Scientific paper

N,N'-Bis(4-Bromo-2-hydroxybenzylidene)ethylenediamine and Its Copper(II), Zinc(II) and Cobalt(III) Complexes: Synthesis, Crystal Structures and Urease Inhibition

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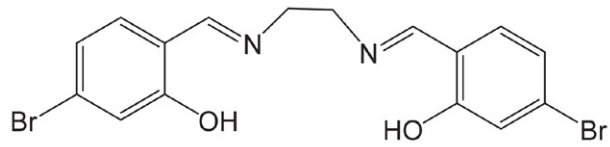
Abstract

A new Schiff base compound *N,N'*-bis(4-bromo-2-hydroxybenzylidene)ethylenediamine (H_2L) was prepared by reaction of 4-bromosalicylaldehyde with ethane-1,2-diamine in methanol. Reaction of H_2L with copper acetate and zinc acetate in methanol, respectively, afforded two mononuclear complexes [CuL] (**1**) and [ZnL(OH_2)] (**2**). Reaction of H_2L with cobalt nitrate in the presence of ammonium thiocyanate in a mixture of methanol and dimethylformamide (DMF) afforded a mononuclear cobalt(III) complex [CoL(NCS)(OH_2)]·DMF (**3**). The free Schiff base and the complexes were characterized by elemental analysis and infrared spectroscopy, as well as single crystal X-ray determination. ^{1}H NMR analysis was also performed for H_2L. The urease inhibitory assay reveals that the copper(II) complex has the most effective activity, with IC_{50} (half maximal inhibitory concentration) value of 0.17 ± 0.08 μmol L^{-1}.

Keywords: Cobalt complex; copper complex; Schiff base; urease inhibition; zinc complex

1. Introduction

Urease is a nickel containing enzyme which catalyzes urea decomposition to ammonia.[1] Ammonia is harmful for agriculture and animals, and even our human beings. Recently, a number of urease inhibitors with different kinds of compounds have been reported.[2] Among the compounds, Schiff bases have received particular attention.[3] Some copper and nickel complexes show interesting urease inhibitory activities.[3a,3f] Schiff bases have interesting biological activities like antioxidant,[4] antibacterial,[5] antitumor,[6] cytotoxic[7] and anti-inflammatory,[8] *etc.* Schiff bases bearing N and O donor atoms are a kind of excellent ligands in coordination chemistry, which form a large number of complexes with interesting and versatile structures.[9] Copper, zinc and cobalt are biological active trace elements in biological systems. In continuation of our work,[10] and in pursuit of new urease inhibitors, three new copper(II), zinc(II) and cobalt(III) complexes [CuL] (**1**), [ZnL(OH_2)] (**2**), and [CoL(NCS)(OH_2)]·DMF (**3**), where L is the dianionic form of *N,N'*-bis(4-bromo-2-hydroxybenzylidene)ethylenediamine (H_2L; Scheme 1) are present. Single crystal structures of the complexes are reported for the first time, and urease inhibition of these complexes have never been reported.



Scheme 1. H_2L

2. Experimental

2. 1. Materials and Methods

4-Bromosalicylaldehyde, ethane-1,2-diamine, copper acetate, zinc acetate, cobalt nitrate, and ammonium thiocyanate with AR grade were purchased from Aldrich. Solvent and other chemicals with AR grade were obtained from Xiya Chemical Co. Ltd. CHN elemental analyses were performed on a Perkin-Elmer 240C elemental analyzer. Infrared spectra were recorded on a Jasco FT/IR–4000 spectrophotometer. Electronic absorption spectra were recorded with a Lambda

35 spectrophotometer. ^{1}H NMR spectrum for H_2L was recorded on a Bruker 500 MHz spectrometer. Single crystal X-ray diffraction was carried out with a Bruker Apex II diffractometer. The molar conductivities were measured at 25 °C with a Synstronics conductivity bridge.

2. 2. Synthesis of *N,N'*-Bis(4-Bromo-2-hydroxybenzylidene)ethylenediamine (H_2L)

4-Bromosalicylaldehyde (4.0 g, 0.020 mol) was dissolved in 50 mL MeOH to which was added dropwise 40 mL methanolic solution of ethane-1,2-diamine (0.60 g, 0.010 mol). The mixture was stirred for 30 min under reflux. The solvent was removed by distillation under reduced pressure. The yellow solid residue was recrystallized from MeOH to give yellowish crystalline product. Yield 3.7 g (87%). Anal. Calcd for $C_{16}H_{14}Br_2N_2O_2$: C, 45.10; H, 3.31; N, 6.57%. Found: C, 44.93; H, 3.38; N, 6.65%. FT-IR data (KBr, cm^{-1}): ν(C=N) 1635, ν(Ar–O) 1285. UV–Vis data [10^{-3} mol L^{-1} in MeOH, λ/nm (ε/L mol^{-1} cm^{-1})]: 220 (21,320), 246 (12,590), 265 (13,880), 317 (5,266), 395 (2,633). ^{1}H NMR (500 MHz, d_6–DMSO, ppm): δ 13.83 (s, 2H, OH), 8.59 (s, 2H, CH=N), 7.36 (d, 2H, ArH), 7.06 (d, 2H, ArH), 7.02 (d, 2H, ArH), 3.91 (t, 4H, CH_2). Single crystals suitable for X-ray diffraction were obtained by slow evaporation of methanol solution of the compound.

2. 3. Synthesis of [CuL] (1)

The Schiff base H_2L (0.43 g, 1.0 mmol) was dissolved in MeOH (30 mL) to which was added a methanolic solution of copper acetate monohydrate (0.20 g, 1.0 mmol). The mixture was stirred at room temperature for 30 min and filtered. The filtrate was kept still in air for 5 days to give green block-shaped single crystals. Yield: 0.26 g (53%). Anal. Calcd for $C_{16}H_{12}Br_2CuN_2O_2$: C, 39.41; H, 2.48; N, 5.74. Found: C, 39.23; H, 2.56; N, 5.67%. FT-IR data (KBr, cm^{-1}): 1639 ν(C=N), 1586, 1512, 1455, 1422, 1386, 1332, 1285, 1236, 1188, 1134, 1053, 917, 865, 782, 632, 596, 507, 469. UV-Vis data [10^{-3} mol L^{-1} in methanol, λ/nm (ε/L mol^{-1} cm^{-1})]: 230 (19,220), 248 (19,650), 275 (13,820), 352 (5,766). Λ_M (10^{-3} M in MeOH): 27 Ω^{-1} cm^2 mol^{-1}.

