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Synthesis and Spectroscopic methods on the complexation of Co^{II}, Ni^{II} and Cu^{II} with 2-(((1H-indol-3-yl) methylene) amino) acetohydrazide hydrate

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ABSTRACT: The Ligand was synthesized by condensation of Indol 3-hydroxy aldehyde, Glycine and Hydrazine hydrate. The reaction of the ligand with ions (Co^{II}, Ni^{II} and Cu^{II} ions) yielded complexes, these were characterized by physical and spectroscopic techniques. The conductivity showed a non-electrolytic nature for these complexes. The elemental analysis indicated the ligand to metal ratio is 1:1 with a formula $M(L)(H_2O)_nCl_2$ (L=ligand; M=metal ions. IR data showed the ligand coordinated to the metal ion via azomethine nitrogen and amine of hydrazide in addition to the amine of indol ring with Cu^{II}. The spectroscopic and magnetic investigations revealed that octahedral geometry for Co^{II} and Ni^{II}, while distorted octahedral geometry for Cu^{II}. The particle size and strain of these compounds have been discussed using X-ray diffraction. The antioxidant study for ligand proved to be a good antioxidant. The compounds' antibacterial activity against diverse pathogens has been assessed.

CONTENTS

1. INTRODUCTION

1.1 Schiff Bases and Hydrazides

Hugo Schiff, a German chemist, first described Schiff bases in 1864, therefore referred to his name. While some of them use the formula R1CH=NR2, where carbon is bonded to a hydrogen instead of a carbon, they are all represented by the generic formula R1R2C=NR3. The Schiff bases are also called Imines, Anilis and Azomethine [2]**.** They are employed as polymer stabilizers, catalysts, intermediates in organic synthesis, and pigments.

They exhibit a variety of biological activities, such as antifungal, antibacterial, antimalarial, antiviral [3], anti-inflammatory [4], and antipyretic characteristics [5]. Antitumor [6], Antifertility , Antiproliferative, Herbicidal [7], Antioxidant, Analgesic, Cardiovascular [1], Anticonvulsant, Plant Growth Regulator, Antitubercular Agents [2], Antiparasitic [8], Herbicidal, Cytotoxic Activity [9], Clinical [10]. Hydrazides include active group-$C(=O)NHNH_2$ [11]. These molecules are referred to as practical syntheses of different heterocyclic rings with one or more heteroatoms that have fascinating uses as medicines, herbicides, antibacterial agents, and colors. In addition to its anticonvulsant, antidepressant, anti-inflammatory, anti-malarial, anti-mycobacterial, anti-cancer, and antimicrobial properties, hydrazide also exhibits other biological functions. Hydrazides are bidentate as ligands. Depending on acidity [11].

2.1 Experimental

The chemicals used were available from BDH. the melting points were determined in glass capillary tubes in degrees Celsius. Molar Conductance and Molar ratio were measured on Jenway conductivity meter model 4510, Products were characterized by comparison of spectroscopic data, Using dry KBr as the standard reference, the IR spectra of the ligand and metal complexes were measured using (FT/IR - 140, Jasco, Japan), ^1H and ^{13}C NMR spectra were recorded in a Varian FT – 300 MHz spectrometer in d_6- DMSO solvent using TMS as internal standard, UV-Visible and antioxidant using (specord 200, Analytilk Jena, Germany) using DMSO as the reference for UV-Visible spectra and a methanol as solvent for antioxidant activity measurements. A magnetic susceptibility balance from the Johnson Metthey and Sherwood model was used to test the complexes' magnetic susceptibilities at room temperature using Gouy's procedure. (CHN) were estimated by Vario ELFab . Nr . 11042023. Chlorine percentage was measured by titration with $AgNO_3$ Shimadzu ED-720 X-ray powder diffractometer, at a voltage of 35 KV, a current of 20 mA, a CuKα radiation generator in the range of $5^o<2\theta<70^o$, a ten (10 min^{-1} scanning rate, and a wavelength of 0.154056 nm, was used to get the XRD diffraction of the ligand and complexes. Microbiological analysis was carried out using the filter paper disc method**.**

2.2 Synthesis of the ligand

The ligand was produced by swirling an ethanolic solution of the aldehyde (0.01mol) while adding dropwise in 1:1:1 molar ratio to an ethanolic solution of glycine (0.01mol). The mixture was refluxed for 3 hours with constant stirring and heating[12] until a light brown solution of the Schiff base is formed .Then adding hydrazine hydrate drop by drop to the hot solution of the Schiff base with constant stirring until a colored precipitate formed. The precipitate was collected through filtering and then dried after being thoroughly washed with ethanol.

2. 3 Synthesis of the Complexes

The solid complexes were made by stirring a methanolic solution of the ligand (Schiff base hydrazide) into which hydrated metal chlorides (0.008mol) were added dropwise**.** With steady stirring, the mixture of each was refluxed for 4 to 6 hours until colored precipitates developed**.** There was a 1:1 molar ratio in all material solutions**.**

The precipitates that were produced were filtered off, cleaned with methanol several times, and then allowed to dry.

2. Results and Discussion

All the compounds are colored solids and soluble in common organic solvents (Table 1). These complexes are non-electrolytic (in DMSO solvent), as shown by the molar conductance values (Table 2), which also reveal that the anions are coordinated with the metal ions [13] [14].

