

Synthesis, Characterization and Biological Activity of 5 - Methyl, Thiophene -2- Carboxaldehyde Derivatives of Copper (II), Cobalt (II) and Nickel (II) Complexes

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ABSTRACT

The Copper (II), Cobalt (II) and Nickel(II) complexes of 5 methyl thiophene-2-carboxaldehyde-thiosemicarbozone have been synthesized by a template method. The complexes are characterized by elemental analysis, conductivity measurements and electronic, IR, VSM and ESR spectral techniques. The molar conductivity data show them to be non-electrolytes. The electronic spectral data suggest square planar geometry for all the complexes. Various ESR parameters have been calculated. The bacterial and anti fungal activities of the complexes have been screened in vitro against the organisms Bacillus, E.coli, pseudomonas, Staphylococcus and fungi species such as F. oxysporum, M.phaseolina, A.flavus, A.niger.

Keywords: Copper (II) complex, Cobalt (II) complex, Nickel (II) complex, 5-methyl thiophene-2-carboxaldehyde derivative, Biological activity, ESR and VSM.

1. INTRODUCTION

Transition metal coordination compounds with multi-donor ligands containing Nitrogen and Sulphur atoms have versatile chelating ability with transition metal ions. These complexes have attracted considerable interest in biological systems because of the presence of copper in enzymes. It is both micro-nutrient as well as toxic element for living beings, depending up on the concentration level. The significance of Cobalt as a transition metal lies in its wide spectrum of applications covering many frontier areas of study, particularly in medicine. Even though Cobalt is not considered to be as toxic as most of the heavy metals, it is an equally harmful element. Among various ligands that form complexes with copper ion, Thiosemicarbazone derivatives possess broad pharmacological activity<sup>[1]</sup>. It is also highly interesting to study copper (II) complexes, which are important anticancer drugs because of their ability to adopt different coordination numbers, which leads to different geometries<sup>[2]</sup>. Copper, in divalent oxidation state, has been found to exhibit many types of coordination ranging from square planar to distorted trigonal bipyramidal, square pyramidal and octahedral. Copper complexes have attracted much attention in bioinorganic chemistry because of their structure and spectral properties in the

solid state<sup>[3]</sup>. Earlier investigations on Cu (II) complexes containing tridentate and tetradentate ligands have given interesting result<sup>[4-6]</sup>. It should be of interest to study ligands containing amine as ligands, which show interesting structural and functional properties<sup>[7,8]</sup>. For this reason, we have studied Cu (II), Co (II) and Ni (II) complexes of 5-methyl-thiophene-2-carboxaldehyde-thiosemicarbazone (TCATS). The free TCATS ligand could not be isolated in pure state. Hence metal complexes of TCATS are derived from metal assisted Schiff base condensation (Template synthesis) of Thiosemicarbozide with 5-Methyl-thiophene-2-carboxaldehyde. Metal ion template assistance has been a boon to the rational design of complex multidentate ligand systems<sup>[9-13]</sup>. The synthetic utilization of metal ions have been particularly valuable<sup>[14-17]</sup> in Schiff base condensations. Therefore in this type of situation that metal ions have been so useful in providing template for directing the course of reaction. These complexes have been characterized by elemental analysis and analytical, ESR, electronic, VSM and antimicrobial activities.

2. Experimental

All chemicals of AR grade are used without further purification. 5-methyl-Thiophene-2-carboxaldehyde and Thiosemicarbazone compounds are Aldrich chemicals. The metal

chelates were prepared using insitu reaction (Template synthesis) as the free ligand (TCATS) could not be isolated in the pure state.

Copper complex was prepared by reacting 5-methyl-thiophene-2-carboxaldehyde, Thiosemicarbozide and  $\text{Cu}(\text{NO}_3)_2$  in 1: 2: 2 molar proportions. To a boiling solution of Thiosemicarbozide (1.690 g, 0.01854 mol) in methanol, a solution of 5- methyl-thiophene-2-carboxaldehyde (2.34 g, 0.01854 mol ) in methanol was added and the reaction mixture was refluxed for 9 hours. A solution of  $\text{Cu}(\text{NO}_3)_2$  (2.23 g, 0.00927 mol) in minimum quantity of methanol was added to the boiling mixture, which was further refluxed for 4 hours and then cooled. The complex was separated out and washed with hot water for several times and finely with Hexane. Cobalt and Nickel complexes of TCATS also prepared accordingly. Elemental (C, H, N and S) analysis is performed. The molar conductance is measured using a systronics 303 direct reading conductivity bridge. The electronic spectrum of the sample dissolved in DMF solvent is recorded at room temperature on Carry 5000 in UV-Vis, N-IR region. The powder samples are put into quartz tubes and ESR spectra are recorded at LNT on a Varian E-112 X-band spectrometer.

