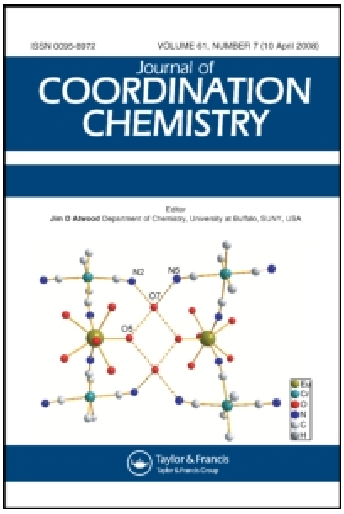


Journal of Coordination Chemistry
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713455674

Complexation of (1Z, 2Z)-<i>N</i>'-1-,<i>N</i>'-2-dihydroxy-<i>N</i>-1-, <i>N</i>-2-dipyridin-2-ylethanedimidamide in mono and dinuclear Zn(II), Cd(II), Hg(II) and Sn(IV) complexes

Ali Kakanejadifard[a]; Abedien Zabardasti[a]; Motaleb Ghasemian[a]; Esmaiel Niknam[a]
[a] Faculty of Science, Department of Chemistry, Lorestan University, Khorramabad, Iran

To cite this Article Kakanejadifard, Ali , Zabardasti, Abedien , Ghasemian, Motaleb and Niknam, Esmaiel(2008) 'Complexation of (1Z, 2Z)-**<i>N</i>**'-1-,**<i>N</i>**'-2-dihydroxy-**<i>N</i>**-1-, **<i>N</i>**-2-dipyridin-2-ylethanedimidamide in mono and dinuclear Zn(II), Cd(II), Hg(II) and Sn(IV) complexes', Journal of Coordination Chemistry, 61: 11, 1820 — 1826

To link to this Article: DOI: 10.1080/00958970701621217

URL: http://dx.doi.org/10.1080/00958970701621217

Journal of Coordination Chemistry
Vol. 61, No. 11, 10 June 2008, 1820–1826

Taylor & Francis
Taylor & Francis Group

Complexation of (1Z, 2Z)-*N′*-1-,*N′*-2-dihydroxy-*N*-1-, *N*-2-dipyridin-2-ylethanedimidamide in mono and dinuclear Zn(II), Cd(II), Hg(II) and Sn(IV) complexes

ALI KAKANEJADIFARD*, ABEDIEN ZABARDASTI,
MOTALEB GHASEMIAN and ESMAIEL NIKNAM

Faculty of Science, Department of Chemistry, Lorestan University, Khorramabad, Iran

(*Received 2 May 2007; in final form 13 June 2007*)

Mononuclear O,O-coordinated complexes $K_2(MLCl_2)$ M = Zn(II), Cd(II) and dinuclear complexes $(MZnLCl_2R_2)^x$ along with dinuclear *N*,*N*-coordinated complexes $(M'ZnH_2LCl_2R_2)^y$ (where M = Zn(II), Cd(II), Hg(II) and M′ = M and Sn(IV); R = Cl, CH_3; $x = 0, -2$; $y = 0, +2$) of *N′*-1-,*N′*-2-dihydroxy-*N*-1-,*N*-2-dipyridin-2-ylethanedimidamide (H_2L) have been prepared. All complexes have been characterized by ^{1}H NMR, IR, EI-mass spectroscopy and elemental microanalysis. These results are in agreement with our prediction for structures of mono and dinuclear complexes of H_2L and L^{-2} with Zn(II) in the gas phase by theoretical studies.

