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Synthesis, characterization, semi-empirical study, and biological activities of organotin(IV) and transition metal complexes with *o*-methyl carbonodithioate

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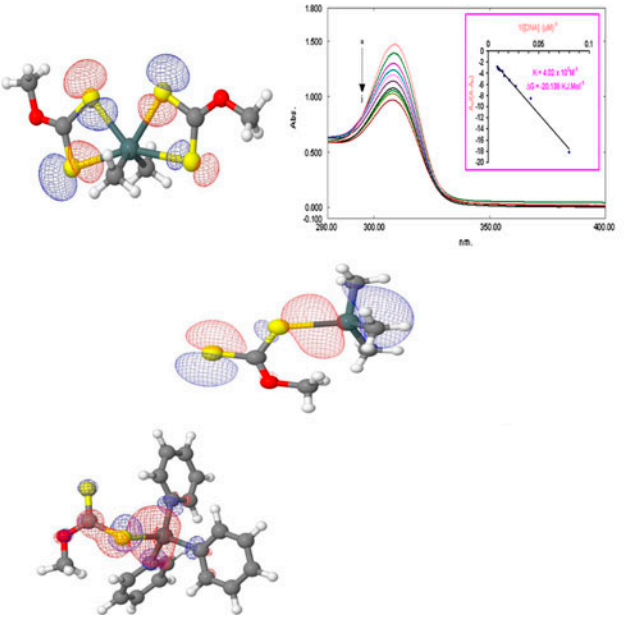

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Three transition metal and six organotin(IV) complexes have been synthesized by treating potassium *o*-methyl carbonodithioate with $ZnCl_2$/$CdCl_2$/$HgCl_2$ and R_2SnCl_2/R_3SnCl under stirring. The complexes were characterized by IR, ^1H, and ^{13}C NMR spectroscopies. IR results show that the ligand is bidentate in **1–3** while monodentate in **4–9**, which is also confirmed by semi-empirical study. NMR data reveal four-coordinate geometry in solution. HOMO–LUMO study shows that **7** and **9** are thermodynamically unstable. The enzyme inhibition study shows that **1** is a potent inhibitor of ALP, EC 3.1.3.1, resulting in very slow rate of formation and breakdown of enzyme–substrate complex. UV/visible spectroscopy was used to assess the mode of interaction and binding of the complexes with DNA which shows that **9** exhibits higher binding constant when compared to **6**. In protein kinase inhibition assay, **1** was active, while antifungal activity shows that organotin(IV) complexes are more active than transition metal complexes.

Keywords: *o*-Methyl carbonodithioate; Transition metal complexes; Organotin(IV); IR; NMR; Semi-empirical study; HOMO–LUMO calculations; Enzyme inhibition study; DNA interaction; Antifungal activity

1. Introduction

Metal-sulfur chemistry is used technologically in electronics (e.g. vapor deposition, doping, and electro-optical devices), battery technology, photovoltaic materials, and magnetic resonance imaging and contrast agents. Many metal–sulfur enzymes and electron transfer proteins incorporate metals (V, Fe, Ni, Cu, Zn, Mo, and W) and sulfur-containing ligands or moieties; the latter includes the amino acids cysteine (a thiolate) and methionine (a thioether), sulfide, hydrosulfide, polysulfides, sulfur radicals, and dithiolenes [1]. Similarly, many species were declared as inhibitors of alkaline phosphatase (ALP) like vanadates, arsenates, L-phenylalanine, and L-tryptophan. These inhibitors have been used in studies geared towards better understanding of the physiological role of ALP [2, 3]. The enzyme is termed ALP because it works under alkaline (non-acidic) conditions, as opposed to acid phosphatase [4]. With few exceptions, ALPs are homodimeric enzymes and each catalytic site contains three metal ions, i.e. two Zn and one Mg, necessary for enzymatic activity. Based on the high-resolution crystal structure of the enzyme–phosphate complex, a detailed catalytic mechanism of the enzyme has been proposed [5]. Zinc is an essential element for organisms, an intrinsic component of a variety of proteins which are involved in virtually all aspects of metabolism, transfer of inheritance message, and growth [6]. The inhibition of ALP presents a unique challenge since the active site pocket is characteristically shallow. Inorganic phosphate, one of the tightest binding inhibitors of ALP, essentially fills the entire volume of the active site [7]; this feature allows the enzyme to hydrolyze a wide variety of substrates close to the same rate regardless of the nature of the *R* group. It does not afford many opportunities for enzyme–ligand interactions. For this reason, phosphonates [8] widely used as non-hydrolysable analogs of the parent phosphate monoesters are generally not very strong inhibitors of the enzyme. Like dithiocarbamates, xanthates also form simple complexes because of the $–CS_2$ group which makes them more reactive towards various metals. However, xanthates are more prone to form polymeric complexes. Polymeric metal xanthates are formed usually as a result of bridging through the bidentate xanthate moiety (i.e. M–S–C–S–M bridge). The tendency for polymerization [9] is particularly pronounced in complexes of zinc, cadmium, and mercury [10]. Protein kinases, responsible for the phosphorylation of various proteins, act as regulatory agents in several metabolic pathways [11]. Organotin compounds as well as dithiocarbamate ligands [12] are known for their antifungal [13], antibacterial [14], and antitumoral [15–18] activities.