### 3. RESULTS AND DISCUSSION

The metal complexes are stable at room temperature, non-hygroscopic, insoluble in water, but slightly soluble in ethanol and methanol, and readily soluble in DMF and DMSO. The colour, molecular weight and molar conductance data are summarized in TABLE-1. The analytical data of the complexes indicate that the metal to ligand ratio is 1 : 2. The molar conductance values of these complexes in DMF are in the range 4-6  $\text{ohm}^{-1} \text{cm}^2 \text{mol}^{-1}$  indicate their non-electrolytic nature [18].

#### 3.1. Infrared spectra

Infrared spectra of the copper and cobalt complexes of TCATS are presented in Table-5. As free ligand could not be isolated, the spectra of metal complexes cannot be compared with the free ligand. The  $>\text{C}=\text{N}$  (imine band) is observed at  $1670 \text{ cm}^{-1}$ ,  $1583 \text{ cm}^{-1}$  and  $1570 \text{ cm}^{-1}$  in the IR spectra of  $\text{Cu}(\text{TCATS})_2$ ,  $\text{Co}(\text{TCATS})_2$  and  $\text{Ni}(\text{TCATS})_2$  respectively [19]. Additional bands are observed in Far IR spectra of metal complexes in  $445\text{-}430$  and  $345\text{-}335 \text{ cm}^{-1}$  regions due to  $\text{V}(\text{M-N})$  and  $\text{V}(\text{M-S})$  modes respectively [20-22].

#### 3.2. Magnetic susceptibility and Electronic spectra

The magnetic moment values of  $\text{Cu}(\text{TCATS})_2$  and  $\text{Co}(\text{TCATS})_2$  were observed as 1.77 BM and 2.6 BM respectively. In the electronic spectra of  $\text{Cu}(\text{II})$  complex of TCATS bands observed at  $15,952 \text{ cm}^{-1}$  and  $21,946 \text{ cm}^{-1}$  may be assigned as, probably, the transitions  ${}^2\text{A}_{1g} \leftarrow {}^2\text{B}_{1g}$  and  ${}^2\text{E}_g \leftarrow {}^2\text{B}_{1g}$  respectively [23-26]. For  $\text{Co}(\text{II})$  complex of TCATS a strong band is observed at  $19,230 \text{ cm}^{-1}$  and low intensity band is at  $7692 \text{ cm}^{-1}$  are in favour of square planar geometry [27-29].

The diamagnetic character of  $\text{Ni}(\text{II})$  complex of TCATS probably indicates its square planar geometry. The electronic spectral data display three bands at  $12,807 \text{ cm}^{-1}$  ( $\nu_1$ ),  $25,568 \text{ cm}^{-1}$  ( $\nu_2$ ) and  $29,337 \text{ cm}^{-1}$  ( $\nu_3$ ). Thus the obtained data confirm a square planar geometry around the  $\text{Ni}(\text{II})$  ion [29-31].

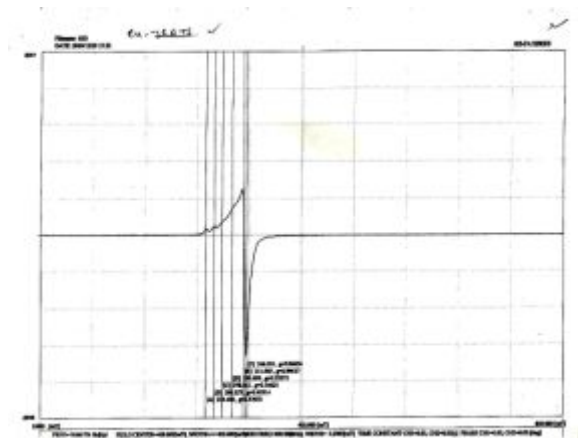


Fig: 1. ESR spectra of Cu-TCATS at LNT

The spin Hamiltonian, orbital reduction and bonding parameters of  $\text{Cu}(\text{TCATS})_2$  complex is presented in Table-6. Kivelson and Neiman [32] have reported that  $g_{\parallel}$  value is less than 2.3 for covalent character metal ligand bond and is greater than 2.3 for ionic character. Applying this criterion, the covalent character of the metal ligand bond in complex under study can be predicted. The trend  $g_{\parallel} > g_{\perp}$  observed for the complex suggests that the unpaired electron is localized in  $dx^2-y^2$  orbital [33] of the Copper (II) ion.

