

**Article**

**Synthesis, Characterization and Antibacterial Activity of Schiff-Base Ligand Derived from Naphthaldehyde with its Complexes**

**Hadeel, Jalal. Abbas\* , A'ala, Baddai. Nashter and Montaha, Kadhim. Sultan**

The General Directorate of Education- Al-Rusafa/1

\*Corresponding Author: Email: [hadeeljalal31@gmail.com](mailto:hadeeljalal31@gmail.com) ,  
[alla.bdai1205a@ihcoedu.uobaghdad.edu.iq](mailto:alla.bdai1205a@ihcoedu.uobaghdad.edu.iq)

**Abstract**

The formation of a Schiff-Base ligand 2-((2-hydroxynaphthalen-1-yl)methylene)hydrazine/1-carboxamide (L) with its complexes are set. This ligand has obtained from the condensation of 2-hydroxy-1-naphthaldehyde by semicarbazide. A series of metal complexes were produced by the ligand's interaction with the metal chlorides of Mn(II), Co(II), Ni(II), Cu(II), Zn(II) in addition to Cd(II) . So the analyses showed that the general formula of complexes gave  $[M(L)Cl]_2$  where M= Mn(II), Co(II), Ni(II), Cu(II), Zn(II) and Cd(II). According to these investigations, the tetrahedral arrangement for Mn(II), Co(II), Ni(II), Cu(II), Zn(II) and Cd(II) was disturbed. Then biological activity for the synthesised compounds was measured and checked against *Bacillus subtilis*, *Staphylococcus aureus*, *Escherichia coli* and *Klebsiella Pneumoniae*. The results were compared with Ampicillin that is used as a main standard antibiotic. Consequently, set of these compounds gave an identical antibacterial activity to the Ampicillin.

**Keywords: Structural characterisation, Schiff base ligand Antibacterial activity and Ampicillin**

**Introduction**

In the past decades, Schiff-base metal complexes became the focus of attention because of their role in coordination chemistry [1,2], ease of preparation and structural diversity. Schiff base is considered as an important and essential substance that is used as metal ion complexing agent [3] because of their ability to form invariable compounds with any metal ion[4]. These compounds are used in medicine[5,6], copyist of bioactive molecules[7], catalysis[8], analytical[9], environmental chemistry[10] and as scavengers for the removal of heavy metal ions[11]. Their bioavailability makes the materials excellent antiviral, anti-inflammatory[12], anti-apoptotic[13] in addition to antibacterial agents[14]. Schiff base compounds containing (N,O) chelating sites to complexation are known as semicarbazones[15]. Their biological and pharmacological capabilities are among the many uses for which they bind transition and non-transition ions [16]. Semicarbazone

Schiff base compounds have been found to have a number of applications, including DNA binding and antibacterial and antifungal properties [17, 18]. Antiviral, analgesic, antispasmodic[19], anticancer[20], and antioxidant agents Capacity[21]

The aim of the study was to characterize and synthesize Schiff-bases with aldehyde groups taken from (2-hydroxy-1-naphthaldehyde) and semicarbazide to test the effective bioactivity of the ligands and their complexes against different kinds of bacteria.

## **Experimental**

### **Materials and Methods**

The reagents utilized in this investigation were applied exactly as described. CsI discs and KBr from 4000 to 250  $\text{cm}^{-1}$  were employed to set the spectra of compounds using the Shimadzu Fourier Transform Infrared Spectrometer (FTIR-600). A Shimadzu 160 spectrophotometer was used to measure and evaluate the electronic spectra for  $10^{-3}$  M solutions in DMSO at room temperature, covering the wavelength range of 200–1100 nm. Melting points were determined for the ligand and its metal complexes utilizing an Eager 300 for EA1112 and a specific electrothermal Stuart apparatus/model SMP40 elements analysis (C.H.N.). Metal with chloride percentages of compounds were measured using a potentiometric titration method using a 686-titro processor - 665 Dosimat - Metrom Swiss, and a Shimadzu (A.A) 680G atomic absorption spectrophotometer. A Eutech Instruments Cyberscan con 510 digital conductivity meter was used to record the molar conductance for complexes. Sherwood Scientific Devised was used to achieve and complete the magnetic measurements at 298.6 K. The Central Service Laboratory of the Iraqi Ministry of Science and Technology examined the biological activity of several substances.

### **The Synthesis of 2-((2-hydroxynaphthalen-1-yl)methylene)hydrazine-1-carboxamide (L)**

An equimolar mixture 2-hydroxy-1-naphthaldehyde(0.001 mol) in ethanol (15 mL) has been added with stirring a solution of semicarbazide (0.07g) in 10ml of EtOH was refluxed with a catalytic amount of glacial acetic acid (2 drops) for 8 h and permitted to restrict evaporation at RT. The pale -Brown crystals formed were accumulated during filtration and washed with some cold ethanol (5ml)/ diethyl ether (10ml) and then dried in the air and cold ethanol (5ml) .

