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Salicylaldehyde Thiazolyl Hydrazones as Ligands

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ABSTRACT: *Novel bidentate Schiff base ligands, 2-(2-hydroxy-5-chloro/nitro)benzaldehyde-[4-(3-methyl-3-mesitylcyclobutyl)-1,3-thiazol-2-yl]hydrazone, and their metal complexes have been prepared and characterized by elemental analyses, IR, ^{13}C and ^{1}H NMR spectra, and magnetic susceptibility measurements. All the complexes were found to be mononuclear.* © 2003 Wiley Periodicals, Inc. Heteroatom Chem 14:617–621, 2003; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/hc.10201

INTRODUCTION

Schiff bases from the condensation of salicylaldehyde with alkyl- and arylamines are widely used in coordination chemistry [1]. They display biological activity, play an important role in biological systems [2–7], and are considered to be suitable models for pyridoxal and, in general, B_6 vitamins [8]. Adducts of nontransition, early transition, and f-metals with ortho-hydroxy Schiff bases [9] have been studied. Thiazoles are of interest because of their pharmaceutical, phytosanitary, analytical, and industrial applications e.g., as fungicides, anthelmintics, and herbicides [10]. On the other hand, cyclobutane carboxylic acids were described as L-glutamate, *N*-methyl-D-aspartate (NMDA) agonist, NMDA antagonists, and anticonvulsive drugs [11–13]. Compounds containing cyclobutane, thiazole, and Schiff base functions in their molecules seem to be suitable candidates for further chemical modifications and may be pharmacologically active and useful as ligands in coordination chemistry. This paper deals with the preparation and characterization of the complexes formed from the Schiff base ligands L^1H, L^2H (Scheme 1) and cobalt(II), copper(II), nickel(II), and zinc(II) acetates.

RESULTS AND DISCUSSION

The data of **1, 2**, L^1H, L^2H, and of the complexes are summarized in Tables 1–3. The complexes correspond to the general formula L_2M: They are stable at room temperature and are soluble in Me_2CO, DMF, and DMSO, and sparingly soluble in $CHCl_3$. Attempts to crystallize the ligand complexes from different solvents failed.

The IR spectra of **1** and **2** showed five different strong and sharp peaks in the 3450–3120 cm^{-1} region. Two of them are from $-NH_2$, one from $-NH-$, and one from $-OH$; the other one has not been identified. No C=O peak is observed.

There are no C=S, C=O, $-CH_2-Cl$, and $-NH_2$ absorptions in the IR spectra of the ligands L^1H and L^2H, which indicates the formation of the expected compounds. The strong bands observed at 3115 and 3114 cm^{-1}, respectively for the ligands L^1H and L^2H, can be attributed to the $-NH-$ vibration. In the complexes, these bands are not shifted, but have lost intensity, and it may therefore be that the nitrogen atom of this group is not coordinated to the metal ion. The ligands exhibit broad medium intensity bands in the 2700–2560 cm^{-1} range which are

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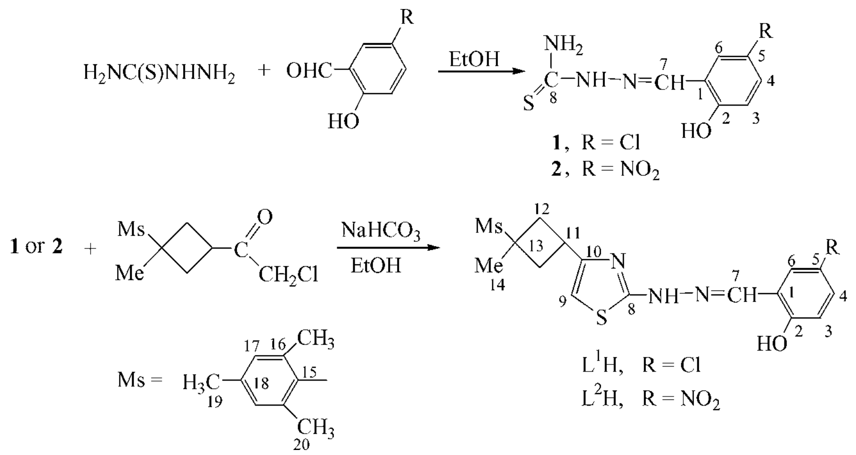
TABLE 1 Analytical and Physical Data of the Compounds

