ELSEVIER

Studies of the reaction of dimethyltin dichloride with mercaptoacetic acid in the presence of amines and crystal structure of [(n-Pr)$_3$NH][Me$_2$Sn(μ^2-SCH$_2$COO)Cl]

Guiyun Zhong [a], Qingfu Liu [a], Xueqing Song [b,*], George Eng [b], Qinglan Xie [c]

[a] Biochemistry Department, XingTai University, Xingtai 054001, PR China
[b] Department of Chemistry and Physics, University of the District of Columbia, 4200 Connecticut Avenue, NW, Washington, DC 20008, USA
[c] Institute of Elemento-Organic Chemistry, NanKai University, Tianjin 300071, PR China

Abstract

A series of new five-coordinated ionic organotin(IV) complexes with general formula [Q][Me$_2$Sn(μ^2-SCH$_2$COO)Cl](Q = diethylammonium, triethylammonium, di-i-propylammonium, tripropylammonium, tri-n-butylammonium, pyrimidium, 3-picolinium, methylphenylammonium, dimethylphenylammonium) were synthesized by the reaction of mercaptoacetic acid with dimethyltin dichloride in the presence of an organic base. These complexes have been characterized by elemental analyses, IR and ^{1}H NMR spectroscopies. The crystal structure of [(n-Pr)$_3$NH][Me$_2$Sn(μ^2-SCH$_2$COO)Cl] was determined by X-ray crystallography. The structure consists of an anion part, and a tri-n-propylammonium cation part as a counterion. The tin atom has a distorted cis-tbp geometry with two carbon and one sulfur atoms occupying the equatorial positions and the O atom and Cl atom occupying the axial positions. The organotin anion and its counterion are connected through a hydrogen bond between the N atom in the ammonium and the O atom of the carbonyl group with a N–O length of 2.766 Å.
© 2005 Elsevier B.V. All rights reserved.

Keywords: Five-coordinated Tin(IV) complex; Ionic organotin; Crystal structure

1. Introduction

While most of the studies on organotin compounds have been focused on the organotin carboxylates owing to their diversified molecular structures [1,2] and wide range of applications, such as biological activities [3–5], organotin sulfides are another group of organotin compounds that have drawn much current attention because of their good thermal stability and their applications as stabilizers for PVC and related plastic materials. Although compounds of general formulae R$_3$Sn(SR′), RSn(SR′)$_3$ and Sn(SR′)$_4$ were all claimed

to have stabilization properties, diorganotin sulfur compounds, with the general formula R$_2$Sn(SR′)$_2$ are still the mostly studied as the stabilizers [6].

Recently, much interest of organotin sulfide compounds has been concentrated on the syntheses and structure determinations of a series of oragnotin 1,2 dithiolate complexes, the ligand used include aliphatic derivative, e.g., SCH$_2$CH$_2$S(edt) [7], SCH$_2$CHMeS [7], alkenyl derivatives [8], e.g., SCH=CHS [9], SC(CN)=C(CN)S(mnt) [9], aryl derivatives, SC$_6$H$_4$S(bdt)[10]. The key feature of this type of organotin compounds lies in that they are made up of two parts, an anionic unit which consists of a cis-tbp C$_2$SnXS$_2$, and a cation which is an organoammonium. In the reaction of the mnt (mnt = (CN)$_2$C$_2$S$_2$) ligand with MeSnCl$_3$ and PhSnCl$_3$ in the presence of

* Corresponding author. Tel.: +1 2022747420; fax: +1 2022746237.
E-mail address: xsong@udc.edu (X. Song).

tetraalkylammonium chloride, tin–carbon cleavage occurred to yield [Sn(mnt)$_3$] or [Sn(mnt)$_2$Cl$_2$]$^{2-}$ salts [11], depending on the ligand ratio and reaction temperature. In our previous studies, the reaction of triphenyltin chloride and mercaptoacetic acid in the presence of an organic base has been investigated [12,13], an unexpected tin–carbon cleavage process was observed in the reaction; while the reaction of mercaptoacetic acid with phenyltin trichloride in the presence of an amine generated no Sn–C cleavage products [14]. Our interest in the mechanism of the tin–carbon cleavage of organotin induced by ligand containing S atom has prompted us to further investigate the reaction of some other organotin chorides. With this in mind, the reaction of mercaptoacetic acid with dimethyltin dichloride in the presence of different amines is reported herein.

