

Synthesis Reaction and Characterization of Sterically Hindered Tricyclohexyl Bismuth Dicarboxylates

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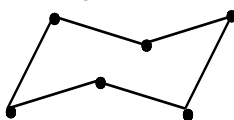
Abstract

A series of hitherto unknown solid salt of tricoordinated complexes of the general formula $R_nBiX_{(m-n)}$ (R = organic group; n = 1, 2 and m = 3; n = 3, 4 and m = 5; X = halide, pseudohalide, oximes, amides etc.) have been isolated in presence of tricyclohexyle bismuth chloride. The newly synthesized complexes have been formulated and characterized on the basis of elemental analysis, molar conductance, molecular weights, solid state, IR, and solution state 1H NMR spectral data the physico-chemical data are consistent with pyramidal structure of the complexes.

Keywords: Arylbismuth(III) cationic complexes; IR; 1H NMR; Molecular Weight and Molar Conductance

Introduction

There has been considerable interest centered on the chemistry of organobismuth (III) halides over the past two decades. As a result a variety of parent $R_nBiX_{(m-n)}$ compounds (where X = halide, pseudohalide, oximes, amides) According to the findings of Sachse and Mohr [1], the carbon atoms in 5-membered and smaller rings can lie in a single plane as postulated by Bayer, but in 6-membered (e.g. cyclohexyl) and larger rings the carbon atoms lie in different planes. Therefore, the angle of strain calculated for such rings by Bayer on the basis of their planarity is not correct. A ring with 6 or more carbon atoms can assume a "puckered" arrangement so that there is little distortion of the normal tetrahedral angle and there is a negligible angle strain in the molecule. The two puckered forms of cyclohexane can be inter converted by just rotation about single bonds and are the conformation of cyclohexane. It can be shown similarly by construction of models that rings larger than six members can also have almost negligible angle strain by assuming puckered conformations.



(a)

Chair conformation



(b)

Boat conformation

The four bonding orbitals of a carbon atom are disposed tetrahedrally (sp^3 orbitals) i.e. the angle between any pair of orbitals is 109.5° . For the overlapping to be most effective (or the bond to be strongest) the bonding sp^3 orbitals must be so directed that they face each other. In planar cyclopropane, this bond angle cannot be 109.5° and has to be 60° . Thus decreasing the stability of cyclopropane due to relatively poor overlapping of atomic orbitals in the formation of carbon-carbon bonds. In contrast, overlapping of orbitals in ring containing 5 or more carbon atoms open chain compounds is very efficient and resulting bonds are quite stable. It is evident from this depiction that all the pairs of the carbon-carbon bonds in the chair form of cyclohexane are perfectly staggered bonds, whereas in the boat form they are eclipsed bonds. The chair conformation of cyclohexane is thus free of angle strain as well as torsional strain. In contrast, the boat conformation of cyclohexane has considerable torsional strain and also steric strain. It may be pointed out that among the chair form and twist form the chair conformation is of course the most

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stable configuration of cyclohexane. The relative distribution of cyclohexane molecule with chair conformation and twist conformations is about 1,000 to 1 at room temperature. For all practical purpose cyclohexane exists almost exclusively in the chair conformation.

In sharp contrast to well documented organobismuth compounds of the type $R_nBiX_{(m-n)}$ (R = organic group; $n = 1, 2$ and $m = 3$; $n = 3, 4$ and $m = 5$; X = halide, pseudohalide, oximes, amides etc.), synthetic routes to the corresponding carboxylate derivatives of bismuth in either of its oxidation state + 3 or + 5 with biologically active carboxylate acids moieties, have been paid no attention [2-4]. It is more surprising in the light of the fact that the corresponding derivatives of other group 15 elements viz. As and Sb have been extensively studied by various group of workers. Lucknow workers [5-7] have earlier reported on the synthesis of triarylbismuth diamides and dioximates. However, synthesis of sterically hindered naphthyl or cyclohexyl bismuth carboxylates has not been reported to date. It may be noted that bulkier organic group impart considerable stability to organometallic compounds as well as making them hydrolytically stable. The additional advantage with bismuth compounds is that in general bismuth inorganic compounds are non-toxic and Bi-C bond on decomposition form non-toxic bismuth compounds. Moreover, recent studies have shown that bismuth compounds, especially, thiolates and other nitrogen containing derivatives are better antitumor agents and even in certain cases can supersede known platinum based drugs where efficacy is restricted to 70% only. Keeping in view the above facts we initiated a systemic study on sterically hindered organo-bismuth compounds, especially containing Bi-O and Bi-N bond(s). [8-11] Since the carboxylates have found increasing importance as antitumor agents of carboxylates derivatives has been synthesized and series reported. The compounds reported herein were characterized by elemental analysis, melting points and spectroscopic data.

