Polyhedron 30 (2011) 2790–2794

Contents lists available at SciVerse ScienceDirect

Polyhedron

journal homepage: www.elsevier.com/locate/poly

Synthesis and spectral characterization of mercury(II) complexes with the bidentate Schiff base ligand *N*,*N*′-bis(2,3-dimethoxybenzylidene)-1,2-diaminoethane: The crystal structures of [Hg((23-MeO-ba)$_2$en)I$_2$] and [Hg((23-MeO-ba)$_2$en)Br$_2$]

Aliakbar Dehno Khalaji [a,*], Gholamhossein Grivani [b], Morteza Rezaei [b], Karla Fejfarova [c], Michal Dusek [c]

[a] *Department of Chemistry, Faculty of Science, Golestan University, Gorgan, Iran*
[b] *School of Chemistry, Damghan University, P.O. Box 36715-364, Damghan, Iran*
[c] *Institute of Physics of the ASCR, v.v.i., Na Slovance 2, 182 21 Prague 8, Czech Republic*

ARTICLE INFO

Article history:
Received 8 June 2011
Accepted 7 August 2011
Available online 31 August 2011

Keywords:
Mercury(II) complexes
Schiff base
Spectroscopy
X-ray crystallography
Tetrahedral

ABSTRACT

Three mercury(II) complexes, [Hg((23-MeO-ba)$_2$en)X$_2$] (X = I (**1**), Br (**2**) and Cl(**3**)), and the ligand (23-MeO-ba)$_2$en ((23-MeO-ba)$_2$en = *N*,*N*′-bis(2,3-dimethoxybenzylidene)-1,2-diaminoethane) have been synthesized and characterized by elemental analyses, FT-IR and ^{1}H NMR spectroscopy. The crystal and molecular structures of **1** and **2** were determined by X-ray crystallography from single-crystal data. The metal-to-ligand ratio was found to be 1:1. The mercury(II) center in **1** and **2** has a distorted tetrahedral geometry with HgN$_2$I$_2$ and HgN$_2$Br$_2$ chromophores, respectively. The Schiff base ligand (23-MeO-ba)$_2$en acts as a chelating ligand, coordinating via the two nitrogen atoms to the mercury(II) center, and it adopts an *E*,*E* conformation. The coordination sphere of the mercury(II) center in **1** and **2** is completed by the two I and Br atoms, respectively. In complex **1** an inter-molecular non-classical hydrogen bond of the type C–H···O was found, while in complex **2** inter- and intra-molecular non-classical hydrogen bonds of the type C–H···X (X = O and Br) were found. The ^{1}H NMR spectra of the complexes exhibit downfield as well as upfield shifts of the free ligand resonances, reflecting changes in the ligand's geometry during its coordination.

1. Introduction

Schiff base ligands have been connected with the progress of coordination chemistry since the late 19th century. They have played a major role in the development of complexes, providing the effects of steric interactions on coordination geometries [1–7]. Schiff base transition metal complexes have good ability to reversibly bind oxygen in epoxidation reactions, interesting biological properties, a catalytic role in the hydrogenation of olefins and remarkable photochromic properties [8–13]. Recent interest in the coordination chemistry of the group XII metals, with a stable d^{10} electron configuration, has concentrated on complexes of Zn and Cd with bidentate Schiff base ligands [1–3,14–25]. There is also a substantial interest in the coordination chemistry of mercury(II) because of its toxic environmental effects. In a continuation of our studies on fourfold coordinated complexes of the group XII metals with bidentate Schiff base ligands [15,26,27], we describe herein the synthesis and spectral characterization of three mercury(II) complexes, [Hg((23-MeO-ba)$_2$en)X$_2$] (X = I (**1**), Br (**2**) and Cl(**3**)) where (23-MeO-ba)$_2$en represents the *N*,*N*′-bis(2,3-dimethoxybenzylidene)-1,2-diaminoethane ligand (Scheme 1). For [Hg((23-MeO-ba)$_2$en)I$_2$] (**1**) and [Hg((23-MeO-ba)$_2$en)Br$_2$] (**2**), crystal structures are presented.

