Investigation of Pyridyl-Piperazine Ligands as the Building Block for Metal Organic Framework (MOF's)

Dissertation (II) submitted to

Lovely Professional University, India

For the partial fulfillment of the award

Of

Master of Science in Chemistry

By

Ruhana Begum

(11501934)

Under the guidance of

Dr. SUMAN MAJI

School of Physical Sciences, Department of Chemistry

Lovely Professional University, Punjab, India

April, 2017

TOPIC APPROVAL PERFORMA

School of Chemical Engineering and Physical Sciences

Program : P266-H::M.Sc. (Hons.) Chemistry

COURSE CODE : CHE688 REGULAR/BACKLOG : Regular GROUP NUMBER : SCRGD0013

Supervisor Name : Dr. Suman Maji UID : 18432 Designation : Assistant Professor

Qualification : _____ Research Experience _____

SR.NO.	NAME OF STUDENT	REGISTRATION NO	BATCH	SECTION	CONTACT NUMBER
1	Ruhana Begum	11501934	2015	G1503	9612402253

SPECIALIZATION AREA : Inorganic Chemistry Supervisor Signature: _____

PROPOSED TOPIC : Investigation of pyridyl piperazine lignads as the building blocks for Metal Organic Frameworks (MOFs)

Qualitative Assessment of Proposed Topic by PAC		
Sr.No.	Parameter	Rating (out of 10)
1	Project Novelty: Potential of the project to create new knowledge	8.00
2	Project Feasibility: Project can be timely carried out in-house with low-cost and available resources in the University by the students.	7.33
3	Project Academic Inputs: Project topic is relevant and makes extensive use of academic inputs in UG program and serves as a culminating effort for core study area of the degree program.	7.33
4	Project Supervision: Project supervisor is technically competent to guide students, resolve any issues, and impart necessary skills	8.00
5	Social Applicability: Project work intends to solve a practical problem.	6.33
6	Future Scope: Project has potential to become basis of future research work, publication or patent.	7.67

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Final Topic Approved by PAC: Investigation of pyridyl piperazine ligrads as the building blocks for Metal Organic Frameworks (MOFs)

Overall Remarks: Approved

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Certificate

This is to certify that this investigatory work on Inorganic Chemistry, entitled "Investigation of Pyridyl-piperazine ligands as the building block for Metal Organic Framework (MOF's)" has been completed by Ruhana Begum of MSc. in Chemistry Honors, bearing University registration number 11501934 of Lovely Professional University has been submitted in partial fulfillment of the course in Inorganic Chemistry. This is an original work of the candidate and has not been submitted anywhere else for any work.

Signature Signature

Guide Candidate

Acknowledgement

It is my pleasure that I am presenting my report on "Investigation of Pyridyl-Piperazine Ligands as the Building Block for Metal Organic Framework (MOF's)".

A number of people inspire and helped me to do this work with their ideas. I would like to thank all the people who have helped me in my work.

I wish to express my sincere gratitude to Dr. SUMAN MAJI for his guidance. I would like to thank my seniors; they helped me in my work.

I would like to thank the head of department Dr.RAMESH CHAND THAKUR for guiding me.

RUHANA BEGUM

LOVELY PROFESSIONAL UNIVERSITY

Table of content:-

1. Introduction

Metal Organic Framework (MOF's) are compounds which consist of organic ligands coordinated to metal ions or clusters so as to form one-, two-, or three-dimensional structures. MOFs are taxonomic category of coordination polymers. Metal Organic Frame work (MOF'S) are the compounds in which interaction between ligand to metal produce porous coordination networks with record setting surface areas with outstanding activated zeolites and carbons. The MOF's application includes sensors, catalysis, separation and storage of gases and others. MOF's compounds in pure N,N- diethylformamide or N,N-dimethylformamide are usually prepared which then slowly decompose upon heating and generation of base takes place which is capable of acting as a nucleophile deprotonating organic linear molecules. The latter part then reacts with the inorganic metal salts and three dimensional meta-organic networks are produced. These compounds are generally characterized by a modular construction principle which allow for a rational design made for the individual order pore systems. Using these appropriate building blocks, the specific combination of interactions for molecules inside the MOFs will be used for the separation of molecular species, storage, sensing, transformation inside MOF's. New materials for energy storage will be constructed in this way. [1]

The Metal Organic frameworks are linked by strong bonds by inorganic and organic units. Within the past decades there has been an explosive growth in the characterization and preparation of MOFs compounds. Their geometry, size and functionality which is flexible has led to more than 20,000 different MOFS being reported till date. Each year the organic linkers and secondary units of metal can be varied and has led to thousands being studied and prepared. The organic ligands must be ditopic and polytopic organic carboxylates or negatively charged molecules which can act as nucleophile. The connectivity and chemical composition of the MOFs compounds has been widely known of their underlining constituent of secondary units of inorganic and organic. [2]

MOFs are consist of two major components that is first an organic linker that is a ligand and a metal ion or cluster a metal ion or cluster. Because of this reason, the materials of the MOFs are generally called as hybrid organic-inorganic materials as mixing of inorganic and organic compounds takes place. The organic units should be of mono di tri or tetravalent ligand and these tells us about the structure of the overall compound and also properties of the MOFs. For example, the metal's coordination influences which prefers the shape and size of pores by stating that how many ligands will bind to the metal centre and in which orientation it will

bind. In MOFs, the framework has a pattern called the SBU (secondary building unit) and the organic ligands. A pattern or approach that is useful for the MOFs compounds has planned for storage of gas and also for metal-binding solvents such as water and N, N-diethylformamide..When the solvent is removed the metal binding site is opens which allow hydrogen for the binding at this site. [2, 3]

In most cases the MOFs organic ligands bind reversibly, the defect gets redissolved because of the slow formation of the crystals. This results that the material with near- equilibrium defect and millimeter- scale crystals defect density. Solvothermal synthesis is to produce chemical compounds which are useful in growing crystal formation prior to its structural determination. MOFs compound which is used as a storage material for consumer products demands has led to an immediate rise in their synthesis. The rise of MOFs has not been widely studied, but also though several groups have proved that microwaves can be used to nucleate MOF's crystals rapidly from solution. This technique is generally termed as microwave-assisted solvothermal synthesis. This technique is widely used in the literature of zeolites and produces micron-scale crystals in just seconds to minutes which give same like the slow growth methods. The permanent porosity of the Metal Organic Framework (MOF's) has been more extensive in their variety and multiplicity than any other class of porous materials. These particular have made MOF's an ideal channel for gas storage (methane and hydrogen), take up carbon dioxide and catalysis applications. [3]

Pyridyl-piperazine ligands

Piperazine [4] is an organic chemical compound which consists of a six membered ring containing two opposing nitrogen atoms. Piperazine is a compound having saline taste and which have a tendency to form liquid that is as a alkaline deliquescent crystals. [5] The piperazines are considered as derivatives of cyclic diamine or ethylenediamine . They are also called cyclizines. Piperazines is a heterocyclic saturated compound containing two nitrogen at first and fourth position that is why it is called 1, 4-hexahydropyrazine. The molecular formula of piperazine is $C_{14}H_{10}N_{2.}$ And the molecular weight is 86.14 g per mole.[6]

Pyridyl-piperazine is a simple chemical compound where pyridine is attached to piperazine ring. The structure of pyridine-piperazine is shown below,

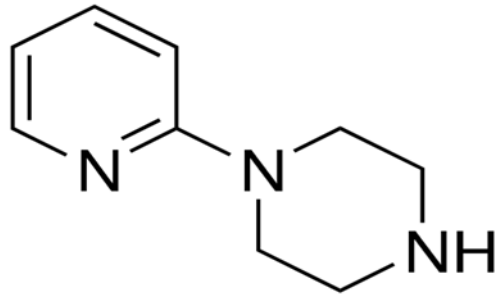


Fig:- 1-(2-pyridyl)piperazine [7]

Piperazine is insoluble in diethylether and soluble ethylene glycol and water. It is generally act as a weak base and at 25 degree its pKa value is 5.35 and 9.73 . Piperazine can absorb carebondioxide and water from its surroundings as they are hygroscopic in nature. Pyridine is soluble in water and mostly in all organic solvents. They are sickly basic, and it forms a crystalline hydrochloride salt when they come into contact with HCl which melts at 145–147 °C. [8]

The compounds of pyridyl-piperazine usually act as a ligand and form complexation with the transition metal ions. Pyridine is having the ability to act as either sigma (σ) or pi (π) type ligands. However, the pyridine nitrogen donates its pi (π) electron system randomly to the electronic shell of a metal atom. Pyridine forms a dipole with the electron density localized on the nitrogen atom. Moreover, the lone pair of pyridine's N- electrons which has a geometry that makes it easily able to reach for the donation of the electrons to its central metal atom which results in the resultant complex. Pyridine forms complexation in both enloic and ketonic forms. During the formation of complex pyridine can experience enolisation. Pyridine can form complexation with Ni^{2+} and Cu^{2+} metal ions as it is itself a weak ligand having the log k_1 values at around 1.9 and 2.6 respectively. [9]

Piperazine is having the tendency to bind a metal ion in two ways that is as a monodentate ligand or as a bridging ligand between two metal ions. [10]

Pyridyl-piperazines may be use as a reagent for the determination of both aromatic and alipathic isocyanates in air by reversed-phase HPLC. It may also be used as reagent for the fluorometric determination of airborne di-isocynates. Pyridine-piperazine compounds are also used in the manufacture of anti HIV-1 virus medicament. [11]

2. Aim and scope of the project

Aim:-

The aim of this project is to synthesize and characterize the complexes of pyridyl-piperazine ligands with the transition metal ion (copper). The characterization of the synthesized compound will be done with the help of various techniques like TLC (Thin Layer Chromatography), UV- Spectroscopy, IR- Spectroscopy and Nuclear Magnetic Resonance Spectroscopy.

Scope:-

As we know that pyridyl-piperazine ligands can form complexation with the transition metals. The scope of this project is to synthesize the pyridyl-piperazine ligands and complexation of these ligands with the transition metal (Copper). Their complexation could show their geometry, size, and functionality and whether they form chain like structures or not. The main motive of this project is to investigate pyridyl-piperazine ligands as the building block for Metal Organic Framework (MOF's) which will also help us to understand the interaction of these groups like piperazine or pyridine in biological systems.

3. Literature review

Synthesis

P. C. Jain and N. Anand have described the concept of a chemical compound having a molecular structure wherein there is attachment of one nitrogen atom of a piperazine nucleus to the metal centre nitrogen atom of a nitro-substituted pyridyl group. [12]

The idea of this invention is that the final product composition possesses the inherent characteristics of having significant pharmacological activity without adverse toxicity. Here N-phenylpiperazine bears one or more lower alkyl radicals. The specific N-phenylpiperazine starting materials have been described and substituted N-phenylpiperazine has been prepared. [12]

The methods for synthesis of some of the phenyl piperazine derivatives or the pyridyl piperazine derivatives are describes below

Synthesis of 1-phenyl-4-(3-nitro-4-pyridyl)piperazine:-

A solution of 4- chloro-3-nitropyridine in dry toluene was added dropwise with stirring to a solution of N-phenylpiperazine in dry toluene. The reaction mixture was then stirred and heat for two hours, cooled and filtered. The filtrate is extracted with 2N HCl. The acidic extract was treated with decolorize carbon ammonium hydroxide. The product was separated out as a yellow solid that was filtered and crystallized from ethanol. Its melting point is 138-140°. [12]

Synthesis of 1-phenyl-4(3-amino-4-pyridyl) piperazine:-

A solution of 1-phenyl-4-(3-nitro-4-pyridyl)piperazine, prepared as described in the above synthesis, in THF was hydrogenated in presence of hydrogen for about half hour. The reaction mixture was then filtered and the catalyst washed with hot THF. The solvent was removed under reduced pressure and the residue placed in ethanol from which is crystallized the product. Its melting point was 191° C.[12]

Synthesis of Bis-1-4-(3-nitro-4-pyridyl) piperazine:-

A solution of anhydrous piperazine in dry chloroform was added with stirring to a solution of 4-chloro-3-nitripyridine and trimethylamine in dry toluene (ml). The reaction mixture was stirred for additional 60 minutes at 25-30° and then heated on a steam bath for 3 hours. It was then cooled and filtered. The residue was washed with water and the product crystallized from pyridine/water. The melting point was observed as 252°.[12]

Synthesis of 1-(2, 5-dimethoxyphenyl) piperazine dihydrochloride:-

A mixture of bis (2-chloroethyl)aminehydrochloride, anhydrous K_2CO_3, freshly distilled 2,5-dimethoxyanaline, and diglyme was heated at reflux for 48 hours. The mixture was allowed to cool at room temperature. To the above mixture distilled water was poured. The aqueous layer was made basic by the addition of a saturated KOH solution and was extracted with ethylacetate three times. The combined organic portion was washed with distilled water three times and dryed over $MgSO_4$. The solvent was evaporated to dryness under reduced pressure to yield a dark oil. Vacuum distillation afforded 62% amine as light yellow liquid.[12]

Potassium benzylpiperazine dithiocarbamate synthesis:-

V. T. Yilmaz have synthesized and characterized Potassium benzylpiperazine dithiocarbamate (KBPDTC) and performed complexation with Mn (II), Co(II), Cu(II) and Zn(II). Their thermal reactivity has been studied by DTA and TG techniques. The

monoanionic BPDTC ligand coordinates to the metal ions via sulphur atoms of the –NCS group. Its complexation with NI (II) shows square planar geometry. The thermoanalytical data show that the decomposition of the metal complexes of KBPDTC under Nitrogen gives the corresponding metal thiocynates as stable intermediates. [13] Benzylpiperazine was dissolved in diethylether and aqueous KOH was added into it. CS_2 was added into it dropwise and stirred for one hour at 0°. The layers are separated in a separatory funnel from where the aqueous layer was separated and then evaporated in water bath at 95°. The solid potassium benzylpiperazine dithiocarbamate was obtained. The above solid was then washed with diethylether for several times and dry in air. [13]

$M(pp)_2$ complexes have been studied using spectroscopic methods. These complexes give Hoffmann type host structures. Here, M is metal which could be Co, Ni, Mn, Zn etc and (**pp**) is 1-phenylpiperazine. Through different spectroscopic methods it has been found that the complex consist of infinite polymeric layers that is, M with 1-phenylpiperazine ligands bounded to the central metal atom.[14]. In the synthetic method MCl_2 was dissolved in distilled water. Then another solution $K2Ni(CN)_4$ was prepared in distilled water. Both the solutions are mixed with constant stirring. After a while drop wise (**pp**) was added to the above solution. The final mixtures was left for a week under constant stirring at room temperature. The product obtained is filtered and washed with distilled water and ethanol. [14]

Metal can also form complexation with ligands involving halides ions. Halide ions can be fluorine, chlorine, bromine or iodine ions. Here ligand is 1-phenylpiperazine. These phenylpiperazine ligands can be used in various metal complexes. Here metal can be used is palladium or mercury. The final complex formed is $M(pp)_2Cl_2$.[15] These type of complex can be prepared by 2 mmol of pp liquid to 1 mmol of MCl_2 dissolved in distilled water. The above solution is then filtered with distilled water, ethanol, ether and we get the final dried product.[15]

Synthesis of phenylpiperazine

Panchal N.B.et.al. have synthesized many derivatives of phenylpiperazine following the methods described below. All of these methods give high yield of product in the range of 60-70%. TLC was checked for all prepared derivative using a mixture of chloroform and methanol in 9:1 ratio as the mobile phase. [16] The synthesis of many phenylpiperaizine derivatives given below,

Synthesis of 1-phenylpiperazine

A mixture of aniline and of bis(2-chloroethyl)amine HCl were placed in a round bottom flask and kept in the microwave oven. Evolved HCl gas was trapped into NaOH solution kept outside the oven. To neutralize the HCl gas released during the reaction NaOH solution was kept outside the released gas was bubbled through it, and chloroform was distilled out. The oil was extracted after cooling and subjected to column chromatography using silica gel to give 1-phenyl piperazine weighing 0.52g.

