

**JIMMA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
COLLEGE OF NATURAL SCIENCES
DEPARTMENT OF CHEMISTRY**



M.Sc. THESIS

ON:

**SYNTHESIS, CHARACTERIZATION AND ANTIMICROBIAL STUDY OF
DITHIOCARBAMATE AND SCHIFF BASE LIGANDS AND THEIR Cu (II)
AND Zn (II) COMPLEXES**

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NOVEMBER, 2018

JIMMA, ETHIOPIA

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AND Zn (II) COMPLEXES

A THESIS SUBMITTED TO SCHOOL OF GRADUTE STUDIES JIMMA UNIVERSITY IN
PARTIAL FULFILLMENT OF THE REQUIRMENTS FOR THE DEGREE OF MASTERS OF
SCIENCE IN INORGANIC CHEMISTRY

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Declaration

I hereby declare that the thesis work entitled “**synthesis, characterization and antimicrobial study of dithiocarbamate and Schiff base ligands and their Cu (II) and Zn (II) complexes**” is the original work carried out in the department of chemistry Jimma University in partial fulfillment of the requirements for the degree of masters of sciences in inorganic chemistry.

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Abbreviations and acronyms

AAS	Atomic Absorption Spectroscopy
AR	Analytical Reagent
CHNS	Carbon hydrogen nitrogen Sulfur
CSS	Carbon Sulfur, Sulfur
DMSO	Dimethyl Sulfoxide
DPDTC	Diphenyl dithiocarbamate
DTC	Dithiocarbamate
FT-IR	Fourier Transform Infrared
NCCLS	National Committee for Clinical Laboratory Standards
NMR	Nuclear Magnetic Resonance Spectroscopy
TLC	Thin Layer Chromatography
TMS	Tetra Methyl Silane

Acknowledgment

First, I would like to thank my God who helped me throughout my life. I am very thankful to my advisor Dr. Guta Gonfa for his help in all my work by guiding me thoroughly and giving me unreserved advice. My deepest gratitude goes to my co-adviser Mr. Tilahun Wubalem for his support and guiding me in all my work. Also I would like to thanks Mr. Kemal Menza, Maseret Melaku and all laboratory assistants and teachers of Jimma University chemistry department for the cooperation they made in all my work. Also I would like to thank Addis Ababa university for cooperation they made in my work.

My heartfelt and great thanks go to my lovely mother w/o Hirut Sadi and my father Jabesa Nemera for their deep love, care, encouragement, moral support, spiritual praying and help starting from childhood that enable me to achieve my goal and realize my long term dream and also for providing me a sustainable support to my family with patience throughout my study. I am deeply indebted thanks to my lovely wife Ms. Debele Jaleta and my great love children Felmeta Dugasa and Injifano Dugasa for their unconditional love, encouragement and moral support throughout the study.

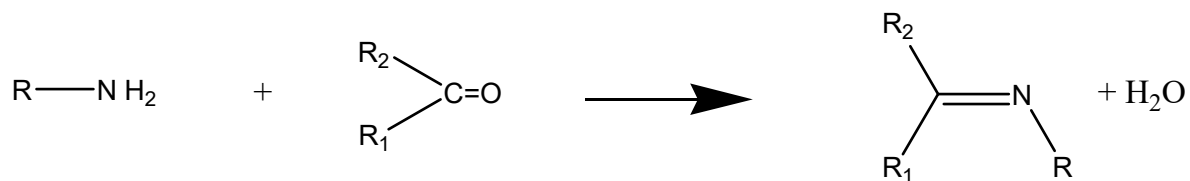
Finally, I would like to express my appreciation to all my classmates for their special help in my study.

Abstract

Chemistry of transition metal complexes with Schiff base and dithiocarbamate mixed ligands are much interest in bioinorganic chemistry. They have many applications including as catalyst and medicine. Due to the increase in resistance of pathogenic microorganism to the available antibiotics, efforts are being made to develop chemotherapeutic agents. Thus, the aim of this study is to synthesize, characterize and evaluate antimicrobial activities of Zn (II) diphenyl dithiocarbamate and Cu (II) complex containing Schiff base of 1,10-phenanthroline and diphenyl dithiocarbamate. Meanwhile, the sodium diphenyl dithiocarbamate ligand was synthesized by the reaction of CS₂ with diphenylamine in the presence of NaOH. The mixed ligand Cu (II) complex was synthesized by reaction of CuCl₂.2H₂O with sodium diphenyl dithiocarbamate and 1, 10-phenanthroline. Also Zn (II) complex was synthesized by reaction of ZnCl₂.6H₂O with diphenyl dithiocarbamate. The synthesized ligand and its metal complex was characterized by melting point, chloride test, conductivity measurement, CHNS elemental analysis, AAS, FT-IR, UV-Visible spectroscopy and NMR spectroscopy. The data obtained from this instruments confirm that bidentate nitrogen group of 1, 10-phenanthroline coordinate to copper ion (N→M), Sulfur group of diphenyl dithiocarbamate coordinated to copper ion (S→M) and coordination of water molecules through oxygen atoms (O→M). These data also indicate bidentate sulfur group of diphenyl dithiocarbamate coordinated to zinc ion. The result of molar conductivity shows 1:1 electrolytic nature of Cu (II) complex and non-electrolytic nature of Zn (II) complex. These data show octahedral geometry of Zn (II) complex and distorted octahedral geometry in the case of the Cu (II) complex. All the synthesized compounds were screened for their antibacterial and antifungal activity against bacterial and fungal strains. From the bioassay result, both metal complexes are potent against all bacterial strain. Cu (II) complex and Zn (II) complex appeared to display strong to inhibitory effect (25-29 mm) and (23-29 mm) respectively.

1. Introduction

The chemistry of Schiff base ligands and their metal complexes attracts much current interest and cover a vast area of metal complexes containing organic compounds and bioinorganic chemistry [1]. Schiff bases that have been widely used as ligands in transition metal complexes contains the donor atoms such as O, N and S elements. They are easily prepared by condensation of aldehyde or ketone with amine and able to stabilize different metals in various oxidation state [2, 3]. It is a nitrogen analog of an aldehyde or ketone in which C=O group is replaced by C=N-R group. Where R, may be an alkyl or an aryl group (Scheme 1) [4].



Scheme 1. Formation of Schiff base

The reactivity and stability of this ligand is depending on the conjugation. Those ligands having effective conjugation are more stable. But those of aliphatic aldehydes are relatively unstable and readily polymerizable. The formation of this compound from an aldehyde or ketone is a reversible reaction and generally takes place under acid or base catalysis, or upon heating. The driving force in the formation of this compound is separation of the product or removal of water or both. Schiff base can be hydrolyzed back to their aldehyde or ketones and amine by aqueous acid or base [4,5].

Schiff base is largely studied because of synthetic flexibility, selectivity and sensitivity towards central metal atoms, structural similarities with natural biological compounds and due to the presence of azomethine group (-N=CH-) which imports in elucidating the mechanism of transformation and racemization reaction [6].

The metal complex containing this type of ligand have much application including catalyst, medicine, crystal engineering and anti-corrosion agent. The presence of multifunctional groups in heterocyclic Schiff base ligand with their coordination compounds have interests of the many chemists in current years to find applications as potential drugs [5].

The complexes of Schiff bases having chelation with oxygen, nitrogen etc. donors' atoms have been used as drugs and have several applications in a wide variety of biological activities against bacteria, fungi, and a certain type of tumors and also, they have many biochemical, clinical and pharmacological properties [5]. The synthesis of chelating ligands containing donor atoms are not only interested in the structural chemistry of their multifunctional coordination modes but also showed importance in the medicinal pharmaceutical field. Generally, the transition metal complexes of Schiff base having nitrogen donor atoms can show broad biological activities. Due to this reason, Schiff base ligands containing these donor atoms are of much interest [6,7].

There has been a prodigious upsurge of knowledge in the chemistry of transitional metal complexes with sulfur donor ligands. The reaction of carbon disulfide with different nucleophiles such as RO^- , RNH^- and R_2N^- can give considerable interest sulfur containing-ligands [8]. Organosulfur compounds can make a bond with several important biomolecules such as amino acid and vitamins. Because of this reason, a number of researchers have interested on synthesis and characterization of metal complexes containing sulfur donor ligands [9,10,11]. Dithiocarbamate ligands are organosulfur compounds having the remarkable complexing capacity. This may be due to the small bite angle of CSS group which can coordinate almost with all metal ions even in unusual oxidation states like Ni (IV) and Cu (III) [9]. Dithiocarbamate has the capability to form monodentate as well as bidentate. Due to this reason, it can generate varied structures like macrocycle, capsules, and cylinders, cages, cryptands, catenanes and loops [10, 11].

From the structural point of view dithiocarbamate ligands and their complexes are very interesting and intriguing. Dithiocarbamate and their metal complexes have diverse applications and interesting biological, structural, magnetic, electrochemical and thermal properties. Due to this reason it invited much research attentions. The nickel complex of dithiocarbamate, copper complex and zinc complex are used as pesticides with an estimated annual global consumption of 25,000–35,000 metric tons [10, 11].

The characterization, antibacterial and toxicological activities of the mixed ligand with transition metal complexes have been studied by many researchers. The role of transition metals complexes with mixed ligand in the biological activities has been recognized [10, 11].

It has been found that a majority of the transition metals complexes of mixed ligand containing quinolone possess biological activities. The anti-microbial properties of a range of copper (II) complexes of mixed ligand have been evaluated against several pathogenic bacteria and fungi [12]. Generally, the nitrogenous bases of dithiocarbamate such as pyridine, picoline, and 2,2-bipyridine with metals complexes have been reported [10]. But, the metal complexes containing Schiff base and dithiocarbamate are scarce. Still now, the metal complexes containing dithiocarbamate derived from carbon disulfide and diphenylamine with Schiff base of 1,10-phenanthroline have not been reported. Therefore, the researcher was interested to synthesize, characterize and evaluate antimicrobial activity of Zn (II) diphenyl dithiocarbamate and Cu (II) mixed ligand complex containing Schiff base of 1,10-phenanthroline (figure 1b) and diphenyl dithiocarbamate derived from diphenylamine (figure 1a) and carbon disulfide. The synthesized ligand and its metal complexes were characterized by various physio-chemical techniques such as chloride test, molar conductance, elemental analysis, AAS, electronic spectra, FT-IR and NMR spectroscopy.