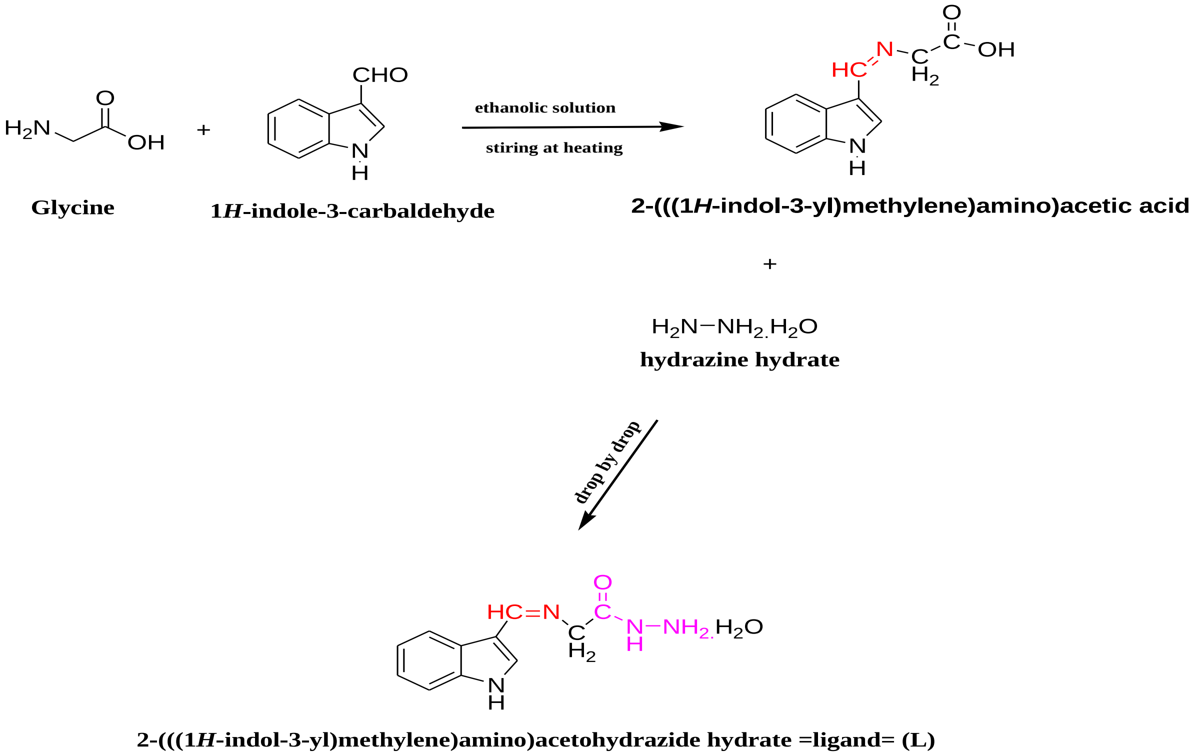


Table 1: Some physical properties of the ligand and its complexes

Comp. Proposed formula	**Color**	**M.p/ ˚C**	**Yield %**	**Solubility**										
				H_2O	EtOH	MeOH	Hex	CCl_4	$CHCl_3$	Acet	Benz.	D.E.	DMF	DMSO
L ($C_{11}H_{14}N_4O_2$)	Yellow	207	72.04	Ins	Ins	S	S	S	S	p.s	p.s	Ins	S	S
[Co (L) (H_2O)$_2$ Cl_2] [Co($C_{11}H_{16}N_4O_3$)Cl_2]	Light brown	>300	54.23	Ins	Ins	Ins	Ins	Ins	Ins	Ins	S	Ins	S	S
[Ni (L) 2(H_2O)$_2$ Cl_2] [$NiC_{11}H_{16}N_4O_3$)Cl_2]	Brown	>300	61.12	Ins	Ins	Ins	Ins	Ins	Ins	Ins	p.s	Ins	S	S
[Cu (L) H_2O Cl_2] [Cu($C_{11}H_{14}N_4O_2$)Cl_2]	Olive green	>300	51.77	Ins	Ins	Ins	Ins	Ins	Ins	Ins	p.s	Ins	p.s	S

S=soluble, P.S= partially soluble, Ins.=Insoluble

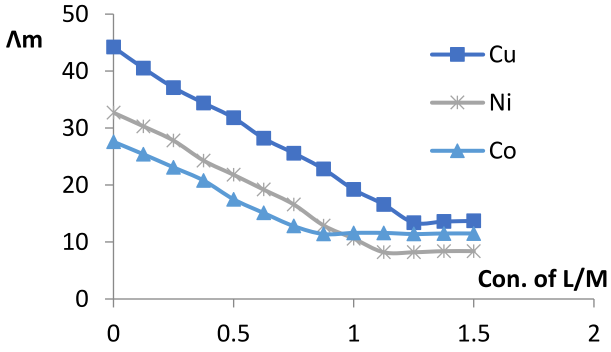
Table 2: Molecular weight, Elemental Analysis and Molar Conductance of the ligand and its complexes

Com. Proposed formula	**Molecular weight**		**Elemental analysis**										**Λm- cm^2mol^{-} $^{11}\Omega^{-}$**
			%C		%H		%N		%M		%CI		
	Calc.	found	Calc.	found	Calc	found	Calc.	found	Calc.	found	Calc.	found	
L	234.25	234.30	56.40	56.41	6.02	6.06	23.92	23.93	-	-	-	-	-
[Co (L) 2(H_2O) Cl_2]	382.11	382.19	34.58	43.57	4.22	4.23	4.661	14.66	15.42	15.41	18.56	18.58	**7.81**
[Ni (L) 2(H_2O) Cl_2]	381.87	381.92	34.60	34.59	4.22	4.24	14.67	14.68	15.37	15.37	18.57	18.59	**5.46**
[Cu (L) H_2O Cl_2]	368.71	368.76	35.83	35.84	3.83	3.85	15.20	15.19	17.23	17.25	19.23	19.25	**9.25**

3.1 Molar ratio by conductivity measurements

To Calculate the molar ratio between the ligand and the metal ions cobalt, nickel, and copper. Starting with 0.008 moles of metal chloride and adding 0.001 moles of ligand, a series of complex molar concentrations in DMSO was created. The conductivity of each concentration was then measured until the constant value appeared then the ratio between the ligand and metal ions was calculated. The following was found:

1- The conductivity was very low, and this was proven using silver nitrate, as it did not give any positive results, this indicates that, these complexes do not have ionic conductivity[13].



2- By measuring the different molar concentrations of the complexes as shown in (Figure 1), it was found that the conductivity decreased and remained stable at a molar value indicating that the ratio between the ligand and metals is 1:1[15][16].

3.2 The ligand's and its complexes' IR spectra

The IR spectra of the ligand exhibit an absorption band at 1622 cm^{-1} due to $\upsilon_{C=N}$, which was shifted to a higher frequency range of 1653–1654 cm^{-1} in the complexes, demonstrating the contribution of the azomethine nitrogen atom to the coordination (Table 3 and Figure 2) [17].

The NH_2 band of the ligand. observed at 3214 cm^{-1} is shifted to higher wave number in the spectra of complexes of Co^{II} and Ni^{II} indicating the coordination of amine group via nitrogen with metals[18], while the ligand coordinate with Cu^{II} throw NH of amide and amine groups[19][20].

