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EFFECT OF ADDITIONAL METHYLENE GROUPS OF TRIPHENYLTIN(IV) COMPLEX DERIVATIVES OF DICARBOXYLIC ACIDS ON CYTOTOXICITY TESTS ON HUMAN PROMYELOCYTIC LEUKEMIC CELLS AND ^{119}Sn NMR RESONANCE

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*The complexes of triphenyltin(IV) derivatives of malonic acid (MaH), succinic acid (ScH), glutaric acid (GtH) and adipic acid (DpH) were successfully synthesized and obtained in solid form. The free ligands and complexes were characterized quantitatively using C, H and Sn elemental analysis as well as spectroscopic methods such as infrared (FTIR) and nuclear magnetic resonance (^{1}H, ^{13}C & ^{119}Sn NMR). Results of the analysis on the free ligands and the complexes showed that the coordination took place via one of the oxygen atoms from the carboxylate group. This indicated that the malonate (Ma), succinate (Sc), glutarate (Gt) and adipate (Dp) anions acted as monodentate ligands. ^{119}Sn NMR data showed that additional methylene groups across the ligands in the complexes **1** to **4** caused the ^{119}Sn peaks of the complexes to be shifted upfield. The cytotoxicity of the complexes was tested against promyelocytic leukemic cells, HL-60. The cytotoxic dose (CD_{50}) was determined using microtitration 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay. Our results showed that the four complexes synthesized gave CD_{50} values lower than etoposide. Furthermore, the addition of methylene groups to the dicarboxylic ligands causes the CD_{50} to drop gradually from complexes **1** to **4**.*

Keywords: *Bis[triphenyltin(IV)] carboxylate complexes, ^{119}Sn NMR, Cytotoxicity*

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INTRODUCTION

The synthesis and study of organotin(IV) carboxylate complexes have received considerable attention in recent years as these complexes display a large array of applications in industries as well as biocidal properties (Molloy, Purcell and Quill 1984; Evans and Karpel, 1985; Gielen *et al.* 2000; Ng *et al.* 1991a; Teoh *et al.* 1997; Zuo *et al.* 2001). Organotin(IV) carboxylate complexes are well known as biocides, homogeneous catalysts and as stabilizers in the PVC industry (Evans and Karpel 1985). In general, the biocidal activities of organotin(IV) carboxylate complexes are influenced greatly by the structure of the molecule and the coordination number of the tin atom (Parulekar *et al*. 1990). The discovery of *cis*-platin and carboplatin as anti tumor drugs are considered a major breakthrough in combating certain human cancers (Bonire and Fricker 2001; Pruchnik *et al.* 2003). However, certain side-effects of *cis*-platin have led to the search of other organometallic compounds as new anti tumor drugs, which possess high anti tumor properties but with less side-effects. Hence, compounds analogous to *cis*-platin or having tetracoordinated structures are highly targeted for anti tumor screening activity. At the early stage, organotin(IV) compounds with general formula $R_2SnX_2.L_n$ or R_2SnL_2 (R = alkyl, aryl or phenyl, X = halogen, L = coordinated ligands and n = 1 or 2) belong to the largest group selected for the anti tumor screening (Pruchnik *et al.* 2003).

Based on literature review which are well documented over the past 20 years, there are many different types of tri- and diorganotin(IV) carboxylate compounds that have been tested for their *in-vitro* activities against a large array of tumor cell lines (Willem *et al.* 1997; Gielen *et al.* 2000; Zuo *et al.* 2001). In general, among tri-, di- and mono-organotin(IV) compounds, triorganotin(IV) compounds are found to display a higher biological activity. Among organotin(IV) compounds, organotin(IV) carboxylate complexes derivatives were used as anticancer and antitumor agents *in vivo* and *in vitro* (Danish *et al.* 1995). Moreover, structure-activity relationship studies suggest that triorganotin carboxylates with a tetrahedral tin moiety or a *trans*-R_3SnO_2 geometry show significantly greater activity than compounds with the monomeric *cis*-R_3SnO_2 structural type (Baul *et al.* 2002). The function of the anionic carboxylate ligand is to aid the transport of the active organotin cationic group, R_3Sn^+ to the cell or active site (receptor site) (Danish *et al.* 1995; Nath *et al.* 2005).

