New Diorganotin(IV) complexes of tridentate Schiff bases derived from 1,3-indanedione derivative: Synthesis, Spectral studies and in vitro antimicrobial activities

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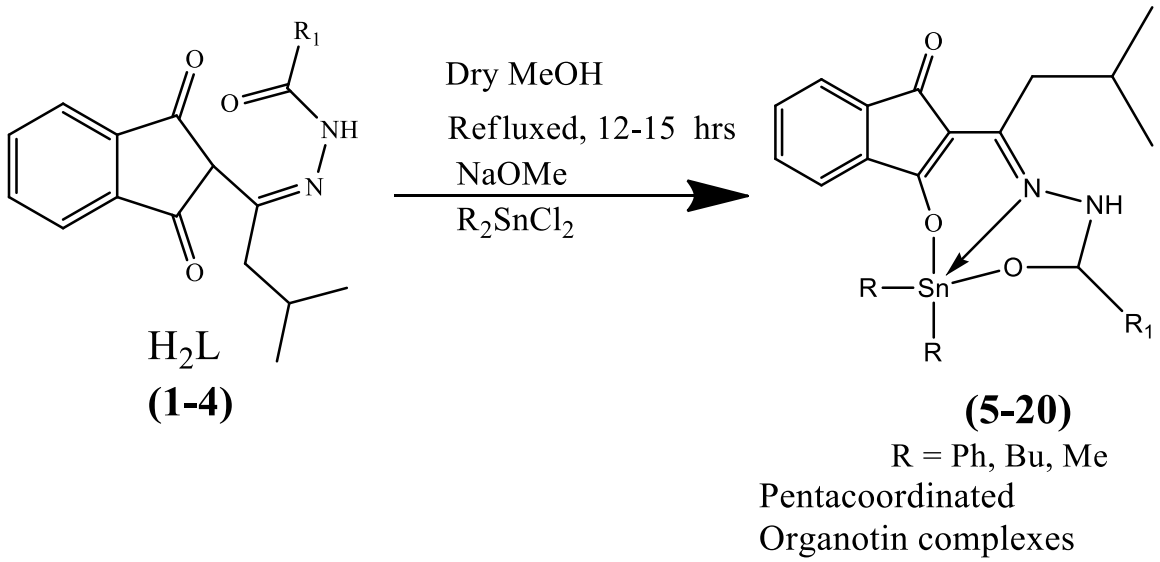
Abstract

A series of sixteen pentacoordinated diorganotin(IV) complexes has been reported here which were synthesized by reacting the appropriate dialkyl/diaryltin(IV)dichloride with four newly synthesized Schiff bases. The dianionic tridentate(ONO) Schiff base hydrazones have been conveniently synthesized in good yields by reacting 2,2-(3-methylbutanoyl)-1H-indene-1,3(2H)-dione with different acid hydrazides. The structures of the synthesized Schiff bases and their complexes Have been established on the basis of IR, Mass Spectra, ^{1}H, ^{13}C, ^{119}Sn NMR Spectroscopy and different physical techniques. The compounds have also been screened for antimicrobial activity against four bacterial strains i.e. Gram positive Bacillus ceres (MTCC 10072), Styphyllococus aureus (MTCC 2901) and Gram negative Escherichia.coli (MTCC 732), Pseudomonas aeruginosa (MTCC 424), and three fungal strains i.e. Aspergillus flavus (ITCC 7680), Aspergillus niger (MTCC 7678), *Candida albicans* (MTCC 227) by

serial dilution method and it was found that most of the synthesized compounds were relatively active with the standard drugs especially in Gram positive bacteria and fungal strains.



H_2L
(1-4)

(5-20)
R = Ph, Bu, Me
Pentacoordinated
Organotin complexes

Keywords

2-(3-methylbutanoyl)-1*H*-indene-1,3(2*H*)-dione; hydrazones; ^{119}Sn NMR; antimicrobial activity

INTRODUCTION

Despite of continuous research in the area of drug resistance towards pathogenic microbes, problem is getting severe day by day. So to combat the above said problem there is a need of the hours to design new antimicrobial drugs with reduced toxicity, improved efficacy and better mechanism of action. Consequently, the most demanding thing for researcher is to identify and design more novel and potent structural leads.[1,2] In recent years, Schiff base metal complexes are attractive target compounds for new drug development owing to their prominent pharmacological applications.[3,4] Schiff bases shows broad spectrum biological activity owing to its ability to degrade DNA of the microorganisms.[5] Further, these Schiff base metal complexes expanded enormously due to high thermal stability, flexibility, medicinal efficiency[6] and have shown amazing superior biological activity. Some tumors, particularly leukemia and neuroblastoma, are susceptible to metal ion chelation therapy because metal complexes become more bacteriostatic and carcinostatic upon chelation as described by several *in vitro* studies and clinical trials.[7,8] Even the lethal cancer like disease was cured by these chelating metal complexes.[9]

Particularly, some distinct characteristics of organotin complexes like variation in coordination number, geometries, thermodynamic and kinetic characteristics and the intrinsic properties of the metal ion itself, developed the interest of chemistry researchers to formulate utilization of the assorted approaches in different fields like industrial, agricultural and biomedical fields as wood preservatives, surface disinfectants,[10] insecticides,[11,12] antifouling agents, and environmental applications.[13] Further, Schiff bases and their derived organotin complexes displayed, promising chemotherapeutic applications such as antimicrobial,[14] anti

inflammatory,[15] antitumor,[16,17] antiviral,[18] antitubercular,[19] antifertility.[20] Prompted by these facts, present study was designed to modify the bioactivities and optimization of lipophilic character of organotin complexes by coordinating them with the Schiff bases hydrazones. Therefore, we synthesized new organotin complexes in the surge of more potent and biospecific antimicrobial and pharmacoactive drugs with better curing effects, which are less toxic to the environment and host. During this course, a series of organotin complexes with tridentate Schiff bases derived from the condensation of 2-(3-methylbutanoyl)-1*H*-indene-1,3(2*H*)-dione with acid hydrazides were synthesized and characterized with the aid of elemental analysis, various spectroscopic technique (^{1}H, ^{13}C, ^{119}Sn, Mass). The compounds were also screened for antibacterial and antifungal activities.

RESULTS AND DISCUSSION

The Organotin(IV) complexes have been synthesized by reacting 2-(3-methylbutanoyl)-1H-indene-1,3(2H)-dione derived hydrazones with dialkyl/diaryltin(IV)dichloride in 1:1 molar ratio. The purity of synthesized compounds was checked by thin layer chromatography (TLC). All the metal complexes were colored solids, and were stable on exposure to air. The synthetic procedure for the preparation of organotin compounds linked hydrazones (3) is presented in Scheme 1. The Spectroscopic techniques (FT-IR, ^{1}HNMR, ^{13}C NMR, ^{119}Sn NMR, Mass and XRD) were used to determine the geometry of complexes which were found to be trigonal bipyramidal. The ligands were found to be tridentate (ONO) and chelated to the central tin atom with the replacement of hydrogen atom through enolization and due to chelation the biocidal activity of the complexes was enhanced. The structures of all the newly synthesized compounds i.e. Schiff bases and tin metal linked complexes were predicted by adequate spectral (IR, ^{1}H

NMR, ^{13}C NMR, ^{119} Sn NMR and mass) data. The ^{1}H NMR, ^{13}C NMR, ^{119}Sn NMR spectra of compounds exhibited signals owing to different protons, carbons, and tin respectively in the expected regions (vide experimental).

