



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

Md. Tariqul Islam ^a, Md. Nur Amin Bitu ^a,
Md. Saddam Hossain ^b, Md. Ali Asraf ^a,
Choudhury M. Zakaria ^a, Md. Kudrat-E-Zahan ^a
and Md. Faruk Hossen ^{a*}

^a Department of Chemistry, Rajshahi University, Rajshahi, Bangladesh.

^b Department of Chemistry, Begum Rokeya University, Rangpur, Bangladesh.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

S-benzylthiocarbamate (SBDTC) and S-methylthiocarbamate (SMDTC) are working as a preliminary reactant for the synthesis of several 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

*Corresponding author: E-mail: fhossen.chem@ru.ac.bd;

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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 considered 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 (NO), Nitrogen-Sulfur (NS), Sulfur-Nitrogen-Nitrogen-Sulfur (SNNS), and Nitrogen-Oxygen-Sulfur(NOS) 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 that S-methyldithiocarbazate (SMDTC), and S-benzylthiocarbazate (SBDTC), a nitrogen-sulfur donor, have enormous interest in bioinorganic chemistry. From then onwards, many Schiff bases prepared from SMDTC and SBDTC have been described 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 O play a vital role in biological processes. It has been stated that biologically active compounds' action could have increased when metal ions are bonded to them [9,10]. The existing functional group (-NH-C(=S)-NH₂) 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 exhibit boosted stability, reactivity, and selectivity in a wide range of chemical transformations and applications. Dithiocarbazate and its substituted derivatives have become promising molecule of interest in the past few decades. The Schiff base of methyl/benzyl dithiocarbazate exists in tautomeric isomerization: thione and thiol. In a monomeric system, the group (C=S) is comparatively unstable. However, if at least one hydrogen atom is nearby, enethionization tends to alter the unstable C=S bond to a stable C-S single bond. The molecule can act as a uni-negatively chelating agent [11,12]. A unique sequence of ligands is derived from S-alkyl and S-benzyl esters with dithiocarbazic acid. Various NO, NS, SNNS, SNNNS donor Schiff bases have been produced from several carbonyl

compounds with SMDTC and SBDTC by the condensation reaction. The numbers of these compounds continue to increase due to the remarkable finding that distinct ligands exhibit various biological activities. Schiff base complexes synthesized from S-alkyldithiocarbazates have been the theme of great contemporary importance in this field due to their attractive physico-chemical properties and possibly useful biological action [13-19]. However, most preceding reviews on dithiocarbazates complexes were recognized as tri, tetra, penta, and hexadentate chelating agents [20,21]. Much attention has not been focused on pentadentate ligands produced by S-alkyldithiocarbazates. Majumder *et al.* have reported on complexes of the pentadentate Schiff base derived from S-methyldithiocarbazate (R=CH₃ and 2, 6-diacetylpyridine) [22]. Thus, the aims of this review are to show the various synthesis procedure of Schiff bases prepared from SBDTC and SMDTC and their metal complexes and study their structural properties and biological activity to 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” by Ali *et al.* “The Ni(SNNS) complexes are diamagnetic and square-planar (Fig.1). The Zn(SNNS) complexes are assigned polymeric structures with mercapto sulfur-bridging. The Cd(SNNS) complexes presumably have polymeric structures” [23].

“Tris- and bis-ligand complexes of Ni(II) with SBDTC having the general formulae Ni(SBDTC)₃X₂.H₂O (X = Cl, Br and NO) and Ni(SBDTC)₂X₂ (X = Cl and NCS) respectively, were synthesized and characterized” by Ali *et al.* “The ligand acts as a bidentate sulphur-nitrogen

chelating agent (Fig. 2). Both the tris- and bis ligand cationic Ni(II) complexes have high 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 $M(\text{SBDTCA})_2$ [$M = \text{Ni(II)}$ and Zn(II) ; $\text{SBDTCA} =$ anion of SBDTC] were isolated. The Ni(II) complex is square-planar” [24].

