University of Benghazi

Faculty of Science

Department of Chemistry

Synthesis, Characterization and Biological Activity of Divalent Transition Metals Schiff base Complexes Derived from 3, 3’, 4, 4’-Biphenyltetramine and Salicylaldehyde

Thesis
Submitted in partial fulfillment of the requirements for the degree
of Master in Chemistry Science

by:

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بسم الله الرحمن الرحيم

سورة التوبة أي(105)ـة

DEDICATION

TO MY

PARENTS, SISTER, BROTHER
AND HUSBAND

Abstract

Schiff base ligand and its complexes of divalent metal ions [Fe(II), Co(II), Ni(II) and Cu(II)] of 3,3',4,4'-tetra(salicylideneimino)-1,1 biphenyl were synthesized and characterized by using elemental analysis, thermal analyses, infrared , electronic spectra and ^{1}H- NMR spectral studies. Elemental and spectral data show that complexes are formed with 2:1 [M:L] molar ratio. Tetradentate Schiff base ligand with a $2N_2O_2$ donor atoms coordinate to ions to forming the corresponding complexes. Antibacterial and antifungal activity of the synthesized ligand and its complexes was tested against selected pathogenic bacteria and fungi. The ligand and its complexes possess microorganism activity, the complexes show higher than that of the free ligand.

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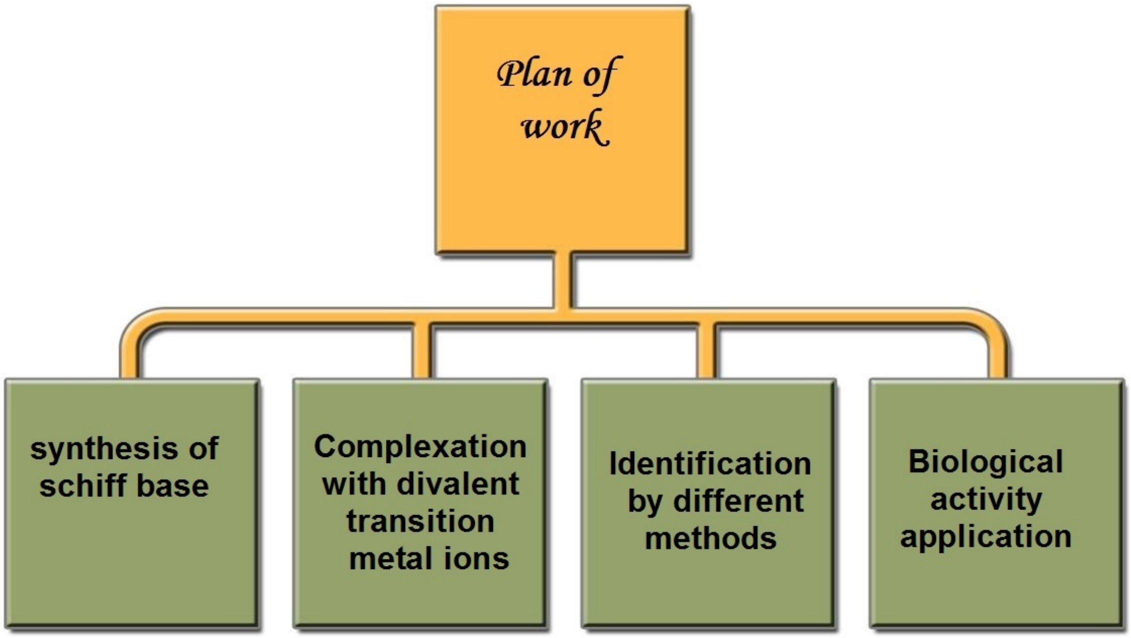
Hala S. AL-Alagi

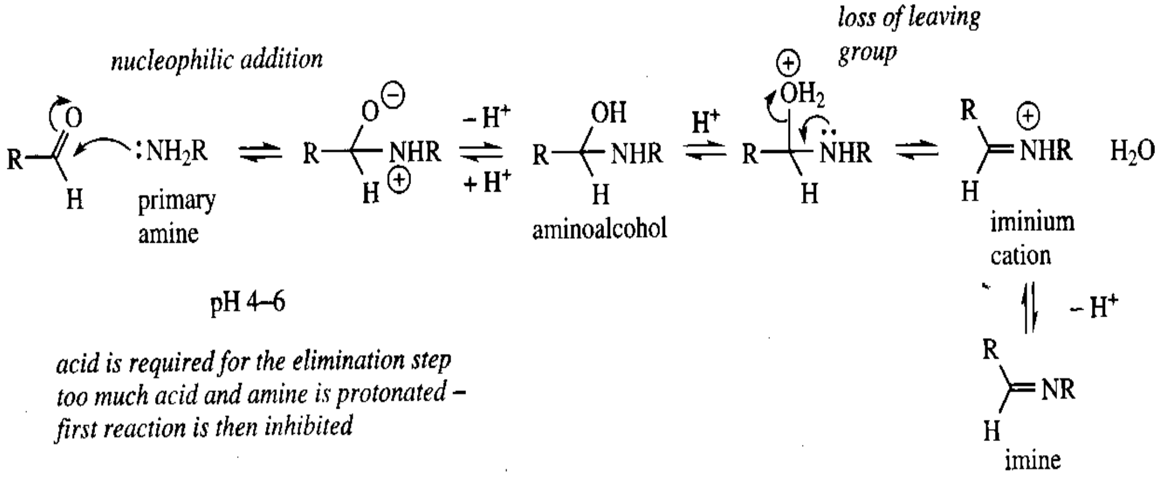
Aim of the work:



The aim of this research work will be directed toward the synthesis and characterization of symmetrical tetradentate Schiff base complexes of Co(II), Ni(II), Cu(II) and Fe(II) derive from 3,3',4,4'-biphenyltetramine and salicylaldehyde and screen their antibacterial activity on some pathogenic bacteria and fungi.

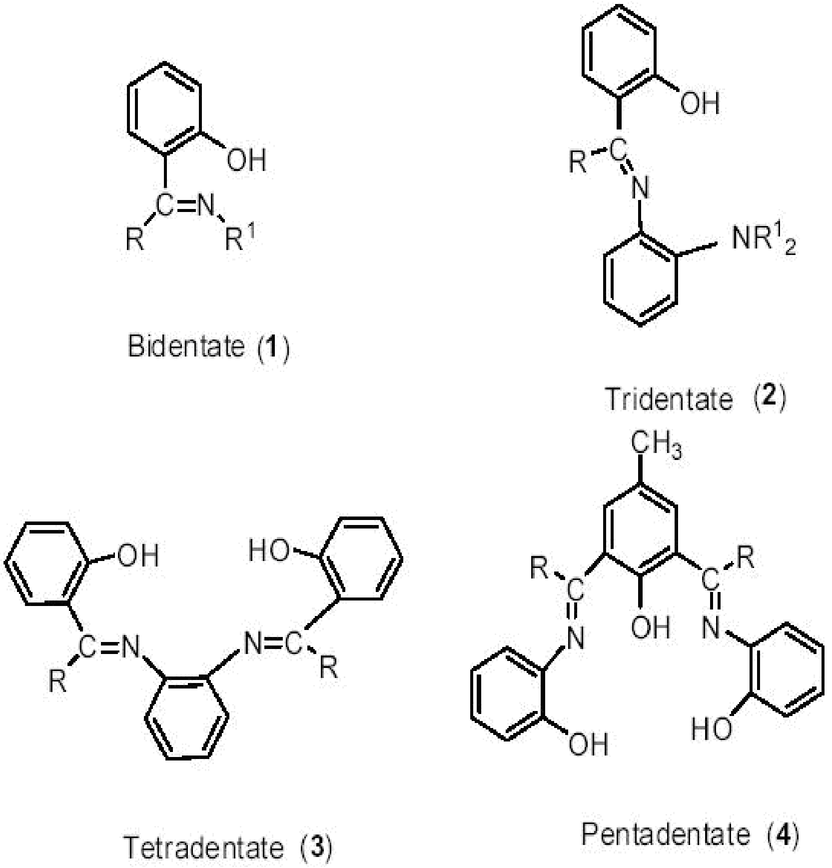
1.1. Schiff bases

Schiff bases have been playing an important role in the development of coordination chemistry. Schiff base metal complexes have been studied extensively due to their attractive physical properties and also, their wide applications in numerous scientific areas [1,2]. Schiff bases were typically formed by the condensation of a primary amine and an aldehyde/ketone. The resultant compound, $R_1R_2C{=}NR_3$, is called a Schiff base (named after Hugo Schiff), where R_1 is an aryl group, R_2 is a hydrogen atom and R_3 is either an alkyl or aryl group. However, usually compounds where R_3 is an alkyl or aryl group and R_2 is an alkyl or aromatic group are also regarded as Schiff bases. Schiff bases that contain aryl substituents are substantially more stable and more readily to synthesize, while those which contain alkyl substituents are relatively unstable. Schiff bases of aliphatic aldehydes are relatively unstable and readily polymerizable[3], while those of aromatic aldehydes having effective conjugation are more stable. In general, aldehydes react faster than ketones in condensation reactions, leading to the formation of Schiff bases as the reaction centre of aldehyde 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 aldehyde[4]. The mechanism of imine formation begins as nucleophilic addition to the carbonyl group, in this case the nucleophilic is the amine which reacts with the aldehyde or ketone to give an imines [5]. In the first stage of the reaction, the amine added to the carbonyl group to give a species known as a carbinolamine, **Scheme (I)**. Once formed the carbinolamine undergoes dehydration to yield the product of reaction, an N-alkyl or N-aryl substituted imines [6].



Scheme (I): formation of Schiff base

Schiff bases are generally found as bidentate (**1**), tridentate (**2**), tetradentate (**3**) or polydentate (**4**) ligands **Scheme (II)** capable of forming very stable complexes with transition metal ions. They can only act as coordinating ligands if they bear a functional group, 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. Schiff bases derived from aromatic amines and aromatic aldehydes have a wide variety of applications in many fields, *e.g.*, biological, inorganic and analytical chemistry[7-9]. Applications of many new analytical devices require the presence of organic reagents as essential compounds of the measuring system.



Bidentate (**1**)

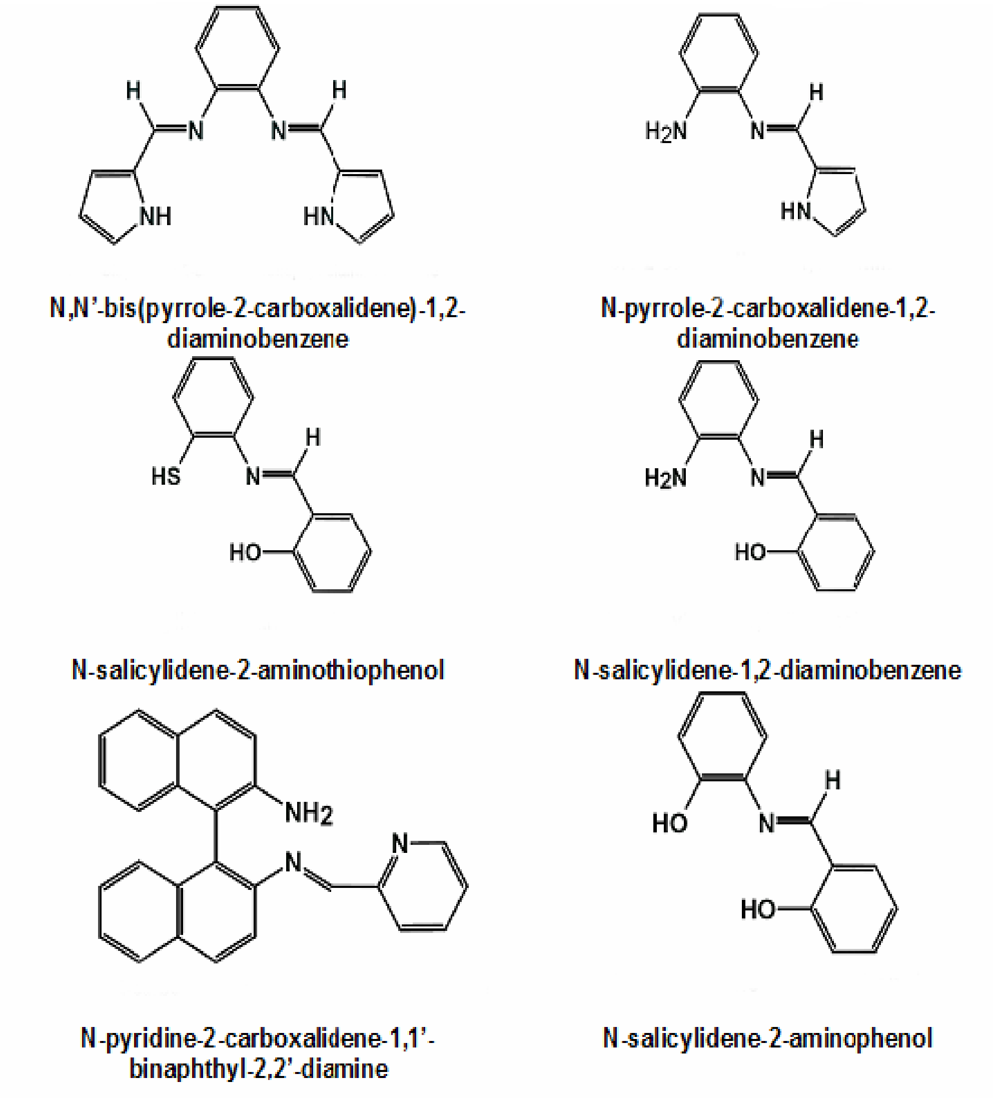
Tridentate (**2**)

Tetradentate (**3**)

Pentadentate (**4**)

Scheme (II): **Type of Schiff base ligands**

The common structural feature of these compounds is the azomethine group presence of a lone pair of electrons in an sp^2 hybridised orbital of nitrogen atom of the azomethine group is of considerable chemical importance and impart excellent chelating ability especially when used in combination with one or more donor atoms close to the azomethine group. Examples of compounds are given in **Scheme (III)**. This chelating ability of the Schiff bases combined with the ease of preparation and flexibility in varying the chemical environment about the C=N group makes it an interesting ligand in coordination chemistry.



