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SYNTHESIS, CHARACTERIZATION AND ANTIBACTERIAL ACTIVITY OF COMPLEXES OF PALLADIUM WITH SCHIFF BASES DERIVED FROM 1, 3-DIAMINOPROPANE

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ABSTRACT

In this communication, six Schiff base ligands were synthesized by condensation of salicylaldehyde/ benzaldehyde/ pyrrole-2-carboxaldehyde/ *p*-hydroxybenzaldehyde / isatin/ *o*-hydroxyacetophenone with 1,3-diaminopropane in 2:1 molar ratio. Complexes of these Schiff bases with Pd (II) metal were synthesized in 1:1 / 1:2 stoichiometric ratio. The complexes were formulated as [Pd(L)] and [Pd(L)₂]Cl₂; where L is Schiff base. Complexes were characterized by elemental analysis, molar conductance, UV-Visible, FT-IR, ¹H-NMR, ¹³C-NMR, ²D-NMR and ESI-Mass spectrometry. Schiff bases were coordinated with metal through phenolic oxygen and azomethine-N or by azomethine-N itself only, giving simple square planar geometry to complexes. Complexes were tested for antibacterial activity MIC against gram-negative bacteria *E. coli* and gram positive bacteria *S. aureus* and were found more potent than Schiff bases and precursor reagents.

Keywords: *Palladium Complexes, Schiff Base, Antibacterial Activity*

INTRODUCTION

In the last decade Schiff base ligands have received more attention mainly because of their wide application in the field of catalysis, anticorrosion, antimicrobial, anti-tuberculosis, antitumor and anti mouse hepatitis virus (MHV) activity. They have been studied extensively as a class of ligands and are known to coordinate with most transition metal ions through the azomethine nitrogen atom to form stable complexes (Joshi *et al.*, 2011; Osowole, 2008; Satyanarayana *et al.*, 2008; Jarrahpour *et al.*, 2004; Kumar *et al.*, 2009; Uddin *et al.*, 2014). Schiff base ligands which usually contain O and N donor atoms have played an important role in coordination chemistry and recently, considerable attention has been paid to the chemistry of the metal complexes of Schiff bases containing nitrogen and other donors. This may be attributed to their stability, biological activity and potential applications in many fields such as oxidation catalysis, electrochemistry etc (Liu *et al.*, 1996; Djebbar *et al.*, 1998; Hamada, 1997).

Metal complexes of Schiff bases are extensively studied due to synthetic flexibility, selectivity and sensitivity towards a variety of organism. Platinum (IV) and palladium (II) complexes have revealed significantly greater activity in human than that of cisplatin. The high activity was ascribed to high cellular uptake, but *in vivo* reduction alters the pharmacological properties and thus the effectiveness of the drug. The significant similarity between the coordination chemistry of palladium(II) and platinum(II) compounds has advocated studies of Pd(II) complexes as antitumor drugs (Rau *et al.*, 1996). A key factor that might explain why platinum is most useful comes from the ligand exchange kinetics. The hydrolysis in palladium complexes is too rapid: 105 times faster than for their corresponding platinum analogues. They dissociate readily in solution leading to very reactive species that are unable to reach their pharmacological targets.

Therefore, it will be illuminating to study the reaction of biologically active Schiff bases with the palladium metal, in order to explore the reactivity and biological activity of the complexes formed.

MATERIALS AND METHODS

Salicylaldehyde, Benzaldehyde, Pyrrole-2-carboxaldehyde, *p*-hydroxybenzaldehyde, Isatin, *o*-hydroxyacetophenone, Palladium chloride, 1,3-diamino propane (All E. Merck) were purchased and used

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without further purification. Mueller Hinton Agar media (Himedia) was used as received. Analytical reagent grade ethanol and other solvents were used throughout the experiment.

Electronic absorption spectra were recorded with Systronics 2201 UV-Visible double beam spectrophotometer equipped with PC. Conductivity measurements were carried out at 25°C on the EI-181 digital conductivity bridge with a dipping type. FT-IR spectra were recorded in KBr pellets on a Shimadzu-8400 PC FT-IR spectrophotometer. ¹H-NMR, ¹³C-NMR, ²D-NMR (HETCOR) spectra were recorded in DMSO-d₆ on Bruker DRX-300 spectrophotometer. The ESI spectra were recorded on JEOL-Accut of JMS-T100LC Mass spectrometer having a DART source. Elemental analyses (C, H and N) were performed on ElementarVario EL III, elemental analyzer.

Synthesis of Ligand

Synthesis of Schiff Base Ligands

Aldehyde (salicylaldehyde/ benzaldehyde/ pyrrole-2-carboxaldehyde/ *p*-hydroxybenzaldehyde/ *o*-hydroxyacetophenone) was taken in 30 mL ethanol, mixed with 1,3-diaminopropane dissolved in 30 mL ethanol in 2:1 molar ratio and the mixture was refluxed for 12 - 15 h. A sandy yellowish coloured solution was obtained which was reduced to one fourth of its volume and poured into ice cold water. A yellow/ sandy white/ black/ sandy yellow/ yellow coloured precipitate was obtained, which was filtered off, vacuum dried and recrystallized from acetonitrile: acetone: chloroform solvent mixture. Schiff base of indole-2,3-dione (isatin) was prepared by a different method. A paste of isatin (0.2205g, 1.5 mmol) and 1,3-diaminopropane (0.20, 3 mmol) in a sealed carius tube was heated in a furnace at 110-120°C for 5h. The colour of melt was changed from orange to dark red. After cooling to room temperature, the solid mass was ground and heated in boiling ethanol for 30 min the product was filtered off and washed several times with hot ethanol to remove unreacted materials giving sandy yellow crystals.

N, N'-bis(salicylidene)-1,3-propylenediamine Schiff base, (L¹)

Colour = Yellow, Yield: 2.772g (98.18%); m.p. = 80°C; Found: C, 72.25; H, 6.43; N, 9.89; C₁₇H₁₈N₂O₂ (M_r = 282.34). Requires: C, 72.31; H, 6.42; N, 9.92. Selected infrared absorption (KBr, cm⁻¹): ν(OH)_{arom}, 3550(br); ν(CH=N), 1635(s); ν(C-N), 1211(br); ν(-CH₂-CH₂-), 860(m), 876(sh). ¹H-NMR spectra (δ value in ppm): δ(CH=N), 8.13 (s, 2H); δ(Ar-H)_{phenol}, 7.45(d, 2H); 7.12(t, 2H); 6.85(t, 2H); 6.75(d, 2H); δ(Ar-OH), 5.0(s, 2H); δ(N-CH₂), 3.55(q, 4H); δ(CH₂), 2.01(t, 2H). ¹³C-NMR (δ value in ppm): δ(CH=N), 160.9; δ(Ar-C)_{phenolic}, 161.1(C₁), 124.6(C₂), 130.6(C₃), 121.5(C₄), 132.5(C₅), 116.0(C₆); δ(N-C), 59.5; δ(C-CH₂), 32.3. ESI-Mass spectra, m/z: [C₆H₅O]⁺ = 93.10, [C₁₁H₁₃N₂O]⁺ = 189.23, [C₁₇H₁₈N₂O₂]⁺ = 282.34.

N, N'-bis(benzylidene)-1,3-propylenediamine Schiff base, (L²)

Colour = Sandy white, Yield: 1.180g (47.20%); m.p. = 140°C; found: C, 81.50; H, 7.22; N, 11.16; C₁₇H₁₈N₂ (M_r = 250.34). Requires: C, 81.56; H, 7.24; N, 11.19. Selected infrared absorption (KBr, cm⁻¹): ν(CH=N), 1645(s); ν(C-N), 1219(br), ν(-CH₂-CH₂-), 868(m), 880(sh). ¹H-NMR spectra (δ value in ppm): δ(CH=N), 8.11 (s, 2H); δ(Ar-H)_{phenyl}, 7.60(d, 2H); 7.50(t, 2H); 7.43(t, 2H) 7.30(t, 2H); 6.70(d, 2H); δ(N-CH₂), 3.58(q, 4H); δ(CH₂), 2.11(t, 2H). ¹³C-NMR (δ value in ppm): δ(C=N), 160.6; δ(Ar-C)_{phenyl}, 139.3(C₁), 129.0(C₂), 128.4(C₃), 130.1(C₄), 128.3(C₅), 129.0(C₆); δ(N-C), 59.1; δ(C-CH₂), 31.7. ESI-Mass spectra, m/z: [C₆H₅]⁺ = 77.10, [C₁₁H₁₃N₂]⁺ = 173.23, [C₁₇H₁₈N₂]⁺ = 250.34.

