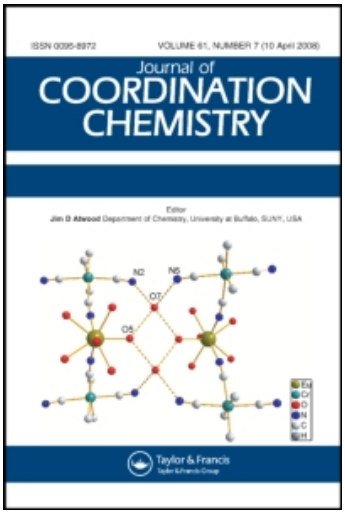

Journal of Coordination Chemistry
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713455674

Synthesis, characterization, and biological properties of Ni(II), Co(II), and Cu(II) complexes of Schiff bases derived from 4-aminobenzylamine

Cahıt Demetgül[a]; Mürüvvet Karakaplan[b]; Selahattın Serın[b]; Metın Diğrak[c]
[a] Faculty of Sciences and Letters, Department of Chemistry, Mustafa Kemal University, 31040, Hatay, Turkey [b] Faculty of Sciences and Letters, Department of Chemistry, Çukurova University, 01330, Adana, Turkey [c] Faculty of Sciences and Letters, Department of Biology, University of Kahramanmaraş Sütçü İmam, 46100, K. Maraş, Turkey

First published on: 22 September 2010

To cite this Article Demetgül, Cahıt , Karakaplan, Mürüvvet , Serın, Selahattın and Diğrak, Metın(2009) 'Synthesis, characterization, and biological properties of Ni(II), Co(II), and Cu(II) complexes of Schiff bases derived from 4-aminobenzylamine', Journal of Coordination Chemistry, 62: 21, 3544 — 3551, First published on: 22 September 2010 (iFirst)
To link to this Article: DOI: 10.1080/00958970903082192
URL: http://dx.doi.org/10.1080/00958970903082192

Journal of Coordination Chemistry
Vol. 62, No. 21, 10 November 2009, 3544–3551

Synthesis, characterization, and biological properties of Ni(II), Co(II), and Cu(II) complexes of Schiff bases derived from 4-aminobenzylamine

CAHİT DEMETGÜL*†, MÜRÜVVET KARAKAPLAN‡, SELAHATTİN SERİN‡ and METİN DIĞRAK§

†Faculty of Sciences and Letters, Department of Chemistry, Mustafa Kemal University, 31040, Hatay, Turkey
‡Faculty of Sciences and Letters, Department of Chemistry, Çukurova University, 01330, Adana, Turkey
§Faculty of Sciences and Letters, Department of Biology, University of Kahramanmaraş Sütçü İmam, 46100, K. Maraş, Turkey

(*Received 16 February 2009; in final form 3 April 2009*)

New Schiff bases, N,N′-*bis*(salicylidene)-4-aminobenzylamine (H_2L^1), N,N′-*bis*(3-methoxysalicylidene)-4-aminobenzylamine (H_2L^2), and N,N′-*bis*(4-hydroxysalicylidene)-4-aminobenzylamine (H_2L^3), with their nickel(II), cobalt(II), and copper(II) complexes have been synthesized and characterized by elemental analyses, electronic absorption, FT-IR, magnetic susceptibility, and conductance measurements. For the ligands, ^1H and ^{13}C NMR and mass spectra were obtained. The tetradentate ligands coordinate to the metal ions through the phenolic oxygen and azomethine nitrogens. The keto-enol tautomeric forms of the Schiff bases H_2L^1, H_2L^2, and H_2L^3 have been investigated in polar and apolar solvents. All compounds were non-electrolytes in DMSO ($\sim 10^{-3}$ M) according to the conductance measurements. Antimicrobial activities of the Schiff bases and their complexes have been tested against *Acinobacter baumannii*, *Pseudomonas aeruginosa*, *Micrococcus luteus*, *Bacillus megaterium*, *Corynebacterium xerosis*, *Staphylococcus aureus*, *Escherichia coli*, *Candida albicans*, *Rhodotorula rubra*, and *Kluyveromyces marxianus* by the disc diffusion method; biological activity increases on complexation.

