

## Research Article

# A New Mannich Base Derived from Benzamide, Benzaldehyde and Pyrrolidine: Preparation, Spectral Characterization and Biological Studies of Some of its Transition Metal Chelates

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## Abstract

The synthesis of a new Mannich base ligand *N*-[Phenyl(pyrrolidin-1-yl)methyl]benzamide was carried out by the reaction between the ethanolic solution of benzamide, benzaldehyde and pyrrolidine. Elemental analysis and spectral data (IR, <sup>1</sup>H NMR, <sup>13</sup>C NMR, UV-Vis and Mass) confirm the structure of the synthesized ligand. Some transition metal complexes of VO<sup>IV</sup>, Mn<sup>II</sup>, Fe<sup>II</sup>, Ni<sup>II</sup> and Cu<sup>II</sup> with the above Mannich base ligand have been prepared and characterized by elemental analysis, conductivity and magnetic measurements, IR, UV and EPR spectral studies. Based on the IR data, it was found that the ligand acts as a neutral bidentate in nature. The complexes are

non-electrolytic in DMF. The presence of the coordinated water molecules in some of the complexes was indicated by IR spectra. It was found that Ni<sup>II</sup> chloro and nitrate and Cu<sup>II</sup> sulphato complexes exhibit tetrahedral geometry and the remaining show octahedral geometry. All the synthesized compounds were evaluated *in vitro* for their antimicrobial activity against six bacterial species and two fungal species using Disc Diffusion technique. Most of them exhibit significant antibiological activity, when compared with standard drugs.

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## Introduction

Coordination chemistry stands as a landmark in the field of scientific advancement, embracing most diverse branches of science, engineering and technology[1]. Metal complexes of Mannich bases form a group of less investigated compounds. However, recently more efforts are being made to synthesize, characterize and investigate the biological activities of these compounds[2]. Many Mannich base complexes possess very promising biological activities[3-5] as anticancer agents, antibacterial agents, anticonvulsant agents, anti-tuberculosis agents, pain-relief agents, anti-dermatitis agents and antimicrobial agents. In addition to their medical uses, some of the complexes have found other uses in the agricultural and industrial fields[6,7]. The reactivity of coordination compounds has dramatically changed as inferred from the present studies. Some interesting reactions of substituted benzamide chelates[8] of copper and nickel, in which the organic groups attached to nitrogen of the donors are altered, have been reported. The importance and application of metal complexes in analytical chemistry are well known. The Mannich base ligands play an important role in some biological systems and their function is related, at

least in part, to its chelating ability with metals[9]. In view of the importance of such a work and in continuation of our recent work on the synthesis of unreported Mannich base complexes, it was therefore considered worthwhile to synthesize some new benzamide derivatives with pyrrolidine residue. Thus, the synthesis of a new compound *N*-[Phenyl(pyrrolidin-1-yl)methyl]benzamide has been carried out.

## Experimental

All the reagents used for synthesizing the ligand and its complexes were of A.R. grade and the solvents used were commercial products of the highest available purity and were further purified by distillation.

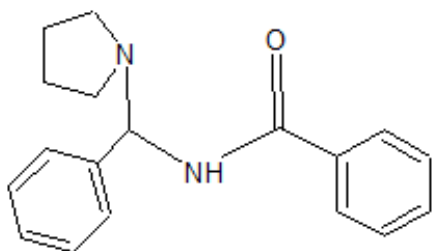
Micro elemental data were obtained with Carlo Erba 1108 elemental analyzer. Metal contents were estimated by usual procedure[10], after digesting the complexes with con.HNO<sub>3</sub>. Conductance data were obtained in ~10<sup>-3</sup> M DMF solution of the complexes using digital conductivity meter. IR spectra were recorded using Perkin Elmer FT-IR spectrometer by

using KBr pellets. Absorbance in UV-Visible region was recorded in DMF solution using UV-Visible spectrometer. The  $^1\text{H}$  and  $^{13}\text{C}$  NMR of the ligand were recorded on a Bruker instrument employing TMS as internal reference and DMSO- $d_6$  as solvent. The FAB mass for the ligand was carried out using Mass spectrometer. The room temperature magnetic susceptibility measurements of the complexes were made by using a Gouy Magnetic Balance.

