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The Crystal Structure of Tetra(3-methylphenyl)tin

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The crystal structure of tetra(3-methylphenyl)tin, $(3\text{-}CH_3C_6H_4)_4Sn$, has been determined from three-dimensional X-ray intensity data collected by counter methods on a computer-controlled diffractometer. The compound crystallizes in the tetragonal space group $I4_1/a$ (C_{4h}^6) with unit-cell dimensions $a = 17.370$ (13), $c = 8.285$ (9) Å and $Z = 4$. The structure was refined by a full-matrix least-squares procedure to a conventional R index of 0.031 for 1102 independent reflections. The crystal structure consists of discrete molecules with crystallographically imposed $\bar{4}$ symmetry, separated by normal van der Waals contacts. The observed Sn—C and C(aryl)—C(methyl) distances are 2.150 (3) Å and 1.517 (5) Å respectively. The methyl group is twofold disordered. Rotation of the aryl ring plane from the C—Sn—C plane is 41° which differs considerably from the value of 140.3° predicted by a geometrical analysis [Maly & Teply, Chem. Zvesti, (1953), 7, 553–562].

Introduction

We have been interested in the crystal structures of aryl Group IVa compounds of the type $(aryl)_4M$ in order to provide accurate structural parameters for use in a continuing study of the crystal packing and energetics of such molecular compounds. Of particular interest are those derivatives which retain molecular $\bar{4}$ symmetry in crystals of tetragonal symmetry (Kitaigorodsky, 1961; Karipides, Forman, Thomas & Reed, 1974). This paper is concerned with the structural investigation of one such derivative, tetra(3-methylphenyl)tin (Teply & Maly, 1953).

Experimental

Tetra(3-methylphenyl)tin was prepared following the procedure described by Krause & Becker (1920) and suitable crystals were obtained by recrystallization from ethanol. A single crystal, approximately $0.28 \times 0.28 \times 0.36$ mm, mounted along the longest dimension (c^*) was used. The tetragonal space group was uniquely determined to be $I4_1/a$ from indexed Weissenberg photographs based on the systematic absences $h +$ $k + l = 2n + 1$ for hkl; $h(k) = 2n + 1$ for $hk0$; $l = 4n$ $+ 1$ for $00l$. Accurate values of the unit-cell dimensions were obtained from the least-squares refinement of the angular settings of 12 reflections carefully measured on a Picker FACS-I automated diffractometer. The experimental density was determined by flotation in an aqueous solution of KI. The pertinent crystal data are presented in Table 1.

Three-dimensional X-ray intensity data were collected on the diffractometer already mentioned using Zr-filtered Mo $K\alpha$ ($\lambda = 0.71069$ Å) radiation. 1327 reflections out to 50° in 2θ were recorded by the θ–2θ scan technique with a 1° min^{-1} scan rate and a scan range of $2\theta(\text{Mo } K\alpha_1) - 1.0°$ to $2\theta(\text{Mo } K\alpha_2) + 1.0°$. A background count for 20 s at the start and end of each scan was taken. During the data collection the intensities of

Table 1. *Crystal data for* tetra(3-methylphenyl)tin

$(3\text{-}CH_3C_6H_4)_4Sn$	Space group $I4_1/a$ (C_{4h}^6)
$a = 17.370$ (13) Å	$M_r = 483.2$ g mol^{-1}
$c = 8.285$ (9)	$F(000) = 984$
$\lambda(\text{Mo } K\alpha) = 0.17069$ Å	$\mu(\text{Mo } K\alpha) = 10.4$ cm^{-1}
$Z = 4$	$D_o = 1.30$ g cm^{-3}
$V = 2500$ Å^3	$D_c = 1.284$

three standard reflections in different regions of reciprocal space were monitored after each 100 measurements and none showed any significant variation throughout the data collection.

