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MONONUCLEAR COBALT(II) COORDINATION COMPOUNDS OF ACETOHYDRAZONES WITH QUINOLINE CORE

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ABSTRACT

This research work aimed at synthesis of some new cobalt coordination compounds using ligands of acetohydrazone Schiff bases with quinoline core in their structure. Four derivatives of acetohydrazone ligands were synthesized using 2-(quinolin-8-yloxy) acetohydrazide and condensed with different aromatic aldehydes. These ligands were used further in preparing mononuclear Co(II) complexes. The synthesized compounds structures were elucidated by different analytical methods. Their potential antimicrobial activities were assessed *in vitro* against different bacterial and fungal strains. Co(II) coordination compounds showed little enhancement in the activity against the gram-positive bacterial strains compared to their parent organic ligands. The compound $[Co(HL_3)_2]$ was the most active chemical against both gram-positive *S. aureus and E. faecalis* bacteria.

Keywords: Acetohydrazone, Quinoline moiety, Co(II) coordination compounds, Antimicrobial activity

1. INTRODUCTION

Chemical compounds containing quinoline ring are considered excellent pharmacophore for tailoring and developing novel versatile compounds with different structural features that have wide scope of biological potential activities **[1, 2]**. Moreover, the chemical derivative compounds of quinoline-hydrazones are excellent class of ligands and enjoyed

popular use in the chemistry of metal complexes because of their ability to react with metal ions producing different coordination metal complexes **[3-5]**. There are a lot of research work have been reported the hydrazone derivatives of quinoline and their metal coordination compounds and have been shown to have significant antituberculosis, antimalarial, antiplasmodial and anticancer capacity **[6-9]**. The hydrazones containing quinoline moiety have polar and nonpolar characteristics, which makes them convenient for the penetration of the cell wall and interfere with the cell environment causing adverse effects in the natural function of the cell and enzymes leading to the death of the cell **[8]**.

Keeping the reported facts and the importance features of the imine compounds containing quinoline moiety, we encouraged and focused our investigation to tailor new ligand compounds and use then in preparing coordination complexes with cobalt(II) metal ion. The suggested acetohydrazone-quinoline Schiff base ligands were derived from 2-(quinolin-8-yloxy)acetohydrazideas a primary amine condensed with different aromatic aldehydic compounds: salicylaldehyde, o-vaniline, 2-hydroxy-1-naphthaldehyde, 3-pyridinecarbaldehyde. The prepared ligands and their cobalt(II) coordination compounds were examined *in vitro* for their antimicrobial potential activities.

2. MATERIALS AND METHODS

2.1. *Materials* and Analysis

All the starting chemicals and solvents used in this research were of reagent grade, obtained from Sigma-Aldrich, Luba, and BDH. 2-(quinolin-8-yloxy) acetohydrazide was prepared by the condensation of 8-hydroxy quinoline with ethyl chloroacetate followed by reaction with hydrazine hydrate in our laboratory following reported procedure **[10-12]**.

The prepared compounds were characterized using different physical and spectroscopic analysis techniques. Micro-elemental analysis of C, H, N, O were done on elemental analyzer instrument and metal percentage was determined using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). Mass spectroscopy was obtained on Thermo Scientific mass spectrometer. UV-visible absorption spectra measurements were performed on Thermo Fisher double beam Spectrophotometer. FT-IR spectra were obtained Thermo Scientific FT-IR spectrophotometer ^{1}H and ^{13}C NMR spectra of the ligands and the metal complexes were recorded via Bruker 400 MHz spectrometer. The magnetic susceptibilities of complexes were measured

by the Gouy-method at room temperature. Molar conductance of10^{-3} M solutions of the metal complexes in DMSO was measured using AP85 Portable Waterproof PH/conductivity meter. Thermal analysis measurements was performed on Shimadzu thermo-analyzer in the temperature range 25-800°C.

2.2. Preparation of acetohydrazide Schiff bases ($HL_1 – HL_4$)

The acetohydrazide Schiff base lignads ($HL_1 – HL_4$) were prepared following same standard procedure as reported in literature **[13]**. The 2-(quinolin-8-yloxy)acetohydrazide (0.02mol) was condensed with (0.02 mol) salicyladehyde, o-vaniline, 2-hydroxy-1-naphthaldehyde and Nicotinaldehyde using ethanol as solvent and the reaction mixtures were stirred with heating and refluxing for 2-3 hours. The obtained ligands were separated and purified by recrystallization to get pure compounds.The obtained ligands were: HL_1: yellowish white solid, M.P. =132°C; yield= 82%.HL_2: off-white solid, M.P. =117°C; yield= 89%.HL_3: yellow solid, M.P. =180°C; yield= 94%.HL_4: Beige solid, M.P. =105°C; yield= 81%.

