Bangladesh Pharmaceutical Journal **17**(2): 157-162, 2014

Synthesis, Characterization and Antibacterial Studies of the Mixed Ligand Complexes of Pd(II) and Pt(II) Ions with Phthalic Acid and Heterocyclic Amines

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Received: May 01, 2014; Accepted: May 26, 2014; Published (Web): July 23, 2014

Abstract

Mixed ligand complexes of Pd(II) and Pt(II) ions with phthalic acid and heterocyclic amines were synthesized and characterized. The general formula of the complexes is [MLL′]; where, M = Pd(II)(1-2), Pt(II)(3); L = phthalate, $C_8H_4O_4$, L′ = pyridine, C_5H_5N(1); 2-aminopyridine, $C_5H_6N_2$(2) and 4-picoline, C_6H_7N(3). The complexes were synthesized in the solid form and characterized by elemental analysis, electrical conductivity, magnetic measurements, and spectroscopic studies. Spectral analyses and magnetic measurements revealed the coordination of metal ion with ligands and geometry of the complexes. Anti-bacterial activity of the complexes against seven pathogenic bacteria (three gram positive and four gram negative) was assessed by the disc diffusion method. Complexes [Pd(Ph)(2-apy)] and [Pt(Ph)(4-pico)$_2$] showed the highest anti-bacterial activity (when, Ph = bidentate phthalate, 2-apy = 2-aminopyridine and 4-pico = 4-picoline).

Key words: Mixed ligand complex, phthalate, 2-aminopyridine, 4-picoline, anti-bacterial.

Introduction

Extensive antibacterial screenings of mixed ligand complexes revealed their importance in the biological processes. Several mixed-ligand complexes of Pd(II) and Pt(II) have been prepared and characterized by elemental analysis, conductivity measurements, I.R., electronic absorption and ^{1}H-NMR spectroscopic techniques (Biyala *et al.,* 2008; Sarmistha *et al.,*2008; Pandey *et al.,*2010). A very few survey has been done on the Pd(II) complexes with tridentate dianionic ligand pyridine-2,6-dicarboxylate (Pablo *at al.,* 1996). Some workers synthesized square planar Pd(II), Pt(II), and Au(III) terpyridine complexes and determined their physical properties, supramolecular constructions and biomedical applications (Eryazici *et al*., 2008).

There are many reports on Pd(II) complexes of heterocyclic amine with structural and magneto structural characterization (Shayma *et al.,*2010; Anshu *et al.,*2011; Edit *et al.* 2010; Kuduk-Jaworska *et al.* 2004). The metal complexes of phthalic acid have been studied both from pharmacological and industrial points of view as indicated by available literature (Reza *et al*., 2003). Some complexes of transition metal ion with malonic, phthalic and maleic acid are very important from antimicrobial and medicinal point of view (Reza *et al*., 2003; Islam *et al*., 2003). Considering these facts, the present paper describes the preparation of some mixed ligand complexes of palladium(II) and platinum(II) with phthalic acid (PhH_2) as primary and heterocyclic bases, viz., pyridine (Py), 2-aminopyridine(2-apy), 4-picoline (4-pico) as secondary ligands and their antibacterial activity has been evaluated to perform primary selection of these complexes as therapeutic agents.

Materials and Methods

Chemicals and reagent: All the chemicals were analytical grade and were used as received. The solvents were purified using conventional methods.

Physical Measurement: Infrared spectra were recorded on FTIR spectrophotometer (IR-Prestrige-21) in the region 4500-400 cm^{-1} at the Department of Chemistry, University of Dhaka, Bangladesh. Carbon, hydrogen and nitrogen

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analyses were carried out by LECO CHEN-932, organic elemental analyzer, University Kebangsaan, Malaysia. Metal was determined by direct ignition method as oxide. The molar conductance of 10^{-3} M solutions of the metal complexes in DMF was measured at 30°C using a Jenway 4310 conductivity meter and a dip-cell with platinized electrode. Melting points were determined using an electrothermal digital melting point apparatus. Magnetic susceptibility was measured by Magnetic Susceptibility Balance at 298°K (Model: Mk1, Sherwood Scientific, Cambridge, England) at the Department of Chemistry, University of Dhaka, Bangladesh. All susceptibilities were corrected for diamagnetic contribution using Pascal's constant (Vogel, 1961).

