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Organoboron(III) and Organolead(IV) Complexes as Antimicrobial and Antimycobacterial Agents: Synthetic, Structural, and Biological Aspects[1]

M. Swami[a], K. Mahajan[a], S. Arya[b], S. K. Mehla[c], and R. V. Singh[a]

[a] *Department of Chemistry, University of Rajasthan, Jaipur 302004, India*

[b] *Department of Zoology, University of Rajasthan, Jaipur 302 004, India*

[c] *Department of Chemistry, College of Engineering and Technology, Bikaner–334004*

e-mail: rvsjpr@hotmail.com

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Abstract—Phenylboron(III) and triorganolead(IV) derivatives of the types PhB(OH)(DTCZ), $PhB(DTCZ)_2$, and $Ph_3Pb(DTCZ)$ (where $DTCZ^-$ is the anion of a S-benzyldithiocarbazate ligand) have been synthesized by the substitution reactions of phenylboronic acid and triphenyllead chloride with S-benzyldithiocarbazate. The resulting complexes have been characterized by elemental analyses, molecular weight determinations, and conductivity measurements. The mode of bonding has been established on the basis of infrared and ^1H, ^{13}C, and ^{11}B NMR spectroscopic studies. Probable tetrahedral and trigonal bipyramidal structures for the resulting derivatives have been proposed. The X-ray powder diffraction study of the compound [$PhB(OH)(L^1)$] was carried out in order to have an idea about the molecular symmetry of the compound. The results show that the compound belongs to the orthorhombic crystal system. In the quest for better fungicides and bactericides, the studies were conducted to assess the growth inhibiting potential of the synthesized complexes against various fungal and bacterial strains. The studies demonstrate the concentration reached levels which are sufficient to inhibit and kill the pathogens. The antimycobacterial effects of the organolead(IV) compounds were also examined. The results obtained indicated that the compounds display antimycobacterial activity.

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INTRODUCTION

To overcome the alarming problem of microbial resistance to antibiotics, the discovery of novel active compounds against new targets is a matter of urgency. However, plant-based drugs have shortened the life span of the source of material. There is a continuous search for more potent and cheaper raw material to feed the industry. Coordination compounds exhibit different characteristic properties, which depend on the metal ion to which they are bound, the nature of the metal, as well as the type of ligand. These metal complexes have found extensive applications in various fields of human interest. The nature of a coordination compound depends on the metal ion and the donor atoms, as well as on the structure of the ligand and the metal–ligand interaction [1]. With increasing knowledge of the properties of functional groups, as well as the nature of donor atoms and the central metal ion, ligands with more selective chelating groups, i.e., imines or azomethines which are more commonly known as Schiff bases, are used for complex formation studies. It is reported that the rapidly developing field of bioinorganic chemistry is centered on the presence of coordination compounds in living systems [2].

Although syntheses of S-benzyldithiocarbazate Schiff bases and their complexation products were reported in the recent past [3–5], the evaluation of their biological properties has not been described. In addition, their complexes with transition metals have extensively been studied [6–8]. A variety of complexes of phenyldihydroxyborane with substituted dihiocarbazates were also prepared in a benzene solution. The pathogenicity of microbial infection associated with the complexes has been subjected to a variety of biointeraction studies and the results are discussed [9]. Boron complexes of benzothiazolines with N∩S donor system are gaining enormous importance on account of their inherent biological potential [10]. A number of boron azomethine derivatives have been reported, and these were synthesized by the reaction of isopropoxyborane and phenyldihydroxyborane [11].

A variety of organolead compounds possess antimicrobial and fertility regulatory activities [12–13]. The antimycobacterial activities of some lead compounds

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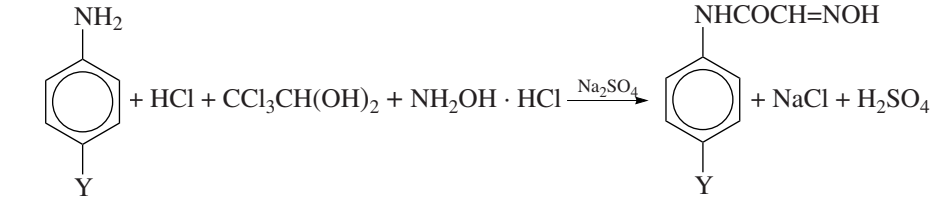
have been investigated by many of researchers in the recent past [14].