2.3. Preparation of Cobalt(II) coordination compounds

The Co(II) coordination compounds were prepared following standard general method reported in literature **[14]**. The calculated amount of cobalt metal salt was dissolved in ethanol and mixed with different solutions of the prepared ligands ($HL_1 – HL_4$) in 1:2 metal to ligand stoichiometric ratio. Each reaction mixture was placed on hot-stage magnetic stirrer and was refluxed with stirring for nearly five hours. After cooling, we obtained colored precipitates, which were filtered and purified by recrystallization and finally dried at room temperature. The obtained cobalt complexes were: $[Co(HL_1)_2]$: Greenish brown solid, yield (93.5%), decomposed above 275 °C. $[Co(HL_2)_2]$: brown solid, yield (89.5%), decomposed above 300 °C. $[Co(HL_3)_2]$: brown solid, yield (76.2%, decomposed above 300 °C. $[Co(HL_4)_2 .H_2O]$: violet brown solid, yield (65%, decomposed above 250 °C.

2.4 *In vitro* Antimicrobial Potential activity

The antibacterial and antifungal potential activity of the prepared ligands and their Co(II) coordination compounds were examined against two Gram-negative bacterial strains *P.aeruginosa* (*ATCC 27853*) and *E. coli* (*ATCC25922*), and two Gram-positive bacterial strains *S. aureus* (*ATCC 25923*) and *E. faecalis* (*ATCC 29212*). *C. albicans* (*ATCC10231*) fungal strains were used in antifungal tests. The assessment tests

were carried out at the Department of Clinical Microbiology, Blood Bank Centre, Al-Baha city, KSA. The method followed was agar disk-diffusion assessment **[15]**. 0.02 g of each tested chemical was used in 5 mL of DMSO solvent for preparation of the Stock solutions. Amoxicillin as antibacterial and fluconazole antifungal drugs were used as standards for comparison. The space around each compound that showed the complete inhibition (in mm) was measured after the incubation period.

3. RESULTS AND DISCUSSION

3.1 Synthesis, elemental analysis and mass spectra

We have successfully synthesized quinoline-acetohydrazide Schiff base lignads (HL_1 – HL_4) using 2-(quinolin-8-yloxy) acetohydrazide as primary amine and condensed with salicyladehyde, o-vaniline, 2-hydroxy-1-naphthaldehyde and nicotinaldehyde as aromatic aldehydes in 1:1 stiochiometric molar ratio. The purposed structure of these ligands were confirmed using different analytical techniques. The elemental analysis **(Table 1)** were consistent with the suggested structures of the prepared ligands.

The designed cobalt(II) coordination compounds were prepared successfully following the template method described before. The obtained colored cobalt coordination compounds were solids, insoluble in common organic solvents, stable at room temperature and non-hygroscopic. They were soluble in hot DMF and DMSO. The obtained complexes were decomposed without melting above 275°C. The elemental analysis measurements for the obtained cobalt (II) coordination compounds **(Table 1)** were in agreement with the calculated percentage of the elements according to the suggested structures. The elemental analysis observations suggested mononuclear nature and hexa-coordinate Co(II) complexes with 2:1 ligand to metal stoichiometric ratio **(Figure 1)**. The suggested general formula was $[Co(HL_{1-3})_2]$ for the cobalt complexes of the tridentate HL_1-HL_3 ligands. In case of the ligand HL_4 it behave as bidentate (NO) only forming mononuclear Co(II)coordination compound with the general formula $[Co(HL_4)_2(H_2O)_2]$ with two coordination water molecules.

The observed mass spectra for the ligands HL_1-HL_4 were in agreement with the suggested structures and the observed m/z peaks were 322.17, 352.17, 372.25 and 3.6.08 for HL_1, HL_2, HL_3 and HL_4 respectively. These values are similar to the theoretically calculated molecular weight values according to the suggested molecular

formulae: HL_1: $C_{18}H_{15}N_3O_3$, M. Wt. =321g/mol; HL_2: $C_{19}H_{17}N_3O_4$, M. Wt. =351 g/mol; HL_3: $C_{22}H_{17}N_3O_3$, M. Wt. =371 g/mol and HL_4: $C_{17}H_{14}N_4O_2$, M. Wt. =306 g/mol respectively.

Similarly, in case of the mass spectrometry analysis of the obtained cobalt coordination compounds complexes the measured (m/z) peaks were comparable to the theoretically estimated formula weights according to the proposed structures **(Figure 1)**.

The obtained mass spectra values were 700.00 for $[Co(HL_1)_2]$ (mol. formula: $CoC_{36}H_{28}N_6O_6$, M. Wt. = 698.93); 760.08 for $[Co(HL_2)_2]$ (mol. formula: $CoC_{36}H_{32}N_6O_8$, M. Wt. = 758.93), 800.33 for $[Co(HL_3)_2]$ (mol. formula: $CoC_{44}H_{32}N_6O_6$, M. Wt. =798.93), and 705.08 for $[Co(HL_4)_2(H_2O)_2]$ (mol. formula: $CoC_{34}H_{30}N_8O_5$, M. Wt. = 704.93). This supports and confirms the proposed structures for the prepared cobalt coordination compounds.

