

Structural Chemistry of Organotin(IV) Complexes

S. Shahzadi and S. Ali*

Department of Chemistry, Quaid-i-Azam University, Islamabad- 45320, Pakistan

(Received 14 September 2007, Accepted 16 November 2007)

The amazing structural diversity in organotin compounds is discussed in the systems containing -O and -S donor ligands. It is demonstrated that there exist a fascinating range of structural diversity for organotin(IV) complexes, including differences in coordination number and molecular geometry. The difference in structure is correlated with the nature of tin and ligand bonded R groups. Despite the large number of different structures found in organotin(IV) carboxylates, there is limited range of coordination geometries about the Sn atom. The four coordinated Sn atom in triorganotin(IV) complexes is invariably distorted tetrahedral and five coordinated Sn is distorted trigonal bipyramidal. A large range has been observed for diorganotin carboxylate structures, where five, six and seven coordinate geometries have been reported. The Sn atom in mono-organotin has only been demonstrated to exist in distorted octahedral geometries (the single exception being a pentagonal bipyramidal geometry). In the case of organotin(IV) complexes of S donor ligands, it has been shown that there exists a rich diversity in Sn atom geometries and coordination modes of the sulfur donor ligands themselves. As in related carboxylate systems, the assignment of coordination numbers to the Sn centers in some compounds is controversial. As a general trend, it has been shown that, the overall coordination number at the Sn atom decreases with the increasing number of organic substituents at the Sn atom. This phenomenon is usually achieved by increased asymmetry in the mode of coordination of the sulfur donor ligands.

Keywords: Organotin(IV) complexes, O-donor ligands, S-donor ligands, Structural chemistry

INTRODUCTION

The increasing interest in organotin(IV) carboxylates of substituted benzoic acids in recent years has, to a large extent, been prompted by their new structural diversity [1] and broad therapeutic activity [2]. Information on the structure of organotin(IV) carboxylates continues and at the same time some new applications of such a high importance are being discovered which are relevant to ecological medicinal applications. The increasing interest in the chemistry of organotin(IV) compounds has led to the extended studies on their reactions with different biomolecules including carbohydrates [3-5], nucleic acid derivatives [6-8], amino

acids [9-11] and peptides [12-14].

The aim of this review is to summarize each category of organotin carboxylates in order to illustrate the diverse modes of coordination/association of the carboxylate ligand/dithiocarbamate ligand, as determined by crystallographic methods. We will discuss the structural chemistry of organotin(IV) complexes under the two categories: oxygen donor ligands and sulfur donor ligands.

OXYGEN DONOR LIGANDS

Oxygen donor ligands coordinate to the organotin moiety in monodentate or bidentate fashion in different stoichiometries giving the diversity of structures. We will discuss this section

*Corresponding author. E-mail: drsa54@yahoo.com

as four-, five- and six-coordinated complexes and distannoxanes.

Four Coordinated Complexes

When the oxygen donor ligands act as monodentate, the geometry around the tin atom will be distorted tetrahedral, as reported in the literature [15-18]. Representative structure of this class is given in Fig. 1, which shows that the Sn atom exists in a distorted tetrahedral geometry defined by three *ipso*-C atoms of the phenyl groups and O1 atom [Sn1-O1 = 2.0557(14) Å] of the (E)-3-(3-fluorophenyl)-2-(4-chlorophenyl)-2-propenoate. The major distortion from the ideal tetrahedral geometry is found in the O1-Sn1-C1 angle of 96.54(7)°. The relatively close interaction between O2 and Sn1 [Sn1...O2 = 2.8309(5) Å] does not disrupt the O1-Sn1-C7 and O1-Sn1-C13 angles significantly, which are 108.91(7)° and 110.10(7)°, respectively. However it is noteworthy that C7-Sn1-C13 angle of 119.06(8)° is the next major distortion from the ideal geometry. The monodentate mode of coordination of (E)-3-(3-fluorophenyl)-2-(4-chlorophenyl)-2-propenoate is reflected in the disparate O1-C19 and O2-C19 bond distances of 1.313(2) and 1.229(2) Å, respectively, with the longer separation being associated with the stronger Sn1-O1 interaction [15]. Another example of this class is given in

Fig. 2 in which also the distorted tetrahedral geometry is observed [16,18].

Five Coordinated Complexes

Among the organotin(IV) complexes, trimethyltin derivatives form a polymeric structure with trigonal bipyramidal geometry [19-22]. The representative structure of this class is given in Fig. 3. Here the geometry around the tin atom is distorted trigonal bipyramidal. Three methyl groups are bonded to the Sn atom at equatorial positions with essentially identical bond distances [mean Sn-C = 2.119(6) Å]. The Sn atom lies 0.065(2) Å out of the equatorial plane formed by three methyl C atoms, towards the more strongly bonded atom O1. The O-Sn-O angle is approximately linear [171.21(9)°] and the C-Sn-C and O-Sn-C angles are within the expected range of values [C-Sn-C = 119.24(15)°-120.62(15)° and O-Sn-C = 84.47(12)-97.24(12)°] [21].

Earlier reports [23-26] have shown that the coordination of different alkyl groups with O-donor ligands does not change the coordination geometry of triorganotin complexes and they show a polymeric structure with the trigonal bipyramidal geometry. Examples are given in Figs. 4 [23], 5 and 6 [24].

The tetrameric structure shown in Fig. 7 is also reported in the literature [27] which is formed with tributyltin moiety. The

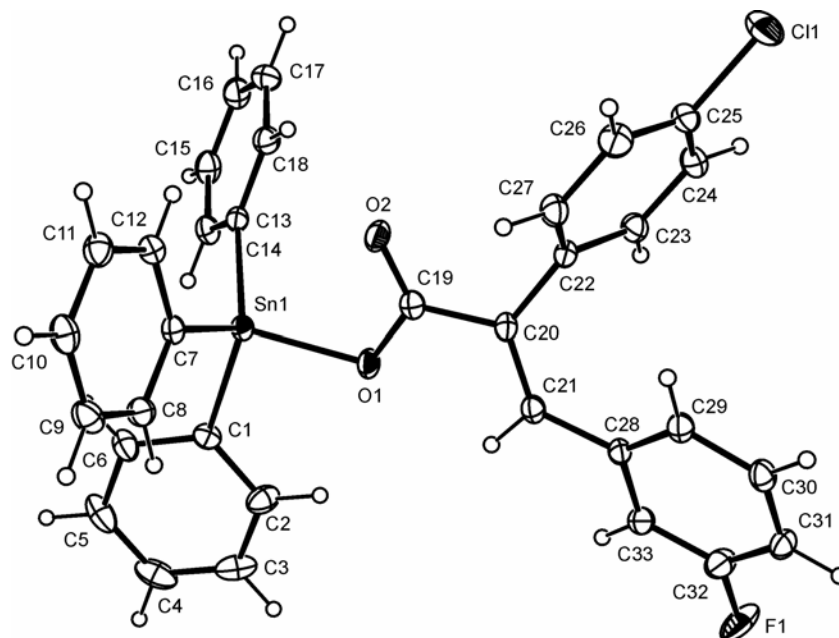


Fig. 1. Triphenyltin(IV) [3-(3-fluoro-phenyl)-2-(4-chlorophenyl)-2-propenoate] [15].