2. Experimental

2.1. Materials and instrumentation

Mercaptoacetic acid (HSCH$_2$COOH), dimethyltin dichloride and various alkyl or aromatic amines were purchased from Alfa Aesar, Ward Hill, MA, USA were used without further purification. Solvent evaporations were always carried out under vacuum using a rotary evaporator. All syntheses were carried out under a Nitrogen atmosphere. The solvents used in the reaction were of AR grade and dried using standard procedures.

Elemental analyses (C, H, N) were determined on a Vario EL model instrument. The ^{1}H NMR spectra were measured on a BRUKER AC-P 200 spectrometer at room temperature with DCCl$_3$ as solvent and TMS as internal standard. IR spectra were recorded in the range of 400–4000 cm^{-1} on a Brucher-FT-IR-Equinqx55 as KBr disc.

2.2. Synthesis of products

The products were synthesized according to Scheme 1, and general procedure is described as following:

A solution of Me$_2$SnCl$_2$ (0.55 g, 2.5 mmol) in acetone (20 ml) is added dropwise to a solution of HSCH$_2$COOH (0.23 g, 2.5 mmol) in 20 mL acetone under nitrogen. The mixture was then stirred magnetically at the room temperature for 0.5 h, and then an appropriate amine (5 mmol) was added, white solid formed immediately.

The mixture was stirred and refluxed for 2 h. The solid was filtered off and the solvent and the excessive amount of amine were removed from the filtrate under vacuum and the white solid was obtained. The white solid was recrystallized from ethanol by cooling for several days to yield colorless crystals.

2.2.1. [Me$_2$SnCl(SCH$_2$COO)][H$_2$NEt$_2$] 1
Yield: 57%, m.p. >220 °C. ^{1}H NMR (CDCl$_3$): δ 0.85(6H, t, SnCH$_3 \cdot 2$, J_{Sn-H} = 73.8), 1.39(6H, t, CH$_3 \cdot 2$, J = 6.5 Hz), 3.05(4H, m, NCH$_2 \cdot 2$), 3.45(2H, t, SCH$_2$, $^3J_{Sn-H}$ = 39.6 Hz) ppm. IR (KBr, cm^{-1}): 2987 v(HN$^+$), 1574 v(OCO)$_{asym}$, 1403 v(OCO)$_{sym}$, 555 v(Sn–C), 430 v(Sn–O). Anal. Calc. for C$_8$H$_{20}$ClNO$_2$SSn: C, 27.58; H, 5.79; N, 4.02. Found: C, 27.39; H, 5.57; N, 3.89%.

2.2.2. [Me$_2$SnCl(SCH$_2$COO)][HNEt$_3$] 2
Yield: 50%, m.p. 152–154 °C. ^{1}H NMR (CDCl$_3$): δ 0.87(6H, t, SnCH$_3 \cdot 2$, J_{Sn-H} = 73.6), 1.32(9H, t, CH$_3 \cdot 3$, J = 6.6 Hz), 3.05(6H, m, NCH$_2 \cdot 3$), 3.56(2H, t, SCH$_2$, $^3J_{Sn-H}$ = 46.4 Hz) ppm. IR (KBr, cm^{-1}): 2987 v(HN$^+$), 1559 v(OCO)$_{asym}$, 1347 v(OCO)$_{sym}$, 552 v(Sn–C), 436 v(Sn–O). Anal. Calc. for C$_{10}$H$_{24}$ClNO$_2$SSn: C, 31.90; H, 6.44; N, 3.72. Found: C, 31.51; H, 6.60; N, 3.59%.

