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Preparation, Spectroscopy, Antimicrobial Assay, and X-Ray Structure of Dimethyl bis-(4-methylpiperidine dithiocarbamato-S,S′)-tin(IV)

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Dimethyl bis(4-methylpiperidine dithiocarbamato-S,S′)-tin(IV) was synthesized and characterized by elemental analysis, IR and mass spectrometry, multinuclear NMR (^{1}H- and ^{13}C-NMR), and X-ray single crystal analysis. IR data showed that the ligand acts as a bidentate in the solid state. X-ray data showed the unsymmetrical nature of the ligand towards coordination to tin. It crystallized in the monoclinic $P2_1/n$ space group. Its geometry is distorted octahedral. Antimicrobial activity data shows that the complex exhibits significantly more activity than the free ligand.

Key Words: Dithiocarbamate, NMR, mass, antimicrobial study, X-ray structure.

Introduction

Complexes containing 1,1-dithiolato ligands have been used as fungicides, pesticides, vulcanization accelerators, flotation agents, and lubricant additives, and in the deposition of ZnS or CdS thin film by metal organic chemical vapor deposition (CVD).[1]

Recently, 1,1-dithiolate ligands have attracted much attention, mainly because of interesting photophysical properties derived from their extensive electron delocalization onto all of the ligand atoms.[2] The complexing ability of dithiocarbamates (DTCs) with metals has been known for many years. DTCs form a chelate with metals through their 2 donor sulfur atoms[3] and have been used for analytical application, especially for the separation and determination of metals as metal chelates in thin layer[4] and liquid[5] chromatography. Some DTC salts are used as antidotes[6]. Large quantities of water-soluble DTC complexes are used in agriculture as fungicides or pesticides,[7] and have also been tested in various medical applications.[8]

Among the variety of the ligands, organotin complexes of DTCs have been extensively studied because of their various structures and biological activities.[9−15] One of the reasons for such extensive work is the biological activity of both organotin and dithiocarbamate compounds. With the structural and

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biological diversity of organotin(IV) DTCs in mind,[15] we herein report the synthesis, characterization, and *in vitro* biological activity of dimethyl bis(4-methylpiperidine-dithiocarbamato-S,S′)-tin(IV). The synthesis and multinuclear NMR data have been reported earlier,[16] but we synthesized the title compound by adopting a different route and we also report the crystal structure of the title complex by using the X-ray single crystal method.

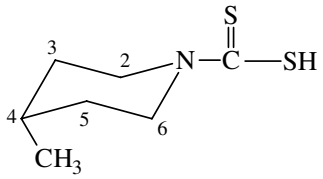


Figure 1. The structure and numbering scheme of 4-methyl-1-piperidine carbodithioic acid.

Experimental

Chemicals and instrumentation

Dimethyltin dichloride, 4-methylpiperidine, and CS_2 were procured from Aldrich and used without further purification. The ligand, 4-methyl-1-piperidine carbodithioic acid (4-MePCDTA), was synthesized according to the literature.[17,18] All the solvents were dried before use as described by Armarego and Chai.[19]

Melting points were determined in capillary tubes using an MPD Mitamura Riken Kogyo (Japan) electrothermal melting point apparatus and are uncorrected. Carbon, hydrogen, nitrogen, and sulfur analyses were performed with a Perkin-Elmer 2400 Series II instrument. IR spectra in the range 4000-400 cm^{-1} were obtained on a Bio-Rad FTIR spectrophotometer, with samples investigated as KBr disks. The ^{1}H- and ^{13}C-NMR spectra were recorded on a Bruker Avance 500 spectrometer, operating at 500 MHz. Mass spectra were recorded on a MAT-112S mass spectrometer. The m/z values were evaluated assuming that H = 1, C = 12, N = 14, S = 32, and Sn = 120.

