Cu (II) complex with 2-(p-thiomethyl phenyl)benzimdazole: Synthesis, Characterization and Antibacterial Activity

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Abstract

The coordination product $Cu(tmpbi)_2Cl_2$ was created when 2-(p-thiomethyl phenyl) benzimdazole (tmpbi) was reacted with the appropriate metal halides. The complex has been characterized using element analysis, conductance measurements, Fourier transform infrared spectroscopy, ultraviolet-visible spectroscopy, and magnetic susceptibility tests. It has been suggested that the complex has a tetrahedral shape. Tmpbi is a ligand that exhibits N-benzimidazole coordination. The ligand and its Cu complex were tested for their antimicrobial (antibacterial) capabilities in vitro against gram-positive (Staphylococcus aureus) and gram-negative (Escherichia coli) bacterial strains using the paper disc diffusion technique. Both of these bacteria are known to cause illnesses in humans, including dysentery and food poisoning, so they were selected for study. The copper (II) complex is more potent against Escherichia coli and Staphylococcus aureus than the ligand. More activity is shown in the complex than in the free ligand.

Keywords: Cu (II) complex; 2-(p-thiomethyl phenyl) benzimdazole (tmpbi); Antibacterial activity.

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Introduction

Antibacterial and antifungicidal activity has been shown by a variety of benzimidazole derivatives in the previous decade [1-14]. These include derivatives with thiazolyl, ester, carboxyl, alkyl, and amine groups. Therapeutic promise also exists in transition metal coordination molecules of benzimidazole derivatives. There is cytotoxic [15–17], antiviral [17], and antiamoebic [18] action in complexes containing 2-substituted benzimidazole. Since one of vitamin B12's five nitrogen atoms is coordinated to cobalt(II) by the benzimidazole derivative 5,6-dimethylbenzimidazole, researchers have been interested in studying coordination compounds of benzimidazole and its derivatives [19]. Copper (II) is a crucial trace element for all known biological processes [20]. Evidence suggests that copper (II) complexes containing organic ligands can lower pain, fever, inflammation, and platelet aggregation. Apoptosis induction [21] and antibacterial activity [22, 23] are two effects of copper complexes of ligands containing a -diimino (N=C-C=N) moiety, such as phenanthroline or 2-(4'-thiazolyl) benzimidazole. Numerous biological effects of copper (II) complexes have been discovered, including antiamoebic activity against the parasite Entamoeba histolytica [24]. TMPBI Cu (II) complexes have been created, and research has been done on their chemical makeup and antibacterial properties.

2. Experimental

2.1. Materials and physical measurements

The compounds were all of reagent grade, so further purification was not necessary. The usual procedures were used to purify the solvents, such as methanol, ethanol, N, N-dimethylformamide, acetonitrile, etc. At air temp, a digital conductivity meter was used to determine the complexes' conductivity in nitrobenzene (10^{-3}M) (Elico model-180). To conduct their elemental studies, scientists used Carlo Erba-1108 and elementarVario EI III machines. In order to capture tmpbi and its constituents in KBr pellet FTIR spectra in the range 4000-400 cm^{-1}, a Nicolet impact 400D spectrometer was used. The melting point measurements were taken using electrothermal melting point devices. The electronic spectra of a solid were acquired using a UV-Vis-NIR spectrophotometer using the mull method, which covers the range 200-2000 nm [26]. A Johnson-Mathey DG8 5HJ balance was used to record room-temperature magnetic susceptibility measurements of powdered materials using the Faraday technique.

2.2. Antibacterial activity measurements

The paper disc diffusion technique [24, 25] was used to examine the ligand and its copper complexes for in vitro antimicrobial (antibacterial) activity against strains of G (+) Staphylococcus and G (-) Escherichia coli. In liquid medium, injectable bacterial subcultures were sterilized by autoclaving for 20 minutes at 121 °C and 15 lbs of pressure. After that, the bacteria spent 24 hours in an incubator at 36 degrees Celsius. When the nutrient agar in the plate had set, it was removed. A filter paper disc 10 mm in diameter was placed in the middle of each agar plate, and test chemicals (DMF solutions) were applied dropwise. After 1 hour at 5 degrees Celsius, the plates were moved to a 36 degree Celsius incubator. After 24 hours of incubation, the growth-inhibiting zone's circumference was measured. There were four copies of each therapy produced.