### **The Synthetic procedure for complexes**

The solution of (L) (0.1g 0.28mmol) has been added a hot ethanolic solution (15 mL) of respective metal chlorides (0.001 mol). The reaction mixture was bounced on a water bath for 4h. The pH of the reaction mixture was adjusted ca. 9 this was by adding alcoholic solution of potassium hydroxide and refluxing continued for about an hour more. The reaction mixture was cooled to room temperature and then poured into distilled water. So the colored solids separated were collected by filtration, washed with sufficient quantity of distilled water.

### **Antibacterial Activity**

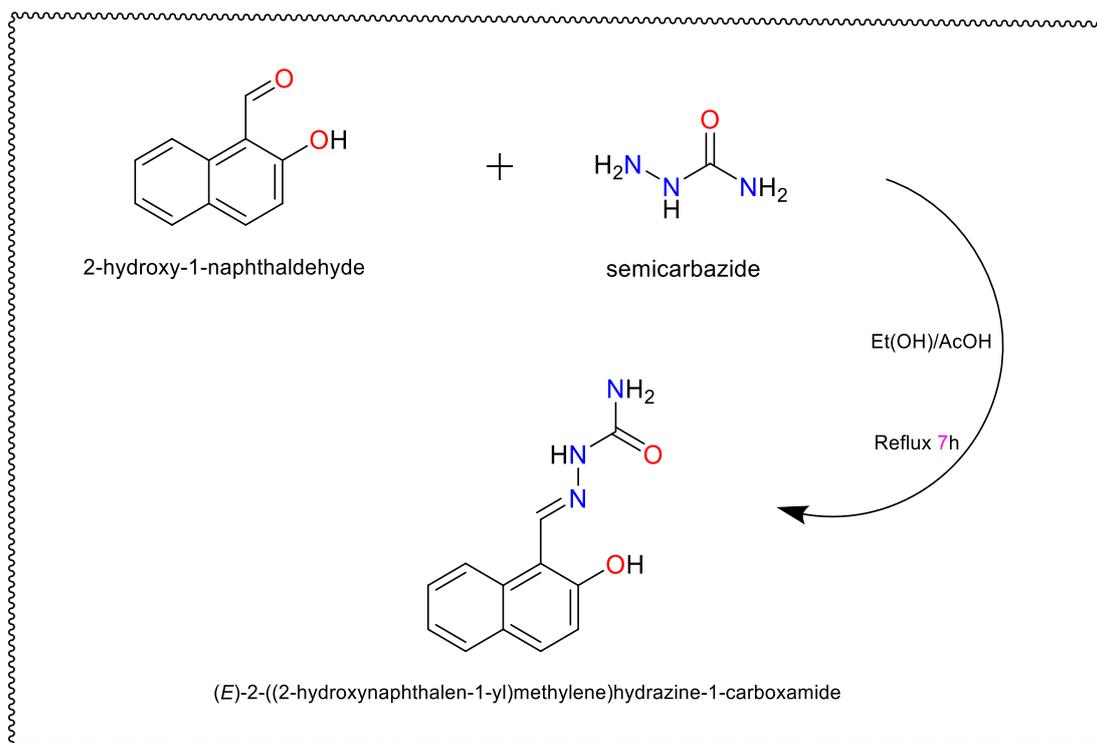
The ligand (L) in addition to its transition metal complexes were all screened for their antibacterial activity against (*Staphylococcus aureus*, *Bacillus subtilis*, *Escherichia coli*, and *Klebsiella Pneumoniae* ). This task was completed by employing the agar well diffusion method, in which sterile metallic borers with a minimum center diameter of 6 mm were used to drill wells in the media [15,16]. The antibiotic standard, ampicillin, was used to compare this activity. These produced compounds were placed in an incubator for 24 h at 37°C after dissolving in DMSO. It was done what (DMSO) was supposed to do. This suggested that it has no primary impact. The evaluated substances were centered on the antibiotic standard of 50 mg/ml. Obtained information in Table 4

