

# Synthesis and Antibacterial Activity of Isatin Schiff Base Derivative with 3-Aminoacetophenone and its Ni<sup>II</sup>, Co<sup>II</sup> Transition Metals Complexes

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**Abstract**—The (E)-3-(3-acetylphenylimino) indolin-2-one (Bidentate) ligand type [HL] has been prepared from Isatin and 3-aminoacetophenone in the presence of KOH. In general, the ligand contains oxygen (O) and nitrogen (N) donor atoms. The reaction of Isatin and 3-aminoacetophenone was carried out in ethanol by condensation reaction at 80°C with reflux for 4 h, to form [HL] ligand type. This ligand has been used to prepare Ni<sup>II</sup> and Co<sup>II</sup> complexes in the ratio of 1:1 metal-ligand. All compounds have been characterized by spectroscopic methods (Fourier transform infrared and ultraviolet-visible), C.H.N, thin-layer chromatography, mass spectrum, X-ray diffraction, magnetic moment, conductivity measurements and melting point, the synthesized ligand and its metal complexes have been tested for their antibacterial activity against *Staphylococcus aureus* and *Bacillus subtilis* using agar disc diffusion method. The ligand and its complexes showed significant activities against *S. aureus* and *B. subtilis*. Our study revealed the formation of four coordinate square planar complexes around Ni<sup>II</sup> and Co<sup>II</sup> metal ions.

**Index Terms**—3-aminoacetophenone, Bidentate ligand and (N) donor atoms, Isatin, Schiff base.

## I. INTRODUCTION

Schiff bases have played an important role in the development of coordination chemistry as they readily form stable complexes with most of the transition metals. The chemistry of Schiff base ligands species has been gaining considerable interest primarily because of their fascinating structural diversities (Asadi, et al., 2011; Monfared, et al., 2011; Chamayou, et al., 2011). The electrophilic carbon atoms of aldehydes and ketones can be targets of nucleophilic attack by amines. The end result of this reaction is a compound in which the C=O double bond is replaced by a C=N double bond. This type of compound is known as an imines, or Schiff base with the general formula R<sub>1</sub>R<sub>2</sub>C=NR<sub>3</sub>,

where R is an organic side chain. In this definition, Schiff base is synonymous with azomethine. Many Schiff base complexes show excellent catalytic activity in various reactions and in the presence of moisture (Abu-Dief Ahmed and Mohamed Ibrahim, 2015). The Schiff bases are widely used for industrial purposes and also exhibit a broad range of biological activities. This short review compiles examples of the most promising antimalarial, antibacterial, antifungal, and antiviral Schiff bases. An overview of synthetic methodologies used for the preparation of Schiff bases is also described (Da Silva Cleiton, et al., 2011). Isatin is a yellowish red crystalline compound soluble in hot water, used for the preparation of vat dyes. Formula: C<sub>8</sub>H<sub>5</sub>NO<sub>2</sub>. Is found in many plants and Schiff bases of Isatin are investigated for their pharmaceutical properties (Jarrahpour and Khalili, 2005). This was prepared according to the literature method, Isatins can be made from the corresponding indole in good yield by a mixing of InCl<sub>3</sub> and IBX in an acetonitrile-water solution at 80°C (Yadav, et al., 2007). The electrophilic carbon atoms of Isatin carbonyl group can be targets of nucleophilic attack by amines (Jarrahpour and Khalili, 2005). 3-Aminoacetophenone is one of the most typical aromatic carbonyls which show photochemical properties 3-aminoacetophenone with molecular formula C<sub>8</sub>H<sub>9</sub>NO, having melting point 96–98°C. Another additional interest that 3-aminoacetophenone derivatives possess some degree of local anesthetic activities (Nomenclature of Organic Chemistry, 2014). Acetophenone is used for the synthesis of many pharmaceuticals (Braish and Gadamasetti, 2007). Acetophenone is recovered as a by-product of the oxidation of ethylbenzene to ethylbenzene hydroperoxide (Siegel H., Eggersdorfer M., 2005). In this work, we report the synthesis characterization of Isatin compound with 3-aminoacetophenone and its complexes with selected transition elements such as Ni<sup>II</sup> and Co<sup>II</sup>, the antibacterial activity of the prepared complexes has been tested against Gram-positive *Staphylococcus aureus* and *Bacillus subtilis* (Shaker, et al., 2013) (Fig. 1).

## II. EXPERIMENTAL

Reagents were purchased from Fluka and Redial - Dehenge Chemical Co. and used without further putrefaction. Fourier transform infrared (FT-I.R) spectra were recorded in the range 4000–400/cm. Electronic spectra of the prepared compounds

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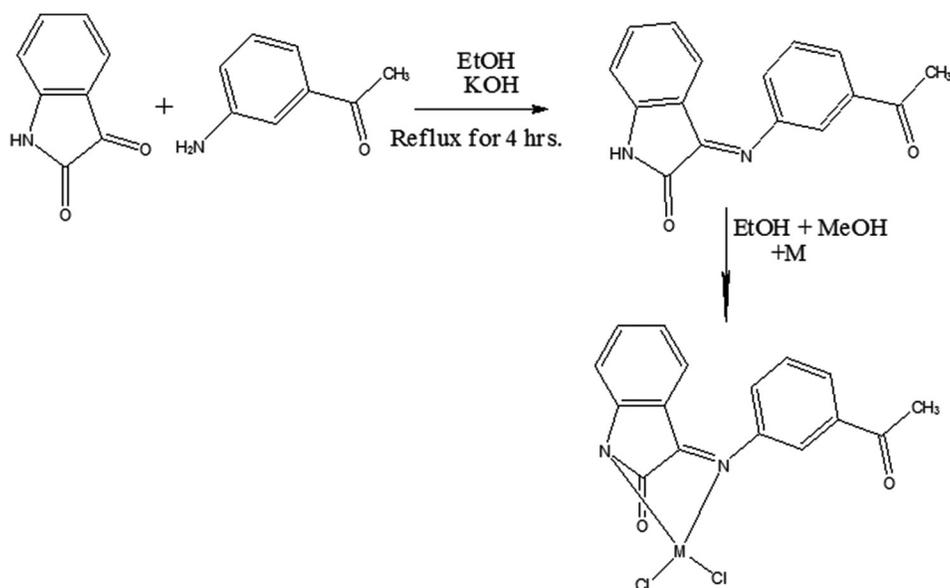