General method of complex preparation: An appropriate solution of 1 mmol of metal(II) salts {Pd(II) and Pt(II)} in absolute ethanol (25mL) was added to an ethanolic solution (30mL) of phthalic acid(1 mmol) with constant stirring at 70°C. No precipitate was observed. Then 25 ml of an ethanolic solution of heterocyclic amine bases e.g. 1 mmol of Py (for complex 1), 1 mmol of 4-pico (for complex 3) and 1 mmol of 2-apy (for complex 2) was added to the resulting hot plate with constant stirring. The volume of the solution was reduced to 50% and allowed to cool at room temperature. The precipitate formed and was filtered, washed several time with ethanol and then dried in a desiccator over anhydrous $CaCl_2$.

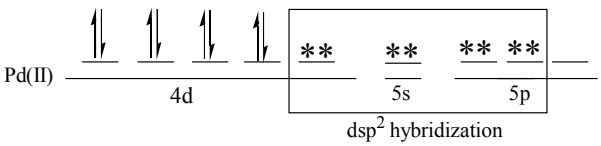
Antimicrobial screening: Seven pathogenic bacteria viz., *Pseudomonas aeruginosa* (Gram negative), *Salmonella bovis morbificans* (Gram negative), *Salmonella typhi* (Gram negative), *Escherichia coli* (Gram negative), *Listeria monocytogenes* (Gram positive), *Staphylococcus aureus* (Gram positive), *Enterococcus faecalis* (Gram positive) were collected from the Fish Inspection & Quality Control Division, Department of Fishery, Boyra, Khulna, Bangladesh. Nutrient agar was used as bacteriological media. The complexes were dissolved separately in acetonitrile to get a concentration of 50-μg $disc^{-1}$. Then *in vitro* anti-bacterial activity of these complexes was carried out by disc diffusion method (Rios *et al*., 1988; Bauer *et al*., 1966). The diameter of the zone of inhibition produced by the complexes was compared with Kanamycin (30-μg $disc^{-1}$).

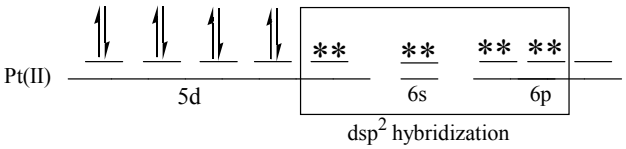
Results and Discussion

Elemental analysis and conductivity measurement: The analytical data and their physical properties of the complexes are given in Table 1. The analytical data are in good agreement with the proposed empirical formula of the present complexes.

The molar conductance was measured in *N, N′*-dimethyl formamide. The conductance values of the Pt(IV) complexes were in the range (10.65 – 11.65) Ω^{-1} cm^2 mol^{-1} indicated that these complexes were non-electrolyte in nature (Islam *et al.,*1991, 2002).

Magnetic moment: The observed magnetic moment of the complexes at room temperature is given in Table 1. The magnetic moment values of the complexes indicated that these complexes are diamagnetic. This diamagnetism is supported by the small negative values obtained for their magnetic susceptibility. It appears from the magnetic moment data that the complexes of Pt(IV) ion display diamagnetic property and an octahedral geometry with d^2sp^3 hybridization which are consistent with the published structure (Islam *et al.,*1991, 2002).