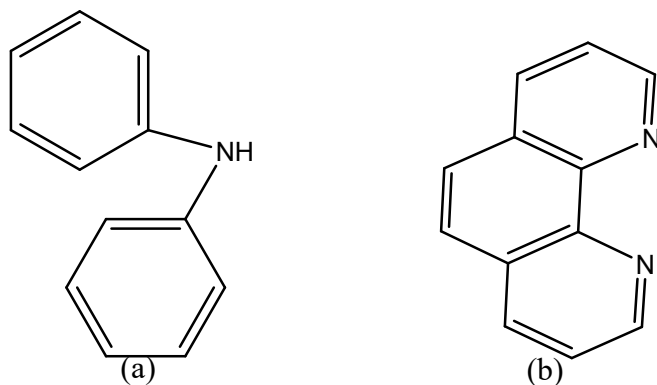


Figure 1. Structure of diphenylamine (a) and 1, 10-phenanthroline (b)

1.2 Statement of the problem

The discovery and development of antimicrobial are among the most powerful and successful achievements of modern science and technology for the control of infectious disease. In the overall world, utilizing of transition metal complexes as the drugs for the treatment of microorganisms' diseases is increased from time to time. Those transition metal complexes were very active to the antimicrobial activities. In the chemistry of the metal complexes, transition metal complexes containing Schiff base and dithiocarbamate ligands are used for the treatments of antimicrobial activities [13]. But, the ability of these two ligands individually used as an antimicrobial is reduced because of adaptation of bacteria. In another case, the metal complex containing mixed ligand of Schiff base and dithiocarbamate have been synthesized and antibacterial activity of the synthesized compounds has been evaluated. But, metal complexes of diphenyl dithiocarbamate and 1,10-phenanthroline have not been reported. Thus, the researcher designed a study on synthesis, characterization and evaluation of antimicrobial activity of metal complexes of diphenyl dithiocarbamate and Schiff base of 1, 10-phenanthroline to answer the following questions.

1. How to synthesize copper (II) complex from mixed ligands of 1, 10-phenanthroline and diphenyl dithiocarbamate?
2. How to synthesis zinc (II) diphenyl dithiocarbamate?
3. Do the synthesized metal complexes show effective antimicrobial activity?
4. What are the geometries of the synthesized complexes?

1.3 Objective of the study

1.3.1 General objective

The general objective of the study is to synthesize, characterize, and evaluate antimicrobial activity of dithiocarbamate and Schiff base ligands and their Cu (II) and Zn (II) complexes

1.3.2 Specific objectives

- To synthesize sodium diphenyl dithiocarbamate ligand from diphenyl amine and carbon disulfide.
- To synthesize Zinc (II) diphenyl dithiocarbamate and Cu (II) complex containing 1,10-phenanthroline and diphenyl dithiocarbamate.
- To characterize the synthesized compounds by molar conductivity, elemental analysis, AAS, FT-IR, NMR, and UV-Visible spectroscopy.
- To evaluate the antimicrobial activity of the ligands and their metal complex.

1.4 Significance of the study

The treatment of infectious diseases still remains as one of the challenging problem because of a combination of factors including emerging infectious diseases and increasing number of multi-drug resistant microbial pathogens. In spite of a large number of antibiotic and chemotherapeutic available for medical use, at the same time, the emergence of old and new antibiotic resistance created in last decades revealed a substantial medical need for new classes of metal complexes of antimicrobial agents. Therefore, the proposed Cu (II) complex containing mixed ligand of diphenyl dithiocarbamate and 1, 10-phenanthroline and Zn (II) diphenyl dithiocarbamate have the following significance.

1. The complexes that were prepared are expected to be good promising antimicrobial activity that will be used as a drug.
2. The complex compound that was synthesized from the Schiff base of 1, 10-phenanthroline and dithiocarbamate derived from carbon disulfide and diphenylamine can develop the knowledge on the structure of complex compound.

2. Review of related literature

2.1 Overview of Schiff bases

Schiff bases are the condensation product of a primary amine and carbonyl compound. From the reaction product, the formed compound is $R_1R_2C=NR_3$. In these molecular compound R_1 , R_2 and R_3 can represent a different group, where R_1 is an aryl group, R_2 is a hydrogen atom and R_3 is either an alkyl or aryl group. Aryl substituents of this ligand is substantially more stable and readily synthesized. But Schiff bases of aliphatic aldehyde is relatively unstable and readily polymerizable [14]. The aromatic aldehydes of these ligand having effective conjugation is more stable. In general, aldehydes react faster than ketones in condensation reactions, leading to the formation of these compounds as the reaction center of aldehydes are sterically less hindered than that of ketone. Furthermore, the extra carbon of ketone donates electron density to the azomethine carbon and thus makes the ketone less electrophilic compared to aldehydes [15]. The bidentate, tridentate, tetra dentate or polydentate (Figure 2) Schiff base have capable to form very stable complexes with transition metals. Because of these, ligands can bear a functional group that they can act as coordinate ligands, usually the hydroxyl, sufficiently near the site of condensation in such a way that a five or six membered ring can be formed when reacting with a metal ion [16].

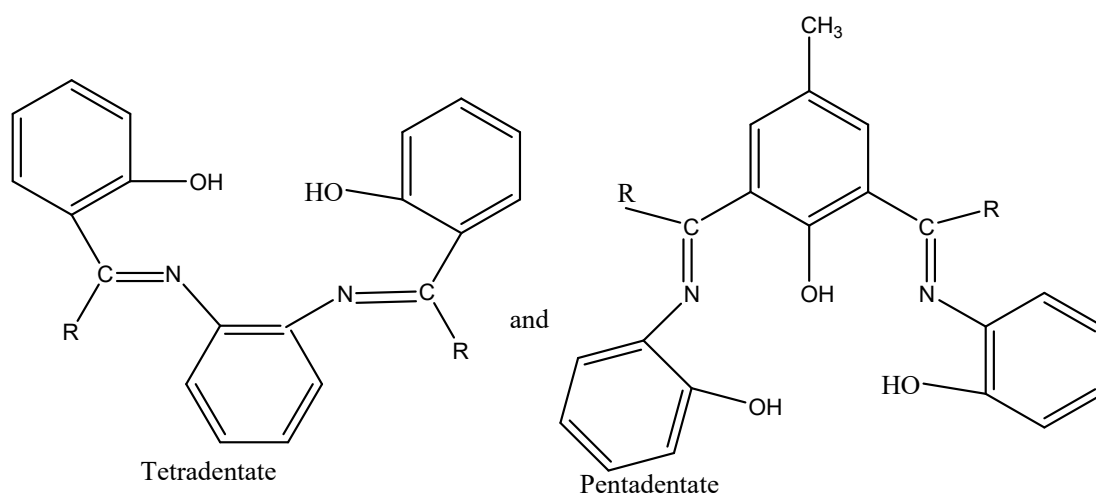


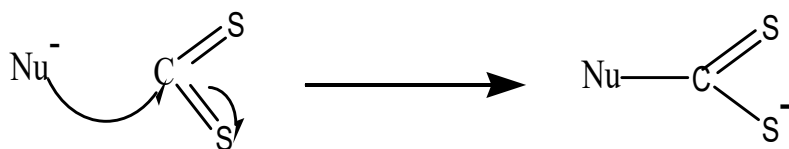
Figure 2. Tetra dentate and pentadentate molecules

2.2. Chemistry and biological importance of Schiff bases.

Schiff bases have a large number of synthetic uses in organic chemistry. Acylation of Schiff bases by acid anhydrides, acid chlorides and acyl cyanides is initiated by the attack at the nitrogen atom and leads to the net addition of the acylating agent to the carbon-nitrogen double bond. Reactions of this type have been put to good use in natural product synthesis. Schiff bases appear to be an important intermediate in a number of enzymatic reactions involving the interaction of an enzyme with an amino or a carbonyl group of the substrate [16]. One of the most important types of the catalytic mechanism is the biochemical process which involves the condensation of a primary amine in an enzyme usually that of a lysine residue, with a carbonyl group of the substrate to form an imine, or Schiff base. Stereo-chemical investigation carried out with the aid of molecular model showed that Schiff base formed between methyl glyoxal and the amino group of the lysine side chains of proteins can bent back in such a way towards the N atom of peptide groups that a charge transfer can occur between these groups and oxygen atoms of the Schiff bases [16]. In the present work 1, 10-phenanthroline compound used as a Schiff base to synthesize the metal complexes.

2.3 Overview of dithiocarbamate

Dithiocarbamates belongs to a class of compounds known as 1,1-dithioles and this group of the compound also includes the thiophosphates, dithiophosphinates, dithiocarbamate and other related compounds. A major class of sulfur-containing ligands is obtained by the general reaction of carbon disulfide with various nucleophiles. Carbon disulfide enters into the reaction with a variety of nucleophiles (Scheme 2). Its reaction with nucleophiles such as RO^- , RNH^- and R_2N are of considerable interest; the products in these cases are o-alkyldithiocarbonates (xanthates), N-mono alkyl dithiocarbamates and N, N-dialkyl dithiocarbamates respectively. From these types of compounds, the $(\text{R}_2\text{NCS}_2^-)$ are the semi-amides of dithiocarbamic acid. The structure of these mono anionic 1,1-dithio ligand can be described by four resonance structure [17]



Scheme 2. Nucleophilic attack of carbon disulfide

Dithiocarbamate has considerable industrial and technological significance and has a variety of uses. Organic dithiocarbamate has received much attention due to their pivotal role in agriculture and their intriguing biological activities. Recently they are used in the synthesis of ionic liquids. Their chelating properties allow them to be used as antidotes against nickel and copper poisoning (Wilson's disease), in analytical determination of heavy metals, in waste water treatment and as rubber vulcanization accelerators. In the field of medicine, these compounds also find application in the treatment of chronic alcoholism and in fungi and bacteria related diseases, and they have also received some attention as potential auxiliaries in oncological chemotherapy and in the prevention of arteriosclerosis [17].

2.4 Metal coordination chemistry

Metal coordination compounds are often referred to as metal complexes. Such complexes consist of a coordination center (metal or ion) and molecules that bind to it called ligands. The set of the ligands makes the coordination sphere around the metal center. The number of ligand atoms bonded to the metal is called its coordination number. A homoleptic complex is when the ligands are the same type, otherwise it is heteroleptic. A metal complex can be cationic, anionic or neutral depending on the sum of the charges of the metal centers and the ligands. It can form a mono-, di- or poly nuclear molecule [18]. The challenging topics now a day in the chemistry of metal complexes are the aspects where the unique chemical properties of transition metals can be used; their usage in catalysis and optical and magnetic devices; in biological field – chemotherapy or use as optical triggers and probes of proteins. The metal complexes find applications as dyes, pigments, drugs and contrast agents [19].

2.5 Dithiocarbamate metal complexes

Dithiocarbamate ligands have shown the ability to stabilize of metal centers in a variety of oxidation states and can coordinate to a wide range of transition metals. Dithiocarbamate ligands have been found to act as uninegative bidentate ligand coordinately through both Sulphur atoms, in both tetra- and hexa-coordination transition metal complexes. An extremely large number of dithiocarbamate complexes with a transition and non-transition metal ions have been known. A large number of metal complexes with various aliphatic and aromatic dithiocarbamate ligands have been synthesized and characterized in the past few years [20].

Copper (II) dithiocarbamate were first reported by Delphine as water-insoluble precipitates obtained when aqueous Cu (II) ions were treated with aqueous solutions of the R_2Dtc^- ligands. Copper forms dithiocarbamate complexes in both +1 and +2 oxidation states. The Cu (I) dithiocarbamate are pale yellow to reddish-yellow diamagnetic solids and their melting points decrease with increasing size of the alkyl groups on the ligands. The substituted dithiocarbamates of Cu (II) are stable compounds and under acidic conditions do not decompose to CS_2 and the amine salt [20, 21]. Zinc has a strong affinity for chalcogenide ligands with RS^- or ArS^- groups. Zinc complex of dithiocarbamate is used as antioxidants, antimicrobial and anti-abrasive in motor oils [23].