## **Results and Discussion**

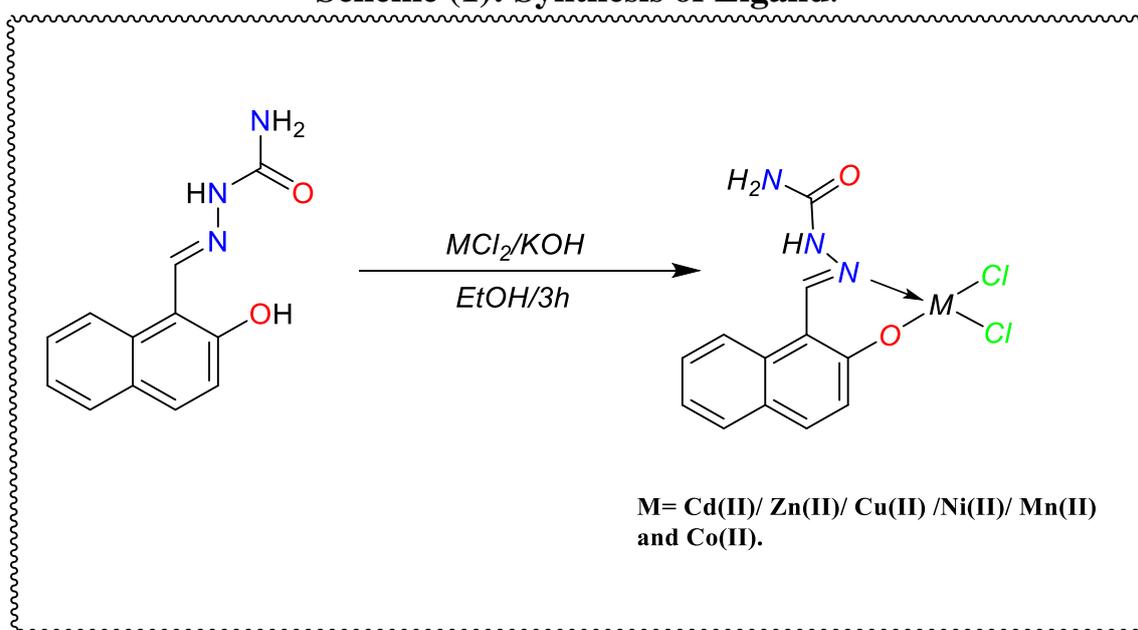
### **Chemistry**

The formation of the Schiff-Base Ligand of condensation reaction of the 2-hydroxy-1-naphthaldehyde and the semicarbazide in (1:1) mole ratio in (EtOH) medium conducted in the formation of the title ligand 2-((2-hydroxynaphthalen-1-yl)methylene)hydrazine(1)carboxamide (L) Scheme (1).

The ligand-to-molecule (L:M) mole reaction was conducted with metal chlorides of (Mn(II), Co(II), Ni(II), Cu(II), Zn(II) and Cd(II) in a 1:1 ratio, employing EtOH as a medium and KOH as a base. It investigated the separation of (complexes with four coordinates) Scheme 2. The use of (KOH) was necessary to generate the monobasic species and deprotonate the ligand, consequently, no reaction may be proceeded without arranging the (pH) of the reaction to *ca.* 9. The prepared compounds (ligand and complexes) were characterised by a range of physicochemical techniques. These include metal and chloride ratio with micro-elemental analyses (Table 1). FT-IR (Table 2). UV-Vis spectroscopy (Table 3). The conductance measurement of the complexes in (DMSO) solutions showed the isolation of the nonelectrolyte complexes. According to the given data, the complexes of the general formula  $[M(L)Cl_2]$  (where; M= Mn(II), Co(II), Ni(II), Cu(II), Zn(II) and Cd(II)) were isolated.



Scheme (1): Synthesis of Ligand.



Scheme 2: Synthesis of complexes.

**FT-IR data**

The FT-IR of (L). Figure 1 showed some bands at 3437 and 3176  $cm^{-1}$  which is attributed to  $\nu(NH_2)$  and  $\nu(NH)$ , respectively of the hydrazine group [15]. The spectrum showed bands in (1685) and (1597)  $cm^{-1}$  which attached to  $\nu(C=O)_{amide}$  semicarbazone group and  $\nu(C=N)_{imine}$  [18,19] in sequence.

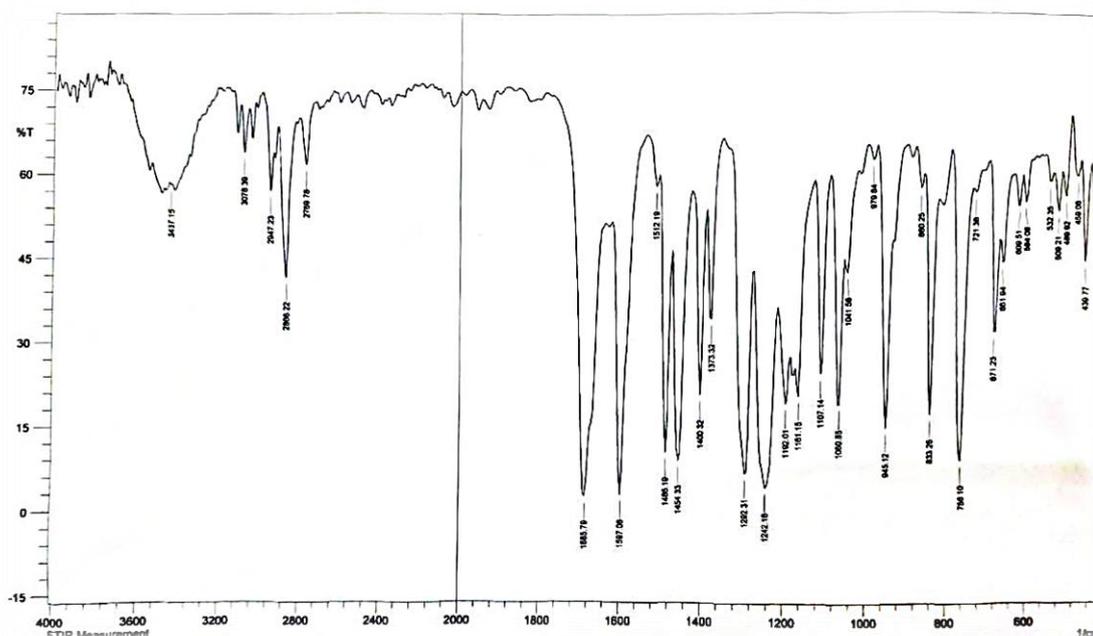


Figure 1: FT-IR spectrum of Ligand.

