



SYNTHESIS, CHARACTERIZATION AND BIOLOGICAL ACTIVITY OF Co (II) TERNARY COMPLEXES DERIVED FROM 2-SUBSTITUTED BENZOTHAZOLE AND AMINO ACIDS LIGANDS

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ABSTRACT

The synthesis and biological activity of ternary complexes of Co (II) of the composition [CoCl (L-L) (A-A) (H₂O)] and [Co(L-L') (A-A') (H₂O)₂], where A-A = glycine (Gly), alanine (Ala), L-L = 2-(2'-aminophenyl) benzothiazole (APBT) and L-L' = 2-(2'-hydroxyphenyl) benzothiazole (HPBT), 2-(2'-mercaptophenyl) benzothiazole (MPBT) are reported here. All the complexes have been characterized by elemental analysis, molecular weight determination, conductivity, magnetic measurements, infrared, electronic spectra and TGA studies. All the complexes are thermally stable and behave as non-electrolyte. An octahedral structure has been proposed for these complexes tentatively.

The ligands and their metal complexes were tested against pathogenic fungi *Aspergillus niger* and *Fusarium oxysporum* to assess their fungicidal properties. The antifungal activity data reveal that these metal complexes are more fungitoxic than the parent ligands.

Key words: Benzothiazole, Spectral studies, Conductivity, Antifungal activity.

INTRODUCTION

Benzothiazole and their derivatives are well known biological active compounds¹. Studies of transition metal complexes of oxazole, benzoxazole and related ligands have gained importance because of their biological significance and it was observed that biological activity of these ligands increases on complexation with metal ions^{2,3}. These are active components of biocides such as fungicides and insecticides⁴. In addition to their biological importance, these ligands are strongly coordinating agents and form stable complexes with various transition metal ions^{5,6}. The ligational behaviour of benzimidazole,

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benzothiazole and their derivatives have been reported by Seth *et al.*⁷ and also by others^{8,9}. In this study, we report the synthesis, characterization and biological activity of Co (II) ternary complexes derived from 2-substituted benzothiazole viz. 2-(2'-aminophenyl) benzothiazole (APBT), 2-(2'-hydroxyphenyl) benzothiazole (HPBT), 2-(2'-mercaptophenyl) benzothiazole (MPBT) and amino acids viz. glycine (Gly), alanine (Ala) ligands. The structure of ligands used to synthesize the Co (II) ternary complexes are presented in Fig. 1.

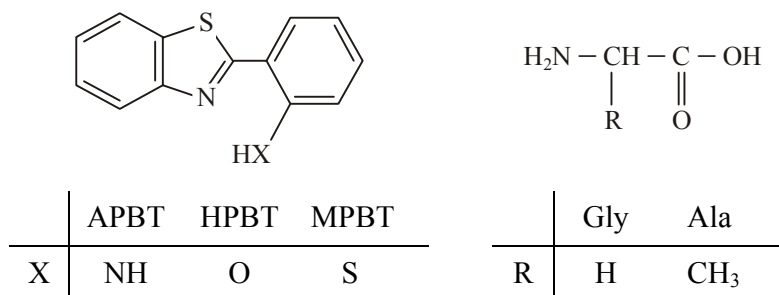


Fig. 1: Structure of the ligands APBT, HPBT, MPBT, Gly and Ala

EXPERIMENTAL

Materials

All the solvents were distilled prior to use, *o*-aminothiophenol, anthranilic acid, salicylic acid, thiosalicylic acid and CoCl₂.6H₂O were purchased from Merck and used as such.

Physical measurements

Microanalysis were carried out at the CDRI Lucknow, India. Melting points were determined on a capillary melting point apparatus and are uncorrected, IR spectra were recorded (with KBr pellets) on a Shimadzu 8400 FTIR spectrophotometer. Electronic spectra were recorded on a Varian-Cary UV/Visible spectrometer. Magnetic moments were measured on a Gouy balance. Molar conductance were measured in 10⁻³ M DMF on a Systronics conductivity bridge Model 305. Molecular weights were determined by the Rast camphor method. Nitrogen was determined by the Kjeldahl method, and sulfur was estimated by the Messenger's Method. Chloride was determined by the Volhard method. Cobalt was estimated gravimetrically.¹⁰

Synthesis of 2-substituted benzothiazoles (APBT, HPBT, MPBT)

The 2-substituted benzothiazoles viz. 2-(2'-aminophenyl) benzothiazole (APBT), 2-

(2'-hydroxyphenyl)benzothiazole (HPBT) and 2-(2'-mercapto)phenyl)benzothiazole (MPBT) were prepared by reported methods in literature¹¹.

