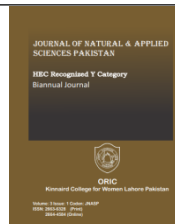




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SYNTHESIS, SINGLE CRYSTAL X-RAY AND BIOLOGICAL STUDY OF TRANSITION METAL COMPLEXES OF N, N-DONOR SCHIFF BASE LIGAND: N¹, N²-BIS[(4-METHOXYPHENYL) METHYLIDENE]-1,2-ETHANEDIAMINE

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Abstract

A Schiff base ligand, *N*¹, *N*²-bis[(4 methoxyphenyl) methylidene]-1,2-ethanediamine (SBL), was derived by the condensation of 4-methoxybenzaldehyde with ethylene diamine followed by complexation with divalent transition metals. The synthesized Schiff base ligand (SBL) and its complexes 1-5 were characterized on the basis of IR, ¹H-NMR, ¹³C-NMR, MS spectral, molar conductance and elemental analyses data. The structure of Schiff base ligand (SBL) was also confirmed by single crystal x-ray crystallographic study. The conductivity data suggests non-electrolytic nature of these complexes. The complexes have higher antibacterial activity than the parent Schiff base ligand.

Keywords

Schiff Base Ligand, X-ray Diffraction, Enzyme Inhibition, Antioxidant Activity, Antibacterial Activity



1. Introduction

The most important aspect of today research in the field of chemistry has focused its dimensions and orientations towards the synthesis of novel compounds which could be used as templates against harmful pathogens. The development of new templates is based on the fact that different strains of bacteria and fungi have developed immunity against the commonly used antibacterial and antifungal agents (Dueke-Eze *et al*, 2011). In this context, Schiff bases have been found as promising antimicrobial agents. These compounds were first of all reported by Hugo (Schiff, 1864). Schiff bases are compounds having azomethine ($-C=N-$) functionality. Literature shows that these compounds are antibacterial, herbicidal (Zhu *et al*, 2016), antifungal (Zhang *et al*, 2006) and anti-tumor (Billman & Schmidgall, 2006) agents. Moreover, there is an increased use of these Schiff bases as ligands in making mononuclear and as well as polynuclear complexes with transition metals (Adsule *et al*, 2006). The remarkable development in the field of Schiff base chemistry has turned the attention of scientific community to synthesize more and more Schiff base ligands with novelty and

diversity in structural aspects which may act as models for various biologically significant systems after complexation (Dharmaraj *et al*, 2001). The Schiff bases have been used as templates in electroluminescent complexes of zinc (Yu *et al*, 2007). Schiff bases have found their use as carriers of potentiometric sensors for determination of cations and anions (Shamspur *et al*, 2005). Aroyl hydrazones have been used as ligands in corrosion inhibition, antimicrobial and tuberculosis activity. The medicinal importance of Schiff bases has encouraged the researchers to use them for designing medicinal compounds (Patole *et al*, 2006). Due to versatile biological and chemical significance of Schiff bases, prompted us to synthesize new Schiff base ligands and their metal complexes. Herein, we report the synthesis of Schiff base ligand, *N*¹, *N*²-bis[(4-methoxyphenyl) methylidene]-1,2-ethanediamine (SBL) from the condensation of 4-methoxybenzaldehyde with ethylene diamine and its complexes with Co (II), Cu (II), Pb (II), Ni (II) and Cd (II) metal ions, their structure elucidation and biological potentials such as antibacterial, antioxidant, lipoxygenase and urease inhibition.

2. Experimental

2.1 Materials and methods

All the chemicals and solvents used for the synthesis were purchased from the Merck and as such. The hydrated metal (II) salts were used in chlorides or acetates form [CoCl₂.6H₂O, CuCl₂.2H₂O, Pb(OOCCH₃)₂.3H₂O, Ni(OOCCH₃)₂.4H₂O and Cd(OOCCH₃)₂.2H₂O].