Keywords: vic-dioxime; *N*,*N*-coordination Mono and Dinuclear Complexes; O,O-Coordinated; Complexes

1. Introduction

Vic-dioximes are easily modified by substitution with various groups; reaction of amines or thiols with (*E*,*E*)-dichloroglyoxime or cyanogen-di-N-oxide yielded various symmetrically substituted diaminoglyoxime or dithioglyoxime derivatives [1–3]. Oximes are widely used in organic [4, 5], inorganic [6–9], bioinorganic [10], pigment [11], analytical [12, 13] and dyes [14]. Metal containing oxime complexes are utilized in medicine; technetium (V) and copper (II) complexes containing vicinal dioxime are currently used as cerebral and myocardial perfusion imaging agents [15–18]. In a preceding article, we reported synthesis and *N*,*N*-coordination mono and dinuclear complexes of *N′*-1-, *N′*-2-dihydroxy-*N*-1-, *N*-2-dipyridin-2-ylethanedimidamide (H_2L) with Zn(II), Cd(II), Hg(II) in acidic media (figure 1) [19].

We continue to develop coordination chemistry of H_2L, introducing *N*,*N* as well as O,O-coordinated complexes of H_2L with Zn(II), Cd(II), Hg(II), and Sn(IV).

---

*Corresponding author. Email: kakanejadi.a@lu.ac.ir

Journal of Coordination Chemistry
ISSN 0095-8972 print/ISSN 1029-0389 online
DOI: 10.1080/00958970701621217

2. Results and discussion

Mononuclear complexes, **1a–c** were prepared from reaction of H_2L and chloride salts of Zn(II), Cd(II), Hg(II) [19]. Compounds **2–4** were prepared from reaction of **1a–c** with Me_2SnCl_2 in methanol (figure 2). The solubility of these complexes in common organic solvents allowed their full characterization. In the IR spectrum of **2** the O–H, N–H, C=N and N–O stretching vibrations were at 3091–3205, 3326, 1643 and 988, respectively. In the ^1H NMR of **2** the D_2O exchangeable protons of OH and NH groups appeared as two singlets at $\delta = 13.38$ and 12.41 ppm, respectively. In the ^{13}C NMR spectrum of **2** the carbon resonance of oxime groups is found at higher field ($\delta = 150.79$ and 149.36 ppm) compared with **1a–g** [19].

By addition of a solution of $ZnCl_2$ to a solution of H_2L in methanol, at $pH \geq 5$, a white precipitate of **6** $[K_2(ZnLCl_2)]$ was formed (figure 3). The IR spectrum of **6** showed stretches for NH, C=N and N–O at 3245, 1647 and 931, respectively, while the OH absorption vanished. The EI mass spectrum showed the molecular ion peak at m/z 406 $(M - 78)$ and elemental analysis is consistent for $K_2(ZnLCl_2)$. The proton spectrum has a singlet at $\delta 13.12$ ppm for NH and a multiplet for pyridine protons at 6.98–8.85 ppm. In the ^{13}C NMR spectrum of **6**, resonance of dioxime groups was

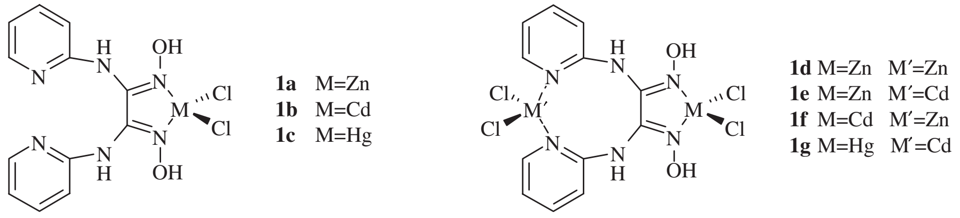


Figure 1. Suggested structure of the tetrahedral *N*,*N*-coordination $(MM'H_2LCl_4)$ complexes (M,M′ = Zn(II), Cd(II), Hg(II)).