2.2.3. [Me$_2$SnCl(SCH$_2$COO)][H$_2$N(i-Pr)$_2$] 3
Yield: 57%, m.p. >220 °C. ^{1}H NMR (CDCl$_3$): δ 0.77(6H, t, SnCH$_3 \cdot 2$, J_{Sn-H} = 73.9), 1.39(12H, d, CH$_3 \cdot 4$, J = 6.0 Hz), 3.12(2H, m, NCH $\cdot 2$), 3.55(2H, t, SCH$_2$, $^3J_{Sn-H}$ = 40.0 Hz) ppm. IR (KBr, cm^{-1}): 2987 v(HN$^+$), 1620 v(OCO)$_{asym}$, 1389 v(OCO)$_{sym}$, 553 v(Sn–C), 432 v(Sn–O). Anal. Calc. for C$_{10}$H$_{24}$ClNO$_2$SSn: C, 31.90; H, 6.44; N, 3.72. Found: C, 32.10; H, 6.20; N, 3.65%.

2.2.4. [Me$_2$SnCl(SCH$_2$COO)][HN(n-Pr)$_3$] 4
Yield: 72%, m.p. 120–122 °C. ^{1}H NMR (CDCl$_3$): δ 0.83(6H, t, SnCH$_3 \cdot 2$, J_{Sn-H} = 74.6), 1.02(9H, t, CH$_3 \cdot 3$, J = 6.4 Hz), 1.69(6H, m, CH$_2 \cdot 3$), 2.95(6H, m, NCH$_2 \cdot 3$), 3.42(2H, t, SCH$_2$, $^3J_{Sn-H}$ = 44.6 Hz) ppm. IR (KBr, cm^{-1}): 2970 v(HN$^+$), 1587 v(OCO)$_{asym}$, 1359 v(OCO)$_{sym}$, 548 v(Sn–C), 436 v(Sn–O). Anal. Calc. for C$_{13}$H$_{30}$ClNO$_2$SSn: C, 37.30; H, 7.24; N, 3.35. Found: C, 37.19; H, 6.85; N, 2.97%.

2.2.5. [Me$_2$SnCl(SCH$_2$COO)][HN(n-Bu)$_3$] 5
Yield: 63%, m.p. 70–72 °C. ^{1}H NMR (CDCl$_3$): δ 0.81(6H, t, SnCH$_3 \cdot 2$, J_{Sn-H} = 74.2), 0.96(9H, t, CH$_3 \cdot 3$, J = 6.5 Hz), 1.38(6H, m, CH$_2 \cdot 3$), 1.67(6H, m, CH$_2$3), 2.93(6H, m, NCH$_2 \cdot 3$), 3.41(2H, t, SCH$_2$, $^3J_{Sn-H}$ = 37.8Hz) ppm. IR (KBr, cm^{-1}): 2974 v(HN$^+$), 1599 v(OCO)$_{asym}$, 1374 v(OCO)$_{sym}$, 554 v(Sn–C), 453 v(Sn–O). Anal. Calc. for C$_{16}$H$_{36}$ClNO$_2$SSn: C, 41.71; H, 7.89; N, 3.04. Found: C, 41.70; H, 7.67; N, 3.31%.

Scheme 1. NR$_3$ = HNEt$_2$ (1), NEt$_3$ (2), HN(i-Pr)$_2$ (3), N(n-Pr)$_3$ (4), N(n-Bu)$_3$ (5), pyridine (6), 3-picoline (7), HNPhMe (8), NPhMe$_2$ (9).

2.2.6. [Me₂SnCl(SCH₂COO)][pyridinium] 6

Yield: 56%, m.p. >220 °C. ^{1}H NMR (CDCl$_3$): δ 0.87(6H, t, SnCH$_3$ · 2, $J_{Sn–H}$ = 74.0), 3.71(2H, t, SCH$_2$, $^3J_{Sn–H}$ = 42.8Hz), 7.82(2H, m, o-H), 8.15(1H, m, p-H), 8.28(2H, m, m-H) ppm. IR (KBr, cm^{-1}): 3089 v(HN$^+$), 1582v(OCO)$_{asym}$, 1395 v(OCO)$_{sym}$, 555 v(Sn–C), 432 v(Sn–O). Anal. Calc. for C$_9$H$_{14}$ClNO$_2$SSn: C, 30.50; H, 3.99; N, 3.95. Found: C, 30.78; H, 4.39; N, 4.17%.