	Formula Weight (g mol^{-1})	Color	Yield (%)	m.p. (°C)	μ_{eff} (BM)	Calc. (Found) (%)			
						C	H	N	S
1	229.7	White	94	290	–	41.8 (41.7)	3.5 (3.5)	18.3 (17.9)	14.0 (13.8)
2	240.2	Light yellow	96	>320	–	40.0 (39.9)	3.4 (3.3)	23.3 (23.4)	13.4 (13.5)
L^1H	440.0	Pink	83	240	–	65.5 (65.6)	6.0 (6.1)	9.6 (9.5)	7.3 (7.3)
L^1_2Co	936.9	Dark brown	65	>330	4.15	61.5 (61.6)	5.4 (5.3)	9.0 (9.1)	6.8 (6.9)
L^1_2Cu	941.5	Green	57	272	1.89	61.2 (61.4)	5.4 (5.3)	8.9 (9.2)	6.8 (7.0)
L^1_2Ni	936.7	Lemon	81	>320	3.81	61.6 (61.5)	5.4 (5.5)	9.0 (9.0)	6.9 (7.0)
L^1_2Zn	943.4	Yellow	68	>320	Dia	61.1 (61.0)	5.3 (5.4)	8.9 (8.7)	6.8 (7.0)
L^2H	450.6	Yellow	81	222	–	64.0 (64.1)	5.8 (5.7)	12.4 (12.5)	7.1 (7.2)
L^2_2Co	958.0	Dark yellow	73	>320	4.23	60.2 (60.1)	5.3 (5.3)	11.7 (11.8)	6.7 (6.8)
L^2_2Cu	962.6	Dark brown	64	279	1.79	59.9 (60.0)	5.2 (5.3)	11.6 (11.7)	6.7 (6.8)
L^2_2Ni	957.8	Lemon	77	>320	3.74	60.2 (60.4)	5.3 (5.3)	11.7 (12.0)	6.7 (6.9)
L^2_2Zn	964.5	Yellow	69	299 (dec)	Dia	59.8 (60.0)	5.2 (5.4)	11.6 (12.0)	6.8 (6.4)

TABLE 2 Characteristic IR Bands (cm^{-1}) of the Ligands and Complexes as KBr Pellets

Compound	ν (OH)	ν (N–H)	ν (CH$_3$)/ν(CH$_2$)	ν (C=N)		ν (C–O)	ν (C=S)
				Thiazole	Azomethine		
1	3274	3171	–	–	1612	1190	951
2	3271	3180	–	–	1617	1080	964
L^1H	3283	3115	2978–2927	1567	1619	1157	–
L^1_2Co	–	3113	2978–2927	1562	1612	1074	–
L^1_2 Cu	–	3113	2978–2927	1562	1606	1074	–
L^1_2Ni	–	3121	2978–2927	1562	1606	1082	–
L^1_2Zn	–	3113	2978–2927	1573	1600	1074	–
L^2H	3265	3114	2978–2927	1548	1619	1080	–
L^2_2Co	–	3114	2978–2927	1548	1606	1099	–
L^2_2Cu	–	3114	2978–2927	1548	1600	1105	–
L^2_2Ni	–	3114	2978–2927	1554	1606	1099	–
L^2_2Zn	–	3114	2978–2927	1554	1606	1099	–



SCHEME 1

TABLE 3 ^{1}H NMR Spectral Data of the Starting Substances **1** and **2** and Schiff Base Ligands