N,N'-bis(pyrrole-2-carboxalidene)-1,2-diaminobenzene

N-pyrrole-2-carboxalidene-1,2-diaminobenzene

N-salicylidene-2-aminothiophenol

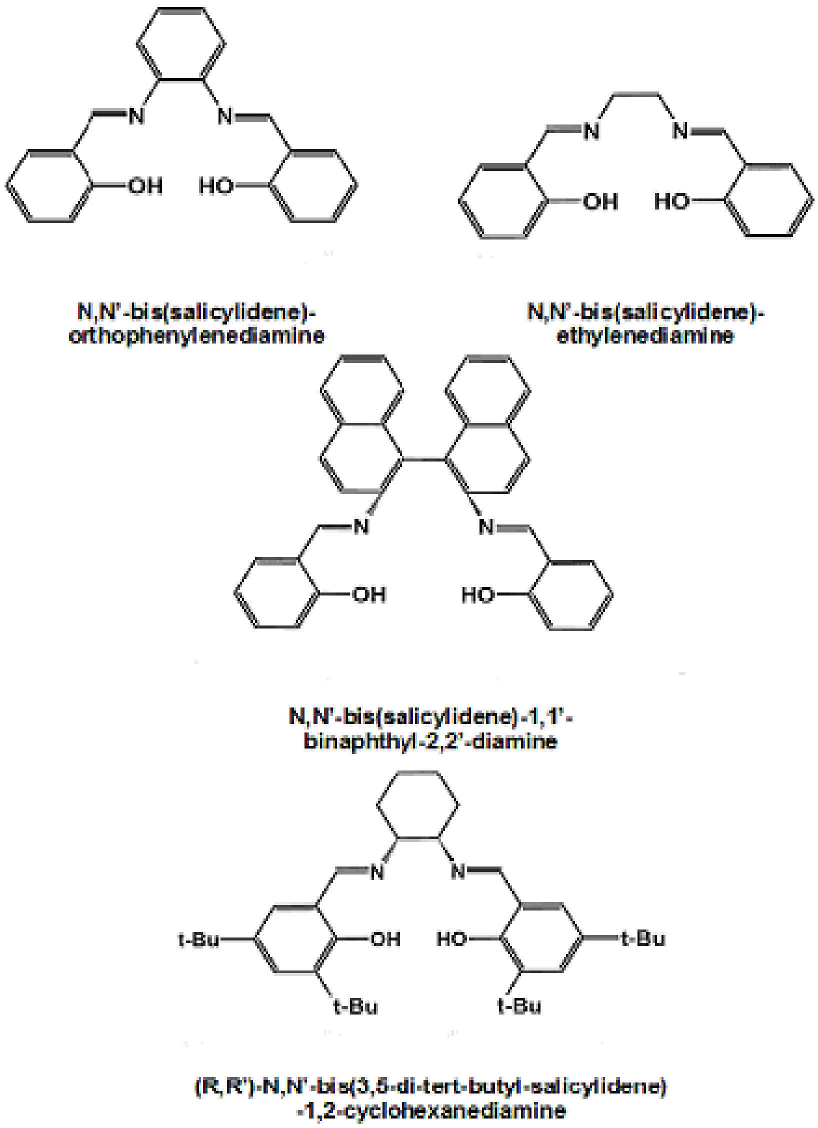
N-salicylidene-1,2-diaminobenzene

N-pyridine-2-carboxalidene-1,1'-binaphthyl-2,2'-diamine

N-salicylidene-2-aminophenol

Scheme (III): Examples of Schiff bases

When aldehyde is a salicylaldehyde derivative and amine is a diamine derivative, the condensation produces interesting N_2O_2 Schiff base compounds (salen) **Scheme (IV)**. Salen ligands are very much like porphyrins and, unlike the latter, can be easily prepared [10]. Although, the term salen was originally used only to describe the tetradentate Schiff bases derived from salicylaldehyde and ethylenediamine. Interest in the chemistry of metal chelates of tetradentate N_2O_2 Schiff bases has increased in recent decades, because of wide applications of these complexes in various fields[11].



N,N'-bis(salicylidene)-orthophenylenediamine

N,N'-bis(salicylidene)-ethylenediamine

N,N'-bis(salicylidene)-1,1'-binaphthyl-2,2'-diamine

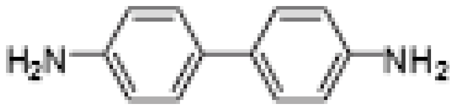
(R,R')-N,N'-bis(3,5-di-tert-butyl-salicylidene)-1,2-cyclohexanediamine

Scheme (IV): N_2O_2 Schiff base compounds

Schiff bases are used in optical and electrochemical sensors, as well as in various chromatographic methods, to enable detection of enhanced selectivity and sensitivity [12-14]. 3,3',4,4'-tetra(salicylideneimino)-1,1 biphenyl strongly inhibits bovine liver catalase in two distinct ways [15]. One of these was competitive with respect to H_2O_2. Among the organic reagents actually used, Schiff bases possess excellent characteristics, structural similarities with natural biological substances, relatively simple preparation procedures and the synthetic flexibility that enables design of suitable structural properties [16]. Schiff bases are widely applicable in analytical determination [17], using reactions of condensation of primary amines and carbonyl compounds in which the azomethine bond is formed (determination of compounds with an amino or carbonyl group); using complex formation reactions (determination of amines, carbonyl compounds and metal ions); or utilizing the variation in their spectroscopic characteristics following changes in pH and solvent[18]. Schiff bases play an important roles in coordination chemistry as they easily form stable complexes with most transition metal ions[19]. In organic synthesis, Schiff base reactions are useful in making carbon-nitrogen bonds.

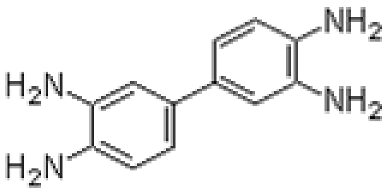
1.2. Benzidine

It is a well known compound **(scheme V)**, which has been widely used in the past in different areas of science. Benzidines also play an important role in cell biology and clinical work as valuable staining reagents. Due to its potential risks, research has been carried out to develop analogues for biological and medical purposes [20].



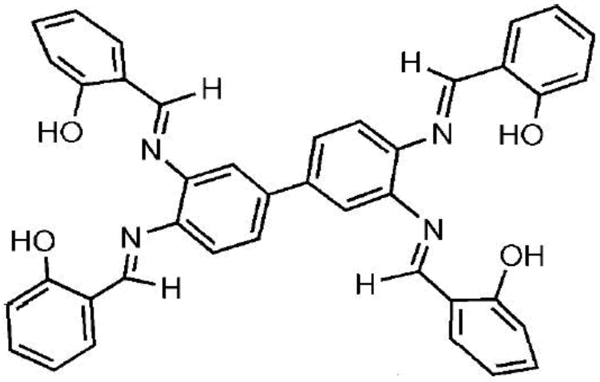
Scheme (V): Benzidine

The neutral 3,3',4,4- biphenyltetramine contains two *o*-phenylenediamine groups that are bonded together, as shown in **scheme (VI)**



Scheme (VI): 3,3-diaminobenzidine, 3,3',4,4- biphenyltetramine

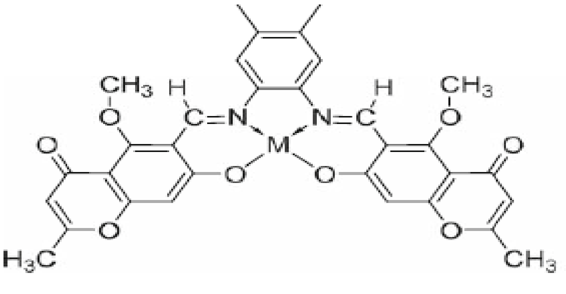
In this thesis, the diimines ligand, [H_4L] was obtained from the condensation of salicylaldehyde and 3,3',4,4-biphenyltetramine to give 3,3',4,4'-tetra(salicylideneimino)-1,1 biphenyl. Tetradentate Schiff base ligand ($C_{40}H_{30}N_4O_4$), **Scheme (VII)** with $2N_2O_2$ donor atoms coordinate with various metal ions, such as iron(II), cobalt(II), nickel(II) and copper(II) ions to form the corresponding complexes.



Scheme (VII): 3,3',4,4'-tetra(salicylideneimino)-1,1 biphenyl

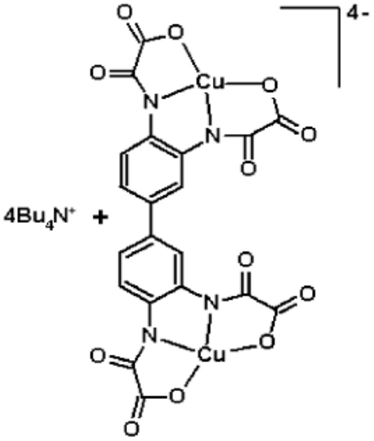
1.3 Literature survey

Schiff bases, named after Hugo Schiff (1834-1915), and their transition metal complexes continue to be of interest even after over a hundred years of study[21-24]. Schiff bases have a chelating structure and are in demand because they are straight forward to prepare and are moderate electron donors with easily-tunable electronic and steric effects thus being versatile [25]. Schiff base ligands can form adducts or chelates with metals depending on the reaction conditions used[26]. Review articles dealing with complexation of Schiff base ligands with metal ions have been published [27-33]. Structural modification of organic molecule has considerable biological relevance. Further, coordination of biomolecules to the metal ions significantly alters the effectiveness of the biomolecules[34]. Schiff bases derived from o-phenylenediamine have a variety of biological applications. The synthesis and antibacterial activity of bis – substituted benzylidene –1,2 phenylenediamine produced from condensation of o-phenylene diamine (II) with substituted salicylaldehyde or substituted o-hydroxoy acetophenone [35]. Four platinum(II) complexes of Schiff bases derived from salicylaldehyde and 2-furaldehyde with *o*- and *p*-phenylenediamine were reported [36]. Study of the coordination capability of two potentially tetradentate (N_2O_2) Schiff bases diamine ligands toward Co(II), Cu(II), Ni(II), and Fe(III) have been published [37], **Scheme (VIII)**.



Scheme (VIII): 6,60-(1E,10E)-(4,5-dimethyl-1,2-phenylene)bis(azan-1-yl-1-ylidene)bis(methan-1-yl-1-ylidene)bis(7-hydroxy-5-methoxy-2-methyl-4Hchromen-4-one)

Two complexes of Co(II) and Cu(II) ions with Schiff base derived from o-phenylenediamine and 2-hydroxyacetophonone have been synthesized. The antibacterial activity of the Schiff base and its complexes have been also studied, showing that the complexes were of higher antibacterial activity than the free Schiff bases [38]. A series of Mn(II) and Cu(II) complexes with Schiff bases derived from o-phenylenediamine have been prepared and characterized[39]. Copper based ligand using diaminobenzidine which has four coordination sites, opening possibilities to synthesize extended structures with magnetic interactions. where Cu_2(bopba) is a polydentate ligand, were successfully obtained and characterized by elemental analysis, IR-spectroscopy, X-ray diffraction and magnetic measurements [40]. **Scheme (IX)**.



Scheme (IX): Cu_2(bopba) complex

However, a brief survey of literature reveal that, not much work has been carried out on the chelating tendency of Schiff bases derived from salicylaldehyde and 3,3',4,4' biphenyltetramine with bivalent transition metal ions. In view of the above observation, it appeared worthwhile to study the synthesis, characterization and antimicrobial activity of metal complexes

1.4 Biological importance of Schiff bases

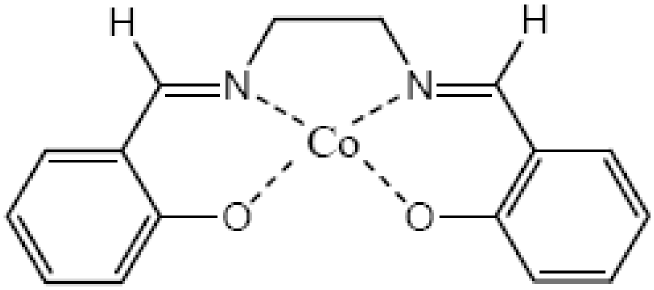
Many biologically important Schiff bases have been reported in the literature possessing, antimicrobial, antibacterial, antifungal, anti-inflammatory, anticonvulsant, antitumor and anti HIV activities [41-48]. Earlier work has shown that some drugs showed increased activity when administered as metal chelate rather than as organic compounds. The Cr(III), Fe(III) and Co(III) complexes formed form tetradentate (N_2O_2) Schiff base ligands, 1,4-bis[3-(2-hydroxy-1-naphthaldimine)propyl]piperazine and 1,8 bis[3-(2-hydroxy-1-naphthaldimine)-*p*menthane, show moderate antimicrobial activity [49], compared to standard antibiotics[50]. The antibacterial activity of the tridentate Schiff base, formed by condensation of 2-amino-3-carboxyethyl-4,5-dimethylthiophene with salicylaldehyde, was found to increase on chelation with transition metal ions [51]. Co(II), Ni(II), Cu(II) and Zn(II) complexes of the Schiff base derived from vanillin and DL-α-aminobutyric acid were also found to exhibit higher antibacterial activity compared to the free Schiff bases [52]. Several mono and binuclear transition metal complexes of the Schiff base derived from phenylaminoacetohydrazide and dibenzoylmethane, are more potent bactericides and fungicides than the ligand[53]. Binuclear copper(II) complexes having the Schiff base ligand, N,N'-bis(3,5-tert-butylsalicylidene-2-hydroxy)-1,3-propanediamine, have found to be effective in the cleavage of plasmid DNA without the addition of any external agents and in the presence of hydrogen peroxide at pH = 7.2 and 37 °C. DNA cleavage mechanism studies show that, complexes may be capable of promoting DNA cleavage through an oxidative DNA damage pathway[54]. The DNA electrophoretic mobility studies show that, these compounds interact with DNA either by a simple mode of coordination, leading to the formation of a DNA complex cationic adduct or by acting as chemical nucleases able to promote its degradation. Schiff bases appear to be important intermediates in a number of enzymatic reactions involving interaction of the amino group of an enzyme, usually that of a lysine residue, with a carbonyl group of the substrate [55]. The antibacterial activity of ligand and its complexes have been carried out against bacteria like *S.qureus, E.Coli, B.Subtilis* using nutrient agar medium by the well diffusion method.

The neutral tetradentate $2N_2O_2$ type complexes of iron(II), cobalt(II), nickel(II) and copper(II) ions have been investigated[56].

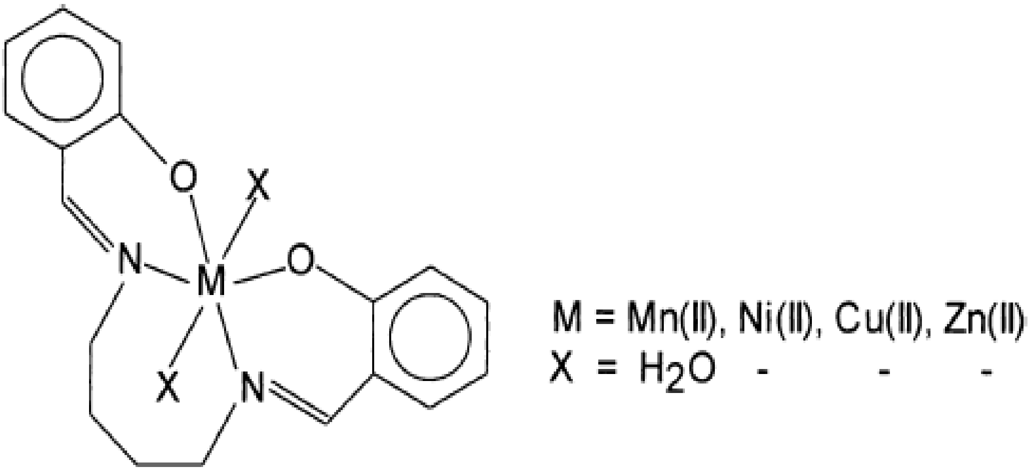
1.5 Schiff base metal complexes

Schiff bases and their metal complexes have many numbers of properties such as several colors, magnetic properties, structures and chemical reactions; therefore, the study of coordination compounds has received a major attention in inorganic chemical research. Schiff base complexes play a vital role in designing metal complexes related to synthetic and natural oxygen carriers. Metal complexes make these compounds effective as stereospecific catalysts toward oxidation, reduction, hydrolysis, biological activity and other transformations of organic and inorganic chemistry. In organic compounds the presence of –C=N– along with other functional groups form more stable complexes compared to compounds with only –C=N coordinating moiety[57]. Schiff base metal complexes have occupied a central place in the development of coordination chemistry after the work of Jørgensen and Werner[58]. However, there was no comprehensive, systematic study until the preparative work of Pfeiffer and associates [59]. Pfeiffer and his et al. [60] reported a series of complexes derived from Schiff bases of salicylaldehyde and its substituted analogues. Structure and mechanism of the formation of the Schiff base complexes and stereochemistry of four complexes formed from Schiff bases and their analogues have been discussed in several reviews [61]. The configuration of the chelate group in the four coordinate complexes may be square-planar, tetrahedral, distorted tetrahedral or distorted trigonal pyramidal with the metal atom ions.

