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A Review : Synthetic and Applied Aspects of Organotin(IV) Complexes of Schiff Bases

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ABSTRACT

The coordinating atoms of oxygen, nitrogen, sulfur, or phosphorus in Schiff bases with different coordination numbers create complexes with organotin(IV) moiety. The structure was usefully revealed by the development of novel spectroscopic techniques such as FT-IR, multinuclear (^{1}H, ^{13}C, ^{119}Sn) NMR, and X-ray crystallography. A lot of research has been done recently on organotin(IV) complexes of Schiff base because of their antibacterial, antinematicidal, anti-inflammatory, antitumor, and antiurease properties. In order to understand the synthesis, spectroscopic characterization, biological significance, and hazardous behavior of tin(IV) complexes of Schiff bases described in recent years, this article presents the literature on organotin(IV) complexes synthesis.

1. Introduction

Tin has attracted a lot of attention to the study of coordination chemistry because it can form complexes with a wide range of geometries and coordination numbers, including both inorganic and organometallic complexes [1]. The literature has long shown that organotin(IV) combine with Schiff bases containing nitrogen, oxygen, and sulfur to generate more stable complexes [2-9]. Recently, bioinorganic chemists have become interested in Schiff base organotin(IV) complexes. Organotin(IV) moieties can be coupled to medicinal drugs, systematically substituted compounds, and other biomolecules to monitor variation and investigate their biological impact in biological systems [10,11].

However, important environmental problems have forced some nations to prohibit the use of such materials. Inspite of such drawbacks, organotin(IV) complexes among most widely used organometallic compounds as their potential applications such as their antiproliferative, anti-tumour, antibacterial, antifungal, antinematicidal, anti-inflammatory, DNA cleavage and cancer chemotherapy activities [4-25]. The development in this field has been comprehensively reviewed and reflecting the continued and enhancing interest in organotin(IV) complexes specially of ON; NS; ONO; and ONNO; bi-, tri-, and tetra-dentate Schiff bases. This present concern about the synthesis, characterization, biological applications, toxic behaviour as well as future aspects of organotin(IV) complexes of Schiff bases.

2. Experimental Methods

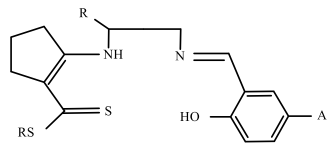
The preparation of organotin derivatives that contain Schiff base involves three methods: (a) the replacement reaction between organotin chlorides and the sodium salt of Schiff base; or the reaction between organotin chloride and Schiff base in the presence of triethylamine or sodium hydroxide (b) the condensation reaction between organotin oxides and Schiff base; (c) the reaction of organotin alkoxides with Schiff base.

2.1 From Organotin(IV) Chlorides and Sodium or Potassium or Triethyl Ammonium Salt of Schiff Base

Organotin complexes have been synthesized by replacement reaction of organotin chloride with corresponding salt of the Schiff base according to the equation.

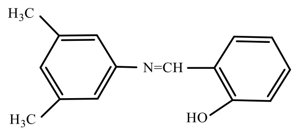
$$R_nSnCl_{4-n} + zHL / H_2L \xrightarrow[\text{Reflux}]{\text{Solvent}} R_nSnCl_{4-n}(HL)_z / H_2L \quad (1)$$

H_2L =



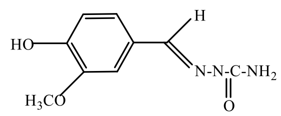
R_n : R = Me, n = 2
A = H, OMe, Br, Cl, NO_2
Solvent = Methanol [3]

HL =



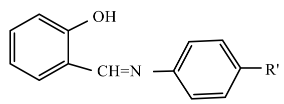
R_n : R = Me, Ph, Cy, n-Bu,
n = 3, z = 1
Solvent = Toluene [10]

HL =



R_n : R = Bu, Me; n = 2, z = 1
Solvent = THF [11]