2.6 Copper

Copper can form three oxidation states which may have different geometries: Cu (I), Cu (II) and Cu (III) and the geometry of the central atom depends on the oxidation state (Table 1). The Cu (0) compounds are not confirmed as stable, however, reactive intermediates do occur [22].

Table 1. Oxidation state and stereochemistry of copper

Oxidation state	Coordination number	Geometry
Cu (I) d^{10}	4	Tetrahedral
	5	Square pyramidal
Cu(II) d^9	4	Square planar
	6	Octahedral, distorted octahedral

2.6.1 Copper (II) complexes

Most copper (I) compounds can be oxidized to copper (II) compounds, but further oxidation to copper (III) compounds is more difficult. The copper (II) complexes have d^9 electron configuration. This configuration of copper is characteristic of Jahn-Teller distortion for regular octahedral or tetrahedral symmetry, which has an effect on its stereochemistry. A typical distortion for 6-coordinate is an elongation along one four-fold axis so that there is a planar array of four short Cu-L bonds and two trans long ones [22].

Four-coordinate complexes with chelate ligands have mostly square planar coordination geometry. In some cases, however, the additional ligands form a very elongated octahedron or where the dimerization of type presented in (Figure 3). For the β form of bis (8-quinolinolato) copper (II), where each metal atom is 5-coordinate.

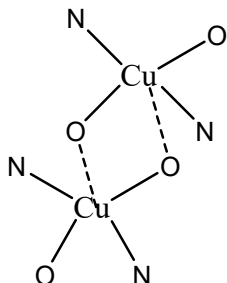


Figure 3. A schematic structure of the β form of bis (8-quinolinolato) copper (II), in which each copper atom is 5-coordinate.

The copper complexes are generally blue or green. Sometimes they can appear as red or brown due to the strong UV absorption of charge-transfer transitions. The most common colors that appeared in the region of 600-900 nm spectrum is due to the presence of weak d-d transitions. Copper (II) forms many binary complexes with halides or salts of oxo acids such as $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$. Many copper (II) complexes can be obtained by treating aqueous solutions with ligands. Copper (II) carboxylates, which are easily made by an interaction of the acid with CuCO_3 , form binuclear complexes with four carboxylate bridges [22]. Copper (II) forms enormously many complexes with the nitrogen donor ligands (polydentate aliphatic amine ligands and heterocyclic nitrogen donor ligands) [19].

2.6.2 Biological properties of copper

Many researchers were interested to use copper elements in the synthesis of complex due to an essential element for life. It is associated with a number of copper-dependent enzymes that are key in biological processes. The most important copper-dependent enzymes in mammals are listed in (table 2) [23].

Table 2. Recognized copper-dependent enzymes and their biochemical function

Cu-dependent enzyme	Function
Cytochrome C oxidase	Cellular utilization of oxygen
Superoxidase dismutase	Disproportionation of superoxide
Tyrosinase (catechol oxidase)	Synthesis of dopa from tyrosine
Dopamine-B-hydroxylase	Synthesis of norepinephrine from dopamine
Alfa-Amidating enzyme	Modifies the C-terminal ends of hypothalamic peptide hormones ending in glycine
Diamine oxidase	Inactivation of histamine and polyamines
Amine oxidase (extracellular)	Inactivation of histamine, tyramine, dopamine, serotonin
Peptidylglycine monooxygenase	Bioactivation of peptide hormones
Hephaestin	Ferroxidase, in trans-golgi of enterocytes; aids iron absorption homology to ceruloplasmin

Elevated copper levels in plasma can be important for the etiology of some illness [24]. For example, copper ions are closely involved in neurodegenerative disorders [25]. Moreover, there has been interest in the medical uses of copper, in particular as a complexing ion of known biologically active ligands and drugs. Throughout the years of scientific research copper (II) complexes have been found to possess various antimicrobial activities [27-33].

2.6.3 Copper complexes with antimicrobial and antifungal activity

There are many studies that show the antimicrobial activity of copper (II) complexes with different ligands [34]. Common anti-bacterial agents have been also used as ligands to complex with copper ions. It was noticed that the antimicrobial activity against *M. Smegmatis* of a metal ion complex in comparison to free ciprofloxacin, a bacterial gyrase inhibitor, increased three times [35].

It may result from facilitated diffusion of the drug through the cell membranes, presumably by an increase in the lipophilicity of the drug [36]. The activity against *Streptococcus* can also be influenced by the slow release of the ligands inside the bacterial cell. This was noticed with the copper complex of isoniazide and ethambutol. It seems that intercellular reduction of Cu (II) into Cu (I) can activate the oxygen which is toxic for bacteria [37]. In general, copper (II) complexes show antimicrobial activity against both types; Gramm (+) (*Staphylococcus aureus*, *Bacillus subtilis*) and Gramm (-) (*Escherichia coli*, *Pseudomonas aeruginosa*), More often though a slightly higher activity is found in Gram (-) bacteria [38].

2.7 Zinc

Zn belongs to the group 12 elements following copper in the periodic table. While copper can give rise to compounds in oxidation states II and III, but metals of group 12 can't form. Zinc is therefore not classified in to the group of transition elements. Nevertheless, it forms numerous complexes. The oxidation state of II is the only important one for Zinc (table 3) [22].

Table 3. Stereochemistry of Zinc.

Oxidation state	Coordination number	Geometry
Zn (II)	2	Linear
	3	Planar
	4	Tetrahedral
	5	Trigonal bipyramidal
	5	Square pyrimidal
	6	Octahedral

2.7.1 Biological properties of zinc

The element of Zinc can be found in a variety of tissues, such as skin, bone, liver, muscle, or brain of a human body. In fact, this element is the most abundant transition metal in the brain after iron [39], and concentrations of Zinc may reach 0.1-0.5 mm in the gray matter of the brain. Zinc is an essential trace element. It is important for their biological activity as a constituent of proteins and enzymes that belong to cellular signaling pathways.

Zinc is important for the folding of DNA-binding domains of transcription factors (Zinc-finger and hormone receptor families) [40]. Also it has a variety of effects on the nervous system. It is used in regulating the aspects of cellular metabolism, including protein, hormone, transcription and replication functions [41]. However, the in excess levels of Zinc can lead to neuronal death [42]. Both Zinc overload and deficiency lead to pathologic processes in the central nervous system [43]. For example, zinc deficiency has been noticed in patients with head and neck cancer. Zinc is also required for the biological activity of such proteins as metallothioneins and alfa-2 macroglobulin, which protect the cells from the oxidative damage and therefore prevent the cell death. Metallothioneins belong to the family of intracellular metal-binding proteins that play a key role in the effect of Zinc on the immune system [44].

2.7.2 Zinc complexes with antimicrobial activity

Zn (II) complexes of different ligand appeared to have good antibacterial activity; e.g., a strong inhibitive effect was noticed towards *E. coli* and *S. aureus* [45]. In the search for zinc (II) complexes of known antimicrobial drugs strong antibacterial activity has been achieved; e.g. the interaction between zinc and the gyrase inhibitor ciprofloxacin and various nitrogen-donor ligands have been studied and the complexes were found more effective than the drugs alone [46]. Zinc (II) complexes with amino acids have been developed with antimicrobial activity. The antibacterial activity of zinc (II) complex with S-phenylalaninato ligand was greater than the simple metal salt. A very good inhibitory activity was also found by the yeast *Candida albicans* [47]. Another zinc (II) complex containing N-donor ligand also possessed strong antimicrobial activities [48]. Generally, in the present work commercial manufactured 1, 10-phenanthroline was used as Schiff base ligand and dithiocarbamate was synthesized from diphenylamine and carbon disulfide. Also, hydrated Copper and Zinc chloride was used to synthesize metal complex.

3. Materials and methods

3.1 Chemicals

Chemicals that were used for this study include $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ (Aldrich), $\text{ZnCl}_2 \cdot 6\text{H}_2\text{O}$, carbon disulfide, NaOH, 1, 10-phenantroline and diphenylamine which are AR reagents grade bought from Aldrich. Solvents such as ethanol, methanol, acetone, petroleum ether, dimethyl ether, dimethyl sulfoxide (DMSO) and chloroform was used. All the solvents employ 99% purity.

3.2 Instruments and apparatus

3.2.1 Apparatus

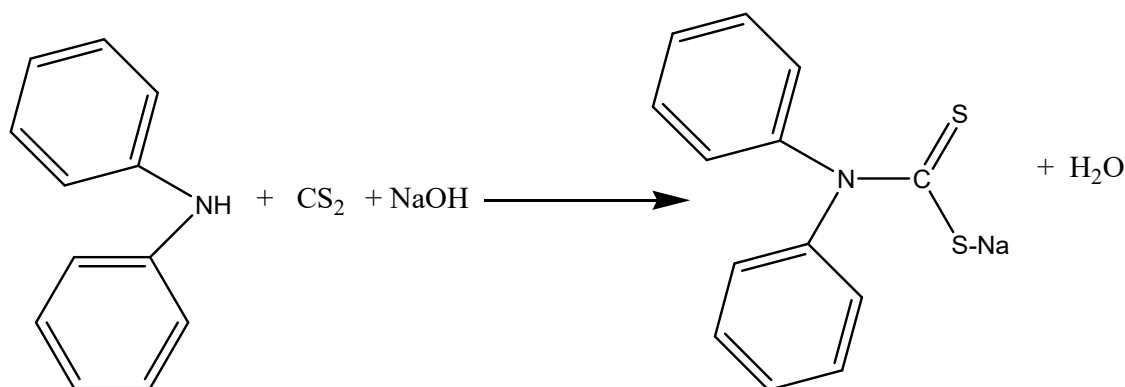
Polyethylene bottle, beaker, measuring cylinders, analytical digital balance, wash bottle, plastic bags, beakers, flat bottom flask, funnel, and cuvette were used.

3.2.2 Instruments

TLC with visualizing UV light, melting point apparatus, molar conductivity meter, UV-Visible spectroscopy, CHNS elemental analyzer (EA1112), Fourier Transform Infrared (FT-IR) spectrophotometer (PE IR SUBTECH SPECTRUM) in the range of 4000 cm^{-1} - 400 cm^{-1} in KBr medium. The ^1H and ^{13}C NMR spectra of the ligand was recorded in DMSO on Bruker ultra-shield TM 400 spectrometer using TMS as internal standard and AAS.