3.2 UV-visible spectral analysis and magnetic Susceptibility

The UV-visible absorption spectra measurements of the ligands showed lower wavelength bands at 295, 284, 262 and 301 nm in the spectrum of HL_1, HL_2, HL_3 and HL_4 respectively, which can be allocated to $\pi\rightarrow\pi^*$ transitions within the quinoline and benzene **[16, 17]**. Moreover, another bands in the spectrum of the ligands HL_1, HL_2, HL_3 and HL_4 were shown at wavelength 324, 326, 322 and 317 nm respectively, which may be due to $\pi\rightarrow\pi^*$ and $n\rightarrow\pi^*$ transitions of the (>C=N-) group **[17]**.

The UV-visible and magnetic moment susceptibility (μ_{eff}) measurements were used as helpful tools to understand the nature of the ligand field around the metal ion and the geometry of the obtained Co(II) coordination compounds. In the UV-vis spectra of the Co(II) coordination complexes showed absorption bands given in **Table (2)**. The UV-visible spectra indicates that there is a relative shift to lower frequencies (bathochromic shift) of the absorption bands due to π-π^* and n-π^* transitions that observed in the spectrum of the free prepared Schiff base ligand. This observation may be because of coordination of the ligands to the metal core, which causes a change in the distribution of electrons between the ligands and the metal ions **[18, 19]**.

The obtained UV-visible spectrum of the Co(II) complexes showed three peaks appeared at a range around 716-722, 672-680 and 415-435 nm that may be assigned to $^4T_1g \rightarrow {}^4T_2g\ (F)(\nu_1)$, $^4T_1g \rightarrow {}^4A_2g\ (F)(\nu_2)$ and $^4T_1g \rightarrow {}^4T_1g\ (P)(\nu_3)$ transitions respectively **[20]**. These transitions suggest and octahedral

environment around the cobalt metal ion center. This suggestion was supported by the magnetic moment measurements **(Table 2)**. According to literature and reported research work, the octahedral cobalt complexes exhibit μ_{eff} values in the range of 4.8-5.6 BM **[20, 27]**. Our obtained results for magnetic moment measurements at room temperature of the cobalt complexes were in the range μ_{eff} = 4.92-5.06 BM, which are similar to the values reported in the literature. This demonstrate that the obtained cobalt complexes were paramagnetic and have high-spin octahedral geometry with $4T_{1g}$ (F) ground state **[20]**. Some absorption bands were also observed in the spectra of the Co(II) complexes at the range of 269-430 nm which may be due to π- π^* and n- π^* transitions of the ligands **[16]**.

The octahedral geometry of the mononuclear Co(II) complexes is achieved through the coordination of the Schiff bases (HL_1 – HL_3) as tridentate ligands (NOO). That is these ligands coordinate to the cobalt metal center through two N atoms of the azomethine group and two O atoms of the phenolic groups and two O atom of the amide (C=O) groups from the same two Schiff base ligands in trans position. While, the HL_4ligand behave as bidentate and coordinate to the cobalt metal center through two N atoms of the azomethine group and two O atom of the amide (C=O) groups from the same two ligands in trans position and the octahedral geometry is completed through the coordination of two H_2O molecules to the cobalt center.

3.3 FT-IR spectral analysis

The exhibited characteristic peaks of IR spectral analysis were very helpful in proving the suggested structures of the ligands and their corresponding cobalt coordination compounds. The formation of azomethine group (>CH==N-) was proved through the appearance of the characteristic bands at 1500, 1502, 1504, 1505 cm-1 in the spectrum of the ligands HL_1, HL_2, HL_3 and HL_4 respectively **[4]**.

The involvement of the nitrogen atom of this azomethine group in coordination to the cobalt atom was indicated through the shift (blue shift nearly 46-61 cm^{-1}) of the νC=N band in the IR spectrum of the cobalt complexes compared to the free organic ligands. Moreover, a new weak band in the spectrum of the cobalt complexes at the range of 437-485 cm^{-1}referred to the formation of M-N bonds. The formation of M-N bond causes weakening of the C=N band because of the donation of electrons from the N atom to the vacant d-orbitals in the cobalt atom, which leads to the shift of

the azomethine band in the IR spectra of thecobalt coordination compounds **[4, 17]**.

The bands exhibited at the range of 3500 – 3600 cm^{-1} in the IR spectrum of the HL_1-HL_3ligands may be assigned to the phenolic (-OH) group. In addition, other peaks were shown in the range 1225-1255 in the spectrum of HL_1-HL_3 ligands can be attributed to the phenolic C-O linkage **[21]**. In the IR spectrum of the cobalt coordination compounds, it was observed that the bands due to the phenolic (-OH) group were disappeared and the intense bands due to the phenolic C-O linkage were shifted in position by nearly (10-15 cm^{-1}). Moreover, a weak band was observed in the IR spectrum of the cobalt coordination compounds at the range of 462 – 595 cm^{-1}, which may be attributed to the νM-O mode. These observations are an evidence for the formation of M-O bonds and involvement of the oxygen atom of the phenolic group in HL_1- HL_3 ligands in bonding to the cobalt atom center **[21, 22]**.