2. 4. Synthesis of [ZnL(OH$_2$)] (2)

The Schiff base H_2L (0.43 g, 1.0 mmol) was dissolved in MeOH (30 mL) to which was added a methanolic solution of zinc acetate dihydrate (0.22 g, 1.0 mmol). The mixture was stirred at room temperature for 30 min and filtered. The filtrate was kept still in air for 7 days to give colorless block-shaped single crystals. Yield: 0.22 g (43%). Anal. Calcd for $C_{16}H_{14}Br_2N_2O_3Zn$: C, 37.87; H, 2.78; N, 5.52. Found: C, 38.02; H, 2.85; N, 5.45%. FT-IR data (KBr, cm^{-1}): 3436, 1640 ν(C=N), 1583, 1521, 1471, 1454, 1417, 1386, 1281, 1183, 1130, 1046, 985, 946, 919, 850, 788, 717, 675, 621, 600, 557, 505, 465. UV-Vis data [10^{-3} mol L^{-1} in methanol, λ/nm (ε/L mol^{-1} cm^{-1})]: 230 (21,150), 246 (23,420), 275 (10,870), 350 (6,839). Λ_M (10^{-3} M in MeOH): 23 Ω^{-1} cm^2 mol^{-1}.

2. 5. Synthesis of [CoL(NCS)(OH$_2$)]·DMF (3)

The Schiff base H_2L (0.44 g, 1.0 mmol) was dissolved in MeOH (30 mL) to which was added a methanolic solu-

Table 1. Crystal data for the complexes

	H_2L	**1**	**2**	**3**
Formula	$C_{16}H_{14}Br_2N_2O_2$	$C_{16}H_{12}Br_2CuN_2O_2$	$C_{16}H_{14}Br_2N_2O_3Zn$	$C_{20}H_{21}Br_2CoN_4O_4S$
FW	426.11	487.64	507.48	632.22
Crystal system	Monoclinic	Orthorhombic	Orthorhombic	Orthorhombic
Space group	$P2_1/c$	$P2_12_12_1$	$Pnma$	$Pccn$
a (Å)	17.4332(18)	7.0559(12)	8.2466(12)	13.8040(16)
b (Å)	7.3715(13)	7.5903(13)	28.6675(16)	27.0232(19)
c (Å)	6.1273(12)	28.7213(19)	7.6148(12)	12.6340(16)
a (°)	90	90	90	90
b (°)	94.0230(10)	90	90	90
g (°)	90	90	90	90
V (Å^3)	785.5(2)	1538.2(4)	1800.2(4)	4712.8(9)
Z	2	4	4	8
m (MoKa) (cm^{-1})	5.168	6.625	5.819	4.243
R_{int}	0.0638	0.0902	0.0638	0.1253
Reflections/parameters	4275/103	9067/209	8051/115	25351/297
Unique reflections	1457	2870	1525	4243
Observed reflections [I ³ 2s(I)]	1115	1887	1108	2324
Restraints	1	0	7	3
Goodness of fit on F^2	1.051	0.991	1.041	1.028
R_1, wR_2 [I ³ 2s(I)]	0.0396, 0.0948	0.0470, 0.0829	0.0552, 0.1308	0.0848, 0.2005
R_1, wR_2 (all data)	0.0590, 0.1061	0.0956, 0.1035	0.0809, 0.1482	0.1530, 0.2382

tion of cobalt nitrate hexahydrate (0.29 g, 1.0 mmol) and ammonium thiocyanate (0.076 g, 1.0 mmol). The mixture was stirred at room temperature for 30 min and 1 mL DMF was added to dissolve the insoluble product. The solution was kept still in air for 11 days to give brown block-shaped single crystals. Yield: 0.22 g (35%). Anal. Calcd for $C_{20}H_{21}Br_2CoN_4O_4S$: C, 38.00; H, 3.35; N, 8.86. Found: C, 38.15; H, 3.41; N, 8.80%. FT-IR data (KBr, cm^{-1}): 2149 ν(NCS), 1640 ν(C=N), 1580, 1518, 1465, 1451, 1418, 1382, 1331, 1287, 1200, 1133, 1087, 1053, 1033, 978, 961, 915, 853, 787, 727, 685, 647, 600, 569, 529, 498, 465. UV–Vis data [10^{-3} mol L^{-1} in methanol, λ/nm (ε/L mol^{-1} cm^{-1})]: 230 (18,870), 250 (18,550), 277 (13,560), 356 (5,266). Λ_M (10^{-3} M in MeOH): 33 Ω^{-1} cm^2 mol^{-1}.

2. 6. X-Ray Crystallography

X-ray diffraction data for the three complexes were collected at 298(2) K with graphite–monochromated Mo-Kα radiation (0.71073 Å). The collected data were reduced with SAINT.[11] Multi-scan absorption correction was performed with SADABS.[12] Structures of the complexes were solved by direct method with SHELXTL, and refined against F^2 by full-matrix least-squares method.[13] All non-hydrogen atoms the complexes were refined anisotropically. The H1 atom in H_2L, H2 atom in **2**, H3A and H3B atoms in **3** were located from difference Fourier maps and refined with O–H and H···H distances restrained to 0.85(1) and 1.37(2) Å, respectively. Atom C8 in complex **2** is slightly disordered and treated as isotropic behavior. The remaining H atoms were placed in calculated positions and constrained to ride on their parent atoms. Crystallographic data for the complexes are summarized in Table 1. Selected bond lengths and angles are given in Table 2.

