

## Research Article

# Synthesis Characterization and Biological Activity Study of New Schiff and Mannich Bases and Some Metal Complexes Derived from Isatin and Dithiooxamide

Ahlam J. Abdulghani and Nada M. Abbas

Department of Chemistry, College of Science, University of Baghdad, Jaderiya, Baghdad, Iraq

Correspondence should be addressed to Ahlam J. Abdulghani, prophahlam@yahoo.com

Received 6 December 2010; Revised 5 February 2011; Accepted 27 February 2011

Academic Editor: Zhe-Sheng Chen

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Two new Schiff and Mannich bases, namely, 1-Morpholinomethyl-3-(1'-N-dithiooxamide)iminoisatin ( $L_IH$ ) and 1-diphenylaminomethyl-3-1'-N-dithiooxamide)iminoisatin ( $L_{II}H$ ), were prepared from condensation reaction of new Schiff base 3-(1'-N-dithiooxamide)iminoisatin (SBH) with morpholine or diphenylamine respectively in presence of formaldehyde. The structures were characterized by IR,  $^1H$ NMR, mass spectrometry, and CHN analyses. Metal complexes of the two ligands were synthesized, and their structures were characterized by elemental analyses, atomic absorption, IR and UV-visible spectra, molar conductivity, and magnetic moment determination. All complexes showed octahedral geometries except palladium complexes which were square planar. The biological activity of the prepared compounds and some selected metal complexes was tested against three types of bacteria and against cell line of human epidermoid larynx carcinoma (Hep-2).

## 1. Introduction

Various Mannich Schiff bases of isatin have been found to be of biological importance [1] and have shown anticonvulsant [2], antibacterial [3, 4], antimicrobial [5–7] and anti-HIV activities [8, 9]. Dithiooxamide (dto) is an effective flexidentate complexing agent with varied coordination chemistry. Due to the intense chromophoric character, dto can be used in an imaging processes [10], coordination polymers [11], histological agents, and as a source for duplicating processes [12]. The transition metal complexes of dto and its derivatives are characterized by semiconductor, magnetic, and spectroscopic properties [12–15]. The aim of this work is to synthesize and study the coordination behavior of the two new Schiff and Mannich base ligands  $L_IH$  and  $L_{II}H$  shown in Scheme 1, from condensation reaction of a new Schiff base 3-(1'-N-dithiooxamide) iminoisatin (SBH) with morpholine or diphenylamine, respectively, in presence of formaldehyde in a mole ratio of (1:1:1), respectively, or from reaction of Mannich bases N-morpholinomethyl isatin ( $M_I$ ) and N-diphenylaminomethyl isatin ( $M_{II}$ ) [16] with dithiooxamide.

The biological activity of the two ligands and some of their metal complexes was investigated against selected types of bacteria and against cancer cell line of human epidermoid larynx carcinoma (Hep-2).

## 2. Experimental/Materials and Methods

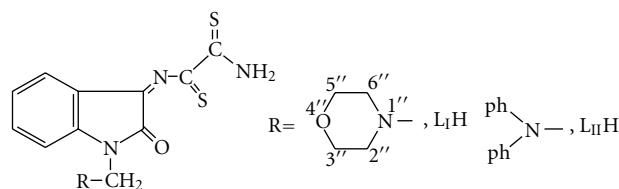
Melting points (uncorrected) were determined by using Gallenkamp MFB600–010f m.p apparatus. The purity of the synthesized compounds was checked by T.L.C. techniques using a mixture of chloroform and acetone (2:2 V/V) and various ratios of methyl acetate: acetone solvent mixture as eluents and iodine chamber for spot location. The HPLC of the Schiff base (SBH) and the derived two ligands were obtained by using HPLC (LKB), mobile phase  $CH_3CN:H_2O$  (80:20). Infrared spectra were recorded on a Perkin-Elmer 1310 IR spectrophotometer and Shimadzu corporation 200–91527 IR spectrophotometer using KBr and CsI disks.  $^1H$  n.m.r spectra of the organic compounds were recorded on a 300 MHz n.m.r spectrophotometer (Joel) using TMS as internal reference. Mass spectra were recorded on a Joel 700

mass spectrometer. Elemental CHN analyses were obtained by using EA elemental analyzer (Fison Ision Instrument). Electronic spectra of the ligands and their metal complexes in the region 200–1100 nm were recorded on a Shimadzu UV-visible-160 spectrophotometer. The metal contents were determined by atomic absorption technique using a Varian-AA-775 atomic absorption instrument. Electrical conductivity of metal complexes was measured at room temperature in DMF ( $10^{-3}$  M) using Elkta Lictfahigkeit conductivity meter (SIMENS). Magnetic moments ( $\mu_{\text{eff}}$  BM) for the solid metal complexes at room temperature were determined according to Faraday's method by using Johnson Matthey magnetic balance system division. Chloride content of metal complexes was determined by potentiometric titration using 1686-titroprocessor-665 Dosinametrom (Swiss). All organic and inorganic materials were of high purity and used as received except ethanol, methanol, and DMF which were dried and distilled prior to use [17]. Palladium(II) chloride was converted to dichlorobis(benzonitrile)palladium(II) [18], and  $\text{H}_2\text{PtCl}_6 \cdot 6\text{H}_2\text{O}$  was converted to potassium hexachloroplatinate(IV) hexahydrate [19] prior to use. Mannich bases N-morpholinomethylisatin ( $M_I$ ) and N-diphenylaminomethyl isatin ( $M_{II}$ ) were prepared according to methods mentioned in the literature [16]. Complex formation was studied in solutions to obtain the molar ratio of the ligand to metal ion (L:M) using ethanol, or DMSO as solvents. A series of solutions containing constant concentration of the metal ion ( $1 \times 10^{-4}$  M) were treated with various amounts of the same concentration of the ligand. The results of (L:M) ratio were obtained by plotting absorbance of solution mixtures at detected  $\lambda_{\text{max}}$  against  $[\text{L}]/[\text{M}]$ .

### 3. Preparation of Ligands

**3.1. 3-(1'-N-dithiooxamide)iminoisatin (SBH).** A solution mixture of isatin (0.01 mole, 1.47 g) and dto (0.01 mole, 1.021 g) in dry ethanol (50 mL) containing 2-3 drops glacial acetic acid was heated under reflux for 8 h with continuous stirring. The mixture was then left at room temperature for 24 h. A yellow precipitate was formed. The product was filtered, washed with warm ethanol, and crystallized from ethanol:dichloromethane solvent mixture (1:1). m.p.  $190^\circ\text{C}$  yield 60%; IR (KBr)  $\nu(\text{cm}^{-1})$ : 3296, 3203 ( $\text{NH}_2$ ); 3147 ( $\text{NH}$ -isatin); 1733 ( $\text{C}=\text{O}$ ), 1614 ( $-\text{C}=\text{N}$ ); 1540 ( $\text{C}-\text{S} + \delta\text{NH}$ , I); 1430 ( $\text{C}-\text{N} + \text{C}-\text{S}$ , II); 1197 ( $\text{C}-\text{S}$ , III); 835 ( $\text{C}=\text{S}$ , IV).  $^1\text{H}$  n.m.r.  $\delta(\text{ppm})$  ( $\text{CD}_2\text{Cl}_2$ ) 12.012 (1H, s, NH); 7.653–6.94 (4H, m, aromatic); 2.022 (2H, d,  $\text{NH}_2$ ). MS, (m/z) (I%) (EI) calculated for  $\text{C}_{10}\text{H}_7\text{N}_3\text{O}_2\text{S}_2$  m.wt 249 g/mole: 250 (10) [M+1]; 221 (3.2) [M-CO]; 207 (4) [M-NCO]; 162 (2); 119 (24); 90 (7.5).

**3.2. 1-Morpholinomethyl-3-(1'-N-dithiooxamide)iminoisatin ( $L_I\text{H}$ ) and 1-diphenylaminomethyl-3-1'-N-dithiooxamide Iminoisatin ( $L_{II}\text{H}$ ).** (a) To a stirred solution of 3-(1'-N-dithiooxamide)iminoisatin (SBH) (0.01 mole, 2.49 g) and formaldehyde 37% (0.015 mole) in warm dry ethanol (20 mL) was added, drop by drop, (0.01 mole) of morpholine ( $L_I\text{H}$ ) or diphenylamine ( $L_{II}\text{H}$ ). The mixture was heated



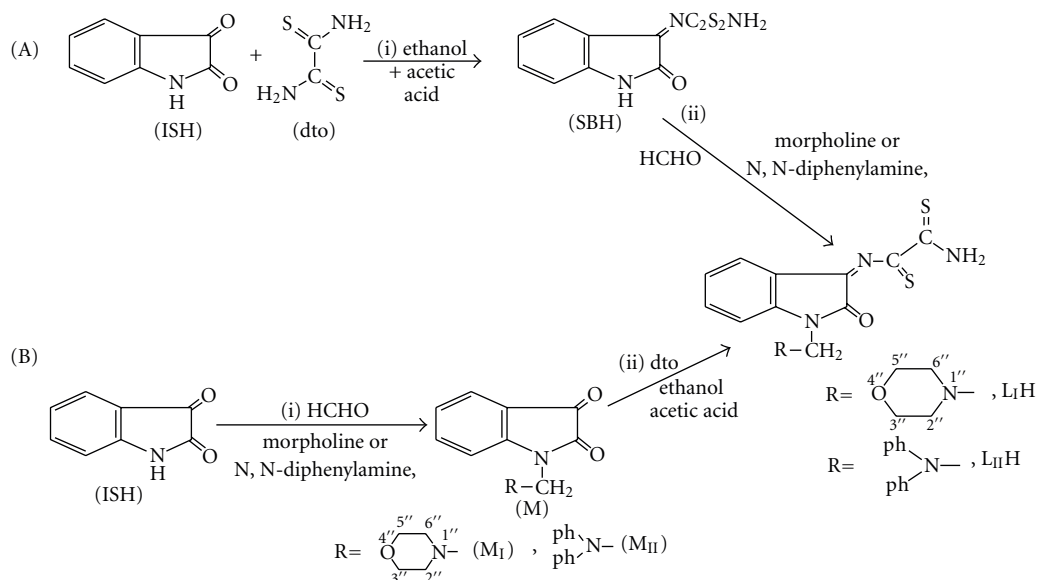
SCHEME 1: The structures of the prepared ligands.

under reflux for 3 h with continuous stirring, and then left to cool at room temperature. A solid precipitate was formed. The products were filtered, washed with warm ethanol, and then crystallized from ethanol:chloroform (1:1 v/v) mixture; yield 35 and 28.2%, respectively.