IR spectra

The coordination sites of the ligands were assigned on the basis of shifts in the frequency and lowering in the intensities of the absorptions in the complexes as compared to the ligands. The IR spectra of Schiff bases hydrazones displayed medium intensity absorption bands in the region at 3410-3460cm^{-1} (N–H stretching) which completely disappeared in the tin complexes, indicating the loss of a proton on the nitrogen due to tautomerization after complexation with the tin atom and sharp frequency in the regions at 1630–1655 cm^{-1}>C=N– stretching, which was shifted to a lower frequency in the complexes by 10-25 cm^{-1} signifying that coordination had also certainly taken place through the azomethine nitrogen to the tin atom.[21,22] The coordination through the carbonyl oxygen to the tin after deprotonation was confirmed by appearance of 2 new bands in the region 1340 cm^{-1}, 1215 cm^{-1} due to ν(NCO) and ν(C–O).[14] In the complexes the coordination occurs through nitrogen attached to C-1 rather than C-10 which gives a five-membered stable ring after coordination, with lesser strain. The formation of the complexes was also ascertained by appearance of new bands due to ν(Sn–O), ν(Sn–N) and ν(Sn–C) at 530 ± 10, 445 ± 15 and 608-731 ± 10cm^{-1} respectively.[14,23,25]

NMR Spectral analysis

The binding sites (ONO) of the Schiff base ligands were further confirmed by comparing the ^{1}H NMR with their complexes which was in accordance with the IR spectra. The main characteristic peak in the ligands was a singlet due to azomethine proton observed in the region

at δ 11.92-12.04,[24] and a singlet due to proton attached to C-2 was observed in the range δ 9.07-9.43 in the ligands which get completely disappeared in the ^{1}H NMR of the complexes which confirmed the coordination mode of the carbonyl oxygen with central tin atom through tautomerization. The signals due to the remaining aliphatic protons in the ligands show a regular pattern 6H of $2CH_3$ group as a doublet, 1H of CH as a multiplet and 2H of CH_2 as doublet in the range δ 0.88-3.03 which remained unchanged in the complexes showing non participation of these protons. However, tin complexes exhibited additional signals at δ 0.73-0.93, δ 0.91-1.51, δ 0.82-1.52 and δ 7.23-8.23 owing to the protons of the methyl, ethyl, butyl and phenyl groups respectively as expected.

The ^{13}C NMR spectral data of all the synthesized compounds were found to be in the expected regions. The structure was further confirmed by comparing the shifts in the ^{13}C NMR spectra of the complexes and the spectra of ligands. The signal appeared as a singlet due to carbonyl carbon and azomethine carbon appeared at δ 172.4-191.5, δ 147.3- 157.2 respectively. The signals due to carbonyl carbon, azomethine carbon and the carbon adjacent to the coordinating atoms shifted to downfield on complexation because of an electron-density transfer from the ligand to the tin metal atom supported the coordination modes through azomethine nitrogen and carbonyl carbon which favors the tridentate (ONO) coordinating mode of the ligands.[25] Aliphatic carbon atoms of ligands appeared in the range of δ 16.1-49.3 and the aromatic carbons appeared in the expected range and remained unaffected in the complexes, signifying their non participation in bond formation with central atom. In the complexes, the new signals due to methyl, ethyl, butyl attached to central tin atom appeared at δ 26.8-28.1, δ 13.1-40.8, δ 13.1-42.6 and phenyl carbon appeared in their normal aromatic range.[14, 23, 25]The value of

^{119}Sn spectra reflects the coordination number of the nucleus in the corresponding metal complexes. The spectra in each case show only a sharp singlet, indicating the formation of a single species, which is indicative of pentacoordinated environment around the tin atom. ^{119}Sn NMR spectra were recorded in $CDCl_3$ and DMSO-d_6. The δ value varies with coordination number and the R group attached to the central tin atom. A large upfield shift was observed in the spectra of complexes with increase in coordination number. The occurrence of chemical shift in ^{119}Sn NMR spectra in the ranges δ -143.11 to -161.3, δ -172.4 to -179.7, δ -179.4 to -220.5, δ -323.1 to -351.2 for methyl, ethyl, butyl and phenyl complexes respectively were in accordance with the literature and pentacoordinated geometries were implicit for all the synthesized complexes.[23,25,26]

Mass spectra

The ESI mass spectra of all the synthesized compounds were found to be in good agreement with their molecular formula. The main base peaks was clearly visible which corresponds to the whole ligand and the molecular ion peaks of the tin complexes were found with very low abundance. In the spectra, mass fragments display the natural abundance of the central tin atom and the major mass fragment ions were due to the $[R_2SnL]^+$, $[L]^+$, $[RSnL]^+$, $[SnL]^+$, $[Sn]^+$ which were in accordance with the literature reports.[27] The molecular ion and base peaks with the individual tin isotopes of n-Bu_2SnL^1 at *m/z* 349.10, 581.10 and Ph_2SnL^2 *m/z* 351.00, 623.00 due to $[L]^+$ and $[M+1]^+$ respectively, were measured and compared with the theoretically calculated one and were found in agreement with the theoretical values.[28] Sample NMR and ESI-mass spectra are presented in Figures S 1 – S 58 (Supplemental Materials)

X-ray diffraction

XRD study of the synthesized compounds was done by the X-ray powder diffraction method over the range 2θ = 20-80° which was in agreement with the crystalline nature of the complexes[29]; the peaks are depicted in Figure S 61 (Supplemental Materials). An X-ray diffraction study of the complexes showed a clear crystalline peak with maxima at 2θ = 28.640° and d = 3.114.[2]

Molar conductance

The values of molar conductance of compounds were found in accordance to the literature values. The non-electrolytic nature of complexes was confirmed by the low observed conductance values of 10^{-3} M solution which was in the range of 9–16 ohm^{-1} cm^2 mol^{-1}.

Antimicrobial activities

The newly synthesized hydrazones and their organotin complexes (**1–20**) were screened for their *in vitro* antimicrobial activity against four bacterial strains i.e. Gram positive *Bacillus ceres* (MTCC 10072), *Styphyllococus aureus* (MTCC 2901) and Gram negative *Escherichia.coli* (MTCC 732), *Pseudomonas aeruginosa* (MTCC 424), and three fungal strains i.e. *Aspergillus flavus* (ITCC 7680), *Aspergillus niger* (MTCC 7678), *Candida albicans* (MTCC 227) by Serial dilution technique. Ciprofloxacin and Fluconazole were used as reference drugs for antibacterial and antifungal evaluation, respectively The data for the antibacterial and antifungal activity are presented in Table S 1 and Figures S 59 – S 60 (Supplemental Materials). The occurrence of C=N groups in the Schiff bases and R group attached to tin atom plays a vital role for biological activity which helps in modification reaction in biological systems. The activity alters with deviation of R groups, attached with the Sn atom. In fact, the purpose of the ligand is only to