2. Experimental

2.1. Materials and methods

All organic solvents were commercially available and were used as received without further purification. The 2,3-dimethoxybenzaldehyde, ethane-1,2-diamine, HgI$_2$, HgBr$_2$ and HgCl$_2$ were purchased from Merck Chemical Company. Fourier Transform Infrared spectra were recorded as a KBr disk on a FT-IR Perkin–Elmer spectrophotometer. Elemental analyses were carried out using a Heraeus CHN-O-Rapid analyzer. ^{1}H NMR spectra were measured on a BRUKER DRX-500 AVANCE spectrometer at 500 MHz for the Schiff-base ligands and its complexes. All chemical shifts are reported in δ units downfield from TMS.

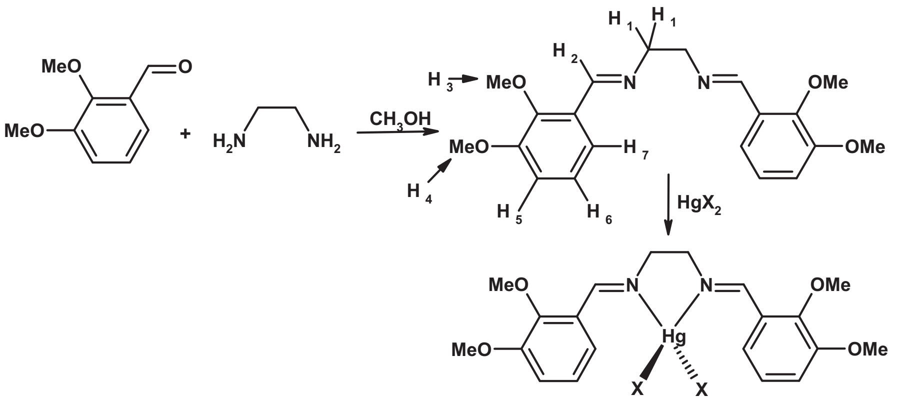
2.2. Preparation of (23-MeO-ba)$_2$en

(23-MeO-ba)$_2$en was prepared by condensation of 2,3-dimethoxybenzaldehyde with ethane-1,2-diamine following methods

---

[*] Corresponding author. Tel./fax: +98 171 4427050.
E-mail addresses: alidkhalaji@yahoo.com, ad.khalaji@gu.ac.ir (A.D. Khalaji).

0277-5387/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.poly.2011.08.024



Scheme 1. Synthesis of the mercury(II) complexes [Hg((23-MeO-ba)$_2$en)X$_2$], X = I (**1**), Br (**2**) and Cl(**3**). Hydrogen atoms important for discussion of NMR spectra are indicated.

Table 1
Crystallographic data and structure refinement for **1** and **2**.

	1	2
Empirical formula	$C_{20}H_{24}N_2O_4HgI_2$	$C_{20}H_{24}N_2O_4HgBr_2$
Formula weight	810.8	716.8
Crystal system	monoclinic	monoclinic
Space group	$C2/c$	$P2_1/c$
T (K)	120	150
a (Å)	29.4352(15)	15.1569(3)
b (Å)	7.1690(3)	15.6692(2)
c (Å)	12.3260(5)	9.8671(2)
β (°)	110.896(5)	105.957(2)
V (Å^3)	2430.0(2)	2253.11(7)
Z	4	4
μ (mm^{-1})	8.9	10.43
T_{min}	0.228	0.121
T_{max}	0.537	0.581
Measured reflections	18 033	32 584
Independent reflections	3115	4604
Parameters	132	262
Reflection with $I > 3\sigma(I)$	2370	3845
θ_{max} (°)	29.34	26.4
R_{int}	0.042	0.043
S	1.06	1.20
$R[F^2 > 2\sigma(F^2)]$	0.028	0.021
$wR(F^2)$	0.081	0.048
$\Delta\rho_{max}$ (e Å^{-3})	0.94	0.72
$\Delta\rho_{min}$ (e Å^{-3})	−0.56	−0.39
Crystal size (mm)	0.28 × 0.23 × 0.10	0.40 × 0.16 × 0.07