2.2.7. [Me₂SnCl(SCH₂COO)][picolinium] 7

Yield: 65%, m.p. >220 °C. ^{1}H NMR (CDCl$_3$): δ 0.87(6H, t, SnCH$_3$ · 2, $J_{Sn–H}$ = 73.8), 2.57(3H, s, CH$_3$), 3.71(2H, t, SCH$_2$, $^3J_{Sn–H}$ = 2.8 Hz), 7.75-8.22(4H, m, C$_5$H$_4$) ppm. IR (KBr, cm^{-1}): 3093 v(HN$^+$), 1554v(OCO)$_{asym}$, 1400 v(OCO)$_{sym}$, 552 v(Sn–C), 436 v(Sn–O). Anal. Calc. for C$_{10}$H$_{16}$ClNO$_2$SSn: C, 32.60; H, 4.39; N, 3.80. Found: C, 32.78; H, 3.89; N, 3.67%.

2.2.8. [Me₂SnCl(SCH₂COO)][H₂NPhMe] 8

Yield: 60%, m.p. >220 °C. ^{1}H NMR (CDCl$_3$): δ 0.79(6H, t, SnCH$_3$ · 2, $J_{Sn–H}$ = 74.3), 2.97(6H, s, NCH$_3$), 3.47(2H, t, SCH$_2$, $^3J_{Sn–H}$ = 46.8 Hz), 7.35-8.42(5H, m, C$_6$H$_5$) ppm. IR (KBr, cm^{-1}): 3051 v(HN$^+$), 1571 v(OCO)$_{asym}$, 1390 v(OCO)$_{sym}$, 558 v(Sn–C), 434 v(Sn–O). Anal. Calc. for C$_{11}$H$_{18}$ClNO$_2$SSn: C, 34.54; H, 4.75; N, 3.66. Found: C, 34.24; H, 4.74; N, 3.56%.

2.2.9. [Me₂SnCl(SCH₂COO)][HNPhMe₂] 9

Yield: 71%, m.p. 101–103 °C. ^{1}H NMR (CDCl$_3$): δ 0.80(6H, t, SnCH$_3$ · 2, $J_{Sn–H}$ = 74.4), 2.97(6H, s, NCH$_3$ · 2), 3.47(2H, t, SCH$_2$, $^3J_{Sn–H}$ = 46.8Hz), 7.35–8.42(5H, m, C$_6$H$_5$) ppm. IR (KBr, cm^{-1}): 3027 v(HN$^+$), 1569v(OCO)$_{asym}$, 1380 v(OCO)$_{sym}$, 560 v(Sn–C), 436 v(Sn–O). Anal. Calc. for C$_{12}$H$_{20}$ClNO$_2$SSn: C, 36.35; H, 5.09; N, 3.53. Found: C, 36.30; H, 4.79; N, 3.67%.

2.3. Crystal structure determination

The colorless crystals of [(n-Pr)$_3$NH][Me$_2$Sn(μ^2-SCH$_2$COO)Cl] suitable for X-ray crystallography study were obtained from a dilute ethanol solution. A crystal with approximate dimensions of $0.40 \times 0.25 \times 0.20$ mm was selected for data collection on a BRUKER SMART 1000 diffractometer with graphite monochromated Mo Kα radiation (λ = 0.71073 Å) at 293(2) K. The structure was solved by direct methods and refined on F^2 with anisotropic parameters for all non-hydrogen atoms. All calculations were performed using SHELXL program on PC computer.

Of the 5705 reflections measured (max = 26.52°), 3985 were independent, of which 3185 had $I > 2\sigma$ (I). The positions of the non-hydrogen atoms were found from the three-dimensional Patterson and Fourier synthesis. Block-diagonal least squares refinement with

isotropic temperature factors for hydrogen atoms, and non isotropic for other atoms, gave the final R = 0.0704 (Rw = 0.0786, S = 0.990). Final atomic coordinates are listed in Table 1, selected bond lengths and bond angles in Table 2. The structure of 1, together with atomic numbering scheme, is depicted in Fig. 1.