In continuation of our previous work [19–22], we have synthesized transition metal and organotin(IV) complexes with potassium *o*-methyl carbonodithioate. These complexes were

characterized by different spectral techniques and semi-empirical study. The complexes were also screened to check various biological activities.

2. Experimental

2.1. *Materials and methods*

Methanol, potassium hydroxide, carbon disulfide, *p*-nitrophenylphosphate hexahydrate (*p*-NPP), diethanolamine, and magnesium chloride were purchased from Sigma Aldrich and used as received. Human serum was used as a source of ALP. Solvents were purified before use [23]. Melting points were recorded with a Bio-Cote Model SMP10 melting point apparatus and are uncorrected. Elemental analyses were performed using a CHNS-932 analyzer Leco (USA). FT-IR spectra were recorded as KBr/CsBr pellets from 4000 to 250 cm^{-1} with a Thermo Scientific Nicolet-6700 FTIR spectrometer and NMR spectra were obtained with a Bruker Avance 300 MHz NMR spectrometer. Absorption spectra were measured on a UV–visible spectrometer, Shimadzu 1800, at 25 ± 1 °C. Sodium salt of DNA (Acros) was used as received. Solutions of DNA in 10 mM L^{-1} phosphate buffer (pH 7.0) gave a ratio of UV absorbance at 260 and 280 nm, A_{260}/A_{280}, of 1.8–1.9, indicating the purity of DNA. Concentrated stock solution of DNA was prepared in 10 mM L^{-1} phosphate buffer (pH 7.0). The concentration of DNA was determined by UV absorbance at 260 nm after 1 : 100 dilution. The molar absorption coefficient has been taken as 6600 $(M\,L^{-1})^{-1}$ cm^{-1}. Stock solutions were stored below 4 °C and used within four days.

2.2. *Procedure for the synthesis of potassium o-methyl carbonodithioate (HL)*

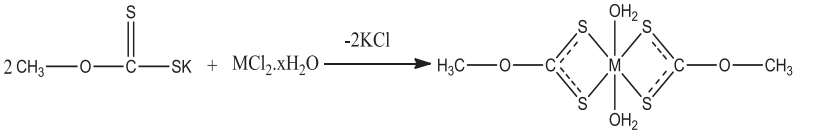
Potassium *o*-methyl carbonodithioate was prepared by stirring methanol (1 mM), potassium hydroxide (1 mM), and carbon disulfide (1 mM) at room temperature for 4 h. Precipitates obtained were filtered off and dried in air. Elemental Anal. Calcd (Found (%)): C, 22.22 (22.26); H, 3.70 (3.66); S, 59.26 (59.22).

2.3. *General procedure for the synthesis of transition metal complexes 1–3 with potassium o-methyl carbonodithioate*

Solution of zinc chloride dihydrate/cadmium chloride dihydrate/mercuric chloride (1 mM) in 10 mL methanol was added to solution of potassium *o*-methyl carbonodithioate (1 mM) in methanol (30 mL) in a two-necked round bottom flask (100 mL) with continuous stirring at room temperature for 4 h. The solvent was evaporated slowly at room temperature and the solid product obtained was filtered off and dried in air. The product was recrystallized in chloroform : *n*-hexane (1 : 1).

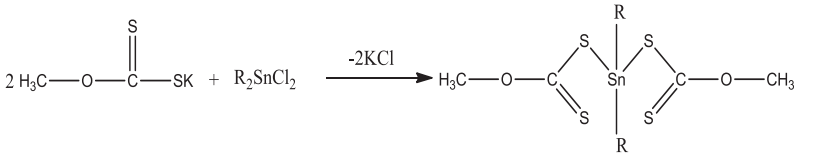
2.4. *General procedure for the synthesis of organotin(IV) complexes 4–9 with potassium o-methyl carbonodithioate*

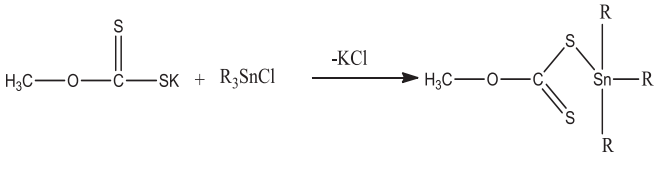
Potassium *o*-methyl carbonodithioate (1 mM) was dissolved in methanol (20 mL) in a round bottom two-necked flask (100 mL) with continuous stirring at room temperature. Then to the above solution, R_2SnCl_2/R_3SnCl (2 mM/1 mM) was added as solid in portions. The reaction mixture was continuously stirred for 4 h at room temperature. Solvent was evaporated slowly at room temperature. Solid product obtained was dried in air and recrystallized from acetone : petroleum ether (1 : 1).