(b) To a solution of dto (5 mmole, 0.6 g) in warm ethanol (10 mL) containing 2-3 drops glacial acetic acid was added (5 mmole) of Mannich base N-Morpholinomethylisatin ( $M_I$ ) or N-Diphenylaminomethyl isatin ( $M_{II}$ ) [16] in ethanol (10 mL) with continuous stirring, and the mixture was heated under reflux for 10 h. After leaving the mixture at room temperature for 24 h a precipitate was formed. The products were filtered, washed with warm ethanol, and crystallized; yield 20.3 and 21%, respectively (m.p. 215 and  $283^\circ\text{C}$ , resp.).

**1-Morpholinomethyl-3-(1'-N-dithiooxamide) iminoisatin ( $L_I\text{H}$ ):** yellowish orange crystals, m.p.  $162^\circ\text{C}$ ; IR (KBr).  $\nu(\text{cm}^{-1})$ : 3203, 3138 ( $\text{NH}_2$ ); 3030–3000 (arom CH); 2815–2364 ( $\text{CH}_2$ ); 1730 ( $\text{C}=\text{O}$ ); 1614 ( $-\text{C}=\text{N}$ ); 1589 ( $\text{C}=\text{C}$  arom.); 1540 ( $\nu\text{C}=\text{N}$ ,  $\delta\text{NH}$ , I); 1429 ( $\text{C}-\text{N} + \text{C}-\text{S}$ , II); 1195 ( $\text{C}-\text{S}$ , III); 835 ( $\text{C}=\text{S}$ , IV); 1149, 1328 (morpholine).  $^1\text{H}$  n.m.r.  $\delta(\text{ppm})$  (DMSO): 7.59–6.898 (4H, m, aromatic +NH); 4.09 (2H, d, N- $\text{CH}_2\text{N}$ ); 3.65 (4H, d, 2'', 6''  $\text{CH}_2$  morph.); 2.33 (4H, d, 3'', 5''  $\text{CH}_2$  morph.); 1.567 (1H, br, SH). MS (FAB) m/z (I%) calculated for  $\text{C}_{15}\text{H}_{16}\text{N}_4\text{O}_2\text{S}_2$ , m.wt 348.45 g/mole: 349.1 (93) [M]; 320 (38) [M-CO]; 235 (100); 234 (80); 220 (15), 207 (40). 131 (43); 104 (78%); (EI) m/z (I%): 348.5 (84) [M]; 320 (25) [M-CO]; 234 (38); 207 (17); 130 (19); 117 (24); 104 (57); 90 (30); 78 (22%). CHN% Calculated for  $\text{C}_{15}\text{H}_{16}\text{N}_4\text{O}_2\text{S}_2$  C, 51.67; H, 4.59, N, 16.07% found C, 50.69; H, 4.20; N, 15.75%;  $\nu_{\text{max}}$  ( $\text{cm}^{-1}$ ) (DMF) ( $\epsilon_{\text{max}}$   $\text{mol}^{-1} \text{cm}^{-1}$ ) 34013 (20030)  $\pi \rightarrow \pi^*$ ; 2415 (2980),  $n \rightarrow \pi^*$  (DMSO) 38461 (19519)  $\pi \rightarrow \pi^*$ .

**Diphenylaminomethyl-3-(1'-N-dithiooxamide) Iminoisatin ( $L_{II}\text{H}$ ):** yellow red crystals, m.p. 182, IR (KBr)  $\nu(\text{cm}^{-1})$ : 3193, 3034 ( $\text{NH}_2$ ); 1730 ( $\text{C}=\text{O}$ ); 1614 ( $\text{C}=\text{N}$ ); 1540, 1434, 1195, 833 ( $\text{C}-\text{N} + \delta\text{NH}$ ,  $\text{C}-\text{N} + \text{C}-\text{S}$ ,  $\text{C}-\text{S}$ ,  $\text{C}=\text{S}$  I-IV, resp.).  $^1\text{H}$  n.m.r. ( $\delta$ , ppm) ( $\text{CD}_2\text{Cl}_2$ ): 7.59–6.89 (14H, m, aromatic); 4.83 (2H, d,  $\text{CH}_2$ ); 2.17 (2H, b,  $\text{NH}_2$ ). MS m/z (I%) (EI): calculated for  $\text{C}_{23}\text{H}_{18}\text{N}_4\text{O}_2\text{S}_2$ , m.wt 430.55 g/mol: 430.9 (5.5) [M]; 402 (2.5) [M-CO]; 235 (21); 129.2 (1.8); 104 (4.8); 89 (10.3); 78.1 (3.5%). CHN (%) calculated for  $\text{C}_{23}\text{H}_{18}\text{N}_4\text{O}_2\text{S}_2$ : C, 64.18, H, 4.21; N, 13.02% found: C, 64.02; H, 4.22; N, 13.52%.  $\nu_{\text{max}}$  ( $\text{cm}^{-1}$ ) (DMF) ( $\epsilon_{\text{max}}$ ,  $\text{L mol}^{-1} \text{cm}^{-1}$ ) 32258 (22970)  $\pi \rightarrow \pi^*$ ; 24509 (3530)  $n \rightarrow \pi^*$ ; (DMSO): 38461 (19540); 28571 (14120)  $\pi \rightarrow \pi^*$ .



SCHEME 2: Synthesis of Schiff Mannich base ligands from isatin and dithiooxamide.

#### 4. Synthesis of Metal Complexes

To a solution of Schiff Mannich base ligand (2 mmole) in absolute ethanol ( $L_IH$ ) or ethanol and dimethylsulfoxide (1:1 v/v) ( $L_{IIGH}$ ) (5 mL) was added an alcoholic solution (5 mL) of the metal salt (chlorides, nitrates, or acetates) (1 mmol), and the mixture was heated under reflux with continuous stirring for 3 h. Precipitation of products took place after heating time of 30 min for (Co(II)), Ni(II), and complexes of  $L_IH$  and  $L_{IIGH}$  ( $C_2$ ,  $C_3$ ,  $C_8$ , and  $C_9$ , resp.), 1 h for (Mn(II), Cu(II), and Ir(III) complex of  $L_IH$  and Cd(II) complex of  $L_{IIGH}$  ( $C_1$ ,  $C_4$ ,  $C_5$ , and  $C_{12}$ , resp.), 1.5 h for Pt(IV) complex of  $L_IH$  ( $C_7$ ), 2 h for Pd(II) complex of  $L_IH$  and Pt(IV) complex of  $L_{IIGH}$  ( $C_6$  and  $C_{11}$ , resp.) and 3 h for Pd(II) complex of  $L_{IIGH}$  ( $C_{10}$ ). The products were filtered and purified from reactants by washing many times with ethanol and ether ( $C_1$ – $C_7$ ) or with DMSO, ethanol and ether ( $C_8$ – $C_{12}$ ), and vacuum dried. Purity of the products was detected by TLC, using silica gel as a stationary phase and a mixture of chloroform and acetone (2:2 V/V) or various ratios of methyl acetate: acetone solvent mixture as eluents.

#### 5. Biological Activity Study

**5.1. Antibacterial Action.** Antibacterial activities of the prepared compounds were tested against three types of pathogenic bacteria, namely, *Escherichia coli*, *Staphylococcus aureus*, and *Proteus mirabilis* using the antibiotic Ceftriaxone as a control. Bacterial cultures were prepared by streaking (0.1) mL of  $10^6$  CFU/mL broth of indicator strain on the whole surface of nutrient agar plate. In each plate four wells (pores) were created on the nutrient agar layer using sterile cork porer. In each hole was injected  $50 \mu\text{L}$  of  $10^{-3}$  M of the studied compounds in DMSO by micropipette. The resulting cultures were incubated at  $37^\circ\text{C}$  for 24 h. The

inhibition zones caused by each compound were measured, and the results were interpreted according to diameter measurements.

