# THE MUTUAL INFLUENCE OF LIGANDS AND THE NATURE OF CHEMICAL BONDS IN TIN(IV) OCTAHEDRAL COMPLEXES

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## Summary

By considering the bond length Sn—Lig, determined by X-ray structure analysis in *cis*- and *trans*-complexes of general formula $(CH_3)_n SnHal_{4-n} \cdot 2 D$, where $n = 0—2$, Hal = Cl or Br, D = hexamethylphosphoric triamide, dimethyl sulphoxide or dimethyl formamide, it was observed that in all complexes the tin atom is surrounded by ligands in a slightly deformed octahedral. The interactions of ligands in the considered complexes differ strongly from the interactions of ligands in octahedral and quadratic complexes of transition metals. All bond lengths are in good agreement with contributions from $HV_I$, $HV_{II}$ hypervalent and covalent bonds in the formations of Sn—Lig bonds and also with the participation of the 5d-orbital of tin.

## Introduction

The mutual influence of ligands in the quadratic and octahedral complexes of the transition metals has been studied and consists of two principle effects, *trans*- and *cis*-effects, which were revealed by Chernaev [1] and Grinberg and Kukushkin [2]. *Trans*-effect of the electron-donating ligand (D) on the electron-acceptor *trans*-partner (A) in transition metal (M) complexes is specifically demonstrated by the elongation of the interatomic distance M—A and contraction in the interatomic distance M—D in the linear trinuclear fragment D—M—A, compared with the distances between the same atoms in complexes which have linear trinuclear fragments A—M—A or D—M—D. One can well see this effect, for example, by comparing the interatomic distances in complexes $MCl_3 \cdot 3 L$ and $MCl_4 \cdot 2 L$ (M = W, Re, Os, Ir, Pt) [3].

The structure of non-transition metal complexes have not been so extensively studied. In the present work, to investigate the mutal influence of ligands in non-transition metal complexes, we used some tin(IV) octahedral compounds.

It is well known that the nature of the chemical bonds determines the chemical properties and the structures of complexes; one of the most interesting questions

concerning the structure of six-coordinated tin(IV) complexes is the nature of the chemical bond Sn—Lig.

The most popular interpretation for the six-coordinating bond of the tin atom is $5sp^3d^2$-hybridisation. However, Tobias [4], considering the structures of anions $[(CH_3)_2SnHal_4]^{2-}$, believed that the vacant $5d$-orbitals of the tin atom do not take an observed part in the formation of the bonds in those anions. From the NMR and IR spectra data, he concluded that in the tin—methyl group bonds tin contributes a $5s$-orbital with one of the $5p$-orbitals, since the tin—halogen bonds which lie in the equatorial plane (relative to the Sn—$CH_3$ bond), have the prefered character of the three-centre two-electron bond using $\sigma$-orbitals of halides and the remaining two $5p$ tin orbitals.

This agrees with the view of Pimentel [5] and Rundle [6] who introduced the concept of an orbital-deficient bond. These considerations were later generalized by Masher [7] who called orbital-deficient bonds hypervalent bonds. Orbital-deficient bonds, in which the s-character equals zero was called a hypervalent bond of the first kind ($HV_I$) and the hypervalent bond of the second kind ($HV_{II}$) is an orbital-deficient bond in which a pure $p$-orbital does not take part, but hybridised $s$- and $p$-orbitals do. It follows that the degree of orbital deficiency of $HV_I$ bond is larger than $HV_{II}$. Therefore, in the Tobias model, the covalent bonds Sn—$CH_3$ are combined with the hypervalent bonds $HV_I$ Sn—Cl.

In the anion complexes studied by Tobias [4], $[(CH_3)_2SnHal_4]^{2-}$, electronic structure and properties of ligands are quite different. On the one hand, methyl groups are strong electron-donor ligands which need a maximum contribution of $s$-orbital of tin atom, on the other hand the chlorine atoms are strong electron-acceptor ligands, which form the prefered bond with the $p$-orbital of tin.