sustain the transfer of the active organotin (IV) moiety to the site of action where it is released by hydrolysis. The tin complexes were found to be more active as compared to their parent Schiff base ligands against the same micro-organism. This phenomenon was explained by the chelation theory,[29,30] in accordance to this concept the possible π electron delocalization occurs within the whole chelate ring system and the polarity of the metal atom decreases due to partial sharing of its positive charge with the donor R groups, due to this the lipophilic character of metal complexes increases, which leads the penetration of them through the lipid layer of the cell membrane[31] there by deactivating respiration process by cleaving the DNA of the micro-organism. The inhibitory activity of the organotin complexes increases in the order Sn-Ph> Sn-Bu> Sn-Et > Sn-Me. Among the tested complexes, most of the compounds were found to be more potent against microbial strains due to the fact that the R group increases the lipophilicity of the complexes so that these complexes can bind easily with biological molecules by π - π interactions which boost up the bioactivity of these complexes. Further, all compounds were found to be more active against Gram positive bacterial strains as compared to Gram negative because outer membrane of Gram negative bacteria is more complex, containing lipopolysaccharide. Moreover, comparison of antibacterial and antifungal evaluation results revealed that the antifungal activities are more prolific than antibacterial activities. With the help of antimicrobial results, subsequently structure activity relationships (SAR) may be inferred-

1. The presence of azomethine (C=N) moiety in the ligands also show moderate antimicrobial activity which further enhanced by ligating with tin atom against all the tested bacterial and fungal strains in most of the cases.

2. The presence of tin moiety augmented the antimicrobial activity but antifungal efficacy was found to be more prominent against *Aspergillus flavus, Aspergillus niger, Candida albicans as compared to the antibacterial activity.*
3. In some cases, presence of pyrazine moiety in the ligand improved the antimicrobial activity.
4. In most of the cases, presence of phenyl, butyl moiety in the tin complexes increased the antimicrobial potency against all the tested microbial strains as compared to the ethyl and methyl groups.

From these results, we conclude that there are necessities of unique structures for a compound to be effective against different microbial strains still, no general trend towards structure activity relationship (SAR) has been recognized for the antimicrobial activity of the tested compounds.

Experimental

All the chemicals such as diphenyltin(IV) dichloride, di-*n*-butyltin(IV) dichloride, diethyltin (IV) dichloride, dimethyltin (IV) dichloride were purchased from (Aldrich) were used as received without further purification and 2-(3-methylbutanoyl)-1*H*-indene-1,3(2*H*)-dione were prepared according to the methods reported in the literature[32]. Solvents such as methanol, hexane (Qualigens) were dried using standard procedures before use. All the synthesis were carried out under an inert atmosphere. Melting points (mp, °C) of all the synthesized compounds were measured on an electrothermal apparatus and are uncorrected. The elemental analyses were analyzed on Thermo Scientific FLASH-2000 CHN analyser. IR spectra in the range 4000–400 cm^{-1} were obtained on a Perkin Elmer 983 spectrophotometer by using KBr pellets. The NMR spectra (^{1}H, ^{13}C, and ^{119}Sn) were obtained on a Bruker Avance 400MHz spectrometer by using Me_4Si as internal standard and there chemical shifts were recorded in ppm. Tin was estimated

gravimetrically as SnO_2. The mass spectra were recorded on LCMS-MS 6410 Agilent technologies spectrophotometer. XRD powder diffraction measurement were carried out by using Rigaku table top X-ray diffractometer with scan rate of 2 min in the range 20-80°. Molar Conductances of the compounds were measured in DMSO with a conductivity bridge type Model-306 Systronics The Supplemental Materials contain sample ^{1}H, ^{13}C, ^{119}Sn NMR and ESI-MS spectra for the ligands and tin complexes (Figures S 1 – S 58)

Synthesis of Schiff Base Ligands

The 2-(3-methylbutanoyl)-1*H*-indene-1,3(2*H*)-dione needed for the synthesis was prepared by the Claisen condensation of diethylphthlate and appropriate ketone under the influence of sodium methoxide according to the procedure as described in literature.[32,33] Schiff bases were synthesized by dissolving 1:1 molar ratio methanolic solution of 2-(3-methylbutanoyl)-1*H*-indene-1,3(2*H*)-dione with benzoic acid, pyrazine acid, nicotinic acid and isonicotinic acid hydrazides. The solution was stirred and refluxed for 5-6 h .The solution was kept overnight at room temperature. The white and red color solids so obtained were filtered and recrystallized in methanol and chloroform solution (1:1, v/v).

(Benzoic acid [1-(1,3-dioxo-indan-2-yl)-3-methyl-butylidene]-hydrazide) H_2L^1(1).

White solid; m.p: 170-172°C. Yield: 90%; Anal. Calc. for $C_{21}H_{20}N_2O_3$ (348.40): C, 72.40; H, 5.79; N, 8.04; O, 13.78%. Found: C, 72.34; H, 5.71; N, 8.02; O, 13.72 %. ESI-MS *m/z*: 349.32$[M + H]^+$. IR (KBr pellets, cm^{-1}): 3212 ν(N–H), 1588.46 ν(C=N), 1638.28 ν(C=O). ^1H NMR ($CDCl_3$, 400 MHz, δ_H): 11.95 (s, 1H, NH), 9.38 (s, 1H, C_2-H), 8.03(d, 1H, *J* = 8 Hz), 7.86 (d, 2H, *J* = 8Hz), 7.60-7.38 (m, 6H), 2.92 (d, 2H, CH_2, *J* = 8Hz), 2.07-1.93 (m, 1H, CH), 0.88 (d,

6H, CH_3, *J* = 4Hz) ppm. ^{13}C ($CDCl_3$, 100 MHz, δ_C): 193.2, 170.1 (C=O), 144.0 (C=N), 143.3, 143.2, 143.2, 142.9, 139.6, 138.1, 121.0, 99.4, 33.6, 27.9, 22.1ppm.

(Pyrazine-2-carboxylic acid [1-(1,3-dioxo-indan-2-yl)-3-methyl-butylidene]-hydrazide) H_2L^2(2).

White solid; m.p.: 129°C. Yield: 86%; Anal. Calc. for $C_{19}H_{18}N_4O_3$ (350.37), C, 65.13; H, 5.18;N, 15.99; O, 13.70%. Found: C, 65.07; H, 5.15; N, 15.95; O, 13.67 %. ESI-MS *m/z*: 351.21$[M + H]^+$. IR (KBr pellets, cm^{-1}): 3334.24 ν(N–H), 1568.02 ν(C=N), 1643.73 ν(C=O). ^1H NMR ($CDCl_3$, 400 MHz, δ_H): 12.04 (s, 1H, NH), 9.43 (s, 1H, C_2-H), 9.60 (s, 1H), 8.89 (d, 1H, *J* = 8Hz), 8.06 (d, 1H, *J* = 8Hz), 7.62 (d, 2H), 7.73 (dd, 2H), 3.00 (d, 2H, CH_2, *J* = 8Hz), 2.14-2.07 (m, 1H, CH), 1.05 (d, 6H, CH_3, *J* = 8Hz) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz, δ_C): 188.9, 170.4 (C=O), 162.0, 147.3(C=N), 142.9, 139.6, 138.1, 133.1, 132.9, 121.0, 120.7, 101.8, 33.6, 27.9, 22.1 ppm.

(Isonicotinic acid [1-(1,3-dioxo-indan-2-yl)-3-methyl-butylidene]-hydrazide) H_2L^3(3).