Table 1
Crystal and structure refinement data for compound **4**

Empirical formula	C$_{13}$H$_{30}$ClNO$_2$SSn
Formula weight	418.58
Crystal system	Triclinic
Space group	$P\bar{1}$
Unit cell dimensions	
a (Å)	10.497(5)
b (Å)	10.515(4)
c (Å)	10.844(5)
α (°)	74.734(7)
β (°)	68.943(7)
γ (°)	62.203(6)
Volume (Å^3)	981.4(8)
Z	2
Absorption coefficient (mm^{-1})	1.543
$F(000)$	428
Crystal size (mm)	$0.40 \times 0.25 \times 0.20$
θ Range for data collection	2.82–24.45°
Reflections collected	5705
Independent reflections [R_{int}]	3985 [0.0232]
Data/restraints/parameters	3985/0/175
Goodness-of fit on F^2	0.990
Final R indices [$I > 2\sigma(I)$]	R_1 = 0.0327, wR_2 = 0.0730
R indices (all data)	R_1 = 0.0474, wR_2 = 0.0786
Goodness-of-fit on F^2	0.991
Final R indices [$I > 2\sigma(I)$]	R_1 = 0.0327, wR_2 = 0.0730
R indices (all data)	R_1 = 0.0474, wR_2 = 0.0786
Largest diff. peak and hole (e A^{-3})	0.478 and −0.383

Table 2
Bond lengths (Å) and angles (°) for[(n-Pr)$_3$NH][Me$_2$Sn(μ^2-SCH$_2$COO)Cl]

|			
Sn(1)–C(4)	2.115(4)	O(1)–Sn(1)–S(1)	81.28(7)
Sn(1)–C(3)	2.116(4)	C(4)–Sn(1)–Cl(1)	95.71(14)
Sn(1)–O(1)	2.213(2)	C(3)–Sn(1)–Cl(1)	93.81(13)
Sn(1)–S(1)	2.4026(12)	O(1)–Sn(1)–Cl(1)	170.72(7)
Sn(1)–Cl(1)	2.5138(13)	S(1)–Sn(1)–Cl(1)	89.61(4)
O(1)–C(1)	1.265(4)	C(11)–N(1)–C(8)	114.1(3)
O(2)–C(1)	1.236(4)	C(11)–N(1)–C(5)	112.8(2)
S(1)–C(2)	1.802(4)	C(8)–N(1)–C(5)	110.6(2)
C(1)–C(2)	1.517(5)	C(1)–O(1)–Sn(1)	21.3(2)
C(5)–C(6)	1.475(5)	C(2)–S(1)–Sn(1)	98.45(13)
C(6)–C(7)	1.511(5)	O(2)–C(1)–O(1)	123.2(3)
C(8)–C(9)	1.502(5)	O(2)–C(1)–C(2)	117.5(3)
C(9)–C(10)	1.510(5)	O(1)–C(1)–C(2)	119.3(3)
C(11)–C(12)	1.498(5)	C(1)–C(2)–S(1)	117.1(3)
C(12)–C(13)	1.522(5)	C(6)–C(5)–N(1)	114.0(3)
C(4)–Sn(1)–C(3)	121.89(19)	C(5)–C(6)–C(7)	111.7(3)
C(4)–Sn(1)–O(1)	90.10(15)	C(9)–C(8)–N(1)	114.5(3)
C(3)–Sn(1)–O(1)	89.22(15)	C(8)–C(9)–C(10)	110.4(3)
C(4)–Sn(1)–S(1)	117.60(13)	N(1)–C(11)–C(12)	114.1(3)
C(3)–Sn(1)–S(1)	119.65(14)	C(11)–C(12)–C(13)	111.1(3)
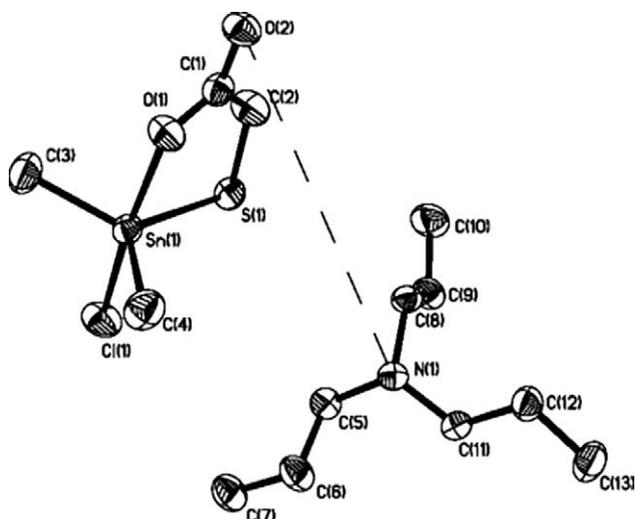
Fig. 1. Molecular structure of [(n-Pr)$_3$NH][Me$_2$Sn(μ^2-SCH$_2$COO)Cl], H-atoms omitted for clarity.

