



Research Article

SYNTHESIS, CHARACTERIZATION AND ANTIMICROBIAL STUDIES OF NOVEL ORGANOBISMUTH(III) COMPLEXES

GUPTA PRAMILA, RANI PREETI AND RAVI KANT *

Department of Chemistry, Mewar University, Chittorgarh, 312901, Rajasthan, India

*Corresponding Author: Email- drravikant78@gmail.com

Received: March 21, 2018; Revised: March 24, 2018; Accepted: March 25, 2018; Published: March 30, 2018

Abstract- The Present Manuscript deals the synthesis of some novel organobismuth(III)aryloxyacetates followed by their characterization by melting points, elemental analysis, U.V., I.R and NMR spectral analysis to confirm their structures and geometry. The compounds were also screened for their antibacterial and antifungal efficacy against pathogenic bacterial and fungal strains. It was found that these compounds exhibit higher activity than the standard drug for bactericidal and fungicidal activity.

Keywords- Organobismuth, aryloxyacetates, antibacterial, antifungal.

Citation: Gupta Pramila, et al., (2018) Synthesis, Characterization and Antimicrobial studies of Novel Organobismuth(III) Complexes. International Journal of Microbiology Research, ISSN: 0975-5276 & E-ISSN: 0975-9174, Volume 10, Issue 3, pp.-1086-1089. DOI: <http://dx.doi.org/10.9735/0975-5276.10.3.1086-1089>

Copyright: Copyright©2018 Gupta Pramila, et al., This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

Introduction

The acetates in organic derivatives of group 15 elements could behave as monodentate, bidentate or as bridging ligands depending on the oxidation state (+3 or +5); physical state of the compound (solid or solution) and the various substituents present on the acetate group itself [1-10]. It has been found that major influences in determining mode of bonding, geometry and stability of the acetate system in general are the absence of ligand atom trans to an organic group; the preservation of the preferred angle of 120° at bounded oxygen atom and maximizing of secondary bonding via a bridging for acetate. Another important group of ligand which has not attracted much attention, but closely resembles to carboxylates is aryloxyacetates. However unlike acetate, aryloxyacetates has one extra donor site i.e. Ax-O-, in addition to the -C=O functionality. It is noteworthy that despite such a great variety of structural possibilities, as discussed above exhibited by organometallic carboxylates and by the variety of metals for which such derivatives have been synthesized, corresponding aryloxyacetates are mainly confirmed to transition metal derivatives [11] with an occasional reference on organotin and organoantimony [12] derivatives. A perusal of the literature further reveals that the complexes of aryloxyacetic acids in case of organotin possess intramolecular O→Sn coordination; particularly for alkyl tin derivatives and the compounds are monomeric in solid state. In sharp contrast to this triaryltin derivatives having pentaco-ordination, were found to be polymeric with bridging carboxylic group [13-19]. On the basis of ultraviolet and infrared spectra it has been concluded that aryloxyacetate behave as monodentate ligand towards bismuth. The principal objective of this work was to synthesize and characterized biomedically unreported organobismuth (III) aryloxyacetate derivatives; to investigate the role of ethereal oxygen of aryloxyacetate group i.e. whether it participates in bonding or not and thus raising the coordination number of bismuth(III) beyond three; to ascertain the mode of bonding of aryloxyacetate group towards bismuth i.e. whether the acetate group (s) acts as monodentate or bidentate group or as a both; to compare and contrast the behavior of aryloxyacetate ligand with that of

acetate and to evaluate the newly synthesized organobismuth compounds for their biomedical importance against various pathogenic diseases.

Experimental

The diorganobismuth (III) chloride, R₂BiCl and organobismuth (III) dichloride, RBiCl₂ was prepared by the redistribution reaction [20]. The syntheses of some representative compounds are as follows.