Preparation of cobalt (II) ternary complex

A solution of $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ (0.90 g, 0.004 mol) in dry EtOH (25 mL) was added to APBT (0.85 g, 0.004 mol) / HPBT (0.86 g, 0.004 mol) / MPBT (0.92 g, 0.004 mol) and Glycine (0.28 g, 0.004 mol) / Alanine (0.34 g, 0.004 mol) in dry EtOH (25 mL). The reaction mixture was then refluxed in the presence of a drop of pyridine with constant stirring for 4 h, and allowed to stand at room temperature overnight. These were filtered, recrystallized from EtOH and dried in vacuo.

RESULTS AND DISCUSSION

The Co (II) ternary complexes were synthesized by $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ with 2-substituted benzothiazoles (APBT, HPBT and MPBT) or amino acids (Gly or Ala) in 1 : 1 : 1 molar ratio according to the following equations :



Where

L-L = APBT

L-L' = HPBT, MPBT, and

A-A = Gly, Ala

These reactions processed easily and lead to the formation of coloured solids, which are stable to air and moisture. The resulting Co (II) ternary complexes are soluble in DMSO and DMF. The molar conductance values of 10^{-3} M solutions of these complexes lie in the range $10\text{-}20 \Omega^{-1} \text{cm}^2 \text{mol}^{-1}$ in dry DMF, indicating their nonelectrolytic behaviour. The monomeric nature of these complexes has been confirmed by the molecular weight determination. The analytical data and physical properties of the ligands and their Co (II) ternary complexes are given in Table 1. The compounds have been characterized on the basis of following studies.

Table1 : Analytical data and physical properties of 2-substituted benzazoles and their Co (II) complexes with Gly and Ala

Compound and empirical formula	Colour	Yield (%)	M.P. (°C)	Elemental Analysis Found (Calcd.) %							Molecular weight Found (Calcd.)
				C	H	N	S	Cl	Co		
[CoCl(APBT)(Gly)(H ₂ O)] CoC ₁₅ H ₁₆ O ₃ N ₃ SCl	Light blue	61	215	43.60 (43.65)	3.85 (3.91)	10.11 (10.18)	7.69 (7.77)	8.51 (8.59)	14.22 (14.28)	408.61 (412.77)	
[CoCl(APBT)(Ala)H ₂ O] CoC ₁₆ H ₁₈ O ₃ N ₃ SCl	Light blue	60	220	44.98 (45.03)	4.18 (4.25)	9.78 (9.84)	7.46 (7.51)	8.25 (8.31)	13.76 (13.81)	422.78 (4.26.80)	
[Co(MPBT)(Gly)(H ₂ O) ₂] CoC ₁₅ H ₁₆ O ₄ N ₂ S ₂	Yellowish green	65	230	43.72 (43.80)	3.86 (3.92)	6.75 (6.81)	15.81 (15.89)	-	14.22 (14.32)	407.41 (411.37)	
[Co(MPBT)(Ala)(H ₂ O) ₂] CoC ₁₆ H ₁₈ O ₄ N ₂ S ₂	Yellowish blue	62	235	45.09 (45.18)	4.19 (4.26)	6.51 (6.58)	15.01 (15.07)	-	13.74 (13.85)	421.36 (425.40)	
[Co(HPBT)(Gly)(H ₂ O) ₂] CoC ₁₅ H ₁₆ O ₅ N ₂ S	Pinkish blue	68	243	45.50 (45.58)	4.00 (4.08)	7.00 (7.09)	8.03 (8.11)	-	14.84 (14.91)	392.29 (395.31)	
[Co(HPBT)(Ala)(H ₂ O) ₂] CoC ₁₆ H ₁₈ O ₅ N ₂ S	Pinkish blue	66	247	46.86 (46.95)	4.38 (4.43)	6.75 (6.84)	7.77 (7.83)	-	14.35 (14.40)	406.31 (409.33)	

Infrared spectra

The important IR spectral bands and their tentative assignments are summarized in Table 2. The ligands APBT, HPBT, MPBT, Gly and Ala act as bidentate ligands in these Co (II) ternary complexes using nitrogen, oxygen and sulfur as donor atoms. The IR spectra of APBT, Gly/Ala shows two strong bands in the region 3400-3370 cm^{-1} and 3310-3250 cm^{-1} due to ν_{as} (N-H) and ν_{s} (N-H) vibrations of NH_2 of these ligands, respectively. These bands are shifted to lower frequency by 40-80 cm^{-1} in the respective Co (II) ternary complexes, suggesting the coordination through nitrogen lone pair of the NH_2 group to the Co atom without any deprotonation.¹³ It is further supported by appearance of the new bands in the region 435-420 cm^{-1} due to $\nu(\text{Co-N})$ vibration. The appearance of absorption bands in the region 445-442 cm^{-1} may be assigned to $\nu(\text{Co} \leftarrow \text{O})$ vibration. The occurrence of non-ligand absorption band in the region 290-288 cm^{-1} may be attributed to $\nu(\text{Co-Cl})$ vibration.¹⁴