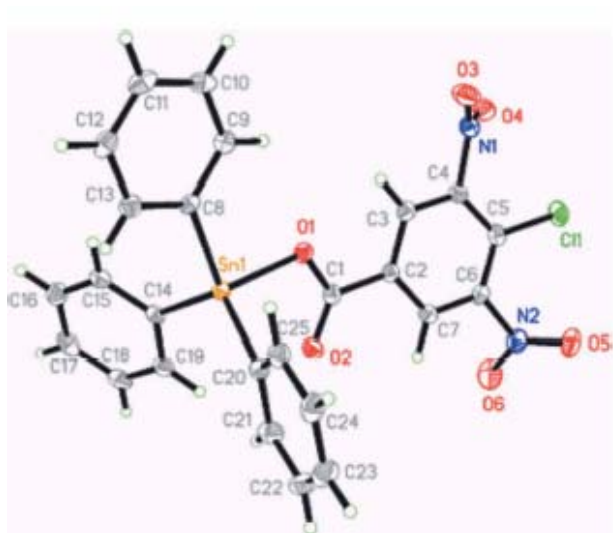


Fig. 2. Triphenyltin(IV)-(4-chloro-3,5-dinitrobenzoate) [16].

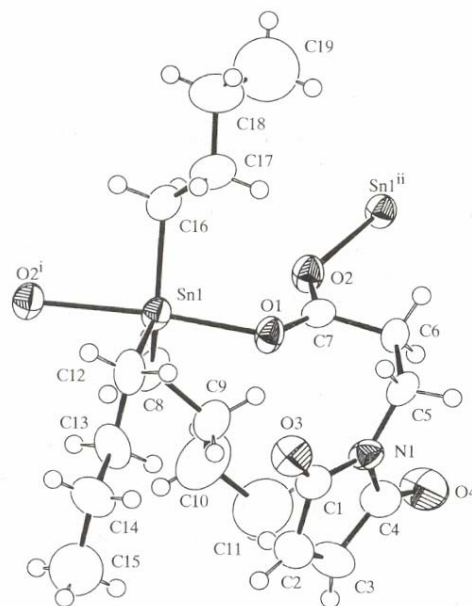


Fig. 4. Tri-*n*-butyl(N-maleoyl- β -alaninato)tin [23].

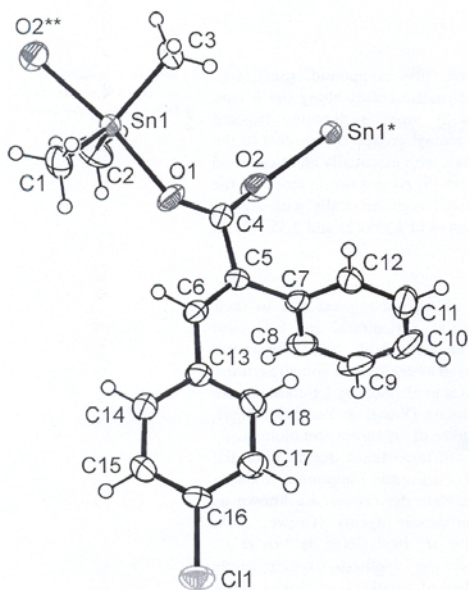


Fig. 3. *catena*-Poly[[tri-methyltin]- μ -2-phenyl-3-(4-chlorophenyl) propenoatoO:O] [21].

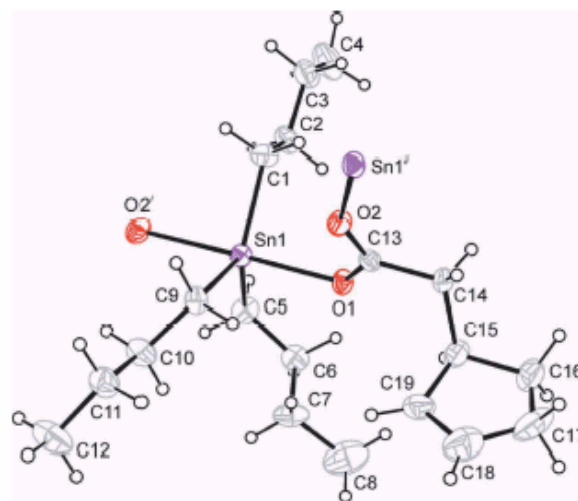


Fig. 5. *catena*-Poly[[tri-*n*-butyltin(IV)]- μ -cyclopent-2-enylacetato-O:O] [25].

structure forms an isolated cyclotetrameric 16-membered ring that is located about crystallographic centre of inversion so that two independent *n*-Bu₃SnL units comprise the asymmetric unit. This aggregation arises as the carboxylate ligands are bidentate bridging, albeit forming asymmetric bond distances of approximately 2.2 and 2.6 Å. The individual tin atom coordination geometry is based on the *trans*-R₃SnO₂ trigonal

bipyramid with the above mentioned disparity in the Sn-O bond distances notwithstanding. The axial angle of 171.19(10)° for the Sn1 atom is more significantly distorted from the ideal angle compared with Sn2 atom, for which the equivalent angle is 177.62(11)°. There are three R₃Sn(O₂CR') structures reported in the literature [27-29] that adopt tetrameric motif. The rationalization of the appearance of

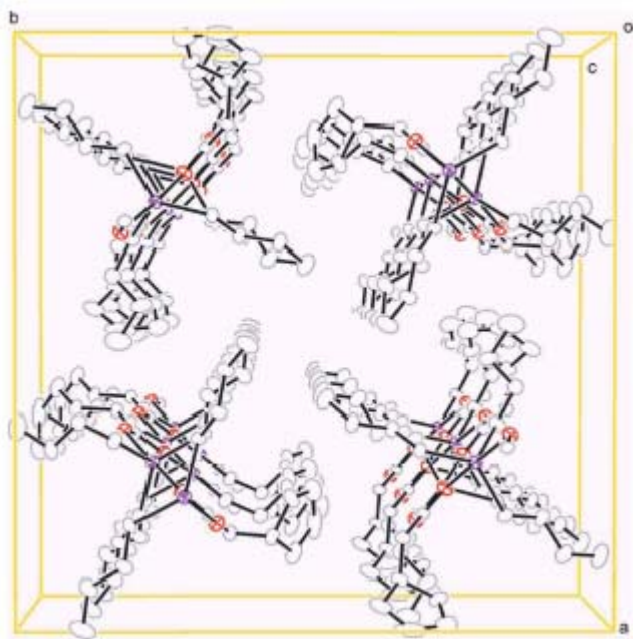


Fig. 6. *catena*-Poly[[tri-*n*-butyltin(IV)]- μ -cyclopent-2-enylacetato-O:O] [25].

