

Synthesis and characterization of macrocyclic Cd(II) complexes

Salih İlhan^{a,*} & Hamdi Temel^b

^aSiirt University, Faculty of Art and Science,
Chemistry Department, Siirt, Turkey

^bDicle University, Faculty of Education, Chemistry Department,
21280 Diyarbakır, Turkey

Email: salihsiirt@gmail.com, salihilhan@dicle.edu.tr

Received 30 July 2007; revised 28 January 2008

Ten new Cd(II) complexes have been synthesized with $\text{Cd}(\text{ClO}_4)_2 \cdot 6\text{H}_2\text{O}$, $\text{Cd}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ in chloroform-methanol. The complexes have been characterized by elemental analysis, IR, ^1H NMR, UV-vis spectra, magnetic susceptibility, conductivity measurements and mass spectra. On the basis of the spectral studies, four-coordinated tetrahedral geometry may be assigned to these complexes.

IPC Code: Int. Cl.⁸ CO7F3/08

Macrocyclic ligands containing a heteroatom are important complexing agents for cations, anions and molecules¹⁻⁵. The stability of macrocyclic metal complexes depends upon a number of factors, including the number and type of donor atoms present in the ligand and their relative positions within the macrocyclic skeleton, as well as the number and size of the chelate rings formed on complexation. For transition metal ions, features such as the nature and magnitude of crystal-field effects play also an important role⁶. Synthetic macrocycles are a growing class of compounds with varying chemistry a wide range of different molecular topologies and sets of donor atoms⁷⁻¹³. There are now reports on the transport of transition and post-transition metal ions through bulk liquid membranes using synthetic ionophores¹⁴⁻¹⁹. For example, the competitive extraction and transport of transition and post-transition metal ions using mixed-donor cyclic and acyclic ligands as ionophores have now received considerable attention²⁰⁻²³.

We report herein the synthesis of ten macrocyclic Schiff base complexes with $\text{Cd}(\text{ClO}_4)_2 \cdot 6\text{H}_2\text{O}$ and $\text{Cd}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$. Spectral properties of the new compounds have been studied in detail.

Experimental

Elemental analysis was carried out on a Leco CHNS model 932 elemental analyzer. ^1H NMR spectra were recorded using Bruker Avance DPX-400 NMR spectrometer. IR spectra were recorded on Perkin-Elmer Spectrum RX1 FTIR spectrophotometer on KBr pellets in the wave number range of 4000-400 cm^{-1} . Electronic spectra were conducted on Shimadzu model 160 UV-vis spectrophotometer in the wavelength 200-600 nm. Molar conductivities were measured with a WTW LF model 330 conductivity meter, using prepared solution of the complexes in DMSO-DMF (1:1, v:v) solvents. Electrospray ionization mass spectrometric analysis (ESI-MS) was obtained on the Agilent 1100 MSD spectrometer.

The ligands (Scheme 1) used in the synthesis were prepared from salicylaldehyde derivatives with 2,6-diaminopyridine as known already²⁴. All the chemicals and solvents were of analytical grade and used as received.

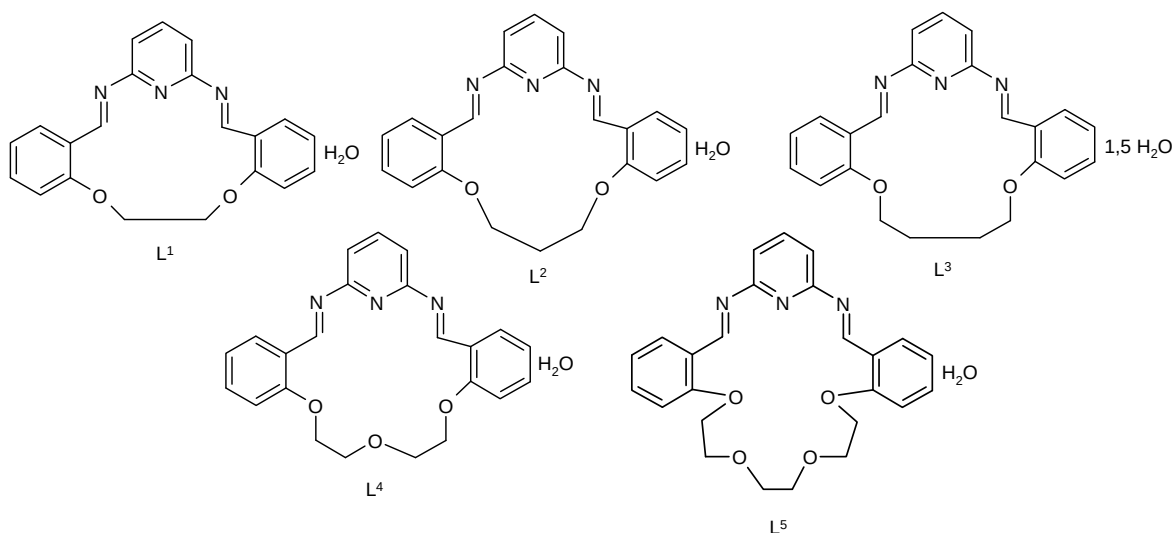
To a stirred solution of ligands (2 mmol) in chloroform (60 mL) was added $\text{Cd}(\text{ClO}_4)_2 \cdot 6\text{H}_2\text{O}$ or $\text{Cd}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ (2 mmol) in methanol (40 mL) by dropwise addition. Stirring was then continued for 2 h. Then, the precipitate was filtered and washed with chloroform and methanol and then dried in air. The complexes have no clearly defined melting point and begin to decompose in the temperature range 250-350°C.