**5.2. Cytotoxic Activity.** A preliminary study of cytotoxic activity of some of the prepared compounds was performed against human epidermoid larynx carcinoma cell lines (Hep-2) of 52-year-old patient. Hep-2 monolayer cell lines were prepared by subculturing cell line into (RPMI-1640) medium supplemented with 10% heat deactivated fetal bovine serum. The resulting media were incubated at  $37^\circ\text{C}$  for 48 h until confluent layer was achieved. Four concentrations of investigated compounds were prepared: 62.5, 125, 250, and  $500 \mu\text{g/mL}$  using dimethyl sulfoxide (DMSO) as a diluent. Hep-2 cell line was plated into 96-well microtiter plates. Then 0.2 mL of each tested compound was added to each well in triplicates, and incubation was carried out for 48 h. Cultures were stained with  $50 \mu\text{L/well}$  Neutral Red (NR) solution. The stained cultures were left in the incubator for further 2 h, washed with phosphate buffered saline solution followed by (0.1 mL) ethanol phosphate buffered solution ( $\text{NaH}_2\text{PO}_4$ : ethanol (1:1), vehicle ethanol). The cytotoxic effects of the applied compounds were measured in terms of optical density of viable cells at  $\lambda = 492 \text{ nm}$  using a Micro ELISA reader.

#### 6. Results and Discussions

**6.1. Synthesis.** The synthesis of the two new ligands has been achieved by following two different pathways A and B as is illustrated by Scheme 2. Pathway A involves the synthesis of Schiff base precursor of isatin (SBH) followed by condensation with the secondary amine, morpholine or diphenylamine, in presence of formaldehyde to form  $L_IH$  and  $L_{IIGH}$ , respectively. Pathway B involves the formation

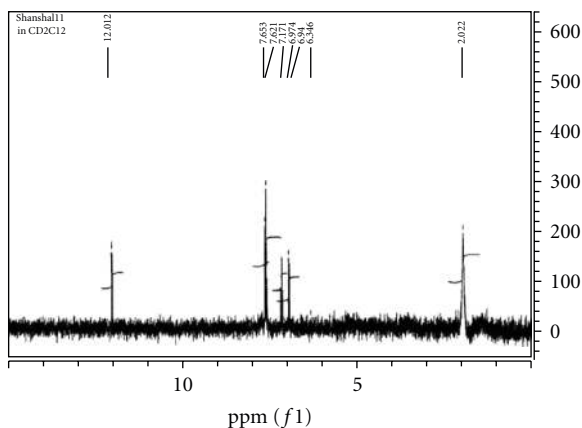


FIGURE 1:  $^1\text{H}$ NMR Spectrum of SBH in  $\text{CD}_2\text{Cl}_2$ .

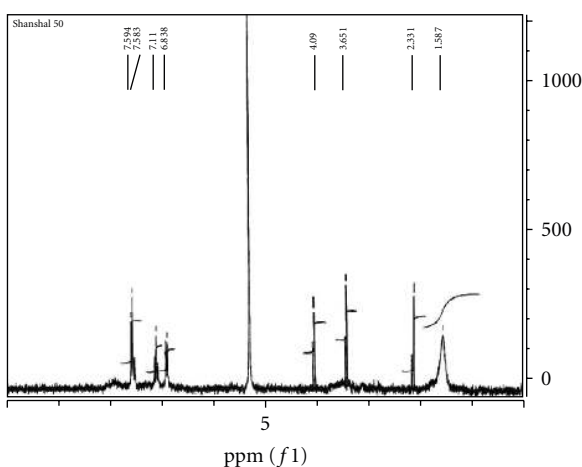


FIGURE 2:  $^1\text{H}$ NMR Spectrum of  $\text{L}_1\text{H}$  in DMSO.

of Mannich base precursor of isatin ( $\text{M}_I$  and  $\text{M}_{II}$ ) followed by condensation reaction with dithioamide. The second method showed lower yield and longer reaction time.

The  $^1\text{H}$  n.m.r spectrum of the Schiff base precursor SBH in  $\text{CD}_2\text{Cl}_2$  (Figure 1) is characterized by the appearance of chemical shift related to the  $\text{NH}_2$  protons of dto moiety at  $\delta 2.022$  ppm [11, 20, 21] and the appearance of NH proton of isatin ring at  $\delta 12.012$  ppm [5–7, 22–25] which is quite agreeable with the suggested structure of SBH. The  $^1\text{H}$  n.m.r spectrum of  $\text{L}_{II}\text{H}$  in  $\text{CD}_2\text{Cl}_2$  exhibited chemical shifts of  $\text{NH}_2$  protons at 2.17 ppm while that of  $\text{L}_I\text{H}$  in DMSO (Figure 2) gave chemical shifts at  $\delta 1.567$  ppm. This was attributed to tautomerism of  $\text{L}_I\text{H}$  in DMSO to iminosulphydryl structure in equilibrium with dithioamide structure, as a result of solvent polarity [26, 27]. Such behavior was confirmed by the appearance of the signal assigned to imino NH group at lower field. The spectrum of  $\text{L}_{II}\text{H}$  (Figure 3) exhibited chemical shifts of aromatic protons of isatin ring and diphenylamine at  $\delta 6.89$ – $7.11$  and at  $\delta 7.68$ – $7.59$ , respectively, while those of methylene group appeared at high fields [22–24].

The mass spectra of the two Mannich and Schiff base ligands as well as SBH are shown in Figures 4, 5, and 6, respectively. The EI mode of mass spectrum displayed

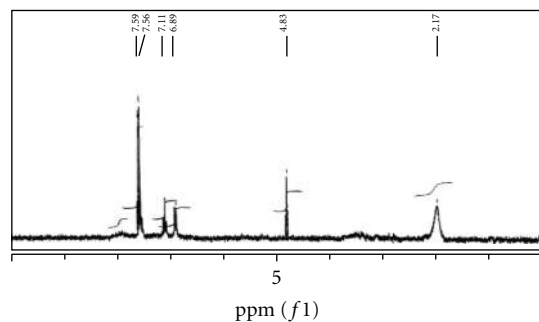


FIGURE 3:  $^1\text{H}$ NMR of  $\text{L}_{II}\text{H}$  spectrum in  $\text{CD}_2\text{Cl}_2$ .

by SBH (Figure 6) gave a peak at  $m/z = 250$  which was assigned to  $[\text{M}+1]$ , while the two Mannich base ligands displayed peaks corresponding to  $[\text{M}^+]$  molecular ions. Smaller fragments were also observed and were characteristic of isatin behavior of other compounds [1, 22, 26, 28–34]. The FAB and EI modes of  $\text{L}_I\text{H}$  (Figures 4(a) and 4(b)) showed different intensities of common fragments ions.

The IR spectra of the three organic compounds exhibited the disappearance of stretching modes assigned to C-3 carbonyl of isatin ring and appearance of stretching modes of azomethine group of Schiff base products at  $1614\text{ cm}^{-1}$  [35]. Stretching vibrations of C-2 carbonyl group of isatin ring for SBH and the two Mannich Schiff base ligands were observed at  $1733$ – $1730\text{ cm}^{-1}$  [35]. The presence of bands assigned to  $\text{NH}_2$  asymmetric symmetric stretching vibrations indicates that the formation of Schiff bases was through one  $\text{NH}_2$  group only. Both ligands exhibited the absence of stretching vibrations assigned to NH of isatin ring, and instead vibrational modes of N– $\text{CH}_2$  groups were observed at  $2813$ – $2304\text{ cm}^{-1}$  [35]. Bands observed at 1149, 1328 in the spectrum of  $\text{L}_I\text{H}$  were attributed to C–O–C and C–N–C vibration of morpholine ring, respectively [35–38].

**6.2. Physical Properties and Analytical Data of Metal Complexes.** The color, melting points, yields, and elemental analyses of the prepared metal complexes of isatin Schiff Mannich base ligands are described in Table 1. Most results were in agreement with the suggested formula. Some deviations in elemental analyses may be attributed to incomplete combustion of the complexes. The low yield resulted from extensive purification of products from the starting materials as was indicated from TLC results.

**6.3. Infrared Spectra.** The important stretching vibrations of  $\text{L}_I\text{H}$  and  $\text{L}_{II}\text{H}$  metal complexes are described in Table 2. The Mn(II), Co(II) and Ni(II) complexes of  $\text{L}_I\text{H}$  ( $\text{C}_1$ – $\text{C}_3$ , resp.) and Co(II) complex of  $\text{L}_{II}\text{H}$  ( $\text{C}_8$ ) exhibited shifts of the thioamide groups to lower frequencies indicating the involvement of thiocarbonyl sulfur atoms in coordination with these metal ions [39, 40]. The spectra of  $\text{C}_1$  and  $\text{C}_2$  demonstrated further shift of  $\text{NH}_2$  group vibrational modes to lower frequencies as a result of bonding. On the other hand the spectra of Cu(II), Ir(III), and Pt(IV) complexes of  $\text{L}_I\text{H}$  ( $\text{C}_4$ ,  $\text{C}_6$ ,  $\text{C}_7$ , resp.) and Pd(II), Pt(IV),

