ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Electron Density and Biological Investigations on Metal Complexes with an ONO functionalized ligand

Majed M Hania

Chemistry Department, Islamic University, Gaza, P.O. Box 108, Palestine.

ABSTRACT

Co(II), Ni(II) and Cu(II) complexes have been prepared by reacting metal chlorides with 2-formylfuransemicarbazone as a ligand containing a trifunctional ONO-donor system in alcoholic medium in 2:1 ligand to metal mole ratio. All the complexes are colored crystalline solids. IR spectral analysis, UV/Vis spectral information in addition to elemental analysis suggests that metal complexes exhibit an octahedral geometry. Electron densities and biological activity of complexes have been studied and compared with their ligand which gave significant results on antibacterial activity.

Key words: Semicarbazone ligands, electron density, biological activity.

Corresponding author

ISSN: 0975-8585

INTRODUCTION

In past years, the chemistry of coordination compounds has shown a rapid development in different fields as a result of the possible use of these new compounds in biological applications. Transition metal complexes with potential biological activities are the focus of extensive investigations.

Synthesis of various heterocyclic semicarbazones and their complexes with different transition metals are reported in the literature [1-10] and found to be active as antibacterial [1-7], antitubercular [8], antilepral [11], antiviral [12], antimalarial [13], and active against certain kinds of tumors [14,15]. In previous papers, the complexation and antibacterial activity of new ligands and their various transition metal complexes were reported [9,10]. Due to the importance of this field and in continuance of interest in studying the relation between antibacterial activity and electronic effect of oxime, semicarbazone and phenylhydrazone compounds, synthesis, characterization and antibacterial activity of Co (II), Ni (II) and Cu (II) complexes with 2-formylfuransemicarbazone are reported herein, and the difference in antibacterial activity between the free ligand and complexes were studied.

MATERIALS AND METHODS

Melting points were determined in open capillaries and are uncorrected. IR spectra were recorded in KBr on a Perkin - Elmer 883 spectrometer in the range 4000-400 cm^{-1}. The UV/Vis spectra were recorded on a Perkin-Elmer Lambda 20 spectrometer in the range 900-200 nm. All compounds gave satisfactory analysis. 2-Formylfuran, cobalt chloride, nickel chloride, and copper chloride were obtained from Sigma-Aldrich Ltd. and used without further purification. All compounds were tested for their antibacterial activity against negative *E.Coli* bacteria at a concentration of 50 and 100 µg/disc using cup-plate method [16]. 2-formylfuransemicarbazone has been prepared according to the previous work [7]. Electron densities were calculated using Spartan '04 software. The semi-empirical method of calculation with PM3 was used for geometry optimization.

Synthesis of 2-formylfuransemicarbazone:

2-Formylfuran (0.015 mol) in (15 mL) ethanol was added to aqueous solution of semicarbazide hydrochloride (0.025 mol); the mixture was heated at 80-90 ^{o}C for 4 h and then left to precipitate and was collected, and purified by crystallization from ethanol to give 80% yield.

Complexes of 2-formylfuransemicarbazone with (Cu^{2+}, Ni^{2+}, Co^{2+}):

2- Formylfuransemicarbazone (0.02 mol) was dissolved in 15 ml ethanol and was added to dissolve copper, nickel and cobalt chloride (0.01) in 15 ml ethanol. The mixture was heated at 60 ^{o}C for 2 h and then left to cool. The precipitate was collected and purified by crystallization from ethanol. Yield (94%, 86% and 84%, respectively).

ISSN: 0975-8585

RESULTS AND DISCUSSION

The physical and spectral data are presented in (Table 1). From the literature [17], this ligand reveals 2:1 (ligand to metal) Stoichiometry. The infrared spectrum of free ligand (2-formylfuransemicarbazone) shows characteristic bands at 3457 cm^{-1} and 3279 cm^{-1} which can be assigned to ν (N-H) stretching modes according to literature [18]. The spectra of all metal complexes show the amino bands without significant changes. This clearly indicates the non-involvement of nitrogen atom of the mentioned groups in the coordination with metal ion.

