitates of the product obtained on cooling at 0°C were recovered through gravity filtration and recrystallized from ethyl-alcohol. ISIS-draw and Chem-draw were separately adopted to generate the chemical structure as well as the nomenclature of the Schiff base ligand. Molecular weight, 217.186 g/mol, Yield: 66%. Shade: brown, m.p: 236-238 $^\circ\text{C}$. IR(KBr) ν/cm^{-1} : 3408m (H...N), 3146s (CH), 1699s (C=O), 1606s (C=N), 1434s (C=C), 1374s (C-N), 1161m (C-C), 1020s (C-S), 868s, 784s, 668s δ (C-H). ^1H NMR (300 MHz, $DMSO-d_6$) δ ppm: 7.85 (s, H-C=N); 8.66-8.67 (d d, 2H, $H_{5,6}$ pyrazine); 8.23 (s, 1H, H_2 pyrazine); 8.81 (d, 1H, H_{12} thiophene); 9.16 (d, 1H, H_{13} thiophene); 7.94 (d, 1H, H_{11}). ^{13}C NMR (75 MHz, $DMSO-d_6$) δ ppm: 145.4 (C_2), 143.7 (C_3), 165.5 ($C_{5,6}$); 147.8 (C_9), 144.1 (C_7), 40.5 (C_{10}), 40.3 (C_{13}), 40.1 (C_{11}) and 39.9 (C_{12}). UV/visible (cm^{-1}): 36215, 35811 ($\pi-\pi^*$), 26661, 25635 ($n-\pi^*$); Anal.(Cald). for $C_{10}H_7N_3OS$ (%): C, 55.29 (55.26), H, 3.25 (3.31), N, 19.35, (19.29).



Scheme 1: Synthetic Routes for the Synthesis of the Schiff Base Ligand

Synthesis of Bivalent Metallic Compounds

Approximately, 5000 mg (0.000012 mmol) of $(C_2H_2NC_2HN)C(O):N=CH(C_4H_3S)$ ligand liquefied in ethyl alcohol (30 mL) was reacted with an molar concentrations of the metallic acetate salts of Co(II), Ni(II) and Cu(II) pre-dissolved in ethyl alcohol (20 mL) separately. The subsequent uniform solution was buffered using trimethylamine (0.3 mL) until a pH of 9 was reached and then refluxed for 240 mins at 50-55°C temperature choice. Obtained products were cooled to 0°C, filtered under gravity, recrystallized using ethyl-alcohol, and dried over $CaCO_3$. The test of stability indicates all metallic compounds at room temperature were non-hygroscopic and stable exhibiting realistic solubility majorly in DMSO and DMF.

Antibacterial Activity

This study employed disc-diffusion procedure for the examination of the anti-bacterial actions of the synthesized $(C_2H_2NC_2HN)C(O):N=CH(C_4H_3S)$ ligand against gram negative microbes; *Pseudomonas aeruginosa*, *Protus mirabilis*, *Klebsiella oxytoca* and *Escherichia coli*, and gram positive species; *Staphylococcus aureus* and *Bacillus cereus* as reported in our earlier works^{26,27} with slight modifications. All bacterial cultures were cultured at the microbiology laboratory, University of Ibadan, Nigeria. The bacterial concentration was attuned to 0.5 McFarland standard components and the suspension then spread over Mueller–Hinton agar plates using sterilized cotton swabs. Thereafter, wells were drilled on the hardened agar-medium using sterile borer (9 mm). Consequently, 10 mL test compound (10 mg/mL liquefied in dimethylsulphoxide) was poured onto corresponding drilled well. For 24 h, all the plates were incubated at 35 °C. The inhibition zones growth (mm) were obtained after two replicates of individual test compound.

Streptomycin was applied as a standard measure whereas dimethylsulphoxide was adopted as the non-positive measure.

IV. RESULTS AND DISCUSSIONS

Equal-molar ratio reaction of thiophene and pyrazine derivatives in an alcohol medium gave the HL ligand, $(C_2H_2NC_2HN)C(O):N=CH(C_4H_3S)$. The Schiff ligand was further reacted with acetate salts of Co^{2+} , Ni^{2+} and Cu^{2+} ions to afford the resultant M^{2+} compounds. The spectral, analytical, theoretical and magnetic data validated the molecular formulas and structures of the synthesized Schiff base ligand as well as its M^{2+} compounds. The metallic compounds were intensely colored and unchanging solids.