In the present work, the complexes of boron(III) and lead(IV) with different substituted S-benzyldithiocarbazates have been synthesized. Further, their antimicrobial activity toward some clinically important bacteria and fungi was evaluated. Also, the peculiar behavior of organolead complexes in chemical and biochemical processes has led us to synthesize such type of complexes and screened them for their antitubercular activity, so as to contribute in the field of bioinorganic chemistry and their clinical uses.

EXPERIMENTAL

Materials and methods. All the chemicals were dried and purified before using and the purity was checked by thin layer chromatography (TLC). All the solvents used were of high purity and distilled before use. Solvents used were dried and purified by standard methods. Glass apparatus free from moisture and fitted with quickfit interchangeable standard ground joints were used throughout the experimental work and moisture was excluded from the glass apparatus using $CaCl_2$ drying tubes.

Synthesis of *p*-chloro/nitroindolindione derivatives. First step To a solution of chloral hydrate (0.11 mol, 18.12 g) in water (250 ml) was added a solution of *p*-nitroaniline/*p*-chloroaniline (0.01 mol) in HCl (5.5 ml) and finally a solution of hydroxylamine hydrochloride (0.33 mol, 22.0 g) in water. The reaction mixture was heated at such a rate that vigorous boiling started within 45 min. The boiling was continued for further 10 min. The mixture was cooled when colored needles separated out. These were filtered and recrsytallized from ethanol. The synthetic procedure is shown below:

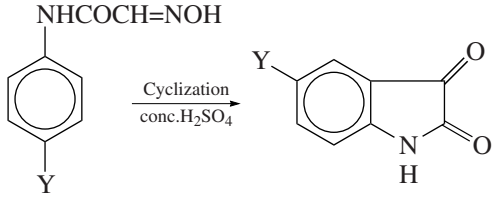


p-Chloro-/nitroaniline

p-Chloro-/*p*-nitroisonitrosoacetanilide

Y = Cl/NO_2

Second step. *p*-Nitroisonitrosoacetanilide/*p*-chloroisonitrosoacetanalide (0.05 mol) was added to the concentrated H_2SO_4 (50 ml) in about 30 min with constant stirring. After the addition was complete, the reaction mixture was heated at 80°C for 10 min and poured into tenfold excess of crushed ice. The resultant precipitate was filtered after an hour and dried in air. It was purified by recrystallization from glacial acetic acid. The cyclization reaction is shown below:

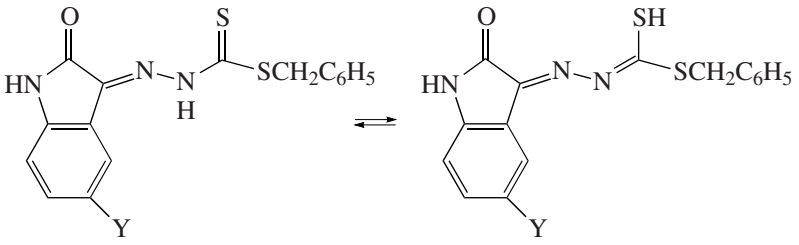


p-Chloro-/nitro-isonitrosoacetanilide

5-Chloro-/5-nitro-3-indolin-2-one

Synthesis of hydrazinecarbodithioic acid. To a cold solution of KOH (5.7 g) in 90% ethanol (35 ml) was added hydrazinehydrate (5 g) slowly with constant stirring. A solution of CS_2 (7.6 g) was added dropwise with continuous stirring over a period of 3 h and the temperature of reaction mixture was kept below 10°C during addition. The reaction mixture separated into two different layers. The lower oily layer was separated and dissolved in cold 40% ethanol (40 ml). The solution was kept in ice and benzyl chloride (12.5 g) was added dropwise with stirring for 6–7 h. The dim white solid was separated by filtration. This solid was washed with distilled water and dried in air. The crude product (m.p. 118°C) was recrystallized from benzene.