Although the chemistry and crystal structure of bis[triphenyltin(IV)] succinate have been studied (Samuel-Lewis *et al.* 1992), the effects of

additional methylene (-CH_2-) groups across the ligands in the complexes on the cytotoxic properties and ^{119}Sn NMR resonance of this series have not been reported.

In this study, we are interested in the effect of adding methylene groups to the aliphatic chain between the dicarboxylic acid from MaH to DpH on cytotoxic properties and on ^{119}Sn NMR during the complexation with triphenyltin(IV). Four bis[triphenyltin(IV)] carboxylate complexes were obtained by condensation of triphenyltin(IV) hydroxide with the respective dicarboxylic acid. The complexes obtained were characterized quantitatively by microanalysis (C, H & Sn) as well as spectroscopic methods such as infrared (FTIR) and nuclear magnetic resonance (NMR). The cytotoxicity of the complexes obtained was tested against promyelocytic leukemic cells.

METHODS

Triphenyltin(IV) hydroxide (Ph_3SnOH), glutaric acid (GtH) and adipic acid (DpH) were purchased from Aldrich Chemical Company (USA). Malonic acid (MaH) and Succinic acid (ScH) were obtained from Sigma (USA) and Avocado (England), respectively. Elemental C and H analyses were carried out on a Fison EA 1108 CHNS-O analyzer. Tin was determined gravimetrically by igniting a known quantity of each complex to SnO_2. Melting points were determined in open capillaries and are uncorrected. Infrared spectra were recorded using a Perkin-Elmer FTIR GX spectrophotometer as KBr discs in the frequency range 4000–400 cm^{-1} while the polyethylene nujol mull technique was used for the range 400–200 cm^{-1}. The spectra for ^{1}H and ^{13}C NMR were recorded on a JEOL ECP 400MHz NMR Spectrometer ^{119}Sn NMR was recorded on a Bruker AC-P 400MHz FTNMR Spectrometer using deuterated chloroform, $CDCl_3$ as the solvent and tetramethylsilane, TMS was used as the internal standard.

Experimental

Bis[triphenyltin(IV)] malonate, $(Ph_3Sn)_2Ma$, **1**

The complex bis[triphenyltin(IV)] malonate, $(Ph_3Sn)_2Ma$, **1** was obtained by heating under reflux a 2:1 molar mixture of triphenyltin(IV) hydroxide, Ph_3SnOH (4 mmole, 1.47 g) and malonic acid, MaH (2 mmole, 0.21 g) in acetone (60 mL) for two hours. The Dean and Stark apparatus

was used to remove the water formed during the reaction. A clear transparent solution was isolated by filtration and kept in a bottle. After two weeks a white precipitate (1.04 g, 65% yield) was obtained. Melting point, M.p.: 146.5°C–147.7°C. Analysis found for $C_{39}H_{32}O_4Sn_2$: C, 57.96; H, 4.35; Sn, 28.73%. Calculated found for $C_{39}H_{32}O_4Sn_2$: C, 58.40; H, 4.02; Sn, 29.60%. FTIR as KBr disc (cm^{-1}): $\nu(COO)_{as}$ 1656, $\nu(COO)_s$ 1335, ν(Sn-O) 633, $\nu(Sn\text{-}Ph)_{as}$ 271, $\nu(Sn\text{-}Ph)_s$ 228. ^{1}H-NMR: δ: phenyl protons 7.41–7.48 (18H, m, $H_{meta + para}$); 7.65–7.78 (12H, m, H_{ortho}); CH_2 3.59 (2H, s) ppm. ^{13}C-NMR: δ: phenyl carbons C_{ipso} 137.77, C_{ortho} 136.78, C_{meta} 128.88, C_{para} 130.14, CH_2 41.65, COO 173.34 ppm. ^{119}Sn-NMR: δ: -100.43 ppm