M = Zn(**1**), Cd(**2**), Hg(**3**)

x = 2 (Complex (**1**) and (**2**)) and 0 (Complex (**3**))





For diorganotin R = Me (**4**), *n*-Bu (**5**), Ph (**6**)

For triorganotin R = Me (**7**), *n*-Bu (**8**), Ph (**9**)

2.5. *UV/vis spectroscopy*

The electronic spectra of known concentrations of complexes were recorded first without DNA then spectroscopic response of the same amount of complex was monitored by the addition of small aliquots of DNA solution. The DNA-binding constants of the compounds were calculated by UV–vis spectroscopy using the following equation:

$$\frac{A_0}{A - A_0} = \frac{\varepsilon_G}{\varepsilon_{H-G} - \varepsilon_G} + \frac{\varepsilon_G}{\varepsilon_{H-G} - \varepsilon_G} \frac{1}{K[\mathrm{DNA}]}$$

Intercept to slope ratio of the plot 1/[DNA] *versus* $A_0/A - A_0$ gives the binding constant K [24].

2.6. *ALP inhibition study*

All the complexes and ligands were screened for their inhibitory activity against the enzyme ALP. Working substrate was prepared by mixing four parts of reagent A (diethanolamine pH 9.8, 2 M/dm^3 and magnesium chloride 0.5 mM/dm^3) and one part of reagent B (*p*-NPP 50 mM/dm^3). Substrate was incubated at 25 °C for 5 min. Then 2 mL of the substrate was taken in a cell cuvette and 40 µL of human serum containing ALP was added. After incubation for 1 min, blank reading was taken to check the activity of enzyme by measuring the increase in absorbance by yellow *p*-nitrophenol because of hydrolysis of *p*-NPP at 405 nm against water.

$$p\text{-Nitrophenyl phosphate} + Mg^{2+} + H_2O \xrightarrow{ALP} p\text{-Nitrophenol} + Pi$$

where *p*-NPP is the substrate on which ALP reacts and Pi is inorganic phosphate. The activity of enzyme was 165 IU/L. Then various concentrations of **1** (20, 40, 60, and 80 µL) were added from the 25 mM stock solution and again incubated for three minutes. Absorbance was recorded again after 1, 2, 3, 4, and 5 min, then average and percent inhibition were calculated [25].

2.7. *Protein kinase inhibition study*

Protein kinase inhibition test was performed by disc diffusion [26]. After sterilization of petri plates, the mineral salt media was poured in the plates and kept at room temperature for setting. Then streptomyces fungal strain in tryptic soy broth (Merck) was swabbed on the plates, and test samples in the final concentration of 0.1 µM were placed on the disks placed on the media. Then the plates were incubated at 37 °C for 48 h. After incubation, zones of inhibition were measured.

2.8. *Antifungal activity*

In antifungal test, the antifungal potential of test samples was determined using five fungal species, i.e. *Aspergillus niger*, *Aspergillus flavus*, *Aspergillus fumigates*, *Fusarium solani*, and *mucor specie*. The disc diffusion method was employed [26]. Briefly, fungal strains were streaked on the petri plates containing sterilized sabouraud dextrose agar. Test samples were placed on the disks at 0.1 µM. Plates were incubated for 24 h at 37 °C. After the incubation period, zones of inhibition were measured to detect the efficiency of samples against each fungal strain utilized.

2.9. *Semi-empirical study*

Semi-empirical studies were done by MOPAC2007 [27] program in gas phase using PM3 method [28]. Selected parts of the complexes not containing the metal ion were pre-optimized using molecular mechanics methods. Several cycles of energy minimization had to be carried for each of the molecules. Geometry was optimized using Eigen Vector. The Root

Mean Square Gradients for molecules were all less than one. Self-Consistent Field was achieved in each case. Absences of imaginary frequencies were checked consistently.

3. Results and discussion

The synthesized complexes (**1–9**) are stable and soluble in common organic solvents. The physical data are given in table 1.

