SYNTHESIS, STRUCTURAL AND HYDROLYTIC STUDIES OF ZINC (II) COMPLEX OF N,N'-BIS (2-AMINOPHENYL)-2,4-DIIMNOPENTANE

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BY

ADEN TADELE

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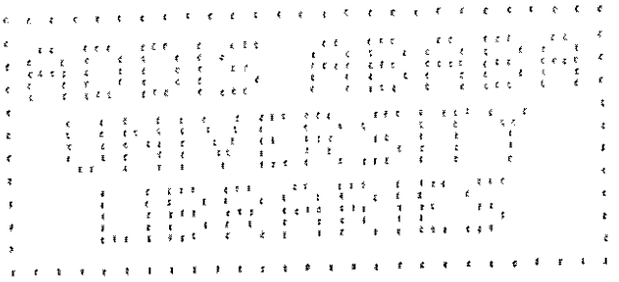

TO FATUMA

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Synthesis, structural and hydrolytic studies of zinc(II) complex of N,N'-bis (2-aminophenyl) -2,4-diiminopentane.

By: Aden Tadele

Advisor: Prof. Negussie Retta

ABSTRACT

In this study the synthesis of [N, N'-bis (2-chloroquinoxaline-3-yl)-1,3-diaminopropane and the synthesis, structure and hydrolytic activity of a zinc(II) complex of N,N'-bis (2-aminophenyl)-2,4-diiminopentane are presented.

In the first part attempt was made to synthesize a macrocyclic ligand derived from 2,3-dichloroquinoxaline and diamine. The reaction between 2,3-dichloroquinoxaline and excess 1,3-diaminopropane led to the formation of a pale yellowish solid. The IR, ^{1}H NMR and ^{13}N MR of the compound indicated that it is a non-cyclic molecule.

The reaction of 1,2-phenylenediamine with acetylacetone in water resulted in the formation of a ligand that forms a complex with zinc(II) ion. The complex was characterized by ^{1}H NMR, ^{13}C NMR, IR, conductivity measurement, etc. The preliminary test indicated that rate enhancement by the complex on the hydrolysis of tri (p-nitrophenyl) phosphate, p-nitrophenylacetate and 4-nitrophenylbenzoate is in decreasing order, in 10% (H_2O) aq. acetonitrile at 35°C and above.

1. INTRODUCTION

The overlap region between inorganic chemistry and the biological science is where exciting and significant developments are taking place. It is now appreciated that metal ions control a vast range of processes in biology; that life is dependent upon inorganic chemistry as organic chemistry.

On the other hand, synthetic and structural studies of metal complexes of various ligands are important to provide insight into the spectroscopic, magnetic, structural thermodynamic and kinetic properties of the complexes. As a result, a large number of ligands have been synthesized and investigated for metal binding and other characteristic properties.

Ligands are classified according to the number of bonding sites that are available for forming a coordinate covalent bond to metal ion. Monodentate (or unidentate) ligands such as ammonia, halides are attached to the central metal ion directly through only one coordinating atom while multidentate ligands such as the polyamine ligands are attached to a central metal ion by more than one coordinating atom. Multidentate ligands that are at least quadridentate and that can completely encircle the metal ion are called macrocyclic ligands [1-3].

Transition metal ions have played an important role in the development of coordination chemistry as they readily form stable complexes with molecules containing N, O, S, C, P or halogens as donor atoms. This is a result of some interesting properties of the metals such as small cation size, comparatively large

nuclear charge and availability of sufficient number of low lying vacant d-orbitals for binding purposes [3].

The chemistry of transition metal macrocycle is an extensive area of research in view of close relationship of these macrocycles to biologically significant and naturally occurring metal complexes. The complexity of biological molecules, and the associated problems in their study makes often worthwhile to examine the behavior of simpler molecules that contain what appears to be the essential features of the original molecule, uncomplicated by other features of that molecule. Thus, the use of model compounds has allowed the build up of much information regarding the structure, bonding, stability and reactivity of biological molecules. The model compounds may also have other useful properties such as solubility, not possessed by original species.

The present interest in designing new macrocyclic ligands stems from these advantages and successful use of the ligands for diverse processes. They may serve as models for metalloenzymes [4-5], protein-metal binding sites in biological systems [6], model to study the magnetic exchange phenomena [7], catalysts [8-10], medical imaging agents, therapeutic reagents for the removal of toxic metals [11,12], chemical sensors [11], in fuel cell applications [13], separation of ions by transport through artificial and natural membranes as well as in biological molecules. Macrocycles such as the polyethers may provide clues to the discrimination shown by biological tissues toward various ions[14].

The field of macrocyclic chemistry has grown rapidly during the past two to three decades. Nowadays a large series of synthetic macrocyclic ligands capable of binding cations or anions have been prepared and investigated. Many of these macrocyclic polyetheres, polyamines, ploythioeteres and other related molecules have been shown to possess very interesting and unusual properties [15].

Macroclcylic ligands containing nitrogen oxygen, sulfur and phosphorus atoms as well as varying combinations of these donor atoms have been found to show selectivities towards metal ions of different sizes [15-17]. Two aspects of metal ion selectivity for macrocycles are of importance. These are the preference of metal ions to the type of donor atoms and the selectivity for metal ions based on their size.

Some metal ions prefer to bind with oxygen donor macrocycles while others prefer to bind with nitrogen donor macrocycles. This is because the geometry of minimum strain ring sizes that involves neutral oxygen donors is rather different from that involving neutral nitrogen donors [16]. Macrocyclic rings containing neutral oxygen donors will have low strain when a trigonal planar geometry around the coordinated oxygen is achieved and this is obtained with larger metal ions. An important consequence is that the oxygen donor macrocycles tend to complex well with metal ions such as the larger alkali and alkaline earth metal ions, and the larger post-transition metal ions such as Pb(II), Tl(I), or Hg(II). The nitrogen donor macrocycles, on the other hand, complex well with transition metal ions, as well as the post-transition metal ion as achievement of close to the tetrahedral coordination geometry

will be important. The sulfur donor macrocycles resemble the nitrogen donor ligands more closely in their coordinating properties [16,17].

When the ligands are macrocycles that are restricted by steric constraints which could be the origin of unusual behavior in a range of metals containing such systems, the fitness of a metal ion for its surrounding coordination shell is a parameter of major importance in influencing the chemical properties of the resulting metal complex. As a result many of the properties of the resulting metal complex of macrocycles appear to be controlled by the size of the cavity in the center of the macrocycle, *viz.*, size match selectivity [18]. Size match selectivity means that a metal ion will show its maximum stability with the member of series of macrocycles where the match between the size of the metal ion and of the cavity in the macrocycle is closest [16].

Busch *et al.* [19] have calculated using molecular mechanics (MM), the best fit metal nitrogen (M-N) bond lengths for metal ions fitting into the cavities of saturated tetraaza macrocycles. Boeyes and Hancock supported the values obtained by Busch using similar calculations [20]. In these studies, unusual, potentially useful, ring size discrimination effects of metal ions have been observed in both the thermodynamics and kinetic behavior of a number of such compounds. They have also found out that there is a need for matching ring size in such ligands to the radii of particular metal ions especially to use these macrocyclic ligands as metal ion selective reagents.

However, the selectivities displayed by macrocyclic ligands, particularly multidonor ligand systems towards particular metal ions are more complex than might be

supposed form the simple size match selectivity idea. Other factors that must be dealt with are ligand field strengths observed in complexes of many nitrogen donor ligands than that of their open chain analogues and ability to stabilize unusual oxidation states [21,22].

These macrocycles can be tailored to accommodate specific metal ions by systematic modification of variables that control the ligand design systems. These features include variables such as nature and number of the donor atoms, size of the macrocyclic cavity formed, ligand conjugation, flexibility of the system, relative positions of the donor atoms or on the carbon skeleton [22]. As a result, it is believed that the complexes of macrocyclic ligands are flexible enough to change conformation to accommodate metal ion of different sizes or ligands of different size [16].