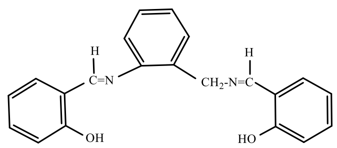
HL =



R_n : R = Me, Ph,
n = 2, z = 2
R' = Me, Cl, OMe
Solvent = Ethanol [26]

$$R_2SnCl_2 + M(L) \rightleftharpoons R_2SnCl_2 \cdot M(L) \quad (2)$$

L =



R= Me, Bu, n-Bu, Ph
M = Mn(II) or Zn(II)
Solvent = N,N'-dimethylformamide (DMF) [27]

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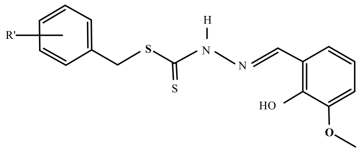
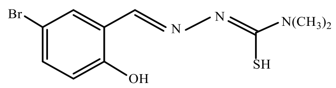
$$R_nSnX_{4-n} + HL / H_2L \xrightarrow[\text{Reflux}]{\text{Solvent}} R_nSnL / R_nSn(L)X + (4\text{-}n)\ HCl \quad (3)$$

H_2L =



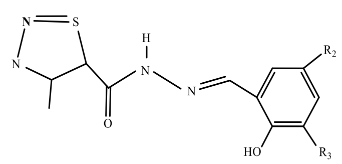
R_n : R = Ph, Me; n = 2
R' = o-CH_3, p-CH_3 or H
Solvent = chloroform, dimethyl sulfoxide (DMSO) and dimethylformamide (DMF) [4]

H_2L =



R_n: R = n-Bu, Ph, Me; n = 1
Solvent = Methanol [5]

H_2L =



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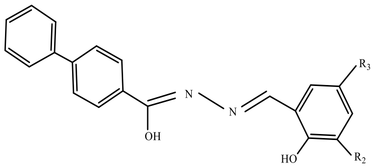
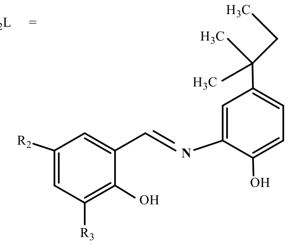
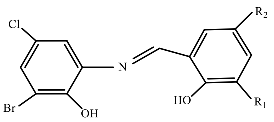


R_n : R = Ph, Bu, Et, Me; n = 2
R_2 and R_3 = H
Solvent = Methanol and THF [14]

H_2L =

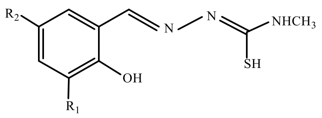


H_2L =



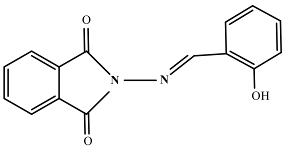
R_n : R = Ph, Bu, Et, Me; n = 2
R_1 = H, OC_2H_5, OCH_3, Br
R_2 = H, NO_2, Br
Solvent = Methanol and THF [14]

H_2L =



R_n: R = n-Bu, Ph, Me; n = 1
R_1 = H, OH; R_2 = H, Me
Solvent = Methanol [15]

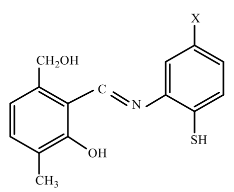
HL =



R_n : R = CH_3; n = 2
Solvent = Methanol and THF [19]

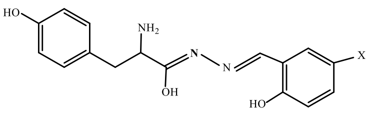
$$R_2SnCl_2 + H_2L + Et_3N \xrightarrow{\text{Solvent}} R_2SnL + Et_3N.2HCl \quad (4)$$

H_2L =



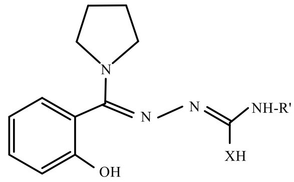
R = Ph, Bu, Et, Me
Z = 2
X = H, Cl
Solvent = THF [6]