Aim of the Study

IR Study of Sterically Hindered Tricyclohexyl Bismuth Dicarboxylates.

Experimental

Tricyclohexyl bismuth was prepared from bismuthtrichloride by a Grignard reaction and was converted into its dichloride; tricyclohexyl bismuth dichloride by direct chlorination.

IR spectra were recorded on perkin-Elmer 577 spectrophotometer in the range 4000-400 cm^{-1} using KBr discs. Special precautions were taken to exclude moisture. Anhydrous benzene (Aldrich) was used as the solvent. Some typical experiments are given below and further physico-chemical data for the complexes are given in tables 1-5.

Reaction of tricyclohexylbismuth dichloride with Sodium salt of Salicylic acid

Tricyclohexylbismuth dichloride (0.530 g; 1 mmol) and sodium salt of salicylic acid (0.320 g; 10 mmol) were stirred in benzene (30 ml) at room temperature for 2 h. The reaction mixture was then refluxed for an h to ensure completion of the reaction.

The white precipitate of NaCl was filtered off. The filtrate on concentration in vacuo, afforded the corresponding product which was precipitated out by adding petroleum ether (40-60°) to concentrated mixture.

M.P. - 241°C. Yield - 78%

Reaction of tricyclohexylbismuth dichloride with Sodium salt of Benzoic acid:

To a stirred solution of tricyclohexylbismuth dichloride (5.30 g; 1 mmol) and sodium salt of benzoic acid (0.5 g; 2 mmol) were stirred in benzene (30 ml) at room temperature. The reaction mixture was stirred for 2 h and further refluxed for an h to ensure completion of the reaction. The white precipitate of NaCl was filtered off and the filtrate was distilled off under vacuum under nitrogen atmosphere and then 40 ml of petroleum ether (40-60°) was added to give the desired compound.

M.P. - 220°C Yield - 70%

Reaction of tricyclohexylbismuth dichloride with sodium salt of 2-pyrazine carboxylic acid:

To a stirred solution of tricyclohexylbismuth dichloride (0.530 g; 1 mmol) and sodium salt of 2-pyrazine carboxylic acid (0.292 g; 2 mmol) in benzene (50 ml) was added at room temperature. The reaction mixture was stirred for 3 h further it was refluxed for an h to ensure completion of the reaction. The white precipitate of NaCl was filtered off. The filtrate was concentrated at reduced pressure, followed by addition of petroleum ether (40-60°) to yield the desired compound.

M.P. - 158°C Yield - 70%

Reaction of tricyclohexylbismuth dichloride with sodium salt of Hippuric acid

To a stirred solution of tricyclohexylbismuth dichloride (0.530 g, 1 mmol) and sodium salt of hippuric acid (0.402 g, 2 mmol) in benzene (50 ml) was added at room temperature. The reaction mixture was stirred for 3 h further it was refluxed for an h to ensure completion of the reaction. The white precipitate of NaCl was filtered off. The filtrate was concentrated at reduced pressure, followed by addition of petroleum ether (40-60°) to yield the desired compound.