Keywords: Schiff base; Antimicrobial activity; 4-Aminobenzylamine; Nickel(II), copper(II) and cobalt(II)

1. Introduction

Schiff-base complexes have been widely studied coordination compounds and are becoming increasingly important as biochemical, analytical, and antimicrobial reagents [1]. Complexes of Schiff bases derived from substituted salicylaldehydes and various aromatic amines have been widely investigated [2, 3] and represent an important class of coordination chemistry with unusual configuration, structural lability, and sensitivity to molecular environments [4]. Such complexes have a crucial role in some

*Corresponding author. Email: cdemetgul@hotmail.com

ISSN 0095-8972 print/ISSN 1029-0389 online © 2009 Taylor & Francis
DOI: 10.1080/00958970903082192

biological processes such as the biological function of bacterorhodopsin [5, 6] and are used [7–9] as catalysts and biological models in understanding the structure of biomolecules and biological processes [10, 11]. Cobalt complexes of tetradentate Schiff-base ligands have been widely used to mimic cobalamine (B_{12}) co-enzymes [12].

Schiff bases derived from the salicylaldehydes coordinate in deprotonated or neutral forms [13, 14]. Complexes of Schiff bases containing O, N donors have significant antifungal, antibacterial, and anticancer activity [15]. Schiff-base complexes derived from 4-hydroxysalicylaldehyde and amines have strong anticancer activity *e.g. Ehrlich ascites carcinoma* (EAC) [16].

In this study, the preparation, characterization, and antimicrobial studies of Schiff bases and their complexes with Ni(II), Co(II), and Cu(II) are described.

2. Experimental

2.1. *Physical measurements*

Elemental analyses (C, H, and N) were carried out with a LECO-CHNS-932 elemental analyzer. The infrared and UV-Vis spectra were measured using Perkin-Elmer RX-1 FT-IR and Perkin-Elmer Lambda 25 UV-Vis spectrometers. FT-IR spectra were recorded using KBr discs (4000–400 cm^{-1}). Schiff bases were characterized using ^1H NMR spectra (Bruker Biospin 300 MHz spectrometer, USA) recorded at 25°C using deuterated DMSO as a solvent. Tetramethylsilane was used as internal standard. In addition, ^{13}C NMR spectra were recorded at 25°C using $CDCl_3$. Molar conductances of the Schiff bases and their transition metal complexes were determined in DMSO ($\sim 10^{-3}$ M) at room temperature using a Jenway Model 4070 conductivity meter. Mass spectra of the ligands were recorded on a LC/MS-APIES mass spectra AGILENT model 1100 MSD. Metal analyses were carried out by AAS Perkin-Elmer 3100 in solutions prepared by decomposing the complexes in aqua regia and then subsequently digesting in concentrated HCl. Magnetic measurements were carried out with a Sherwood magnetic susceptibility balance (Model MK1) with $CuSO_4 \cdot 5H_2O$ as the calibrant. Magnetic susceptibilities were calculated (BM) using $\mu_{\text{eff}} = 2.82\sqrt{(X_m \cdot T)}$ equation.

2.2. *Materials*

Salicylaldehyde and 3-methoxysalicylaldehyde were supplied from Merck; 4-aminobenzylamine, 4-hydroxysalicyaldehyde and acetate salts of Ni(II), Co(II), and Cu(II) were obtained from Fluka Chemical Co. without purification. Solvents were purified by distillation.

2.3. *Synthesis of Schiff bases from 4-aminobenzylamine*

The ligands were synthesized according to the literature [17]. An ethanol solution (20 mL) of salicylaldehyde derivative (0.08 M) was mixed with 4-aminobenzylamine (0.04 M) in 25 mL ethanol. The mixture was refluxed for 2 h. After cooling, the reaction

