ISSN 1070-3632, Russian Journal of General Chemistry, 2008, Vol. 78, No. 7, pp. 1458–1462. © Pleiades Publishing, Ltd., 2008.

Synthesis, Electrochemical, and Antibacterial Activity of Some Novel N_4O_2 Ligand Derivativies[1]

Ibrahim Demir[a], Ertugrul Sahmetlioglu[a], Gokcen Y. Celik[b], and Murat Unal[a]

[a]*Nigde Universty, Faculty of Science and Arts, Department of Chemistry, Nigde, Turkey,*
phone: +90 388 225 2093
fax: +90 388 225 0180
e- mail: idemir@nigde.edu.tr, ibrahimdemir75@gmail.com

[b]*Nigde Universty, Faculty of Science and Arts, Department of Biology, Nigde, Turkey*

Received March 11, 2008

Abstract—A novel ligand has been synthesized by the condensation of 1,3-diaminoprophane (HL) wıth isonitroso-*p*-chloroacetophenone. The complexes of cobalt(II), nicel(II), cupper(II) and zinc(II) with HL were prepared. All compounds were characterized by spectroscopic techniques and its antibacterial activities were determined by the disc diffusion method used against to those gram-positive and -negative bacteria. All compounds were investigated by cyclic voltammetry at 25°C. The voltammograms were recorded with a potential scan of 100 mV s^{-1}.

DOI: 10.1134/S1070363208070311

INTRODUCTION

Oximes and their metal complexes have been widely recognized. The early studies on oxime complexes have been reviewed by Chakravorty [1]. Then Tschugaeff isolated dimethylglyoxime Co(III) complexes which played an important role as model compounds for study some biological and biochemical mechanisms [2]. Some oximes and their metal copmlexes are widely used for various purposes in organic, analytical, inorganic, bio and industrial chemistry. For example, Pt vic-dioximes complexes have been studied as anti-tumor agents in chemotherapy [3]. Liquid crystal properties of some vic-dioxime complexes have been studied and further applications include column packing material in chromatographic separation of nucleotides and nucleosides after binding to natural resins as functional groups [4, 5]

In this study, new Schiff base ligand (as shown in Fig. 1) and its transition metal complexes were synthesized and the type of coordination which takes place to the metal ions were interpreted. Furthermore we have investigated antibacterial and electrochemical activity of these compounds.

RESULT AND DISCUSSION

The analytical data for the ligand and its metal complexes are listed in Table 1. The result of the elemental analyses show that the metal to ligand ratio is 1 : 1 in all the complexes. The composition of the complexes is $[ML_2]\cdot nH_2O$ for all complexes ($n = 0$ or 2). The Schiff base ligand is soluble in common organic solvents. All complexes are soluble in DMF, DMSO and insoluble in the other organic solvents.

Infrared Spectra

The tentative assignments of the most characteristic IR bands were observed and are given in Table 1. The vibration of the sterically hindered oxime groups of the free Schiff base ligand HL is observed at 3400–3500 cm^{-1} respectively [6, 7]. When the spectra of the complexes are compared with that of the uncomplexed Schiff base ligand the ν(C=N) band are shifted to lower frequency [8].This indicated that the imine nitrogen is coordinated to the metal ion. A weak and broad band occurring around 3450–3455 cm^{-1} may be attributed to the ν(O–H) which takes places in the complex of the hydrated water molecule with Co metal ion. The spectra of complexes show a few expected absorption bands 520–560 cm^{-1} and 450–465 cm^{-1} ranges assigned to ν(M–N) [9] and ν(M–O) [10, 11].

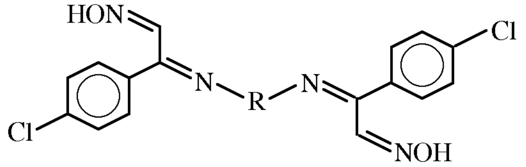

Fig. 1. Structure of the Ligand HL, R= $(CH_2)_3$.

