Structural and Potential Biological Properties of SBDTC and SMDTC Containing Metal Complexes: A Brief Review

Abstract

S-benzyldithiocarbazate (SBDTC) and S-methyldithiocarbazate (SMDTC) are working as a starting material for the synthesis of various Schiff base ligands. SBDTC and SMDTC can act as NS, SNNS, SNNNS, and NOS chelating agents and have biological and chemical potential for synthesizing many transition and inner transition metal complexes. The metal complexes prepared from SBDTC, SMDTC, and their derivatives have shown promising biological activities like antibacterial, cytotoxicity, antioxidant, antitumor, and anticancer activity. Last few decades,a lot of works have been reported on SBDTC and SMDTC containing Schiff base metal complexes.In this review,it is cosidered to show the various synthesis procedures,and structural and biological activities of SBDTC and SMDTC-containing metal complexes.

Keywords: Schiff base, metal complexes, SBDTC, SMDTC, antibacterial activity, antioxidant properties, anticancer activity.

1. Introduction

Nitrogen-oxygen, Nitrogen-Sulfur, Sulfur-Nitrogen-Nitrogen-Sulfur, and Nitrogen-Oxygen-Sulfur chelating agents have drawn prime interest to the researchers for the synthesis of new metal complexes that may provide an important path for the development of chemotherapeutic agents and to improve the field of bioinorganic chemistry [1,2]. It was also reported thatS-methyldithiocarbazate (SMDTC), and S-benzyldithiocarbazate (SBDTC), a nitrogen-sulfur donor, haveenormous interest in bioinorganic chemistry. From then onwards, many Schiff bases derived from SMDTC and SBDTC have been reported for their multipurpose coordination chemistry and increasingly important biological activities [3-8].Because of their unique electrical characteristics, metal complexes with donor atoms in the locations of N, S, and Oplay a vital role in biological processes. It was reported that the presence of metal ions bonded to biologically active compounds may enhance their activities[9,10]. The existing functional group (-NCS□R) of these compounds not only confers chelating properties but also imparts interesting electronic and steric effects to the resulting Schiff bases. As a consequence, SMDTC and SBDTC Schiff bases exhibitboosted stability, reactivity, and selectivity in a wide range of chemical transformations and applications.Di-thiocarbazateand its substituted derivatives have become promising interest in the past few decades.It exists in two tautomeric forms, thione and thiol. The thione group (C=S) is relatively unstable in the monomeric system and tends to turn to a stable C–S single bond by enethioneization if at least one hydrogen atom is adjacent to the C=S bond. The molecule can act as a NOS uni negatively charged tridentate chelating agent[11,12]. Dithiocarbazic acid and the ligands obtained from S-alkyl and S- benzyl esters produce an interesting series of ligands. Various NO, NS, SNNS, SNNNS donor Schiff base ligands have been synthesized by condensation reaction of numerous aldehydes and ketones with SMDTC and SBDTC. The numbers of these types of compounds continue to increase due to the intriguing investigation that different ligands show different biological activity.Metal complexes of Schiff bases derived from S-alkyldithiocarbazates have been the theme of great contemporary importance because of their fascinating physico-chemical properties and possibly useful biological action [13–18].However, most preceding revisions on metal-dithiocarbazates were established on tri, tetra, penta, and hexadentate chelating agents [20,21]. Pentadentate ligands derived from S-alkyldithiocarbazates have not received much devotion. Transition metal complexes of the pentadentate ligand formed from 2,6-diacetylpyridine, and S-methyldithiocarbazate(R=CH_3) have been reported by Majumder *et al.*[22].Thus, the aims of this review are to show thevarious synthesisprocedure of Schiff bases derived from SBDTC and SMDTC and their metal complexesand studied their structural properties and biological activityto find the potential agent against various pathogenic bacteria and fungi.

2. Structural Properties

Two novel quadridentate Schiff base ligands formed from 2,5-hexanedione and S-alkyldithiocarbazic acids and their Ni(II), Zn(II), and Cd(II) complexes having the general formula [M(SNNS)] ((SNNS) is the dinegatively charged ligands) have been synthesized and characterized byM.A. Ali *et al.* The Ni(SNNS) complexes are diamagnetic and square-planar(figure-1). The Zn(SNNS) complexes are assigned polymeric structures with mercaptosulfur-bridging. The Cd(SNNS) complexes presumably have polymeric structures [23].

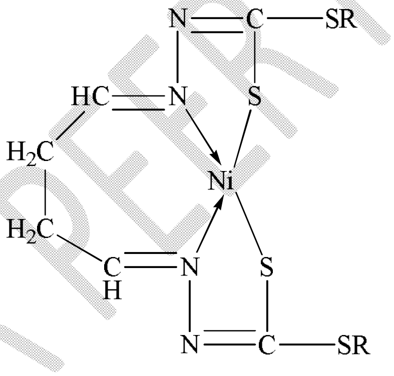
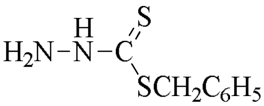


Figure1: Structure of Ni(II) complex.