3. Results and discussion

3.1. IR

In the spectrum of the ligand, the strong, well-developed band at 1600 cm^{-1} is assigned to v(S–H). However, the absence of the characteristic absorption of v(S–H) indicates the S involving in the coordination to tin atom. Medium to weak bands in the region 430–453 cm^{-1} are assigned to Sn–O, those in the region 548–560 cm^{-1} indicate the presence of Sn–C bands [15]. The absorption frequencies of asymmetry (vCO$_2^{as}$) and symmetry (vCOO^s) of carbonyl groups are in the region 1554–1620 and 1347–1403 cm^{-1}, respectively. The difference between the two frequencies (ΔvCO$_2$) is 154–171 cm^{-1}. This is much lower than the ΔvCOO value for a monodentate carboxylate. This can be ascribed to the fact that there exists a strong hydrogen bonding between N atom in the ammonium ion and the O atom in the carbonyl group. The carbonyl oxygen donates part of its electrons to the hydrogen bonding, which makes the difference between the absorption frequencies of asymmetry (vCOO^{as}) and symmetry (vCOO^s) of carbonyl groups decrease.

3.2. ^{1}H NMR

^{1}H NMR spectra of the compounds are mainly composed of three parts: methyl protons (SnCH$_3$), methylene protons in SCH$_2$ moiety and amine protons. The existence of the hydrogen bonding between protons in R$_3$HN$^+$ and carbonyl (C=O) oxygens cause the ammonium protons to appear in a much lower field range from 10 to 11 ppm as a weak signal than those in the original amines. In some cases, the rapid exchange of ammonium protons with deuterated solvent would

cause the weak signals to disappear. Methyl protons are in the region of 0.77–0.87 ppm. The chemical shifts of the protons in SCH$_2$ exhibit signals at 3.41–3.71 ppm as a triplet which is caused by the long distance (^{119}Sn–^{1}H) coupling. The spin–spin coupling constant ^3J(^{119}Sn–^{1}H) is in the range 37.4–46.8 Hz. Protons on the carbon atoms of the ammonium ions have observed in their normal positions.

3.3. Crystal structure

The molecular structure and molecular packing of **4**, [(n-Pr)$_3$NH][Me$_2$Sn(μ^2-SCH$_2$COO)Cl], are shown in Figs. 1 and 2, respectively. The crystal data are listed in Table 1. Selected bond lengths and bond angles are in Table 2.

The Fig. 1 shows that the tin atom in anion is coordinated by five atoms with O(1) and Cl(1) at axial positions and C(3),C(4),S(1) forming the equatorial plane. The anion has a slightly-distorted cis-trigonal bipyramidal geometry around tin atom with the Sn–S–C–C–O metallocycle having envelope conformation. Few examples of cis-tbp geometries are found in the structural literature of triorganotin carboxylate compounds. The structure of the [Me$_2$SnCl(mercaptoacetato)] anion in the present stannate is similar to that in literature in that both compounds possess a five-membered chelate ring. The axial skeleton is a little bent, (Cl–Sn–O angle of 170.72°). In such a structure, the sum of the angles between the tin atom and the equatorial ligating atoms (i.e. two C atoms and one S atom) is the 359.1(2)° compared to the ideal octahedral value of 360°C. The distribution of these 360°, which should normally be 120° for each angle, is almost equal with C(4)–Sn(1)–C(3), C(4)–Sn(1)–S(1) and C(3)–Sn(1)–S(1) being 121.89(19)°, 117.60(13)° and 119.65(14)°, respectively. This indicates that the Sn atom is almost exactly on the equatorial plane. It is displaced only 0.0443 Å out of the plane defined by C(3), C(4), S(1), which well agrees with the ideal
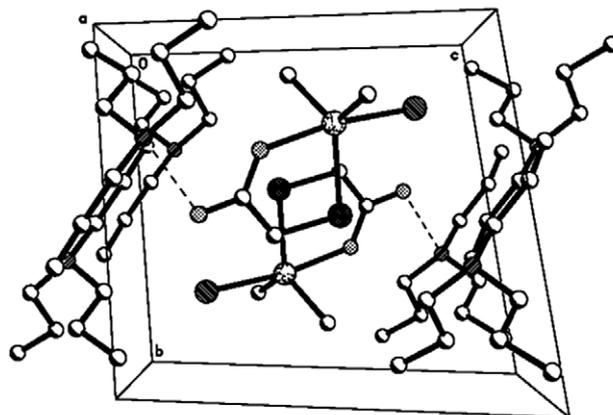