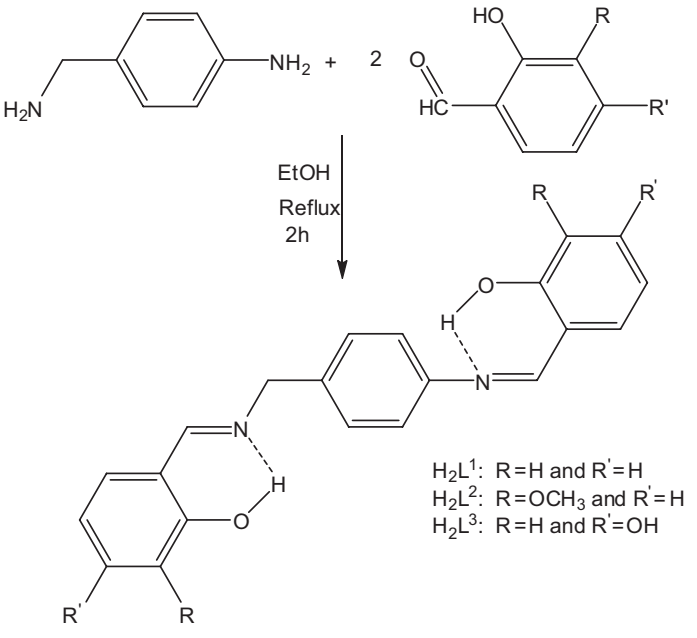

Figure 1. Synthesis of the ligands.

mixture was filtered, the residue was washed several times with ethanol and dried in vacuum. The composition of the ligands was confirmed by C, H, and N analyses, FT-IR, UV-Vis, LC/MS, and NMR spectra. The structures of N,N′-*bis*(salicylidene)-4-aminobenzylamine (H_2L^1), N,N′-*bis*(3-methoxysalicylidene)-4-aminobenzylamine (H_2L^2), and N,N′-*bis*(4-hydroxysalicylidene)-4-aminobenzylamine (H_2L^3) are given in figure 1.

2.4. *Synthesis of the metal complexes*

All of the complexes were synthesized by the general method detailed below. Metal acetate salts (4 mM) in 20 mL methanol were added dropwise to a stirred warm solution of the ligand (4 mM) in 20 mL methanol. The resulting solutions were stirred for 2 h. Crystals of the complexes obtained in 1 or 2 days at room temperature were filtered, then washed with methanol and diethyl ether and finally dried in vacuum. All complexes were isolated as crystals but are not suitable for X-ray analyses (figure 2).

2.5. *Preparation of microorganism cultures*

Growth inhibitory activities of the compounds were tested against seven bacteria (*Acinobacter baumannii*, *Pseudomonas aeruginosa* 9028, *Micrococcus luteus* LA2971, *Bacillus megaterium* DSM 32, *Corynebacterium xerosis* ATCC 15753, *Staphylococcus aureus*, *Eschericha coli* ATCC 8739) and three yeasts (*Candida albicans* CCM 314, *Rhodotorula rubra* 116, *Kluyveromyces marxianus* 332). The bacteria were first

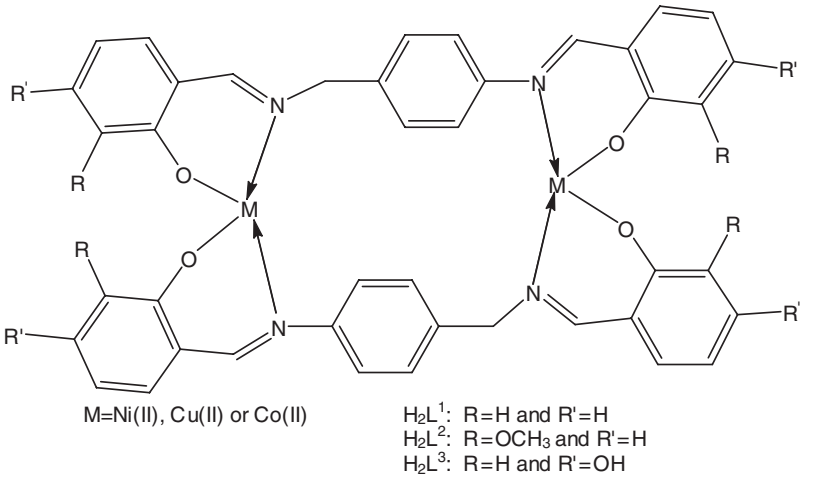

Figure 2. Proposed structures of the metal complexes.