3.1. *Infrared spectroscopy*

IR spectra of the ligand and **1–9** were recorded as KBr/CsBr pellets from 4000 to 250 cm^{-1}. The characteristic infrared absorption frequencies (cm^{-1}) are listed in table 2. IR spectra of **1** and **2** exhibit a band at 3440–3446 cm^{-1}, which is attributed to the presence of H_2O. It has been reported [29] that a single νC=S absorption around 1000 cm^{-1} is indicative of dithiocarbamate groups that are bonded symmetrically or bidentate as in **1–3** at 1015–1026 cm^{-1}. The presence of two νC=S absorptions in **4–9** at 1365–1462 and 1010–1072 cm^{-1} indicates monodentate ligand. The ν(C–S) band is at 945–961 cm^{-1} [30] in **1–3**, while 958–988 cm^{-1} for **4–9**. M–S bond formation is confirmed by the appearance of a new band at 335–374 cm^{-1} [31]. The ν(Sn–C) was observed at 530–549 cm^{-1} for **4**, **5**, **7**, and **8** but at 286 and 280 cm^{-1} for **6** and **9**, respectively, which are di- and tri-phenyltin derivatives.

3.2. *^{1}H NMR spectroscopy*

^{1}H NMR spectra of the ligand and complexes were recorded in deutrated DMSO; the data are presented in table 3. The number of protons calculated by integration of peaks are in excellent agreement to those theoretically calculated by the incremental method [32]. One resonance appeared as a singlet at 3.72 ppm for methyl protons in the free ligand. This signal shifted downfield to 3.89–4.13 in **1–9**.

The CH_3 protons in **4** are a singlet at 1.48 ppm with $^2J[^{119}Sn–^1H] = 79$ Hz. In **5** and **8**, the protons of butyl are a multiplet at 0.88–0.94 ppm. The terminal CH_3 of butyl is a triplet at 1.44 and 1.33 ppm with $^3J[^1H–^1H]$ value of 7.3 Hz for **5** and **8**. The methyl in **7**, attached to Sn, gives a singlet at 0.53 ppm with $^2J[^{119}Sn–^1H] = 56$ Hz. The phenyl moieties

Table 1. Physical data of complexes with potassium *o*-methyl carbonodithioate.

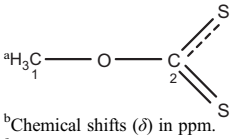
Comp. no.	Molecular formula	Molecular mass	% Yield	M.p. (°C)
HL	$C_2H_4OS_2$	108	70	200 (dec.)
1	$C_4H_{10}O_4S_4Zn$	315.79	92	>300
2	$C_4H_{10}O_4S_4Cd$	362.79	82	305
3	$C_4H_6O_2S_4Hg$	414.94	80	134
4	$C_6H_{12}O_2S_4Sn$	363.13	92	156
5	$C_{12}H_{24}O_2S_4Sn$	447.29	82	178
6	$C_{16}H_{16}O_2S_4Sn$	487.91	82	155
7	$C_5H_{12}OS_2Sn$	270.99	82	167
8	$C_{14}H_{30}OS_2Sn$	397.23	92	172
9	$C_{20}H_{18}OS_2Sn$	457.20	92	182

Table 2. IR spectral data (cm^{-1}) of complexes with potassium *o*-methyl carbonodithioate.

Comp. no.	νH_2O	$\nu C{=}S$	$\nu C{-}S$	$\nu M{-}S$	$\nu Sn{-}C$
HL	–	1499, 1015	989	–	–
1	3440	1026	945	374	–
2	3446	1015	957	352	–
3	–	1023	961	335	–
4	–	1431, 1072	977	358	531
5	–	1373, 1068	985	360	549
6	–	1436, 1044	958	371	286
7	–	1365, 1010	963	360	530
8	–	1462, 1069	988	366	542
9	–	1427, 1055	972	360	280

Table 3. ^{1}H NMR data[a–c] of complexes with potassium *o*-methyl carbonodithioate.

Compound no.	H-1	R
HL	3.72s	–
1	3.91s	–
2	3.97s	–
3	4.04s	–
4	4.11s	1.48 (6H, s, H-1, ^{2}J ($^{119}Sn{-}^{1}H = 79$ Hz)
5	4.13s	0.94 (6H, t, $^{3}J = 7.2$ Hz), 1.44 (4H, m, $^{3}J = 7.3$ Hz),1.88 (4H, m), 2.07 (4H, m)
6	3.95s	7.49 (6H, m), 7.98 (4H, m)
7	4.04s	0.53 (9H, s, H-1, ^{2}J ($^{119}Sn{-}^{1}H = 56$ Hz)
8	4.02s	0.88 (9H, t, $^{3}J = 7.2$ Hz), 1.33 (6H, m, $^{3}J = 7.3$ Hz), 1.35 (6H, m), 1.58 (6H, m)
9	3.89s	7.47 (9H, m), 7.69 (6H, m)



[b]Chemical shifts (δ) in ppm.
[c]Multiplicity is given as, s = singlet, t = triplet, m = multiplet.

of di- and tri-phenyltin(IV) derivatives show a complex pattern and were assigned according to the literature [33].