N, N'-bis(pyrrolidene)-1,3-propylenediamine Schiff base, (L³)

Colour = Sandy white, Yield: 1.550g (67.98%); m.p. = 120°C; found: C, 68.32; H, 7.03; N, 24.45; C₁₃H₁₆N₄ (M_r = 228.30). Requires: C, 68.39; H, 7.06; N, 24.54. Selected infrared absorption (KBr, cm⁻¹): ν(CH=N), 1637(s); ν(C-N), 1247(br), ν(-CH₂-CH₂-), 861(m), 883(sh). ¹H-NMR spectra (δ value in ppm): δ(CH=N), 8.14 (s, 2H); δ(Ar-H)_{pyrrole}, 6.65(d, 2H); 6.38(t, 2H); 6.17(t, 2H); δ(NH) 5.60(s, 4H); δ(N-CH₂), 3.59(d, 4H); δ(CH₂), 2.09(t, 2H). ¹³C-NMR (δ value in ppm): δ(C=N), 160.1; δ(Ar-C)_{pyrrole}, 117.8(C₁), 108.2(C₂), 111.3(C₃), 132.4(C₄); δ(N-C), 53.1; δ(C-CH₂), 31.3. ESI-Mass spectra, m/z: [C₄H₄N]⁺ = 66.08, [C₉H₁₂N₃]⁺ = 162.21, [C₁₃H₁₆N₄]⁺ = 228.30.

N, N'-bis(4-hydroxybenzylidene)-1,3-propylenediamine Schiff base, (L⁴)

Colour = Black, Yield: 1.072g (31.01%); m.p. = 140°C; found: C, 72.20; H, 6.40; N, 9.82; C₁₇H₁₈N₂O₂ (M_r = 282.34). Requires: C, 72.31; H, 6.42; N, 9.92. Selected infrared absorption (KBr, cm⁻¹): ν(OH)_{arom},

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3680(br); $\nu(\text{CH}=\text{N})$, 1637(s); $\nu(\text{C}-\text{N})$, 1213(br), $\nu(-\text{CH}_2-\text{CH}_2-)$, 865(m), 885(sh). ^1H -NMR spectra (δ value in ppm): $\delta(\text{CH}=\text{N})$, 8.14 (s, 2H); $\delta(\text{Ar}-\text{H})_{\text{phenol}}$, 7.48(s, 4H); 6.71(s, 4H); $\delta(\text{Ar}-\text{OH})$, 5.1(s, 2H); $\delta(\text{N}-\text{CH}_2)$, 3.52(d, 4H); $\delta(\text{CH}_2)$, 2.08(t, 2H). ^{13}C -NMR (δ value in ppm): $\delta(\text{CH}=\text{N})$, 160.0; $\delta(\text{Ar}-\text{C})_{\text{Phenolic}}$, 132.2(C_1), 130.1(C_2, C_6), 115.3(C_3, C_5), 160.1(C_4); $\delta(\text{N}-\text{C})$, 58.7; $\delta(\text{C}-\text{CH}_2)$, 32.0. ESI-Mass spectra, m/z : $[\text{C}_6\text{H}_5\text{O}]^+ = 93.10$, $[\text{C}_9\text{H}_{10}\text{NO}]^+ = 149.18$, $[\text{C}_{17}\text{H}_{18}\text{N}_2\text{O}_2]^+ = 282.34$.

Schiff base of indole-2,3-dione (Isatin), (L^5)

Colour = Sandy yellow, Yield: 2.234g (67.20%); m.p. = 160°C ; found: C, 68.65; H, 4.86; N, 16.86; $\text{C}_{19}\text{H}_{16}\text{N}_4\text{O}_2$ ($M_r = 332.36$). Requires: C, 68.66; H, 4.85; N, 16.85. Selected infrared absorption (KBr, cm^{-1}): $\nu(\text{C}=\text{N})$, 1649(s); $\nu(\text{C}-\text{N})$, 1207(br); $\nu(\text{CONH})_{\text{indolin-2-one}}$, 1716(s). ^1H -NMR spectra (δ value in ppm): $\delta(\text{CO}-\text{NH})$, 8.03 (s, 1H); $\delta(\text{Ar}-\text{H})_{\text{indolin-2-one}}$, 7.62(d, 2H); 7.25(t, 2H); 7.07(t, 2H); 7.58(d, 2H); $\delta(\text{N}-\text{CH}_2)$, 3.59(d, 4H); $\delta(\text{N}-\text{C}-\text{CH}_2)$, 2.07(t, 2H). ^{13}C -NMR (δ value in ppm): $-(\text{CONH})_{\text{indolin-2-one}}$, 166.5; $\delta(\text{C}=\text{N})$, 160.3; $\delta(\text{Ar}-\text{C})_{\text{indolin-2-one}}$, 146.2(C_1), 121.3(C_2), 131.2(C_3), 124.1(C_4), 129.2(C_5), 122.7(C_6); $\delta(\text{N}-\text{CH}_2)$, 51.7; $\delta(\text{C}-\text{CH}_2)$, 31.0. ESI-Mass spectra, m/z : $[\text{C}_{11}\text{H}_{11}\text{N}_2\text{O}]^+ = 187.11$, $[\text{C}_{13}\text{H}_{11}\text{N}_3\text{O}_2]^+ = 242.16$, $[\text{C}_{19}\text{H}_{16}\text{N}_4\text{O}_2]^+ = 333.18$.

N, N'-bis(1-methyl-2-hydroxybenzylidene)-1,3-propylenediamine Schiff base, (L^6)

Colour = Yellow, Yield: 2.951g (95.07%); m.p. = 120°C ; found: C, 73.51; H, 7.15; N, 9.01; $\text{C}_{19}\text{H}_{22}\text{N}_2\text{O}_2$ ($M_r = 310.40$). Requires: C, 73.52; H, 7.14; N, 9.02. Selected infrared absorption (KBr, cm^{-1}): $\nu(\text{OH})_{\text{arom}}$, 3630(br); $\nu(\text{C}=\text{N})$, 1642(s); $\nu(\text{C}-\text{N})$, 1234(br). ^1H -NMR spectra (δ value in ppm): $\delta(\text{Ar}-\text{H})_{\text{phenol}}$, 7.42(d, 2H); 7.11(t, 2H); 6.82(t, 2H); 6.73(d, 2H); $\delta(\text{Ar}-\text{OH})$, 5.15(s, 1H); $\delta(\text{N}-\text{CH}_2)$, 3.54(d, 4H); $\delta(\text{CH}-\text{CH}_2)$, 2.06(t, 2H). ^{13}C -NMR (δ value in ppm): $\delta(\text{C}=\text{N})$, 160.4; $\delta(\text{Ar}-\text{C})_{\text{Phenolic}}$, 160.8(C_1), 124.2(C_2), 130.1(C_3), 121.1(C_4), 132.2(C_5), 115.6(C_6); $\delta(\text{N}-\text{CH}_2)$, 46.6; $\delta(\text{CH}_2-\text{CH}_2)$, 32.2; $\delta(\text{C}-\text{CH}_3)$, 16.2. ESI-Mass spectra, m/z : $[\text{C}_8\text{H}_8\text{NO}]^+ = 134.16$, $[\text{C}_{13}\text{H}_{17}\text{N}_2\text{O}]^+ = 217.29$, $[\text{C}_{19}\text{H}_{22}\text{N}_2\text{O}_2]^+ = 310.40$.