“Ni(II), Cu(II), and Co(II) complexes of Schiff bases formed from SBDTC and some aldehydes

and ketones were prepared” by Tarafder *et al.* [25]. “The Schiff base S-methyl-P-N-(2-hydroxyphenyl) methyldithiocarbazate, 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 acetylaceton Schiff base 2-hydroxy-4-methyl-5,6-diaza-7-thiono-8-thianona-2,4-diene, $\text{CHC(OH) = CHC(CH}_3\text{) = NNHC(=S)SCH}_3$, was also prepared. The Cu(II) ion form stable complexes (Fig. 3) with the synthesized ligands” [26].

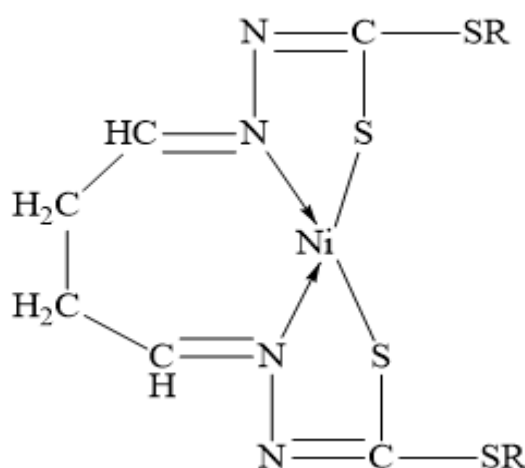


Fig. 1. Structure of Ni(II) complex

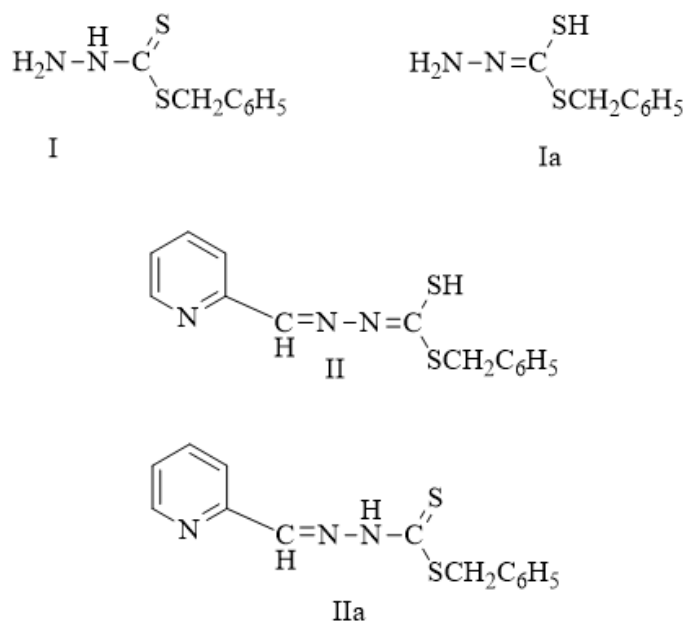


Fig. 2. Structure of ligands

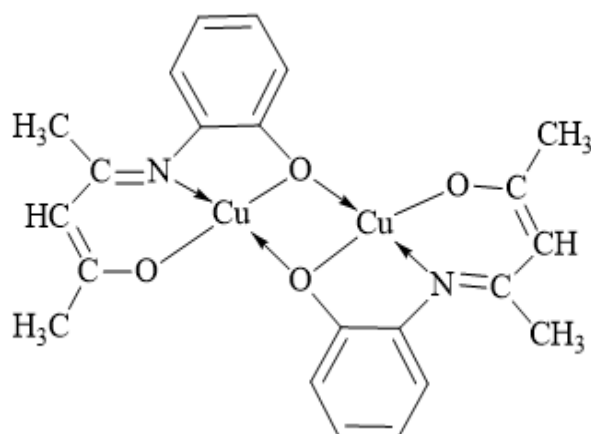


Fig. 3. Structure of the schiff base copper(II) complexes

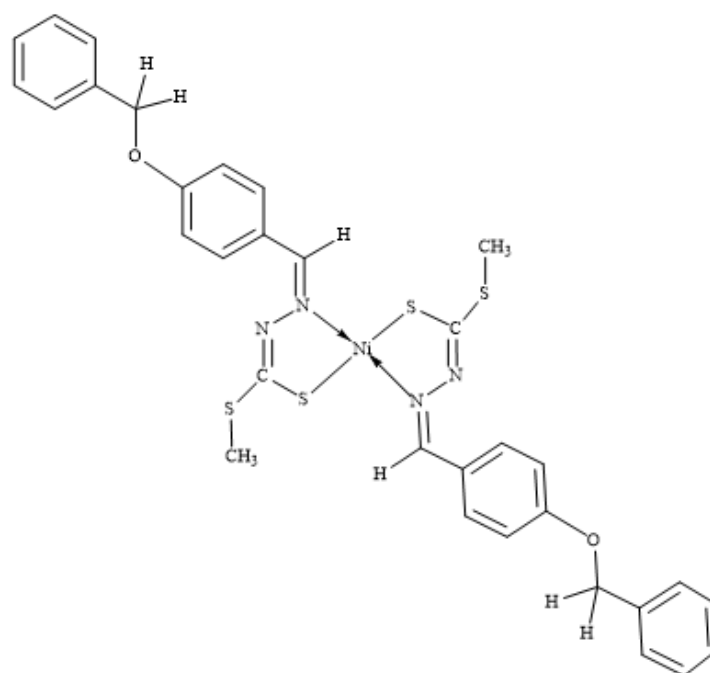


Fig. 4. Structure of the schiff base nickel(II) complexes

E. Zangrando et al. synthesized Ni (II) complex from Schiff base via the condensation reaction of SMDTC with 4-benzyloxybenzaldehyde. The Schiff base displayed uninegetively bidentate (NS) in thione tautomeric form of azomethine C=N bond, according to the analytical data, and Ni(II) complex (Fig.4) revealed a deformed square planar geometry [27].