$[\text{CdL}^1](\text{ClO}_4)_2 \cdot \text{H}_2\text{O}$

Yield: 0.16 g (13.1%). Anal Calcd for $\text{CdC}_{21}\text{H}_{17}\text{N}_3\text{O}_{10}\text{Cl}_2 \cdot \text{H}_2\text{O}$: C, 41.2, H, 3.1, N, 6.9. Found: C, 41.3, H, 3.2, N, 6.8. ^1H NMR (DMSO- d_6 , δ ppm): 3.42 (H_2O), 4.25 (s, 4H, $-\text{OCH}_2$), 7.02-8.04 (m, 11H, Ar-H), 10.38 (s, 2H, $\text{HC}=\text{N}$). Selected IR data (KBr, ν cm^{-1}): 3368 $\nu(\text{H}_2\text{O})$ 3076 $\nu(\text{Ar}-\text{CH})$, 2969, 2887 $\nu(\text{Alph.}-\text{CH})$, 1656 $\nu(\text{C}=\text{N})$, 1598 $\nu[(\text{C}=\text{N})(\text{pyridine})]$, 1492, 1452 $\nu(\text{Ar}-\text{C}=\text{C})$, 1292, 1241 $\nu(\text{Ar}-\text{O})$, 1118, 623 $\nu(\text{ClO}_4^-)$, 754 $\nu(\text{Substituted benzene})$, 523 $\nu(\text{Cd}-\text{N})$. $\Lambda_M = 148 \Omega^{-1} \cdot \text{mol}^{-1} \cdot \text{cm}^2$ (in DMSO-DMF (1:1, v:v)). Mass spectra (m/z): 654 $[[\text{CdL}^1](\text{ClO}_4)_2]^+$.

$[\text{CdL}^2](\text{ClO}_4)_2 \cdot 2\text{H}_2\text{O}$

Yield: 0.11 g (8.5%). Anal Calcd for $\text{CdC}_{22}\text{H}_{19}\text{N}_3\text{O}_{10}\text{Cl}_2 \cdot 2\text{H}_2\text{O}$: C, 41.0, H, 3.6, N, 6.5. Found: C, 41.1, H, 3.7, N, 6.5. ^1H NMR (DMSO- d_6 , δ



Scheme 1

ppm): $\delta = 2.34$ (t, 2H, $J = 5.3$ Hz) (CH_2), $\delta = 3.41$ (H_2O), $\delta = 4.32$ (t, 4H, $J = 5.8$ Hz) (OCH_2), $\delta = 6.98$ – 8.03 (m, 11H, Ar-H), $\delta = 10.40$ (s, 2H, $\text{HC}=\text{N}$). Selected IR data (KBr, $\nu \text{ cm}^{-1}$): 3371 $\nu(\text{H}_2\text{O})$, 3073 $\nu(\text{Ar-CH})$, 2958, 2881 $\nu(\text{Alph.-CH})$, 1657 $\nu(\text{C}=\text{N})$, 1598 $\nu[(\text{C}=\text{N})(\text{pyridine})]$, 1491, 1456 $\nu(\text{Ar-C}=\text{C})$, 1118, 624 $\nu(\text{ClO}_4^-)$, 1293, 1243 $\nu(\text{Ar-O})$, 1162, 1041, $\nu(\text{R-O})$, 754 $\nu(\text{Substituted benzene})$, 531 $\nu(\text{Cd-N})$. $\Lambda = 156 \Omega^{-1} \cdot \text{mol}^{-1} \cdot \text{cm}^2$ (in DMSO-DMF (1:1, v:v)). Mass spectra (m/z): 669 $[[\text{CdL}^2](\text{ClO}_4)_2 + \text{H}]^+$.

$[\text{CdL}^3](\text{ClO}_4)_2 \cdot 2\text{H}_2\text{O}$

Yield: 0.57 g (43.3%). Anal Calcd for $\text{CdC}_{23}\text{H}_{21}\text{N}_3\text{O}_{10}\text{Cl}_2 \cdot 2\text{H}_2\text{O}$: C, 41.9, H, 3.8, N, 6.4. Found: C, 42.0, H, 3.9, N, 6.3. ^1H NMR (DMSO- d_6 , δ ppm): $\delta = 2.36$ (t, 4H, $J = 6.2$ Hz) (CH_2), $\delta = 3.43$ (H_2O), $\delta = 4.26$ (t, 4H, $J = 5.4$ Hz, OCH_2), $\delta = 7.02$ – 8.04 (m, 11H, Ar-H), $\delta = 10.38$ (s, 2H, $\text{HC}=\text{N}$). Selected IR data (KBr, $\nu \text{ cm}^{-1}$): 3380 $\nu(\text{H}_2\text{O})$, 3066 $\nu(\text{Ar-CH})$, 2941 $\nu(\text{Alph.-CH})$, 1658 $\nu(\text{C}=\text{N})$, 1598 $\nu[(\text{C}=\text{N})(\text{pyridine})]$, 1488, 1455 $\nu(\text{Ar-C}=\text{C})$, 1286, 1242 $\nu(\text{Ar-O})$, 1161 $\nu(\text{R-O})$, 752 $\nu(\text{Substituted benzene})$, 526 $\nu(\text{Cd-N})$. $\Lambda = 22 \text{ W}^{-1} \cdot \text{mol}^{-1} \cdot \text{cm}^2$ (in DMSO-DMF(1:1, v:v)). Mass spectra (m/z): 684 $[[\text{CdL}^3](\text{ClO}_4)_2]^+$.