3.3 Synthesis of sodium diphenyl dithiocarbamate compound

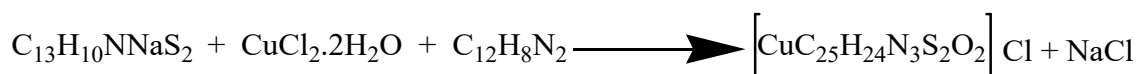
In a round bottom flask placed in an ice bath, diphenylamine (16.92 g, 0.1 mol) was dissolved in methanol (40 mL). Then, NaOH (4 g, 0.1 mol) which was dissolved in a minimum amount of distilled water and ice cold carbon disulfide (6.4 mL, 0.1 mol) was slowly added. The reaction mixture was stirred for 9 h. with periodically addition of crushed ice to keep the reaction temperature below $4\text{ }^\circ\text{C}$ which gave the white precipitate. The resulting white precipitate (Scheme 3) was filtered, washed several times with the petroleum ether followed by ice-cold methanol and dried in a desiccator over anhydrous CaCl_2 . The reaction completion was monitored by TLC [49].



Scheme 3. Formation of sodium diphenyl dithiocarbamate

3.4 Synthesis of $[\text{CuC}_{25}\text{H}_{22}\text{N}_3\text{S}_2\text{O}_2] \text{Cl}$.

The copper (II) complex was synthesized by mixing diphenyl dithiocarbamate, 1, 10-phenanthroline and $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ in ethanol. In round bottom flask, sodium diphenyl dithiocarbamate (2.29 g, 9.2 mmol) in ethanol (10 mL), 1, 10-phenanthroline (1.77 g, 9.2 mmol) in ethanol (10 mL) mixed and stirred for 5 minutes. Then, to the resulting mixture, $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ (1.55 g, 9.2 mmol) dissolved in 10 mL of ethanol was slowly added and immediately afforded black color that shows the formation of new compound. The black color was changed to deep green after stirred for 7 h. Finally, a colored precipitate obtained (scheme 4) was filtered and washed several times with petroleum ether to remove impurities and was dried in a desiccator over anhydrous CaCl_2 [50].

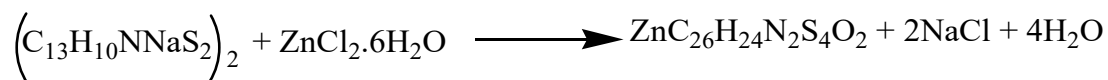


Scheme 4. Formation of $[\text{CuC}_{25}\text{H}_{22}\text{N}_3\text{S}_2\text{O}_2]\text{Cl}$.

3.5 Synthesis of $\text{ZnC}_{26}\text{H}_{24}\text{N}_2\text{S}_4\text{O}_2$

The Zn (II) complex was synthesized by mixing diphenyl dithiocarbamate and $\text{ZnCl}_2 \cdot 6\text{H}_2\text{O}$ in ethanol. In round bottom flask, a pre synthesized sodium diphenyl dithiocarbamate (4.58 g, 18.4 mmol) was dissolved in 15 mL of ethanol. Then, to the solution, $\text{ZnCl}_2 \cdot 6\text{H}_2\text{O}$ (1.24 g, 9.2 mmol) was slowly added and stirred for 7 h. While stirring, the white yellowish color precipitate was observed.

Finally, a colored precipitate obtained (Scheme 5) was filtered and washed several times with petroleum ether to remove impurities and was dried in a desiccator over anhydrous CaCl₂ [50].



Scheme 5. Formation of ZnC₂₆H₂₄N₂S₄O₂

3.6. Antibacterial Activities

Screening for antibacterial activity was carried out in sterilized antibiotic discs (6 mm), following the standards for antimicrobial disc susceptibility tests, outlined by the National Committee for Clinical Laboratory Standards (NCCLS). The density of the bacterial suspension was standardized by using a McFarland standard method. According to this standard protocol all the bioassays were carried out at 37 °C against four bacterial strain viz. *Escherichia coli*, *Pseudomonas aeruginosa* (Gram-negative) and *Bacillus subtilis*, *Staphylococcus aureus* (Gram positive). Gentamicin was used as a positive control to test bacteria, whereas DMSO was used as a negative control. In this method, liquefied agar medium having uniform thickness was poured in petri-plates. After solidification plates inoculate with test micro-organisms, after which filter paper discs dipped in the solution of ligand and metal complexes dissolve in DMSO (100 µg/mL) and gentamycin was placed in each quadrant of the plate. Plates were first kept at 4 °C for 2 h. to allow for diffusion of chemicals, follows by incubation at 37 °C.

3.7 Antifungal activities

Fungicidal activity of tested complexes was assessed against *Fusarium Oxysporum* by disc diffusion method [51]. Testing method, the base layer was obtained by pouring about 10-15 mL of base layer medium into each sterilized Petri dishes and was allowed to attain room temperature. Overnight grown subcultures of fungi are mixed with layer medium and immediately was poured into petri dishes containing the base layer and then allowed to attain room temperature. Antifungal discs having diameter of 6 mm, was soaked in test solution, are dispensed on to the surface of inoculated agar plate. Each disc must be pressed down to ensure its complete contact with the agar surface. These plates were subsequently incubated at 37 °C for 24 h. The zone of inhibition was measured in mm for the particular complex. Zinc oxide and DMSO was used as a positive and negative control respectively.

4. Results and discussion

4.1 Physical properties of the compounds

The sodium diphenyl dithiocarbamate, 1, 10-phenanthroline and its mixed ligand metal complexes were characterized by the different physico-chemical properties such as TLC analysis, chloride test, conductivity measurement, melting point, Elemental analysis, FT-IR spectroscopy, NMR Spectroscopy, and UV-visible spectroscopy. The synthesized ligand and its metal complexes are soluble in water and most organic solvents such as methanol, ethanol, dimethyl sulfoxide and insoluble in petroleum ether and diethyl ether. The physical properties of the synthesized compounds are summarized in the following (Table 4).

Table 4. Physical properties of the ligand and its metal complexes

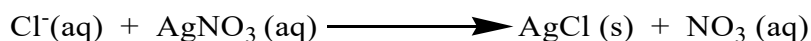
Compounds	Molecular formula	Molecular weight (g/mol)	Color	% Yield	M.pt (°C)
1,10-phe.	C ₁₂ H ₈ N ₂	180	White		117
Diphenyl dtc	C ₁₃ H ₁₀ NNaS ₂	267	White	68.8	63-67
Cu complex	[CuC ₂₅ H ₂₂ N ₃ S ₂ O ₂]Cl	558	Deep green	73.62	248-250
Zn complex	ZnC ₂₆ H ₂₄ N ₂ S ₄ O ₂	589	White yellowish	79.61	222-224

4.2 TLC test

The Purity of the synthesized ligand and its metal complex was checked on TLC plates and a single spot was visualized under ultraviolet light. For this purpose, the compound was dissolved in Ethanol. Ethanol was used as eluting agent. Also, the purity of the synthesized compounds was checked by melting point as described above (Table 4).

4.3 Chloride analysis

The presence of chloride ion in the complexation of titled complex compounds were checked by chloride test. The result of chloride test in inner coordination sphere of both synthesized complexes indicate the absence of chloride ion in the inner coordination sphere. On the other hand, copper complex and zinc complexes dissolved in methanol in separated beaker and 0.1N of the AgNO₃ solution was added slowly to the solution. As a result, copper complex shows white precipitate (Scheme 6) which indicate the formation of AgCl (s). This results confirm the presence of chloride ion in the outer coordination sphere of the synthesized complex compound. But zinc complex cannot form white precipitate which confirm the absence of chloride ion in outer coordination sphere.



Scheme 6. Formation of silver chloride

4.4 Molar conductivity measurement.

The molar conductivity measurements of the metal complexes in DMSO at room temperature provides information about the presence of chloride ion in the synthesized complexes. The measurement afforded specific conductance (K) of 87.2 μS/cm for the copper complex and 19.6 μS/cm for the zinc complex. The molar conductivity (Λ_M) of the complexes were calculated using the relation Λ_M = 1000K/C (where C is the molar concentration of the metal complex solution and K is specific conductance). The synthesized copper complex indicate 1:1 electrolytes in nature and may be formulated [CuC₂₅H₂₂N₃S₂O₂]Cl, implying the non-coordination of chloride anion to the central metal ion and shows one chlorine ion in outer coordination sphere. But the molar conductivity value of zinc complex shows non-electrolytic nature that confirm the absence of an ion in outer coordination sphere. The conductivity value of chelated complex appeared in the range of (50 - 90) Ω⁻¹ cm²mol⁻¹ in DMSO shows 1:1 electrolytic nature and below 50 Ω⁻¹ cm²mol⁻¹ indicate non-electrolytic nature of the complex [51, 52].

Table 5. Conductivity value of the synthesized complex compounds

Complexes	Solvent	Molar conductivity (Λ_M) ($\Omega^{-1} \text{ cm}^2 \text{ mol}^{-1}$)	Electrolytic nature
[CuC ₂₅ H ₂₂ N ₃ S ₂ O ₂]Cl	DMSO	87.2	1:1 electrolytic
ZnC ₂₆ H ₂₄ N ₂ S ₄ O ₂	DMSO	19.6	Non-electrolytic

4.5 Elemental analysis

Elemental analysis can give an idea about the presence of carbon, hydrogen, nitrogen and Sulfur in the ligands and complexes which provide a method to determine the empirical formula of the complexes. The elemental analysis result of the synthesized ligand and its metal complexes is presented as follows (Table 6).

Table 6. Elemental analysis of the ligand and its complexes

Compounds	Found (calculated) %				
	C %	H %	N %	S %	M %
Diphenyl DTC sodium salt	59.80 (58.42)	4.31 (3.74)	5.60 (5.24)	21.67 (23.97)	-
[CuC ₂₅ H ₂₂ N ₃ S ₂ O ₂]Cl	53.29 (53.76)	3.67 (3.94)	7.63 (7.52)	10.22 (11.46)	11.66 (11.29)
ZnC ₂₆ H ₂₄ N ₂ S ₄ O ₂	52.74 (52.97)	4.21 (4.07)	4.85 (4.75)	20.55 (21.73)	11.10 (11.04)

4.6 Estimation of metal ions by AAS

The metal content in the complexes were determined using the atomic absorption spectroscopy following a uniform procedure. Based on the absorbance data, the percent of metal in the complex was calculated using the following formula.

$$\%M = \frac{\text{Concentration (ppm)} \times \text{Volume diluted} \times 100}{\text{mass of sample taken} \times 1000}$$

The metal percentage obtained from this calculation was used to assess the molecular mass of the complex as well as the metal to ligand ratio in the complex. The percentage of copper in the complex was determined to be 11.66, while the theoretically calculated percentage composition of copper in the synthesized copper complex is 11.21. whereas the percentage of zinc in the complex was determined to be 11.10% in experimental value and 11.04% as theoretically calculated from the percentage composition of zinc in the synthesized complex.

Based on the data obtained from AAS supported with elemental analysis the proposed chemical formula of the copper (II) and zinc (II) complex is $[\text{CuC}_{25}\text{H}_{22}\text{N}_3\text{S}_2\text{O}_2]\text{Cl}$ and $\text{ZnC}_{26}\text{H}_{24}\text{N}_2\text{S}_4\text{O}_2$ respectively.