	Chemical Shift (δ, ppm)			
Functional Group	***1***	***2***	*L^1H*	*L^2H*
–NH_2	8.17 (s, 2H)	8.27 (s, 2H)	–	–
N=CH	8.31 (s, 1H)	8.38 (s, 1H)	8.14 (s, 1H)	8.21 (s, 1H)
>CH–	–	–	3.40 (q, $J = 8.9$, 1H)	3.43 (q, $J = 8.9$, 1H)
–CH_3	–	–	1.53 (s, 3H)	1.52 (s, 3H)
o-CH_3	–	–	2.12 (s, 6H)	2.15 (s, 6H)
p-CH_3	–	–	2.16 (s, 3H)	2.18 (s, 3H)
–CH_2–	–	–	2.47–2.87 (m, 4H)	2.47–2.61 (m, 4H)
C–H, thiazole	–	–	6.44 (s, 1H)	6.45 (s, 1H)
–OH–	10.22 (br, 1H)	11.54 (s, 1H)	10.45 (br, 1H)	12.11 (br, 1H)[a]
–NH–	11.44 (br, 1H)	11.57 (s, 1H)	12.06 (br, 1H)	12.11 (br, 1H)[a]
Arom/mesityl	–	–	6.72 (s, 2H)	6.71(s, 2H)
Aromatics	6.88 (d, $J = 8.8$, $1H_3$) 7.24 (dd, $J_o = 8.8$; $J_m = 2.8$, $1H_4$) 8.10 (d, $J = 2.8$, $1H_6$)	7.05 (d, $J = 8.9$, $1H_3$) 8.13 (dd, $J_o = 8.8$; $J_m = 2.9$, $1H_4$) 8.87 (d, $J = 2.9$, $1H_6$)	6.89 (d, $J = 8.7$, $1H_3$) 7.21 (dd, $J_o = 8.7$; $J_m = 2.7$, $1H_4$) 7.58 (d, $1H_6$)	7.05 (d, $J = 9.0$, $1H_3$) 8.13 (dd, $J_o = 9.0$; $J_m = 2.9$, $1H_4$) 8.48 (d, $J = 2.9$, $1H_6$)

[a]—OH and —NH— are seen at the same resonance.

assigned the intermolecular H-bonding vibrations (ÕH···N). This situation is common for aromatic azomethine compounds containing *o*-OH groups [15]. In the complexes, these bands disappear completely. The azomethine group vibrations of the free ligands occur at 1619 cm^{-1}. In the IR spectra of complexes, these bands shift to lower frequencies and, at the same time, lose intensity. This indicates that the azomethine groups were highly affected by complexation. For the free ligands L^{1}H and L^{2}H, the bands at 1157 and 1080 cm^{-1}, respectively can be attributed to the phenolic group vibration [16]. In the metal complexes, these bands are shifted to lower frequencies (1074–1082 cm^{-1}) for L^{1}H and higher frequencies (1099–1105 cm^{-1}) for L^{2}H, indicating coordination of oxygen to the metal atoms. In the complexes, the bands in the 586–480 and 463–434 cm^{-1} range can be attributed to the ν(M—N) and ν(M—O) modes.

The ^{1}H NMR spectra of **1** and **2** demonstrate aromatic, —N=CH—, —NH—, —NH$_2$, and —OH protons. The latter three are D$_2$O-exchangeable. —OH signals of both compounds are broad singlets. This results from intramolecular hydrogen bonding [17]. The ^{1}H NMR spectral data of **1, 2** are given in Table 3, and a more detailed spectral investigation of a similar cyclobutane compound, can be found in the literature [18]. The ^{13}C NMR assignments of both compounds given in the Experimental.

Very similar spectra were obtained for the ligands L^{1}H and L^{2}H. The ^{1}H resonance of the O—H is a broad singlet for both ligands due to the presence of hydrogen bonding [17] between OH and the azomethine N. The —OH and —NH— signals disappeared upon addition of D$_2$O to the solution. The detailed ^{1}H NMR spectral data of the ligands are given in Table 3. The Zn(II) complexes L^1_2Zn and L^2_2Zn showed the same resonances as those of L^{1}H and L^{2}H except for the absence of the OH resonance, and a small shift of the azomethine proton resonance. The detailed ^{13}C NMR spectral data are given in the Experimental section. Azomethine carbon atoms are observed at 144.45 ppm and 141.82 ppm respectively for L^{1}H and L^{2}H. The ^{13}C NMR spectral data of the ligands confirm the ^{1}H spectral results. The data obtained from elemental analyses, IR, and ^{1}H and ^{13}C NMR spectra of L^{1}H and L^{2}H are consistent with data expected from the formula given in Scheme 1.