$[\text{CdL}^4](\text{ClO}_4)_2 \cdot \text{H}_2\text{O}$

Yield: 0.13 g (9.9%). Anal Calcd for $\text{CdC}_{23}\text{H}_{21}\text{N}_3\text{O}_{11}\text{Cl}_2 \cdot \text{H}_2\text{O}$: C, 42.1, H, 3.5, N, 6.4. Found: C, 42.2, H, 3.6, N, 6.4. ^1H NMR (DMSO- d_6 , δ ppm): $\delta = 3.42$ (H_2O), $\delta = 3.82$ (t, 4H, $J = 5.2$ Hz) (OCH_2), $\delta = 4.34$ (t, 4H, $J = 4.3$ Hz) (CH_2OPh), $\delta = 6.98$ – 8.11 (m, 11H, Ar-H), $\delta = 10.38$ (s, 2H, $\text{HC}=\text{N}$). Selected IR data (KBr, $\nu \text{ cm}^{-1}$): 3382 $\nu(\text{H}_2\text{O})$, 3065

$\nu(\text{Ar-CH})$, 2936 $\nu(\text{Alph.-CH})$, 1649 $\nu(\text{C}=\text{N})$, 1598 $\nu[(\text{C}=\text{N})(\text{pyridine})]$, 1488, 1455 $\nu(\text{Ar-C}=\text{C})$, 1286, 1241 $\nu(\text{Ar-O})$, 1161, 1042 $\nu(\text{R-O})$, 754 $\nu(\text{Substituted benzene})$, 527 $\nu(\text{Cd-N})$. $\Lambda = 155 \Omega^{-1} \cdot \text{mol}^{-1} \cdot \text{cm}^2$ (in DMSO-DMF(1:1, v:v)). Mass spectra (m/z): 585 $[[\text{CdL}^4](\text{ClO}_4)_2 + \text{H}]^+$.

$[\text{CdL}^5](\text{ClO}_4)_2 \cdot 2\text{H}_2\text{O}$

Yield: 0.82 g (57.1%). Anal Calcd for $\text{CdC}_{25}\text{H}_{25}\text{N}_3\text{O}_{12}\text{Cl}_2 \cdot 2\text{H}_2\text{O}$: C, 41.8, H, 4.0, N, 5.9. Found: C, 41.9, H, 4.2, N, 5.9. ^1H NMR (DMSO- d_6 , δ ppm): $\delta = 3.36$ (t, 4H, $J = 5.3$ Hz, H1), $\delta = 3.44$ (H_2O), $\delta = 3.84$ (t, 4H, $J = 4.2$ Hz) (H2), $\delta = 4.26$ (t, 4H, $J = 4.3$ Hz) (H3), $\delta = 7.02$ – 8.00 (m, 11H, Ar-H), $\delta = 10.40$ (s, 2H, $\text{HC}=\text{N}$). Selected IR data (KBr, $\nu \text{ cm}^{-1}$): 3377 $\nu(\text{H}_2\text{O})$, 3067 $\nu(\text{Ar-CH})$, 2937 $\nu(\text{Alph.-CH})$, 1654 $\nu(\text{C}=\text{N})$, 1598 $\nu[(\text{C}=\text{N})(\text{pyridine})]$, 1487, 1452 $\nu(\text{Ar-C}=\text{C})$, 1286, 1242 $\nu(\text{Ar-O})$, 1161 $\nu(\text{R-O})$, 755 $\nu(\text{Substituted benzene})$, 515 $\nu(\text{Cd-N})$. $\Lambda = 179 \Omega^{-1} \cdot \text{mol}^{-1} \cdot \text{cm}^2$ (in DMSO-DMF (1:1, v:v)). Mass spectra (m/z): 546 $[\text{Cd}(\text{L}^5) + \text{H}]^+$.