Fig.1. The synthesis route of the complexes (Where M = Ni<sup>II</sup> and Co<sup>II</sup>)

were measured in the region 200–900 nm for 10<sup>-3</sup> M solutions in methanol for the ligand and in distilled water for the complexes at 25°C using a Shimadzu 160 spectrophotometer with 1.000–0.001 cm matched quartz cell. Elemental microanalyses were performed on a (C.H.N) analyzer.

#### A. Syntheses of the ligand (E)-3-(3-acetylphenylimino)indolin-2-one [HL]

The ligand (E)-3-(3-acetylphenylimino)indolin-2-one type [HL] has been prepared from dissolving (0.3 g and 2.039 mmole) of Isatin in 25 ml ethanol, and mixed with a solution of 3-aminoacetophenone (0.275 g and 2.034 mmole) under refluxed for 4 h to gain (0.2 g) of a pale brown precipitate after filtration and drying at room temperature, to yield 66.6%, mp (63°C).

#### B. Syntheses of [Ni(L)Cl<sub>2</sub>] complex

[Ni(L)Cl<sub>2</sub>] complex has been prepared from 0.15 g, 0.567 mmole of [HL] dissolved in 25 mL methanol with a solution of 0.134 g, 0.663 mmole of NiCl<sub>2</sub>·6H<sub>2</sub>O. Moreover, refluxed for 2 h to obtain (0.11 g) pale yellow precipitate. Yield 73%, mp 134°C.

#### C. Syntheses of [Co(L)Cl<sub>2</sub>] complex

The same method used to prepare [Ni(L)Cl<sub>2</sub>] complex was used to prepare [Co(L)Cl<sub>2</sub>] complex but with a solution of 0.13 g, 0.546 mmole of CoCl<sub>2</sub>·6H<sub>2</sub>O to form (0.13 g) deep brown precipitate. Yield 86.6%, 118°C. Table I shows the microanalysis results and some physical properties for the ligand and its complexes.

### III. RESULTS AND DISCUSSION

#### A. Synthesis of the ligand [HL]

The (FT-I.R) spectra for the starting materials of the ligand [HL], the essential infrared data are summarized in Table II.

In the spectrum of 3-aminoacetophenone, there are two sharp absorption bands at 3470 and 3450/cm that assigned to the stretching vibration of  $\nu_{\text{sy}}(\text{N-H})$  and  $\nu_{\text{asy}}(\text{N-H})$  of the primary amine (R-NH<sub>2</sub>) group (Nakamoto, 1997) (Fig. 2). These bands have been disappeared in the spectrum of the ligand [HL], because of its condensation reaction with Isatin.

In the spectrum of Isatin Fig. 3., there is a band at 3450.6/cm due to the  $\nu(\text{N-H})$  of the secondary amine (R<sub>2</sub>-NH) group (Rostkowska, et al., 1993), is shifted to lower frequency about (50/cm) as shown in the spectrum of the ligand [HL] as a consequence of the coordination between both of Isatin and 3-aminoacetophenone.

The appearance of a new band at 1550/cm range in the spectrum of [HL] ligand was assigned to the  $\nu(\text{C=N})$  stretching, indicating formation a new compound and Schiff base reactions (Ali, et al., 1981; Ivanov and Nikolova, 2008) 3-aminoacetophenone and Isatin. Figs. 2 and 3 displayed strong bands at 1728/cm and 1695/cm range, assigned to the stretching vibration of  $\nu(\text{C=O})$  group, respectively, which are shifted to lower frequency at 1650/cm compared with the spectra of the ligand [HL] (Anuradha and Rajarel, 2011; Colchoubian, et al., 1999) (Fig. 4).

U.V-Vis spectrum for [HL], Fig.5. exhibits a high intense absorption peak at 240 nm (41666/cm) ( $\epsilon_{\text{max}} = 450/\text{molar}/\text{cm}$ ), assigned for  $n \rightarrow \pi^*$ . A shoulder peaks at 290 nm (34482/cm) ( $\epsilon_{\text{max}} = 366/\text{molar}/\text{cm}$ ) and (339 nm) (29498/cm) ( $\epsilon_{\text{max}} = 120/\text{molar}/\text{cm}$ ) were assigned to  $\pi \rightarrow \pi^*$  transitions (Colchoubian, et al., 1999; Kindeel, et al., 2013) (Table III).

#### B. Synthesis of the complexes

The reaction of the ligand [HL] with Co<sup>II</sup> and Ni<sup>II</sup> was carried out in methanol under reflux. All complexes are stable in the solid state. The analytical and physical data, Table I and spectral data Table III are compatible with the suggested structures. FT-I.R spectra of the complexes are shown in Figs. 6 and 7 and the predominant bands are summarized in Table II.