In the next step the above prepared solution of 1-phenyl piperazine, respective substituted aniline formaldehyde and conc. Hydrochloric acid were taken in round bottom flask. All the reagents are taken in 0.01mol in quantity. The solution was stirred and was followed by refluxing. Reaction mixture was poured into the crushed ice and kept in refrigerator for overnight. Product obtained was recrystallized from ethanol. [16]

Synthesis of N-(4-phenylpiperazine-1-methyl) benzamine

A solution of 1-phenyl piperazine was taken in round bottom flask. Formaldehyde and concentrated HCl were added and stir the mixture for an hour followed by refluxing for 10-12 hours. The reaction mixture was poured into crushed ice and sodium bisulphate solution was added. The solution was kept in the fridge. The product obtained was filtered and recrystallized from ethanol. [16]

Synthesis of substituted phenylpiperazine

This method was given by Vibhor k. j.et.al and percentage yield obtained from this method is approximately 60-70%. This method do not require much time. With the help of this method we can also synthesized para (methoxyphenyl)piperazine, meta(methoxyphenyl)piperazine and ortho(methoxyphenyl)piperazine etc. we can also substitute phenyl with pyridine so by substituting phenyl with pyridinewe can synthesized 1-(2-pyridyl0)piperazine, 1-(3-pyridyl)piperazine and 1-(4-pyridyl)piperazine. The analysis of the synthesized compound was done by IR spectroscopy and NMR spectroscopy. [17]

Synthesis of bis(2-chloroethyl)amine hydrochloride

A mixture of chloroform and thionylchloride was added to a solution of diethanolamine in chloroform and stirred. The refluxing was continued until a clear solution was obtained. Upon cooling at room temperature white crystals starts to appear. The product was filtered off after overnight stay of the reaction mixture in the refrigerator. The white solid obtained

was first washed with cold chloroform and then with ether. The solid crystal of bis (2-chloroethyl) amine hydrochloride was obtained. [17]

Synthesis of 1-(4-chlorophenyl) piperazine hydrochloride

Dichloroethane amine was added to and p-Chloroanisidine. The above solution was dissolved in butanol and refluxed. The reaction was cooled and potassium carbonate was added to it and again refluxed. Progress of reaction can be done with TLC. The reaction mixture was filtered while hot after completion of the reaction and was kept in the refrigerator. The crystals formed were filtered on the suction pump. The violet crystals of 1-(4-chlorophenyl) piperazine hydrochloride were taken. [17]

Synthesis of (1, 3, 5-triazinyl piperazine)

Microwave synthesis is carried out in microwave reactor. All the melting points are taken in capillary. Microwave radiations speed up the rate of nucleophilic substitution reaction. Microwave methods take less time as compared to normal synthesis. [18]

Synthesis of (4, 6-dichloro-1, 3, 5-triazin-2-yl) phenylamine

A solution of 2, 4, 6,-trichloro-1, 3, 5,-triazine was added to anhydrous THF and aniline were added to the above mixture in an RB and stirred. The resultant product was quenched with crushed ice. The product was filtered and recrystallized from acetone. [18]

Synthesis of 7-(4-chloro-6-phenylamine-1, 3, 5-triazin-2-yl-oxy)-4-methylchromen 2-one

A mixture of 7-hydroxy-4-methyl-coumarin was added with NaOH in anhydrous THF and was stirred for two hours at room temperature. The stirring was continued further. The resultant mixture was quenched with crushed ice. The solution was filtered and the solid obtained was recrystallized from acetone. Microwave reactor methods are very easy to perform. By these methods we got yield approximately 80-90%. Structure analysis of compound was done with IR spectroscopy or NMR spectroscopy. [18]

Synthesis N-(2-pyridyl)piperazinium tetrachlorocuprate(II) complex

An aqueous solution of $CuCl_2.2H_2O$ was mixed slowly with N-(2- pyridyl)piperazine in deionized water which yielded a dark brown colored precipitate. It was then dissolved in concentrated hydrochloric acid which was followed by the addition of deionized water in drop wise to the mixture. The resulting clear solution was filtered and kept at room temperature. Brown crystals of N-(2-pyridyl)piperazinium tetrachlorocuprate(II) were obtained. The crystals were washed with 95% ethanol, diethyl ether and dried.

Metal complexation of pyridyl-piperazine

H. Hou have synthesised new piperazine-pyridine ligand that is N,N'-bis(4-pyridylmethyl)piperazine(bpmp) which was prepared from the reaction of piperazine hexahydrate with 4-chloromethylpyridine hydrochloride. From the X-Ray analysis it has been observed that the sructure is linear and the lone pairs of nitrogen of piperazine are in the Trans position. Zigzag polymers with mercury were acquired in THF. The ligand N, N'-bis(4-pyridylmethyl)piperazine is retained in its chair conformation on the polymer. Hg^{2+} coordinates to two nitrogen atoms from different bpmp ligands and two I atoms. [19]

The preparation of various polymeric structures containing transition metals by which organic units take control of their sizes and rigidity that are connected through covalent or non-covalent bonding such as hydrogen bonding which results in different enlarged structures.[20] On the basis of this bi-pyridine based ligands with inflexible backbone has been prepared. By observing their ability of hydrogen bonding and metal complexation, we found out that piperazines has been an interesting moiety for supramolecular coordination chemistry.[21] The distinctive attribute of piperazine is that it folds into a chelating mode which is prevented by the inflexible backbone, which makes it functionally and structurally directing building block.[22]

Here the ligand N,N'-bis(4-pyridylmethyl)piperazine(bpmp) is a bidentate ligand where the two pyridine groups are in the equatorial position to the piperazine ring. From this fact, this ligand without any chelation capability form coordination polymer.[22]. The ligand N,N'-bis(4-pyridylmethyl)piperazine was composed by a solution of NaOH and piperazine hexahydrate in water, after that 4-chloromethylpyridine hrdrochloride in water was added with constant stirring until the pH decreased to 8-9. The resultant product obtained is deep red solution and was refluxed in an open beaker for two hours with the volume of the solution reduced. White products were formed and were recrystallized from a minimum amount of methanol. [19] And for the preparation of the complex $\{HgI_2[bpmp]_n$, two solutions have been prepared, a solution of bpmp in THF was added to a solution of HgI_2 in THF solvent , after a weel later, the product obtained was a colourless crystals. The product obtained was stable in air and insoluble in common solvents. From the X-Ray diffraction it has been revealed that the N, N'-(4-pyridylmethyl)piperazine ligand shows a linear structure with a crystallographic symmetry center. The piperazine ring forms a chair like conformation. All the bond distances are similar to the corresponding ones that was observed in the 2-pyridylmethyl derivatives of piperazine[23]. The lone pair of nitrogen of piperazine are in

trans position and the lone pair of pyridine are away from the center of the piperazine ring. It is favorable for polymeration and not for chealation.

The crystal packing shows the A-B-A-B repeated occururance of layers of ligands. The shortest distance between two parallel bpmp ligands is approximately 9.24 angstrom, which means that there is no interaction in the formation of crystal layers. [23]

The mercury containing metal complexation is not well developed because there has been a limitation for the solubility in solvents. The main aim of this is to synthesize two dimensional structure of the N, N'-bis(4-pyridylmethyl)piperazine(bpmp) ligand with complexation with mercury. The molar ratio of 2:1 of bpmp and HgI_2, gets crystallised in the ratio of 1:1 and thus showed a one dimensional chain like structure in which the piperazine is in its stable chair conformation. And doses not adopt boat conformation. [24]. the bond angle of N-Hg-N is less as compared to the bond angle of N-Hg-I. Bond length and bond angles are close to the free ligands. Here the Iodine groups have a steric effect and rigidity of bpmp which further leads to the formation of zigzag like polymeric structure. Inorder to coordinate with metal ions to form zigzag liner polymer with its chaie conformation the bpmp ligand have to break the chelating mode with the metal ions. From this we got the evident that conformation of ligands plays an important role in the formation of the structure. [24]

4. Experimental section:-

The chemicals used, like thionylchloride, diethanolamine, 2-amionpyridine, 3-aminopyridine, 4-aminopyridine, chloroform, methanol, butanol were purchased from commercial sources and are used without further purification. IR spectra were recorded by Shimadzu FTIR-8400s with pressed KBr pellets. NMR spectra were recorded by Bruker advance II 400 spectrometer. UV-Vis spectra were recorded by Shimadzu UV-1800s, ranging from 800 nm to 200 nm.

Synthesis

Synthesis of bis (2-chloroethyl) amine:-

A mixture of 13 ml thionylchloride in 14 ml chloroform was added to a solution of 5g diethanolamine in 14 ml chloroform for about 10 minutes. The mixture was refluxed continuously until a clear solution obtained. The reaction mixture was cooled at room temperature whereby white crystals start to appear. The reaction mixture kept overnight in the refrigerator and the product filtered off. The precipitated solid was first washed with cold chloroform and then with ether. The white crystals of bis (2-chloroethyl) amine hydrochloride were obtained. The reaction is given below,

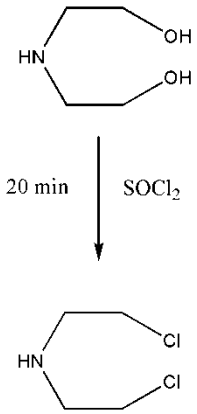
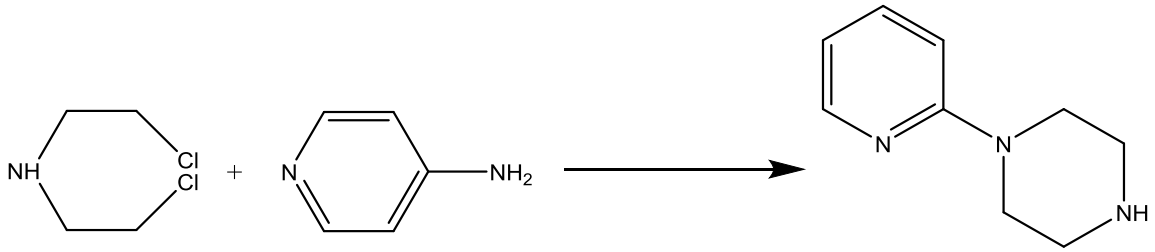


Fig:- bis(2-chloroethyl)amine

Synthesis of 1-(2-pyridyl)piperazine (L1):-

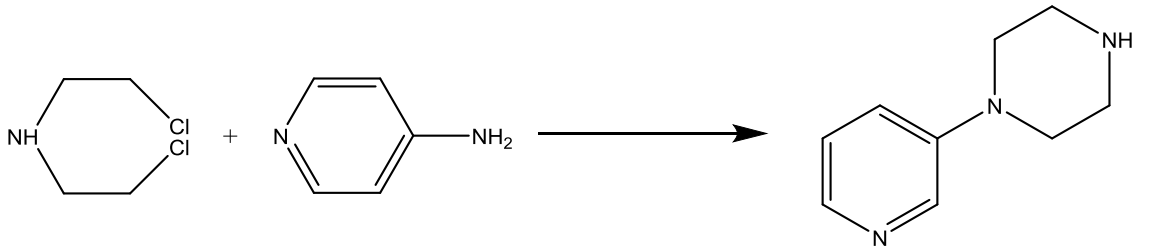
3g of the product bis(2-chloroethyl)amine and 2g of the 2-aminopyridine were taken in 30 ml butanol and refluxed the solution for 8 hours. The reaction mixture was cooled and 2g of potassium carbonate was added to it and again refluxed for 10 hours. The progress of the reaction can be done with the help of TLC. After the completion of the refluxing, the mixture was filtered while hot. During filtration washing was done with small quantity of hot butanol. The product was kept in the refrigerator for 8 hours and the crystal were filtered on the suction pump.



1-(pyridin-2-yl)piperazine

Synthesis of 1-(3-pyridyl)piperazine (L2):-

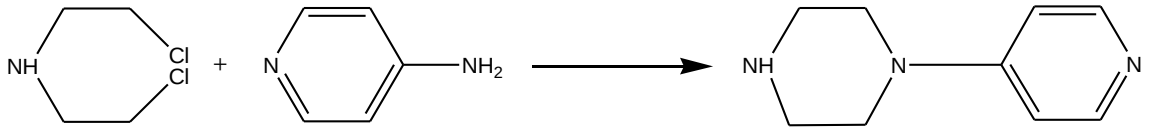
3g of the product bis(2-chloroethyl)amine and 2g of 3-aminopyridine were taken in 30 ml butanol and refluxed the solution for 8 hours. The reaction mixture was cooled and 2g of potassium carbonate were added to the solution and again refluxed it for 10 hours. After the completion of the refluxing , the reaction mixture is filtered hot and washing can be done with small amout of hot butanol and the product is kept in the refrigerator for 8 hours. The progress of the reaction can be done with the help of TLC.



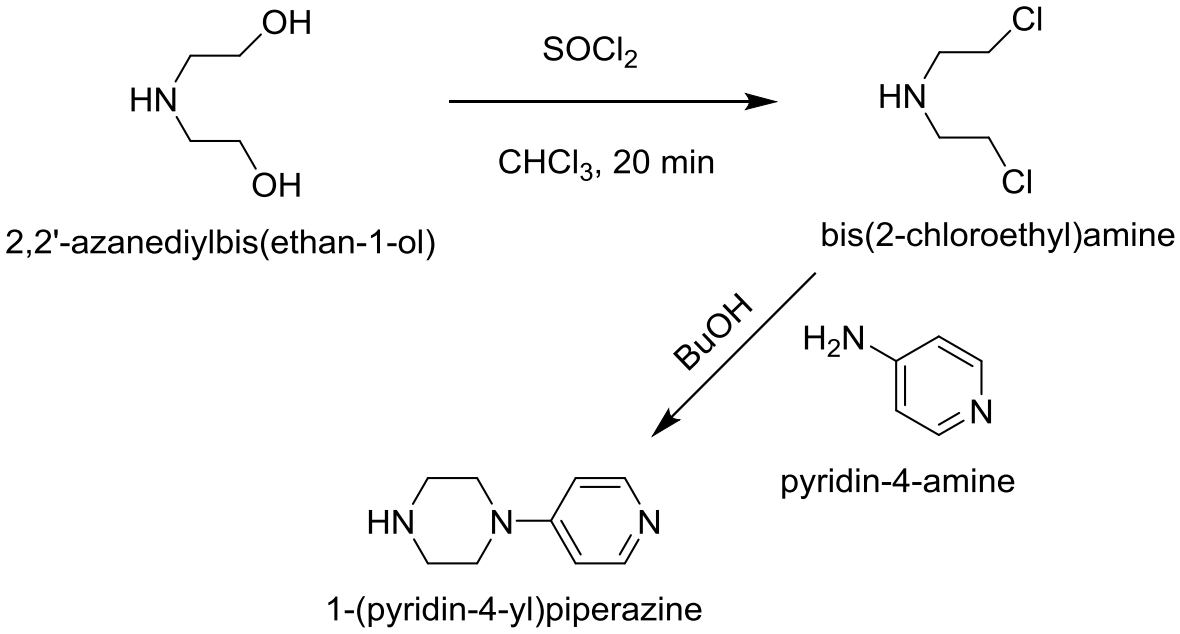
1-(pyridin-3-yl)piperazine

Synthesis of 1-(4-pyridyl)piperazine (L3):-

3g of the product bis(2-chloroethyl)amine and 2g of 4-aminopyridine were taken in 30 ml butanol and refluxed it for 8 hours. The reaction is cooled at room temperature after 8 hours of refluxing and 2g of potassium carbonate is added to the mixture and again refluxed for another 10 hours. After the completion of 10 hours of refluxing the reaction is filtered while hot and washing can be done with small amount hot butanol and then the final product is kept in the refrigerator for 8 hours to get the desired product. The progress of the reaction can be done with the help of TLC.



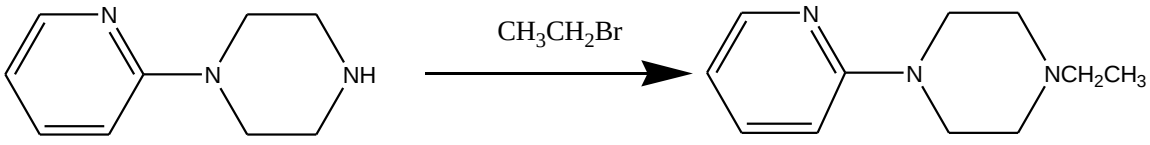
1-(pyridin-4-yl)piperazine



Scheme 1: Overall scheme for synthesis of ligands

Synthesis of 1-ethyl-4-(pyridin-2-yl)piperazine (L4):-

2.4 g of 1-(2-pyridyl)piperazine was mixed with 1.60 g of bromoethane. 2.031 g of potassium carbonate was added to the above mixture and refluxed for two hours. The progress of the reaction was done with the help of TLC. After refluxing for two hours, the solution was filtered and the filterate were collected. Column chromatography was done with the filtrate. The solvent that used to run the column was 9:1 ratio of chlroform and methanol. After running the filtrate through the column the desired product is obtained. Solvent used for TLC was 7:3 ratios of chloroform and methanol.



The synthesis of 1-ethyl-4-(pyridine-3-yl)piperazine (**L5**) and 1-ethyl-4-(pyridine-4-yl)piperazine (**L6**) were done using similar methods as described above.

Stoichiometric analysis:-

Solutions of different stoichiometric ratios were prepared by mixing the stock solutions prepared with the metal salt and the ligands separately at different volume ratios. The UV-vis characteristics of these solutions were then checked to find out the stoichiometric ratio of the metal with the different ligands during formation of the metal complex.

Following stock solutions were prepared in acetonitrile

$Cu(NO_3)_2$= $1x10^{-3}$ M in CH_3CN

Ligands (**L1** to **L6**) = $1x10^{-3}$ M in CH_3CN

Table 1:- Preparation of solutions for UV-vis study

Sl. No.	Vol. of ligand sol.	Vol. of metal sol.	Vol. of CH_3CN	Total vol.
1	1 ml	1 ml	3 ml	5 ml
2	2 ml	1 ml	2 ml	5 ml
3	4 ml	1 ml	0 ml	5 ml

Synthesis of metal complexes

1**. Metal complex of copper with 1-(2-pyridyl)piperazine (L1):-**

0.24 g of the cupric nitrate was added to 0.32 g of 1-(2-pyridyl)piperazine. The above mixture was then dissolved in a minimum amount of methanol. The solution mixture was stirred for 10 minutes and was kept in a water bath to evaporate the solvent (methanol). The final product that was left after the solvent has been evaporated was kept in a beaker inside the desiccator to dry completely.

2**. Metal complex of copper with 1-(3-pyridyl)piperazine (L2):-**

0.24 g of the cupric nitrate was added to 0.35 g of 1-(2-pyridyl)piperazine. The above mixture was then dissolved in a minimum amount of methanol. The solution mixture was stirred for 10 minutes and was kept in a water bath to evaporate the solvent (methanol). The final product that was left after the solvent has been evaporated was kept in a beaker inside the desiccator to dry completely.