3.3. *^{13}C NMR spectroscopy*

Table 4 lists the chemical shifts of ^{13}C and tin–carbon coupling constants for **1–9**. The ^{13}C NMR chemical shifts as the phenyl groups are observed at positions comparable to similar compounds [34, 35]. The ^{13}C NMR chemical shift due to –CSS carbon atom (C-2) is at 230.8 ppm in the free ligand while in the complexes it shifts upfield to 178.7–223.7 ppm. Coordination of tin in di- and tri-organotin has been related to $^{n}J(^{119}Sn{-}^{13}C)$ coupling constants. The $^{n}J(^{119}Sn{-}^{13}C)$ coupling for **7** is 397 Hz, which is indicative of four-coordinate geometry [34] in solution.

3.4. *The effects of complexes on the activity of ALP*

The ALP activity takes advantage of the fact that the enzyme is non-specific and utilizes the colorless non-biological substrate *p*-NPP to give yellow *p*-nitrophenol upon hydrolysis

Table 4. ^{13}C NMR data (ppm) of complexes with potassium *o*-methyl carbonodithioate.

Comp. no.	C-1	C-2	R
HL	58.1	230.8	–
1	49.0	193.1	–
2	55.0	178.7	–
3	62.5	220.6	–
4	62.0	222.7	10.3, ^{1}J (^{119}Sn–^{13}C = 593 Hz)
5	62.0	223.7	13.7, 26.4, ^{3}J (^{119}Sn–^{13}C = 118 Hz) 28.8, ^{2}J (^{119}Sn–^{13}C = 39 Hz) 30.2, ^{1}J (^{119}Sn–^{13}C = 534 Hz)
6	62.1	219.4	135.2, ^{3}J (^{119}Sn–^{13}C = 56 Hz), 141.2, 129.1, ^{2}J (^{119}Sn–^{13}C = 88 Hz), 130.2, ^{1}J (^{119}Sn–^{13}C = 18 Hz)
7	61.0	217.9	−2.8, ^{1}J (^{119}Sn–^{13}C = 379 Hz)
8	60.9	218.3	13.6, 27.0, ^{3}J(^{119}Sn–^{13}C = 65 Hz), 28.6, ^{2}J (^{119}Sn–^{13}C = 21 Hz), 15.6, ^{1}J (^{119}Sn–^{13}C = 336 Hz)
9	61.2	215.3	136.5, ^{3}J (^{119}Sn–^{13}C = 44 Hz), 137.8, 129.0, ^{2}J (^{119}Sn–^{13}C = 61 Hz) 129.9, ^{1}J (^{119}Sn–^{13}C = 13 Hz)

which helps to monitor the reaction. Only **1** shows remarkable activity against ALP. The effect of Zn^{2+} on ALP was studied for hydrolysis of *p*-NPP. Zn^{2+} inhibited the enzyme in a concentration-dependent manner (figure 1). The presence of Zn^{2+} results in inactivation of the enzyme which is confirmed by decrease in the formation of product (*p*-nitrophenol) and hence, less absorbance. The activity of ALP is decreased by increasing the Zn^{2+} concentration. The enzyme completely lost its activity at higher concentrations of Zn^{2+} [36].

3.5. *Protein kinase inhibition assay*

In protein kinase inhibition assay, **1–9** show a varying degree of inhibition and produced zones of inhibition ranging from 4.5 ± 0.7 to 14 ± 1 mm. Compound **1** was most effective, producing maximum zone of inhibition on the culture plates. Thus, **1** may be considered as an effective candidate to inhibit tumor initiation. The data are given in table 5.

3.6. *Antifungal activity*

The synthesized compounds (**1–9**) were tested for antifungal activity against five fungal strains including *A. flavis*, *A. niger*, *F. solani*, *A. fumigates*, and *M. specie* by disc diffusion

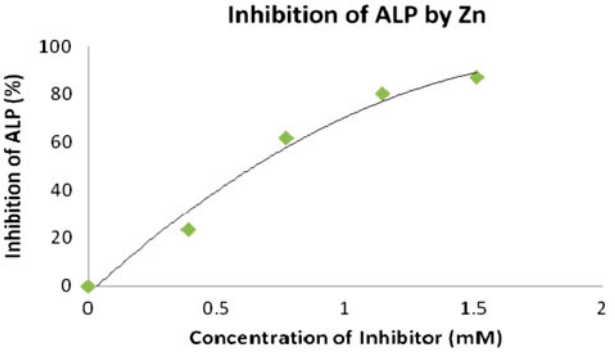


Figure 1. Concentration-dependent inhibition of ALP by **1**.

Table 5. Protein kinase inhibition assay of complexes with potassium *o*-methyl carbonodithioate.