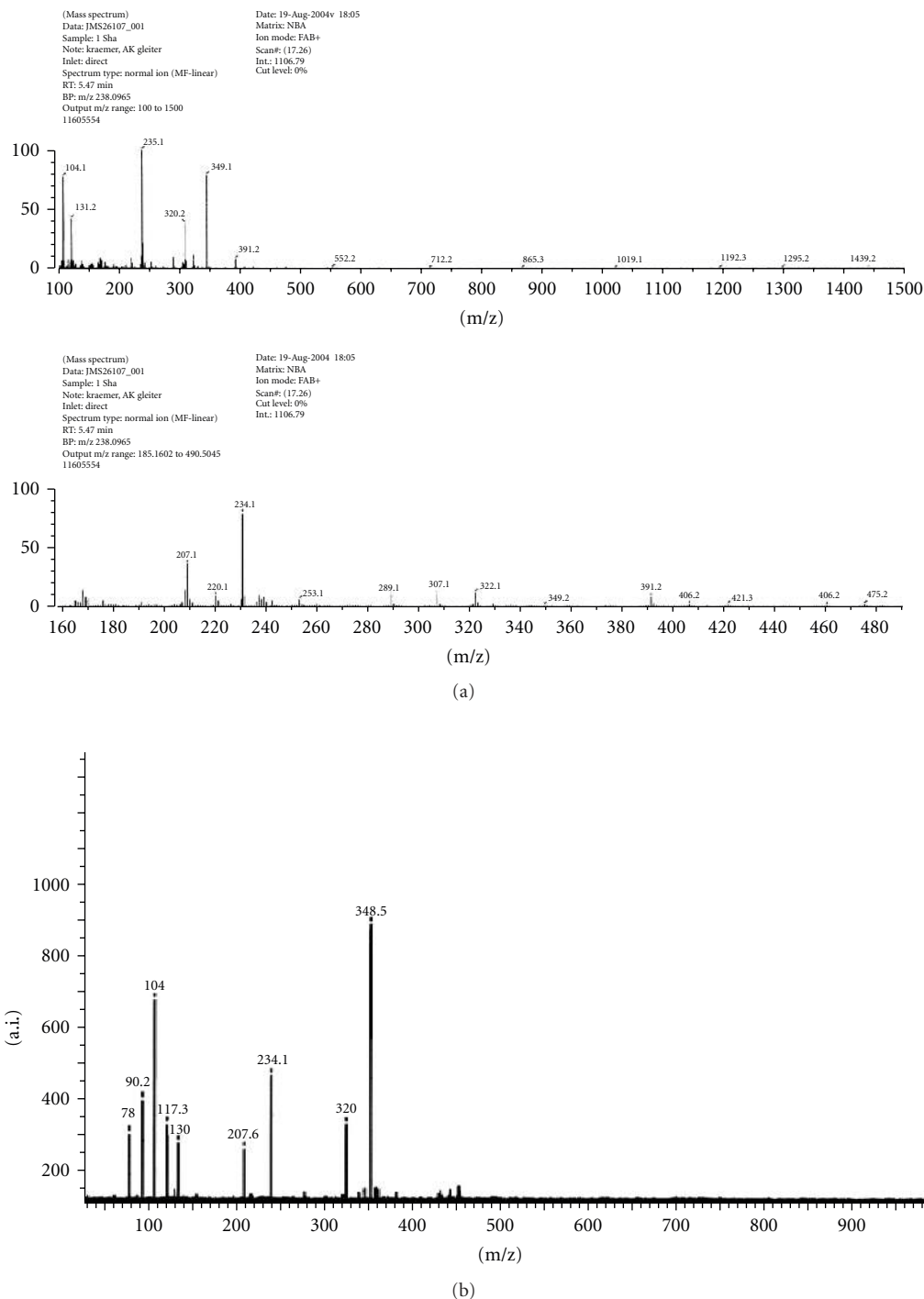


FIGURE 4: Mass spectrum of  $L_1H$  by (a) FAB and (b) EI modes.

and Cd(II) complexes of  $L_{II}H$  ( $C_{10}$ – $C_{12}$ , resp.) displayed the disappearance of the stretching mode of thioamide  $NH_2$  group and the shift of C–S band to lower frequencies. This refers to the bonding of metal ion to the deprotonated group

of the ligand in the form of  $\text{—}\overset{\text{NH}}{\parallel}{\text{C}}\text{—SH}$  as in  $C_4$ ,  $C_6$ , and  $C_9$  or in the form of  $\text{—}\overset{\text{NH}}{\parallel}{\text{C}}\text{—S}^\ominus$  anion as in the case of  $C_5$ ,  $C_7$ ,

and  $C_{10}$ – $C_{12}$ . The appearance of stretching modes assigned to NH and C=N of  $\text{—C=NH}$  groups was observed at 3371–3100 and 1640–1620  $\text{cm}^{-1}$ , respectively [15, 35, 39, 41]. The stretching vibrations of azomethine group of the Schiff base ligands were shifted to lower frequencies in all spectra except those of  $C_6$ ,  $C_{10}$ , and  $C_{12}$ , whereas stretching vibrations of carbonyl group were shifted to lower frequencies in all spectra except  $C_1$ ,  $C_4$ ,  $C_6$ , and  $C_{10}$  indicating additional

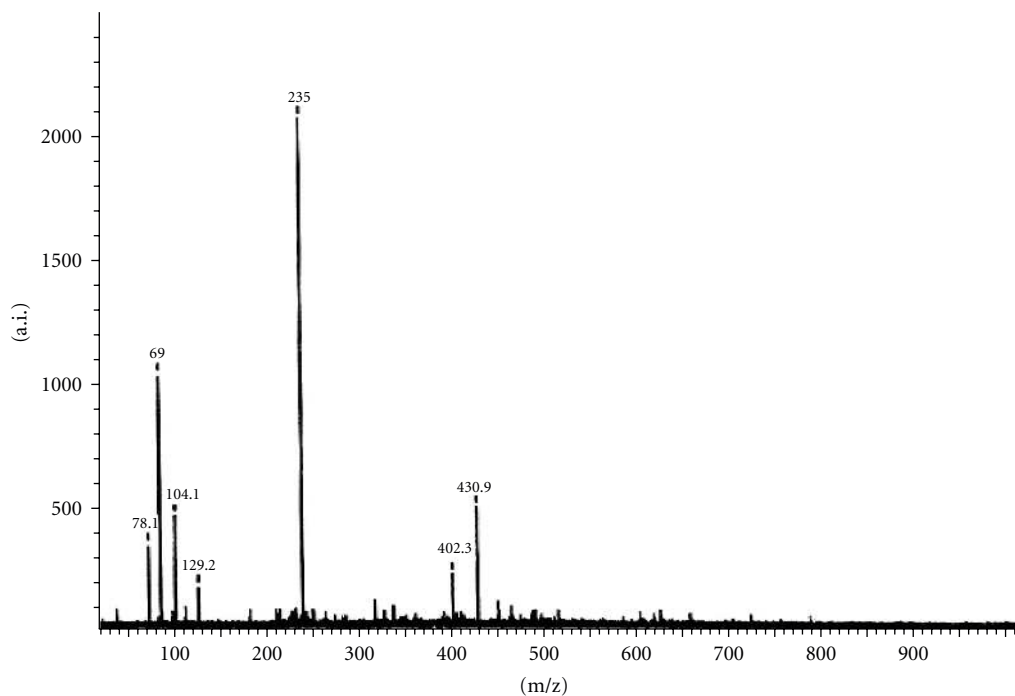
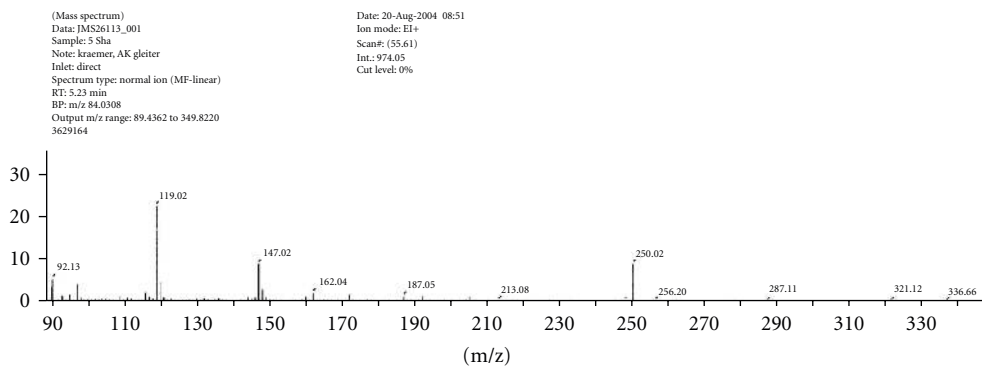
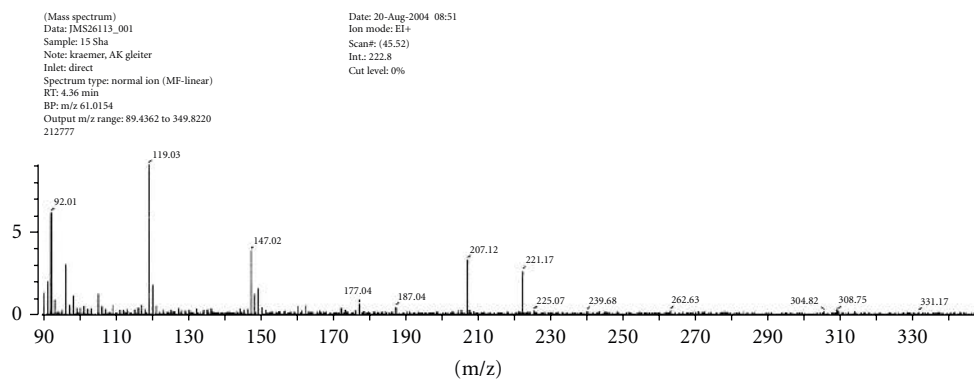
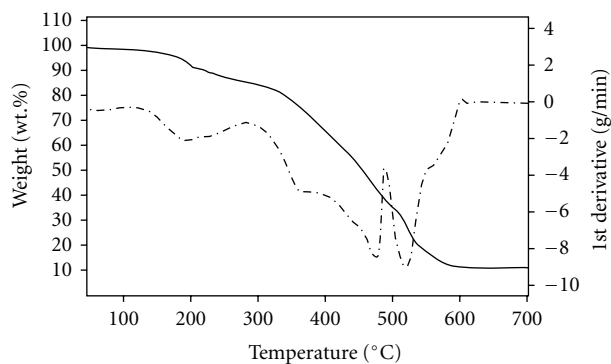
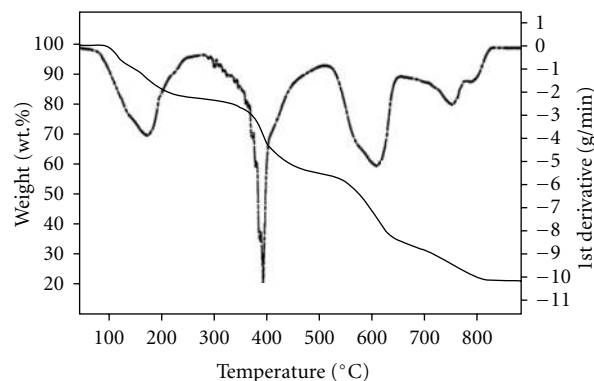
FIGURE 5: Mass spectrum of L<sub>11</sub>H.