Tris- and bis-ligand complexes of Ni(II)with SBDTC having the general formulae Ni(SBDTC)$_3$X$_2$.H$_2$O(X = Cl, Br and NO) and Ni(SBDTC)$_2$X$_2$(X = Cl and NCS) respectively, were synthesized and characterized by M.A. Ali *et al.* The ligand acts as a bidentate sulphur-nitrogen chelating agent (figure-2). Both the tris- and bis ligand cationic Ni(II) complexes havehigh spin magnetic moments of ca. 3.10 B.M. Based on magnetic and spectral information octahedral structures are assigned to these complexes. Under alkaline conditions complexes of the deprotonated ligand having the formulae M(SBDTCA)$_2$ [M= Ni(II) and Zn(II); SBDTCA= anion of SBDTC]were isolated. The Ni(II)complex is square-planar [24].



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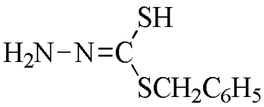

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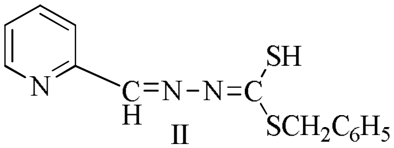


II

Figure2: Structure of ligands

Ni(II),Cu(II), and Co(II) complexes of Schiff bases formed from SBDTC and some aldehydes and ketones were prepared by M.T.H. Tarafder*et al.*[25].The Schiff base S-methyl-P-N-(2-hydroxyphenyl) methylendithiocarbazate, o-HO.GHGH = NNHC(=S)SCH$_3$, and the corresponding chloro, 5-bromo, 5-nitro, and 3-methoxy derivatives were prepared from the appropriate salicylaldehyde and SMDTC. The acetylacetone Schiff base 2-hydroxy-4-methyl-5,6-diaza-7-thiono-8-thianona-2,4-diene, CHC(OH) = CHC- (CH) = NNHC(= S)SCH, was also prepared.The Cu(II) ion form stable complexes (figure-3) with the synthesized ligands [26].

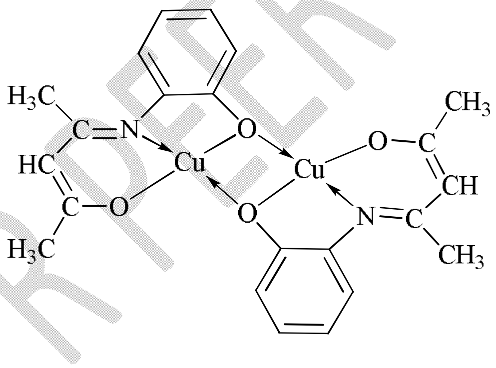


Figure3: Structure of the Schiff base Copper(II) complexes

E. Zangrando *et al.*synthesized Ni(II) complex from Schiff base via the condensation reaction of SMDTC with 4-benzyloxybenzaldehyde.The crystallographic results show that the Schiff base exists uninegetively bidentate (NS) in thione tautomeric form with respect to the C=N bond of the group and the Ni(II) complex(figure-4)exhibited a distorted square planar geometry [27].

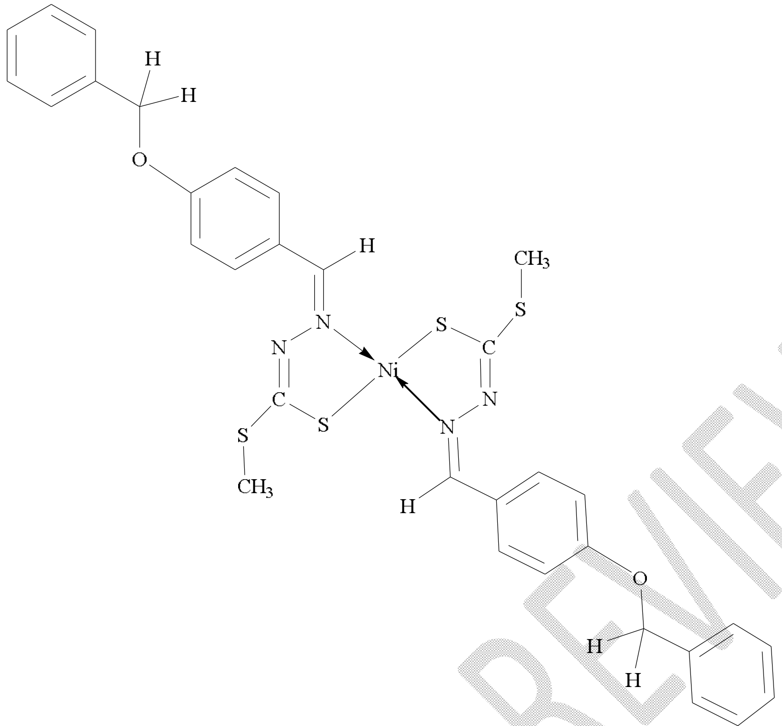


Figure4: Structure of the Schiff base Nickel(II) complexes

Y. Ji *et al.* synthesized a cobalt (II) complex of general formula [Co(PMBP-smdtc)$_2$]·2H$_2$O. The novel tridentate Schiff base was derived from the condensation of l-phenyl-3-methyl-4-benzoyl-5-pyrazolone andSMDTC. The single-crystal X-ray diffraction studies indicated that the complexes showed an octahedrally coordinated compound [28].Novel bidentate Schiff bases (figure-5)having nitrogen-sulfur donor sequence were synthesized from condensation of racemate camphor, (R)-camphor, and (S)-camphor with methyl hydrazinecarbodithioate.The NS Schiff bases formed complexes of the general formula, [M(NS)$_2$] or [M(NS)$_2$.H$_2$O] where M is Bi(III) or Ag(I), the expected geometry is octahedral for Bi(III) complexes while Ag(I) is expected to oxidize to Ag(II) forming square planner complexes [29].

