Synthesis, Characterization and Chelating Properties of 4-Butyrylsemicarbazone-1-phenyl-3-methyl-2-pyrazolin-5-one

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Abstract: 4-Butyrylsemicarbazone-1-phenyl-3-methyl-2-pyrazolin-5-one (BUMP-SC) was prepared and its metal chelates of Cu^{2+} , Ni^{2+} , Co^{2+} , Mn^{2+} , Fe^{2+} , Fe^{3+} , Cr^{3+} , UO_2 and OV were prepared. The ligands and its chelates were characterized by elemental analysis, metal:ligand (M:L) stoichiometry, IR-electronic spectral studies and magnetic properties. The compounds also were screened for their antimicrobial activity.

Keywords: 4-Butyrylsemicarbazone-1-phenyl-3-methyl-2-pyrazolin-5-one, Spectral studies, Magnetic moment, Metal complexes, Antifungal activity.

Introduction

Number of 1-phenyl-2-pyrazolin-5-one derivatives have been studied for their metal complexation study¹⁻³. Recently the thiosemicarbazone derivatives of 4- butyryl-1-phenyl-3-methyl-2-pyrazolin-5-one have been prepared in our laboratory⁴ and studied their metal complexation properties. As the semicarbazones derivatives of 4-butyryl-1-phenyl-3-methyl-2-pyrazolin-5-one (BUMP-SC)⁵⁻⁷ have been reported so far for their metal complexation. Hence, the present communications comprised the work in connection with the metal complexation study (BUMP-SC) shown in Scheme 1.

Experimental

All the chemicals used in the present work were of pure grade. For the preparation of the metal chelates of the Cu^{2+} , Ni^{2+} , Co^{2+} , Mn^{2+} , Fe^{3+} , Cr^{3+} , UO_2 and OV metal nitrates were used. The $\text{FeSO}_4(\text{NH}_4)\text{SO}_4 \cdot \text{H}_2\text{O}$ was used in the preparation of the Fe^{2+} chelates respectively.

Scheme 1*Synthesis of 4-Butyrylsemicarbazone-1-phenyl-3-methyl-2-pyrazolin-5-one (BUMP-SC)*

The ligand BUMP-SC was prepared in two steps described below:

Preparation of 4-butyryl-2-pyrazolin-5-one

The 1-phenyl-3-methyl-2-pyrazolin-5-one (0.1 mole, 17.4 g) was placed in a flask equipped with a stirrer, separating funnel and reflux condenser. It was then dissolved in dioxane (85 mL) by application of heat. To the reaction mixture, calcium hydroxide (0.2 mole, 14.81 g) was added, followed by the drop wise addition of the butyryl chloride (0.1 mole). At this stage, the mixture become a thick paste and its temperature also increased, as this being a exothermic reaction. The reaction mixture was then refluxed for half an hour. The resulting calcium complex was then decomposed by pouring it into the dilute hydrochloric acid (200 mL, 2 M). The resultant colored crystals were then collected on a Buchner-funnel and recrystallized from an acidified methanol-water mixture 20:40(v/v)^{1,2}.

Preparation of 4-butyrylsemicarbazone-1-phenyl-3-methyl-2-pyrazolin-5-one(BUMP-SC)

Following procedure has been adopted in the preparation of semicarbazone of BUMP used in the present study. The semicarbazone was prepared by refluxing 1:1 mole 4-butyryl-2-pyrazolin-5-one and semicarbazide hydrochloride in methanol for 1 h. The semicarbazone of BUMP, thus obtained was filtered, recrystallized from methanol and designated as BUMP-SC. Yield was 85%. Its m.p. was 228 °C (uncorrected).

Elemental analysis

C₁₅H₁₉N₅O₂ (301.30)

	C%	H%	N%
Calculated:	59.78	6.36	23.25
Found	59.63	5.98	23.56

IR Features

3410 cm ⁻¹	N-H (w, br)	2972 cm ⁻¹	C=N (w, sh)
3052 cm ⁻¹	C-H(m,br)	2957 cm ⁻¹	C-H(w,sh)
1630 cm ⁻¹	C=N azomethine (w,sh)		
1700 cm ⁻¹	C=O(w,sh)	1017 cm ⁻¹	N-N (m,sh)
1219 cm ⁻¹	O-H (m,sh)		

NMR

(DMSO)	7.2-7.6 ppm multiplet aromatic H
	2.1-2.4 ppm (1H) Singlet CH
	1.8-2.0 ppm (3H) Singlet CH ₃

Synthesis of metal chelates of BUMP-SC

All the metal chelates of BUMP-SC were prepared in the similar manner. The general procedure is as follows:

The metal salt (0.01 mole) was dissolved in a minimum amount of hot water (30 mL). The hot ligand (0.021 mole) solution in DMF (30 mL) (The ligand solution for Cr⁺³ and Fe⁺³ was 0.031 mole) was added drop wise with constant stirring. To the resulting mixture 2 g of sodium acetate was added and then the mixture was refluxed for 1 h. The resulting mixture thus obtained was then concentrated to half of its original volume. The product was filtered and washed several times with hot water. The product was air-dried and then kept in desiccator. The yield of all chelates were almost quantitative.