H_2L =



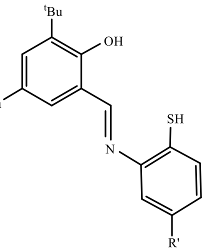
R = Me, n-Bu, n-Oct
Z = 2
X = Cl, Br
Solvent = Methanol [22]

H_2L =



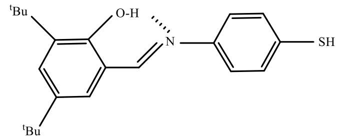
R = Me
Z = 2
R' = -H, -C_6H_5
X = S, O
Solvent = THF [7]

H_2L =

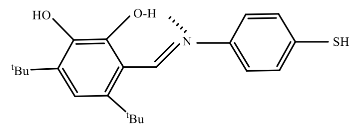


R = Et, Ph
Z = 2
R' = H, CF_3
Solvent = MeCN [8]

HL =

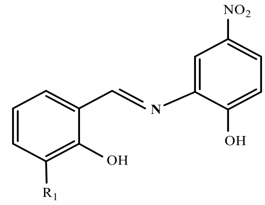


HL =



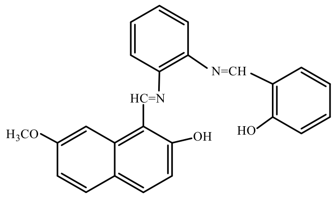
R = Ph
Z = 1
Solvent = MeCN [8]

H_2L =



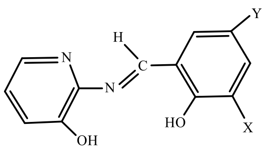
R = C_6H_5, ${}^tBu$
Z = 2
R_1 = H, OCH_3
Solvent = Methanol [16]

H_2L =



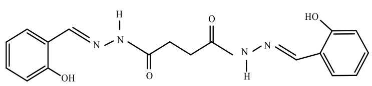
R = -CH_3, -CH_2CH_3, -$CH_2CH_2CH_2CH_3$, -C_6H_5, -$CH_2C_6H_5$
Z = 2
Solvent = Triethylamine [23]

H_2L =



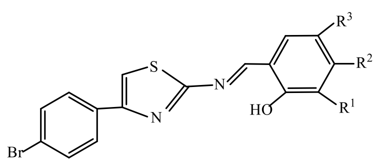
R = Me; Z = 2
X = -H, -Cl, -I
Y = -CH_3, -NO_2, -Cl, -I
Solvent = Methanol [28]

H_4L =



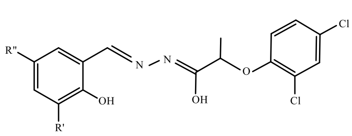
R = CH_3, C_2H_5, C_4H_9, C_6H_5, *tert*-C_4H_9
Z = 4
Solvent = Ethanol and Toulene [29]

HL =



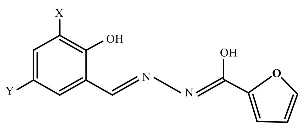
R = Me, Et, Bu, Ph
Z = 1
R^1 = H, Br; R^2 = H, OH; R^3 = H, Br, NO_2
Solvent = THF [30]

H_2L =



R = Me, Et, Bu, Ph
Z = 2
Solvent = THF [31]

H_2L =



R = Oct, Ph, Bu, Me
Z = 2; X = -OMe, -H
Y = -H, -Cl
Solvent = Methanol [32]

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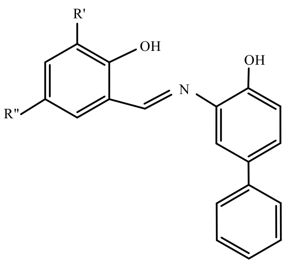
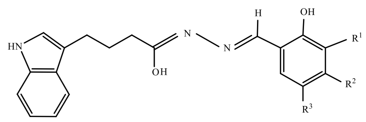
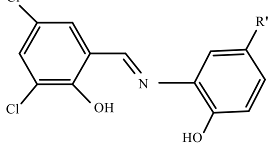
$$R_2SnCl_2 + H_2L \xrightarrow[\text{Reflux}]{\text{Solvent}} R_2SnL + 2HCl \quad (5)$$