3. **Metal complex of copper with 1-(4-pyridyl)piperazine (L3):-**.

0.24 g of the cupric nitrate was added to 0.35 g of 1-(2-pyridyl)piperazine. The above mixture was then dissolved in a minimum amount of methanol. The solution mixture was stirred for 10 minutes and was kept in a water bath to evaporate the solvent (methanol). The final product that was left after the solvent has been evaporated was kept in a beaker inside the diccator to dry completely.

4. **Metal complex of copper with 1-ethyl-2-(pyridine-2-yl)piperazine (L4):-**

0.24 g of the cupric nitrate was added to 0.36 g of 1-ethyl-2-(pyridine-2-yl)piperazine. The above mixture was then dissolved in a minimum amount of methanol. The solution mixture was stirred for 10 minutes and was kept in a water bath to evaporate the solvent (methanol). The final product that was left after the solvent has been evaporated was kept in a beaker inside the diccator to dry completely.

5. **Metal complex of copper with 1-ethyl-2-(pyridine-3-yl)piperazine (L5):-**

0.24 g of the cupric nitrate was added to 0.35 g of 1-ethyl-3-(pyridine-2-yl)piperazine. The above mixture was then dissolved in a minimum amount of methanol. The solution mixture was stirred for 10 minutes and was kept in a water bath to evaporate the solvent (methanol). The final product that was left after the solvent has been evaporated was kept in a beaker inside the diccator to dry completely.

6. **Metal complex of copper with ligand 1-ethyl-2-(pyridine-4-yl)piperazine (L6):-**

0.24 g of the cupric nitrate was added to 0.37 g of 1-ethyl-4-(pyridine-2-yl)piperazine. The above mixture was then dissolved in a minimum amount of methanol. The solution mixture was stirred for 10 minutes and was kept in a water bath to evaporate the solvent (methanol). The final product that was left after the solvent has been evaporated was kept in a beaker inside the diccator to dry completely.

5. Result analysis:-

IR spectroscopy of ligands:-

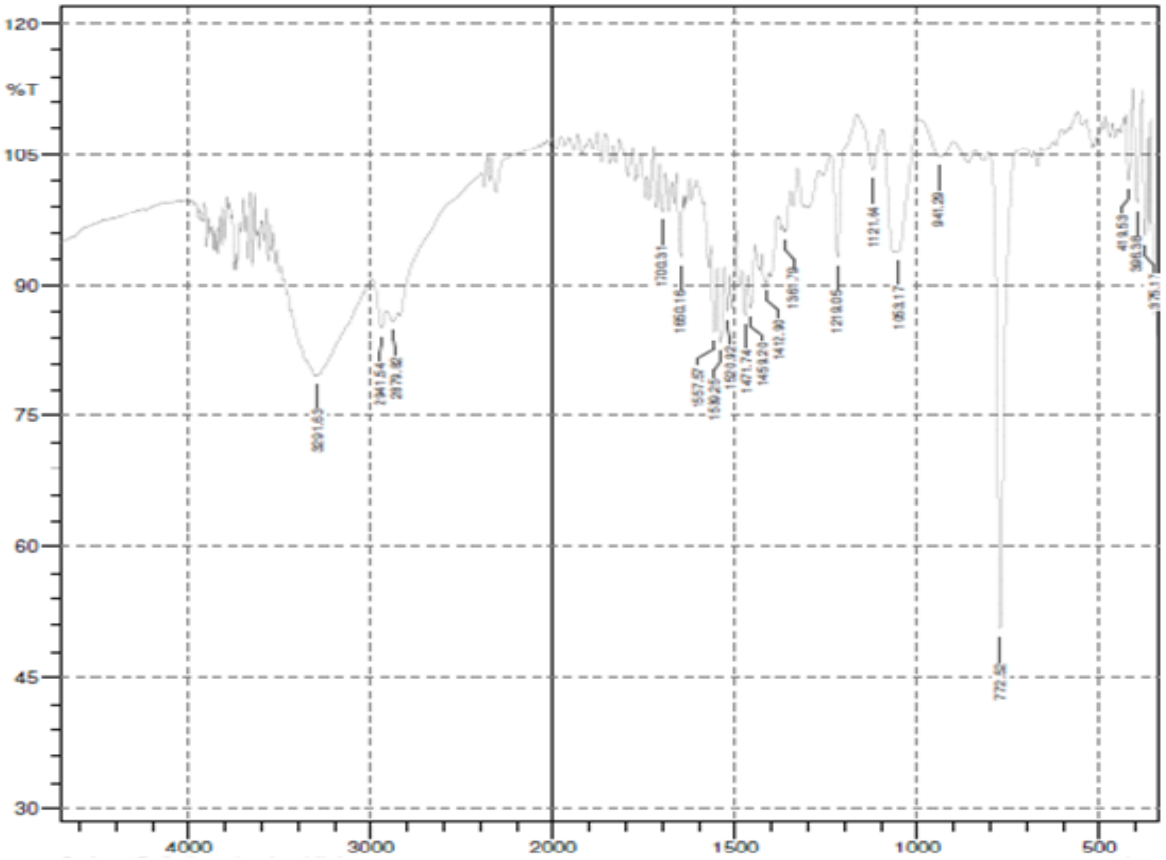


Figure 2:- IR spectrum of diethanolamine

Table 2:- IR Peaks of diethanolamine

Functional group	Peak (cm^{-1})	Type of vibration
OH	3201	Stretching
CH	2941	Stretching

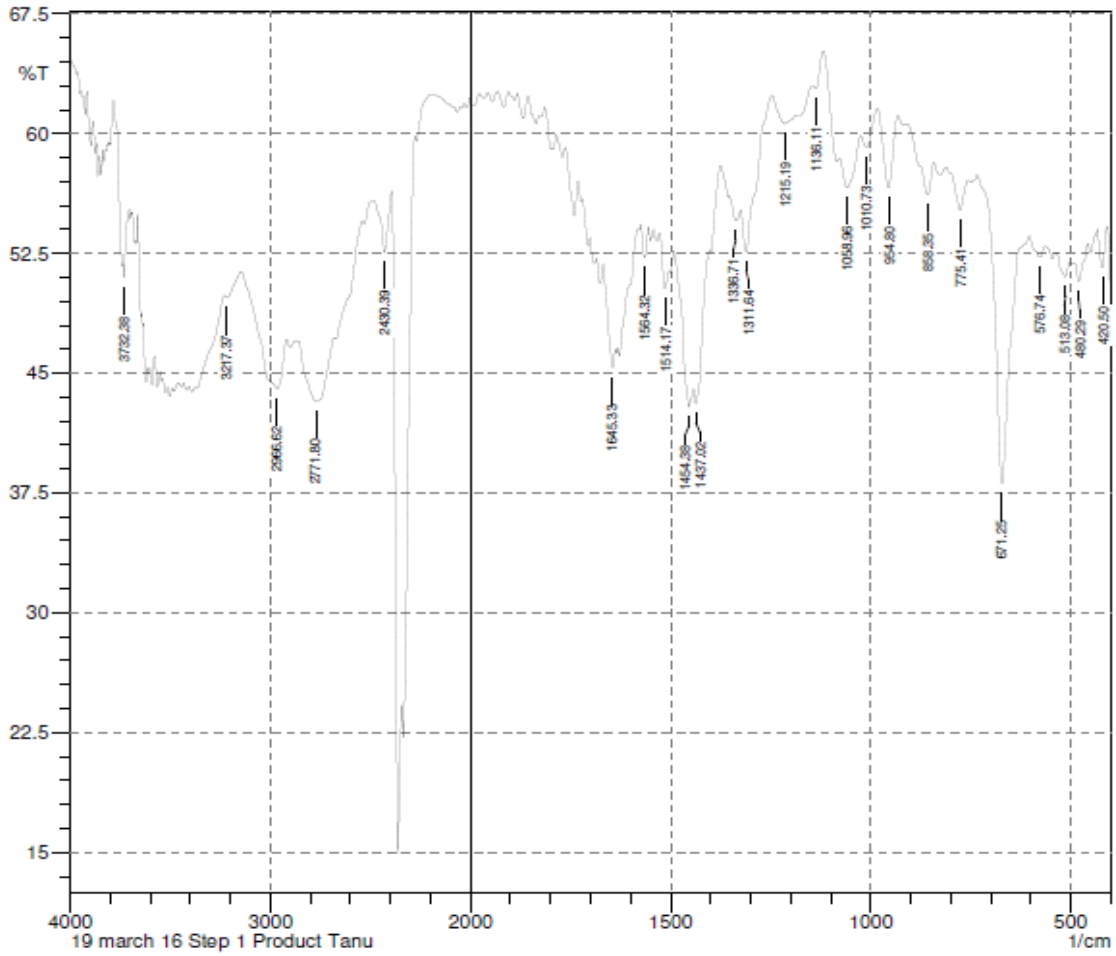


Figure 3:- IR spectrum of dichloroethaneamine

Table 3:- IR peaks of dichloroethaneamine

Functional group	Peak (cm^{-1})	Type of vibration
C-Cl	671	Stretching
CH	2966	Stretching

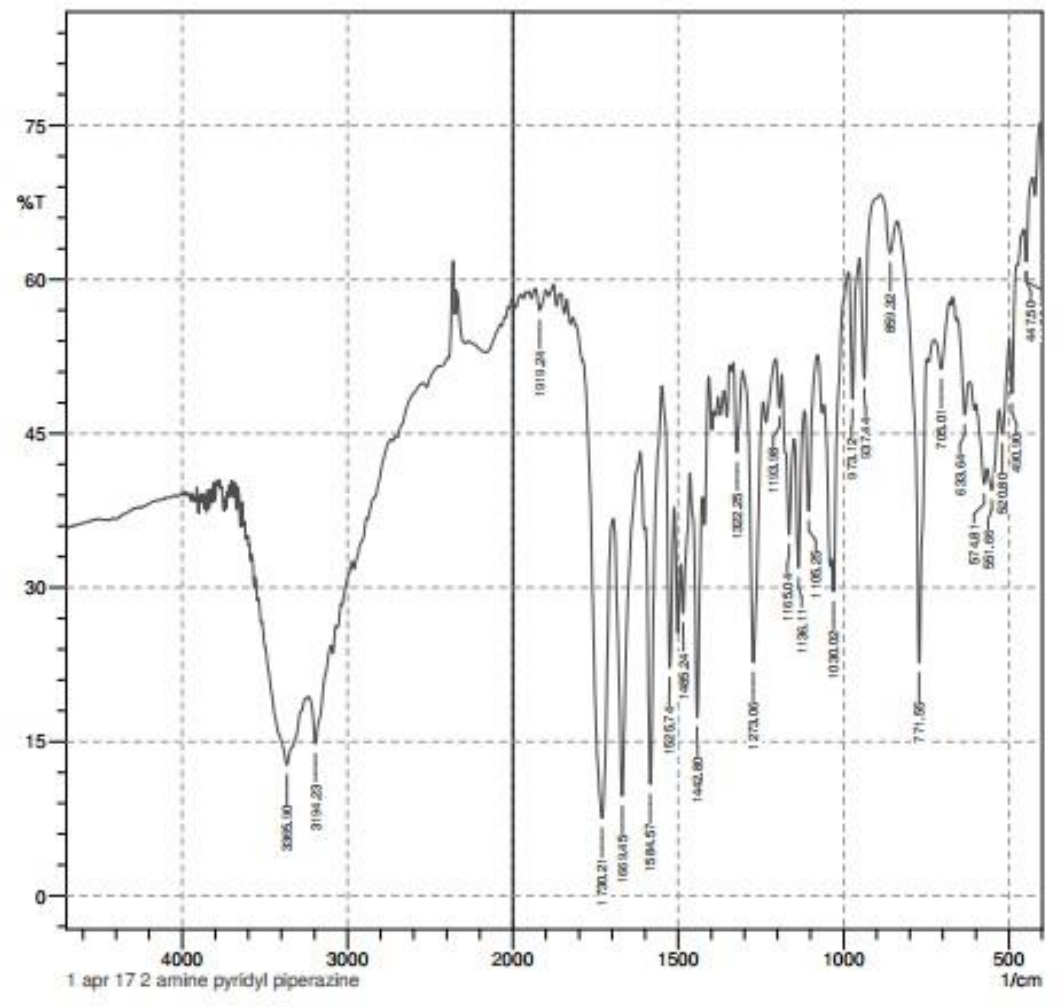


Figure 4:- IR spectrum 1-(2-pyridyl)piperazine of (L1)

Table 4:- IR peaks of L1

Functional group	Peak (cm^{-1})	Type of vibration
NH	3345	Stretching
C-C	1504	Stretching
Ar. NH	1305	Stretching
Ar. CH	3104	Stretching

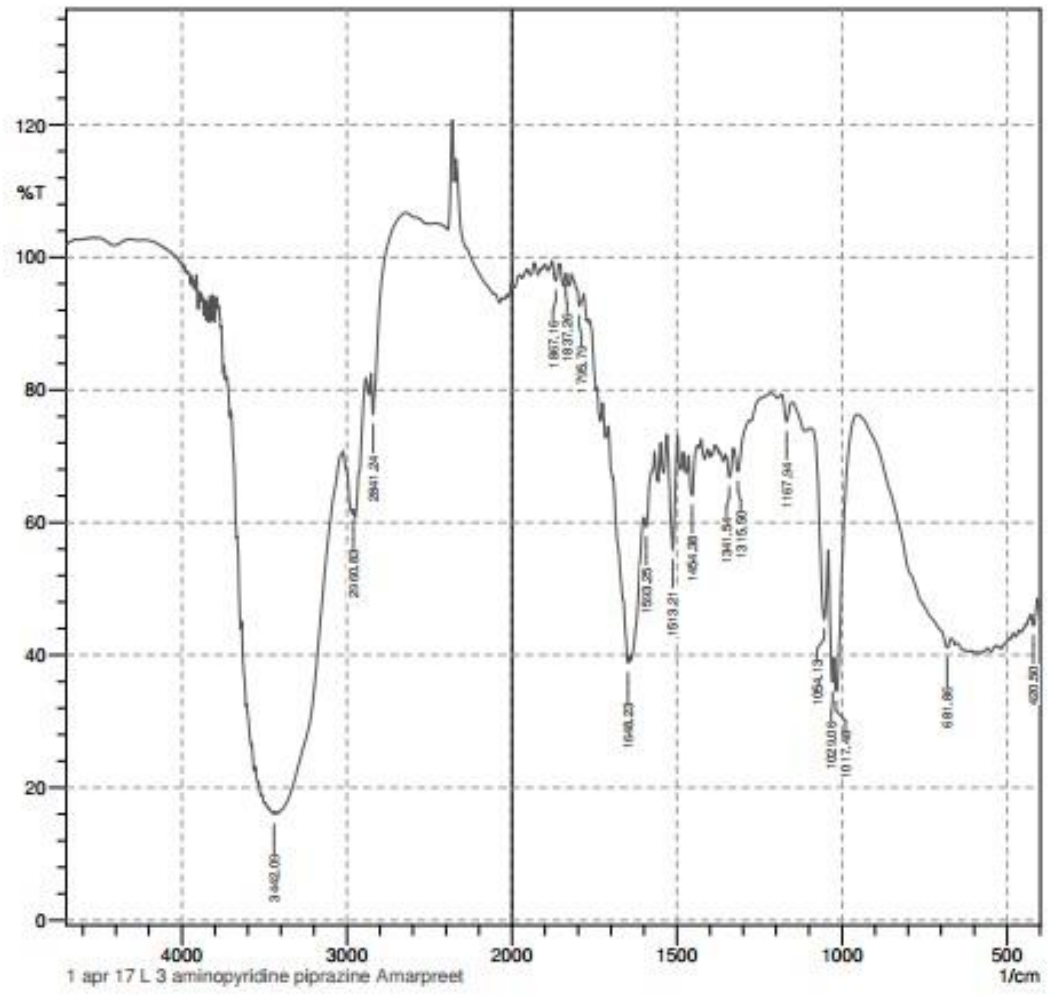


Figure 5:- IR spectrum of 1-(3-pyridyl)piperazine (L2)

Table 5:- IR peaks for L2

Functional group	Peak	Type of vibration
NH	3442	Stretching
C-C	1624	Stretching
Ar. CH	2962	Stretching
Ar. NH	1341	Stretching