2.2 Physical measurement

The TLC was performed on aluminium plates coated with silica gel G-25-UV₂₅₄ and detection was done under UV lamp at 254 and 366 nm. FTIR were recorded at Thermo Nicolet Avatar 320 spectrophotometer via KBr pellet. Melting points were measured at Gallenkamp apparatus and are uncorrected. For the elemental analyses, Perkin Elmer 2400 series II elemental analyser is used and

Jenway 4010 is used to record the molar conductances in DMSO solution (1×10^{-3} M) at room temperature. The mass spectra were recorded through FAB (Fast atomic bombardment) on JEOL SX102/DA-6000 mass spectrometer, using glycerol as matrix and ions are given in m/z (%). The H-NMR spectra were recorded on a Bruker AMX-400 spectrometer in DMSO- d_6 . The chemical shifts (δ) are given in ppm, relative to tetramethylsilane as an internal standard, and the scalar coupling constants (J) are reported in Hertz. Single-crystal x-ray

The methanol solution of 4-methoxybenzaldehyde (0.02 mol) was refluxed with the methanol solution of ethylenediamine (0.01 mol) for 4 hours at 100 °C with constant stirring on water bath. The resulting reaction mixture was concentrated to one-third of its original volume by rotary evaporator. Then added the ethyl acetate and petroleum ether (1:1) and cold

diffraction data was collected on Bruker Smart APEX II, CCD 4-K area detector diffractometer (Madison, 1996). Data reduction was performed by using SAINT program. The structure was solved by direct method (Altomare *et al*, 1993), and refined by full-matrix least squares on F2 by using the SHELXTL-PC package (GM, 1997). The figures were plotted with the aid of ORTEP program (CK, 1976).

2.3 Synthesis

2.3.1 Synthesis procedure of Schiff base ligand (SBL)

on ice-water. The concentrated resulting mixture was kept at room temperature and light yellow transparent crystals were observed after five days. The obtained crystals were filtered, washed with cold methanol, dried and recrystallized with methanol and then dried over anhydrous CaCl_2 . The purity of the product was checked by TLC (Fig., 1).

*N*¹,*N*²-Bis[(4-methoxyphenyl)methylidene]-1,2-ethanediamine (SBL): Light yellow crystals; yield: 87 %; m.p.: 110 °C; IR (KBr) ν_{max} cm^{-1} : 2841 (C-H), 1638 (C=N), 1459 (C=C); ¹H-NMR (DMSO- d_6 , 400 MHz) δ : 8.23 (2H, s, H-7, -7'), 7.63 (4H, d, J = 8.8 Hz, H-2, -6, -2', -6'), 6.95 (4H, d, J = 8.8 Hz, H-3, -5, -3', -5'), 3.79 (4H, s, H-9, -9'), 3.70 (6H, s, OMe (4, 4')); ¹³C-NMR (DMSO d_6 , 400 MHz) δ : 165.4 (C-7, -7'), 163.6 (C-4, -4'), 131.0 (C-2, -6, -2', -6'), 129.7 (C-1, -1'), 115.1 (C-3, -5, -3', -5'), 61.9 (C-9, -9'), 55.9 (OMe (4, 4')); FAB-MS (+ve) m/z : 297.2 $[\text{M}+\text{H}]^+$ (calcd. 296.1 for $\text{C}_{18}\text{H}_{20}\text{N}_2\text{O}_2$); Elemental analysis (%): C 72.93, H 6.92, N 9.50 (calcd. C 72.95, H 6.80, N 9.45)

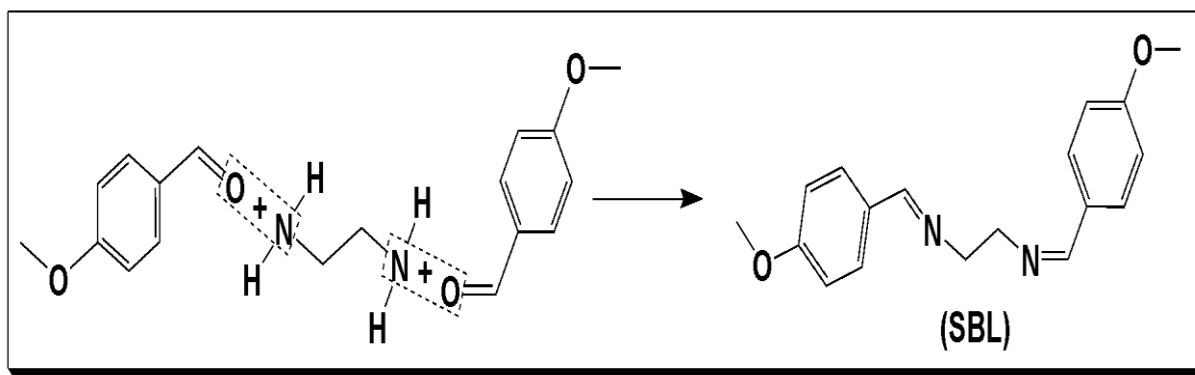


Figure 1: Synthesis of Schiff base ligand (SBL)