TABLE I  
THE MICROANALYSIS RESULTS AND SOME PHYSICAL PROPERTIES OF [HL] AND ITS COMPLEXES

compound	M.W	Yield%	M p.°C	Color	Formed (cal. %)-(theo. %)				
					C	H	N	Cl	Metal
[HL]	264.28	66.6	63	Pale-Brown	71.55 72.72	4.01 4.58	9.16 10.60	-	-
[Ni (L) Cl <sub>2</sub> ]	463.78	73	134	Pale-Yellow	45.65 48.91	2.122.82	6.01 7.13	16.89 18.05	13.22 14.94
[Co (L) Cl <sub>2</sub> ]	464.02	86.6	118°	Deep-Brown	44.01 48.88	2.31 2.82	6.11 7.13	17.00 18.04	13.06 14.99

TABLE II  
FT-IR SPECTRAL DATA (WAVE NUMBER  $\nu$ )/CM OF THE DERIVATIVE LIGAND [HL] AND ITS PRECURSORS WITH THE COMPLEX

Compound	$\nu$ (N-H)	$\nu$ (N-H) Secondary R <sub>2</sub> -NH	$\nu$ (C=O)	$\nu$ (C=N)-Imine	M-O
	Primary-R-NH <sub>2</sub>				M-N
3-aminoacetophenone	3470 3450	-	1695	-	-
Istian	-	3450.6(sh)	1728(sh)	-	-
[HL]	-	3400	1650	1550	-
[Ni (L) Cl <sub>2</sub> ]	-	-	1670	1592	530
[Co (L) Cl <sub>2</sub> ]	-	-	1665	1595	526
	-	-	-	-	580

TABLE III  
ELECTRONIC SPECTRAL DATA AND CONDUCTANCE MEASUREMENTS OF THE LIGAND AND ITS COMPLEXES

Compound	$\lambda$ nm	cm <sup>-1</sup> $\nu$ wave number	$\epsilon_{\text{Max}}$ /molar/cm	Assignments	conductance	B.M
[HL]	240	41666	450	n $\rightarrow$ $\pi^*$		
	290	34482	366	$\pi\rightarrow\pi^*$		
	339	29498	120	$\pi\rightarrow\pi^*$		
[Ni (L) Cl <sub>2</sub> ]	240	41666	1141	Ligand field	20	2.9
	285	35087	440	C.T		
	410	24390	200	<sup>1</sup> A <sub>1</sub> $\rightarrow$ <sup>1</sup> E'		
	425	23529	180	<sup>1</sup> A <sub>1</sub> $\rightarrow$ <sup>1</sup> E		
[Co (L) Cl <sub>2</sub> ]	255	39215	904	Ligand field	16	1.6
	291	34364	1122	C.T		
	394	25380	309	<sup>4</sup> A <sub>2g</sub> $\rightarrow$ <sup>4</sup> T <sub>1g</sub> (F)		
	447	22371	103	<sup>4</sup> A <sub>2g</sub> $\rightarrow$ <sup>4</sup> T <sub>2g</sub>		

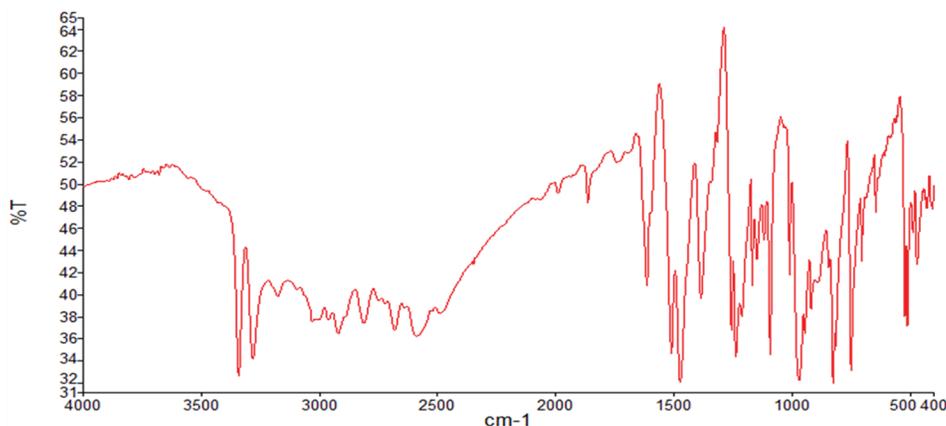


Fig. 2. The Fourier transform infrared spectrum of 3-aminoacetophenone

The band at 1650/cm<sup>-1</sup> of the  $\nu$ (C=O) stretching vibration (Ali, et al., 1981; Ivanov and Nikolova, 2008) of the ligand is shifted

to higher frequencies at 1670–1665 range for Ni<sup>II</sup> and Co<sup>II</sup> complexes because of the coordination with the metal ions.