Red solid; m.p.: 241-243°C. Yield: 82%; Anal. Calc. for $C_{20}H_{19}N_3O_3$ (349.38): C, 68.75; H, 5.48; N, 12.03; O, 13.74%. Found: C, 68.71; H, 5.45; N, 11.98; O, 13.71 %. ESI-MS *m/z*: 349.14 $[M + H]^+$. IR (KBr pellets, cm^{-1}): 3324 ν(N–H), 1578.67 ν(C=N), 1659.18 ν(C=O). ^1H NMR (DMSO-d_6, 400 MHz, δ_H): 11.99 (s, 1H, NH), 9.38 (s, 1H, C2-H), 8.83 (d, 2H, *J* = 8Hz), 7.85 (d, 2H, *J* = 8Hz), 7.70-7.66 (d, 4H, *J* = 8Hz), 3.03 (d, 2H, CH_2, *J* = 8Hz), 2.08-2.00 (m, 1H, CH), 0.95 (d, 6H, CH_3, *J* = 8Hz) ppm. ^{13}C NMR (DMSO-d_6, 100 MHz, δ_C): 181.0, 173.9 (C=O), 149.4 (C=N), 148.5, 142.4, 132.3, 130.7, 128.6, 122.5, 93.6, 35.7, 22.2, 20.2 ppm.

(Nicotinic acid [1-(1,3-dioxo-indan-2-yl)-3-methyl-butylidene]-hydrazide) H_2L^4(4).

Orange solid; m.p.: 179-182°C. Yield: 93%; Anal. Calc. for $C_{20}H_{19}N_3O_3$ (349.38): C, 68.75; H, 5.48; N, 12.03; O, 13.74%. Found: C, 68.73; H, 5.44; N, 12.01; O, 13.72 %. ESI-MS *m/z*: 349.14$[M + H]^+$. IR (KBr pellets, cm^{-1}): 3245 ν(N–H), 1582.54 ν(C=N), 1676.58 ν(C=O). ^{1}H NMR (DMSO-d_6, 400 MHz, δ_H): 11.92 (s, NH), 9.07(s, 1H, C_2-H), 9.43 (d, 1H, *J* = 8Hz), 8.64 (d, 1H, *J* = 8Hz), 7.94-7.56 (m, 6H), 2.91 (d, 2H, CH_2, *J* = 8Hz), 2.07-1.92 (m, 1H, CH), 0.83 (d, 6H, CH_3, *J* = 8Hz) ppm. ^{13}C NMR (DMSO-d_6, 100 MHz, δ_C): 182.0, 172.6(C=O), 151.5, 149.6 (C=N), 148.2, 137.3, 136.3, 133.4, 131.7, 130.7, 129.7, 95.5, 34.6, 21.4, 20.4 ppm.

Synthesis of Organotin complexes

Organotin(IV) complexes of the Schiff base-ligands were synthesized from the the Schiff base and suitable diorganotin(IV)dichloride as follows: Schiff base ligand (2.0 mmol) was dissolved in specially dried methanol (15 mL), a few drops of concentrated sodium methoxide in methanol were added, and the mixture was stirred and then refluxed for 3 h. under an inert atmosphere of dry nitrogen. The solution was allowed to cool and a methanolic solution of R_2SnCl (1 mmol) was added to it with constant stirring. The solution was further refluxed at 40–50◦C for another 12-15 h. The mixture was kept overnight at room temperature. The mixture was filtered in order to remove sodium chloride salt formed and the excess solvent was slowly removed by evaporation under a vacuum pump. The solid thus obtained was recrystallized from methanol-chloroform (1:1, v/v) mixture. The depiction of the individual complexes was as follows:

(4*E*,6*Z*)-7-isobutyl-2,2,4-triphenyl-8*H*-indeno[2,1-*h*][1,3,5,6,2]dioxadiazastannonin-8-one Ph_2SnL^1 (5).

Yellow solid; m.p.: 159-163°C. Yield: 71%; Anal. Calc. for $C_{33}H_{28}N_2O_3Sn$: C, 64.00; H, 4.56; N, 4.52; O, 7.75; Sn, 19.17%. Found: C, 63.98; H, 4.53; N, 4.49; O, 7.73; Sn, 19.14%. ESI-MS *m/z*: 620.11$[M + H]^+$. IR (KBr, cm^{-1}): 1698 ν(C=O), 1569 ν(C=N), 1543 ν(C–O), 525 ν(Sn–O), 446 ν(Sn←N). ^{1}H NMR ($CDCl_3$, 400 MHz, δ_H): 8.21-7.26 (m, 19H), 3.45 (d, 2H, CH_2, *J* = 8Hz), 2.77-2.42 (m, 1H, CH), 1.06 (d, 6H, CH_3, *J* = 8Hz) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz, δ_C): 190.3, 183.4 (C-O), 171.9 (C=O), 157.2 (C=N), 136.5, 134.4, 132.4, 130.3, 129.9, 129.1, 128.2, 125.8, 128.13, 121.3, 114.8, 102.2, 41.4, 23.9, 21.5, ppm. ^{119}Sn NMR ($CDCl_3$, 149 MHz, δ_{Sn}): -323.76 ppm.

(4*E*,6*Z*)-2,2-dibutyl-7-isobutyl-4-phenyl-8*H*-indeno[2,1-*h*][1,3,5,6,2]dioxadiazastannonin-8-one n-Bu_2 SnL^1 (6).

Yellow solid; m.p.: 134-136°C; Yield: 73%; Anal. Calc. for $C_{29}H_{36}N_2O_3Sn$: C, 60.12; H, 6.26; N, 4.84; O, 8.29; Sn, 20.49%. Found: C, 60.09; H, 6.22; N, 4.81; O, 8.26; Sn, 20.45%. ESI-MS *m/z*: 581.60 $[M + H]^+$. IR (KBr pellets, cm^{-1}): 1571 ν (C=N), 1701 ν(C=O), 676 ν(Sn -C), 741.44 ν(Sn -O), 449 ν(Sn -N). ^{1}HNMR ($CDCl_3$, 400 MHz, δ_H): 8.06-8.03 (d, 2H),7.90-7.88 (d, 2H, *J* = 8Hz), 7.76-7.38 (m, 5H) 3.66 (d, 2H, *J* = 8Hz), 3.06-3.00 (m, 2H), 2.29-2.13 (d, 1H, *J* = 8Hz), 2.11-2.02 (m, 1H), 1.79-1.41 (m, 6H), 1.39-1.20 (m, 2H), 1.08-0.94 (m, 10H), 0.88-0.82 (m, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz, δ_C): 186.7, 177.3, 167.2, 149.5 (C=N), 140.3, 136.7, 131.7, 129.4, 127.4, 123.1, 120.2, 103.1, 45.4, 35.5, 27.6, 26.0, 25.0, 21.7, 13.5 ppm. ^{119}Sn NMR ($CDCl_3$, 149 MHz, δ_{Sn}): -184.7 ppm.

(4*E*,6*Z*)-2,2-diethyl-7-isobutyl-4-phenyl-8*H*-indeno[2,1-*h*][1,3,5,6,2]dioxadiazastannonin-8-one n-Et_2 SnL^1(7).