It can be supposed that in those tin(IV) complexes in which ligand properties differ greatly, such as in $[(CH_3)_2SnHal_4]^{2-}$, each of the two models $sp^3d^2$ hybridization and $HV_I$ hypervalent bonds, do not quite describe the true structure of the complexes. It is important to know what is the mutual influence of ligands in complexes with different contributions of hypervalent bonds. We therefore carried out systematic X-ray crystal and molecular structure studies on some methyltin halide complex compounds with electron-donor molecules (D) having the general formula $(CH_3)_nSnHal_{4-n} \cdot 2D$, where $n = 0-2$, Hal = Cl or Br, D = hexamethylphosphoric triamide (HMPT), dimethyl sulphoxide (DMSO) or dimethylformamide (DMF).

Preliminary studies involved the synthesis [8], NQR [9], Mössbauer [10] and NMR [11] spectra of these compounds.

Experimental

Diffracted reflection intensities for single crystals of all compounds were collected by means of four-circles single crystal automatic diffractometer Hilger & Wats Y 290. Structures have been determined by the heavy-atom method and refined by the least square method.

Detailed information about the unit cell parameters, space groups and refinements of all the structures studied will be published separately [12]. Here we shall discuss only the stereochemical results.

Data on complexes investigated together with the necessary literature data for

D
CH₃ —Hal_I
Hal_I CH₃
D

(I-IV)

Hal_I
CH₃ —Hal_I
D CH₃
D

(V-VI)

D
CH₃ —Hal_I
Hal_I Hal_II
D

(IX-X)

Hal_I
CH₃ —Hal_I
D Hal_II
D

(XI)

D
Hal_II —Hal_I
Hal_I Hal_II
D
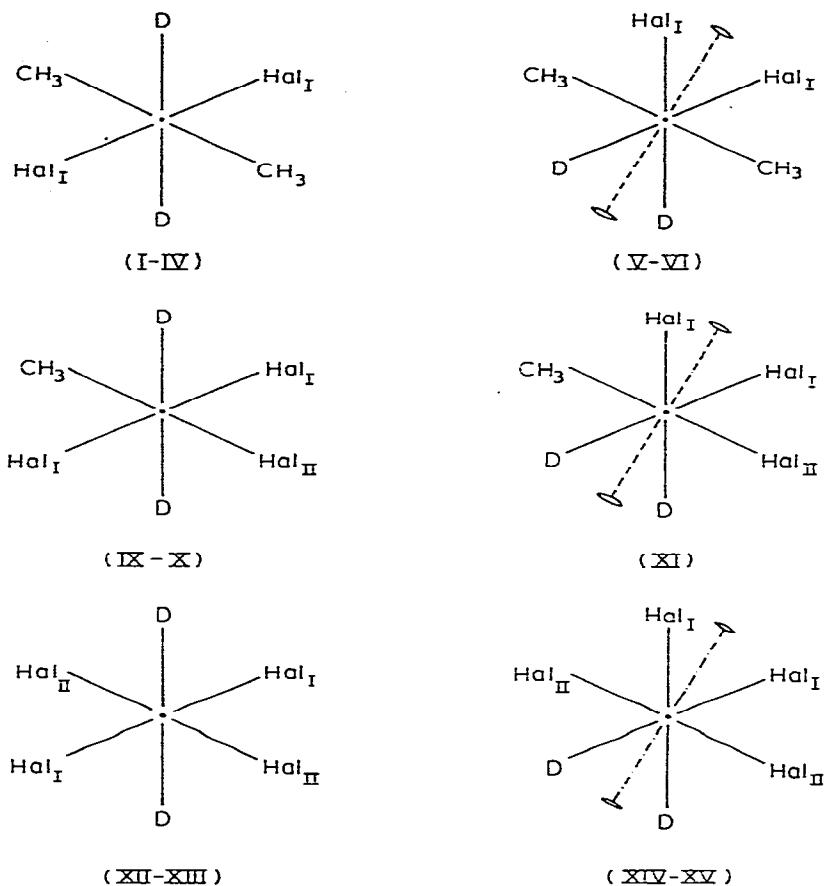
(XII-XIII)

Hal_I
Hal_II —Hal_I
D Hal_II
D

(XIV-XV)

Fig. 1. Structures of investigated complexes.

the discussion are listed in Table 1; structures of the compounds studied are represented in Fig. 1.