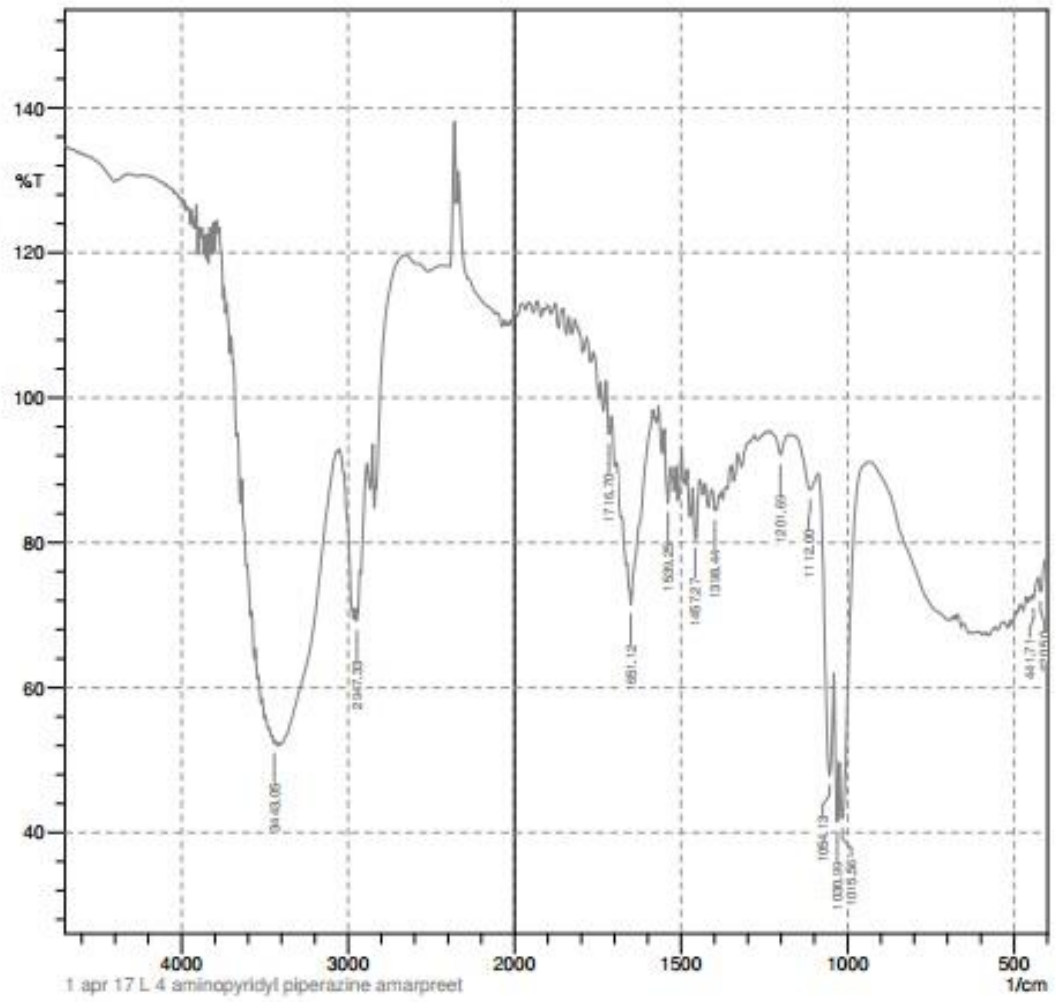


Figure 6:-IR spectrum of 1-(4-pyridyl)piperazine (L3)

Table 6:- IR peaks of L3

Functional group	Peak (cm^{-1})	Type of vibration
NH	3443	Stretching
C-C	1550	Stretching
Ar. NH	1201	Stretching
Ar. CH	2947	Stretching

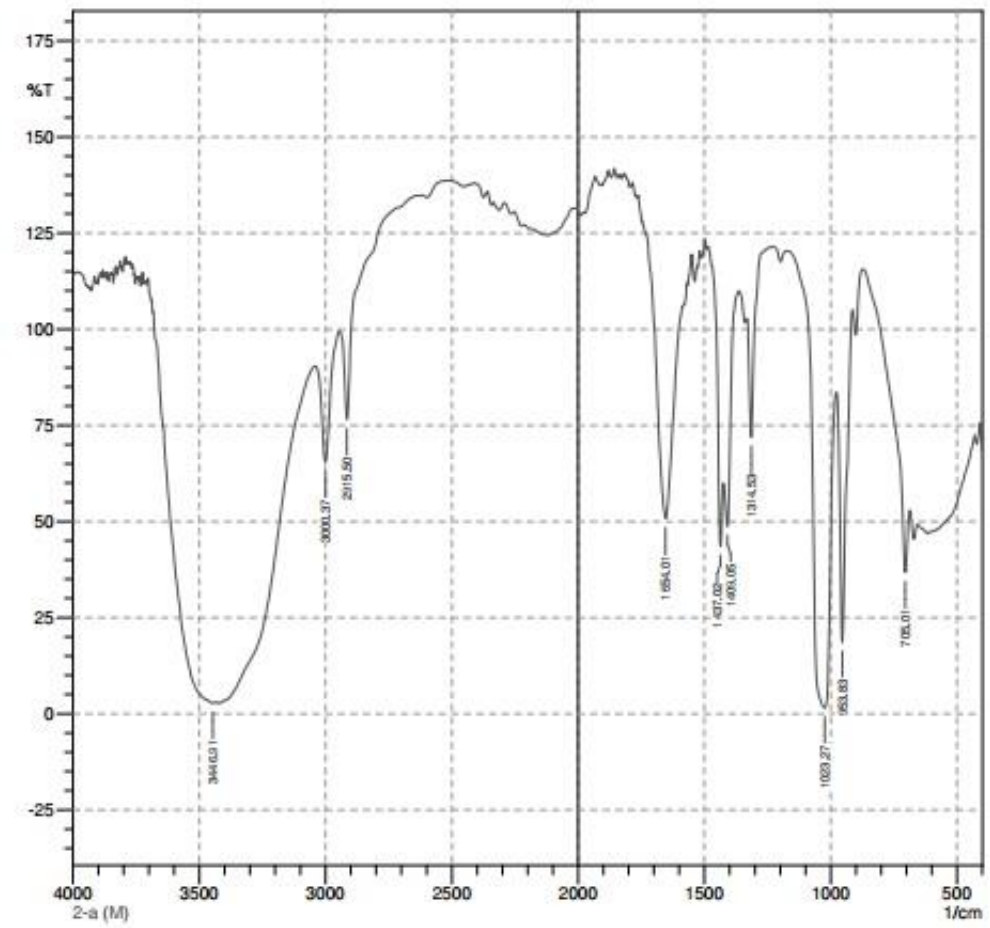


Figure 7:- IR spectrum of 1-ethyl-2-(pyridine-2-yl)piperazine (L4)

Table 7:- IR peaks observed for L4

Functional group	Peak (cm^{-1})	Type of vibration
NH	3446	Stretching
C=C	1654	Stretching
Ar. CH	3000	Stretching
CH	2915	Stretching

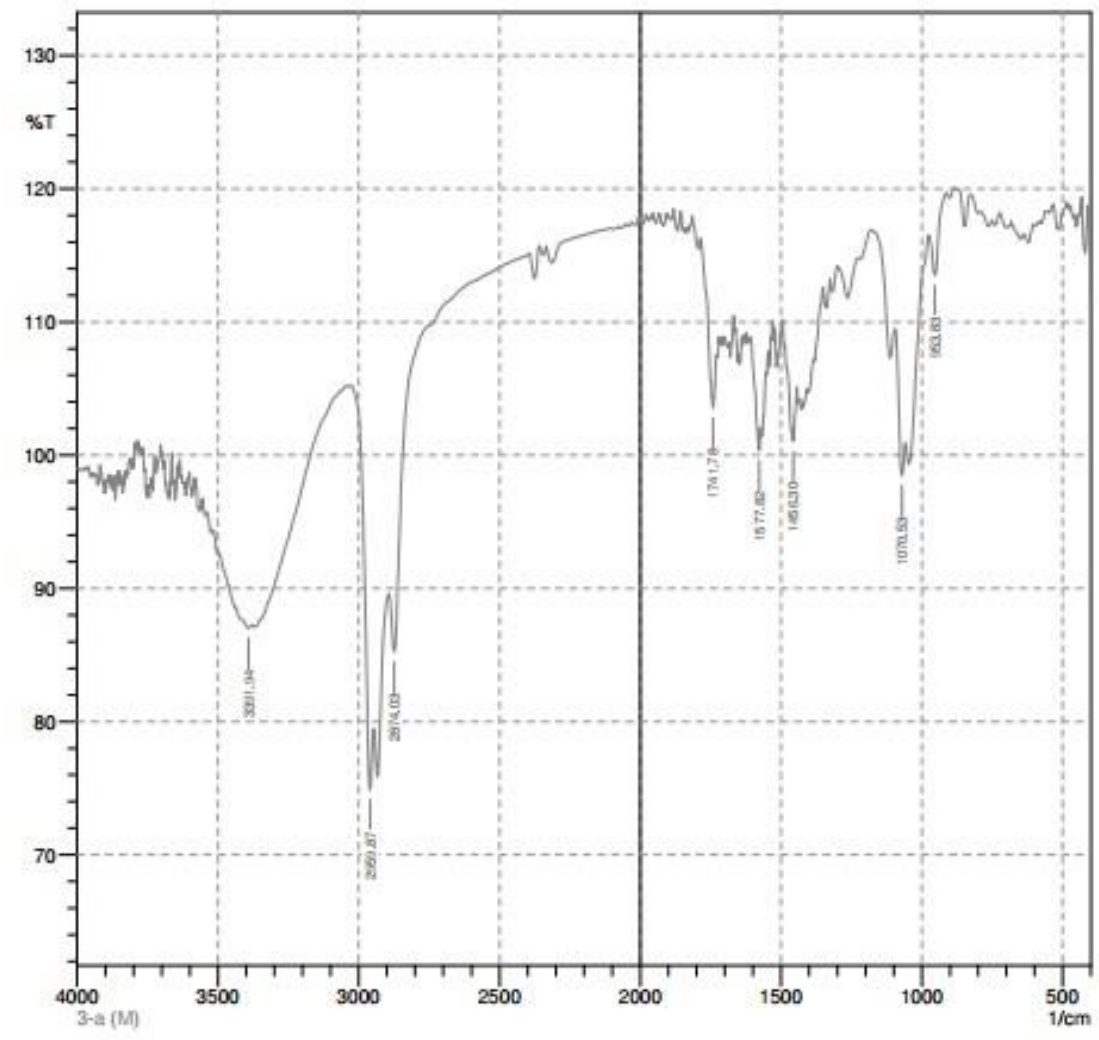


Figure 8:- IR spectrum of 1-ethyl-2-(pyridine-3-yl)piperazine (L5)

Table 8:- IR peaks of L5

Functional group	Peak (cm^{-1})	Type of vibration
NH	3391	Stretching
Ar. CH	2959	Stretching
C-H	2874	Stretching
C=C	1577	Stretching

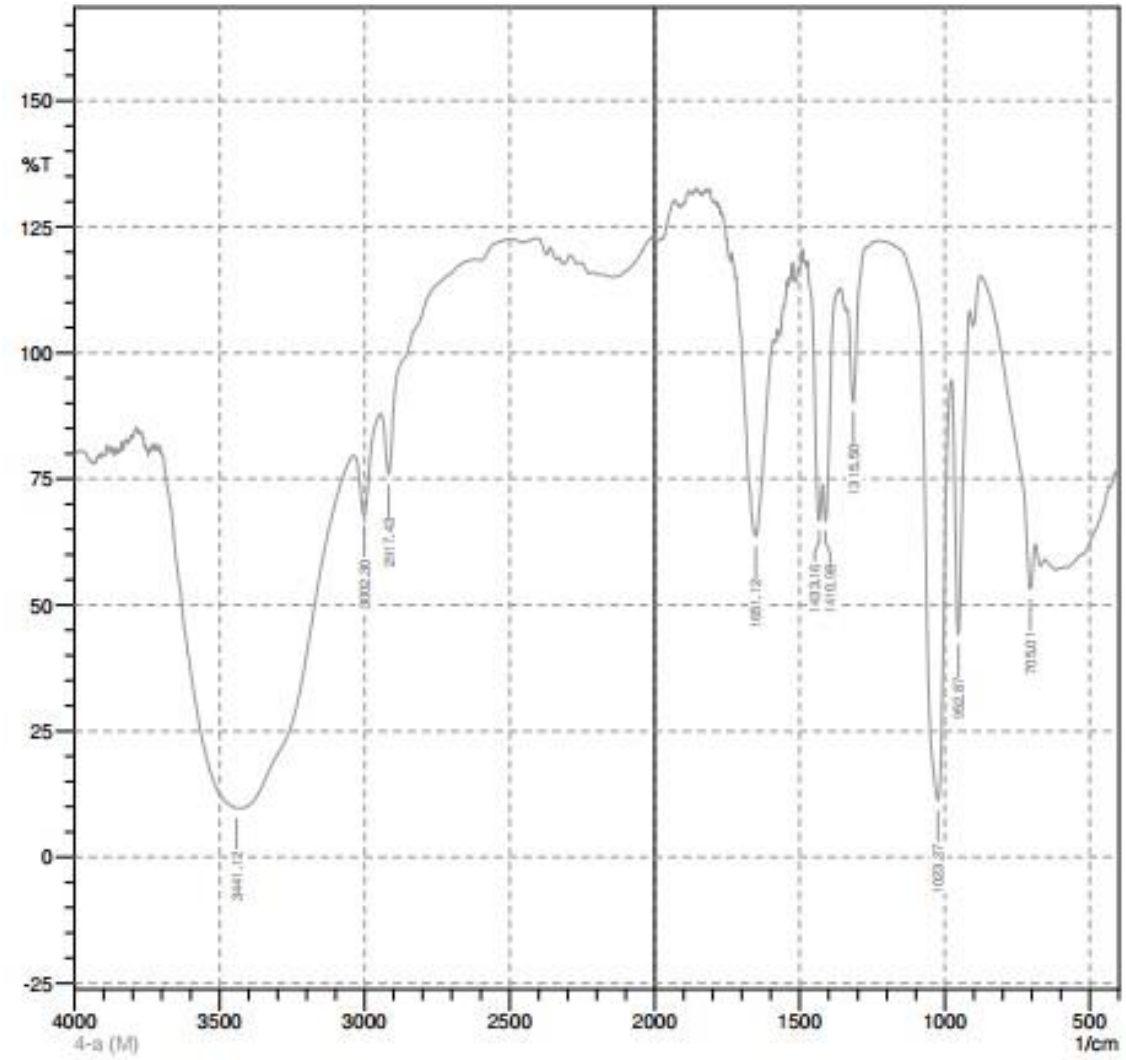
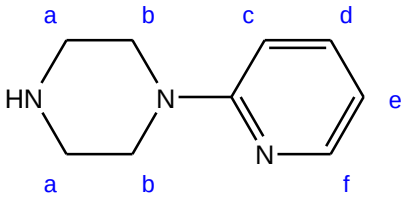


Figure 9:- IR spectrum of 1-ethyl-2-(pyridine-4-yl)piperazine (L6)

Table 9:- IR peaks of L6

Functional group	Peak (cm^{-1})	Type of vibration
NH	3441	Stretching
Ar. CH	3002	Stretching
CH	2917	Stretching
C=C	1651	Stretching

NMR spectroscopy of ligands:-



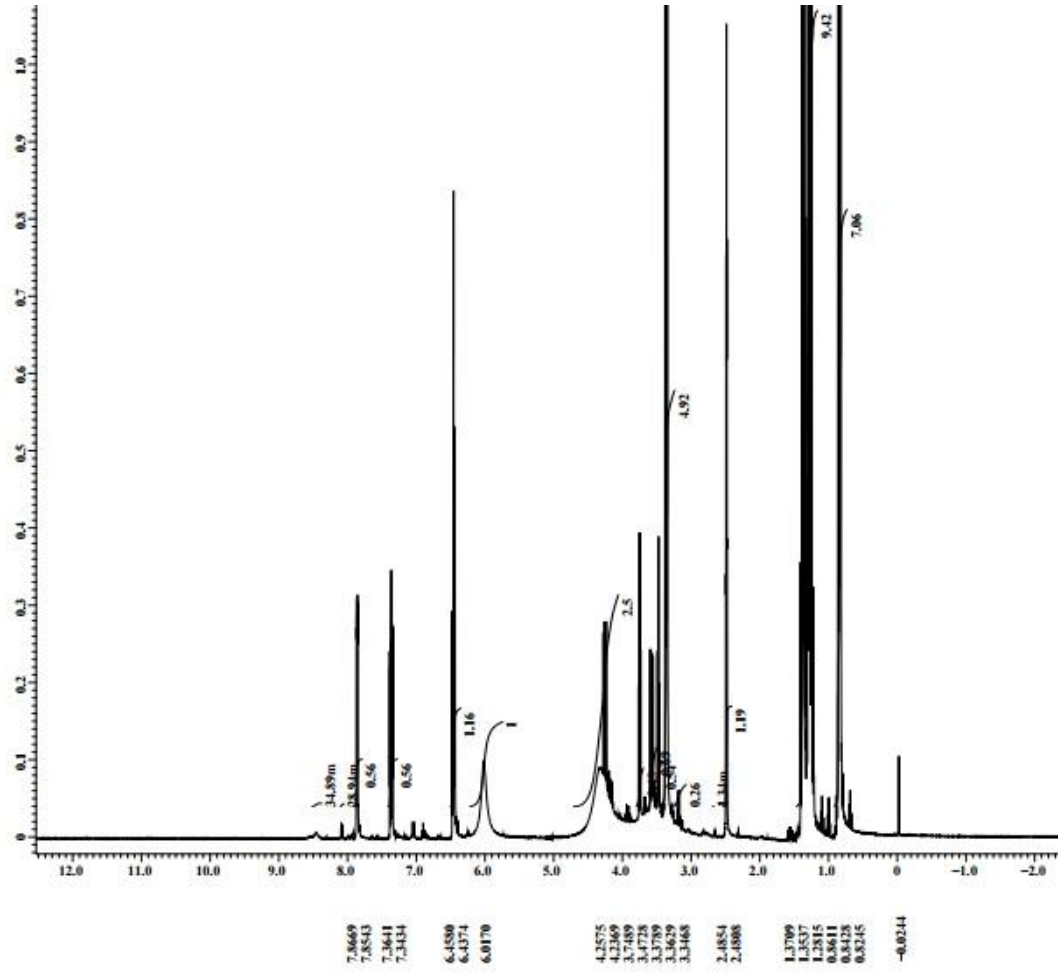
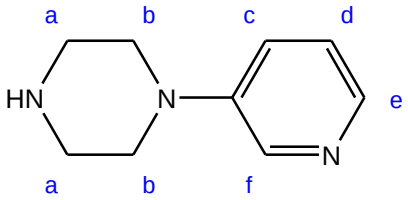