Reaction of (C₆H₅)₂Bi(III)Cl with (C₆H₅OCH₂COOH) (1)

In the stirring solution of diphenylbismuth(III)chloride (0.398gm;1mmol), phenoxyacetic acid (0.152gm;1mmol) was added in presence of triethylamine (1 ml) in benzene and was stirred in anhydrous oxygen free, nitrogen conditions for 6h, followed by refluxing for 2h to ensure completion of the reaction. A flocculent white precipitate of Et₃N.HCl (M.P.240°C) was formed which was filtered off. The filtrate on concentration gave a light brown solid which was recrystallised by petroleum ether (40°-60°C).

Reaction of (C₆H₅)₂Bi(III)Cl with (p-CH₃C₆H₄OCH₂COOH) (2)

In the stirring solution of diphenylbismuth(III)chloride (0.398gm;1mmol), *p*-methyl phenoxyacetic acid (0.166gm;1mmol) was added in presence of triethylamine (1ml) in benzene and was stirred in anhydrous oxygen free, nitrogen atmosphere for 6h, followed by refluxing for 2h to ensure completion of the reaction. A flocculent white precipitate of Et₃N.HCl (M.P.240°C) was formed which was filtered off. The filtrate on concentration afforded a light brown solid which was recrystallised by petroleum ether (40°-60°C).

Reaction of (C₆H₅)₂Bi(III)Cl with (p-ClC₆H₄OCH₂COOH) (3)

In the stirring solution of diphenylbismuth(III)chloride (0.398gm;1mmol), *p*-chloro phenoxyacetic acid (0.186gm;1mmol) was added in presence of triethylamine (1ml) in benzene and was stirred in anhydrous oxygen free, nitrogen atmosphere for 6h, followed by refluxing for 2h to ensure completion of the reaction. A white

colour precipitate of $\text{Et}_3\text{N.HCl}$ (M.P.240°C) was formed which was filtered off and the filtrate on concentration in vacuum afforded a light brown solid which was recrystallised by petroleum ether (40°-60°C).

Reaction of $(\text{C}_6\text{F}_5)_2\text{Bi(III)Cl}$ with $(\text{C}_6\text{H}_5\text{OCH}_2\text{COOH})$ (4)

In the stirring solution of bis(pentafluorophenyl) bismuth(III)chloride (0.578gm; 1mmol), phenoxyacetic acid (0.152gm;1mmol) was added in presence of triethylamine (1 ml) in benzene and was stirred in anhydrous oxygen free, nitrogen conditions for 6h, followed by refluxing for 2h to ensure completion of the reaction. A flocculent white precipitate of $\text{Et}_3\text{N.HCl}$ (M.P.240°C) was formed which was filtered off. The filtrate on concentration gave a light brown solid which was recrystallised by petroleum ether (40°-60°C).

Reaction of $(\text{C}_6\text{F}_5)_2\text{Bi(III)Cl}$ with $(p\text{-CH}_3\text{C}_6\text{H}_4\text{OCH}_2\text{COOH})$ (5)

In the stirring solution of bis(pentafluorophenyl) bismuth (III) chloride (0.578gm; 1mmol), *p*-methyl phenoxyacetic acid (0.166gm;1mmol) was added in presence of triethylamine (1ml) in benzene and was stirred in anhydrous oxygen free, nitrogen conditions for 6h, followed by refluxing for 2h to ensure completion of the reaction. A flocculent white precipitate of $\text{Et}_3\text{N.HCl}$ (M.P.240°C) was formed which was filtered off. The filtrate on concentration afforded a light brown solid which was recrystallised by petroleum ether (40°-60°C).

Reaction of $(\text{C}_6\text{F}_5)_2\text{Bi(III)Cl}$ with $(p\text{-ClC}_6\text{H}_4\text{OCH}_2\text{COOH})$ (6)

In the stirring solution of bis (pentafluorophenyl) bismuth(III)chloride (0.578gm; 1mmol), *p*-chloro phenoxyacetic acid (0.186gm;1mmol) was added in presence of triethylamine (1ml) in benzene and was stirred in anhydrous oxygen free, nitrogen conditions for 6h, followed by refluxing for 2h to ensure completion of the reaction. A white colour precipitate of $\text{Et}_3\text{N.HCl}$ (M.P.240°C) was formed which was filtered off and the filtrate on concentration in vacuum afforded a light brown solid which was recrystallised by petroleum ether (40°-60°C).