H_2L =


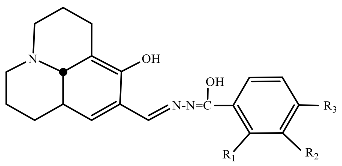
R = Ph, Bu, Et, Me
R' = Br, H;
R" = Br, H, NO_2
Solvent = THF [20]

H_2L =


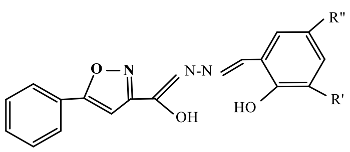
R = Ph, Bu, Et, Me
R^1 = H, Br; R^2 = H, $N(C_2H_5)_2$;
R^3 = H, Br, NO_2
Solvent = Methanol and THF [24]

H_2L =


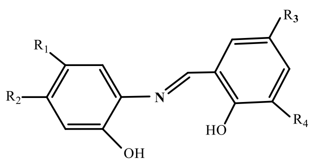
R = n-Bu, CH_2Ph
R' = H, Cl, NO_2
Solvent = Methanol [25]

H_2L =


R = Ph, Bu, Et, Me
R_1 = H, NO_2; R_2 = H, OCH_3; R_3 = H, CH_3
Solvent = THF [33]

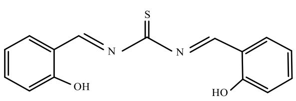
H_2L =


R = Me, Bu, Ph
R' = H, OC_2H_5; R" = H, Cl, Br, NO_2
Solvent = Methanol-THF [34]

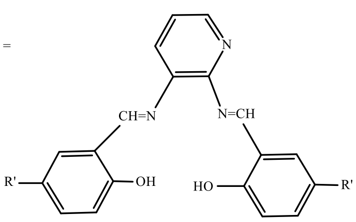
H_2L =


R = Me, Bu, Ph
R_1 = H, CO_2Me; R_2 = H, CO_2Me; R_3 = H, Br, NO_2; R_3 = H, Br, OC_2H_5
Solvent = Methanol-THF [35]

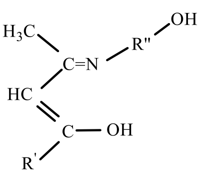
$$R_2SnCl_2 + HL \xrightarrow[\text{Solvent}]{\text{Na}} R_2SnCl.L + NaCl \quad (6)$$

HL =


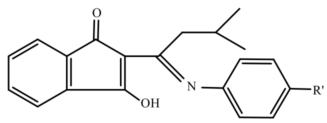
R = C_2H_5, Ph, Bz
Solvent = methanol, chloroform, petroleum ether, acetone and benzene [36]

H_2L =


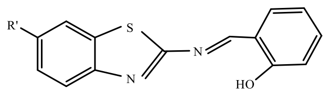
R = Ph, Bu, Et, Me
R' = H, Br
Solvent = Methanol [37]

H_2L =


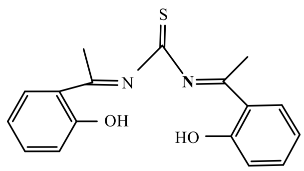
R = C_6H_5, C_4H_9, CH_3
R′ = —C_6H_5, —CH_3,;
R″ = —$(CH_2)_3$—, —$(CH_2)_2$—
Solvent = THF [38]

HL =


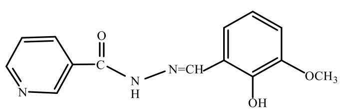
R = Ph, n-Bu, Et, Me
R' = OCH_3, NO_2, CH_3, Cl
Solvent = Methanol [39]

HL =


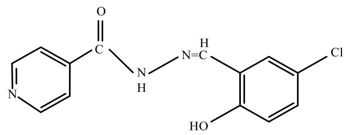
R = Ph, Bu, Bu, Et, Me
R' = -OC_2H_5, NO_2, OCH_3, -CH_3
Solvent = Methanol [40]