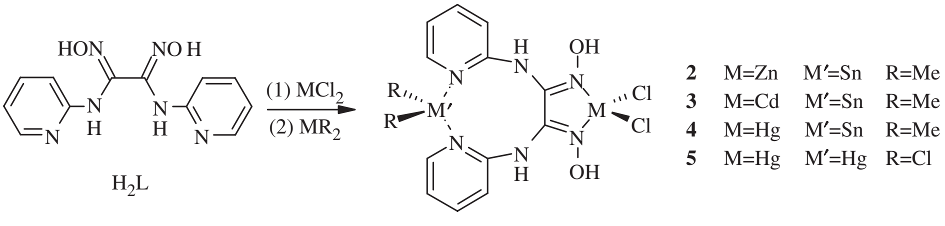


Figure 2. Suggested structures for *N*,*N*-coordinated complexes $(MM'H_2LCl_2R_2)$.

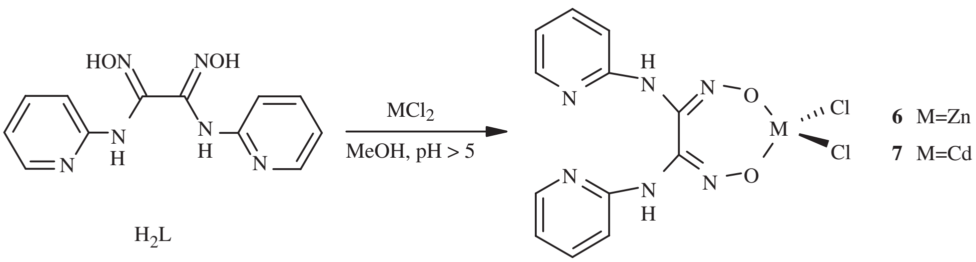


Figure 3. Suggested structure for $K_2[MLCl_2]$ complexes.

observed at 151.65. The aromatic pyridine carbons appeared at 138.75–111.98 ppm. Coordination complexes in which the H_2L forms a seven-member chelate ring by coordination to a metal through the O,O atoms, figure 3, have been reported previously [20]. Compound **7** was obtained in a similar condition. By doing these reactions at pH ≤ 3 the *N,N*-coordinated compounds **1a–c** are obtained.

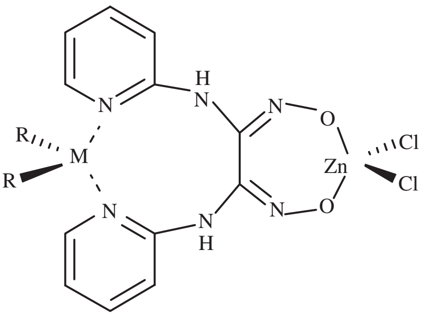
In order to synthesize homo and hetero dinuclear O,O-coordinated complexes of the type $K_2[ZnMLCl_4]$ M = Zn(II), Cd(II), and Hg(II) reactions of **6** were carried out with solutions of chloride salts of Zn(II), Cd(II) and Hg(II), **8–10** (figure 4). In the case of **8**, the EI mass spectrum, showed the molecular ion at *m*/*z* 542 [M − 78] and elemental analysis is consistent for $K_2[ZnMLCl_4]$. In the IR spectrum of **8**, the NH, C=N and N–O stretches are at 3245, 1643 and 948 cm^{-1}, respectively, and lack OH absorption. In the ^1H NMR spectrum of **8**, NH was observed at $\delta = 8.61$ ppm as a singlet and disappeared with D_2O exchange. The pyridyl protons are at $\delta = 7.01$–7.94 ppm, as a multiplet. The results show that, H_2L acts as a bidentate bridging ligand toward metal ions. Therefore, we assume that one metal ion coordinates to the *vic*-dioxime groups as an O,O-coordinating complex of H_2L and the other coordinates to N atoms of pyridyl aromatic rings (figure 4).

Compound **11** was prepared by refluxing a solution of **6** and Me_2SnCl_2 in methanol (figure 4). The EI mass spectrum, showed the molecular ion at *m*/*z* 555 and elemental analysis is consistent for $[Me_2SnLZnCl_2]$. In the IR spectrum of **11** the N–H, CH_3, C=N and N–O stretching vibrations were at 3219, 2920–2960, 1645 and 999, respectively. In the ^1H NMR of **11** the NH was observed at 8.62 ppm as a singlet and disappeared with D_2O exchange. The pyridyl protons appeared at $\delta = 6.88$–8.02 ppm, as a multiplet.