Synthesis of Complexes

Palladium chloride and recrystallized Schiff base of reagents were mixed in 1:1 and 1:2 molar ratio in 30 mL of ethanol and the reaction mixture was kept under stirring for 2 h in an inert atmosphere. The colour of reaction mixture changes from dark yellow to dark brown. Thereafter, reaction mixture was refluxed for 2-3 h. A black solid was isolated after reduction of volume by evaporation, which was filtered off, washed with ethanol and dried under vacuum. The solid obtained was recrystallized by an appropriate solvent mixture.

$[\text{Pd}(\text{L}^1)]$, Complex 1

Colour = Black, Yield: 0.255g (55.67%); m.p. 180°C^d ; Found: C, 52.80; H, 4.15; N, 7.23; $\text{C}_{17}\text{H}_{16}\text{N}_2\text{O}_2\text{Pd}$ ($M_r = 386.63$). Requires: C, 52.81; H, 4.14; N, 7.24. Molar conductance ($\Omega^{-1}\text{cm}^2\text{mol}^{-1}$): 6 in DMSO. Selected infrared absorption (KBr, cm^{-1}): $\nu(\text{CH}=\text{N})$, 1616(s), $\nu(\text{Pd}-\text{O})$, 462(s). ^1H -NMR spectra (δ value in ppm): $\delta(\text{CH}=\text{N})$, 8.40 (s, 1H); $\delta(\text{Ar}-\text{H})_{\text{phenol}}$, 7.45(d, 1H); 7.12(t, 1H); 6.85(t, 1H); 6.75(d, 1H); $\delta(\text{N}-\text{CH}_2)$, 3.50(d, 1H); $\delta(\text{C}-\text{CH}_2)$, 2.00(t, 2H). ^{13}C -NMR (δ value in ppm): $\delta(\text{CH}=\text{N})$, 162.9; $\delta(\text{Ar}-\text{C})_{\text{Phenolic}}$, 161.1(C_1), 124.6(C_2), 130.6(C_3), 121.5(C_4), 132.5(C_5), 116.0(C_6); $\delta(\text{N}-\text{CH}_2)$, 59.5; $\delta(\text{C}-\text{CH}_2)$, 32.3. Electronic spectra (λ_{max} , nm (ϵ in $\text{M}^{-1}\text{cm}^{-1}$)) in DMSO: 464(48), 424(69), 380(124). ESI-Mass spectra, m/z : $[\text{C}_7\text{H}_5\text{NOPd}]^+ = 225.54$, $[\text{C}_{10}\text{H}_{11}\text{NOPd}]^+ = 267.62$, $[\text{C}_{11}\text{H}_{12}\text{N}_2\text{O}_2\text{Pd}]^+ = 310.65$, $[\text{C}_{17}\text{H}_{16}\text{N}_2\text{O}_2\text{Pd}]^+ = 386.63$.

$[\text{Pd}(\text{L}^2)_2]\text{Cl}_2$, Complex 2

Colour = Black, Yield: 0.138g (81.42%); m.p. 160°C^d , Found: C, 60.26; H, 5.32; N, 8.25; $\text{C}_{34}\text{H}_{36}\text{N}_4\text{Cl}_2\text{Pd}$ ($M_r = 677.75$). Requires: C, 60.25; H, 5.31; N, 8.26. Molar conductance ($\Omega^{-1}\text{cm}^2\text{mol}^{-1}$): 34 in DMSO. Selected infrared absorption (KBr, cm^{-1}): $\nu(\text{CH}=\text{N})$, 1623(s). ^1H -NMR spectra (δ value in ppm): $\delta(\text{CH}=\text{N})$, 8.38 (s, 4H); $\delta(\text{Ar}-\text{H})_{\text{phenyl}}$, 7.58(d, 8H) C_1, C_5 ; 7.28(t, 8H) C_2, C_4 ; 6.68(t, 4H) C_3 ; $\delta(\text{N}-\text{CH}_2)$, 3.54(d, 8H); $\delta(\text{CH}-\text{CH}_2)$, 2.09(t, 4H). ^{13}C -NMR (δ value in ppm): $\delta(\text{CH}=\text{N})$, 162.4; $\delta(\text{Ar}-\text{C})_{\text{Phenyl}}$, 138.3(C_1), 128.4(C_2), 128.0(C_3), 129.7(C_4), 127.6(C_5), 128.2(C_6); $\delta(\text{N}-\text{CH}_2)$, 57.6; $\delta(\text{CH}-\text{CH}_2)$, 27.7. Electronic spectra (λ_{max} , nm (ϵ in $\text{M}^{-1}\text{cm}^{-1}$)) in DMSO: 464(48), 424(69), 380(124). ESI-Mass spectra, m/z : $[\text{C}_{11}\text{H}_{13}\text{N}_2\text{Pd}]^+ = 279.65$, $[\text{C}_{17}\text{H}_{18}\text{N}_2\text{Pd}]^+ = 356.76$, $[\text{C}_{34}\text{H}_{36}\text{N}_4\text{Pd}]^+ = 607.10$, $[\text{C}_{34}\text{H}_{36}\text{N}_4\text{PdCl}_2]^+ = 677.75$.

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[Pd(L³)₂]Cl₂, Complex 3

Colour = Black, Yield: 0.054g (17.14%); m.p. 169°C^d; Found: C, 49.27; H, 5.04; N, 17.70; C₂₆H₃₂N₈Cl₂Pd (M_r= 633.70). Requires: C, 49.28; H, 5.05; N, 17.68. Molar conductance (Ω⁻¹cm²mol⁻¹): 38 in DMSO. Selected infrared absorption (KBr, cm⁻¹): ν(CH=N), 1620(s). ¹H-NMR spectra (δ value in ppm): δ(CH=N), 8.36 (s, 4H); δ(Ar-H)_{pyrrole}, 6.63(d, 4H); 6.36(t, 4H); 6.15(d, 4H); δ(NH) 5.61(s, 4H); δ(N-CH₂), 3.56(d, 8H); δ(CH-CH₂), 2.04(t, 4H). ¹³C-NMR (δ value in ppm): δ(CH=N), 161.5; δ(Ar-C)_{pyrrole}, 115.9(C₁), 107.8(C₂), 110.7(C₃), 131.7(C₄); δ(N-C), 51.4; δ(CH-CH₂), 39.1. Electronic spectra (λ_{max}, nm (ε in M⁻¹ cm⁻¹)) in DMSO: 464(48), 424(69), 380(124). ESI-Mass spectra, m/z; [C₉H₁₂N₃Pd]⁺ = 268.63, [C₁₃H₁₆N₄Pd]⁺ = 334.71, [C₂₆H₃₂N₈Pd]⁺ = 563.01, [C₂₆H₃₂N₈PdCl₂]⁺ = 633.70.

[Pd(L⁴)₂]Cl₂, Complex 4

Colour = Black, Yield: 0.065g (96.29%); m.p. 180°C; found: C, 55.06; H, 4.86; N, 7.54; C₃₄H₃₆N₄O₄Cl₂Pd (M_r= 741.75). Requires: C, 55.05; H, 4.85; N, 7.55. Molar conductance (Ω⁻¹cm²mol⁻¹): 45 in DMSO. Selected infrared absorption (KBr, cm⁻¹): ν(CH=N), 1614(s). ¹H-NMR spectra (δ value in ppm): δ(CH=N), 8.35 (s, 4H); δ(Ar-H)_{phenol}, 7.46(d, 8H)C₁,C₅; 6.68(t, 8H)C₂,C₄; δ(Ar-OH), 5.0(s, 4H); δ(N-CH₂), 3.48(d, 8H); δ(CH-CH₂), 2.03(t, 4H). ¹³C-NMR (δ value in ppm): δ(CH=N), 162.4; δ(Ar-C)_{phenolic}, 131.3(C₁), 129.3(C₂,C₆), 115.0(C₃,C₅), 159.2(C₄); δ(N-CH₂), 58.2; δ(CH-CH₂), 31.2. Electronic spectra (λ_{max}, nm (ε in M⁻¹ cm⁻¹)) in DMSO: 464(48), 424(69), 380(124). ESI-Mass spectra, m/z; [C₁₁H₁₃N₂OPd]⁺ = 295.65, [C₁₇H₁₈N₂O₂Pd]⁺ = 388.76, [C₃₄H₃₆N₄O₄Pd]⁺ = 671.09, [C₃₄H₃₆N₄O₄PdCl₂]⁺ = 741.75.