The stretching carboxyamide (C=O) group absorption bands were appeared at 1660, 1665, 1685 and 1671 cm^{-1} in the spectra of HL_1, HL_2 HL_3 and HL_4 respectively **[9, 23]**. On comparing with the IR spectra for the corresponding Co(II) coordination compounds we observed That these bands had suffered ahypsochromic shift (nearly 10 - 15 cm^{-1}). This is an indication of binding of the carboxyamide (C=O) group through the oxygen atom to the cobalt central atom **[24]**. The IR spectral analysis for the ligands also showed weak absorption bands appeared in the range 2985-2988 cm^{-1}can be attributed to –N-H amide group **[9, 23]**. Moreover, the absorption bands observed at 1115, 1114, 1110, and 1112 cm^{-1} in the spectra of HL_1, HL_2, HL_3 and HL_4 respectively may be marked to the –N-N- linkage **[25]**. These bands remained unchanged at the same position in the spectra of the cobalt coordination compounds, which indicated the non-participation of the atoms of these groups in coordination to the cobalt atom.

From these observations we can deduce that the tridentateligands HL_1-HL_3Coordinated to the Co(II) central atom through the O atom of the phenolic (OH) group, through the N atom of the –CH=N- linkage and through the O atom of the carboxyamide C=O group. While the bidentate HL_4 ligand bind to the cobalt atom center through the N atom of the –CH=N- linkage and the O atom of the carboxyamide C=O group.

3.4 ^{1}H NMR and ^{13}C NMR spectra Analysis

The ^{1}H NMR Spectrums of the quinoline-acetohydrazone Schiff base ligands showed

the imine protons at range of 8.58 – 8.98 ppm as singlets. The aromatic (OH) protons singlets were observed at the peaks in the range of 11.05 – 12.23 ppm **[22]**. The singlets visibled in the range of (12.18 – 12.52 ppm) may be attributed to the proton of the –NH- linkage. The aromatic hydrogen peaks were visible in the range of (7.00 – 8.98 ppm) **[23]**.

In the^{13}C NMR spectra of the ligands the peaks observed at 148.75, 148.48, 147.62 and 145.69 ppm positions are possibly due to the carbon atom of the azomethine group **[22]**. The singlet peaks of the C=O group were visible in the range of 164.81 - 169.57 ppm **[26]**. In addition, the carbon atoms of the aromatic rings were shown in the range of 109.00 – 154.49 ppm **[9]**.

The ^{1}H NMR analysis the cobalt coordination compounds showed that on complexation the peaks due to the proton of the imine group in the Schiff base ligands were showed field up shift slightly by Δ_{δ} = 0.40 – 0.80 ppm. The singlet peaks due to the phenolic (OH) proton in the ^{1}H NMR spectra of HL_1, HL_2 and HL_3 were disappeared indicating the deprotonation of this group. These observations supported the coordination of the N atom of the azomethine (>CH=N-) group and the O atom of the phenolic (–OH) group to the cobalt atom **[22]**. While the peaks due to the –NH- proton remained in the same position indicating the non-participation of this group in coordination to the cobalt metal atom.

3.5 Thermal analysis

Thermal analysis studies for the obtained cobalt coordination compounds were investigated to support the characterization of the prepared cobalt coordination compounds. The results of the thermal analysis measurements are presented in **Table (3)** and representative TG/DTA plots of the analyzed compounds are shown in **Figures (2-5)**. The anhydrous cobalt coordination compounds derived from the ligands HL_1-HL_3 showed thermal stability up to 204 °C in the TGA curves and no mass loss was observed. This asserts the absence of water molecules in the chemical structure of these compounds and hence supports the suggested structures. The decomposition of cobalt coordination compounds obtained from these ligands showed three successive steps of decomposition and mass loss to reach the stable cobalt(II) oxide CoO as final productas presented in **Table 3**.

The TGA curve of $[Co(HL_4)_2(H_2O)_2]$ **(Figure 3) (or Table 3)** prepared from the Schiff base HL_4 exhibited four steps of decomposition. That is with an additional step (below 150°C) which is an indication for

the presence of coordinated H_2O molecules in the structure of this coordination compound. This observation showed harmony with the proposed structure for this compound in which two water molecules are coordinated to the central cobalt atom.

Moreover, it is observed in DTA curves of the cobalt(II) coordination compounds lost mass in the 92–558 °C temperature range were shown as endothermic peaks.

3.6 Molar conductance measurements

The results of the molar conductance values **(shown in Table 2)** for the freshly prepared 0.001M in DMSO solutions of the synthesized cobalt coordination compounds at room temperature were in the range of (18.5 – 22.2 $\Omega^{-1}.cm^2.mol^{-1}$). These values are considered very low and suggested non-electrolytic nature of the prepared cobalt(II) coordination compounds and the ligands are take part in the coordination sphere **[27]**.

3.7. *In vitro* Anti-microbial Potentials

The ligands and their corresponding Co(II) coordination complexes were assayed *in vitro* for their potential antibacterial and antifungal activities utilizing agar disc-diffusion method. The zones of complete inhibition (in mm) are tabulated in **Table 4** as arithmetic mean values.

The Results observed **(Table 4)** indicated that the ligands marked moderate antibacterial activity against the Gram-positive bacterial types with zones of inhibitions in the range of (15-24) mm and were inactive against the gram-negative bacterial and the fungal strain. HL_2 and HL_3 ligands observed to show better activity compared to other ligands with zone of inhibition of 24 mm against *S. aureus* but still very low compared to the reference drug amoxicillin.