Recently we proposed different models for coordination of H_2L to Zn(II) in mono and dinuclear complexes [21]. *Ab initio* and density functional calculations were used to study the coordination and thermodynamic properties of mono- and dinuclear complexes of zinc(II) with H_2L at HF/3-21G* and B3LYP/6-311 + G(2d,p)//HF/3-21G* computational levels.

For complexation of $ZnCl_2$ with H_2L four mononuclear as well as two dinuclear model structures were considered.

In H_2L because of resonance between amines N lone pairs with the C=N bond of oximic functions nitrogens show diminished tendency for coordination to Zn atom. Theoretical calculation predicts less tendency of amines (N21, N23) for coordination to Zn(II), oximic (N27,N28) and pyridines (N6,N19) atom a comparable tendency for



8 M=Zn R=Cl
9 M=Cd R=Cl
10 M=Hg R=Cl
11 M=Sn R=Me

Figure 4. Suggested structure for O,O-coordinated $K_2(ZnMLCl_4)$, M = Zn, Cd, Hg, and $(Me_2SnLZnCl_2)$ complexes.

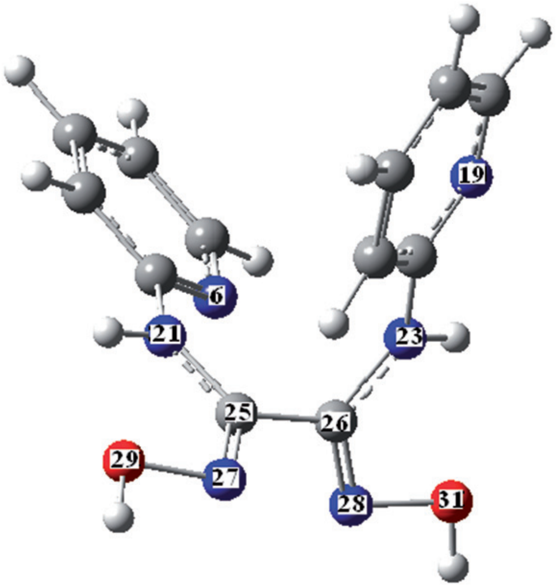


Figure 5. Structure of H_2L and L^{2-} optimized at HF/3-21G* [21].

coordination to Zn(II) and unusual O,O-coordination (through L^{-2}) gives the most stable model for mono nuclear complexes [21].

On the other hand, for dinuclear complexes theoretical calculations are indicating that coordination through O,O- and pyridines N atoms for L^{2-} and oximic and pyridines N atoms for H_2L were preferred. Experimental results of present work are confirming the predictions of our previous theoretical studies.

3. Experimental

3.1. *Material and measurements*

All chemical reagents were obtained from Merck or Fluka and used without further purification. Melting points were measured on an Electrothermal 9200 apparatus and are uncorrected. Elemental analyses for C, H and N were performed using a Heraeus CHN–O rapid analyzer. Mass spectra were recorded on a Shimadzu 5050 QD spectrometer. ^1H and ^{13}C NMR spectra were recorded with a Bruker DRX-500 AVANCE in DMSO-d_6 as solvent. The IR spectra were recorded on a Shimadzu IR-460 spectrometer.