Table 2
Selected bond distances (Å) and angles (°) of **1** and **2.**

1			
Hg1–I1	2.6556(4)	N1–C1	1.473(7)
Hg1–I1^i	2.6556(4)	N1–C2	1.262(8)
Hg1–N1	2.398(4)	C1–C1^i	1.509(9)
Hg1–N1^i	2.398(4)		
I1–Hg1–I1^i	134.547(14)	I1^i–Hg1–N1	103.45(9)
I1–Hg1–N1	112.64(9)	I1^i–Hg1–N1^i	112.64(9)
I1–Hg1–N1^i	103.45(9)	N1–Hg1–N1^i	73.90(16)
Hg1–N1–C2	131.6(3)	Hg1–N1–C1	108.9(3)
N1–C1–C1^i	109.7(4)	N1–C2–C3	124.7(4)
C1–N1–C2	117.9(4)		
2			
Hg1–Br1	2.5067(4)	N1–C2	1.265(4)
Hg1–N1	2.351(2)	C1–C11	1.510(5)
Hg1–Br2	2.5050(4)	N2–C11	1.464(4)
Hg1–N2	2.410(2)	N2–C12	1.271(4)
N1–C1	1.464(4)		
Br1–Hg1–Br2	126.629(12)	Hg1–N2–C11	104.18(16)
Br1–Hg1–N1	111.22(6)	Hg1–N2–C12	138.6(2)
Br2–Hg1–N1	111.89(7)	N1–C1–C11	110.1(3)
N1–Hg1–N2	75.95(8)	N1–C2–C3	124.6(3)
Br1–Hg1–N2	110.63(7)	C1–N1–C2	117.9(3)
Br2–Hg1–N2	119.12(6)	N2–C11–C1	110.0(3)
Hg1–N1–C1	107.73(17)	N2–C12–C13	126.4(3)
Hg1–N1–C2	133.5(2)	C11–N2–C12	117.2(2)

Symmetry codes: (i) −x + 1, y, −z + ½.

described in [28]. A solution of 2,3-dimethoxybenzaldehyde (3.30 g, 0.02 mol) in 25 ml methanol was heated for 15 min at 50 °C and then stirred for about 15 min. To this stirring solution, a solution of ethane-1,2-diamine (0.6 g, 0.01 mol) in 15 ml methanol was added dropwise under constant stirring. The mixture was heated at about 50 °C for 1.5 h and then allowed to cool overnight at 273 K. The resulting crude solid was collected by filtration and dried at room temperature. Crystals were grown by the slow evaporation technique at room temperature in 25 ml methanol as a solvent over 5 days. At the period of super saturation, tiny crystals were nucleated. They were allowed to grow to the maximum possible dimensions and then filtered. Yield: 3.03 g, 85%. Colorless crystals. *Anal.* Calc. for $C_{20}H_{24}N_2O_4$: C, 67.42; H, 6.74; N, 7.86. Found: C, 67.35; H, 6.69; N, 7.79%. IR (KBr pellet, cm^{-1}): 2830–3010 (m, C–H aromatic and aliphatic), 1639 (s, C=N). ^{1}H NMR ($CDCl_3$, δ (ppm)): 3.76 (s, 6H$_3$), 3.84 (s, 6H$_4$), 3.99 (s, 4H$_1$), 6.91 (dd, 2H$_7$), 7.02 (t, 2H$_6$), 7.51 (dd, 2H$_5$), 8.64 (s, 2H$_2$).

2.3. Preparation of [Hg((23-MeO-ba)$_2$en)I$_2$] (1)

To a stirring solution of the (23-MeO-ba)$_2$en ligand (0.071 g, 0.2 mmol) in 5 ml of chloroform was added HgI_2 (0.091 g, 0.2 mmol) in 10 ml of methanol. The mixture was stirred for 10 min in air at room temperature and then left at room temperature for several days without disturbance, yielding suitable crystals of **1**. They were filtered off and washed with Et_2O. Yield: 75%. Colorless crystals. *Anal.* Calc. for $C_{20}H_{24}N_2O_4HgI_2$: C, 29.63; H, 2.98; N, 3.45. Found: C, 29.44; H, 2.8; N, 3.49%. IR (KBr pellet, cm^{-1}): 2840–3002 (m, C–H aromatic and aliphatic), 1651 (s, C=N). ^{1}H NMR ($CDCl_3$, δ (ppm)): 3.66 (s, 6H$_3$), 3.79 (s, 6H$_4$), 3.88 (s, 4H$_1$), 7.05 (t, 2H$_6$), 7.10 (dd, 2H$_7$), 7.39 (dd, 2H$_5$), 8.54 (s, 2H$_2$).