Elemental analysis, metallic ions' proportion contents and molar conductance evaluation

The C.H.N.S content analysis corroborated a 1:1 and 2:1 stoichiometric ratio for the synthesized HL ligand and its the metallic compounds. All experimental data obtained strongly conformed with the theoretical values and were in agreement with suggested elemental compositions for all the synthesized compounds. Largely, the metallic compounds assumed stability and anhydrous nature at distinctive conditions exhibiting numerous shades. Results of metallic ions' proportions acquired by means of complexometric technique indicated excellent agreements between experimental as well as theoretical data in contents proportion of metallic ions in all complexes. Similarly, the molar conductivity evaluation for the metallic compounds in DMSO assumed values in the range 97.50–1129.01 $ohm^{-1}cm^2mol^{-1}$. The values describes 2:1 mole electrolytic compounds, as values beyond 30 $ohm^{-1}cm^2mol^{-1}$ and 90 $ohm^{-1}cm^2mol^{-1}$ are repeatedly associated with 1:1 and 2:1 electrolytes separately^{28,29}.

Table 1: Analytical Data of the Synthesized Compounds

Compound	FW (g/mol)	Shade	Elemental Analysis (%)					% Yield	Melting Point (°C)
			(observed/theo)						
			C	H	N	S	M		
HL	217.244	Brown	55.19 (55.28)	3.21 (3.25)	6.44 (6.45)	14.72 (14.75)	-	66.07	235-238
$C_{10}H_7N_3OS$ [Co(L) ₂]	493.418	Gray	48.61 (48.68)	2.15 (2.19)	16.96 (17.03)	12.93 (12.99)	11.89 (11.94)	59.14	300-302
$C_{20}H_{14}N_6O_2S_2$ Ni(L) ₂ ·H ₂ O	511.212	Redish-	47.03 (46.98)	3.11 (3.15)	16.39 (16.44)	12.49 (12.54)	11.51 (11.48)	77.81	248-251
$C_{20}H_{16}N_6O_3S_2$ [Co(L) ₂]	498.028	Brown	48.17 (48.23)	2.79 (2.83)	16.79 (16.87)	12.92 (12.87)	12.69 (12.75)	61.09	286-290

Nuclear Magnetic Resonance (¹H- and ¹³C-NMR) Studies

The HL ligand proton spectrum acquired in *d*₆-DMSO and presented as figure 1 indicates the non-existence of a resonance signal (20.0–15.0 ppm) characteristic of an OH moiety and frequently associated with hydroxyl derivatives of thiophene, however, a peak at 7.85 ppm was spotted. The latter corroborates enolimine tautomeric structure for the synthesized HL ligand giving credence to a pyrazinethiophene

Schiff base formation. The proposed structure for the Schiff base ligand was established by the presence of a singly resonated peak around 7.85 ppm supportive of an imine (H-C=N) functional group. The peaks at 8.67 ppm (double-doublet) and 8.23 ppm (lone peak) were typical of the aromatic pyrazine protons, while the doublet peaks at 7.94 ppm, 8.81 ppm and 9.16 ppm were associated with the thiophene hydrogen atoms. The carbon-13 spectrum of the

ligand shown in figure 3 exhibited resonance signals arising from the pyrazine carbon atoms (C_2 , C_3 , $C_{5,6}$) at 145.5, 143.7 as well as 165.5 ppm. The signals within the range 39.90-40.53 ppm were cautiously allocated to C_{11} , C_{12} and C_{13} atoms

independently of the thiophene ring. Similarly, identified single signals separately at 147.8 ppm and 144.1 ppm were attributed to C_9 and C_7 atoms of the azomethine and ketonic functional groups