Cyclization of linear polyamine ligands as well as other ligands produce striking changes in the properties of the metal complexes when compared to the equivalent complexes of the linear ligands.

The following are some typical properties exhibited by metal complexes of macrocyclic ligands than the corresponding open chain analogues.

1. They possess considerably greater kinetic inertness [23] both to the formation of the complexes from the ligand and metal ion (metallation reaction) and to reverse, the dissociation of the metal ion from the ligand (demetallation reaction), which might be advantageous in some applications, and detrimental in others.

2. They are capable of stabilizing unusual oxidation states of metals that are not normally readily attainable.

The ability of macrocyclic ligands to stabilize a wide range of oxidation states of a coordinated metal ion has been amply demonstrated by studies of Olson and Vasilevskis [24]. It has been shown that oxidation states of copper, nickel and cobalt which are not normally accessible can be stabilized with macrocyclic ligands. The facile redox behavior of iron, especially in naturally occurring systems, in conjunction with the many favorable characteristics of macrocyclic ligands, makes the study of these systems especially appealing. Unusual oxidation states that have been stabilized by nitrogen donor macrocycleds include Ni(III), Ni(I), Cu(III), Co(I), Pd(III) and Pt(III) [23-26].

3. Metal complexes of macrocylclic ligands have also high thermodynamic complex stability [16].

This unusual greater complex stability was first noted by Cabbiness and Margerum [27] in complexes of tetraaza macrocycles as compared to their open-chain analogues. They suggested the term "macrocyclic effect" to describe this phenomenon which seemed to be a logical extension of the well known chelate effect.

Factors have been considered generally to account for the macrocyclic effect are greater preorgainzation of the macrocyclic ligand as compared to its open chain analogues, steric hindrance to solvation of the donor atoms in cavity of the macrocycle [27, 28], intrinsic basicity effects [29] due to the electron releasing

(inductive) effects of ethylene bridges between donor atoms, and enforced electrostatic repulsion between lone pairs [30] of the donor atoms in the cavity of the macrocycle which is relieved on complex formation.

Metal ions play vital role in a vast number of widely differing biological processes. Some of these processes are quite specific in their metal ion requirements in that only certain ions, in specific oxidation states can fulfill the necessary catalytic or structural requirements, while other processes are much less specific, and it is possible to replace one metal by another, although the activity may be reduced [31] .

A wide range of metalloprotien (enzymes) catalyzes the hydrolysis of organic and inorganic esters. The Zn(II) ion is biologically essential and often constitutes active centers of hydrolytic enzymes. The zinc atoms in metalloprotiens are designed by nature to generate nucleophiles (e.g. OH^-, OR^- or H^-) to attack at electrophilic centers, such as carbonyl $C^{\delta+}$ and phosphate $P^{\delta+}$ [32].

Some of metalloenzymes and metal activated enzymes involved in hydrolysis and group transfer reactions are listed in table 1.1. The main classes of hydrolytic enzymes may be summarized in terms of nature of the substrate being hydrolyzed.

Table 1: Some hydrolytic enzymes

Enzyme	Reaction catalyzed	Metal ion
Carboxypeptidase	hydrolysis of C-terminal peptide residue	Zn(II)
Leucine amino peptidase	" " leucine N-terminal peptide residue	"
Dipeptidase	" " dipeptides	"
Collagenase	" " collagen	"
Phospholipase C	" " phospholipids	"
β- Lactamase II	" " lactam ring	"
Thermolysin	" " peptide	Ca(II), Zn(II)
α- Amylase	" " glucosides	Zn(II), Ca(II)
Alkaline phosphatase	" " phosphate ester	Zn(II)
Carbonic anhydrase	hydration of CO_2	"

Zinc is necessary for the activity of many of these enzymes, although a second metal is sometimes required. The preferred ligand-binding group for zinc(II) is an imidazole [31] in carboxypeptidase, carbonicanhydrase and alkalinephosphatase.

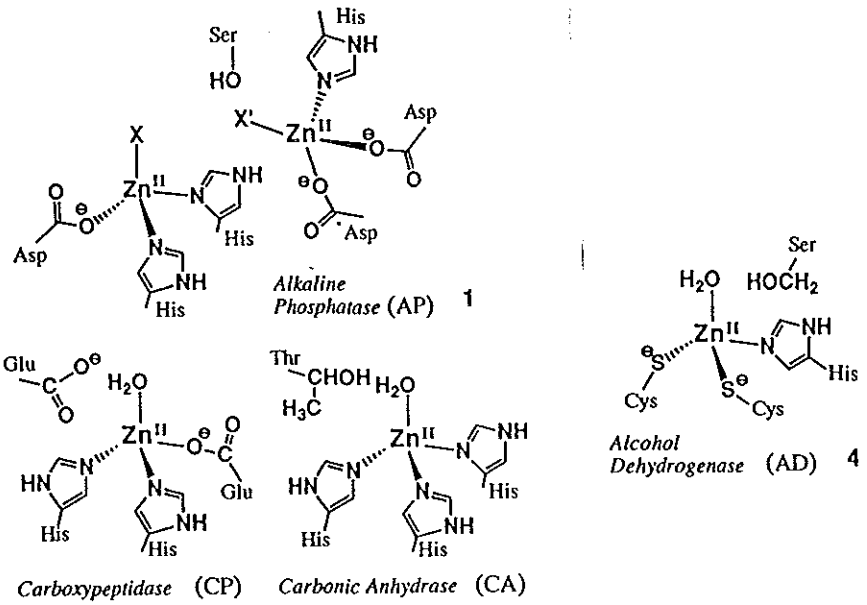
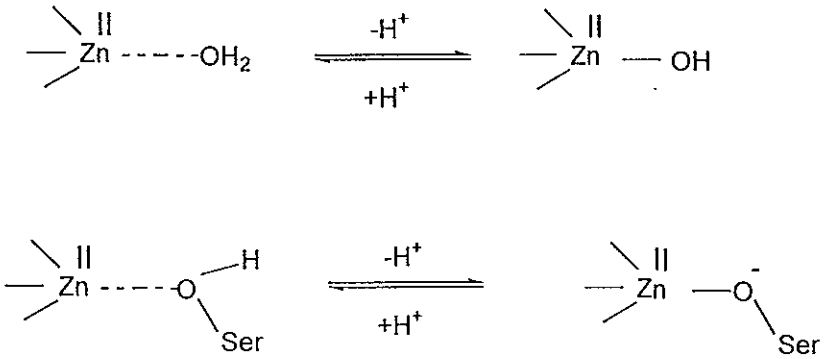


Fig. 1 Active centers of typical Zn(II) enzymes

The mechanistic role of metal ion is one of general acid catalysis, but differ from proton catalysis in that (a) the metal ion can coordinate to several ligands simultaneously and (b) metal ion catalysis is possible in pH ranges where proton catalysis could be ineffective [31].



Scheme I Deprotonation of Zn(II) binding hydroxyl groups

Most of the recent work on model compounds of alkalinephosphatase has involved synthesis of mononuclear or binuclear zinc complexes with tri- or tetra-dentate ligands and attached often hydroxo or aquo donor groups. These compounds are then studied for their catalysis of hydrolysis using phosphate esters such as 4-nitrophenylphosphate or bis-4-nitrophenylphosphate as substrate to test the ability of the model compounds to hydrolyze phosphate esters [33].