$[\text{CdL}^1](\text{NO}_3)_2 \cdot 2\text{H}_2\text{O}$

Yield: 0.68 g (61.3%). Anal Calcd for $\text{CdC}_{21}\text{H}_{17}\text{N}_5\text{O}_8 \cdot 2\text{H}_2\text{O}$: C, 45.4, H, 3.8, N, 12.6. Found: C, 45.5, H, 3.8, N, 12.5. ^1H NMR (DMSO- d_6 , δ ppm): 3.40 (H_2O), 4.33 (s, 4H, $-\text{OCH}_2$), 6.95–8.01 (m, 11H, Ar-H), 10.39 (s, 2H, $\text{HC}=\text{N}$). Selected IR data (KBr, $\nu \text{ cm}^{-1}$): 3372 $\nu(\text{H}_2\text{O})$, 3072 $\nu(\text{Ar-CH})$, 2969, 2886 $\nu(\text{Alph.-CH})$, 1652 $\nu(\text{C}=\text{N})$, 1598 $\nu[(\text{C}=\text{N})(\text{pyridine})]$, 1452 $\nu(\text{Ar-C}=\text{C})$, 1162, 653 $\nu(\text{NO}_3^-)$, 1274, 1241 $\nu(\text{Ar-O})$, 1146 $\nu(\text{R-O})$, 752 $\nu(\text{Substituted benzene})$, 531 $\nu(\text{Cd-N})$. $\Lambda_M = 189 \Omega^{-1} \cdot \text{mol}^{-1} \cdot \text{cm}^2$ (in DMSO-DMF (1:1, v:v)). Mass spectra (m/z): 579 $[\text{CdL}^1(\text{NO}_3)_2]^+$.

[CdL²](NO₃)₂·2H₂O

Yield: 0.85 g (74.53%). Anal Calcd for CdC₂₂H₁₉N₅O₈·2H₂O: C, 46.40, H, 4.04, N, 12.30. Found: C, 46.54, H, 4.11, N, 12.32. ¹H NMR (DMSO-*d*₆, δ ppm): δ = 2.34 (t, 2H, J = 5.5 Hz) (CH₂), δ = 3.42 (H₂O), δ = 4.28 (t, 4H, J = 6.0 Hz) (OCH₂), δ = 6.99-8.02 (m, 11H, Ar-H), δ = 10.42 (s, 2H, HC=N). Selected IR data (KBr, ν cm⁻¹): 3378 ν(H₂O), 3076 ν(Ar-CH), 2961, 2886 ν(Alph.-CH), 1658 ν(C=N), 1598 ν[(C=N)(pyridine)], 1488, 1452 ν(Ar-C=C), 1161, 651 ν(NO₃⁻), 1292, 1242 ν(Ar-O), 1162, 1046 ν(R-O), 752 ν(Substituted benzene), 536 ν(Cd-N). Λ = 138 Ω⁻¹·mol⁻¹·cm² (in DMSO-DMF (1:1, v:v)). Mass spectra (*m/z*): 594 [CdL²(NO₃)₂+H]⁺.

[CdL³](NO₃)₂·H₂O

Yield: 0.69 g (61.1%). Anal Calcd for CdC₂₃H₂₁N₅O₈·H₂O: C, 48.9, H, 4.1, N, 12.4. Found: C, 49.0, H, 4.2, N, 12.3. ¹H NMR (DMSO-*d*₆, δ ppm): δ = 2.39 (t, 4H, J = 5.7 Hz) (CH₂), δ = 3.46 (H₂O), δ = 4.25 (t, 4H, J = 5.4 Hz, OCH₂), δ = 7.00-8.06 (m, 11H, Ar-H), δ = 10.39 (s, 2H, HC=N). Selected IR data (KBr, ν cm⁻¹): 3382 ν(H₂O), 3076 ν(Ar-CH), 2944 ν(Aliph.-CH), 1654 ν(C=N), 1598 ν[(C=N)(pyridine)], 1486, 1452 ν(Ar-C=C), 1286, 1241 ν(Ar-O), 1161 ν(R-O), 754 ν(Substituted benzene), 524 ν(Cd-N). Λ = 194 Ω⁻¹·mol⁻¹·cm² [in DMSO-DMF (1:1, v:v)]. Mass spectra (*m/z*): 607 [{CdL³(NO₃)₂}]⁺.

[CdL⁴](NO₃)₂·3H₂O

Yield: 0.67 g (54.3%). Anal Calcd for CdC₂₃H₂₁N₅O₈·3H₂O: C, 44.7, H, 4.4, N, 11.3. Found: C, 44.8, H, 4.3, N, 11.4. ¹H NMR (DMSO-*d*₆, δ ppm): δ = 3.46 (H₂O), δ = 3.81 (t, 4H, J = 4.8 Hz) (OCH₂), δ = 4.26 (t, 4H, J = 5.0 Hz) (CH₂OPh), δ = 6.97-8.04 (m, 11H, Ar-H), δ = 10.40 (s, 2H, HC=N). Selected IR data (KBr, ν cm⁻¹): 3375 ν(H₂O), 3066 ν(Ar-CH),