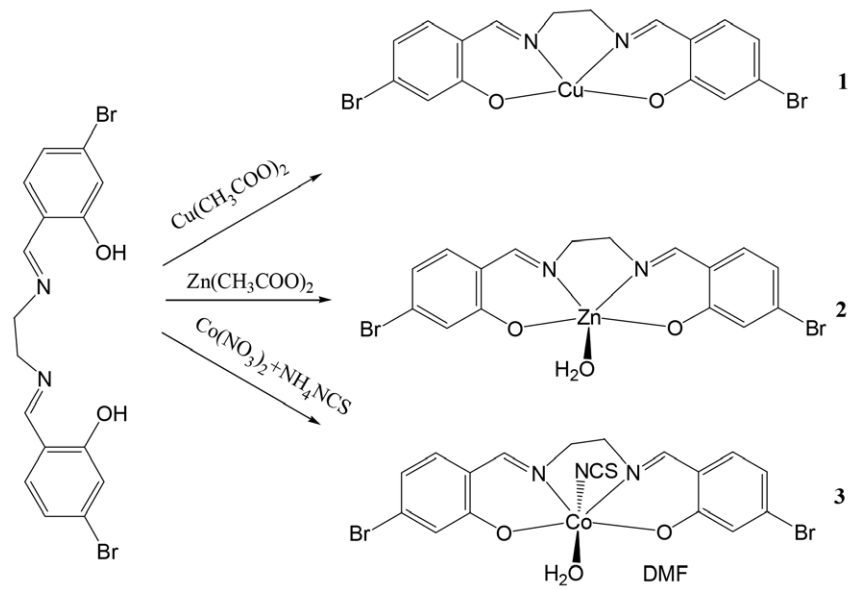
Table 2. Selected bond lengths (Å) and angles (°) for the complexes

1			
Cu1–O1	1.905(9)	Cu1–O2	1.923(8)
Cu1–N1	1.962(10)	Cu1–N2	1.940(10)
O1–Cu1–O2	90.1(3)	O1–Cu1–N2	176.3(4)
O2–Cu1–N2	93.1(4)	O1–Cu1–N1	92.6(4)
O2–Cu1–N1	172.2(4)	N2–Cu1–N1	84.1(4)
2			
Zn1–O1	1.981(4)	Zn1–O2	2.005(6)
Zn1–N1	2.078(6)		
O1–Zn1–O1A	93.9(3)	O1–Zn1–O2	100.30(19)
O1–Zn1–N1A	154.5(2)	O2–Zn1–N1	104.3(2)
O1–Zn1–N1	88.0(2)	N1–Zn1–N1A	79.8(4)
Symmetry code: A: *x*, 3/2 – *y*, *z*.			
3			
Co1–O1	1.898(6)	Co1–O2	1.896(6)
Co1–N1	1.906(8)	Co1–N2	1.880(9)
Co1–N3	1.932(10)	Co1–O3	1.938(8)
N2–Co1–O2	94.6(3)	N2–Co1–O1	179.0(4)
O2–Co1–O1	85.6(3)	N2–Co1–N1	85.4(4)
O2–Co1–N1	178.9(3)	O1–Co1–N1	94.5(3)
N2–Co1–N3	88.2(4)	O2–Co1–N3	92.2(4)
O1–Co1–N3	90.9(3)	N1–Co1–N3	89.0(4)
N2–Co1–O3	92.2(4)	O2–Co1–O3	89.3(3)
O1–Co1–O3	88.7(3)	N1–Co1–O3	89.6(4)
N3–Co1–O3	178.5(4)		

3. Results and Discussion

3. 1. Synthesis

The free Schiff base H_2L was facile synthesized from the condensation reaction of 4-bromosalicylaldehyde with ethane-1,2-diamine in methanol. The copper(II) and zinc(II)



Scheme 2. Synthetic procedure for the complexes

complexes were synthesized from the Schiff base with copper acetate and zinc acetate, respectively in methanol (Scheme 2). The cobalt(III) complex was synthesized from the Schiff base with cobalt nitrate in the presence of ammonium thiocyanate in methanol and DMF (Scheme 2). Single crystals of H_2L and the three complexes were formed by slow evaporation of their filtrates. Molar conductivities of the three complexes at concentration of 10^{-3} mol L^{-1} are 23–33 Ω^{-1} cm^2 mol^{-1}, indicating their non-electrolytic nature.[14]

3. 2. Structure Description of H_2L

Molecular structure of the free Schiff base H_2L is shown in Figure 1. The molecule possesses crystallographic inversion center symmetry, with the center located at the midpoint of C8 and C8A. The distance between C7 and N1 is 1.269(5) Å, indicating it a typical double bond. The bond lengths are comparable to those observed in Schiff base compounds.[15] There forms intramolecular O1–H1···N1 hydrogen bonds (Table 3) in the molecule as shown in dashed lines. In addition, there exists π···π interactions among the molecules (Table 4).

Figure 1. Molecular structure of H_2L, showing the atom-numbering scheme. Displacement ellipsoids are drawn at 30% probability level. Atoms labeled with the suffix A are related to the symmetry operation 1 – *x*, 1 – *y*, – *z*.

3. 3. Structure Description of Complex 1

Molecular structure of the mononuclear copper(II) complex is shown in Figure 2. The Schiff base adopts a dianionic form, and coordinates to the Cu atom through two imino nitrogen (N1, N2) and two phenolate oxygen (O1, O2), forming square planar geometry. The Cu atom deviates from the least-squares plane defined by the four donor atoms by 0.049(2) Å. There is a five-membered chelate ring Cu1-N1-C8-C9-N2 in the complex molecule, which leads to the deviation of the square planar geometry. The distortion of the geometry is demonstrated from the *cis* and *trans* bond angles of 84.1(4)–93.1(4)° and 172.2(4)–176.3(4) °, respectively. The bond lengths around the Cu atom are within normal values with the Schiff base copper(II) complexes.[16] The two benzene rings form a dihedral angle of 32.9(4)°.