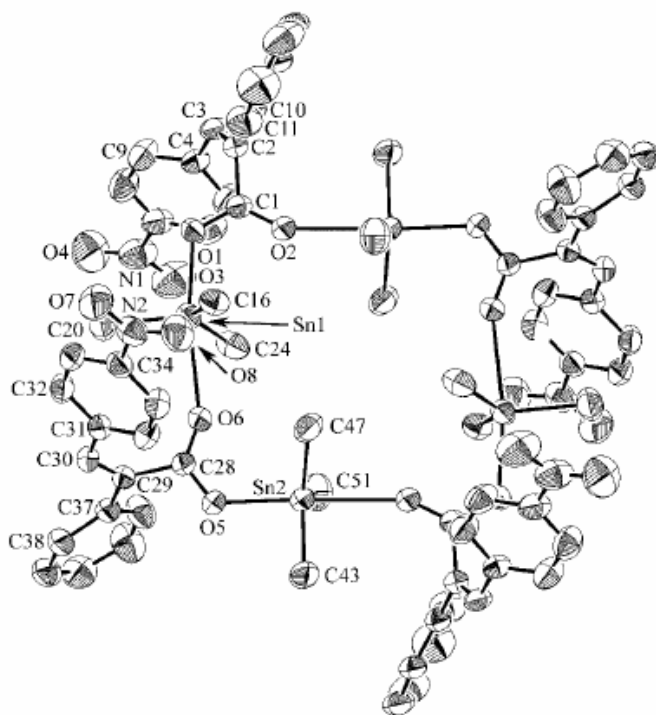


Fig. 7. Tetrameric *catena*-poly[[tri-*n*-butyltin(IV)]- μ -cyclopent-2-enylacetato-O:O] [27].

these cyclotetrameric structures, which may be thought of as being intermediate between monomeric and polymeric extremes described above, remains elusive.

In contrast to tributyltin(IV) [30,31] and polymeric and dimeric triphenyltin(IV) [32] analogues, tribenzyltin complexes [33] exhibit the same monomeric *trans*-R₃SnO₂ structural motifs. The Sn atom has slightly distorted trigonal bipyramidal coordination geometry with equatorial benzyl groups and the axial positions occupied by an O atom from the carboxylate ligand and the O atom from the water ligand.

Six Coordinated Complexes

In organotin complexes, distorted octahedral geometry results by asymmetrical coordination of the carboxylate ligands to the Sn atom. Representative structure of this class is given in Fig. 8 [34]. The structure is composed of discrete monomeric molecules in which six-coordinated Sn atoms are bonded to two *n*-butyl groups and two 2,3-bis(4-chlorophenyl)propenoates ligands. The geometry around the Sn atom is highly distorted octahedral and can be best described as a skew-trapezoidal planar geometry with two additional axial ligands. The Sn atom lies 0.190(2) Å out of the plane formed by asymmetrically bonded O atoms of the carboxylate ligands, while the two *n*-butyl groups lie above and below this plane. The mean Sn-C distance of 2.117(13) Å and a C-Sn-C angle of 139.18(18)° is observed. The carboxylate ligands are asymmetrically coordinated to the Sn atoms, with Sn-O covalent bonds [mean = 2.098(6) Å] that are significantly shorter than the dative bonds [mean = 2.602(12) Å].

Distorted octahedral geometry was observed by coordination of different R groups with O-donor ligands. An example of this class with dimethyltin moiety is shown in Fig. 9 [35].

Distannoxanes

Within the diorganotin complexes, distannoxanes are reported in the literature with five or six coordinated geometry [36-39]. These distannoxanes observed with different alkyl groups such as ethyl [36] (Fig. 10), methyl [37] (Fig. 11) and butyl groups [38,39] (Figs. 12 and 13). In Fig. 10, the complex is composed of two independent centrosymmetric dimers lying about inversion centers. In each dimer, the central

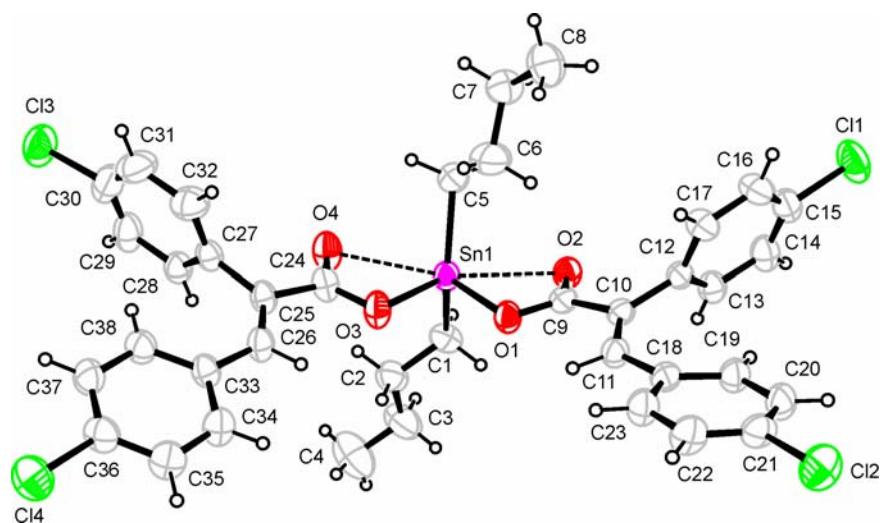


Fig. 8. Di-*n*-butyltin(IV) bis-[2,3-bis(4-chlorophenyl)propenoato-O,O'] [34].

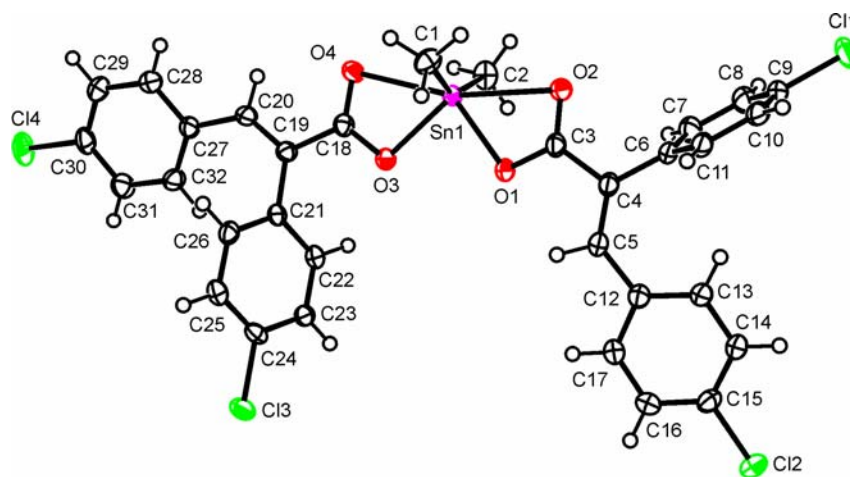


Fig. 9. Dimethyltin(IV) bis[2,3-bis(4-chlorophenyl)propenoato-O,O'] [35].

Sn_2O_2 core is fused with two four membered (Sn_2O_2) and two six membered $\text{Sn}_2\text{O}_3\text{C}$ rings. The endocyclic Sn atoms are six coordinated in a skew trapezoidal bipyramidal arrangement. The exocyclic Sn atoms are five coordinate and show distorted trigonal bipyramidal geometry. The cyclopentenylacetate ligand shows different modes of coordination with tin. In both dimers, the Sn-C distances lie in a very narrow range [2.118(4)-2.134(4) Å], while the Sn-O distances range between 2.042(2) and 2.314(3) Å for strong bonds and

between 2.683(3) and 2.658(3) Å for relatively weaker Sn-O bonds.

SULFUR DONOR LIGANDS

It was demonstrated that seemingly closely related compounds may adopt different structures even though the only difference between the compounds was in the nature of the tin or carboxylate-bound R groups.