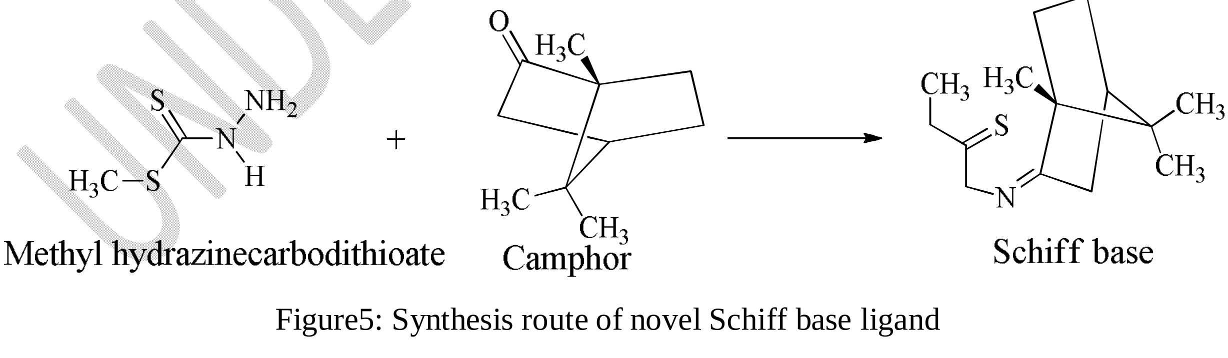


Figure5: Synthesis route of novel Schiff base ligand

A one-dimensional indented chain structure is generated when two water molecules make an H-bond along the b-axis, bridging the molecules together.The monobasic bidentate Schiff base S-methyl β-N-(4-methoxyphenylmethyl)methylene dithiocarbazate (NS) and its Bis-chelated metal complexes [M(NS)$_2$], [M = Co(II), Ni(II) & Cu(II)], were synthesized and characterized by R. Singh *et al.* [30]. M.A. Ali*et al.* synthesized new Cu(II) complexes of the general formula, [Cu(mpsme)X] (mpsme=anionic form of the methylpyruvate Schiff base of S-methyldithiocarbazate. based on magnetic and spectral evidence, an oxygen-bridged square-planar structure is assigned to this complex. The crystal and molecular structures of the Schiff base, Hmpsme, and its chloro copper(II) complex, [Cu(mpsme)Cl] have been determined by X-ray diffraction. The [Cu(mpsme)Cl] complex has a distorted square-planar structure with the ligand coordinated to the Cu(II) ion as a uni-negatively charged tridentate chelating agent via the carbonylic oxygen atom, the azomethine nitrogen atom, and the thiolato sulfur atom. The fourth coordination position around the Cu(II) ion is occupied by the chloride ligand[31]. The distortion from regular square-planar geometry is attributed to the restricted bite size of the ligand. A. Alim *et al.* [32]synthesized Cu(II), Ni(III) Zn(II), Cd(II), Co(II), Sb(III) and Fe(III) containing bidentate Schiff base (figure-6), [NI-(4-chloro-benzylidene)-hydrazecarbodithioicacid methyl ester] derived from the condensation of SMDTC and P-chlorobenzaldehyde.

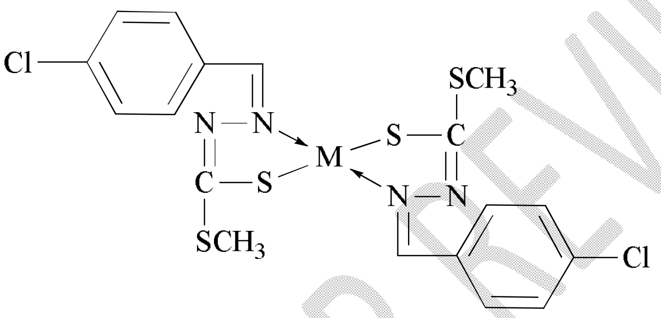
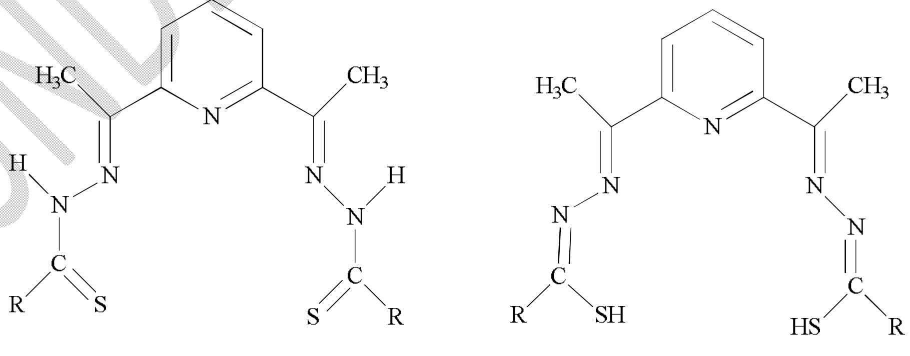