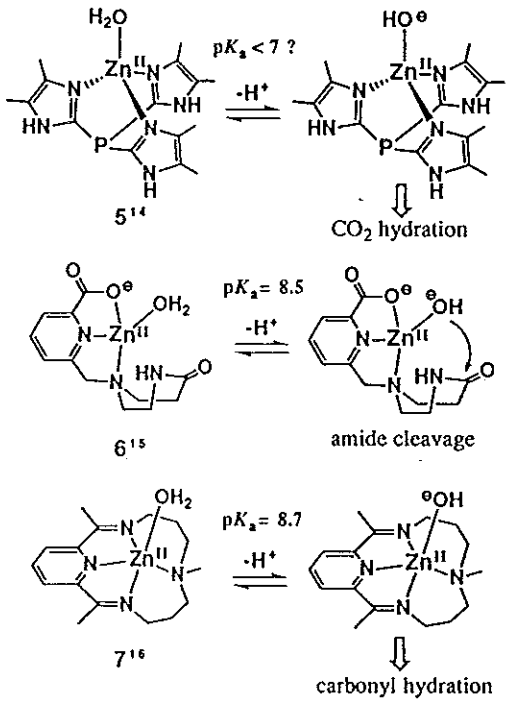


Fig. 2 Conventional Zinc Enzyme Models

Macrocyclic polyamine ligands have been found to be quite advantageous in the synthesis of zinc(II) coordination environment as model of zinc enzymes, because of the enormous stability (macrocyclic effect) of the zinc(II) complex they form [32] at physiological pH.

The 12-membered macrocyclic triamine is proven to be very useful and versatile ligands to build a model for carbonic anhydrase, where four $\rightleftharpoons$ five coordination seems to be prevalent in catalytic cycles [34].

One of the problems in developing efficient, zinc based hydrolytic agents is the precipitation of polymeric hydroxide above neutral pH. Inspite of a number of attempts to develop zinc imidazole ligands whose zinc complexes might imitate the zinc imidazole system in alkalinephosphatase or carbonic anhydrase, one of the few zinc complexes so far known to hold up to alkaline condition is the macrocyclic system [35].

A zinc complex of tetraaza macrocycle catalyzes the hydrolysis of diphenylp-nitrophenylphosphate in aqueous acetonitrile [36].

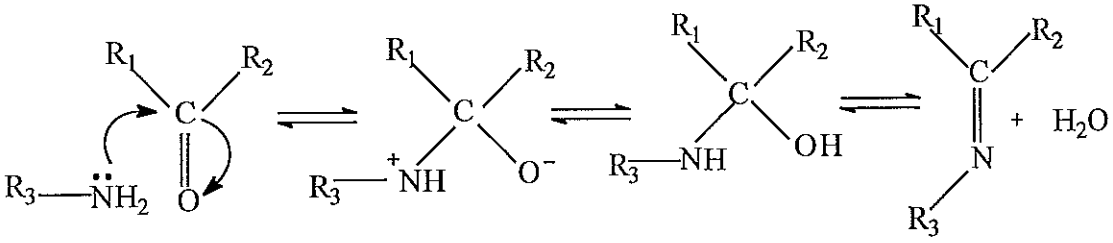
The chemistry of constituent exchange, such as hydrolysis, at phosphorus (V) centers has received considerable attention because such processes occur in many crucial reactions and are relevant to the detoxification of some pesticides and chemical weapons [36].

The current project aims at the preparation of zinc(II) complex of tetradentate macrocyclic ligand as model for the active center of zinc hydrolytic enzyme.

templating cation and the "hole" size of the macrocycle contributes to the effectiveness of the synthetic pathway and to the geometry of the resulting complex.

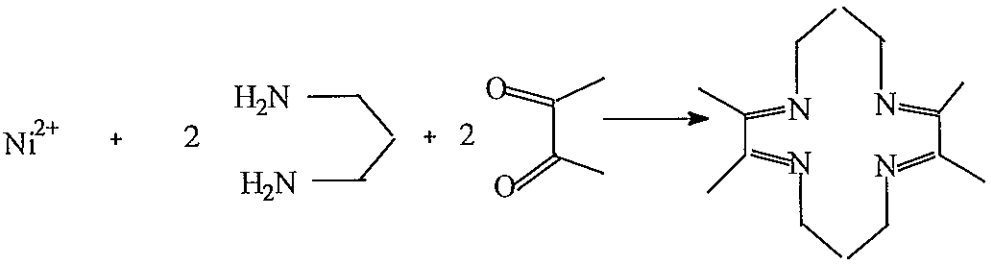
Reagents that contain carbonyl groups as well as amine donors have been particularly useful in the synthesis of certain cyclic structures via template processes.

There are many examples of the condensation reaction of diketones containing imine group. The reaction to prepare these compounds program through a carbinol amine and requires the removal of water according to the reaction scheme shown below.



Scheme III – Mechanism of the Condensation of a Primary Amine with Carbonyl Group

The first example of a ring closure utilizing such a reagent was reported by Baldwin and Rose [50].

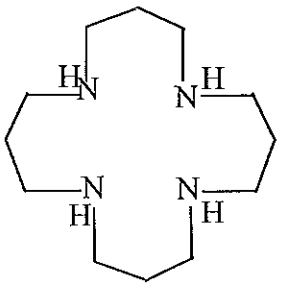


Scheme IV The First Example of Template Synthesis

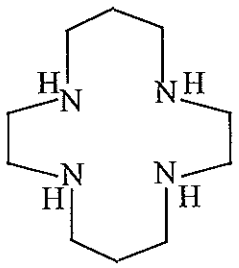
2.2. Nitrogen Donor Macrocycles

The sphere of coordination chemistry of polyazamacrocycles had undergone a rapid change after the early 1960's chiefly due to the pioneering contribution of Curtis [52] and Busch [29]. A large variety of cyclic polyamines having three to six functional groups in the ring have been synthesized. Perhaps the most thoroughly studied macrocyclic ligands have been those containing four nitrogen atoms (quadridentate) capable of coordination because of their relationship to the porphyrins. To fully encircle a first row transition metal ion, a macrocyclic ring size between 13 and 16 membered are required provided that the nitrogen donors are spaced such that five, six or seven membered chelate rings are produced on coordination [53].

The metal complexes of the 14-membered cyclic tetraamines, 1,4,8,11-tetraazacyclo tetradecane (cyclam) are the most fascinating and represents reference systems [41] in the coordination chemistry of tetraaza macrocycles (see Fig. 2). Studies [54] have shown that they form very stable complexes with transition metals.



16-aneN$_4$



14-aneN$_4$ (cyclam

Fig.3 Some Nitrogen Donor Macrocyclic Ligands

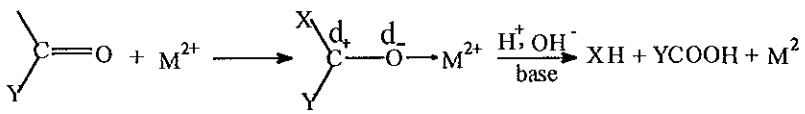
2.3. Models for Hydrolytic Metalloenzymes

The complexity of biological macromolecules, and the associated problems in their study, means that it is often worthwhile to examine the behavior of simpler molecules that contain what appear to be the essential features of the original molecule, uncomplicated by other features of that molecule. The model compounds may also have other useful properties such as solubility, not possessed by the original species [31].

Despite the fact that good chemical models are available for the most enzymatic reactions, it should be emphasized that a comparison of rates, in general, shows that the reaction undergone by the models are very much slower than the enzymatic reactions.

The role of metal ion as a Lewis acid has been clearly demonstrated.

Bender and Turnquest [55] have studied the copper(II)- catalysed hydrolysis of esters of α-amino acids. Based on oxygen-18 exchange data and kinetic studies they have suggested a mechanism involving the formation of a complex in which the ester is chelated via the amino and carbonyl groups. Polarization of the carbonyl group then results in enhanced susceptibility of the carbon to nucleophilic attack by a base.