Synthesis of hydrazinecarbodithioic acid ligands: 5-chloro–1H-indole–2,3-dione hydrazinecarbodithioic acid (**L^1H**), 5-nitro–1H-indol–2,3-dione hydrazinecarbodithioic acid (**L^2H**), and 2-hydroxy benzamidehydrazinecarbodithioic acid (**L^3H_2**) were carried out by the condensation of 5-nitro-1H-indole-2,3-dione and 2-hydroxybenzamide with S-benzyldithiocarbazate in an ethanol medium according to [15]. Elemental analysis data and some physical properties of these ligands are recorded in Table 1. Tautomeric forms of L^1H, L^2H, and L^3H_2 are given below:



Thioketo form Thioenol form

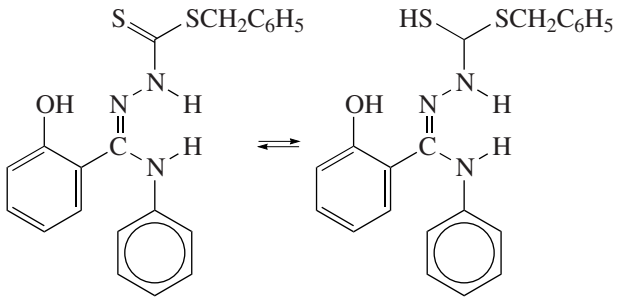
L^1H if Y = Cl and L^2H if Y = NO_2 , N⌒SH = monofunctional bidentate ligand.

Table 1. Elemental analysis data and some physical properties of these ligands

Compound	Fw (calcd/found)	M.p., °C	Color	Contents (calcd/found), %	
				N	S
L^1H ($C_{16}H_{12}N_3OS_2Cl$)	355.67/361.86	129	Brown	11.08/11.61	17.35/17.22
L^2H ($C_{16}H_{12}N_4O_3S_2$)	369.92/372.42	155	Brownish-yellow	14.91/15.04	17.09/17.22
L^3H_2 ($C_{21}H_{19}N_3OS_2$)	386.89/393.52	130	Gray	10.06/10.68	16.15/16.30

Table 2. Synthetic and analytical data of the organoboron(III) and organolead(IV) complexes

Reactants, g		Molar ratio	Compound	Color and state	M.p., °C	Contents (found/calcd), %			FW
compound of B/Pb	ligand					N	S	B/Pb	
$PhB(OH)_2$ (0.44)	L^1H (1.34)	1 : 1	$[PhB(OH)L^1]$	Brown	188	8.97/9.02	13.45/13.76	2.15/2.31	462/465.79
$PhB(OH)_2$ (0.26)	L^1H (1.51)	1 : 2	$[[PhB(L^1)_2]$	Red	194	10.05/10.37	15.63/15.84	1.09/1.33	798.12/809.65
$PhB(OH)_2$ (0.32)	L^2H (0.99)	1 : 1	$[PhB(OH)L^2]$	Mustard	267	11.58/11.76	13.29/13.46	2.05/2.26	473/476.33
$PhB(OH)_2$ (0.22)	L^2H (1.77)	1 : 2	$[PhB(L^2)_2]$	Coke	245	13.39/13.48	15.25/15.43	1.12/1.30	826.62/830.74
Ph_3PbCl (0.22)	L^1H (0.17)	1 : 1	$[Ph_3PbL^1]$	Brick red	277	5.09/5.25	7.95/8.02	25.72/25.91	772.89/799.36
Ph_3PbCl (0.20)	L^2H (0.16)	1 : 2	$[Ph_3PbL^2]$	Black	285	6.75/6.91	7.68/7.91	25.32/25.58	802.35/809.92
Ph_3PbCl (0.19)	L^3H_2 (0.16)	1 : 1	$[Ph_3Pb(L^3H)]$	Black	>300	4.94/5.05	7.55/7.71	24.70/24.93	825.52/831.03



Thioketo form Thioenol form

L^3H_2, HO⌒N⌒SH = bifunctional tridentate ligand.

Synthesis of organoboron(III) complexes was carried out according to [16]. In a round-bottom flask (100 ml capacity) 40 ml of benzene were mixed with the calculated amount of phenyldihydroborane. The equimolar and bimolar amounts of the ligands, L^1H and L^2H, were added to it. To the calculated amount of the ligands dissolved in dry benzene was added dihydroxyphenylborane in unimolar and bimolar ratios. The reaction mixture was refluxed for 10–12 h on a fractionating column, and the progress of the reaction was monitored by the liberation of water/benzene azeotrope. After the completion of the reaction, excess of the solvent was distilled off, and products were dried. The resulting products were washed with dry cyclohexane and then finally dried in vacuo for 3–4 h.

Synthesis of organolead(IV) complexes. In a round-bottom flask (100 ml capacity) 40 ml of benzene were mixed with the calculated amount of Ph_3PbCl. The equimolar amount of the ligands (L^1H, L^2H, and L^3H) was added to it. The reaction mixture was refluxed for 10–12 h and then cooled to room temperature. After the completion of the reaction, an excess of the solvent was distilled off. Then the compound was repeatedly washed with *n*-hexane followed by drying in vacuum for two h. It gave final purified solid product. The synthetic and analytical data of organoboron(III) and organolead(IV) complexes are recorded in Table 2.