M.P. - 210°C Yield - 75%

Reaction of tricyclohexylbismuth dichloride with sodium salt of Ethyl aceto acetate

Tricyclohexylbismuth dichloride (0.530 g; 1 mmole) and sodium salt of ethyl aceto acetate (0.304 g; 2 mmol) were stirred in benzene (50 ml) at room temperature for 3 h. The reaction mixture was then refluxed for an h to ensure completion of the reaction. The white precipitate of NaCl was filtered off and the filtrate was distilled off, followed by addition of 40 ml of petroleum ether (40-60°) to obtain the desired product.

M.P. - 168°C Yield - 72%

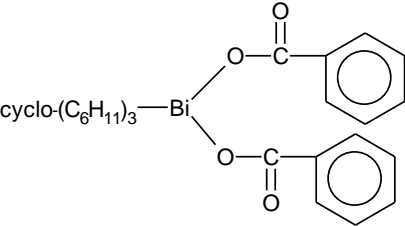
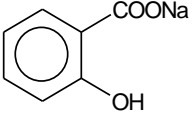
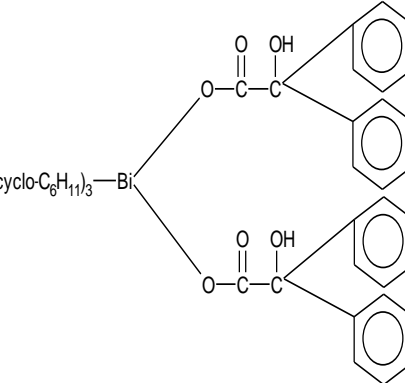
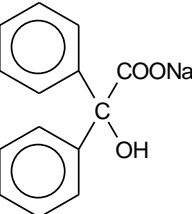
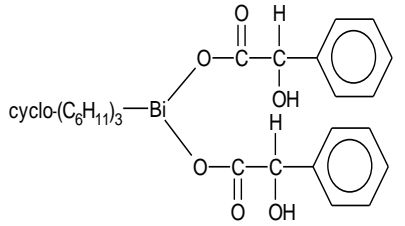
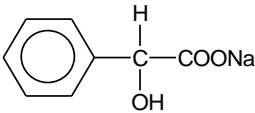
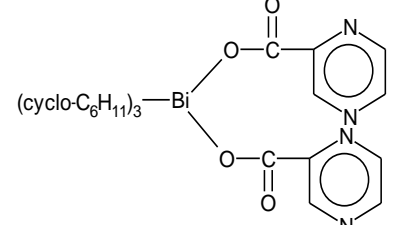
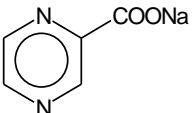
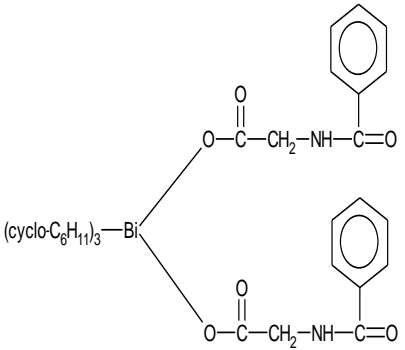
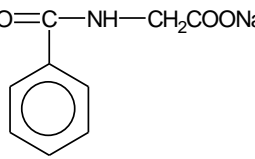
Reaction of tricyclohexylbismuth dichloride with sodium salt of 3,5-dinitrobenzoic acid

To a stirred solution of tricyclohexylbismuth dichloride (0.530 g; 1 mmol) and sodium salt of 3,5-Dinitrobenzoic acid (0.668 g; 2 mmol) in solvent benzene (50 ml) was added at room temperature. The reaction mixture was stirred for 3 h then it was

refluxed for an h to ensure completion of the reaction. The white precipitate of NaCl was filtered off and then filtrate was distilled off and to it 40 ml of petroleum

ether (40-60) was added to give a desired product. M.P. - 184 °C Yiele - 76%

Table-1: Preparation and Properties of Tricyclohexyl Bismuth (V) Dicarboxylates.