Compound	Zone of inhibition (mm)
1	14 ± 1
2	–
3	12.5 ± 0.7
4	8 ± 1
5	4.5 ± 0.7
6	10.5 ± 0.7
7	12.5 ± 0.7
8	11 ± 1
9	–

method [26]. The results are summarized in table 6. It was evident that the synthesized complexes exhibited various fungicidal activities. Complex **5**, exhibited maximum activity (40.0 ± 0) against *A. fumigates*. Complex **3** showed lowest inhibition zone (4.5 ± 0.7) against *M. specie*. It is noted that dibutyltin complex **5** showed the greatest inhibitory effect against fungi when compared to other alkyl groups. From the data, it is evident that organotin(IV) complexes exhibit significant fungicidal activity when compared to transition metal complexes.

3.7. *UV–vis spectroscopy*

UV–visible absorption spectroscopy is the simplest technique for studying both the stability of DNA and interaction with small molecules. Compounds **6** and **9** show maximum absorption at 309 and 310 nm with a blueshift up to 1 nm (figures 2 and 3). The hypochromism may be due to intercalation of these compounds into the DNA base pairs [37].

3.8. *Structure activity relationship*

Although it is difficult to make an exact structure-activity relationship chelation as well as the addition of substrate enhance the activity of the complexes. Complexes of tin inhibit growth of micro-organisms to a greater extent than transition metal complexes. The greater activity of the organotin(IV) complexes may be due to higher solubility.

Table 6. Antifungal activity data of complexes with potassium *o*-methyl carbonodithioate.

	Zone of inhibition (mm)				
Compound	*A. flavus*	*A. niger*	*Fusirum solani*	*A. fumigates*	*M. specie*
1	–	–	7 ± 1	–	–
3	11 ± 1	11.5 ± 0.7	6.0 ± 0	12 ± 1	4.5 ± 0.7
4	8.5 ± 0.7	7 ± 1	–	4.0 ± 0.7	–
5	27 ± 1	36.5 ± 0	–	40.0 ± 0	–
6	8.5 ± 0.7	9.0 ± 0	–	10.0 ± 0	–
7	21.5 ± 0.7	23 ± 1	20 ± 2	28.0 ± 0	20.0 ± 0
8	5 ± 1	6.5 ± 0.7	–	8.0 ± 0.7	–

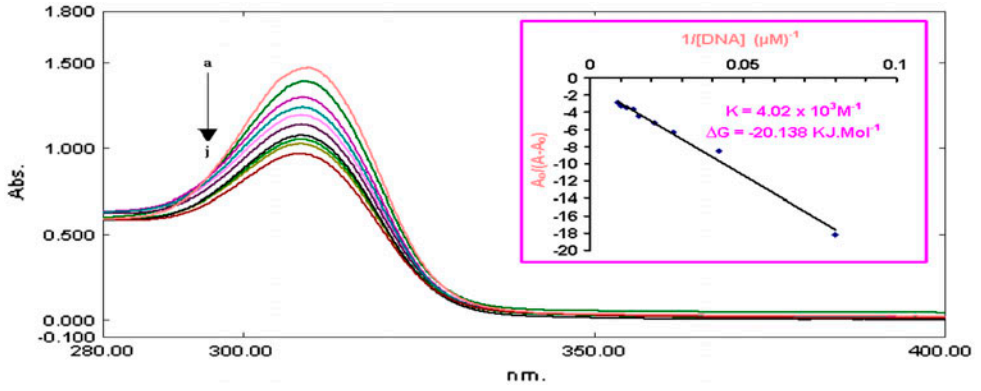


Figure 2. UV–vis spectroscopic response of 0.8 mM L^{-1} **6** in the absence and presence of (a) 20, (b) 40, (c) 62, (d) 83, (e) 104, (f) 125, (g) 150, (h) 170, and (i) 192 μM DNA.