### (FT- IR )spectra for complexes

The complexes spectra in ( imine stretching band) revealed a shift, (C=N) by 4-28  $\text{cm}^{-1}$  contrasted with that at 1597  $\text{cm}^{-1}$  in ligand which found in 1588, 1580, 1569, 1573, 1593 and 1580  $\text{cm}^{-1}$  in Mn(II), Co(II), Ni(II), Cu(II), Zn(II) and Cd(II) Frequently, The distribution of the nitrogen atom for the -C=N group to the imine for the metal centre causes the band shifting[22, 23]. In Mn(II), Co(II), Ni(II), Cu(II), Zn(II) and Cd(II) complexes, the band at 1685  $\text{cm}^{-1}$  from  $\nu(\text{C}=\text{O})$ amide in the free ligand is routinely displaced by 15–21  $\text{cm}^{-1}$  into a lower frequency and detected at 1670, 1666, 1664, 1670, 1664, and 1665  $\text{cm}^{-1}$  Nevertheless, such shifting is assigned as a part of evidence of the assortment of the oxygen atom for the semicarbazone to the metal centre [19]. So, the spectra of this free ligand showed peak at 3437 which is went with  $\nu(\text{NH}_2)$  stretching of the hydrazine set. So, the peak lacked a shift against spectrum of the ligand then found in 3402, 3400, 3340, 3383, 3313 and 3332 for Mn(II), Co(II), Ni(II), Cu(II), Zn(II) and Cd(II) Complexes. The bands which attributed at 3170, 3109, 3159, 3175, 3199 and 3109  $\text{cm}^{-1}$  where set to  $\nu(\text{NH})$  in Mn(II), Co(II), Ni(II), Cu(II), Zn(II) and Cd(II) complexes regularly. New bands were observed in the spectra at 562, 569, 546, 533, 549, and 549  $\text{cm}^{-1}$ . These bands were indicative of regular  $\nu(\text{M}-\text{O})$  of Mn(II), Co(II), Ni(II), Cu(II), Zn(II) and Cd(II) complexes [19, 23]. For Mn(II), Co(II), Ni(II), Cu(II), Zn(II) and Cd(II) regular bands associated with  $\nu(\text{M}-\text{N})$  were observed at 452, 454, 433, 432, 443, and 445  $\text{cm}^{-1}$  [17, 18, 24]. Afterwards, the (FT-IR) spectra showed bands at 241  $\text{cm}^{-1}$  for  $\nu(\text{Mn}-\text{Cl})$ , 240  $\text{cm}^{-1}$  for  $\nu(\text{Co}-\text{Cl})$ , 255  $\text{cm}^{-1}$  for  $\nu(\text{Ni}-\text{Cl})$ , 249

$\text{cm}^{-1}$  for  $\nu$  (Cu-Cl),  $236 \text{ cm}^{-1}$  for  $\nu$  (Zn-Cl), and  $241 \text{ cm}^{-1}$  for  $\nu$  (Cd-Cl) [23, 24]. These bands demonstrated that the metal center was responsible for the chlorido moiety