In many zinc containing enzymes the metal center acts as a strong Lewis acid and participates in solvolysis and hydrolysis reactions [56-58]. The d^{10} electron configuration of zinc rules out ligand field stabilizing effects for zinc complexes and leads to a considerable flexibility of coordination numbers and strongly distorted coordination polyhedra [59].

Several small molecule model zinc complexes have been developed to study the hydrolysis of phosphate esters [60, 61]. In these models relatively rigid ligands providing three sites were used as such ligands leave Zn(II) coordinatively unsaturated and so enable coordination of the water that is believed to play an essential role in the mechanism of hydrolysis.

Other support for the effectiveness of metal-bound hydroxide in the hydrolysis of esters and amides comes from work on labile metal ions, which catalyze the hydrolysis of esters more efficiently than does OH^-. The pH dependence of the observed rate constant for certain of these reactions suggest that the catalytically active form of the metal complex of the ester contains M-OH [62].

3. OBJECTIVES

The literature survey revealed that synthetic polyazamacrocyclic ligands and their metal complexes could play essential roles in diverse chemical and biological processes. Hence the objectives of the present research work were:

(i) to synthesize a tetra dentate polyazamacrocyclic ligand in the presence of Zn(II) ion,

(ii) to characterize the synthesized complex using physico-chemical techniques and

(iii) to test the reactivity of the complex as catalyst for hydrolysis of esters.

4. EXPERIMENTAL

4.1. Materials and Chemicals

The chemicals used are of analar grade. Solvents were purified following standard methods. The following chemicals :o-phenyldiamine (BDH), hydrochloric acid (BDH), zinc (II) chloride (Riedel-de Haen), potassium hydroxide (BDH), Riedel-de Haen), methanol (BDH), acetylacetone (Riedel-de Haen), ammonia solution (BDH), silver nitrate (Riedel-de Haen), nitric acid (Riedel-de Haen), DMF (BDH) were used as received without further purification.

4.2 Physical Measurements

Melting point of the complex was determined with Bock-Monoscop apparatus and is uncorrected.

Infrared photospectra was obtained using Pye-Unicam SP 2000 infrared spectrophotometer in the range of 4000-200 cm^{-1} and with Buck Scientific Model 500 infrared photo spectrometer with range of 4000-600 cm^{-1} as potassium bromide disks.

^{1}H NMR and ^{13}C NMR spectra were recorded in $CDCl_3$ using BRUCKER AVANCE 400MHz machine with Me_4Si as internal standard.

UV-Visible spectrophotometric studies of freshly prepared 10^{-3} M methanolic solution of the complex in the range 200-1100 nm were conducted using SPECTRONIC GENESYS 2PC spectrophotometer at room temperature.

The electrical conductivity of freshly prepared 10^{-3} M solution in methanol of the complex was obtained from Harris Conductivity meter at room temperature. The cell constant was first determined using KCl solutions of known concentration and conductivities.

4.3 Elemental Analysis

The metal complex has been analyzed for metal by using the volumetric method of analysis (EDTA titration using Eriochrom black T as indicator) [63].

The chloride content of the product was estimated by gravimetric analysis method as AgCl [63].

4.4 Purity Test

The purity of the complex has been checked by TLC technique by dissolving the sample in methanol, using the mixture of ethanol: DMF: H_2O (1:1:1 ratio by vol.)

as an eluant and developing in an iodine chamber using pre-coated thin layer chromatographic plates (Polygram SIL G/UV_{254}, Mackerey-Nagel).

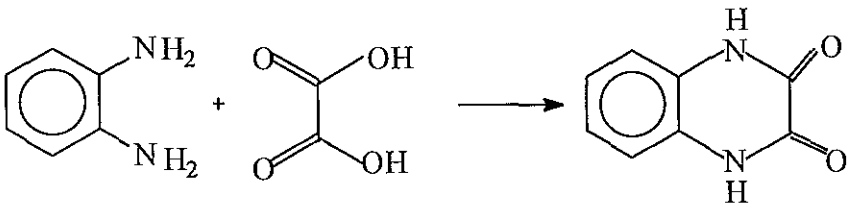
SECTION - A

4.5 Synthesis of a Ligand Derived from 2,3-Dichloroquinoxaline

Synthesis of a ligand from 2,3-dichloroquinoxaline consists of three steps.

4.5.1 Preparation of Quinoxaline-2, 3-dione [64]

Quinoxaline-2, 3-dione is synthesized by boiling a mixture of orthophenyldiamine (5.5 g) and oxalic acid dihydrate (6.5 g) in 4M HCl (30 mL) for 15 minutes on water bath. A crystalline solid formed was cooled, filtered, washed with water and dried in vacuo. The solid was dissolved in alkali, filtered and acidified with HCl, up on which quinoxaline-2, 3-dione as white needle precipitate obtained with 65% yield and m.pt. >350 °C. Literature m.p. >350°C, [64].

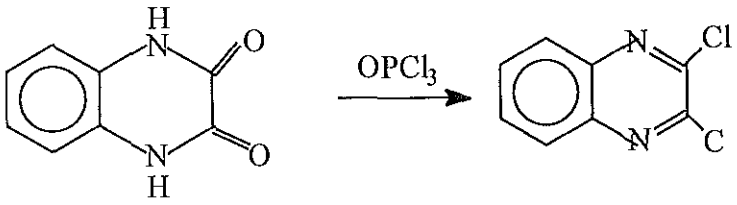


Scheme V Preparation of Quinoxaline-2, 3-dione

The solid obtained is insoluble in acids, matches the M.P. cited in the literature and its IR spectrum shows the C=O and N-H (2^0) stretching bands.

4.5.2 Preparation of 2,3-Dichloroquinoxaline [65]

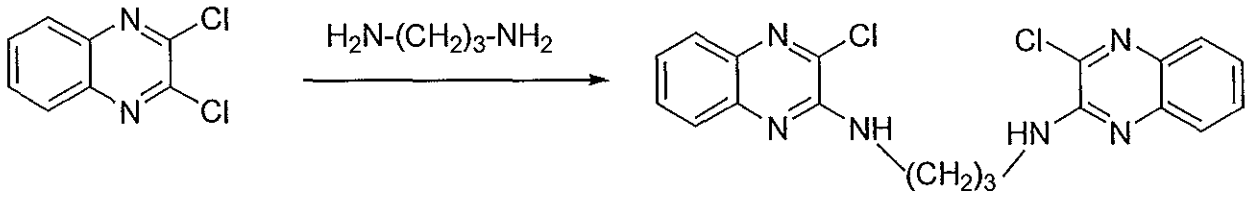
Quinoxaline-2, 3-dione (15 g) was heated under reflux with freshly distilled phosphorylchloride (45 mL) and N, N-diethylaniline (15 mL) for 2.5 hr. The cooled mixture was slowly poured into crushed ice, and the precipitated 2,3-dichloroquinoxaline was filtered and washed with water. Crystallization from benzene gave yellow needles with yield 40% and m.pt. 151. Literature m.p. 151-153°C [65].



Scheme VI Synthesis of 2,3-Dichloroquinoxaline

4.5.3 Preparation of the Macrocyclic Ligand (compound 3).

To 2,3-dichloroquinoxaline (2.05 g, 0.01mol.) dissolved in hot methanol (50 mL) 1.48 g (0.02 mol) of 1,3-diaminopropane was added and refluxed with stirring for 7 hours. The pale yellow solid obtained was filtered in hot condition and washed three times with portions of 15 ml of hot methanol and water. The solid was dried in vacuo. The yield was 0.78 g (38%) and m.p. 180-181^{0}C.