S. No.	Complex	Ligand (Sodium salt)	Molar ratio	M.P. (°C)	Yield (%)	Colour
1.		 (0.320 g, 2 mmol) Salicylic acid	1:2	241	78	Off white
2.		 (0.5 g, 2 mmol) Benzoic acid	1:2	220	70	Light brown
3.		 (0.348 g, 2 mmole) Mandelic acid	1:2	222	72	White
4.		 (0.292 g, 2 mmol) 2-Pyrazine carboxylic acid	1:2	198	70	Off white
5.		 (0.402 g, 2 mmol) Hippuric acid	1:2	210	75	White

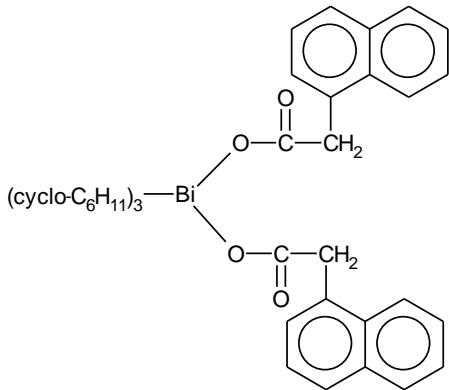
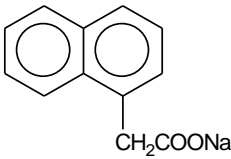
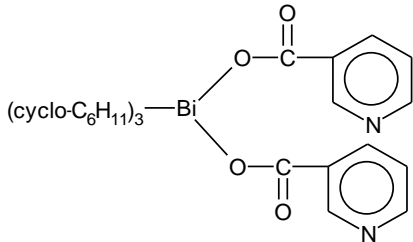
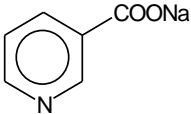
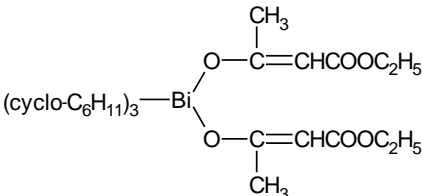
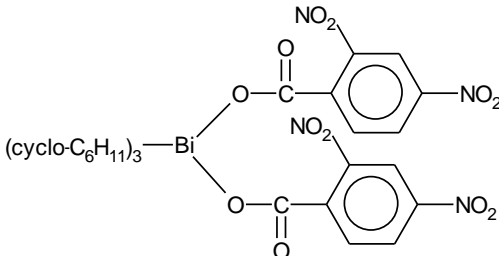
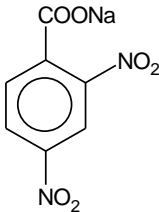
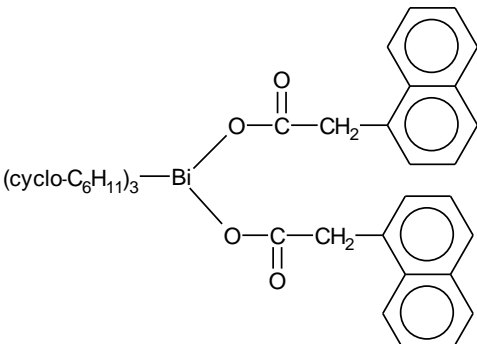
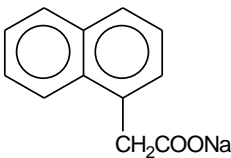
S. No.	Complex	Ligand (Sodium salt)	Molar ratio	M.P. (°C)	Yield (%)	Colour
6.	 <p>(cyclo-C₆H₁₁)₃-Bi</p>	 <p>CH₂COONa</p> <p>(0.418 g, 2 mmol) Naphthyl acetic acid</p>	1:2	204	74	Dull white
7.	 <p>(cyclo-C₆H₁₁)₃-Bi</p>	 <p>COONa</p> <p>(0.290 g, 2 mmol) Nicotinic acid</p>	1:2	209	70	Off white
8.	 <p>(cyclo-C₆H₁₁)₃-Bi</p>	<p>CH₃-C(ONa)CHCOOC₂H₅</p> <p>(0.304 g, 2 mmol) Ethyl acetoacetate</p>	1:2	168	72	White
9.	 <p>(cyclo-C₆H₁₁)₃-Bi</p>	 <p>COONa</p> <p>(0.668 g, 2 mmol) 3,5-dinitrobenzoic acid</p>	1:2	184	76	Off white
10	 <p>(cyclo-C₆H₁₁)₃-Bi</p>	 <p>CH₂COONa</p> <p>(0.434 g, 2 mmol) Naphthyl acetic acid</p>	1:2	192	72	Off white