The sharp and strong band at 1693 cm^{-1} is due to ν (-N-C=O) stretching vibration. The IR spectra of all the metal complexes of 2-formylfuransemicarbazone show downshift in ν(-N-C=O) from 1693 cm^{-1} to 1661 cm^{-1}, 1666 cm^{-1} and 1678 cm^{-1} for Cu^{2+}, Ni^{2+} and Co^{2+} complexes respectively. This clearly indicates the involvement of oxygen atom of the carbonyl group in the coordination with metal ion.

The next IR band of structural significance in the spectra of the ligand appears at 1600 cm^{-1}. This band can be assigned to the ν(C=N) group. This band has also downshift to the 1554-1555cm^{-1} and clearly indicates the coordination of nitrogen to the metal ion.

The ultraviolet visible electronic spectrum of the 2-formylfuransemicarbozone indicates the maximum absorbance at 280 nm. The electronic spectra of 2-formylfuransemicarbozone metal complexes were detected and results are depicted in (Table 1). It is observed that the λ_{max} of the metal complexes is shifted to the visible region indicating the complex formation and this transition may be attributed to π → π* electronic transition [19].

Table 1: Analytical and spectral data of metal complexes

Metal Complexes		Color	λ_{max} nm	m.p	ν(N-H) cm^{-1}	ν(C=O) cm^{-1}	ν(C=N) cm^{-1}
2-Formylfuran semicarbozone	Co^{2+}	Pink	528	230 °C	3281	1678	1554
	Ni^{2+}	Pale green	382	280 °C	3278	1666	1554
	Cu^{2+}	Green	377	157 °C	3267	1661	1555

On the basis of the above results, it is strongly suggested that all of the complexes can show an octahedral geometry in the cis form, in which the two ligands act as tridentate ligands (Figure 1). This is consistent with many reported similar complexes [20].

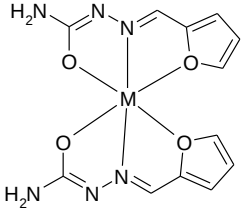

Figure 1. Proposed structure of the metal (II) complexes

ISSN: 0975-8585

2-formylfuransemicarbazone gave poor antibacterial activity due to the high electron density which caused by mesomeric effect [9] while complexes gave moderate antibacterial activity (Table 2). This comparative study indicates that the metal complexes are more active than the free Ligands due to the decrease in electron density of complexes.

Table 2. Antibacterial activity of free ligand and metal complexes (Zone of inhibition in mm)

Compound		Antibacterial activity	
		50 µg	100 µg
Free ligand		-	-
Complexes	Co^{2+}	+	+
	Ni^{2+}	+	+
	Cu^{2+}	+	+
Legends of table, +: active, - : No activity.			

The electrostatic potential can be mapped onto the electron density by using color to represent the value of the potential. The resulting model simultaneously displays molecular size and shape and electrostatic potential value. Colors toward “red” indicate negative values of the electrostatic potential, while colors toward “blue” indicate positive values of the potential.

Molecular electrostatics has become an important way to visualize electron density on the surface of a molecule. One way to compare the electronic character of free ligand and metal complexes is to compare electrostatic potential maps of the electron density surfaces. Maps for Co(II), Ni(II) and Cu(II) complexes with 2-formylfuransemicarbazone are shown in (Figure 2) [ligand-upper left, Cu(II) complex-upper right, Ni(II) complex-□ □bottom left, Co(II) complex-bottom right]. Colors toward “red” indicate negative values of the electrostatic potential, while colors toward “blue” indicate positive values of the potential.

The potential is positive everywhere on each map, the most positive potentials (blue and green) are found around the free ligand and the metal complexes, while the most negative regions (red) in these compounds lie between oxygen's and nitrogen in free ligand, but the nitrogen's bonded to metal are slightly less negative (yellow) in metal complexes. On the basis of the above observations, it is strongly suggested that all of the complexes have lower electron density than free ligand.