2.4. Preparation of [Hg((23-MeO-ba)$_2$en)Br$_2$] (2)

This complex was prepared in a similar manner to **1** using $HgBr_2$. Yield: 68%. Colorless crystals. *Anal.* Calc. for $C_{20}H_{24}N_2O_4HgBr_2$: C, 33.51; H, 3.37; N, 3.90. Found: C, 33.48; H, 3.31; N, 3.85%. IR (KBr pellet, cm^{-1}): 2832–3012 (m, C–H aromatic and aliphatic), 1631 (s, C=N). ^{1}H NMR ($CDCl_3$, δ (ppm)): 3.67 (s, 6H$_3$), 3.80 (s, 6H$_4$), 3.89 (s, 4H$_1$), 7.06 (t, 2H$_6$), 7.11 (dd, 2H$_7$), 7.40 (dd, 2H$_5$), 8.58 (s, 2H$_2$).

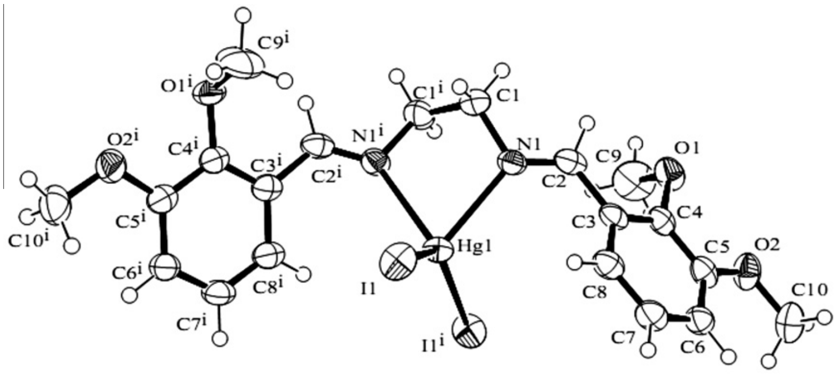


Fig. 1. The molecular structure of **1**, showing 50% probability displacement ellipsoids and the atom-numbering.

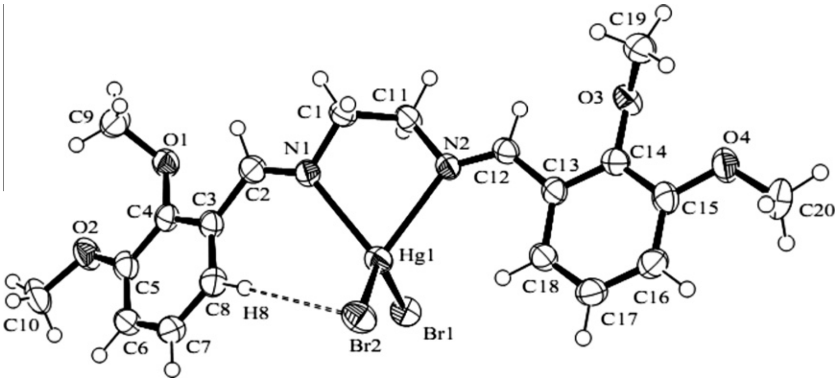


Fig. 2. The molecular structure of **2**, showing 50% probability displacement ellipsoids and the atom-numbering. The dashed line indicates a non-classical C–H···Br hydrogen bond.

Table 3
Inter-molecular non-classical hydrogen bond in complex **1**.

D–H···A	D–H (Å)	H···A (Å)	D···A (Å)	D–H···A (°)
C10–H10b···O1	0.96	2.55	3.496(7)	168

2.5. Preparation of [Hg((23-MeO-ba)$_2$en)Cl$_2$] (3)

This complex was prepared in a similar manner to **1** using $HgCl_2$. Yield: 68%. Colorless micro-crystals. *Anal.* Calc. for $C_{20}H_{24}N_2O_4HgCl_2$: C, 38.25; H, 3.85; N, 4.46. Found: C, 37.83; H, 3.64; N, 4.43%. IR (KBr pellet, cm^{-1}): 2836 (s, CH=N), 2862–3037 (m, C–H aromatic and aliphatic), 1631 (s, C=N). ^{1}H NMR ($CDCl_3$, δ (ppm)): 3.66 (s, 6H$_3$), 3.79 (s, 6H$_4$), 3.89 (s, 4H$_1$), 7.06 (t, 2H$_6$), 7.11 (dd, 2H$_7$), 7.40 (dd, 2H$_5$), 8.57 (s, 2H$_2$).