The stretching vibration of OH is thought to be responsible for the appearance of a broad band at 3348-3323 cm^{-1}. This demonstrates that coordination water is present[10][21]. It is possible to attribute the bands at 405-409 cm^{-1} to v(M-Cl) vibrations[22]. The stretching vibrations

low intensity bands that were seen[23][24]

Comp.	C=N	C=O	C=C	C-N Amid.	C-N Amin.	C=C Aliph.	NH amide	NH_2	NH amine	=C-H	N-N	CH_2	OH	M-O M-N M-Cl
L	1622^s	1669^m	1492^m	1362^m	1337^m	1614^s	3109^m	3214^m	3190^m	3058^m	1086^w	1437^s	3348^{br}	-
[Co (L)(H_2O)$_2$$Cl_2$]	1654^m	1669^w	1492^m	1362^m	1336^m	1614^s	3117^m	3225^m	3190^m	3058^m	1086^w	1437^s	3348^{br}	430^s, 568^m
[Ni (L)(H_2O)$_2$$Cl_2$]	1654^m	1670^w	1492^m	1363^m	1337^w	1607^w	3110^m	3227^w	3190^w	3059^m	1087^w	1438^s	3423^{br}	430^m, 569^w
[Cu (L)(H_2O) Cl_2]	1653^m	1673^w	1491^m	1364^m	1337^m	1612^s	3121^w	3220^m	3110^m	3059^m	1072^w	1437^m	3346^{br}	426^s,

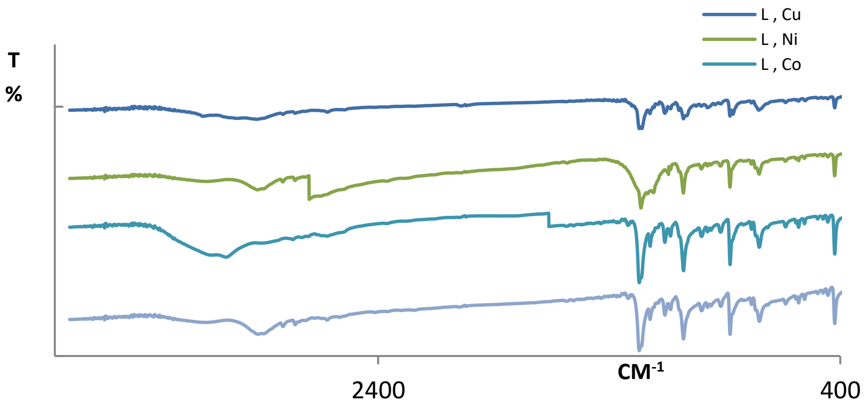


Figure 2: IR spectra of the ligand and its complexes

3.3 NMR of the ligand

3.3.1 ^{1}HNMR

The ^{1}HNMR spectrum (Table 4 and Figure 3) shows a signal at 8.967 ppm attributed to the CH=N group[25]. The signals at 8.005 and 8.140 ppm, respectively assigned to the protons of NH and NH_2 groups[26]. The signal of the proton of NH in the indole ring was present at 9.22 ppm[25].

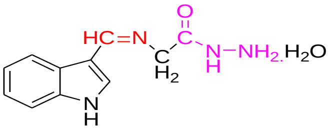
The ligand gives multiple signals in the region 7.500-7.799 ppm which can be assigned to the aromatic protons of the benzene ring[27]. The proton of CH group of indole appeared at 8.165 ppm[28], and signals of CH_2 and H_2O appeared at 2.5 ppm [29] and 3.5 ppm [13], respectively.

3.3.2 ^{13}CNMR

The signal of carbon atom for azomethine group appears at 158.19 ppm[30]. The carbon of amide group appears at 158.941 ppm [19][29]. At 129.225-134.809 ppm due to the carbons of the aromatic ring[30], also 138.809 ppm and 127.078 ppm due to carbon of C and CH atoms which are present in the indole ring, respectively[28]. The signal in the position 40.260 ppm due to the carbon of CH_2 group[31], all these signals obtained in (Table 4 and Figure 4).

Table 4: ^{1}H and ^{13}C NMR positions (ppm) of the ligand

NMR Spectroscopy of the ligand			
^{1}HNMR		^{13}C NMR	
Site	Chemical Shift (ppm.)	Site	Chemical Shift (ppm.)
CH=N-	8.967	CH=N-	158.19
NH	8.005	A.R.	129.225-134.809
NH_2	8.140	CH_2	40.001
$NH_{Ind.}$	9.22	CH_2	40.260
A.R.	7.500-7.799	C=O	158.941
CH_2	2.5	$C_{ind.}$	138.809
H_2O	3.5	$CH_{ind.}$	127.078



2-(((1*H*-indol-3-yl)methylene)amino)acetohydrazide hydrate =ligand= (L)