### Synthesis and characterization of the ligand

*N*-[Phenyl(pyrrolidin-1-yl)methyl]benzamide (PBB) was synthesized by employing the Mannich synthetic route[11]. Benzamide (12.1 g, 0.1 mol) was dissolved in minimum quantity of ethanol. To this solution, benzaldehyde (10 mL, 0.1 mol) followed by pyrrolidine (7.1 mL, 0.1 mol) were added with constant stirring in an ice bath. After 20 days, the pale yellow solid obtained was washed with water and with acetone. The compound was dried in air and then in an air oven and recrystallised from ethanol. It was insoluble in water and soluble in organic solvents.

Molecular formula:  $\text{C}_{18}\text{H}_{20}\text{N}_2\text{O}$ , Yield: 86%, MP: 76-80°C, Mol.wt: 280, FT-IR KBr in  $\text{cm}^{-1}$ : 3346(NH), 1634(C=O), 3057, 3033( $\nu_{\text{CH}}$  aromatic), 2965, 2873( $\nu_{\text{CH}}$  alicyclic), 2801( $\nu_{\text{CH}}$  aliphatic), 1147(C-N-C), 1578( $\nu_{\text{C=C}}$ ,  $\nu_{\text{C-N}}$ ), 1515( $\delta_{\text{NH}}$  secondary amide), 1029( $\delta_{\text{CH}}$  i.p.b benzene), 930( $\delta_{\text{CH}}$  + o.p.b of pyrrolidine), 908, 868( $\delta_{\text{NH}}$  wagging and twisting), 719( $\delta_{\text{CH}}$  o.p.b benzene), 540( $\pi_{\text{C=O}}$ ), 505(o.p.b ring C=C).  $^1\text{H}$  NMR (300MHz, DMSO- $d_6$ )  $\delta$  8.92(s, NH), 5.86 & 5.83 (d, CH), 7.93 - 7.54(m, 5H amido phenyl ring), 7.48 - 7.25(m, 5H aldehydic phenyl ring), 2.56(s,  $\text{N}(\text{CH}_2)_2$  at  $\alpha$ ,  $\alpha^1$ ), 1.69(s,  $(\text{CH}_2)_2$  at  $\beta$ ,  $\beta^1$ ).  $^{13}\text{C}$  NMR (300MHz, DMSO- $d_6$ ) 168.39 (s, C=O), 141.58- 127.75(m, 6C aldehydic phenyl ring), 134.83- 127.95(m, 6C, amido phenyl ring), 70.44(s, methine C), 49.60 (s, Pyrrolidine  $\text{N}(\text{CH}_2)_2$  at  $\alpha$ ,  $\alpha^1$ ), 23.71 (s, Pyrrolidine  $(\text{CH}_2)_2$  at  $\beta$ ,  $\beta^1$ ). UV-Vis(DMF) 263( $n \rightarrow \pi^*$ ), 235( $\pi \rightarrow \pi^*$ ). FABMS  $m/z$  = 280( $\text{C}_{18}\text{H}_{20}\text{N}_2\text{O}$ ),  $m/z$  = 204 ( $\text{C}_{12}\text{H}_{15}\text{N}_2\text{O}^+$ ),  $m/z$  = 126 ( $\text{C}_6\text{H}_{10}\text{N}_2\text{O}^+$ ),  $m/z$  = 70 ( $\text{C}_4\text{H}_8\text{N}^+$ ). Calculated: C 77.14%, H 7.14% and N 10.00%. Found: C 76.91%, H 7.28% and N 9.06%.



**Figure 1** PBB

(Tentative structure proposed for *N*-[Phenyl(pyrrolidin-1-yl)methyl]benzamide)

Based on the data obtained from various physical[12] and chemical studies[13], the molecular structure of PBB is shown in **Figure 1**.

### Synthesis of metal complexes

The methanolic solution of the metal salts was added slowly with constant stirring to the ethanolic solution of the ligand in 2:1 mol ratio at warm condition. The insoluble complexes[14] formed were filtered, washed with ethanol and methanol to remove the unreacted metal and ligand, and then dried at 80°C.

### Antimicrobial Screening

Antibacterial and antifungal activities[15] of the ligand and seven of its metal complexes were tested *in vitro* against six bacterial species viz *E.coli*, *P.aeruginosa*, *S.typhi*, *B.subtilis*, *S.pyogenes*, *S.aureus* and two fungal species *A.niger* and *A.flavus* by disc diffusion method<sup>8</sup> using agar nutrient as medium and gentamycin as control. The paper disc containing the compound (10, 20 and 30  $\mu\text{g}/\text{disc}$ ) was placed on the surface of the nutrient agar plate, previously spread with 0.1 mL of sterilized culture of microorganism. After incubating this at 37°C for 24 hrs, the diameter of inhibition zone around the paper disc was measured.