2.3.2 General procedure for the synthesis of metal complexes (1-5)

The methanol solution of the respective metal salt [CoCl₂.6H₂O, CuCl₂.2H₂O, Pb(OOCCH₃)₂.3H₂O, Ni(OOCCH₃)₂.4H₂O, Cd(OOCCH₃)₂.2H₂O] was added slowly to a hot methanol solution of ligand (SBL) with stirring in 2:1 (L:M) ratio. The reaction

mixture was further refluxed for 45 min. The pH of the reaction mixture was maintained by drop wise adding 1M NaOH in MeOH for the complex formation and the precipitation of complex. The precipitates of the complexes were filtered, washed with cold methanol and dried over anhydrous CaCl₂ under reduced pressure.

[Pb(BMBE)₂(OAc)₂] (1): White solid; yield: 78 %; m.p.: 284 °C (decomp.); IR (KBr) $\nu_{\max}$ cm⁻¹: 2924 (C-H), 1641 (COO)_{as}, 1545 (C=N), 1390 (C=C), 1246 (COO)_s, 519 (Pb-N); Molar conductance (DMSO) λ_m (Ohm⁻¹cm²mol⁻¹): 5.93; FAB-MS (+ve) m/z : 919.5 [M+H]⁺ (calcd. 918.3 for C₄₀H₄₆N₄O₈Pb); Elemental analysis (%):C 52.38, H 5.12, N 6.17, Pb 22.61 (clacd. C 52.33, H 5.05, N 6.10, Pb 22.57)

[Ni(BMBE)₂(H₂O)₂] (2): Stonewash green solid; yield: 81 %; m.p.: 201 °C (decomp.); IR (KBr) $\nu_{\max}$ cm⁻¹: 3286 (OH), 2928 (C-H), 1554 (C=N), 1404 (C=C), 523 (Ni-N); Molar conductance (DMSO) λ_m (Ohm⁻¹cm²mol⁻¹): 10.12; FAB-MS (+ve) m/z : 687.4 [M+H]⁺ (calcd. 686.2 for C₃₆H₄₄N₄O₆Ni); Elemental analysis (%):C 62.92, H 6.53, N 8.20, Ni 8.59 (clacd. C 62.90, H 6.45, N 8.15, Ni 8.54)

[Co(BMBE)₂(H₂O)₂] (3): Fatigue green solid; yield: 79 %; m.p.: 245 °C (decomp.); IR (KBr) $\nu_{\max}$ cm⁻¹: 3495 (OH), 3094 (C-H), 1569 (C=N), 1461 (C=C), 577 (Co-N); Molar conductance (DMSO) λ_m (Ohm⁻¹cm²mol⁻¹): 7.91; FAB-MS (+ve) m/z : 688.3 [M+H]⁺ (calcd. 687.2 for C₃₆H₄₄N₄O₆Co); Elemental analysis (%):C 62.89, H 6.53, N 8.18, Co 8.58 (clacd. C 62.87, H 6.45, N 8.15, Co 8.57)

[Cu(BMBE)₂(H₂O)₂] (4): Dark chocolate solid; yield: 72 %; m.p.: 258 °C (decomp.); IR (KBr) $\nu_{\max}$ cm⁻¹: 3364 (OH), 2974 (C-H), 1604 (C=N), 1462 (C=C), 583 (Cu-N); Molar conductance (DMSO) λ_m (Ohm⁻¹cm²mol⁻¹): 12.61; FAB-MS (+ve) m/z : 692.3 [M+H]⁺ (calcd. 691.2 for C₃₆H₄₄N₄O₆Cu); Elemental analysis (%):C 62.49, H 6.51, N 8.13, Cu 9.23 (clacd. C 62.46, H 6.41, N 8.09, Cu 9.18)

[Cd(BMBE)₂(H₂O)₂] (5): Light yellow solid; yield: 69 %; m.p.: 204 °C (decomp.); IR (KBr) $\nu_{\max}$ cm⁻¹: 3599 (OH), 2909 (C-H), 1551 (C=N), 1401 (C=C), 514 (Cd-N); Molar conductance (DMSO) λ_m (Ohm⁻¹cm²mol⁻¹): 12.13; FAB-MS (+ve) m/z : 743.4 [M+H]⁺ (calcd. 742.2 for C₃₆H₄₄N₄O₆Cd); Elemental analysis (%):C 58.39, H 6.02, N 7.59, Cd 15.19 (clacd. C 58.34, H 5.98, N 7.56, Cd 15.17)

2.4 Biological studies

The antioxidant potential with DPPH scavenging and urease inhibition activity were measured by reported protocol (Ferheen et al, 2009), while lipoxygenase (LOX) inhibiting activity was measured by reported modified method (Ali et al, 2009). The antibacterial activity was measured as

diameter of zone of inhibition to calculate the % inhibition by using modified method (Bibi et al, 2011).