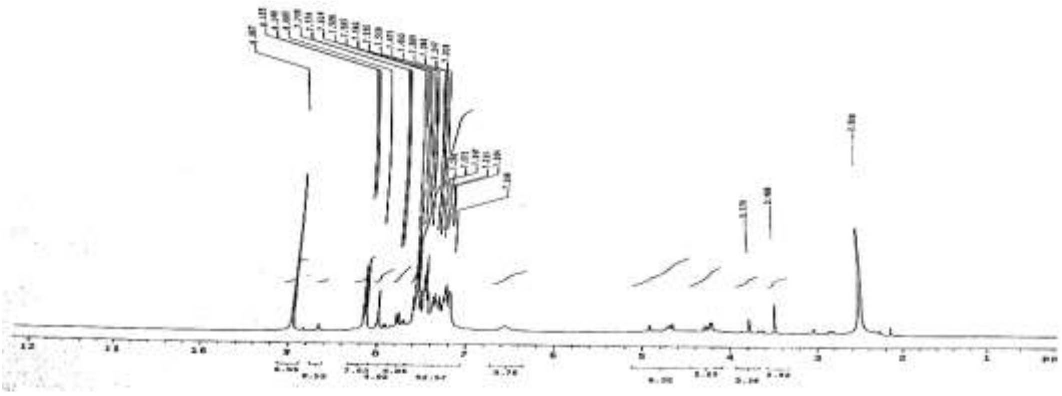


Figure 3: ^{1}HNMR Spectrum of the ligand

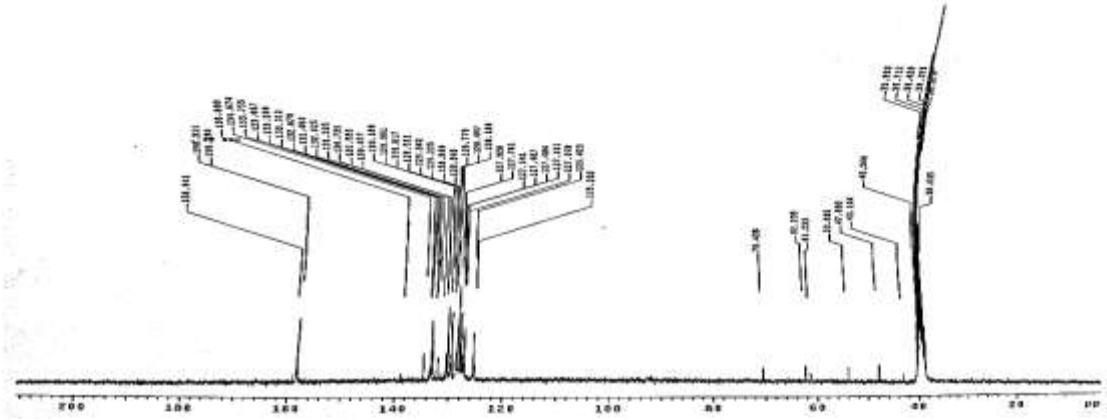


Figure 4: ^{13}CNMR Spectrum of the ligand

3.4 Magnetic and Electronic Spectral Studies of the ligand and its Complexes

The compounds that were measured in DMSO solution had ligand absorption bands that emerged at 37037 cm^{-1} and 41666 cm^{-1} in there spectra. The lone pair of electrons in the p orbital of the N-atom in the C=N group and a conjugated bond of phenyl rings undergoes n-π* transitions, which are responsible for the band at low energy.

The phenyl group's internal π-π^*transitions and the C=N group's internal π-π^* transitions are what cause the band to form at higher energy [32]. The Co^{II} complex is hexa-coordintion suggested (structure 1). This is based on the appearance of 14705 cm^{-1} and 16129 cm^{-1} in the spectra (Table 5 and Figure 5), which are attributed to the $^4T_{1g} \rightarrow {}^4A_{2g}(\nu_2)$ and $^4T_{1g} \rightarrow {}^4T_{1g}(\nu_3)$ transitions, respectively[33][34]. The Co^{II} complex has a magnetic moment of 4.7 B.M, which is within the range described for a high-spin octahedral geometry around the Co^{II} ion [35], however the spectra of the third band assigned to ν_1 cannot be observed due to the instrument's limited range (400-1000 nm). Moreover, the light brown color of the complex is in good agreement with those reported for octahedral Co^{II} complexes [36]. While The magnetic moment data as well as the electronic spectra of the Ni^{II} complex that assist with identifying its structure is given in (Table 5).

The magnetic moment of the Ni^{II} complex is 3.1 B.M., which is within the range predicted by [36][13] for an octahedral geometry centered on the Ni ion with a $^3A_{2g}$ ground term. Furthermore, according to (Figure 6) UV-vis spectra, the complex exhibits two bands at 13157 cm^{-1} and 12987 cm^{-1} that are likely caused by the (ν_1) $^3A_2g \rightarrow {}^3T_2g$ [37] [13]. The brown color is an additional evidence of the octahedral structure (Structure 2) [13].

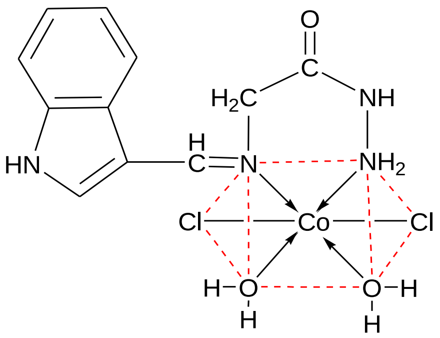
The Cu^{II} complex's significant electronic absorption band and magnetic moments are provided in (Table 5). The distorted octahedral geometry is indicated (Structure 3)[38] based on the low bandwidth at 12658 cm^{-1} in the electronic spectra of the Cu complex (Figure 5), which was designated as the 10 Dq band corresponding to the $^2E_g \rightarrow {}^2T_{2g}$ transition. The Jahn-Teller effect, which amplifies the distortion of the octahedral geometry, may be the cause of the observed band's broadness[28].

Furthermore, the green color is another indicator of octahedral structure[39]. The magnetic moment values (1.9 B.M.) were discovered to be within the range reported for the d^9-system containing one unpaired electron [13].

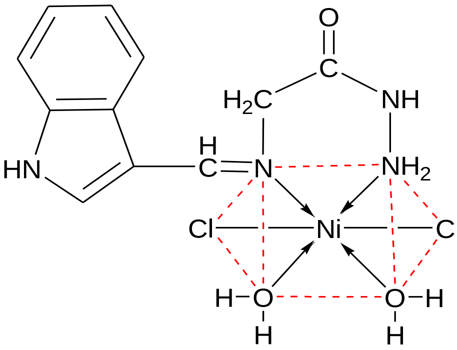
Furthermore, the broad bands centered at 23255cm^{-1}, 22727cm^{-1}, and 22988cm^{-1} should be attributed to charge-transfer transitions for the Co^{II} [39], Ni^{II} [39] and Cu^{II} [13][38] complexes, respectively.