Fig. 2. Cell packing of [(n-Pr)$_3$NH][Me$_2$Sn(μ^2-SCH$_2$COO)Cl].

TBP. The Fig. 2 shows that there is existence of mutual interaction through the hydrogen-bonding between the cation and the anion moities; the distance of N–O is 2.766 Å, which is much shorter than the sum of Van der Waals radii for N and O of 3.2 Å. The hydrogen bonding greatly affects the distribution of the electrons on the carbonyl group, this is observed by the two identical C–O bond distances at 1.237(4) Å (O(1)-C(23)) and 1.261(4) Å (O(2)–C(23)). This is in agreement with the lowering value of the difference between the absorption frequencies of asymmetry (νCO_2^{as}) and symmetry (νCO_2^{s}) of carbonyl groups.

Acknowledgements

Appendix A. Supplementary data

Crystallographic data for the structures reported in this paper have been deposited with Cambridge Crystallographic Data Center and allocated the deposition number CCDC 264151 for 4. Copies of this information may be obtained free of charge from the Director, CCDC, 12 Union Road, Cambridge CB2 1EZ, UK (fax: +44 1223 336033; e-mail: deposit@ccdc.cam.ac.uk or www: http://www.ccdc.cam.ac.uk). Supplementary data associated with this article can be found, in the on-line version at doi:10.1016/j.jorganchem.2005.04.022.

References

[1] E.R.T. Tiekink, Trends Organomet. Chem. 1 (1994) 71.
[2] E.R.T. Tiekink, Appl. Organomet. Chem. 5 (1991) 1.
[3] R. Willem, M. Biesemans, M. Boualam, Appl. Organomet. Chem. 7 (1993) 311.
[4] S.W. Ng, V.G. Kumar Das, J. Holecek, A. Lycka, M. Gielen, M.G.B. Drew, Appl. Organomet. Chem. 11 (1997) 39.
[5] R. Willem, M. Biesemans, F. Kayser, Inorg. Chim. Acta 197 (1992) 25.
[6] E.W. Abel, D.A. Armitage, Adv. Organomet. Chem. 6 (1965) 49.
[7] G. Bandoli, U. Casellato, V. Peruzzo, G. plazzogna, J. Organomet. Chem. 352 (1988) 283.
[8] E.W. Abel, S.K. Bhargava, K.g. Orrell, V. Ski, J. Chem. Soc. Dalton Trans. (1982) 2073.
[9] E.W. Abel, C.R. Jenkins, J. Chem. Soc. A (1967) 1344.
[10] Z.H. Zahid, R.A. Howie, J.L. Wardell, J. Organomet. Chem., 577 (1999) 140.
[11] E.S. Bretschneider, C.W. Allen, J. Organomet. Chem. 38 (1972) 43.
[12] X. Song, Q. Xie, X. Fang, Chin. Chem. Lett. 9 (1998) 977.
[13] L.J. Sun., X.Q. Song, J.X. Chen, G.Y. Zhong, Q.L. Xie, Chem. J. Chinese Universities 4 (2004) 646.
[14] G.Y. Zhong, H.B. Song, L.J. Sun, Q.L. Xie, Chem. Res. Chinese Universities 3 (2004) 274.
[15] R. Okawara, K. Yasuda, J. Organomet. Chem. 1 (1964) 356.