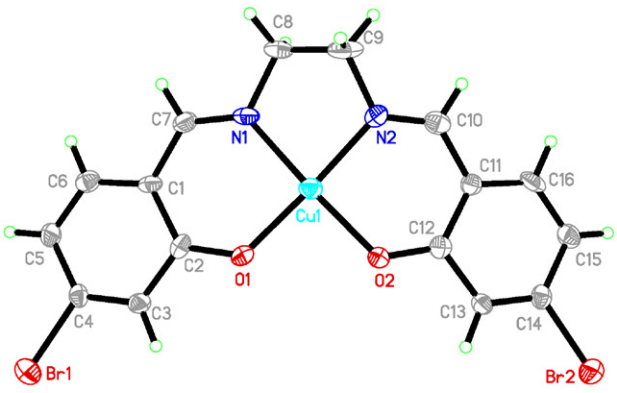


Figure 2. Molecular structure of the copper complex, showing the atom-numbering scheme. Displacement ellipsoids are drawn at 30% probability level. Atoms labeled with the suffix A are related to the symmetry operation 1 – *x*, 1 – *y*, 1 – *z*. Hydrogen atoms except for OH groups are omitted for clarity.

3. 4. Structure Description of Complex 2

Molecular structure of the mononuclear zinc(II) complex is shown in Figure 3. The compound possesses crystallographic mirror plane symmetry. The Schiff base adopts a dianionic form, and coordinates to the Zn atom through two imino nitrogen (N1, N1A) and two phenolate oxygen (O1, O1A). The Zn atom is in square pyramidal coordination, with the four donor atoms of the Schiff base ligand defining the basal plane, and with one oxygen (O2) occupying the apical position. The Zn atom deviates from the least-squares plane defined by the four basal donor atoms by 0.428(2) Å. There is a five-membered chelate ring Zn1-N1-C8-C8A-N1A in the complex molecule, which leads to the deviation of the square pyramidal geometry. The distortion of the geometry is demonstrated from the *cis* and *trans* bond angles of 79.8(4)–93.9(3)° and 154.5(2)°, respectively in the basal plane, and from the bond angles among apical and basal donor atoms of 100.30(19)–104.3(2)°. The τ value for the coordination is 0, which suggests a typical square pyramidal geometry.[17] The bond lengths around the Zn(II) atoms are within normal values with the Schiff base zinc(II) complexes.[18] The two benzene rings form a dihedral angle of 33.1(5)°.

In the crystal structure of the complex, molecules are linked by intermolecular hydrogen bonds of O–H···O (Table 3; Figure 4).

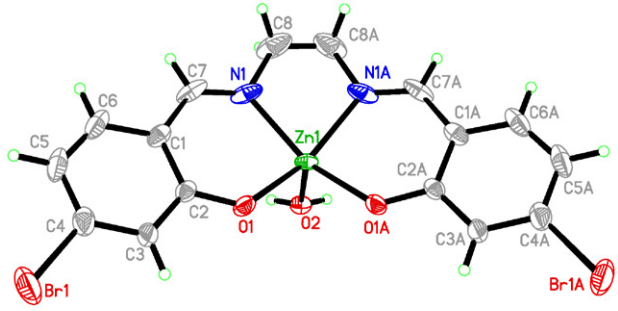


Figure 3. Molecular structure of the zinc complex, showing the atom-numbering scheme. Displacement ellipsoids are drawn at the 30% probability level. Atoms labeled with the suffix A are related to the symmetry operation *x*, 3/2 – *y*, *z*.

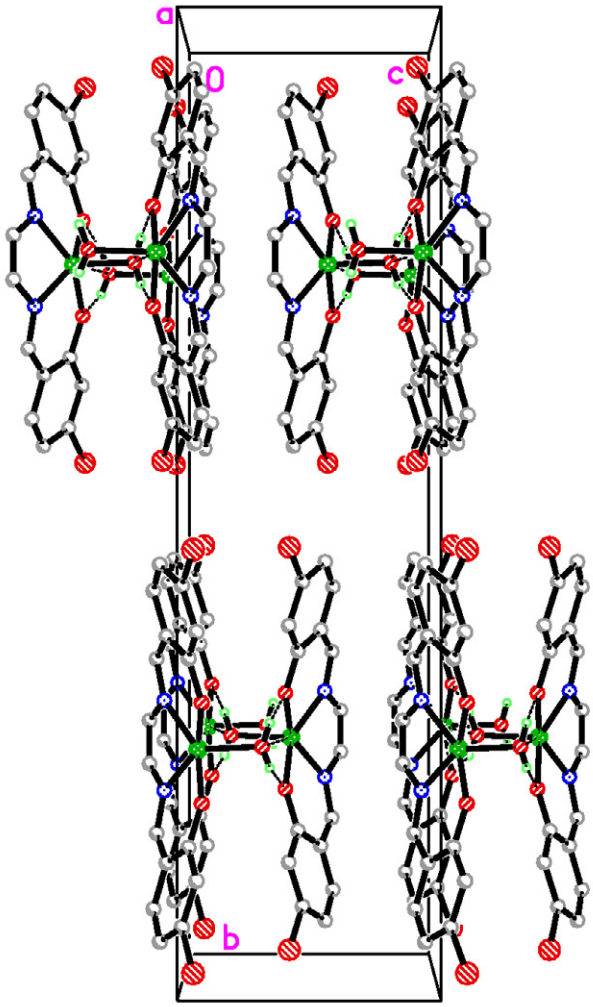


Figure 4. Molecular packing structure of the zinc complex, viewed down the *a* axis. Hydrogen bonds are drawn as dotted lines.

3. 5. Structure Description of Complex 3

Molecular structure of the mononuclear cobalt(III) complex is shown in Figure 5. The Schiff base adopts a dianionic form, and coordinates to the Co atom through two imino nitrogen (N1, N2) and two phenolate oxygen (O1, O2). The Co atom is in octahedral coordination, with the four donor atoms of the Schiff base ligand defining the equatorial plane, and with one oxygen (O3) of a water ligand, and one nitrogen (N3) of a thiocyanate ligand at the axial sites. There is a four-membered chelate ring Co1-N1-C8-C9-N2 in the complex molecule, which leads to the deviation of the octahedral geometry. The distortion of the octahedral geometry is demonstrated from the *cis* and *trans* bond angles of 85.4(4)–94.6(3)° and 178.9(3)–179.0(4)° at the equatorial plane, and from the angles among the axial and equatorial donor atoms of 88.2(4)–92.2(4)°. The bond lengths around the Co atoms are within normal values with the Schiff base cobalt(III) complexes.[19] The two benzene rings form a dihedral angle of 8.4(6)°.