Comp.	**μ_{eff} (B.M)**	**UV bands (cm^{-1})**		**Charge transfer bands(cm^{-1})**	***d-d* transition bands(cm^{-1})**	**Supposed structure**
		$\pi \rightarrow \pi^*$	$n \rightarrow \pi^*$			
L	-	41666	37037	-	-	-
$[Co (L)(H_2O)_2Cl_2]$	4.7	-	-	23255	16129, 14705	Octahedral
$[Ni (L)(H_2O)_2Cl_2]$	3.1	-	-	22727	13157,12987	Octahedral
$[Cu (L)(H_2O)Cl_2]$	1.9	-	-	22988	12658	Distorted Octahedral

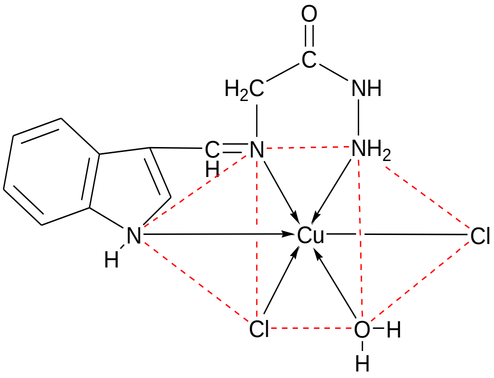
Table 5 : Magnetic moment, electronic spectral data in DMSO solution for the ligand and its Complexes



Structure 1: Complex of L with Co^{II}



Structure 2: Complex of L with Ni^{II}



Structure 3: Complex of L with Cu^{II}

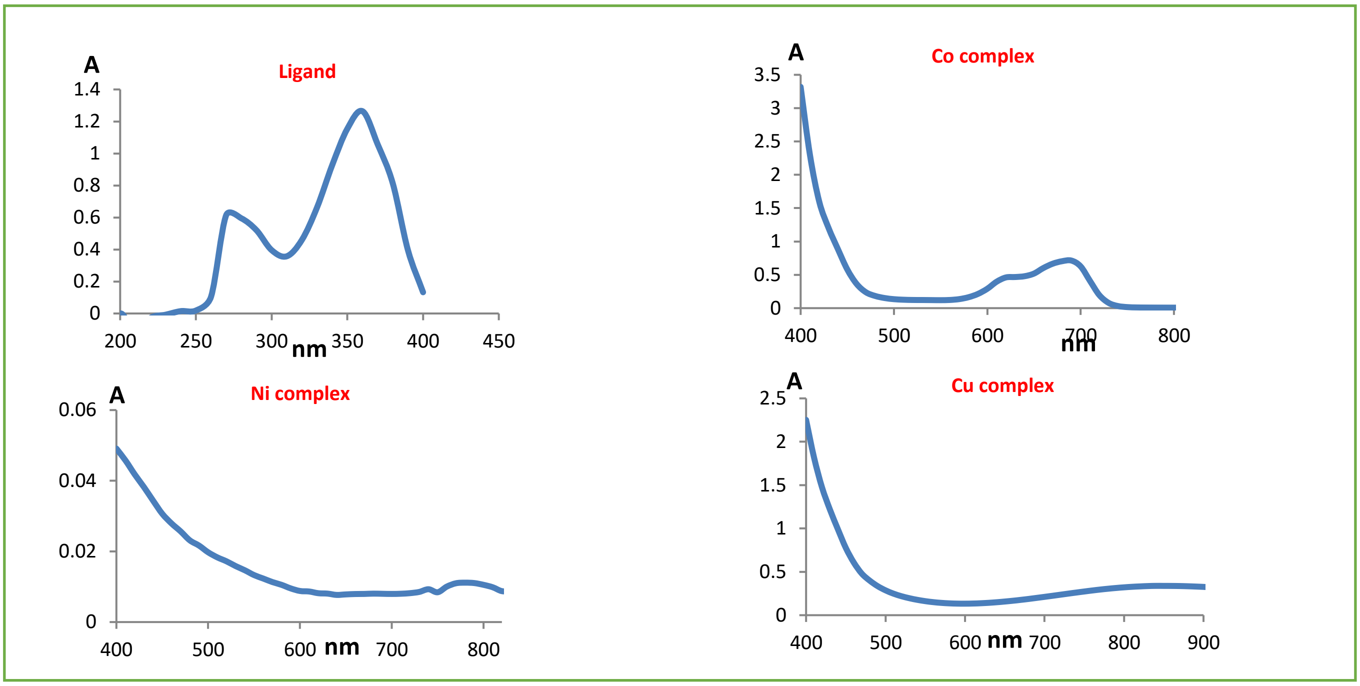


Figure 5 : UV-visible Electronic Spectrum of the ligand and its complexes in DMSO solution

3.5 X-ray diffraction of the ligand and its complexes

The ligand and its complexes are located in the nano-domain (12.54 to 30.94 nm), and this was calculated and proven by using Deby-scherrer equation [40].

$$D = K\lambda / \beta \cos \theta$$

Where θ is the Bragg diffraction angle in radians, β is the full width at half maximum (FWHM), and K is the Scherrer constant, which is equal to 0.94, and λ is the X-ray wavelength of Cu-Kα radiation (0.15405nm). The crystalline strain was also calculated by applying the slope of William's equation[41],

Strain (ε) =β*cos θ /4 sin θ

which showed that these compounds possess the crystal tensile property as shown in (Table 6). through the positive tensile values. These compounds' X-ray images are captured and displayed in (Figure 6). The integrated peak areas of the major peaks were used to calculate the percentage of crystallinity, Xc(%)[40]. Calculating the complex's crystallinity in relation to the ligand's crystallinity as a ratio

where the areas under the major peaks of the complex and ligand samples are designated as $A_{complex}$ and A_{ligand}, respectively. The results of the crystal ratio calculations proved that the complexes have a much higher crystalline property than the ligand.

$$X_c(\%) = A_{complex}/A_{ligand} *100$$

Table 6 : XRD spectrum data of the ligand and its complexes at greatest value of intensity

Comp.	θ (Radian)	β(FWHM) (Radian)	βcosθ	4sinθ	D(nm)	Strain (ε)	X%
L	0.1152	0.004712	0.004681	0.4597	30.94	0.0102	100
$[Co(L)(H_2O)_2Cl_2]$	0.1259	0.006720	0.006666	0.5020	21.72	0.0133	4825.75
$[Ni(L)(H_2O)_2Cl_2]$	0.1257	0.006789	0.006736	0.5013	21.50	0.0134	3404.43
$[Cu(L)(H_2O)Cl_2]$	0.1251	0.0116416	0.01155	0.4992	12.54	0.0231	469.72