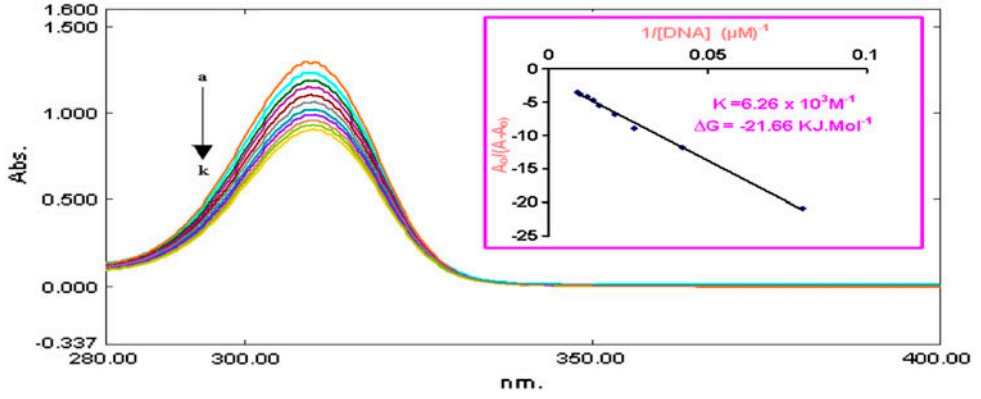


Figure 3. UV–vis spectroscopic response of 0.8 mM L^{-1} **9** in the absence and presence of (a) 20, (b) 40, (c) 62, (d) 83, (e) 104, (f) 125, (g) 150, (h) 170, (i) 192, and (j) 222 μM DNA.

3.9. *Semi-empirical study*

In the geometry-optimized structures of **4**, **7**, and **9**, one sulfur of the ligand bonds with monodentate which is also confirmed by FT-IR data. The other positions are occupied by methyl or phenyl groups. The Sn–C and Sn–S bonds are typical [38]. The bond angles and bond lengths and are given in tables 7 and 8, respectively.

Computed positive heat of formation indicates that **7** and **9** are thermodynamically unstable (table 9). The calculated HOMO and LUMO orbitals of **4**, **7**, and **9** are shown in figures 4–6. In organotin(IV) complexes, the HOMO orbital is primarily located on a sulfur. The calculated HOMO and LUMO energies are given in table 10. A large HOMO–LUMO gap indicates stable molecule, while a small E_{HOMO} is associated with unstable molecule with high chemical reactivity. Complex **4** is stable and chemically reactive. The ability of the molecule to donate electrons, (-ionization potential), E_{LUMO} represents (-electron affinity), and electrophilicity values ($\omega = \mu^2/2\eta$) [39], chemical potential values $\mu = -(I + A)/2$ [40],

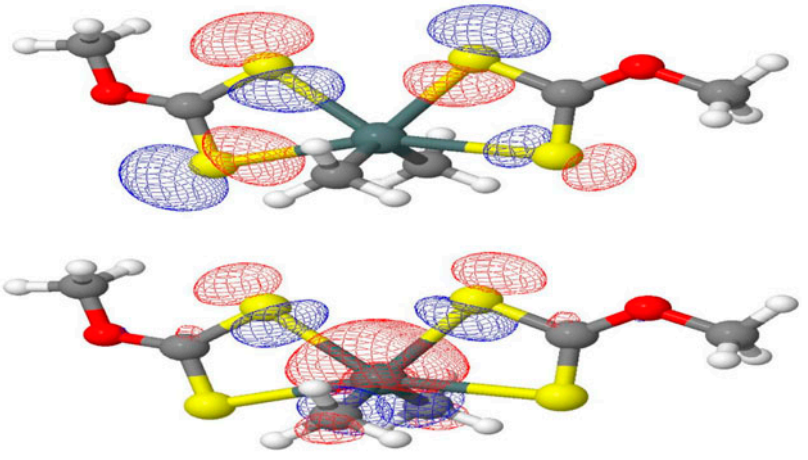


Figure 4. HOMO–LUMO of **4**.

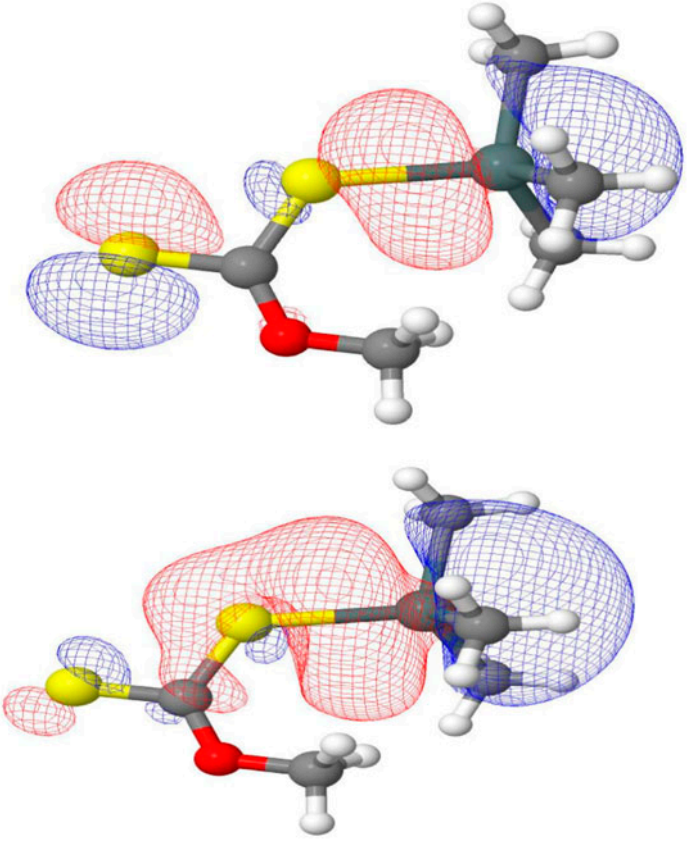


Figure 5. HOMO–LUMO of **7**.