In the crystal structure of the complex, complex molecules and DMF molecules are linked through intermolecular hydrogen bonds of O–H···O and O–H···S (Table 3), to form a three-dimensional network (Figure 6). In addition, there exists π···π interactions among the molecules (Table 4).

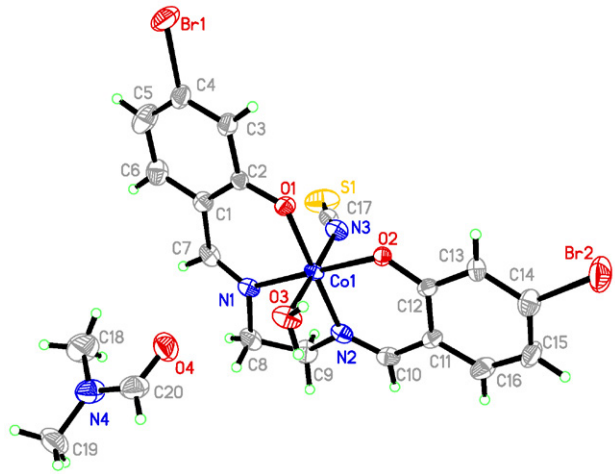


Figure 5. Molecular structure of the cobalt complex, showing the atom-numbering scheme. Displacement ellipsoids are drawn at the 30% probability level.

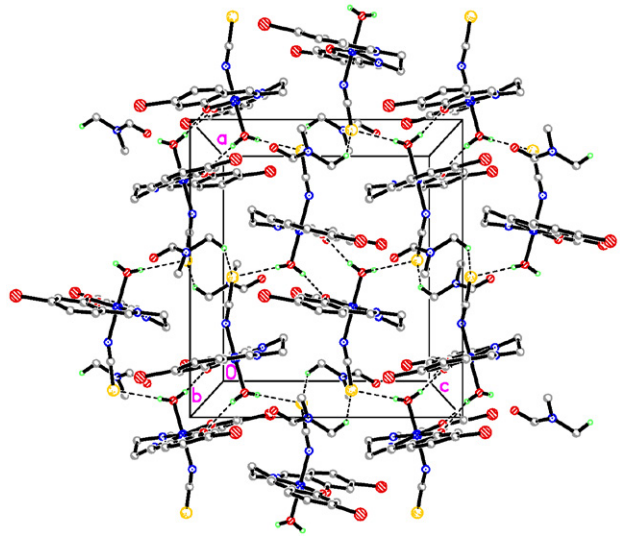


Figure 6. Molecular packing structure of the cobalt complex, viewed down the *b* axis. Hydrogen bonds are drawn as dotted lines.

3. 4. IR and UV-Vis Spectroscopy

In the infrared spectrum of the free Schiff base, the band at 1635 cm^{-1} can be assigned to the C=N stretching vibration. In the infrared spectra of the complexes, the bands are shifted to higher wavenumbers (1639–1640 cm^{-1}).[20] The intense band at 2149 cm^{-1} of the cobalt complex can be assigned to the thiocyanate ligand.[21] The UV–Vis spectra of H_2L and the three complexes show bands in

Table 3. Hydrogen bond distances (Å) and bond angles (°)

D–H···*A*	*d*(*D*–H; Å)	*d*(H···*A*; Å)	*d*(*D*···*A*; Å)	Angle (*D*–H···*A*; °)
H_2L				
O1–H1···N1	0.85(1)	1.84(3)	2.605(4)	148(5)
2				
O2–H2···O1$^{\#1}$	0.85(1)	1.80(4)	2.581(6)	153(7)
3				
O3–H3A···O1$^{\#2}$	0.85(1)	2.17(4)	2.997(10)	163(11)
O3–H3B···S1$^{\#3}$	0.85(1)	2.665(16)	3.510(9)	174(10)

Symmetry transformations used to generate the equivalent atoms: #1: –½ + *x*, *y*, ½ – *z*; #2: 1 – *x*, 1 – *y*, 1 – *z*; #3: ½ + *x*, 1 – *y*, 3/2 – *z*.

Table 4. Parameters between planes for the compounds

Cg	Distance between ring centroids (Å)	Dihedral angle (°)	Perpendicular distance of *Cg*(I) on *Cg*(J) (Å)	Beta angle (°)	Gamma angle (°) on *Cg*(I) (Å)	Perpendicular distance of *Cg*(J)
H_2L						
*Cg*1···*Cg*1$^{\#4}$	4.8278	47	–2.2395	17.14	62.36	–4.6135
*Cg*1···*Cg*1$^{\#5}$	4.7579	47	2.1560	17.80	63.05	4.5300
3						
*Cg*2···*Cg*3$^{\#6}$	3.9433	7.552	3.6469	24.34	22.36	3.5929

Symmetry codes: #4: *x*, 1/2 – *y*, 1/2 + *z*; #5: *x*, 3/2 – *y*, –1/2 + *z*; #6: 2 – *x*, – *y*, 1 – *z*; *Cg*1 is C1–C6 ring centroid in H_2L; *Cg*2 and *Cg*3 are C1–C6 and C11–C16 ring centroids, respectively, in **3**.

the region 240–320 nm, which are assigned to the n–π^* transitions.[22] The LMCT (ligand to metal charge transfer) bands of the complexes are located in the region 350–360 nm.[22]