2.6. Crystallography data collection and refinement

Single crystal of dimensions 0.28 × 0.23 × 0.10 mm of **1**, and 0.40 × 0.16 × 0.07 mm of **2** were chosen for the X-ray diffraction study. Crystallographic measurements were done at 120 K for **1** and 150 K for **2** with a four circle CCD Gemini diffractometer of Oxford diffraction, Ltd., using graphite-monochromated Mo Kα radiation (λ = 0.71069 Å), with a Mo-enhance fiber optics collimator and Atlas CCD detector. The crystal structures were solved by direct methods with the program SIR2002 [29] and refined with the JANA2006 program package [30] by the full-matrix least-squares technique on F^2. The molecular structure plots were prepared by ORTEP III [31]. Hydrogen atoms were mostly discernible in the difference Fourier maps and could be refined to a reasonable geometry. According to common practice they were nevertheless kept in ideal positions during the refinement. The isotropic atomic displacement parameters of the hydrogen atoms were evaluated as $1.2U_{eq}$ of the parent atom. Crystallographic data and details of the data collection and structure solution and refinements are listed in Table 1. Selected bond lengths and angles of **1** and **2** are listed in Table 2.

3. Results and discussion

3.1. Synthesis

The Schiff-base ligand (23-MeO-ba)$_2$en was prepared by condensation of ethylenediamine with 2,3-dimethoxybenzaldehyde following the method in [28]. The reaction of HgX_2 with (23-MeO-ba)$_2$en in a methanol–chloroform solvent mixture at room temperature resulted in monomeric mercury(II) complexes, as shown in Scheme 1.

The solubility of the Schiff base ligand (23-MeO-ba)$_2$en and its mercury(II) complexes were determined by adding the solvent to a known amount of compound until complete dissolution. It was found that the Schiff base ligand is moderately soluble in methanol, ethanol and acetonitrile, insoluble in water and completely soluble in chloroform, dichloromethane, DMF and DMSO, while the mercury(II) complexes are only soluble in coordinating solvents such as DMF and DMSO, but are insoluble in a range of common organic solvents such as methanol, ethanol, chloroform, dichloromethane, acetone, acetonitrile and water. In order to confirm the chemical composition of the synthesized compounds, CHN analysis was carried out on the recrystallized compounds. The results of the analysis are presented in Section 2.

3.2. ^{1}H NMR spectra

The ^{1}H NMR spectra of the (23-MeO-ba)$_2$en ligand and its mercury(II) complexes were recorded using $CDCl_3$ and DMSO, respectively. The ^{1}H NMR spectra suggest that both the free ligand and the complexes have symmetrical structures. All methylene and methoxy protons (H_1, H_3 and H_4) appear as singlets in the region 3.6–4.0 ppm. The signals appearing in the region 6.91–7.51 ppm have been assigned to the hydrogens atoms of the aromatic rings (H_5, H_6 and H_7) of the free Schiff base ligand. The H_7 protons exhibit a downfield shift relative to the free ligand and show no significant differences by changing the anion. We have found non-classical hydrogen bonds of the type C–H···Br between the H_7 and Br atoms in complex **2**. The azomethine group (H_2) in the Schiff base ligand (23-MeO-ba)$_2$en shows up at 8.64 ppm as a single signal [28]. In the complexes, the signal related to this group is shifted to a higher region [8.54 (**1**), 8.58 (**2**) and 8.57 (**3**)]. This shift shows that the nitrogen atom of the azomethine group is coordinated to the mercury(II) ion.