Analytical methods and physical measurements. The various analytical methods were adopted for the proper characterization of the compounds. Nitrogen and sulfur [17] were estimated by the Kjeldahl's and Messenger's methods, respectively. Molecular weights were determined by the Rast camphor method [18]. Boron and lead were estimated volumetrically as boric acid and gravimetrically as lead sulfate, respectively. The UV spectra were recorded on a Hitachi-U-2000 spectrophotometer. The IR spectra of the ligands and their complexes were recorded in the range 4000–200 cm^{-1} with Perkin Elmer 577 grating spectrophotometer. The spectra were recoded as KBr pellets or Nujol mulls. The ^1H and ^{13}C NMR spectra were recorded in DMSO-d_6 using TMS as the standard on a JEOL AL 300 FT NMR instrument. X-ray powder diffraction patters of the finally grinded complexes were recorded on a Phillips X-ray diffractometer (PW 1840). Reflections from 20 to 80 were recorded almost in all the cases. The conductivity of the resulting derivatives was determined at the room temperature in dry DMF by the Systronics conductivity bridge (model 305) using a cell having a cell constant (0.5 cm^{-1}).

In vitro study. Fungicidal screening was carried out by poisoned food technique according to [19]. Potato dextrose agar medium was prepared in a flask and sterilized. Accurate amounts of all the compounds were added after being dissolved in methanol, so as to get certain final concentrations of 50, 100, and 200 ppm. Aliquots of 15 ml of medium were poured in sterilized petriplates. A culture of test fungus is grown on PDA for certain days at the optimum temperature for growth. Small disc of the fungus culture is cut with a sterile cork borer and transferred aseptically in the center of petridisc containing the medium with a certain amount of fungi and incubated for 4 days at 25 ± 2°C. The colony diameter was measured after the incubation period of growth. The percentage inhibition of growth was calculated by $(C–T)\ C^{-1} \times 100$, where C = growth in control, T = growth in treatment.

Bactericidal screening was carried out by inhibition zone technique according to [19]. Flat bottomed petridiscs were used and nearly 15 ml of the beef extract medium (peptone 5 g, beef extract 5 g, NaCl 5 g, agar-agar 20 g, and distilled water 1000 ml were pipetted out into the petridisc. Then bacterial suspension was added and after sometime bacterial growth was seen in the medium. The test compounds were dissolved in methanol to give 500 and 1000 ppm final concentrations. Paper discs of Whatman no. 1 filter paper of 5 mm in diameter were soaked in these solutions of varied concentrations. The discs were dried and placed on the medium with organism in petridiscs at suitable distances. These petridiscs were incubated for 24 h at 25 ± 2°C, and zone of inhibition was measured in mm.

Antimycobacterial studie. Mycobacterium tuberculosis is the etiologic agent of tuberculosis in humans; other human pathogens belonging to the mycobacterium genus include mycobacterium bovis and mycobacterium avium, which cause a TB-like disease especially prevalent in AIDS patients, and mycobacterium lepra, the causative agent of leprosy.

Sputum of patients suffering from TB was collected. Smear was prepared on the glass slides, and temperature was then fixed. This smear was then stained by Ziehl–Neeslen acid-fast staining procedure and examination under oil immersion lens (100 X) of light microscope. Under light microscope acid-fast bacilli ranges from 1 to 10 μm in length and 0.2 to 0.6 μm in width. They typically appear as slender, rod-shaped bacilli, but they may also appear as curved or bent. Individual bacteria may display heavily stained areas referred to as beads and areas of alternating stain producing a banded appearance. There are several methods for the reporting of numbers of AFB seen in a smear.

Table 3. ^{1}H NMR spectral data (δ, ppm) of the ligands and their corresponding organoboron(III) and organolead(IV) complexes*

Compound	–NH/ϕ–NH (b.s.)	–NH (free) (b.s.)	ϕ–OH	$-SCH_2$	Aromatic protons (m.)
L^1H	11.94	11.24		4.50	6.82–8.28
[PhB(OH) L^1]	11.95			4.58	6.95–8.25
[PhB(OH) $(L^1)_2$]	11.98			4.56	6.84–8.22
[Ph_3PbL^1]	11.96			4.54	6.83–8.31
L^2H	11.96	11.28		4.62	6.70–8.18
[PhB(OH) L^2]	11.94			4.72	6.72–8.20
[PhB(OH) $(L^2)_2$]	11.96			4.71	6.70–8.22
[Ph_3PbL^2]	11.94				6.72–8.21
L^3H_2		12.15	10.46	4.98	6.81–8.35
[$Ph_3Pb(L^3H)$]			10.50	4.99	6.84–8.32

b.s. = broad singlet and m. = complex pattern.