Ji et al. synthesized a cobalt (II) complex of [Co(PMBP-smdtc)₂].2H₂O. The Schiff base was prepared from SMDTC and l-phenyl-3-methyl-4-benzoyl-5-pyrazolone by condensation reaction.

X-ray crystallography data indicated that the complexes exhibited an octahedrally compound [28]. The nitrogen-sulfur donor sequence of novel bidentate Schiff bases (Fig. 5) was developed from methyl hydrazinecarbodithioate with (R)-camphor, and (S)-camphor by condensation reaction. The bidentate ligands formed complexes of [M(NS)₂], where M is Ag(I) or Bi(III). X-ray crystallography data indicated that Bi(III) complexes exhibited octahedral geometry, and Ag(II) exhibited square planner complexes [29].

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 Singh *et al.* [30]. 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. Alim *et al.* [32] synthesized Cu(II), Ni(III) Zn(II), Cd(II), Co(II), Sb(III) and Fe(III) containing bidentate Schiff base (Fig. 6), $[Ni-(4-chlorobenzylidene)-hydrazecarbodithioicacid\ methyl\ ester]$ derived from the condensation of SMDTC and P-chlorobenzaldehyde.

2, 6-diacetylpyridinebis(S-benzylidithiocarbazate) (H_2SNNNS) pentadentate ligand (Fig. 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].