3. Results and Discussion

The reaction of 4-methoxybenzaldehyde (anisaldehyde) with ethylene diamine produces the Schiff base ligand, *N*¹,*N*²-bis[(4-

methoxyphenyl)methylidene]-1,2-ethanediamine (SBL), while treatment of this Schiff base with metal (II) salt resulted in the formation of complexes (1-5). The melt points of complexes (1-5) were provide clear evidence that the complexes (1-5) are fairly stable.

3.1 Infrared spectra

The absence of characteristic bands of the carbonyl group $\nu(\text{C=O})$ of 4-methoxybenzaldehyde and the amino group $\nu(-\text{NH}_2)$ of free ethylene diamine revealing the complete condensation taken place, and the absorption band at 1638 cm^{-1} further revealed the formation of azomethine bond. The binding positions of the Schiff base ligand with the metal ion in complexes were revealed by comparing the IR spectra of the ligand with the IR spectra of all the complexes. In the IR spectra of the complexes, the shifting of SBL band from 1638 cm^{-1} to $1545\text{--}1604\text{ cm}^{-1}$ indicating the formation of coordinate covalent bond between nitrogen of the C=N group and the metal atom. This can be explained by the donation of electrons from nitrogen to the d-orbital of the metal atom (Zhu et al, 2006). Furthermore, the appearance of band with medium intensity at $514\text{--}583\text{ cm}^{-1}$ is assigned to $\nu(\text{M-N})$ (Chohan and Pervez, 1993), confirmed the formation of complexes. The absorption bands at 1641 and 1246 cm^{-1} in IR of complex 1 were assigned to the $\nu(\text{COO}^-)_{as}$ asymmetric stretching vibrations and to the $\nu(\text{COO}^-)_s$ symmetric stretching vibration of the acetate ion, respectively. This indicates that the acetate group was present in the complex (Fig., 2). In complexes 2-5, the presence of broad band at $3286\text{--}3599\text{ cm}^{-1}$

suggesting the presence of water in the complexes (Fig., 2) (Nakanishi and Solomon, 1977).

3.2 $^1\text{H-NMR}$ spectra

In the $^1\text{H-NMR}$ spectrum of the ligand (SBL), the singlet at 8.23 ppm of methane proton revealing the formation of azomethine bond in the Schiff base ligand. The down field signals at 7.63 and 6.95 ppm were of aromatic ring protons and the signals at 3.79 and 3.70 ppm were of $-\text{CH}_2$ and $-\text{OCH}_3$, respectively.

3.3 Molar conductance

The molar conductivities of the complexes 1-5 of $1 \times 10^{-3}\text{ M}$ DMSO solutions were measured at room temperature. The observed molar conductance value for complex 1 was $5.93\text{ ohm}^{-1}\text{cm}^2\text{mol}^{-1}$, showing the non-ionic nature while complexes 2-5 have molar conductance values in the range of $7.91\text{--}12.61\text{ ohm}^{-1}\text{cm}^2\text{mol}^{-1}$, revealing the ionic nature of these complexes (Geary, 1971).

3.4 FAB mass spectra

The masses of the ligand (SBL) and the complexes 1-5 were determined through the FAB (positive mode) mass spectra. A molecular ion peak $[\text{M}+\text{H}]^+$ was observed at $m/z\ 297.2$ which revealed the ligand and confirms the molecular weight i.e., 296.1 . The observed molecular ion peaks for the complexes 1-5, confirming the complexes with metal to ligand ratio 1:2. The elemental analysis values are also in good agreement with these values.

3.5 Electronic spectra and magnetic moment

The position, number of d-d transitions and charge transfer formed the basis of geometry of metal ions in complexes 1-5 and geometry was assigned by observing electronic spectra. The octahedral geometry was suggested for all complexes by

observing electronic spectra and magnetic moment values (Table 1), which was further strengthened by

the low value of molar conductance, indicating the nature of complexes as non-electrolytic.