Table 2: IR spectral data (cm^{-1}) of ternary complexes of Co (II)

Compound	ν (C=C)	ν (C=N)	ν (C=O)	ν (NH_2)		ν (Co-N)	ν (Co-S)	ν (Co-O)	ν (Co-Cl)
				Asym.	Sym.				
[CoCl(APBT)(Gly) H_2O]	1580	1605	1660	3350	3235	430	-	445	290
[CoCl(APBT)(Ala) H_2O]	1578	1602	1658	3348	3240	426	-	442	288
[Co(HPBT)(Gly)(H_2O) ₂]	1582	1610	1676	3355	3235	435	-	450	-
[Co(HPBT)(Ala)(H_2O) ₂]	1577	1608	1671	3351	3231	432	-	448	-
[Co(MPBT)(Gly)(H_2O) ₂]	1578	1602	1666	3349	3225	425	330	435	-
[Co(MPBT)(Ala)(H_2O) ₂]	1576	1600	1661	3343	3225	420	328	432	-

The broad band at 3330 cm^{-1} due to $\nu(\text{O-H})$ phenolic mode of HPBT, disappears in the Co (II) ternary complexes indicating deprotonation of phenolic oxygen and coordination to the Co atom with the formation of Co-O bond. This gets further supports by the appearance of band in the region 450-448 cm^{-1} due to $\nu(\text{Co-O})$ vibrations.¹⁵ The IR spectrum of MPBT shows a band at 2560 cm^{-1} due to $\nu(\text{S-H})$ (thioprotic) vibration, which disappears in the Co (II) ternary complexes, suggesting the deprotonation of -SH group and coordination through thiophenolic sulfur with the Co atom. It is further supported by the appearance of a new band in the region 330-328 cm^{-1} due to $\nu(\text{Co-S})$ vibration.

A medium or relatively weak band in the 1620-1615 cm^{-1} region in the IR spectra of the free ligands (APBT, HPBT, and MPBT) is due to $\nu(\text{C=N})$ vibration. This band is shifted

to lower frequency by 15-20 cm^{-1} in Co (II) ternary complexes indicate the bonding of the benzothiazole tertiary nitrogen with Co atom.¹⁶ It is further confirmed by the appearance of band in the region 435-420 cm^{-1} due to $\nu(\text{Co-N})$ vibration.

Electronic absorption spectra and magnetic studies

The electronic spectral data and magnetic moments of the Co (II) ternary complexes are given in Table 3. The electronic spectra of Co (II) ternary complexes were recorded in nujol mull. These complexes display two absorption bands of low intensity due to d-d transitions in the region 9825-9510 cm^{-1} and 20840-20100 cm^{-1} assigned to the ${}^3\text{A}_{2g}(\text{F}) \rightarrow {}^3\text{T}_{2g}(\text{F})$ (ν_1); ${}^3\text{A}_{2g}(\text{F}) \rightarrow {}^3\text{T}_{2g}(\text{F})$ (ν_2) and ${}^3\text{A}_{2g}(\text{F}) \rightarrow {}^3\text{T}_{1g}(\text{p})$ (ν_3) transitions,¹⁸ respectively. The position of these bands are similar to those reported for Co (II) complexes with an octahedral geometry¹⁷. The ν_2 band compounding to the transition ${}^4\text{T}_{1g}(\text{F}) \rightarrow {}^4\text{A}_{2g}(\text{p})$ has not been observed probably because of low intensity as it is a two electron transition. Further using the relationship $\nu_2 = \nu_1 + 10 \text{Dq}$, the ν_2 band would be expected to occur around 20,000 cm^{-1} , which is very close to the ν_3 band. The room temperature magnetic moments of these complexes indicate the paramagnetic nature of the Co (II) ion. The magnetic moments of these complexes have been found in the range 4.77-4.68 B.M., which are in the consistency with the high spin state at the Co (II) ion and in the range expected for octahedral complexes.