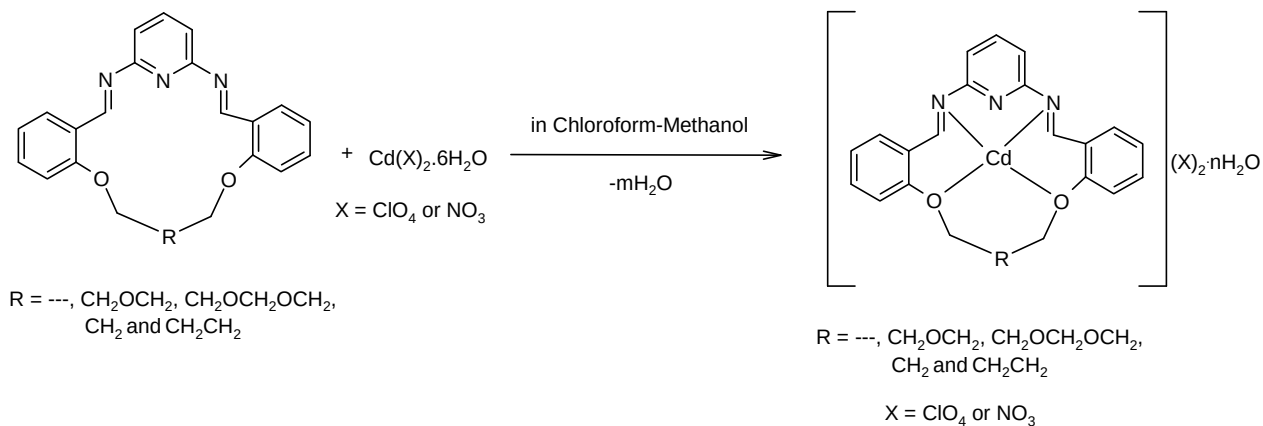
2937 ν(Aliph.-CH), 1655 ν(C=N), 1598 ν[(C=N)(pyridine)], 1487, 1451 ν(Ar-C=C), 1286, 1242 ν(Ar-O), 1159 ν(R-O), 754 ν (Substituted benzene), 529 ν(Cd-N). Λ = 131 Ω⁻¹·mol⁻¹·cm² (in DMSO-DMF (1:1, v:v)). Mass spectra (*m/z*): 562 [CdL⁴(NO₃)₂]⁺.

[CdL⁵](NO₃)₂·2H₂O

Yield: 0.82 g (63.8%). Anal Calcd for CdC₂₅H₂₅N₅O₈·2H₂O: C, 46.7, H, 4.5, N, 10.9. Found: C, 46.8, H, 4.6, N, 10.8. ¹H NMR (DMSO-*d*₆, δ ppm): δ = 3.24 (t, 4H, J = 5.1 Hz, H1), δ = 3.48 (H₂O), δ = 3.83 (t, 4H, J = 5.5 Hz) (H2), δ = 4.26 (t, 4H, J = 5.4 Hz) (H3), δ = 7.00-8.06 (m, 11H, Ar-H), δ = 10.44 (s, 2H, HC=N). Selected IR data (KBr, ν cm⁻¹): 3376 ν (H₂O), 3071 ν (Ar-CH), 2938 ν (Aliph.-CH), 1658 ν (C=N), 1598 ν [(C=N)(pyridine)], 1488, 1450 ν (Ar-C=C), 1288, 1243 ν (Ar-O), 1161 ν (R-O), 752 ν (Substituted benzene), 535 ν(Cd-N). Λ = 173 Ω⁻¹·mol⁻¹·cm² [in DMSO-DMF (1:1, v:v)]. Mass spectra (*m/z*): 546 [CdL⁵+H]⁺.

Results and discussion

We have found during the present investigations that during the reaction of the Schiff base macrocyclic ligands (dissolved in chloroform) with cadmium(II) perchlorate or cadmium(II) nitrate (dissolved in methanol), the [1+1] macrocycle Schiff-base complexes are formed. The macrocyclic complexes were characterized by elemental analysis, mass, IR and UV-vis spectrometry and conductivity measurements. The mass spectra of complexes play an important role in confirming the monomeric [1+1] (ligands and metal salt) nature of complexes. On the bases of the spectral studies, four-coordinated tetrahedral geometry may be assigned to these complexes (Scheme 2). The ligand is soluble in

**Scheme 2**

DMSO, DMF, CHCl_3 , CH_2Cl_2 and CH_3CN but insoluble H_2O , EtOH and MeOH. The complexes are stable in air, partly soluble in DMF, DMSO and insoluble in CHCl_3 , CH_2Cl_2 and CH_3CN . The crystals were unsuitable for single-crystal X-ray structure determination and are insoluble in most common solvents, including water, ethanol, ethyl acetate, and acetonitrile.

IR of Cd(II) complexes were recorded in KBr pellet from 4000 to 400 cm^{-1} . The IR spectra of all complexes show $\nu(\text{C}=\text{N})$ bands at 1650-1665 cm^{-1} and it is found that the $\nu(\text{C}=\text{N})$ bands in the complexes shift by about *ca.* 30 cm^{-1} to lower energy regions compared to that in the free ligand (L)²⁵. This phenomenon appears to be due to the coordination of azomethine nitrogen to the metal ion²⁶. The broad bands in the range 3380-3370 cm^{-1} for all Cd(II) complexes can be attributed to stretching vibrations of water molecule $\nu(\text{H}_2\text{O})$ ²⁷. The spectra of all the Cd(II) metal complexes are dominated by bands between 2960-2890 cm^{-1} due to $\nu(\text{Alph.}-\text{CH})$ groups. Also, IR spectra of the Cd(II) complexes exhibit an intense band at 1183-1111 cm^{-1} and a weak band between 649-624 cm^{-1} which are due to $\nu(\text{Cl}-\text{O})$ of uncoordinated perchlorate anions²⁸. The absorption of the nitrate counterions, at *ca.* 1460- 1452(ν_5), 1300 (ν_1) and 1040 (ν_2) cm^{-1} suggest the presence of bidentate nitrate groups. An intense band at 1384 cm^{-1} is attributed to the presence of the ionic nitrate²⁹. The stretching vibrations $\nu(\text{Ar}-\text{C}=\text{C})$ show very strong band in the 1494-1489 and 1458-1456 cm^{-1} range³⁰. Conclusive evidence of the bonding is also shown by the observation that new bands in the IR spectra of the Cd(II) complexes appear at 510-530 cm^{-1} assigned to $\nu(\text{Cd}-\text{N})$ and 460-505 cm^{-1} assigned to $\nu(\text{Cd}-\text{O})$ stretching vibrations³¹. A band appearing in the 1598 cm^{-1} region was assigned to $\nu(\text{C}=\text{N})_{(\text{pyridine})}$ mode, and discharged in the ligands and complexes^{25,27,29}.