### **The Magnetic Moment Measurements and Electronic Spectra**

The UV-Vis known as the spectrum of (L) exhibits which peaks at (263) and (315) nm that is resulted from ( $\pi \rightarrow \pi^*$  and  $n \rightarrow \pi^*$ ) [25-28], respectively. The spectrum of the Mn(II)-complex showed peaks in the visible region at 467 and 845 nm attributed  ${}^6\text{A}_1 \rightarrow {}^4\text{T}_{2(\text{G})}$  and  ${}^6\text{A}_1 \rightarrow {}^4\text{A}_{1(\text{G})}, {}^4\text{E}_{(\text{G})}$ , regularly. The data propose the attribution sphere for the (Mn atom) is tetrahedral [29]. Co(II) complex showed the peaks in a visible area at 541-831 nm which attached to  ${}^4\text{T}_{1(\text{F})} \rightarrow {}^4\text{T}_{1(\text{P})}$  with  ${}^4\text{T}_{1(\text{F})} \rightarrow {}^4\text{A}_{2(\text{F})}$  transitions regularly with showing tetrahedral structure over Co atom [25]. So spectrum of Ni(II)-complex contained absorption peaks at 751-845 nm related to  ${}^3\text{T}_{1(\text{F})} \rightarrow {}^3\text{T}_{1(\text{P})}$  and  ${}^3\text{T}_{1(\text{F})} \rightarrow {}^3\text{A}_{2(\text{F})}$  rehearsing the tetrahedral arrangement of the Ni atom [29]. The peaks has been recorded at 355- 867 nm within the spectrum of the Cu(II)/complex were specified to  ${}^2\text{B}_{1\text{g}} \rightarrow {}^2\text{B}_{2\text{g}}$  and  ${}^2\text{B}_{1\text{g}} \rightarrow {}^2\text{A}_{2\text{g}}$ , regularly proposing some distorted square planar geometry of the Cu(II). The spectra of the Zn(II) and Cd(II) complexes showed peaks at 281 nm that were specific to the ligand field. A specific peak about 358 nm is associated with the charge-transfer transition type M $\rightarrow$ L. No prominent bands were visible in the d-d region [24/25/28/30] of the spectrum. Furthermore, various characterization tools served as the foundation for the tetrahedral geometry that was proposed regarding the metal center of the  $d^{10}$  configuration. Table 3 displays the values of the magnetic susceptibility data for the ligand complexes. The Mn(II),Co(II) and Ni(II) complexes' magnetic moment measurements consistently yield values of 5.46, 3.70 and 2.28 B.M. The values showing the metal center's tetrahedral geometry[31]. Using the complex of Cu(II) 1.50 B.M., the magnetic data may show the Cu atom's distorted square planer shape. [31].

**Table(1):Microanalysis and physical properties of Ligand and complexes**

Comp.	M.Wt	Colour	m.p	Y. (%)	Microanalysis; calculated found (%)				$\Lambda_m$ S.cm <sup>2</sup> · mole <sup>-1</sup>
					C	H	N	Cl	
C <sub>12</sub> H <sub>11</sub> N <sub>3</sub> O <sub>2</sub>	229	Light-brown	122-124	52	(62.87) 67.87	(4.84) 6.79	(18.33) 19.65	-	-
[Mn(L)Cl <sub>2</sub> ]	354	Deep brown	211-213	60	(40.71) 41.56	(2.85) 2.82	(11.87) 11.70	(20.02) 20.11	16.05
[Co(L)Cl <sub>2</sub> ]	359	Red brown	225-227	71	(40.25) 41.25	(2.82) 2.28	(11.74) 11.84	(19.80) 19.92	9.36
[Ni(L)Cl <sub>2</sub> ]	358	brown	236-238	68	(40.28) 40.19	(2.82) 2.78	(11.74) 11.70	(19.81) 19.90	11.74
[Cu(L)Cl <sub>2</sub> ]	363	Dark blue	222-225	62	(39.74) 40.53	(2.78) 2.22	(11.59) 11.68	(19.55) 19.66	13.42
[Zn(L)Cl <sub>2</sub> ]	365	Light brown	231-233	64	(39.54) 40.31	(2.77) 2.64	(11.53) 11.58	(19.45) 19.81	14.02
[Cd(L)Cl <sub>2</sub> ]	641	Light brown	241-243	70	(44.99) 44.36	(3.30) 3.60	(13.12) 13.14	(11.06) 11.11	16.44

**Table (2): FT-IR data (cm<sup>-1</sup>) of Ligand and its complexes**

Comp.	$\nu(\text{NH}_2)$	$\nu(\text{NH})$	$\nu(\text{C=O})$	$\nu(\text{C=N})$	$\nu(\text{C=C})$	$\nu(\text{M-O})$	$\nu(\text{M-N})$	$\nu(\text{M-Cl})$
C <sub>12</sub> H <sub>11</sub> N <sub>3</sub> O <sub>2</sub>	3437	3176	1685	1597	1454	-	-	-
[Mn(L)Cl <sub>2</sub> ]	3402	3170	1670	1588	1444	562	452	241
[Co(L)Cl <sub>2</sub> ]	3400	3109	1666	1580	1442	569	454	240
[Ni(L)Cl <sub>2</sub> ]	3340	3159	1664	1569	1412	546	433	255
[Cu(L)Cl <sub>2</sub> ]	3383	3175	1670	1573	1431	533	432	249

[Zn(L)Cl <sub>2</sub> ]	3313	3199	1664	1593	1412	533	443	236
[Cd(L)Cl <sub>2</sub> ]	3332	3109	1665	1580	1435	549	445	241

Table (3): UV-Vis data of Ligand and its complexes.