3.3. FT-IR spectra

The FT-IR spectra of the free ligand (23-MeO-ba)$_2$en exhibits the characteristic band of the azomethine group (–C=N–), which appears at 1638 cm^{-1} [28]. This band is shifted in the complexes towards higher frequency in **1** and lower frequencies in **2** and **3** because of the coordination of the nitrogen atoms to the mercury(II) ion, and appears at 1651 (**1**), 1630 (**2**) and 1632 cm^{-1} (**3**). The ligand's stretching vibrations at about 2830–3015 cm^{-1}, assigned to the C–H azomethine, aromatic and aliphatic hydrogens, are shifted to higher frequency in **1** and lower frequencies in **2** and **3**.

3.4. Crystal and molecular structures of **1** and **2**

The molecular structures of [Hg((23-MeO-ba)$_2$en)I$_2$] (**1**) and [Hg((23-MeO-ba)$_2$en)Br$_2$] (**2**) with the atom-numbering schemes are presented in Figs. 1 and 2, respectively. Selected bond distances and angles are given in Table 2. In both structures, the mercury(II) center is coordinated by the bidentate Schiff-base ligand (23-MeO-ba)$_2$en and two halide ions. Our results show that **1** and **2** are isostructural. The structures of these complexes are quite different from the mercury(II) complex $Hg_3I_6(en)_2$ reported by Grdenic et al. [32] and the mercury(II) complexes $[HgBr_2en]_n$ and $[HgI_2en]_n$ reported by Matkovic-Calogovic and Sikirica [33]. The mercury(II) complex $Hg_3I_6(en)_2$ [32] was prepared by the reaction of ethane-1,2-diamine with mercury(II) iodide in an aqueous solution of potassium iodide, while the polymeric mercury(II) complexes $[HgBr_2en]_n$ and $[HgI_2en]_n$ [33] were prepared by the reaction of ethane-1,2-diamine with mercury(II) iodide in methanol solution. In this paper, we prepared the Schiff base ligand (23-MeO-ba)$_2$en from the reaction of ethane-1,2-diamine with 2,3-dimethoxybenzaldehyde, and the complexes **1** and **2** were prepared from the reaction of this ligand with mercury(II) halide in mixture of chloroform and methanol (1:2).

The tetrahedral geometry might be expected for the fourfold coordinated mercury(II) atom in **1** and **2** from the restricted bite of the Schiff-base ligand (23-MeO-ba)$_2$en, with a N–Hg–N chelate angles of 73.90(16)° in **1** and 75.95(8)° in **2**. This angle is smaller than the range of 82–89° found for ethane-1,2-diamine chelate compounds [15]. This angle is fixed by the size of the ligand (N···N = 2.883(2) Å in **1** and 2.930(4) Å in **2**). On the contrary the X–Hg–X bond angles have opened up to 134.547(14)° in **1** and 126.629(12)° in **2**. The N–Hg–X bond angles are also distorted from the tetrahedral values (see Table 2).

The average Hg–N bond lengths of 2.398 Å in **1** and 2.38 Å in **2** and Hg–X bond lengths of 2.66 Å in **1** and 2.51 Å in **2** agree well with the corresponding distances in other tetrahedral mercury(II) complexes [20–22], which also have distorted tetrahedral geome-

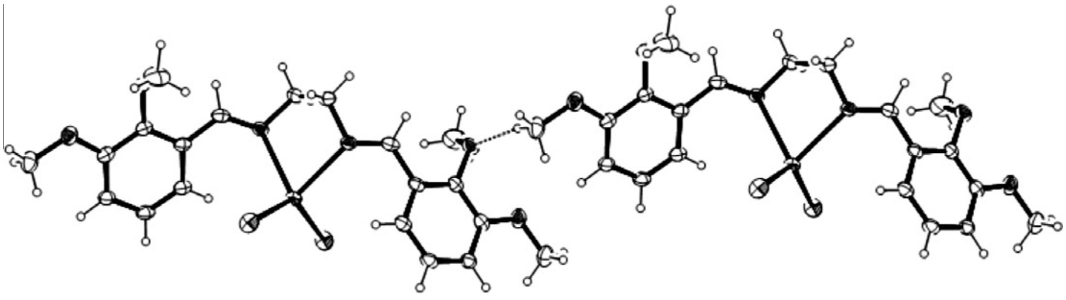


Fig. 3. Non-classical C10–H10b···O1 hydrogen bond in complex **1** (dashed line).