Measurements

The elemental analysis for C, H and N were carried out on elemental analyzer. IR spectra of BUMP-SC and its metal complexes were scanned on a PerkinElmer 983(USA) spectrophotometer KBr. Estimation of metal in each compound was carried out by gravimetric oxide method and EDTA titration as described by Flaschka. The vibrating sample magnetometer (VSM), model 7304(4-inch electromagnet VSM system), lakeshore crytronics, Inc., USA, was used to characterize magnetic properties of metal chelates. The diffused reflectance spectra of solid metal complexes were recorded on a Beckman-DK-2A spectrophotometer with a solid reflectance compound. The thermograms of the chelates were recorded on SDT-2960 simultaneous DSC-TGA. The electrical conductivity of all the complexes were measure in DMF using conductivity Bridge 305 (systronics).

Antifungal activity

The fungicidal activity of all the compounds was studied at 1000 ppm concentration *in vitro* plant pathogenic organisms listed in Table 3. The antifungal activities of all the samples were measured by cup plate method. Each of the plant pathogenic strains on potato dextrose agar (PDA) medium. Such a PDA medium contained potato 200 g, dextrose 20 g, agar 20 g and water 1 liter. 5 days old cultures were employed. The compounds to be tested were suspended (1000 ppm) in a PDA medium and autoclaved at 120 °C for 15 min. at 15 atm pressure. These medium were poured into sterile Petri plate and the organisms were inoculated after cooling the Petri plate. The percentage inhabitation for fungi was calculated after 5 days using the formula given below.

$$\text{Percentage of inhibition} = \frac{100(X-Y)}{X}$$

Where, X: Area of colony in control plate, Y: Area of colony in test plate.

The fungicidal activity all compounds are shown in Table 3.

Results and Discussion

The parent ligand BUMP-SC was amorphous powdered, soluble in various solvents like dioxane, DMSO and DMF. The results of elemental analysis of the ligands are reported in a Table 1. They are consistent with the predicted structure as Scheme 1. The ligand was synthesized as shown in Scheme 1. Examination of IR spectrum of BUMP-SC reveals that a broad band of N-H is observed at 3410 cm^{-1} as well as 1630 cm^{-1} C=N(azomethine), 1700 cm^{-1} (C=O). The NMR data also confirm the structure of BUMP-SC. The metal complexes of BUMP-SC with the metal ions Cu^{2+} , Ni^{2+} , Co^{2+} , Mn^{2+} , Fe^{2+} , Fe^{3+} and Cr^{3+} vary in colours. On the basis of the proposed structure as shown in Scheme 1, the molecular formula of the BUMP-SC ligand is $\text{C}_{15}\text{H}_{19}\text{N}_5\text{O}_2$ (301.30) which upon complex ion coordinates with one central metal atom at four coordinates sites and with one water molecules. Therefore the general molecular formula of the resulting metal complex is $[\text{C}_{15}\text{H}_{19}\text{N}_5\text{O}_2]_2 \cdot \text{M} \cdot \text{H}_2\text{O}$ for divalents metal ions. This has been confirmed by results of elemental analysis of all the metal chelates and their parent ligand. The data of elemental analysis reported in Table 1 are in arrangement with the calculated values of C, H and N based on the above mentioned molecular formula of parent ligand as well as metal complex. The electrical conductivity of these complexes in acetonitrile indicates that the complexes are essentially non-electrolytes.