3. 5. Pharmacology Study

The assay for the urease inhibition was carried out with the literature method.[23] H_2L has weak activity, with percentage inhibition of 13.2 ± 1.3 at 100 μmol L^{-1}. The three complexes have better activity than H_2L. The copper(II) complex has effective activity with percentage inhibition of 97.3 ± 2.5 at 100 μmol L^{-1}, and with IC_{50} of 0.17 ± 0.08 μmol L^{-1}. The zinc(II) complex has weak activity with percentage inhibition of 21.7 ± 2.0 at 100 μmol L^{-1}. The cobalt complex has medium activity with percentage inhibition of 83.2 ± 1.8 at 100 μmol L^{-1}, and with IC_{50} of 11.23 ± 0.27 μmol L^{-1}. The copper(II) and cobalt(III) complexes have obviously higher activity than acetohydroxamic acid (IC_{50} = 28.1 μmol L^{-1}), which was used as a standard drug. As a comparison, the copper(II) complex has better activity than copper perchlorate (IC_{50} = 8.8 μmol L^{-1}), and the copper complexes reported in literature.[3c,24] Thus, it may be used as a new urease inhibitor.

4. Conclusion

In summary, three mononuclear copper(II), zinc(II) and cobalt(III) complexes with the Schiff base ligand *N,N'*-bis(4-bromo-2-hydroxybenzylidene)ethylenediamine have been synthesized. The Cu atom in the copper complex is in square planar coordination. The Zn atom in the zinc(II) complex is in square pyramidal coordination. The Co atom on the cobalt complex is in octahedral coordination. The Schiff base coordinates to the metal atoms through phenolate oxygen and imino nitrogen atoms. The copper complex shows the most activity on urease inhibition (IC_{50} = 0.17 ± 0.08 μmol L^{-1}), which deserves further study to explore new urease inhibitors.

Supplementary Data

CCDC 2426820 (H_2L), 2426821 (**1**), 2426822 (**2**) and 2426823 (**3**) contain the supplementary crystallographic data for this paper. 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.

5. References

1. (a) K. Shahzadi, S. M. Bukhari, A. Zaidi, T. A. Wani, M. S. Jan, S. Zargar, U. Rashid, U. Farooq, A. Khushal, S. Khan, *Pharmaceuticals* **2023**, *16*, 1552; **DOI:**10.3390/ph16111552
(b) L. Z. Li, C. S. Zhao, X. H. Wang, Y. Tan, X. K. Wang, X. Z. Liu, B. B. Guo, *Environ. Res.* **2023**, *237*, 116781. **DOI:**10.1016/j.envres.2023.116781