Yellow solid; m.p.: 146-149°C. Yield: 73%; Anal. Calc. for $C_{25}H_{28}N_2O_3Sn$: C, 57.39; H, 5.39; N, 5.35; O, 9.17; Sn, 22.69%. Found: C, 57.37; H, 5.36; N, 5.31; O, 9.12; Sn, 22.64%. ESI-MS *m/z*: 524.63 $[M + H]^+$. IR (KBr pellets, cm^{-1}): 1571 ν(C=N), 1697 ν(C=O), 672 ν(Sn -C), 736 ν(Sn -O), 441 ν(Sn -N). ^{1}HNMR (CDCl3, 400 MHz, δ_H): 7.94-7.72 (m, 9H), 2.97(d, 2H), 1.99-1.88 (m, 1H, CH), 1.47-1.38 (m, 4H, CH_2), 1.19-0.87 (m, 12H, CH_3) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz, δ_C): 181.8, 179.1, 174.2 (C=O), 157.4 (C=N), 133.0, 132.7, 131.4, 130.4, 129.8, 129.1, 128.1, 102.0, 49.4, 38.2, 28.3, 21.7, 18.9, ppm. ^{119}Sn NMR ($CDCl_3$, 149 MHz, δ_{Sn}): -179.3 ppm.

(4*E*,6*Z*)-7-isobutyl-2,2-dimethyl-4-phenyl-8*H*-indeno[2,1-*h*][1,3,5,6,2]dioxadiazastannonin-8-one Me_2SnL^1(8).

Yellow solid; m.p.: 140-143°C. Yield: 76%; Anal. Calc. for $C_{23}H_{24}N_2O_3Sn$: C, 55.79; H, 4.89; N, 5.66; O, 9.69; Sn, 23.97%. Found: C, 55.73; H, 4.86; N, 5.62; O, 9.64; Sn, 23.92%. ESI-MS *m/z*: 497.36 $[M + H]^+$. IR (KBr pellets, cm^{-1}): 1679 ν(C=O), 1563 ν(C=N), 1542 ν (C–O), 1311 ν(C–O), 529 ν(Sn–O), 443 ν(Sn←N). ^{1}H NMR ($CDCl_3$, 400 MHz, δ_H): 8.62 (d, 1H, *J* = 8Hz), 8.06-8.03 (m, 3H), 7.86-7.39 (m, 5H), 3.65 (d, 2H, CH_2, *J* = 8Hz), 2.16-2.09 (m, 1H, CH), 0.92 (d, 6H, CH_3, *J* = 8Hz), 0.73 (s, 6H, CH_3) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz, δ_C): 183.4, 178.8, 173.6, 156.1 (C=N), 138.3, 131.1, 130.7, 129.5, 129.7, 129.1, 128.1, 102.1, 39.2, 28.0, 23.3, 21.4, ppm. ^{119}Sn NMR ($CDCl_3$, 149 MHz, δ_{Sn}): -143.1 ppm.

(4*E*,6*Z*)-7-isobutyl-2,2-diphenyl-4-(pyrazin-2-yl)-8*H*-indeno[2,1-*h*][1,3,5,6,2]dioxadiazastannonin-8-one Ph_2SnL^2(9).

Yellow solid; m.p.: 109-111°C. Yield: 68%; Anal. Calc. for $C_{31}H_{26}N_4O_3Sn$: C, 59.93; H, 4.22; N, 9.02; O, 7.73; Sn, 19.11%. Found: C, 59.90; H, 4.19; N, 8.99; O, 7.69; Sn, 19.10 %. ESI-MS *m/z*: 622.19 $[M + H]^+$. IR (KBr pellets, cm^{-1}): 1553.02 ν(C=N), 1631.73 ν(C=O), 679 ν(Sn-C), 716 ν(Sn -O), 453 ν(Sn←N). ^{1}H NMR **(**$CDCl_3$, 400 MHz, δ_H)**:** 8.86 (s, 1H), 8.51-8.47 (dd, 2H), 7.64-7.42 (m, 14H), 2.93 (d, 2H, *J* = 8Hz), 2.10-2.02 (m, 1-H), 0.95 (d, 6H, *J* = 8Hz) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz, δ_C) 189.4, 178.0, 174.4 (C=O), 158.9(C=N), 135.6, 133.24, 132.8, 130.7, 129.5, 129.1, 127.9, 126.2, 125.0, 124.2, 124.2, 101.0, 40.2 (C-7), 24.7, 20.2, ppm. ^{119}Sn NMR ($CDCl_3$, 149 MHz, δ_{Sn}): -334.8 ppm

(4*E*,6*Z*)-2,2-dibutyl-7-isobutyl-4-(pyrazin-2-yl)-8*H*-indeno[2,1-*h*][1,3,5,6,2]dioxadiazastannonin-8-one n-Bu_2 SnL^2(10).

Red solid; m.p.: 119-121°C. Yield: 73%; Anal. Calc. $C_{27}H_{34}N_4O_3Sn$: C, 55.79; H, 5.90; N, 9.64; O, 8.26; Sn, 20.42%. Found: C, 55.76; H, 5.88; N, 9.61; O, 8.24; Sn, 20.39%. ESI-MS *m/z*: 581.60 $[M + H]^+$. IR (KBr pellets, cm^{-1}): 1573 ν(C=N), 1633 ν(C=O), 672 ν(Sn -C), 736.44 ν(Sn -O), 451 ν(Sn ←N). ^{1}HNMR ($CDCl_3$, 400 MHz, δ_H): 9.44-9.36 (m, 2H), 8.89-8.60 (m, 2H), 8.45 (d, 1H, *J* = 8Hz), 7.74 (d, 2H, *J* = 4Hz), 7.61 (d, 2H, *J* = 4Hz), 3.54 (d, 2H, *J* = 8Hz), 3.07-2.98 (m, 2H), 2.99 (d, 2H, *J* = 8Hz), 2.39-2.33 (d, 1H, *J* = 8Hz), 2.09 (d, 6H, *J* = 8Hz), 1.59-1.24 (m, 6H), 1.07-1.03 (m, 12H), 0.86-0.82, ppm. ^{13}C NMR ($CDCl_3$, 100 MHz, δ_C): 191.7, 178.1, 173.2 (C=O), 155.18 (C=N), 135.3, 132.4, 131.1, 130.4, 129.0, 128.3, 99.4, 42.8, 41.5, 25.7, 24.3, 22.0, 20.4, 13.4, ppm. ^{119}Sn NMR ($CDCl_3$, 149 MHz, δ_{Sn}): -210.5 ppm.

(4*E*,6*Z*)-2,2-diethyl-7-isobutyl-4-(pyrazin-2-yl)-8*H*-indeno[2,1-*h*][1,3,5,6,2]dioxadiazastannonin-8-one n-Et_2 SnL^2(11).