Table 1: Electronic and magnetic moment data of ligand and complexes

Compound	Electronic spectra wavelength (cm ⁻¹)	Magnetic moment (B.M.)	Assignment	Geometry
1	94500, 13450, 19500	4.9	${}^4T_{1g}(F) \rightarrow {}^4T_{2g}(F)$ ${}^4T_{1g}(F) \rightarrow {}^4A_{2g}(F)$ ${}^4T_{1g}(F) \rightarrow {}^4T_{1g}(P)$	Octahedral
2	12889, 16542, 24435	3.2	${}^3A_{2g}(F) \rightarrow {}^3T_{2g}(F)$ ${}^3A_{2g}(F) \rightarrow {}^3T_{1g}(F)$ ${}^3A_{2g}(F) \rightarrow {}^3T_{1g}(P)$	Octahedral
3	17705, 22100	4.6	${}^4T_{1g}(F) \rightarrow {}^4T_{2g}(F)$ ${}^4T_{1g}(F) \rightarrow {}^4T_{1g}(P)$	Octahedral
4	15525	1.9	${}^3A_{2g}(F) \rightarrow {}^3T_{1g}(F)$	Octahedral
5	9500, 14500, 20500	4.7	${}^4T_{1g}(F) \rightarrow {}^4T_{2g}(F)$ ${}^4T_{1g}(F) \rightarrow {}^4A_{2g}(F)$ ${}^4T_{1g}(F) \rightarrow {}^4T_{1g}(P)$	Octahedral

3.6 Proposed molecular structure of metal complexes (1-5)

On the bases of analytical and spectral data, it is imagining that the metal ions are bonded to the

Schiff base ligand (SBL) via the nitrogen atom; the tentative proposed structures of the complexes are illustrated in Fig., 2.

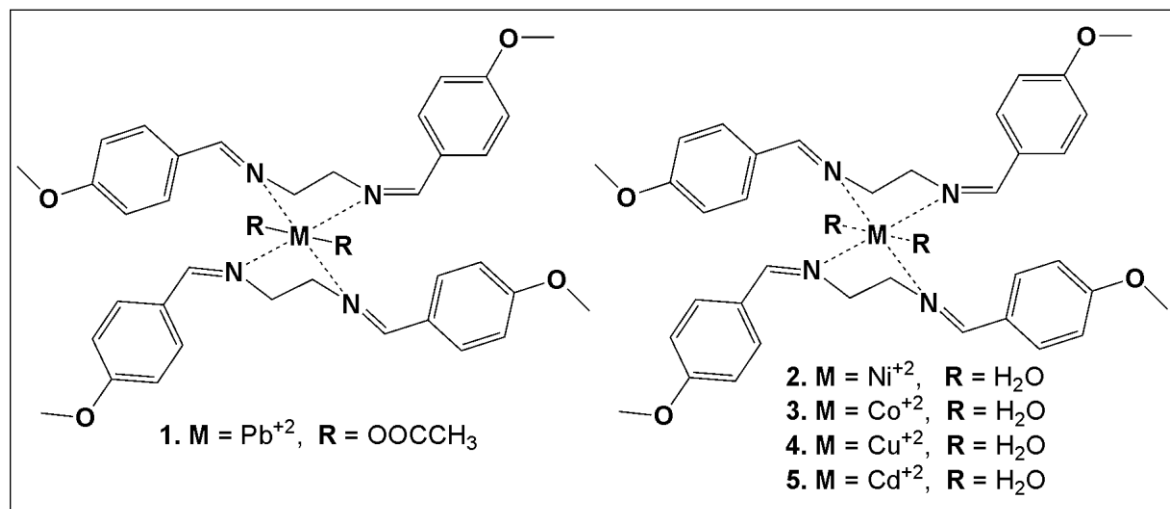


Fig2: Proposed structure complexes 1-5

3.7 Single crystal XR

The crystal structure of ligand (SBL) (Fig., 3) is centrosymmetric with a centre of inversion located in the midpoint of the compound. Therefore, the

complete molecule of the Schiff base ligand, $C_{18}H_{20}N_2O_2$ is generated by the application of a centre of inversion. The azomethine double bond adopts an E-configuration, with torsion angle of