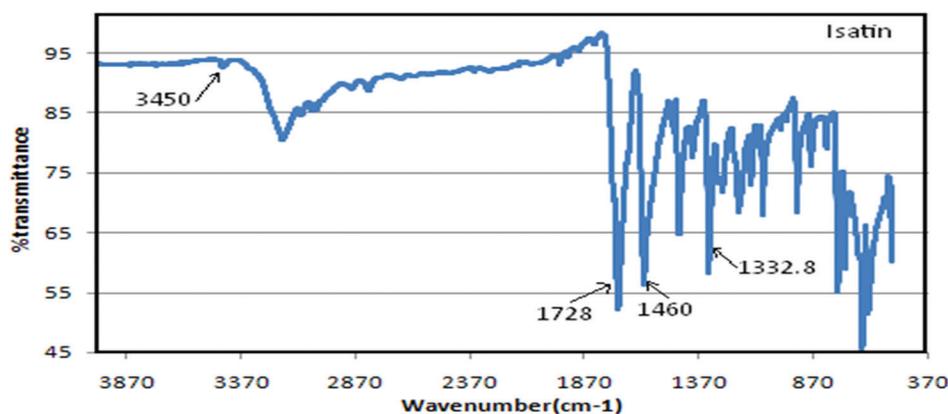


Fig. 3. The Fourier transform infrared spectrum of Isatin

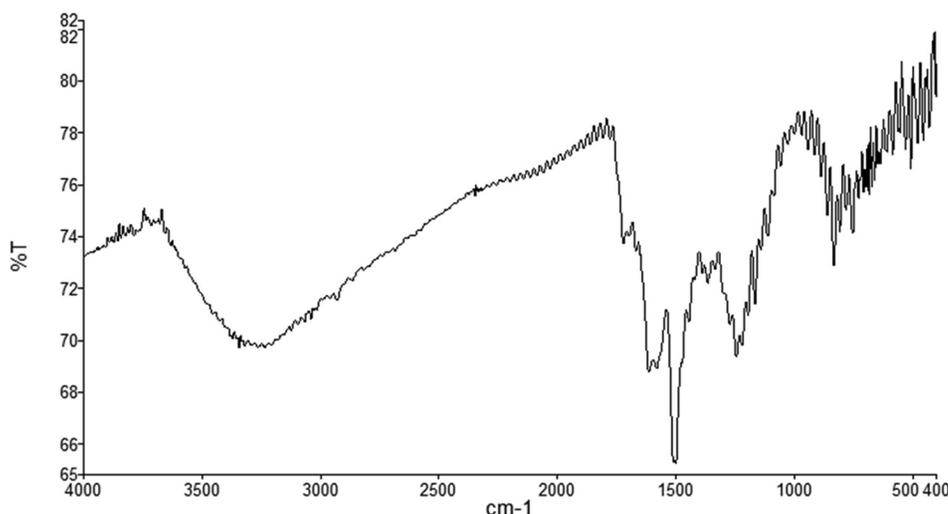


Fig.4. The Fourier transform infrared spectrum of [HL] ligand

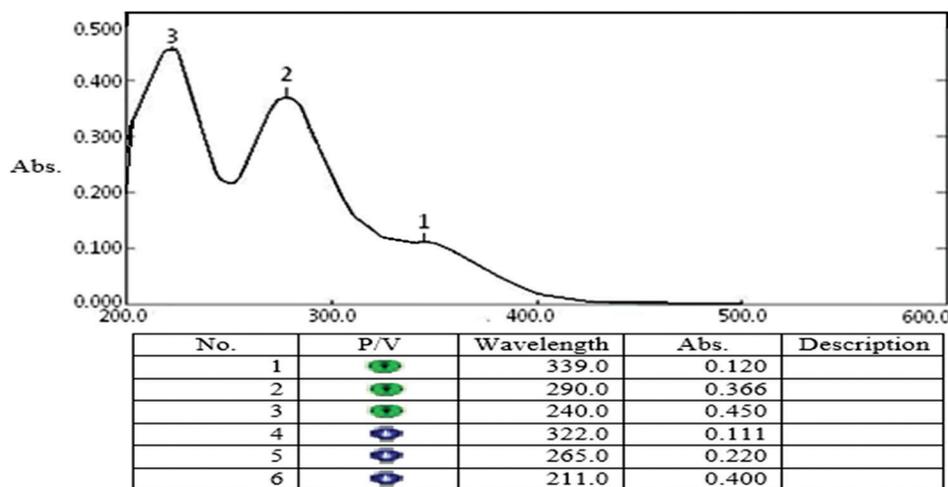
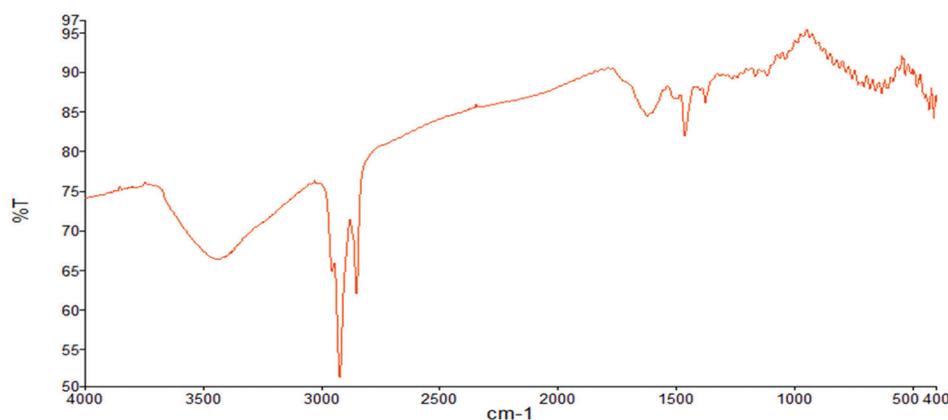
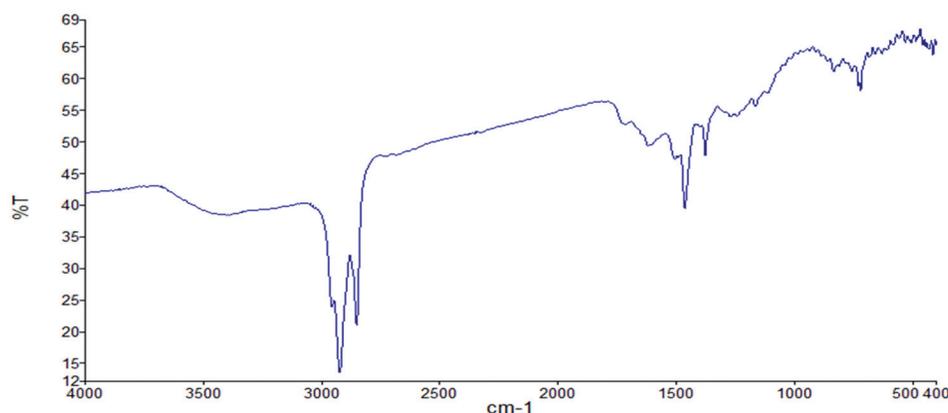
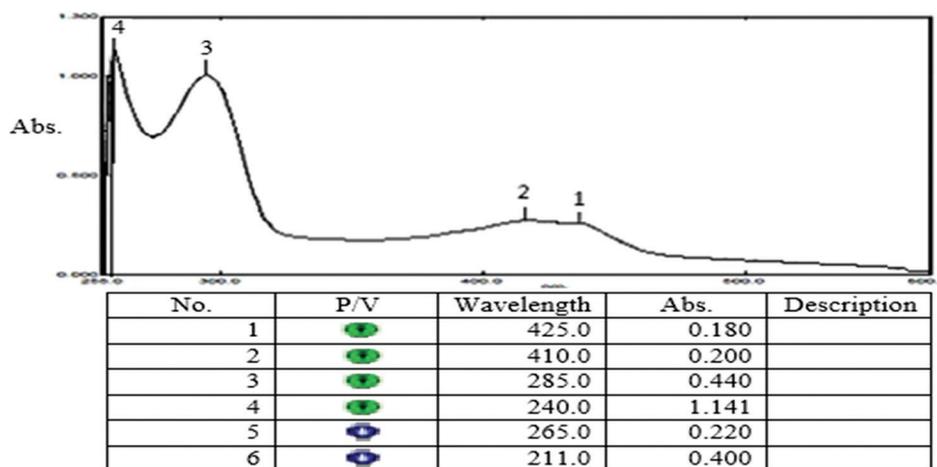