incubated at 37°C for 24 h in Nutrient Broth (Difco), and the yeasts were incubated in Sabouraud Dextrose Broth (Difco) at 25°C for 24 h. In the disc diffusion method, the sterile Mueller Hinton Agar (Oxoid) for bacteria and Sabouraud Dextrose Agar for yeast (sterilized in a flask and cooled to 45–50°C) were separately inoculated with the test microorganisms. The compounds dissolved in DMF as 100 μg/disc solutions and absorbed on the sterile paper antibiotic discs were placed in wells (8 mm diameter) in the agar media (the petri dishes were left at 4°C for 2 h), and then the plates were incubated at 37°C for bacteria (24 h) and at 30°C for yeast (24 h) [18]. At the end of the period, inhibition zones formed on the medium were evaluated in millimeters (mm). The control samples were only absorbed in DMF. The data reported in table 1 are the average of three experiments.

3. Results and discussion

The physical data for the ligands and their metal complexes in table 2 are in good agreement with the expected values. The ligands prepared in this way are formed in nearly quantitative yields and are of high purity. The yields of the complexes are lower than the ligands, perhaps due to steric hindrance around the coordination center [19]. All compounds are stable at room temperature in the solid state and soluble in common organic solvents (MeOH, EtOH, $CHCl_3$, and THF).

Solution conductivity measurements (5.2–8.0 $Ohm^{-1} cm^2 M^{-1}$) show that all metal complexes are non-electrolytes [20].

Magnetic measurements were recorded at room temperature and effective magnetic moments (μ_{eff}) are listed in table 2. The nickel(II) complexes are diamagnetic, indicating square-planar geometry. Magnetic moments of the copper(II) and cobalt(II) complexes were in the range 1.78–1.82 and 4.09–4.14 B.M., respectively [17].

Table 1. Antimicrobial activities for Schiff bases and their complexes[a].

Compound	Microorganisms (Inhibition zone[b])										
	B1	B2	B3	B4	B5	B6	B7	Y1	Y2	Y3	Control
H_2L^1	–	–	–	–	–	–	–	–	–	–	–
$[Ni_2(L^1)_2]$	12	14	12	8	10	12	8	13	9	13	–
$[Cu_2(L^1)_2]$	11	17	18	17	20	16	15	12	13	13	–
$[Co_2(L^1)_2]$	10	10	8	9	8	8	9	10	11	8	–
H_2L^2	–	–	–	–	–	–	–	–	–	–	–
$[Ni_2(L^2)_2]$	15	12	18	10	13	19	10	14	18	12	–
$[Cu_2(L^2)_2]$	17	11	10	9	12	10	8	8	10	11	–
$[Co_2(L^2)_2]$	16	16	18	18	16	16	18	16	20	22	–
H_2L^3	–	–	–	–	–	–	–	–	–	–	–
$[Ni_2(L^3)_2]$	14	12	18	16	17	19	16	17	21	19	–
$[Cu_2(L^3)_2]$	8	10	11	9	10	8	9	8	8	8	–
$[Co_2(L^3)_2]$	9	11	10	8	10	9	8	9	11	10	–

[a]Compound concentration: 100 μg/disc. [b]Including disc diameter (8 mm). The symbol '–' reveals that the compounds have no activity against the microorganisms.
Y1 – *Candida albicans* CCM 314.
Y2 – *Rhodotorula rubra* 116.
Y3 – *Kluyveromyces marxianus* 332.
B1 – *Acinobacter baumannii* (Klinik izolat).
B2 – *Pseudomonas aeruginosa* 9027.
B3 – *Micrococcus luteus* LA2971.
B4 – *Bacillus megaterium* DSM 32.
B5 – *Corynebacterium xerosis* ATCC 15753.
B6 – *Staphylococcus aureus* clinic isolate.
B7 – *Escherichia coli* ATCC 8739.
Y – Yeast, B–Bacteria.

Table 2. Analytical and physical data for the Schiff-base ligands and their complexes.