By using the above procedure, sputum that was 3+ on smear examination was selected for inoculation on Lowenstein Jensen medium. The culture tubes inoculated using light inoculum with suitable samples. This is to ensure that each culture tubes have equal number of tubes bacilli. Then inoculated culture tubes were incubated with loosened caps at 35°C in 5–10% CO_2. These were read at weekly intervals for at least 2 months. If these are no growth after 2 months, it is considered as negative. If growth is present at any stage, it is considered as positive. The results were further confirmed by Ziehl–Neeslen staining of growth culture. Three concentrations (1000, 500, and 250 ppm) for each compound were selected for the activity, and 3 culture tubes were inoculated for each concentration.

RESULTS AND DISCUSSION

Phenylboronic acid reacts with ligands (L^1H and L^2H) hydrazinecarbodithioic acid in unimolar and bimolar ratios a medium of benzene. The reactions proceed with the successive replacement of hydroxy groups according to the following equations:

$$PhB(OH)_2 + N\frown SH \longrightarrow PhB(OH)(N\frown S) + H_2O,$$

$$PhB(OH)_2 + 2N\frown SH \longrightarrow PhB(N\frown S)_2 + 2H_2O,$$

where N⌒S is the donor system of the ligands.

Triphenyllead chloride reacts with sodium salt of the ligands (L^1H, L^2H, and L^3H_2) in anhydrous MeOH by replacement of chloride to give products:

—for monofunctional bidentate ligands

$$Ph_3PbCl + N\,S\frown Na \longrightarrow Ph_3Pb(N\frown S) + NaCl,$$

where N⌒S is the donor system of the ligands;

—for bifunctional tridentate ligand

$$Ph_3PbCl + OH\frown N\frown SH \longrightarrow Ph_3Pb\,(OH\frown N\frown S) + NaCl,$$

where HO⌒N⌒S is the donor system of the ligand.

The products, obtained within 12–14 h of refluxing in dry benzene, as well as in dry methanol, are colored solids. These are soluble in DMSO, THF, and DMF. Their monomeric nature is proved by molecular weight determinations. The low molar conductance values of these derivatives show them to be nonelectrolytic in nature. These reactions proceed easily and the resulting colored solids are soluble in DMF and DMSO. The molar conductance of 10^{-3} M solutions of the complexes in DMF lie in a range of 10–15 $Ohm^{-1}\,cm^2\,mol^{-1}$ indicating that they are nonelectrolytes. Molecular weight determinations indicate their monomeric nature.

In the electronic spectra of the ligands and their complexes, the bands at ~264 and 319 nm were assigned to π–π* electronic transitions. These bands remained unaltered [20] in the boron, as well the lead complexes, whereas an additional band due to *n*–π* transitions appears at 350–375 nm due to the >C = N group, which undergoes a bathochromic shift of 15–20 nm in the complexes, due to boron ligand as well as lead ligand electronic interaction and polarization within the >C = N chromophore resulting after chelation.

The IR spectra of the free ligands and their boron and lead complexes were scanned in the form of KBr pellets. A band due to ν(NH) vibrations appears at 3410–3100 cm^{-1} which is absent in the spectra of the complexes. In the spectrum of the complex (Ph_3PbL^3H), band due to ν(NH) is absent, while ν(OH) remains unaltered showing no involvement of OH in bond forma-

Table 4. ^{13}C NMR data (δ, ppm) of the ligands and their corresponding organoboron(III) and organolead(IV) complexes