The electronic spectra of Cd(II) complexes in DMSO-DMF show three peaks in the visible-ultraviolet region. The absorption bands at *ca.* 270 nm are practically identical and can be attributed to $\pi \rightarrow \pi^*$ transitions in the benzene ring and azomethine ($-\text{C}=\text{N}$) groups. The absorption bands observed within the 320-380 nm range are likely due to the transitions of $n \rightarrow \pi^*$ of imine groups³².

^1H NMR spectra of the complexes in DMSO- d_6 solution show that they are NMR active. However, ^{13}C NMR of the complexes could not be obtained because of the low solubility degree of the complexes in common solvents. The ^1H NMR spectra

of the free ligands showed a singlet at *ca.* 10.4 ppm due to the imine protons, multiplied in the range *ca.* 7.0-8.0 ppm due to the aromatic protons, and H_2O proton at *ca.* 3.4 ppm. The other entire proton values are also shown in the experimental section. The ^1H NMR spectra of the complexes exhibited almost the same values as that of the ligand. Although we expected a shift on the position of $\text{CH}=\text{N}$ signal for the NMR spectra of the complexes, no significant shift could not be observed^{25,27,28,32}.

The molar conductivities of the compounds in DMSO-DMF (1:1, v:v) are range 131-194 $\Omega^{-1}\text{mol}^{-1}\text{cm}^2$ reported for 1:2 electrolytes^{25,27,28,32}.

The mass spectra of the complexes play an important role in conforming the monomeric [1+1] (dicarbonyl and diamine) nature of the complexes.

The fragmentation mass spectra of the complexes are described below:

$[\text{CdL}^1] (\text{ClO}_4)_2 \cdot \text{H}_2\text{O}$ — 79 ($[\text{C}_6\text{H}_6+\text{H}]^+$, 7.2%), 101 (C_7NH_3^+ , 100%), 103 (C_7NH_5^+ , 4.7%), 112 (Cd^{+2} , 1.3%), 179 ($\text{C}_{12}\text{N}_2\text{H}_7^+$, 12.9%), 339 ($[\text{L}-4\text{H}]^+$, 3.8%), 341 ($[\text{L}-2\text{H}]^+$, 6.1%), 342 ($[\text{L}-\text{H}]^+$, 13.4%), 343 ($[\text{L}]^+$, 17.1%), 454 ($[\text{CdL}^1-\text{H}]^+$, 7.7%), 455 ($[\text{CdL}^1]^+$, 14.9%), 553 ($[[\text{CdL}^1] (\text{ClO}_4)-\text{H}]^+$, 4.9%), 554 ($[[\text{CdL}^1] (\text{ClO}_4)]^+$, 8.6%), 654 ($[[\text{CdL}^1] (\text{ClO}_4)_2]^+$, 17.1%); $[\text{CdL}^2] (\text{ClO}_4)_2 \cdot 2\text{H}_2\text{O}$ — 79 ($[\text{C}_6\text{H}_6+\text{H}]^+$, 9.2%), 101 (C_7NH_3^+ , 100%), 103 (C_7NH_5^+ , 4.7%), 179 ($\text{C}_{12}\text{N}_2\text{H}_7^+$, 8.2%), 356 ($[\text{L}^2-\text{H}]^+$, 29.4%), 357 ($[\text{L}^2]^+$, 61.5%), 468 ($[\text{CdL}^2-\text{H}]^+$, 4.3%), 469 ($[\text{CdL}^2]^+$, 18.3%), 568 ($[[\text{CdL}^2] (\text{ClO}_4)]^+$, 14.7%), 569 ($[[\text{CdL}^2] (\text{ClO}_4)+\text{H}]^+$, 6.3%), 668 ($[[\text{CdL}^2] (\text{ClO}_4)_2]^+$, 10.7%); $[\text{CdL}^3] (\text{ClO}_4)_2 \cdot 2\text{H}_2\text{O}$ — 79 ($[\text{C}_6\text{H}_6+\text{H}]^+$, 8.6%), 101 (C_7NH_3^+ , 100.0%), 103 (C_7NH_5^+ , 5.2%), 179 ($\text{C}_{12}\text{N}_2\text{H}_7^+$, 5.9%), 370 ($[\text{L}^3-\text{H}]^+$, 4.1%), 372 ($[\text{L}^3+\text{H}]^+$, 2.6%), 399 ($[\text{L}^3, 1.5\text{H}_2\text{O}+\text{H}]^+$, 77.6%), 486 ($[\text{CdL}^3+\text{H}]^+$, 3.4%), 583 ($[[\text{CdL}^3] (\text{ClO}_4)-\text{H}]^+$, 4.3%), 585 ($[[\text{CdL}^3] (\text{ClO}_4)]^+$, 16.2%), 684 ($[[\text{CdL}^3] (\text{ClO}_4)_2]^+$, 1.7%); $[\text{CdL}^4] (\text{ClO}_4)_2 \cdot \text{H}_2\text{O}$ — 79 ($[\text{C}_6\text{H}_6+\text{H}]^+$, 13.1%), 101 (C_7NH_3^+ , 100%), 103 (C_7NH_5^+ , 12.1%), 179 ($\text{C}_{12}\text{N}_2\text{H}_7^+$, 14.3%), 386 ($[\text{L}-\text{H}]^+$, 15.4%), 387 ($[\text{L}]^+$, 29.6%), 388 ($[\text{L}+\text{H}]^+$, 13.7%), 442 ($[\text{CdL}^4]^+$, 31.9%), 443 ($[\text{CdL}^4+\text{H}]^+$, 14.9%), 541 ($[[\text{CdL}^4] (\text{ClO}_4)-\text{H}]^+$, 7.9%), 585 ($[[\text{CdL}^4] (\text{ClO}_4)+\text{H}]^+$, 6.3%); $[\text{CdL}^5] (\text{ClO}_4)_2 \cdot 2\text{H}_2\text{O}$ — 79 ($[\text{C}_6\text{H}_6+\text{H}]^+$, 15.3%), 101 (C_7NH_3^+ , 100%), 103 (C_7NH_5^+ , 17.7%), 179 ($\text{C}_{12}\text{N}_2\text{H}_7^+$, 9.3%), 429 ($[\text{L}-2\text{H}]^+$, 5.7%), 430 ($[\text{L}-\text{H}]^+$, 11.1%), 432 ($[\text{L}+\text{H}]^+$, 4.5%), 544 ($[\text{CdL}^5-\text{H}]^+$, 3.7%), 545 ($[\text{CdL}^5]^+$, 13.6%), 546 ($[\text{CdL}^5+\text{H}]^+$, 2.1%); $[\text{CdL}^1] (\text{NO}_3)_2 \cdot 2\text{H}_2\text{O}$ — 79 ($[\text{C}_6\text{H}_6+\text{H}]^+$, 22.4%), 101 (C_7NH_3^+ , 43.1%), 103 (C_7NH_5^+ , 16.3%), 179 ($\text{C}_{12}\text{N}_2\text{H}_7^+$, 7.9%), 339