Scheme VII Synthesis of the Ligand (Compound 3)

4.6 Result and discussion

Table 4.1 Physical Properties of the Compound 3

colour	Yield	m.p. (^{0}C)	λ_{Max} (nm)
Pale yellow	38%	180-181	353

4.6.1 IR spectrum

The IR spectrum of the compound presents fundamental bands corresponding to the expected structure.

Table 4.2 Characteristic Infra Red frequencies (cm^{-1}) of compound 3.

νN-H	νC-H	νC-H (Ar)	νC=N (ring)	δC-H	νC-N	Ring vibration
3400	2875	3080	1594	1470	1090	1524,1542,1584

4.6.2 ^{1}H NMR and ^{13}C NMR spectrum of the compound 3.

The ^{1}H NMR spectrum of the compound in $CDCl_3$ shows two doublets in the aromatic region at 7.8-7.7 ppm; which may be assigned to the aromatic protons (2H) ortho (adjacent) to hetero atomic ring fused to the benzene ring (at positions 5 and 8, respectively). Signals observed at 7.4 and 7.6 ppm (t, 2H) may be assigned to aromatic protons at positions 6 and 7. The broader signal at 6.1ppm (2H) may be assigned to amine (-NH-). The quintet at 2.1ppm (2H) and quartet in the region 3.8-3.7 ppm (4H) are due to the methylenes ($-CH_2-$,b) and ($-CH_2-N-$, a) respectively.

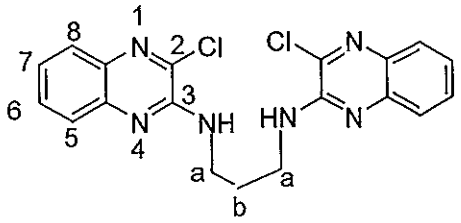


Fig 3. Compound 3

The ^{13}C NMR spectrum of the compound in $CDCl_3$ shows two types of aliphatic carbons at 38.7ppm and 30ppm in the intensity ratio of 2:1 which are confirmed to be the methylene groups, ($-CH_2-$) carbons by DEPT. They may correspond to the ($-CH_2-$

NH-, a) and (C-CH_2-C, b) respectively. The two aromatic carbon signals at 125 ppm and 126 ppm may be attributed to the carbons at positions 6 and 7. The two signals at 128 ppm and 130 ppm may be due to the carbon atoms at positions 5 and 8 of the benzene ring (adjacent to the hetero atomic ring). The quaternary carbon signals at 148.7 ppm and 14.6 ppm seem to be those attached to Cl and N in the hetero atomic ring of quinoxaline, at positions 2 and 3, respectively. The signals at 136.8 ppm and 138 ppm may be the carbon atoms through which the hetero atomic ring is fused to the benzene ring.

According to the ^{1}H NMR spectrum of the compound, the proportion of aromatic protons to aliphatic protons and amine protons is 4:3:1. However, the structure proposed in the reaction scheme has the proportion mentioned above as 2:3:1.
On the other hand, ^{13}C NMR shows ten different carbons. However, according to the scheme there should have been only six different carbons. The qualitative test also revealed that it contains chlorine. The use of excess diamine or diamine with n=2,3,4 didn't bring about the necessary macrocycllic compound.

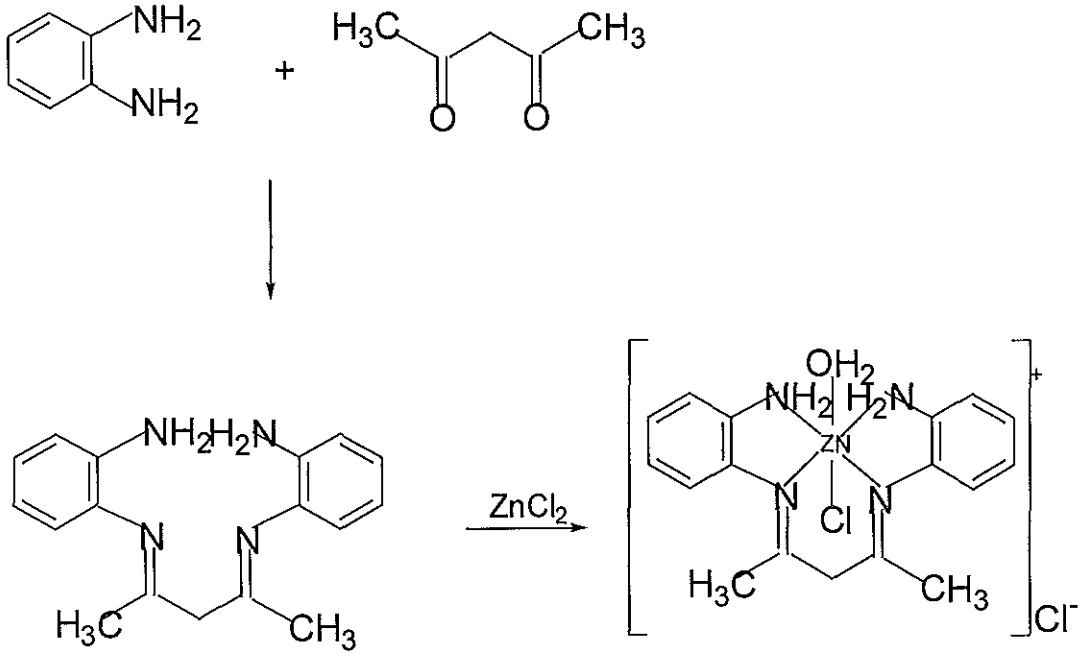
4.6.3 UV-Vis Spectra

The electronic spectrum of the compound shows a band of maximum absorptions at 265 nm and 353 nm, which are ascribed to chromophore of the conjugation of the fused ring.

4.7 Synthesis of a Zn (II) Complex Derived from Orthophenylenediamine and Acetylacetone

To 3 g (0.03 mol) of 1,2-phenylenediamine solution in water 2.8 g (2.9 mL, 0.03 mol.) of acetylacetone was added and refluxed for one hour. The resulting solution cooled and treated with dilute alkali until the last drop stops producing solid. The solid was separated and the filtrate was treated with Zn(II) chloride solution, up on which a yellowish solid precipitate, until the last drop stops forming solid. This precipitate was collected and washed with portions of 100 mL of water. The solid, [zinc(II) complex] collected, dried in vacuo. M.pt. 229-230^{0}C, yield 1.63 g.

4.8 Results and Discussion



Scheme VIII Synthetic pathway of the Zn(II) complex of N, N'- bis (2-aminophenyl) - 2,4-diiminopentane

4.8.1 Physical and Analytical Studies

The metal and chloride analysis were conducted using common analytical methods. The chloride content of the complex was estimated by gravimetric analysis as AgCl by sodium fusion method [63]. The metal ion was determined by volumetric method of analysis using EDTA titration with Eriochrom black T as an indicator [63].

Table 4.3 Analytical Data

Calcd. (found) %Zn	Calcd.(found) % Cl
15.04 (15.00)	16.32 (16.62)

Table 4.4 Physical Properties and Conductivity Data of the Complex

Color	M.Pt. (^{0}C)	Λ_m ($cm^2\,\Omega^{-1}mol^{-1}$)
Yellow	229-230	64.4

The molar conductance (Λ_m) value of the metal complex solution in MeOH was calculated from conductivity measurement of the solvent (MeOH), metal complex solution in MeOH and determination of cell constant using the relation: Λ_m ($cm^2\,\Omega^{-1}mol^{-1}$) = 1000 κ/c. Where κ -the specific conductivity;

κ ($\Omega^{-1}cm^{-1}$) = ($1/R-1/R_{meOH}$) b, c-concentration in mol^{-1}, b- (cm^{-1}) = l/A and –length, A-area.

The molar conductivity value of the freshly prepared 10^{-3} molar solution of the complex in ethanol at room temperature, suggests that the complex is a 1:1 electrolyte [66], which implies the presence of one ionizable chloride out of the coordination sphere.