2.3. Syntheses of compounds

2.3.1. Synthesis of the ligand 2-(*p*-thiomethylphenyl) benzimidazole (tmpbi)

The desired product was produced by heating a combination of o-phenylenediamine (10 mmol) and p-thiomethylbenzaldehyde (10 mmol) in benzene (100 mL) at 80 degrees for two hours. After being left alone for the night, a crystalline yellow solid formed. The resulting product was filtered and washed in a solvent composed of n-hexane and water. Ethanol crystallisation followed by vacuum drying over P_2O_5 produced pale yellow crystals (Yield 90 percent).

2.3.2 Copper Chloride Complex Synthesis

The divalent salt of copper (1 mmol) was diluted in ethanol (25 mL) and added to four vials containing a solution of tmpbi (2 mmol). For metal halide, it was refluxed for about 6 hours. The filter solid was employed after filtering, thorough washing with cold ethanol, and vacuum drying over P_2O_5 (yield 85–90%).

3. Results and discussion

3.1. Syntheses

Table 1 summarizes analytical tests on tmpbi and its metal complex. Based on the experimental data, it is expected that the complex will have the general formula $[M(tmpbi)_2X_2]$ (where M is Cu and X is Cl^-). When kept at room temperature, they retain their original shape quite well. Only three common organic solvents may dissolve the complex: nitrobenzene, dimethyl sulfoxide, and N,N-dimethylformamide. The abundance of the M+1 species is shown by the molecular ion peak at m/z 240 in the mass spectrum of the tmpbi particle. The fact that the complex in 10^{-3} M nitrobenzene doesn't act as an electrolyte suggests that the halogen atoms are coordinated to the metal [26]. These compounds characteristics were established by the following experiments.

Table 1
Physical and analytical data of the compounds

Compound	Empirical formula (mol.wt)	Colour	Anal.found (Cald) (%)			
			C	H	N	S
tmpbi	$C_{14}H_{12}N_2S$ (240)	Yellow	69.71 (76.74)	4.32 (5.04)	12.41 (11.66)	12.95 (13.32)
$Cu(tmpbi)_2Cl_2$	$C_{28}H_{24}N_4S_2Cl_2Cu$ (614.4)	Green	54.51 (54.68)	3.99 (3.90)	9.43 (9.11)	10.65 (10.61)

3.2. Spectral studies

3.2.1. Infrared spectra

Table 2 shows the IR spectra of tmpbi and its metal complex. The origin of bands in the IR spectra of the ligand tmpbi has been traced to the bending vibrational modes of certain groups within the molecule. An overview of the whole distribution is given in Table 2. The NH of the benzimidazole ring is responsible for the 1471 cm^{-1} signal in the tmpbi's IR spectra. The stretching vibrations of (C=N) and (C-N) have been identified as the origin of the 1604 cm^{-1} and 1331 cm^{-1} bands, respectively. The peaks at 2800 cm^{-1} are caused by the symmetric CH stretching mode in the SCH_3 group. A band at 1130 cm^{-1} has been shown to be related to an in-plane C-H deformation mode in the p-substituted benzene ring of the ligand. Between 1593 and

1615 cm^{-1}, the C=N stretching band may be seen in the spectra of metal complexes containing tmpbi. The spectra of complexes show a shift in a prominent band at 1604 cm^{-1} in the free ligand, which is attributable to the C=N stretching mode and shows that the metal atom coordinates with the tertiary nitrogen of the benzimidazole ring. Table 2 [27] does not show bands at 1284, 1016, 602, and 457 cm^{-1}, but they are believed to be caused by the benzimidazole ring vibrating. Around 1322-1370 cm^{-1} is the frequency range where C-N stretching occurs. The lower frequency range characteristic of metal halide vibrations is of special interest to us. The complex provides evidence of metal halide bonding, including a band at around 455 cm^{-1}.To emphasize, this substance does not include any salts. The conductivity readings backed this up as well.