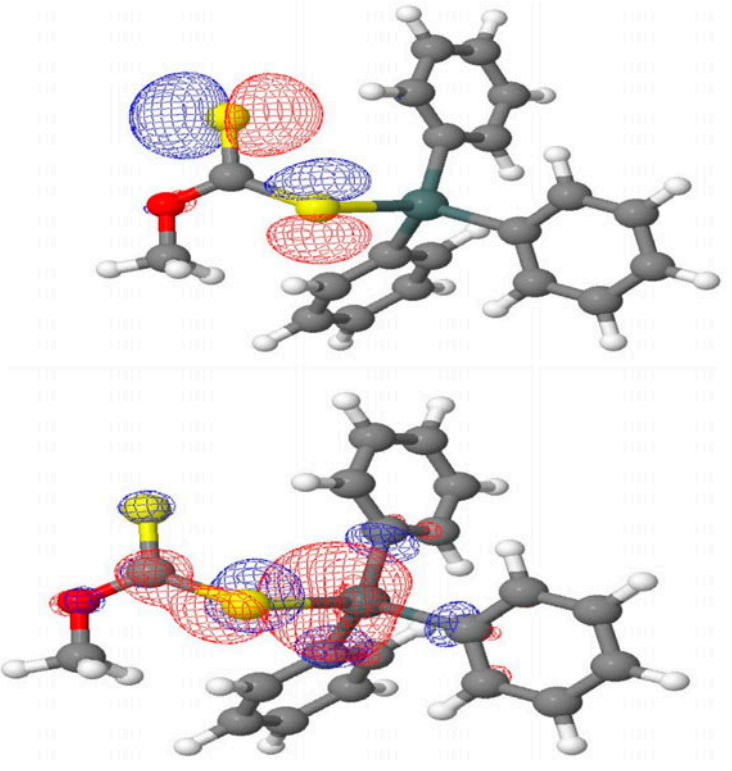


Figure 6. HOMO–LUMO of **9**.

Table 7. Selected bond angles (°) of **4**, **7**, and **9**.

	4	**7**	**9**
S–C–S	116.9	123.0	109.2
C–Sn–C	132.7	110.2, 111.9, 111.9	110.1, 111.2, 111.5

Table 8. Selected bond lengths (Å) of 4, 7, and 9.

	4	**7**	**9**
Sn–S	2.67, 2.83	2.56	2.56
C–O	1.42, 1.42, 1.35, 1.35	1.36, 1.41	1.36, 1.41
C–S	1.68, 1.73, 1.73, 1.69	1.80, 1.61	1.60, 1.77

Table 9. Computed thermodynamic parameters.

	4	**7**	**9**
Heat of formation (kcal/M)	−9.291	109.506	2.644
Enthalpy (kcal/M-K)	10,046.3434	1,1014.3765	8,963.1497
Entropy (kcal/M-K)	121.9069	128.0221	114.9255
Heat capacity (Cp) (cal/M-K)	57.2905	72.5161	48.5097

Table 10. Computed molecular descriptors.

	4	**7**	**9**
HOMO energy (eV)	−9.31077	−8.85423	−8.93784
LUMO energy (eV)	−2.46295	−2.28576	−2.37927
HOMO–LUMO (eV)	6.84782	6.56847	6.55857
Dipole moment (Debye)	1.123	5.350	5.981
Global hardness (η, eV)	−3.42391	−3.28424	−3.27929
Global softness (S, eV^{-1})	0.14604	0.152242	0.15247
Chemical potential (μ, eV)	−5.88686	−5.569995	−5.658555
Electrophilicity (ω)	5.06075	4.72330	4.88205

global hardness ($\eta = I - A/2$) values [41], and global softness values ($S = 1/2\eta$) [42] have been calculated in each case (table 10).

4. Conclusion

We have synthesized organotin(IV) and transition metal complexes with potassium *o*-methyl carbonodithioate. The ligand and complexes were characterized by IR and NMR spectroscopies. IR data show bidentate ligand in **1–3**, while monodentate is exhibited by the ligand in **4–9**. Theoretical calculations show that **7** and **9** are thermodynamically unstable when compared to other alkyltin dithiocarbamates. UV/visible spectroscopy shows that **9** exhibits higher binding constant when compared to **6**. In protein kinase inhibition assay, **1** was active. The antifungal activity data shows that organotin(IV) complexes are biologically more active than transition metal complexes.

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