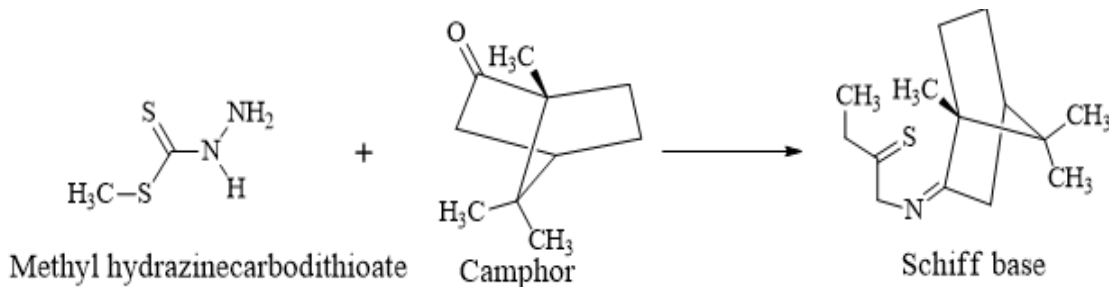


Fig. 5. Synthesis route of novel schiff base ligand

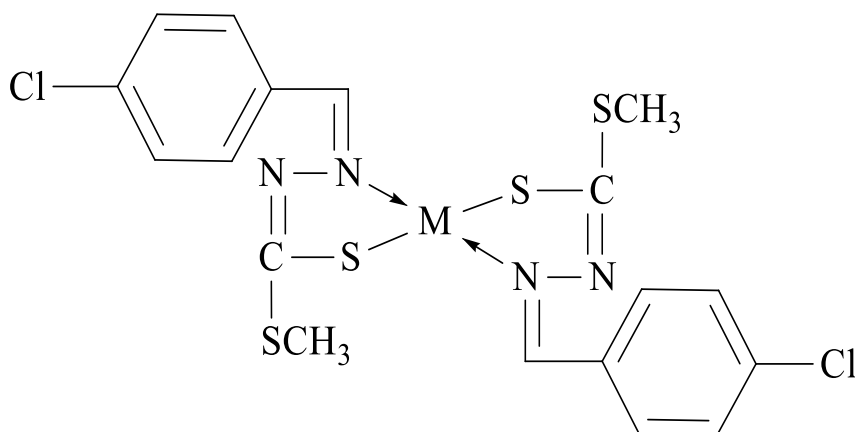


Fig. 6. Structure of the schiff base metal complexes

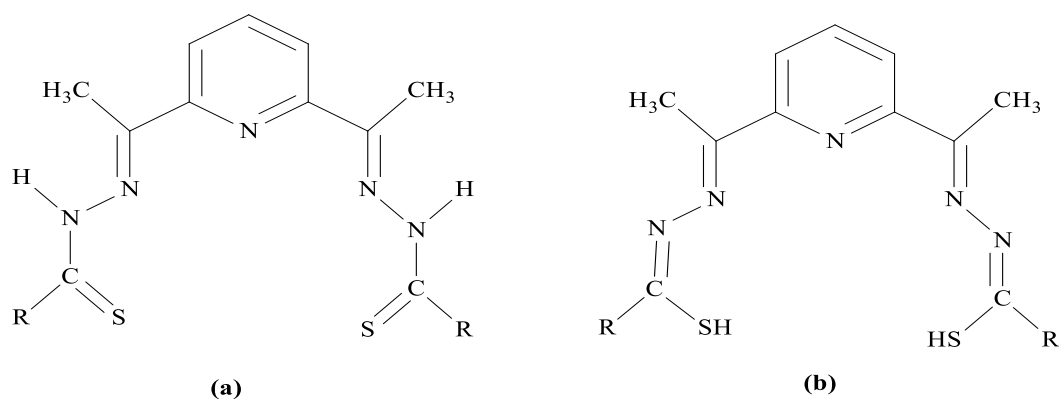


Fig. 7. Thione-thiol tautomerism in the ligand (a) thione form (b) thiol form

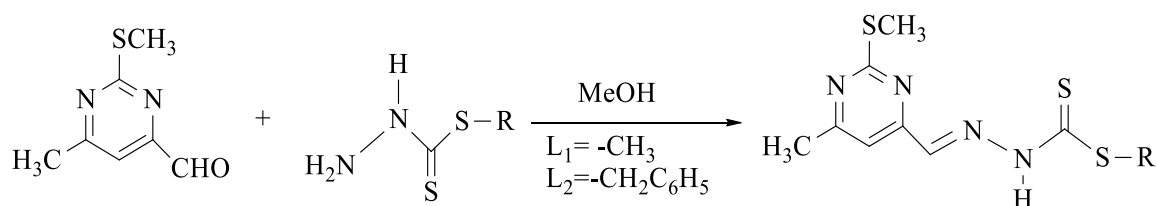


Fig. 8. Synthesis route of novel Schiff base ligand

“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 Ali *et al.* [34]. Alshaheri *et al.* produced a variety of complexes of dithiocarbamate Schiff bases (abbreviated as NiSMdiAP, CoSMdiAP, FeSMdiAP, MnSMdiAP, and ZnSMdiAP, where SMdiAP indicates the Schiff base). S-methyl dithiocarbamate 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 (Fig. 8) has been prepared from condensation of 2-S-methylmercapto-6-methylpyrimidine-4-carbaldehyde and S-methyl/S-benzyl dithiocarbamate” 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 azomethine pyrimidyl 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].