---

[1] The text was submitted by the authors in English.

Table 1. Infrared spectral data of the free ligand and its complex

Compound	ν(OH)[a]	ν(OH)[b]	$\nu(C{=}N)_{im}$	$\nu(C{=}N)_{ox}$	ν(C–N)	ν(C–Cl)	ν(M–N)	ν(M–O)
HL	–	3400–3500	1643	1605	1107	740	–	–
$[CoL_2]\cdot 2H_2O$	3450	–	1620	1600	1097	750	520	465
$[NiL_2]$	–	–	1610	1603	1100	760	560	460
$[CuL_2]$	–	–	1618	1600	1100	745	555	455
$[ZnL_2]$	–	–	1613	1603	1137	755	545	450

[a] ν(OH) is a vibration of the hydrated water molecule; [b] ν(OH) is a vibration of sterically hindered oxime.

Table 2. Some analytical data and physical properties of the Schiff base ligand and its complexes

Compound	Formula	Molecular weight	Color	mp, °C	Yield, %	Found (calculated), %		
						C	H	N
HL	$C_{19}H_{18}N_4O_2CI_2$	405.2	Orange	145[a]	62	56.20 (56.31)	4.40 (4.48)	14.13 (13.82)
$[CoL_2]\cdot 2H_2O$	$C_{19}H_{20}Cl_2CoN_4O_4$	498.2	Red	215	70	45.75 (45.80)	4.00 (4.05)	11.12 (11.25)
$[NiL_2]$	$C_{19}H_{16}N_4O_2CI_2Ni$	461.9	Green	225[a]	60	49.35 (49.40)	3.45 (3.49)	12.05 (12.13)
$[ZnL_2]$	$C_{19}H_{16}N_4O_2CI_2Zn$	468.6	Yellow	157	55	48.65 (48.69)	3.32 (3.44)	11.75 (11.95)
$[CuL_2]$	$C_{19}H_{16}N_4O_2CI_2Cu$	466.8	Dark-green	105	64	48.85 (48.89)	3.40 (3.45)	11.81 (12.00)

[a] Decomposition points of corresponding molecules.

Electronic Spectra

The electronic absorption spectral data of the free ligand and its complexes are given in Table 3. In the spectra of the Schiff base ligand bands at 238–273 nm are attributed to the benzene π–π^* transitions [12, 13]. The bands at 314–336 nm are assigned to the imine π–π^* transition. Compared to the free ligand, the imine π–π^* transitions of the complexes were shifted to some extent, because the imine nitrogen is involved in coordination with the metal ion.

Conductance Measurements

The molar conductance values of the synthesized schiff base ligand and its Ni(II), Co(II), Cu(II) and Zn(II) complexes are in the range 0 to 56 Ω^{-1} cm^2 mol^{-1} in 10^{-3} M DMF solutions indicating the non-electrolytic nature of these compounds [14].

Table 3. Magnetic moments and electronic spectral data of the ligand and its metal complexes

Compound	μ_{eff}	λ_{max}, nm
HL	–	466, 332, 314, 273, 238 sh
$[CoL_2]\cdot 2H_2O$	4.12	650 sh, 394, 379, 367, 351, 324, 300, 244
$[NiL_2]$	Diamag	346, 315, 274, 246
$[CuL_2]$	1.71	273, 241
$[ZnL_2]$	Diamag	280, 270, 243

NMR Spectra of the Schiff Bases

In order to understand the solution structure of the free Schiff base ligand, ^{1}H NMR spectra have been employed. The ^{1}H NMR assignments are listed in Table 4. The doublet-doublet observed at 7.60–7.20 ppm (*J* 8.65 Hz) is assigned to the aromatic ring proton of the ligand HL. The singlets at 8.20 and 12.50 ppm Are assigned to the protons of CH and the proton and of the oxime group, respectively. The multiplets at 3.40 ppm and 3.00 ppm are assigned to protons of methylene groups.