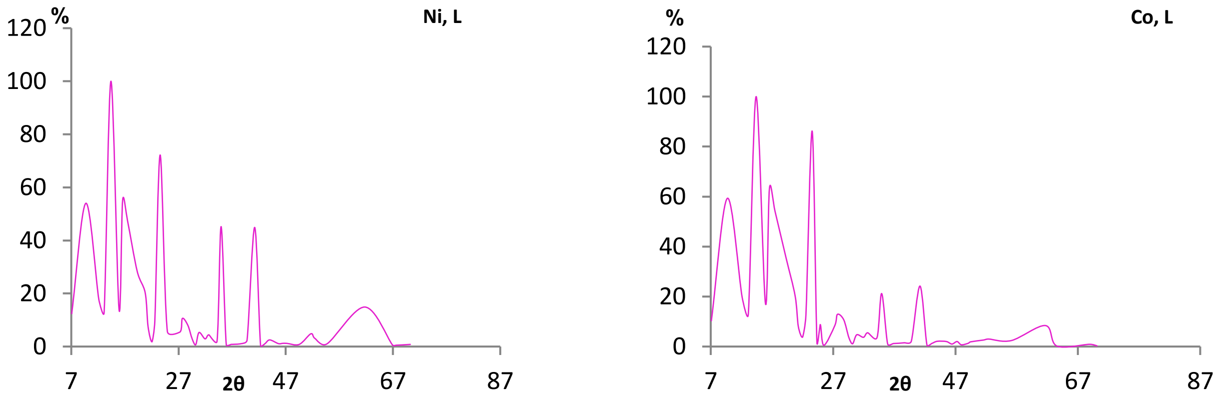


Figure 6: XRD patterns of the ligand and its complexes

3.6 Antioxidant of the ligand

Using a method of the FBRC [42]. The ligand was compared with (ascorbic acid) as the antioxidant, it was found that, this ligand can be used as an antioxidant, with less effectiveness than ascorbic acid which was used as a standard material in this analysis, the ligand gave

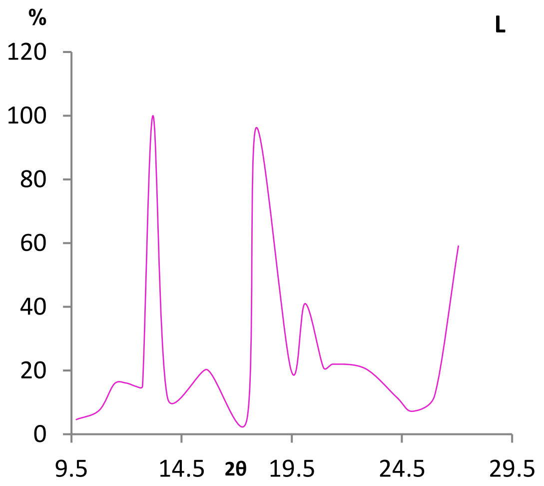
2.0811mg. compared with ascorbic acid which was 1mg. while the standard deviation of this ligand was ±1*10^{-8}(Table 7).

3.7 Antimicrobial Studies

By using the disc filtration method, the ligand and its complexes were evaluated for their antibacterial activity against two species of fungi (*Candida albicans* and *Aspergillus flavus*) and four types of bacteria (*Staphylococcus aureus*, *Bacillus subtilis*, *Escherichia coli*, and *Pseudomonas aeruginosa*) [43][44]. By dissolving the compounds In DMSO as 1000 µg/ml. The surface of Hinton-hardened agar plates cultured with the tested bacteria and Chapek-Dox medium plates cultured with fungi laboratory. At the end of the incubation periods-24 hours at 37°C for bacteria, 2 days at 37°C for *Aspergillus flavus*, and 5 days at 37°C for *Candida albicans*, the diameters of the inhibitory zones (mm) were determined [45][46].These compounds have both bacterial and fungal efficacy against the examined species, according to the antimicrobial properties of the compounds (Table 8 and illustrated in (Figures 7 and 8). These complexes' effectiveness against antibacterial action is due to the altered lipid behavior of these compounds. These substances inhibit a range of cellular enzymes that are essential to the different metabolic pathways that these organisms use. Furthermore, it has been proposed that the toxin's ultimate effect is the denaturation of one or more cell proteins, which compromises regular cellular functions [21][47][48].

Comp.	**Ascorbic acid**	**Ligand**
number of replicates	6	3
Standard deviation	2.96222*10^{-3}±	**1*10^{-8}**
Effectiveness(mg)	1	**2.0811**