Reaction of $(p\text{-FC}_6\text{H}_4)_2\text{Bi(III)Cl}$ with $(\text{C}_6\text{H}_5\text{OCH}_2\text{COOH})$ (7)

In the stirring solution of bis(*p*-fluorophenyl)bismuth(III)chloride (0.434gm;1mmol), phenoxyacetic acid (0.152gm;1mmol) was added in presence of triethylamine (1 ml) in benzene and was stirred in anhydrous oxygen free, nitrogen conditions for 6h, followed by refluxing for 2h to ensure completion of the reaction. A flocculent white precipitate of $\text{Et}_3\text{N.HCl}$ (M.P.240°C) was formed which was filtered off. The filtrate on concentration gave a light brown solid which was recrystallised by petroleum ether (40°-60°C).

Reaction of $(p\text{-FC}_6\text{H}_4)_2\text{Bi(III)Cl}$ with $(p\text{-CH}_3\text{C}_6\text{H}_4\text{OCH}_2\text{COOH})$ (8)

In the stirring solution of bis(*p*-fluorophenyl)bismuth(III)chloride (0.434gm;1mmol), *p*-methyl phenoxyacetic acid (0.166gm;1mmol) was added in presence of triethylamine (1ml) in benzene and was stirred in anhydrous oxygen free, nitrogen conditions for 6h, followed by refluxing for 2h to ensure completion of the reaction. A flocculent white precipitate of $\text{Et}_3\text{N.HCl}$ (M.P.240°C) was formed which was filtered off. The filtrate on concentration afforded a light brown solid which was recrystallised by petroleum ether (40°-60°C).

Reaction of $(p\text{-FC}_6\text{H}_4)_2\text{Bi(III)Cl}$ with $(p\text{-ClC}_6\text{H}_4\text{OCH}_2\text{COOH})$ (9)

In the stirring solution of bis(*p*-fluorophenyl)bismuth(III)chloride (0.434gm;1mmol), *p*-chloro phenoxyacetic acid (0.186gm;1mmol) was added in presence of triethylamine (1ml) in benzene and was stirred in anhydrous oxygen free, nitrogen conditions for 6h, followed by refluxing for 2h to ensure completion of the reaction. A white colour precipitate of $\text{Et}_3\text{N.HCl}$ (M.P.240°C) was formed which was filtered off and the filtrate on concentration in vacuum afforded a light brown solid which was recrystallised by petroleum ether (40°-60°C).

Antibacterial activity

The antibacterial activity of these organobismuth (III) compounds was determined by disc diffusion method [21]. In this technique, the filter paper (Whatman No. 1) sterile discs of 5 mm diameter, impregnated with the test compounds (10 µg/ml of ethanol) were placed on the nutrient agar plate at 37°C for 24 hrs. The inhibition

zones around the dried impregnated discs were measured after 24 hrs. The activity was classified as 'highly active' (diameter > 14 mm); 'moderately active' (diameter = 10-14 mm) and 'slightly active' (diameter = 6-10). The diameter less than 6 mm was regarded as inactive.

Antifungal activity

The antifungal activity of these compounds was tested by agar diffusion method [22] using two concentrations of the test compound, viz., 50 and 100 µg/ml; against *Aspergillus flavus* and *Aspergillus niger*. The one ml of each organobismuth compound was poured into a petri dish having about 20-25 ml of molten potato dextrose agar medium. As the medium gets solidify, petri dishes were inoculated separately with the fungal isolates and kept at 26°C for 96 hrs in incubator. All the values (% inhibition) were recorded after 96 hrs. The % inhibition of these compounds was calculated by using following mathematical equation.

$$\text{Percent (\% Inhibition)} = \frac{C-T}{C} \times 100$$

Here: C = Diameter of fungus in control.

T = Diameter of fungus in test compound.