Bis[triphenyltin(IV)] succinate, $(Ph_3Sn)_2Sc$, **2**

A similar method as in the synthesis of **1** was utilized. Ph_3SnOH (6 mmole, 2.20 g) and substituting succinic acid, ScH (3 mmole, 0.35 g) for malonic acid was applied. After two weeks, white crystals (1.18 g, 48% yield) was obtained. Melting point, M.p.: 154.6°C–155.2°C. Analysis found for $C_{40}H_{34}O_4Sn_2$: C, 58.58; H, 4.17; Sn, 29.75%. Calculated found for $C_{40}H_{34}O_4Sn_2$: C, 58.87; H, 4.20; Sn, 29.09%. FTIR as KBr disc (cm^{-1}): $\nu(COO)_{as}$ 1645, $\nu(COO)_s$ 1344, ν(Sn-O) 582, $\nu(Sn\text{-}Ph)_{as}$ 269, $\nu(Sn\text{-}Ph)_s$ 228. ^{1}H-NMR: δ: phenyl protons 7.40–7.42 (18H, m, $H_{meta + para}$); 7.67–7.69 (12H, m, H_{ortho}); CH_2 2.79 (4H, t) ppm. ^{13}C-NMR: δ: phenyl carbons C_{ipso} 138.24, C_{ortho} 136.89, C_{meta} 128.92, C_{para} 130.13, CH_2 30.23, COO 178.98 ppm. ^{119}Sn-NMR: δ: -108.52 ppm

Bis[triphenyltin(IV)] glutarate, $(Ph_3Sn)_2Gt$, **3**

A similar method as in the synthesis of **1** was utilized, substituting glutaric acid (2 mmole, 0.26 g) for malonic acid. After a month, a white precipitate (0.78 g, 47% yield) was obtained**.** Melting point, M.p.: 115.5°C–116.8°C. Analysis found for $C_{41}H_{36}O_4Sn_2$: C, 59.54; H, 4.76; Sn, 28.12%. Calculated found for $C_{41}H_{36}O_4Sn_2$: C, 59.32; H, 4.37; Sn, 28.60%. FTIR as KBr disc (cm^{-1}): $\nu(COO)_{as}$ 1531, $\nu(COO)_s$ 1332, ν(Sn-O) 534, $\nu(Sn\text{-}Ph)_{as}$ 272, $\nu(Sn\text{-}Ph)_s$ 234. ^{1}H-NMR: δ: phenyl protons 7.42–7.45 (18H, m, $H_{meta + para}$); 7.71–7.73 (12H, m); CH_2 1.98–2.02 (2H, m, H_{ortho}), 2.46 (4H, t) ppm. ^{13}C-NMR: δ: phenyl carbons C_{ipso} 138.24, C_{ortho} 136.84, C_{meta} 128.86, C_{para} 130.08, CH_2 21.56, 33.28; COO 179.75 ppm. ^{119}Sn-NMR: δ: -110.78 ppm

Bis[triphenyltin(IV)] adipate, $(Ph_3Sn)_2Dp$, **4**

A similar method as in the synthesis of **1** was utilized, substituting adipic acid (2 mmole, 0.29 g) for malonic acid. After heating under reflux, a white precipitate (0.81 g, 48% yield) was obtained and washed with acetone (20 mL) and dried in a desicator. Melting point, M.p.: 146.7°C–147.3°C. Analysis found for $C_{42}H_{38}O_4Sn_2$: C, 59.76; H, 5.27; Sn, 29.33%. Calculated found for $C_{42}H_{38}O_4Sn_2$: C, 59.76; H, 4.54; Sn, 28.12%. FTIR as KBr disc (cm^{-1}): $\nu(COO)_{as}$ 1633, $\nu(COO)_s$ 1334, ν(Sn-O) 557, $\nu(Sn\text{-}Ph)_{as}$ 269, $\nu(Sn\text{-}Ph)_s$ 224. ^{1}H-NMR: δ: phenyl protons 7.42–7.44 (18H, m, $H_{meta\ +\ para}$); 7.71–7.74 (12H, m, H_{ortho}); CH_2 1.66–1.68 (4H, m), 2.41 (4H, t) ppm. ^{13}C-NMR: δ: phenyl carbons C_{ipso} 138.52, C_{ortho} 137.06, C_{meta} 129.07, C_{para} 130.29, CH_2 25.37, 33.92; COO 180.42 ppm. ^{119}Sn-NMR: δ: -112.19 ppm An outline of the reaction scheme for 1, 2, 3, and 4 is given in Figure 1.