The configuration depends primarily on the nature of the metal atom and also on the magnitude and symmetry of the ligand field. Metal complexes have also been reported with other ligands mixed with Schiff bases. Of all, the Schiff base complexes, those derived from salicylaldiimines have been thoroughly studied so far. A variety of physiochemical investigations on these complexes provide a clear understanding of their stereochemical and electronic properties[13]. The advantage of the salicylaldiimines ligand systems is the considerable flexibility of the synthetic procedures, which have resulted in the preparations of a wide variety of complexes with a given metal whose properties are often dependent on the ligand structure. Schiff base metal complexes have been widely studied because they have industrial, antifungal, antibacterial, anticancer, antiviral and herbicidal applications, **Scheme (X)** shows structure of salen used in construction of some anion selective membrane sensors and **Scheme (XI)** shows complexes formed form tetradentate (N_2O_2) Schiff base ligand[11].



Scheme (X): Structure of salen used in construction of some anion selective membrane sensors.



Scheme (XI): complexes formed form tetradentate (N_2O_2) Schiff base ligands

Chelating ligands containing N, S and O donor atoms show broad biological activity and are of special for interest because of the variety of ways in which they are bonded to metal ions. The chelate effect is important in biological complexes. There is tetradentate ligand of particular importance to biological system the porphryin ring. The basic structure of this complex is shown in (Figure 1.1). The space in the center is the right size for many metal ions [62].

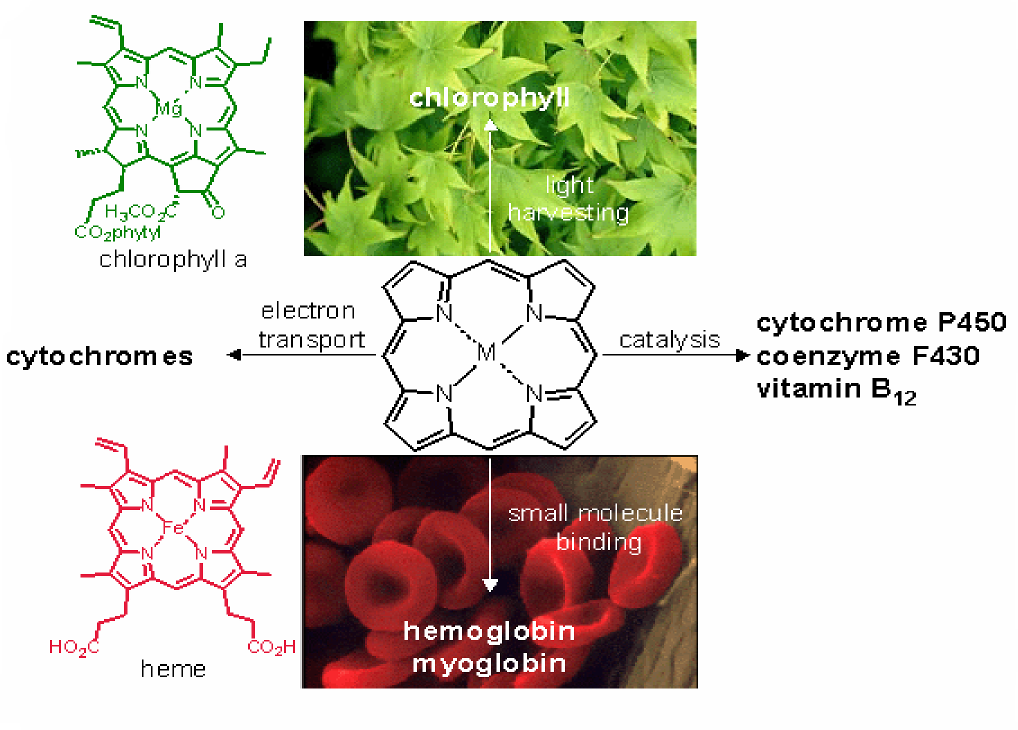


Figure 1.1: Diverse functions of metalloporphyrins in nature

1.6 Coordination compounds

Transition elements may be strictly defined as those that as elements have partly filled d or f shells. The compounds of transition metal have always held a special interest for inorganic chemists. Whereas the compounds of the main group metals are almost always white, the transition metal compounds come in intence color of the rainbow [62]. The coordination compounds, or complexes are formed when a lewis base (ligands) is attached to a lewis acid (acceptor) by means of a "lone-pair" of electrons. Where the ligand is composed of a number of atoms and the one which is directly attached to the acceptor is called the "donor atom". Tetradentate ligands produce 2 ring systems when coordinated to a single metal ion and in consequence may impose structural limitations on the complex, particularly where rigidity is introduced by the incorporation of conjugated double bonds within the rings[63]. In 1963 Parson coined the term hard and soft to describe metal ions and ligands. As a general rule, hard cations form their most stable complexes with hard ligands and soft cations with soft ligands. Hard metal ions (characterized by small ionic radii or high charge) have little electron density to share with ligand. Hard ligands do not readily give up their electron density. On the other hand, metal ion and ligands (typically possessing polarizable electron clouds) and more prone to sharing electron density with a greater degree of covalency in the bonding, and so form a mutually stable complex[64]. In this thesis, the metals were intermediate acids they bind moderately strong either to soft or hard bases. Complexes of multidentate ligands tend to be more stable than those with comparable monodentate ligands, this is called chelate effect [65].

1.6.1 Chemistry of metal ions

1.6.2 Iron(II) d^6

Iron(II) forms salts with virtually every stable anion, generally as green. Iron(II) forms a number of complexes, most of them octahedral[66]. Oxidation state (II) d^6, this is the second of the common oxidation state. Iron(II) forms complexes with a variety of ligands. As is to be expected, in view of its smaller cationic charge, these are usually less stable than those of Fe(III) but the antipathy to N-donor ligands is less marked. Thus $[Fe(NH_3)_6]^{2+}$ is known whereas the Fe(III) analogue is not; also there are fewer Fe(II) complexes with O-donor ligands such as acac and oxalate, and they are less stable than those of Fe(III). Low spin octahedral complexes are formed by ligands such as bipy, phen, and CN^- and their stability is presumably enhanced by the symmetrical t^6_{2g} configuration. Iron is the most important transition element involved in living system; iron plays crucial roles in the transport and storage of oxygen and also in electron transport [63].

1.6.3 Cobalt d^7

Co(II) it's one of the two most stable oxidation states, whereas, for the others it is of only minor importance. Complexes of cobalt(II) are less numerous than those of cobalt(III) but, lacking any configuration comparable in stability with the t^6_{2g} of Co^{III}, they show a greater diversity of types and are more labile. The most common type is high-spin octahedral, though spin-pairing can be achieved by ligands such as CN^- which also favour the higher oxidation state. tetrahedral complexes are also common, being formed more readily with cobalt(II) than with the cation of any other truly transitional elements. Square planar complexes are also well authenticated if not particularly numerous and include [Co(phthalocyanine)] as well as [Co(salen)] and complexes with other Schiff bases [63].

1.6.4 Nickel(II), d^8

The absence of any other oxidation state of comparable stability for nickel implies that compounds of Ni(II) are largly immune to normal redox reactions. The coordination number of Ni(II) rarely exceeds six and its principal stereochemistries are octahedral and square planar (four coordination sites) with rather fewer examples of trigonal bipyramidal (five coordination sites), square pyramidal (five coordination sites), and tetrahedral (four coordination sites). Octahedral complexes of Ni^{II} are obtained especially with neutral N-donor ligands and the O-donor. Of the four-coordinate complexes of Ni(II), those with the square planar stereochemistry are the most numerous. They include the yellow $[Ni(CN)_4]^2$, the red bis(N-methylsalicylaldiminato)nickel(II) and well-known bis(dimethylglyoximato) nickel(II). Although less numerous than the square planar complexes, tetrahedral complexes of Ni(II) slso occur [63].

1.6.5 Copper(II), d^9

Cu(II) is the most effective avalibale divalent ion for bending to organic molecule [67]. The most common coordination number of Copper(II) are four, five and six, but regular geometries are rare and the distinction between square planar and tetragonally distorted square planar. the octahedral coordination is generally not easily made. The reason for this is ascribed to the Jan-Teller effect arising from the unequal occupation of the e_g pair of orbitals ($d_z{}^2$ and $d_x{}^2{}_{-y}{}^2$) when a d^9 ion is subjected to an octahedral crystal field. Copper(II) also forms stable complexes with O-donor ligands. Mixed O, N-donor ligands such as Schiff bases are of interest in that they provide example square planar coordination[63].

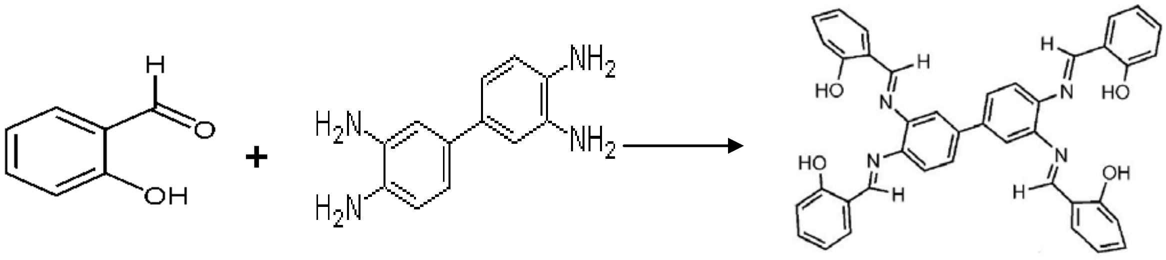
2.1 Chemicals and reagents

All chemicals used in this study were laboratory pure including:

Chemicals and reagents	**The company**
3,3',4,4'-biphenyltetramine Tetra hydrochlorid	BDH Chemicals
Salicylaldehyde	CDH Laboratory Reagent
Sodium carbonate	E. Merck. Darmstadt
Ethanol absolute	E. Merck. Darmstadt
Methanol	BDH Laboratory
Acetone	Century building
DMF	Riedel-De Haenag
Nickel acetate $Ni(C_2H_3CO_2)_2 .4H_2O$	Codex
Cupric chloride $CuCl_2.2H_2O$	PKD
Cobalt(II)chloride $CoCl_2 . 6H_2O$	Riedel-De Haenag
Ferrous chloride $FeCl_2 . 2H_2O$	Riedel-De Haenag

2.2 Synthesis of the Schiff base

Schiff base ligand was synthesized by condensation of 3,3'-diaminobenzidine (1mol) and salicylaldehyde (4 mol) in ethanol (100 ml) To a stirred solution was added dropwise followed by the addition of solution of salicylaldehyde to 3,3'-diaminobenzidine solution**, Scheme (XII)**. The mixture was kept stirred at 80 ^{o}C in water bath for 1 hour. The product was filtered and washed with ethanol.. Orang plate-shaped obtained and dry in a desiccator over silica gel.



Salicylaldehyde 3,3'-diaminobenzidine H_4L

Scheme (XII) the Schiff base

2.3 Synthesis of the Schiff base complexes

2.3.1 Synthesis of the Fe(II) complex

Ferrous chloride $FeCl_2.2H_2O$ (2 mol) was dissolved in absolute methanol (50 ml) and added to the corresponding Schiff base (1 mol), dissolved in methanol (100 ml) dropwise with stirring. The mixture was kept stirred at room temperature for 1 day. The product formed was filtered off and washed with methanol , the green precipitate obtained was dried in a desiccator over silica gel.

2.3.2 Synthesis of the Cu(II) complex

Cupric chloride $CuCl_2.2H_2O$ (2 mol) was dissolved in absolute methanol (50 ml) and added to the corresponding Schiff base (1 mol), dissolved in methanol (100 ml) was added dropwise with stirring. The resulting mixture was kept stirred at room temperature for 1 day and the product was filtered off and washed with methanol. The obtained brown precipitate was dried in a desiccator over silica gel.

2.3.3 Synthesis of the Co(II) complex

Cobalt(II)chloride $CoCl_2.6H_2O$ (2 mol) was dissolved in absolute methanol (50 ml) was added to the corresponding Schiff base (1 mol), dissolved in methanol (100 ml) dropwise with stirring. The mixture was kept stirred at room temperature for 1 day and the final complex filtered off and washed with methanol, the resulted brown reddish precipitate was dried in a desiccator over silica gel.

2.3.4 Synthesis of the Ni(II) complex

Nickel acetate $Ni(C_2H_3O_2)_2.4H_2O$ (0.01 mol, g) was dissolved in absolute methanol (50 ml) and was added to the corresponding Schiff base

(0.002 mol), dissolved in methanol (75 ml) dropwise with stirring. The mixture was kept stirred at room temperature for 1 day and the complex was filtered off and washed with methanol. The red precipitate was dried in a desiccator over silica gel.

2.4 Characterization of the ligand and its complexes

2.4.1 Physical measurements

2.4.1.1 Elemental analysis

The Schiff base ligand and its complexes under investigation were analyzed (C, H and N) the C H N analysis were performed by using 2400 elemental analyzer at the Micro-Analytical Center, Faculty of Science, Assiut University, Assiut, Egypt.

2.4.1.2 Thermal analyses

The differential thermal analysis (DTA) and thermogravimetric analysis (TGA) of the Schiff base complexes were carried out using shimadzu DTH-60H thermal analysis with heating rate of 10 C^o\min at thermal analysis unit of central laboratory of Assiut University (Egypt).

2.4.1.3 Melting point

The melting point of ligand and its complexes were measured in capillary tubes Philip Haris, Shenston-England serial NO.B/A-211, at Chemistry Department. Faculty of Science, University of Benghazi.

2.4.1.4 Infrared spectra

The IR spectra of the Schiff base ligand and its complexes under investigation were recorded as KBr discs on a Shimadzu IR400-91527, Japan at the Faculty of Pharmacy, Assiut University, Assiut, Egypt.

2.4.1.5 ^{1}H nuclear magnetic resonance spectrum

The ^{1}H - NMR spectrum of the Schiff base ligand was recorded using a Varian Jeol JNM EX-400 (^{1}H, 400 MHz) spectrometer at the NMR Laboratory Center, Assiut University, Egypt.