Results and Discussion

All the reactions were conducted at room temperature and the products were recrystallised from petroleum ether (40-60°C) or in benzene. The complexes are off-white to light brown solids and obtained as a sticky mass which on treatment with sodium in dry benzene gets solidified and subsequently crystallized with benzene/pet-ether. The complexes are fairly stable on air and moisture and have sharp melting point. There is no regular trend of the melting point of the complexes and they melt without decomposition. Complexes are also soluble in chloroform and acetonitrile. They can be stored at room temperature without decomposition for several weeks. The consistency in melting points after repeated crystallization as well as TLC run in chloroform hexane mixture (1:1) with the observation of a single spot excluded the presence of mixture of reactants. The molar conductance value of 10-3 M solution of these compounds were recorded in methanol and found in the range of 15-25 $\text{Ohm}^{-1} \text{mole}^{-1} \text{cm}^2$ indicating the absence of ionic species in solution. The complexes were found to be monomeric in nitrobenzene.

IR Spectra

As expected infrared absorptions inherent to phenyl and fluorophenyl groups bound to bismuth have no difference appreciably and hence not discussed. The Infrared absorptions having diagnostic value for organobismuth aryloxyacetates, related to the ligand, have been identified which on preliminary stage indicates the mode of bonding with aryloxy ligand. The characteristic $\nu(\text{OH})$ absorption band of ligands which appeared around 3400cm^{-1} in the free ligand, was found missing in the newly synthesized complexes. A medium strong intensity band appearing at $1690\text{-}1700 \text{cm}^{-1}$ can confidently be assigned to $\nu_{\text{asy}}(\text{OCO})$ mode while comparatively weaker band in the range $1380\text{-}1400 \text{cm}^{-1}$ can be attributed to $\nu_{\text{sym}}(\text{OCO})$ band. The deformation mode as a medium intensity band was found in the range $780\text{-}815 \text{cm}^{-1}$. The absorption associated with the bismuth-oxygen appears in the range between $400\text{-}430 \text{cm}^{-1}$ and the absorption due to bismuth-carbon corresponding to γ -mode occurs in the range $450\text{-}470\text{cm}^{-1}$. These values clearly indicated the formation of organobismuth (III) aryloxyacetates. The comparison of IR spectra of the compounds with those of respective ligands in solid and solution states did not show any significant shift in $\nu_{\text{asy}}(\text{C}=\text{O})$, $\nu_{\text{sym}}(\text{C}-\text{O})$ and $\nu(\text{C}-\text{O}-\text{C})$ deformation bands which in turn showed the lack of coordination with bismuth through $-\text{C}=\text{O}$ or $\text{C}-\text{O}-\text{Ar}$ center of the ligand. Since the separation observed in the present compounds is fairly large (2300cm^{-1}), monomolecular constitution seems to be most plausible where bismuth would be have a coordination number three. This observation is clearly sharp contrast to organotin complexes of aryloxyacetates which have been found to be polymeric involving carboxylic bridges. In addition to this intermolecular interaction involving the ethereal oxygen has also been demonstrated in some cases particularly.

¹H NMR Spectra

¹H NMR spectra of these compounds was recorded in CDCl_3 using TMS as an

internal reference at 25°C. The disappearance of OH proton signals (89.1 ppm) present in the ligand clearly indicates the formation of aryloxyacetate derivatives. The appearance of singlet for -CH₃ protons at 84.85 ppm showed the ligand is in one plane. The phenyl protons for both the derivatives appear as multiplets in the range δ7.80-7.20 ppm.

UV Spectra

The electronic spectra obtained for representative compounds were recorded in chloroform in the range 200-400 nm. The UV absorption due to COO group appears at 274+6 and 294+2 are due to aryloxy moieties. Since there was no significant change in absorption peaks of the ligands indicates that -C=O and -C-O-Ar centre of aryloxyacetates are not coordinated to bismuth in any of the compounds. This also lends to support to the fact that aryloxyacetates behave as monodentate ligand towards bismuth in +3 oxidation state.