Table 1. Analysis of BUMP-SC ligand and its metal chelates

Empirical formula	Mol. wt.	Yield, %	Elemental Analysis							
			C%		H%		N%		M%	
			Calcd	Found	Calcd	Found	Calcd	Found	Calcd	Found
$\text{C}_{15}\text{H}_{19}\text{N}_5\text{O}_2$	301.30	85	59.78	59.63	6.36	5.98	23.25	23.56	----	----
$\text{C}_{30}\text{H}_{38}\text{N}_{10}\text{O}_4\text{Cu}^{2+}2\text{H}_2\text{O}$	700.5	83	48.26	48.09	5.40	5.55	20.65	20.58	13.71	13.77
$\text{C}_{30}\text{H}_{38}\text{N}_{10}\text{O}_4\text{Ni}^{2+}2\text{H}_2\text{O}$	695.7	79	51.64	51.79	6.07	5.81	20.09	20.51	8.41	8.38
$\text{C}_{30}\text{H}_{38}\text{N}_{10}\text{O}_4\text{Co}^{2+}2\text{H}_2\text{O}$	695.9	81	51.92	51.75	6.07	5.69	20.09	20.18	8.41	8.44
$\text{C}_{30}\text{H}_{38}\text{N}_{10}\text{O}_4\text{Mn}^{2+}2\text{H}_2\text{O}$	691.9	86	51.92	52.46	6.10	5.26	20.20	19.98	7.92	7.80
$\text{C}_{30}\text{H}_{38}\text{N}_{10}\text{O}_4\text{Fe}^{2+}2\text{H}_2\text{O}$	695.8	78	51.85	52.15	6.09	5.54	20.18	20.12	8.04	7.96
$\text{C}_{30}\text{H}_{38}\text{N}_{10}\text{O}_4\text{Fe}^{+3}\text{NO}_3\text{H}_2\text{O}$	739.8	88	48.76	48.56	5.40	5.17	20.87	21.13	7.56	7.50
$\text{C}_{30}\text{H}_{38}\text{N}_{10}\text{O}_4\text{Cr}^{+3}\text{NO}_3\text{H}_2\text{O}$	738	87	56.55	56.31	6.01	5.47	21.99	21.95	5.43	5.44
$\text{C}_{30}\text{H}_{38}\text{N}_{10}\text{O}_4\text{OVH}_2\text{O}$	685	84	52.41	52.42	5.86	5.23	20.38	20.22	7.4	7.63
$\text{C}_{30}\text{H}_{38}\text{N}_{10}\text{O}_4\text{UO}_2$	871	86	41.27	41.17	4.39	4.51	16.06	16.33	28.30	28.10

IR spectra of metal complexes reveal that all the spectra are identical in all respects. The comparison of IR spectrum of the parent ligand BUMP-SC with that of its each metal complex has revealed certain characteristics differences.

One of the significant differences to be expected between the IR spectrum of the parent ligand and its metal complex is the presence of more broadened bands in the region of $3450\text{--}3100\text{ cm}^{-1}$ for the metal complex as the oxygen of the O-H, nitrogen of N-H of ligands forms a coordination band with the metal ions. It is gratifying to note that the ligand band at 1017 cm^{-1} assigned to $\nu(\text{N-N})$, shifts to $990\text{--}1000\text{ cm}^{-1}$ on complexation leading further support to the involvement of nitrogen of azomethine moiety in the complex formation.

The ligand band at 1700 cm^{-1} show an absorption due to O-H in the region $1250\text{--}1210\text{ cm}^{-1}$. This peak is either missing or shows a significance lowering of intensity in the chelates. A strong

band 960 cm^{-1} in a vanadyl complex may be assigning to $\nu\text{ C=O}$. A peak 900 cm^{-1} in the uranyl complexes may be assigned to asymmetric stretching of O=U=O moiety⁸. Examination of data of the metal content in each compound revealed a 1:2 metal: ligand (M:L) stoichiometry in all of the complex of divalent metal ions and 1:3 for trivalent ions. Magnetic moment (μ_{eff}) of each of the metal complex is given in Table 2. Examination of these data reveals that all complexes of Zn^{+2} and UO_2^{+2} are diamagnetic while other is paramagnetic.

Table 2. Spectral features and magnetic moment of BUMP-SC metal chelates.