Fig. 5. The ultraviolet-visible spectrum of [HL] ligand

Moreover, the band at 1550/cm<sup>1</sup> of  $\nu(\text{C}=\text{N})$  imine (Anuradha and Rajarel, 2011; Colchoubian, et al., 1999) is shifted to higher frequencies about (40/cm) range for the complexes due to the forming ring system with the metal ions. Metal oxygen and metal nitrogen band further confirmed by the presence of

peaks at 530–590/cm and 526–580/cm range were assigned to  $\nu(\text{M}-\text{O})$  and  $\nu(\text{M}-\text{N})$  (Halli, et al., 2012; Jakels, et al., 1983) stretches for the Ni<sup>II</sup> and Co<sup>II</sup> complexes, respectively.

UV-Vis spectra of Ni<sup>II</sup> and Co<sup>II</sup> complexes Figs. 8 and 9, respectively, showed two intense peaks in the range 240 nm,

Fig. 6. The Fourier transform infrared spectrum of [Ni(L)Cl<sub>2</sub>] complexFig. 7. The Fourier transform infrared spectrum of [Co(L)Cl<sub>2</sub>] complexFig. 8. The ultraviolet-visible spectrum of [Ni(L)Cl<sub>2</sub>] complex

(41666/cm), ( $\epsilon_{\max} = 1141/\text{molar}/\text{cm}$ ) and 255 nm, ( $39215/\text{cm}^{-1}$ ), ( $\epsilon_{\max} = 904/\text{molar}/\text{cm}$ ) range assigned to the ligand field for Ni<sup>II</sup> and Co<sup>II</sup>, respectively (Lever, 1984). Another two peaks at 285 nm, ( $35087/\text{cm}$ ), ( $\epsilon_{\max} = 440/\text{molar}/\text{cm}$ ) and (291 nm), ( $34364/\text{cm}$ ), ( $\epsilon_{\max} = 1122/\text{molar}/\text{cm}$ ) range assigned to the charge transfer transition for Ni<sup>II</sup> and Co<sup>II</sup>, respectively (AL-Shihri, 2004). Another two peaks are detected in the visible region for Ni<sup>II</sup> complex at 410 nm, ( $24390/\text{cm}$ ), ( $\epsilon_{\max} = 200/$

molar/cm) and (425 nm), ( $23529/\text{cm}$ ), ( $\epsilon_{\max} = 180/\text{molar}/\text{cm}$ ) are due to ( ${}^1A_1 \rightarrow {}^1E'$ ) and ( ${}^1A_1 \rightarrow {}^1E''$ ) transitions indicating a tetrahedral structure (Lever, 1984) around Ni<sup>II</sup>. So that for the two peaks of Co<sup>II</sup> complex at 394 nm, ( $25380/\text{cm}$ ), ( $\epsilon_{\max} = 309/\text{molar}/\text{cm}$ ) and (447 nm), ( $22371/\text{cm}$ ), ( $\epsilon_{\max} = 103/\text{molar}/\text{cm}$ ) are assigned to ( ${}^4A_g \rightarrow {}^4T_{1g(F)}$ ) and ( ${}^4A_g \rightarrow {}^4T_{2g}$ ) transitions (AL-Shihri, 2004), suggesting a tetrahedral structure around Co<sup>II</sup> ion. is assigned to d-d transitions (AL-Shihri, 2004).