Table-1 Physicochemical studies of organobismuth (III) aryloxyacetates

S.N.	Compounds	Formula	M.P. (°C)	Color	Yield (%)	Solvent
1	(C ₆ H ₅) ₂ Bi(OOC.CH ₂ OC ₆ H ₅)	C ₂₀ H ₁₇ O ₃ Bi	190	Light Brown	60	Pet-ether
2	(C ₆ H ₅) ₂ Bi(OOC.CH ₂ OC ₆ H ₄ .CH ₃)	C ₂₁ H ₁₉ O ₃ Bi	156	Light Brown	75	Pet-ether
3	(C ₆ H ₅) ₂ Bi(OOC.CH ₂ OC ₆ H ₄ .Cl)	C ₂₀ H ₁₆ O ₃ ClBi	214	Light Brown	70	Pet-ether
4	(C ₆ F ₅) ₂ Bi(OOC.CH ₂ OC ₆ H ₅)	C ₂₀ F ₁₀ H ₇ O ₃ Bi	184	Light Brown	65	Pet-ether
5	(C ₆ F ₅) ₂ Bi(OOC.CH ₂ OC ₆ H ₄ .CH ₃)	C ₂₁ F ₁₀ H ₉ O ₃ Bi	176	Light Brown	60	Pet-ether
6	(C ₆ F ₅) ₂ Bi(OOC.CH ₂ OC ₆ H ₄ .Cl)	C ₂₀ F ₁₀ H ₆ O ₃ ClBi	204	Light Brown	60	Pet-ether
7	(p-FC ₆ H ₄) ₂ Bi(OOC.CH ₂ OC ₆ H ₅)	C ₂₀ F ₂ H ₁₅ O ₃ Bi	192	Light Brown	60	Pet-ether
8	(p-FC ₆ H ₄) ₂ Bi(OOC.CH ₂ OC ₆ H ₄ .CH ₃)	C ₂₁ F ₂ H ₁₇ O ₃ Bi	182	Light Brown	75	Pet-ether
9	(p-FC ₆ H ₄) ₂ Bi(OOC.CH ₂ OC ₆ H ₄ .Cl)	C ₂₀ F ₂ H ₁₄ O ₃ ClBi	198	Light Brown	70	Pet-ether

Table-2 Analytical studies organobismuth (III) aryloxyacetates

S.N.	Compounds Formula	Formula weight	Elemental Analysis		IR Absorption frequencies		
			C (%)	H (%)	ν _{asy} (OCO)	ν _{sym} (OCO)	ν (Bi-C)
1	C ₂₀ H ₁₇ O ₃ Bi	514	46.69	3.30	1695	1395	411
2	C ₂₁ H ₁₉ O ₃ Bi	528	47.73	3.60	1694	1385	415
3	C ₂₀ H ₁₆ O ₃ ClBi	548.5	43.76	2.92	1694	1387	417
4	C ₂₀ F ₁₀ H ₇ O ₃ Bi	694	34.58	1.01	1696	1390	419
5	C ₂₁ F ₁₀ H ₉ O ₃ Bi	708	35.59	1.27	1700	1397	410
6	C ₂₀ F ₁₀ H ₆ O ₃ ClBi	728.5	32.94	0.82	1697	1400	425
7	C ₂₀ F ₂ H ₁₅ O ₃ Bi	550	43.64	2.72	1692	1406	428
8	C ₂₁ F ₂ H ₁₇ O ₃ Bi	564	44.68	3.01	1688	1394	422
9	C ₂₀ F ₂ H ₁₄ O ₃ ClBi	584.5	41.06	2.39	1694	1408	431