4.8.2 Infrared Spectral Studies

Table 4.5 Characteristic IR Frequencies (cm^{-1})

νN-H (asy)	νN-H (sy)	νC-H	δC-H	νC=N	νC-N	Ring vibrations
3400	3211	2875,2940	1423	1650	1301	1613,1557,1466

The bands at 3400 and 3211cm^{-1} are attributed to asymmetric and symmetric N-H stretchings of primary amines. This implies an open structure instead of cyclic system.

The bands observed in the region 2950-2870 cm^{-1} may be due to C-H stretching vibrational mode and 1423 cm^{-1}due to $-CH_3$ deformations. The bands in the region 1613 cm^{-1}, 1557 cm^{-1} and 1466 cm^{-1} may be due to aromatic ring vibrations and the band at 790 cm^{-1} is due to ortho- substituted (four adjacent protons) benzene ring [66]. The band at 1301 cm^{-1} is attributed to C-N stretching of aromatic amine. The

broad band in the region 3100-3311 cm^{-1} is due to merging together of νO-H of coordinated water and νN-H stretching.

4.8.3 ^{1}H NMR and ^{13}C NMR Spectra

The ^{1}H NMR spectrum of the ligand in $CDCl_3$ shows three singlates at 2.6 ppm (2H), 2.3ppm (6H) and a broader band at 2.9 ppm (4H), which are ascribed to protons of methylene ($-CH_2-$), methyl ($-CH_3$) and amine (NH_2) groups respectively. The two multiplates at 7.2 ppm and 7.4 ppm are due to the aromatic protons (8H) of the two benzene rings.

The ^{13}C NMR spectrum of the ligand shows two signals which may be assigned to the methylene and methyl groups at 43.6 ppm and 28.0 ppm respectively. The signals at 127.9 ppm and 125.4 ppm may stand for the pairs of non quaternary aromatic carbon atoms of the benzene rings. The signal at 158.2 ppm is attributed to the imine quaternary carbon. The two signals appearing at 140.6 and 122.4 ppm are assigned to two substituted aromatic carbon atoms.

4.8.4 Electronic Spectrum

The electronic spectrum of the ligand shows a band of absorbance maxima (λ_{max}) at 239 nm, which may be attributed to the imine conjugated to the aromatic ring.

SECTION -B

5. Reactivity Test of the Zinc (II) Complex as Catalyst for the Hydrolysis of P-nitrophenylesters.

In this section, tests of zinc complex (synthesized above) as an agent for hydrolysis of some p-nitrophenylesters are discussed. The esters were prepared using the known preparatory procedures and the products confirmed by their M.points from literature and IR (for acetate and benzoate) which indicates the introduction of the C=O stretching and removal of O-H stretching bands.

5.1 Preparation of Esters (substrates)

5.1.1 4-Nitrophenylacetate [67]

1g (0.007 mol.) of para- nitrophenole was dissolved in 5 mL of 3M sodium hydroxide solution. 20 g of crushed ice was added followed by 1.5 g (1.5 mL) of acetic anhydride. The mixture was shook vigorously for 60 seconds. The acetate separated was collected, washed with water and recrystallised from dilute ethanol. M.Pt. 74-76^{0}C; literature m.p. 77-79 °C, [68].

5.1.2 4-Nitrophenyl benzoate [67]

To 1g (7m mol) of the p-nitrophenol dissolved in 3mL of dry pyridine 0.5g (0.4 mL, d=1.211) of benzoylchloride was added. After the initial reaction has subsided, the mixture was warmed up over a small flame for two minutes and

poured, with vigorous stirring, in to 15 mL of water. The precipitate formed was allowed to settle and the supernatant liquid was decanted. The residue stirred thoroughly with 10 mL of M sodium carbonate solution, filtered and recrystallized from light petroleum and air-dried. m.p. 144-145^{0}C; literature m.p. 148°C [68].

5.1.3 Tri (4-nitrophenyl) phosphate [69].

The preparation of tri (4-nitrophenyl) phosphate consists of two steps.

5.1.3.1 Sodium 4-nitrophenoxide.

Sodium hydroxide (11mL of 10N) was added with stirring to a suspension of p-nitrophenole (15 g) in boiling water (70 mL). To the resulting clear solution, further 10 mL of 10N alkali was added and the mixture rapidly cooled. The yellow sodium salt, which separated, was collected by filtration and washed three times with 60 mL portions of ice water. After drying thoroughly at 110 ^{0}C and pulverizing, the anhydrous salt was obtained as a red powder (14 g, 80% and m.p. >300^{0}C). Literature m.p. >300°C [69].

5.1.3.2 Tri (4-nitrophenyl) phosphate.

Rigorously dried, finely powdered sodium p-nitrophenoxide (3.7g, 0.023 mol.) was added slowly to anhydrous ethereal (THF) solution (13 mL) of phosphoryl chloride (0.5 mL, 5.4 mmol.). The mixture was mechanically stirred at room temperature for 30minutes and then refluxed for two hours. The resulting mixture of orange and white solids

was collected by filtration and washed repeatedly with cold water (total volume of 500 mL) until the washing was colorless. The white crystalline residue of tri-nitrophenylphosphate was dried in vacuo over phosphorous pentaoxide. The yield was 1.25 g (46%) and the m.p. 150-151^{0}C. which was raised to 152-153^{0}C up on recrystallization from acetone or ethylacetate. Literature m.p. 156°C [69].The λ_m and some physical Subject:properties of esters and starting materials are given in Table 5.1.

Table 5.1 Physical Properties of Esters and Starting Materials

Compound	Physical state	m.p. (^{0}C) Exp. (Literature)	λ_m in aqueous acetonitrile
4-Nitrophenole	Solid	110-112 (113-115) [68]	405nm
4-nitrophenyl-acetate	"	74-76 (77-79) [68]	271nm
4benzoate	"	144-145 (148) [70]	271nm
Zn(II) complex	"	229-230	245nm
tri (4-nitrophenyl)-phosphate	"	(152-153) 156 [69]	310nm

5.1.4 Preparations and Procedure

5.1.4.1 Buffers

Mixing 25mL of 0.2molar KCl and 67mL of 0.2molar HCl and making the final volume 100mL prepared PH 1.0.

PH 7.4 was prepared by mixing 50mL of 0.1 molar KH_2PO4 and 39.1mL of 0.1molar NaOH and making the final volume 100mL.

5.1.4.2 Solvents

(i) pH 6.15 aqueous acetonitrile was prepared by mixing 10mL water with 90mL acetonitrile

(ii) pH 7.4 and 8 were prepared by mixing acetonitrile, water and buffer (7.4).

(iii) pH 1.1 was prepared by mixing acetonitrile with buffer (pH1.0).

(iv) pH 5.76 was prepared by mixing 20mL of water with 80mL of acetonitrile.

(v) Neat acetonitrile (99.5%)was also used.

5.1.4.3 Solutions

Solutions of esters (0.1m mol.) and zinc complex (0.05m mol.) were prepared at specific pHs using the above solvents.

5.1.4.4 Method

The hydrolysis was followed by the increase in absorption maximum at 405nm assigned to the p-nitrophenolate anion) using SPECTRONIC GENESYS 2PC Spectrophotometer. PH measurements were done using HI8521 microprocessor bench top digital pH meter. Rate measurements were started by running the ester solution before and after mixing with the Zn (II) complex in a 2:1 molar ratio (ester solutions to complex solution) at different temperatures for a given pH. The progress of the reaction was detected as the instrument measures the absorbance at the analytical wavelength (405nm) at a preset interval of time. The data automatically calculated and the best-fit curve, reaction order and rate (in absorbance /min.) displayed at the end of the run time. The rates of hydrolysis for different esters in different solvents at different temperatures are given in Table 5.2.