“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-methyldithiocarbamate) have been synthesized” by 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 bicondensed pentadentate 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) methylenedithiocarbamate (H_2L), $[Co(HL)_2]NO_3 \cdot EtOH$ 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 Antimicrobial Activity

“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]. “Hossain et al. prepared Cu (II) complexes containing Schiff base ligands (Fig. 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].

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-methylthiocarbamate and cinnamaldehyde”. “All the complexes of Schiff base exhibited antibacterial activity against four gram-positive (*Bacillus subtilis*, *Staphylococcus aureus*, *Bacillus megatherium*, *Streptococcus-β-haemolyticus*) and four gram-negative (*Escherichia coli*, *Shigella dysenteriae*, *Shigella sonnei*, *Shigella shiga*) and antifungal activity against four

Aspergillus Candidus, *Penicillium Marneffeii*, *Candida Albicans*, *Aspergillus niger*” [42]. 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 complexes were 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. equisetii*, 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 (Fig. 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].

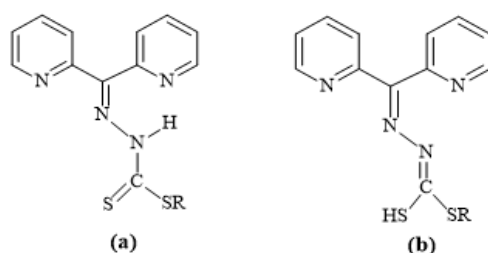


Fig. 9. Thione-thiol tautomerism in the ligand (a) thione form (b) thiol form

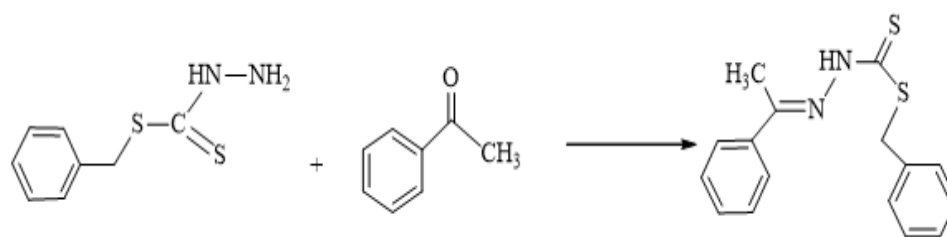


Fig. 10. Synthesis route of schiff base

“A new tridentate nitrogen–oxygen–sulfur Schiff base has been prepared from the condensation reaction of S-methylthiocarbamate and methylsalicylaldehyde” by 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-benzylthiocarbamate (SBDTC) and salicylaldehyde was reported by Bitu *et al.* The complexes of Zr(IV), Th(IV), and U(VI) ions have 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 *Shigella dysenteriae*), 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)(NO₃)(H₂O)]·H₂O and [Cu(NNS)₂] (NNS=anionic form of the 6-methyl-2-formylpyridine 4-N-dimethylthiosemicarbazone) have been synthesized and characterized” by 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-methylthiocarbamate (Hdpksme) reacts with Ni(II) salts giving both mono- and bis-chelated complexes were synthesized” by 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”. [50]

“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= H₂O, 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 ochraceus* fungi” [51]. “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-methylthiocarbamate 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 dithiocarbamate lessens the antifungal activity” [52]. “Cu(II) complexes containing Schiff base ligand α-N-methyl-S-methyl-b-N-(2-pyridyl)methylenedithiocarbamate (NNS) were synthesized and characterized” by 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 cerevisiae* and *Aspergillus ochraceus* but its Cu(II) complexes, Cu(NNS)₂ are strongly active against these organisms” [53]. Mono- and bis-chelated Cd(II) complexes of the di-2-pyridylketone Schiff base of S-methylthiocarbamate (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 *Shigella dysenteriae*, *Bacillus cereus*, *Staphylococcus aureus*, and *Escherichia coli*. They are also mildly fungitoxic against the phytopathogenic fungi, *Alternaria alternata* and *Macrophomina phaseolina* [54].