3.1.1. Synthesis of [$ZnH_2LCl_2SnMe_2$]Cl_2 (2). To a stirred solution of **1a** [19] (0.405 g, 1 mmol) in 35 mL methanol, a solution of Me_2SnCl_2 (0.219 g, 1 mmol) in 15 mL methanol was added dropwise at room temperature. The mixture was refluxed for 2 h and the solvent was removed by evaporation. The brown precipitate was washed with 2-propanol, chloroform, diethyl ether and recrystallized from acetonitrile/water (2/1). Yield: 0.41 g (74.32%); m.p. 218°C. Elemental analysis, calculated for

$C_{14}H_{18}N_6O_2Cl_4SnZn$: C, 26.75; H, 2.87; N, 13.38. Found: C, 26.68; H, 2.80; N, 13.26. EI–MS: m/z 557 [M – 71] +. IR (KBr): υmax (cm^{-1}): 3091–3205 (υ OH), 3326 (υ NH), 1643 (υ C=N), 1620,1500 (υ C=C), 1257 (υ C–N), 988 (υ N–O), 769. 1H NMR ppm: 13.38 (s, 2H, OH), 12.41 (s, 2H, NH), 7.30–8.66 (m, 8H, ArH_{Py}), 2.57 (s, 6H, CH_3). ^{13}C NMR ppm: 150.79, 149.36, 146.82, 146.67, 138.44, 137.19, 136.66, 129.35, 116.49, 115.64, 111.29, 111.11, 40.41.

3.1.2. Synthesis of [$MH_2LCl_2SnMe_2$](M = Cd, Hg)Cl_2 (3,4). To a stirred solution of H_2L (0.272 g, 1 mmol) in 30 mL methanol, a solution containing 1 mmol of MCl_2 (0.201 g $CdCl_2$, 0.272 g $HgCl_2$) in 10 mL methanol was added dropwise at 50°C. The mixture was refluxed for 2 h then a solution of Me_2SnCl_2 (0.219 g, 1 mmol) in 15 mL methanol was added dropwise at room temperature. The mixture was refluxed for 2 h again then solvent was removed by evaporation. The brown precipitate was washed several times with chloroform, diethyl ether and recrystallized from acetonitrile/water (2/1).

Compound **3**: Yield: 0.42 g (69.50%); m.p. 199.5°C. Elemental analysis, calculated for $C_{14}H_{18}N_6O_2CdCl_4Sn$: C, 24.88; H, 2.68; N, 12.44. Found: C, 24.71; H, 2.61; N, 12.45. EI–MS: m/z 604 $[M-71]^+$. IR (KBr): υ_{max} (cm^{-1}): 3085–3190 (υ OH), 3132 (υ NH), 1664 (υ C=N), 1650, 1523 (υ C=C), 1242 (υ C–N), 995 (υ N–O). ^1H NMR ppm: 13.51 (s, 2H, OH), 12.46 (s, 2H, NH), 7.30–8.66 (m, 8H, ArH_{Py}), 2.53 (s, 6H, CH_3). ^{13}C NMR ppm: 150.43, 149.24, 147.02, 146.64, 138.20, 136.80, 133.34, 129.34, 116.59, 115.99, 111.09, 40.09.

Compound **4**: Yield: 0.53 g (76.60%); m.p. 202.5°C. Elemental analysis, calculated for $C_{14}H_{18}N_6O_2HgSnCl_4$: C, 22.02; H, 2.36; N, 11.01. Found: C, 21.96; H, 2.35; N, 11.00. EI–MS: m/z 692 $[M-71]^+$. IR (KBr): υ_{max} (cm^{-1}): 3115–3211 (υ OH), 3238 (υ NH), 1649 (υ C=N), 1631, 1523 (υ C=C), 1264 (υ C–N), 945 (υ N–O). ^1H NMR ppm: 13.49 (s, 2H, OH), 12.45 (s, 2H, NH), 7.31–8.66 (m, 8H, ArH_{Py}), 2.53 (s, 6H, CH_3). ^{13}C NMR ppm: 150.47, 149.26, 146.97, 146.82, 138.24, 136.85, 136.74, 133.41, 129.34, 116.55, 115.92, 111.08, 40.09.