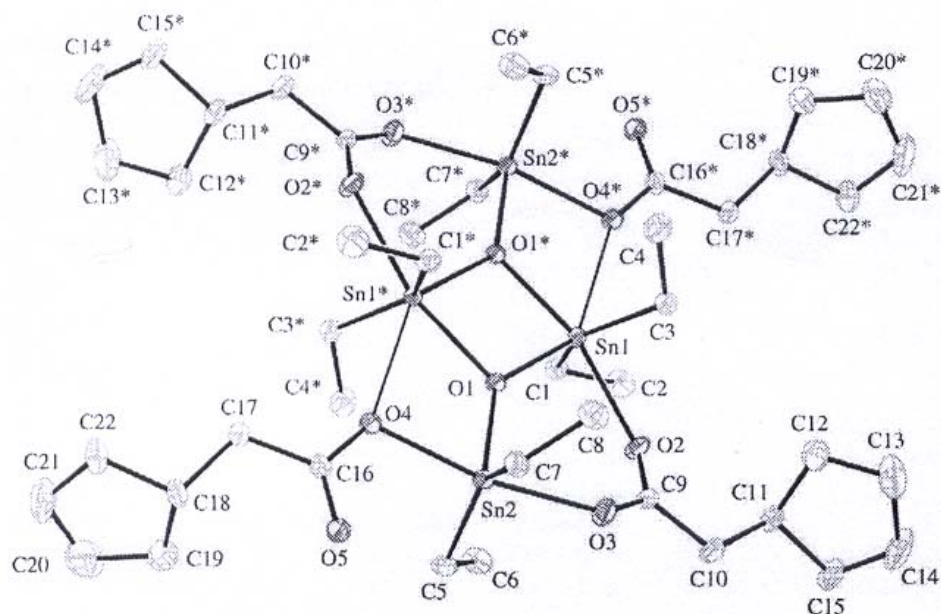


Fig. 10. Bis(cyclopentylacetato)tetraethyldistannoxane dimer [36].

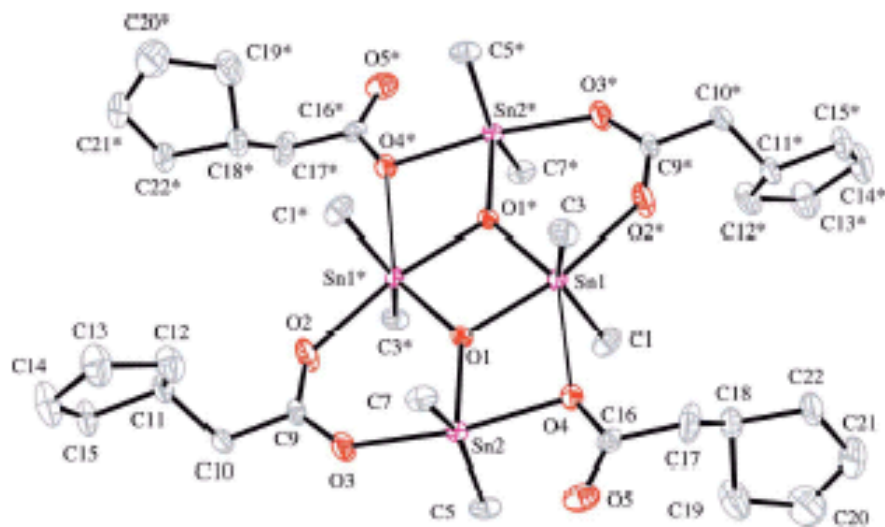


Fig. 11. Bis(cyclopentylacetato)tetramethyldistannoxane dimer [37].

Four Coordinated Complexes

Representative compound of this class with distorted tetrahedral geometry is shown in Fig. 14 [40]. The mean Sn-C [2.135 Å] and Sn-S bond lengths [2.148 Å] are comparable with those in related structures such as Ph_3SnSPh [41]. The

distortion in tetrahedral geometry is evidence by the spread of angles about the central metal. Tetragonal geometry is also observed in organotin complexes with S donor ligands (Fig. 15) [42]. As shown in the Fig. 15, the two carbamates are monodentate, coordinating to the Sn atom through S1 and S3.

Structural Chemistry of Organotin(IV) Complexes

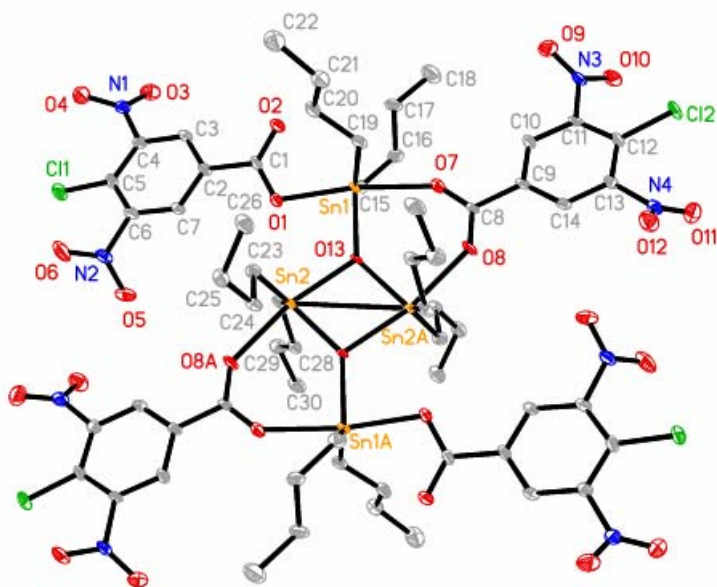


Fig. 12. Octa-*n*-butylbis-(μ -2,4-chloro-3,5-dinitrobenzoato-O:O')bis(4-chloro-3,5-dinitrobenzoato-O')di- μ -3-oxo-tetratin(IV) [38].

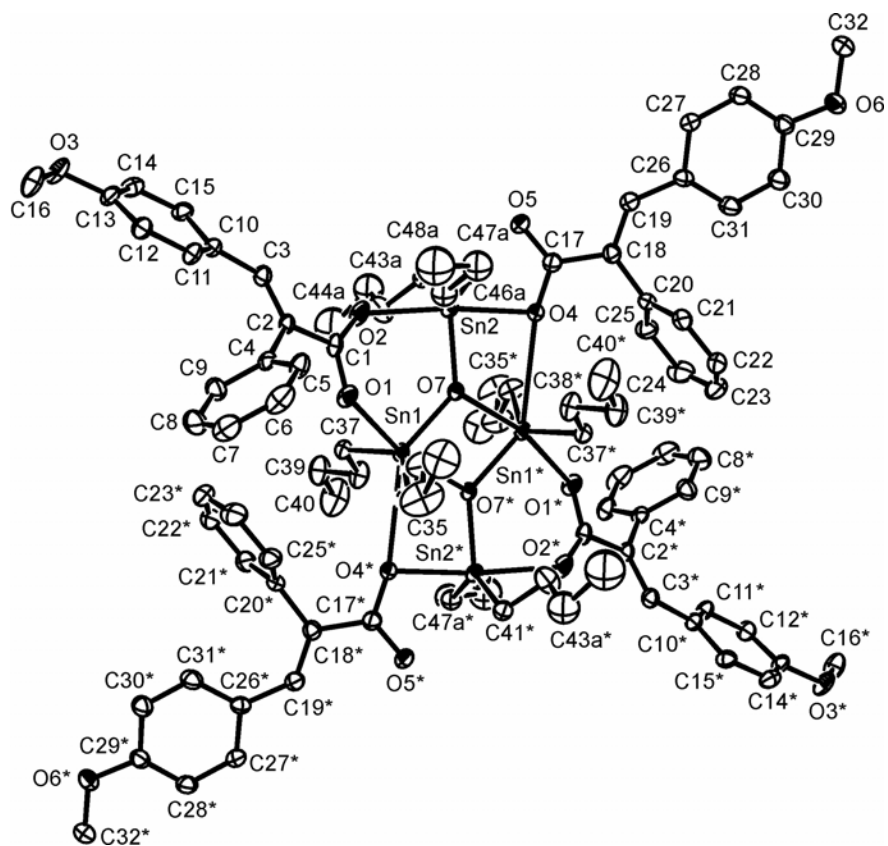


Fig. 13. Tetrabutylbis[3-(4-methoxyphenyl)-2-phenyl-2-propenoato]distannoxane dimer [39].