3.2 Anti-Cancer Activity

Low *et al.* prepared various complexes of Cu(SBCM)₂, Zn(SBCM)₂, and Re₂(SBCM)₂ derived from Schiff base of S-Benzylthiocarbamate and 3-acetylcoumarin by the condensation reaction. 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. The anticancer data indicated that, Among the complexes, Cu(II) and Re(I) exhibit activity against lines MCF-7 and MDA-MB-231 [55]. Li *et al.* have synthesized Cu(II) and Zn(II) complexes from Schiff base which were derived from 2-benzoylpyridine with S-methylthiocarbamate (L¹), and S-phenylthiocarbamate (L²). The general formula of synthesized complexes, Cu₂(L¹)₂(CH₃COO)(ClO₄)(1), [Zn₂(L¹)₂(ClO₄)₂](2), [Zn(L²)₂](3). The spectroscopic data 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 focus attention that Zn(II) complex (3) magnificently inhibits the K562 leukemia cell line lower than HL², on the other hand, Cu(II) complex (1) prevents leukemia cell line lower than Schiff base, Importantly, The QSG7701 cell line exhibited higher IC₅₀ values for Zn(II) complexes 2 and 3 compared to the K562 leukemia cell line, indicating that both complexes exhibit tumor cell selectivity [56]. Low *et al.* prepared Cu(II) complexes from two novel Schiff bases. The Schiff base was synthesized from 2,5-hexanedion with S-methyl- and S-benzylthiocarbamate respectively by the condensation reaction. Cu(II) complexes exhibited good activity against cell lines MDA-MB-231 and MCF-7 [57]. Break *et al.* synthesized various macrocyclic Schiff bases from various dicarbonyls with S-methylthiocarbamate and S-benzylthiocarbamate through condensation reaction and corresponding their Cu(II) complexes(1-9). The

compound with the most cytotoxic effect on MDA-MB-231 and MCF-7 breast cancer cells was compound (1); its IC₅₀ values were 1.7 μM and 1.4 μM, respectively. [58]. A series of novel Cu(II)(1), Ni(II)(2), and Zn(II)(3) complexes from Schiff base which was prepared from S-(4-methylbenzyl) dithiocarbamate and 2-methoxybenzaldehyde by Yusof *et al.* According to the cytotoxic findings, complex (1) significantly lessened the progress of cell lines MCF-7 and MDA-MB-213. The compounds demonstrated strong hydrogen bonding, Van der Waals force, and hydrophobic DNA-binding capabilities [59]. The Schiff bases, which are produced from S-methylthiocarbamate, are RR'C=NNHC(S)SCH₃. The Schiff bases of type M(RR'C=NN=CSSCH₃)₂ complexes (where M = Ni, Cu, Zn, Pd, and Pt) have been isolated most of the time. The nickel ion catalyzes the hydrolysis of the Schiff base when R' = Bu'' or Bu', and simultaneously produces the S-methylthiocarbamate complex [Ni(H, NNHCSSCH₃,)] (NO). Research is being done on the metal complexes' anti-cancer properties [60]. Chena *et al.* have synthesized various complexes of Co(II) and Mn(II) containing 2-acetylpyridine and S-methylthiocarbamate. In vitro biological activity investigations performed on the K562 leukemia have demonstrated that both Schiff base and their complexes showed unique and strong anticancer activity, as evidenced by their IC₅₀ values in the μM range [61]. The antifungal activities of over 70 alleviated thiosemicarbazones and various metal complexes involving these compounds have been investigated. The substituted groups at both the 1N and 4N of the thiosemicarbazone moiety have an enormous effect on their activity. With variations shown for 2-formylpyridine, 2-acetylpyridine, and 2-benzoylpyridine derivatives and their metal complexes, the highest activity is seen for 2-substituted pyridine thiosemicarbazones. Changes in the substituent size within each of these subgroups as well as variations in the activity of 4N-alkyl-, 4N-aryl-, 4N-dialkyl-, and 3-azacyclothiosemicarbazones and their metal complexes are also seen. The activity of uncomplexed thiosemicarbazones is commonly comparable to that of Ni(II) complexes, although Cu(II) complexes are generally more active than the latter. The thiosemicarbazone ligand's reduction potential in a Cu(II) complex, the ligand field's strength [62]. Ali *et al.* prepared Pd(II) and Pt(II) complexes from Schiff bases of SMDTC, SBDC via a condensation reaction. The Schiff base and its complexes were evaluated by spectroscopic