As is known, magnetic susceptibility measurements provide information regarding the structure of the complexes. The magnetic moments of the complexes were measured at room temperature and are listed in Table 1. Co(II), Cu(II), and Ni(II) complexes of both ligands are paramagnetic, while their Zn(II) complexes are diamagnetic. The data indicate two unpaired electrons for Ni(II) and three for Co(II). The magnetic moments of the Co(II) complexes of both ligands at room temperature fall in the range 4–5 BM, which is characteristic for mononuclear, high-spin, tetrahedral Co(II) complexes. The magnetic moment values of the Ni(II) complexes of the ligands are also consistent with a tetrahedral geometry [19]. On the basis of the spectral and magnetic data, the cobalt, nickel, copper, and zinc complexes have tetrahedral geometry [20]. The suggested structure of the complexes is shown in Fig. 1.

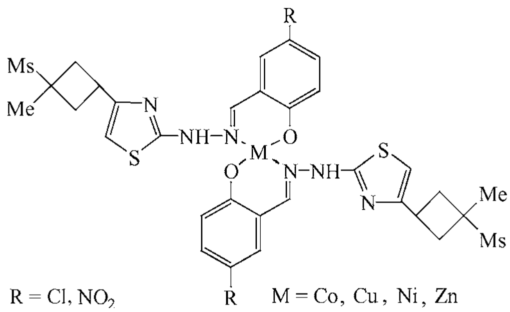


FIGURE 1 Suggested structure of the complexes.

EXPERIMENTAL

2-Hydroxy-5-chlorobenzaldehyde, 2-hydroxy-5-nitrobenzaldehyde, and thiosemicarbazide were purchased from Merck (pure) and were used without further purification. 1-Mesityl-1-methyl-3-(2-chloro-1-oxoethyl) cyclobutane was prepared according to the previously published procedure [14]. Elemental analyses were determined on a LECO CHNSO-932 auto elemental analysis apparatus. IR spectra were recorded on a Mattson 1000 FT-IR spectrometer as KBr pellets. ^{1}H and ^{13}C NMR spectra were recorded on a Varian-Gemini 200 MHz at 50.34 MHz spectrometer. Magnetic susceptibilities were determined on a Sherwood Scientific magnetic susceptibility balance (Model MK1) at room temperature (20°C) using Hg[Co(SCN)$_4$] as calibrant; diamagnetic corrections were calculated from Pascal's constants. Melting points were determined on a Gallenkamp apparatus; they were checked by DSC technique and are uncorrected.

*1-(2-Hydroxy-5-chlorbenzylidene) Thiosemicarbazide (**1**)*

To a solution of thiosemicarbazide (0.91 g, 10 mmol) in 50 ml absolute EtOH, a solution of 5-bromosalicylaldehyde (2.01 g, 10 mmol) in 20 ml absolute EtOH was added dropwise at 60–70°C with continuous stirring. The reaction was monitored by IR spectroscopy. After completing the reaction, the mixture was left overnight. The solid product was filtered off, washed with H_2O several times, dried in air, and crystallized from aqueous EtOH (1:3). Characteristic ^{13}C NMR (DMSO-d_6, TMS, δ ppm): 124.11 (C_1), 156.90 (C_2), 119.47 (C_3), 132.14 (C_4), 125.22 (C_5), 127.22 (C_6), 139.22 (C_7), 179.67 (C_8).

*1-(2-Hydroxy-5-nitrobenzylidene) Thiosemicarbazide (**2**)*

This compound was prepared by an analogous procedure, using 2-hydroxy-5-nitrobenzaldehyde in ethanol. Characteristic ^{13}C NMR (DMSO-d_6, TMS, δ ppm): 128.05 (C_1), 163.61 (C_2), 118.23 (C_3), 124.00 (C_4), 142.11 (C_5), 123.15 (C_6), 138.63 (C_7), 179.84 (C_8).