### Results and Discussion

The percentages of the metal ions, anions and CHN were determined in order to find the stoichiometry[16] of the complexes. The electrical conductance measurements of the  $\sim 10^{-3}$  M DMF solutions at room temperature revealed that, all the complexes are non-electrolytes(**Table 1**).

The IR spectrum of the  $\text{VO}^{\text{II}}$ ,  $\text{Mn}^{\text{II}}$  and  $\text{Fe}^{\text{II}}$  sulphato complexes registered lower frequency values for the C=O and CNC by about 90, 12 & 14 and 21, 25 & 03  $\text{cm}^{-1}$  (when compared to the free ligand values) respectively. In  $\text{Ni}^{\text{II}}$  chloro & nitrate and  $\text{Cu}^{\text{II}}$  nitrate & sulphato complexes, the carbonyl stretching frequency of the free ligand at 1634  $\text{cm}^{-1}$  suffers a negative shift of 12, 06, 07 & 22  $\text{cm}^{-1}$  and the  $\nu_{\text{CNC}}$  of the free ligand at 1147  $\text{cm}^{-1}$  suffers a negative shift of 46, 44, 46 & 55  $\text{cm}^{-1}$ . The above data suggest a bidentate coordination of the ligand[17] (**Table.2**).

The IR spectra of the nitrate complexes of  $\text{Ni}^{\text{II}}$  and  $\text{Cu}^{\text{II}}$  show a band at 1305, 1300 ( $\nu_1$ ), 1052, 1062( $\nu_2$ ), 1384, 1391( $\nu_5$ ) and 834, 992 ( $\nu_6$ )  $\text{cm}^{-1}$  respectively due to the nitrate group. The difference between  $\nu_5$  and  $\nu_1$  is 79 and 91  $\text{cm}^{-1}$ , which points to the unidentate behaviour of nitrate.

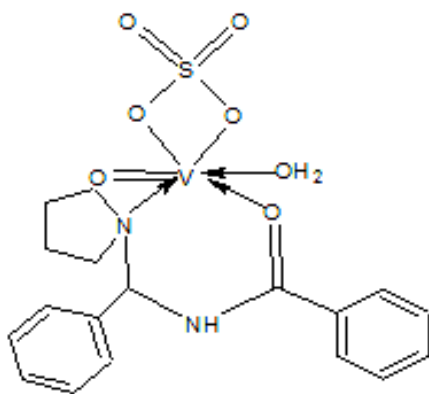
The  $\nu_3$  of sulphato group bands appear at 1126, 1122, 1144 & 1154 and 1050, 1018, 1017 & 1092 and 1013 & 996  $\text{cm}^{-1}$ . The corresponding  $\nu_4$  bands appear at 682, 653, 664 & 659 and 660, 626, 625 & 634 and 648, 607,

603 & 618  $\text{cm}^{-1}$ . The  $\nu_1$  and  $\nu_2$  modes occur at 771, 823, 828 & 865 and 536, 529, 526 & 498  $\text{cm}^{-1}$  respectively. Absorption bands observed in all the sulphato complexes were associated with the bidentate[18] chelating sulphato group.

Bands appearing at (3657, 3376, 3354, 3548 & 3448), (1645, 1622, 1637, 1627 & 1615), (771, 823, 828, 835 & 848), (682, 653, 665, 679 & 596) and (536, 529, 526, 457 & 454)  $\text{cm}^{-1}$  are assigned to  $\nu_{\text{OH}}$ ,  $\delta_{\text{HOH}}$ ,  $\rho_{\text{rHOH}}$ ,  $\rho_{\text{wHOH}}$  and  $\nu_{\text{M-O}}$  modes respectively of coordinated water[19] in the sulphato complexes of  $\text{VO}^{\text{II}}$ ,  $\text{Mn}^{\text{II}}$ ,  $\text{Fe}^{\text{II}}$  and  $\text{Cu}^{\text{II}}$  and chloro complex of  $\text{Cu}^{\text{II}}$ .

