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The synthesis and tin-119m Mössbauer spectra of a series of di (4-substituted phenyl) tin dichloride complexes with nitrogen-donor ligands

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The synthesis and ^{119m}Sn Mössbauer spectra of a series of 12 new and 3 other organotin complexes of general structure $(4\text{-}ZC_6H_4)_2SnCl_2.L_2$ ($Z = CH_3$, CF_3, F, Cl, OCH_3, L_2 = 2,2′-bipyridyl, 1,10-phenanthroline, 2-aminomethylpyridine) are reported. A convenient method for the preparation of the intermediate diaryltin(IV) dihalides is given. The complexes fall into two isomeric types with either a *trans*- or *cis*-[ArSnAr] geometry. For this series 2-aminomethylpyridine gives exclusively the *cis*-[ArSnAr] geometry in its complexes.

Keywords: Organotin complexes, Mössbauer spectra, anti-tumour agents, aryltin chlorides

INTRODUCTION

Recent primary screening studies[1–3] on the anti-tumour activity of diorganotin(IV) dihalide complexes have revealed many compounds active towards the P388 lymphocytic leukaemia in mice. The compounds reported here, of general structure $R_2SnX_2.L_2$, have been modelled on the active platinum complexes. Structure-activity relationships have indicated that the nature of the group R (alkyl or aryl) plays an important role in determining activity. In view of this observation we have prepared for antitumour testing a series of di-(4-substitutedphenyl)-tin(IV) dichloride complexes which are summarised in Table 1.

The various investigations involving *cis*-platin analogues have shown that activity is usually associated with square planar platinum (II) and octahedral platinum (IV) complexes which possess two *cis*-nitrogen donor ligands, each bearing at least one hydrogen atom and two good leaving groups such as chloride, bromide and carboxylate, also in a *cis*-configuration.[4–6]

The model tin analogues described in this paper have bidentate ligands and can exist in three possible stereoisomeric forms (1, 2 and 3).

Mössbauer spectroscopic data has already been used to assign configuration to many octahedral organotin(IV) complexes.[7] Reported in this paper are the ^{119m}Sn Mössbauer spectroscopic parameters for the series of complexes and the present writers' configurations which are tentatively assigned.

EXPERIMENTAL

Preparation of tetra-aryltins

All five tetra(4-substituted)phenyltins (Table 1) were prepared using standard Grignard procedures.[8] A solution of anhydrous tin tetrachloride in a hydrocarbon solvent was added to the appropriate aryl magnesium chloride or bromide prepared in tetrahydrofuran solution.

In each case the reaction mixture was boiled under reflux for about 2 hours and then poured into water. The tetra-aryltin was isolated by extraction with hot petroleum ether or toluene. The combined extracts were then evaporated to yield the crude solid product.

Preparation of diaryltin(IV) dichlorides

Previous methods of synthesis for these compounds include reacting together the tetra-aryltin with tin tetrachloride under pressure at elevated temperatures.[13–14] The present writers have

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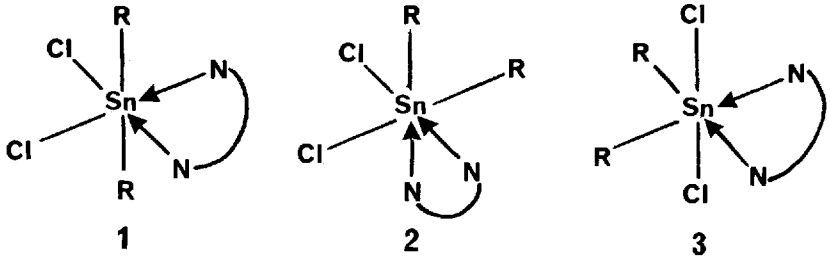


Structures 1–3 (Isomeric forms)

Table 1 Melting point and analytical data for tetra (4-substituted phenyl)tin compounds, $(4\text{-}ZC_6H_4)_4Sn$

Compound Z	Micronanalytical data. Found (calcd) (%) C	H	m.p. (°C)
OCH_3	61.53	5.06	121–22
	(61.45)	(5.16)	(134.8)[9]
F	58.09	3.51	137–39
	(57.76)	(3.23)	(144–45)[10]
CF_3	48.24	2.34	143-44
	(48.10)	(2.31)	(150–50.7)[11]
CH_3	69.74	5.87	233–34
	(69.59)	(5.84)	(236–37)[12]
Cl*	51.65	(3.13)	188–89
	(51.03)	(2.86)	(197–98)[12]

*% Cl = 24.98 (calcd 25.10).