2. (a) J. Valentová, L. Lintnerová, B. Sláviková, P. Baran, *Inorg. Chim. Acta* **2023**, *558*, 121707; **DOI:**10.1016/j.ica.2023.121707
(b) S. Ahmad, M. A. Qadir, M. Ahmed, M. Imran, M. Ahmad, N. Yousaf, T. A. Wani, S. Zargar, I. Ali, M. Muddassar, *ACS Omega* **2023**, *8*, 46165–46181; **DOI:**10.1021/acsomega.3c07275
(c) B. Awan, M. A. Khan, I. Ahmad, A. Masood, A. Raza, S. Khaliq, F. Ullah, J. Ahmed, M. R. Khan, *Future Med. Chem.* **2023**, **DOI:**10.4155/fmc-2023-0225
(d) W.-L. Duan, M.-Y. Yan, F. Yan, J. Luan, *Cryst Eng Comm* **2023**, **DOI:**10.1039/D3CE01109G
(e) W. Yang, Z. Y. Peng, G. C. Wang, *J. Enzyme Inhib. Med. Chem.* **2023**, *38*, 361–375; **DOI:**10.1080/14756366.2022.2150182
(f) A. Saeed, A. Ahmed, M. B. Haider, H. Ismail, K. Hayat, G. Shabir, H. R. El-Seedi, *RSC Advances* **2024**, *14*, 1018–1033; **DOI:**10.1039/D3RA06812A
(g) H. Pervez, N. Khan, J. Iqbal, S. Zaib, M. Yaqub, M. M. Naseer, *Acta Chim. Slov.* **2018**, *65*, 108–118. **DOI:**10.17344/acsi.2017.3649
3. (a) S. Han, Y. Wang, *Acta Chim. Slov.* **2021**, *68*, 961–969; **DOI:**10.17344/acsi.2021.6965
(b) H. Zhao, X.-R. Liu, X. Wang, J. Hu, Y.-J. Cai, Q.-A. Peng, *Acta Chim. Slov.* **2021**, *68*, 804–810; **DOI:**10.17344/acsi.2021.6781
(c) B. H. He, Q. Y. Wang, X. Q. Zhang, D. H. Shi, Z. L. You, *Inorg. Chim. Acta* **2023**, *558*, 121738; **DOI:**10.1016/j.ica.2023.121738
(d) Q. Y. Wang, B. H. He, X. Q. Zhang, Y. Cao, A. Li, J. Q. Wang, D. H. Shi, Z. L. You, *J. Coord. Chem.* **2023**, **DOI:**10.1080/00958972.2023.2256935
(e) L. Zhang, Y.-Q. Gu, X.-H. Feng, T. Yang, X. Y. Li, J. Wang, Z. L. You, *Acta Chim. Slov.* **2022**, *69*, 674–680; **DOI:**10.17344/acsi.2022.7578
(f) J. Jiang, P. Liang, H. Y. Yu, Z. L. You, *Acta Chim. Slov.* **2022**, *69*, 629–637. **DOI:**10.17344/acsi.2022.7513
4. (a) Y. M. Abdel-Baky, A. M. Omer, E. M. El-Fakharany, Y. A. Ammar, M. S. Abusaif, A. Ragab, *Sci. Rep.* **2023**, *13*, 22792; **DOI:**10.1038/s41598-023-50130-3
(b) L. Yabo-Dambagi, A. Cakir, M. Akyuz, A. Karakucuk-Iyidogan, A. Aslan, *Acta Chim. Slov.* **2024**, *71*, 566–579; **DOI:**10.17344/acsi.2024.8703
(c) M. Yaqoob, W. Jamil, M. Taha, S. Solangi, *Acta Chim. Slov.* **2022**, *69*, 772–778. **DOI:**10.17344/acsi.2022.7422
5. (a) M. Patel, T. Kikani, K. Patel, S. Thakore, *J. Mol. Struct.* **2024**, *129*, 136691; **DOI:**10.1016/j.molstruc.2023.136691
(b) S. H. Sumrra, W. Zafar, S. A. Malik, K. Mahmood, S. S. Shafqat, S. Arif, *Acta Chim. Slov.* **2022**, *69*, 200–216; **DOI:**10.17344/acsi.2021.7182
(c) F. M. Elantabli, R. G. Mohamed, S. M. El-Medani, M. Haukka, R. M. Ramadan, M. A. Afifi, *J. Mol. Struct.* **2024**, *1299*, 137230; **DOI:**10.1016/j.molstruc.2023.137230
(d) Y.-H. Wu, W.-L. Wei, W. Li, Z. L. You, *Acta Chim. Slov.* **2024**, *71*, 580–586; **DOI:**10.17344/acsi.2024.8928
(e) K.-S. Cao, L.-W. Xue, Q.-R. Liu, *Acta Chim. Slov.* **2023**, *70*, 516–523; **DOI:**10.17344/acsi.2023.8359
(f) S. H. Sumrra, W. Zafar, S. A. Malik, K. Mahmood, S. S. Shafqat, S. Arif, *Acta Chim. Slov.* **2022**, *69*, 200–216; **DOI:**10.17344/acsi.2021.7182
(g) H.-Y. Qian, *Acta Chim. Slov.* **2021**, *68*, 638–644. **DOI:**10.17344/acsi.2021.6656
6. (a) K. S. Kumar, K. K. Aravindakshan, *Pharm. Chem. J.* **2022**, *55*, 1378–1389; **DOI:**10.1007/s11094-022-02585-3
(b) M. Diz, M. L. Durán-Carril, J. Castro, S. Alvo, L. Bada, D. Viña, J. A. García-Vázquez, *J. Inorg. Biochem.* **2022**, *236*, 111975; **DOI:**10.1016/j.jinorgbio.2022.111975
(c) E. M. Fathalla, M. A. M. Abu-Youssef, M. M. Sharaf, A. El-Faham, A. Barakat, A. M. A. Badr, S. M. Soliman, A. M. Z. Slawin, J. D. Woollins, *Inorg. Chim. Acta* **2023**, *555*, 121586. **DOI:**10.1016/j.ica.2023.121586
7. (a) R. N. Gomes, M. L. Silva, K. S. Gomes, J. H. G. Lago, G. Cerchiaro, *J. Inorg. Biochem.* **2024**, *250*, 112401; **DOI:**10.1016/j.jinorgbio.2023.112401
(b) M. Strzelecka, B. Wiatrak, P. Jawien, Z. Czyznikowska, P. Swiatek, *Bioorg. Chem.* **2023**, *139*, 106758. **DOI:**10.1016/j.bioorg.2023.106758
8. (a) Seema, S. Sharma, P. Yadav, S. Kumari, M. Ranka, *Trans. Met. Chem.* **2023**, *48*, 389–400; **DOI:**10.1007/s11243-023-00551-w
(b) Q. U. Sandhu, M. Pervaiz, A. Majid, U. Younas, Z. Saeed, A. Ashraf, R. R. M. Khan, S. Ullah, F. Ali, S. Jelani, *J. Coord. Chem.* **2023**, *76*, 1094–1118. **DOI:**10.1080/00958972.2023.2226794
9. Y. Yuan, X.-K. Lu, G.-Q. Zhou, X.-Y. Qiu, *Acta Chim. Slov.* **2021**, *68*, 1008–1015; **DOI:**10.17344/acsi.2021.7070
(c) J.-L. Hou, H.-Y. Wu, C.-B. Sun, Y. Bi, W. Chen, *Acta Chim. Slov.* **2020**, *67*, 860–865; **DOI:**10.17344/acsi.2020.5824
(d) P. Middya, Y. Chakravarty, S. Maity, S. Chattopadhyay, *J. Coord. Chem.* **2023**, *76*, 1777–1790; **DOI:**10.1080/00958972.2023.2280514
(e) Q.-U. Sandhu, M. Pervaiz, A. Majid, U. Younas, Z. Saeed, A. Ashraf, R. R. M. Khan, S. Ullah, F. Ali, S. Jelani, *J. Coord. Chem.* **2023**, *76*, 1094–1118; **DOI:**10.1080/00958972.2023.2226794
(f) J. P. Remiya, B. Shyni, T. S. Sikha, U. R. Parvathy, *J. Coord. Chem.* **2023**, *76*, 729–748; **DOI:**10.1080/00958972.2023.2199440
(g) Q. W. Yang, G. D. Li, J. Liu, W. Q. Xiao, Y. Lei, X. C. Xiao, Y. Liu, *Acta Chim. Slov.* **2024**, *71*, 288–294; **DOI:**10.17344/acsi.2024.8720
(h) S. Mandal, D. B. Cordes, A. M. Z. Slawin, N. C. Saha, *Acta Chim. Slov.* **2024**, *71*, 110–122; **DOI:**10.17344/acsi.2023.8392
(i) M. Chowdhury, N. Biswas, S. Saha, E. Zangrando, N. Sepay, C. Roy, *Acta Chim. Slov.* **2023**, *70*, 479–488. **DOI:**10.17344/acsi.2023.8136
10. (a) W. Chen, Y. G. Li, Y. M. Cui, X. A. Zhang, H. L. Zhu, Q.-F. Zeng, *Eur. J. Med. Chem.* **2010**, *45*, 4473–4478; **DOI:**10.1016/j.ejmech.2010.07.007
(b) Y. M. Cui, Y. G. Li, Y. J. Cai, W. Chen, H. L. Zhu, *J. Coord. Chem.* **2011**, *64*, 610–616; **DOI:**10.1080/00958972.2011.552110