MS Studies

In the MS spectra of the ligand HL, *m/e* 405 [M^+, 5%], 343 [$M^+ - 2NOH$, 10 %], 203 [$M^+ - C_8H_7N_2O_2Cl$, 35%], 189 [$M^+ - C_8H_7N_3O_2Cl$, 30%], 147 [$M^+ - C_{11}H_{13}N_3O_2Cl$, 65%], 124 [$C_7H_4Cl^+$, 100%].

Electrochemical Studies

The electrochemical behaviors of the H_2L ligand and the CuL, CoL, NiL and ZnL complexes were examined by means of cyclic voltammetry in DMSO.

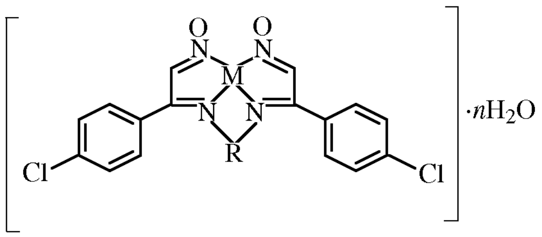

Fig. 2. Structure of metal complexes (M = Ni, Cu, Zn, Co).

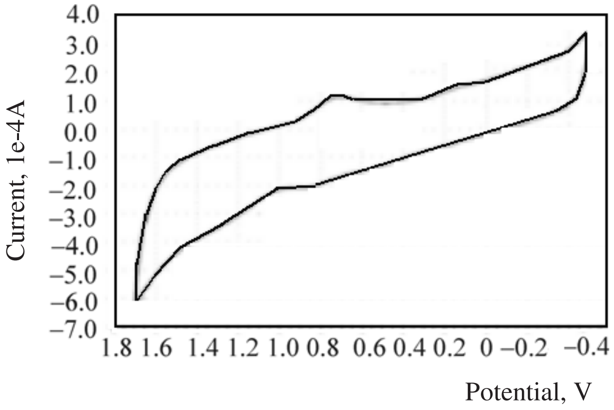

Fig. 3 Cyclic voltammogram of CuL.

A typical cyclic voltammogram of CuL is shown in Fig. 3. But H_2L and its other complexes have not redox peak.

The cyclic voltammogram of the Cu(II) complex obtained in DMSO (Fig. 3) solution at room temperature shows a redox process corresponding to the copper(II)/copper(III) couple at *Epa* = +1.11 V and the associated cathodic peak at *Epc* = +0.90 V. This couple is found to be quasi-reversible as the peak separation between the anodic and cathodic potential is very high. But the ratio between the anodic and cathodic currents suggests that the process is simple one-electron transfer, quasi-reversible process [15, 16, 17].

Biological Activities

In the present study, the antibacterial activities of compounds were determined and given Table 5. Compound HL Cu and HL Co showed moderate inhibition effect against all the tested bacteria while compound HL Ni and HL Zn have inhibition effect against some test bacteria. Especially compound HL Zn has highly activity towards *B. subtilis* and *B. cereus*. Also, Table 5 showed that most of metal complexes show more inhibition effect against tested bacteria than the free ligand.

However there is increase in the antimicrobial activity of these complexes as according to free ligand, it could not reach the effectiveness of the conventional reference antibiotics.

EXPERIMENTAL

Material

$Ni(CH_3COO)_2$, $Co(CH_3COO)_2$, $Cu(CH_3COO)_2$ and $Zn(CH_3COO)_2$ and *p*-chloroacetophenone, 1,3-diaminoprophane, were obtained from Merck (KGaA, Germany) and all of them were purified according to literature [18].

Physical Measurement

The carbon, hydrogen and nitrogen analyses were obtained using a Carlo Erba 1106 auto elemental analyzer. Jasco FT/IR–300 E Spectrometer was used for characterisation. The electronic spectra in the 200-800 nm range were recorded in DMF on a Shimadzu UV-160A spectrophotometer. Conductivities were measured in DMF using a LF 330/SET Conductivity measuring were performed at 22°C. Magnetic moments were measured by the Gouy method by using $Hg[Co(SCN)_4]$ as calibrant. The ^{1}H-NMR spectra of the ligand HL were recorded with a Bruker Avance-500 NMR instrument .