Synthesis

$[Me_2Sn(4\text{-MePCDTA})_2]$ (**1**)

A solution of 4-methyl-1-piperidine carbodithioic acid (4-MePCDTA) (10 mL, 1.0 mmol) in dry methanol (15 mL) was added dropwise to the solution of dimethyltin dichloride (6.25 g, 0.5 mmol) in anhydrous methanol (15 mL) in a round bottom 2-necked flask. The reaction mixture was stirred for 4 h. The solvent was gradually removed by evaporation under vacuum until a solid product was obtained. The solid was then recrystallized from chloroform-petroleum ether. (1:2), (yield: 83%, mp 120-121 °C). Analysis Calc. for $C_{16}H_{30}N_2S_4Sn$: C, 38.36; H, 6.03; N, 5.63; S, 25.75. Found C, 38.67; H, 6.09; N, 5.60; S, 25.71 (%). IR (KBr, cm^{-1}), 420 ν(Sn-S), 556 ν(Sn-C), 964, 1075 $\nu(CS_2)$. ^{1}H-NMR: (DMSO-d_6, ppm, $^nJ(^1H, ^1H)$, 0.42 (s, 6H, $SnCH_3$), 0.90 (d, 6H, CH_3, (7.1)), 1.68 (m, 8H), 1.74 (m, 2H), 2.76 (m, 8H). ^{13}C-NMR: (DMSO-d_6, ppm,$^nJ[^{119}Sn, ^{13}C]$, 21.49 (CH_3), 29.60 [635.48] ($SnCH_3$), 30.85 (C-4), 33.64 (C-3), 51.25 (C-2), 198.01 (CSS).

Results and Discussion

X-ray analysis

The predictions on the basis of spectroscopic data are entirely borne out in the structure of the title compound, as determined by XRD. Figure 2 shows the title molecule with the atom-numbering scheme. The crystal data, and the selected bond lengths and angles are given in Tables 1 and 2, respectively. The geometry around the tin atom is a highly distorted octahedral surrounded by 4 S atoms and 2 methyl groups. The 4 S atoms lie in the equatorial plane and distortion is reflected in S-Sn-S angles. The cis angles, S4-Sn1-S3 [65.15(3)°], S4-Sn1-S1 [86.34(3)°], S4-Sn1-S3 [65.27(3)°], and S2-Sn1-S3 [143.28(3)°], and the trans angles, S4-Sn1-S2 [151.39(3)°] and S1-Sn1-S3[151.57(3)°], are close to the S-Sn-S bond angles [65.4(3)° to 149.7(3)°] found in $Me_2Sn(S_2CN(CH_2)_4)_2$.[20] The DTC ligand through 4 Sn-S bonds is chelated to tin in anisobidentate fashion, with 2 shorter and 2 longer Sn-S bonds [Sn1-S2 2.895(12)Å, Sn1-S4 2.536(14)Å, Sn1-S3 2.917(12)Å, and Sn1-S1 2.557(11)Å]. The shorter Sn-S bond lengths are very close to the sum of the covalent radii (3.2 Å) of tin and sulfur, the longer Sn-S distances are significantly less than the sum of the van der Waals radii (4.0 Å), and the coordination number is effectively 6.[21] Furthermore, the longer C-S bonds [S1-C1 1.743(3)Å, S4-C8 1.755(3)Å] are associated with the shorter Sn-S bond, and the shorter C-S bonds [S2-C1 1.689(3)Å and S3-C8 1.678(3)Å] are associated with the longer Sn-S bond.[15,16] The Me-Sn-Me [147.39(18)°] angle is intermediate between cis and trans, and longer than those observed in $Me_2Sn[S_2CN(CH_2)_5]$ [131.29(15)°].[16] The angle observed in solution (DMSO-d_6) is smaller [132.18°].

Table 1. Crystal, data collection, and structure refinement parameters.

Empirical formula: $C_{16}H_{30}N_2S_4Sn$
Formula weight = 497.35
X-rays: Mok_α
Crystal system: Monoclinic
Space group: $P2_1/n$ Z = 4
a = 12.153 (5) Å
b = 13.481 (5) Å
c = 14.107 (6) Å
V = 2259.6(15) $Å^3$
D_x = 1.462 Mg/m^3
Absorption coefficient = 1.501 mm^{-1}
Crystal size: 0.18 ×0.12 × 0.10 mm
No. of reflections collected/unique = 3985 [$R_{(int)} = 0.0248$]
No. of reflections used [$I > 2\sigma(I)$] = 10, 936
Refinement: full matrix least squares on F2
Goodness-of-fit on F2 = 1.081
Final R indices = $R_1 = 0.0282, wR_2 = 0.0677$
R indices (all data) = $R_1 = 0.0394, wR_2 = 0.0750$
Measurement: Bruker Smart APEX CCD Diffractometer
Monochromator: graphite
Structure determination: SHELXS-97

Table 2. Selected bond lengths [Å] and angles [°].