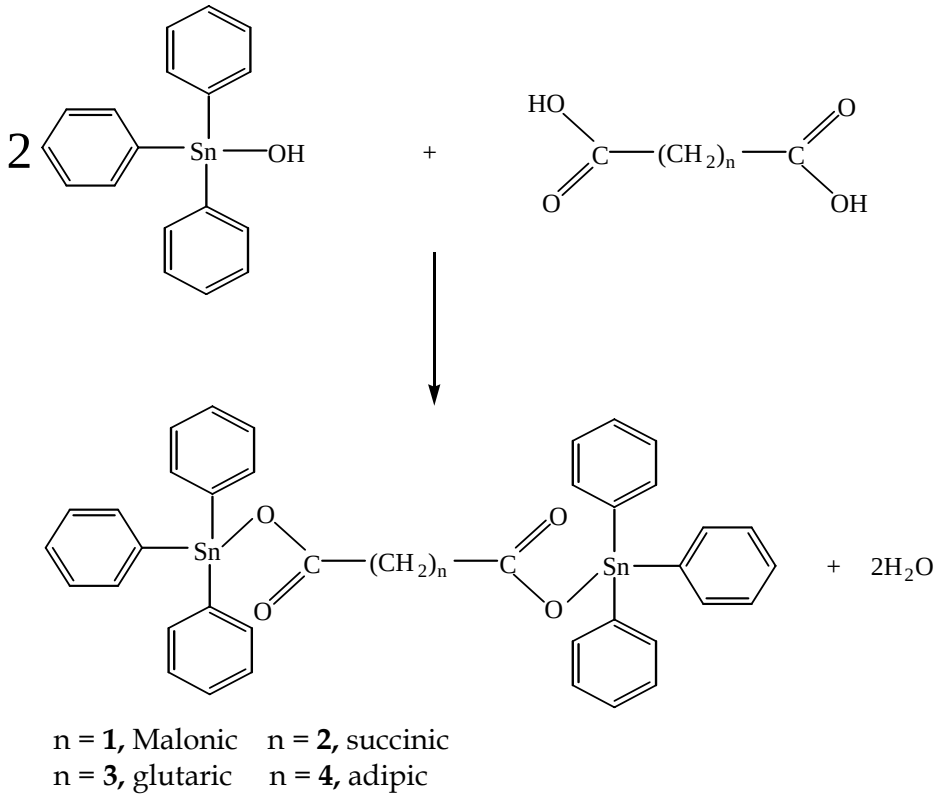


Fig. 1: Reaction scheme for the syntheses of **1–4.**

Cytotoxic Assay

Cytotoxic assay was carried out against human promyelocetic leukemic cells, HL-60 which was obtained from RIKEN Cell Bank (Tsukuba, Japan). The cells were maintained in RMPI-1640 medium supplemented with 10% fetal calf serum and 100 IU/Ml penicillin and 100 µg/mL streptomycin. Cytotoxicity was determined using the microtitration 3-(4, 5-dimethylthiazol-2-yl)-2, 5-diphenyltetrazolium bromide (MTT) assay (Ali *et al.* 2000). The assay for each concentration of compound was performed in triplicate. The fraction of surviving cells was measured relative to the untreated cells populations by measuring the absorbance values at 550 nm with the reference at 630 nm using ELISA microplate reader (Bio Tek EL 340, USA). Cytotoxicity was expressed as fifty percent cytotoxic dose (CD_{50}), i.e., the concentration to reduce the absorbance of treated cells by 50% with reference to the control (untreated cells). The CD_{50} and the S.E.M. (standard error of the mean) was determined using Probit Analysis (SPSS, version 12.0.1)