Table-2: Elemental Analysis of Tricyclohexyl Bismuth (V) Dicarboxylates

S. No.	Molecular Formula	Molecular Weight	Found (Calcd.) %		
			Carbon	Hydrogen	Nitrogen
1.	C ₃₂ H ₄₃ O ₆ Bi	700.66	54.55 (54.85)	5.00 (6.19)	–
2.	C ₄₆ H ₅₇ O ₆ Bi	912.91	59.80 (60.52)	5.85 (6.07)	–
3.	C ₃₄ H ₄₇ O ₆ Bi	760.72	53.32 (53.68)	6.00 (6.23)	–
4.	C ₂₈ H ₃₉ N ₄ O ₄ Bi	704.62	47.95 (47.72)	5.00 (5.58)	7.70 (7.95)
5.	C ₃₆ H ₄₉ N ₂ O ₆ Bi	814.77	53.87 (53.07)	5.75 (6.06)	3.10 (3.44)
6.	C ₄₂ H ₅₁ O ₄ Bi	828.84	60.55 (60.86)	6.00 (6.20)	–
7.	C ₃₀ H ₄₁ O ₄ N ₂ Bi	702.65	51.00 (51.28)	5.25 (5.88)	3.70 (3.99)
8.	C ₃₀ H ₅₁ O ₆ Bi	716.70	50.52 (50.27)	6.95 (7.17)	–
9.	C ₃₂ H ₃₉ N ₄ O ₁₂ Bi	880.66	43.10 (43.64)	4.00 (4.46)	6.10 (6.36)
10.	C ₄₂ H ₅₁ O ₄ Bi	828.83	60.25 (60.86)	5.95 (6.20)	–

Table-3: Important IR Data of Tricyclohexylbismuth(V) Dicarboxylates (Cm⁻¹)

S. No.	Compounds	$\nu_{\text{asym}}(\text{OCO})$	$\nu_{\text{sym}}(\text{OCO})$
1.	C ₃₂ H ₄₃ O ₆ Bi	1650	1334
2.	C ₄₆ H ₅₇ O ₆ Bi	1635	1312
3.	C ₃₄ H ₄₇ O ₆ Bi	1640	1335
4.	C ₂₈ H ₃₃ N ₄ O ₄ Bi	1636	1320
5.	C ₃₂ H ₄₁ O ₄ Cl ₂ Bi	1600	1313

Table-4: Important IR Data of Tricyclohexylbismuth(V) Dicarboxylates (Cm⁻¹)

S. No.	Compounds	$\nu_{\text{asym}}(\text{OCO})$	$\nu_{\text{sym}}(\text{OCO})$
1.	C ₃₂ H ₄₃ O ₆ Bi	1650	1334
2.	C ₄₆ H ₅₇ O ₆ Bi	1635	1312
3.	C ₃₄ H ₄₇ O ₆ Bi	1640	1335
4.	C ₂₈ H ₃₃ N ₄ O ₄ Bi	1636	1320
5.	C ₃₂ H ₄₁ O ₄ Cl ₂ Bi	1600	1313