4.7 UV-Visible spectrum of the ligand and its complexes

The electronic spectra data of the ligand and its metal complexes were recorded at room temperature in (DMSO) solution at 200-800 nm and summarized in (Table 8) with their assignments. The electronic spectra of diphenyl DTC (Appendix 1) in DMSO shows a band at 270 nm which can be assigned to ($\pi \rightarrow \pi^*$) transitions [53]. Also, another broad band observed at 314 nm is may be due to ($n \rightarrow \pi^*$) which is located in sodium diphenyl dithiocarbamate. The electronic spectra of the synthesized sodium diphenyl dithiocarbamate is different from the diphenylamine which shows the formation of expected ligand as supported by IR spectrum. The electronic spectra of Schiff base 1, 10-phenanthroline in DMSO (Appendix 2) high intensity band appeared as a doublet with two maximum absorptions at 321 nm and 342 nm attributed to ($\pi \rightarrow \pi^*$) transition and a band observed at 370 nm indicate ($n \rightarrow \pi^*$) transition [54, 55]. The electronic spectra of copper (II) complex (Appendix 3) exhibit two absorption bands at 321 nm and 734 nm. The first band 321 nm is assignable to the metal to ligand charge transfer. The second band at 734 nm is assigned to be d-d electronic transition, indicating the complex have distorted octahedral geometry. Though in the cases where the ${}^2\text{E}_g$ and ${}^2\text{T}_{2g}$ states of the octahedral Cu (II) ion split under the influence of the tetragonal distortion, the two transitions $b_{2g} \rightarrow b_{1g}$ and $e_g \rightarrow b_{1g}$ are expected, their very close energies could have made them appear in the form of one broad band envelope. Especially in octahedral d^9 complexes, John-Teller effect is the most pronounced when an odd electron occupies the E_g orbitals [56].

Zinc complex (Appendix 4) displayed a band at 305 nm indicates metal to ligand charge transfer and the ground term symbol shows no splitting with d^{10} configuration because of d-orbitals are completely occupied by electrons. In the spectra of metal complexes, the bands are hypochromically (blue shift) affected clearly, suggesting the ligands have coordinated to the metal ions. Supported with FT-IR spectrum and elemental analysis, the octahedral geometry was proposed with the possible assignment charge transfer which is consistent with a literature report [53, 57, 63]

Table 7. Electronic spectral data of the ligand and its complex

Compounds	Absorption maximum		Band Assignments	Geometry of the complexes
	(nm)	cm^{-1}		
1,10-phen.	321, 342 370	31153, 29240	$\pi \rightarrow \pi^*$ $n \rightarrow \pi^*$	-
$\text{C}_{13}\text{H}_{10}\text{NNaS}_2$	270 314	38760, 37037	$\pi \rightarrow \pi^*$ $n \rightarrow \pi^*$	-
$[\text{CuC}_{25}\text{H}_{22}\text{N}_3\text{S}_2\text{O}_2]\text{Cl}$	321 734	31,153 13624	CT $b_{2g} \rightarrow b_{1g}, e_g \rightarrow b_{1g}$	Distorted octahedral
$\text{ZnC}_{26}\text{H}_{20}\text{N}_2\text{S}_4\text{O}_2$	305	32787	CT	octahedral

4.8 FT-IR spectrum of the ligand and its metal complexes

The important IR frequencies of synthesized free ligands and its metal complexes are summarized in (Table 9). In order to get information about the coordination behavior of the ligands of diphenyl DTC and 1, 10-phenanthroline, comparison of the infrared spectra of the free ligand and their complexes were made. As reported from the literature the bands observed at the region of 1500-1430 and 1100- 950 indicates the vibration frequency of $\nu(\text{C-N})$ and $\nu(\text{CSS}^-)$ respectively [53]. In the present finding of diphenyl DTC ligand (Appendix 5), the stretching vibration band observed at 1024 cm^{-1} indicate the presence of CSS bond in the molecule of the compound. While another stretching vibration band of carbon- nitrogen bonds of NCSS^- group appeared at 1496 cm^{-1} .

The band observed at 1321 cm^{-1} due to the presence of C-N group of diphenyl DTC [58]. These three appeared bands of our interest indicates the formation of a dithiocarbamate compound which is comparable with the literature report [58].

The FT-IR spectra of the Cu (II) complexes (Appendix 6) showed the presence of differences functional group in the compound. The frequency observed at 3434 cm^{-1} is due to the intermolecular hydrogen bonding as well as O-H stretching vibration of the water molecules. The $\nu(\text{C-H})$ stretching vibration band coordinating in aromatic compound observed at 3051 cm^{-1} . The stretching vibration band observed at 1519 cm^{-1} is due to the presence of $\nu(\text{C=C})$ group of titled ligand which participates in the complexation [59]. The stretching vibration bands observed at 1433 cm^{-1} is due to the presence of carbon-nitrogen bonds of NCSS group by undergoing hypsochromic shift which means that the sulfur atoms involved in coordination. In the present finding, also the observed band at 1035 cm^{-1} corresponding to bidentate symmetrical coordination of the dithiocarbamate group which is similar as reported [53]. Furthermore, the bands of coordinated water observed at the range of 853 cm^{-1} support the proof that there is the presence of water in the lattice of the complexes [60, 61, 62]. Copper-oxygen, Copper-nitrogen and Copper-Sulphur bands were further confirmed as coordination sites by the presence of the stretching vibrations of $\nu(\text{Cu-O})$, $\nu(\text{Cu-N})$ and $\nu(\text{Cu-S})$ bonds observed at 559 cm^{-1} , 479 cm^{-1} and 442 cm^{-1} respectively [63, 53]. These three important vibration bands were not observed on FT-IR spectrum of the ligand which indicated coordination of the ligand to the metal ion. The M-Cl vibration occurs at the far infra-red region.

Similarly, the FT-IR spectra of zinc complex (Appendix 7) show a band at 3436 cm^{-1} assigned to OH stretching vibration in water molecule which bonded to the metal atom. The other observed band at 3056 cm^{-1} is due to the presence of C-H stretching molecule on the aromatic ring of diphenyl dithiocarbamate [58]. The stretching vibration bands observed at 1422 cm^{-1} and 1048 cm^{-1} is assigned to NCSS and CSS group in dithiocarbamate compound respectively. These two bands indicate the presence of dithiocarbamate in the molecule of complex compound [60, 61, 62, 63]. The other stretching vibrational bands observed at 492 cm^{-1} and 442 cm^{-1} are assigned to Zn-O, and Zn-S respectively. These two bands confirmed the coordination of water molecule and diphenyl dithiocarbamate with the metal atom which not observed on FT-IR spectra of the ligand [53].

Table 8. FT-IR spectral data (cm⁻¹) of the ligand and its metal complexes

Compounds	OH	C-H	C=C	NCSS	CSS	M-O	M-N	M-S
C ₁₃ H ₁₀ NNaS ₂	-	3071	1597	1496	1024	-	-	-
[CuC ₂₅ H ₂₂ N ₃ S ₂ O ₂]Cl	3434	3051	1519	1433	1035	559	479	442
ZnC ₂₆ H ₂₄ N ₂ S ₄ O ₂	3436	3056	1516	1422	1048	492	-	442

4.9 NMR spectrum

4.9.1 ¹H-NMR and ¹³C-NMR Spectra of diphenyl DTC

The ¹H-NMR spectrum of diphenyl DTC (Appendix 8) shows a peak at chemical shift 8.32 ppm corresponding C-H proton on the phenyl ring which attached to the carbon that attached to the most electronegativity of nitrogen group (Ortho position). The other chemical shift appeared at 8.15 ppm indicates C-H proton on para position of diphenyl dithiocarbamate. Also there is another chemical shift that indicate C-H proton on meta position of aromatic diphenyl appeared at 7.84 ppm which consistent with values in the literatures [64, 65]. The ¹³C-NMR spectra of diphenyl DTC (Appendix 9) intense chemical shifts shown at δ 143.88 ppm indicate carbon atoms where bounded with a strongly electronegative element such as nitrogen and Sulphur (-NCS₂). The peak appeared at chemical shift δ 129.62 ppm indicates two carbon atoms on diphenyl dithiocarbamate which is bonded to the nitrogen atom. The other peak appeared at chemical δ 120.10 ppm corresponding to carbon on Orto position of aromatic diphenyl dithiocarbamate and the last chemical shift appeared at 117.17 ppm indicates two carbon atoms on aromatic diphenyl dithiocarbamate which is far from the most electronegativity atom as reported in the literature [66].

4.9.2 ¹H NMR and ¹³C-NMR spectra of Zn complex

The ¹H NMR data spectrum of Zn complex (Appendix 10) shows peak at the chemical shift of δ 8.89 ppm is assigned to CH proton of diphenyl dithiocarbamate that attached to carbon atom which is bonded to nitrogen atom (¹H of Orto position). The long intense singlet peak, appeared at chemical shift of δ 8.27 ppm indicates the equivalent environment of symmetric protons in diphenyl group that appeared at para position of diphenyl dithiocarbamate.

The less intensity peak found at the chemical shift of δ 8.04 ppm shows protons of diphenyl dithiocarbamate appeared at meta position in the diphenyl ring which consistent values with literatures [65, 66]. The chemical shift of proton found on phenyl is shifted downfield, which reveals the bonding of diphenyl dithiocarbamate to zinc ion. The ^{13}C -NMR spectra of the zinc complex (Appendix 11) exhibit weak signals at chemical shift δ 149.25 ppm assign to NCS_2 carbon atom of the diphenyl dithiocarbamate compound. It is highly deshielded due to the carbon atom is bonded with strong electronegativity group of nitrogen and Sulphur atoms. The chemical shift appeared at 140.26 ppm display the presence of carbon atoms that bonded to electronegativity of the nitrogen group on diphenyl dithiocarbamate ligand. The intensity peak appeared at chemical shift of δ 129.27 ppm indicates carbon atoms of diphenyl group having the same chemical environment which bonded to the carbon that bonded to most electronegativity of nitrogen atom. The other peak found at chemical shift of δ 127.65 ppm indicates the carbon atoms having the same chemical environment found on diphenyl ring that is far from the most electronegativity group. The last peak appeared at δ 126.06 ppm is due to the carbon atoms which have same chemical environment found on the middle of diphenyl dithiocarbamate ring (meta position) as reported in the literatures [65, 67, 68].

Table 9. ^1H NMR and ^{13}C NMR spectral data of the DPDTC ligand and its zinc complex

Compounds	^1H NMR		^{13}C NMR	
	Chemical shift	Assignment	Chemical shift	Assignment
$\text{C}_{13}\text{H}_{10}\text{NNaS}_2$	8.32	^1H of Orto position	143.	NCSS
	8.15	^1H of para position	129.67	C-N of phenyl
	7.81	^1H of meta position	120.10	C-C-N on (phenyl)
117.5			C-C-C-N on(phenyl)	
$\text{ZnC}_{26}\text{H}_{24}\text{N}_2\text{S}_4\text{O}_2$	8.89 - 8.85	^1H of Orto position	149.25	NCSS
			140.26	C-NCSS
	8.27	^1H of para position	129.27	C on Orto position
	8.02 - 8.04	^1H of meta position	127.65	C on para positon
			126.06	C on meta position

Based on the analytical data, the following structural compounds (Figure 4) are proposed for the synthesized metal complexes.