Compound	Thiolic carbon	Azomethinic carbon	Aromatic carbon
L^1H	162.35	156.20	148.08, 144.06, 137.25, 136.28, 133.25, 132.13
[PhB(OH) L^1]	161.42	153.48	147.64, 143.51, 137.42, 136.05, 133.47, 132.49
[PhB(OH) $(L^1)_2$]	162.59	154.15	146.42, 144.25, 136.31, 136.48, 132.56, 133.47
[Ph_3PbL^1]	163.41	156.45	148.12, 143.91, 138.33, 136.85, 133.58, 133.56
L^3H_2	165.34	157.32	143.35, 147.02, 131.24, 133.14, 128.43, 112.43
[$Ph_3Pb(L^3H)$]	164.85	156.38	143.58, 147.62, 130.54, 133.74, 128.53, 113.43

tion. The absorption at *ca.* 1620 cm^{-1} due to the azomethine (>C = N) group in the spectra of the ligands get split into two sharp bands at *ca.* 1615 and 1630 cm^{-1} in 1 : 2 complexes. This splitting suggests that the azomethine group is in different chemical environments. The band at *ca.* 1630 cm^{-1} (higher wavenumber) suggests the coordination of the azomethine nitrogen to the boron atom, where as the band at *ca.* 1610 cm^{-1} is assigned to the uncoordinated azomethine group. However, the band due to >C = N at *ca.* 1620 cm^{-1} shifts to the lower frequency in the lead complexes. The band due to ν(C=S) in the spectra of the ligands appears at 1025–1055 cm^{-1} and disappears on complexation, showing the chelation through the thiolic sulfur. The ν(OH) band in the case of the 1 : 1 boron complexes appears at *ca.* 3450 cm^{-1}.

New bands in the complexes appear in the ranges 835–840, 1525–1545, and 1235–1250 cm^{-1} and are due to ν(B–S) [21], ν(B ← N) [22], and ν(Ph–B) frequencies, respectively. The appearance of new bands in the range 1400–600 cm^{-1} in the lead complexes may be assigned to ν(Pb–S) and ν(Pb ← N) vibrations.

The free ligands displayed two bands at 2900 and 2960 cm^{-1} attributed to symmetric and asymmetric vibrations of CH_2 of SCH_2 C_6H_5 grouping and get reduced to a weak doublet in the spectra of the complexes [23].

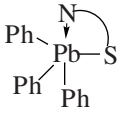
The ^1H NMR spectra of the free ligands (L^1H and L^2H) show signals due to NH of the isatin ring in the region δ 11.94 and 11.96 ppm and –NH of the remaining ligand unit (11.24–12.15 ppm) disappears indicating deprotonation and simultaneous covalent bond formation between thiolic sulfur and the boron and lead atoms. The ν(OH) proton signal of the ligand (L^3H_2) remains as such in the complexes, showing non-participation of OH group in bond formation. The SCH_2 protons in the ligands appear at δ 4.50–4.99 ppm, which remain almost the same in the complexes. The aromatic protons in the complexes appear at δ 6.70–8.35 ppm in almost the same positions as in the ligands. The ^1H NMR spectra of the ligands and their complexes are listed in the Table 3. The additional signals in the region δ 6.92–7.18 are due to the (C_6H_5Pb) group.

In ^{13}C NMR spectral data of the ligands (L^1H and L^3H_2) and their corresponding complexes, shifts in the positions of carbon atoms involved in the complex formation clearly indicate the bonding of the azomethine nitrogen (156.20 and157.32 ppm) and thiolo sulfur (162.35–165.34 ppm) to the boron and lead atoms. The ^{13}C NMR spectra of the ligands and their complexes also support the authenticity of the proposed structures (Table 4).

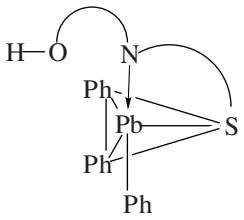
The ^{11}B NMR spectra of the organoboron(III) complexes have also been recorded, and signals were found in the range δ 4.25–4.31 ppm, which suggests a tetracoordinated environment around the boron atom and the presence of a B ⟶ N coordinate bond [24].

The X-ray powder diffraction study of the compound [PhB(OH)L^1] was carried out in order to have an idea about the molecular symmetry of the compound. The results show that the compound belongs to the orthorhombic crystal system.

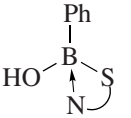
Thus, on the basis of the above spectral factors, as well as on the analytical data, tetra- and pentacoordinated, tetrahedral and trigonal bipyramidal geometries [25, 26] have been established for the organoboron(III), as well as organolead(IV) complexes, are given below:



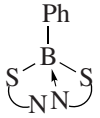
1 : 1 Organolead(IV) complexes



1 : 1 Organolead(IV) complexes



1 : 1 Organoboron(III) complexes



1 : 2 Organoboron(III) complexes

Fungicidal and bactericidal activities of the ligands and their corresponding orgaboron(III) and organolead(IV) complexes against different fungi and bacteria have been recorded in Table 5. On the basis of these studies, it may be concluded that fungitoxicity and bacteriostatic properties of the compound may be