The raw intensity data were assigned estimated standard deviations and reduced to values of F_o and $\sigma(F_o)$ (assuming an 'uncertainty factor', $p = 0.04$) in the manner previously described (Karipides *et al.*, 1974). Absorption corrections were not applied. 1106 reflections had $I > \sigma(I)$ and these were used in the structure determination.

Structure determination and refinement

The space group $I4_1/a$ has 16 general positions which requires the four $(3\text{-}CH_3C_6H_4)_4Sn$ molecules in the unit cell to lie on crystallographic special positions with $\bar{4}$ symmetry. There is, therefore, only one 3-methylphenyl group in the asymmetric unit. The seven independent C atoms were located from a difference Fourier map phased by the Sn atom placed at the origin. The trial structure was initially refined by a full-matrix least-squares procedure by assuming isotropic thermal motion for all atoms. At this stage a difference electron density map revealed a twofold rotational disorder of the H atoms of the methyl group. This disorder of the methyl group was accommodated by including the six experimentally found H atoms in the structure factor calculations each at half weight. The positions of these H atoms were adjusted so that the individual C—H bond lengths equalled 1.08 Å but their angular orientations were kept intact at those found from the difference Fourier map. This adjustment of the C—H distances to their true internuclear value is required in order to later establish the accurate intermolecular contact distances involving H atoms (Churchill, 1973). The aryl ring H atoms were introduced by placing them in theoretical positions assuming that the C—H bond (length fixed at 1.08 Å) bisects the calculated C—C—C angle. Also at this stage careful examination of the $|F_o|$ and $|F_c|$ list revealed that the 020, 200, 121, and 321 reflections were severely affec-

ted by secondary extinction; these reflections were not included in subsequent calculations.

The structure was further refined by full-matrix least-squares calculations assuming anisotropic motion for the Sn and C atoms. All H atoms were assigned the average isotropic temperature factors calculated from the anisotropic thermal parameters of the C atoms to which they were attached; however, H atom parameters were not varied. The quantity minimized was $\Sigma w(|F_o| - |F_c|)^2$ where the weight applied to each observation was taken to be $1/\sigma^2(F_o)$. New H parameters were calculated after each least-squares run. The final refinement resulted in a conventional R value, $\Sigma(|F_o| - |F_c|)/\Sigma|F_o|$, of 0.031 and a weighted R value, $[\Sigma w(|F_o| - |F_c|)^2/\Sigma w|F_o|^2]^{1/2}$, of 0.036. The final standard deviation in an observation of unit weight was 1.34. There were 1102 data and 66 variable parameters yielding a data:parameter ratio of 16.7:1. An analysis of $w(|F_o| - |F_c|)^2$ as a function of $|F_o|$ or $\sin\theta/\lambda$ revealed no dependence on these quantities suggesting that the chosen weighting scheme was reasonable. A final difference Fourier map was featureless.

The neutral atomic scattering factors for Sn (corrected for $\Delta f'$ and $\Delta f''$) and C were taken from Cromer & Mann (1968) and Cromer & Liberman (1970). The

Table 3. *Positional and isotropic thermal parameters for hydrogen atoms* $(\times 10^4)$

The methyl hydrogen atoms marked with an asterisk are disordered and are half-weighted.

	x	y	z	B
H(2)	981	36	3231	5.7
H(4)	1722	−2260	4162	6.5
H(5)	1063	−2699	1705	6.9
H(6)	359	−1772	−6	5.6
H1(C7)*	2405	−633	5018	9.8
H2(C7)*	1840	−1258	6256	9.8
H3(C7)*	1507	−332	5859	9.8
H4(C7)*	2331	−1170	5510	9.8
H5(C7)*	1498	−846	6459	9.8
H6(C7)*	2047	−230	5174	9.8

Table 2. *Final positional and thermal parameters and their estimated standard deviations* $(\times 10^4)$

The anisotropic thermal coefficients are of the form: $\exp[-\beta_{11}h^2 + \beta_{22}k^2 + \beta_{33}l^2 + 2\beta_{12}hk + 2\beta_{13}hl + 2\beta_{23}kl)]$.