RESULTS AND DISCUSSION

The cytotoxic activity of the complexes **1–4** were evaluated against human promyelocytic leukemic cells, HL-60 which was obtained from RIKEN Cell Bank (Tsukuba, Japan) using the standard MTT assay. The CD_{50} value for complexes **1–4** are given in Table 1. The CD_{50} value for complexes **1–4** were 0.35, 0.37, 0.39 and 0.44 µM, respectively. All the CD_{50} values for complexes **1–4** were less than the reference cytotoxic compound etoposide (1.02 µM). Hence, complexes **1–4** have been demonstrated to possess potent cytotoxic properties against human

Table 1: CD_{50} value for complexes **1–4**

Complexes	CD_{50} (µM) Human promyelocetic leukemic cells, HL-60	δ(^{119}Sn), ppm
1	0.35 ± 0.012	-100.43
2	0.37 ± 0.017	-108.52
3	0.39 ± 0.014	-110.78
4	0.44 ± 0.018	-112.19
Etoposide (reference)	1.02 ± 0.051	-

The cytotoxicity values are expressed as mean ± S.E.M. from the triplicate.

promyelocytic leukemic cells, HL-60. In this study, we observed that when the ^{119}Sn signals shifted slightly to upfield region across complexes **1–4**, there was a slight decrease in cytotoxic activity. From complexes **1–4**, the ^{119}Sn peak has moved slightly upfield in the NMR spectra in the interval 2 to 4 ppm. This may due be to shielding phenomena arising from the addition of methylene (-CH_2-) group across complexes **1–4** (Nath *et al.* 2005). This phenomenon is attributed to the electron back-donation of the methylene group to the tin atom in conjunction with the additional one methylene group from complexes **1–4**. The upfield shift can be explained in terms of an increase in the electron density on the central tin atom and finally the increase of its s-character; hence a relatively more stable Sn-O bonding is formed upon complexation (Holeček *et al.* 1983b). As a result, our study showed the slightly decreased cytotoxic activity from complexes **1–4** may be due to strong Sn-O bonding upon complexation leading to the decrease of hydrolytic properties of complexes to form Ph_3Sn^+ cations.

The chemical shifts δ(^{119}Sn) for triphenyltin(IV) carboxylate lie in a broad range from -40 to -260 ppm (Holeček *et al.* 1983b), but four-coordinated triphenyltin(IV) carboxylate complexes display chemical shifts δ(^{119}Sn) in the range -40 to -120 ppm (Holeček *et al.* 1983a, 1983b) as it is well known that the δ(^{119}Sn) values in the ^{119}Sn NMR are markedly dependent on the coordination properties around the tin atom in the triphenyltin(IV) carboxylate complexes. For complexes **1** and **2**, sharp peaks were observed at -100.43 and -108.52 ppm, respectively. Complexes **3** and **4** showed signals at -110.78 and -112.19 ppm, respectively. All the ^{119}Sn signals for the complexes **1–4** indicate that the tin atom is four-coordinated. The ^{n}J(^{119}Sn-^{13}C) data for complexes **1–4** in $CDCl_3$ solution are also in accord with triphenyltin compounds with four-coordinated tin (Holeček *et al.* 1983a, 1983b). The ^{119}Sn NMR data for complexes **1–4** in $CDCl_3$ solution are listed in Table 2.

Table 2: ^{119}Sn NMR and ^{n}J(^{119}Sn-^{13}C) data for complexes **1–4**

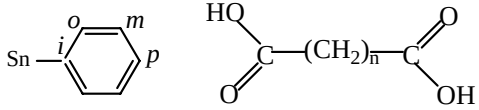
Complexes	δ(^{119}Sn), ppm	^{n}J(^{119}Sn-^{13}C), Hz			
		n = 1	n = 2	n = 3	n = 4
1	-100.43	a	49.20	63.80	a
2	-108.52	647.27	48.43	63.04	13.07
3	-110.78	a	47.78	64.74	12.33
4	-112.19	a	47.66	63.04	13.07