Figure6: Structure of the Schiff base metal complexes

2, 6-diacetylpyridinebis(S-benzyldithiocarbazate) (H_2SNNNS) pentadentate ligand (figure-7)reacts with Zn(II) and Cd(II) ions forming stable complexes. The crystal and molecular structure of the Zn(II) complex has been determined by X-ray diffraction. The complex is a dimer in which the pyridine nitrogen atom, the azomethine nitrogen atom, and the thiolate sulfur atom from one ligand coordinate to one of the Zn(II) ions whereas the azomethine and thiolate sulfur atoms from another ligand complete penta coordination around the Zn(II) ion, the ligands being coordinated in their deprotonated forms. The coordination geometry of each Zn(II) can be considered as intermediate between a square-pyramidal and trigonal-bipyramidal. The Cd(II) complex is also assigned with a dimeric structure [33].



(a) **(b)**

Figure7: Thione-thiol tautomerism in the ligand (a) thione form (b) thiol form

Ni(II), Cu(II), Pd(II), and Pt(II) complexes of the thiophene-2-aldehyde Schiff bases of SMDTC and SBDTC have been synthesized and characterized by M.A. Ali *et al.*[34].A.A.Alshaheri*et al.*produced a variety of complexes of dithiocarbazateSchiff bases (abbreviated as NiSMdiAP, CoSMdiAP, FeSMdiAP, MnSMdiAP, and ZnSMdiAP, where SMdiAP indicates the Schiff base). S-methyl dithiocarbazate and diacetylpyridine were condensed to create the Schiff base. Every complex functions effectively as a catalyst for oxidation reactions [35].The novel pyrimidine based NNS tridentate Schiff base ligands (figure-8)has been preparedfrom condensation of 2-S-methylmercapto-6-methylpyrimidine-4-carbaldehyde and S-methyl/S-benzyl dithiocarbazate by S. Roy *et al.* All the complexes exhibited a distorted octahedral arrangement with an N_4S_2 chromophore around the central metal ion. Each ligand molecule binds the metal ion using azomethinepyrimidyl nitrogen and thiolato sulfur. Among the complexes, the Ni(II) complex, behaves as a neutral tridentate, and the other complexes the Co(III) and Fe(III) complexes, the ligand molecules behave as monoanionic tridentate. All the complexes were investigated by single crystal X-ray diffraction and indicated a distortion from an octahedral geometry of the coordination environment was observed [36].

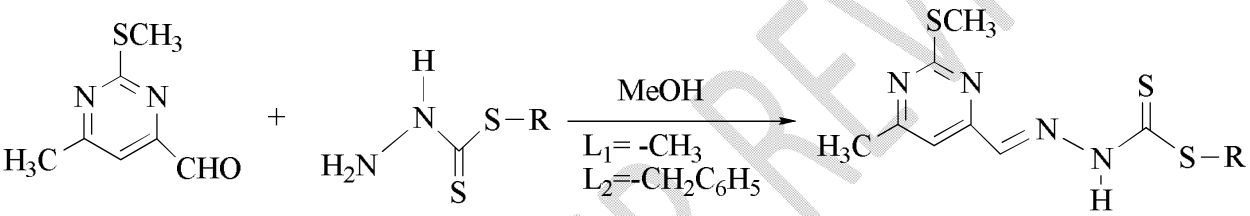


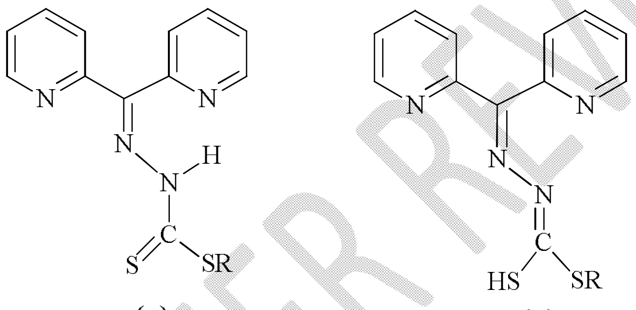
Figure8: Synthesis route of novel Schiff base ligand