In all the investigated six-coordinated complexes ligands are arranged around $Sn^{IV}$ atom at the apices of slightly distorted octahedral, i.e., electron-donor molecules D are oriented both *trans* and *cis* to each other. All the *trans*-complexes have $C_i$ symmetry in crystals; the centres of symmetry are customarily occupied by the tin atoms. It is known from the literature [13] that the six-coordinated *trans*-complex $(CH_3)_2SnCl_2 \cdot 2$ pyo, where pyo = pyridine oxide, also has $C_i$ symmetry. The following *cis*-complexes have been investigated and have different symmetry: $C_1$, $(CH_3)_2SnCl_2 \cdot 2$ DMSO [14]; $C_2$, $SnCl_4 \cdot 2$ OSeCl₂ [15]; $C_2$, $SnCl_4 \cdot 2$ NCCH₃ [16]; and $C_v$, $SnCl_4 \cdot 2$ OPCl₃ [17]; VI and XI *cis*-complexes have $C_2$ symmetry.

In spite of the impossibility for the methyltin trihalide complexes to have a centre of symmetry in the *trans*- or the *cis*-complexes and two-fold axis in the crystals of IX, X and XI tin atoms are located in a special position. This being in centres of symmetry and on the two-fold axes, i.e. the halogen atom $Hal_{II}$ and methyl groups, Fig. 1, which are arranged in *trans*-position, are statis-

TABLE I

THE INTERATOMIC DISTANCES IN $(CH_3)_n SnHal_{4-n}$ · 2 D COMPLEXES

| No. | n | Hal | D | Type of the configuration | $r(Sn-C)$ (Å) | $r(Sn-O)$ (Å) | $r(Sn-Hal_I)$ (Å) | $r(Sn-Hal_{II})$ (Å) | Ref. |
|---|---|---|---|---|---|---|---|---|---|
| I | 2 | Br | DMSO | Trans | 2.15(4) | 2.22(2) | 2.75(2) | | Present paper |
| II | 2 | Br | HMPT | Trans | 2.14(1) | 2.23(1) | 2.74(1) | | Present paper |
| III | 2 | Cl | Pyo | Trans | 2.22(2) | 2.25(2) | 2.58(1) | | 13 |
| IV | 2 | Cl | HMPT | Trans | 2.14(1) | 2.26(2) | 2.57(1) | | Present paper |
| V | 2 | Cl | DMSO | Cis | 2.12(2); 2.13(2) | 2.27(1); 2.31(1) | 2.53(1); 2.49(1) | | Present paper |
| VI | 2 | Cl | DMF | Cis | 2.13(2) | 2.39(2) | 2.47(1) | | Present paper |
| VII | 2 | Br | bis(1,2-diethoxy-I carbonyl-ethyl) MO-DIF. | Cis | 2.26(6); 2.26(5) | 2.44(3); 2.46(3) | 2.588(6); 2.516(6) | | 18 |
| VIII | | Br | bis(1,2-diethoxy-II carbonyl-ethyl) MO-DIF. | Cis | 2.24(3) | 2.49(2) | 2.504(5) | | 19 |
| IX | 1 | Br | HMPT | Trans | | 2.16(1) | 2.65(1) | 2.40(1) [a] | Present paper |
| X | 1 | Cl | HMPT | Trans | | 2.18(1) | 2.40(1) | 2.31(1) [a] | Present paper |
| XI | 1 | Cl | DMF | Cis | | 2.22(2) | 2.43(1) | 2.35(1) [a] | Present paper |
| XII | 0 | Br | HMPT | Trans | | 2.09(1) | 2.56(1) | 2.54(1) | Present paper |
| XIII | 0 | Cl | HMPT | Trans | | 2.13(2) | 2.40(1) and 2.36(1) [b] | | Present paper |
| XIV | 0 | Cl | OPCl₃ | Cis | | 2.25(5); 2.30(4) | 2.31(2); 2.32(2) | 2.33(2); 2.33(2) | 17 |
| XV | 0 | Cl | OSeCl₂ | Cis | | 2.121(16) | 2.360(7) | 2.409(6) | 15 |

[a] The distance between tin atom and $(Hal_{II} + CH_3)$ superimposed peak; see experimental mark. [b] $SnCl_4$ · 2 HMPT and $(CH_3)_2SnCl_2$ · 2 HMPT are not isostructural, therefore, it is not known, which of the chlorine atoms in $SnCl_4$ · 2 HMPT is $Hal_I$ and which $Hal_{II}$.

tically replacing each other. Therefore, IX, X, XI must be considered as pseudo-centrosymmetrical.