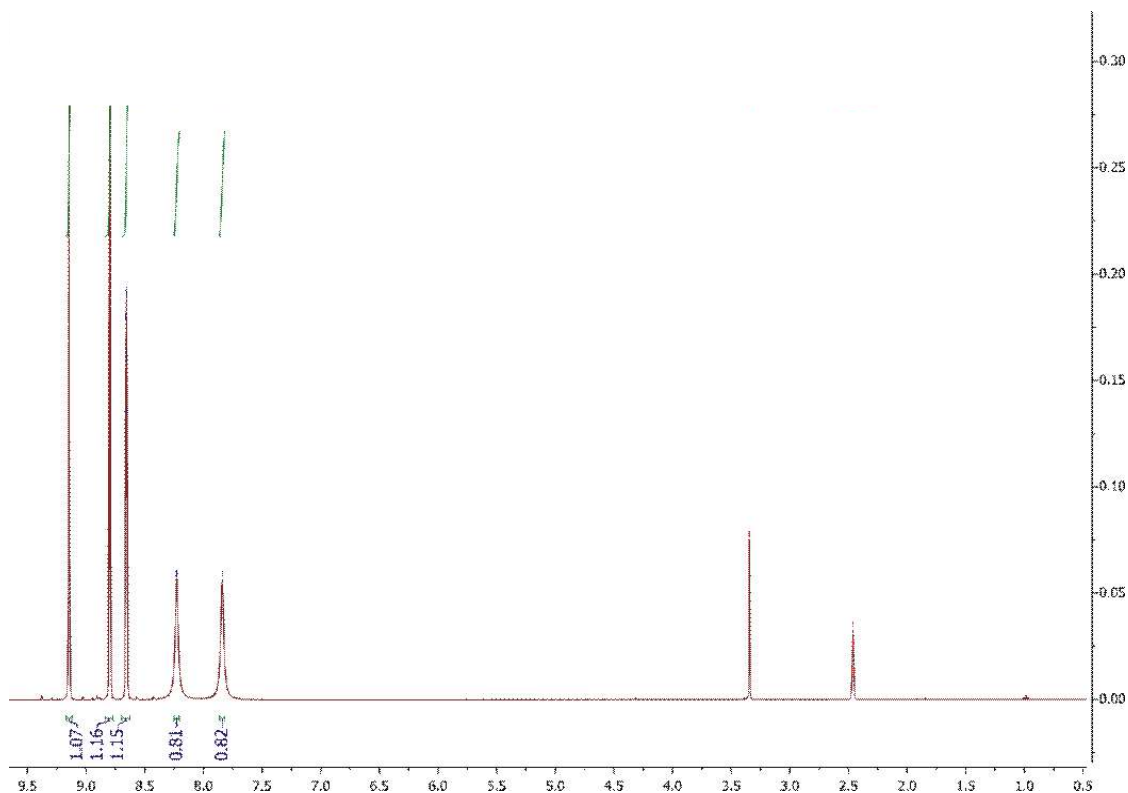


Figure 1: ^1H NMR spectrum of $(\text{C}_2\text{H}_2\text{NC}_2\text{HN})\text{C}(\text{O})\text{:N}=\text{CH}(\text{C}_4\text{H}_3\text{S})$ Ligand