[Pd(L⁵)]Cl₂, Complex 5

Colour = Black, Yield: 0.255g (87.56%); m.p. 180°C^d; Found: C, 44.70; H, 3.16; N, 10.96; C₁₉H₁₆N₄O₂PdCl₂ (M_r= 509.57). Requires: C, 44.78; H, 3.14; N, 10.99. Molar conductance (Ω⁻¹cm²mol⁻¹): 41 in DMSO. Selected infrared absorption (KBr, cm⁻¹): ν(C=N), 1618(s), ν(Pd-O), 459(s). ¹H-NMR spectra (δ value in ppm): δ(CO-NH), 7.96(s, 1H); δ(Ar-H)_{indolin-2-one}, 7.60(d, 2H); 7.22(t, 2H); 7.04(t, 2H); 6.3(d, 2H); δ(N-CH₂), 3.55(d, 2H); δ(C-CH₂), 2.02(t, 2H). ¹³C-NMR (δ value in ppm): δ(C=N), 163.2; δ(Ar-C)_{indolin-2-one}, 145.6(C₁), 120.4(C₂), 130.5(C₃), 123.3(C₄), 128.5(C₅), 122.1(C₆), 166.0(C₈); δ(N-CH₂), 50.2; δ(C-CH₂), 30.4. Electronic spectra (λ_{max}, nm (ε in M⁻¹ cm⁻¹)) in DMSO: 464(48), 424(69), 380(124). ESI-Mass spectra, m/z; [C₁₁H₈N₄O₂Pd]⁺ = 334.63, [C₁₅H₁₂N₄O₂Pd]⁺ = 386.70, [C₁₅H₁₂N₄O₂PdCl₂]⁺ = 457.61, [C₁₉H₁₆N₄O₂PdCl₂]⁺ = 509.57.

[Pd(L⁶)]Cl₂, Complex 6

Colour = Black, Yield: 0.161g (59.35%); m.p. >200°C; Found: C, 55.02; H, 4.81; N, 6.76; C₁₉H₂₀N₂O₂Pd (M_r= 414.66). Requires: C, 55.03; H, 4.82; N, 6.75. Molar conductance (Ω⁻¹cm²mol⁻¹): 13 in DMSO. Selected infrared absorption (KBr, cm⁻¹): ν(C=N), 1699(s), ν(Pd-O), 464(s). ¹H-NMR spectra (δ value in ppm): δ(Ar-H)_{phenol}, 7.40(d, 2H); 7.07(t, 2H); 6.78(t, 2H); 6.70(d, 2H); δ(N-CH₂), 3.51(d, 4H); δ(CH-CH₂), 2.01(t, 2H). ¹³C-NMR (δ value in ppm): δ(C=N), 162.6; δ(Ar-C)_{phenolic}, 160.2(C₁), 123.6(C₂), 129.3(C₃), 120.5(C₄), 131.4(C₅), 115.1(C₆); δ(N-CH₂), 46.1; δ(CH-CH₂), 31.7; δ(C-CH₃), 15.3. Electronic spectra (λ_{max}, nm (ε in M⁻¹ cm⁻¹)) in DMSO: 464(48), 424(69), 380(124). ESI-Mass spectra, m/z; [C₉H₉NO₂Pd]⁺ = 269.59, [C₁₃H₁₆N₂O₂Pd]⁺ = 338.70, [C₁₇H₁₈N₂O₂Pd]⁺ = 388.76, [C₁₉H₂₀N₂O₂Pd]⁺ = 414.66.

RESULTS AND DISCUSSION

Characterization of Ligands

ESI-MS Spectra of Ligands

The C, H, N analytical data for the synthesized ligands were in full agreement with the proposed empirical formula. ESI-Mass spectra of all the six ligands exhibit several peaks depending upon the fragmentation pattern. Isotopic pattern of molecular ion peak gave clear evidence about molecular mass. The ESI-MS spectra of one of the ligand, L⁵ Schiff base of indole-2,3-dione, (Isatin) was given in Figure 1. The ESI-MS of this ligand shows peaks at 187.11, 242.16 and 333.18 attributed for [C₁₁H₁₁N₂O]⁺; [C₁₃H₁₁N₃O₂]⁺; [C₁₉H₁₆N₄O₄]⁺. Similar ESI-MS assignment and fragmentation pattern were proposed in other ligands which gave idea about molecular ion peak.

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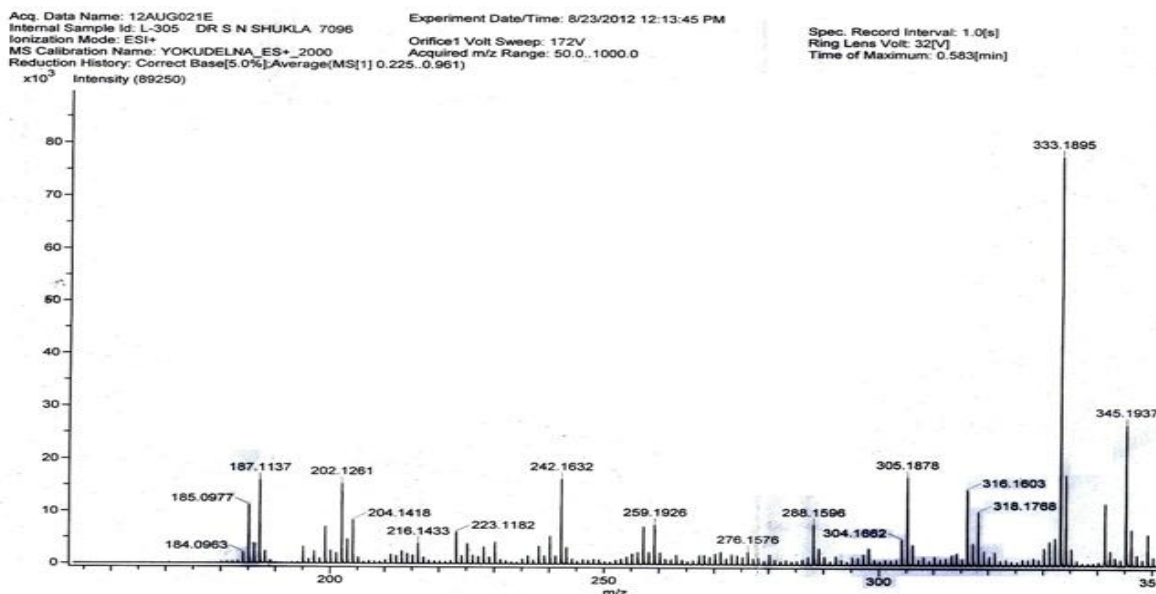


Figure 1: ESI-MS of Ligands

FT-IR Spectra of Ligands

FTIR spectra of ligands display a sharp signal, between $1649\text{--}1635\text{ cm}^{-1}$ attributed to $\nu(\text{HC}=\text{N})/\nu(\text{C}=\text{N})$ which was not present in the precursor compounds. All the ligands exhibit significant bands at about 1210 cm^{-1} assigned to $\nu(\text{C}-\text{N})$ (Chakrawarti *et al.*, 1993). Ligand L^1 and L^6 shows a peak in between $3550\text{--}3600\text{ cm}^{-1}$ attributed for $\nu(\text{-OH})$.