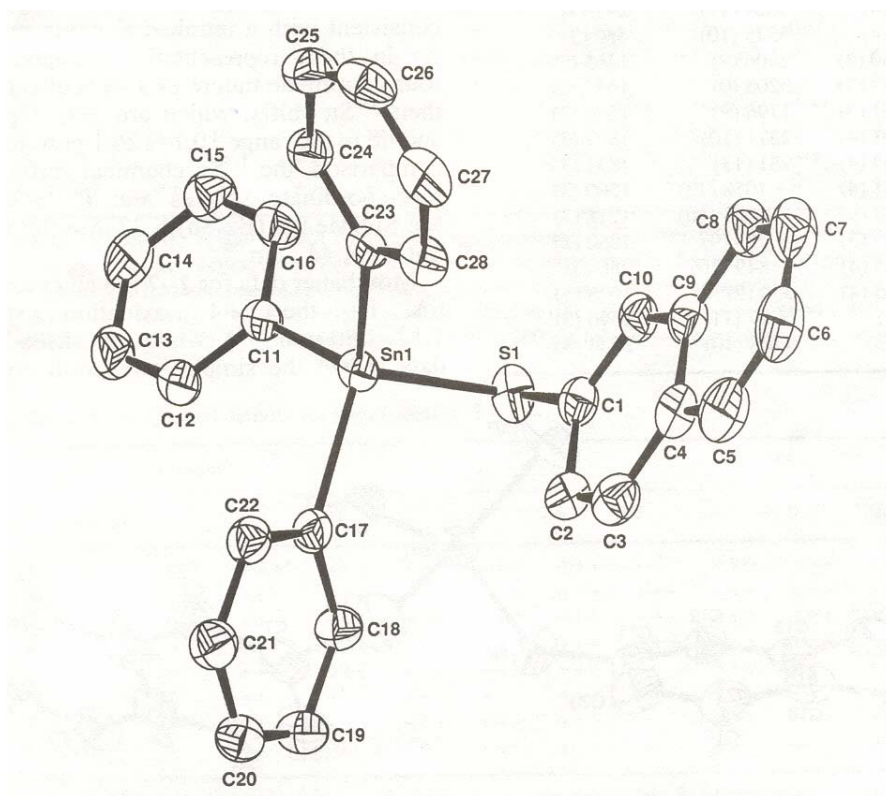


Fig. 14. Triphenyltin(IV) (naphthalenethiolato-S) [40].

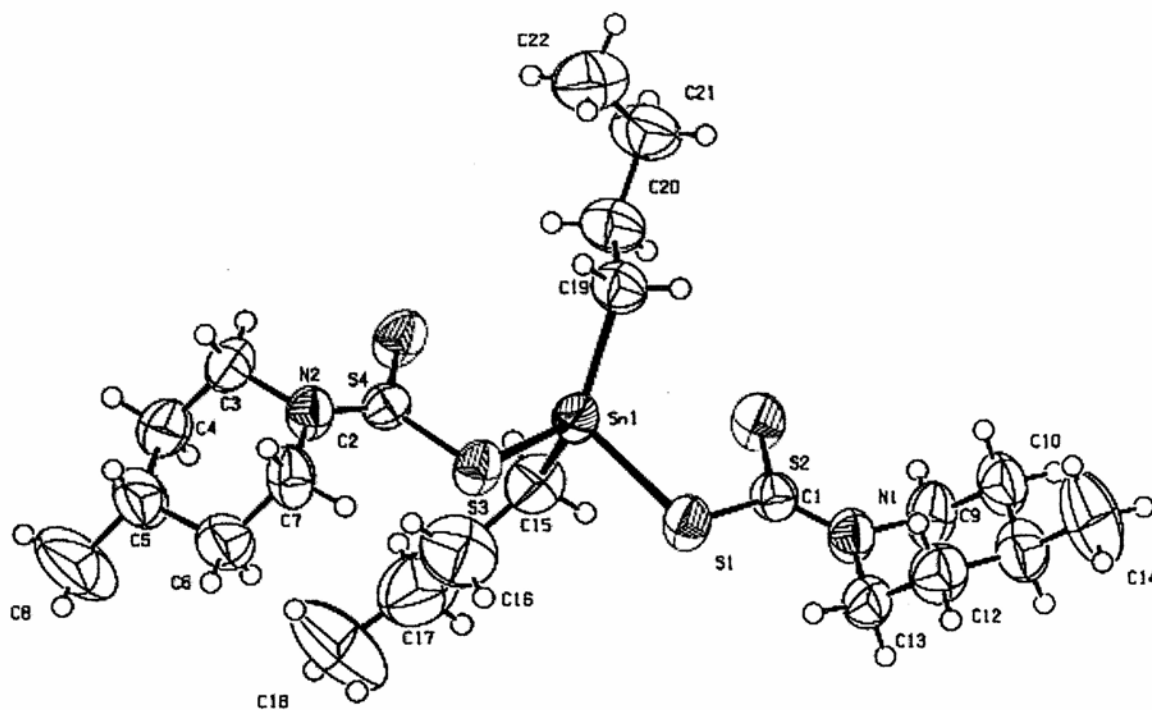


Fig. 15. 1,1-Dibutyl,1,1-bis[(4-methyl-1-piperidinyldithiocarbamato)]tin(IV) [42].