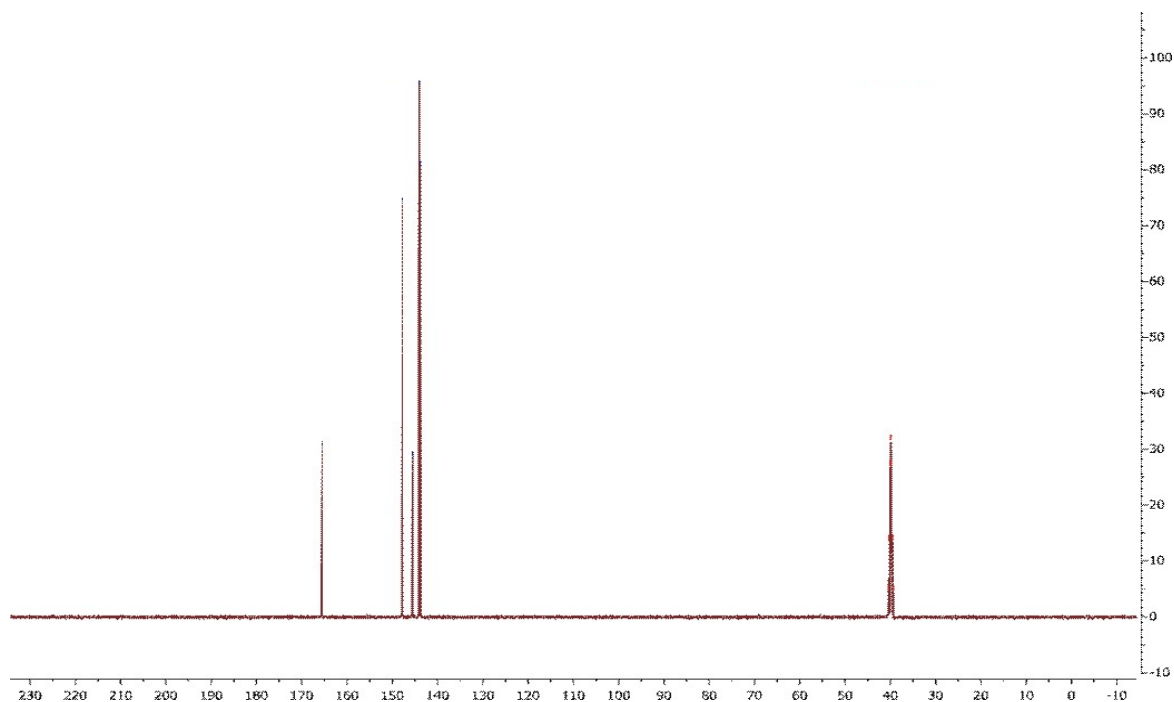


Figure 2: ^{13}C NMR spectrum of $(\text{C}_2\text{H}_2\text{NC}_2\text{HN})\text{C}(\text{O})\text{:N}=\text{CH}(\text{C}_4\text{H}_3\text{S})$ Ligand

Mass Spectral Studies

The Schiff base ligand $(C_2H_2NC_2HN)C(O):N=CH(C_4H_3S)$ was studied for fragmentations of its constituents as well as to determine its stoichiometric assemblages using mass spectrometry. The base peak was detected at m/z 229.186 conforming to the calculated formula weight of 217.186 of the

Schiff base ligand. The increase in the m/z value is a consequence of the extra mass unit of impure carbon-13. Resonated peaks at m/z 202.162, 174.188 and 117.187 were owing to a loss of the moieties $H-C=N$, CO , $H-C_2S$ separately. Additionally, the mass spectrum presented in figure 3 exhibited a polymerization peak at m/z 579.241.

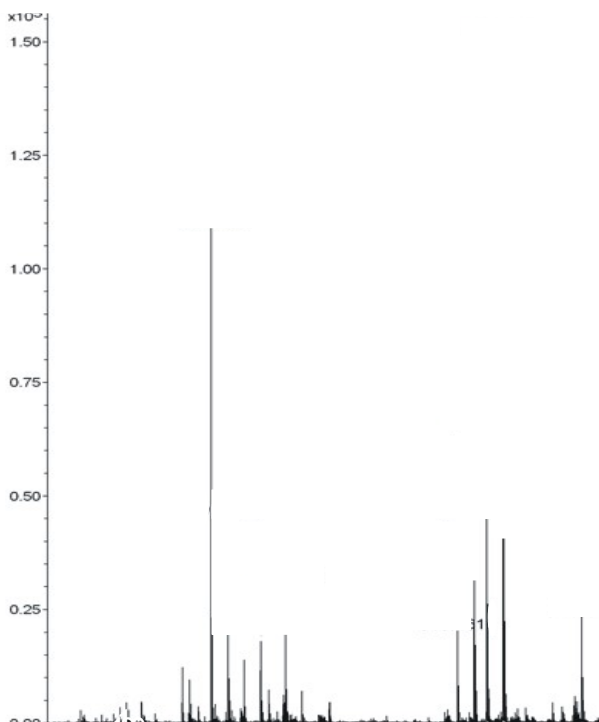


Figure 3: Electrospray Ionization Mass Spectrum of $(C_2H_2NC_2HN)C(O):N=CH(C_4H_3S)$ ligand

Vibrational (FT-IR) Studies

Significant vibrational bands in the FT-IR spectra of the synthesised compounds (Figures 6-9) stood carefully apportioned on comparison with reported literature of similar structures^{30,31}. The medium band in the FT-IR spectrum of the chelator, $(C_2H_2NC_2HN)C(O):N=CH(C_4H_3S)$ at 3408 cm^{-1} was entirely lacking in the spectra of the M^{2+} compounds, but assignable to intramolecular hydrogen bonding ($\nu_{H\dots N}$) and typical of an enol tautomeric assemblage giving credibility to the formation of the Schiff base. The appearance of the band further corroborates dehydration of the reaction intermediate, carbanolimine as well as non-existence of OH and NH vibrational bands frequently observed in precursors²⁶. The characteristic band at 3146 cm^{-1} observed in the ligand's spectrum due to C-H vibrations underwent slight shift to lesser/higher frequencies in the spectra of the M^{2+} compounds. The M^{2+} compounds in their respective spectrum indicated that vibrational bands arising from the ketonic (C=O) and