New bis-chelated Zn(II) and Cd(II) complexes of empirical formula, $[M(mpsme)_2]$ (mpsme) the anionic form of the tridentate ONS donor ligand formed from methylpyruvate and S-methyldithiocarbazate) have been synthesized by M.A. Ali *et al.* [37]. Both complexes are allotted a distorted octahedral geometry in which the ligands are organized meridionally around the metal ions. The distortion from systematic octahedral geometry is attributable to the constrained bite angles of the ligand.Condensation of 2,6-diacetylpyridine (dap) with SMDTC in a 1:2 molar ratio yields a bicondensedpentadentate Schiff base (H_2dapsme) which reacts with K_2MCl_4 (M= Pd(II), Pt(II) giving stable complexes of empirical formula, [M(dapsme)].0.5Me_2CO [38]. These complexes have been characterized by a variety of physico-chemical techniques and Single X-ray crystal measurement. The complex has a distorted square-planar structure in which the ligand is coordinated to the Pd(II) ion as a uninegatively charged tridentate chelating agent via the pyridine nitrogen atom, the azomethine nitrogen atom, and the thiolate sulfur atom; the oxygen atom of the acetyl group does not participate in coordination.Two new Co(III) complexes with S-benzyl-N-(5-methylpyrazole-3-yl)methylenedithiocarbazate (H_2L), $[Co(HL)_2]NO_3EtOH$ and $[Co(HL)(L)]\cdot H_2O$, have been synthesized and characterized using single-crystal X-ray diffraction and spectroscopic (electronic, IR and NMR) techniques. Both complexes exhibited a distorted octahedral geometry and ligands in the mer configuration [39]

3. Biological Properties

3.1: AntimicrobialActivity

SMDTC and SBDTC when condensed with glyoxal, five coordinated ligands will produce that also make stable crystalline complexes of the general formula, M(SNNS) (M = Ni(II), Cu(II), Zn(II) and Cd (II); SNNS= ligand dianion). The Schiff bases and metal complexes display good antifungal and antibacterial properties. All the complexes showed activities against two pathogenic bacteria (*E. coli and B. subtilis*) and three phytopathogenic fungi (*D. oryzae, I. padwickii, and F. moniliforme*) [40].M.E. Hossain *et al.* prepared Cu(II) complexes containing Schiff base ligands (figure-9) derived from the condensation reactions of 2-benzoylpyridine with SMDTC and SBDTC respectively. The antifungal and antibacterial properties of the Schiff bases and their Cu(II) complexes have been evaluated against three pathogenic fungi and two bacteria. The Schiff bases and Cu(II) complexes display moderate antifungal activity,but their activities are less than that of the commercially important antifungal agent nystatin[41].



(a) **(b)**

Figure9: Thione-thiol tautomerism in the ligand (a) thione form (b) thiol form

M.K.E. Zahan *et al.* synthesized a series of metal complexes of Mn(II), Fe(III) Co(II), Ni(II), Cu(II), and Sb(III) containing the bidentate Schiff base derived from the condensation of S-methyldithiocarbazate and cinnamaldehyde. All the complexes of Schiff base exhibited antibacterial activity against four gram-positive (*Bacillus subtilis, Staphlococcus aureus,Bacillus megatherium, Streptococcus-β-haemolyticus*) and four gram-negative(*Escherichia coli, Shigelladysenteriae, Shigellasonnei, Shigellashiga*) and antifungal activity against four *AspergillusCandidus, PenicilliumMarneffei, Candida Albicans, Aspergiliusniger*[42]. M.L. Low *et al.*[43] synthesized a series of Cu(II) complexes from SMDTC and SBDTC with methyl levulinate, levulinic acid, and 4-carboxybenzaldehyde.The Synthesized ligands and their respective Cu(II) complexes showed moderate antibacterial activity against both Gram-negative and Gram-positive bacteria.The Copper complexeswere highly effective against *Staphylococcus aureus* with a minimum inhibition concentration (MIC) of 0.5-1 µM.Cu(II) complexes of the general formula [Cu(Ap-SMe)X] or [Cu(Ap-SBz)X] (where HAp-SMe and HAp-SBz, respectively, represent the 2-acetylpyridine Schiff bases of SMDTC or SBDTC; X=Cl, Br, NO_3) have been prepared and characterized by M.E. Hossain *et al.*. The geometry of the complex was a distorted square pyramid with the NNS tridentate ligand and an oxygen atom of the nitrate ion occupying the basal plane. The fifth coordination position was occupied by oxygen from the nitrate ion. The anti-fungal and anti-bacterial properties of the Schiff bases and their copper(II) complexes have been evaluated against the phytopathogenic fungi *A. solanyi*, *F. equisetti*, and *M. phaseolina* and the pathogenic bacteria *E. coli* and *S. aureus*. The fungi toxicity of the five-coordinated [Cu(Ap-SBz)NO_3] complex approaches that of nystatin, whereas the Schiff base

HAp-SMe and its copper(II) complex [Cu(Ap-SMe)NO_3] display significant antibacterial activity against *E. coli* and *S. aureus*[44].A new Schiff Base ligand [$(SBDTC)_2AP$] has been synthesized by the 1:2 condensation of acetophenone and SBDTC. A group of selected ions such as Cu(II), Cd(II), Zn(II), Ni(II), and Co(II) complexes of [$(SBDTC)_2AP$] have been prepared and characterized by N.Amerama*et al.*The Schiff base(figure-10), and its metal complexes have been evaluated for their biological activities against *Staphylococcus aureus, S.Typhy M.H.,*and*Aeromonas sp.*All metal complexes were inactive against *S.Typhy M.H.*[45]