Infrared spectra studies: In the Infrared spectra strong band at ~ 1686.78 and ~ 1404.20 cm^{-1} revealed the presence of carboxylic group of malonic acid due to $\nu_{C=O}$ and ν_{C-O} which were shifted to 1610.0-1659.6 cm^{-1} and 1385.8-1399.3 cm^{-1} in the spectra of all the complexes. This indicates the coordination of malonic acid through the carboxylic group. The characteristic ring vibration of the heterocyclic amines in the range 1400-1600 cm^{-1} generally show significant changes on complexation but in our present complexes these bands could not be distinguished because of overlapping with $\nu_{C=O}$ and ν_{C-O} stretching bands. The in-plane and out-plane ring deformation modes of the heterocyclic amines observed at ~520 and ~720 cm^{-1}, respectively undergo a positive shift

in mixed ligand complexes conforming a co-ordination through nitrogen. Presence of M-O bonding is evident from the appearance of ν_{M-O} modes at 510.0- 537.1 cm^{-1} in the spectra of the complexes. The presence of M-N bonding in the complexes is evident form the appearance of ν_{M-N} modes at 421.4-470.0 cm^{-1}. The infrared spectrum of amino pyridine shows ν_{NH_2} modes at ~3443.96 and ~3193.21 cm^{-1}. Both of thesebands are shifted to lower frequencies in the complexes (3) at ~3320.2 cm^{-1} and ~3056.0 cm^{-1}, respectively which indicate the coordination with amino nitrogen (Hossain *et al.,* 2004, 2012, 2012; Islam *et al.,* 2004). Major I.R. spectral data for the complexes are given in Table 2.

Electronic spectra: The Electronic spectra of the Pd(II) complex in DMSO showed three spin allowed d-d transitions and two charge transfer bands. The bands were obtained at 22,800-23050, 28,300-28300, 31000-31300, 34800-35000 and 40000-40200 cm^{-1} corresponding to the transitions $^1A_{1g} \rightarrow {}^1A_{2g}$, $^1A_{1g} \rightarrow {}^1B_{1g}$, $^1A_{1g} \rightarrow {}^1E_g$, $^1A_{1g} \rightarrow {}^1A_{2u}$ & $^1A_{1g} \rightarrow {}^1E_u$ respectively, which indicates square planar stereochemistry (Islam *et al*., 2002).

The Pt(II) complex gave three bands at 36,000, 39,650 and 41,000 cm^{-1} corresponding to the transitions $^1A_{1g} \rightarrow {}^1B_{1u}$, $^1A_{1g} \rightarrow {}^1E_u$ and $^1A_{1g} \rightarrow {}^1A_{2u}$, respectively. All of these bands are characteristic of a square-planar Pt(II) complex (Islam *et al.,* 2002). Electronic spectral data are presented in Tables 3 and 4.

Antimicrobial activity: Antibacterial activity of target compounds was determined against Gram-positive bacteria (*Listeria monocytogenes*, *Staphylococcus aureus*, *Enterococcus faecalis)* and Gram-negative bacteria (*Psudomonas aeruginosa*, *Salmonella bovis morbificans*, *Salmonella typhi*, *Escherichia coli).* Results from the agar disc diffusion tests for antibacterial activity are presented in Table 4 and illustrated in Figures 4 and 5. The diameters of zone of inhibition (in mm) of the standard drug kanamycin against bacteria *Pseudomonas aeruginosa* (Gram negative), *Salmonella bovis morbificans* (Gram negative), *Salmonella typhi* (Gram negative), *Escherichia coli* (Gram negative), *Listeria monocytogenes*(Gram positive), *Staphylococcus aureus* (Gram positive), *Enterococcus faecalis* (Gram positive) were found to be 22, 22,20,20,25, 23, and 21 mm, respectively & the graphical comparision of zone of inhibition are shown in Fig. 6. Under identical conditions, Table 4 shows that complex 1 has 12, 0, 21, 23,26,18 and 10 mm, complex 2 has 38, 25, 21, 30, 21, 34 and 12 mm, complex 3 has 32, 33, 33, 40, 41, 12 and 17 mm, for *Pseudomonas aeruginosa, Salmonella bovis morbificans*, *Salmonella typhi*, *Escherichia coli*, *Listeria monocytogenes*, *Staphylococcus aureus*, *Enterococcus faecalis,* respectively. The complexes containing 2-aminopyridine and 4-picoline as secondary ligands are much more microbial active than the other complexes. Moreover, the complexes [Pd(Ph)(2-apy)] and [Pt(Ph)(4-pico)$_2$] show the highest antibacterial activity against all bacteria tested. From the data it may conclude that our synthesized complexes have show mild to moderate antibacterial activity.