Far-IR spectrum furnishes information regarding the formation of metal-chloride bond[20] in  $\text{Cu}^{\text{II}}$  chloro complex. The bands observed at 570 & 526, 484, 422 & 380 and 250  $\text{cm}^{-1}$  are assigned to the M-O, M-N and M-Cl stretching modes respectively.

The UV-Visible spectrum[21] of  $\text{VO}^{\text{IV}}$  sulphato complex shows absorption bands at 14499, 16602 and 27030  $\text{cm}^{-1}$  which indicate  ${}^2\text{B}_2 \rightarrow {}^2\text{E}_2$ ,  ${}^2\text{B}_2 \rightarrow {}^2\text{B}_1$  and  ${}^2\text{B}_2 \rightarrow {}^2\text{A}_1$  transitions. The EPR spectrum of this complex shows only one resolution at  $g_{\parallel}$  region; so it can be assumed that  $g_x$  and  $g_y$  are same or nearly the same[22]. The  $g$  value of 1.8903 indicates the strong interaction between the ligand and the metal ion. The complex displays a strong V=O stretching at 771  $\text{cm}^{-1}$ . The room temperature magnetic moment value is 1.57 B.M. which suggests a hexa coordinate geometry around  $\text{VO}^{\text{IV}}$  ion (Figure 2).

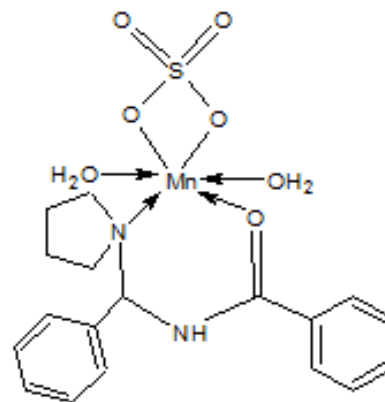


**Figure 2**  $\text{VO}\text{SO}_4\cdot\text{PBB}\cdot\text{H}_2\text{O}$   
(Tentative structure proposed for VO sulphato complex)

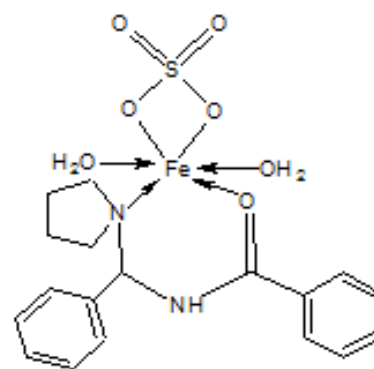
The UV-Visible spectrum[23] of  $\text{Mn}^{\text{II}}$  sulphato complex shows absorption bands at 18049  $\text{cm}^{-1}$  due to  ${}^6\text{A}_{1g} \rightarrow {}^4\text{T}_{1g}(\text{G})$  transition, at 24986  $\text{cm}^{-1}$  due to  ${}^6\text{A}_{1g} \rightarrow {}^4\text{E}_g$ ,  $\text{A}_{1g}(\text{G})$  transition, at 29135  $\text{cm}^{-1}$  due to  ${}^6\text{A}_{1g} \rightarrow {}^4\text{E}_g(\text{D})$  transition and at 31274  $\text{cm}^{-1}$  due to  ${}^6\text{A}_{1g} \rightarrow {}^4\text{T}_{1g}(\text{P})$  transitions respectively. The magnetic

moment value was found to be 5.96 B.M. suggestive of a high spin octahedral geometry (Figure 3).

The electronic spectrum of  $\text{Fe}^{\text{II}}$  sulphato complex exhibits a strong intense band at 11258  $\text{cm}^{-1}$  due to  ${}^5\text{T}_{2g} \rightarrow {}^5\text{E}_g$  transition and the CT band at 23402  $\text{cm}^{-1}$  which obscures the other very low intensity d-d absorption bands. The  $\mu_{\text{eff}}$  value of 5.67 B.M. points to a hexa coordinate[23] geometry (Figure 4).