techniques. The Pd(II) complex exhibited a distorted cis-square planar geometry. The metal coordinated with the ligands through bidentate NS linkage where nitrogen from azomethine and sulfur atoms from mercaptide. The ligands' confined bite angles are the cause of the alteration from a typical square-planar geometry. According to a biological assay that the metal complex showed robust activities against methicillin-resistant *Staphylococcus aureus*, mutant defective DNA repair-producing *Bacillus subtilis*, *B. subtilis* (wild type), and *Pseudomonas aeruginosa*, as well as *Candida albicans* (CA), *Candida lyptotica* (2075), *Saccharomyces cerevisiae* (20341), and *Aspergillus ochraceous* (398). These compounds exhibited activity that was higher than those of the common antifungal and antibacterial medications, nystatin and streptomycin, respectively. A large number of these species had no effect by the Pd(II) and Pt(II) complexes; however, the Pt(II) complexes exhibited an important sensitivity against *Pseudomonas aeruginosa*. When the cytotoxicity activities of their compounds were verified against T-lymphoblastic leukemia, it was found that the S-benzyl derivative (Hasbz) is inactive and S-methyldithiocarbazate Schiff base (Hasme) has very less active. However, the Pd(II) complexes show significant cytotoxicities against this cancer; these activities exceed those of tamoxifen, a standard anticancer treatment. While [Pt(اسبز)] is ineffective against cancer cells, the [Pt(اسمه)] complex exhibited little cytotoxicity [63]. Zhang *et al.* synthesized a complex from the Schiff base. The two novel Schiff bases were prepared from pyridine-2-carboxaldehyde with S-methyldithiocarbazate (HL¹) and S-benzylthiocarbazate (HL²) via condensation reaction. Only Ligand (1) and manganese complex II exhibited considerable anticancer activity against the K562 leukemia cell line among complexes since their IC₅₀ values were in the μM range [64].

3.3 Antioxidant Activity

The transition metal complexes were derived from the novel Schiff base ligand by Elsayed *et al.* The Schiff base was synthesized from pyridoxal and SBDTC by the condensation reaction. To evaluate the antioxidant properties of various complexes, the 2,2-diphenyl-1-picrylhydrazyl radical (DPPH) was a suitable indicator in this procedure. Among the various complexes, the oxovanadium (IV) exhibited the highest scavenging activity against DPPH with the lowest value of IC₅₀ [65]. Two novel isomeric

Schiff bases, S-methyl-b-N-(2-furylmethyl) methylene (NS') and S-methyl-b-N-(5-methyl-2-furyl) methylenedithiocarbazate (NS'') have been introduced to Bis-chelated complexes of Cu (II), Ni (II), and Zn (II) by Tarafder *et al.* The peroxide value in the first stage of lipid oxidation was determined by the FTC methods. These methods were also used for evaluating the complexes' antioxidant activity. The data evaluated that SBDTC exhibited more antioxidant activity than the standard α-tocopherol (vitamin E) [66]. Bidentate and quartidentate Schiff base ligands were synthesized by Tarafder *et al.* from S-benzylthiocarbazate with 2,3 butanedione through the condensation reaction. According to analytical data, the synthesized ligand may function as an NS and NNSS coordinating agent during complexation with Cu(II) and Ni(II) ions. According to antioxidant activity, complexes of copper and nickel were more active than those of vitamin E [67].

4. CONCLUSIONS

This review shows various synthesis modes of Schiff bases from SBDTC, SMDTC, and their complexes. This study also explains how the Schiff base metal complexes are potentially active against several 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 reveals that the Schiff bases and their metal complexes derived from SBDTC and SMDTC could be a suitable approach to progress innovative therapeutic tools for medical treatment.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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