Sn1-C15	2.110(3)	C15-Sn1-C16	147.39(18)
Sn1-C16	2.115(3)	C15-Sn1-S4	102.03(10)
Sn1-S4	2.536(14)	C16-Sn1-S4	101.65(12)
Sn1-S1	2.557(11)	C15-Sn1-S1	99.28(12)
Sn1-S2	2.895(12)	C16-Sn1-S1	104.31(13)
Sn1-S3	2.917(12)	S4-Sn1-S1	86.34(3)
N1-C1	1.326(4)	C15-Sn1-S2	85.66(11)
N1-C2	1.464(4)	C16-Sn1-S2	84.20(11)
N1-C6	1.469(4)	S4-Sn1-S2	151.39(3)
S1-C1	1.743(3)	S1-Sn1-S2	65.15(3)
S2-C1	1.689(3)	C15-Sn1-S3	85.88(12)
S3-C8	1.687(3)	C16-Sn1-S3	83.99(12)
S4-C8	1.755(3)	S4-Sn1-S3	65.27(3)
C8-N2	1.327(4)	S1-Sn1-S3	151.57(3)
N2-C13	1.464(4)	S2-Sn1-S3	143.28(3)
N2-C9	1.477(4)	C1-S1-Sn1	92.89(11)
C9-C10	1.507(5)	C1-S2-Sn1	82.91(11)
C13-C12	1.504(5)	S2-C1-S1	118.50(18)

Previously, we reported a chloro-dimethyltin derivative of the same ligand, which has 2 Sn-S bonds, one is shorter [2.466(7)Å] and other is longer [2.739(9)Å][15]. When we compare the chloro-dimethyltin derivative with **1**, it is clear that ligand is unsymmetrically coordinated with the tin atom in both cases, but the difference in Sn-S bonds presumably arises due to the presence of the electronegative chloride ligand, which increases the Lewis acidity of the tin center. The Sn-C distances [Sn1-C8 2.111(5)Å and Sn1-C9 2.114(5)Å] are similar to those found in Me_2SnCl(4-MePCDTA)[15] and $Me_2Sn[S_2CN(CH_2)_5]$ (131.2°).[16]

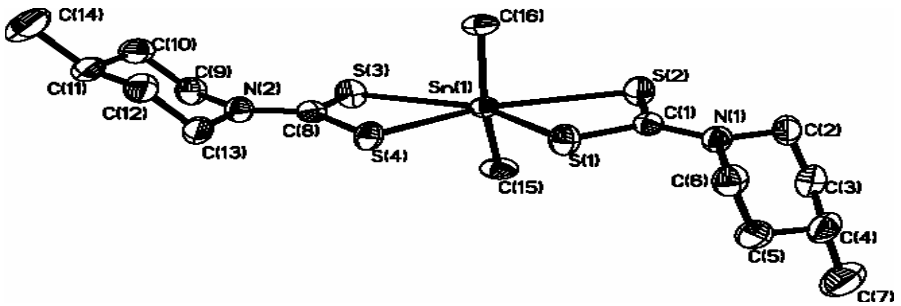


Figure 2. Molecular structure of complex (**1**) with atomic numbering scheme. Displacement ellipsoids are drawn at 50% probability level.