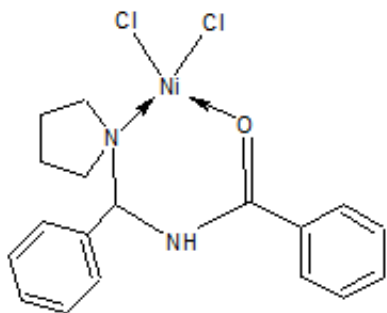
**Figure 3**  $\text{MnSO}_4\cdot\text{PBB}\cdot 2\text{H}_2\text{O}$   
(Tentative structure proposed for Mn sulphato complex)



**Figure 4**  $\text{FeSO}_4\cdot\text{PBB}\cdot 2\text{H}_2\text{O}$   
(Tentative structure proposed for Fe sulphato complex)

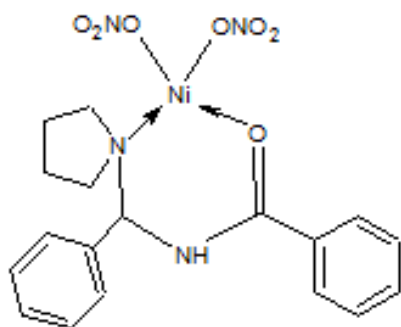
The  $\text{Ni}^{\text{II}}$  chloro and nitrate complexes exhibit bands at 3917 & 3870  $\text{cm}^{-1}$  due to  ${}^3\text{T}_{1g}(\text{F}) \rightarrow {}^3\text{T}_{2g}(\text{F})$  transition, at 8402 & 8413  $\text{cm}^{-1}$  due to  ${}^3\text{T}_{1g}(\text{F}) \rightarrow {}^3\text{A}_{2g}(\text{F})$  transition and at 15036 & 15389  $\text{cm}^{-1}$  due to  ${}^3\text{T}_{1g}(\text{F}) \rightarrow {}^3\text{T}_{2g}(\text{P})$  transition respectively. The charge transfer transition band for the chloro compound occurs at 25675  $\text{cm}^{-1}$  and for the nitrate complex appears at

28561 & 24555  $\text{cm}^{-1}$ . The  $\mu_{\text{eff}}$  values for the chloro and nitrate complexes are 3.80 and 4.36 B.M. respectively, indicating tetrahedral environment[24] around  $\text{Ni}^{\text{II}}$  ion(**Figure 5&6**).



**Figure 5**  $\text{NiCl}_2\cdot\text{PBB}$

(Tentative structure proposed for VO chloro complex)



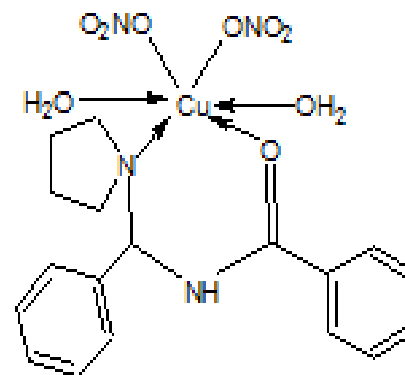
**Figure 6**  $\text{Ni}(\text{NO}_3)_2\cdot\text{PBB}$

(Tentative structure proposed for VO nitrate complex)

The sulphato complex of  $\text{Cu}^{\text{II}}$  exhibits electronic absorption bands: at 9145  $\text{cm}^{-1}$  due to  ${}^2\text{B}_{1g} \rightarrow {}^2\text{A}_{1g}$ , at 11078  $\text{cm}^{-1}$  due to  ${}^2\text{B}_{1g} \rightarrow {}^2\text{B}_{2g}$ , at 12804  $\text{cm}^{-1}$  due to  ${}^2\text{E}_g \rightarrow {}^2\text{T}_{2g}(\text{F})$  and the bands observed at 34472 & 35699  $\text{cm}^{-1}$  due to charge transfer transitions. The  $\mu_{\text{eff}}$  value of sulphato complex is 2.78 B.M. which suggests a distorted tetrahedral geometry. Nitrate complex of  $\text{Cu}^{\text{II}}$  exhibits electronic absorption bands at 8245  $\text{cm}^{-1}$  due to  ${}^2\text{B}_{1g} \rightarrow {}^2\text{A}_{1g}$ , 11328  $\text{cm}^{-1}$  due to  ${}^2\text{B}_{1g} \rightarrow {}^2\text{B}_{2g}$ , 14650  $\text{cm}^{-1}$  due to  ${}^2\text{E}_g \rightarrow {}^2\text{T}_{2g}(\text{F})$  and the bands at 26392 & 35675  $\text{cm}^{-1}$  are assigned due to charge transfer transitions respectively. The  $\mu_{\text{eff}}$  value (1.89 B.M.) of nitrate complex indicate that the complex is magnetically diluted and has a distorted octahedral geometry[25].