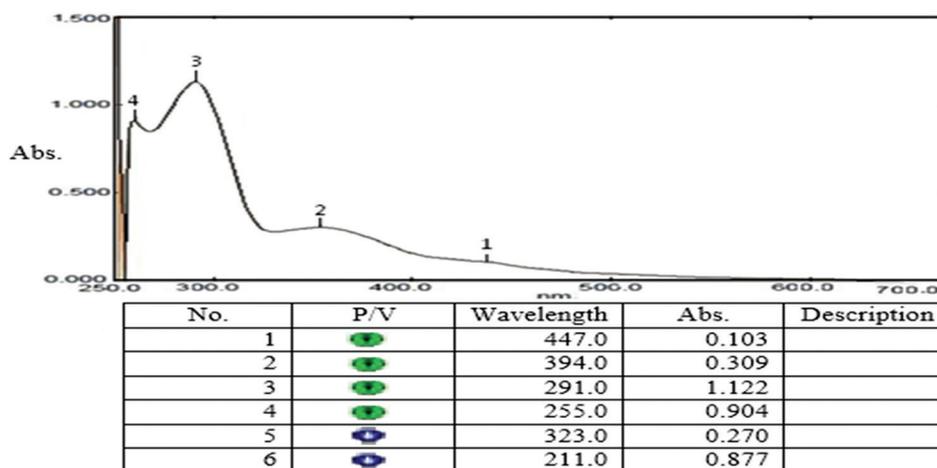


Fig. 9. The ultraviolet-visible spectrum of [Co(L)Cl<sub>2</sub>] complex

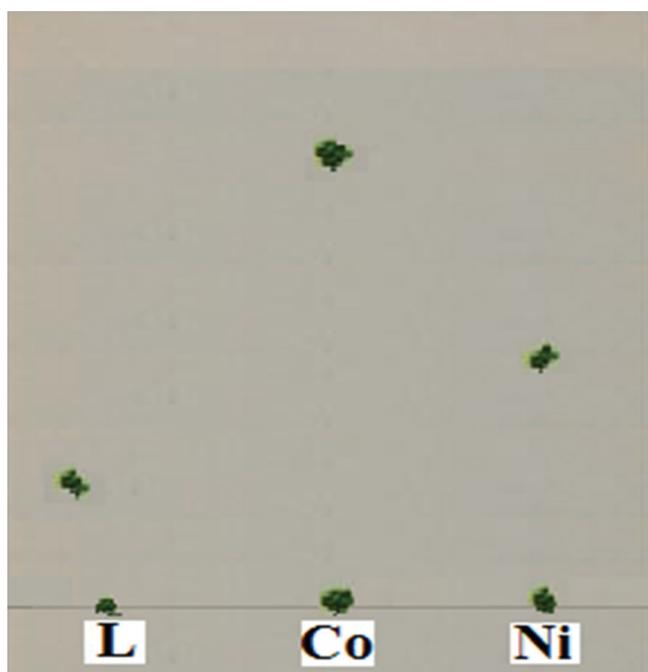


Fig. 10. The thin-layer chromatography for the ligand and its Ni<sup>II</sup>, Co<sup>II</sup> complexes

Thin-layer chromatography (TLC) measurement for the derivative ligands [HL] and its complexes were performed with Co<sup>II</sup> and Ni<sup>II</sup> is shown in Fig. 10. and Table IV. The appearance of new spots with different R<sub>f</sub> compared with the R<sub>f</sub> of the ligands, for Co<sup>II</sup> and Ni<sup>II</sup> indicated the formation of the complexes. The spots positions belong to Co<sup>II</sup>, and Ni<sup>II</sup> ion complexes are differ from the positions of the ligands spot.

Biological activity of the [HL] ligand and its two complexes was tested on two types of pathogenic bacteria using inhibition method (Anacona, 2006; Sultana and Arayne,2007). The two types of bacteria were Gram-positive *S. aureus* and *B. subtilis*. The ligand [HL] showed inhibition diameter against the two types of bacterial after 24 h and this inhibition diameter was increased after 48 h (Fig. 11). Furthermore, experimental results indicated that

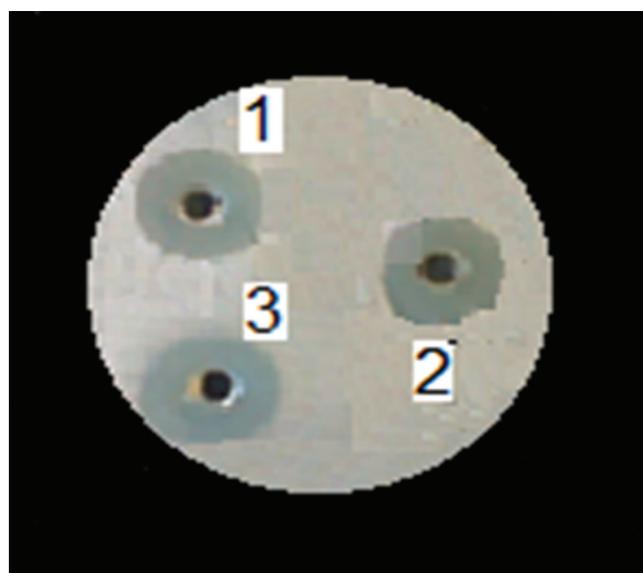


Fig. 11. The biological activity of [HL] and its Ni<sup>II</sup>, Co<sup>II</sup> complexes

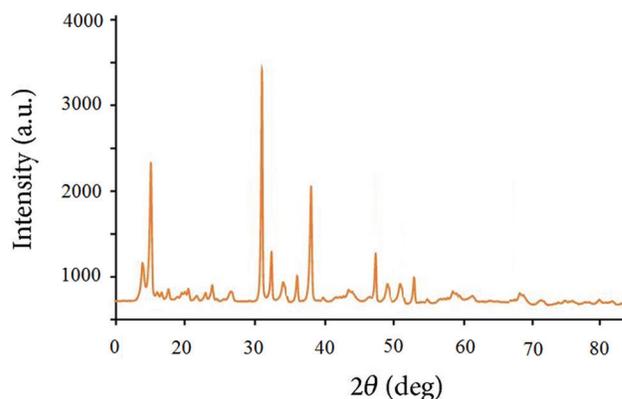


Fig. 12. The X-ray powder diffraction of [Co(L)Cl<sub>2</sub>] complex

the complexes show more activity than the ligand under similar experimental conditions with the same kinds of bacteria.