ISSN: 0975-8585

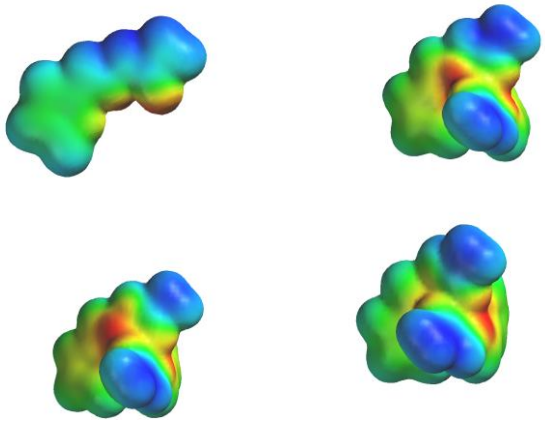

Figure 2. Electrostatic potential maps of free ligand and metal complexes [ligand-upper left, Cu (II) complex-upper right, Ni (II) complex-bottom left, Co (II) complex-bottom right].

Electron density calculations supports quite well with the practical results where the negative charge value of ligand more than the negative charge value of complexes (Table 3). The resulting electron density data indicate that the ligand has higher electron density than the metal complexes which prevent the inhabitation throw the body of the bacteria [21].

Table 3. Electron density calculations free ligand and its metal complexes

Compound		The potential range kcal mol^{-1}	
Free ligand		-83.0708	39.4977
Complexes	Co^{2+}	-77.78	42.93
	Ni^{2+}	-63.61	43.67
	Cu^{2+}	-71.54	44.99

CONCLUSION

Co(II), Ni(II) and Cu(II) complexes with the trifunctional ONO-donor atoms have been prepared and characterized on the basis of elemental analysis and spectroscopic (electronic, IR, and UV/Vis spectra) data. All of the complexes have been shown an octahedral geometry, in which the two ligands act as tridentate, bonding to the metal(II) ion through furan ring oxygen, imines nitrogen and amide oxygen. Electron densities and biological activity of complexes have been compared with their ligand which gave higher antibacterial activity and lower electron density than ligand. This might come from the difference in total electron density between the free ligand and metal complexes. This means that the free ligands have higher electron density than complexes which prevent the inhabitation throw the body of the bacteria. This will support our future rule (the higher electron density compound the lower antibacterial active).

ISSN: 0975-8585

ACKNOWLEDGEMENT

The author would like to acknowledge the staff of the Medical Technology Department at the Islamic University for testing the antibacterial activity of the compounds.

REFERENCES

[1] Desai JJ, Desai PG, Mehta AG. Asian J Chem 1999; 11:519.
[2] Desai JJ, Desai PG, Mehta AG. Asian J Chem 2000; 12:1067.
[3] Hania MM. Asian J Chem 2002; 14:1074.
[4] Rai BK. Asian J Chem 2002; 14:1595.
[5] Rai BK. Asian J Chem 2002; 14:312.
[6] Hania MM. Asian J Chem 2005; 17:439.
[7] Dobeck AS, Klayman D. Antimicrob Agents Chemother 1980; 18: 27.
[8] Wagner WH, Winkelman E. Arzneim Forschi 1972; 22:1713.
[9] Hania MM. Asian J Chem 2007; 17:439.
[10] Hania MM. E-Journal of Chemistry 2009; 6(S1):S508-S514.
[11] Morrison NE, Collins FM. Int J Leprosy 1981; 49:180.
[12] Jones DH, Slack R, Squires S. J Med Chem 1965; 2:676.
[13] Klayman DL, Joseph F. J Med Chem 1979; 22: 855.
[14] Bauer DJ, Vincent LS, Kempe CH, Dowine AW. Lancet 1963; 2: 494.
[15] Petering HG, Buskik HH, Underwood GE. Cancer Res 1963; 64: 367.
[16] Kavanagh F. Analytical Microbiology, Academic press, New York, 1963; 125.
[17] Chohan HZ. Synth Reac Inorg Met Org Chem 2001; 31: 1.
[18] Patil MS, Shah JR. J Indian chem Soc 58: 944.
[19] Sutton D. Electronic Spectra of Transition Metal Complexes. McGraw- Hill. London, 1968.
[20] El-Halabi NM, Awadallah AM, Faris WM, Seppelt K and Shorafa H. The Islamic University Journal (Series of Natural Studies and Engineering) 2009; 17(2):1-10.
[21] Hania MM. Mater Sci Res 2006; 4:1.