3.1.3. Synthesis of [$Hg_2H_2LCl_4$] (5). A solution of $HgCl_2$ (0.272 g, 1 mmol) in 10 mL methanol was added dropwise to a stirred solution of H_2L (0.272 g, 1 mmol) in 35 mL pyridine at room temperature. The mixture was refluxed for 2 h then a solution of $HgCl_2$ (0.272 g, 1 mmol) in 15 mL methanol was added slowly to this solution. The mixture was refluxed for 2 h again before solvent removal by evaporation. The yellow precipitate was washed with diethyl ether and recrystallized from acetonitrile/pyridine (2/1). Yield: 0.506 g (62.3%); m.p. 207°C. Elemental analysis, calculated for $C_{12}H_{12}N_6O_2Cl_4Hg_2$: C, 17.67; H, 1.47; N, 10.31. Found: C, 17.64; H, 1.45; N, 10.29. EI–MS: m/z 815 $[M-1]^+$. IR (KBr): υ_{max} (cm^{-1}): 3312–3393 (υ OH), 3226 (υ NH), 1650 (υ C=N), 1698 (υ C=C), 1291 (υ C–N), 981 (υ N–O). ^1H NMR ppm: 12.07 (s, 2H, OH), 11.19 (s, 2H, NH), 6.43–7.89 (m, 8H, ArH_{Py}). ^{13}C NMR ppm: 157.92, 156.86, 150.99, 149.85, 142.54, 140.10, 134.34, 127.42, 116.45, 116.14, 109.17, 108.23.

3.1.4. Synthesis of $K_2[ZnLCl_2]$ (6). A solution of $ZnCl_2$ (0.137 g, 1 mmol) in 10 mL methanol was added dropwise to a stirred solution of H_2L (0.272 g, 1 mmol) in 30 mL methanol at 60°C. The pH dropped to about 3 and rose to 4.8–5 by addition of KOH (0.056 g, 1 mmol) in 10 mL methanol. The mixture was refluxed for 2 h and the solvent was removed by evaporation. The orange precipitate was washed several times with acetonitrile and diethyl ether and recrystallized from H_2O. Yield: 0.276 g (68%); m.p. 204.5°C. Elemental analysis, calculated for $C_{12}H_{10}N_6O_2Cl_2K_2Zn$: C, 29.75; H, 2.07; N, 17.36. Found: C, 29.70; H, 2.00; N, 17.32. EI–MS: m/z 406 $[M-78]^+$. IR (KBr): υ_{max} (cm^{-1}): 3245 (υ NH), 1647 (υ C=N), 1604, 1502 (υ C=C), 1294, 1137 (υ C–N), 931 (υ N–O). ^1H NMR ppm: 13.12 (s, 2H, NH), 6.98–8.85 (m, 8H, ArH_{Py}). ^{13}C NMR ppm: 151.65, 138.75, 131.15, 130.67, 117.61, 111.98.

3.1.5. Synthesis of $K_2[CdLCl_2]$ (7). A solution of $CdCl_2$ (0.201 g, 1 mmol) in 10 mL methanol was added dropwise to a stirred solution of H_2L (0.272 g, 1 mmol) in 35 mL pyridine at room temperature. The mixture was refluxed for 2 h and the solvent was removed by evaporation. The orange precipitate was washed several times with acetonitrile, pyridine and diethyl ether and recrystallized from 1-propanol/diethyl ether/chloroform (1/1/1). Yield: 0.337 g (78.8%); m.p. 201.5°C. Elemental Analysis, Calcd for C12H10N6O2Cl2K2Cd: C, 27.12; H, 1.88; N, 15.82. Found: C, 27.08; H, 1.80; N, 15.78. EI–MS: m/z 453 [M – 78] +. IR (KBr): υmax (cm^{-1}): 3234 (υ NH), 1651 (υ C=N), 1612, 1511 (υ C=C), 1328 (υ C–N), 1139 (υ C–N), 933 (υ N–O). ^1H NMR ppm: 12.60 (s, 2H, NH), 7.37–8.58 (m, 8H, ArH_{Py}). ^{13}C NMR ppm: 149.58, 141.53, 136.47, 129.41, 124.04, 117.53.