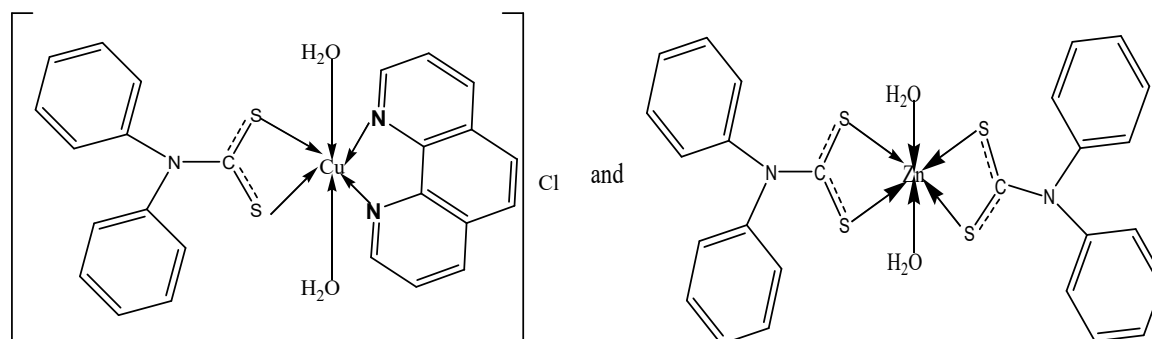


Figure 4: The proposed structure of metal complexes

4.10 Antimicrobial activity test

The individual ligands; 1, 10-phenanthroline and diphenyl dithiocarbamate and its mixed ligand of copper (II) complex and zinc (II) complex were screened against four human pathogenic bacteria namely *Staphylococcus aureus*, *Bacillus subtilis* (gram-positive), *Pseudomonas aeruginosa*, and *Escherichia coli* (gram-negative) using disc diffusion method. Also the ligand and its metal complexes were screened against one human pathogenic fungus namely fusarium using the same method. Activity was determined by measuring the diameter zones of inhibition in (mm) and the standard drugs used as positive control were zinc oxide and gentamycin for fungus and bacterial strain respectively. Whereas dimethyl sulfoxide was used as negative control (10).

Table 10. Antimicrobial activity of the ligand and its complexes

Compounds	Zone of inhibition (mm)				
	Bacterial strain				Fungus
	<i>B. Subtilis</i>	<i>S. aureus</i>	<i>E. coli</i>	<i>Ps. aeruginosa</i>	<i>F. Oxysporum</i>
1,10-phen.	20	22	20	20	25
DPDTC	8	7	6	7	11
[CuC ₂₅ H ₂₂ N ₃ S ₂ O ₂]Cl	25	28	26	29	26
ZnC ₂₆ H ₂₄ N ₂ S ₄ O ₂	23	25	29	25	30
Gentamycin	18	24	28	28	NT
Zinc oxide	NT	NT	NT	NT	19
DMSO	NI	NI	NI	NI	NI

NI= no Inhibition, NT= not tested

Diphenyl dithiocarbamate was not active against selected bacterial strain. The measured inhibition zone showed (Appendix 12) 8 mm and 6 mm against bacillus subtilis and *Escherichia coli* respectively. But it showed 7 mm against *S. aureus* and *Ps. aeruginosa*. Also 1, 10-phenanthroline showed identical activities 20-22 mm against selected bacterial strain (Appendix 13).

Based on inhibition zones (Appendix 14), Cu complex appeared to display the strongest to inhibitory effect (25-29 mm). The most susceptible microorganism towards copper (II) complex was *Pseudomonas aeruginosa*, whereas the most resistant bacteria was *Bacillus subtilis* with inhibition zones of 25 mm and 29 mm respectably. Also the inhibition zones of zinc (II) complex (Appendix 15) appeared to display the stronger to inhibitory effect (23-29 mm). The inhibition zones against *Bacillus subtilis* was 23 mm and *Escherichia coli* was 29 mm. In comparison to gentamycin, the inhibition zone against *Bacillus subtilis* was 18 mm and *Escherichia coli* was 29 mm. The mixed ligand metal complexes involving diphenyl dithiocarbamate and 1, 10-phenanthroline showed better antibacterial activity compared to those of diphenyl dithiocarbamate and 1, 10-phenanthroline ligand (figure 5).

The reason behind of this result can be defined chelation is tended to make the ligand to act as a more powerful and potent bacterial agent. The antimicrobial activity of the mixed-ligand complexes may be attributed to the fact that dithiocarbamate and 1, 10-phenanthroline are known to possess antimicrobial property; hence, their structural combination gave rise to heteroleptic metal complexes with improved antimicrobial character. Also, the presence of metal ions in the compound increased toxicity of the ligands towards the microbes. The variation in the effectiveness of different compounds against different organisms depends either on the impermeability of the cells of the microbes or on differences in ribosome of microbial cells [69, 70, 71].

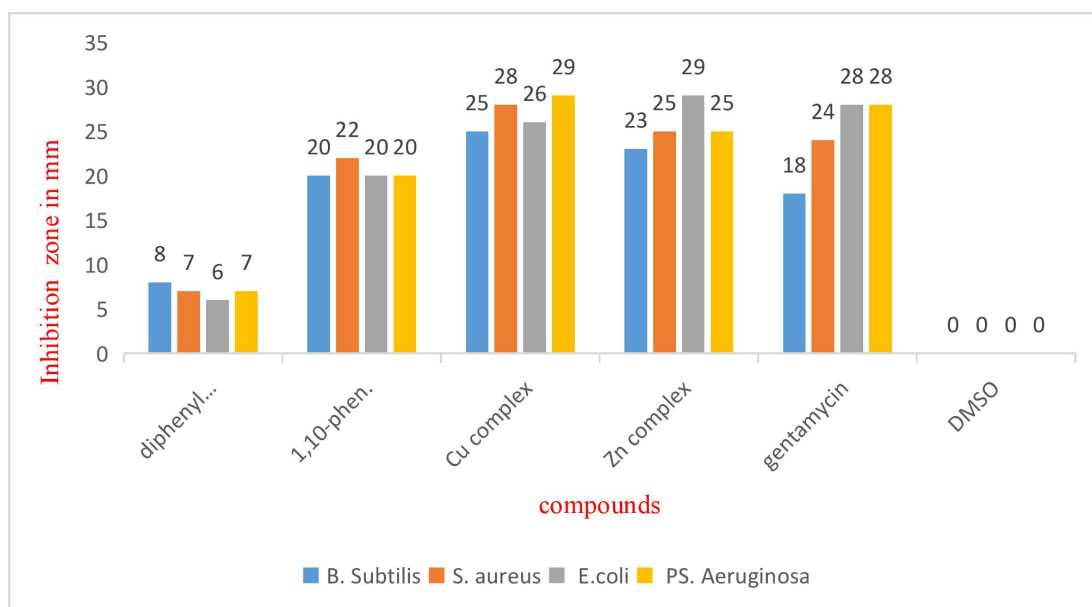


Figure 5: The antibacterial test of compounds.

The ligands and its metal complexes were also screened against one human photogenic fungus by disc diffusion method (Table 10). The metal complexes exhibited moderate to high activity against one selected fungi stain. From comparative study $ZnC_{26}H_{24}N_2S_4O_2$ is more active than the ligands and $[CuC_{25}H_{22}N_3S_2O_2]Cl$. This behavior may be attributed to the effective interaction between the metal complex and the receptor molecules (amino acids) [72].

5. Conclusion and Recommendation

5.1 Conclusion

The current research involves synthesis, characterization and antimicrobial study of zinc (II) diphenyl dithiocarbamate and copper (II) complex containing 1, 10-phenanthroline and diphenyl dithiocarbamate. Diphenyl dithiocarbamate has been synthesized from diphenylamine and carbon disulfide. The synthesized ligand and its metal complexes were characterized by melting point, chloride test, molar conductivity, elemental analysis, AAS, FT-IR, NMR and UV-vis spectroscopy. The conductivity measurements data indicates that Cu (II) complex is 1:1 electrolyte in nature and Zn (II) complex is non-electrolytic in nature. The electronic spectra along with IR spectral data support proposed octahedral geometry of Zn (II) complex and distorted octahedral geometry of Cu (II) complex. The Cu (II) complex of FT-IR spectrum shows bidentate 1, 10-phenanthroline ligand coordinated to the central metal through Pyridine-N groups and bidentate diphenyl dithiocarbamate ligand coordinated to the metal atom through sulfur group. Also, it indicates the presence of water molecule which is bonded to the central metal. FT-IR spectra of Zn (II) complex indicate coordination of bidentate Sulphur group and water molecule to the zinc ion. Antimicrobial activities of the ligand and its complexes have also been studied. From comparative study, antibacterial activity of $[\text{CuC}_{25}\text{H}_{22}\text{N}_3\text{S}_2\text{O}_2]\text{Cl}$ complex was more effective against selected human pathogenic bacteria except for *Escherichia coli*. But $\text{ZnC}_{26}\text{H}_{24}\text{N}_2\text{S}_4\text{O}_2$ complex showed greatest inhibition zone against *Escherichia coli* and selected fungus strain. The variation in the effectiveness of different complexes against different organisms may be due the effective interaction between the metal complex and receptor molecules.

5.2 Recommendation

The method used to synthesize this metal complexes is limited to direct method but it is also appreciable to use other methods. The in vitro activity of the synthesized mixed ligand metal complexes of diphenyl dithiocarbamate and 1, 10-phenanthroline are effective towards some human pathogenic bacteria. But it needs to study in vivo activity for further drug analysis. The application studied in this work is limited to antimicrobial test only, but, it is important to study other applications such as catalytic activity as far as possible. The work done in this thesis is limited to use the titled ligands, so it is important to synthesize this metal complexes by other derivative of dithiocarbamate and Schiff base ligand.