Table 5.2: Rates (in Abs./Min) Observed for Different Esters at Different pH and Corresponding Temperatures

Ester	Temp. (^{0}C)	PH				
		1.1	5.6 (20%) H_2O	6.16 (10%) H2O	7.4	7.4(neat) (99.5%)
Tri (4-NP) phosphate	25	10^{-4}	$9x10^{-4}$	$1x10^{-4}$	-	-
	35	$2.8x10^{-4}$	$9.6x10^{-4}$	$17x10^{-4}$	-	$1x10^{-4}$
	45	$4x10^{-4}$	$10x10^{-4}$	$20x10^{-4}$	$10x10^{-4}$	$1.4x10^{-4}$
4-NP-benzoate	25	-	-	$0.67x10^{-4}$	-	-
	35	$1.2x10^{-4}$	-	$0.7x10^{-4}$	$3x10^{-4}$	-
	45	$1.6x10^{-4}$	-	$10x10^{-4}$	$2.6x10^{-4}$	$1x10^{-4}$
4-Nphenylacetate	25	-	-	-	-	-
	35	$0.7x10^{-4}$	-	$20x10^{-4}$	-	-
	45	$1x10^{-4}$	$1.5x10^{-4}$	$24x10^{-4}$	$10x10^{-4}$	$0.16x10^{-4}$

5.1.5 Result and discussion

The data obtained from the preliminary kinetics study, using the UV-Vis electronic method, indicate that the Zn (II) complex can enhance the hydrolysis of esters. All reactions are found to be second order. However, differences are observed for different conditions.

- Generally rates increase with the temperature of the reactions at all pH for all esters.
- Rates are higher for tri (p-NP)phosphate ester than acetate and benzoate.
- Rates diminish at lower pH, beyond 7and in medium (solvent) with least water content.

Mechanistic investigations have revealed that a Zn(II)–OH^- intermediate formed from the deprotonation of coordinated water is the essential active species in ester hydrolysis [60, 61].

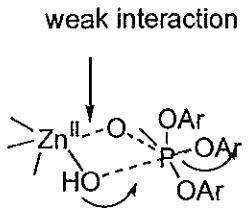


Fig 4. Proposed Mechanism for Tri-nitrophenyl phosphate [32]

According to the mechanism proposed, Zn^{II}-OH^- acts as a nucleophile to phosphate, Zn^{II} may have dual roles; while interacting with the substrate by +2 charge, Zn^{II}-OH^- intramolecularly attackes the electrophile $P^{\delta+}$ center. Therefore, Zn^{II}-OH^- is abetter nucleophile than free OH^- [32].

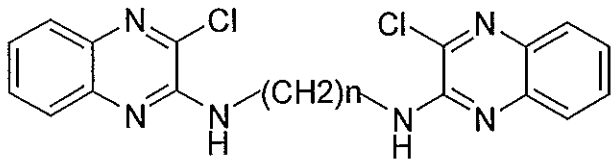
According to data, the rate of hydrolysis for tri (p-nitrophenyl) phosphate ester is higher than that of p-NP-acetate and benzoate, which may be ascribed to the fact that phosphorus has d-orbitals which are relatively lower in energy to accept the nucleophile.

Rate diminishes at lower pH values (at higher hydrogen ion concentration) which may be attributed to the suppression to the generation of the nucleophile, Zn(II)-OH. At higher pH values, an increase in the concentration of the free OH^- ions may influence the function of the complex. That is free OH^- ions might have involved in the hydrolysis and hydrolysis might have taken place before the complex is introduced. On the other hand as the absence of water molecules prevent the generation of the nucleophile (Zn(II)-OH) rate may diminish as a consequence [33].

6. CONCLUSION

1 The attempt to synthesize macrocyclic ligand from 2,3-dichloroquinoxaline and diamines [$(CH_2)n$, n=2,3,4] in different solvents (MeOH, EtOH, and benzene) resulted in an opened system with partial substitution of chlorine from 2,3-dichloroquinoxaline, according to the ^1H NMR, ^{13}C N MR and qualitative test for chlorine.

According to the data, (^1H NMR and ^{13}C NMR) the possible structure of compound 3 is:



n=3

Fig 5 Compound. 3 [N, N'-bis (2-chloroquinoxaline-3-yl-)-1,3-diaminopropane]

The change of the solvent and the amine group also didn't form the expected cyclic system.

2. A new ligand, with two imine and two amine donor groups, and its Zn complex has been synthesized and characterized. The results obtained from the metal and chloride analysis as well as spectronic studies agreed with the proposed scheme of reaction and geometry.

As supported by analytical and spectronic data, Zn(II) is octahedrally coordinated with one ionizable chloride,

3. The preliminary test indicated that the zinc(II) complex enhances the hydrolysis of tri (par-nitrophenyl) phosphate, para-nitrophenylacetate and para-nitrophenylbenzoate respectively in decreasing order, in 10% aqueous acetonitrile at 35°C and above.

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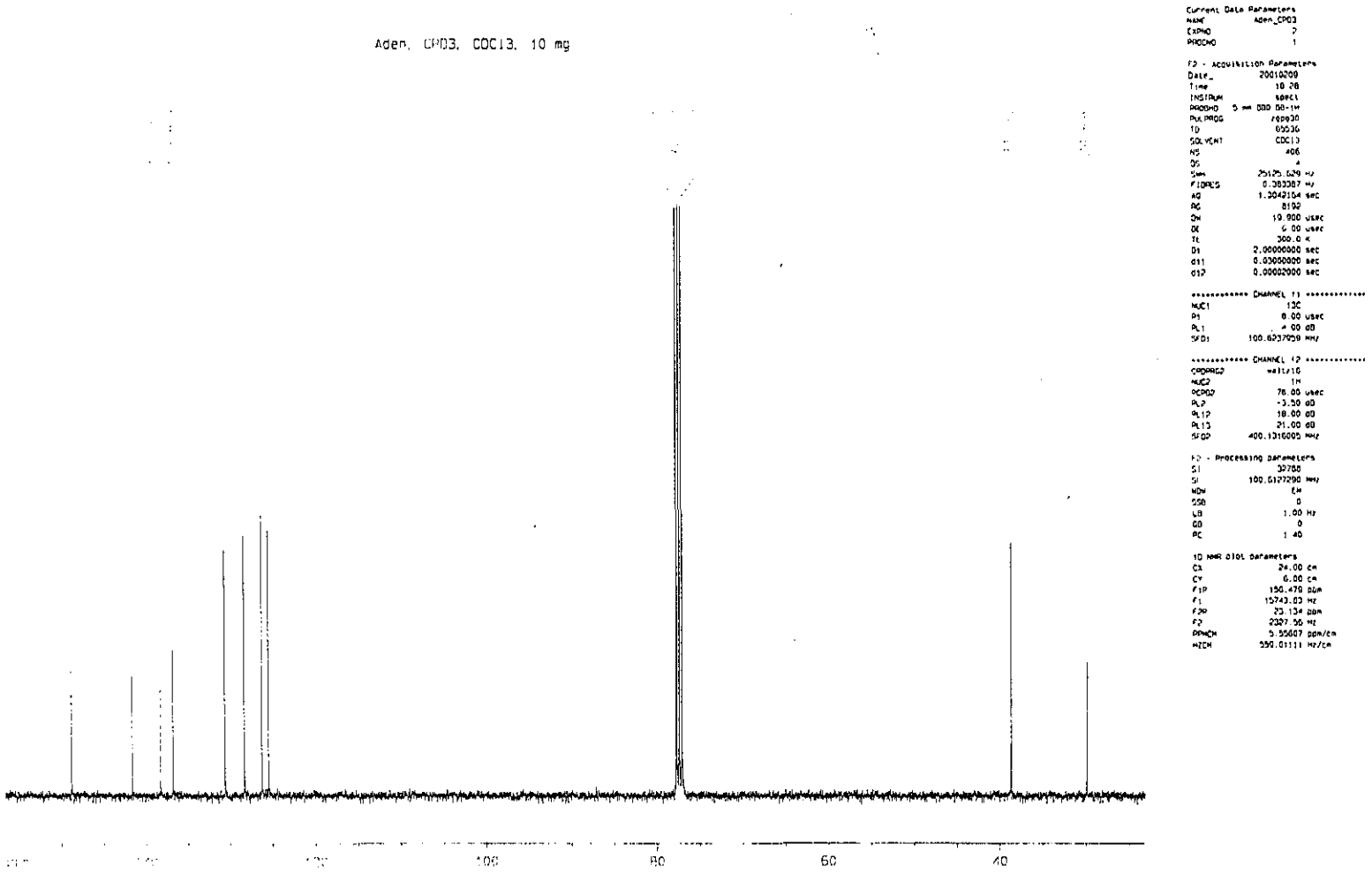
APPENDICES