The ESR parameters  $g(\text{parallel})$ ,  $g(\text{perpendicular})$ ,  $A(\text{parallel})$  and  $A(\text{perpendicular})$  of complex, the energies of d-d transition are used [32-38] to evaluate the orbital reduction parameters, the bonding parameters ( $\alpha^2$ ) and the dipolar interaction (P). The observed  $K_{\text{parallel}} > K_{\text{perpendicular}}$  relation indicates the presence of significant in-plane  $\text{Pi}$ -bonding [39]. The  $\alpha^2$  value for the present chelate lie at 0.6971 supporting the covalent nature of the complex. Giordano and

Bereman <sup>[40]</sup> suggest the present complex is consistent with bonding of copper through Sulphur donor atom. The shape <sup>[41]</sup> of ESR lines,

ESR data (Table-6) together with electronic spectral data suggest a square planar geometry for the copper complex.

Table-1: Analytical data of Metal complexes of TCATS

Compound	Color	M.P( <sup>o</sup> c) Yield(%)	Molecular Weight	C	H	N	S	M
Cu-(TCATS) <sub>2</sub>	Black	>300 <sup>o</sup> c(dc)	262.5	35.25 (36.40)	3.50 (3.90)	17.90 (18.20)	25.65 (27.73)	13.01 (13.75)
Co-(TCATS) <sub>2</sub>	Dirty Green	>300 <sup>o</sup> c(dc)	257.9	36.22 (36.76)	3.02 (3.93)	17.95 (18.38)	26.95 (28.01)	12.02 (12.89)
Ni-(TCATS) <sub>2</sub>	Greenish blue	>300 <sup>o</sup> c(dc)	257.69	36.02 (36.78)	3.07 (3.94)	17.96 (18.39)	27.25 (28.02)	12.01 (12.85)

Table-2: Molar Conductance data of TCATS metal complexes

Complex	Conductance (ohm <sup>-1</sup> cm <sup>2</sup> mol <sup>-1</sup> )
Cu-(TCATS) <sub>2</sub>	4.0
Co-(TCATS) <sub>2</sub>	6.0
Ni-(TCATS) <sub>2</sub>	4.0

Table-3: Selected IR bands (cm<sup>-1</sup>) with tentative assignments

Compound	$\nu$ C=N	$\nu$ C=S	$\nu$ C-S	$\nu$ C-CH <sub>3</sub>	$\nu$ M-N	$\nu$ M-s
Cu-(TCATS) <sub>2</sub>	1670	1250	621.25	1450.70	445	345
Co-(TCATS) <sub>2</sub>	1583	1233	707	1444.88	440	340
Ni-(TCATS) <sub>2</sub>	1570	1240	650	1440.50	430	335

Table-4: Magnetic moment data of metal complex of TCATS

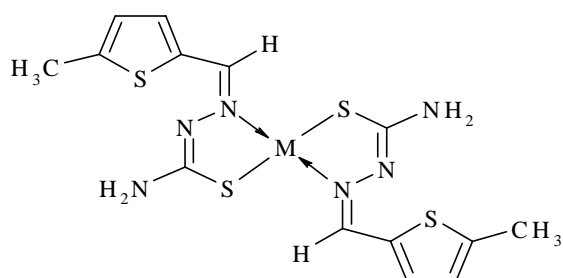
Complex	Magnetic moment(B.M)
Cu-(TCATS) <sub>2</sub>	1.77
Co-(TCATS) <sub>2</sub>	2.60
Ni-(TCATS) <sub>2</sub>	Diamagnetic

Table-5: Electronic spectral data and ligand field parameters of a Nickel complex

Complex	Method of evaluation	$\nu_1$	$\nu_2$	$\nu_3$	B	B <sub>35</sub>	10 Dq	$\nu_2 - \nu_1$	$\nu_2 / \nu_1$	h
Ni-(TCATS) <sub>2</sub>	A	12807	25568	29337	965.2	0.85	12807	10755	1.839	1.25

Table-6: Spin Hamiltonian and orbital reduction parameters of Cu-TCATS

Parameter	Cu (TCATS) <sub>2</sub>
g (parallel)	2.341
g (perpendicular)	1.7541
g <sub>avg</sub>	1.9497
G	1.3646
A (parallel)	0.0145
A(perpendicular)	0.0042
K(parallel)	0.9796
K(perpendicular)	0.7813
α <sup>2</sup>	0.6971
P	0.0351