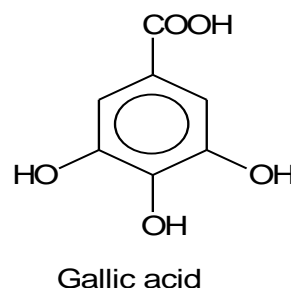
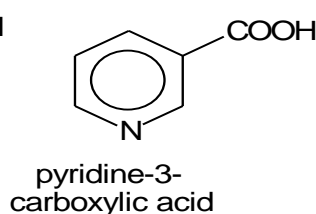
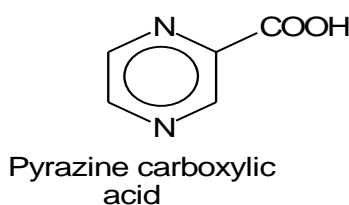
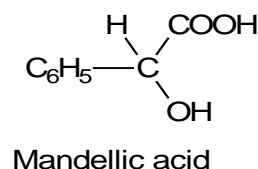
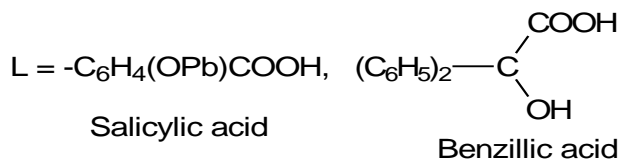
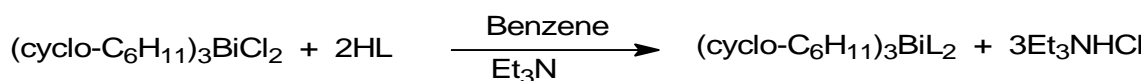
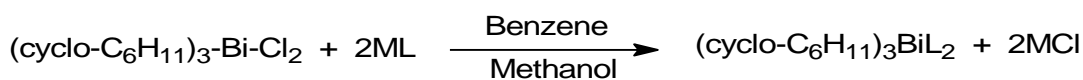
Table-5: Important IR Data of Tricyclohexylbismuth(V) Dicarboxylates (Cm⁻¹)

S. No.	Compounds	$\nu_{\text{asym}}(\text{OCO})$	$\nu_{\text{sym}}(\text{OCO})$
1.	C ₃₂ H ₄₃ O ₆ Bi	1650	1334
2.	C ₄₆ H ₅₇ O ₆ Bi	1635	1312
3.	C ₃₄ H ₄₇ O ₆ Bi	1640	1335
4.	C ₂₈ H ₃₃ N ₄ O ₄ Bi	1636	1320
5.	C ₃₂ H ₄₁ O ₄ Cl ₂ Bi	1600	1313

Results and Discussion

The tricyclohexyl bismuth was prepared from bismuth trichloride by a Grignard reaction and was converted into its dichloride. Tri(cyclohexyl) bismuth dichloride by direct chlorination, the reaction takes place in an anhydrous oxygen free atmosphere. Tri(cyclohexyl)bismuth carboxylate may be synthesized conveniently by the reaction of

tri(cyclohexyl) bismuth dichloride with carboxylic acid in presence of triethylamine as hydrogen chloride acceptor or with sodium salt of corresponding carboxylic acid. But due to the higher yield and high purity of product, the method employed was the reaction of tri(cyclohexyl) bismuth dichloride with corresponding metallic salt of carboxylic acid. The reaction can be represented in the sense of equation.



All the reaction proceeds smoothly to give almost quantitative yield of the products. The complexes are soluble in common organic solvent except in few non-polar solvent viz. petroleum ether and n-hexane. They are off-white, light brown or grey crystalline solids with sharp melting point. The molecular weight data in freezing benzene indicate that these compounds have molecular monomeric constitution. The molar conductance value for 10⁻³ M solution at room temperature suggests the absence of ionic species in solution. The carboxylates thus synthesized were confirmed by elemental analysis IR and ¹H NMR spectral data.