([L-4H]⁺, 3.4%), 341 ([L-2H]⁺, 13.4%), 342 ([L-H]⁺, 25.4%), 343 ([L]⁺, 53.4%), 454 ([CdL¹-H]⁺, 5.3%), 455 ([CdL¹]⁺, 100%), 456 ([CdL¹+H]⁺, 37.9%), 516 ([CdL¹ (NO₃)-H]⁺, 21.4%), 517 ([CdL¹ (NO₃)⁺, 9.3%), 579 ([CdL¹ (NO₃)₂]⁺, 8.1%), 580 ([CdL¹ (NO₃)₂+H]⁺, 20.5%); [CdL² (NO₃)₂·2H₂O — 79 ([C₆H₆+H]⁺, 22.4%), 101 (C₇NH₃⁺, 100%), 103 (C₇NH₅⁺, 16.3%), 179 (C₁₂N₂H₇⁺, 7.9%), 356 ([L²-H]⁺, 56.4%), 357 ([L²]⁺, 23.1%), 469 ([CdL²]⁺, 34.7%), 470 ([CdL²+H]⁺, 17.2%), 531 ([CdL² (NO₃)⁺, 6.1%), 593 ([CdL² (NO₃)₂]⁺, 4.3%), 594 ([CdL² (NO₃)₂+H]⁺, 3.9%); [CdL³ (NO₃)₂·H₂O — 79 ([C₆H₆+H]⁺, 15.7%), 101 (C₇NH₃⁺, 21.6%), 103 (C₇NH₅⁺, 13.2%), 179 (C₁₂N₂H₇⁺, 23.7%), 369 ([L³-2H]⁺, 17.4%), 370 ([L³-H]⁺, 27.3%), 371 ([L³]⁺, 59.7%), 481 ([CdL³-2H]⁺, 5.3%), 482 ([CdL³-H]⁺, 37.5%), 483 ([CdL³]⁺, 100%), 544 ([CdL³ (NO₃)-H]⁺, 10.3%), 545 ([CdL³ (NO₃)⁺, 21.2%), 546 ([CdL³ (NO₃)+H]⁺, 3.7%), 605 ([CdL³ (NO₃)₂-2H]⁺, 29.8%), 607 ([CdL³ (NO₃)₂]⁺, 18.1%); [CdL⁴ (NO₃)₂·3H₂O — 79 ([C₆H₆+H]⁺, 13.1%), 101 (C₇NH₃⁺, 100%), 103 (C₇NH₅⁺, 9.1%), 179 (C₁₂N₂H₇⁺, 5.3%), 386 ([L-H]⁺, 14.7%), 387 ([L]⁺, 23.8%), 388 ([L+H]⁺, 10.7%), 499 ([CdL⁴]⁺, 13.2%), 561 ([CdL⁴ (NO₃)-H]⁺, 4.9%), 562 ([CdL⁴ (NO₃)⁺, 17.3%), 563 ([CdL⁴ (NO₃)+H]⁺, 41.3%); and [CdL⁵ (NO₃)₂·2H₂O — 79 ([C₆H₆+H]⁺, 15.3%), 101 (C₇NH₃⁺, 100%), 103 (C₇NH₅⁺, 17.7%), 179 (C₁₂N₂H₇⁺, 9.3%), 429 ([L-2H]⁺, 5.7%), 430 ([L-H]⁺, 11.1%), 432 ([L+H]⁺, 4.5%), 545 ([CdL⁵]⁺, 13.6%), 546 ([CdL⁵+H]⁺, 2.1%).