imine (C=N) functional groups at 1699 cm^{-1} and 1606 cm^{-1} within the spectrum of the ligand moved to higher/lesser frequencies at the ranges $1654\text{--}1702\text{ cm}^{-1}$ and $1585\text{--}1634\text{ cm}^{-1}$, confirming the participation of the ketonic oxygen and imine nitrogen atoms in complexation with the metallic ions^{32,33,27}. The downward shift in the vibrational band of the aromatic C=C function noticed at 1434 cm^{-1} in the ligand spectrum to $1425\text{--}1376\text{ cm}^{-1}$ within the spectra of the metallic compounds corroborates the effect of complexation and aromatic conjugation. Very prominent bands at the ranges $1374\text{--}1376\text{ cm}^{-1}$, $1161\text{--}1166\text{ cm}^{-1}$, $1084\text{--}1022\text{ cm}^{-1}$ and $868\text{--}668\text{ cm}^{-1}$ in the spectra of the synthesised compounds were credited to $\nu(C-N)$, $\nu(C-C)$, $\nu(C-C)$ and $\delta(Ar-H)$ vibrations separately. Additionally, the M-N, M-O and M-S stretching bands within the metallic compounds resonated at the lesser frequency region of $556\text{--}500\text{ cm}^{-1}$, $482\text{--}449\text{ cm}^{-1}$ and $433\text{--}430\text{ cm}^{-1}$ ranges validating the complexation through imine nitrogen, ketonic oxygen and cyclic sulphur atoms of the Schiff base³³.

Table 2: Infrared Data of the synthesized Compounds

Compounds	NH	C-H	C=O	C=N	C=C	C-N	C-C	C-S	δ C-H	M-N	M-O	M-S
HL, C ₁₀ H ₇ N ₃ OS	3408	3146	1699	1606	1434	1374	1161	1084	868	-	-	-
[Co(C ₂₀ H ₁₄ N ₆ O ₂ S ₂)]	-	3219	1654	1585	1425	1376	1164	1048	868	571	452	433
[Ni(C ₂₀ H ₁₆ N ₆ O ₃ S ₂)]	-	3153	1702	1634	1591	1329	1166	1056	668	508	482	434
[Cu(C ₂₀ H ₁₄ N ₆ O ₂ S ₂)]	-	3219	1654	1629	1526	1310	1164	1022	738	569	449	430

Electronic and Magnetic Moment Studies

The electronic data of the Schiff base ligand as well as its M²⁺ compounds are presented in Table 3. The absorption bands within the ligand spectrum around 29.67 kK and 30.84 kK attributable to the intra-ligand transitions; n→π* and π→π* of the cyclic C=C and imine C=N moieties had significant shifts in the spectra of the M²⁺ compounds [34] due to the influence of complexation of the ligand donor atoms to the M²⁺ ions²⁶. Two absorption bands observed within visible region of the Co²⁺ complex at 24.92 kK and 22.25 kK characteristic of ⁴T_{1g}→⁴A_{2g} (ν₁) and ⁴T_{1g}→⁴T_{1g}(P) (ν₃) transitions corroborates a six coordinate environment around the cobalt ion. The experimental magnetic susceptibility value of 4.67 BM confirms the assigned high spin octahedral shape to the synthesized Co²⁺ complex as magnetic moments for six coordinate Co²⁺ complexes were expectedly higher compared to spin-only value, a consequence of orbital contributions³⁵. The synthesized Co²⁺ complex displayed three bands at 25.12

kK, 37.99 kK and 42.45 kK in its ultraviolet spectrum consistent with n→π*, π→π* and charge transfer transitions. The visible spectrum of the Ni²⁺ complex indicated strong three bands around 17.70 kK, 18.65 kK and 21.20 kK attributable to the transitions; ³A_{2g}→³T_{2g}, ³A_{2g}→³T_{1g} and ³A_{2g}→³T_{1g}(P) separately³⁶. The transitions conforms with high spin octahedral geometry and were substantiated by the magnetic susceptibility figure of 3.21 BM acquired for the synthesized Ni²⁺ complexes as six coordinate Ni²⁺ complexes were predictably estimated to display magnetic values around 2.80–3.30 BM. The double electronic bands (32.12 kK and 56.64 kK) detected in the UV spectrum of the Ni²⁺ compound conforms to the transitions; π→π* and charge transfer. The synthesized Cu²⁺ complex exhibited a symmetric absorption band at 21.19 kK typical to the ²E_g→²T_{2g} transition, indicative of octahedral geometry. Likewise the magnetic susceptibility of 2.18 BM further confirms the assigned geometry. The UV band at 47.93 kK was typical of charge transfer transition.