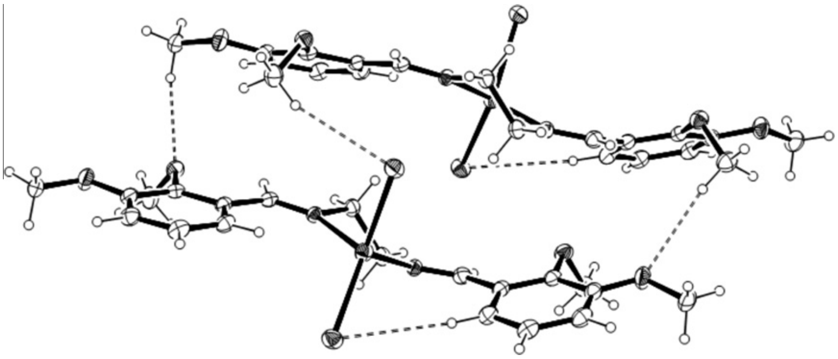


Fig. 4. Inter- and intra-molecular non-classical C–H···X (X = O, Br) hydrogen bonds in complex **2** (dashed lines).

Table 4
Intra- and inter-molecular non-classical hydrogen bonds in complex **2**.

D–H···A	D–H (Å)	H···A (Å)	D···A (Å)	D–H···A (°)
C8–H8···Br2	0.96	3.09	4.048(3)	174.04
C19–H19b···Br1	0.96	2.97	3.875(4)	158.65
C20–H20b–O3	0.96	2.41	3.326(4)	158.73
C9–H9b–O2	0.96	2.73	3.652(4)	162.26

tries about the mercury(II) center with unequal metal–ligand bond distances and angles. The Schiff-base ligand (23-MeO-ba)$_2$en adopts a *E,E* configuration in these complexes. The value for the torsion angle C1–N1–C2–C3 is 178.6(4)° in **1** and −178.9(3)° in **2** and N1–C2–C3–C4 is 153.0(8)° in **1** and −156.6(4)° in **2**, indicating an almost planar configuration of this moiety for the complexes studied here.

While there is no intra-molecular packing feature of interest in complex **1**, its molecules are eventually linked together via an inter-molecular non-classical C10–H10b···O1 hydrogen bond (Table 3 and Fig. 3).

Complex **2** contains one intra- and several inter-molecular non-classical hydrogen bonds of the type C–H···X (X = O, Br) (Fig. 4 and Table 4). The intra-molecular hydrogen bonds are formed between aromatic H-atoms of the bidentate Schiff base ligand and the coordinated bromine atom (Figs. 2 and 4). The [Hg((23-MeO-ba)$_2$en)Br$_2$] (**2**) molecules are eventually linked together via inter-molecular non-classical hydrogen bonds formed between aromatic and aliphatic H-atoms of the ligand and the bromine atoms (Fig. 4).

Acknowledgements

We acknowledge Golestan University (GU) and Damghan University (DU) for partial support of this work, the institutional research plan No. AVOZ10100521 of the Institute of Physics and the project P204/11/0809 of the Grant Agency of the Czech Republic.

Appendix A. Supplementary data

CCDC 821624 and 821625 contain the supplementary crystallographic data for complex **1** and **2**. These data can be obtained free of charge via http://www.ccdc.cam.ac.uk/conts/retrieving.html, or from the Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge CB2 1EZ, UK; fax: (+44) 1223-336-033; or e-mail: deposit@ccdc.cam.ac.uk.