[a] non-observed

Table 3: ^{1}H and ^{13}C NMR data for complexes **1–4**

Complexes	^{1}H NMR (ppm)		^{13}C NMR (ppm)			
	δH(phenyl)	**δH$(CH_2)_n$**	**δC(phenyl)**		**δC$(CH_2)_n$**	**δC(COO)**
1	H_{m+p}; 7.41–7.48 (m) 18H H_o; 7.65–7.78 (m) 12H	n = 1; 3.59 (s) 2H	C_i; 137.77 C_o;136.78	C_m; 128.88 C_p;130.14	n = 1; 41.65	173.34
2	H_{m+p}; 7.40–7.42 (m) 18H H_o; 7.67–7.69 (m) 12H	n = 2; 2.79 (t) 4H	C_i; 138.24 C_o;136.89	C_m;128.92 C_p;130.13	n = 2; 30.23	178.98
3	H_{m+p}; 7.42–7.45 (m) 18H H_o; 7.71–7.73 (m) 12H	n = 3; 1.98–2.01 (m) 2.46 (t) 4H	C_i; 138.24 C_o;136.84	C_m;128.86 C_p;130.08	n = 3; 21.56, 33.28	179.75
4		n = 4; 1.66–1.68 (m) 4H 2.41 (t) 4H	C_i; 138.52 C_o;137.06	C_m;129.07 C_p;130.29	n = 4; 25.37, 33.92	180.42
GtH		n = 3; 2.03–2.07 (m) 2H 2.47 (t) 4H	-		n = 3; 19.89, 33.11	178.19

s = singlet, t = triplet, m = multiplet
i = ipso, *o* = ortho, *m* = meta, *p* = para



The relevant data obtained from the ^{1}H and ^{13}C NMR spectra for the complexes **1–4** are presented in Table 3. Chemical shift values are relative to an internal standard, tetramethylsilane (TMS). The ^{1}H NMR spectra for the complexes **1–4** and the integration of peaks concurred with the number of protons postulated from the structures proposed for the complexes. The ^{13}C NMR spectra of complexes **1–4** show that the chemical shifts of the $\delta(^{13}C)_{ipso}$ lie in the range 137.77–138.52 ppm indicative of a tetrahedrally coordinated Sn atom (Holeček *et al.* 1983a).

Single crystal data and crystal refinement parameters of complex **2** are presented in Table 4 and the *ORTEP* plot for complex **2** is shown in Figure 2. Crystallographic studies show that the crystal structure obtained for complex **2** is similar to the crystal structure reported by Ng (1998). However, in this study the crystal of complex **2** was obtained from acetone instead of ethyl acetate which has been used by Ng (1998). The crystal structure of complex **2** shows that each carboxylate anion of the succinic acid is bonded to each tin atom in monodentate mode. Hence, the tin atom moiety of complex **2** are four coordinated and exhibits distorted tetrahedral geometry with sp^3 hybrid orbitals (Ford and Sams 1970).

Table 4: Crystallography data for complex **2**

Data	**Bis[triphenyltin(IV)] succinate, 2**
Empirical formula	$C_{40}H_{34}O_4Sn_2$
Formula weight	816.05
Temperature	273(2) K
Wavelength, λ	Mo *K*α, 0.71073 Å
Crystal system, space group	Monoclinic, $P2_1/n$
Unit cell dimensions	a = 9.5257(7) Å, b = 19.2278(14) Å, c = 9.7482(7) Å α = 90°, β = 102.9070(10) °, γ = 90°
Volume	1740.4(2) Å^3
Z, D_c	2, 1.557 g cm^{-3}
μ & $F(000)$	1.475 mm^{-1}, 812
Crystal size	0.58 x 0.37 x 0.31 mm
θ range	2.19°–22.00°
Limiting indices index	-9<=h<=10, -20<=k<=20, -10<=l<=5
Reflections collected / unique	6661 / 2135 [R(int) = 0.0196]
S, θ = 22.00	100.0%
Max. and min. transmission	6578 and 0.4818
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	2135 / 0 / 197
Goodness-of-fit on F^2	1.078
Final R indices [I>2σ (I)]	R_1 = 0.0239 wR_2 = 0.0592
R indices (all data)	R_1 = 0.0253 wR_2 = 0.0601
$\Delta\rho_{maks}$ dan $\Delta\rho_{min}$	0.490 e Å^{-3}, -0.475 e Å^{-3}