179.54(13)° C8/N1/C6-C7. The phenyl group (C1---C6) and azomethine moiety, C6/N1/C7---C8, are each planar with a dihedral angle between their least square planes being 7.44 (18)°. The bond lengths and angle were similar to the reported structurally related compounds (Cox et al, 2008). The bond length of azomethine bond was found to be 1.249(2) Å. In the crystal structure of the ligand, the molecules were arranged in parallel sheets along b-axis (Fig., 4) without any classical hydrogen bonding between molecules. Crystal data of Schiff base ligand (SBL): C₁₈H₂₀N₂O₂, Mr = 296.36, Monoclinic, space group

*P*2₁/*n*, *a* = 10.2089(8) Å, *b* = 7.9659(7) Å, *c* = 10.6366(9) Å, β = 111.747(2)°, *V* = 803.44(12) Å³, *Z* = 2, ρ_{calc} = 1.225 mg/m³, *F*(000) = 316, μ (Mo Kα) = 0.71073 Å⁻¹, max/min transmission 0.9896/0.9570 crystal dimensions 0.55 x 0.26 x 0.13, 2.36° < 2θ < 25.5°, 4577 reflections were collected, of which 1464 reflections were observed (*R*_{int} = 0.0141). The *R* values were: *R*₁ = 0.0438, w*R*₂ = 0.1239 for *I* > 2σ(*I*), and *R*₁ = 0.0515, w*R*₂ = 0.1334 for all data; max/min residual electron density: 0.160 / -0.143 e Å⁻³.

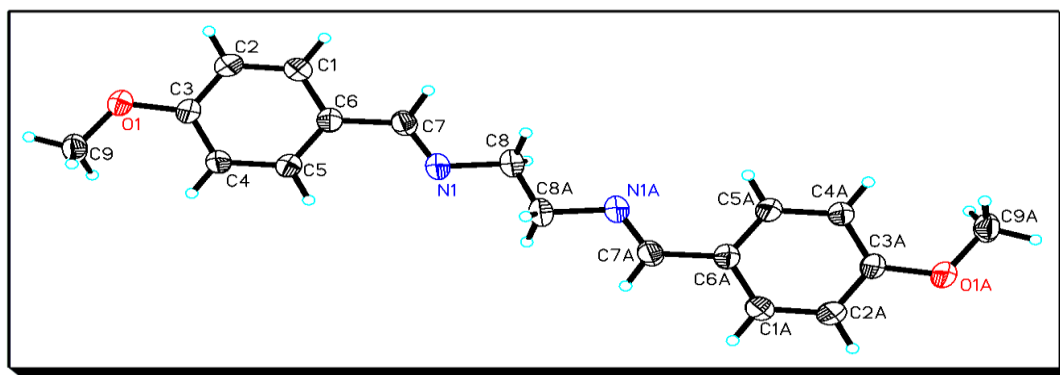


Fig., 3: The molecular structure (ORTEP) of Schiff base ligand (SBL) with displacement ellipsoids drawn at 30% probability level.

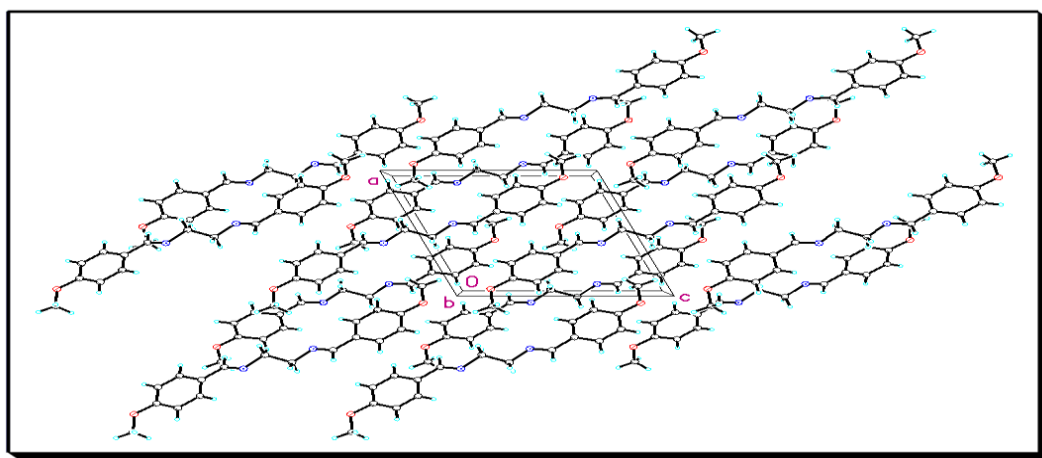


Fig., 4: The crystal packing of the ligand (SBL)