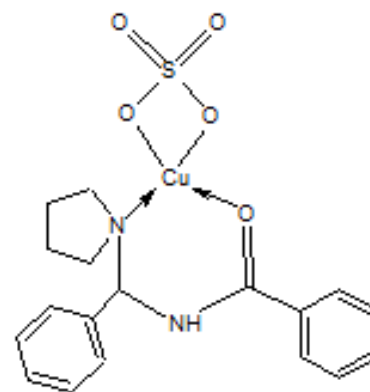
The X band EPR spectra[22] of the nitrate and sulphato complexes of  $\text{Cu}^{\text{II}}$  were recorded at LNT(**Table 3**). The  $g$  values of the nitrate complex of  $\text{Cu}^{\text{II}}$  are in the trend,  $g_{\parallel} > g_{\perp} > g_{\text{DPPH}}$  suggesting that the unpaired electron lies predominantly in the  $d_{x^2-y^2}$  orbital. The complex showed EPR spectra of axial symmetry type indicating planar based distorted octahedral geometry around copper centre.

The  $g_{\parallel}$  values of nitrate and sulphato complexes are less than 2.30 indicating the covalent nature. The higher  $g_{\parallel}$  values may be due to the coordination of  $\text{H}_2\text{O}$  to the  $\text{Cu}^{\text{II}}$  ion in the nitrate complex. The axial symmetry parameter  $G$  value[26] which is a measure of interaction between the metal centers in the crystalline solid for the sulphato complex of  $\text{Cu}^{\text{II}}$  is 4.95 and this suggests the lack of charge interaction between two  $\text{Cu}^{\text{II}}$  centres in the unit cell of the complex. The value of  $G$  is less than 4 for the nitrate complex of  $\text{Cu}^{\text{II}}$ . It shows considerable coupling and appreciable misalignment of the local tetragonal axes, leading to an exchange interaction of free electron between two copper centers in the solid state. Based on the above discussions, six coordinated tetragonally distorted octahedral geometry may be assigned to the nitrate complex and pseudo tetrahedral structure for the sulphato complex of  $\text{Cu}^{\text{II}}$ (**Figure 7&8**).



**Figure 7**  $\text{Cu}(\text{NO}_3)_2\cdot\text{PBB}\cdot 2\text{H}_2\text{O}$

(Tentative structure proposed for Cu nitrate complex)



**Figure 8**  $\text{CuSO}_4\cdot\text{PBB}$

(Tentative structure proposed for Cu sulphato complex)

**Table 1** Analytical and Conductance Data for VO<sup>IV</sup>, Mn<sup>II</sup>, Fe<sup>II</sup>, Ni<sup>II</sup> and Cu<sup>II</sup> Complexes of PBB

Complex	% C Obs (Cal.)	% H Obs. (Cal.)	% N Obs. (Cal.)	%Metal Obs. (Cal.)	%Anion Obs. (Cal.)	$\Lambda_M$ ohm <sup>-1</sup> cm <sup>2</sup> mol <sup>-1</sup>
VOSO <sub>4</sub> .PBB. H <sub>2</sub> O	38.70 (39.20)	4.12 (3.63)	4.85 (5.08)	8.99 (9.25)	18.10 (17.42)	31.65
MnSO <sub>4</sub> . PBB.2H <sub>2</sub> O	39.32 (40.07)	4.04 (3.71)	4.75 (5.19)	10.63 (10.19)	18.00 (17.42)	19.82
FeSO <sub>4</sub> .PBB. 2H <sub>2</sub> O	36.68 (36.36)	3.10 (3.37)	5.08 (4.71)	9.16 (9.40)	16.97 (16.16)	24.07
NiCl <sub>2</sub> .PBB	42.34 (41.70)	3.29 (3.86)	5.01 (5.41)	10.89 (11.33)	14.19 (13.68)	43.13
Ni(NO <sub>3</sub> ) <sub>2</sub> .PBB	38.00 (37.83)	3.90 (3.50)	5.12 (4.91)	9.95 (10.28)	22.14 (21.72)	15.49
Cu(NO <sub>3</sub> ) <sub>2</sub> . PBB.2H <sub>2</sub> O	39.32 (38.71)	4.19 (3.94)	4.96 (5.02)	12.07 (11.39)	21.85 (22.22)	29.41
CuSO <sub>4</sub> .PBB	41.22 (40.83)	4.09 (3.78)	4.95 (5.29)	11.74 (12.01)	18.81 (18.15)	12.55