NMR Spectra of Ligands

^1H -NMR of the ligands (except L^5 and L^6) shows a signal at about $\delta\ 8.10\text{ ppm}$ assigned for azomethine ($>\text{CH}=\text{N}$) proton. Ligand L^1 , L^2 , L^4 , L^5 and L^6 also exhibit signal for aromatic proton, however, L^3 shows signal assigned for proton associated with pyrrole carbon and nitrogen. L^1 , L^4 and L^6 also exhibit signal for hydroxyl proton at $\sim\delta 5.0\text{ ppm}$. Ligand L^6 also exhibit signal for methyl proton. ^{13}C -NMR spectra of ligands exhibit a signal at $\sim\delta 160.00$ assigned for $-\text{CH}=\text{N}/>\text{C}=\text{N}$ carbon. It is a confirmatory evidence for the formation of the Schiff base. Ligand L^1 , L^2 , L^4 , L^5 and L^6 exhibit signal for aromatic carbon and L^3 shows signal for pyrrole carbon. Thus on the basis of C,H,N analyses, ESI-MS, FT-IR, ^1H -NMR and ^{13}C -NMR probable structure of the ligands were suggested as below in Figure 2 – Figure 7.

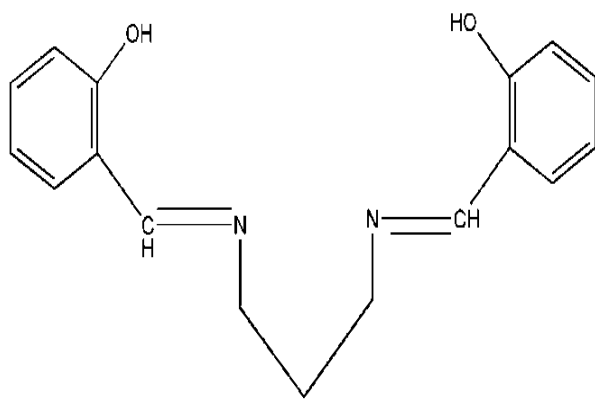


Figure 2: N, N'-bis(salicylidene)-1,3-propylenediamine Schiff base, (L^1)

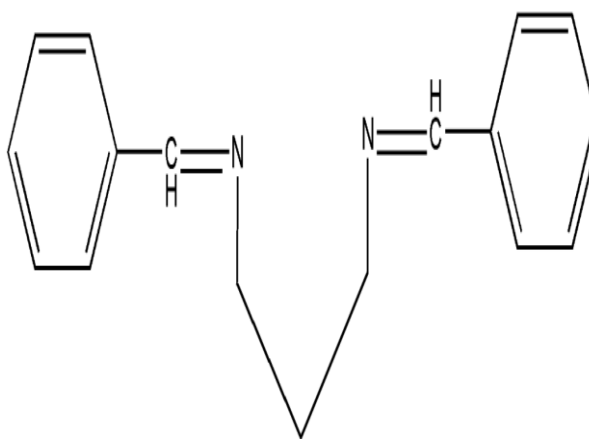


Figure 3: N, N'-bis(benzylidene)-1,3-propylenediamine Schiff base, (L^2)

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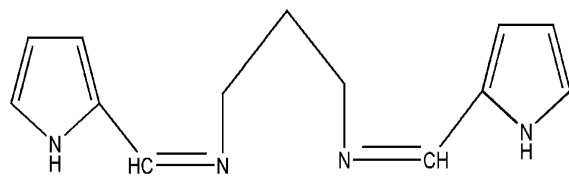


Figure 4: , N,N' -bis(pyridine)-1,3-propylenediamine Schiff base, (L^3)

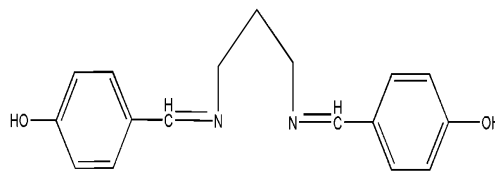


Figure 5: N,N' -bis(4-hydroxybenzylidene)-1,3-propylenediamine Schiff base, (L^4)

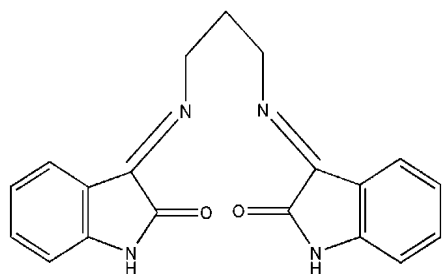


Figure 6: Schiff base of indole-2,3-dione (Isatin), (L^5)

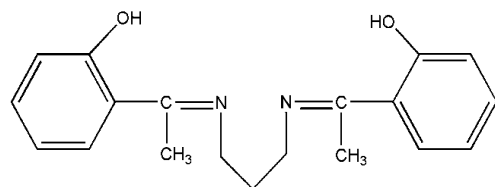


Figure 7: N,N' -bis(1-methyl-2-hydroxybenzylidene)-1,3-propylenediamine Schiff base, (L^6)

Characterization of Complexes

The stoichiometries of the complexes were in agreement with elemental analyses data. The molar conductance of complexes 1 and 6 are in range $6-13 \text{ ohm}^{-1} \text{ cm}^2 \text{ mol}^{-1}$ indicating their non-electrolytic nature, however, other complexes exhibit molecular conductance in range $34 - 49 \text{ ohm}^{-1} \text{ cm}^2 \text{ mol}^{-1}$ confirming their 1:2 electrolytic nature.

ESI-MS Spectra of Complexes

ESI-Mass spectra of all the six complexes exhibit several peaks depending upon the fragmentation pattern. Isotopic pattern of molecular ion peak gave clear evidence about molecular mass. The ESI-MS spectra of $[\text{Pd}(L^5)]\text{Cl}_2$, Complex 5, was given in Figure 8, shows peaks at 334.63; 386.70; 457.61; 509.57 attributed for $[\text{C}_{11}\text{H}_8\text{N}_4\text{O}_2\text{Pd}]^+$; $[\text{C}_{15}\text{H}_{12}\text{N}_4\text{O}_2\text{Pd}]^+$; $[\text{C}_{15}\text{H}_{12}\text{N}_4\text{O}_2\text{PdCl}_2]^+$; $[\text{C}_{19}\text{H}_{16}\text{N}_4\text{O}_2\text{PdCl}_2]^+$. Similar ESI-MS assignment and fragmentation pattern were proposed for other complexes which gave idea about molecular ion peak.