Yellow solid; m.p.: 112-115°C. Yield: 73%; Anal. Calc. $C_{23}H_{26}N_4O_3Sn$: C, 52.60; H, 4.99; N, 10.67; O, 9.14; Sn, 22.60%. Found: C, 52.58; H, 4.99; N, 10.67; O, 9.11; Sn, 22.55%. IR (cm^{-1}): 1577 ν (C=N), 1678 ν(C=O), 667 ν(Sn -C), 737 ν(Sn -O), 458 ν(Sn←N). ESI-MS *m/z*: 526.10 $[M + H]^+$. ^{1}HNMR ($CDCl_3$, 400 MHz, δ_H): 8.82 (s, 1H), 8.71 (d, 1H, *J* = 8Hz), 8.38 (d, 1H, *J* = 8Hz), 7.79 (d, 2H, *J* = 8Hz), 7.52 (d, 2H, *J* = 8Hz) 2.31-2.00 (m, 1H, CH), 1.49-1.39 (m, 6H, CH_2), 1.28-0.91 (m, 12H, CH_3) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz, δ_C): 181.2, 179.8, 170.3 (C=O), 153.5 (C=N), 135.0, 130.7, 129.1, 132.0, 131.1, 129.7, 128.1, 100.8, 41.5, 40.5, 24.0, 22.7, 21.4 ppm. ^{119}Sn NMR ($CDCl_3$, 149MHz, δ_{Sn}): -178.5 ppm

(4*E*,6*Z*)-7-isobutyl-2,2-dimethyl-4-(pyrazin-2-yl)-8*H*-indeno[2,1-*h*][1,3,5,6,2]dioxadiazastannonin-8-one Me_2SnL^2(12).

Yellow solid; m.p.: 101-103°C. Yield: 65%; Anal. Calc. for $C_{21}H_{22}N_4O_3Sn$: C, 50.74; H, 4.46; N, 11.27; O, 9.65; Sn, 23.88%. Found: C, 50.72; H, 4.43; N, 11.26; O, 9.62; Sn, 23.84%. ESI-MS *m/z*: 498.17 $[M + H]^+$. IR (KBr pellets, cm^{-1}): 1682 ν(C=O), 1573 ν(C=N), 1546 ν(C–O), 1309 ν(C–O), 531 ν(Sn–O), 449 ν(Sn←N). ^{1}H NMR($CDCl_3$, 400 MHz, δ_H): 8.69 (d, 1H, *J* = 8Hz), 8.50 (d, 2H, *J* = 8Hz), 7.72 (d, 1H, *J* = 8Hz), 7.58-7.47 (m, 4H), 2.90 (d, 2H, CH_2, *J* = 8Hz), 2.02-1.81 (m, 1H, CH), 1.32 (s, 6H, CH_3, *J* = 8Hz), 0.87 (d, 6H, CH_3) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz, δ_C): 180.2, 178.1, 170.3 (C-10, C=O), 155.1 (C=N), 137.7, 131.4, 130.7, 130.1, 129.7, 129.0, 101.4, 128.5, 40.8, 28.3, 22.4, 21.0, ppm. ^{119}Sn NMR ($CDCl_3$, 149 MHz, δ_{Sn}): -161.4 ppm.

(4*E*,6*Z*)-7-isobutyl-2,2-diphenyl-4-(pyridin-4-yl)-8*H*-indeno[2,1-*h*][1,3,5,6,2]dioxadiazastannonin-8-one Ph_2SnL^3(13).

Red solid; m.p.: 153-155°C. Yield: 63%; Anal. Calc. for $C_{32}H_{27}N_3O_3Sn$: C, 61.96; H, 4.39; N, 6.77; O, 7.74; Sn, 19.14%. Found: C, 61.94; H, 4.36; N, 6.75; O, 7.76; Sn, 19.13%. ESI-MS *m/z*: 621.13 $[M + H]^+$. IR (KBr pellets, cm^{-1}): 1681 ν(C=O), 1575 ν(C=N), 1542 ν(C–O), 1302 ν(C–O), 537 ν(Sn–O), 451 ν(Sn←N). ^1H NMR (DMSO-d_6, 400 MHz, δ_H): 8.18 (d, 2H, *J* = 8Hz), 8.10 (d, 2H, *J* = 8Hz), 8.02 (d, 2H, *J* = 8Hz), 7.26-7.98 (m, 12H) 3.05 (d, 2H, CH_2, *J* = 8Hz), 2.05-2.22 (m, 1H, CH), 1.07-0.85 (d, 6H, CH_3 *J* = 8Hz) ppm. ^{13}C (DMSO-d_6, 100 MHz, δ_C): 193.9, 181.3 (C-O), 173.1 (C=O), 155.1(C=N), 149.9, 138.9, 136.8, 131.5, 129.5, 129.1, 128.7, 127.9, 127.4, 125.0, 101.8, 43.9, 23.9, 21.8, ppm. ^{119}Sn NMR (DMSO-d_6, 149 MHz, δ_{Sn}): -351.3 ppm.

(4*E*,6*Z*)-2,2-dibutyl-7-isobutyl-4-(pyridin-4-yl)-8*H*-indeno[2,1-*h*][1,3,5,6,2]dioxadiazastannonin-8-one n-Bu_2 SnL^3(14).

Yellow solid; m.p.: 196-198°C. Yield: 73%. Anal. Calc. $C_{28}H_{35}N_3O_3Sn$: C, 57.95; H, 6.08; N, 7.24; O, 8.27; Sn, 20.46%. Found: C, 57.93; H, 6.06; N, 7.21; O, 8.25; Sn, 20.43%. IR (KBr pellets, cm^{-1}): 1675 ν(C=O), 1569 ν(C=N), 671 ν(Sn -C), 721 ν(Sn -O), 462 ν(Sn←N). ESI-MS *m/z*: 581.60 $[M + H]^+$. ^{1}HNMR ($CDCl_3$, 400 MHz, δ_H): 8.61 (d, 2H, *J* = 8Hz), 7.90-7.52 (m, 4H), 7.56-7.48 (d, 2H, *J* = 4Hz), 3.19 (d, 2H, *J* = 8Hz), 2.56-2.12 (m, 1H), 1.57-1.41 (m, 6H), 1.04-0.77 (m, 18H), ppm. ^{13}C NMR ($CDCl_3$, 100 MHz, δ_C): 186.7, 179.5, 172.6 (C=O), 154.5 (C=N), 134.4, 131.7, 129.8, 101.4, 137.3, 129.3, 128.1, 41.5, 40.1, 25.7, 24.3, 22.4, 20.0, 13.8, ppm. ^{119}Sn NMR ($CDCl_3$, 149 MHz, δ_{Sn}): -188.7 ppm.

(4*E*,6*Z*)-2,2-diethyl-7-isobutyl-4-(pyridin-4-yl)-8*H*-indeno[2,1-*h*][1,3,5,6,2]dioxadiazastannonin-8-one n-Et_2 SnL^3(15).

Red solid; m.p.: 180-182°C. Yield: 73%; Anal. Calc. $C_{24}H_{27}N_3O_3Sn$: C, 54.99; H, 5.19; N, 8.02; O, 9.16; Sn, 22.65%. Found: C, 54.96; H, 5.17; N, 8.00; O, 9.12; Sn, 22.63%. IR (KBr pellets, cm^{-1}): 1689 ν(C=O), 1573 ν(C=N), 669 ν(Sn -C), 729 ν(Sn -O), 471 ν(Sn←N). ESI-MS *m/z*: 525.11 $[M + H]^+$. ^{1}HNMR ($CDCl_3$, 400 MHz, δ_H): 8.72 (d, 2H, *J* = 8Hz), 7.76 (d, 2H, *J* = 8Hz), 7.67-7.52 (m, 4H), 2.31-1.98 (m, 1H, CH), 1.51-1.42 (m, 6H, CH_2), 1.31-0.97 (m, 12H, CH_3) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz, δ_C): 179.8, 178.5, 171.3 (C=O), 151.2 (C=N), 133.7, 131.1, 129.7, 99.18, 135.07, 130.4, 128.13, 38.8, 32.5, 25.1, 22.7, 22.0, ppm. ^{119}Sn NMR ($CDCl_3$, 149 MHz, δ_{Sn}): -172.5 ppm.