Table-3 Anti-bacterial activity of organobismuth (III) aryloxyacetates

S. N.	Compounds	Control	<i>Pseudomonas aeruginosa</i>	<i>Staphylococcus aureus</i>	<i>Klebsiella pneumoniae</i>
1	(C ₆ H ₅) ₂ Bi(OOC.CH ₂ OC ₆ H ₅)	-	+++	+++	++
2	(C ₆ H ₅) ₂ Bi(OOC.CH ₂ OC ₆ H ₄ .CH ₃)	-	++	++	++
3	(C ₆ H ₅) ₂ Bi(OOC.CH ₂ OC ₆ H ₄ .Cl)	-	+++	++	++
4	(C ₆ F ₅) ₂ Bi(OOC.CH ₂ OC ₆ H ₅)	-	++	++	++
5	(C ₆ F ₅) ₂ Bi(OOC.CH ₂ OC ₆ H ₄ .CH ₃)	-	++	++	+++
6	(C ₆ F ₅) ₂ Bi(OOC.CH ₂ OC ₆ H ₄ .Cl)	-	+++	++	++
7	(p-FC ₆ H ₄) ₂ Bi(OOC.CH ₂ OC ₆ H ₅)	-	++	++	++
8	(p-FC ₆ H ₄) ₂ Bi(OOC.CH ₂ OC ₆ H ₄ .CH ₃)	-	++	++	+++
9	(p-FC ₆ H ₄) ₂ Bi(OOC.CH ₂ OC ₆ H ₄ .Cl)	-	+++	+++	++

Table-4 Anti-fungal activity of organobismuth (III) aryloxyacetates at 50 µg/ml conc.

S. N.	Compounds	<i>Aspergillus flavus</i> Col. Dia. (mm)	% Inhibition	<i>Aspergillus niger</i> Col. Dia. (mm)	% Inhibition
1	(C ₆ H ₅) ₂ Bi(OOC.CH ₂ OC ₆ H ₅)	0.7	76.6	0.6	70.0
2	(C ₆ H ₅) ₂ Bi(OOC.CH ₂ OC ₆ H ₄ .CH ₃)	0.2	93.3	0.7	65.0
3	(C ₆ H ₅) ₂ Bi(OOC.CH ₂ OC ₆ H ₄ .Cl)	0.2	93.3	0.7	65.0
4	(C ₆ F ₅) ₂ Bi(OOC.CH ₂ OC ₆ H ₅)	0.5	83.3	0.4	80.0
5	(C ₆ F ₅) ₂ Bi(OOC.CH ₂ OC ₆ H ₄ .CH ₃)	0.2	93.3	0.7	65.0
6	(C ₆ F ₅) ₂ Bi(OOC.CH ₂ OC ₆ H ₄ .Cl)	0.2	93.3	0.7	65.0
7	(p-FC ₆ H ₄) ₂ Bi(OOC.CH ₂ OC ₆ H ₅)	0.7	76.6	0.7	65.0
8	(p-FC ₆ H ₄) ₂ Bi(OOC.CH ₂ OC ₆ H ₄ .CH ₃)	0.8	73.3	0.8	60.0
9	(p-FC ₆ H ₄) ₂ Bi(OOC.CH ₂ OC ₆ H ₄ .Cl)	0.8	73.3	0.8	60.0
10	Control	3.0	-	2.0	-

On the basis of IR, NMR and UV spectral analysis data, it may tentatively concluded that aryloxyacetate under the present study behaves as a monodentate ligand. Conductance measurement and molecular weight data showed that these aryloxyacetates have monomeric nature and are non conducting in nature. The experimental data are thus consistent with three coordinate pyramidal structures.

Antibacterial activity

The organobismuth (III) aryloxyacetates were tested for antibacterial activity against three bacterial strains *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Klebsiella pneumoniae* using 10 µg/ml concentration of test compound. All the

compounds show higher to moderate activity against the bacterial strains. It was found that compounds having fluoro and pentafluorophenyl ring are more effective because of their water and lipid solubility. The fluorine containing compounds may generally form complexes with metalloenzymes, particularly those which responsible in basic physiology such as *cytochrome oxidase*. These compounds may react with peptidoglycan layer of bacterial cell wall and damage it by penetrating in such a manner that the phenyl ring gets entered inside the cell by puncturing it followed by death of bacterial cell. Sometimes these compounds in low concentration may cause bacteriostatic condition by slow down the growth of bacteria.