3.1.6. Synthesis of $K_2[Zn_2LCl_4]$ (8). (a) A solution of $ZnCl_2$ (0.137 g, 1 mmol) in 10 mL methanol was added dropwise to a stirred solution of H_2L (0.272 g, 1 mmol) in 30 mL methanol at room temperature. The pH dropped to about 3 and rose to 4.8–5 by addition of KOH (0.056 g, 1 mmol) in 10 mL methanol. Then a solution of $ZnCl_2$ (0.137 g, 1 mmol) in 15 mL methanol was added dropwise to the reaction mixture at room temperature. The mixture was refluxed for 2 h and the solvent was evaporated to dryness under reduced pressure. The orange-yellow precipitate was washed several times with acetonitrile, 1-propanol, ethylacetate and diethyl ether and recrystallized from acetonitrile/water (2/1). Yield: 0.424 g (78.2%); m.p. 248°C. Elemental analysis, calculated for $C_{12}H_{10}N_6O_2Cl_4K_2Zn_2$: C, 23.22; H, 1.61; N, 13.54. Found: C, 23.19; H, 1.58; N, 13.49. EI–MS: m/z 542 [M – 78]+. IR (KBr): υmax (cm^{-1}): 3245 (υ NH), 1643 (υ C=N), 1604, 1542 (υ C=C), 1338 (υ C–N), 948 (υ N–O). 1H NMR ppm: 8.61 (s, 2H, NH), 7.01–7.94 (m, 8H, ArHPy). (b) To a stirred solution of 6 (0.405 g, 1 mmol) in 35 mL methanol, a solution of $ZnCl_2$ (0.137 g, 1 mmol) in 15 mL methanol was added dropwise at room temperature. The pH was kept about 4.85–5 by addition of KOH (0.056 g, 1 mmol) in 10 mL methanol. The mixture was refluxed for another 2 h then solvent was evaporated to dryness under reduced pressure.

3.1.7. Synthesis of $K_2[ZnMLCl_4]$(M=Cd, Hg) (9,10). The procedure 2.8 (b) was carried out but with 1 mmol of MCl_2 (0.201 g $CdCl_2$, or 0.272 g $HgCl_2$). A white precipitate was obtained, washed with 1-propanol and diethyl ether and recrystallized from acetonitrile/pyridine (1/1).

Compound **9**: Yield: 0. 425 g (76.7%); m.p. 308°C Elemental analysis, calculated for $C_{12}H_{10}N_6O_2$ Cl_4CdK_2Zn: C, 21.55; H, 1.50; N, 12.57. Found: C, 21.50; H, 1.45; N, 12.53. EI–MS: m/z 590 $[M-78]^+$, 589 $[M-79]^+$. IR (KBr): υ_{max} (cm^{-1}): 3253 (υ NH), 1633 (υ C=N), 1612, 1487 (υ C=C), 1220 (υ C–N), 1012 (υ N–O). ^1H NMR ppm: 8.58 (s, 2H, NH), 7.39–7.81 (m, 8H, ArH_{Py}).

Compound **10**: Yield: 0. 497 g (73.4%); m.p. 238°C Elemental analysis, calculated for $C_{12}H_{10}N_6O_2Cl_4HgK_2Zn$: C, 19.05; H, 1.32; N, 11.11. Found: C, 18.98; H, 1.27; N, 11.07. EI–MS: m/z 678 $[M-78]^+$, 677 $[M-79]^+$. IR (KBr): υ_{max} (cm^{-1}): 3227 (υ NH), 1647 (υ C=N), 1604, 1466 (υ C=C), 1226 (υ C–N), 1010 (υ N–O). ^1H NMR ppm: 8.63 (s, 2H, NH), 6.79–7.97 (m, 8H, ArH_{Py}).