References

[1] W. Wang, F.X. Zhang, J. Li, W.B. Hu, Russ. J. Coord. Chem. 36 (2010) 33.
[2] H. Chowdhury, R. Ghish, Sk.H. Rahaman, B.K. Ghosh, Polyhedron 26 (2007) 5023.
[3] S. Das, B.N. Sarkar, K. Bhar, S. Chattopadhyay, H.-K. Fun, P. Mitra, B.K. Ghosh, Inorg. Chem. Commun. 13 (2010) 353.
[4] S. Chattopadhyay, K. Bhar, S. Khan, P. Mitra, R.J. Butcher, B.K. Ghosh, J. Mol. Struct. 966 (2010) 102.
[5] G. Zhang, G. Yang, J.S. Ma, Inorg. Chem. Commun. 7 (2004) 994.
[6] Q. Shi, L. Xu, J. Ji, Y. Li, R. Wang, Z. Zhou, R. Cao, M. Hong, A.S.C. Chan, Inorg. Chem. Commun. 7 (2004) 1254.
[7] R.H. Layee, Inorg. Chim. Acta 360 (2007) 439.
[8] M. Dolaz, V. McKee, A. Golcu, M. Tumer, Spectrochim. Acta A71 (2009) 1648.
[9] M. Dolaz, V. McKee, S. Urus, N. Demir, A.E. Sabik, A. Golcu, M. Tumer, Spectrochim. Acta A76 (2010) 174.
[10] M. Samir, El-Medani, A.M.A. Omyana, R.N. Ramaden, J. Mol. Struct. 738 (2005) 171.
[11] M.T.H. Tarafder, M.A. Ali, S. Saravana, W.Y. Weng, S. Kumar, N.U. Tsafe, K.A. Crouse, Transition Met. Chem. 25 (2000) 295.
[12] J. Zhan, B. Zhan, J. Liu, W.J. Xu, Z. Wang, Spectrochim. Acta A57 (2001) 149.
[13] W. Liu, Y. Zou, Y. Li, Y.G. Yao, Q.J. Meng, Polyhedron 23 (2004) 849.
[14] H. Komatsu, B. Ochiai, T. Hino, T. Endo, J. Mol. Catal. A273 (2007) 289.
[15] A.D. Khalaji, M. Weil, G. Grivani, S. Jalali Akerdi, Monatsh. Chem. 141 (2010) 539.
[16] M. Montazerozohori, S.A. Musavi, J. Coord. Chem. 61 (2008) 3934.
[17] I. Sheikhshoaei, J. Coord. Chem. 56 (2003) 463.
[18] R. Fan, Y. Yang, Y. Yin, W. Hasi, Y. Mu, Inorg. Chem. 48 (2009) 6034.
[19] K.K. Sarker, B.G. Chand, K. Suwa, J. Cheng, T.-H. Lu, J. Otsuki, C. Sinha, Inorg. Chem. 46 (2007) 670.
[20] B. Notash, N. Safari, H.R. Khavasi, Inorg. Chem. 49 (2010) 11415.
[21] S.Y. Lee, S. Park, H.J. Kim, J.H. Jung, S.S. Lee, Inorg. Chem. 47 (2008) 1913.
[22] C. Pettinari, A. Marinelli, F. Marchetti, J. Ngoune, A. Galindo, E. Alvarez, M. Gomez, Inorg. Chem. 49 (2010) 10543.
[23] G. Mahmoudi, A. Morsali, Cryst. Growth Des. 8 (2008) 391.
[24] M. Montazerozohori, S. Joohari, S.A. Musavi, Spectrochim. Acta A73 (2009) 231.
[25] S. Salehzadeh, S. Dehghanpour, M. Khalaj, M. Rahimishakiba, Acta Crystallogr., Sect. E67 (2011) m327.
[26] A.D. Khalaji, Y. Zhang, S. Mojdekanlou, Anal. Sci. 24 (2008) x131.
[27] A.D. Khalaji, F. Jian, H. Xiao, S. Mojdekanlou, Anal. Sci. 24 (2008) x91.
[28] A.D. Khalaji, K. Fejfarova, M. Dusek, H.M. Bijanzadeh, J. Chem. Crystallogr., in press.
[29] M.C. Burla, M. Camalli, B. Carrozzini, G. Cascarano, C. Giacovazzo, G. Polidori, R. Spagna, J. Appl. Crystallogr. 36 (2003) 1103.
[30] V. Petricek, M. Dusek, L. Palatinus, JANA2006. Structure Determination Software Programs, Institute of Physics, Praha, Czech Republic, 2008.
[31] L.J. Farrugia, J. Appl. Crystallogr. 30 (1997) 565.
[32] D. Grdenic, M. Sikirica, I. Vickovic, Acta Crystallogr., Sect. B33 (1977) 1630.
[33] D. Matkovic-Calogovic, M. Sikirica, Zeitsch. Kristallogr. 190 (1990) 171.