Figure 10:-NMR spectrum of 1-(2-pyridyl)piperazine (L1)

Table 10:- NMR peaks of L1

Ligands	NH	Ha	Hb	Hc	Hd	He	Hf
L1	2.49 (t)	3.37 (t)	3.55 (t)	6.40 (d)	7.98 (t)	6.81 (t)	8.81 (d)



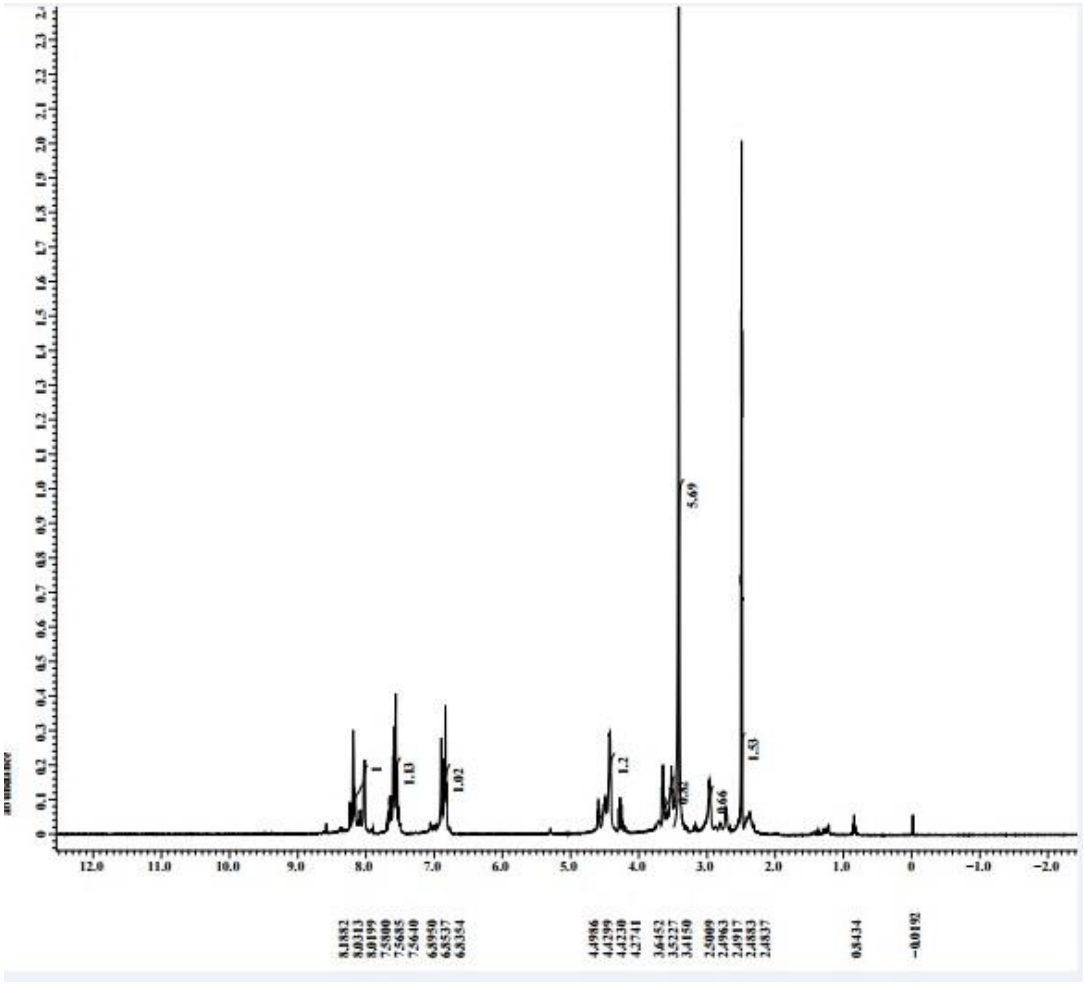
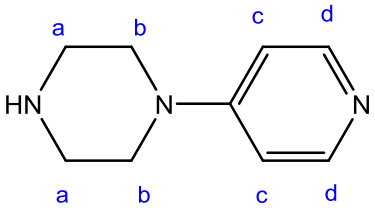


Figure 11:- NMR spectrum of 1-(3-pyridyl)piperazine (L2)

Table 11:- NMR peaks of L2

Ligands	NH	Ha	Hb	Hc	Hd	He	Hf
L2	2.48 (t)	2.50 (t)	3.41 (t)	6.89 (d)	7.56 (t)	7.58 (d)	8.18 (s)



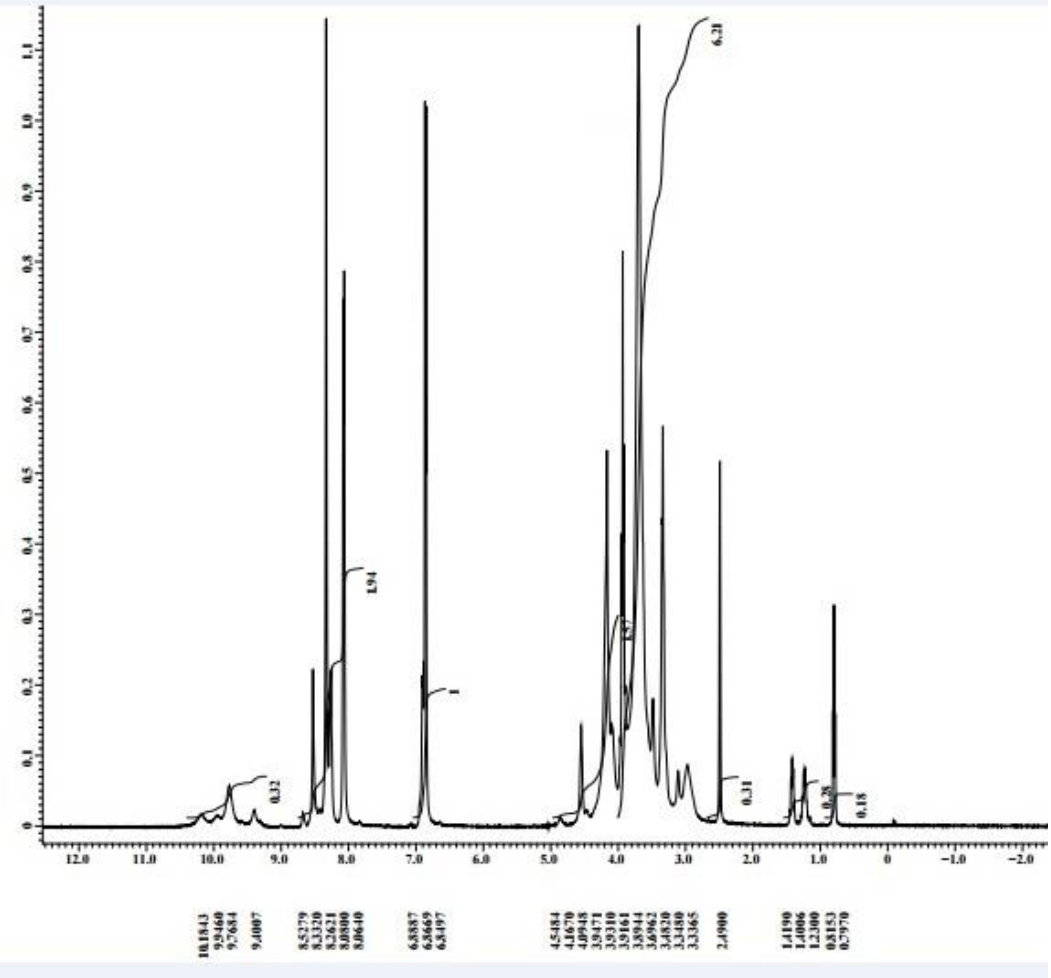
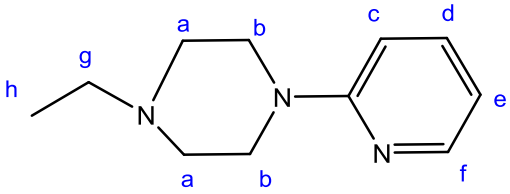


Figure 12:-NMR spectrum of 1-(4-pyridyl)piperazine (L3)

Table 12:- NMR peaks of L3

Ligands	NH	Ha	Hb	Hc	Hd
L3	2.49 (t)	3.33 (t)	3.89(t)	6.84 (d)	8.52 (d)



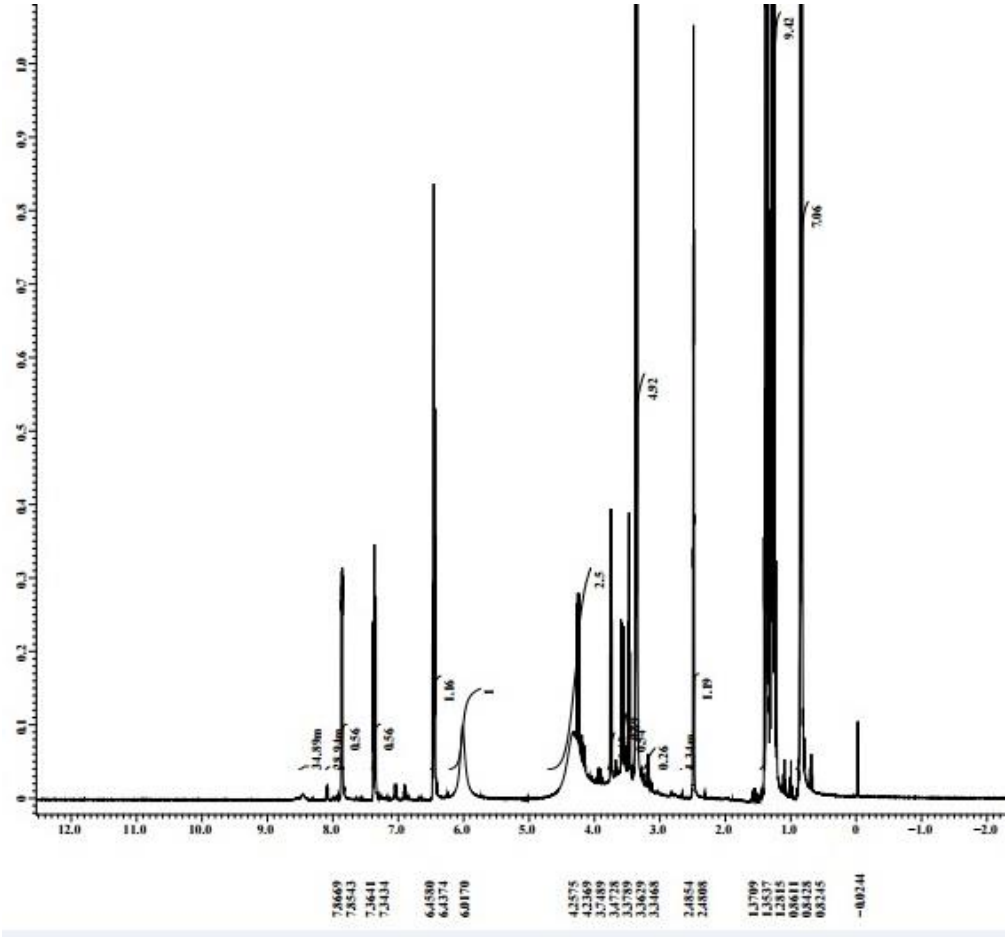
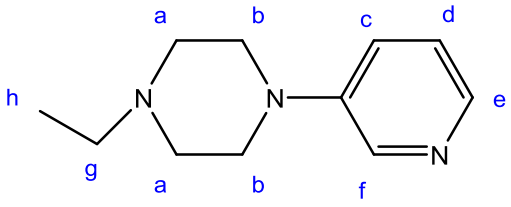


Figure 13:- NMR spectrum of 1-ethyl-2-(pyridin-2-yl)piperazine (L4)

Table 13:- NMR peaks of L4

Ligands	Ha	Hb	Hc	Hd	He	Hf	Hg	Hh
L4	3.37(t)	3.47(t)	7.86(d)	7.36(t)	7.34(d)	6.85(d)	2.43(t)	1.28(m)



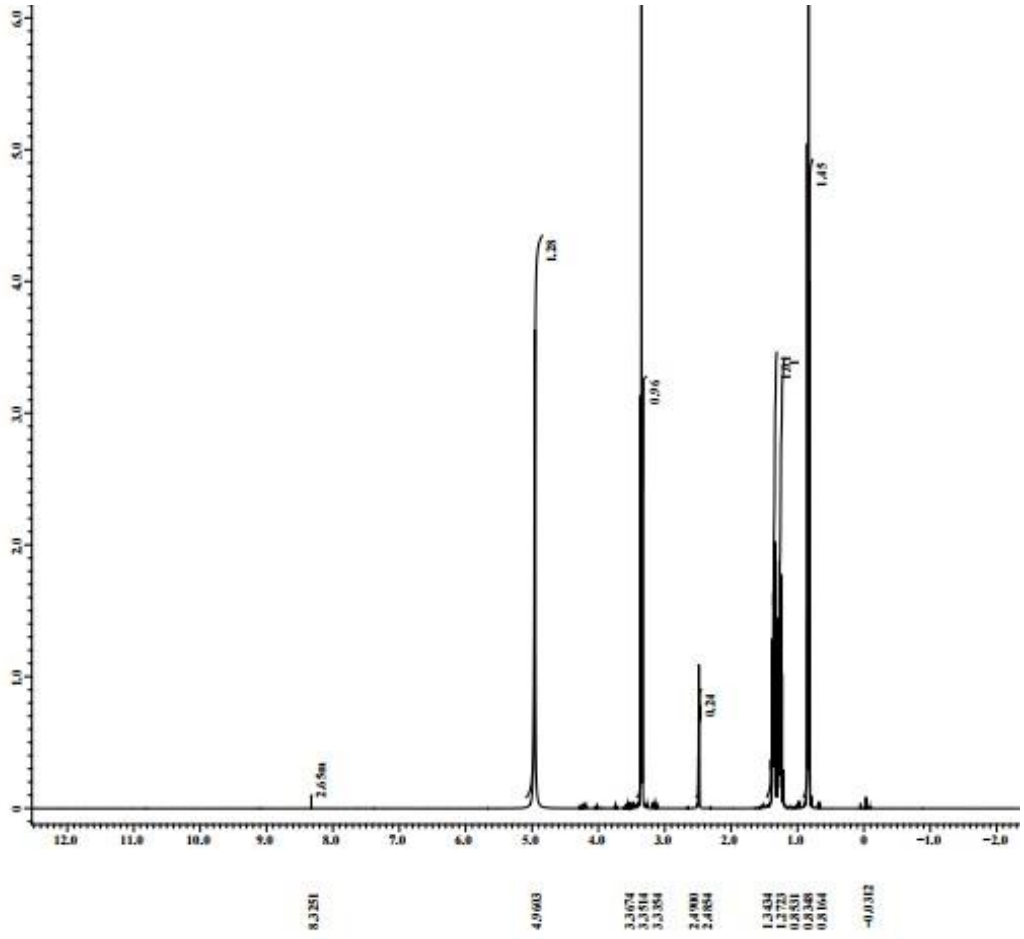
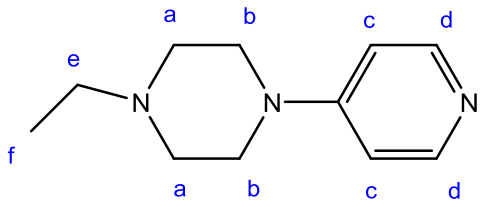


Figure 14:- NMR spectrum of 1-ethyl-2-(pyridin-3-yl)piperazine (L5)

Table 14:- NMR peaks of L5

Ligands	Ha	Hb	Hc	Hd	He	Hf	Hg	Hh
L5	3.33(t)	3.36 (t)	6.34(d)	7.45(d)	7.89(d)	8.3(d)	1.34(t)	1.27(m)