The tested cobalt coordination compounds complexes exhibited little enhancement antibacterial activity against both gram-positive *S. aureus and E. faecalis* bacterial strains and similar to the parent ligands the complexes showed no activity against the gram-negative bacterial stains and the fungal strain. On comparing between the coordination compounds it was noticed that $[Co(HL_3)_2]$ exhibited the highest activity against the gram-positive bacterial strains but still less than the reference drug. The enhancement in the activity of cobalt complexes can be explained according to Tweedy's chelation theory and Overtone's permeability principles **[28]**. Coordination may increase the liposolubility of the cobalt coordination compounds, which facilitate the permeability of cobalt complexes inside the microbial cell and causes an adverse effect in the cell environment and affects the enzymes

inside the cell **[4, 28]**. In addition there is a possibility of hydrogen bond formation between the>CH=N- group present in the compounds and the chemical constituents of the cell, which may interfere with normal cell processes **[24]**.

Table 1: Elemental analysis for the quinoline-acetylhydrazone Schiff bases and their Co(II) coordination compounds

Compound	Mol. Formula	Elemental Analysis				
		%C Cald. (Found)	% H Cald. (Found)	% N Cald. (Found)	% O Calcd. (Found)	% Co Calcd. (Found)
HL_1	$C_{18}H_{15}N_3O_3$	67.34 (67.02)	4.67 (4.77)	13.08 (13.36)	14.95 (14.63)	--
HL_2	$C_{19}H_{17}N_3O_4$	65.01 (64.95)	4.84 (4.71)	11.97 (12.22)	18.23 (17.86)	--
HL_3	$C_{22}H_{17}N_3O_3$	71.22 (71.63)	4.58 (4.54)	11.32 (11.59)	12.94 (12.64)	--
HL_4	$C_{17}H_{14}N_4O_2$	66.72 (66.33)	4.58 (4.85)	18.30 (18.71)	10.46 (10.12)	--
$[Co(HL_1)_2]$	$CoC_{36}H_{28}N_6O_6$	58.78 (59.02)	3.80 (3.96)	11.42 (11.16)	13.06 (13.44)	8.01 (8.37)
$[Co(HL_2)_2]$	$CoC_{38}H_{32}N_6O_8$	66.48 (66.40)	4.65 (4.86)	12.22 (12.08)	18.63 (18.31)	8.56 (8.50)
$[Co(HL_3)_2]$	$CoC_{44}H_{32}N_6O_6$	63.23 (63.67)	3.83 (4.06)	10.06 (9.93)	11.49 (11.55)	7.05 (7.38)
$[Co(HL_4)_2(H_2O)_2]$	$CoC_{34}H_{30}N_8O_6$	57.87 (57.38)	3.68 (4.02)	15.88 (16.24)	9.07 (9.24)	8.35 (8.68)

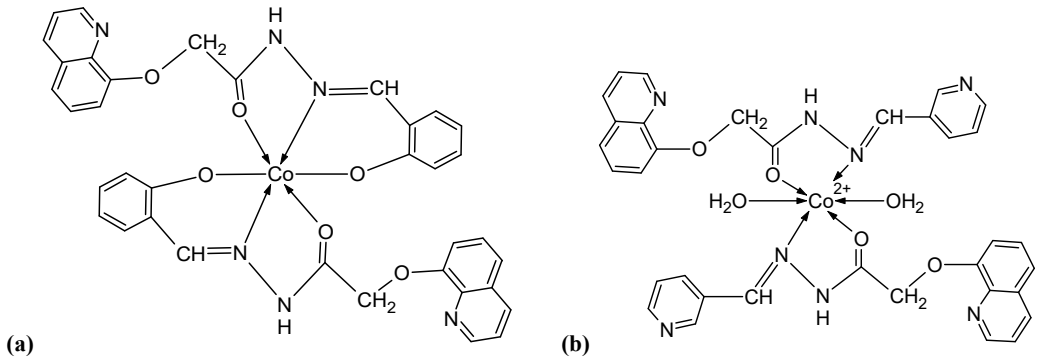

Figure 1: Suggested structure of cobalt complexes, a) $[Co(HL_1)_2]$ and (b): $[Co(HL_4)_2(H_2O)_2]$

Table 2: UV-vis. absorption bands,μ_{eff} and molar conductance Values for the Co(II) coordination compounds

Compound	Absorption bands (λ_{max} in nm)	Magnetic Moment μ_{eff}(B.M.)	Molar Conductance ($\Omega^{-1}.cm^2.mol^{-1}$)
$[Co(HL_1)_2]$	269, 430, 672, 716	4.92	21.4
$[Co(HL_2)_2]$	269, 676, 722	5.25	22.6
$[Co(HL_3)_2]$	323, 415, 674	5.06	21.1
$[Co(HL_4)_2(H_2O)_2]$	270, 419, 680, 718	4.96	18.5