**Table 2** Important IR Absorption Bands ( $\text{cm}^{-1}$ ) of PBB and of  $\text{VO}^{\text{IV}}$ ,  $\text{Mn}^{\text{II}}$ ,  $\text{Fe}^{\text{II}}$ ,  $\text{Ni}^{\text{II}}$  and  $\text{Cu}^{\text{II}}$  Complexes

Compound	$\nu_{\text{NH}}$	$\nu_{\text{C=O}}$	$\nu_{\text{CNC}}$	$\nu_3$	$\nu_4$	$\nu_1$	$\nu_2$	$\nu_5$	$\nu_6$
PBB	3346	1634	1147	-	-	-	-	-	-
$\text{VO}_4\cdot\text{PBB}\cdot\text{H}_2\text{O}$	3409	1544	1126	1126, 1050, 1013	682, 660, 648	771	536	-	-
$\text{MnSO}_4\cdot\text{PBB}\cdot 2\text{H}_2\text{O}$	3376	1622	1122	1122, 1018	653, 626, 607	823	529	-	-
$\text{FeSO}_4\cdot\text{PBB}\cdot 2\text{H}_2\text{O}$	3354	1620	1144	1144, 1100, 1017	664, 625, 603	828	526	-	-
$\text{NiCl}_2\cdot\text{PBB}$	3395	1622	1101	-	-	-	-	-	-
$\text{Ni}(\text{NO}_3)_2\cdot\text{PBB}$	3401	1628	1103	-	-	1305	1062	1384	992
$\text{Cu}(\text{NO}_3)_2\cdot\text{PBB}\cdot 2\text{H}_2\text{O}$	3548	1627	1101	-	-	1300	1052	1384	834
$\text{CuSO}_4\cdot\text{PBB}$	3229	1622	1092	1154, 1092, 996	659, 634, 618	865	475	-	-

**Table 3** EPR Spectral Parameters of  $\text{Cu}^{\text{II}}$  Complexes

Complex	$g_{\parallel}$	$g_{\perp}$	$g_{\text{av}}$	$G$
$\text{Cu}(\text{NO}_3)_2\cdot\text{PBB}\cdot 2\text{H}_2\text{O}$	2.02	1.98	1.99	1.44
$\text{CuSO}_4\cdot\text{PBB}$	2.09	2.02	2.05	4.95

**Table 4** Antibacterial Activity of Ligand and its Complexes

Compound	<i>E. coli</i>			<i>P. aer.</i>			<i>S. typhi.</i>			<i>B. sub</i>			<i>S. pyo</i>			<i>S. aur</i>		
	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30
Conc. ( $\mu\text{g}/\text{disc}$ )	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30
Control	09	12	17	06	09	15	10	12	16	08	14	18	14	19	22	10	10	18
PBB	12	15	20	10	13	18	14	17	22	11	14	18	10	12	16	12	17	20
$\text{VO}\text{SO}_4\cdot\text{PBB}\cdot\text{H}_2\text{O}$	16	18	23	14	19	24	14	19	26	14	19	27	17	23	28	18	23	30
$\text{Mn}\text{SO}_4\cdot\text{PBB}\cdot 2\text{H}_2\text{O}$	14	20	21	16	16	21	14	15	21	12	18	24	16	21	26	12	19	25
$\text{Fe}\text{SO}_4\cdot\text{PBB}\cdot 2\text{H}_2\text{O}$	18	21	24	17	22	27	20	28	30	23	26	32	18	24	29	25	28	35
$\text{NiCl}_2\cdot\text{PBB}$	25	27	36	22	26	39	25	32	40	21	30	39	25	28	35	23	29	39
$\text{Ni}(\text{NO}_3)_2\cdot\text{PBB}$	20	26	30	19	24	35	20	27	33	18	22	28	18	20	26	19	24	30
$\text{Cu}(\text{NO}_3)_2\cdot\text{PBB}\cdot 2\text{H}_2\text{O}$	22	29	32	23	26	32	21	26	32	20	29	31	20	24	31	26	28	34
$\text{Cu}\text{SO}_4\cdot\text{PBB}$	26	32	45	24	28	40	25	34	44	23	31	42	28	32	40	26	32	41