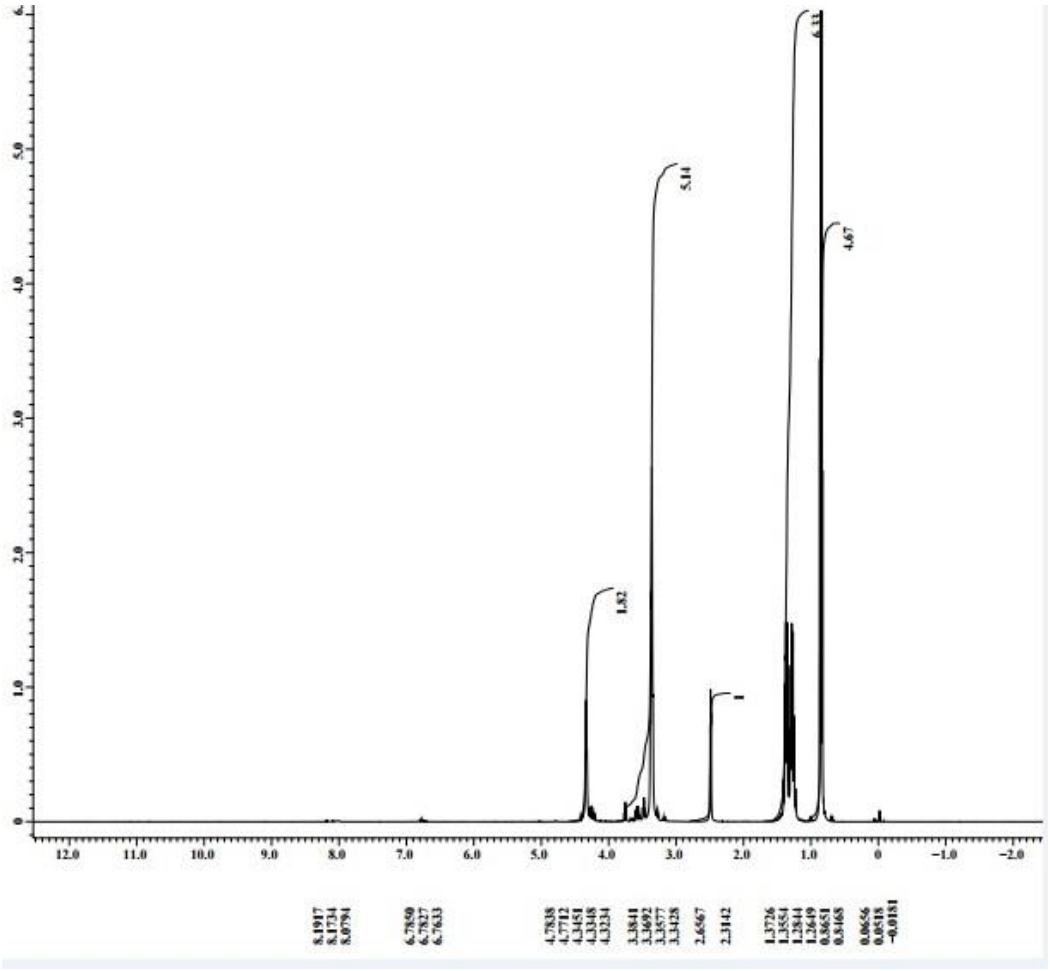


Figure 15:- NMR spectrum of 1-ethyl-2-(pyridine-4-yl)piperazine (L6)

Table 15:- NMR peaks of L6

Ligands	Ha	Hb	Hc	Hd	He	Hf
L6	3.35 (t)	3.76 (t)	6.76 (d)	8.07 (t)	1.37 (t)	1.26 (m)

IR spectroscopy of the complexes:-

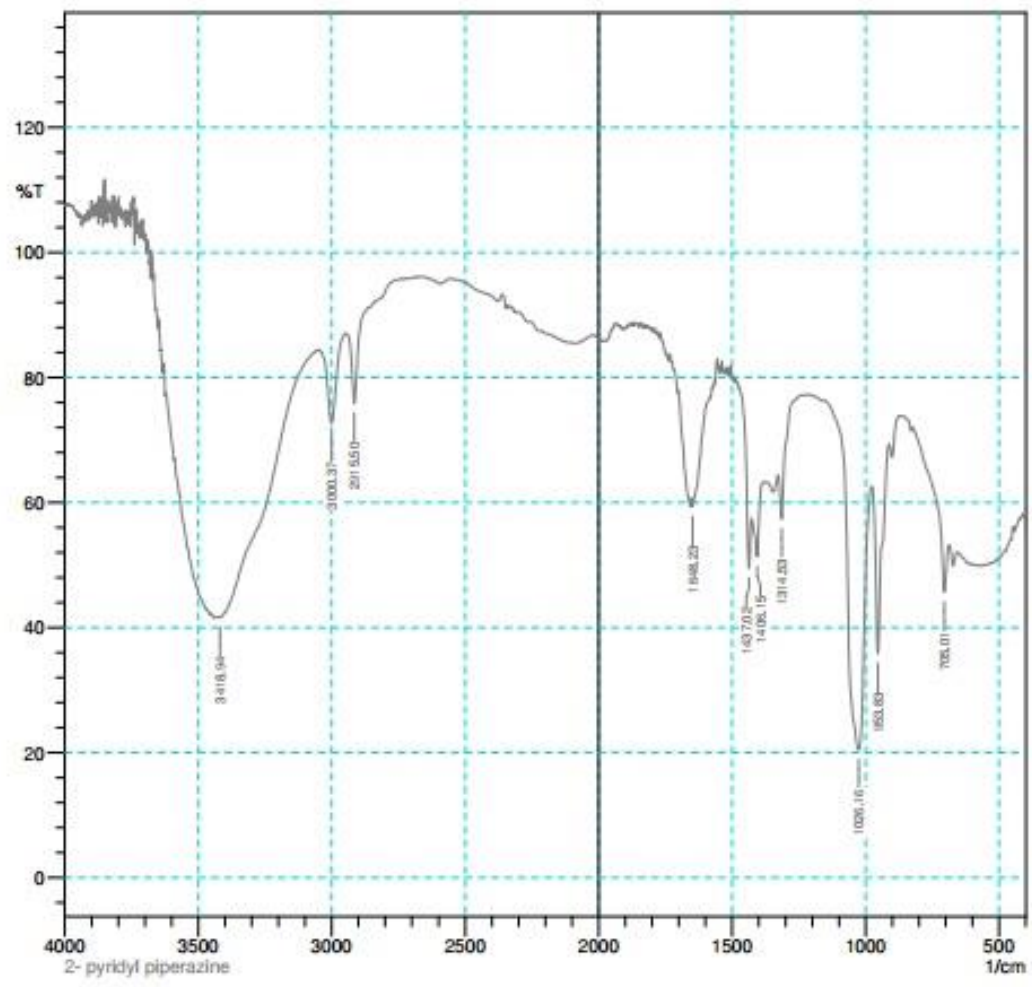


Figure 16:- IR spectrum of copper complex with L1

Table 16:- IR peaks of copper complex with L1

Functional group	Peak (cm^{-1})	Type of vibration
Ar. CH	3000	Stretching
CH	2915	Stretching
C=C	1648	Stretching
Cu-N	705	Stretching

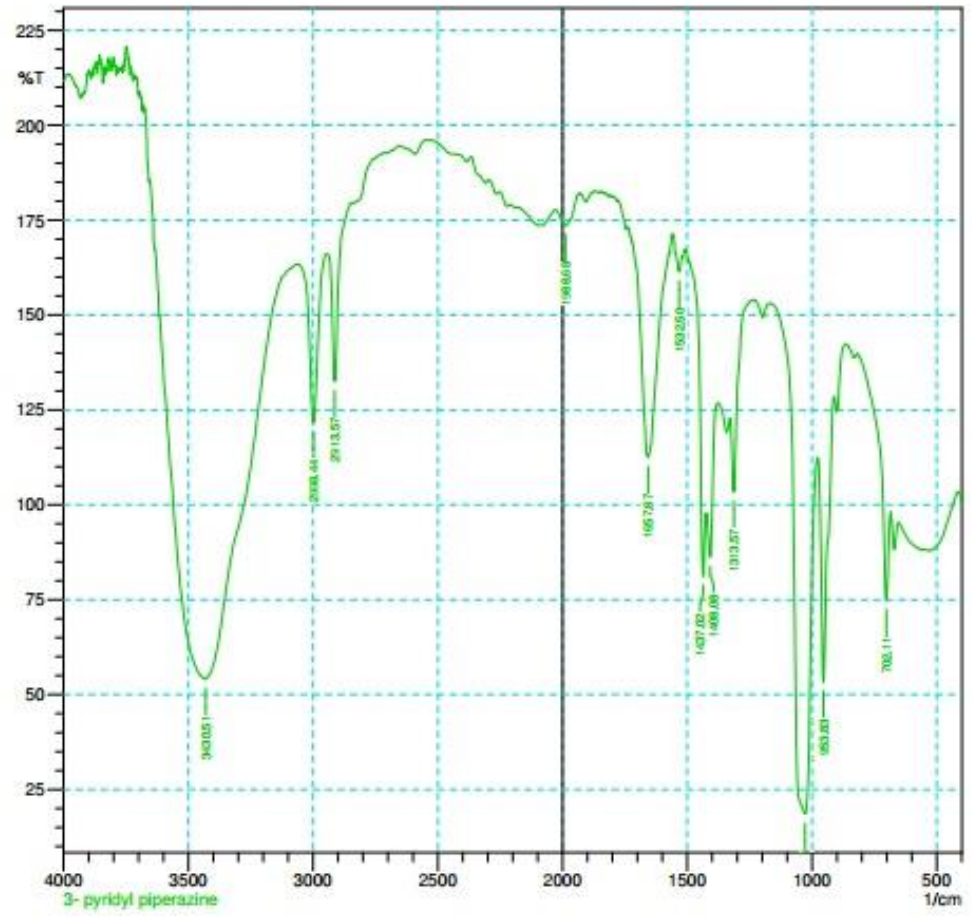


Figure 17:- IR spectrum of copper complex with L2

Table 17:- IR peaks of copper complex with L2

Functional group	Peak (cm^{-1})	Type of vibration
C=C	1657	Stretching
CH	2913	Stretching
Ar. CH	2998	Stretching
Cu-N	702	Stretching

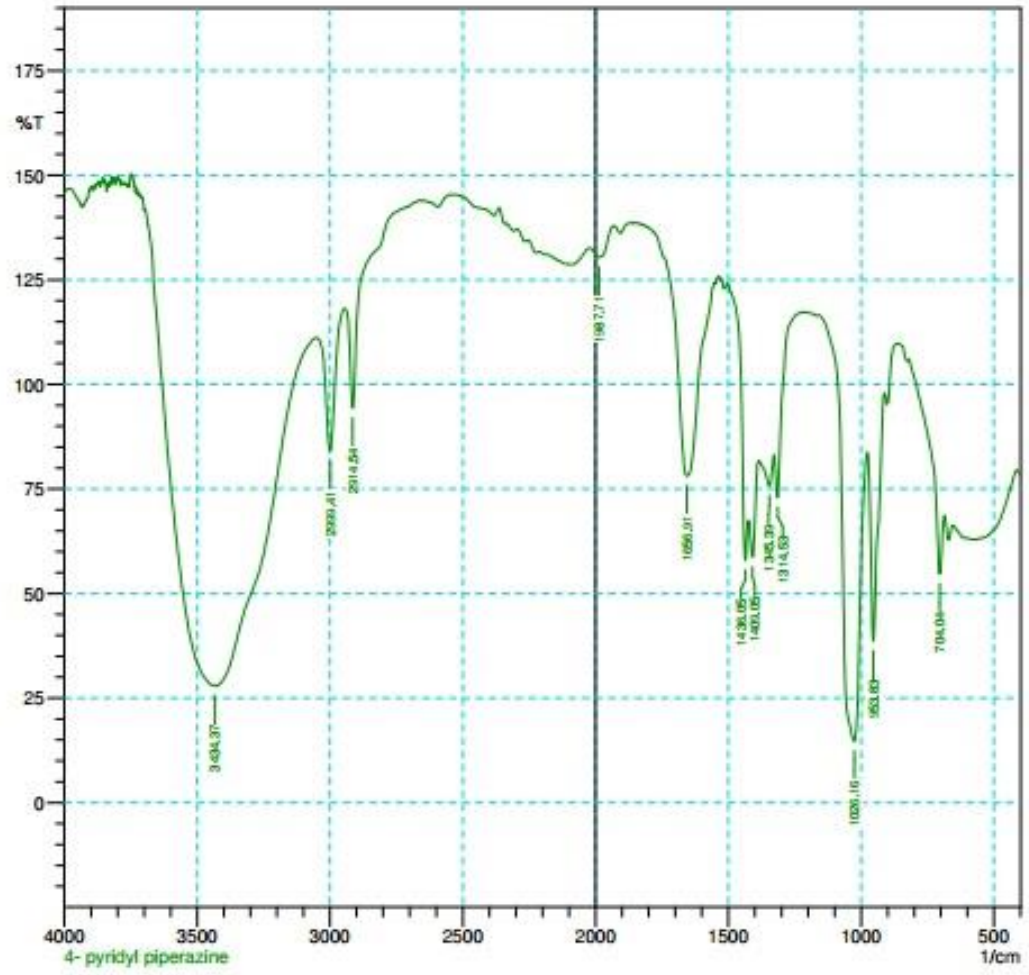


Figure 18:- IR spectrum of copper complex with L3

Table 18:- IR peaks of copper complex with L3

Functional group	Peak (cm^{-1})	Type of vibration
C=C	1656	Stretching
CH	2999	Stretching
Ar. CH	3434	Stretching
Cu-N	704	Stretching

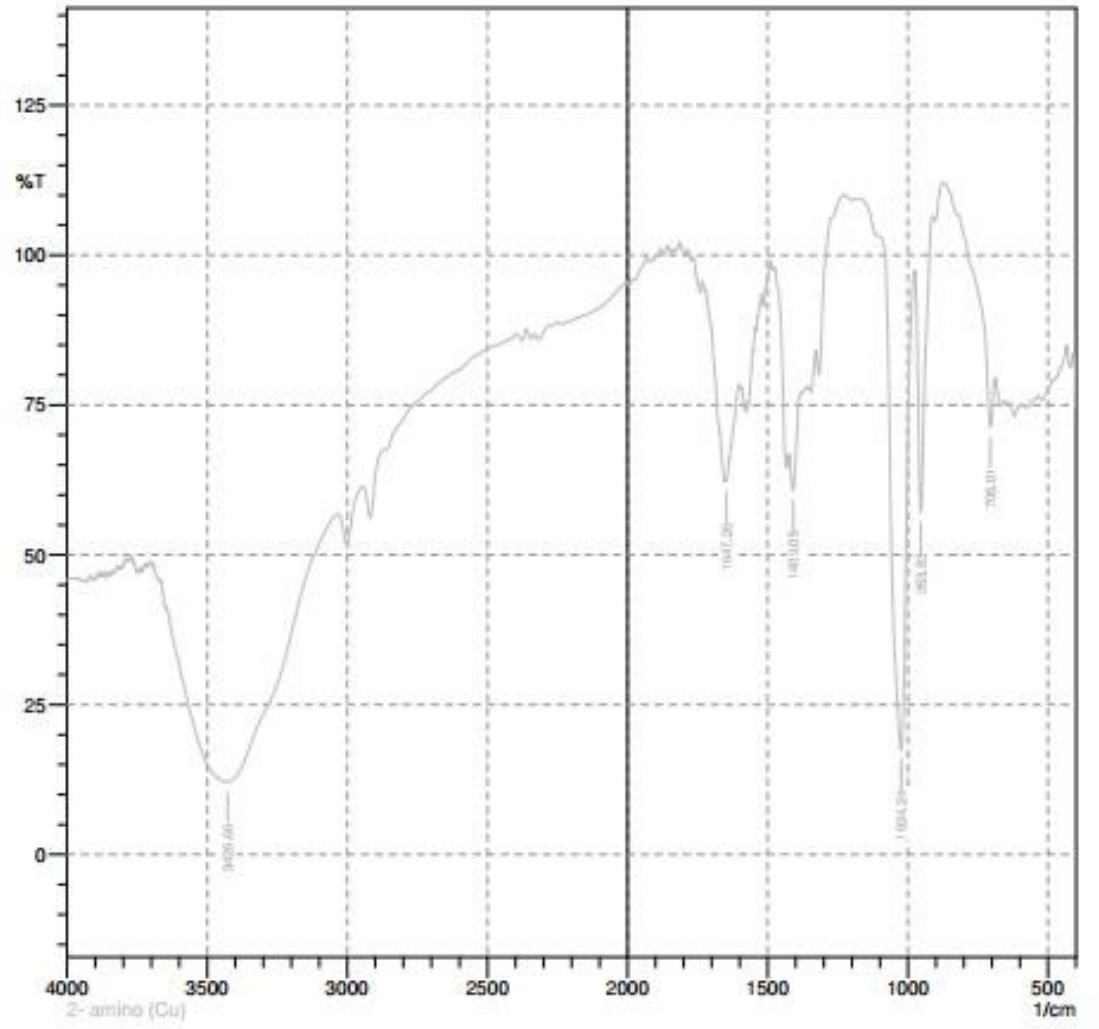


Figure 19:- IR spectrum of copper complex with L4

Table 19:- IR peaks of copper complex with L4

Functional group	Peak (cm^{-1})	Type of vibration
C=C	1648	Stretching
Ar. CH	3000	Stretching
CH	2915	Stretching
Cu-N	705	Stretching