FIGURE 6: Mass spectrum of SBH.

TABLE 1: Physical properties and analytical data of the prepared Schiff and Mannich base complexes.

Molecular formula (Color)	m.p. (decomposition) temp. °C	Yield %	% element analysis found (calculated)				
			C	H	N	M	Cl
[Mn(L <sub>I</sub> H)(H <sub>2</sub> O)Cl <sub>2</sub> ]·2.5H <sub>2</sub> O (Brown) (C <sub>1</sub> )	215	42.24	33.91 (33.46)	4.22 (4.27)	11.18 (10.40)	10.66 (10.20)	13.11 (13.19)
[Co(L <sub>I</sub> H)(NO <sub>3</sub> ) <sub>2</sub> ]H <sub>2</sub> O (Brown) (C <sub>2</sub> )	174	61.11	33.11 (32.77)	3.02 (3.27)	16.09 (15.29)	10.50 (10.73)	—
[Ni(L <sub>I</sub> H) <sub>2</sub> ]2NO <sub>3</sub> ·H <sub>2</sub> O (Bright blue) (C <sub>3</sub> )	>300	50.8	40.90 (40.13)	3.62 (3.78)	16.06 (15.60)	5.78 (6.54)	—
[Cu <sub>2</sub> (L <sub>I</sub> H) <sub>2</sub> Cl(H <sub>2</sub> O) <sub>4</sub> ]Cl <sub>3</sub> (Reddish brown) (C <sub>4</sub> )	>300	77.11	40.25 (39.85)	4.32 (4.43)	6.81 (6.20)	13.73 (14.07)	7.26 (7.86)
[PdL <sub>I</sub> ]Cl·1.5H <sub>2</sub> O (Dark brown) (C <sub>5</sub> )	250	59.21	34.45 (34.82)	3.01 (3.48)	11.32 (10.80)	—	7.01 (6.86)
[Ir(L <sub>I</sub> H) <sub>2</sub> Cl <sub>2</sub> ]Cl·H <sub>2</sub> O (Pale yellow) (C <sub>6</sub> )	230	32.31	34.73 (35.51)	3.32 (3.55)	11.82 (11.05)	19.56 (19.12)	9.98 (10.50)
[Pt(L <sub>I</sub> )Cl <sub>3</sub> ]0.5H <sub>2</sub> O (Yellow brown) (C <sub>7</sub> )	>300	34.01	27.78 (27.31)	2.49 (2.58)	8.82 (8.49)	28.89 (29.60)	16.82 (16.16)
[Co <sub>2</sub> (L <sub>II</sub> H) <sub>2</sub> (NO <sub>3</sub> ) <sub>4</sub> ]·2H <sub>2</sub> O (Dark green) (C <sub>8</sub> )	235	42.15	44.62 (43.74)	3.71 (3.17)	13.64 (13.31)	8.89 (9.34)	—
[Ni(L <sub>II</sub> H)(OAc) <sub>2</sub> ] (Blue) (C <sub>9</sub> )	243	50.32	52.84 (53.40)	3.54 (3.95)	9.43 (9.23)	9.72 (9.23)	—
[PdL <sub>II</sub> ]Cl <sub>2</sub> ·1.5H <sub>2</sub> O (Dark brown) (C <sub>10</sub> )	>280	23.30	46.51 (46.86)	3.81 (3.23)	10.11 (9.51)	—	6.40 (6.03)
[Pt(L <sub>II</sub> )Cl <sub>2</sub> ·H <sub>2</sub> O]Cl·H <sub>2</sub> O (Brown) (C <sub>11</sub> )	250	33.23	36.21 (35.95)	2.13 (2.87)	8.23 (7.29)	24.77 (25.40)	13.09 (13.87)
[CdL <sub>II</sub> (OAc)(H <sub>2</sub> O) <sub>2</sub> ] (Yellow) (C <sub>12</sub> )	260	20.57	46.65 (47.06)	3.62 (3.29)	9.50 (8.77)	16.95 (17.63)	—

FIGURE 7: Thermographs of the Co(II) complex of L<sub>I</sub>H (C<sub>2</sub>).FIGURE 8: Thermographs of the Ir(III) complex of L<sub>I</sub>H (C<sub>6</sub>).

coordination of metal ions to C=N and C=O groups [36–38]. Bands related to coordinated water vibrations were observed in the spectra of C<sub>1</sub>, C<sub>4</sub>, and C<sub>12</sub> at (3490, 756, 640), (3480, 800, 730), and (3500, 864, 710) cm<sup>-1</sup>, respectively, and to lattice water vibrations at frequency range 3519–3464 cm<sup>-1</sup> in the other complexes. The bands related to nitrate ions were observed in the spectra of C<sub>2</sub> and C<sub>3</sub> at (1522, 1478), (1765, 1641) cm<sup>-1</sup> and were assigned to monodentate and free ion behaviors, respectively, whereas that of C<sub>8</sub> appeared

at 1750–1660 and 1406–1380 cm<sup>-1</sup> showing monodentate and bidentate behaviors, respectively [42]. Bands attributed to acetate group vibrations were observed in the spectra of C<sub>9</sub> and C<sub>12</sub> at (1645, 1340) and (1590, 1465) cm<sup>-1</sup>, respectively, indicating monodentate and bidentate bridging behaviors, respectively [42]. Additional bands were observed at lower frequencies (600–250 cm<sup>-1</sup>) and were attributed to M–N, M–O, M–S, and M–X (X = acetate, NO<sub>3</sub><sup>-</sup>, Cl<sup>-</sup>) stretching modes [42].

TABLE 2: Important I.R. vibrations ( $\text{cm}^{-1}$ ) for the two Mannich and Schiff base ligands and their metal complexes.

Symbol	$\nu_{\text{NH}_2}$	$\nu_{\text{C}=\text{N}^{\text{H}}}$	$\nu_{\text{C}=\text{O}}$	$\nu_{\text{C}=\text{N}}$	Thioamide group				$\nu_{\text{M}-\text{N}}$	$\nu_{\text{M}-\text{O}}$	$\nu_{\text{M}-\text{S}}$	$\nu_{\text{M}-\text{Cl}}$
					Band (I) $\delta_{\text{N}-\text{H}} + \nu_{\text{C}-\text{S}}$	Band (II) $\nu_{\text{C}-\text{N}} + \nu_{\text{C}-\text{S}}$	Band (III) $\nu_{\text{C}-\text{S}}$	Band (IV) $\nu_{\text{C}=\text{S}}$				
L <sub>I</sub> H	3138		1730–	1614	1540	1429	1195	835	—	—	—	—
	3203	—	1735									
C <sub>1</sub> Mn(II)	3124		1732	1600	1510	1434	1190	820	248	283	325	246 <sup>a</sup>
	3371	—										
C <sub>2</sub> Co(II)	3072		1724	1602	1530	1433	1163	777	230	460	330	—
	3263	—										
C <sub>3</sub> Ni(II)	3133		1720	1595	1535	1427	1150	827	293	464	330	—
	3213	—										
C <sub>4</sub> Cu(II)				1600	1535	1434	1190	792	250	457	350	222 <sup>b</sup>
	—	3315	1735	1650								
C <sub>5</sub> Pd(II)				1604	1537	1430	1190	815	240	459	323	—
	—	3392	1708	1660								
C <sub>6</sub> Ir(III)				1614	1539	1400	1151	810	350	—	330	253 <sup>a</sup>
	—	3342	1735	1650								
C <sub>7</sub> Pt(IV)				1600	1517	1446	1114	833	254	462	329	297 <sup>a</sup>
	—	3168	1700	1650								
L <sub>II</sub> H	3043		1730	1614	1540	1434	1195	833	—	—	—	—
	3193	—										
C <sub>8</sub> Co(II)	3151		1700	1602	1585	1440	1130	800	393	400	327	—
	3321	—										
C <sub>9</sub> Ni(II)	3128		1695	1600	1583	1484	1150	809	246	478	320	—
	3249	3249										
C <sub>10</sub> Pd(II)		3425		1619	1587	1450	1155	820	464	—	323	240 <sup>b</sup>
	—	3249	1735	1647								
C <sub>11</sub> Pt(IV)				1616	1530	1430	1150	802	468	480	325	291 <sup>a</sup>
	—	3230	1730	1650								
C <sub>12</sub> Cd(II)				1616	1488	1430	1161	800	288	468	325	—
	—	3300	1735	1650								

<sup>a</sup>: terminal; <sup>b</sup>: bridging.