Preparation of Schiff Base Ligand

The ligand was prepared according to literature [19, 20]. Isonitroso-*p*-chloroacetophenone 0.183 g (1 mmol) dissolved in methanol (20 ml), was added with constant stirring to a solution of 1,3-diaminoprophane

Table 4. The ^{1}H NMR spectra of the Schiff base ligand

δ, ppm	Peak	Assignment
3.00	2(H)	CH_2 group
3.40	4(H)	CH_2 groups
7.20–7.60	8(H)	Aromatic ring (H)
8.20	2(H)	CH (aldoxime)proton
12.50	2(H)	OH

Table 5. Inhibition values diameters of compounds against to the test bacteria

Compound	Inhibition values (mm)					
	Staphylococcus aureus ATCC 25923	*Escherichia coli* ATCC 35218	*Bacillus megaterium* RSKK 5117	*Bacillus subtilis* RSKK 244	*Bacillus cereus* RSKK 863	*Staphylococcus epidermidis* Mu 30
HL (Ligand)	–	–	–	–	6	7
HL (Ni)	6	–	8	–	6	–
HL (Cu)	9	8	9	9	9	8
HL (Co)	7	8	7	7	7	8
HL (Zn)	–	–	–	13	13	–
Tetracycline	25	34	24	33	27	–
Penicilin	20	25	31	29	29	–
Vancomisin	21	30	17	24	18	–
Cefepime	–	23	15	26	–	18
Ofloxacin	–	34	29	34	25	9
Ampicilin	24	25	26	24	33	–

(HL) 0.037 g (0.5 mmol) in methanol (10 ml). The mixture was allowed to stirrer magnetically at 50°C during 4.5 h. After cooling to room temperature, the resulting precipitate was filtered and recrystalized by hexane/methanol (1 : 1) .

Preparation of Complexes

All of the complexes were synthesized by the reaction of the Schiff base ligand (1 mmol, in 20 ml methanol) with the corresponding metal salts (0.5 mmol, 10 ml methanol) at 50°C during 2 h. The resulting precipitate was filtered, washed several times with methanol and dried over calcium chloride under vacuum [21].

Electrochemical Study

The cyclic voltammetry experiments were carried out with a three electrode apparatus using a CHI600A electrochemical workstation (Covarda, USA), the working electrode was a Platinum foil, Ag/Ag^+ and Pt wire were used as reference and counter electrodes, respectively. The H_2L and complexes solutions (1.0×10^{-3} mol l^{-1}) in DMSO, with Lithium perchlorate (0.1 mol l^{-1}) as supporting electrolyte were purged of oxygen by bubbling nitrogen for 15 min. and then blanketed with the same gas during the experiments. All compounds were investigated at 25°C.The voltammograms were recorded with a potential scan of 100 mV s^{-1}.

Biological Activity

Antibacterial activity of compounds was determined by the disc diffusion method [22]. The antimicrobial screening was performed using Mueller-Hinton Agar. The culture suspensions were prepared and adjusted by comparing against 0.5 Mc Farland turbidity standard tubes.

Muller-Hinton Agar (20 ml) was poured into each sterile petri dish after injecting cultures (100 µl) of microorganisms and distributing medium in Petri dish homogeneously. Compounds were filtered with a pore size of 0.45 µm. All of the compounds were dissolved in DMSO of 5 mg ml^{-1}. Empty sterilized discs of 6 mm (Whatman No: 1) were each impregnated with 50 ml of compounds. Discs were placed on agar plates, and the plates were incubated at 37°C for 24 h. Inhibition zones formed on the medium were evaluated in mm. The solvent control (DMSO) did not show any antimicrobial activity. Studies performed in duplicate and the inhibition zones were compared with those of reference discs. Reference discs used for control are as follows: Tetracycline (30 μg), Penicilin (10 μg), Vancomisin (30 μg), Cefepime (30 μg), Ofloxacin (5 μg), Ampicilin (10 μg).