Compound	Color	Yield (%)	m.p. (C)	$^a\Lambda_M$	Calcd. (Found)%				μ_{eff} (B.M.)
					C	H	N	M	
H_2L^1	Orange	81	149	1.2	76.34 (76.30)	5.49 (5.51)	8.48 (8.45)	–	
$[Ni_2(L^1)_2]$	Yellow green	63	>250	6.0	65.16 (65.08)	4.17 (4.20)	7.24 (7.19)	15.16 (14.96)	Dia.
$[Cu_2(L^1)_2]$	Green	68	>250	5.2	64.36 (64.29)	4.11 (4.17)	7.15 (7.10)	16.21 (16.25)	1.78
$[Co_2(L^1)_2]$	Brown	60	>250	5.9	65.21 (65.02)	4.16 (4.24)	7.23 (7.20)	15.22 (15.10)	4.09
H_2L^2	Orange	85	146	1.5	70.75 (70.72)	5.68 (5.71)	7.17 (7.13)	–	–
$[Ni_2(L^2)_2]$	Dark green	71	>250	7.1	61.78 (61.72)	4.51 (4.53)	6.27 (6.21)	13.13 (13.00)	Dia.
$[Cu_2(L^2)_2]$	Green	75	>250	7.5	61.12 (61.09)	4.46 (4.48)	6.20 (6.16)	14.06 (13.89)	1.79
$[Co_2(L^2)_2]$	Brown	65	>250	8.0	61.75 (61.68)	4.51 (4.63)	6.26 (6.14)	13.17 (13.03)	4.11
H_2L^3	Orange	80	>250	1.7	69.60 (69.58)	5.01 (5.03)	7.73 (7.70)	–	–
$[Ni_2(L^3)_2]$	Yellow green	66	>250	6.8	60.19 (60.15)	3.85 (3.88)	6.68 (6.65)	14.01 (13.83)	Dia.
$[Cu_2(L^3)_2]$	Green	72	>250	6.1	59.50 (59.45)	3.80 (3.82)	6.61 (6.58)	14.99 (14.81)	1.82
$[Co_2(L^3)_2]$	Brown	56	>250	6.7	60.15 (60.10)	3.85 (3.96)	6.68 (6.61)	14.06 (14.00)	4.14

[a]$\Omega^{-1}\,cm^2\,M^{-1}$.

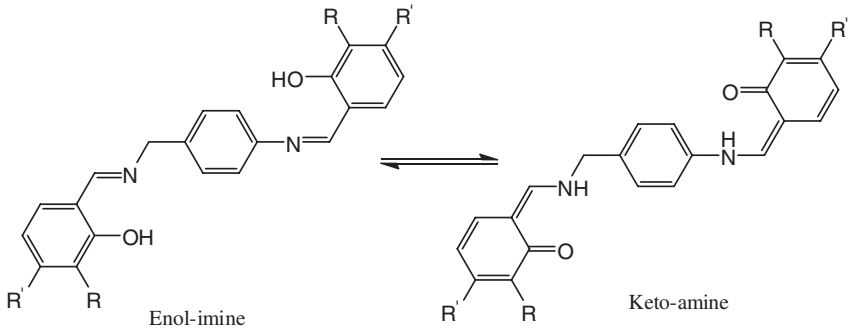

Figure 3. Tautomeric forms of the Schiff-base ligands.

Mass spectra of H_2L^1, H_2L^2, and H_2L^3 show peaks at m/e 330, 390, and 362 respectively, attributed to molecular ion peaks $[M]^+$.

From observations and the literature [17, 21], the structures of the complexes are proposed in figure 2.

3.1. *Electronic spectra*

In order to investigate the keto-enol tautomeric forms of the free ligands, the electronic spectra were measured in toluene, chloroform, and ethanol. In toluene, the ligands exhibit maxima in the range 319–268 nm. However, in ethanol and chloroform new absorption bands in the 446–310 nm range were observed. These data suggest, in toluene, the free ligands have the ketoamine form, but in EtOH and $CHCl_3$ solvents, the enolimine form (figure 3) [22].

Electronic spectra of the complexes have been measured in EtOH and the absorption bands are given in Supplementary Material. Bands of the ligands in the 265–279 nm range are attributed to benzene π–π^* transitions, while bands in the 275–455 nm range are assigned to imine π–π^* transitions. The band around 358 nm (as a shoulder) is due to the n–π^* transition of the non-bonding electrons present on the nitrogen of the azomethine group in the Schiff base. In the spectra of the complexes, the bands of the azomethine n–π^* transition shift to lower frequencies, indicating that imine nitrogen is involved in coordination to the metal ion [17]. Bands in the 576–671 nm region can be attributed to d–d transitions of the metal ions.