Statistical replacement of the methyl group and $Hal_{II}$ atom in IX, X and XI complexes makes it difficult to determine the bond distances $Sn—Hal_{II}$ and $Sn—CH_3$. In all methyltin trihalide complexes studied we have not established the coordinates of the carbon atom of the methyl group and $Hal_{II}$. The coordinates determined are the summation of the two peaks ($Hal_{II} + CH_3$).

As the chlorine atom has a higher atomic number than carbon, it can be considered that the distance between Sn and the superimposed peak ($Hal_{II} + CH_3$) is nearer to the value of the $Sn—Hal_{II}$ distance.

Among the complexes investigated, two groups of isomeric structures can be separated: II, IV, IX, XII and X, XIII. Essential differences in the atomic coordinates and the unit cell parameters were observed in the VI and XI complexes, therefore, they may be cautiously regarded as isomers. All complexes are mononuclear. The electron-donor molecules are bonded to tin through the oxygen atom. The distances between atoms of different complexes exceed 3 Å which are normal for crystals of complexes under the influence of Van der Waals interactions.

### Results and discussion

The mutual influence of the ligands in the octahedral tin(IV) complexes leads to two consequences, firstly, the formation of *trans*- and *cis*-isomers, and secondly, regular changes in the interatomic distances Sn—Lig depending on the relative location of the ligands and their electrical (donor, acceptor) properties.

Earlier [20] it was expressed that the formation of *trans*- or *cis*-isomers depends on the size of the electron-donating ligand D; the isomer formed was that which ensured minimum spatial difficulties inside the complexes.

All the investigated structures confirmed this hypothesis. On the other hand going from chloride [14] to bromide I a change from *cis*- to *trans*-configuration occurs. It must be remembered also that $SnI_4 \cdot 2$ HMPT (NQR method [9]) has a *cis*-configuration.

Apparently, the formation of *cis*- or *trans*-isomer not only depends on the size of the electron-donating ligand D, but also on the other ligands in the complexes, i.e., this principle must be extended to all the ligands of tin(IV) octahedral complexes. From the two possible configurations, *cis* or *trans*, only those are realized which ensure the minimum spatial difficulties between all the ligands of the complex. This conclusion is general for tin(IV) octahedral complexes containing any set of ligands but, as will be discussed later, the mutual influence of the ligands within a complex determined configuration depends on their properties and their relative arrangement. Therefore, for further consideration, all the investigated compounds are suitably collected in groups according to their compositions and we shall consider the essential characteristics of the structures of these complexes.

### $(CH_3)_2SnHal_2 \cdot 2$ D complexes

Table 1 contains beside $(CH_3)_2SnHal_2 \cdot 2$ D complexes, two forms of bis(1,2-diethoxycarbonylethyl)tin dibromide [18,19]. In one, both metallic

cycles of each mononuclear complex belong to $d$- or $l$-form (I), while in the other each complex contains metallic cycles such as $d$- and $l$-form (II). These complexes have approximately an octahedral structure and carbon atoms are *trans* to each other.

The distances $r(\text{Sn—CH}_3)$ in four of the six complexes shown in Table 1, approximate to 2.14 Å. The exceptions to this are in: in $(\text{CH}_3)_2\text{SnCl}_2 \cdot 2$ DMSO, 2.07(6), 2.08(5) Å [14] and $(\text{CH}_3)_2\text{SnCl}_2 \cdot 2$ pyo, 2.22(2) Å [13]. These differences in the Sn—CH$_3$ bond lengths provide evidence for the rehybridisation of the tin atom orbitals, which act on the all bounds in the complex. Therefore, the structure $(\text{CH}_3)_2\text{SnCl}_2 \cdot 2$ DMSO was refined by us, to reduce the values of the standard deviations for the all bond distances, especially $r(\text{Sn—CH}_3)$.