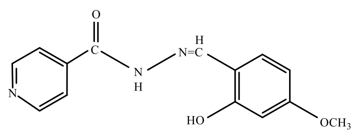
H_2L =


R = Bu, Ph
Solvent = Methanol [41]

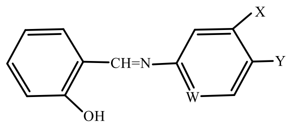
H_2L =


R = C_4H_9, C_6H_5
Solvent = Methanol [42]

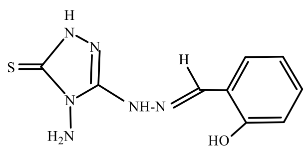
H_2L =


H_2L =


R = CH_3, C_6H_5
Solvent = Methanol [43]

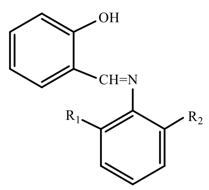
HL =


R = Bu
W = C, N
X = H, NO_2
Y = H, CH_3
Solvent = Benzene-THF [44]

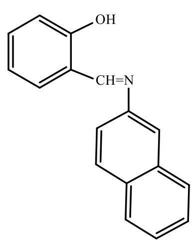
HL =


R = -$CH_2CH_2CH_2CH_3$, -C_6H_{5s}
Solvent = Methanol [45]

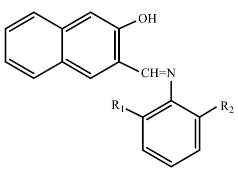
$$Me_2SnCl_2 + 2HL \xrightarrow[\text{Solvent}]{\text{K}} Me_2Sn(L)_2 + 2KCl \quad (7)$$

HL =


R_1, R_2 = H or Me, n = 2; Solvent = THF [46]

HL =


R_1, R_2 = H or Me, n = 2; Solvent = THF [46]

HL =


R_1, R_2 = H or Me, n = 2; Solvent = THF [46]

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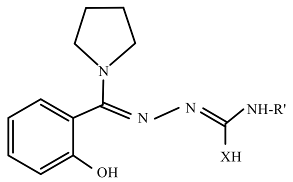
2.2 From Organotin(IV) Oxides and Schiff Base

Different compounds of the kinds R_2SnL_2 and R_3SnL, where R is an alkyl and L is a Schiff base, have been generated by azeotropic distillation of water from benzene or toluene of corresponding organotin oxide and Schiff base.

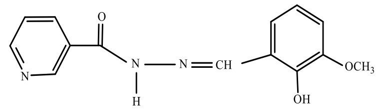
$$R_2SnO + HL/H_2L \xrightarrow{\text{Solvent}} R_2SnL / R_2SnL_2 + H_2O \quad (1)$$

H_2L =



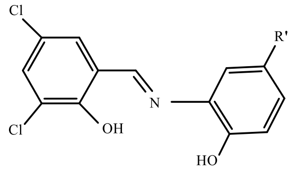
R = Bu; R' = -H, $-C_6H_5$
X = S, O
Solvent = Benzene [7]

H_2L =



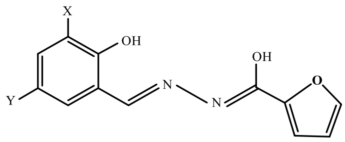
R = CH_3, C_4H_9, C_6H_5
Solvent = Methanol [21]

H_2L =



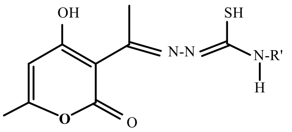
R' = H, Cl, NO_2
R = $-CH_2Ph$, n-Bu
Solvent = Methanol [25]

H_2L =



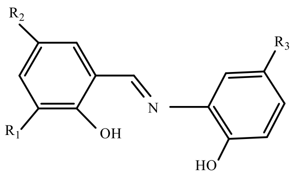
R = Me, Bu, Ph, Oct
X = -OMe, -H
Y = -H, -Cl
Solvent = Methanol [32]