Molar conductance in DMSO solutions lie in the (16 and 20/cm/mole) range indicating its electrolytic nature with (1:1)

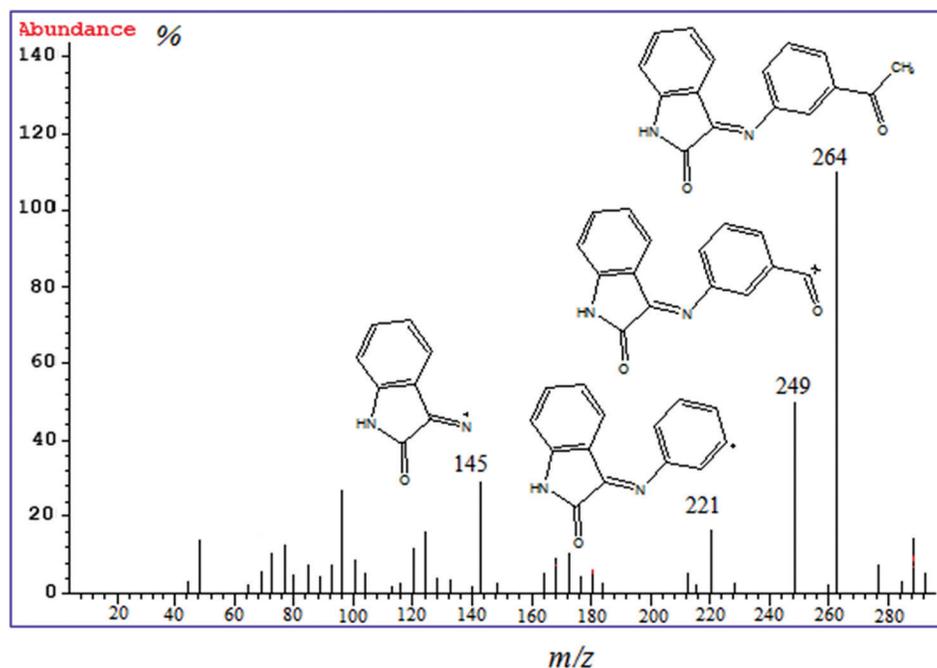


Fig. 13. The mass spectrum of [HL]

TABLE IV  
THE TLC MEASUREMENTS FOR THE [HL] LIGAND AND ITS  $\text{Co}^{\text{II}}$  AND  $\text{Ni}^{\text{II}}$   
COMPLEXES

Compound	Range of $R_f$ (mm)
[HL]	0.7
[Co (L) $\text{Cl}_2$ ]	3.3
[Ni (L) $\text{Cl}_2$ ]	2.2

TLC: Thin-layer chromatography

of the  $\text{Co}^{\text{II}}$  and  $\text{Ni}^{\text{II}}$ , metal ion complexes (Kai, et al., 2009; Refat and Struct, 2007) (Table I).

Magnetic moment (1.6 and 2.9 B.M) value of the  $\text{Co}^{\text{II}}$  and  $\text{Ni}^{\text{II}}$  ion complexes, respectively, as well as the other analytical data Table III is in agreement with the suggested structure of square planar geometry for the two complexes in the solid state (Uppadin, et al., 2001; Al-Jeboori, et al., 2010).

X-ray powder diffraction (XRD) pattern of  $\text{Co}^{\text{II}}$  complex shows well-defined crystalline peaks indicating that the sample is 37% crystalline in nature (Dokken, et al., 2009). An XRD powder diffraction pattern of the copper complex has been given in Fig. 12 of different scale particles are well coincident with each other, and it means that different forms of complexes have the same structure (Guillemet-Fritsch, et al., 2006). The sample has been dried and then scanned in the  $2\theta$  range of  $10\text{--}80^\circ$  confirming square planar geometry around  $\text{Co}^{\text{II}}$  ion complex (Kavitha and Lakshmi, 2017; Zheng, et al., 2017).

Mass spectrum shows the base peak at 264 related to the molecular weight of the ligand. Moreover, all the other fragmentations are compatible with the value of the fragments of the ligand as shown in Fig. 13.

## REFERENCES

- Abu-Dief Ahmed, A.M. and Mohamed, I.M.A., 2015. A review on versatile applications of transition metal complexes incorporating Schiff bases. Beni-Suef University Journal of Basic and Applied Sciences, 4, pp.119-133.
- Ali, H., Al-Azawi, S., Silverschtein, R.M., Bassler, G.C. and Morril, T.C., 1981. *Spectrophotometers Identification of Organic Compounds*. John Wiley and Sons, New York.
- Al-Jeboori, M.J., Al-Tawel, H.H. and Mahmood, R., 2010. New metal complexes of N2S2 tetradentate ligands: Synthesis and spectral studies. *Inorganica Chimica Acta*, 363, pp.1301-1305.
- Al-Shihri, A.S., 2004. *Spectrochimica Acte. Part A*, 60, pp.1189-1192.
- Anacona, J.R. 2006. Synthesis and antibacterial activity of some metal complexes of  $\beta$ -Lactams antibiotics. *Journal of Coordination Chemistry*, 54, pp.355-365.
- Anuradha, K. and Rajareel, R., 2011. Synthesis, spectral characterization and biological activity of new symmetrical macrocyclic binuclear Schiff base complexes. *Internatiol Journal of Pharmacy and Technology*, 2, pp.2217.
- Asadi M., Sepehrpour, H. and Mohammadi, K.H., 2011. "Tetradentate schiff base ligands of 3,4-diaminobenzophenone: Synthesis, characterization and thermodynamics of complex formation with Ni(II), Cu(II) and Zn(II) metal ions. *Journal of the Serbian Chemical Society*, 76, pp.63-74.
- Siegel, H., Eggersdorfer, M., 2005. Ketones, *Ullmann's encyclopedia of industrial chemistry*, weinheim: wiley VCH. doi:10.1002/14356007.a15\_077. (<https://en.wikipedia.org/wiki/Acetophenone>).
- Braish, T. and Gadamasetti, K., 2007. *Process Chemistry in the Pharmaceutical Industry*, Vol. 2. CRC Press, Boca Raton, pp.142-145.
- Chamayou, A.C., Lüdeke, S., Brecht, V., Freedman, T.B., Nafie, L.A. and Janiak, C., 2011. Chirality and diastereoselection of  $\Delta/\nabla$ -configured tetrahedral zinc complexes through enantiopure Schiff base complexes: Combined vibrational circular dichroism, density functional theory,  $^1\text{H}$  NMR, and X-ray structural studies. *Inorganic Chemistry*, 50, pp.11363-11374.
- Colchoubian, H., Waltz, W.L. and Quail, J.W., 1999. Synthesis and characterization of Schiff base folic acid based ligand and its complexes. *Canadian Journal of Chemistry*, pp.37-77.