6. References

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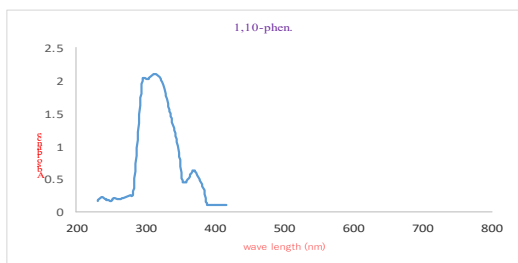
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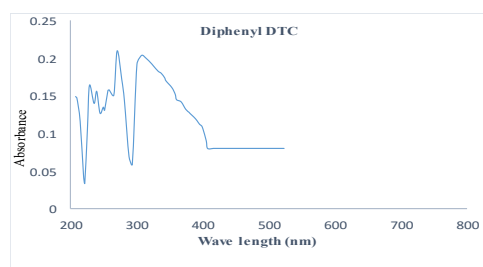
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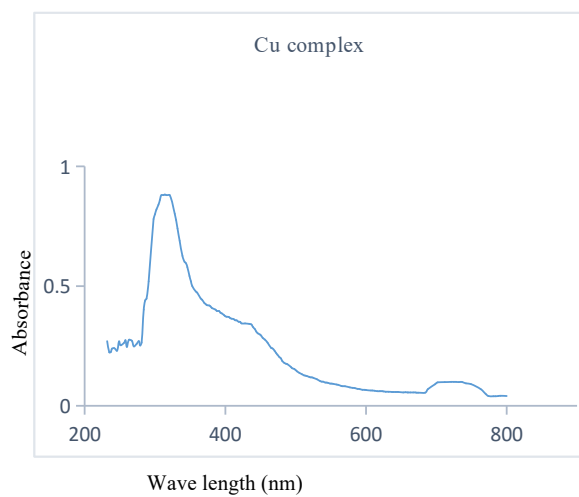
7. Appendices



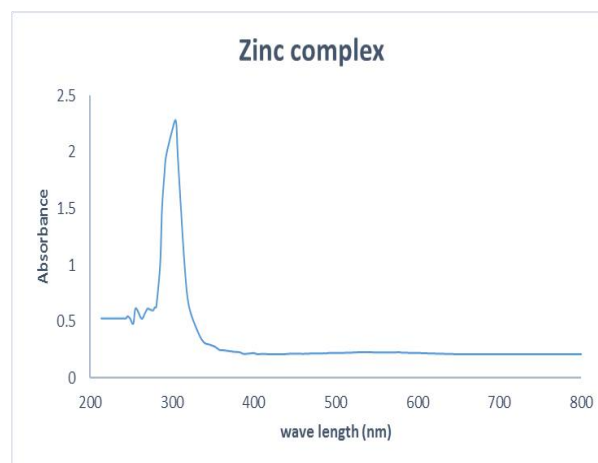
Appendix figure 1; UV-Visible spectrum of 1,10-phen.



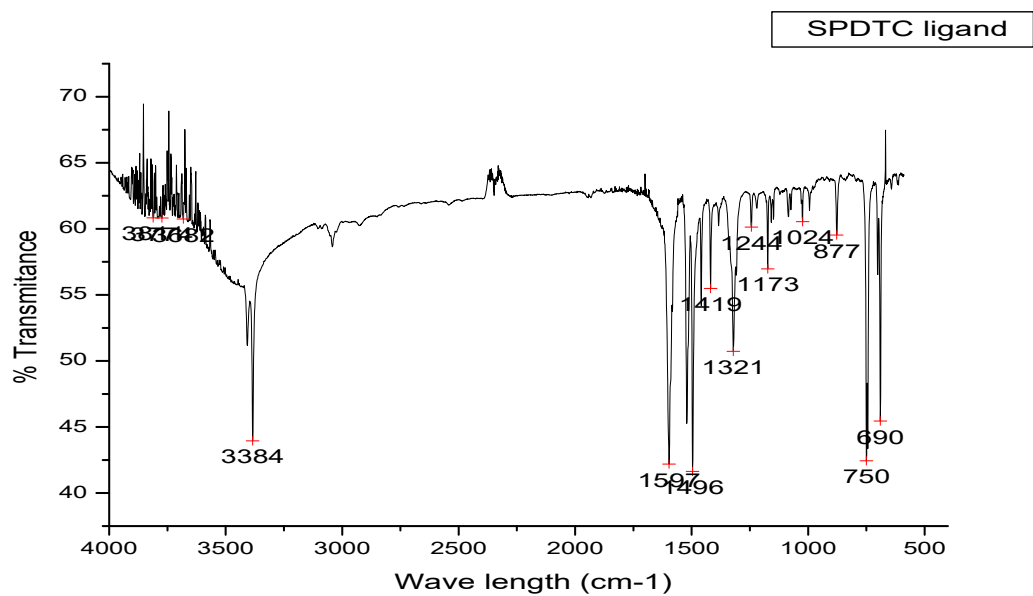
Appendix figure 2; UV-visible spectrum of SPDTC



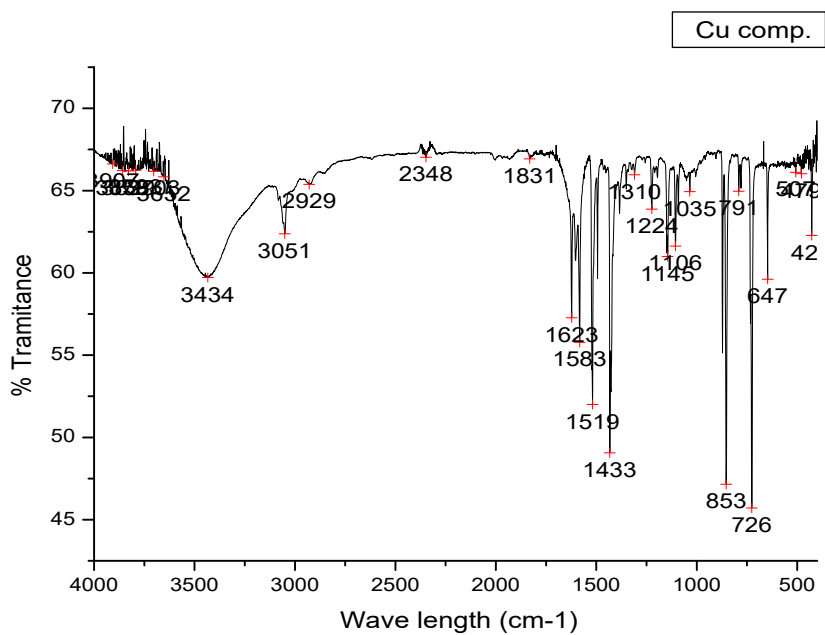
Appendix figure 3; UV-visible spectrum of Cu complex



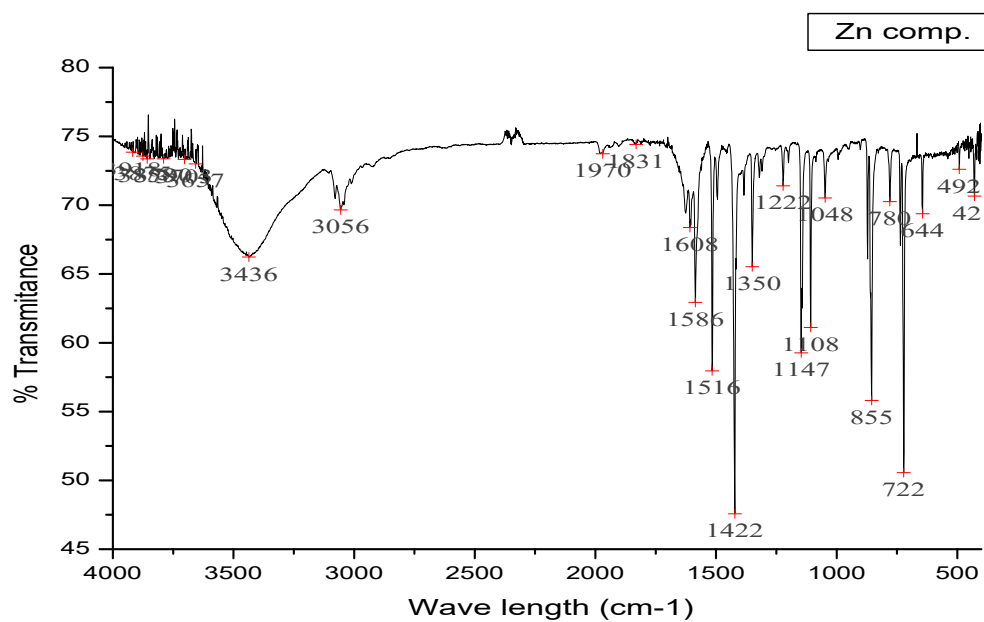
Appendix figure 4; UV-visible spectrum of Zn complex



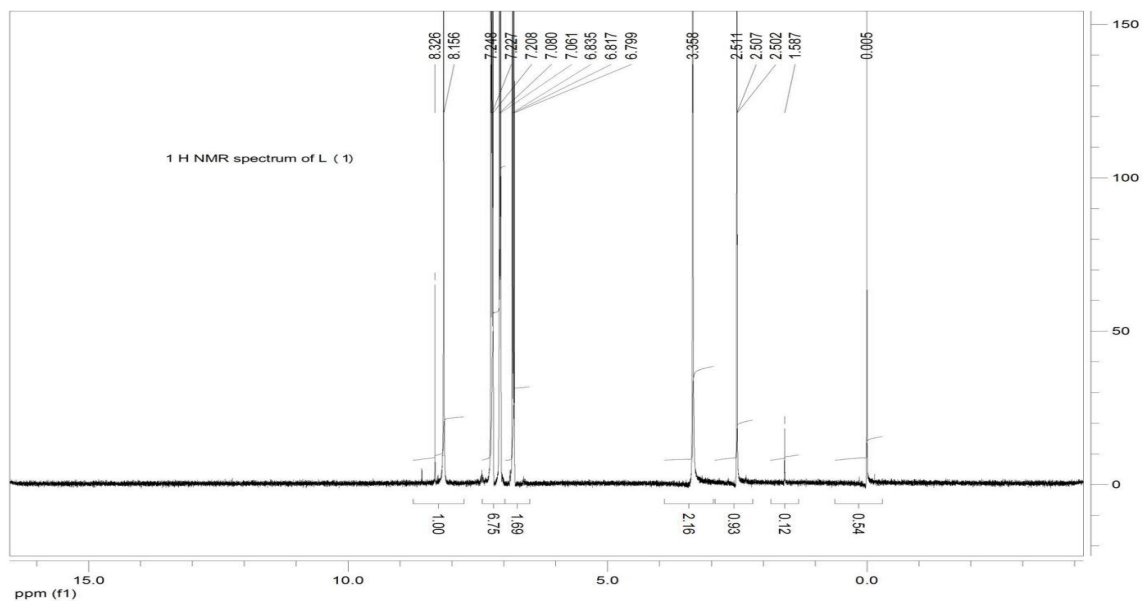
Appendix figure 5; FT-IR spectrum of SPDTC