H_2L =



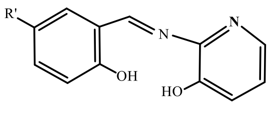
R = Bu, Octyl, Ph, Cy, TMSM
R' = H, Ph, CH_3
Solvent = Toluene [47]

H_2L =



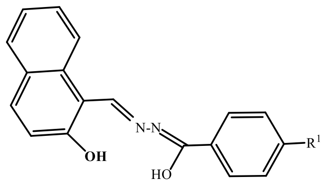
R = Bu
R_1 = OMe, H
R_2 = Br, Cl. H
R_3 = NO_2, Me, H
Solvent = Methanol [48]

H_2L =

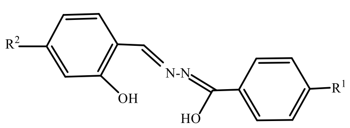


R' = H, Me, t-Bu, F, Cl, Br, I, NO_2
R = Bu Solvent = Toluene:Methanol [49]

H_2L =

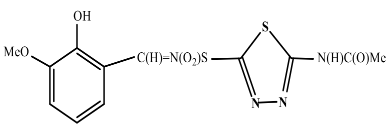


H_2L =



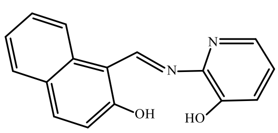
R = n-Bu, Ph
R^1 = NO_2, H
R^2 = Et_2N, MeO
Solvent = Benzene [50]

HL =



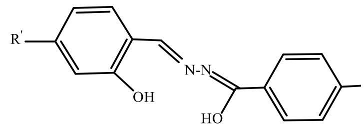
R = n-Bu, n-Oct; Solvent = Methanol [51]

H_2L =



R = Bu, Cy, Ph, $CH_2Si(CH_3)_3$
Solvent = Toluene and Methanol [52]

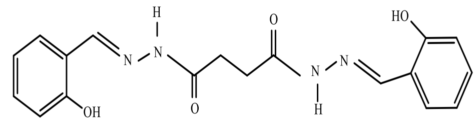
H_2L =



R = Ph, n-Bu
R' = Et_2N, MeO
Solvent = Acetonitrile [53]

$$2R_2SnO + H_4L \xrightarrow[\text{Microwave or Reflux}]{\text{Solvent}} (R_2Sn)_2L + 2H_2O \quad (2)$$

H_4L =



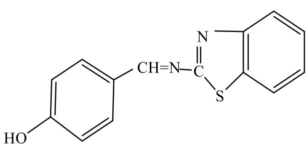
R_n: R = CH_3, C_2H_5, C_4H_9, C_8H_{17}, C_6H_5, *tert*-C_4H_9; n = 2; Solvent = Toulene [29]

2.3 From Organotin(IV) Alkoxides and Schiff Base

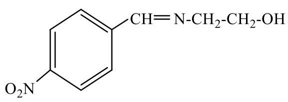
Equations were used to create organotin derivatives by reacting organotin alkoxide with Schiff base and sodium alkoxide.

$$Bu_2Sn(OPr^i)_2 + HL \xrightarrow[\text{reflux}]{\text{Solvent}} Bu_2Sn(L^a)(OPr^i) + Pr^iOH \uparrow \quad (1)$$

HL =



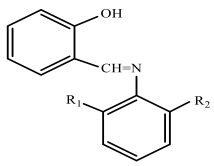
HL =



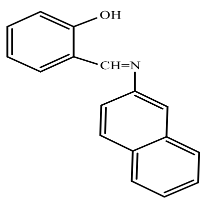
Solvent = Benzene [9]

$$BuSn(OPr^i)_3 + HL + L^aH_2 \xrightarrow[\text{reflux}]{\text{Solvent}} BuSn(L^a)(L^b) + 3Pr^iOH \uparrow \quad (2)$$