Table 2
Infrared spectral data (cm^{-1}) of tmpbi and its metal complex

Compound	ν(C=N)	ν(C-N)	δNH	ν(S-CH_3)
tmpbi	1604	1331	1471	2800
$Cu(tmpbi)_2Cl_2$ **(3)**	1610	1334	1461	2840

3.2.2. Electronic spectra

Table 3 displays the copper complex's electronic absorption spectrum for the visible spectrum. Transitions are seen in the predicted 11,000-13,500 cm^{-1} range, indicating that the copper complex possesses a tetrahedral structure (Table 3). The band between 11,000 and 12,000 cm^{-1} may be ascribed to the $^2B_2 \rightarrow {}^2A_1$ band of the copper(II) ions in the deformed tetrahedral structure seen in copper complexes [28].

Table 3
Magnetic moment and electronic spectral data of copper(II) complex with tmpbi.

Substance	Magnetic moment (B.M.)	Absorption maxima (cm^{-1})
$Cu(tmpbi)_2Cl_2$	1.80	11,200

3.3. Magnetic measurement studies

The complex is found to be paramagnetic at room temperature, as shown by solid-state magnetic moment measurements. Regardless of stereochemistry, the magnetic moment of simple Cu(II) complexes ranges between 1.75 and 2.20 B.M. [29]. As seen in Table 3, the copper complexes' measured magnetic moment of 1.80 B.M. is compatible with the existence of a solitary unpaired electron devoid of antiferromagentic interaction. These values are very near to what is predicted for copper(II) complexes and correspond reasonably well with the spin only $S = 1/2$ system.

3.4. Antibacterial activity

Metal complexes with antibacterial activity have been examined for the following five primary factors: One, the chelate effect There is a significant difference in antibacterial activity between complexes containing unidentate N-donor ligands like pyridine and those containing ligands like bipyridine, phenanthroline, and o-phenyldiamine coupled to metal ions in a bidentate state [30]. The decision to use benzimidazole ligands with a phenyl group at position 2 as the complex's "carrier ligands" in the current investigation was made based on two key factors. Thiol-containing drug detoxification may be slowed down by steric obstructive ligands.

Two typical gram-positive (S. aureus) and gram-negative (E. coli) bacteria were used in antibacterial testing on the ligand and its metal complex. The findings of a concentration-dependent examination of the complexes' antibacterial activity are shown in Table 4. The inert control, DMF, had no impact on bacterial growth. There were four different complex concentrations that were gathered: 5, 10, 15, and 20 mM. Paper discs were cut, dipped into different solutions, and then cleaned. To compare how susceptible various bacterial strains were to the metal complexes, the inhibitory zone width was measured. The growth of the bacterial pathogens Escherichia coli and Staphylococcus aureus were both inhibited. When tested against Escherichia coli and Staphylococcus aureus, the complexes performed better than the ligand alone. Escherichia coli are common in the human colon and seldom cause illness. But the 0157:H7 strain may cause serious, even deadly, illnesses if it comes in contact with water or undercooked food. Most occurrences of atopic eczema are associated with an increase in the amount of Streptococcus aureus bacteria on the afflicted skin. Against S. aureus and E. coli, the complexes are more potent than the free ligand. Complexes thus have the potential to function as powerful antibacterial agents.

Table 4
Antibacterial activity of the ligand tmpbi and its metal complex

Compound	Zone of inhibition (in mm)							
	Streptococcus aureus (conc. in mM)				*E. coli* (conc. in mM)			
	5	10	15	20	5	10	15	20
DMF (control)*	-	-	-	-	-	-	-	-
tmpbi	2	4	6	8	3	5	6	8
$Cu(tmpbi)_2Cl_2$	6	8	12	16	6	12	18	26

*No effect upto 24 hours

4. Conclusion

Mononuclear complexes $M(tmpbi)_2X_2$ (M= Cu; X=Cl) have been discussed, including their production and physical properties. Based on the results of biological tests performed on the ligand and its metal complexes, it seems that the complexes have stronger antibacterial action against microorganisms.

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