Table 5. Antifungal and antibacterial screening data of the ligands and their corresponding organoboron(III) and organolead(IV) complexes

Compound	Antifungal screening						Antibacterial screening			
	average inhibition, % (after 96 h, concentration in ppm)						diameter of inhibition zone, mm (after 24 h, concentration in ppm)			
	Fusarium oxysporum			*Aspergillus niger*			*Staphylococcus aureus*		*Escherichia coli*	
	50	100	200	50	100	200	500	1000	500	1000
L^2H	74	82	86	81	87	92	12	15	7	9
$[PhB(OH)L^2]$	77	84	88	82	88	93	14	16	10	11
$[PhB(OH)(L^2)_2]$	78	85	90	84	90	94	15	17	11	13
$[Ph_3PbL^2]$	79	86	93	85	91	96	17	18	15	16
L^3H_2	68	72	85	68	75	80	8	10	6	8
$[Ph_3Pb(L^3H)]$							9	12	7	10
Bavistin	91	100	100	86	98	100				
Streptomycin							15	17	16	17

slightly enhanced on chelation with the boron and lead atoms. The free ligands (L^1H and L^2H) and their organoboron(III) and organolead(IV) complexes were tested against fungi and bacteria to see their growth inhibitory potential toward the test organisms. The antifungal activity was tested against *Fusarium oxysporum* and *Aspergillus niger* and bacteria used were *Escherichia coli* and *Staphylococcus aureus*. Proper temperature (25–30°C), necessary nutrients, and growth media free from other micro organisms were employed for the preparation of culture media of fungi and bacteria using aseptic techniques.

Fungicidal and bactericidal screening data show that under identical experimental conditions the compounds possess antimicrobial properties. The ligands and their metal complexes have been screened for their antibacterial and antifungal activities and the results obtained are presented in Table 5. It is observed that the activity of the metal complexes increases with an increase in the concentration of the solutions. All the metal complexes are more potent bactericides and fungicides than the ligands. This enhancement in the activity can be explained on the basis of the chelation theory [27]. The lipid and polysaccharides are some important constituents of cell wall and membranes, which are preferred for metal ion interaction. In addition to this, a cell wall also contains many aminophosphates, carbonyl and cysteinyl ligands, which maintain the integrity of the membrane by acting as a diffusion barrier and also provide suitable sites for binding. Chelation can considerably reduce the polarity of the metal ion, which in turn increases the lipophilic character of the chelate, which subsequently favors it permeation through the lipid layers of cell membrane [28] and blocking the metal binding sites on enzymes of microorganism. Thus, the interaction between the metal ion and lipid is favored. This may lead to the breakdown of the permeability barrier of the cell, resulting in interference with the normal cell processes. If the geometry and charge distribution around the molecule are incompatible with the geometry and charge distribution around the pores of the bacterial cell wall, penetration through the wall by the toxic agent cannot take place and this will prevent the toxic reaction in the pores. Chelation is not the only criterion for antimicrobial activity. Some important factors that contribute to the activity are the nature of the metal ion, nature of the ligand, coordinating sites, and geometry of the complex, concentration, hydrophilicity, lipophilicity, and presence of coligands. Certainly, steric and pharmokinetic factors [29] also play a decisive role in deciding the potency of an antimicrobial agent. There is a marked increase in the bacterial and fungi activities of the organoboron(III) and organolead(IV) complexes as compared to the free ligands and other complexes under test.

The data of antimycobacterial studies show that all the culture tubes containing 1000 ppm concentration of L^3H_2 give no growth, while 500 and 250 ppm tubes show growth in all the culture tubes; culture tubes containing 1000 ppm concentration of $[Ph_3Pb(L^3H)]$ give

no growth, while 500 ppm show in one culture tube. However, two tubes of 250 ppm concentration show growth.

The data of overall culture of mycobacterium tuberculosis show that all the culture tubes containing 1000 ppm concentration give no growth, while 500 and 250 ppm tubes show growth in all the culture tubes.

Thus, the S-benzyldithiocarbazate ligands L^1H and L^2H behave as monofunctional bidentate Schiff bases, while the ligand L^3H_2 behaves as bifunctional tridentate with the Ph_3PbCl starting material. The boron complexes obtained by 1 : 1 and 1 : 2 molar reactions with two ligands (L^1H and L^2H) were found to be tetracoordinated, while the lead complexes were found pentacoordinated. Antimicrobial activity of the complexes and the ligands showed that the former are more active than the parent ligands. The data given in Table 5 reveal that lead complexes were found to be more toxic than the boron complexes. Ligand (L^3H_2) and its lead complex are effective in killing of mycobacterium tuberculosis microorganism.