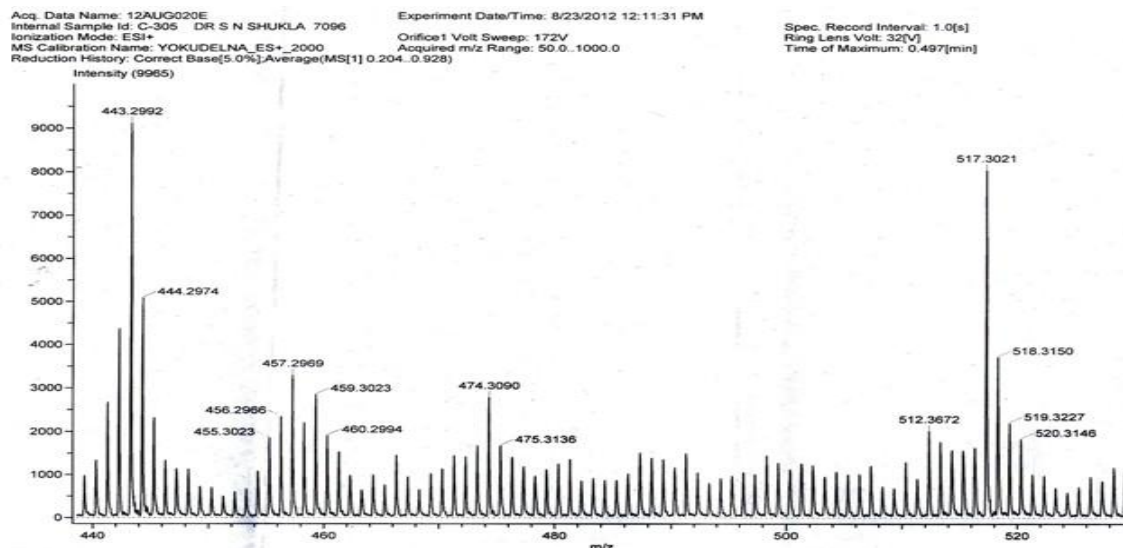


Figure 8: ESI-MS of Complex 5

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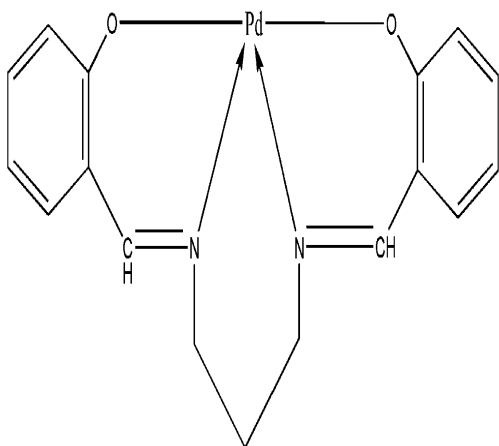


Figure 9: Complex 1

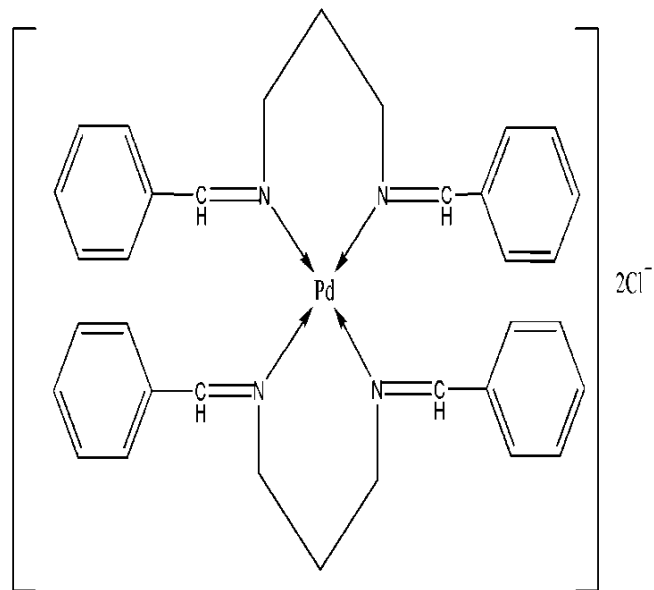


Figure 10: Complex 2

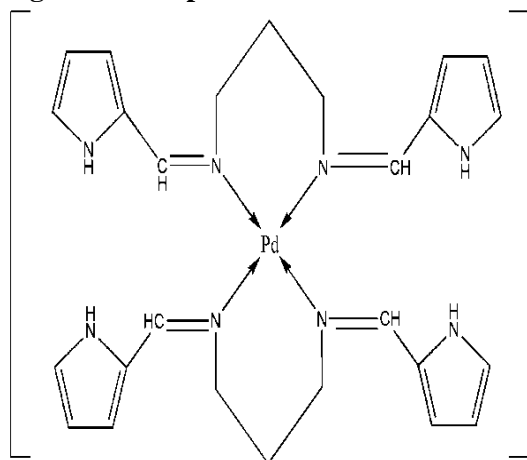


Figure 11: Complex 3

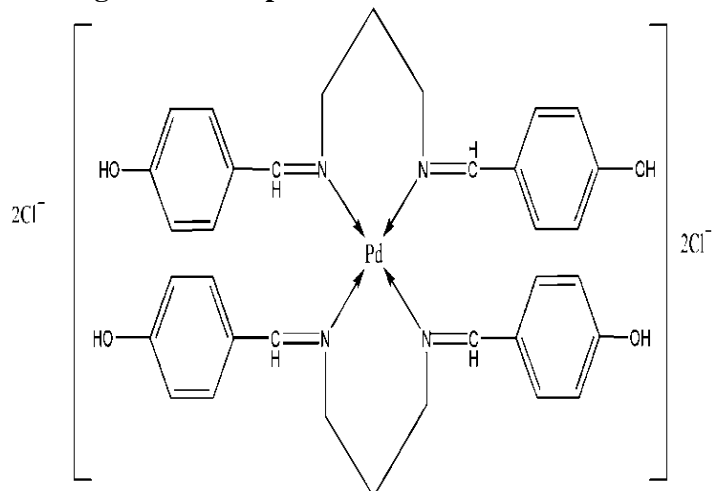


Figure 12: Complex 4

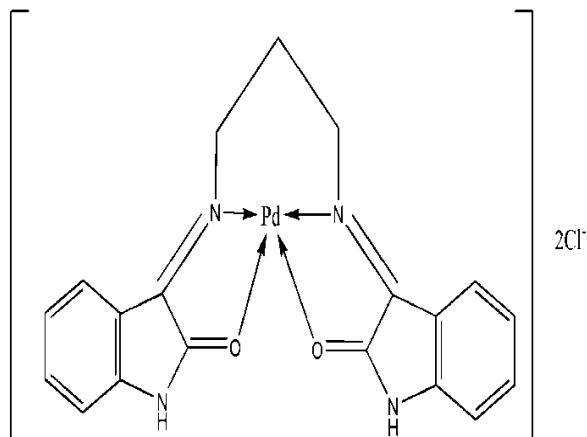


Figure 13: Complex 5

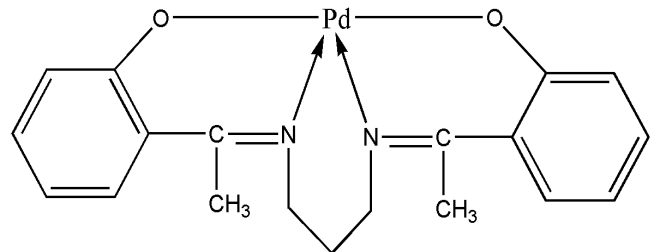


Figure 14: Complex 6

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FT-IR Spectra of Complexes

A strong peak appeared in between $1649\text{--}1635\text{ cm}^{-1}$ in the ligands assigned for azomethine ($-\text{CH}=\text{N}$), was shifted downwards in the complexes, confirming coordination of metal to azomethine nitrogen (Biradar *et al.*, 1984 and Abd-Elzaher, 2001). A new peak of medium intensity was appeared between $470\text{--}451\text{ cm}^{-1}$, in complex 1, 5 and 6 was assigned for new Pd-O bond indicates the bonding of metal to the oxygen by removal of phenolic-H.