Table 3: Magnetic moments (μ_B) and electronic spectral data for the ternary complexes of Co (II) with 2-substituted benzothiazole and amino acids

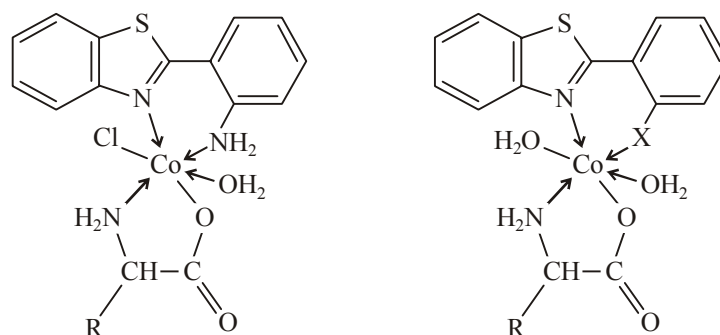
Complex	Magnetic moment (μ_B) B.M.	Electronic transitions and assignments (cm^{-1})	
		${}^4\text{T}_{1g}(\text{F}) \rightarrow {}^4\text{T}_{2g}(\text{F})$ (ν_1)	${}^4\text{T}_{1g}(\text{F}) \rightarrow {}^4\text{T}_{1g}(\text{P})$ (ν_3)
[CoCl(APBT)(Gly)(H ₂ O)]	4.72	9550	20200
[CoCl(APBT)(Ala)H ₂ O)]	4.73	9555	20220
[Co(HPBT)(Gly)(H ₂ O) ₂]	4.76	9820	20820
[Co(HPBT)(Ala)(H ₂ O) ₂]	4.77	9825	20840
[Co(MPBT)(Gly)(H ₂ O) ₂]	4.68	9510	20100
[Co(MPBT)(Ala)(H ₂ O) ₂]	4.69	9515	20120

TGA studies of Co (II) ternary complexes

The existence of coordinated water molecule in these Co (II) ternary complexes is

confirmed by TGA studies. The coordinated water molecules are lost in the temperature range 105 to 315°C. The ultimate product of the thermal decomposition in these complex is cobalt oxide.

Thus, on the basis of analytical data, and other studies, an octahedral geometry may be assigned for these Co (II) ternary complexes.



Where X = O, S

R = H, CH₃

Fig. 2: The suggested chemical structures of the Co (II) ternary complexes

Biological activity

The antifungal activity of ligands (APBT, HPBT and MPBT) and their Co (II) ternary complexes were carried out against pathogenic fungi, namely *Aspergillus niger* and *Fusarium oxysporum* by radial growth method using the solution of the test compound (50, 100 and 200 ppm) in dimethyl formamide. The linear growth of the fungus was recorded by measuring the diameter of the fungus colony after 72 h and the percentage inhibition was calculated as $100(C-T)/C$, where C and T are the diameters of the fungus colony in the control and test plates, respectively. The results of antifungal activity of the ligands and Co (II) ternary complexes have been compared with the conventional fungicide bavistin taken as standards in (Table 4).

The three ligands (APBT, HPBT, and MPBT) and their Co (II) ternary complexes were screened against pathogenic fungi *Aspergillus niger* and *Fusarium oxysporum*, to assess their growth inhibitory potential as antifungal agents. The antifungal screening data (Table 4) reveals that the Co (II) ternary complexes are more fungitoxic than the parent ligands (APBT, HPBT, and MPBT). The enhanced activity of the Co (II) ternary complexes may be ascribed to the increased lipophilic nature of these complexes arising due to the chelation.¹⁸

Table 4: Fungicidal screening data for the ligands (APBT, HPBT, MPBT) and their Co (II) ternary complexes

Complex	Concentration (ppm)					
	<i>Aspergillus niger</i>			<i>Fusarium oxysporum</i>		
	Inhibition after 72 h (%)			Inhibition after 72 h (%)		
	50	100	200	50	100	200
APBT	40	52	62	43	55	64
HPBT	34	46	58	36	48	60
MPBT	46	58	68	48	61	70
[CoCl(APBT)(Gly)H ₂ O]	60	71	86	64	76	88
[CoCl(APBT)(Ala)H ₂ O]	61	72	88	65	77	90
[Co(HPBT)(Gly)(H ₂ O) ₂]	48	66	78	52	68	80
[Co(HPBT)(Ala)(H ₂ O) ₂]	49	67	80	53	69	82
[Co(MPBT)(Gly)(H ₂ O) ₂]	68	82	92	69	83	94
[Co(MPBT)(Ala)(H ₂ O) ₂]	69	83	94	70	85	96
Bavistin (Standard)	86	98	100	87	99	100

The toxicity increased with increasing concentration. The antifungal activity data also reveal that Co (II) ternary complexes of MPBT and Gly/Ala are more fungitoxic than the complexes of APBT and HPBT ligands, respectively¹⁹.

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Revised : 05.09.2010

Accepted : 08.09.2010