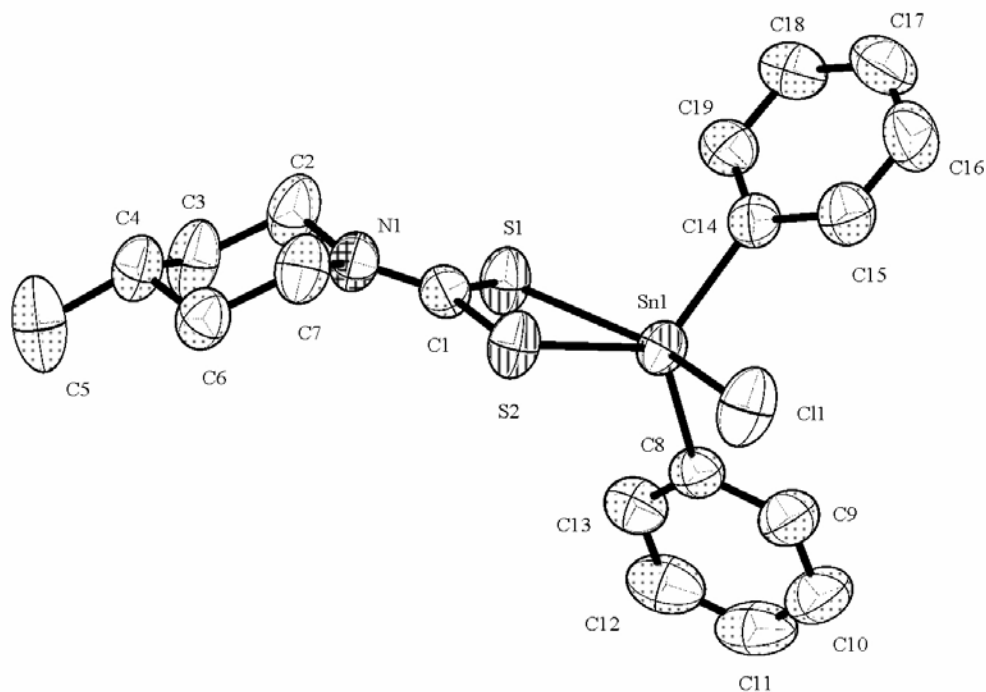


Fig. 16. Chlorodiphenyltin(4-methyl-1-piperidine-dithiocarboxylato) [43].

The bond distances of S atoms 2 and 4 with Sn are 2.919(14) and 2.536(11) Å, which are too long to be strong covalent bonds. The C15-Sn-C19 linkage is not linear, having an angle of 135.3(16)°, which is much larger than the value expected for a regular tetrahedron. The coordination geometry is best described as distorted tetragonal.

Another important distortion is caused by the asymmetric Sn-S bond lengths. Therefore, the S1-Sn-S3 angle of 83.03(14)° is not consistent with true tetrahedral geometry, but instead is consistent with distorted tetragonal geometry. As a result, the Sn atom exists in a distorted tetragonal geometry in which the basal plane is defined by four S atoms and the axial positions are occupied by two butyl substituents.

Five Coordinated Complexes

Figures 16 and 17 show the molecular structures of five coordinated complexes [43]. As seen, the coordination geometry about tin atom is penta-coordinated distorted trigonal bipyramidal with two R groups attached to tin and S(1)/(S2) occupying the equatorial positions while Cl(1) and S(2)/S(1) occupy the apical position. In this way the ligand

behaves as a bidentate species and chelates the tin atom by means of sulfur atoms [43]. Because of the “being apart of chelate” rule, the angle S(1)-Sn-S(2) is not 90° but is only 68.25(2)° so that S(2) cannot occupy exactly the corresponding trans apical position of Cl(1) and the angle between the apical groups is 154.19(3)°. The sum of the equatorial angles is 358.37(10)° showing some distortion from ideal bond angles of 360°. In complexes, the one of Sn-S bond length (Sn-S(1) 2.466(7) Å) is shorter than the other (Sn-S(2) 2.739(9) Å) suggesting the unsymmetrical coordination of the ligand. In addition, the shorter Sn-S bond lengths are very close to the sum of the covalent radii of tin and sulfur and the longer Sn-S distances are significantly less than the sum of van der Waals radii of 4.0 Å [44]. In Fig. 17, the Sn-C distances are (Sn-C(1) 2.109(3) and Sn-C(2) 2.112(3) Å). The Sn-Cl bond length (Sn-Cl(1) 2.485(8) Å) lies in the range of the normal covalent radii of 2.37-2.60 Å [45].

The crystal structure in Fig. 18 shows that the tin atom is coordinated to two sulfur atoms of the ligand and three carbon atoms of the phenyl groups [46]. The Sn-S bonds are Sn(1)-S(1) 2.485(6) Å and Sn(1)-S(2) 2.926(6) Å. Thus, the

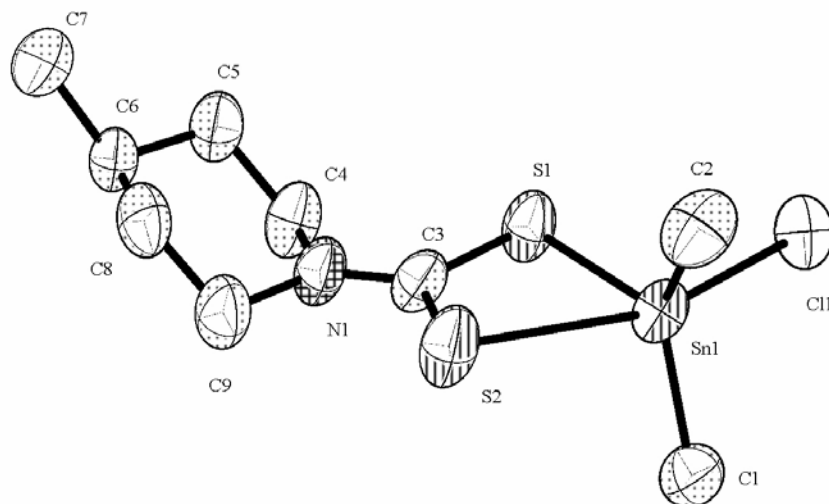


Fig. 17. Chlorodimethyltin(4-methyl-1-piperidine dithiocarboxylato) [43].

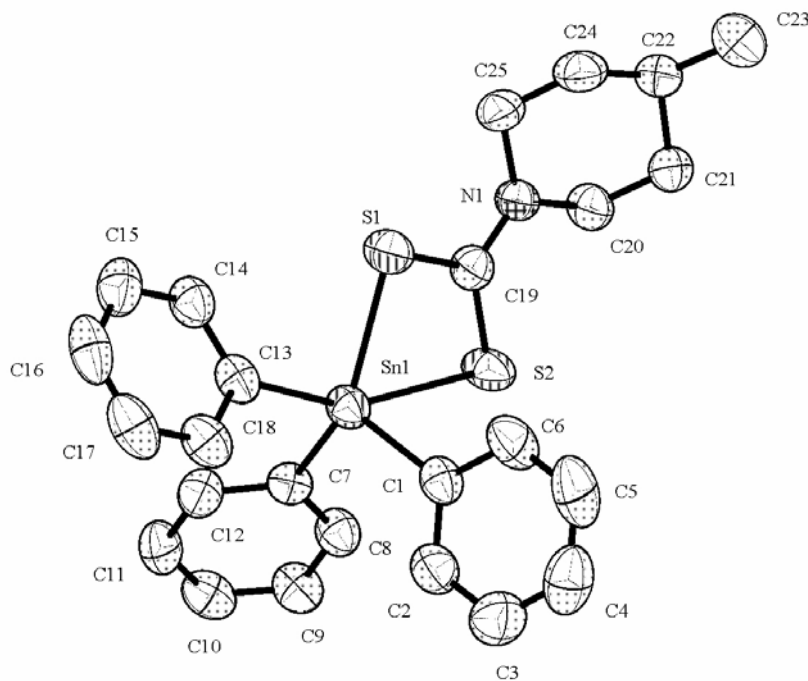


Fig. 18. Triphenyltin(IV)(4-Methylpiperidine-dithiocarbamate-S,S') [46].

shorter bond length is closed to the sum of covalent radii of tin and sulfur (2.42 Å) but longer Sn-S bond length is much smaller than the van der Waals radii (4.0 Å). In this way, the ligand behaves as a bidentate species (more correctly an anisobidentate ligand) and chelates the tin atom by means of sulfur atoms, giving a *cis*-trigonal bipyramid geometry around

the tin atom. The *cis*-trigonal bipyramid environment around tin is defined with C(13) and S(2) in the apical position and S(1), C(1) and C(7) in the equatorial position. The sum of equatorial angles, i.e., C(1)-Sn(1)-C(7) 111.10(8)°, C(1)-Sn(1)-S(1) 111.89(6)°, C(7)-Sn(1)-S(1) 126.78(6)°, is 349.8° instead of the ideal 360°; thus, the bipyramid is distorted.