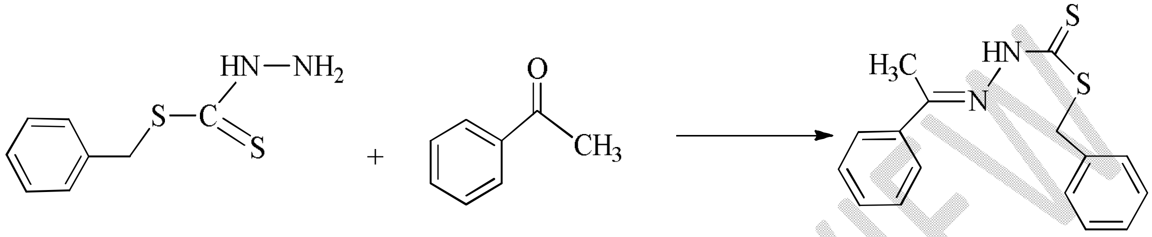


Figure10: Synthesis route of Schiff base

A new tridentate nitrogen–oxygen–sulfur Schiff base has been prepared from the condensation reaction of S-methyldithiocarbazate and methylisatin by M.A.F.A. Manan *et al.*. The Schiff base was found to be selectively active against the selected Gram-positive bacterial strains (*Bacillus subtilis* and *Staphylococcus aureus*) [46].The nitrogen-oxygen-sulfur tridentate Schiff base ligand prepared from condensation of S-benzyldithiocarbazate (SBDTC) and salicylaldehyde was reported by N.A. Bitu*et al.*The complexes of Zr(IV), Th(IV), and U(VI) ionshave been synthesized from the derived Schiff base. The antibacterial activity of all the compounds has been evaluated using Kanamycin (K-30) as a standard against two Gram-negative (*Escherichia coli* and *Shigelladysenteriae*), and two Gram-positive (*Staphylococcus aureus* and *Bacillus subtilis*) bacteria. Against every examined organism, the Zr(IV) complex is less effective against bacteria than the U(VI) and Th(IV) complexes [47].Cu(II) complexes of formulas, [Cu(NNS)$(NO_3)(H_2O)$]$\cdot H_2O$ and [$Cu(NNS)_2$] (NNS=anionic form of the 6-methyl-2-formylpyridine 4-N-dimethylthiosemicarbazone) have been synthesized and characterized byM.A. Ali*et al.*. The ligand and the metal complexes were screened for antifungal activity against the *phytopathogenic fungi, A. alternata, F. equiseti*, and *M. phaseolina* but the complexes are less active than the free ligand due to less solubility in non-aqueous solvents. The copper complexes may have less solubilities in non-aqueous solvents than the Schiff base [48]. The di-2-pyridylketone Schiff base of S-methyldithiocarbazate (Hdpksme) reacts with Ni(II) salts giving both mono- and bis-chelated complexes were synthesized by M.A. Ali*et al.* The ligand and its Ni(II) complexes exhibited weak antimicrobial activity against the pathogenic bacteria, *S. dysenteriae, B. cereus, S. aureus,*and *E. coli* and the fungi, *A. alternata* and *M. phaseolina* [49].A tridentate ONS Schiff base derived from the condensation of SBDTC with salicylaldehyde has been synthesized. The metal complexes of general formula [M(ONS)X], [M=Ni(II), Cu(II), Cr(III), Sb(III), Zn(II), Zr(IV) or U(VI) with X= H_2O, Cl].Antimicrobial tests indicate that the Schiff base and five of the metal complexes of Cu(II), Ni(II), U(VI), Zn(II), and Sb(III) are strongly active against bacteria. Ni(II) and Sb(III) complexes were the most effective against *Pseudomonas aeruginosa*, while the Cu(II) complex proved to be best against *Bacillus cereus*. Antifungal activities were also noted with the Schiff base and the U(VI) complex. These compounds showed positive results against *Candida albicans* fungi, however, none of them were effective against *Aspergillus ochraceous* fungi [50]. M.A. Ali and A.H. Mirza prepared Ni(II) complex with NOS coordinating Schiff base ligand derived from the condensation reaction of N-methyl-S-methyldithiocarbazate with 2-hydroxybenzaldehyde or 5-bromo-2-hydroxybenzaldehyde. The synthesized ligands and Ni(II) complexes were screened for antifungal activity against three pathogenic fungi.The ligands display moderate fungi toxicities against these organisms but their nickel(II) complexes are less active than the free ligands. The chelation of nickel(II) complexes with dithiocarbazate lessens the antifungal activity [51].Cu(II) complexes containing Schiff base ligand α-N-methyl-S-methyl-b-N-(2-pyridyl)methylenedithiocarbazate(NNS) were synthesized and characterized by M.A. Ali*et al*. Antimicrobial tests indicated that Schiff base is inactive against the bacteria, *Bacillus subtilis (mutant defective DNA repair), Pseudomonas aeruginosa, methicillin resistant Staphylococcus aureus and Bacillus subtilis* (wild type) and weakly active against the fungi, *Candida albicans, Candida lypolytica, Saccharomyces cereviseae and Aspergillusochraceous* but its Cu(II) complexes, Cu(NNS)X_2 are strongly active against these organisms [52].Mono- and bis-chelated Cd(II) complexes of the di-2-pyridylketone Schiff base of S-methyldithiocarbazate (Hdpksme) have been synthesized by M. A. Ali and A. H. Mirza.The Schiff base and its Cd(II) complexes were screened for antibacterial activity against *Shigelladysenteriae, Bacillus cereus, Staphylococcus aureus, and Escherichia coli*. They are also mildly fungitoxic against the phytopathogenic fungi, *Alternariaalternata* and *Macrophominaphaseolina*[53].