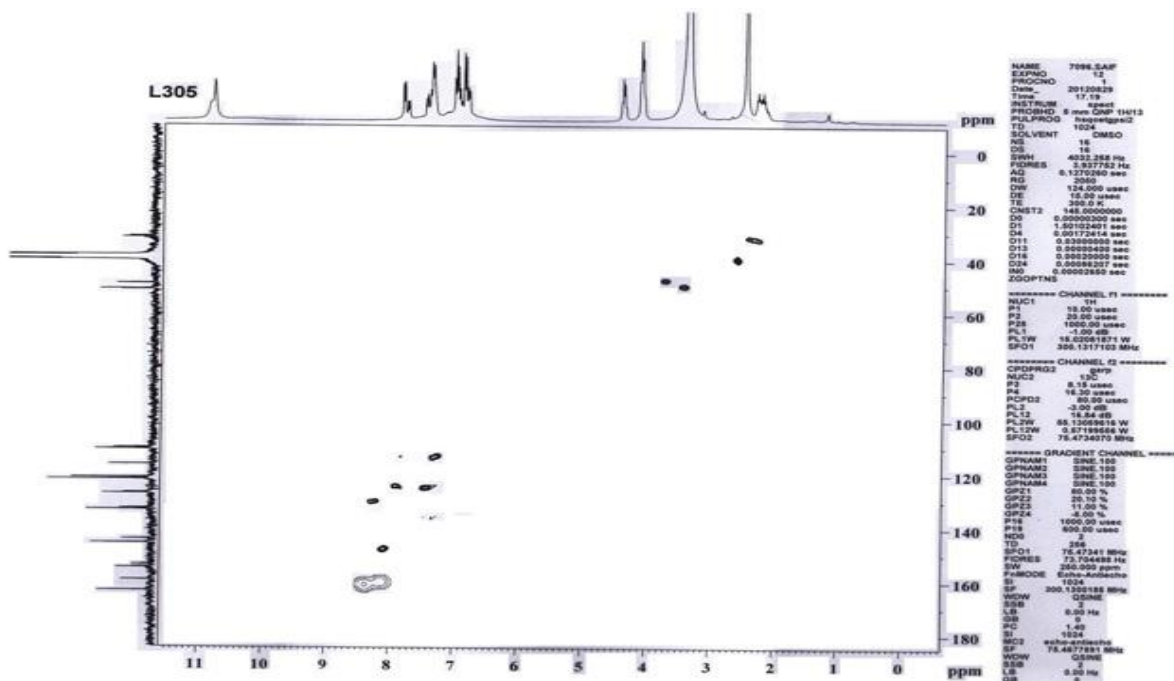


Figure 15: $^2\text{D-NMR}$ of Ligand

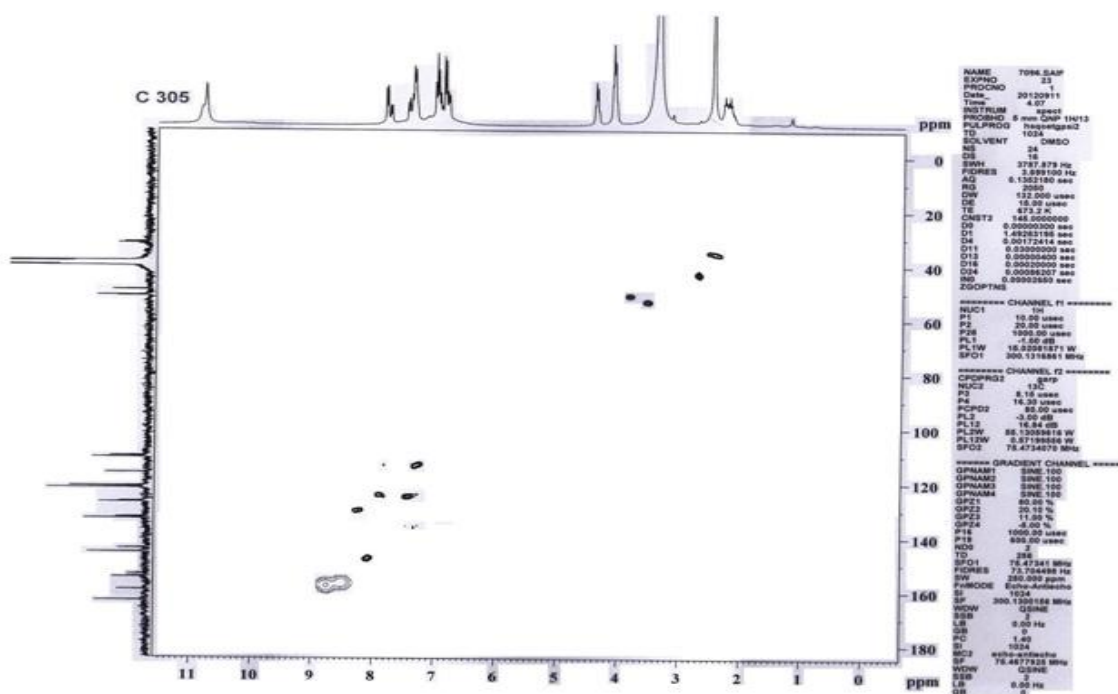


Figure 16: $^2\text{D-NMR}$ of Complex 5

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Electronic Spectra

Magnetic susceptibility data shows diamagnetic behaviour of the complexes. Electronic spectra of the complexes exhibit three bands attributed to the three d-d spin allowed transition corresponding to the three lower lying d-levels to the empty $d_{x^2-y^2}$. The three d-d bands obtained are in the region 464 - 566 nm, 424 - 444 nm and 334 - 380 nm are attributed to $^1A_{1g} \rightarrow ^1A_{2g}$ (ν_1); $^1A_{1g} \rightarrow ^1B_{1g}$ (ν_2) and $^1A_{1g} \rightarrow ^1E_g$ (ν_3) transitions respectively. These assignments suggest a square planar geometry around Pd (II) metal ion in the complexes (Gray *et al.*, 1963).

1H -NMR Spectra of Complexes

A singlet observed at $\sim \delta$ 8.1 ppm in the ligand L^1 , L^2 , L^3 and L^4 , assigned for $-CH=N$ group was down field shifted in all these complexes and appeared at $\sim \delta$ 8.40 ppm, confirming the transfer of one lone pair electron from nitrogen to metal and coordination of azomethine-N to metal. A signal appeared at $\sim \delta$ 5.0 ppm in the ligands **1**, **5** and **6** was disappeared in the complexes confirming the removal of phenolic-H facilitating the coordination of ligand from oxygen to metal and formation of the Pd-O bond.

^{13}C -NMR Spectra of Complexes

A signal observed at $\sim \delta$ 160.0 ppm in ligands assigned for $>C=N$ group was downfield shifted in all the complexes and appeared at $\sim \delta$ 163.0 ppm, confirming the transfer of one lone pair electron from nitrogen to metal and coordination of azomethine-N to metal.

Table 1: Antibacterial Screening against Escherichia Coli and Staphylococcus aureus

S. No.	Compounds	*Diameter of inhibition zone (mm.) \pm SEM				MIC (μ g/mL)	
		E. coli	S. aureus	E. coli	S. aureus	E. coli	S. aureus
1a.	L^1	27 \pm 1.2	28 \pm 0.8	-	-	-	-
1.	[Pd(L^1)]	30 \pm 0.8	32 \pm 1.5	0.35	0.86		
2a.	L^2	27 \pm 1.5	-	-	-	-	-
2.	[Pd(L^2) ₂]Cl ₂	32 \pm 1.5	28 \pm 1.5	0.44	0.74		
3a.	L^3	29 \pm 0.8	24 \pm 0.9	-	-	-	-
3.	[Pd(L^3) ₂]Cl ₂	33 \pm 0.5	27 \pm 1.2	0.47	0.67		
4a.	L^4	29 \pm 0.9	23 \pm 0.9	-	-	-	-
4.	[Pd(L^4) ₂]Cl ₂	34 \pm 1.5	28 \pm 0.9	0.49	0.78		
5a.	L^5	30 \pm 1.2	26 \pm 0.8	-	-	-	-
5.	[Pd(L^5)]Cl ₂	35 \pm 1.2	-	0.52	-		
6a.	L^6	28 \pm 0.5	27 \pm 1.2	-	-	-	-
6.	[Pd(L^6)]	31 \pm 0.9	32 \pm 0.8	0.41	0.87		
7.	Chloramphenicol	40 \pm 0.8	39 \pm 0.7	0.30	0.46		

*Values as mean \pm Standard Error Mean.