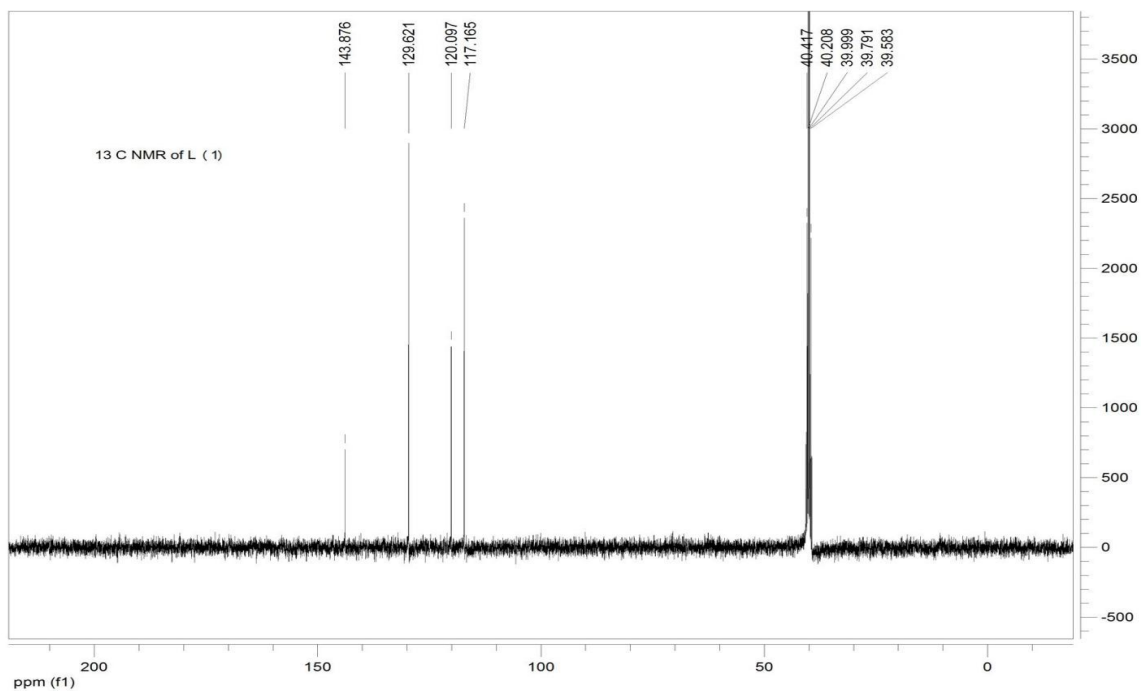
Appendix figure 6; FT-IR spectrum of copper complex



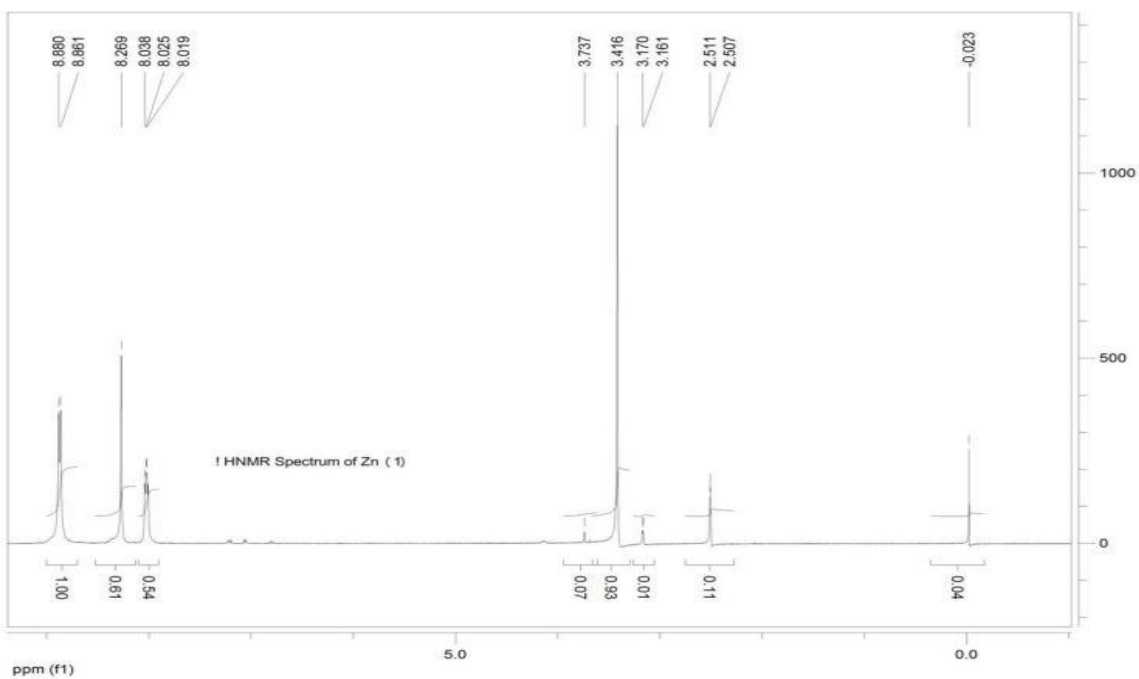
Appendix figure7; FT-IR spectrum of Zn complex



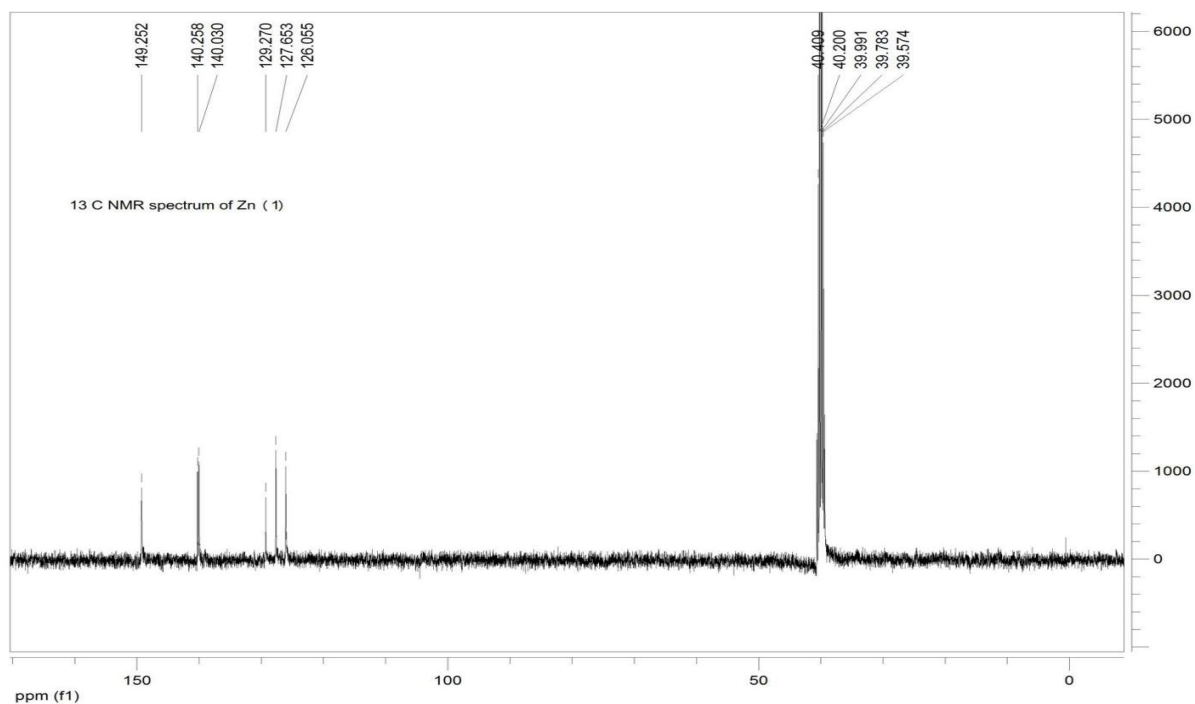
Appendix figure 8; ¹H NMR spectrum of DPDTC



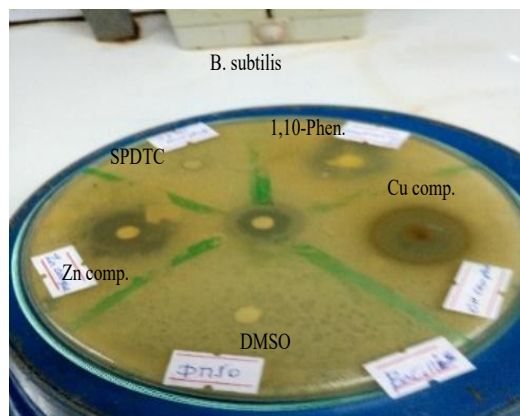
Appendix figure 9; ¹³C NMR spectrum DPDTC



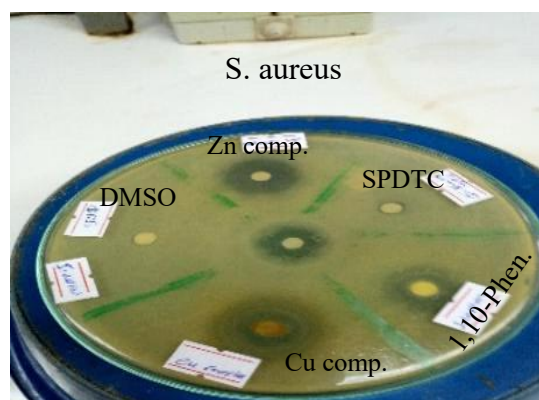
Appendix figure 10; ¹H NMR spectrum of Zn complex



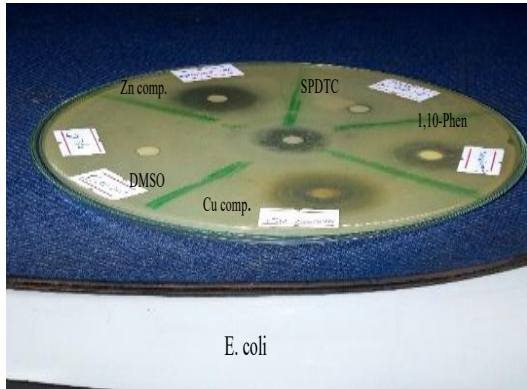
Appendix figure 11; ¹³C NMR spectrum of Zn complex



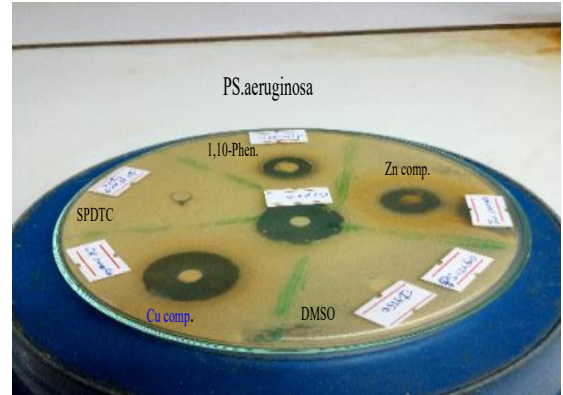
Appendix figure 12; Inhibition zone of *B. subtilis*



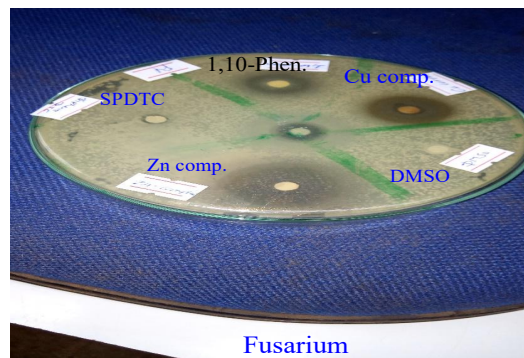
Appendix figure 13; Inhibition zone of *S. aureus*



Appendix figure 14; Inhibition zone of *E. coli*.



Appendix figure 15; Inhibition zone of *Ps. aeruginosa*



Appendix figure 16; Inhibition zone of *Fusarium*