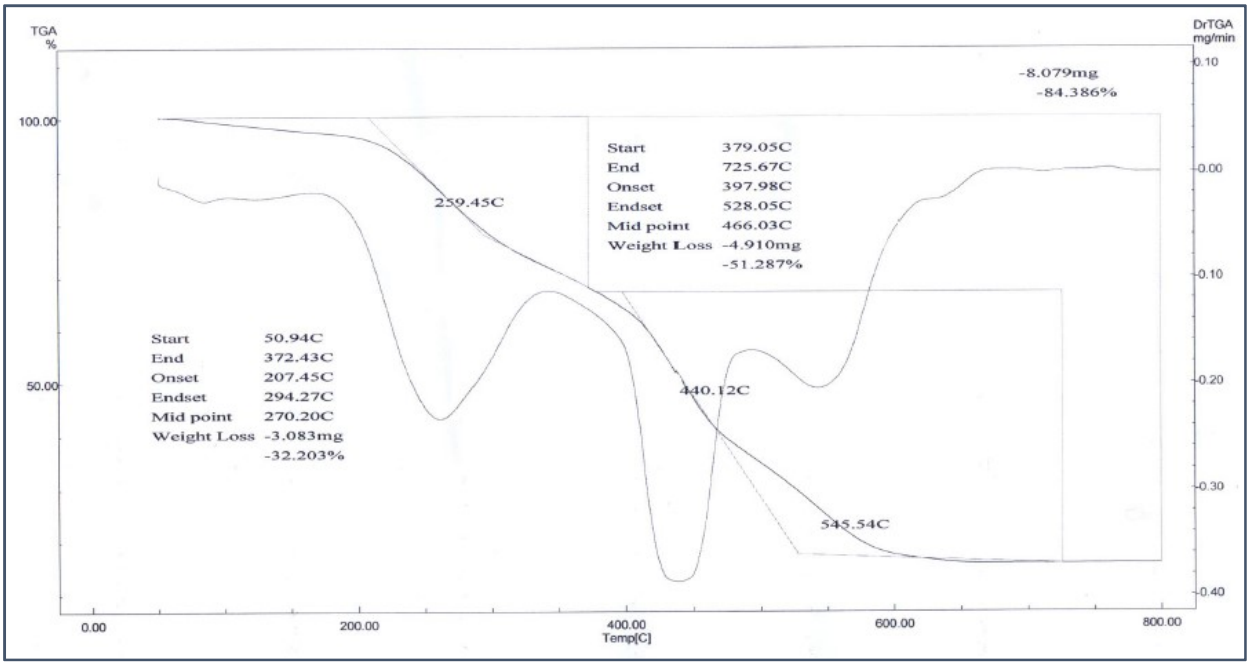

Figure 2: TGA-DTA curves of $[Co(HL_1)_2]$

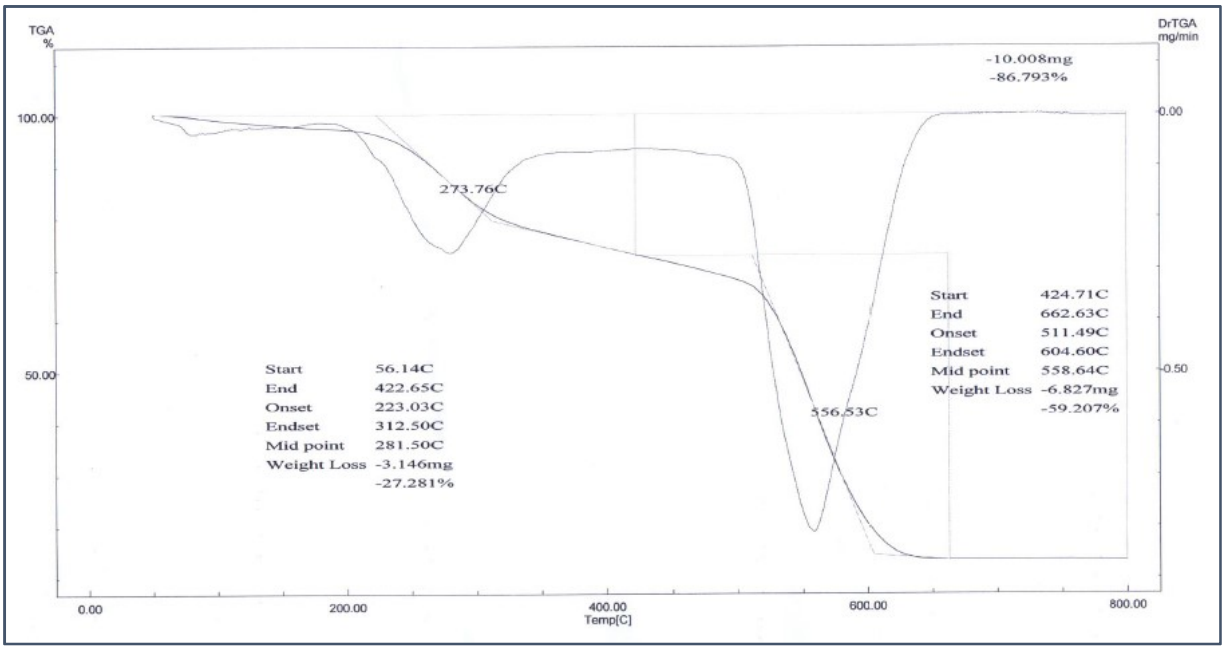

Figure 3: TGA-DTA curves of $[Co(HL_2)_2]$

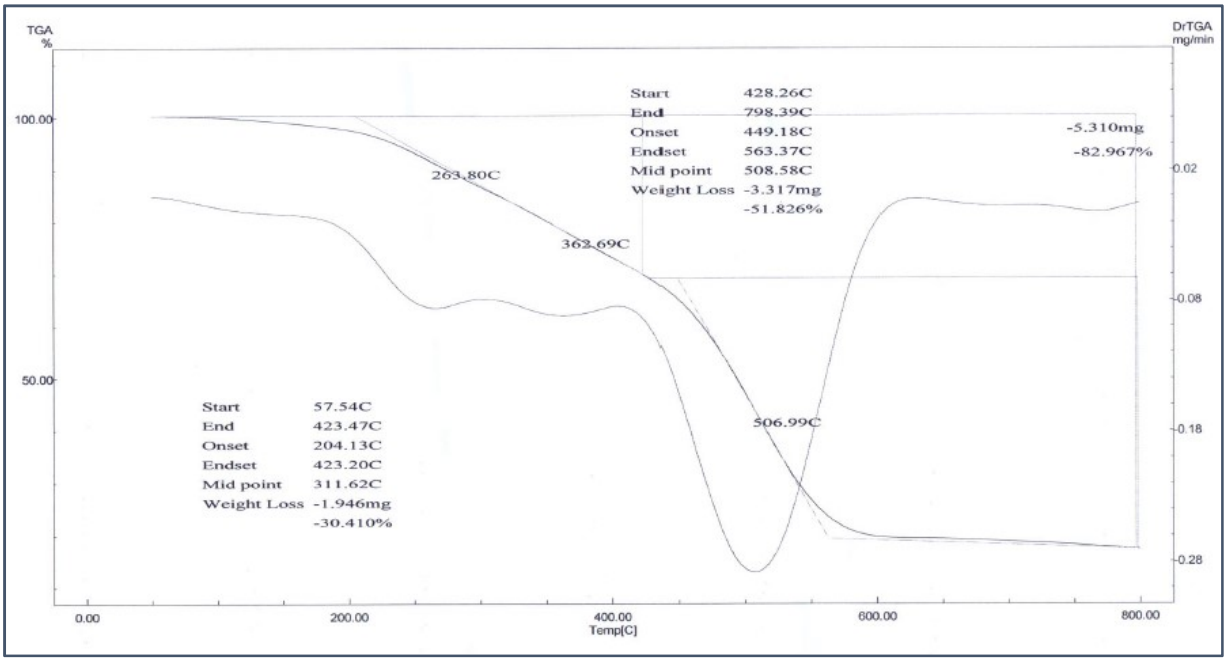

Figure 4: TGA-DTA curves of $[Co(HL_3)_2]$

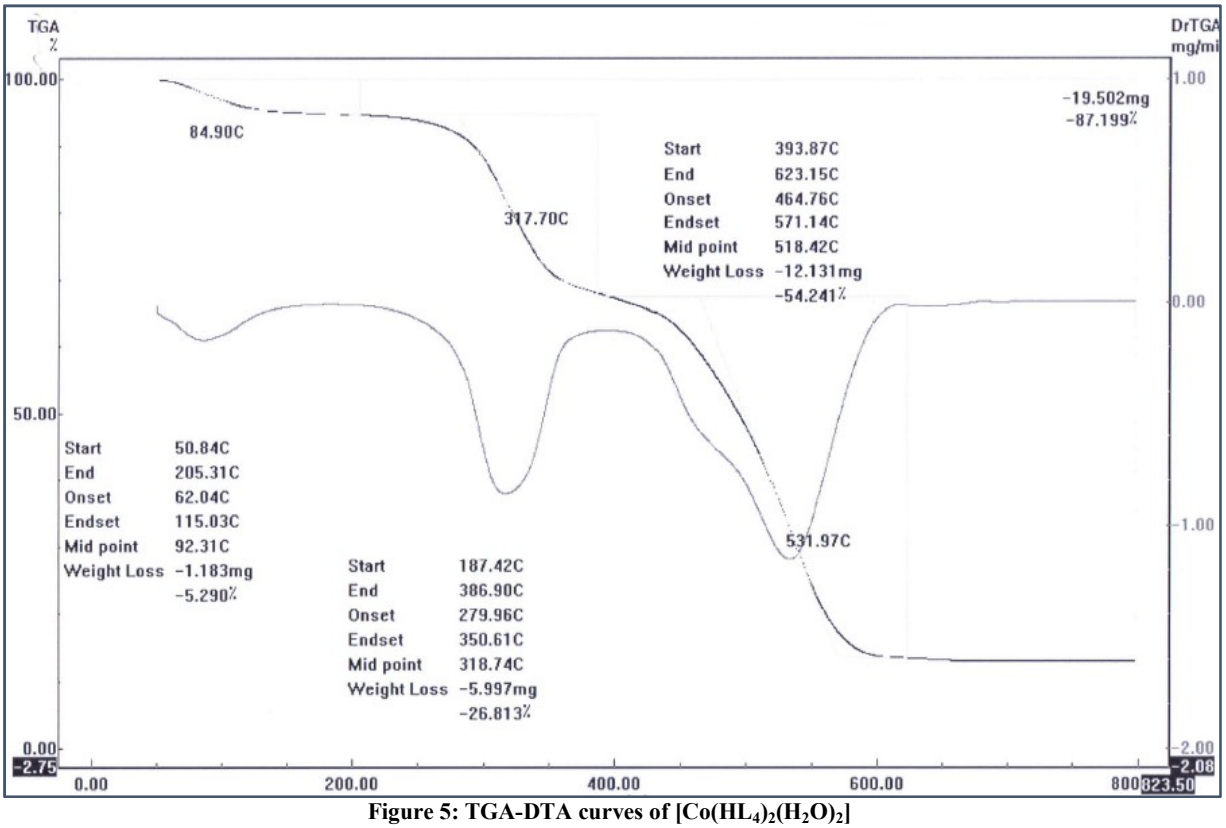

Figure 5: TGA-DTA curves of $[Co(HL_4)_2(H_2O)_2]$

Table 3: Thermal analysis data for cobalt(II) coordination compounds

Complex (Mol. Wt.)	Thermal steps	Temp. range in TG	ΔT_{max} in DTA	Weight loss Found (Calcd.)%	Assignment
$[Co(HL_1)_2]$ (699.58)	Step I	207.45 – 294.27	270.2	32.203 (32.62)	$C_{12}H_{10}N_3O_2$ of ligand
	Step II	397.98 – 528.05	466.03	51.287 (56.66)	Ligand + aromatic ring (C_6H_4)
	Step III	> 600	-	15.61 (10.71)	CoO
$[Co(HL_2)_2]$ (759.63)	Step I	223.03 – 312.50	281.50	27.28 (30.04)	$C_{12}H_{10}N_3O_2$ of ligand
	Step II	51.49 – 604.60	558.64	59.207 (60.09)	Ligand +Ph-OCH_3
	Step III	> 600	-	13.20 (9.86)	CoO
$[Co(HL_3)_2]$ (799.17)	Step I	204.13 – 423.20	311.62	30.41 (28.55)	$C_{12}H_{10}N_3O_2$ of ligand
	Step II	449.18 – 563.37	508.58	51.826 (46.34)	Ligand