HETCOR NMR of Ligand and Complex

One ligand, Schiff base of indole-2,3-dione and its complex [Pd L^5]Cl₂, were studied by $\{^{13}C-^1H\}$ -NMR (HETCOR). In 2D -NMR of the complex signal observed at δ 166.5 ppm for $-CONH$ group of indolin-2-one carbon was connected with H at δ 8.03 ppm. A new signal observed at δ 160.3 ppm, assigned for azomethine carbon was connected with H at δ 8.11 ppm. Four signals observed at about δ 121.3, δ 131.2, δ 124.1 and δ 129.2 in the ligand and complexes assigned for indolin-2-one carbon C_3 , C_4 , C_5 and C_6 were found connected with protons at about δ 7.62, δ 7.25, δ 7.07 and δ 7.58 ppm. A signal observed at δ 51.7

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ppm assigned for N-CH₂ carbon was found tied with one proton at δ 3.59 ppm. A signal observed at δ 31.0 ppm in the ligand and complex assigned for CH-CH₂ connected with the two protons at about δ 2.07 ppm (Kalsi, 2005).

Antibacterial Activity and Structure Activity Relationship

All the ligands **L**¹- **L**⁶ and complexes **1-6**, were screened for antibacterial properties against gram negative bacteria *Escherichia coli* MTCC 1304 and gram positive bacteria *Staphylococcus aureus* ATCC 6538 at different concentrations. Mueller Hinton agar plates (MHA) were prepared and 50 μ L Suspension of *Escherichia coli* and *Staphylococcus aureus* containing approximately 10⁵ - 10⁶ CFC (colony forming unit) was applied to the plate by spread plate technique (Pelczar *et al.*, 2001 and Bauer *et al.*, 1966). The wells are made on the plates and they were filled with 50 μ L of sample solution of 0.03% concentration. The 0.03% drugs and 0.03% ligands were tested for comparison with complexes. These plates were incubated at 37 \pm 1 °C for 24 – 48 hours in refrigerated incubator shakers. The results in the form of zone inhibition were measured in mm and presented in Table 1.

Minimum Inhibitory Concentration (MIC)

Since the appearance of resistance is common in pathogen, it lays the responsibility on investigator to report, an antibiotic sensitivity pattern accurately and rapidly, at reasonable cost (Normark *et al.*, 2002). All six complexes were screened for MIC evaluation by a commonly used method, Successive Dilution Method (Mazzola *et al.*, 2009).

In twelve numbered screw tubes **A-L** (10 x 100 mm), 1 mL of Muller-Hinton broth medium was distributed in each tube, except the tube **A**. All the tubes were placed at autoclave for sterilization. In tube **A** and **B**, 1 mL of test solution (**1-4**) was added; tube **B** was stirred and 1 mL mixture of it was taken out and transferred to tube **C**. This successive transference was repeated until tube **K**. The 0.1 mL suspension of inoculums *Escherichia coli*, MTCC 1304, and *S. aureus*, ATCC 6538, having ~ 5,00,000 cells per μ L were added to all tubes, except the tube **K**. Incubation at 37 \pm 1 °C temperature was developed for 24-48 h. MIC is the concentration of the highest dilution tube, in which bacterial growth was absent and results are presented in Table 1. Complex **5** was the most active to inhibit bacterial growth at 0.52 μ g/mL for *E. coli* and for *S. aureus*, complex **6** was observed as most active at 0.87 μ g/mL.

Conclusion

Six ligands and their complexes with palladium were synthesized in 1:1/ 1:2 molar ratio and characterized by spectroscopic method. These complexes exhibit square planar geometry. All the six complexes were found more potent than ligand and exhibit considerable MIC value. These complexes are novel due to their specific structure and biological activity against *E. coli* and *S. aureus*. Biological activity result indicate that activity of a complex is not additive effect of all toxophoric function.

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REFERENCES

- Abd-Elzaher MM (2001)**. Spectroscopic Characterization of some Tetradentate Schiff Bases and Their Complexes with Nickel, Copper and Zinc. *Journal of Chinese Chemical Society* **48** 153-158.
- Bauer AW, Kirby WM, Sherris JC and Turck M (1966)**. Antibiotic Susceptibility Testing by a Standardized Single Disk Method. *American Journal of Clinical Pathology* **45** 493-496.
- Biradar NS, Roddabasanagoudar VL and Aminabhavi TM (1984)**. Studies of Glycine Acetophenone Complexes of Copper (II), Cobalt (II) and Oxovanadium (IV). *Polyhedron* **3**(5) 575-580.
- Chakrawarti BP, Srivastava B and Vijayvargiya BL (1993)**. Study of Some Transition Metal Complexes of Cephaloridine. *Journal of Indian Chemical Society* **70** 158-159.

Research Article

Djebbar SS, Benali BO and Deloume JP (1998). Synthesis, Characterization, Electrochemical Behavior and Catalytic Activity of Manganese (II) Complexes with Linear and Tripodal Tetradentate Ligands Derived from Schiff Bases. *Transition Metal Chemistry* **23** 443-447.

Gray HB and Ballhausen CJ (1963). A Molecular Orbital Theory for Square-Planar Metal Complexes. *Journal of American Chemical Society* **85** 260.

Hamada YJ (1997). The Development of Chelate Metal Complexes as an Organic Electroluminescent Material. *IEEE Transition Electron Devices* **44** 1208-1217.

Jarrahpour AA, Motamedifar M, Pakshir K, Hadi N and Zarei M (2004). Synthesis of Novel Azo Schiff Bases and Their Antibacterial and Antifungal Activities. *Molecules* **9** 815-824.

Joshi S, Pawar V and Uma V (2011). Synthesis, Characterization and Biological Studies of Schiff Bases Metal Complexes Co (II), Zn (II), Ni (II) and Mn (II) Derived from Amoxicillin Trihydrate with Various Aldehydes. *International Journal of Pharma and Bio Science* **2** 1.

Kalsi PS (2005). Spectroscopy of Organic Compounds. *New Age International Ltd, New Delhi, India* 206-210, 246-256, 342-350.

Kumar S, Dhar DN and Saxena PN (2009). Applications of Metal Complexes of Schiff Bases-A Review. *Journal Scientific & Industrial Research* **68** 184-187.

Liu CM, Xiong RG, You XZ, Liu YJ and Cheung KK (1996). Crystal Structure and Some Properties of a Novel Potent Cu₂Zn₂SOD Model Schiff Base Copper (II) Complex. *Polyhedron* **15** 4565-4571.

Manav N, Mishra AK and Kaushik NK (2004) Triphenyl phosphine adducts of platinum(IV) and palladium(II) dithiocarbamates complexes: a spectral and in vitro study. *Spectrochimica Acta Part A: Molecular Spectroscopy* **60A** 3087-3092.

Marion N, Gealageas R and Nolan SP (2007). [(NHC)Au^I]-Catalyzed Rearrangement of Allylic Acetates. *Organic Letter* **9**(14) 2653-2656.

Mazzola PG, Jozala AF, Novaes LCL, Moriel P and Penna TCV (2009). Minimal Inhibitory Concentration (MIC) Determination of Disinfectant and/or Sterilizing Agents. *Brazilian Journal of Pharmaceutical Science* **45**(2) 241-248.

Normark BH and Normark S (2002). Evolution and Spread of Antibiotic Resistance. *Journal of Internal Medicine* **252** 91-106.

Osowole AA (2008). Synthesis and Characterization of Some Tetradentate Schiff Base Complexes and Their Heteroleptic Analogues. *E-Journal of Chemistry* **5**(1) 130-135.

Pelczar MJ, Chan ECS and Krieg NR (2001). *Text Book of Microbiology*, 5th edition (McGraw-Hill Publishing Company Limited) New Delhi, India 138.

Satyanarayana VSV, Sreevani P, Sivakumar A and Vijayakumar V (2008). Synthesis and Antimicrobial Activity of New Schiff Bases Containing Coumarin moiety and Their Spectral Characterization. *ARKIVOC* **17** 221-233.

Silverstein RM, Bassler GC and Morrill TC (1991). *Spectrometric Identification of Organic Compounds* (John Wiley and Sons, Inc) New York 82-108, 123-131, 219-262.

Uddin N, Chowdhury DA, Rony MM and Halim E (2014). *Metal Complexes of Schiff Bases Derived from 2-thiophenecarboxaldehyde and Mono/Diamine as the Antibacterial Agents* (Science Publishing Group) **2**(2) 6-14.