3.8 Biological studies

The Schiff base ligand (SBL) and its complexes 1-5 were screened out for antioxidant, lipoxigenase, urease inhibition and antibacterial activities. The results of Schiff base ligand (SBL) and complexes 1-5 of DPPH scavenging antioxidant, lipoxigenase and urease inhibition activities are summarized in Table 2. When IC₅₀ values SBL and complexes 1-5 were compared with the standard, it can be seen that the Schiff base ligand (SBL) has good IC₅₀ value only in urease inhibition activity while its complexes 1-5 have non-significant IC₅₀ values. The potential of the Schiff base ligand (SBL) and its complexes 1-5 was checked against various microorganisms such as *S. intermedius*, *B. subtilis*, *S. aureus*, *E. coli* and *S. typhi* in order to establish its bioactivities and results are summarized in Table 3. The antibacterial

activity was evaluated by measuring the diameter of the zone of inhibition in mm and then percentage of growth inhibition was calculated. In order to compare the results obtained, the gentamicin was used as a standard drug. The result obtained showed that Schiff base ligand (SBL) and its complexes (1-5) have good activity against *B. subtilis* and *S. aureus* while moderate activity against *S. intermedius*, *E. coli* and *S. typhi* as compared to the standard drug, proposed that the oxygen of –OCH₃ may bind with the bacteria leading to such kind of results of biological activity. In the mode of action of the Schiff base ligand, may involve the formation of hydrogen bond through the azomethine group with the active Centre of cell constitutes resulting in interference with the normal cell process.

Table 2: IC₅₀ (μM) values of Schiff base ligand (SBL) and complexes (1-5) in the antioxidant, lipoxigenase and urease assay

Compound	DPPH Scavenging Activity IC ₅₀ (μM)	Lipoxigenase Inhibition Activity IC ₅₀ (μM)	Urease Inhibition Activity IC ₅₀ (μM)
BMBE	+	+	51.5
1	+	+	+
2	+	+	+
3	+	+	+
4	+	+	+
5	+	+	+
BHA	44.2	-	-
Baicalein	-	22.6	-
Thiourea	-	-	21.6

Table 3: % Inhibition values of Schiff base ligand in the antibacterial assay

Name of Bacteria	Gentamicin (0.3%)	SBL	1	2	3	4	5
	Inhibition (mm)	Inhibition (%)	Inhibition (%)	Inhibition (%)	Inhibition (%)	Inhibition (%)	Inhibition (%)
<i>S. intermedius</i>	26	58	77	73	46	75	57
<i>B. subtilis</i>	33	27	55	61	67	79	55

<i>S. aureus</i>	30	35	70	57	73	67	73
<i>E. coli</i>	28	28	61	63	57	54	46
<i>S. typhi</i>	29	55	46	52	72	66	62

4. Conclusions

Schiff base ligand and complexes were derived from 4-methoxybenzaldehyde with ethylene diamine, and metal (II) salts, respectively. They characterized by various spectroscopic and analytical techniques. FAB-MS and elemental analyses of the complexes were confirmed its bidentate nature, and stoichiometry was observed as 1:2 (M:L) and its non-electrolytic nature has been deduced from conductance data. The metal complexes have non-significant antioxidant, lipoxigenase and urease inhibition activities and have higher antibacterial activity than the Schiff base ligand.

5. Supplementary Material

CCDC-881753 contains the supplementary crystallographic data for Schiff base ligand (SBL). The data can be obtained free of charge via <http://www.ccdc.cam.ac.uk/conts/retrieving.html> by e-mailing: deposit@ccdc.cam.ac.uk; or by contacting: The Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge CB2 1EZ, UK; Fax: +44(0)1223-336-033.

References

Adsule, S., Barve, V., Chen, D., Ahmed, F., Dou, Q. P., Padhye, S., & Sarkar, F. H. (2006). Novel Schiff base copper complexes of quinoline-2 carboxaldehyde as proteasome inhibitors in human prostate cancer cells. *Journal of medicinal chemistry*, 49(24), 7242-7246.

Ali, S., Maharvi, G. M., Riaz, N., Afza, N., Malik, A., Rehman, A. U., & Iqbal, L. (2009).

Lipoxigenase inhibitory tetraketones: potential Remedial source for inflammation and asthma. *West Indian Med J*, 58(2), 92.