3.2. *FT-IR spectra*

The FT-IR spectral data of the ligands and their metal complexes are given in Supplementary Material. In spectra of the ligands, broad bands in the 3344–3439 cm^{-1} range can be attributed to O–H vibration. In metal complexes of H_2L^1 and H_2L^2 these bands are no longer observed, indicating that all hydroxyl protons are displaced by the metal ions. In spectra of complexes of H_2L^3, bands in the 3363–3380 cm^{-1} range are from *p*-OH vibration. For all the compounds, weak bands in the 2960–2904 cm^{-1} range

are assigned to $-CH_2-$ vibration. The ligands have two different azomethine groups, Ar–N=CH– and $-CH_2-N=CH-$ and vibrations ($-CH_2-N=CH-$ and Ar–N=CH–), are observed in the 1636–1628 cm^{-1} and 1619–1615 cm^{-1} range, respectively [23], slightly shifted to lower frequencies in the complexes. This change in frequencies shows that the imine nitrogen coordinates to the metal. In spectra of the complexes (except for $[Ni_2(L^3)_2]$ and $[Co_2(L^3)_2]$), these bands were broad.

The spectra of the ligands exhibit broad medium intensity bands in the 2750–2530 cm^{-1} range assigned to intramolecular H-bonding (O–H $\cdots$ N) (figure 1) [22]. These bands disappear in the complexes as a result of proton substitution by cation coordination to oxygen. The spectra of H_2L^2 and its metal complexes show vibrations in the 1255–1244 cm^{-1} range attributed to methoxy. The FT-IR spectra of the metal complexes also show new bands in the 573–520 and 504–459 cm^{-1} regions, due to formation of M–N and M–O bonds, respectively [24].

3.3. *^{1}H and ^{13}C NMR spectra*

^{1}H and ^{13}C NMR spectral data of the ligands in DMSO-d_6 and $CDCl_3$, and ^{1}H NMR spectrum of H_2L^1 are shown in Supplementaary material. In ^{1}H NMR spectra of the ligands, multiplets in the 6.10–7.70 ppm range can be attributed to phenyl protons. The $-CH_2-$ protons of the ligands are observed from 4.70–4.85 ppm. In H_2L^1 and H_2L^2, two –OH signals are observed from 13.10–13.65 ppm due to the asymmetric structure of the ligands; H_2L^3 has broad resonances at 10.80 and 13.70 ppm due to *para* and *ortho* –OH protons to the azomethine group [25]. For H_2L^2, the resonance at 3.75 ppm may be assigned to methoxy protons. The two different azomethine groups in the ligands ($-CH_2-N=CH-$ and Ar–N=CH–) are observed in the 8.80–8.95 ppm range and 8.45–8.70 ppm range [26]. The ^{1}H resonance of the O–H at 10.80–13.70 ppm disappears in D_2O.

The ^{13}C NMR spectral data of the ligands confirm the ^{1}H NMR spectra. Carbons of $-CH_2-$ and phenyl rings are observed at 61.0–61.5 ppm and 103–161 ppm, respectively. The spectrum of H_2L^2 shows a peak at 56 ppm for carbon of $-OCH_3$. In spectra of H_2L^1, H_2L^2 and H_2L^3, carbons of azomethine ($-CH_2-N=CH-$) are observed at 168, 167 and 166 ppm, respectively, while carbons of the other azomethine are observed at 164, 163 and 164 ppm, respectively.

3.4. *Antimicrobial activity*

Antimicrobial activities of the Schiff bases and their metal complexes against bacteria and yeast are recorded in table 1. Generally metal(II) complexes have been shown to be, in most cases, more effective than the free ligands. This would suggest that the chelation could facilitate the ability of a complex to cross a cell membrane and can be explained by Tweedy's chelation theory [27].

In this study the ligands have no activity against the microorganism, their metal complexes have variable activity against the same organism; $[Co_2(L^2)_2]$ shows the highest activity against *K. marxianus* (*Y3*).

4. Conclusion

Three new Schiff bases and their Ni(II), Cu(II) and Co(II) complexes were synthesized and characterized. Single crystals of the compounds could not be isolated and definite structures cannot be described. However, the spectroscopic and magnetic data enable us to predict possible structures. Antibacterial results showed metal complexes are more toxic than the free ligands.