The bond distances $r(\text{Sn—CH}_3)$, determined after the refinement by 1211 independent reflections ($R = 0.076$), are 2.12(2) and 2.13(2) Å, slightly different from the mean $r(\text{Sn—CH}_3)$ (2.14 Å) for the above mentioned four compounds. In this case, the distance $r(\text{Sn—CH}_3)$ in $(\text{CH}_3)_2\text{SnCl}_2 \cdot 2$ pyo complex is the single exception from the rule. The uniformity of the bond distance Sn—CH$_3$ for the all investigated complexes $(\text{CH}_3)_2\text{SnHal}_2 \cdot 2$ D indicates that the contribution by $s$-orbitals of tin in formation of the Sn—CH$_3$ bond is constant. It is supposed that the electronegativity of the oxygen atom of any of the electron-donating molecules D used entering into the inner sphere of Sn(IV), essentially larger than that of the methyl group. Therefore, it may be that the 5$s$-orbital of tin is hybridised with one of the 5$p$ orbitals to give two equivalent orbitals to form the Sn—CH$_3$ bond, while the two remaining 5$p$ orbitals of the Sn$^{\text{IV}}$ can be bonded through orbitals of oxygen atoms or halide ions (Cl$^-$, Br$^-$) to form hypervalent bonds of the first group (O—Sn—O, Hal—Sn—Hal and O—Sn—Hal). In this case, Tobias' model can be justified for $(\text{CH}_3)_2\text{SnHAl}_2 \cdot 2$ D complexes.

Now let us consider the X-ray crystal and molecular structure analysis of the methyltin halide complexes (Table 1) incorporating the idea of the co-existence of the covalent and hypervalent bonds in those complexes. The bond distances $r(\text{Sn—O})$ in *cis*-complexes are longer than those in *trans*-complexes, while the opposite is true for the distances $r(\text{Sn—Hal})$. The differences between the distances are rather essential, i.e. $r_{max}(\text{Sn—O}) - r_{min}(\text{Sn—O}) = 0.27$ Å, $r_{max}(\text{Sn—Hal}) - r_{min}(\text{Sn—Hal}) = 0.25$ Å. In the linear trinuclear fragment Hal—Sn—Hal $r(\text{Sn—Hal})$ is a maximum, and is reduced when one of the halogens is replaced by an oxygen atom of the electron-donor molecule (Hal—Sn—O). On the other hand, the distance $r(\text{Sn—O})$ has a minimum value when there are only two oxygen atoms in the linear trinuclear fragment beside the tin atom (O—Sn—O). This increases when a halogen is arranged *trans* relative to the oxygen atom (O—Sn—Hal).

These empirical regularities in the alteration of the bond lengths can be explained on the basis of the consideration of the electron-donating ability of the molecules entering into the inner sphere of the complex and the electron-accepting properties of the halide ions. It is well known that the shorter the bond distance, the higher is the electron density between the bonded atoms in the internuclear space.

In the linear trinuclear fragment Hal—Sn—Hal both atoms at the extremity accept electrons from the internuclear space, reducing the concentration of electrons between tin and halogen atoms, which leads to a maximum bond dis-

tance Sn—Hal among all the Sn—Hal bonds. In the linear trinuclear fragment O—Sn—O oxygen atoms donate electrons to the internuclear space, therefore, the electron concentration will be increased and the bond distance Sn—O becomes a minimum among all the Sn—O bonds. In the case of the mixed linear trinuclear fragment O—Sn—Hal, due to the compensation between the donated electrons from the oxygen atom and the accepted electrons by the halogen atom in the internuclear spaces, the resulting electron density in the internuclear space O—Sn is decreased relative to the O—Sn—O fragment and at the same time, the electron density in the internuclear space Sn—Hal becomes higher than in the Hal—Sn—Hal linear trinuclear fragment. This leads to the elongation in O—Sn and reduction of the Sn—Hal bond lengths.

This hyperthetical mechanism of the ligands interaction in the linear trinuclear fragment Lig—Sn—Lig supposes the ability of tin atom to translate the electron density from one half of the linear trinuclear fragment to the other under the electron-donation and electron-acception characters of ligands. It can be considered that the tricentral orbital of the hypervalent bond of the first kind acts as a "canal", through which the transportation of electrons from one half of the linear trinuclear fragment to the other takes place.