2.4.1.6 Electronic spectra

The electronic spectra of the Schiff base ligand and its complexes measured by the applying dimethylformamide (DMF) as solvent using UV-Vis-NIR 3101pc Shimadzu (Japan) using 1cm matched silica cells, at Chemistry Department, Faculty of Science University of Benghazi.

2.5 Biological activity test

The strains of bacteria and fungi were used are *Escherichia coli,* . *Staphylococcus aureus* , *Staphylococcus epidermidis* , *Micrococcus spp.* , *Pseudomonas Aeruginos, Klebsiella pneumonia, Salmonella typhimurium, Aspragillus niger* and *Candida albicans.* They were grown overnight at

37°C in Mueller-Hinton Broth at pH 7.4 [73,74], this study was done in Faculty of Pharmacy, Microbiology Department, Zagazig University, Egypt.

2.5.1 Testing for antibacterial activity

The cup-plate agar diffusion method was employed to assess the antibacterial activity of the prepared extracts [75]. 20 ml of the nutrient agar were distributed into sterile petri dishes. The agar was left to set and in each of these plates, 5 mm in diameter, were cut using a sterile cork borer No. 4 and the agar discs were removed [76]. Alternate cups were filled with 20 µl of each extracts using microtiter-pipette and allowed to diffuse at room temperature for two hours. The plates were then incubated in the upright position at 37ºC for 18 hours. The respective solvents were used as controls. The diameters of the growth inhibition zones were measured at 24, 48 and 72 hours of incubation averaged and the mean values were tabulated.

2.5.2 Testing for anti fungal activity

The medium was incubated at 25ºC for two days. Yeast and mould extract agar was used for testing antifungal activity and the above method as for bacteria were adopted [77].

- Conc. of samples is 50 mg/ml.
- Conc. of control antibiotics (Cefotaxime & Amoxicillin) is 5mg/ml.
- Conc. of antifungal agents (Nystatin & Amphotericin B) is 5mg/ml.

- Each cup is filled with 100µl. of each sample.

2.5.3 Sensitivity test

The effect of ligand and its complexes on the used bacteria and fungi were compared with sensitivity to common antibiotics (Cefotaxime, Amoxicillin, Nystatin and Amphotericin B). The antibiotics were placed on the surface of the culture medium which contains the same bacteria and fungi used in this study.

3.1 The studies on ligand

The Schiff base ligand under investigation was formed by the condensation reaction of 3,3'-diaminobenzidine and salicylaldehyde (1: 4 molar ratio) and it was investigated by several techniques such as elemental analysis, Infrared, ^{1}H-NMR and UV-Visible spectroscopy to identify its structure.

3.1.1 Elemental analyses of the ligand

Physical characteristics and elemental analysis (C, H and N) of the ligand are listed in Table (1). The results of C, H and N percentage are in good agreements for the ligand and correlated well with the calculated values.

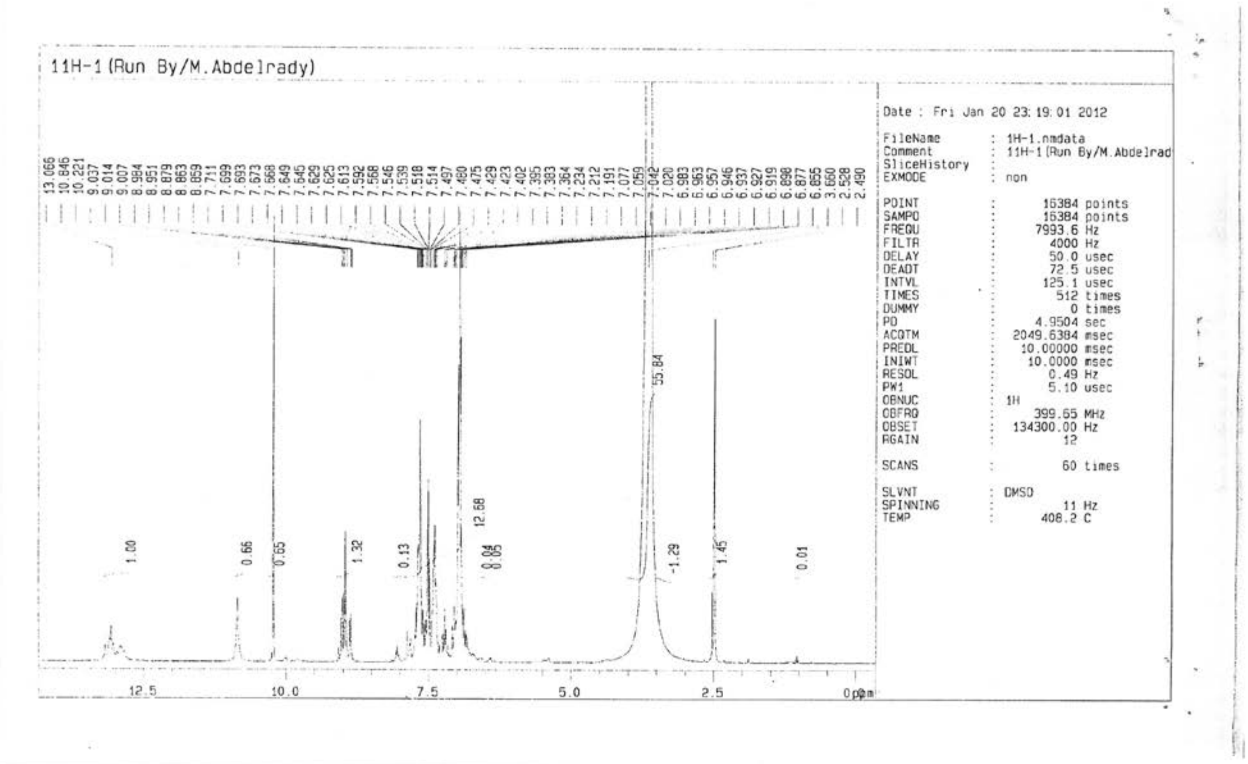
3.1.2 Infrared spectra of the ligand

The important IR absorption frequencies of the prepared Schiff base ligand are given in Table (3) and the IR spectrum is shown in Figure (1). The IR spectrum of the ligand shows two bands in 3520 – 2980 and 2970 – 2350 cm^{-1} range, commensurate the presence of two types of intra- and intermolecular hydrogen bonding of OH with imine group, thus, the higher frequency band is associated with a weaker hydrogen bond and the lower frequency band with stronger hydrogen bond. The strong bands at 3460 and 1603 cm^{-1} are assigned to ν (OH) and ν (imine) groups respectively [68]. The ν

(Ar) group of benzidine ring appears at 1545 and 750 cm^{-1}, however, the salicyaldehyde ring appears at 1556 and 820 cm^{-1}. The ν (C- OH) observed at 1265 cm^{-1}[153].

3.1.3 ^{1}H-nuclear magnetic resonance spectrum of the ligand

The ^{1}H-NMR spectrum of the Schiff base in d^{6}- DMSO shows signals consistent with the proposed structure (Figure 1). The signals appear in the 12.7 – 13.0 ppm are due to the protons of OH group. The protons of bezidine ring observed in the 10.7 – 8.9 ppm range, however, the salicyaldehyde protons appear in the 6.8 – 7.8 ppm as multiple peaks. The ^{1}H- NMR spectrum of the ligand is shown in figure (1).



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INIWT           :    10.0000 msec
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OBFRQ           :     399.65 MHz
OBSET           :  134300.00 Hz
RGAIN           :         12

SCANS           :         60 times

SLVNT           : DMSO
SPINNING        :         11 Hz
TEMP            :      408.2 C
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Fig. (1): ^{1}H NMR of the Schiff base ligand

3.1.4 Ultraviolet spectrum of the ligand

The electronic spectrum of the free ligand (H_4L) in DMF solvent and its band assignment are shown in Table (4). The present Schiff base exhibits useful data, explaining the appearance of the intraligand π-π^* and n-π^* of aromatic and imine group transitions [69].

3.2 Studies on the Schiff base complexes

The new complexes of some divalent transition metal ions (Fe(II), Co(II), Cu(II) and Ni(II)) with Schiff base derived from 3,3'-diaminobenzidine and salicylaldehyde were synthesized. All complexes are insoluble in water but soluble in aprotic solvents, totally soluble in DMF and DMSO. Their empirical formula $[M_2L\ (H_2O)_n]$ were calculated on the basic of elemental analysis and thermal analysis measurements, and they were investigated by several techniques, such as infrared and electronic spectroscopy

3.2.1 Elemental analysis of Schiff base complexes

The general characteristic properties of the complexes are shown in Table (1). The obtained results are in good agreement with the calculated values and the data show the formation of 2:1 [M: L] complexes.

Table (1): Elemental analysis data, and some physical properties of ligand and its complexes

Compound	Formula Weight	M.P./ °C	Microanalysis (Calc.)		
			%C	%H	%N
H_4L	630	240	76.18 (75.25)	4.79 (4.76)	8.88 (8.40)
$[Fe_2L.4H_2O]2H_2O$	737.69	230	53.0 (52.28)	3.52 (3.70)	7.59 (6.13)
$[Co_2L.4H_2O]4H_2O$	743.86	225	54.06 (53.99)	4.73 (4.10)	6.36 (6.88)
$[Cu_2L.4H_2O]\ H_2O$	753.09	294	56.93 (56.55)	4.27 (4.95)	6.64 (7.82)
$[Ni_2L.4H_2O]$	743.38	300	58.86 (58.35)	4.16 (4.49)	6.86 (6.65)

3.2.2 Thermal analyses of the Schiff base complexes

In thermal analysis, the samples to be analyzed are subjected to a controlled heating to high temperature at a specified heating rate. The weight loss of the sample on heating is being recorded as a function of temperature. These methods of analysis open a new possibility for the investigation of metal complexes. They include differential thermal analysis and thermal gravimetric analysis (DTA and TGA) results are given in figures (2-4). The thermal analysis data are collected in Table (2). The thermal curves in temperature 23 – 500 ºC range for ligand and its complexes are thermally stable up to 390 ºC. ligand [H_4L] shows endothermic peak at 40 ºC is due to broken of hydrogen bondings, another endothermic peak appears at 90 ºC may due to phase transformation. Endothermic peak observed at 231 ºC, assigned to melting point. Exothermic peaks appeared at 255, 295, 345, 365 and 385 ºC with weight loss 59.3 % (Calc. 59.4 %), corresponding to loss of 4 C_6H_5O group. The final exothermic peak observed at 435 ºC with weight loss 37.91 % (Calc. 37.21 %) may be due to loss of 2 CO_2.

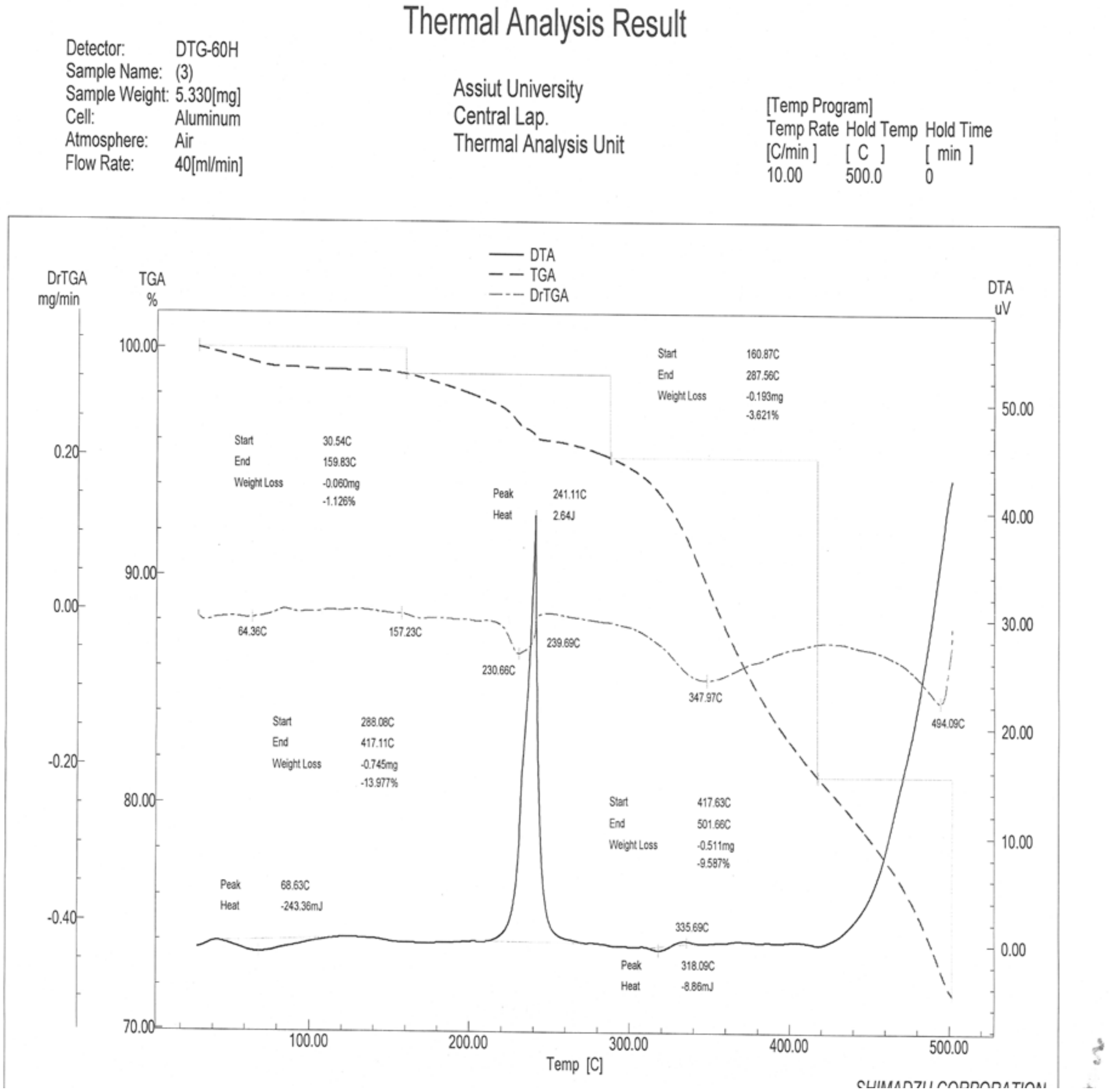
$Fe_2(L)$ complex, shows endothermic peak at 65 ºC, corresponding to loss of two hydrated water [78,79], with weight loss 4.17 % (Calc. 3.92 %). Exothermic peaks at 325, 340 and 380 ºC with weight loss 50.0 % (Calc. 50.89 %) is due to loss of 4 C_6H_5O group. Melting point of the complex observed at 350 ºC as endothermic peak. Oxidative thermal decomposition occurs at 500 ºC with endothermic peak leaving Fe_2O_3 with weight loss 44.79 % (Calc. 55.57 %).

$Co_2(L)$ complex, shows endothermic peak at 70 ºC with weight loss 7.92 % (Calc. 8.11 %) corresponding to loss of four hydrated water molecules, another endothermic peak appeared at 180 ºC with weight loss 8.91 % (Calc. 8.82 %) is assigned to loss of four coordinated water. [78,79] Endothermic peak observed at 310 ºC, may be due to melting point. Elimination of 4 C_6H_5O group occurred at 240, 280, 360 and 425 ºC with exothermic peaks accompanied with weight loss 49.5 % (Calc. 50.0 %). Oxidative thermal decomposition occurs at 450 ºC with exothermic peak leaving Co_2O_3 weight loss 44.55 % (Calc. 44.62 %).