Comp.	$\lambda_{nm}$	$\bar{\nu}(\text{cm}^{-1})$	$\epsilon_{max}^{3-1-1}$ ( $\text{dm}^3 \cdot \text{mol}^{-1} \cdot \text{cm}^{-1}$ )	Assignment	Suggested Geometry	$\mu_B$ BM
C <sub>12</sub> H <sub>11</sub> N <sub>3</sub> O <sub>2</sub>	263 315	38023 21746	2029 1234	$\pi \rightarrow \pi^*$ $n \rightarrow \pi^*$	-----	-
[Mn(L)Cl <sub>2</sub> ]	275 303 467 845	36364 32787 21413 11834	677 1465 380 30	L.F C.T ${}^6A_{1(G)} \rightarrow {}^4T_{2(G)}$ ${}^6A_{1(G)} \rightarrow {}^4A_{1(G)}, {}^4E_{(G)}$	Distorted Tetrahedral	5.46
[Co(L)Cl <sub>2</sub> ]	295 350 541 831	33898 28571 18484 12034	870 1123 38 22	L.F C.T ${}^4T_{1(F)} \rightarrow {}^4T_{1(P)}$ ${}^4T_{1(F)} \rightarrow {}^4A_{2(F)}$	Distorted Tetrahedral	3.70
[Ni(L)Cl <sub>2</sub> ]	295 384 751 845	33898 28736 13316 11834	270 160 40 58	L.F C.T ${}^3T_{1(F)} \rightarrow {}^3T_{1(P)}$ ${}^3T_{1(F)} \rightarrow {}^3A_{2(F)}$	Distorted Tetrahedral	2.28
[Cu(L)Cl <sub>2</sub> ]	280 301 355 867	35712 33223 28169 11534	522 225 145 104	L.F C.T ${}^2B_{1g} \rightarrow {}^2B_{2g}$ ${}^2B_{1g} \rightarrow {}^2A_{2g}$	Distorted square planar	1.50
[Zn(L)Cl <sub>2</sub> ]	281 359	35587 27855	1823 972	L. F C. T	Distorted Tetrahedral	-
[Cd(L)Cl <sub>2</sub> ]	282 358	35460 27932	1558 757	L. F C. T	Distorted Tetrahedral	-

\*L . F=Ligand Field, C . T=Charge Transfer

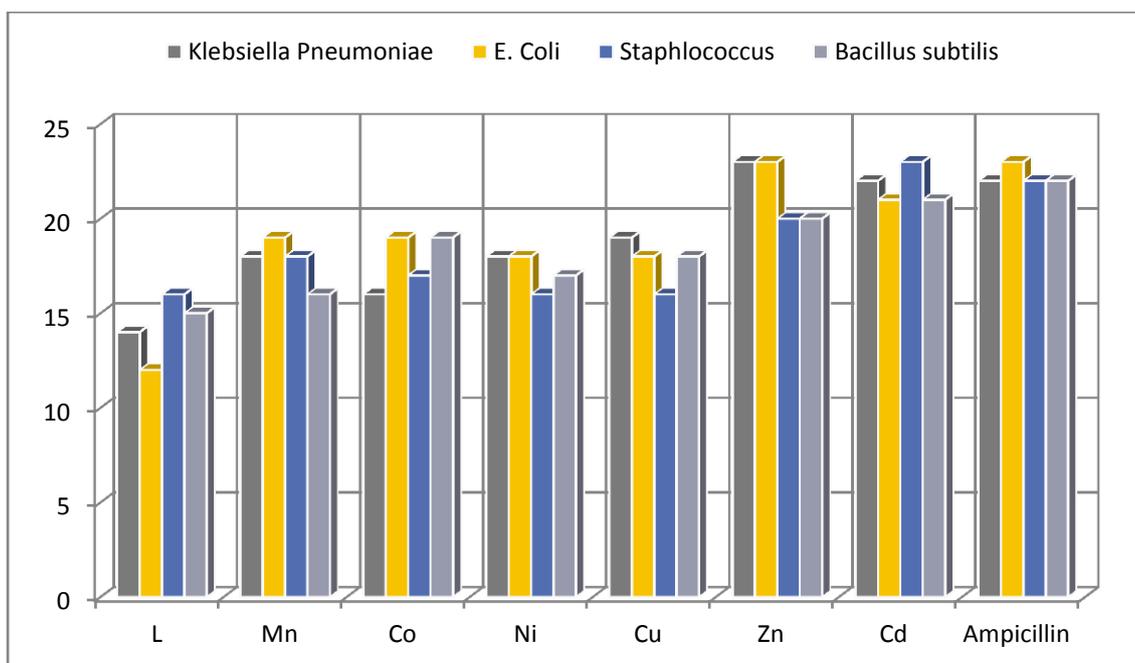
### Biological Activity

The microbiological activity of the metal complexes of the synthesized ligand was evaluated against two types of bacteria: G-positive (*Bacillus subtilis* and *Staphylococcus aureus*) and G- negative (*Klebsiella pneumoniae* and *Escherichia coli*). The selected bacteria are thought to be the most dangerous and lethal variety. Thus, a thorough screening is conducted for these microorganisms in all of the hospital's operating rooms. Additionally, the synthesized compounds demonstrated superior action against bacterial strains when compared to Ampicilin's activity.