Table 2 Melting point, analytical data and yields of diaryltin dichlorides, $(4\text{-}ZC_6H_4)_2SnCl_2$

Compound Z	Microanalytical data. Found (calcd) (%) C	H	Cl	Yield (%)	m.p. (%)
OCH_3	42.04	3.49	17.55	78	80–81
	(41.63)	(3.71)	(17.56)		(76)[15]
F	37.97	2.14	18.89	75	49–50
	(37.95)	(2.12)	(18.67)		(51)[14]
CF_3	35.10	1.67	14.76	60	84–84.5
	(35.05)	(1.68)	(14.78)		(80.5–82)[17]
CH_3	44.84	3.73	19.50	65	41–42
	(45.22)	(3.79)	(19.07)		(42.5–43.5)[13]
Cl	35.17	2.20	34.11	73	83–84
	(34.92)	(1.96)	(34.36)		(86.5)[16]

found that moderate to good yields are obtained for the five diaryltin dichlorides recorded in this paper by heating the two reagents together in toluene under reflux for up to 6 hours using a 1:1 molar ratio. In a typical preparation 0.01 moles of each reagent was used in 5 cm^3 of toluene. The toluene was removed under reduced pressure and the resulting oily product was crystallised from petroleum ether in each case.

The melting point data and yields for these diaryltin(IV) dichlorides are shown in Table 2.

Preparation of diaryltin(IV) dichloride complexes

These compounds were obtained by adding a solution of the diaryltin dichloride in methanol or diethyl ether to the solution of the Lewis base in the same solvent at room temperature. A 1:1 molar ratio of reactants was used. Typically, 0.01 moles of the dihalide and of the complexing agent were each dissolved separately in 5 cm^3 of the solvent. The complexes, which separated rapidly as colourless crystalline precipitates, were filtered off and dried in air. The Lewis bases used [1,10-phenanthroline (phen); 2,2′-bipyridyl(bipy); 2-aminomethylpyridine (AMP)] were obtained commercially. The 2,2′-bipyridyl was recrystallised before use; the others were used without purification.

The analytical and melting point data for the 15 complexes prepared are shown in Table 3.

Mössbauer spectra

^{119m}Sn Mössbauer spectra (Table 4) were obtained using a constant acceleration microprocessor spectrometer (from Cryophysics Ltd, Oxford) with a 512-channel data store. A 15 mCi Ba $^{119m}SnO_3$ source was used at room temperature and samples were packed in perspex discs and cooled to 80K, using a liquid nitrogen cryostat.

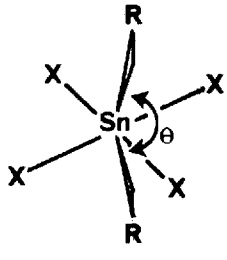
The experimental error in the measured values of isomer shift (δ) and quadrupole splitting (ΔE_Q) parameters is ± 0.05 mm s^{-1}.

Table 3 Melting point and analytical data for diaryltin complexes, $(4\text{-}ZC_6H_4)SnCl_2 . L_2$

Complex		Microanalytical data. Found (calcd) (%) C	H	N	Cl	m.p. (°C)
$Z=OCH_3$,	L_2=AMP	46.97	4.38	5.62	13.73	164–165 (dec)
		(46.92)	(4.33)	(5.47)	(13.85)	
	L_2=bipy	50.77	3.88	4.92	12.47	194–195
		(51.47)	(3.96)	(5.00)	(12.66)	
	L_2=phen	52.48	3.74	4.89	11.86	248
		(53.47)	(3.80)	(4.79)	(12.14)	
Z=F,	L_2=AMP	43.81	3.34	5.97	14.43	164–165 (dec)
		(44.31)	(3.30)	(5.74)	(14.53)	
	L_2=bipy	48.90	3.05	5.38	13.52	228–230
		(49.30)	(3.01)	(5.22)	(13.23)	
	L_2=phen	50.49	3.01	5.05	12.53	302–303
		(51.47)	(2.88)	(5.00)	(12.66)	
$Z=CF_3$	L_2=AMP	40.79	2.81	4.86	12.14	200 (dec)
		(40.86)	(2.74)	(4.76)	(12.06)	
	L_2=bipy	45.43	2.52	4.47	11.07	241–243
		(45.32)	(2.54)	(4.41)	(11.15)	(255–57)[17]
	L_2=phen	47.15	2.43	4.01	10.81	270–272
		(47.31)	(2.43)	(4.01)	(10.81)	
$Z=CH_3$	L_2=AMP	50.00	4.70	5.97	14.47	178 (dec)
		(50.04)	(4.63)	(5.84)	(14.77)	
	L_2=bipy	54.59	4.24	5.31	13.20	218–222 (dec)
		(54.58)	(4.21)	(5.31)	(13.42)	220 (dec)[18]
	L_2=phen	56.44	4.07	5.09	12.57	273
		(56.56)	(4.02)	(5.08)	(12.84)	(263)[19]
Z=Cl	L_2=AMP	42.43	3.38	5.86	26.68	192–193 (dec)
		(41.51)	(3.10)	(5.38)	(27.22)	
	L_2=bipy	46.18	2.88	4.76	24.44	227–228
		(46.45)	(2.84)	(4.92)	(24.93)	
	L_2=phen	48.26	2.89	4.69	23.66	284–285
		(48.62)	(2.72)	(4.72)	(23.92)	

RESULTS AND DISCUSSION

Quadrupole splitting parameters (ΔE_Q) together with recent X-ray diffraction data have been used by others to elucidate the configurations of some diorganotin(IV) dihalide complexes, $R_2SnX_2 . L_2$. Mössbauer ΔE_Q values have a maximum value of *ca.* $4\,mm\,s^{-1}$ for the *trans* R_2Sn isomer(1) but Sham and Bancroft[21] have shown from point charge calculations that the quadrupole splitting parameter decreases smoothly away from $4\,mm\,s^{-1}$ as the structure becomes more distorted as shown in (4) i.e. θ becomes less than 180°.