3.2 Anti-Cancer Activity

M.L. Low *et al*. prepared Cu(II), Zn(II), and Re(I) complexes of the general formula of Cu$(SBCM)_2$, Zn$(SBCM)_{2,}$ and $Re_2(SBCM)_2$ derived from Schiff base of the S-Benzyldithiocarbazate and 3-acetylcoumarin.X-ray diffractometry (XRD) indicated that Rhenium exhibited a centrosymmetric dimeric complex via the Re-S-Re bridge and Cu(II), Zn(II) coordinated to a bidentate ligand of unintuitively thiolate and azomethine nitrogen atom of Schiff base.Cytotoxicity assesses the apparent enhancement of SBCM-H's bioactivity following complexation. Cu(II) and Re(I) complexes have been discovered to exhibit activity against cell lines that represent human breast adenocarcinoma cancer cell lines MCF-7 and MDA-MB-231[54].M.X. Li *et al.*have synthesized a series of Cu(II) and Zn(II) complexes of 2-benzoylpyridine Schiff bases derived from S-methyldithiocarbazate(L^1), and S-phenyldithiocarbazate (L^2) of general formula of $Cu_2(L^1)_2(CH_3COO)](ClO_4)$(1), $[Zn_2(L^1)_2(ClO_4)_2]$(2), $[Zn(L^2)_2]$(3). A single-crystal X-ray diffraction study showed that the Cu(II) complex (1) adopts square-pyramidal and Zn(II) complex (2) distorted pentagonal bipyramidal geometry, Zn(II) complex (3) octahedral coordination geometry.It should be emphasized that Zn(II) complex (3) effectively inhibitsthe K562 leukemia cell line lower than HL^2 and Cu(II) complex (1) inhibitsthe K562 leukemia cell line lower than HL^1Importantly, IC50 values of Zn(II) complexes 2 and 3 are higher in QSG7701 cell line than in K562 leukemia cell line, indicating both of them have tumor cells selectivity [55].M.L. Low *et al.* prepared two novel Schiff base and their Cu(II) complexes. The Schiff base synthesized from the condensation reaction of S-methyl- and S-benzyldithiocarbazatewith 2,5-hexanedion. Cu(II) complexes are strongly active against human breast adenocarcinoma cancer cell lines MDA-MB-231 and MCF-7 [56].M.K.B. Break*et al.* synthesized a series of macrocyclic Schiff base ligands and their Cu(II)complexes(1-9) via a condensation reaction of various dicarbonyls with *S*-methyl dithiocarbazate and *S*-benzyl dithiocarbazate. Among the complexes,Complex (1) exhibited the most cytotoxic effect among the complexes against MDA-MB-231 and MCF-7 breast cancer cells, with IC_{50} values of 1.7 µM and 1.4 µM, respectively[57].A series of novel metal complexespossessing general formula of $[M(L)_2]$ [M= Cu(II)(1), Ni(II)(2), and Zn(II)(3) and Schiff base derived from S-(4-methylbenzyl)dithiocarbazate and 2-methoxybenzaldehyde by E.N.M. Yusof *et al.*According to the cytotoxic findings, complex (1) significantly reduced the growth of MCF-7 and MDA-MB-213 cancer cell lines. The compounds demonstrated strong hydrogen bonding, Van der Waals force, and hydrophobic DNA-binding capabilities[58].The Schiff bases $RR'C=NNHC(S)SCH_3$ derived from S-methyldithiocarbazate have been prepared. The mass spectra of the Schiff bases having R = Me and R' = Ph, 2-furyl, and 2-thienyl and R = R' = Ph are similar and display strong peaks for the molecular ion M and the ions $M-CH_3S$, $M-CH_3SH$, R'C=NH, R'CN, R'H, R', and RI-H. A mechanism of fragmentation is proposed. Complexes of the Schiff bases of the type $Met(RR'C=NN=CSSCH_3)_2$ (Met = Ni, Cu, Zn, Pd, and Pt) have been isolated in most instances. When R' = Bu" or Bu', nickel ion catalyses the hydrolysis of the Schiff base with the concomitant formation of the S-methyldithiocarbazate complex [Ni(H, NNHCSSCH,)] (NO). The metal complexes are being tested for anti-cancer activity [59].C.L. Chena *et al.* have synthesized transition metal complexes of Co(II) and Mn(II) containing 2- acetylpyridine S-methyldithiocarbazate. Biological activity studies carried out in vitro against the K562leukemia cancer cell line have shown that the free ligand and its metal complexes exhibited significant and different antitumor activity since they exhibit IC_{50} values in the µM range [60].More than 70 relieved thiosemicarbazones and several metal complexes of each have been analyzed for their antifungal activity. Their action is significantly affected by the replaced groups involved at both ^1N and ^4N of the thiosemicarbazone moiety. The greatest activity occurs for 2-substituted pyridine thiosemicarbazones with differences experiential for 2-formylpyridine, 2-acetylpyridine, and 2-benzoylpyridine derivatives and their metal complexes. Further, there are activity differences for ^4N-alkyl-, ^4N-aryl-, ^4N-dialkyl- and 3-azacyclothiosemicarbazones and their metal complexes as well as changes in the substituent size among each of these subgroups. Cu(II) complexes are often more active than the uncomplexedthiosemicarbazones, with the latter showing similar activity to Ni(II) complexes in many instances. The reduction potential of the thiosemicarbazone ligand in a Cu(II) complex, the strength of the ligand field, and various spectral properties can be correlated to the inhibitory activity [61].M.A. Ali *et al.* synthesized Pd(II) and Pt(II) complexes containing Schiff bases of S-methyl- and S-benzyldithiocarbazate and characterized them by a variety of physicochemical techniques. The complex has a distorted cis-square planar structure with the ligands coordinated to the Pd(II) ions as uninegatively charged bidentate NS chelating agents via the azomethine nitrogen and the mercaptide sulfur atoms. The distortion from a regular square-planar geometry is attributed to the restricted bite angles of the ligands. Antimicrobial tests indicate that the Schiff bases exhibit strong activities against the pathogenic bacteria, *Bacillus subtilis* (mutant defective DNA repair), methicillin-resistant *Staphylococcus aureus, B. subtilis* (wild type) and *Pseudomonas aeruginosa* and *the fungi, Candida albicans (CA), Candida lypotica (2075),* *Saccharomyces cerevisiae (20341) and Aspergillus ochraceous (398*) the activities exhibited by these compounds being greater than that of the standard antibacterial and antifungal drugs, *streptomycin and nystatin*, respectively. The Pd(II) and Pt(II) complexes were inactive against most of these organisms but, the microbe, *Pseudomonas aeruginosa* shows strong sensitivity to the Pt(II) complexes. Screening of the compounds for their cytotoxicities against *T-lymphoblastic leukemia* cancer cells has shown that the acetone Schiff base of S-methyldithiocarbazate (Hasme) exhibits a very weak activity, whereas the S-benzyl derivative (Hasbz) is inactive. However, the Pd(II) complexes exhibit strong cytotoxicities against this cancer; their activities being more than that of the standard anticancer drug, tamoxifen. The [Pt(asme)] complex exhibits very weak cytotoxicity, 2 whereas [Pt(asbz)] is inactive against leukemic cells [62].The transition metal complexes were synthesized from the Schiff base by L.Z. Zhang *et al.* The two novel Schiff bases derived from S-methyldithiocarbazate(HL^1) and S-benzyldithiocarbazate(HL^2) with pyridine-2-carboxaldehyde. Among the Schiff base and their complexes, only HL^1 and manganese complex II show significant antitumor activity against K562 leukemia cell line, since they exhibit IC_{50} values in the μM range [63].