	x	y	z	β_{11}	β_{22}	β_{33}	β_{12}	β_{13}	β_{23}
Sn	0	0	0	39.9 (3)	39.3 (3)	147.4 (7)	0	0	0
C(1)	615 (2)	−801 (2)	1501 (3)	41 (1)	40 (1)	157 (4)	−1 (1)	1 (2)	4 (2)
C(2)	1000 (2)	−564 (2)	2894 (4)	54 (1)	44 (1)	193 (5)	1 (1)	−10 (2)	−4 (2)
C(3)	1408 (2)	−1077 (2)	3864 (4)	50 (1)	62 (2)	179 (5)	4 (1)	−10 (2)	3 (2)
C(4)	1418 (2)	−1849 (2)	3420 (5)	54 (1)	53 (1)	244 (7)	7 (1)	7 (3)	27 (3)
C(5)	1045 (2)	−2098 (2)	2037 (5)	62 (2)	40 (1)	303 (8)	0 (1)	11 (3)	−0 (2)
C(6)	646 (2)	−1576 (2)	1075 (4)	50 (1)	42 (1)	210 (6)	−2 (1)	−2 (2)	−4 (2)
C(7)	1831 (3)	−806 (3)	5362 (5)	94 (?)	95 (3)	265 (8)	17 (2)	−62 (4)	−16 (4)

H scattering factors were those given by Stewart, Davidson & Simpson (1965). Calculations were carried out on IBM 370/168 and AMDAHL 470V/6 computers with programs previously described (Karipides et al., 1974). The final atomic positional and thermal parameters and their standard deviations are given in Tables 2 and 3.*

Description of the structure and discussion

The molecular symmetry of tetra(3-methylphenyl)tin in the crystalline state is 4. Views of the molecular structure, unit-cell contents and atom-numbering scheme are presented in Figs. 1 and 2. Intramolecular bond distances and angles are given in Table 4.

The observed Sn—C(1) distance is 2·150 (3) Å which is in agreement with 2·147 (6) and 2·14 (1) Å found in tetra(4-methylphenyl)tin (Karipides & Wolfe, 1975) and tetraphenyltin (Chieh & Trotter, 1970; Ahmed & Aleksandrov, 1970) respectively. The aryl C—C distances (average 1·392 ± 0·003 Å) and the aryl–methyl distance, C(4)—C(7) 1·517 (5) Å, are normal. The aryl ring is planar; the equation of the unit-weighted least-squares plane fitted to the six ring C atoms is $0.8276X + 0.1667Y - 0.5360Z + 0.0100 = 0$. The largest deviation of any of the six C atoms from this plane is 0·006 Å. The Sn and methyl C atoms are also in this plane

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* A list of structure factors has been deposited with the British Library Lending Division as Supplementary Publication No. SUP 32121 (6 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 13 White Friars, Chester CH1 1NZ, England.
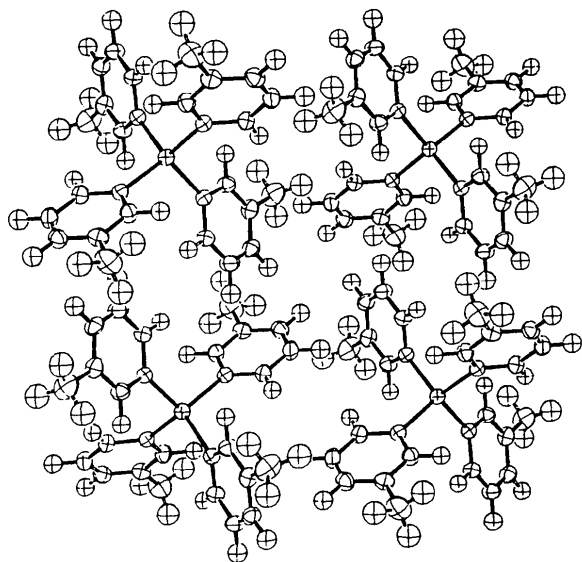
with 0·010 and 0·028 Å displacements respectively. The phenyl ring, however, is distorted from idealized D_{6h} symmetry in a manner summarized by Domenicano, Vaciago & Coulson (1975a,b). In particular the apical C(2)—C(1)—C(6) angle is 118·4 (3)° which compares with 116·4 (6)° for the corresponding angle in the isomeric tetra(4-methylphenyl)tin (Karipides & Wolfe, 1975). This approximately 2° increase in the apical C—C—C angle in the meta substituted compound is consistent with the predicted skeletal deformations of disubstituted benzenes (Domenicano, Vaciago & Coulson, 1975a).