Finally, Cu_2(L) complex shows broad endothermic peak at 45 – 130 ºC, may be due to loss of one hydrated water molecule with weight loss 2.12 % (Calc. 2.13 %) and loss of four coordinated water molecules with weight loss 8.33 % (Calc. 8.72 %). Another endothermic peak appeared at 360 ºC, may be due to melting point of the complex. Exothermic peaks observed at 240, 350, 400 and 440 ºC with weight loss 50.0 % (Calc. 49.34 %) is corresponding to loss of 4 C_6H_5O groups. Oxidative thermal decomposition occurs at 490 ºC with endothermic peak leaving 2 CuO with weight loss 41.67 % (Calc. 41.88 %).

Table (2): Thermal analysis of complexes

complexes	Water of hydration weight loss %	No. of water molec.	Water of Coord. weigh loss	No. of water coord.	$4C_6H_5O$ groups weight loss	Temp. °C	M O weight loss	Temp . °C
$[Fe_2L.4H_2O]2H_2O$	(4.17) (3.92)	2	-	4	(50.0) (50.89)	310-380	(44.79) (55.57)	500
$[Co_2L.4H_2O]4H_2O$	(7.92) (8.11)	4	(8.91) (8.82)	4	(49.5) (50.0)	240- 425	(44.55) (44.62)	450
$[Cu_2L.4H_2O]\ H_2O$	(2.12) (2.13)	1	(8.33) (8.72)	4	(50.0) (49.34)	240-440	(41.67) (41.88)	490



Thermal Analysis Result

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Sample Name: (3)
Sample Weight: 5.330[mg]
Cell: Aluminum
Atmosphere: Air
Flow Rate: 40[ml/min]

Assiut University
Central Lap.
Thermal Analysis Unit

[Temp Program]

Temp Rate [C/min]	Hold Temp [C]	Hold Time [min]
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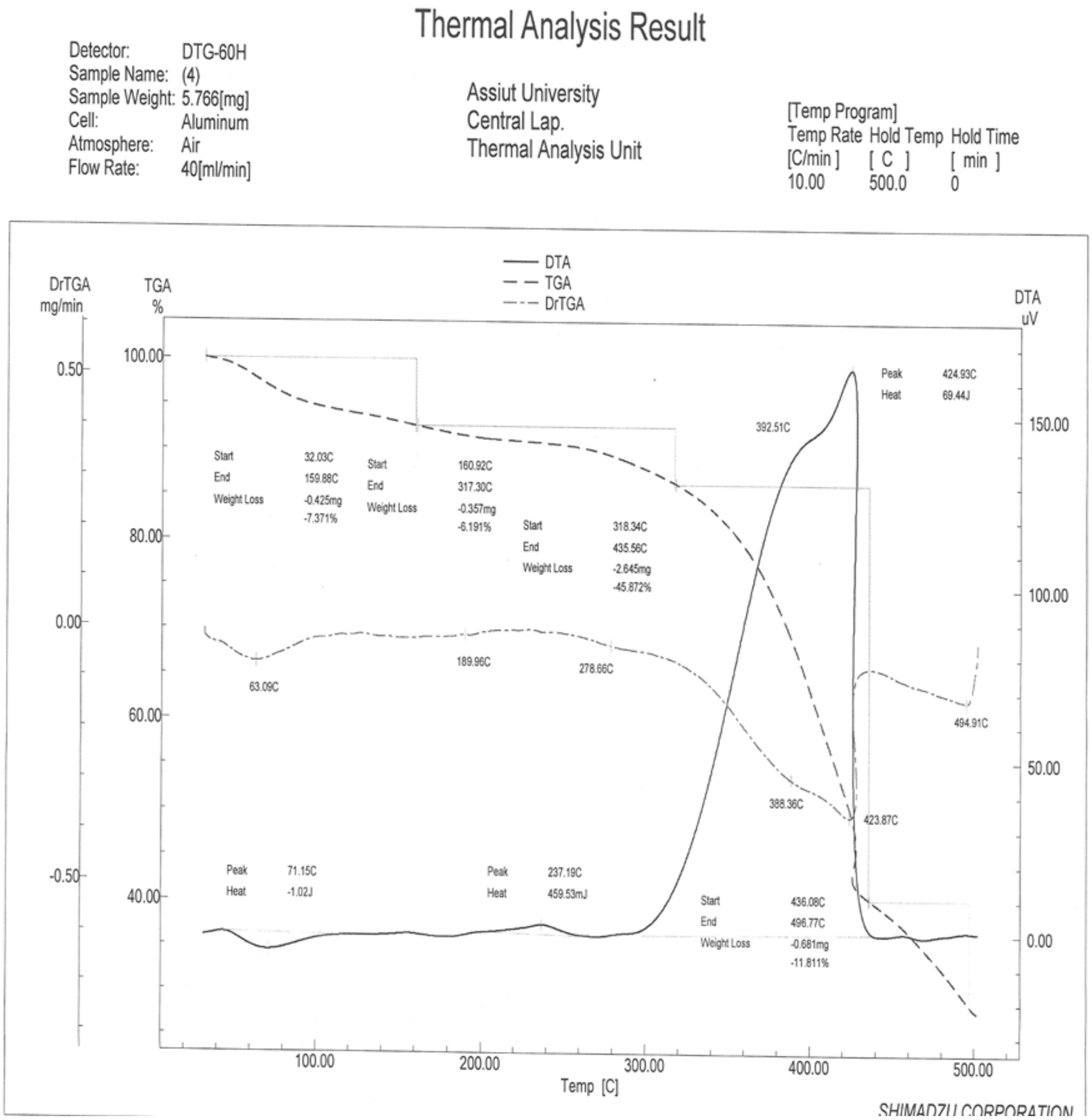
Fig. (2): Thermal analysis of Fe(II) complex



Thermal Analysis Result

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Sample Weight: 5.766[mg]
Cell: Aluminum
Atmosphere: Air
Flow Rate: 40[ml/min]

Assiut University
Central Lap.
Thermal Analysis Unit

[Temp Program]

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End 159.88C
Weight Loss -0.425mg -7.371%

Start 160.92C
End 317.30C
Weight Loss -0.357mg -6.191%

Start 318.34C
End 435.56C
Weight Loss -2.645mg -45.872%

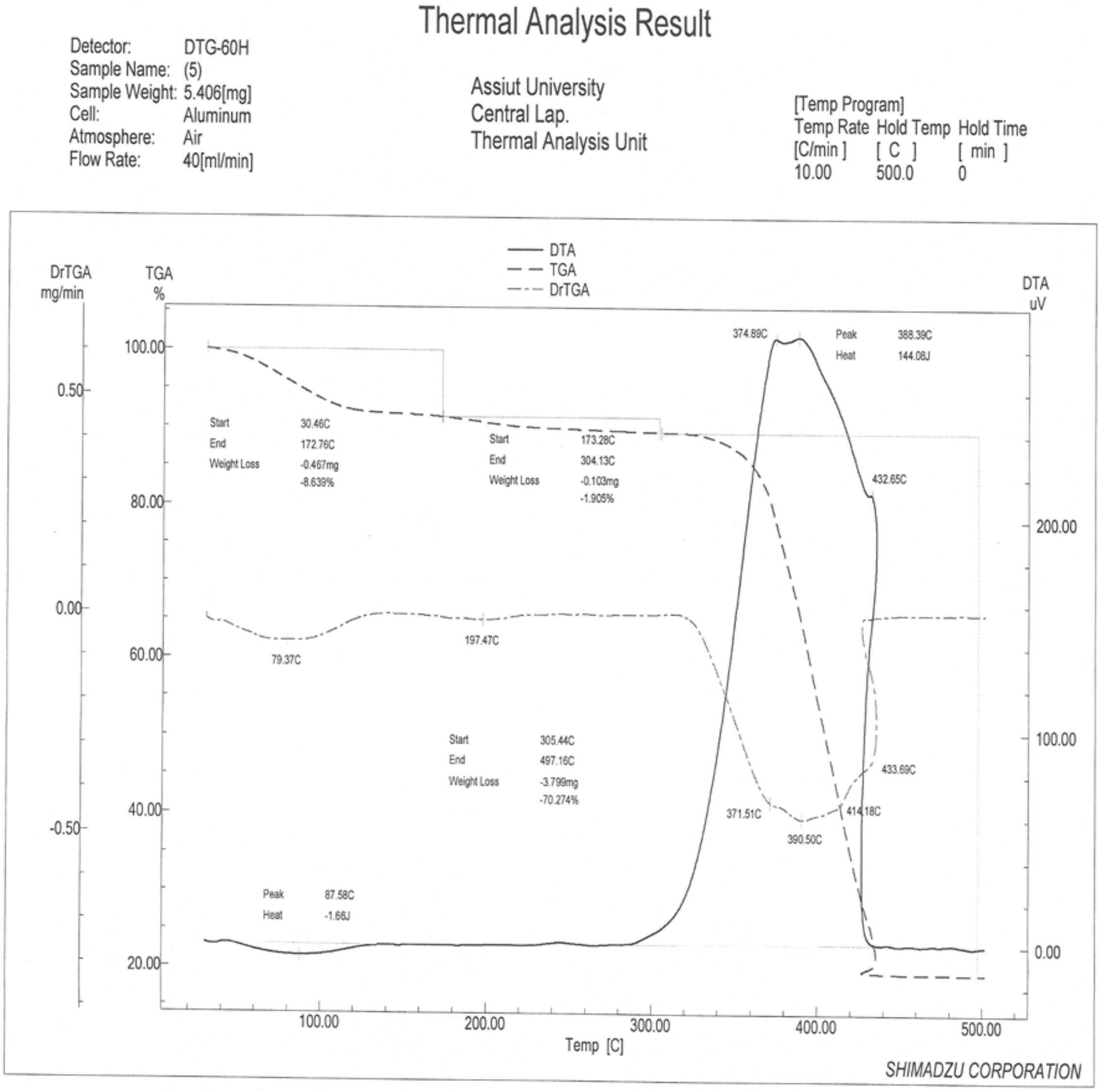
Start 436.08C
End 496.77C
Weight Loss -0.681mg -11.811%

Peak 71.15C
Heat -1.02J

Peak 237.19C
Heat 459.53mJ

Peak 424.93C
Heat 69.44J

Fig. (3): Thermal analysis of Co(II) complex



Thermal Analysis Result

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Sample Name: (5)
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Cell: Aluminum
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Assiut University
Central Lap.
Thermal Analysis Unit

[Temp Program]

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End 172.76C
Weight Loss -0.467mg -8.639%

Start 173.28C
End 304.13C
Weight Loss -0.103mg -1.905%

Start 305.44C
End 497.16C
Weight Loss -3.799mg -70.274%

Peak 87.58C
Heat -1.66J

Peak 388.39C
Heat 144.08J

SHIMADZU CORPORATION

Fig. (4): Thermal analysis of Cu(II) complex

3.2.3 Infrared spectra of Schiff base complexes

The important IR absorption frequencies of the prepared Schiff base complexes compound are given in Table (3) and their spectra are shown in the Figures (6-9). The IR spectra of the complexes are compared with that of the free ligand to determine the changes that might have taken place during the complexation. The band at 1603 cm^{-1} is characteristic of the azomethine nitrogen atom presents in the free ligand. The lowering in this frequency region (1600–1590 cm^{-1}), observed in all the complexes, indicates the involvement of the azomethine nitrogen atom in coordination to the metal(II) ion [70,71]. The complexing process takes place through two nitrogen of imine group, two hydroxyl group of the salicylaldehyde, i.e., the ligand is tetradentate. Abroad bands in the range 3510 – 3220 and 3250 - 3020 cm^{-1} confirms the presence of water molecules in some separated complexes[72]. Characteristic absorption bands for ν (M-N) and ν (M-O) of complexes appear respectively in the spectral region of 545 - 510 cm^{-1} and 590 - 554 cm.$^{-1}$ The C-OH stretching modes of the ligand appears at 1265 cm^{-1}, (table 2) in the spectra of the complexes, these bands shift to higher or lower wave numbers as a result of coordination through the hydroxyl oxygen atoms[39].

Table (3) Infrared band assignments (cm^{-1}) of the ligand and its complexes

Compound	ν(OH) / H_2O / H-bond.	ν(C=N)	ν(C-OH) / ν(C-O)	ν(M-N)	ν(M-O)	ν(Ar)
H_4L	3460 3520 – 2980 2970 - 2350	1603	1265	–	–	1556, 820 1545, 720
$[Fe_2L.4H_2O]2H_2O$	3435 3525 – 3050 3040 - 2560	1600	1182	535	580	1556, 805 1545, 742
$[Co_2L.4H_2O]4H_2O$	3460 – 3220 3210 - 3050	1592	1186	530	585	1555, 801 1540, 748
$[Ni_2L.4H_2O]$	3470 – 3260 3250 – 3150	1590	1180	545	590	1550, 802 1540, 750
$[Cu_2L.4H_2O]$ H_2O	3510 – 3260 3250 - 3020	1595	1182	510	554	1550, 800 1540, 752