**Table 4: Antibacterial screening data ( The zone of existence in mm) for**

<i>Comp.No</i>	<b>Bacteria</b>			
	<b>Gram-negative</b>		<b>Gram-positive</b>	
	<i>Klebsiella Pneumoniae</i>	<i>E. Coli</i>	<i>Staphylococcus Aurius</i>	<i>Bacillus subtilis</i>
<b>C<sub>12</sub>H<sub>11</sub>N<sub>3</sub>O<sub>2</sub></b>	14	12	16	15
<b>[Mn(L)Cl<sub>2</sub>]</b>	18	19	18	16
<b>[Co(L)Cl<sub>2</sub>]</b>	16	19	17	19
<b>[Ni(L)Cl<sub>2</sub>]</b>	18	18	16	17
<b>[Cu(L)Cl<sub>2</sub>]</b>	19	18	16	18
<b>[Zn(L)Cl<sub>2</sub>]</b>	23	23	20	20
<b>[Cd(L)Cl<sub>2</sub>]</b>	22	21	23	21
<b>Ampicillin</b>	22	23	22	22

**Compounds ( The Ligand and its Complexes).**



**Figure 2: The inhibition zones diameter; (mm) against the bacterial species for the ligand with its complexes.**

## References

- [1]Radha V, Chitra S, Jonekirubavathi S, Chung M, Kim S, & Prabakaran M.[2020]: Transition metal complexes of novel binuclear Schiff base derived from 3, 3'-diaminobenzidine: synthesis, characterization, thermal behavior, DFT, antimicrobial and molecular docking studies. *Journal of Coordination Chemistry*, 73(6), 1009-1027.
- [2]Al-Rubaye B, Brink A, Miller G, Potgieter H, & Al-Jeboori M.[2017]: Crystal structure of (E)-4-benzylidene-6-phenyl-1, 2, 3, 4, 7, 8, 9, 10-octahydrophenanthridine. *Acta Crystallographica Section E: Crystallographic Communications*, 73(7), 1092-1096.
- [3]Al-Rubaye B. Potgieter H, & Al-Jeboori, M.[2017]: An efficient one-pot approach for the formation of phenanthridine derivative; synthesis and spectral characterisation. *Der Chemica Sinica*, 8(3), 365-370.

- [4] Sigel R, & Sigel H.[2010]: A stability concept for metal ion coordination to single-stranded nucleic acids and affinities of individual sites. *Accounts of chemical research*, 43(7), 974-984.
- [5] Liu X, Manzur C , Novoa N , Celedón S , Carrillo D , & Hamon J.[2018]: Multidentate unsymmetrically-substituted Schiff bases and their metal complexes: Synthesis, functional materials properties, and applications to catalysis. *Coordination Chemistry Reviews*, 357, 144-172.
- [6] Naeimi H, Sadat Nazifi Z, Matin Amininezhad S , & Amouheidari M. [2013]: Synthesis, characterization and in vitro antimicrobial activity of some new Schiff bases and their complexes. *The Journal of Antibiotics*, 66(11), 687-689.
- [7] Uddin M, Ahmed S, & Alam S.[2020]. Biomedical applications of Schiff base metal complexes. *Journal of Coordination Chemistry*, 73(23), 3109-3149.
- [8] Dalia S, Afsan F, Hossain M , Khan M, Zakaria C, Zahan M, & Ali M.[2018]: A short review on chemistry of schiff base metal complexes and their catalytic application. *Int. J. Chem. Stud*, 6(3), 2859-2867.
- [9] Bouza M, Foest D , Brandt S, García-Reyes J, & Franzke J. [2024]: Enhanced Compound Analysis Using Reactive Paper Spray Mass Spectrometry: Leveraging Schiff Base Reaction for Amino Acid Detection. *Analytical Chemistry*, 96(13), 5289-5297.
- [10] Oiyé É, Ribeiro M, Katayama J, Tadini M, Balbino M, Eleotério I, & de Oliveira M.[2019]: Electrochemical sensors containing Schiff bases and their transition metal complexes to detect analytes of forensic, pharmaceutical and environmental interest. A review. *Critical Reviews in Analytical Chemistry*, 49(6), 488-509.
- [11] Mahmoud R, Mohamed F, Gaber E, & Abdel-Gawad O. [2022]: Insights into the synergistic removal of copper (II), cadmium (II), and chromium (III) ions using modified chitosan based on Schiff bases-g-poly (acrylonitrile). *ACS omega*, 7(46), 42012-42026.