The methyl group is twofold disordered with the two orientations represented by atoms H1(C7), H2(C7), H3(C7) and H4(C7), H5(C7), H6(C7) respectively. The aryl ring plane makes an angle of 92° with the plane H1(C7)—C(7)—C(3) which along with the dihedral
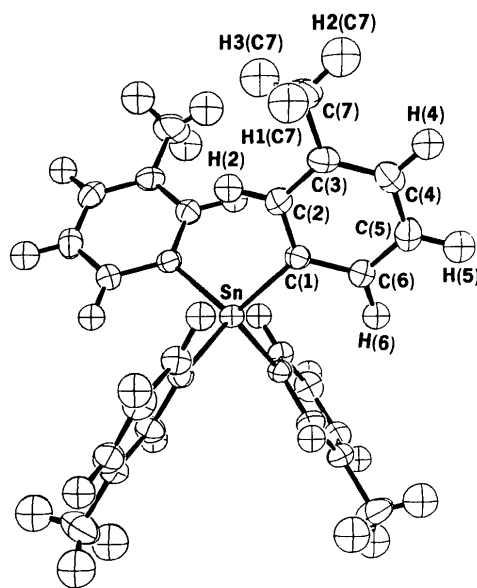

Fig. 2. The atom-numbering scheme and a view of the molecular structure perpendicular to the 4̄ axis.

Fig. 1. A projection of the structure on the *xy* plane viewed along the 4̄ axis.

Table 4. *Bond distances* (Å) *and angles* (°) *in* tetra(3-methylphenyl)tin

Sn—C(1)	2·150 (3)	C(4)—C(5)	1·386 (5)
C(1)—C(2)	1·396 (4)	C(5)—C(6)	1·392 (5)
C(2)—C(3)	1·393 (4)	C(6)—C(1)	1·392 (4)
C(3)—C(4)	1·390 (5)	C(3)—C(7)	1·517 (5)
C(1)—Sn—C(1) (x̄ȳz)	109·3 (1)	C(5)—C(6)—C(1)	120·3 (3)
C(1)—Sn—C(1) (xȳz̄)	109·54 (7)	C(2)—C(3)—C(7)	121·3 (3)
C(2)—C(1)—Sn	121·7 (2)	C(4)—C(3)—C(7)	120·6 (3)
C(6)—C(1)—Sn	119·8 (2)	H1(C7)—C(7)—H2(C7)	111·8
C(6)—C(1)—C(2)	118·4 (3)	H1(C7)—C(7)—H3(C7)	111·7
C(1)—C(2)—C(3)	122·1 (3)	H2(C7)—C(7)—H3(C7)	107·5
C(2)—C(3)—C(4)	118·1 (3)	H4(C7)—C(7)—H5(C7)	107·3
C(3)—C(4)—C(5)	120·9 (3)	H4(C7)—C(7)—H6(C7)	106·2
C(4)—C(5)—C(6)	120·2 (3)	H5(C7)—C(7)—H6(C7)	111·5

angles H2(C7)–C(7)–C(3)–C(2) 149°, H3(C7)–C(7)–C(3)–C(2) 33°, H4(C7)–C(7)–C(3)–C(2) –148°, H5(C7)–C(7)–C(3)–C(2) 93°, H6(C7)–C(7)–C(3)–C(2) –33° specifies the conformation of the disordered methyl group.