Infrared spectra

The explicit feature in the spectra of **1** is the absence of the band in the region 2520 cm^{-1}, which appears in the free ligand due to -SH bond stretching, thus indicating the tin-sulfur bond formation. The stretching vibration υ(C-N) in the region 1460 $cm^{-1}$is similar to that for reported analogues of tin complexes.[22] This suggests that the ligand is linked to tin in a bidentate fashion. The appearance of 2 bands in the region 1075

cm^{-1} and 964 cm^{-1} for the 2 C-S bonds shows the nature of the ligand as anisobidentate, which is further supported by the observation of 2 Sn-S bonds in the X-ray analysis of the complex.[12] Finally the bands at 556 cm^{-1} for ν(Sn-C) indicate the complex formation.[15] The presence of a new band at 420 cm^{-1} may be attributed[23] to υ (Sn-S), confirming the bonding of the central tin atom of the ligand.

NMR spectroscopy

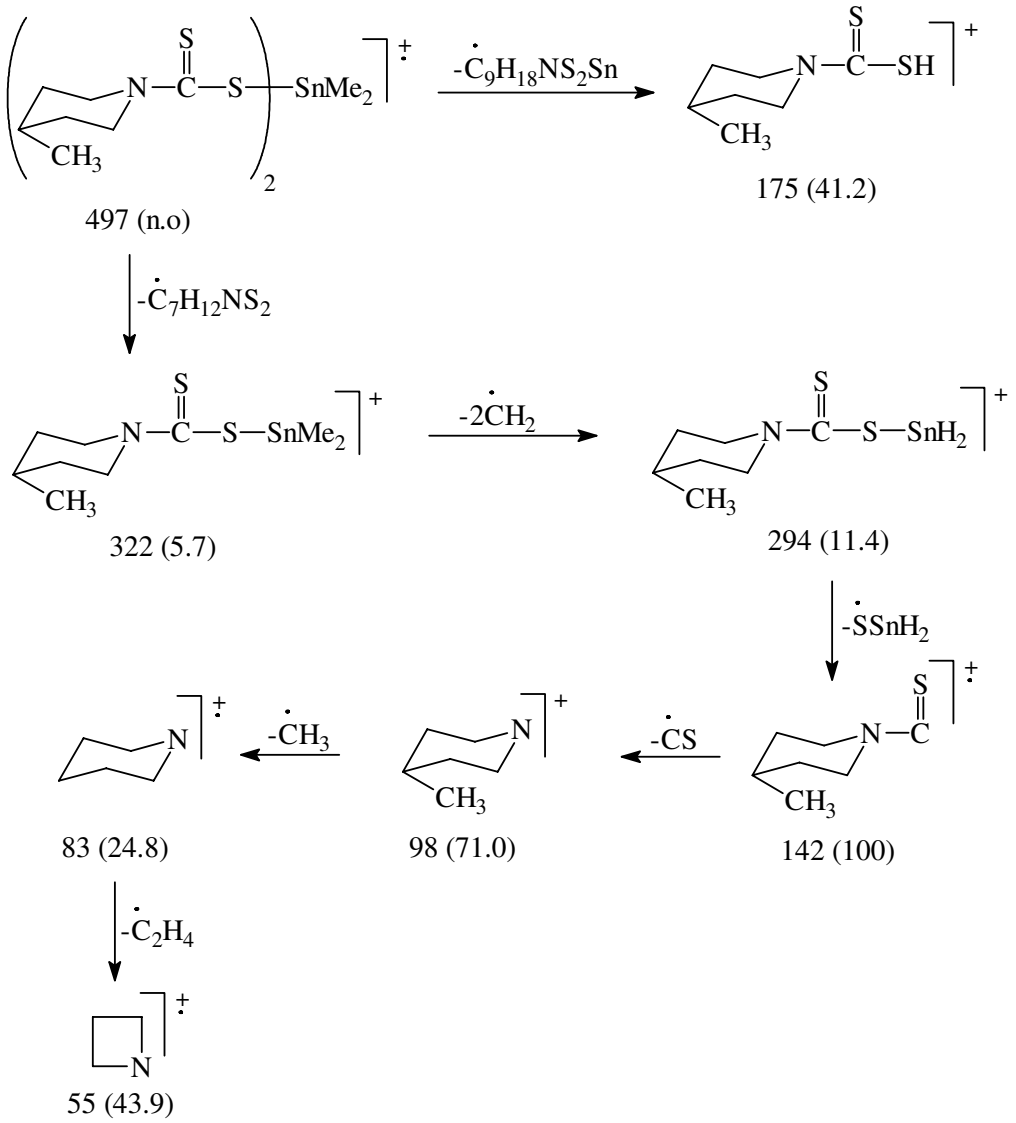
In the ^{1}H-NMR spectra of the complexes, disappearance of the single resonance at 1.27 ppm for the –SH group, which appeared in the spectrum of the ligand, indicates the replacement of the dithiocarboxylic acid proton by organotin moiety. The protons of the piperidine ring and methyl group attached to the ring appeared in the expected region with typical multiplicity and $^{n}J(^{1}H, ^{1}H)$ coupling constants. The chemical shift for the methyl protons attached to tin in **1** exhibits a singlet at 0.42 ppm. In ^{13}C-NMR the assignment of the ^{13}C signal for the –CSS group is straightforward and is assigned in the range of 198.01 ppm for complex **1**, indicating the coordination of sulfur to the tin atom. ^{13}C-NMR spectrum of the title compound indicates a tin-carbon coupling constant $^{1}J(^{119}Sn, ^{13}C)$ of the order of 634.48 Hz. The appearance of a coupling constant value in this region has been attributed to the 6-coordinate[19] environment around the central tin atom. The C-Sn-C angle in the complex is 132.18°, indicating a distorted octahedral environment around the central tin atom. The carbons of the piperidine ring, the methyl group attached to the ring, and organotin moiety give signals in the expected range. The ^{119}Sn chemical shift is found to be –336.47 ppm in the literature[16], which indicates a 6-coordination environment[24] around the central tin atom in this complex.