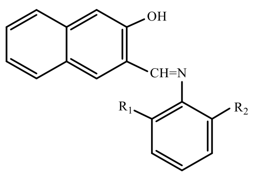
HL =



HL =



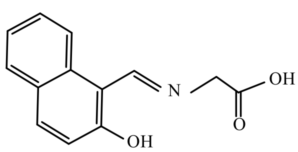
HL =



R_1, R_2 = H or Me
Solvent = Benzene [46]

$$R_2Sn(OPr^i)_2 + zH_2L \xrightarrow[\text{reflux}]{\text{Solvent}} R_2Sn(OPr^i)(HL) / R_2Sn(HL)_2 + zPr^iOH \uparrow \quad (3)$$

H_2L =



R = Me, Bu, Ph; z = 1 or 2
Solvent = Benzene or Toluene [54]

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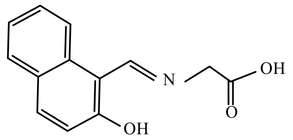
$$R_3Sn(OPr^i) + H_2L \xrightarrow[\text{reflux}]{\text{Solvent}} R_2Sn(HL) + Pr^iOH\uparrow \quad (4)$$

H_2L =



R = Me, Bu, Ph
Solvent = Benzene or Toluene [55]

3. Application

Industrial chemistry, pharmaceuticals, and agriculture all depend on tin(IV) complexes. Ligands, the Sn moiety surrounded by a molecule, are used for the synthesis of complexes called as Schiff bases. Schiff bases with their tin(IV) derivatives are used as antimicrobial, antitumor, anti-inflammatory, anti-leishmanial, antiurease, DNA binding, cytotoxic, anti-liferative and asphaltene dispersion inhibition activities [4-25]. Some complexes also show optical and catalytic activities.

3.1 Toxic Effect

Tin(IV) complexes have accumulated in the environment and in biological systems as a result of the last several decades' tremendous advancements in their biological, industrial, and biological applications. At least one carbon tin(IV)-carbon link is a defining characteristic of organotin(IV) compounds. Depending on how many alkyl or aryl moieties they contain, the organotin(IV) compounds are categorized as mono-, di-, tri-, and tetra-organotin(IV). The majority of organotin(IV) compounds are often extremely hazardous, even in small amounts.

The kind and quantity of Schiff bases or organic groups that cling to the tin atom basically dictate the biological activity. It appears that the anionic group's nature is merely incidental. The combination of triaryltin (IV) and trialkyltin (IV) has a strong toxic effect on the central nervous system. When administered orally, Me_3Sn(IV), Et_3Sn(IV), and R_3Sn(IV) are the most hazardous in the series. Tri-n-propyl and tri-n-octyl are less harmful than the others. Nonetheless, one of the earliest organotin(IV) complexes to be utilized as a biocide agent in ship antifouling paints was tributyloxide (TBTO). However, several nations have been obliged to outlaw the use of certain materials due to serious environmental issues.

4. Conclusion

Organotin(IV) complexes of various Schiff bases are synthesized by various methods. These include reactions between metal or organometal chlorides and appropriate Schiff bases, sodium salts of Schiff bases and Schiff bases in the presence of triethylamine, reactions between metal or organometal alkoxide and appropriate Schiff bases, and reactions between organotin oxides and Schiff bases. Among the more straightforward and frequently used methods of their synthesis are the removal of water and the sodium salt method.

X-ray crystallography, FT-IR, and multinuclear (^{1}H, ^{13}C, and ^{119}Sn) NMR are new spectroscopic techniques that effectively differentiate the different structural features of these compounds. Some organtin(IV)-Schiff bases have demonstrated excellent antibacterial, anticancer, anti-inflammatory, and antiurease properties recently. To understand how the organotin-Schiff base complexes exert their biological activity, new methodologies must be utilized, as the action mechanisms of these complexes are either poorly understood or poorly researched. Nonetheless, one of the earliest organotin(IV) complexes to be utilized as a biocide agent in ship antifouling paints was tributyloxide (TBTO). However, several nations have been obliged to outlaw the use of certain materials due to serious environmental issues. Since there is no substitute yet discovered, therefore, work on organotin(IV) still continued due to scope of their use.

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