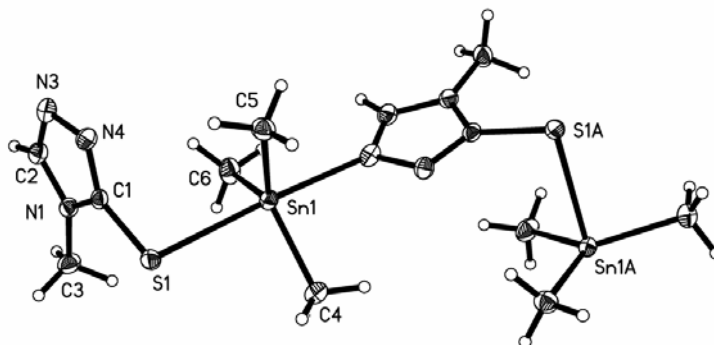


Fig. 19. *catena*-Poly[[trimethyltin(IV)]- μ -4-methyl-4H-1,2,4-triazole-3-thiolato-S:N] [48].

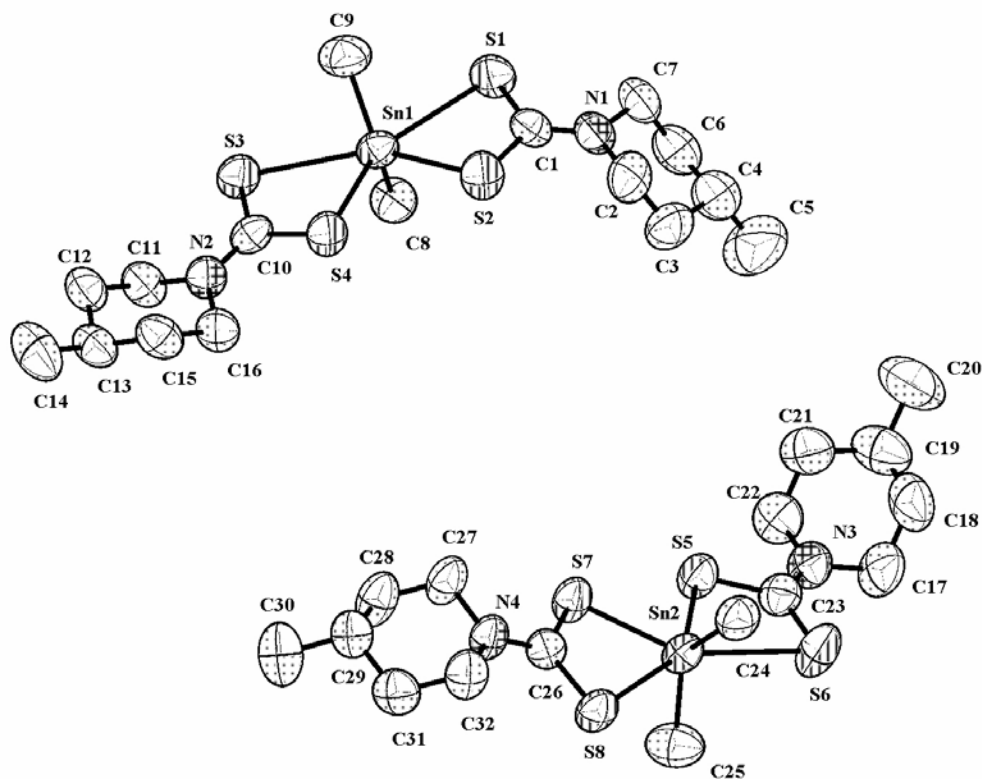


Fig. 20. Dimethylbis(4-methylpiperidine-1-dithiocarbonylato-S,S')tin(IV) [49].

Because of the “being apart of chelate” rule, the angle S(1)-Sn(1)-S(2) is not 90° but is only $65.35(19)^\circ$ so that the S(2) cannot occupy exactly the corresponding *trans* apical position of C(13) and the angle between the apical groups is $156.67(6)^\circ$. The longer S-C bond (S(1)-C(19) $1.785(2) \text{ \AA}$) is associated with shorter Sn-S bond and the shorter C-S bond. The Sn-C bond length, Sn(1)-C(13) $2.170(2) \text{ \AA}$, is very d (S(2)-C(19) $1.687(2) \text{ \AA}$) is associated with the longer Sn-S

similar to the equatorial ones, Sn(1)-C(1) $2.144(2) \text{ \AA}$, Sn(1)-C(7) $2.145(2) \text{ \AA}$. Finally, the S-C bond lengths are characteristic of the dithiocarbamate group that these distances are both intermediate between the values expected for single and double bond [47].

Crystal structure of *catena*-poly[[trimethyltin(IV)]- μ -4-methyl-4H-1,2,4-triazole-3-thiolato-S:N] [48] shown in Fig. 19 demonstrates that it consists of a long chain polymer in

which the Sn atom is bonded to three methyl groups in equatorial positions. The axial positions are occupied by S and N atoms of 4-methyl-4H-1,2,4-triazole-3-thiolato anion, with almost linear S-Sn-N angle; the Sn atom has a distorted trigonal bipyramidal geometry.

Six Coordinated Complexes

When the dithiocarbamate acts as bidentate and coordinates to the Sn atom through two sulfur atoms, a hexa-coordinated geometry results [49,50]. A representative structure is given in Fig. 20 [49]. As seen, there are two independent complexes in the asymmetric unit, with closely comparable geometries. The coordination geometry of Sn is highly distorted octahedral. The S atoms lie in the equatorial plane, with S-Sn-S angles distorted significantly from 90°. The methyl groups define C-Sn-C angles of 138.5(2) and 134.0(2)° in two independent molecules, intermediate between a *cis* and *trans* configuration [49].

CONCLUSIONS

Organotin carboxylates have a rich diversity of structural variations. It was shown that the organotin carboxylates exhibit a limited range of coordination geometries about the Sn atoms. Thus, the four coordinate Sn is invariably distorted tetrahedral, five coordinate Sn is distorted trigonal bipyramidal and six coordinate Sn is distorted octahedral. For the diorganotin complexes 4-, 5- and 6-coordinate geometries have been reported. Whereas, for triorganotin complexes, both 4 and 5-coordinate geometries are reported.