(4*E*,6*Z*)-7-isobutyl-2,2-dimethyl-4-(pyridin-4-yl)-8*H*-indeno[2,1-*h*][1,3,5,6,2]dioxadiazastannonin-8-one Me_2SnL^3 (16).

Yellow solid; m.p.: 176-178°C. Yield: 63%; Anal. Calc. for $C_{22}H_{23}N_3O_3Sn$: C, 53.26; H, 4.67; N, 8.47; O, 9.67; Sn, 23.93%. Found: C, 53.23; H, 4.64; N, 8.45; O, 9.64; Sn, 23.90%. ESI-MS *m/z*: 497.14 $[M + H]^+$. IR (KBr pellets, cm^{-1}): 1678 ν(C=O), 1569 ν(C=N), 1542 ν(C–O), 1307 ν(C–O), 534 ν(Sn–O), 451 ν(Sn←N). ^{1}H NMR ($CDCl_3$, 400 MHz, δ_H): 8.61 (d, 2H, *J* = 8Hz), 8.02 (d, 2H, *J* = 8Hz), 7.47 (d, 2H, *J* = 8Hz), 7.37-7.33 (d, 2H, *J* = 8Hz), 2.88 (d, 2H, CH_2, *J* = 8Hz), 1.91-1.81(m, 1H, CH), 1.32 (s, 6H, CH_3, *J* = 8Hz), 0.98 (d, 6H, CH_3) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz, δ_C): 182.83, 177.89, 173.42 (C=O), 154.7 (C=N), 137.9, 129.8, 129.4, 100.1, 130.7, 129.1, 128.7, 40.1, 28.6, 21.4, 21.0, ppm. ^{119}Sn NMR ($CDCl_3$, 149 MHz, δ_{Sn}): -152.4 ppm.

(4*E*,6*Z*)-7-isobutyl-2,2-diphenyl-4-(pyridin-3-yl)-8*H*-indeno[2,1-*h*][1,3,5,6,2]dioxadiazastannonin-8-one Ph_2SnL^4(17).

Yellow solid; m.p.: 82-84°C. Yield: 76%; Anal. %. Calc. for $C_{32}H_{27}N_3O_3Sn$: C, 61.96; H, 4.39; N, 6.77; O, 7.74; Sn, 19.14%. Found: C, 61.94; H, 4.37; N, 6.75; O, 7.72; Sn, 19.11%. ESI-MS *m/z*: 621.72 $[M + H]^+$. IR (KBr, cm^{-1}): 1577 ν(C=N), 1671 ν(C=O), 1549 ν(C–O), 1312 ν(C–O), 547 ν(Sn–O), 447 ν(Sn←N). ^{1}H NMR (DMSO-d_6, 400 MHz, δ_H): 9.23 (1H, d, J = 8Hz), 8.40-7.36 (m, 17H), 3.06 (d, 2H, CH_2, J = 4Hz), 2.16-2.02 (m, 1H, CH), 0.96(d, 6H, CH_3, J = 8Hz) ppm. ^{13}C NMR (DMSO-d_6, 100 MHz, δ_C): 192.3, 180.5, 172.3 (C=O), 154.87 (C=N), 153.1, 152.8, 136.06, 133.2, 131.9, 130.7, 129.5, 129.9, 126.6, 124.2, 123.4, 123.0, 99.78, 41.0, 22.3, 21.8, ppm. ^{119}Sn NMR (DMSO-d_6, 149 MHz, δ_{Sn}): -326.4 ppm

(4*E*,6*Z*)-2,2-dibutyl-7-isobutyl-4-(pyridin-3-yl)-8*H*-indeno[2,1-*h*][1,3,5,6,2]dioxadiazastannonin-8-one n-Bu_2 SnL^4 (18).

Yellow solid, m.p.: 133-135°C. Yield: 64%; Anal. Calc. for $C_{28}H_{35}N_3O_3Sn$: C, 57.95; H, 6.08; N, 7.24; O, 8.27; Sn, 20.46%. Found: C, C, 57.92; H, 6.05; N, 7.22; O, 8.25; Sn, 20.43 %. ESI-MS *m/z*: 581.60 $[M + H]^+$. IR (KBr pellets, cm^{-1}): 1677 ν(C=O), 1565 ν(C=N), 678 ν(Sn -C), 698 ν(Sn -O), 454 ν(Sn←N). ^{1}H NMR ($CDCl_3$, 400 MHz, δ_H): 8.87-7.36 (m, 8H), 3.63-3.05 (m, 2H), 2.22-2.05 (m, 1H), 1.63 (s, 6H), 1.25-0.85 (m, 18H) ppm. **^{13}C** NMR ($CDCl_3$, 100 MHz, δ_C): 188.0, 178.5, 171.9 (C=O), 155.8 (C=N), 137.7, 132.4, 129.1, 101.4, 133.0, 129.5, 134.0, 128.5, 40.8, 38.2, 25.08, 24.0, 22.4, 20.0, 13.8, ppm. ^{119}Sn NMR ($CDCl_3$, 149 MHz, δ_{Sn}): -179.5 ppm

(4*E*,6*Z*)-2,2-diethyl-7-isobutyl-4-(pyridin-3-yl)-8*H*-indeno[2,1-*h*][1,3,5,6,2]dioxadiazastannonin-8-one Et_2 SnL^4(19).

Yellow solid; m.p.: 136-138°C. Yield: 64%; Anal. Calc. $C_{24}H_{27}N_3O_3Sn$: C, 54.99; H, 5.19; N, 8.02; O, 9.16; Sn, 22.65%. Found: C, 54.96; H, 5.16; N, 7.99; O, 9.12; Sn, 22.63%. ESI-MS *m/z*: 525.11 $[M + H]^+$. **IR** (KBr pellets, cm^{-1}): 1676 ν(C=O), 1565 ν(C=N), 677 ν(Sn -C), 696 ν(Sn -O), 474 ν(Sn -N). ^{1}HNMR ($CDCl_3$, 400 MHz, δ_H): 8.68 (s, 1H), 8.34 (d, 2H, J = 8Hz), 7.94-7.76 (m, 3H), 7.69-7.38 (m, 3H), 3.26 (d, 2H), 2.55-2.33 (m, 1H), 1.14 (d, 6H), 1.04 (s, 6H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz, δ_C): 183.1, 178.37, 172.39 (C=O), 155.4 (C=N), 137.3, 133.0, 132.4, 131.7, 129.1, 129.7, 128.7, 99.1, 41.1, 40.1, 25.7, 24.7, 22.0, ppm. ^{119}Sn NMR ($CDCl_3$, 149 MHz, δ_{Sn}): -173.06 ppm.