*SnHal$_4$ · 2 D complexes*

By comparing the interatomic distances Sn—Lig in SnHal$_4$ · 2 HMTP and (CH$_3$)$_2$SnHal$_2$ · 2 HMTP complexes, it is indicated that, in the absence of a methyl group, the bond distances Sn—O and Sn—Hal become shorter in both *trans*- and *cis*-configurations. This provides evidence for the increasing *s*-character of these bonds [21]. While in (CH$_3$)$_2$SnHal$_2$ · 2 HMTP the *s*-orbital of the tin atom contributes to form an *sp*-hybridised orbital, it contributes to form a second type of hypervalent bond or $sp^3d^2$-hybridised orbital in SnHal$_4$ · 2 HMTP complexes. Both cases lead to equal distribution of the contributed 5*s*-orbital on the Sn—Lig bond. The degree of orbital deficiency in the HV$_{II}$ is smaller than in HV$_I$, but the orbital-deficiency of the bond which is formed from $sp^3d^2$-hybridisation is quite absent. Accordingly, on going from HV$_I$ to HV$_{II}$ and further to $sp^3d^2$-hybridised bonds the electron density between the nuclei must be increased, and the bond length must be decreased. Thus, from the fact of decreasing bond length for Sn—Lig on going from (CH$_3$)$_2$SnHal$_2$ · 2 HMTP to SnHal$_4$ · 2 HMTP, it can be concluded that the bonding in the latter complex contains a contribution from a second type of hypervalent bond or $sp^3d^2$-hybridised bond or both.

In considering the contributions to the *cis*-complex SnCl$_4$ · 2 OSeCl$_2$ [15], the very short distances Sn—O (2.121(16) Å) indicates that the OSeCl$_2$ molecule is a relatively strong electron-donating ligand. The interatomic distances Sn—Cl in the linear trinuclear fragment O—Sn—Cl and Cl—Sn—Cl are equal to 2.360(7) and 2.409(6) Å respectively, which means that in the *trans*-position to the electron-donating ligand a reduction in the Sn—Cl bond length takes place, and not elongation such as is observed in the case of transition metal complexes. This leads us to conclude that the character of the chemical bond of tin(IV) complexes and of the octahedral transition metal complexes are essentially different. Since the chemical bonds in the latter are represented by $sp^3d^2$-hybridised orbital of the metal atom, then it can be concluded that the chemical bonds in SnHal$_4$ · 2 D complexes have a considerable contribution from the second type

of hypervalent orbital, while the contribution from $sp^3d^2$-hybridised orbital is negligible. Owing to the slight inequality of the distances $Sn-Cl_I$ and $Sn-Cl_{II}$ for $SnCl_4 \cdot 2 \ OSeCl_2$ (Table 1) it can be concluded that the contribution from $5s$ orbital is slightly unequally distributed in the linear trinuclear fragments $Lig-Sn-Lig$. In the fragments containing the electron-donating ligand, the contribution of the $5s$-orbital of tin atom is greater than in the fragment $Cl_{II}-Sn-Cl_{II}$, therefore the fragment $O-Sn-Cl_I$ has a covalent constitution and in $Cl_{II}-Sn-Cl_{II}$ hypervalent contribution of the first type.

The molecule $OPCl_3$ has less electron-donating character than $OSeCl_2$ according to the values of the interatomic distances $Sn-O$ 2.25(5) and 2.30(4) Å in cis-complex $SnCl_4 \cdot 2 \ OPCl_3$ [17]. But in both $SnCl_4 \cdot 2 \ OPCl_3$ and $SnCl_4 \cdot 2 \ OSeCl_2$, the distances $Sn-Cl_I$ trans to the electron-donating molecule are equivalent, within the limit of the standard deviations (Table I), and the cis-ligand ($Cl_{II}$) is nearer to the tin atom in the presence of the weaker electron-donating ligands. This mutual influence of the ligands also has no analogy in the transition metal complexes, but it may be explained on the basis of the existence of the second type of hypervalent bonds. Apparently, the contribution of the tin atom $5s$ orbital in the presence of relatively weak electron-donating ligands is distributed more equally in all the bonds of the complex, and therefore all the bond lengths are equivalent. The bond lengths $Sn-Lig$ in the complexes of the type $SnCl_4 \cdot 2 \ D$, which have equally (in strength) electron donating molecules, e.g. HMPT and $OSeCl_2$, are practically equal and consequently do not depend on whether the complexes are cis or trans. This also substantiates the existence of the second type of hypervalent bond in $SnHal_4 \cdot 2 \ D$ complexes, which must ensure enough equal distribution of the contributing $5s$-orbital of the tin atom over all the $Sn-Lig$ bonds. So, for the interpretation of the bond length $Sn-Lig$ in complexes of the type $SnHal_4 \cdot 2 \ D$, differing in configuration and composition, it is necessary to consider the value of contributions of the second type of hypervalent bond and covalent bond for all the bonds of the complex which in the linear trinuclear fragment $Lig-Sn-Lig$, and not in the separate $Sn-Lig$ bonds.