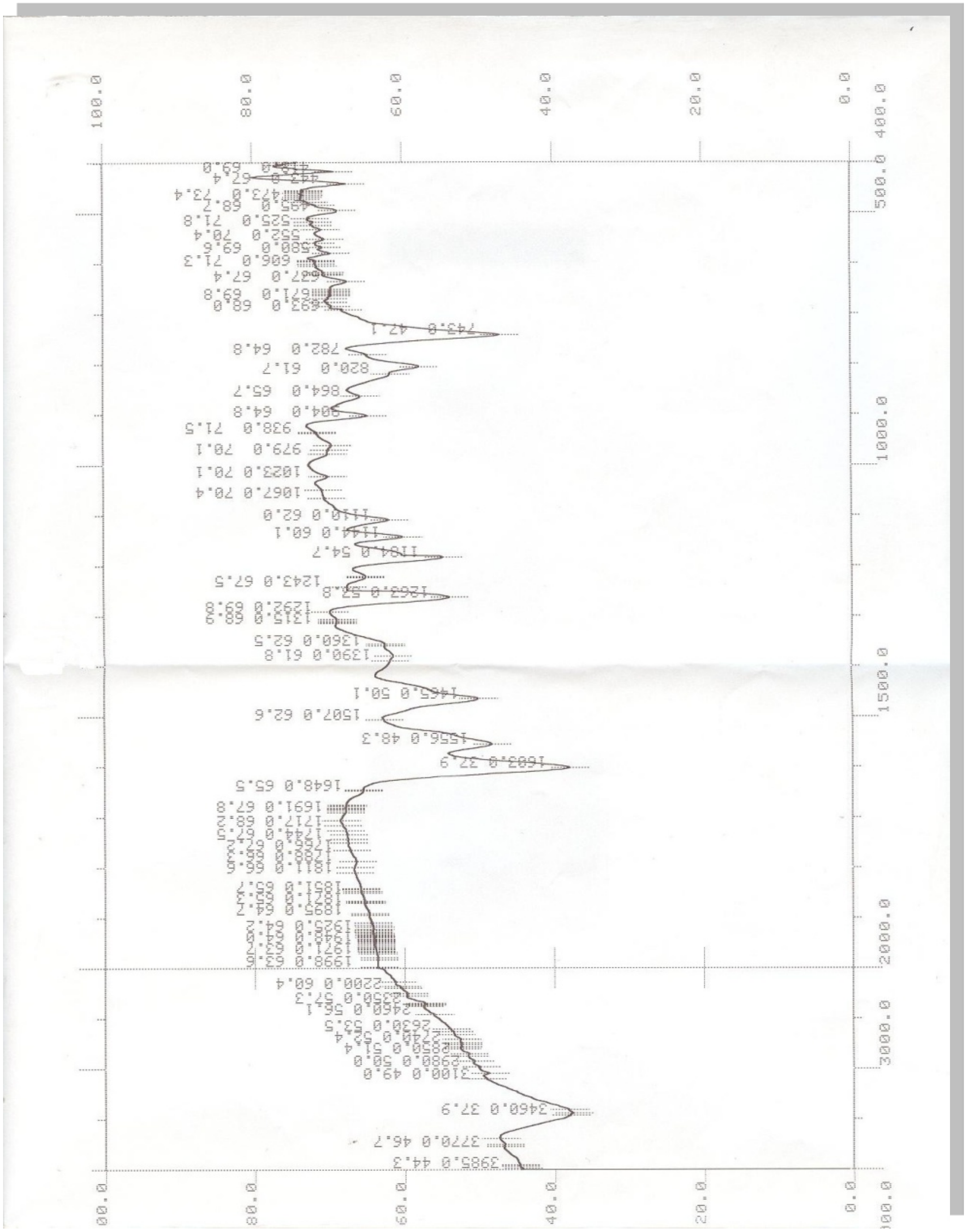


Fig.(5): IR spectrum of the ligand

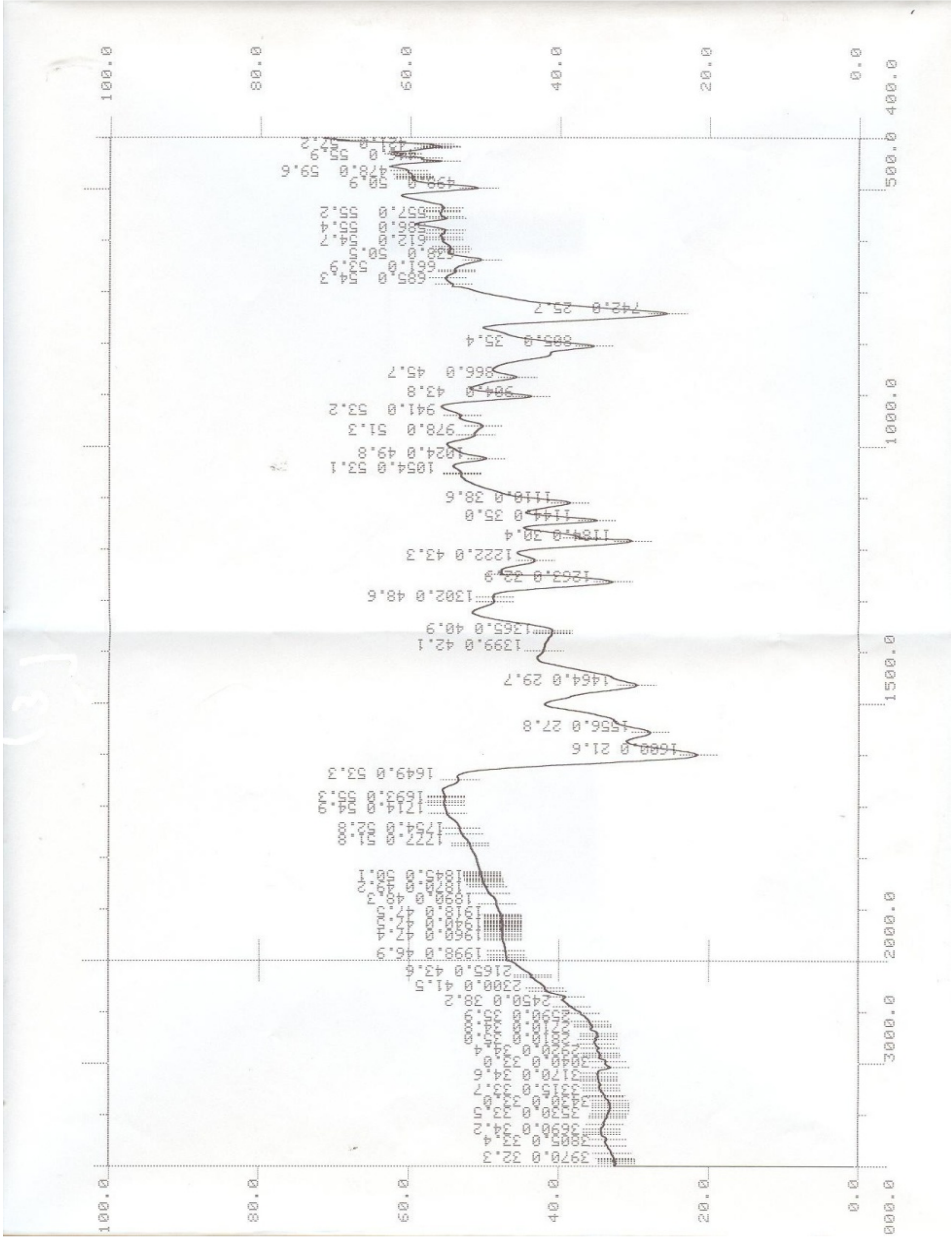


Fig.(6): IR spectrum of Fe(II) complex

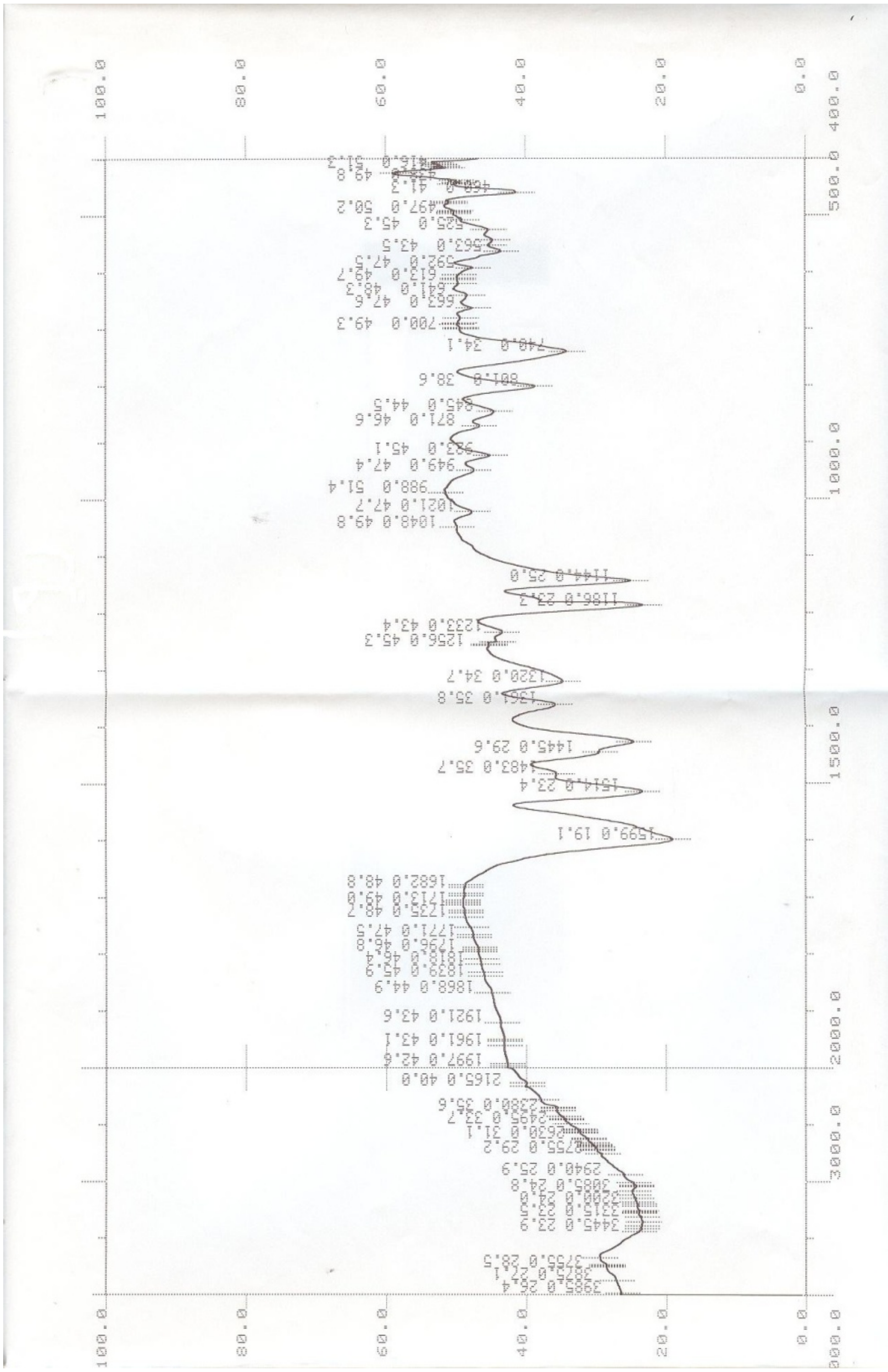


Fig.(7): IR spectrum of Co(II) complex

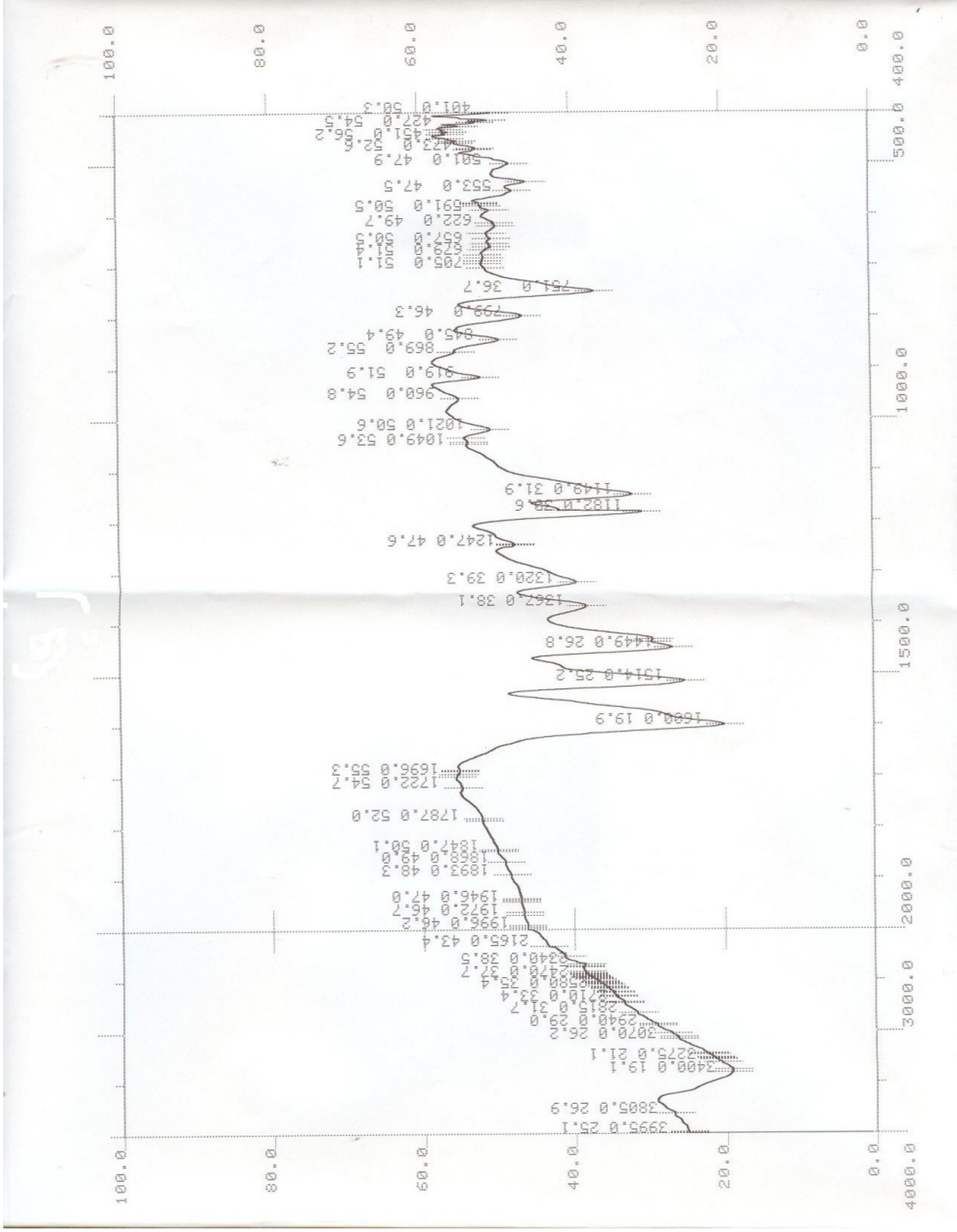


Fig.(8): IR spectrum of Cu(II) complex

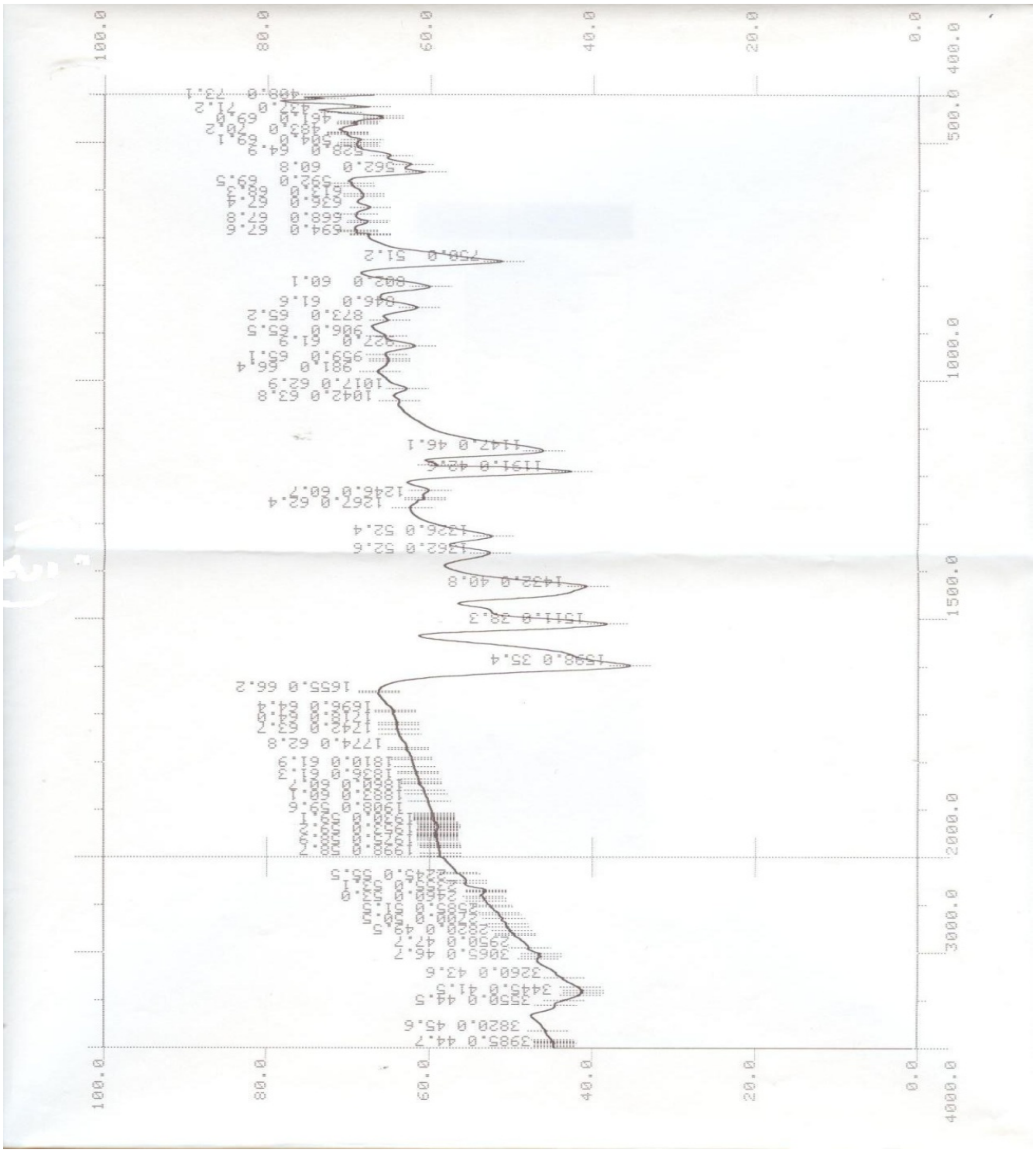


Fig.(9): IR spectrum of Ni(II) complex

3.2.4 Electronic spectra Schiff base complexes

The electronic spectra of Schiff base complexes in DMF solvent.The electronic spectrum depends on the energy of metal d orbital, their degeneracy and the number of electrons distributed**.** These features are in turn controlled by the oxidation state of the metal, number and kind of the ligand and the geometry of the complex**.** whereas their spectra were recorded in DMF solvent and their band assignment are shown in Table (4). Only one broad band is observed at (20202cm^{-1}) in the electronic spectrum of the Fe(II) complex assigned to $^{5}T_{2}g \rightarrow {}^{5}Eg$ transition which is in conformity with octahedral geometry. [80] The electronic spectrum of the Co (II) complex showed two spin allowed transition (assigned as v_2 andv_3 absorption bands respectively) at (18382 cm^{-1} and 19230 cm^{-1}) $^{4}T_{1}g$ (F) → $^{4}A_{2}g$ (F) and $^{4}T_{1}g$ (F) → $^{4}T_{1}g(P)$ transition respectively, which clearly indicate that the complex has six coordination octahedral geometry[82]. For octahedral Cu(II) complexes only a single band due to the transition $^{2}Eg \rightarrow {}^{2}T_{2}g$ (D) an absorption band at (21739 cm^{-1}) is assigned to a slightly distorted octahedral geometry for the complex[81]. The electronic spectrum of the Ni (II) complex displays two bands (assigned as V_2 and V_3 absorption bands respectively), (18050 cm^{-1} and 14367 cm^{-1}), assignable to $^{3}A_{2}g \rightarrow {}^{3}T1g$ (F) and $^{3}A_{2}g$

$\rightarrow{}^3T_1g(P)$ transitions, respectively which clearly indicate that the complex has six coordination octahedral geometry[80].

Table (4): Electronic spectral data (nm, cm^{-1}) of the complexes

ligand / complexes	λ_{max} nm	cm^{-1}
$[Fe_2L.4H_2O]2H_2O$	495	20202
$[Co_2L.4H_2O]4H_2O$	520, 544	19230,18382
$[Cu_2L.4H_2O]\ H_2O$	460	21739
$[Ni_2L.4H_2O]$	554, 696	18050, 14367

3.3 Biological activity

Table (5) and Figures (10 - 16), show the inhibition zones of bacteria and fungi growth of the Schiff base and its complexes Co(II), Ni(II), Cu(II) and Fe(II) against *Escherichia coli*. *Staphylococcus aureus*, *Staphylococcus epidermidis, Micrococcus spp.*, *Pseudomonas Aeruginos, Klebsiella pneumonia, Salmonella typhimurium, Aspragillus niger, Candida albicans.acidophilus*. The Sample (Co_2L) complex showed more activity than the other sample. The sample (Cu_2L) maximum antimicrobial activity was observed against *Micrococcus spp.* Also the samples (Co_2L) and (Cu_2L) showed the more antifungal activity than other sample. The samples (Co_2L) and (Cu_2L) have more antifungal activity than antbacterial activity, and microorganism activity of the complexes is higher than that of the free ligand.

Table (5): Microbiological activity against the microorganisms