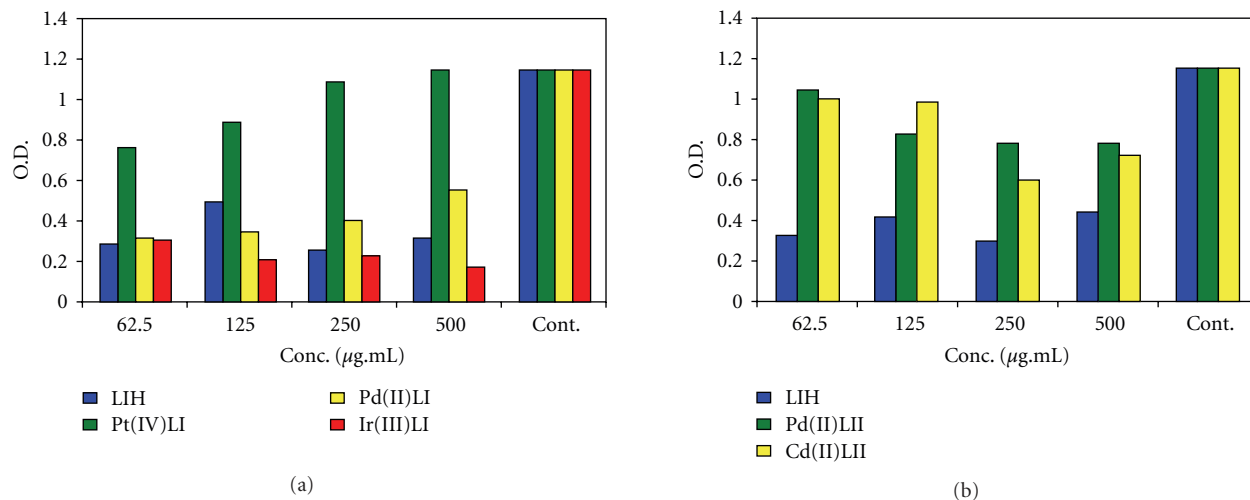


FIGURE 9: Cytotoxic effect of  $L_1H$ ,  $L_{11}H$ , and some selected metal complexes on growth of cancer cell line Hep-2 at different concentrations with exposure time 48 h.

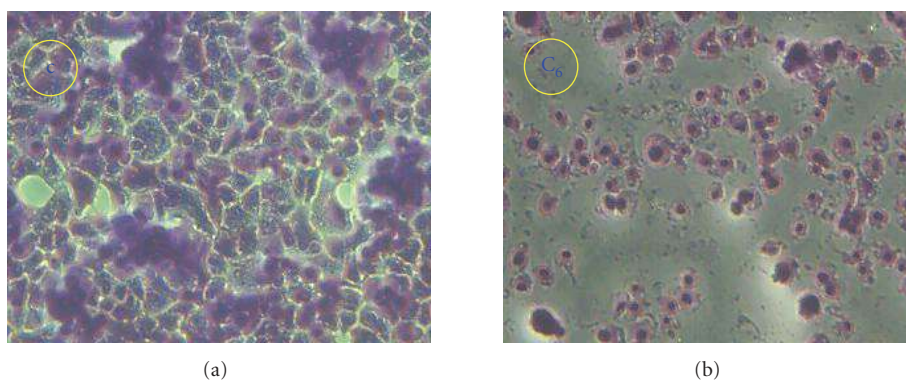


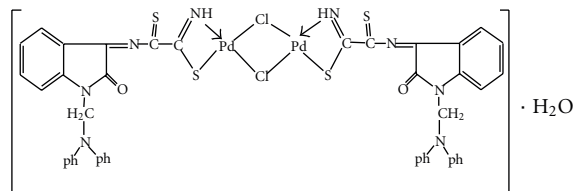
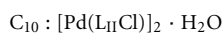
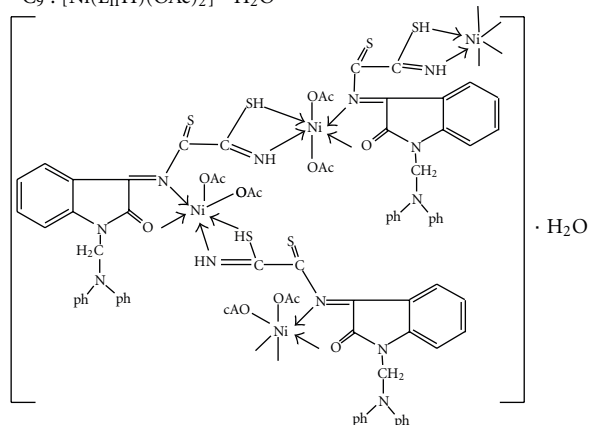
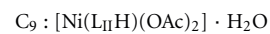
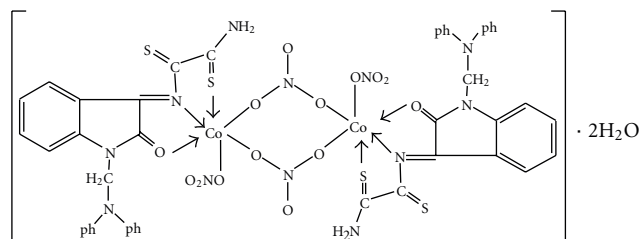
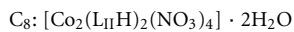
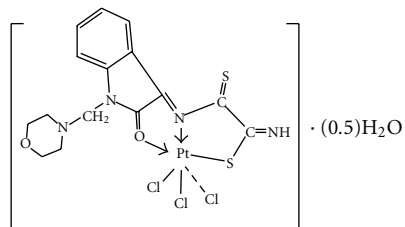
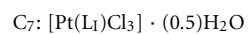
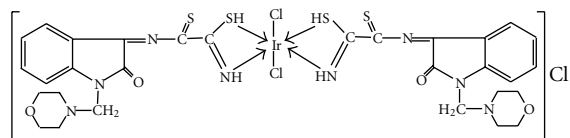
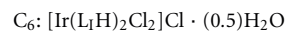
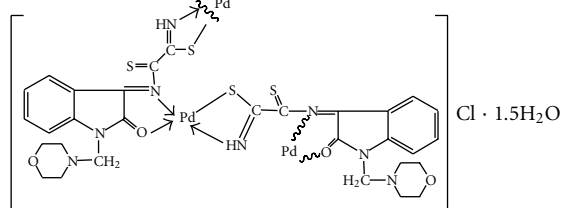
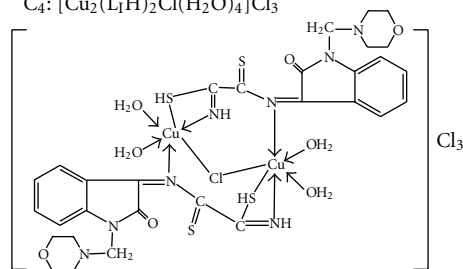
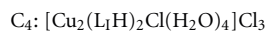
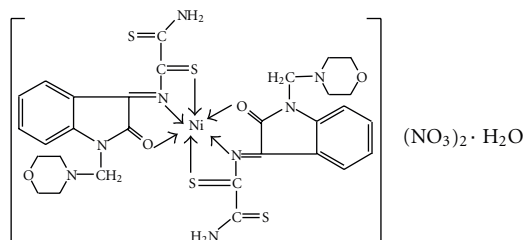
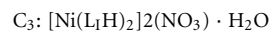
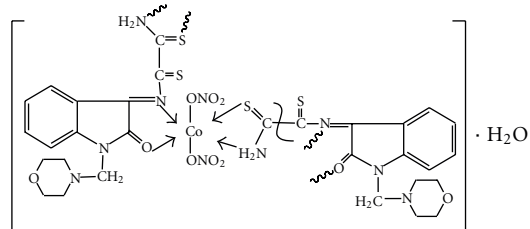
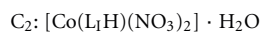
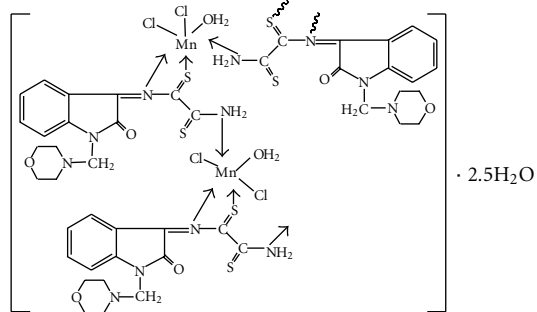
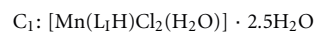
FIGURE 10: Tissue culture sections of Hep-2 cell line before (c) and after treatment with  $IrL_1$  ( $C_6$ ).