The crystal structure consists of discrete (3-$CH_3C_6H_4)_4Sn$ molecules separated by normal van der Waals distances. The shortest C $\cdots$ H intermolecular distance in the structure is C(4) $\cdots$ H(4)($\frac{1}{2} + y, x, z - \frac{1}{4}$) 2·73 Å and there are no non-bonded intramolecular contacts less than 3·18 Å. The shortest H $\cdots$ H contacts all involve methyl H atoms: H(6) $\cdots$ H1(C7)($y, x - \frac{1}{2}, z - \frac{3}{4}$) 2·54; H(4) $\cdots$ H2(C7)($y, x - \frac{1}{2}, z - \frac{3}{4}$) 2·59; H(6) $\cdots$ H4(C7)($y, x - \frac{1}{2}, z - \frac{3}{4}$) 2·67 Å, although these intermolecular distances are appreciably longer than the 2·0 to 2·4 Å range generally accepted as normal H $\cdots$ H van der Waals distances (Bondi, 1964). These long-range and weak methyl H interactions lead to a more flexible intermolecular environment about the methyl group and, perhaps, account for the observed disorder. This situation is in contrast to that found in tetra(4-methylphenyl)tin where the *para* substituted methyl group is rigidly oriented in the crystal (Karipides & Wolfe, 1975).

Maly & Teply (1953) attempted a geometrical analysis of the crystal structure of tetra(3-methylphenyl)tin. Their structure, determined theoretically by optimizing the intermolecular van der Waals contacts of selected non-bonded atom-pair interactions, is not in agreement with the crystal structure reported here. For example, the aryl ring plane in our experimental structure is twisted 41° from the valency angle plane C(1)–Sn–C(1)($\bar{x}, \bar{y}, \bar{z}$) whereas in the structure predicted by Maly & Teply (1953), the corresponding angle is 140·3°. In each case the indicated conformation angle is positive for a clockwise rotation looking from the aryl ring to the Sn atom. These results emphasize that extreme caution must be exercised in predictions of crystal structures using such geometrical analyses based on only a relatively few non-bonded interactions (Karipides & Haller, 1972). Clearly, a preferable procedure is to minimize the total lattice (packing) energy which includes the contributions of all intermolecular interactions.

The crystal structures of a number of tetra(aryl)tin compounds have been reported which crystallize in tetragonal space groups and include tetraphenyltin, $P\bar{4}21c$, (Chieh & Trotter, 1970; Ahmed & Aleksandrov, 1970), tetrakis(pentafluorophenyl)tin, $I4_1/a$, (Karipides *et al.*, 1974), tetra(4-methylphenyl)tin, $I\bar{4}$, (Karipides & Wolfe, 1975), tetra(4-methoxyphenyl)tin, $I\bar{4}$, (Ismailzade, 1958) and tetra(3-methylphenyl)tin, $I4_1/a$, described in this paper. Of particular interest is the constancy of molecular S_4 symmetry in all of these derivatives. Since the nature of the aryl substituent and space groups and hence molecular packing vary considerably, the occurrence of the same molecular symmetry strongly suggests that the molecular conformation of S_4 symmetry is energetically favored in crystals of tetragonal symmetry. This idea is consistent with recent studies on the preferred conformations of tetra(aryl)-methanes and -silanes (Hutchings, Andose & Mislow, 1975; Robbins, Jeffrey, Chesick, Donohue, Cotton, Frenz & Murillo, 1975; Ahmed, Kitaigorodsky & Mirskaya, 1971; Glidewell & Sheldrick, 1971).

Tetra(3-methylphenyl)tin is the first example of a tetra(aryl) Group IV*a* compound involving an unsymmetrically substituted phenyl group. For such a species with molecular S_4 symmetry there are two diastereomeric conformers which are possible corresponding to the structures where the methyl group is relatively nearest the plane through the center of the molecule and normal to the $\bar{4}$ axis (*exo*) or relatively furthest from the same plane (*endo*). The observed conformation in tetra(3-methylphenyl)tin is *exo*. Although empirical force-field calculations on the static stereochemistry of isolated molecules of *meta*-substituted tetra(aryl) derivatives were not reported, the *exo* conformation has been shown to be the most stable in similar studies of tetra(2-methylphenyl)methane and -silane (Hutchings, Nourse & Mislow, 1974; Hutchings, Andose & Mislow, 1975).