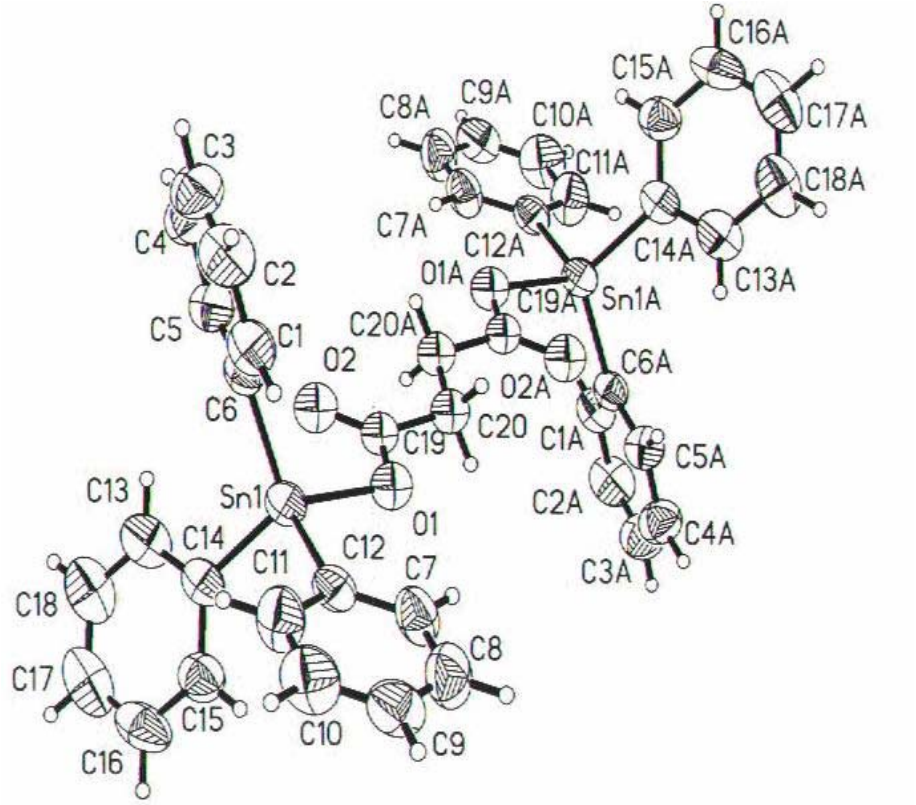


Fig. 2: *ORTEP* plot for complex **2** at 50% probability level with atom numbering scheme.

On the basis of crystal structure, infrared and ^{13}C and ^{119}Sn NMR spectroscopic studies we can conclude that the carboxylate anions in complex **2** are monodentically bonded to the tin atom. Due to the similar spectroscopic data (infrared and NMR), we conclude that complexes **1**, **3** and **4** have the same structural characteristics as complex **2**. The complexes gave sharp melting points indicating the isolation of fairly pure complexes.

The infrared spectra of the complexes **1–4** show distinct differences from the free ligands. The ν(O-H) bands which appeared in the range 2924–2954 cm^{-1} for the free ligands, are absent in the infrared spectra of complexes **1–4**. The $\nu(COO)_{as}$ band of the complexes are shifted to lower wavenumber compared to the free ligands, an observation also reported by others (Harrison and Philips 1979; Ronconi *et al.* 2003). Complexes **1**, **2**, **3** and **4** show $\nu(COO)_{as}$ and $\nu(COO)_{s}$ in the range of 1656–1531 and 1332–1344 cm^{-1} respectively. Generally, the infrared spectra for bidentically

chelated diorganotin(IV) carboxylate complexes show a value greater than 200 cm^{-1} for $\Delta\nu = [\nu(COO)_{as} - \nu(COO)_s]$ (Vatsa *et al.* 1990; Sandhu, Sharma and Tiekink 1991).