**6.4. Thermal Analysis.** Steps of thermal decomposition of the Co(II) and Ir(III) complexes of  $L_1H$  ( $C_2$ ,  $C_6$ ) following TG and DTG curves under nitrogen atmosphere and heating range 50–800°C are described in Table 3, and their thermographs are shown in Figures 7 and 8, respectively. At low temperatures, the initial weight losses were determined from TG curves referred to loss of water of crystallization [43–45]. The final stage of thermal decomposition of  $C_2$  gave the metal oxide whereas the Ir complex ( $C_6$ ) gave the free metal as a final residue [43–45].

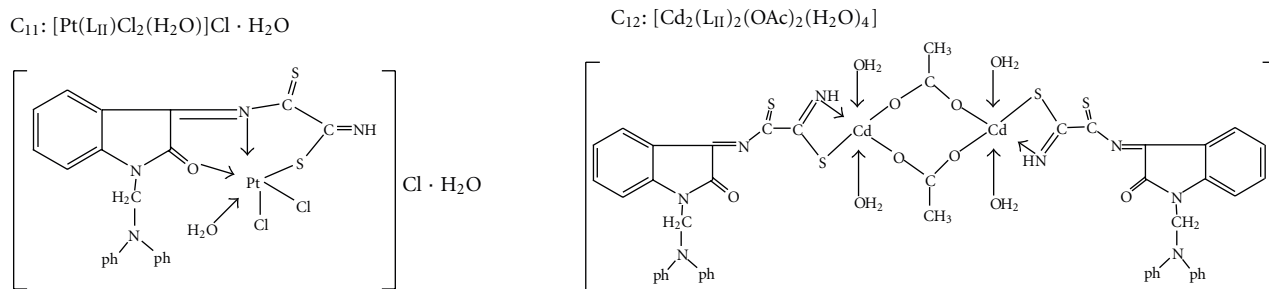
**6.5. Electronic Spectra and Suggested Structures.** Table 4 describes the energies of bands observed in the spectra of metal complexes and their assignments together with magnetic moments and molar conductivity in DMF ( $10^{-3}$  M). The spectral parameters  $10Dq$ ,  $Dq/\bar{B}$ ,  $\bar{B}$ , and  $\beta$  as well as energies of unobserved ligand field bands were obtained by applying observed band energies and band ratios on Tanabe-Saigano diagrams of the specified metal ion [46–48].

All metal complexes exhibited spectra related to octahedral arrangement of ligand atoms around the metal ions except those of palladium(II) as they gave square planar geometries. The high values of magnetic moments of Co(II), Ni(II), and Cu(II) complexes are attributed to spin-orbital coupling [49]. All complexes were of high-spin octahedral geometries except Pt(IV), Ir(III), and Cd(II) complexes which were diamagnetic and so were Pd(II) complexes.

The spectrum of the Cd(II) complex ( $C_{12}$ ) exhibited charge transfer bands only, which is a common phenomenon for  $d^{10}$  metal complexes where d-d transitions are excluded [47, 48]. Conductivity measurement of metal complexes in DMF solution ( $10^{-3}$  M) showed nonelectrolytic nature of Mn(II), Co(II), and Pt(IV) complexes of  $L_1H$  ( $C_1$ ,  $C_2$ , and  $C_7$ , resp.) and Co(II), Ni(II), Pd(II), and Cd(II) complexes of  $L_{11}H$  ( $C_8$ – $C_{10}$  and  $C_{12}$ , resp.) [50]. Electrolytic nature of 1:1 was exhibited by Pd(II), Ir(III) complexes of  $L_1H$  ( $C_5$  and  $C_6$ ) and Pt(IV) complex of  $L_{11}H$  ( $C_{11}$ ), 1:2 by Ni(II) complex of  $L_1H$  ( $C_3$ ) and 1:3 by Cu(II) complex of  $L_1H$  ( $C_4$ )



SCHEME 3: Continued.



SCHEME 3: Suggested structures of Schiff and Mannich base complexes.

TABLE 3: Suggested thermal decomposition steps of  $C_2$  and  $C_6$ .

Stable phase (M.wt) [ $\text{CoL}_1(\text{NO}_3)_2 \cdot \text{H}_2\text{O}$ ( $C_2$ ) (549.193)]	Temp. range of decomp. at TG °C	Peak temp. at DTG °C	%weight loss found (calc.)
$\text{H}_2\text{O}$ (Lattice)	70–120	—	2.91 (3.27)
$\text{NO}_3$	120–220	200	11.62 (11.97)
$\text{C}_{15}\text{N}_4\text{H}_{16}\text{O}_2\text{S}_2$ $\text{NO}_2$	220–600	—	71.38 (71.80)
$\text{CoO}$	—	—	13.28 (13.64)
$[\text{Ir}(\text{L}_1)_2\text{Cl}_2]\text{Cl} \cdot (0.5)\text{H}_2\text{O}$ ( $C_6$ ) (1004.24)			
$0.5\text{H}_2\text{O}$ (lattice)	80–250	190	17.43 (17.62)
$\text{C}_8\text{N}_2\text{H}_{16}\text{O}_2$	250–500	399	24.07 (24.94)
$3\text{Cl}$ $\text{C}_9\text{N}_2\text{H}_8$	500–700	515	24.48 (24.69)
$\text{C}_{10}\text{N}_3\text{H}_6\text{OS}_2$	700–830	760	13.30 (13.14)
$\text{C}_2\text{NS}_2\text{H}_2$	—	—	19.83 (19.12)
$\text{Ir}$	—	—	

[50]. According to the above-mentioned data and those of elemental analyses and i.r. spectra, the structures of the metal complexes can be suggested as illustrated in Scheme 3.

## 7. Biological Activity

**7.1. Antibacterial Activity.** The growth inhibition of the prepared Schiff and Mannich base ligands and some selected metal complexes were studied against three types of pathogenic bacteria, namely, *Proteus mirabilis*, *Escherichia coli*, and *Staphylococcus aureus* by using DMSO as a solvent and the antibiotic Ceftriaxone as a control. Cultures were incubated at 37°C for 24 h. The inhibition zones were measured, and results are described in Table 5. The Schiff base precursor (SBH) and  $\text{L}_1\text{H}$  were potent against all types of bacteria with the latter being more active than Ceftriaxone, while  $\text{L}_{\text{II}}\text{H}$  was inactive. Complexes of  $\text{L}_1\text{H}$  with  $\text{Co}(\text{II})$ ,  $\text{Ni}(\text{II})$ ,  $\text{Pd}(\text{II})$ , and  $\text{Ir}(\text{III})$  ions ( $C_2$ ,  $C_3$ ,  $C_5$ ,  $C_6$ ) showed no activity while the  $\text{Pt}(\text{IV})$  complex ( $C_7$ ) was as active as the

original ligand against all types. Among the selected metal complexes of  $\text{L}_{\text{II}}\text{H}$ , the  $\text{Pd}(\text{II})$  complex ( $C_{10}$ ) was highly potent against all bacterial cultures. These results indicate that the degree of growth inhibition is highly dependent on the structure of ligands, metal complexes, and type of metal ion [51, 52]. Although the inhibition zones of  $\text{L}_1\text{H}$ ,  $C_7$  and  $C_{10}$  were larger than that caused by Ceftriaxone, other categories, like toxicity of these compounds, still have to be studied in detail.

**7.2. Cytotoxic Effect.** Preliminary cytotoxicity tests of the Schiff base (SBH) and its Mannich base ligands ( $\text{L}_1\text{H}$  and  $\text{L}_{\text{II}}\text{H}$ ) with some selected metal complexes were performed in triplicate against cancer cell line of human epidermoid larynx carcinoma (Hep-2) using concentrations of 62.5, 125, 250, and 500  $\mu\text{g}/\text{mL}$  in DMSO with exposure time of 48 h using ELISA spectrophotometer. The three organic compounds showed high toxic activities at 125, 250, 250  $\mu\text{g}/\text{mL}$ , respectively, causing cell death as was confirmed by the drop

TABLE 4: Electronic spectra, spectral parameters, molar conductivity, and effective magnetic moments ( $\mu_{\text{eff}}$ ) of Schiff and Mannich base complexes.