**Table 5** Antifungal Activity of Ligand and its Complexes

Compound	<i>E. coli</i>			<i>P. aer.</i>			<i>S. typhi.</i>			<i>B. sub</i>			<i>S. pyo</i>			<i>S. aur</i>		
	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30
Conc. ( $\mu\text{g}/\text{disc}$ )	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30
Control	08	11	14	06	09	10	08	10	16	07	07	12	10	13	14	09	12	15
PBB	09	13	16	08	12	14	10	12	17	10	13	16	11	15	16	11	14	18
$\text{VO}\text{SO}_4\cdot\text{PBB}\cdot\text{H}_2\text{O}$	12	15	18	10	13	16	11	13	18	12	14	16	14	14	17	13	15	19
$\text{Mn}\text{SO}_4\cdot\text{PBB}\cdot 2\text{H}_2\text{O}$	16	18	20	14	16	18	14	16	20	15	18	21	15	17	20	16	18	24
$\text{Fe}\text{SO}_4\cdot\text{PBB}\cdot 2\text{H}_2\text{O}$	15	18	21	12	17	22	16	19	22	14	19	24	15	20	23	17	20	25
$\text{NiCl}_2\cdot\text{PBB}$	18	21	24	17	22	27	20	28	30	23	26	32	18	24	29	25	28	35
$\text{Ni}(\text{NO}_3)_2\cdot\text{PBB}$	16	20	22	14	18	20	15	18	22	19	20	26	18	18	24	14	20	26
$\text{Cu}(\text{NO}_3)_2\cdot\text{PBB}\cdot 2\text{H}_2\text{O}$	19	23	28	16	22	29	18	23	28	20	27	37	16	22	35	24	29	40
$\text{Cu}\text{SO}_4\cdot\text{PBB}$	21	29	37	19	24	35	18	23	33	26	30	41	22	29	39	26	31	47



### Antimicrobial activity

The inhibition zone of the compounds under investigation is compared and listed in **Tables 4 and 5**. It shows that,  $\text{Cu}^{\text{II}}$  sulphato complex exhibits highest antibacterial and antifungal activity against all the eight species mentioned above. They have larger diameters of inhibition zones than the control gentamycin at the same concentration and identical conditions. Antimicrobial activity of metal chelates can be explained on the basis of chelation theory[27]. Chelation reduces the polarity of the copper ion mainly because of the partial sharing of its positive charge with the donor groups and possibly the  $\pi$ -electron delocalization within the whole chelate ring system thus formed during coordination. This process of chelation thus increases the lipophilic nature of the copper ion, which in turn favors its permeation through the lipid layer of the membrane [28]. This in turn, is responsible for increasing the hydrophobic character and liposolubility of the molecule in crossing cell membrane of the microorganism. Hence it enhances the biological utilization ratio and activity of the testing compound. The enhanced activity of the complexes may also be explained on the basis of their solubility[29]. In  $\text{Cu}^{\text{II}}$  sulphato complex, the unsaturated metal center present, achieves higher coordination number by binding with some of the functional groups of the protein. This leads to the increased uptake of the compound by the bacterium and thereby inhibiting its growth. Steric constraints are less for a tetrahedral complex than for an octahedral complex. So the tetrahedral complexes are biologically more active than the octahedral complexes. Transition metal complexes of many O, N, and S donors show higher antibacterial and antifungal activities compared to the respective ligand[30].

### Conclusion

$\text{VO}^{\text{IV}}$ ,  $\text{Mn}^{\text{II}}$ ,  $\text{Fe}^{\text{II}}$ ,  $\text{Ni}^{\text{II}}$  and  $\text{Cu}^{\text{II}}$  metal chelates of a new Mannich base *N*-[Phenyl(pyrrolidin-1-yl)methyl]benzamide(PBB) were synthesized and characterized by various chemical and spectral analysis. Based on the spectral data, the ligand was found to act as bidentate to the metal ion through CO and CNC groups. Chloro and nitrate complexes of  $\text{Ni}^{\text{II}}$  and  $\text{Cu}^{\text{II}}$  sulphato complex exhibit tetrahedral geometry and the remaining complexes show octahedral geometry. The synthesized ligand and their metal complexes were screened for biological activities. All the compounds showed antibacterial and antifungal activities. The  $\text{Cu}^{\text{II}}$  sulphato complex was more active than the rest.

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