Structure of Metal chelate (M-(TCATS)<sub>2</sub>)

M = Cu (II), Co (II), Ni (II)

## 3.3. Biological activity

Table-7: Fungal activity of Metal complexes of TCATS

Ligand/complex	concentration	F.Oxysporum	M.phaseolina	A.flavus	A.niger
Cu(TCATS) <sub>2</sub>	25 ppm	83.33%	83.33%	82.22%	83.33%
	50 ppm	88.88%	90%	86.66%	86.66%
	100 ppm	90%	90%	91.11%	91.11%
	200 ppm	92.22%	94.44%	92.22%	92.22%
Co-(TCATS) <sub>2</sub>	25 ppm	77.77%	75.55%	77.77%	77.77%
	50 ppm	82.22%	81.11%	77.77%	77.77%
	100 ppm	84.44%	84.44%	84.44%	84.44%
	200 ppm	88.88%	90%	86.66%	86.66%
Ni-(TCATS) <sub>2</sub>	25 ppm	78.88%	78.88%	72.22%	73.33%
	50 ppm	81.11%	80.00%	80.00%	74.44%
	100 ppm	85.55%	82.22%	82.22%	84.44%
	200 ppm	87.77%	88.88%	84.44%	85.55%

The antifungal and antibacterial activity of the Co(II), Ni (II) and Cu(II) complexes of TCATS were tested in vitro for the growth inhibiting potential against various fungal and bacterial strains using Food Poison Technique [42] and Paper Disc Technique<sup>41</sup> respectively. Fungal strains *Fusarium oxysporum*, *Macrophomina phaseolina*, *A. flavus* and *A. niger* and bacterial strains *Bacillus*, *Escherichia coli*, *Psuedomonas* and *Staphylococcus* were used. The concentrations of respective metal complexes were 25, 50, 100 and 200 ppm. DMF was used as solvent for preparing solutions [43].

The data is given in the Table-5 and 6. It is known that chelation reduces the polarity of the metal ion because of partial sharing of its positive charge with the donor groups of ligands.  $\pi$ -Electron delocalization over the chelate ring also reduces the polarity of metal ion. Such chelation increases the lipophilic character of the metal complex which is necessary to cross the permeability barrier of cells resulting in interference with normal cell process [44].

In general the toxicity of metal complexes decreased as the radius of metal ion increases. The growth inhibition against all the fungi and bacteria is found to be in the order Cu > Co and Ni. The results recorded from the fungal activity were also further compared with the standard fungicide Grisofluvin. The results are quite promising.

Table-8: Bacterial activity of metal complexes of TCATS

complex	Type of Bacteria	Zone of Inhibition (cm) / Concentrations(ppm)				
		25 ppm	50 ppm	100 ppm	200 ppm	
Cu-TCATS	Bacillus	0.8		0.9	1.4	1.9
	E. coli	0.8		0.9	1.3	1.8
	Pseudomonas	0.9		1.0	1.3	1.8
	Staphylococcus	0.9		1.1	1.3	1.9
Co-TCATS	Bacillus	-		0.8	0.9	1.2
	E. coli	0.7		0.8	0.9	1.3
	Pseudomonas	0.7		0.9	0.9	1.2
	Staphylococcus	0.5		0.7	1.1	1.2
Ni-TCATS	Bacillus	0.5		0.8	0.9	1.2
	E. coli	-		0.7	0.8	1.2
	Pseudomonas	0.7		0.7	0.9	1.1
	Staphylococcus	-		0.7	1.0	1.2

#### 4. CONCLUSIONS

Metal complexes of Cu-(TCATS)<sub>2</sub>, Co-(TCATS)<sub>2</sub> and Ni-(TCATS)<sub>2</sub> are derived from metal template assisted schiff base condensation (Template synthesis) of 5-methyl-2-thiophenecarboxaldehyde and Thiosemicarbazide. The complexes were characterized by spectral and analytical data. From the spectral and analytical analyses, a square-planar geometry was assigned for the metal complexes. The ESR results of the complex show that  $g_{\parallel} > g_{\perp}$ , which indicate an axial elongation of the ligands. The covalency parameter ( $\alpha^2$ ) confirms the covalent nature of the metal ligand bond. The antimicrobial activity against four fungal and four bacterial isolates are determined.

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