Table 3: Molar conductivity, Magnetic Susceptibility and Electronic Spectral Data of the Synthesized Compounds

Compound	Molar Conductance	μ _{eff} (BM)	Absorption Bands(kK)	Transition(s)/Band Assignment	Geometry
HL, C ₁₀ H ₇ N ₃ OS	-	-	29.67 30.84 22.25	n→π* π→π*	-
[Co(C ₂₀ H ₁₄ N ₆ O ₂ S ₂)]	129.01	4.67	24.92 25.12 37.99 42.45	⁴ T _{1g} → ⁴ T _{1g} (P) ⁴ T _{1g} → ⁴ A _{2g} n→π* π→π* CT	Octahedral
[Ni(C ₂₀ H ₁₆ N ₆ O ₃ S ₂)]	106.49	3.21	17.70 18.65 21.20 32.12 56.64	³ A _{2g} → ³ T _{2g} ³ A _{2g} → ³ T _{1g} ³ A _{2g} → ³ T _{1g} (P) π→π* CT	Octahedral
[Cu(C ₂₀ H ₁₄ N ₆ O ₂ S ₂)]	97.50	2.18	47.93 21.19	CT ² E _g → ² T _{2g}	Octahedral

Antibacterial Studies

The Schiff base ligand (C₂H₂NC₂HN)C(O):N=CH(C₄H₃S) and its metallic compounds have been evaluated for in vitro antibacterial activities. The former displayed activity towards the screened bacteriological organisms; *Staphylococcus aureus*, *P. aeruginosa*, *B. cereus* and *K. oxytoca*, *E. coli* and *P. mirabilis* with inhibitory zones of 9.0-18.0 mm range, which could be attributed to hydrogen bonding between the cellular constituents of the microbial cell and imine nitrogen as well as

the ketonic oxygen atoms³⁶. Expectedly, the metallic complexes of Co²⁺, Ni²⁺ and Cu²⁺ were considerably active against the tested bacterial species with inhibitory growth zones of 17.0-28.0 mm, a consequence of chelation impact. However, all the synthesized compounds were weakly active against the gram positive microbes with inhibitory growth zones lower than those observed for gram negative organisms. Excitingly, Cu²⁺ complex was outstanding with higher growth inhibitory zones greater than that of uncoordinated Schiff base ligand against microorganisms