Table 1. Elemental analyses and physical properties of the synthesized complexes.

Compd #	Complexes (Colour)	Yields %	Metal %	Carbon %	Hydrogen %	Nitrogen %	Melting point (± 5°C)	A_M (ohm^{-1} cm^2 mol^{-1})	μ_{eff} (BM.)
1	$Pd(Ph)(Py)_2$ (YellowGreen)	72	24.85 (24.82)	50.35 (50.42)	3.35 (3.29)	6.50 (6.54)	260	10.80	Dia
2	Pd(ph)(2-apy) (YellowGreen)	67	29.10 (29.18)	42.75 (42.81)	2.70 (2.76)	7.70 (7.68)	258	11.30	Dia
3	$Pt(ph)(4\text{-}pico)_2$ (Yellow)	72	35.70 (35.77)	44.13 (44.03)	3.40 (3.33)	5.11 (5.14)	250	10.65	Dia

Table 2. Infrared spectral data of the complexes (band maxima in cm^{-1}).

Compd. #	Complexes	ν(OH)	ν(N-H)	ν(C=O)	ν(C-O)	ν(M-O)	ν(M-N)
1	$Pd(Ph)(Py)_2$	-	-	1659.6	1399.3	512.1	421.4
2	Pd(Ph)(2-apy)	-	3320.2	1633.6	1385.8	537.1	463.8
3	$Pt(Ph)(4\text{-}pico)_2$	-	-	1610.0	1390.0	510.0	470.0

Table 3. Electronic spectral data (cm^{-1}) of square planar Palladium(II) complexes.

Complexes	Spectral band (cm^{-1}) with assignment				
	$^1A_{1g} \rightarrow {}^1A_{2g}$	$^1A_{1g} \rightarrow {}^1B_{1g}$	$^1A_{1g} \rightarrow {}^1E_g$,	$^1A_{1g} \rightarrow {}^1A_{2u}$	$^1A_{1g} \rightarrow {}^1E_u$
$Pd(Ph)(Py)_2$	23050	28300	31000	34800	40000
Pd(Ph)(2-apy)	22800	28300	31300	35000	40200

Table 4. Electronic spectral data (cm^{-1}) of square planar Platinum(II) complex.

Complex	Spectral band (cm^{-1}) with assignment		
	$^1A_{1g} \rightarrow {}^1B_{1u}$	$^1A_{1g} \rightarrow {}^1E_u$	$^1A_{1g} \rightarrow {}^1A_{2u}$
$Pt(Ph)(4\text{-pico})_2$	36,000	39,650	41,000

where, Dia = Diamagnetic, Ph = Diprotonated phthalic acid, Py = pyridine , 2apy = 2-aminopyridine, 4-pico=4-picoline

Table 5. Results of the antibacterial activity of the complexes.

Test organism	Diameter of zone inhibition (mm)			
	$Pd(Ph)(Py)_2$	Pd(Ph)(2-apy)	$Pt(Ph)(4\text{-pico})_2$	Kanamycin 30µg/disc
Pseudomonas aeruginosa (-ve)	12	38	32	22
Salmonella bovis morbificans (-ve)	0	25	33	22
Salmonella typhi (-ve)	21	21	33	20
Escherichia coli (-ve)	23	30	40	20
Listeria monocytogenes (+ve)	26	21	41	25
Staphylococcus aureus (+ve)	18	34	12	23
Enterococcus faecalis (+ve)	10	12	27	21