However, for triorganotin(IV) carboxylate complexes, the values of $\Delta\nu$, which are in the range greater than 200 cm^{-1} indicating a monodentate bonding mode for the carboxylate moiety (Kumar-Das *et al.* 1986; Ng, Kumar Das and Tiekink 1991b; Baul *et al.* 2002; Stefano *et al.* 2002). For bridging and chelating behaviour, the magnitude of $\Delta\nu$ values would be expected to be smaller or equal to 150 cm^{-1} (Kumar Das *et al.* 1986; Ng, Kumar Das and Tiekink 1991b; Baul *et al.* 2002; Stefano *et al.* 2002; Yeap and Teoh 2003). For triphenyltin(IV) carboxylate complexes, a value greater than 200 cm^{-1} for $\Delta\nu$, has been reported for monodentically coordinated carboxylate group with respect to a single tin atom (Ford and Sams 1970; Huber, Mundus-Glowacki and Preut 1989; Ng, Kumar Das and Tiekink 1991b). This phenomenon has been attributed to the steric effect of the triphenyltin(IV) moiety (Holeček *et al.* 1983a). Hence, the value for $\Delta\nu$ found for **1**, **2**, **3** and **4** which were 321, 301, 199 and 299 cm^{-1}, respectively, could signify the presence of monodentically chelated carboxylates. The assignment of important infrared bands for the free ligands and complexes are presented in Table 5.

A band was observed in the region 534–633 cm^{-1} and may be assigned to vibrations associated with the Sn-O stretching (Okawara and Yasuda 1964; Srivastava and Tandon 1970) indicating that the Sn atom is bonded to the oxygen atom from the acidic group of the ligand. The far-infrared spectra of complexes 1–4 show another two weak bands in the range 269–272 and 224–234 cm^{-1} attributed to the $\nu(Sn\text{-}Ph)_{as}$ and $\nu(Sn\text{-}Ph)_s$ vibration. Generally, ν(Sn-Ph) bands are observed in the far-infrared region (lower wavelength) compared to the ν(Sn-C) of dialkyltin(IV) or trialkyltin(IV) complexes. This lowering of frequencies is merely due to the mass effect of the Sn-Ph. Disappearance of the ν(O-H), shifting of ν(COO) and occurrence of ν(Sn-O) and ν(Sn-Ph) bands in complexes 1–4 indicate the coordination of the carboxylate groups to the Sn atom.

Table 5: Important infrared data for the free ligands and complexes **1–4** (cm^{-1})

Complexes	ν(OH)	$\nu(COO)_{as}$	$\nu(COO)_{s}$	Δν	ν(Sn-O)	$\nu(Sn\text{-}Ph)_{as}$	$\nu(Sn\text{-}Ph)_{s}$
MaH	2947	1728	1315	413	-	-	-
ScH	2933	1693	1311	382	-	-	-
GtH	2954	1708	1305	403	-	-	-
DpH	2924	1703	1355	348	-	-	-
1	-	1656	1335	321	633	271	228
2	-	1645	1344	301	582	269	228
3	-	1531	1332	199	534	272	234
4	-	1633	1334	299	557	269	224

CONCLUSION

The complexes $(Ph_3Sn)_2Ma$, **1**; $(Ph_3Sn)_2Sc$, **2**; $(Ph_3Sn)_2Gt$, **3** and $(Ph_3Sn)_2Dp$, **4** have been successfully synthesized. Elemental analysis C, H and Sn data obtained are in agreement with the predicted formula. The infrared spectra of these complexes show the presence of monodentate carboxylate ligand. The ^{1}H NMR spectra show that the calculated number of protons for each functional group in the complexes is equal to the number predicted from the molecular formula. The ^{13}C and ^{119}Sn NMR spectra of the complexes show that the ligands act in a monodentate manner. Overall, all the four complexes obtained show promising cytotoxic activity compared to reference drug (etoposide).

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