REFERENCES

1. Chakravorty, A., *Coordination Chem. Rev*., 1974, no. 13, p. 1.
2. Tschugaeff, L., *Ber. Deutsch. Chem. Ges*., 1907, no. 40, p. 3498.
3. *Metal Complexes May be Better Anticancer Drugs*, 1982, Chem. Eng. News, 19 April, p. 36
4. Deveci, M.A., *PhD Thesis*, 1994, Selçuk University, Konya-TR.
5. Ersoz, M., Yildiz, S., and Pehlivan, E., *J. Chrom. Sci.* 1993, vol. 31, p. 65.
6. Pekacar, A.İ., Mercimek, B., and Özcan, E., *Synt. React. Inorg. Met. Org. Chem.*, 1997, vol. 27(3), p. 455.
7. Mercimek, B., İrez G., Deveci, M.A., Bedük, A.D., Sarikavakli, N., and Uçan, H.İ., *The Synthesis and Ni(II), Co(II), Zn(II) And Cd(II) Complexes Of Two Novel Tetraoximes*, Macromolecular Reports, 1995, vol. A32, no. 8, p. 1199.
8. Rastoh D.K. and Sharma, C.K., J. *Inorg. Nucl. Chem.*, 1974, vol. 36, p. 2219.
9. Hueso-Urena, F., Illan-Cabeza, N.A., Moreno-Carretero, M.N., and Penas-Chamorro, A.L., *Acta Chim Slov.* , 2000, vol. 47, p. 481.
10. Kim, W.S., Sim, W.J., Chung, K., Sung, Y.E., and Choi, Y.K., *Journal of Power Sources,* 2002, vol. 112, p. 76.
11. Tarek Ismail, M.A., *J. of Coord. Chem.,* 2006, vol. 59, no. 3.
12. Casella, L., Gullotti, M., and Pacchioni, G., *J. Am. Chem. Soc*., 1982, vol. 104, p. 2386.
13. Deiztsch, V., Strauch, P., and Hoyer, E., *Coord. Chem. Rev.*, 1992, vol. 121, p. 43.
14. Demır, I., Akkaya, M., Bayrakcı, M., and Pekacar, A.I., *Asian Journal of Chemistry,* 2007, vol. 19, no. 5, p. 3954.
15. Shirin, Z. and Mukherjee, R.M., *Polyhedron,* 1992, vol. 11, p. 2625.
16. Shyamala, A. and Chakravarty, A.R., *Polyhedron,* 1993, vol. 12, p. 1545.
17. Raman, N., Muthuraj, V., Ravıchandran, S., and Kulandaısamy, A., *Proc. Indian Acad. Sci. (Chem. Sci.)*, 2003, no. 115, p. 161.
18. Casey, M., Leonard, J., Lygo, B., and Proccto, G., *Advanced Practical Organic Chemistry*, Blackie Academic & Professional, 1993, Chp. 4, p. 28.
19. Ibrahim Demir and İhsan Pekacar, A., *Synthesis and Reactivity in Inorganic, Metal-Organic and Nano-Metal Chemistry*, 2005, vol. 35, p. 825.
20. Demır, I. and Pekacar A.I., *Asian Journal of Chemistry* 2007, vol. 19, no. 3, p. 1919.
21. Jian-Hao Zhou, Zheng Liu, Yi-Zhi Li, You Song, Xue-Tai Chen, Xiao-Zeng You., *J. of Coord. Chem.*, 2006, vol. 59, no. 2.
22. *NCCLS (National Committee for Clinical Laboratory Standards)*, Performance Standards for Antimicrobial Disk Susceptibility Test, 1997, 6th ed., Wayne PA: Approved Standard. M2-A6.