Antifungal Activity

The antifungal activity of organobismuth (III) compounds was tested against *Aspergillus flavus* and *Aspergillus niger* using 50 µg/ml concentration. The activity of these compounds was found variable at 50µg/ml concentration against fungal strains. Presence of nitrogen, phenyl and pentafluorophenyl ring along with bismuth in +3 oxidation state are considered for fungal activity. The role of different aryloxyacetates as ligands was also commendable. These compounds generally damage the fungal strains by puncturing the cell wall similarly as in the case of bacteria. Water and lipid solubility of these compounds, due to presence of fluorine, also increases the activity due to presence of fluorine.

Application of research: Applicable for study of antimicrobial activity of Organobismuth compounds

Research Category: Antibacterial activity

Acknowledgement / Funding: Author thankful to Department of Chemistry, Mewar University, Chittorgarh, 312901, Rajasthan

***Research Guide or Chairperson of research: Dr Ravi Kant**

University: Department of Chemistry, Mewar University, Chittorgarh, 312901, Rajasthan

Research project name or number: PhD Thesis

Author Contributions: All author equally contributed

Author statement: All authors read, reviewed, agree and approved the final manuscript

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

References

- [1] Thayer J.S. (1974) *J. Organometal. Chem.*, 76, 265.
- [2] Doak G.O. and Freedman L.D. (1973) *Wiley Interscience, New York*, 1973.
- [3] Christiansen W.G. (1925) Organic derivatives of antimony" *Chem. Catalog. Co., New York*, 101.
- [4] Sijpesteya A.K., Lujiten J.G.A. and Vander Kerk G.J.M. (1969) in B. C. Toregeson (Ed.), *Academic Press, New York*, 331.
- [5] Bernes J.M. and Magos L. (1968) *Organometal. Chem. Rev.*, 3, 137.
- [6] Langer H. G., U.S. 3, 442, 922(C1. 260-429), 7:CO7F, Olm A., A 61K) 06 May 1969, Appl.09April 1964, 4pp *Chem. Abst.*, 72, 12880, 1970.
- [7] Varsanyi D., Margot A. and Sohwin F., S. African 7006908, 94 June 1971, *Swiss Appl.* 15, 234/69, 10 Oct., 1969 35pp, *Chem. Abst.*, 76,141028, 1972.
- [8] Norbury H., *Advances Inorg, Chem. Radio Chemistry*, Eds. H. J. Emeleus and A. G. Sharpe (1975) *Academic Press, New York*, , 17.
- [9] Ham N. S. and Willis J. B. (1960) *Spectrochim. Acta*, 16, 393.
- [10] Lieber E., Rao C.N.R. and Ramachandran J. (1959) *Spectrochim. Acta*, 13, 296.
- [11] Mitchell P.C.H. and Williams R.J.P. (1960) *J. Chem. Soc.*, 1912.
- [12] Caldwell G.L. and Thompson H.W. (1958) *Spectrochim. Acta*, 13, 212.
- [13] Ham N.S. and Willis J. B. (1960) *Spectrochim. Acta*, 16, 289.
- [14] Cummins R.A. and Dunn P. (1964) *Aust. J. Chem.*, 17, 411.
- [15] Sabatini A. and Bertini T. (1965) *Inorg. Chem.*, 4, 959.
- [16] Clark R.J.H. and Williams C.S. (1965) *Spectrochim. Acta*, 22, 1081.
- [17] Bertazzi N., Alonzo G., Silvestru A. and Consiglio G. (1972) *J. Organometal. Chem.*, 37, 281.
- [18] Aynseley E. E., Greenwood N.N., Hunter G. and Sprague M.S. (1966) *J. Chem. Soc.*, 1344.
- [19] Thayer J.S. and West R. (1967) *Academic Press, New York*, 5, 169.

- [20] Kant R., Amresh G., Chandrashekar K. and Anil K.K.S. (2008) *Phosphorus, Sulfur and Silicon*, 183, 1410-1419.
- [21] Soni K.K., Kumar Alok and Kant R. (2015) *Inter. Jour. of Chem. Resear.*, 7(1), 159-163.
- [22] Soni K.K., Kumar Alok and Kant R. (2016) *Inter. Jour. of Chem. Resear.*, 8(1), 168-172.