Thiazolyl Hydrazones L^1H and L^2H

To a suspension of 10 mmol **1** (1.95 g), or **2** (2.742 g) in 30 ml absolute EtOH, a solution of 2.645 g (10 mmol) of 1-mesityl-1-methyl-3-(2-chloro-1-oxoethyl) cyclobutane in 20 ml absolute EtOH was added dropwise at 30–40°C with continuous stirring. After completing the addition, the temperature was raised to 50–55°C. Monitoring the carbonyl group with IR it was easy to determine when the reaction is complete. The solution was then made alkaline with an aqueous solution of NH_3 (5%) and pale yellow solids L^1H or L^2H separated. The precipitates were filtered off, washed with aqueous NH_3 solution several times, dried in air, and crystallized from EtOH. ^{13}C NMR (DMSO-d_6, TMS, δ ppm) L^1H: 123.82 (C_1), 156.40 (C_2), 119.66 (C_3), 131.88 (C_4), 124.94 (C_5), 130.63 (C_6), 144.45 (C_7), 164.13 (C_8), 102.69 (C_9), 145.86 (C_{10}), 40.45 (C_{11}), 42.13 (C_{12}), 42.55 (C_{13}), 26.35 (C_{14}), 136.51 (C_{15}), 135.51 (C_{16}), 131.38 (C_{17}), 136.17 (C_{18}), 22.85 (C_{19}), 21.86 (C_{20}). L^2H: 123.27 (C_1), 153.09 (C_2), 123.03 (C_3), 127.27 (C_4), 136.43 (C_5), 123.18 (C_6), 141.82 (C_7), 169.72 (C_8), 110.41 (C_9), 145.95 (C_{10}), 40.04 (C_{11}), 42.55 (C_{12}), 44.54 (C_{13}), 28.34 (C_{14}), 136.11 (C_{15}), 131.88 (C_{16}), 131.67 (C_{17}), 135.50 (C_{18}), 22.82 (C_{19}), 21.84 (C_{20}).

Complexes

The ligand L^1H (0.2028 g, 0.50 mmol) or L^2H (0.2422 g, 0.50 mmol) was dissolved in absolute ethanol (15–20 ml). A solution of 0.25 mmol of the metal salt $Co(AcO)_2{\cdot}4H_2O$ (0.0623 g), $Cu(AcO)_2{\cdot}H_2O$ (0.0499 g), $Ni(AcO)_2{\cdot}4H_2O$ (0.0623 g), $Zn(AcO)_2{\cdot}2H_2O$ (0.0549 g) in ethanol (10 ml) was added dropwise with continuous stirring. In the case of Co(II) complexes, a slow stream of nitrogen was passed through the solution. Every mixture was refluxed for 1 h and then left to stand overnight at room temperature. The complexes precipitated as microcrystals, were filtered, washed with cold ethanol and water several times, and dried in vacuum at 60°C (over P_4O_{10}) and stored in a desiccator over $CaCl_2$. Yields, melting points, elemental analysis results, and characteristic IR bands (NaCl cell) are given in Tables 1 and 2.

^{1}H NMR spectra of L_2^1Zn (DMSO-d_6, δ, ppm) 1.53 (s, 6H, $-CH_3$), 2.14 (s, 6H, p-CH_3), 2.16 (s, 12H, o-CH_3), 2.46–2.67 (m, 8H, $-CH_2-$), 3.42 (q, $J = 8.9$ Hz, 2H, $>CH-$), 6.44 (s, 2H, $=CH-S$), 6.72 (s, 4H, aromatic on mesitylene), 6.95–7.52 (m, 6H, aromatic), 8.05 (s, 2H, N=CH—), 11.37 (s, 2H, —NH—); L_2^2Zn (DMSO-d_6, δ, ppm) 1.51 (s, 6H, —CH_3), 2.15 (s, 12H, *o*-CH_3), 2.18 (s, 6H, *p*-CH_3), 2.47–2.61 (m, 8H, —CH_2—), 3.43 (q, $J = 8.9$ Hz, 2H, >CH—), 6.58 (s, 2H, =CH—S), 6.89 (s, 4H, aromatic on mesitylene), 7.07–8.47 (m, 6H, aromatics), 8.35 (s, 2H, N=CH—), 11.47 (s, 2H, —NH—).

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