Metal Chelates	μ_{eff} (BM)	Molar conductivity $\text{ohm}^{-1}\text{cm}^2\text{mole}^{-1}$	Electronic spectral data, cm^{-1}	Transition
BUMP -SC- Cu^{2+}	1.97	3.74	15315 26809 10718	Charge transfer $2\text{Eg} \rightarrow 2\text{T}2\text{g}$ $3\text{A}2\text{g} \rightarrow 3\text{T}2\text{g}$
BUMP -SC - Ni^{2+}	2.89	4.45	16835 30120 9737	$3\text{A}2\text{g} \rightarrow 3\text{T}1\text{g}$ $3\text{A}2\text{g} \rightarrow 3\text{T}1\text{g}(\text{p})$ $4\text{A}1\text{g}(\text{F}) \rightarrow 4\text{T}2\text{g}(\text{F})$
BUMP -SC - Co^{2+}	4.508	5.26	18181 23980 23868	$4\text{A}1\text{g}(\text{F}) \rightarrow 4\text{A}2\text{g}$ $4\text{A}1\text{g}(\text{F}) \rightarrow 4\text{T}1\text{g}(\text{P})$ $6\text{A}1\text{g} \rightarrow 6\text{A}2\text{g}$ 4Eg
BUMP -SC - Mn^{2+}	5.83	7.95	18349 16826 22472	$6\text{A}1\text{g} \rightarrow 4\text{T}2\text{g}$ (4G) $6\text{A}1\text{g} \rightarrow 4\text{T}1\text{g}(\text{PG})$ Charge transfer
BUMP -SC - Fe^{2+}	5.68	7.96	16666 25316 18656	$5\text{T}2\text{g} \rightarrow 2\text{Eg}$ $6\text{A}1\text{g} \rightarrow 4\text{T}1\text{g}$ $6\text{A}1\text{g} \rightarrow 4\text{T}2\text{g}$
BUMP-SC- Fe^{+3} - NO_3	6.18	7.48	12820 18587 23980	$6\text{A}1\text{g} \rightarrow 4\text{A}1\text{g}$, 4Eg $4\text{A}2\text{g}(\text{F}) \rightarrow 4\text{T}2\text{g}(\text{F})$ $4\text{A}2\text{g}(\text{F}) \rightarrow 4\text{T}1\text{g}(\text{F})$
BUMP-SC- Cr^{+3} - NO_3	3.56	7.48	39289 13071 18761	$4\text{A}2\text{g}(\text{F}) \rightarrow 4\text{T}1\text{g}(\text{P})$ $\text{dxy} \rightarrow \text{dxz}, \text{dyz}$ $\text{dxy} \rightarrow \text{dx}^2-\text{y}^2$
BUMP -SC-OV	1.90	8.89	24691	$\text{dxy} \rightarrow \text{dz}^2$
BUMP -SC - UO_2	Diamag.	7.95	-----	-----

The diffuse electronic spectrum of $[\text{Cu}(\text{BUMP-SC})_2(\text{H}_2\text{O})_2]$ metal complex shows broad band at 15000 cm^{-1} on a strong charge transfer band⁹ at 25000 cm^{-1} . The electronic spectra of Fe(III) chelates, the $d-d$ transition appear mostly as weak bands¹⁰⁻¹¹. The spectra show bands at 12000 , 18000 and 25000 cm^{-1} . These bands correspond to the ${}^6\text{A}_{1\text{g}} \rightarrow {}^4\text{T}_{1\text{g}}(\text{G})$, ${}^6\text{A}_{1\text{g}} \rightarrow {}^4\text{T}_{2\text{g}}(\text{G})$ and ${}^4\text{A}_{1\text{g}} \rightarrow {}^4\text{E}_{\text{g}}$, ${}^4\text{A}_{1\text{g}}(\text{G})$ transition respectively, in an octahedral stereochemistry¹²⁻¹⁶.

Conductivities of all the complexes were measured in acetonitrile solvent, all the complexes were found to be non-electrolytic in nature of 1:1 type, and molar conductivity values were in the range of $3.28\text{--}22.22\text{ ohm}^{-1}\text{cm}^2\text{mole}^{-1}$ in DMF.

The antifungal activity of all the compounds measured for various plant pathogens. Inspection of the result shown in Table 3 indicated that all compounds are good toxic for fungi. Out of all the compounds copper chelates is more toxic than other. These compounds almost inhibit the fungi about 70%. Hence, produced metal chelates can be employed as garden fungicides. Further work in these directions is in progress.

Table 3. Antifungal activity of bUMP-SC ligand and its metal chelates.

Sample	Zone of inhibition of fungus at 1000 ppm, %						
	BT	N	RN	AN	AF	AA	AK
BUMP-SC	56	52	53	64	62	66	72
BUMP-SC -Cu ²⁺	84	76	76	85	80	80	83
BUMP-SC -Ni ²⁺	79	75	74	75	74	82	81
BUMP-SC -Co ²⁺	66	72	75	72	77	78	84
BUMP-SC-Mn ²⁺	80	73	72	76	82	76	82
BUMP-SC -Fe ²⁺	76	62	64	78	82	85	86
BUMP-SC-Fe ³⁺ - NO ₃	82	83	90	81	86	76	87
BUMP-SC-Cr ³⁺ - NO ₃	79	80	84	79	82	72	82

BT= *Botrydeplaia thiobromine*, N= *Nigrospora Sp.*, RN= *Rhisopus Nigricans*, AN= *Asperginus niger*, AF= *Aeprogines funigalus*, AA= *anida Albicans*, AK= *Andida krusegios candida grabrataHO5*.

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