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Structure 4 (Distorted)

It has been shown[7] that the dialkyl substituted tin dihalide and pseudodihalide complexes adopt the regular configuration with θ close to 180° but that for various complexes of diphenyltin(IV) dihalides $Ph_2SnX_2 \cdot L_2$ the configuration is of the distorted *trans* geometry (4). Eight of the 15 complexes we reported have the distorted *trans* Ar_2Sn geometry, all of them having Mössbauer

Table 4 ^{119}Sn Mössbauer data for diaryltin complexes

Complex		δ (mm s^{-1})	ΔE_Q (mm s^{-1})	Γ_1 (mm s^{-1})	Γ_2 (mm s^{-1})	Inferred structure
Z = OCH_3,	L_2 = AMP	0.93	2.24	1.09	0.97	*cis* (2 or 3)
	L_2 = bipy	1.26	3.54	0.91	0.91	*trans* (4)
	L_2 = phen	1.25	3.49	0.90	0.89	*trans* (4)
Z = F,	L_2 = AMP	0.97	2.19	0.97	0.87	*cis* (2 or 3)
	L_2 = bipy	1.22	3.44	0.93	0.89	*trans* (4)
	L_2 = phen	1.23	3.49	0.94	0.93	*trans* (4)
Z = CF_3	L_2 = AMP	0.93	2.02	0.86	0.80	*cis* (2 or 3)
	L_2 = bipy	1.19	3.31	0.95	0.91	*trans* (4)
	L_2 = phen	1.01	2.01	0.91	1.08	*cis* (2 or 3)
Z = CH_3	L_2 = AMP	1.00	2.30	1.01	0.97	*cis* (2 or 3)
	L_2 = bipy	1.01	2.26	0.87	0.85	*cis* (3)
		0.91[a]	2.25[a]	—	—	
	L_2 = phen	1.27	3.52	1.09	1.12	*trans* (4)
Z = Cl	L_2 = AMP	0.94	2.13	1.06	0.97	*cis* (2 or 3)
	L_2 = bipy	1.23	3.47	0.94	0.91	*trans* (4)
		1.20[a]	3.53[a]	—	—	
	L_2 = phen	1.23	3.49	0.88	0.89	*trans* (4)

[a]Ref. 20.

ΔE_Q values in the range 3.54–3.31. All these complexes have either 1,10-phenanthroline or 2,2′-bipyridyl bidentate ligands.

All of the AMP complexes, however, have ΔE_Q values ranging from 2.02–2.30 mm s^{-1} which are consistent with either of the *cis*-[$SnAr_2$] configurational isomers 2 and 3, in both of which the C-Sn-C angle is 90° is an undistorted model. A comparison of the magnitude of the ΔE_Q values suggests an approximate correlation between this parameter and the electronic effect of the 4-substituent in the benzene ring. The strongly electron withdrawing trifluoromethyl group lowers the value of ΔE_Q to 2.02 mm s^{-1} compared with a value of 2.26 mm s^{-1} recorded for the parent diphenyltin dichloride AMP complex.[7]

The trifluoromethyl group has a pronounced effect on the ΔE_Q values for all three of the complexes prepared. Both the AMP and 1,10-phenanthroline complexes show *cis*-[$SnAr_2$] geometry and the values for ΔE_Q are the lowest encountered for this series.

The bipyridyl complex of bis(4-methylphenyl) tin(IV)dichloride is also exceptional in showing a *cis* configuration as indicated by its ΔE_Q parameter of 2.26 mm s^{-1}. This is the only complex in the series for which X-ray data is available. Kumar Das et al.,[3] have recently shown that this complex exists as the *cis*-[$SnAr_2$] configurational isomer having the distorted octahedral arrangement (3), in which the C-Sn-C angle is 108.7° and the Cl-Sn-Cl angle is 161.4° The present writers are unable, however, on the basis of the Mössbauer data alone to distinguish between configurations (2) and (3) for the remaining six complexes whose ΔE_Q values indicate a *cis* configuration. The Cl-Sn-Cl bond angle may be a factor in determining anti-tumour activity in these compounds, particularly in view of findings in the field of platinum complexes,[22] although some recent studies[3] in closely related tin compounds have revealed both active and inactive materials with very similar angles.

Further work is in progress to establish the structure and stereochemistry of this series of tin complexes, to extend the series and to further establish relationships between structure and activity in organo-tin complexes. The diaryltin complexes described in this paper are being evaluated as anti-tumour agents. Full results of the work will be published when the programme of testing is complete.

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