REFERENCES

1. Heath, O.V.S. and Clark, J. E., *Nature*, 1957, vol. 178, p. 600.
2. Bioinorganic Chemistry, Raymond, K.N. (Ed.), Washington: A.C.S., 1977.
3. Ali, M.A. and Livingstone, S.E., *Coord. Chem. Rev*., 1974, vol. 13, p. 101.
4. Ali, M.A. and Bose, R., *J. Inorg. Nucl. Chem*., 1977, vol. 39, p. 265.
5. Tarafder, M.T.H. and Ali, M.A., *Can. J. Chem*., 1980, vol. 58, p. 727.
6. Tarafder, M.T.H., Ali, M.A., Saravanan N., et al., *Transition Met. Chem*., 2000, vol. 25, no. 3, p. 295.
7. Tarafder, M.T.H., Ali, M.A., Wee, D.J., et al. *Transition Met. Chem*. 2000, vol. 25, no. 4, p. 456.
8. Degaonkar, M.P., Gopinathan, S., and Gopinathan, C., *Synth. React. Inorg. Met.-Org. Chem*., 1989, vol. 19, p. 613.
9. Biyala, M.K., Fahmi, N., and Singh, R.V., *Main Group Met. Chem*., 2004, vol. 27, p. 181.
10. Fahmi, N., Jadon, S.C.S., and Singh, R.V., *Phosphorus, Sulfur, and Silicon*, 1993, vol. 81, p. 133.
11. Biyala, M.K., Fahmi, N., and Singh, R.V., *Indian J. Chem., A*, 2004, vol. 43, p. 1662.
12. Kumari, A., Singh, R.V., and Tandon, J.P., *Phosphorus, Sulfur, and Silicon*, 1993, vol. 66, p. 195.
13. Chaudhary, A., Agarwal, M., and Singh, R.V., *Appl. Organometal. Chem*., 2006, vol. 20, p. 295.
14. Tomioka, H. and Namba, K., *Kekkaku*, 2006, vol. 81, no. 12, p. 753.
15. Mahajan, K., Fahmi, N., and Singh, R.V., *Indian J. Chem. A*, 2007, vol. 46, p. 1221.
16. Gaur, S., Maanju, S., Fahmi, N., and Singh, R.V., *Heterocycl. Commun*., 2005, vol. 11, p. 411.
17. Vogel, A.I., *A Text Book of Quantitative Inorganic Analysis*, London: Longman, ELBS, 1989.
18. Vogel, A.I., *A Textbook of Practical Organic Chemistry*, London: Longman, ELBS, 1978, p. 323.
19. Chaudhary, A., Mahajan, K., and Singh, R.V., *Appl. Organometal. Chem*., 2007, vol. 21, p. 117.
20. Singh, R.V., Mittal, S.P., Swami, M., and Mahajan, K., *Int. J. Chem.* Sci., 2007, vol. 5, p. 1417.
21. Saxena, C. and Singh, R.V., *Main Group Met. Chem*., 1992, vol. 15, p. 31.
22. Singh, V.P., Singh, R.V., and Tandon, J.P., *J. Inorg. Biochem*., 1990, vol. 39, p. 237.
23. Abu El-Reash, G.H., Taha, F., Shallaby, A.M., and El Gamal, O.A., *Indian J. Chem*., *A*, 1991, vol. 80, p. 286.
24. Barba, V., Santillan, R., and Farfan, N., *J. Mex. Chem. Soc*., 2005, vol. 49, p. 211.
25. Singh, R.V. and Biyala, M.K., *Phosphorus, Sulfur, and Silicon*, 2006, vol. 181, p.1.
26. Kumari, A., Tandon, J.P., and Singh, R.V., *Appl. Organomet. Chem*., 2004, vol. 7, p. 655.
27. Tweedy, B.G., *Phytopathology*, 1964, vol. 55, p. 910.
28. Jadon, S.C.S., Gupta, N., and Singh, R.V., *Indian J. Chem*., 1995, vol. 34, p. 733.
29. Mohanan, K. and Murukan, B., Sy*nth. React. Inorg. Met.-Org. Chem*., 2005, vol. 35, p. 837.