Mass spectrometry

The conventional EI mass spectral data for **1** is recorded and different fragmentation patterns have been proposed, which are listed in the Scheme, along with m/z and % intensity. The mass spectrum of the ligand is reported elsewhere.[15] In the mass spectral data for **1**, most fragment ions occur in a group of peaks as a result of tin isotopes. The molecular ion peak is not observed in complex. In general, the complex (**1**) has a base peak (100%) at m/z 142 due to fragment $[C_7H_{12}NS]^+$ after the removal of CS_2 from the molecular ion. The other possible fragments with m/z (%) are reported in the Scheme.

Microbial assay

The free ligand and its organotin complex were tested against various bacterial strains (Table 3) with the agar well diffusion method.[25] The antifungal activity against various fungi (Table 3) was also tested and the results are given in Table 3. The antibacterial studies revealed that the complex shows higher activity against various bacteria, as compared to the free ligand, but lower activity than the reference drug. Similarly, the complex shows higher antifungal activity than the free ligand against *Trichophyton longifusus*, *Fusarium solain*, and *Candida glaberata*, but no activity against *Candida albicans*, *Aspergillus flavus,* or *Microsporum canis.*



Scheme. Mass fragmentation pattern of complex **1**.

Table 3. Antimicrobial activity[a] of the free ligand and its organotin(IV) complex.

Comp.	Fungi					
	T. longifusus	*C. albicans*	*A. flavus*	*M. canis*	*F. solani*	*C. glaberata*
HL	10	0	0	10	20	38
(**1**)	40	0	0	0	10	90
R	70	110.8	20	98.4	73.2	110.8
	Bacteria					
	E. coli	*B. subtilis*	*S. flexenari*	*S. aureus*	*P. aeruginosa*	*S. typhi*
HL	12	15	15	20	20	20
(**1**)	21	25	25	20	18	20
R	35	38	32	38	29	28

[a]Test performed using the tube diffusion method (antifungal) and agar well diffusion method. Well diameter: 6 mm; R = standard drug: miconazole and amphotericin B (antifungal agent), and imipenum (antibacterial agent).

Conclusion

The organotin complex of 4-methyl-1-piperidine carbodithioic acid was synthesized by reacting the acid with corresponding organotin chloride at room temperature and was characterized by X-ray and spectroscopic methods. The complex (**1**) shows a distorted octahedral geometry indicating the unsymmetrical nature of the ligand coordination towards the tin. In addition, the synthesized complex was also checked for its antimicrobial activity against various bacteria and fungi, and shows significantly more activity due to the coordination of tin, as compared to the free ligand.