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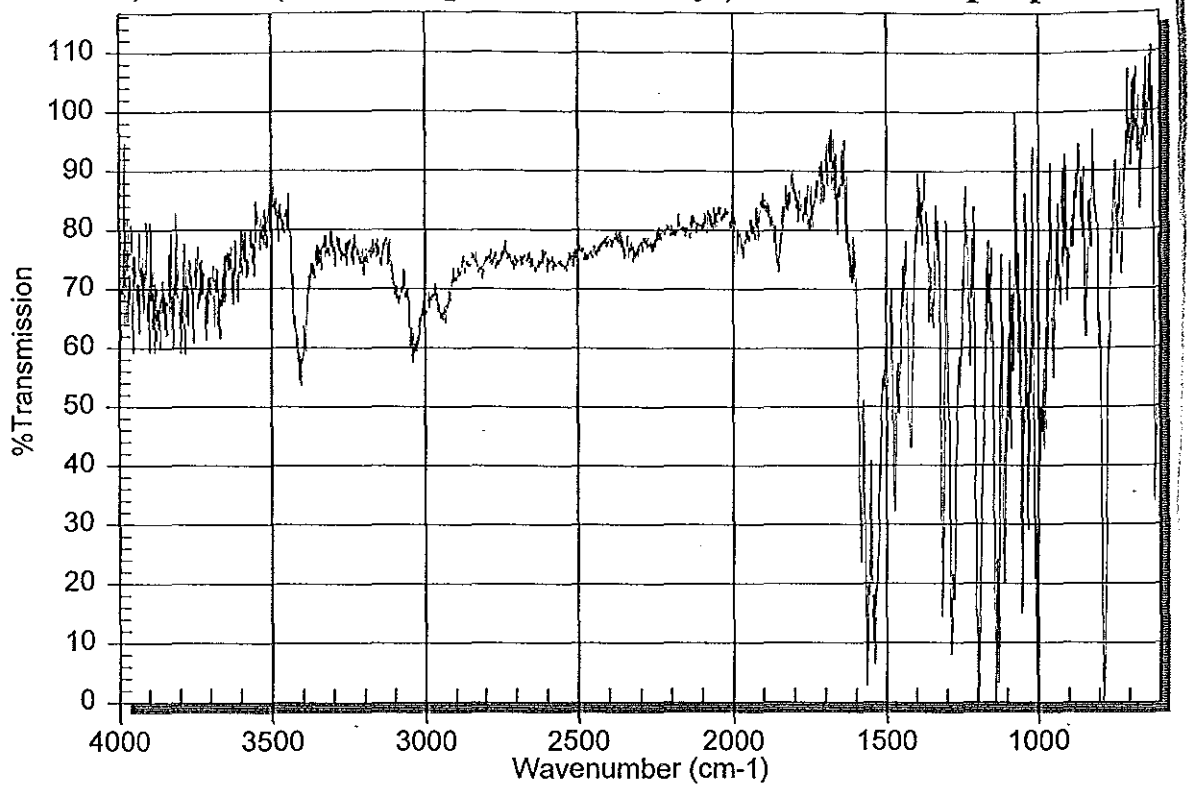
^{13}C NMR Spectrum of of N, N' –Bis (2-Chloroquinoxaline-3-yl) –1,3-Diaminopropane

N, N'-bis (2-chloroquinoxaline-3-yl)-1,3-diaminopropane



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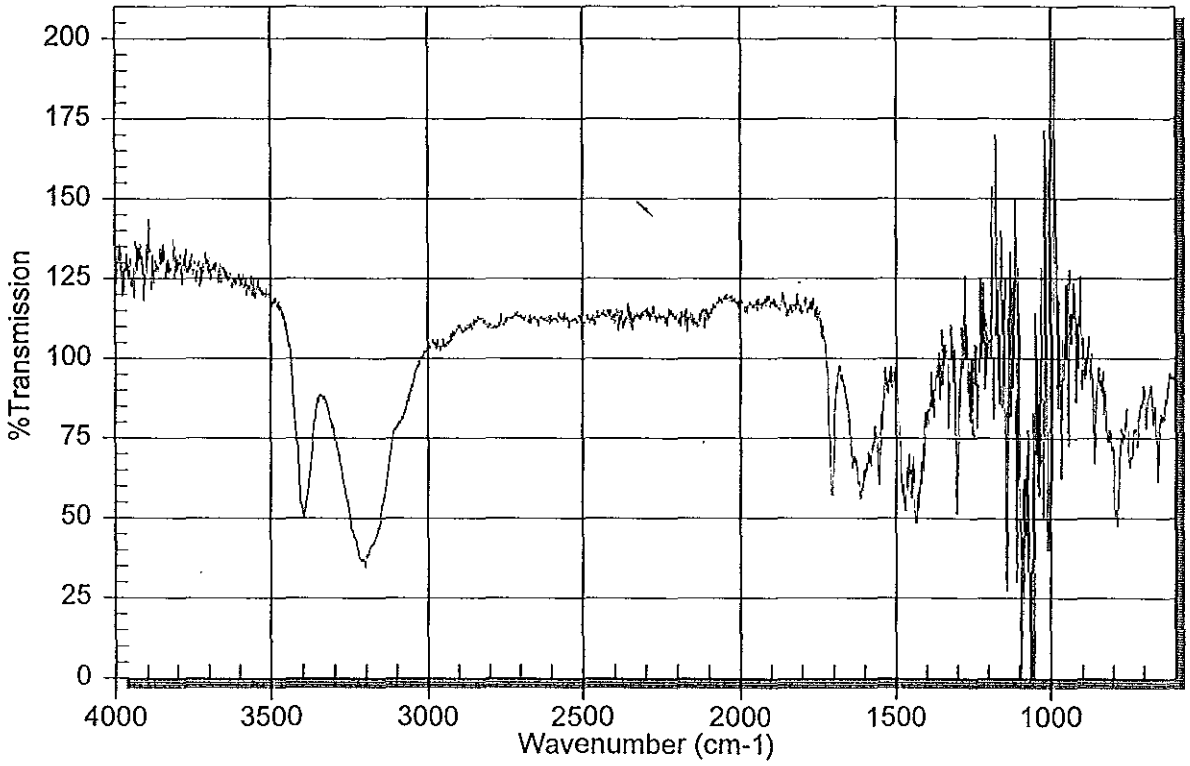

DECLARATION

The thesis is my original work, has not been presented for a degree in this and any other university and that all sources of material used for the thesis have been duly acknowledged.

Name: Aden Tadele Ayele

Signature: _____

This thesis has been submitted for examination with my approval as university advisor.

_____

Prof. Negussie Retta

Place and date of submission: School of Graduate Studies

Addis Ababa University

July 2001