Sample	Diameter (mm) of inhibition zones against the corresponding standard microorganisms								
	Gram-positive bacteria			Gram-negative bacteria				Fungi	
	Staphylococcus aureus ATCC 6538	*Staphylococcus epidermidis* ATCC 12228	*Micrococcus spp.* ATCC 10240	*Pseudomonas aeruginosa* ATCC 9027	*Klebsiella pneumoniae* ATCC 27736	*Salmonella typhimurium* ATCC 14028	*Escherichia coli* ATCC 10536	*Aspragillus niger* ATCC 16404	*Candida albicans* ATCC 10231
ligand	17	16	16	20	21	17	19	15	20
Ni_2L	14	14	16	20	21	16	18	13	20
Fe_2L	18	17	14	16	21	17	19	20	21
Co_2L	21	20	23	21	22	20	21	23	21
Cu_2L	20	19	20	21	22	19	20	24	20
Cefotaxime (control)	34	33	43	30	37	36	35	-	-
Amoxicillin (control)	35	34	40	-	-	29	30	-	-
Nystatin (control)	-	-	-	-	-	-	-	25	20
Amphotericin B (control)	-	-	-	-	-	-	-	16	22
DMF (control)	-	-	-	-	-	-	-	-	-

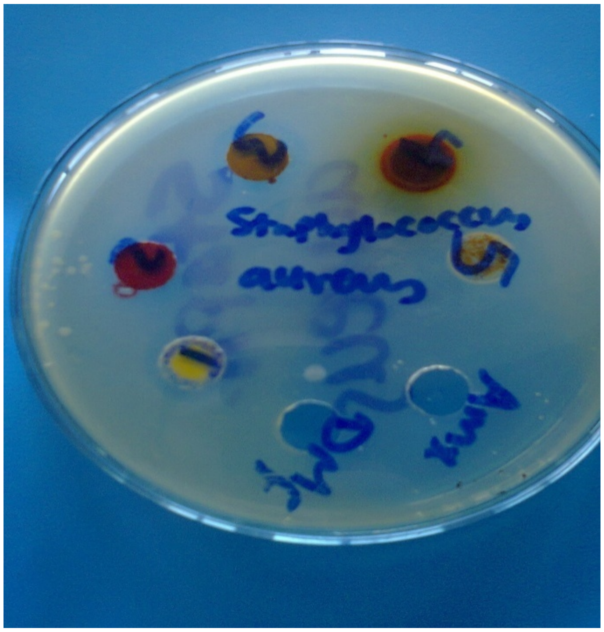


Fig.(10): Effect of *Staphylococcus aureus* on the ligand and its complexes

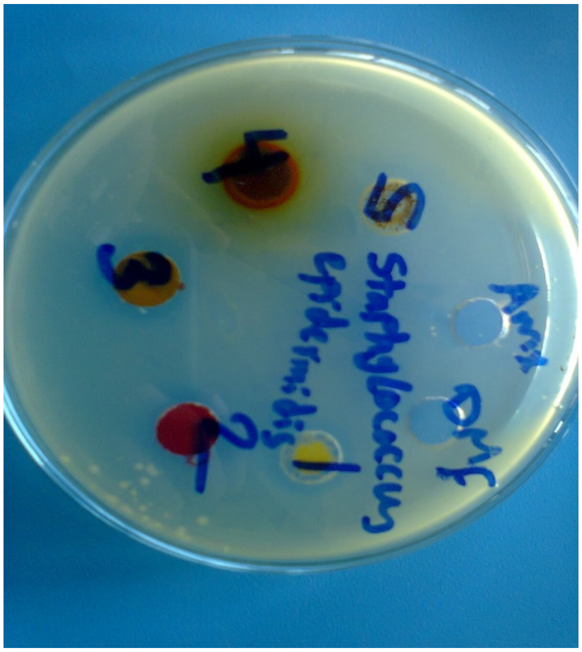


Fig.(11): Effect of *Staphylococcus epidermidis* on the ligand and its complexes

Fig.(12): Effect *Pseudomonas aeruginosa* on the ligand and its complexes

Fig.(13): Effect *Klebsiella pneumoniae* on the ligand and its complexes

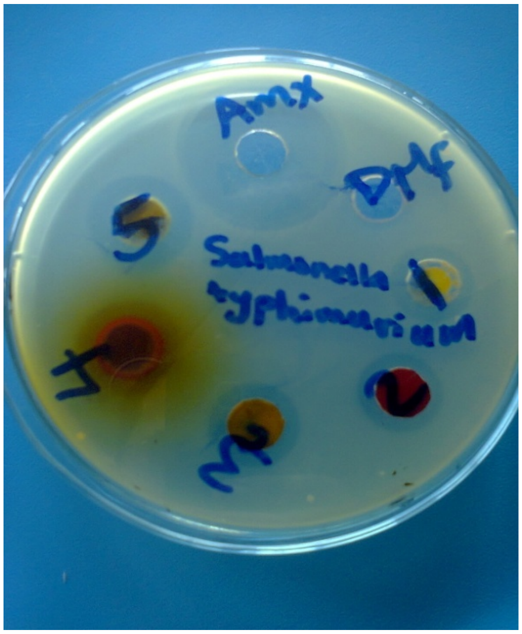


Fig.(14): Effect *salmonella typhimurium* on the ligand and its complexes

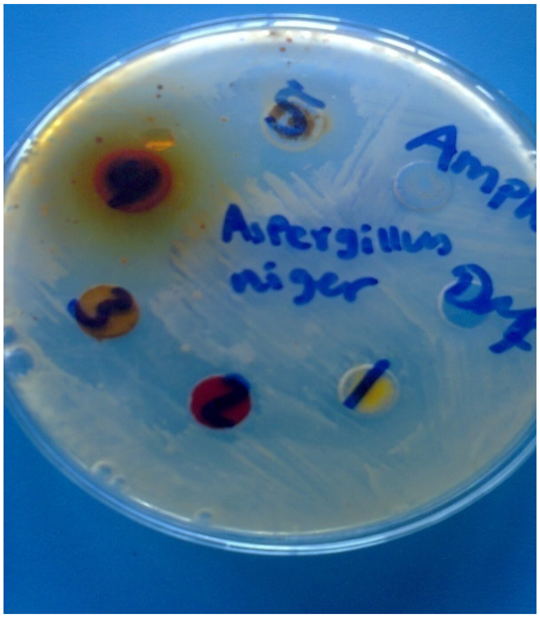


Fig.(15): Effect *Aspragillus niger* on the ligand and its complexes

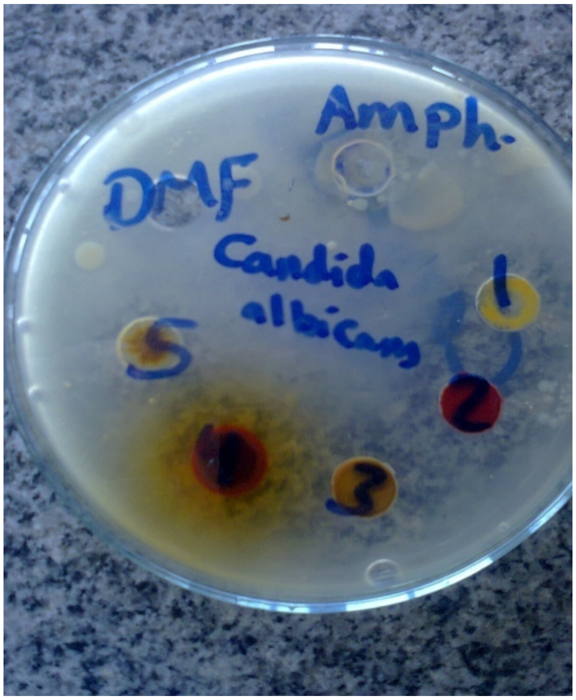
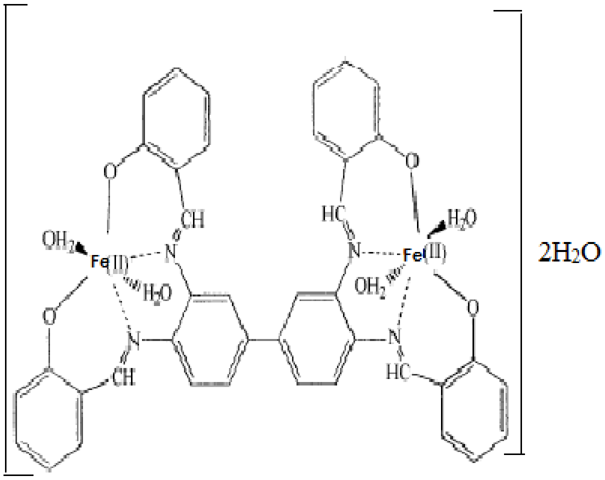


Fig.(16): Effect *Candida albicans* on the ligand and its complexes

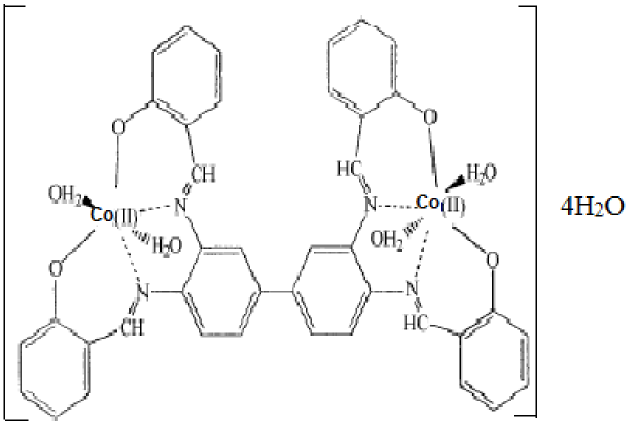
Conclusion

The synthesized Schiff base complexes derived from 3,3',4,4'-biphenyltetramine and salicylaldehyde of iron(II), cobalt(II), nickel(II) and copper(II) have been synthesized and characterized by using elemental and thermal analyses as well as spectroscopic techniques. The analyses data showed that, the ligand behaves as a neutral tetradentate ligand bonded to the metal ion/ions through azomethine nitrogen atoms, deprotonated hydroxyl groups. The IR resulting supported the ligand structure and the site of chelation through the function groups investigations. In all complexes the chelation proved to be through N and O atoms as expected. Thermal analysis gave more evidence of the shape and complexes formations sphere, TGA with electronic spectra confirmed that the complexes under investigation have octahedral geometry around of the donor atom of the ligand . The biological studies showed that the ligand and complexes biologically are active against Gram positive and negative bacterium *(Escherichia coli, Staphylococcus aureus, Staphylococcus epidermidis, Micrococcus spp. Pseudomonas Aeruginos, Klebsiella pneumonia, Salmonella typhimurium).* The sample Co(II) and Cu(II) has more antifungal activity than antibacterial activity (*Aspragillus niger, Candida albican acidophilus*.) in comparing with standard antifungal drug (Nystatin & Amphotericin B). from previous chemical analysis of free ligand and their complexes, we can suggest the following geometrical structures:

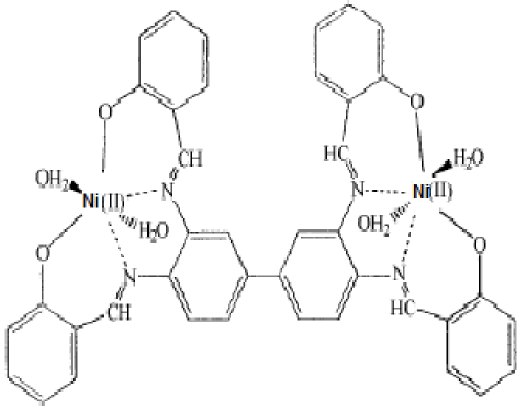
Iron(II) complex



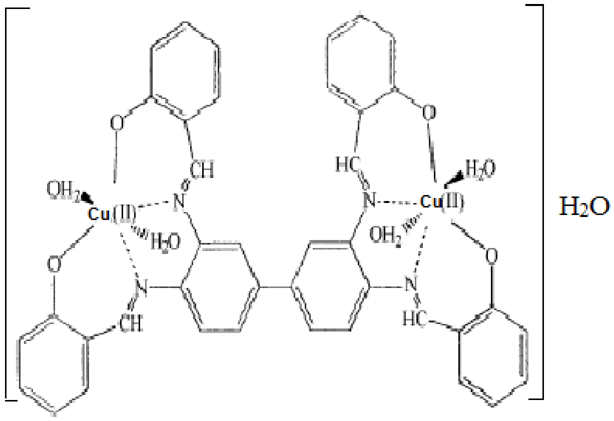
Cobalt(II) complex



Ni(II) complex



Copper(II) complex



Further work

Generally an extensive study of coordination compounds has centered on the behaviour of metal ions rather than the attached Schiff base ligands. But the properties of such ligands can be modified by the coordination to the metal ions. An overview of Schiff base metal complexes reveals that only few works have been carried out in the area of other aldehydes and ketones with 3,3',4,4'-biphenyltetramine, act as the building blocks of many poly and macrocylic ligand systems of Schiff bases and their metal complexes. The present investigation has been designed to provide some modern and advanced results in this field. Schiff base complexes were found to have immense application in various fields. In this study, has been investigated and there is effective for complexes against bacteria, fungi and here comes the role of scientists microbiology and pharmacology research whether these structures can be manufactured and converted into non-toxic materials to be taken as a medicine into the body bio or use killer of microorganisms only on surfaces, and by results previous back to chemists for the synthesis of new complexes either add substituted on the ligand or change metal ions in forms similar to those complexes specialization.

References

[1] N. H.Ahmed, M. Mohamad, M. A. Ahemd, and S.T. Abdou; Journal of the Korean Chem. Soc. **55**(3), 418-429 (2011).

[2] A. K. Mapari and K. V. Mangaonkar; E-Journal of Chemistry, **8**(1), 123-126 (2011).

[3] J. Hine, C.Y. Yeh; J. Am. Chem. Soc. **89**(11), 2669-2676 (1967).

[4] R.J. Fessenden and J.S. Fessenden, "Organic Chemistry", Brooks/Cole Publishing Company, USA, 4th ed (1998).

[5] L. G. Wade. "Organic chemistry" prentice-Hall, 4th ed, p.818 (1999).

[6] R. C Atkins.. and Carey F. A; "Organic Chemistry: a brief course" printed in USA McGraw-Hill, 3rd ed (2002).

[7] Y. Prashanthi1, and S. Raj; J. Sci. Res. **2**(1), 114-126 (2010).

[8] K. Shanker, M. Ashok, P. Muralidhar Reddy, R. Rohini and V.Ravinder; Int .J. ChemTech Res. **1**(3), 777-783 (2009).

[9] N. M. Ibrahim and A. S. Salah; E-Journal of Chemistry. **4**(4) 531-535 (2007).

[10] H. Khanmohammadi, M. Salehifard and M.H. Abnosi; J. Iran. Chem. Soc. **6**(2), 300-309(2009).

[11] T.Hamdi, C.Umit, O.Birol, and H. Ibrahim ; Synth. React. Inorg. Met.-Org. Chem., **31**(8), 1323-1337 (2001).

[12] W. Seong, M.Suc, Y. Kook and K. Hyung; Bull. Korean Chem. Soc. **14**(3), 313-315 (1993).

[13] F. Faridbod, M. R. Ganjali, , R. Dinarvand, P. Norouzi and S. Riahi; Sensors, **8**, 1645-1703 (2008).

[14] R. Yamgar, P. Kamat and S. Sawant; J. Chem. Pharm. Res., **2**(5), 216-224 (2010).

[15] D.Douglas and F.Irwin; Biochem. J. **226**, 781-787(1985).
[16] Z. Cimerman, S.Miljani, and N. Gali; CCACAA. 73 (1), 81-95 (2000).

[17] S. A. Abbas, M. Munir, A. Fatima, S. Naheed and Z. Ilyas; E-Journal of Life Sciences. **1**(2), 37-40 (2010).

[18] C.M. Metzler, A. Cahill, D.E. Metzler; J. Am. Chem. Soc. **102**, 6075 (1980).

[19] E. A. Abdalrazaq, O. M. Al-Ramadane and K. S. Al-Numa; Am. J. Applied Sci., **7**(5), 628-633 (2010).

[20] M. Hmadeh, H. Traboulsi, M. Elhabiri, P. Braunstein, A. M. Albrecht-Gary and O. Siri ; Tetrahedron. **64**, 6522–6529 (2008).

[21] H. Schiff, Ann. **131**, 118, (1864).

[22] H. Schiff, Ann. Chem. Suppl. **3**, 343, (1864).

[23] H. Schiff, Ann. Chem.**150**, 193,(1869).

[24] H. Schiff, Ann. Chem. **151**, 186, (1869).

[25] P. G. Cozzi, Chem. Soc. Rev **33**, 410-421, (2004).

[26] A. D. Garnovskii.; A. L. Nivorozhkin, and V. I. Minkin, Coord. Chem. Rev. 126,1-69 (1993).

[27] A. A. Ahmed and S. A. Benguzzi; Journal of Science and Its Applications. **3**(1), 112-120 (2009).

[28] M. M. EL-Ajaily, F. A. Abdlseed and S. Ben-Gweirif; E-Journal of Chemistry. **4**(4), 461-466 (2007).

[29] N. Raman, Y. P. Raja and A. Kulandaisamy; Proc. Indian Acad. Sci. (Chem. Sci.), **113**(3), 183–189 (2001).

[30] W. T. Huang1, S. J. Wang, J.-M. Lo; Ann. Nucl. Med. Sci. **16**, 31-39 (2003).

[31] U. K. Singh, S. N. Pandeya, A. Singh, B. K. Srivastava, M. Pandey; IJPSDR. **2**(2): 151-154 (2010).

[32] M. Imran, L. Mitu, S. Latif, Z. Mahmood, I. Naimat, S. S. Zaman and S. Fatima; J. Serb. Chem. Soc. **75**(8), 1075–1084 (2010).

[33] H. N. Aliyu and H. J. Abdullahi; African Scientist, **10**(4), 199-202 (2009).

[34] R.Rajavel, M. S. Vadivu and C. Anitha; E-Journal of Chemistry, **5**(3), 620-626 (2008).

[35] V. S. Kalpana, D. N. Mahajan, B. J.Subhash, Y. V. Archana and Y. B. Vibhute, Bulletin of the Catalysis Society of India**, 9**,18-22 (2010).

[36] S. G. Akmal, S. A. Mohsen, S. Barakat and M. T. Said; Spectrochimica Acta Part A, **67**, 114–121 (2007).

[37] N. S. Youssef , E. A. El-Zahany , B. N. Barsoum and A. M. A. El-Seidy; Transition Met. Chem. **2**, 9280 (2009).

[38] A. M. Hamil, K.M. Khalifa, A. AL-Houni and M.M. El-ajaily; RASAYAN J, Chem. **2**(2), 261-266 (2009).

[39] S. Belaid, A. Landreau, S. Djebbar, O. Benali-Baitich, G. Bouet , J. Bouchara; Journal of Inorganic Biochemistry, 102, 63–69 (2008).

[40] M. Kalisz, M.A. Novak, H.S. de Amorim, J.P. Sinnecker and M.G.F. Vaz; Journal of Magnetism and Magnetic Materials **294**, 51–55 (2005).

[41] J. P. Ishwar and J. P Shailesh. ; E-Journal of Chemistry, **7**(2), 617-623(2010).

[42] S. Ghosh and S. Malik; E-Journal of Chemistry, **7**(4), 1391-1395(2010).

[43] M. Jesmin. M.M. Ali and J.A. Khanam: Thai J. Pharm. Sci. **34**, 20-31(2010).

[44] A. Reiss, S. Florea, T. C.ˇAproiu and N. Stanica; Turk. J. Chem. **33**, 775 – 783(2009).

[45] G.G. Mohamed, M. M. Omar and A. M. Hindy; Turk. J. Chem. **30**, 361 – 382(2006).

[46] Y. R. Shah, D. J. Sen and C. N. Patel; J. Chem. Pharm. Res., **2**(2), 581-589(2010).

[47] H. D. Revanasiddappa, K. S. Prasad, L. S. Kumar and B.Jayalakshmi ; Int. J. ChemTech Res. **2**(2), 1344-1349 (2010).

[48] G. Kumar, D. Kumar, S. Devi, A. Kumar and R. Johari; E-Journal of Chemistry, **7**(3), 813-820 (2010).

[49] E. Keskioglu, A.B. Gunduzalp, S. Cete, F. Hamurcu, B. Erk. Spectrochimica Acta Part A, **70**, 634–640 (2008).

[50] H. Katircioglu, Y. Beyatlı, B. Aslim, Z. Yuksekdag, T. Atici. Internet Journal of Microbiology, **2**(2), 8289 (2006).

[51] V.P. Daniel, B. Murukan, B.S. Kumari, K. Mohanan, Spectrochimica Acta Part A, **70**, 403–410 (2008).

[52] M.S. Nair, R.S. Joseyphus, Spectrochimica Acta Part A, **70**, 749–753 (2008).

[53] A.S. El-Tabl, F.A. El-Saied, W. Plass, A.N. Al-Hakimi. Spectrochimica Acta Part A, **71**, 90–99 (2008).

[54] Y. Kou, J Tian, D. Li, W. Gu, X. Liu, S. Yan, D. Liao, P. Cheng. Journal of the Chemical Society, Dalton Transactions, **10**, 2374–2382 (2009).

[55] A.L. Lehlinger, "Principles of biochemistry" 2nd ed. , Worth, New York, 1975.

[56] N.Raman, V.Muthuralj, S.Ravichandran and K.Ulandaisamy; Pro. Indian Acad. Sci. (Chem. Sci). **115**(3), 161-167 (2003).

[57] V. S. V. Satyanarayana, P. Sreevani, A. Sivakumar, and V.Vijayakumar; ARKIVOC. **17**, 221-233 (2008).

[58] C.K. Jørgensen; Acta Chem. Scand. **2**, 73 (1957).

[59] P. Pfeiffer, T. Hesse, H. Pfitzinger, W. Scholl, H. Thielert Inner Komplexsalze der aldeimin And azoreihe, J. Prakt., Chem. **217**, 149 (1937).

[60] P. Pfeiffer, E. Buchholz , O. Baver, and J. Prakt. Chem. **129**, 163 (1931).

[61] M. Calligaris, G. Nardin , L. Randaccio ; Coord. Chem. Rev. **7**, 385-403 (1972).

[62] G. R. Canham " Descriptive Inorganic Chemistry" ; First printing Freeman & Co. New York (1999).

[63] N. N. Greenwood and A. Earnshaw" chemistry of the elements" 4th ed Elsevier Science UK (1990).

[64] J. A. Cowan" Inorganic Biochemistry an Introduction" 2nd ed. Wiley-VCH. USA (1997).

[65] S. M. Owen and A. T. Brooker" A guide to modern inorganic chemistry" NY, Wiley, New York (1991).

[66] F. A.Cotton and Wilkinson." Advanced Inorganic Chemistry" 4th ed Wiley, New York, (1980).

[67] J.J.R. Frausto da Silva and R. J. P. Williams "The Biological Chemistry of the Elements" (the inorganic chemistry of life) 2nd ed Press, Oxford, UK (2004).

[68] C. H. Depuy and F. I. Rinehart, "Introduction to Organic Chemistry", John Wiley Sons, Inc, 2nd ed. London (1975).

[69] J. E. Kovacic, Spectrochim. Acta, **23**A, 183 (1987).

[70] N. Raman, Y. P. Raja and A. Kulandaisamy; Proc. Indian Acad. Sci. (Chem. Sci.), **113**(3), 183–189 (2001).

[71]W.S. Kim, K.I. Chung ,S.K. Kim, S. Jeon, Y. H. Kim, Y. E. Sung and Y. K. Choi; Bull Korean Chem. Soc, **2** , 6, (2000).

[72] S. Djebbar-Sid and O. Benali-Baitich Transition Met. Chem., **23**, 443-447 (1998).

[73] M.B. Okunade, J.A. Adejumobi, M.O. Ogundiya and A.L. Kolapo, Journal Phytopharmacotherapy and Natural products **1**(1), 49-52 (2007).

[74] C.Perez, , A. Pauli and P.Bazerque, Acta Biol. Med. Exp, **15**, 113-115 (1990).

[75] T.O.S. Popoola, O.D. Yangomodu and A.K. Akintokun, Research Journal of Medicinal Plant, **1**(2), 60-64 (2007).

[76] F. Kavanagh, "Analytical Microbiology" 2nd ed. Academic press, New York, London,. **2** ,44-121 (1972).

[77] F. Salie, P.F.K. Eagles and H.M.J. Leng. J Ethanopharmacology **52**, 27-33 (1996).

[78] A. S. El-Tabl and S. M. Imam, Trans. Met. Chem., **22**, 259 (1997).

[79] M. Gaber and M. M. Ayad, Thermochemi. Acta., **176**, 21 (1991).

[80] R. T. Rasheed, Eng. &Tech. Journal, **30**(13), 2295-2302 (2012).

[81] C. Anitha, C. D. Sheela, P. Tharmaraj, and R. Shanmugakala International Journal of Inorganic Chemistry, **10,** 1-10 (2013).

[82] S. P. Ketan, C. P. Jiten, R. D.Hitesh, K. P.Vishal and D. P.Kanuprasad , Open Journal of Metal, **2**, 49-59 (2012).

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Summary