Table 7: result comparison of FBRC for determination of antioxidant activity



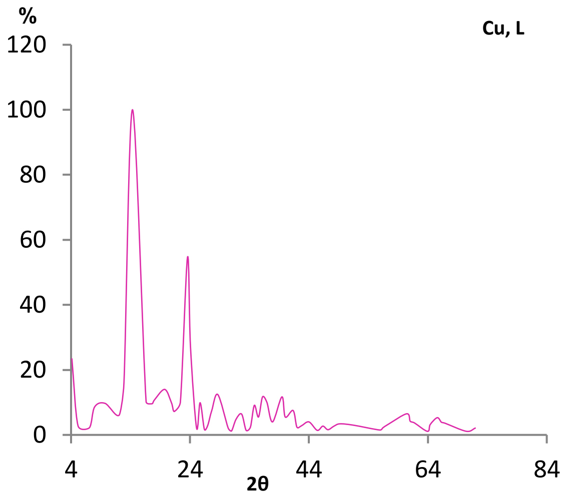
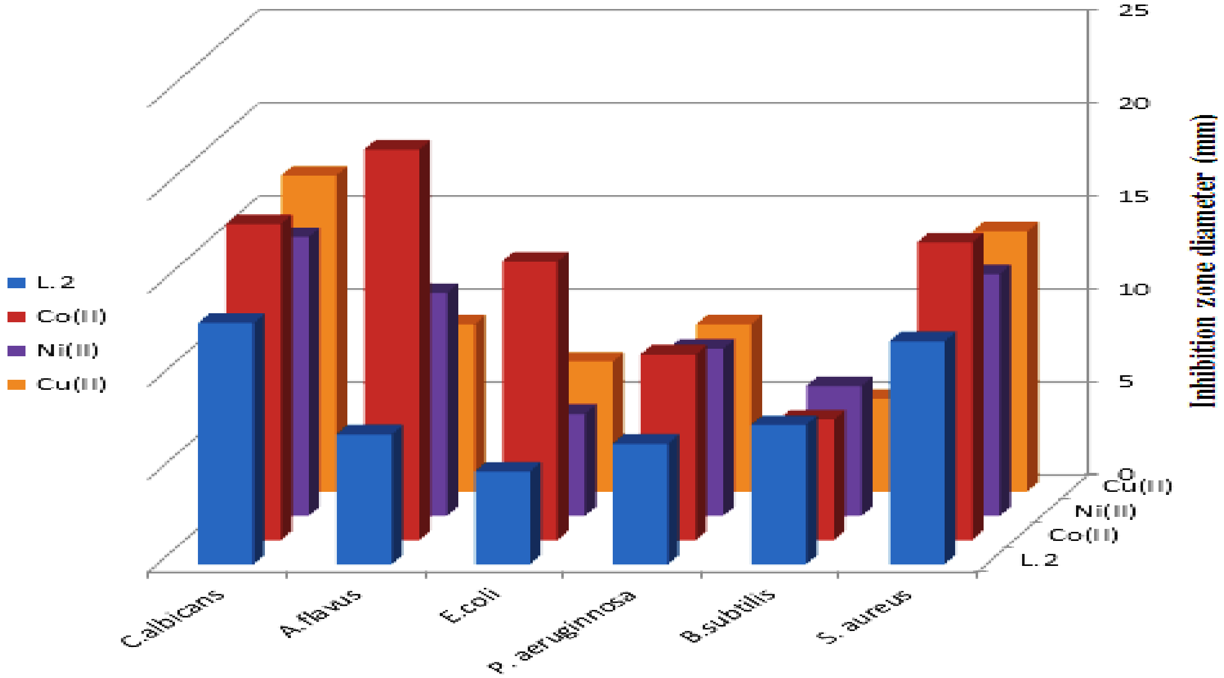
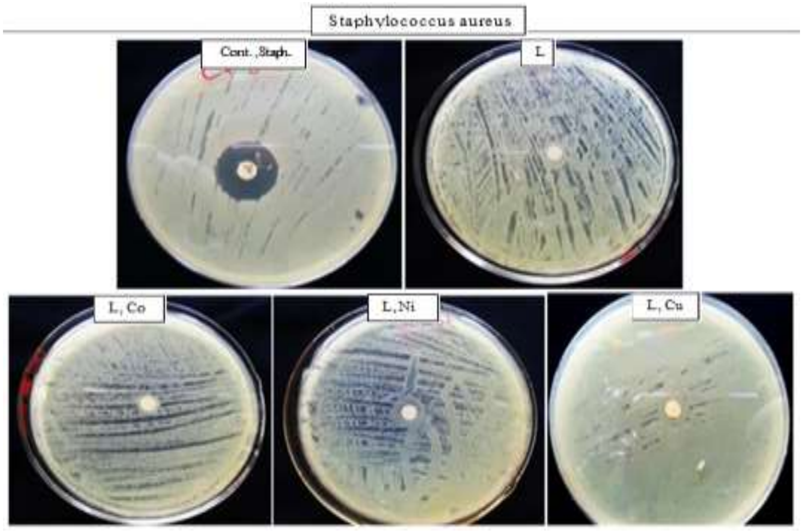


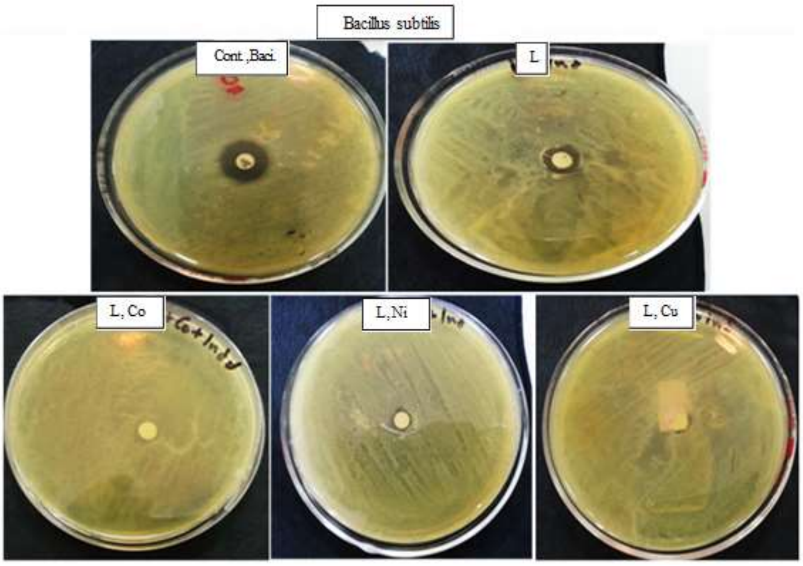
Table 8: The effect of the ligand and its complexes on the growth of Bacteria and fungi (Zone of inhibition in mm).

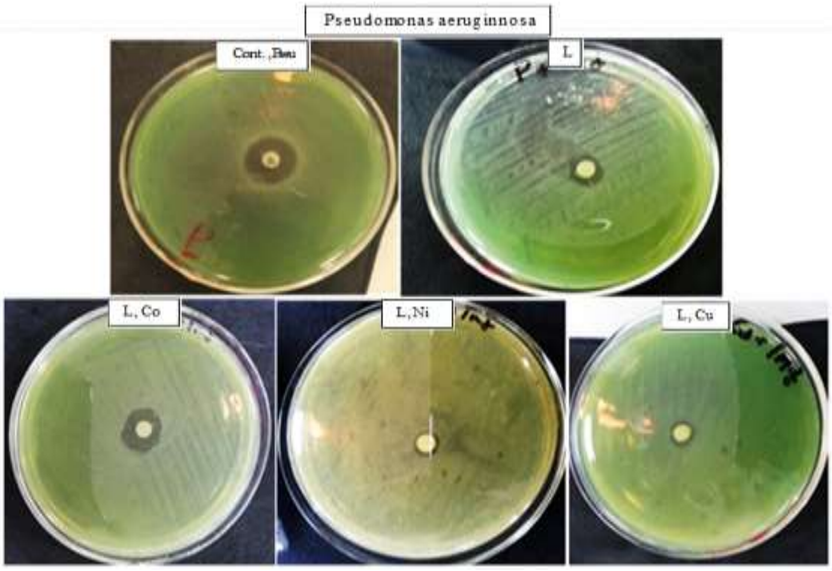
Compound (1000 µg/ml)			Inhibition zone diameter (mm)					
			Bacteria				fungi	
			Gram positive		Gram negative			
			Staphylococcus aureus	Bacillus subtilis	Pseudomonas aeruginosa	Escherichia coli	Asperagillus flavus	Candida albicans
Control DMSO			0.0	0.0	0.0	0.0	0.0	0.0
Standard	Antibacterial agent Gentamicin 120µg/ml		23	22	25	23	-	-
	Antifungal agent	Nystatin 100 µg/ml	-	-	-	-	25	21
		Miconazole 50 µg/ml	-	-	-	-	8	22
		Itraconazole 30 µg/ml	-	-	-	-	18	20
		Metronidazole 5 µg/ml	-	-	-	-	10	17
L			12	7.5	6.5	5	7	13
[Co (L) $(H_2O)_2$ Cl_2]			16	6.5	10	15	21	17
[Ni (L) $(H_2O)_2$ Cl_2]			13	7	9	5.5	12	15
[Cu (L) H_2O Cl_2]			14	5	9	7	9	17