3.3 Antioxidant Activity

A series of metal complexes were synthesized from the novel Schiff base ligand by S.A. Elsayed *et al*. The Schiff base was derived from the condensation reaction of pyridoxal and SBDTC. The antioxidant activity of the complexes was measured by 2,2-diphenyl-1-picrylhydrazyl radical (DPPH). Among the complexes, the oxovanadium (IV) exhibited thehighest scavenging activity against DPPH with lowest value of IC_{50} [64].M.T.H. Tarafder*et al*. prepared Bis-chelated Cu(II), Ni(II) and Zn(II) complexes containing two new isomeric Schiff bases, S-methyl-b-N-(2-furylmethyl)methylenedithiocarbazate(NS') and S-methyl-b-N-(5-methyl-2-furyl)methylenedithiocarbazate (NS"). The antioxidant activity of the complexes was tested by FTC methods which indicated the peroxide value in the primary stage of lipid oxidation. The data evaluated that SBDTC exhibited a higher antioxidant activity than the α-tocopherol (vitamin E) [65].M.T.H. Tarafder*et al.* prepared bidentate and quartidentate Schiff base ligands derived from the condensation reaction of S-benzyldithiocarbazate with 2,3 butanedione. Spectroscopic evidence suggested that the prepared ligand acts as an NS and NNSS coordinating agent during complexation with Cu(II) and Ni(II) ions. Antioxidant activity has shown that nickel and copper complexes were more active than those of Vitamin E [66].

Conclusions

This review shows various synthesismodes of Schiff bases derived from SBDTC and SMDTCand their metal complexes. This article also explains how the Schiff base metal complexes are potentially active against various pathogenic bacteria and fungi. Some of the metal complexes are potentially effective against cancer cells. Improvements in bioinorganic chemistry are important for enlightening the design of compounds to moderate toxic side-effects and understand their mechanisms of action. This review revealsthat the Schiffbases and their metal complexes derived from SBDTC and SMDTC could be a suitable approach to progressinnovative therapeutic tools for medical treatment.

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