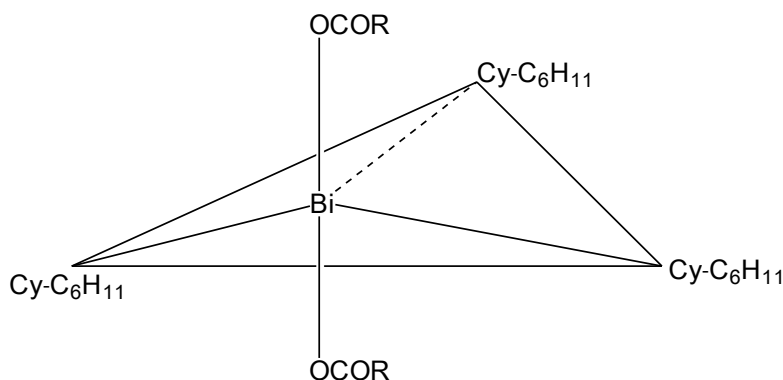
Infrared Spectra

Infrared spectra of all compounds were run in solid state in the region 4000-400 cm⁻¹. Infrared absorptions due to cyclohexyl groups bonded to bismuth do not differ significantly from those reported in the literature and hence not discussed here.

In solid state vibrational spectra of cyclohexyl bismuth (V) dicarboxylates the peaks due to $\nu_{\text{asym}}(\text{OCO})$ stretching mode appear in the range 1600-1650 cm⁻¹ and $\nu_{\text{sym}}(\text{OCO})$ appears in the range 1312-1335 as a medium strong band. Since difference $\Delta\nu$ between $\nu_{\text{asym}}(\text{OCO})$ $\nu_{\text{sym}}(\text{OCO})$ is quite larger $\{\Delta\nu[\nu_{\text{asym}}(\text{OCO}), \nu_{\text{sym}}(\text{OCO})] > 250 \text{ cm}^{-1}\}$ in all the cases it seems reasonable to conclude that the carboxylate moiety behave as unidentate, ester type -OCO group.

On the basis of solid state IR ¹H NMR data and molar conductance value, the newly synthesised complex can be assigned a trigonal bipyramidal structure in which organic group(s) occupy equatorial positions and the carboxylates moiety at axial positions. Similar structure has been suggested earlier for triorganobismuth oximes and amides from our research group.

Suggested structure of Tricyclohexyl Bismuth (V) Dicarboxylates.



Tricyclohexyl Bismuth (V) Dicarboxylates
(Cy-C₆H₁₁)₃ Bi (OCOR)₂

Anthology : The Research**Conclusions**

Synthesized compounds produced moderate yields, in addition low cost and less hazardous methods. Compounds 1, 4, 5, 6, 9 were screened for the antibacterial activity against *Aspergillus coli* all the compounds exhibited moderate activity. Since the carboxylates have found increasing importance as antitumor agents of carboxylates derivatives has been synthesized and series reported. Compounds 6, 8 exhibited good activity against *E.Coli* compounds 6&8 were screened for *invitro* activity. It is concluded that the compounds substituted with Central Drugs Research Institute, Lucknow, India.

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References

1. I.L. Finar, "A Text Book of Organic Chemistry", vol. 1. Sixth edition, Longman (1973) 550.
2. A. Singh, V.D., Gupta, G. Srivastava and R.C. Mehrotra, *J. Organometal. Chem.* 64, (1974) 145.
3. L.D. Freedman, G.O. Doak, *Chem. Rev.*, 82 (1982) 15.
4. G.O. Doak and L.D. Freedman, "Organometallic compounds of arsenic, antimony and bismuth", Wiley interscience (1970) 105.
5. K. Singhal, P. Raj F. Jee, *Synth. React. Inorg. Met. Org. Chem.* 16, (1986) 343.
6. P. Raj, A.K. Saxena, K. Singhal and A. Ranjan, 4, (1985) 251.
7. P. Raj, A. Ranjan, K. Singhal and R. Rastogi, *Synth. React. Inorg. Met. Org. Chem.* 14, (1984) 269.
8. R. Silverstein, G. Clayton Bassler and Terence C. Morrill "Spectrometric Identification of Organic Compounds", 3rd Ed. John. Wiley and Sons, New York (1974).
9. E. Maslowsky (Jr.), *J. Organometal. Chem.* 70 (1974) 153.
10. R.E. Rundle and M. Porsole, *J. Chem. Phys.* 20 (1952) 1487.
11. P.G. Harrison and J.J. Zuckerman, *Inorg. Chem.* 9 (1970) 175.