	Step III	> 600	-	17.03 (9.36)	CoO
$[Co(HL_4)_2(H_2O)_2]$ (707.6)	Step I	62.04 – 115.03	92.31	5.29 (5.09)	2 Coordinated water molecules
	Step II	279.96 – 350.61	318.74	26.813 (26.17)	$C_{11}H_9N_2O$ of ligand
	Step III	464.76 – 571.14	518.42	54.241 (58.14)	ligand + organic moiety ($C_6H_5N_2$)
	Step IV	> 600	-	12.80 (10.59)	CoO

Table 4: Antimicrobial activity for the ligands and their Co(II) coordination compounds

Compound	Zone of inhibition (mm)				
	Gram-positive bacteria		Gram-negative bacteria		Fungus
	S. aureus	*E. faecalis*	*E. Coli*	*P. aeruginosa*	*C. Albicans*
HL_1	18	17	5	R	R
HL_2	24	20	R	R	R
HL_3	24	08	R	R	R
HL_4	15	18	R	R	R
$[Co(HL_1)_2]$	23	22	R	R	R
$[Co(HL_2)_2]$	31	25	15	R	R
$[Co(HL_3)_2]$	32	30	14	R	R
$[Co(HL_4)_2(H_2O)_2]$	21	18	0	R	R
Amoxicillin	42	40	26	---	20
Fluconazole	35	34	36	36	42

CONCLUSION

In conclusion, we have successfully prepared four quinoline-acetohydrazone Schiff base ligands. Moreover, these ligands were used to prepare four co(II) coordination compounds. All the prepared compounds were characterized and structures were elucidated based on spectroscopic and physical measurements. The analysis observations revealed that the ligands (HL_1 – HL_3) behaved as tridentate and coordinated to the Co ion through the N atom of the imine group, O atom of the phenolic group and the O atom of the carboxyamide C=O group forming octahedral configuration around the central metal atom. HL_4 behave as bidentate and the cobalt completed the octahedral geometry through binding with two H_2O molecules. All obtained cobalt coordination compounds were mononuclear non-electrolytic compounds. *In vitro* antimicrobial examination for the prepared ligands and their cobalt coordination compounds showed moderate antibacterial activity against the Gram-positive bacterial types and were inactive against the gram-negative bacteria and fungus strains The cobalt coordination compounds showed little enhancement in the activity against the gram-positive bacterial strains. The compound $[Co(HL_3)_2]$ showed highest activity against both gram-positive *S. aureus and E. faecalis* bacteria, but still less than the reference drugs.

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