Supplementary material

Crystallographic data for the structural analysis have been deposited at the Cambridge Crystallographic Data Centre, CCDC No. 253475 for complex **1**. Copies of this information may be obtained free of charge from the Director, CCDC, 12 Union Road, Cambridge, CBZ 1EZ, UK (Fax: +44-1223-336033; email: deposit@ccdc.cam.ac.uk or www:http://www.ccdc.cam.ac.uk).

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References

1. D. Coucouvanis, **Prog. Inorg. Chem. 11**, 233 (1970).
2. J. Vicente, M.T. Chicote, S. Huertas and P.G. Jones, **Inorg. Chem. 42**, 4268 (2003).
3. A. Hulanicki, **Talanta. 14**, 1371 (1967).
4. K.W. Weissmahr, L. Houghton and D.L. Sedlak, **Anal. Chem. 70**, 4800 (1998).
5. M.L. Riekkola, T. Pakkanen and L. Niinisto, **Acta. Chim. Scand. 37**, 807 (1983).
6. I.A. Shinobu, S.G. Jones and M.M. Jones, **Acta Pharmacol. Toxicol. 54**, 189. (1984).
7. J.H. Montgomery, **Agrochemical Desk Reference Environmental Data**, Lewis Publisher: Michigan. 261(1993).
8. J. Xie, T. Funakoshi, H. Shimida and S. Kojima, **Res. Commun. Mol. Pathol. Pharmacol. 86**, 245 (1994).
9. E.R.T. Tiekink, **Main Group Met. Chem. 15**, 161 (1992).
10. E.R.T. Tiekink, **Main Group Met. Chem. 16**, 129 (1993).
11. P.J. Heard, "**Progress in Inorganic Chemistry Vol. 53"** ed. K.D. Karlin, John Wiley and Sons, 53 (1998).
12. G. Eng, X. Song, Q. Duong, D. Strickman, J. Glass and L. May, **Appl. Organomet. Chem. 17**, 218 (2003).
13. S. Ali, S.U. Ahmad, Sadiq-ur-Rehman, S. Shahzadi, M. Parvez and M. Mazhar, **Appl. Organomet. Chem., 19**, 200 (2005).
14. S. Ali, S.U. Ahmad, S. Shahzadi, Sadiq-ur-Rehman, M. Parvez and M. Mazhar, **Appl. Organomet. Chem. 19**, 201 (2005).

15. S. Shahzadi, S. Ali, M.H. Bhatti, M. Fettouhi and M. Athar, **J. Organomet. Chem. 691**, 1797 (2006).
16. J. Sharma, Y. Singh, R. Bohra and A.K. Rai, **Polyhedron. 15**, 1097 (1996).
17. A. Benedetti, A.C. Fabretti and C. Preti, **J. Chem. Crystallogr. 18**, 685 (1988).
18. A.C. Fabretti and C. Preti, **J. Chem. Crystallogr. 19**, 957 (1989).
19. W.L.F. Armarego and C.L.L. Chai, "**Purification of Laboratory Chemicals"**, 5th ed., Butterworth–Heinemann, London (2003).
20. T.P. Lockhart, W.F. Manders, E.O. Schlemper and J.J. Zuckerman, **J. Am. Chem. Soc. 108**, 4074 (1985).
21. T.P. Lockhart, W.F. Manders and E.O. Schlemper, **J. Am. Chem. Soc. 107**, 7451 (1986).
22. H. Yin, C. Wang, M. Hong and D. Wang, **J. Organomet. Chem. 689**, 1277 (2004).
23. M. Schmidt and H. Schumann, **Z. Anorg. Allg. Chem., 325**, 130 (1963).
24. J. Holecek, M. Nadvornik and K. Handlir, **J. Organomet. Chem., 315**, 299 (1986).
25. A. Rehman, M.I. Choudhary and W.J. Thomsen, "**Bioassay Techniques for Drug Development"**, Harwood Academic Publishers, The Netherlands (2001).