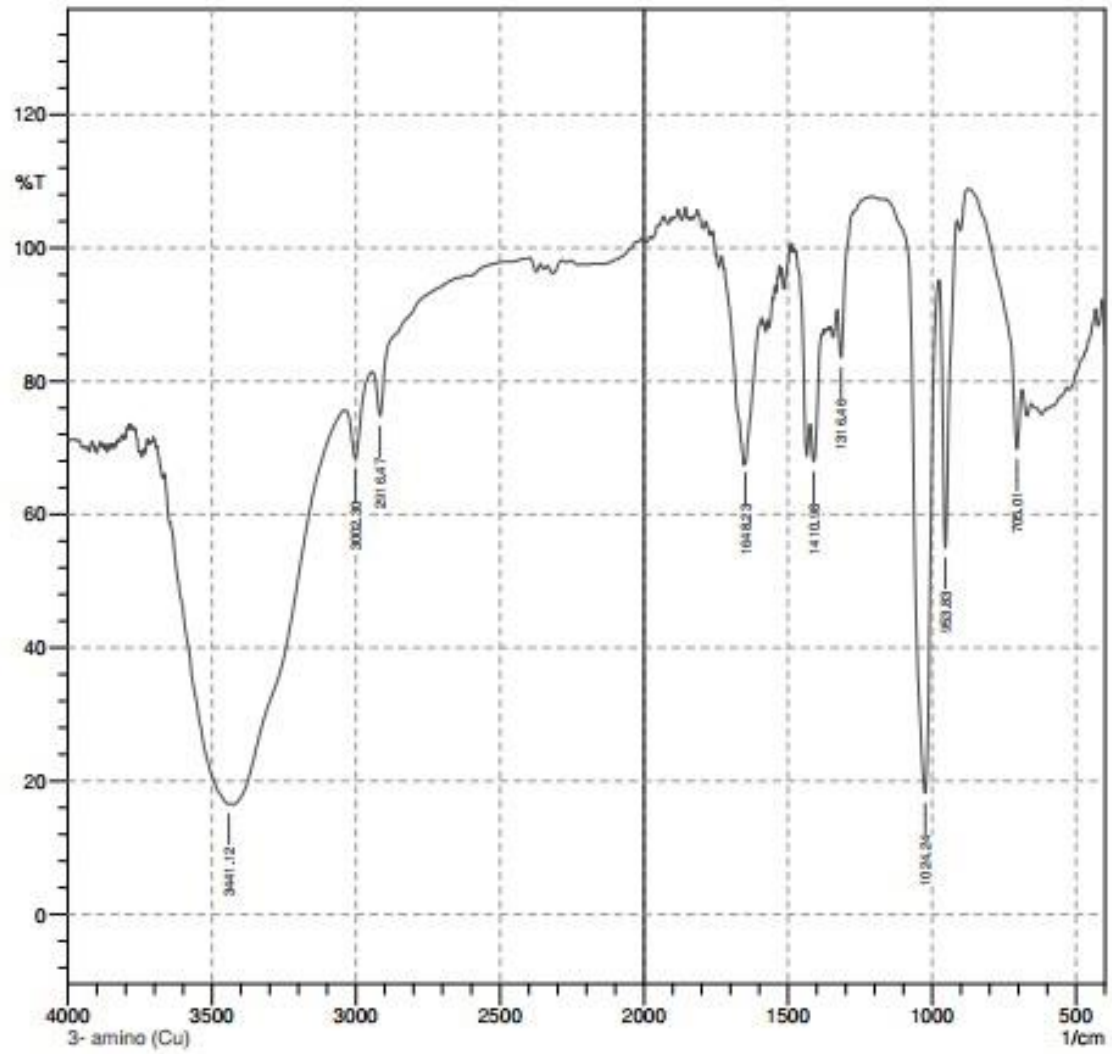


Figure 20:- IR spectrum of copper complex with L5

Table 20:- IR peaks of copper complex with L5

Functional group	Peak (cm^{-1})	Type of vibration
C=C	1657	Stretching
Ar. CH	2998	Stretching
CH	2913	Stretching
Cu-N	705	Stretching

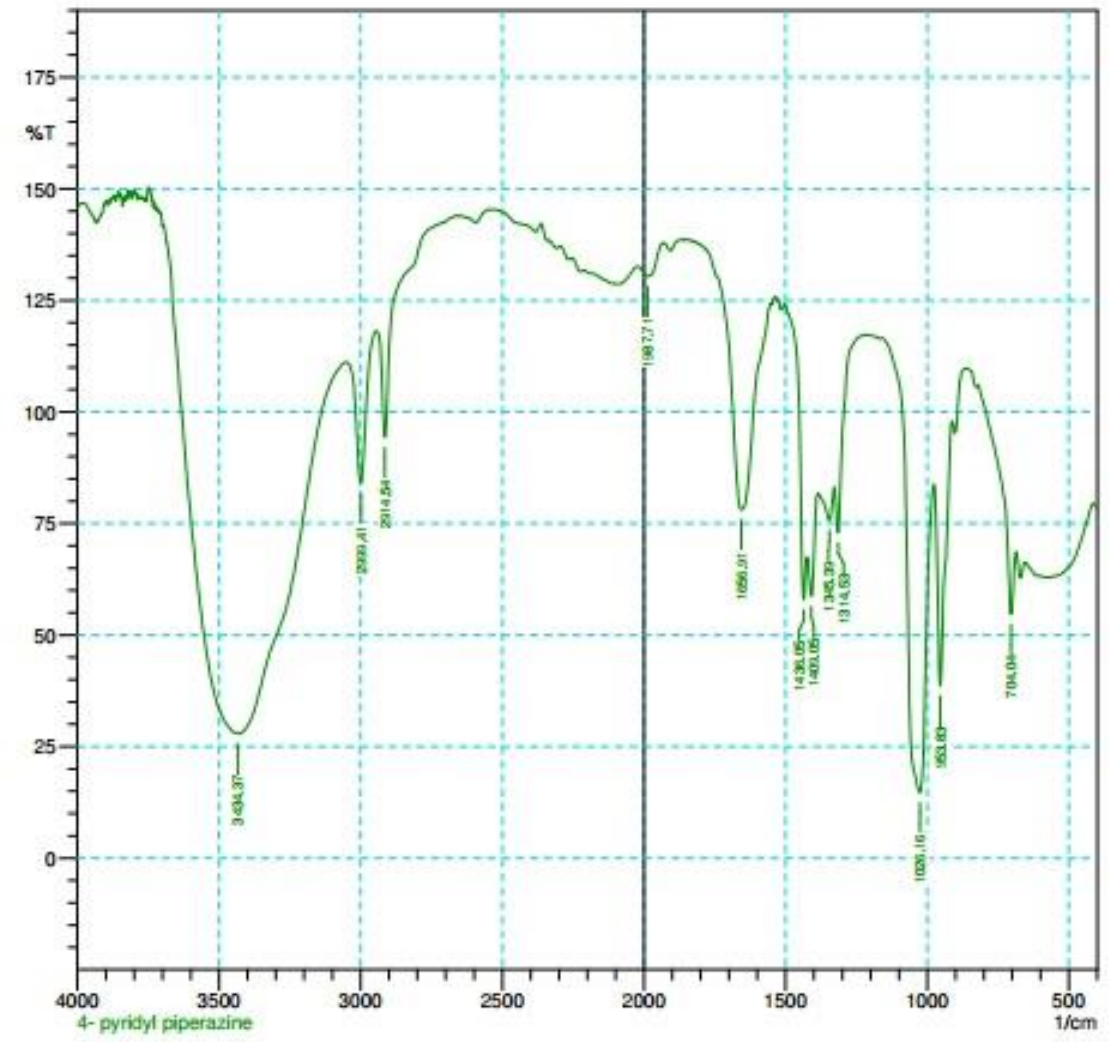


Figure 21:- IR spectrum of copper complex with L6

Table 21: IR peaks of copper complex with L6

Functional group	Peak (cm^{-1})	Type of vibration
C=C	1652	Stretching
Ar. CH	2997	Stretching
CH	2911	Stretching
Cu-N	704	Stretching

UV Spectroscopic study:

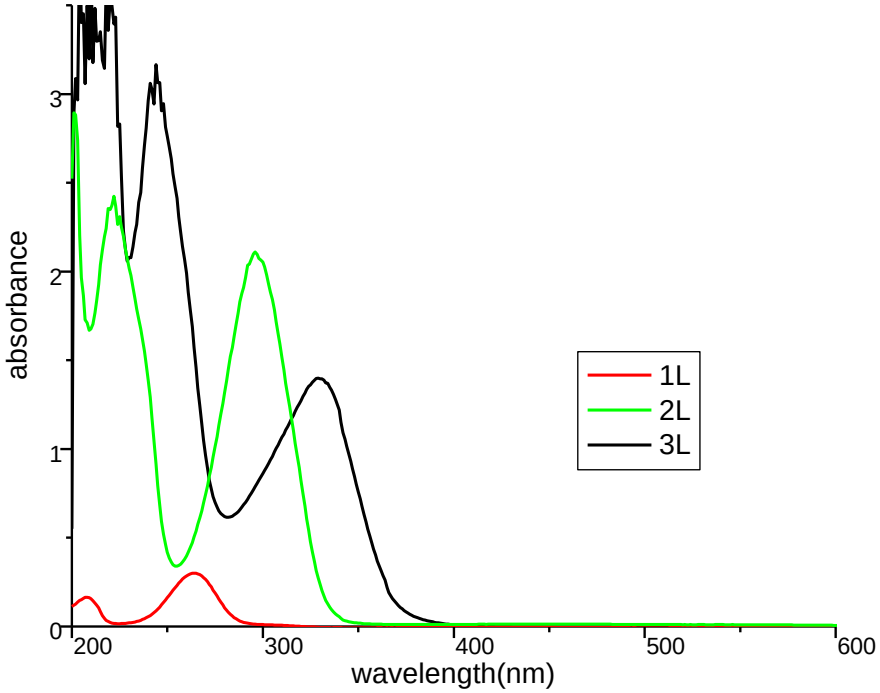


Figure 22: UV spectrum of ligands

Table 22:- Peak table of L1, L2 and L3

Sr. no.	Ligand	Wavelength(nm)	Absorption ($Lmol^{-1}cm^{-1}$)
1.	**L1**	264	0.304
2.	**L2**	222, 297	2.412, 2.096
3.	**L3**	244,330	3.063,1.392

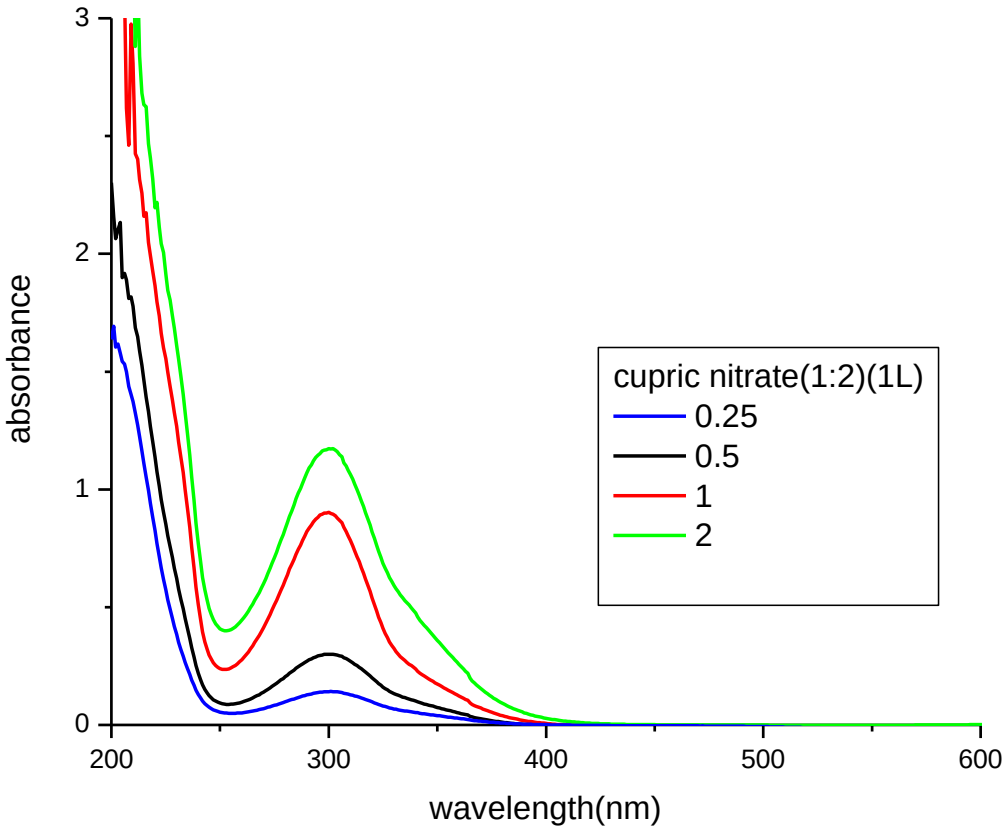


Figure 23:- UV-vis spectrum of copper complex with L1

Table 23:- Peak table of copper complex with L1

Wavelength (nm)	Absorbance (L mol^{-1} cm^{-1})
300	1.187

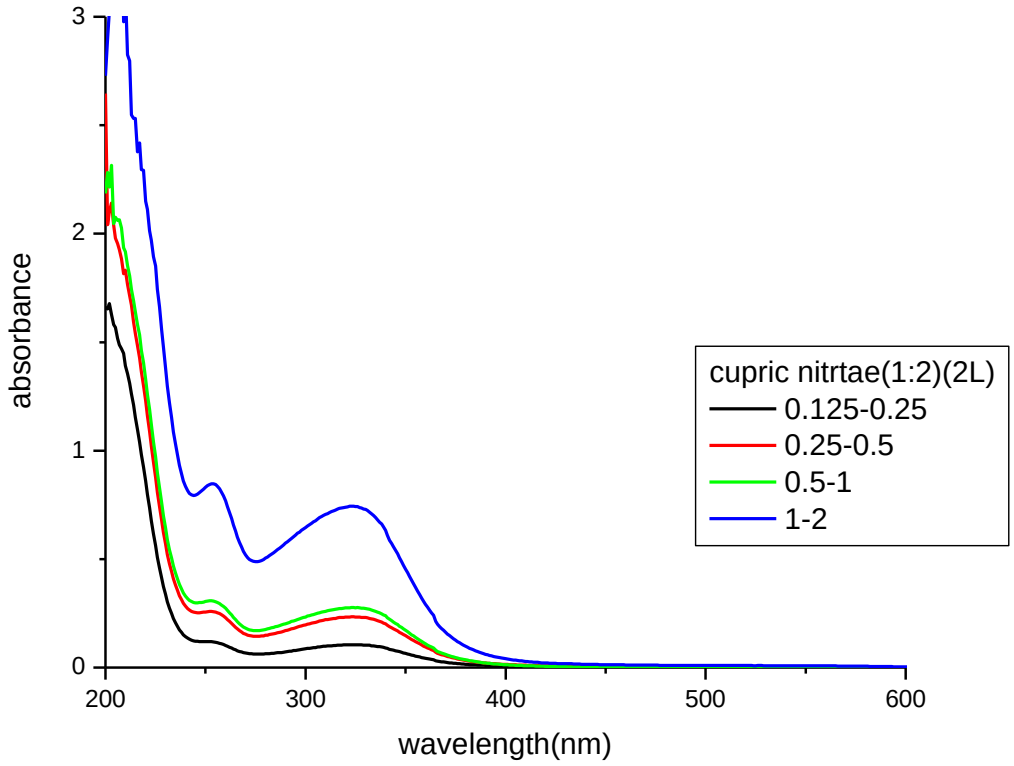


Figure 24:- UV-vis spectrum of copper complex with L2

Table 24:- Peak table of copper complex with L2

Wavelength (nm)	Absorbance (L mol^{-1} cm^{-1})	Molar Absorptivity (M^{-1} cm^{-1})
254	0.8481	8481
324	0.7383	7383