- [12] Sandhu Q, Pervaiz M, Majid A, Younas U, Saeed Z, Ashraf A, Khan R, Ullah S, Ali F, and Jelani S.[2023]: Schiff base metal complexes as anti-inflammatory agents. *Journal of Coordination Chemistry*, 76(9-10), pp.1094-1118.
- [13] Liao W, Song X, Kong Y, Bao R, Li F, Zhou J, & Xie M. [(2021): A novel Schiff base cobalt (III) complex induces a synergistic effect on cervical cancer cells by arresting early apoptosis stage. *BioMetals*, 34, 277-289.
- [14] Naeimi H, Sadat Nazifi Z, Matin Amininezhad S, & Amouheidari M. [2013]: Synthesis, characterization and in vitro antimicrobial activity of some new Schiff bases and their complexes. *The Journal of Antibiotics*, 66(11), 687-689.
- [15] Abaas H, & Al-Jeboori M.[2021]: New dimeric complexes with semicarbazone mannish-based ligand; formation, structural investigation and biological activity. *Revis Bionatura* 2023; 8 (2) 15. In *Journal of Physics: Conference Series* (Vol. 1879, No. 22074, pp. 3-20).
- [16] Al-Rubaye B, Hussien N, Abul Rahman A, Yusoff S, Yousif E. I, & Al-Jeboori M. [2020]: New organotin (IV) complexes derived from 3, 4-dihydroxybenzaldehydeN (4)-ethyl-3-semicarbazone ligand; synthesis, characterisation and biological activity. *Biochemical and Cellular Archives*, 20(2), 6571-6579.
- [17] Saleh H, Abdul Rahman A, & Al-Jeboori M.[2021]: Synthesis, Structural Characterisation and Biological Evaluation of New Semicarbazone Metal Complexes Derived From Mannich-Base. *Biochemical & Cellular Archives*, 21(1).
- [18] Crook A, Lisic E, & Ensor D.[2012]: Thiosemicarbazone and semicarbazone chelating resins and their potential use in environmental applications. *Separation Science and Technology*, 47(14-15), 2225-2229.

- [19] Pósa V , Hajdu B, Tóth G , Dömötör O , Kowol C , Keppler B, & Enyedy E .[2022]: The coordination modes of (thio) semicarbazone copper (II) complexes strongly modulate the solution chemical properties and mechanism of anticancer activity. *Journal of Inorganic Biochemistry*, 231, 111786.
- [20] Petrasheuskaya T, Kovács F, Igaz N , Rónavári A , Hajdu B , Bereczki L , & Enyedy É[2022]: Estradiol-based salicylaldehyde (thio) semicarbazones and their copper complexes with anticancer, antibacterial and antioxidant activities. *Molecules*, 28(1), 54.
- [21] Dalia S , Afsan F , Hossain M , Khan M , Zakaria C , Zahan M , & Ali M.[2018]: A short review on chemistry of schiff base metal complexes and their catalytic application. *Int. J. Chem. Stud*, 6(3), 2859-2867.
- [22] Muat T, & Al-Jeboori M .[2016]: Phenoxo-and azido-bridged complexes with N<sub>2</sub>O<sub>2</sub>S Schiff-base ligand; synthesis, spectral investigation and bacterial activity. *Chem Xpress*, 9(2), 156-171.
- [23] El-Zahed M , El-Sonbati A, Ajadain F, Diab M, & Abou-Dobara M.[2023]: Synthesis, spectroscopic characterization, molecular docking and antimicrobial activity of Cu (II), Co (II), Ni (II), Mn (II) and Cd (II) complexes with a tetradentate ONNO donor Schiff base ligand. *Inorganic Chemistry Communications*, 152, 110710.
- [24] Al-Jeboori M, Abdul-Ghani A, & Al-Karawi A.[2008]: Synthesis and structural studies of new Mannich base ligands and their metal complexes. *Transition metal chemistry*, 33, 925-930.
- [25] Ahmed R, Yousif E, & Al-Jeboori M .[2013]: Co (II) and Cd (II) complexes derived from heterocyclic schiff-bases: synthesis, structural characterisation, and biological activity. *The Scientific World Journal*, 2013 (1), 754868.

- [26] Al-Jeboori M, Hasan H, & Jaafer Al-Sa'idy W.[2009]: Formation of polymeric chain assemblies of transition metal complexes with a multidentate Schiff-base. *Transition metal chemistry*, 34, 593-598.
- [27] Mawat T, & Al-Jeboori M .[2019]: Novel Metal Complexes Derived from Selenosemicarbazone Ligand; Synthesis, Spectral Investigation and Biological Activity. *J. Global Pharma Tech*, 11(09), 126-138.
- [28] Abdul-Ghani A, Al-Jeboori M, & Al-Karawi A.[2009]: Synthesis and spectral studies of new N2S2 and N2O2 Mannich base ligands and their metal complexes. *Journal of Coordination Chemistry*, 62(16), 2736-2744.
- [29] Shaker S, Khaledi H, Cheah S, & Ali H.[2016]: New Mn (II), Ni (II), Cd (II), Pb (II) complexes with 2-methylbenzimidazole and other ligands. Synthesis, spectroscopic characterization, crystal structure, magnetic susceptibility and biological activity studies. *Arabian journal of chemistry*, 9, S1943-S1950.
- [30] Mawat T, & Al-Jeboori M. [2020]: Synthesis, characterisation, thermal properties and biological activity of coordination compounds of novel selenosemicarbazone ligands. *Journal of Molecular Structure*, 1208, 127876.
- [31] 31. Ahmed R, Hamdan T, Numan A, Al-Jeboori M, & Potgieter H.[2014]: Formation of polymeric assemblies of six-coordinate metal complexes with mixed bridges of dicarboxylato-azido moieties. *Complex Metals*, 1(1), 38-45.