Altomare, A., Cascarano, G., Giacovazzo, C., & Guagliardi, A. (1993). Completion and refinement of crystal structures with SIR92. *Journal of Applied Crystallography*, 26(3), 343-350.

Bibi, Y., Nisa, S., Chaudhary, F. M., & Zia, M. (2011). Antibacterial activity of some selected medicinal plants of Pakistan. *BMC complementary and alternative medicine*, 11(1), 1-7.

Billman, J. H., & Schmidgall, R. L. (1970). Preparation and antitumor activity of some Schiff bases of 2'-Amino-4', 5'-Dichlorobenzenesulfonanilide and 2'-Amino-p-Toluenesulfonanilide. *Journal of pharmaceutical sciences*, 59(8), 1191-1194.

Chohan, Z. H., & Pervez, H. (1993). Studies on biologically active complexes of nickel (II), copper (II) and zinc (II) with tridentate NNO, NNS and NNN donor pyrazine derived ligands. *Synthesis and Reactivity in Inorganic and Metal-Organic Chemistry*, 23(7), 1061-1071.

Cox, P. J., Kechagias, D., & Kelly, O. (2008). Conformations of substituted benzophenones. *Acta Crystallographica*

- Section B: Structural Science, 64(2), 206-216.
- Dharmaraj, N., Viswanathamurthi, P., & Natarajan, K. (2001). Ruthenium (II) complexes containing bidentate Schiff bases and their antifungal activity. *Transition Metal Chemistry*, 26(1), 105-109.
- Dueke-Eze, C. U., Fasina, T. M., & Idika, N. (2011). Synthesis, electronic spectra and inhibitory study of some salicylaldehyde Schiff bases of 2-aminopyridine.
- Ferheen, S., Aziz-Ur-Rehman, Afza, N., Malik, A., Iqbal, L., Azam Rasool, M., ... & Bakhsh Tareen, R. (2009). Galinsosides A and B, bioactive flavanone glucosides from *Galinsoga parviflora*. *Journal of enzyme inhibition and medicinal chemistry*, 24(5), 1128-1132.
- Geary, W. J. (1971). The use of conductivity measurements in organic solvents for the characterisation of coordination compounds. *Coordination Chemistry Reviews*, 7(1), 81-122.
- CK, J. (1976). ORTEPII Report ORNL-5138, Oak Ridge National Laboratory.
- Nakanishi, K., & Solomon, P. H. (1977). *Infrared absorption spectroscopy*. Holden-day.
- Patole, J., Shingnapurkar, D., Padhye, S., & Ratledge, C. (2006). Schiff base conjugates of p-aminosalicylic acid as antimycobacterial agents. *Bioorganic & medicinal chemistry letters*, 16(6), 1514-1517.
- Schiff, H. (1864). Mittheilungen aus dem Universitätslaboratorium in Pisa: eine neue Reihe organischer Basen. *Justus Liebigs Annalen der Chemie*, 131(1), 118-119.
- Shamspur, T., & Mostafavi, A. (2009). Application of modified multiwalled carbon nanotubes as a sorbent for simultaneous separation and preconcentration trace amounts of Au (III) and Mn (II). *Journal of Hazardous Materials*, 168(2-3), 1548-1553.
- GM, S. (1997). SHELXTL-PC (Version 5.1). Siemens analytical instruments Inc. WI, USA: Madison.
- Madison, W. I. (1996). SMART and SAINT, Siemens Analytical X-Ray Instruments.
- Yu, T., Su, W., Li, W., Hong, Z., Hua, R., & Li, B. (2007). A schiff base zinc complex and its electroluminescent properties. *Thin Solid Films*, 515(7-8), 4080-4084.
- Zhang, L. X., Liu, Y., Cia, L. H., Hu, Y. J., Yin, J., & Hu, P. Z. (2006). Inhibitory study of some novel Schiff base derivatives on *Staphylococcus aureus* by micro calorimetry. *Thermochemical acta*, 440(1), 51-56.
- Zhu, D., Su, Z., Mu, Z., Qiu, Y., & Wang, Y. (2006). Synthesis, crystal structures and properties of five-coordinate Schiff-base Zn (II) complexes. *Journal of Coordination Chemistry*, 59(04), 409-419.
- Zhu, S., Xu, S., Jing, W., Zhao, Z., & Jiang, J. (2016). Synthesis and herbicidal

activities of p-menth-3-en-1-amine and its Schiff base derivatives. Journal of agricultural and food chemistry, 64(51), 9702-9707.