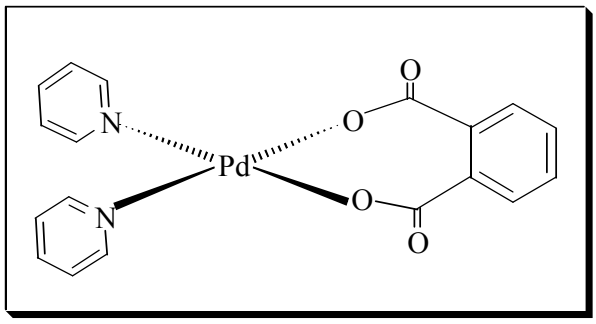


Figure 1(a). Possible structure of the complex-1 $[Pd(II)(Ph)(Py)_2]$.

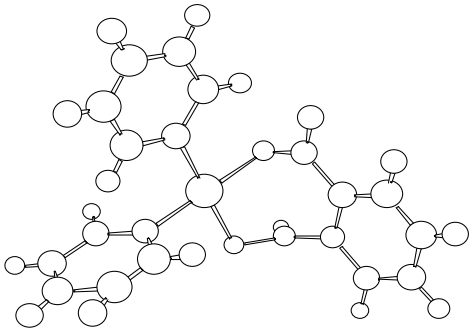


Figure 1(b). Possible ball and stick model of the complex-1 $[Pd(II)(Ph)(Py)_2]$.

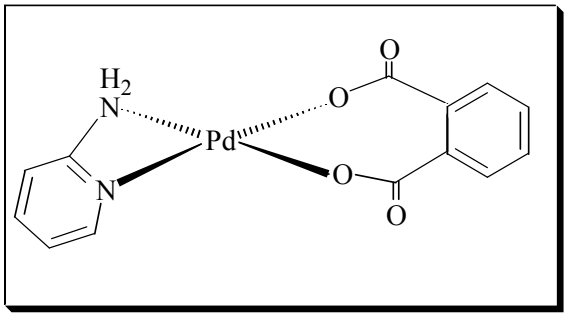


Figure 2(a). Possible structure of the complex-2 [Pd(II)(Ph)(2-apy)].

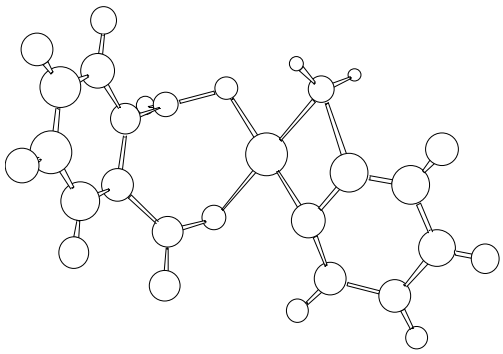


Figure 2(b). Possible ball and stick model of the complex-2 [Pd(II)(Ph)(2-apy)].

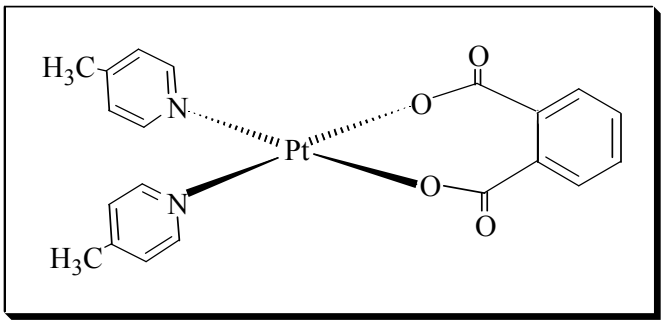


Figure 3(a). Possible structure of the complex-3 [Pt(II)(Ph)(4-pico)$_2$].