(4*E*,6*Z*)-7-isobutyl-2,2-dimethyl-4-(pyridin-3-yl)-8*H*-indeno[2,1-*h*][1,3,5,6,2]dioxadiazastannonin-8-one Me_2SnL^4 (20).

Yellow solid; m.p.: 141-143°C. Yield: 63%; Anal. Calc. for $C_{22}H_{23}N_3O_3Sn$: C, 53.26; H, 4.67; N, 8.47; O, 9.67; Sn, 23.93%. Found: C, 53.24; H, 4.63; N, 8.44; O, 9.65; Sn, 23.92 %. ESI-MS *m/z*: 497.11 $[M + H]^+$. IR (KBr pellets, cm^{-1}): 1674 ν(C=O), 1563 ν(C=N), 1541ν(C–O), 536 ν(Sn–O), 465 ν(Sn←N). ^{1}H NMR ($CDCl_3$, 400 MHz, δ_H): 9.29-7.32 (m, 9H), 3.64 (d, 2H, CH_2, *J* = 8Hz), 2.23-2.29 (m, 1H), 0.87 (d, 6H, *J* = 8Hz), 0.81 (s, 6H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz, δ_C): 180.8, 177.1, 173.9 (C=O), 154.53 (C=N), 136.3, 129.1, 129.4, 99.8, 131.1, 129.8, 130.7, 128.1, 41.8, 26.3, 21.0, 20.43, ppm. ^{119}Sn NMR ($CDCl_3$, 149 MHz, δ_{Sn}): -143.2 ppm.

Pharmacology

All the newly synthesized ligands (1-4) and organotin complexes (5-20) were assesed for their *in vitro* antimicrobial activity against four bacterial strains i.e. Gram positive *Bacillus ceres* (MTCC 10072), *Styphyllococus aureus* (MTCC 2901) and Gram negative *Escherichia.coli* (MTCC 732), *Pseudomonas aeruginosa* (MTCC 424), and three fungal strains i.e. *Aspergillus flavus* (ITCC 7680), *Aspergillus niger* (MTCC 7678), *Candida albicans* (MTCC 227) by employing serial dilution technique.23,27,34 The fresh cultures of bacteria and fungi were prepared by inoculation of respective microorganisms in suitable media i.e Nutrient agar and PDB (Potato dextrose broth), respectively. The stock solution was prepared by by dissolving weighed amounts of synthesized compounds in DMSO (1.0 mg of the test compound in 10 mL DMSO) to get a final concentration of 100 μg/mL and then it was further diluted to make concentration of 50, 25, 12.5, 6.25, 3.12, 1.56, 0.75 μg/mL. The bacteria and the fungi were inoculated to each solution followed by incubation at 37 ± 1 °C for (all bacteria) and 25 ± 1 ºC for 7 days for (fungi). Then, the MIC (minimum inhibitory concentration) was determined in μmol/mL. The experimental values were compared with standard drugs i.e. Ciprofloxacin for antibacterial activity and Fluconazole for antifungal activity which were also tested under analogous conditions for comparison with the synthesized compounds. Microbial growth was checked visually and spectrophotometrically after incubation, and the results were recorded in terms of Minimum Inhibitory Concentration (MIC, μmol/mL). The data for the antimicrobial activity are presented in Table S 1.

Conclusion

We have synthesized a series of twenty new compounds by employing chemical alterations. All the synthesized organotin compounds have been tested for their in vitro antimicrobial activity towards Gram-positive and Gram-negative bacterial strains as well as the fungal strains. Most of the investigated compounds showed moderate to good activity. Among the synthesized derivatives, **9** against *P. aeruginosa* , *A. flavus* ; compound **5** against *P. aeruginosa* , *A. flavus* , *C.albicans,* **13**, **17** against *B. ceres, A . flavus* , *A. niger*, *C.albicans* were found to be as good as with the standard drug against *antimi*crobial strains, which could lead to further potent drug discovery against antimicrobial infections.

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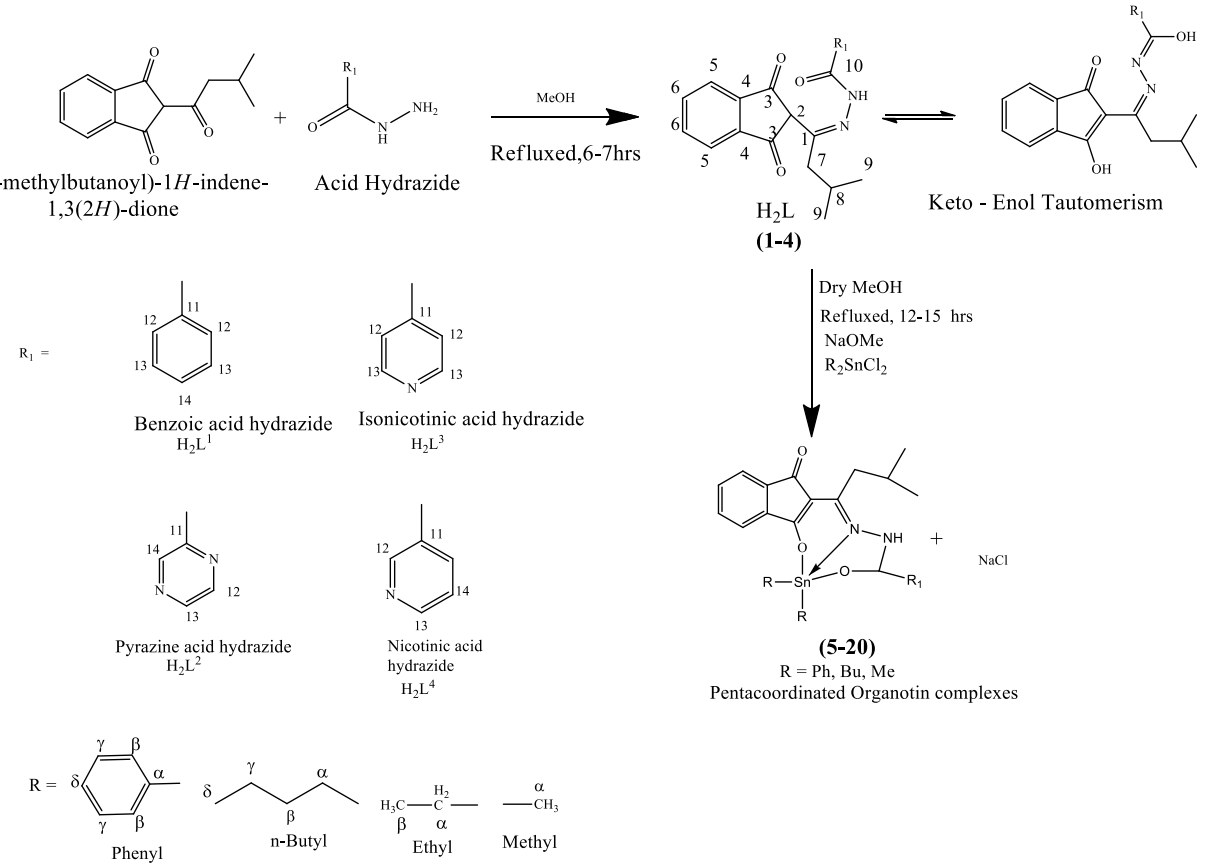

Scheme 1: Synthetic Route for Schiff Base Ligands and their Organotin Complexes