REFERENCES

- [1] T.S. Cameron, P.K. Bakshi, R. Thangarasa, T.B. Grindley, *Can. J. Chem.* 70 (1992) 1623.
- [2] A. Jancso, L. Nagy, E. Moldrheim, E. Sletten, *J. Chem. Soc. Dalton Trans.* 10 (1999) 1587.
- [3] R. Barbieri, A. Silvertri, V. Piro, *J. Chem. Soc. Dalton Trans.* 12 (1990) 3605.
- [4] Q. Li, P. Yang, H. Wang, M. Guo, *J. Inorg. Biochem.* 64 (1996) 181.
- [5] J.D. Cashion, G. Bomazetis, B.D. James, *J. Organomet. Chem.* 185 (1980) 433.
- [6] M.J. Hynes, M.O. Dowd, *J. Chem. Soc. Dalton Trans.* 3 (1987) 553.
- [7] G. Arena, A. Gianguzza, L. Pellerito, S. Musumeci, R. Purello, E. Rizzarelli, *J. Chem. Soc. Dalton Trans.* 8 (1990) 2603.
- [8] N.N. Buzas, T. Gajda, E. Kuzmann, A. Vertes, K. Burger, *Main Group Met. Chem.* 11 (1995) 641.
- [9] G. Arena, R. Cali, A. Contino, A. Musumeci, S. Musumeci, R. Purello, *Inorg. Chim. Acta* 237 (1995) 187.
- [10] P.G. Harrison, N.W. Sharpe, *Appl. Organomet. Chem.* 3 (1989) 141.
- [11] H. Preut, M. Vornefeld, F. Huber, *Acta Crystallogr. Sect. C* 47 (1991) 264.
- [12] P. Surdy, P. Rubini, N. Buzas, B. Henry, L. Pellerito, T. Gajda, *Inorg. Chem.* 38 (1999) 346.
- [13] A.G. Davies, P.J. Smith, *Adv. Inorg. Chem. Radiochem.* 23 (1980) 1.
- [14] W.N. Aldridge, in: J.J. Zuckerman, (Ed.), *Organotin Compounds: New Chemistry and Applications*, *Adv. Chem. Ser.*, Vol. 168, American Chemical Society, Washington, 1976.
- [15] Sadiq-ur-Rehman, K. Shahid, S. Ali, M.H. Bhatti, M. Parvez, *J. Organomet. Chem.* 690 (2006) 1396.
- [16] Aziz-ur-Rehman, S. Ali, M. Helliwell, S. Shahzadi, *Acta Cryst. E* 62 (2006) m1656.
- [17] Aziz-ur-Rehman, S. Ali, M. Helliwell, S. Shahzadi, *Acta Cryst. E* 62 (2006) m1778.
- [18] G. Eng, X. Song, A. Zapata, A.C. de Dios, L. Casabinaca, R.D. Pike, *J. Organomet. Chem.* 692 (2007) 1398.
- [19] M. Parvez, S. Ali, M.H. Bhatti, M. Mazhar, M.A. Choudhary, *Acta Cryst. C* 55 (1999) 1429.
- [20] M.N. Tahir, D. Ulku, M. Danish, S. Ali, A. Badshah, M. Mazhar, *Acta Cryst. C* 53 (1997) 183.
- [21] Sadiq-ur-Rehman, S. Ali, M. Mazhar, M. Parvez, *Acta Cryst. E* 60 (2004) m394.
- [22] Aziz-ur-Rehman, S. Ali, M.N. Haq, S. Shahzadi, K. Wurst, *Acta Cryst. E* 62 (2006) m451.
- [23] Aziz-ur-Rehman, S. Ali, M. Helliwell, S. Shahzadi, *Acta Cryst. E* 62 (2006) m1778.
- [24] M. Parvez, S. Ali, M.H. Bhatti, M.N. Khokhar, M. Mazhar, S.I. Qureshi, *Acta Cryst. C* 55 (1999) 1427.

Structural Chemistry of Organotin(IV) Complexes

- [25] A. Ahmad, A. Khan, S. Ali, M. Parvez, *Acta Cryst.* E62 (2006) m1192.
- [26] M. Danish, S. Ali, M. Mazhar, A. Badshah, T. Masood, E.R.T. Tiekink, *Main Group Met. Chem.* 18 (1995) 27.
- [27] Sadiq-ur-Rehman, S. Ali, A. Badshah, A. Malik, E. Ahmed, G-X. Jin, E.R.T. Tiekink, *Appl. Organomet. Chem.* 18 (2004) 401.
- [28] S.W. Ng, V.G. Kumar Das, G. Pelizzi, F. Vitali, *Heteroatom. Chem.* 1 (1990) 433.
- [29] M. Gielen, A. El-Khloufi, M. Biesemans, F. Kayser, R. Willem, *Organometallics* 13 (1994) 2849.
- [30] T.S. Basu Baul, K.S. Singh, X. Song, A. Zapata, G. Eng, A. Lycka, A. Linden, *J. Organomet. Chem.* 689 (2004) 4702.
- [31] A. Linden, T.S. Basu Baul, K.S. Singh, *Acta Cryst.* E61 (2005) m2711.
- [32] T.S. Basu Baul, K.S. Singh, M. Holcapek, R. Jirasko, R. Rivarola, A. Linden, *J. Organomet. Chem.* 690 (2005) 4232.
- [33] T.S. Basu Baul, K.S. Singh, A. Linden, X. Song, G. Eng, *Polyhedron* 25 (2006) 3441.
- [34] Sadiq-ur-Rehman, H.V. Ly, S. Ali, A. Badshah, M. Parvez, *Acta Cryst.* E60 (2004) m1144.
- [35] Sadiq-ur-Rehman, B. On-On Leung, S. Ali, A. Badshah, M. Parvez, *Acta Cryst.* E60 (2004) m984.
- [36] A. Ahmad, A. Khan, S. Ali, M. Parvez, *Acta Cryst.* E62 (2006) m1088.
- [37] A. Ahmad, A. Khan, S. Ali, M. Parvez, *Acta Cryst.* E62 (2006) m1167.
- [38] Aziz-ur-Rehman, S. Shahzadi, S. Ali, M. Helliwell, *Acta Cryst.* E62 (2006) m1734.
- [39] M. Parvez, Sadiq-ur-Rehman, K. Shahid, S. Ali, M. Mazhar, *Acta Cryst.* E60 (2004) m1465.
- [40] A. Kalsoom, M. Mazhar, S. Ali, M.F. Mahon, K.C. Molloy, M.I. Chaudry, *Appl. Organomet. Chem.* 11 (1997) 47.
- [41] P.L. Clarke, M.E. Cradwick, J.L. Wardell, *J. Organomet. Chem.* 63 (1973) 279.
- [42] Zia-ur-Rehman, S. Shahzadi, S. Ali, A. Badshah, G-X. Jin, *J. Iran. Chem. Soc.* 3 (2006) 157.
- [43] S. Shahzadi, S. Ali, M.H. Bhatti, M. Fettouhi, M. Athar, *J. Organomet. Chem.* 691 (2006) 1797.
- [44] S. Ali, S.U. Ahmad, Sadiq-ur-Rehman, S. Shahzadi, M. Parvez, M. Mazhar, *Appl. Organomet. Chem.* 19 (2005) 200.
- [45] C. Ma, J. Zhang, R. Zhang, *Can. J. Chem.* 81 (2003) 1070.
- [46] S. Shahzadi, S. Ali, M. Fettouhi, unpublished results.
- [47] G. Eng, X. Song, Q. Duong, D. Strickman, J. Glass, L. May, *Appl. Organomet. Chem.* 17 (2003) 218.
- [48] Aziz-ur-Rehman, S. Ali, S. Shahzadi, M. Helliwell, *Acta Cryst.* E62 (2006) m2328.
- [49] S. Shahzadi, S. Ali, M. Fettouhi, *Acta Cryst.* E62 (2006) m1178.
- [50] T.P. Lockhart, W.F. Manders, E.O. Schlemper, *J. Am. Chem. Soc.* 107 (1985) 7451.