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The Structure of an Antihistamine: Cyproheptadine Hydrochloride Sesquihydrate

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Cyproheptadine hydrochloride sesquihydrate ($C_{21}H_{21}N . HCl . 1\frac{1}{2} H_2O$) is orthorhombic, space group $Fdd2$, with $a = 43 \cdot 53$ (1), $b = 18 \cdot 226$ (6), $c = 9 \cdot 587$ (4) Å, $Z = 16$. One water molecule is situated on a twofold axis. The tricyclic part of the molecule is folded and the angle between the planes of the two benzene rings is $124 \cdot 1°$. The piperidine ring has a chair and the seven-membered ring a boat conformation. The cyproheptadine molecule possesses C_s symmetry within the limits of error. The structure was refined to an R of $3 \cdot 9\%$.

Introduction

Several substances are known to antagonize both histamine and serotonin, among which are various phenothiazine derivatives (Gyermek, Lazar & Czák, 1956; Parratt & West, 1958). None of these compounds is, however, particularly outstanding as an antagonist of serotonin. A relatively new antihistamine, cyproheptadine hydrochloride or 4-(5H-dibenzo[a,d]-cycloheptene-5-ylidene)-1-methylpiperidine, is unique in that its antagonism towards both histamine and serotonin is of a high order. In addition cyproheptadine has some weak antropene-like activity and possesses mild central depressing properties (Stone, Wenger, Ludden, Stavorski & Ross, 1961). Clinically, cyproheptadine has been found to be effective in the treatment of various allergies. The most prominent side effect is drowsiness (Miller & Fishman, 1961).

The structure of cyproheptadine resembles in certain respects the phenothiazine antihistamines. It also bears some resemblance to lysergic acid derivatives, which are good serotonin antagonists in that they possess an N-substituted heterocyclic ring. In comparison with simpler indole-type serotonin antagonists, however, there is no structural resemblance. The determination of this crystal structure was undertaken as part of a general study of antihistaminic drugs.

Crystal data

The powdered substance was obtained from Merck, Sharp & Dohme. Crystals of $C_{21}H_{21}N . HCl . 1\frac{1}{2} H_2O$, grown from ethanol, are colourless prisms of rhombic cross-section; space group $Fdd2$, with $a = 43 \cdot 53$ (1), $b = 18 \cdot 226$ (6), $c = 9 \cdot 587$ (4) Å, $V = 7606$ (4) Å^3, $Z = 16$, $D_m = 1 \cdot 215$, $D_x = 1 \cdot 225$ g cm^{-3}, μ(Mo $K\alpha$) $= 2 \cdot 16$ cm^{-1}.

Experimental

A crystal $0 \cdot 41 \times 0 \cdot 41 \times 0 \cdot 37$ mm was used throughout the data collection, mounted along **c**. 2209 reflexions, including 56 with negative intensity, were measured on a paper-tape-controlled Siemens AED diffractometer by the five-value scan technique ($\theta \leq 27°$). 2θ values for several high-order reflexions were measured, and the cell dimensions found by least-squares calculations.

Lp corrections were applied, but absorption corrections were ignored.

Scattering factors computed from numerical Hartree–Fock wave functions (Cromer & Mann, 1968) were used for the non-hydrogen atoms; for H, the values given by Stewart, Davidson & Simpson (1965) were used.

Structure determination and refinement

The structure was solved by direct methods with *MULTAN* 74 (Main, Woolfson, Lessinger, Germain & Declercq, 1974). Phase determination for 300 reflexions with $E \geq 1 \cdot 41$ was carried out with a weighted