3.1.8. Synthesis of [$ZnLCl_2SnMe_2$] (11). According to procedure 2.8 (b) with Me_2SnCl_2 (0.219 g, 1 mmol) an orange product precipitated. The product was washed with acetonitrile, 2-propanol, diethyl ether and chloroform and then recrystallized from water. Yield: 0.423 g (76.21%); m.p. 232°C. Elemental analysis, calculated for $C_{14}H_{16}N_6O_2Cl_2SnZn$: C, 30.27; H, 1.88; N, 15.14. Found: C, 30.24; H, 1.86; N, 15.15. EI–MS: m/z 555 $[M]^+$. IR (KBr): υ_{max} (cm^{-1}): 3335 (υ NH), 2920–2960 (υ CH_3), 1645 (υ C=N), 1596,1541 (υ C=C), 1224 (υ C–N), 999 (υ N–O). ^1H NMR ppm: 8.62 (s, 2H, NH), 6.88–8.02 (m, 8H, ArH_{Py}) 2.53 (s, 6H, CH_3).

References

[1] C. Grandmann, V. Mini, J.M. Dean, H.D. Frommeld. *Liebigs. Ann. Chem.*, **687**, 191 (1965).
[2] J.J. Christensen, J.J. Eatoiugh, R.M. Izatt. *Chem. Rev.*, **74**, 351 (1974).
[3] J.R. Dilworth, S.J. Parrott. *Chem. Soc. Rev.*, **27**, 43 (1998).
[4] M.D. Coburn, J. Heterocyc;lic. *Chem.*, **5**, 83 (1968).
[5] A. Kakanejadifard, M. Farnia, G. Najafi. *Iran. J. Chem. & Chem. Eng.*, **23**, 118 (2004).
[6] A. Chakravorty. *Coord. Chem. Rev.*, **13**, 1 (1974).
[7] A. Bilgin, B. Ertem, F. Dinc-Agin, Y. Gok, S. Karslioglu. *Polyhedron*, **25**, 3165 (2006).
[8] A. Kakanejadifard, E. Niknam, A. Zabardasti. *J. Coord. Chem.*, **60**, 677 (2007).
[9] S. Farhadi, A. Kakanejadifard, N. Dorosti. *Polish J. Chem.*, **79**, 1829 (2005).
[10] B. Ranjbar, S. Afshar, A. Kakanejadifard, K. Khajeh, H. Naderi-Manesh, L. Hassani, N. Alizadeh. *Asian. J. Biochem.*, **1**, 153 (2006).
[11] G.N. Schrauzer, J. Kohnle. *Chem. Ber.*, **97**, 3056 (1964).
[12] A.R. Ghiasvand, S. Shadabi, A. Kakanejadifard, A. Khajehkolaki. *Bull. Korean. Chem. Soc.*, **26**, 781 (2005).
[13] A. Yari, S. Azizi, A. Kakanejadifard. *Sensor & Actuators B.*, **119**, 167 (2006).
[14] M.E.B. Jones, D.A. Thornton, R.F. Webb. *Makromol. Chem.*, **49**, 62 (1961).
[15] M.J. Prushan, A.W. Addison, R.J. Butcher. *Inorg. Chim. Acta*, **992**, 300 (2000).
[16] J.P. Leonard, D.P. Novotnil, R.D. Neirickx. *J. Nucl. Med.*, **27**, 1819 (1986).
[17] M.A. Green. *Adv. Met. Med.*, **1**, 75 (1993).
[18] E.K. John, A.J. Bott, M.A. Green. *J. Pharm. Sci.*, **83**, 587 (1994).
[19] A. Kakanejadifard, E. Niknam. *Polish J. Chem.*, **80**, 1645 (2006).
[20] M.S. Singh, A.K. Singh. *Tetrahedron Lett.*, **46**, 315 (2005).
[21] A. Zabardasti, A. Kakanejadifard, M. Salehnassaj, submitted. *Bill. Chem. Soc(Japan)* (2007).