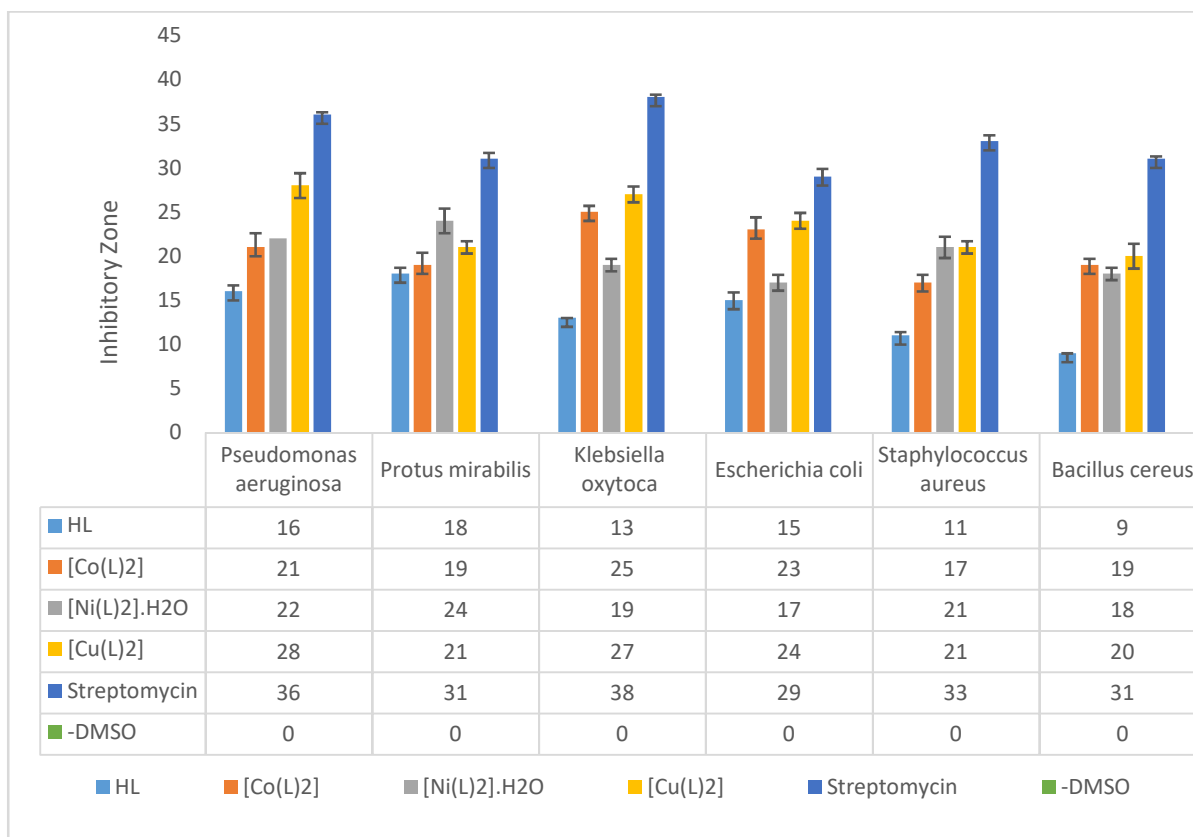


Figure 4: Histogram of the antibacterial activities of $(C_2H_2NC_2HN)C(O):N=CH(C_4H_3S)$ ligand and its metal(II) complexes

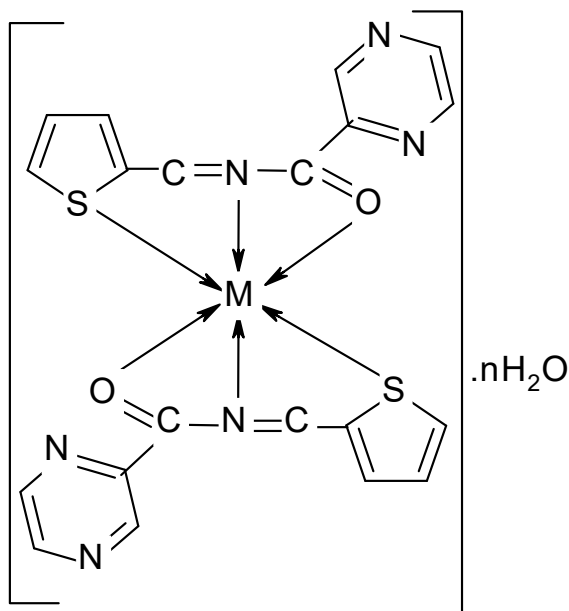


Figure 5: Structure of the Metallic Complexes

$$[M=(Co, n=0; Ni, n=1; Cu, n=0)]$$

V. CONCLUSION

The asymmetric pyrazine Schiff base ligand, $(C_2H_2NC_2HN)C(O):N=CH(C_4H_3S)$ coordinates with Co^{2+} , Ni^{2+} and Cu^{2+} ions in tridentate manner using its imine N-, enol O- and cyclic S- atoms to give six coordinate complexes. The vibrational (FT-IR) data confirmed the involvement of the heteroatoms (N, O, S) in coordination. Also, the assignment of six coordinate geometry to the metallic compounds was corroborated by elemental (CHNS) contents, vibrational (FT-IR), electronic (UV-Vis) and magnetic susceptibility (μ_{eff}) measurements, in the absence of adequate crystals for single crystal structure evaluation. Molar conductivity values obtained substantiates the monomeric and electrolytic nature of the synthesized complexes. Generally, the metallic complexes exhibited better antibacterial activities than the ligand, but the Cu^{2+} complex had the best in vitro activity against all the screened microbes, validating its possibility of exhibiting broad spectrum antibacterial activity.

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