References

- Raman N & Thangaraja C, *Trans Metal Chem*, 30 (2005) 317.
- Castillo-Blum S E & Barbu-Behrens N, *Coord Chem Rev*, 196 (2000) 3.
- Chandra S, Sharma S D & Kumar U, *Synth React Inorg Met - Org Chem*, 34 (2004) 79.
- Izatt R M, Pawlak K & Bradshaw J S, *Chem Rev*, 95 (1995) 2529.
- Khandar A A, Hosseini-Yazdi S A, Khatamian M, McArdle P & Zarei S A, *Polyhedron*, 26 (2007) 33.
- Vance A L, Alcock N W, Busch D H & Heppert J A, *Inorg Chem*, 36 (1997) 5132.
- Choi K Y, Lee H Y, Park B, Kim J H, Kim J, Kim M W & Ryu J W, *Polyhedron*, 20 (2001) 2003.
- Hambley T W, Lindoy L F, Reimers J R, Turner P, Wei W & Cooper A N, *J Chem Soc, Dalton Trans*, (2001) 614.
- Chandra S & Gupta L K, *J Saudi Chem Soc*, 8 (2004) 85; Gao E Q, Sun H Y, Liao D Z, Jiang Z H & Yan S P, *Polyhedron*, 21 (2002) 359.
- Fenton D E, Gauci R, Junk P C, Lindoy L F, Luckay R C, Meehan G V, Price J R, Turner P & Wei G, *J Chem Soc Dalton Trans*, 2185 (2002).
- Chandra S & Gupta K, *Trans Metal Chem*, 27 (2002) 196.
- Chandra S, Jain D & Gupta L K, *J Saudi Chem Soc*, 7 (2003).
- Chandra S & Gupta L K, *Spectrochim Acta Part A*, 62 (2005) 307.
- Bradshaw J S, Maas G E & Lamb J D, *J Am Chem Soc*, 102 (1980) 467.
- Kimura E, Daloimunte C A, Yamashita A & Machida R, *J Chem Soc Chem Commun*, 1041 (1985).
- Kim K S, Lee E K & Kim K, *Supramol Chem*, 54 (1999) 5575.
- Bencheikroun K R, Tisnes C P & Cataux L, *J Incl Phen Mol Recogn*, 415 (1999) 33.
- Adam K R, Lindoy L F, Lip H C, Smith R J & Baker J T, *Aust J Chem*, 30 (1977) 2095.
- Nezhadali A, *J Incl Phenom Macrocyc Chem*, 54 (2006) 307.
- Lee S S, Yoon I, Park K M, Jung J H, Lindoy L F, Nezhadali A & Rounaghi G, *J Chem Soc Dalton Trans*, 2180 (2002).
- Kim J, Leong A J, Lindoy L F, Kim J, Nachbaur J, Nezhadali A, Rounaghi G & Wei G, *J Chem Soc Dalton Trans*, 3453 (2000).
- Fainerman-Melnikova M F, Lindoy L F, Liou S Y, McMurtrie J C, Green N P, Nezhadali A, Rounaghi G & Setzer W N, *Aust J Chem*, 57 (2004) 161.
- Fainerman-Melnikova M, Nezhadali A, Rounaghi G, McMurtrie J C, Kim J, Gloe K, Langer M, Lee S S, Lindoy L F, Nishimura T, Park K M & Seo J, *J Chem Soc, Dalton Trans*, 122 (2004).
- Temel H & İlhan S, *Russian J Coord Chem*, 33(12), (2007) 914.
- İlhan S, Temel H, Yılmaz İ & Şekerci M, *Polyhedron*, 12 (2007) 2795.
- Cakır Ü, Temel H, İlhan S & Ugras H İ, *Spectroscopy Lett*, 36 (5-6), (2003) 429.
- İlhan S, Temel H, Yılmaz İ & Kılıç A, *Trans Metal Chem*, 32 (2007) 3.
- İlhan S, Temel H, Yılmaz İ & Şekerci M, *J Org Chem*, 692 (2007) 3855.
- İlhan S, Temel H, Kılıç A & Taş E, *Trans Metal Chem*, 32 (2007) 1012.
- Temel H, Hoşgören H & Boybay M, *Spectroscopy Lett*, 34 (5) (2001) 1.
- İlhan S & Temel H, *Trans Metal Chem*, 32 (2007) 1039.
- İlhan S, Temel H, Ziyadanoğulları R & Şekerci M, *Trans Metal Chem*, 32 (2007) 584.