- Da Silva Cleiton, M., da Silva Daniel, L., Modolo, L.V., Alves, R.B., de Resende, M.A., Martins, C.V.B. and Ângelode, F., 2011. Schiff bases: A short review of their antimicrobial activities. *Journal of Advanced Research*, 2, pp.1-8.
- Dokken, K.M., Parsons, J.G., McClure, J. and Gardea-Torresdey, J.L., 2009. Synthesis and structural analysis of copper(II) cysteine complexes. *Inorganica Chimica Acta*, 362, pp.395-401.
- Guillemet-Fritsch, S., Lebey, T., Boulos, M. and Durand, B. 2006. Dielectric properties of CaCu<sub>3</sub>Ti<sub>4</sub>O<sub>12</sub> based multiphased ceramics. *Journal of the European Ceramic Society*, 26, pp.1245-1257.
- Halli, M.B., Patil, V.B., Sumathi, R.B. and Mallikarjun, K., 2012. Synthesis, characterization and biological activity of mixed ligand metal (II) complexes derived from benzofuran-2-carbohydrazide schiff base and malonyldihydrazide. *Der Pharma Chemica*, 4, pp.2360-2323.
- Ivanov, I. and Nikolova, S., 2008. *Synthesis of New  $\beta$ -enaminones of Isoquinolines with 5, 5-Dimethyl-cyclohexanedione*. Molbank, Plovdiv. pp.565.
- Jakels, S.C., Ciavola, J., Carter, R.C., Cheek, P.L. and Pascarlhi, T.D., 1983. *Inorganic Chemistry*, 22, pp.3956.
- Jarrahpour, A.A. and Khalili, D., 2005. Synthesis of some new bis-Schiff Bases of Isatin and 5-fluoroisatin in a water suspension medium. *Molecules*, 11, pp.59-63.
- Kai, Y., Gu, Z., Ji, R. and Lou, L.S., 2009. Heterogeneous chiral Mn(II) salen catalysts for the epoxidation of unfunctionalized olefins immobilized on mesoporous materials with different pore sizes. *Tetrahedron*, 65, pp.305-311.
- Kavitha, N. and Lakshmi, P.V.A., 2017. Synthesis, characterization and thermogravimetric analysis of Co(II), Ni(II), Cu(II) and Zn(II) complexes supported by ONNO tetradentate Schiff base ligand derived from hydrazine benzoxazine. *Journal of Saudi Chemical Society*, 21 Suppl 1, pp.S457-S466.
- Kindeel, A.S., Dawood, I.J. and Aziz, M.R., 2013. Synthesis and characterization of some mixed ligand complexes containing (8-hydroxyquinoline) and (2-picoline) with some metal ions. *Baghdad Science Journal*, 10, pp.396.
- Lever, A.B.P., 1984. *Inorganic Electronic Spectroscopy*. 2<sup>nd</sup> ed., Elsevier, New York.
- Monfared, H.H., Vahedpour, M., Yeganeh, M.M., Ghorbanloo, M., Mayer, P. and Janiak, C. 2011. Concentration dependent tautomerism in green [Cu(HL1)(L2)] and brown [Cu(L1)(HL2)] with H<sub>2</sub>L1=(E)-N'-(2-hydroxy-3-methoxybenzylidene) benzoylhydrazone and HL2=pyridine-4-carboxylic (isonicotinic) acid. *Dalton Transactions*, 40, pp.1286-1294.
- Nakamoto, K., 1997. *Infrared and Raman Spectra of Inorganic and Coordination Compounds*, Parts A and B. 5<sup>th</sup> ed. John Wiley Sons, New York.
- Nomenclature of Organic Chemistry: IUPAC Recommendations and Preferred Names. 2013. *Blue Book*. The Royal Society of Chemistry, Cambridge. pp.723.
- Refat, M.S., and Struct, J.M., 2007. Complexes of uranyl (II), vanadyl (II) and zirconyl (II) with orotic acid "vitamin B13": Synthesis, spectroscopic, thermal studies and antibacterial activity. Article in *Journal of Molecular Structure*, 842, pp.24.
- Rostkowska, N.M.J., Lapinski, L., Bertner, M., Kulikowski, T., Les, A. and Adamowicz, L., 1993. *Spectrochim. Acta A*, 49, pp.551.
- Shaker, A.M., Nassr, L.A.E. and Adam, M.M.S.S., 2013. Synthesis, characterization and spectrophotometric studies of seven novel antibacterial hydrophilic iron (II) Schiff base amino acid complexes. *Journal of the Korean Chemical Society*, 5, pp.560.
- Sultana, N. and Arayne, M.S., 2007. *In vitro* activity of cefadroxil, cephalexin, cefatrizine and cefpirome in presence of essential and trace elements. *Pakistan Journal of Pharmaceutical Sciences*, 20, pp.305-10.
- Uppadin, L.H., Weeks, J.M. and Beer, P.D., 2001. Metal-directed self-assembly of terphenyl based dithiocarbamate ligands. *Journal of the Chemical Society Dalton Transactions*, 22, pp.3367-3372.
- Yadav, J.S., Reddy, B.V.S., Reddy, C.S. and Krishna, A., 2007. Indium(III) chloride/2-iodoxybenzoic acid: A novel reagent system for the conversion of indoles to isatins. *Synthesis*, 5, pp.693-696.
- Zheng, Z., Junwei, X., Sisi, Y., Yangli, C., Yan, W., Zhuo, C. and Chunlin, N., 2017. Two organic cation salts containing tetra (isothiocyanate)cobaltate(II): Synthesis, crystal structures, spectroscopic, optical and magnetic properties. *Crystals*, 7, pp.92.