### $CH_3SnHal_3 \cdot 2 \ D$ complexes

We will consider two specific pecularities of structures of these complexes.

Firstly, where the interatomic distances $Sn-O$ and $Sn-Hal_I$ in the trans-complexes have an intermediate value between similar interatomic distances in the $(CH_3)_2SnHal_2 \cdot 2 \ D$ and $SnHal_4 \cdot 2 \ D$ complexes. In the cis-complexes $CH_3SnHal_3 \cdot 2 \ D$ the interatomic distances $Sn-Hal_I$ have an intermediate value between the corresponding interatomic distances in the $(CH_3)_2SnHal_2 \cdot 2 \ D$ and $SnHal_4 \cdot 2 \ D$ complexes. The same tendency in the cis-complexes are observed for the interatomic distance $Sn-O$, with the exception of the $SnCl_4 \cdot 2 \ OPCl_3$ complex, in which the interatomic distances $Sn-O$ increases to 2.25(5) and 2.30(4) Å. This can be explained by the weakness of the electron-donating ability of $OPCl_3$ molecule. Accordingly, all these facts indicate that the nature of the chemical bond in the $CH_3SnHal_3 \cdot 2 \ D$ complexes is intermediate in nature between the bond in $(CH_3)_2SnHal_2 \cdot 2 \ D$ and that in the $SnHal_4 \cdot 2 \ D$, i.e. in all the $Sn-Lig$ bonds of the $CH_3SnHal_3 \cdot 2 \ D$ complexes contributions from the first and second type of hypervalent bonds together with the covalent.

Secondly, in the linear trinuclear fragment $CH_3-Sn-Hal_{II}$, which only exists

in this type of complex, the distance $Sn—Hal_{II}$ was the shortest of all the $Sn—$ Hal distances measured in our work, which would be expected for two reasons. On one hand, the contribution of $HV_I$ in the linear trinuclear fragment $CH_3—$ $Sn—Hal_{II}$ bonds and the strong methyl electron-donating ligand leads to the natural influence of ligands which was considered above. On the other hand, the contribution of the covalency and hypervalency ($HV_{II}$) which are induced in the chemical bonds of the linear trinuclear fragment $CH_3—Sn—Hal_{II}$, increase the $s$-character of the $Sn—Hal_{II}$ bond, i.e. do much to reduce $Sn—Hal_{II}$ distance to a minimal value.

If we had succeeded to fix the coordination of the carbon atom, evidently, the $Sn—CH_3$ bond length in the trinuclear fragment $CH_3—Sn—Hal_{II}$, due to the two above reasons, will result in a shorter bond length than that of $Sn—CH_3$ in the $(CH_3)_2SnHal_2 \cdot 2$ D complexes. The $CH_3—Sn$ bond in $CH_3SnHal_3 \cdot 2$ D really has not a pure covalent character, such as was considered for the $(CH_3)_2SnHal_2$ $\cdot 2$ D complexes, but contain also $HV_I$ and $HV_{II}$ contributions.

We can summarize our conclusions in the following:

The mutual influence of the ligands arranged *trans* to each other in the octahedral tin(IV) complexes is directly opposite to that which was observed in the quadratic and octahedral complexes of the transition metals. Since, in the transition metal octahedral complexes the contribution by $sp^3d^2$-hybridisation orbitals are undoubtable, in the tin(IV) complexes the opposition of the mutual influence of the ligands indicates that the $5d$-orbitals of tin in the bond formation in the octahedral complexes do not take any part. By considering the chemical bonds in the linear trinuclear fragment Lig—Sn—Lig a good opportunity arises to discuss the values of the contributions of the covalent, $HV_I$ and $HV_{II}$, in the interatomic distance Sn—Lig. Therefore, the hypervalent bond contributions actually exist in the octahedral tin complexes, and together with the covalent component determine their constructions and properties.

Since the inert gas compounds and the polyhalide compounds are formed with the aid of those hypervalent bonds, it can be argued that the coordinated compounds of all the elements between Xe and Sn also contain hypervalent bonds. Moreover, as the contribution of the hypervalent bonds in the formation of tin(IV) octahedral complexes is so great, this gives reason to assume the existence of hypervalent bonds in the Cd and In octahedral complexes, i.e. for the all non-transition elements.

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