(c) Y. M. Cui, W. T. Liu, Y. Liu, W. Chen, Y. G. Li, *J. Coord. Chem.* **2011**, *64*, 3960–3968; **DOI:**10.1080/00958972.2011.634006
(d) Y.-M. Cui, X.-W. Dong, W. Chen, W.-J. Wang, Y.-G. Li, H.-L. Zhu, *J. Enzyme Inhib. Med. Chem.* **2012**, *27*, 528–532; **DOI:**10.3109/14756366.2011.599065
(e) Y. M. Cui, X. W. Dong, Y. G. Li, Z. W. Li, W. Chen, *Eur. J. Med. Chem.* **2012**, *58*, 323–331. **DOI:**10.1016/j.ejmech.2012.09.037
11. Bruker, SMART (Version 5.628) and SAINT (Version 6.02); Bruker AXS: Madison, Wisconsin, USA, **1998**.
12. G. M. Sheldrick, SADABS Program for Empirical Absorption Correction of Area Detector, University of Göttingen, Germany, **1996**.
13. G. M. Sheldrick, *Acta Crystallogr.* **2008**, *A64*, 112–122. **DOI:**10.1107/S0108767307043930
14. W. J. Geary, *Coord. Chem. Rev.* **1971**, *7*, 81–120. **DOI:**10.1016/S0010-8545(00)80009-0
15. (a) Y.-L. Sang, X.-C. Li, W.-M. Xiao, *J. Coord. Chem.* **2013**, *66*, 4015–4022; **DOI:**10.1080/00958972.2013.859253
(b) C. Unaleroglu, T. Hokelek, *Spectrosc. Lett.* **2002**, *35*, 317–326.
16. (a) D. Sadhukhan, A. Ray, R. J. Butcher, C. J. G. Garcia, B. Dede, S. Mitra, *Inorg. Chim. Acta* **2011**, *376*, 245–254; **DOI:**10.1016/j.ica.2011.06.024
(b) S. Bandyopadhyay, Jem-Mao Lo, H.-H. Yao, F.-L. Liao, P. Chattopadhyay, *J. Coord. Chem.* **2006**, *59*, 2015–2021; **DOI:**10.1080/00958970600717975
(c) S. Hazra, S. Majumder, M. Fleck, N. Aliaga-Alcalde, S. Mohanta, *Polyhedron*, **2009**, *28*, 3707–3714. **DOI:**10.1016/j.poly.2009.08.007
17. A. W. Addison, T. N. Rao, J. Reedijk, J. van Rijn, G. C. Verschoor, *J. Chem. Soc., Dalton Trans.* **1984**, 1349–1356. **DOI:**10.1039/DT9840001349
18. (a) X.-X. Zhou, H.-C. Fang, Y.-Y. Ge, Z.-Y. Zhou, Z.-G. Gu, X. Gong, G. Zhao, Q.-G. Zhan, R.-H. Zeng, Y.-P. Cai, *Cryst. Growth Des.* **2010**, *10*, 4014–4022; **DOI:**10.1021/cg100612b
(b) J. Reglinski, S. Morris, D. E. Stevenson, *Polyhedron*, **2002**, *21*, 2175–2182;
(c) B. Dutta, P. Bag, U. Florke, K. Nag, *Inorg. Chem.* **2005**, *44*, 147–157. **DOI:**10.1021/ic049056a **DOI:**10.1016/S0277-5387(02)01172-5
19. (a) M. Fleck, M. Layek, R. Saha, D. Bandyopadhyay, *Transition Met. Chem.* **2013**, *38*, 715–724; **DOI:**10.1007/s11243-013-9741-5
(b) B. Morandi, B. Mariampillai, E. M. Carreira, *Angew. Chem. Int. Ed. Engl.* **2011**, *50*, 1101–1104. **DOI:**10.1002/anie.201004269
20. K. R. Sangeetha Gowda, H. S. Bhojya Naik, B. Vinay Kumar, C. N. Sudhamani, H. V. Sudeep, T. R. Ravikumar Naik, G. Krishnamurthy, *Spectrochim. Acta A: Mol. Biomol. Spectrosc.* **2013**, *105*, 229–237. **DOI:**10.1016/j.saa.2012.12.011
21. R. Wei, F. Luo, *J. Coord. Chem.* **2010**, *63*, 610–616. **DOI:**10.1080/00958970903586259
22. A. Ray, D. Sadhukhan, G. M. Rosair, C. J. Gomez-Garcia, S. Mitra, *Polyhedron* **2009**, *28*, 3542–3550. **DOI:**10.1016/j.poly.2009.07.017
23. T. Tanaka, M. Kawase, S. Tani, *Life Sci.* **2003**, *73*, 2985–2990. **DOI:**10.1016/S0024-3205(03)00708-2
24. B. He, C. Dong, X. Wang, Y. Cao, Y. Gao, M. Yang, J. Zhang, C. Jing, D. Shi, Z. You, *Polyhedron* **2023**, *231*, 116254. **DOI:**10.1016/j.poly.2022.116254

Povzetek

Z reakcijo 4-bromosalicilaldehida z etan-1,2-diaminom v metanolu smo pripravili novo Schiffovo bazo *N*,*N*'-bis(4-bromo-2-hidroksibenziliden)etilenediamin (H_2L). Pri reakciji H_2L z bakrovim acetatom oziroma cinkovim acetatom v metanolu smo dobili enojedrna kompleksa [CuL] (**1**) in [ZnL(OH_2)] (**2**). Pri reakciji H_2L s kobaltovim nitratom v prisotnosti amonijevega tiocianata v mešanici metanola in dimetilformamida (DMF) smo dobili enojedrni kobaltov(III) kompleks [CoL(NCS)(OH_2)]·DMF (**3**). Prosto Schiffovo bazo in komplekse smo okarakterizirali z elementno analizo in infrardečo spektroskopijo ter z rentgensko strukturno analizo. H_2L smo okarakterizirali tudi z ^{1}H NMR analizo. Test inhibicije ureaze je pokazal, da ima kompleks bakra(II) največjo aktivnost z vrednostjo IC_{50} 0,17 ± 0,08 μmol L^{-1}.