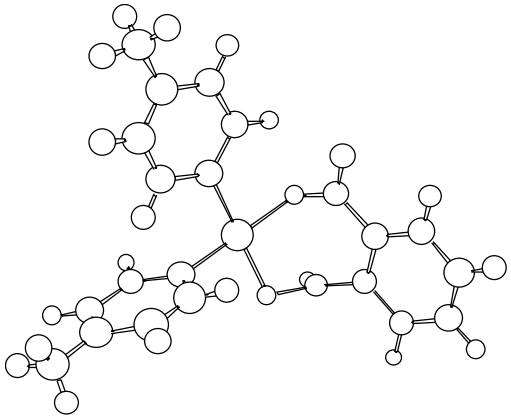


Figure 3(b). Possible ball and stick model of the complex-3 [Pt(II)(Ph)(4-pico)$_2$].

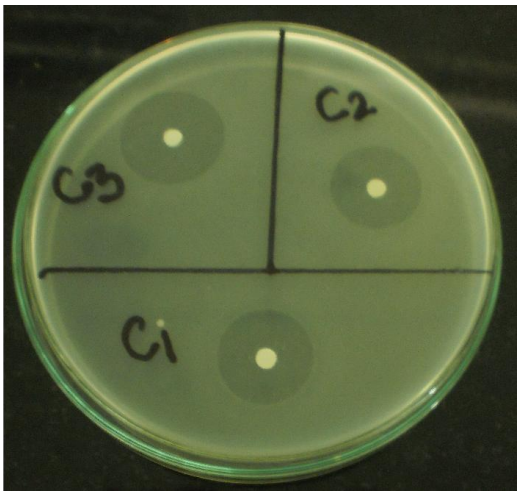


Figure 4. Photographic representation of zone of inhibition of complexes 1, 2 and 3, respectively against *Salmonella typhi*

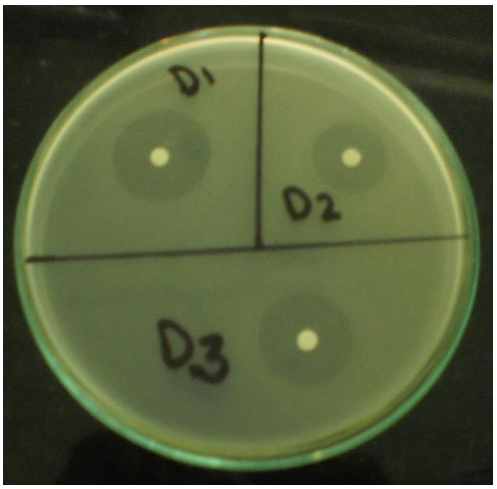


Figure 5. Photographic representation of zone of inhibition of complexes 1, 2 and 3, respectively against *Escherichia coli*

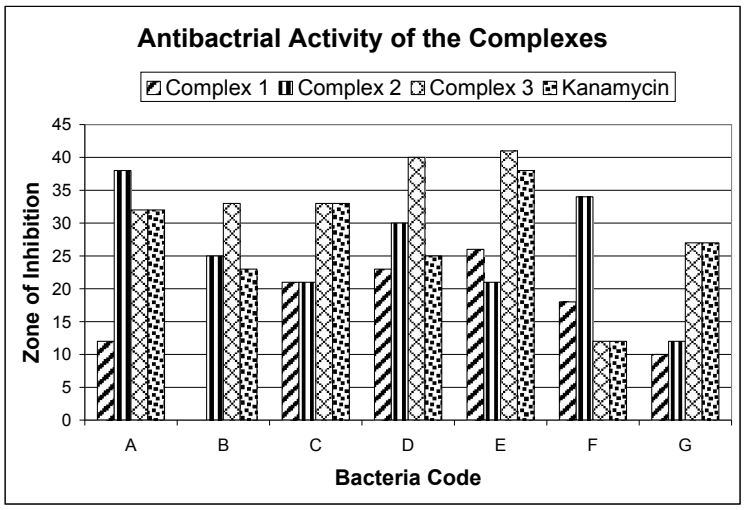


Figure 6. Comparision of zone of inhibition of the complexes with standard

Conclusion

From the above discussion, it is evident that the prepared Pd(II) and Pt(II) complexes are square planar in structure and the probable structures of the complexes have been shown in figures 1-3. Antibacterial screening of our synthesized complexes have shown mild to moderate activity.

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