Acknowledgements

The authors are grateful to the Science Research Fund of the Çukurova University in Turkey for supporting this work (Project number: FEF2006BAP-15) and to the Department of Chemistry for allowing using the laboratory facilities.

References

[1] M. Tümer, H. Köksal, M.K. Şener, S. Serin. *Trans. Met. Chem.*, **24**, 414 (1999).
[2] M. Gaber, R.M. Issa. *Thermochim. Acta*, **155**, 309 (1989).
[3] S. Pilar, V. Garcia, J.R. Masaguer. *Trans. Met. Chem.*, **10**, 410 (1985).
[4] A. Gölcü, M. Tumer, H. Demirelli, R.A. Wheatley. *Inorg. Chim. Acta*, **358**, 1785 (2005).
[5] T. Bassov, M. Sheves. *Biochemistry*, **25**, 5249 (1986).
[6] L. Rousso, N. Friedman, M. Sheves, M. Ottolenghi. *Biochemistry*, **34**, 12059 (1995).
[7] J.P. Costes, G. Cros, M.H. Darbieu. *Inorg. Chim. Acta*, **60**, 111 (1982).
[8] J.P. Costes, G. Cros, M.H. Darbieu, Y.P. Laurent. *Trans. Met. Chem.*, **7**, 219 (1982).
[9] D.F. Averill, R.F. Broman. *Inorg. Chem.*, **17**, 3389 (1978).
[10] J.E. Kovacic. *Spectrochim. Acta A*, **23**, 183 (1987).
[11] R. Atkins, G. Brewer, E. Kokot, G.M. Mockler, E. Sinn. *Inorg. Chem.*, **24**, 128 (1985).
[12] M.M. Ally. *J. Coord. Chem.*, **43**, 89 (1998).
[13] R.H. Holm, G.W. Everett, A. Chakravorty. *Prog. Inorg. Chem.*, **7**, 83 (1966).
[14] M. Tümer, H. Köksal, S. Serin. *Trans. Met. Chem.*, **24**, 13 (1999).
[15] A. Saxane, J.K. Koacher, J.P. Tandon. *Inorg. Nucl. Chem. Lett.*, **17**, 229 (1981).
[16] W. Zishen, L. Zhipping, Y. Zhenhaun. *Trans. Met. Chem.*, **18**, 291 (1993).
[17] C. Çelik, M. Tümer, S. Serin. *Synth. React. Inorg. Met.-Org. Chem.*, **32**, 1839 (2002).
[18] C.H. Collins, P.M. Lyne, J.M. Grange. In *Microbiological Methods*, 3rd edn, p. 410, Butterworth, London (1989).
[19] M. Tümer, B. Erdoğan, S. Serin, M.Y. Nutku. *Synth. React. Inorg. Met.-Org. Chem.*, **28**, 529 (1998).
[20] M. Tümer. *J. Coord. Chem.*, **60**, 2051 (2007).
[21] A.A. Osowole, G.A. Kolawole, O.E. Fagale. *Synth. React. Inorg. Met.-Org. Chem.*, **35**, 829 (2005).
[22] M. Tümer, D. Ekinci, F. Tümer, A. Bulut. *Spectrochim. Acta, Part A*, **67**, 916 (2007).
[23] M. Vazquez, M.R. Bermejo, M. Fondo, A.M. Garcia-Deibe, J. Sanmartin, R. Pedrido, L. Sorace, D. Gatteschi. *Eur. J. Inorg. Chem.*, **6**, 1128 (2003).
[24] H. Köksal, M. Dolaz, M. Tümer, S. Serin. *Synth. React. Inorg. Met.-Org. Chem.*, **31**, 1141 (1997).
[25] C. Demetgül, M. Karakaplan, S. Serin. *Des. Monomers Polym.*, **11**, 565 (2008).
[26] W.H. Correa, S. Papadopoulos, P. Radnidge, B.A. Roberts, J.L. Scott. *Green Chem.*, **4**, 245 (2002).
[27] B.G. Tweddy. *Phytopathology*, **55**, 910 (1964).