Comp. no.	Band positions ( $\text{cm}^{-1}$ )	Assignment	Dq/B'(B') ( $\text{cm}^{-1}$ )	$\beta$	10Dq ( $\text{cm}^{-1}$ )	$\Omega$ ( $\text{S.mol}^{-1}.\text{cm}^2$ )	$\mu_{\text{eff}}$ (BM)
C <sub>1</sub> Mn(II)	$\nu_1$ 17857	${}^6\text{A}_{1g}(\text{S}) \rightarrow {}^4\text{T}_{2g}(\text{G})$	—	—	—	15.0	5.851
	$\nu_2$ 25641	L → M (C.T.)	—	—	—	—	—
	$\nu_1$ 5352(*)	${}^4\text{T}_{1g} \rightarrow {}^4\text{T}_{2g}$	—	—	—	—	—
C <sub>2</sub> Co(II)	$\nu_2$ 13333	${}^4\text{T}_{1g}(\text{F}) \rightarrow {}^4\text{A}_{2g}$	0963 (705)	0.726	6789	6.05	5.446
	$\nu_3$ 16625	${}^4\text{T}_{1g}(\text{F}) \rightarrow {}^4\text{T}_{1g}(\text{P})$	—	—	—	—	—
	$\nu_4$ 27777	L → M (C.T.)	—	—	—	—	—
	$\nu_1$ 10204	${}^3\text{A}_{2g} \rightarrow {}^3\text{T}_{2g}^3$	—	—	—	—	—
C <sub>3</sub> Ni(II)	$\nu_2$ 14388	$\text{A}_{2g} \rightarrow {}^3\text{T}_{1g}(\text{F})^3$	1.65 (619.6)	0.602	10223	186.0	4.18
	$\nu_3$ 21276	$\text{A}_{2g} \rightarrow {}^3\text{T}_{1g}(\text{P})$	—	—	—	—	—
	$\nu_1$ 11111	${}^2\text{B}_{1g} \rightarrow {}^2\text{A}_{1g}$	—	—	—	—	—
C <sub>4</sub> Cu(II)	$\nu_2$ 16667	${}^2\text{B}_{1g} \rightarrow {}^2\text{B}_{2g}$	—	—	—	282.0	2.51
	$\nu_3$ 22222	${}^2\text{B}_{1g} \rightarrow {}^2\text{E}_g$	—	—	—	—	—
	$\nu_4$ 28571	L → M (C.T.)	—	—	—	—	—
C <sub>5</sub> Pd(II)	$\nu_1$ 16393	${}^1\text{A}_{1g} \rightarrow {}^1\text{A}_{2g}$	—	—	—	77.0	Diamag.
	$\nu_2$ 21276	${}^1\text{A}_{1g} \rightarrow {}^1\text{B}_{1g}$	—	—	—	—	—
C <sub>6</sub> Ir(III)	$\nu_1$ 14705	${}^1\text{A}_{1g} \rightarrow {}^3\text{T}_{1g}$	—	—	—	90.0	Diamag.
	$\nu_2$ 18518	${}^1\text{A}_{1g} \rightarrow {}^1\text{T}_{2g}$	—	—	—	—	—
	$\nu_3$ 22222	L → M (C.T.)	—	—	—	—	—
C <sub>7</sub> Pt(IV)	$\nu_1$ 15625	${}^1\text{A}_{1g} \rightarrow {}^3\text{T}_{1g}$	—	—	—	15.0	Diamag.
	$\nu_2$ 21276	${}^1\text{A}_{1g} \rightarrow {}^3\text{T}_{2g}$	—	—	—	—	—
	$\nu_3$ 23255	L → M (C.T.)	—	—	—	—	—
C <sub>8</sub> Co(II)	$\nu_1$ 5471(*)	${}^4\text{T}_{1g} \rightarrow {}^4\text{T}_{2g}$	—	—	—	—	—
	$\nu_2$ 10989	${}^4\text{T}_{1g} \rightarrow {}^4\text{A}_{2g}$	0.843 (762.61)	0785	6430	18.0	4.617
	$\nu_3$ 15795	${}^4\text{T}_{1g}(\text{F}) \rightarrow {}^4\text{T}_{1g}(\text{P})$	—	—	—	—	—
	$\nu_4$ 26315	L → M (C.T.)	—	—	—	—	—
C <sub>9</sub> Ni(II)	$\nu_1$ 10172	${}^3\text{A}_{2g} \rightarrow {}^3\text{T}_{2g}$	—	—	—	—	—
	$\nu_2$ 14845	${}^3\text{A}_{2g} \rightarrow {}^3\text{T}_{1g}(\text{F})$	1.667 (612.2)	0594	10200	20.5	4.251
	$\nu_3$ 22727	${}^3\text{A}_{1g} \rightarrow {}^3\text{T}_{1g}(\text{P})$	—	—	—	—	—
	$\nu_4$ 27027	L → M (C.T.)	—	—	—	—	—
C <sub>10</sub> Pd(II)	$\nu_1$ 16025	${}^1\text{A}_{1g} \rightarrow {}^1\text{A}_{2g}$	—	—	—	9.0	Diamag.
	$\nu_2$ 21739	${}^1\text{A}_{1g} \rightarrow {}^1\text{B}_{1g}$	—	—	—	—	—
	$\nu_3$ 26315	${}^1\text{A}_{1g} \rightarrow {}^1\text{E}_g$	—	—	—	—	—
C <sub>11</sub> Pt(IV)	$\nu_1$ 15908	${}^1\text{A}_{1g} \rightarrow {}^3\text{T}_{1g}$	—	—	—	73.0	Diamag.
	$\nu_2$ 27027	L → M (C.T.)	—	—	—	—	—
C <sub>12</sub> Cd(II)	$\nu_1$ 27777	L → M (C.T.)	—	—	—	8.00	Diamag.
	$\nu_2$ 32786	Intralig $\pi \rightarrow \pi^*$	—	—	—	—	—

\* Calculated.

TABLE 5: Antibacterial activities of the Schiff and Mannich bases and some selected metal complexes showing inhibition zones in diameters (mm).

Entry	Compound	<i>Proteus mirabilis</i>		<i>Escherichia coli</i>		<i>Staphylococcus aureus</i>	
1	SBH	19	++	30	+++	29	+++
2	L <sub>I</sub> H	32	++++	48	+++++	43	+++++
3	Co(II) (C <sub>2</sub> )	—	—	—	—	—	—
4	Pd(II) (C <sub>5</sub> )	—	—	8	—	9	—
5	Ir(III) (C <sub>6</sub> )	—	—	10	—	9	—
6	Pt(IV) (C <sub>7</sub> )	38	+++++	39	+++++	44	+++++
7	L <sub>II</sub> H	9	—	9	—	12	—
8	Co(II) (C <sub>8</sub> )	9	—	8	—	15	+
9	Pd(II) (C <sub>10</sub> )	38	+++++	39	+++++	44	+++++
10	Cd(II) (C <sub>12</sub> )	9	—	8	—	15	+
11	ceftriaxone	28	+++	30	+++	36	++++

in optical absorbance of NR in the treated cells compared with the controls which refers to complete disruption of cell functions [53]. The cytotoxic effect of metal complexes of L<sub>I</sub>H was found to increase in the order of Pt(IV) < Pd(II) << Ir(III) as is shown in Figure 9. The Pt(IV) complex (C<sub>7</sub>) was much less active than the parent ligand, and its performance was found to decrease with concentration that it was totally inactive at 500 µg/mL.

The Pd(II) complex (C<sub>5</sub>) followed the same trend of concentration as the Pt(IV) complex but it was toxic enough to cause cell death. The Ir(III) complex (C<sub>6</sub>) was exceptionally active, and its cytotoxic activity was found to increase with concentration. Figure 10 illustrates the difference in dye distribution in the tissue culture sections of Hep-2 before and after treatment with this complex in comparison with the control. Both the Pd(II) and Cd(II) complexes of L<sub>II</sub>H (C<sub>10</sub> and C<sub>12</sub>) were less toxic than the parent ligand, and their activity slightly increased with concentration. The Cd(II) complex (C<sub>12</sub>) caused 30–60% decrease of ligand activity. The complex was similarly inactive against growth of the three bacterial cultures although Cd<sup>++</sup> ion is well known as an environmental carcinogen at very low concentrations in human and animals [54]. This indicates that the toxicity of Cd<sup>++</sup> ion can be decreased on complexation with some ligands.

The present study describes a narrow scope of the cytotoxic activity of the studied compounds. Extension of this study, in future work to involve other cancer cell lines and other metal complexes, using normal human cell lines as control, may reveal more important data.

## 8. Conclusions

Condensation of dithiooxamide with isatin or its N-Mannich bases occurred from one amino end of the compound which allowed for tautomerism of the resulted compound in solutions as was confirmed by <sup>1</sup>H.n.m.r spectrum of the product and from the IR spectra of some of its coordination compounds. The potent chelating behavior of the two new

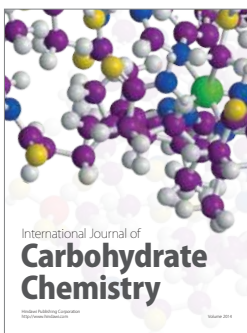
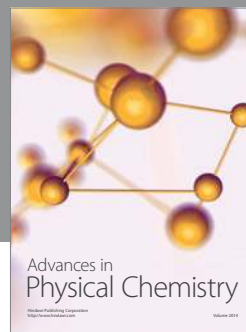
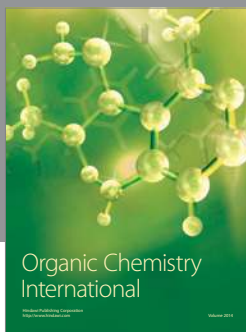
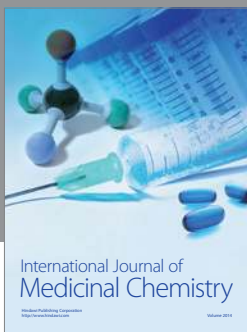
Mannich and Schiff bases led to the formation of bi- and polynuclear metal complexes. The preliminary study of biological activity showed some controversy in performance between bacterial growth inhibition and cytotoxic activities against Hep-2 cell line. The Ir(III) complex of L<sub>I</sub>H which showed the highest cytotoxic effect was almost inactive against bacterial growth.

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