Figure 7: Diagram of the effect of the ligand and its complexes on the growth of Bacteria and fungi (Zone of inhibition in mm).




Staphylococcus aureus
Cont. ,Staph.
L
L, Co
L, Ni
L, Cu


Bacillus subtilis
Cont. ,Baci.
L
L, Co
L, Ni
L, Cu


Pseudomonas aeruginnosa
Cont. ,Pseu
L
L, Co
L, Ni
L, Cu

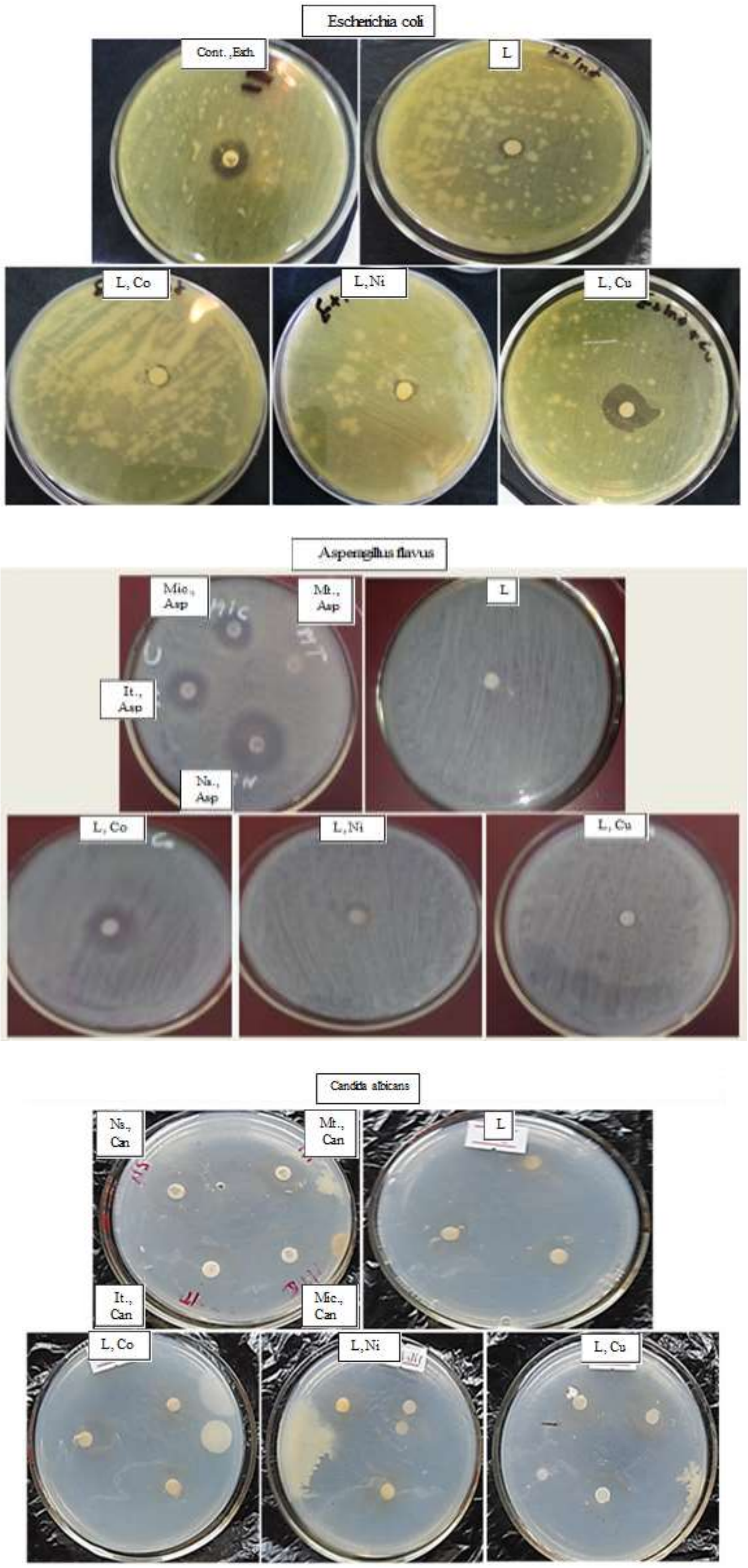


Figure 8: Biological activity of the ligand and its complexes against some Bacteria and fungi.

Conclusions

The prepared ligand has been solid-state isolated, with Co^{II}, Ni^{II} and Cu^{II} ions, it forms complexes. The goal of the current investigation was to examine the ligand's metal complexes' spectrum data and synthesis.

The low molar conductance of the complexes indicates that, they are non-electrolyte and neutral. The IR spectra of all these compounds indicate the coordination site. Analytical results and all physical-chemical research lead to the conclusion that all complexes have a metal:ligand stoichiometric ratio of 1:1. The general compositions of the complexes are [M (L) $(H_2O)_nCl_2$] (where M= Co^{II} ,Ni^{II} and Cu^{II}. According to results obtained, all the complexes are Octahedral geometries The X-ray diffraction indicates that, these compounds are in the nano scale. A good amount of the ligand's antioxidant action has been observed**.** Positive anti-bacterial and anti-fungal activity is present in the free ligand and their metal complexes against all the species using.

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