Table 25:- Molar absorptivity of free L2

Wavenumber (nm)	Absorbance (L mol^{-1} cm^{-1})
222	2.412
297	2.096

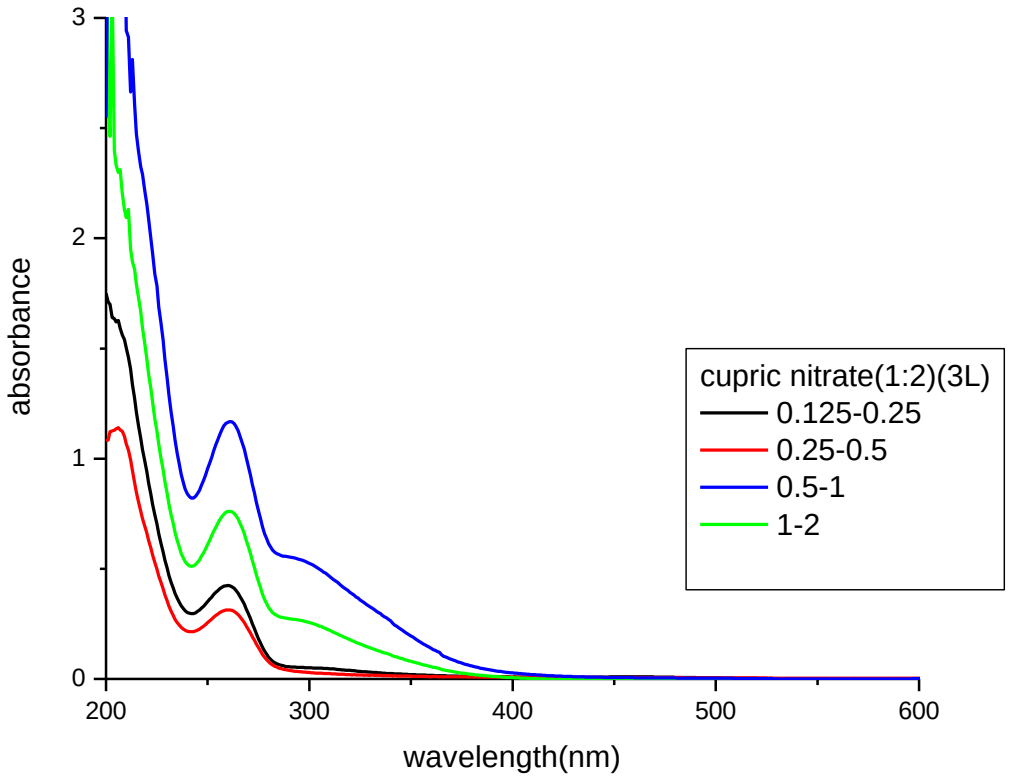


Figure 25:- UV-vis spectrum of copper complex with L3

Table 26:- Peak table of copper complex with L3

Wavelength (nm)	Absorbance (L mol^{-1} cm^{-1})
260	1.179
304	0.510

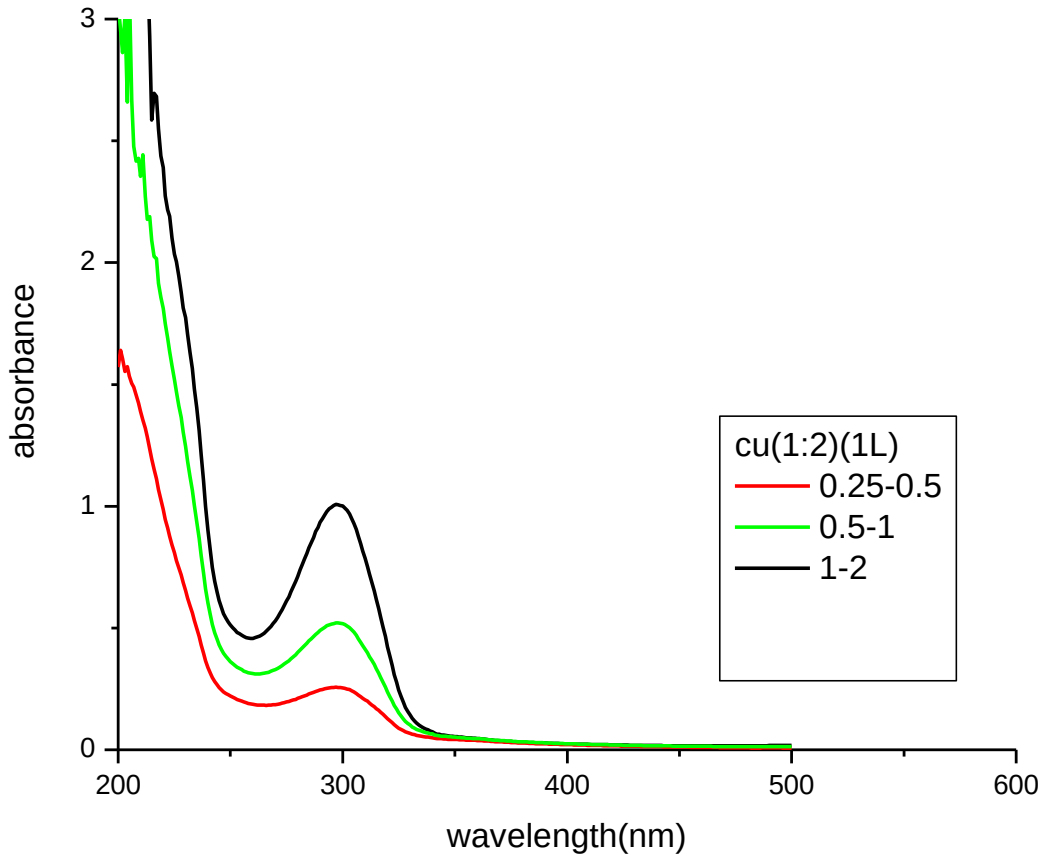


Figure 26:- UV-vis spectrum of copper complex with L4

Table 27:- Peak table of copper complex with L4

Wavenumber (nm)	Absorbance (L mol^{-1} cm^{-1}
298	1.018

Table 28:-Molar absorptivity of free L4

Wavenumber (nm)	Absorbance (L mol^{-1} cm^{-1})
252	0.301

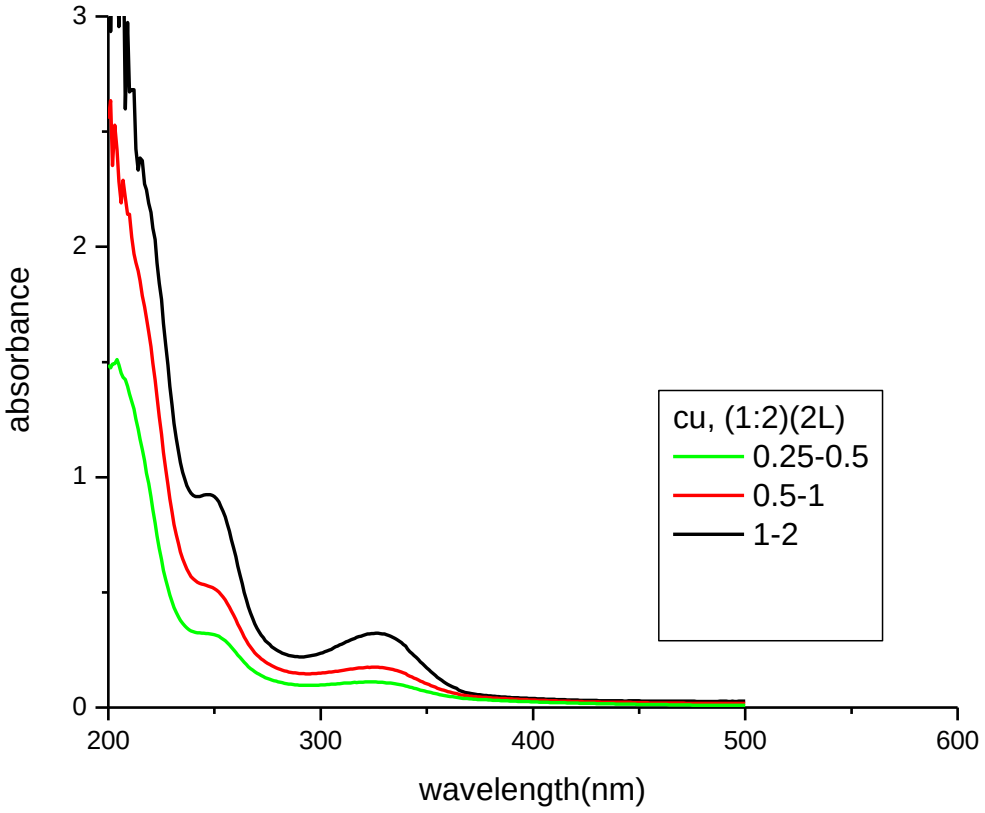


Figure 27:- UV-vis spectrum of copper complex with L5

Table 29:- Peak table of copper complex with L5

Wavenumber (nm)	Absorbance (L mol^{-1} cm^{-1})
329	0.3465
247	0.9027

Table 30:- Peak table of free L5

Wavenumber (nm)	Absorbance (L mol^{-1} cm^{-1})
300	2.213
229	2.092

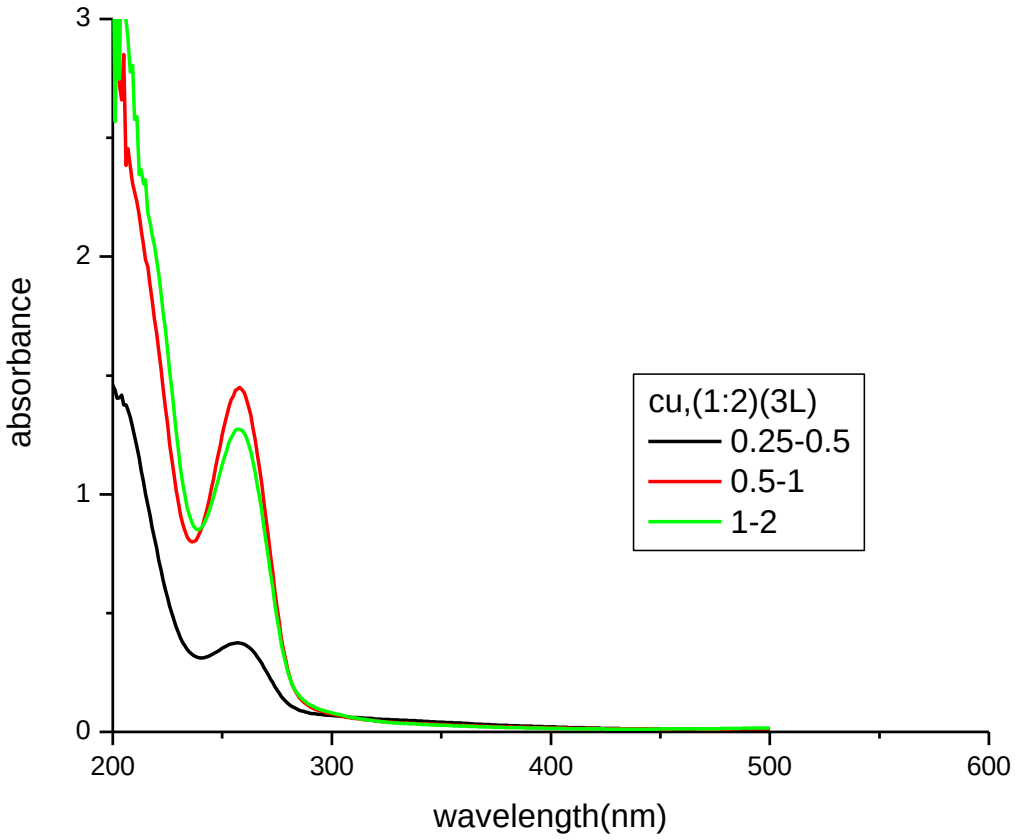


Figure 28:- UV-vis spectrum of copper complex with L6

Table 31:- Peak table of copper complex with L6

Wavenumber (cm^{-1})	Absorbance (L mol^{-1} cm^{-1})
256	1.4377

Table 32:- Peak table of freeL6

Wavenumber (cm^{-1})	Absorbance (L mol^{-1} cm^{-1})
234	3.025

6. Conclusion:-

Three pyridyl piperazine ligands 1-(2-pyridyl)-piperazine (Ligand **L1**), 1-(3-pyridyl)-piperazine (ligand **L2**), and 1-(4-pyridyl)-piperazine (Ligand **L3**) and their ethylated derivatives 1-ethyl-4-(pyridine-2-yl)piperazine (Ligand **L4**), 1-ethyl-4-(pyridine-3-yl)piperazine (Ligand **L5**), and 1-ethyl-4-(pyridine-4-yl)piperazine (Ligand **L6**) were synthesized and characterized by UV-vis, IR and NMR spectroscopic techniques. Complexations of synthesized ligands were done with copper metal ions. From the UV data it is established that the ligands are binding with copper differently as was observed by the change in the absorption pattern of the metal complex from the ligand itself. In general, IR peaks for metal-nitrogen appear near 440-460 cm^{-1}. In the above mentioned complexes peaks appear in this range which confirms the binding of ligand with the metal ions. To find the detailed mode of binding of the ligands with the metal and to identify the type of network structure, a detailed analysis of their structure is required. For this purpose crystals of these complexes are being grown which can be studied using single crystal X-ray diffraction method to identify the three dimensional structure and nature of bonding.

References:

1. Caskey, Stephen R., and Adam J. Matzger. "Selected Applications of Metal− Organic Frameworks in Sustainable Energy Technologies." *Mater. Matters* 4 (2009): 111.
2. Furukawa, Hiroyasu, Kyle E. Cordova, Michael O'Keeffe, and Omar M. Yaghi. "The chemistry and applications of metal-organic frameworks." *Science* 341, no. 6149 (2013): 1230444.
3. Furukawa, Hiroyasu, Ulrich Müller, and Omar M. Yaghi. "'"Heterogeneity within order" in metal–organic frameworks." *Angewandte Chemie International Edition* 54, no. 11 (2015): 3417-3430.
4. www.sigmaaldrich.com/catalog/product/aldrich/408166
5. Hancock, Robert D., Peter W. Wade, M. Patrick Ngwenya, Alvaro S. De Sousa, and Kirty V. Damu. "Ligand design for complexation in aqueous solution. 2. Chelate ring size as a basis for control of size-based selectivity for metal ions." *Inorganic Chemistry* 29, no. 10 (1990): 1968-1974.
6. Atherden LH, Bently and Driver's Text Book of PharmChem, 2004;8:372
7. Beckett AH and Stenlake JB. Practical Pharm Chem. CBS Publishers, 2003; 4:62
8. Jahan, Sarwat, Shamim Akhtar, Zafar Saied Saify, Nousheen Mushtaq, Ali Akbar Sial, Arfa Kamil, and Muhammed Arif. "Synthesis and cytotoxic activity of some derivatives of alkyl piperidine." *Pak. J. Pharm. Sci* 26, no. 3 (2013): 517-523.
9. Jahan, Sarwat, Shamim Akhtar, Zafar Saied Saify, Nousheen Mushtaq, Ali Akbar Sial, Arfa Kamil, and Muhammed Arif. "Synthesis and cytotoxic activity of some derivatives of alkyl piperidine." *Pak. J. Pharm. Sci* 26, no. 3 (2013): 517-523.
10. Kim, Dae-Kee, Youngseok Kim, Jonggill Rim, Ganghyeok Kim, Jongsik Gam, Sungkun Song, Kwanghee Yoo, and Key H. Kim. "Synthesis of carbon-14 labelled cis-malonato [(4R, 5R)-4, 5-bis (aminomethyl)-2-isopropyl-1, 3-dioxolane] platinum (II)(ski 2053R)." *Journal of Labelled Compounds and Radiopharmaceuticals* 34, no. 2 (1994): 157-164.
11. Batten, Stuart R., Neil R. Champness, Xiao-Ming Chen, Javier Garcia-Martinez, Susumu Kitagawa, Lars Öhrström, Michael O'Keeffe, Myunghyun Paik Suh, and Jan Reedijk. "Terminology of metal–organic frameworks and coordination polymers (IUPAC Recommendations 2013)." *Pure and Applied Chemistry* 85, no. 8 (2013): 1715-1724.
12. Chand, Jain Padam, and Anand Nitya. "1-aminopyridyl-4-(phenyl or pyridyl)-piperazines and intermediates." U.S. Patent 3,306,903, issued February 28, 1967.

13. Cesur, Hasan, Turan K. Yazicilar, Bekir Bati, and Veysel T. Yilmaz. "Synthesis, characterization, and spectral and thermal studies of some divalent transition metal complexes of benzylpiperazine dithiocarbamate." *Synthesis and Reactivity in Inorganic and Metal-Organic Chemistry* 31, no. 7 (2001): 1271-1283.
14. Şenyel, Mustafa, Cemal Parlak, and Özgür Alver. "FT-IR spectroscopic investigation of some Hofmann type complexes: M (1-phenylpiperazine) 2 Ni (CN) 4 (M= Ni, Co, Cd, Pd or Mn)." *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* 70, no. 2 (2008): 367-375.
15. Keşan, Gürkan, Özge Bağlayan, Cemal Parlak, Özgür Alver, and Mustafa Şenyel. "FT-IR and Raman spectroscopic and quantum chemical investigations of some metal halide complexes of 1-phenylpiperazine." *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* 88 (2012): 144-155.
16. Panchal NB,Captain AD. International journal for pharmaceutical research scholar. 2015; 4: I-1.
17. Jain, Vibhor K., Bindu Jain, Umesh K. Sharma, and Dibyojoti. Saha. "Synthesis, characterization and antimicrobial screening of some 4-substituted-1-(4-substituted phenyl) piperazine derivatives." *Int J Curr Pharm Res* 3, no. 1 (2011): 66-70.
18. Patel, Divyesh, Rahul Patel, Premlata Kumari, and Navin Patel. "Microwave-assisted synthesis of coumarin based 1, 3, 5-triazinyl piperazines and piperidines and their antimicrobial activities." *Acta Pol. Pharm* 69 (2012): 879-891.
19. Niu, Yunyin, Hongwei Hou, Yongli Wei, Yaoting Fan, Yu Zhu, Chenxia Du, and Xinquan Xin. "A linear piperazine–pyridine ligand and its Hg coordination polymer." *Inorganic Chemistry Communications* 4, no. 7 (2001): 358-361.
20. Rowsell, Jesse LC, and Omar M. Yaghi. "Metal–organic frameworks: a new class of porous materials." *Microporous and Mesoporous Materials* 73, no. 1 (2004): 3-14.
21. Hanack, Michael, and Danilo Dini. "Structure-Related Properties." *The Porphyrin Handbook: Multporphyrins, Multiphthalocyanines and Arrays* 18 (2012): 251.
22. K. Rissanen, J. Breitenbach, J. Hunkskonen, J. Chem. Soc. Chem. Commun(1994) 1265
23. Hancock, Robert D., Susan M. Dobson, Ann Evers, Peter W. Wade, M. Patrick Ngwenya, Jan CA Boeyens, and Kevin P. Wainwright. "More rigid macrocyclic ligands that show metal ion size-based selectivity. Crystallographic, molecular mechanics, and formation constant study of the complexes of bridged cyclen." *Journal of the American Chemical Society* 110, no. 9 (1988): 2788-2794.

24. Ratilainen, Jari, Karri Airola, Roland Fröhlich, Martin Nieger, and Kari Rissanen. "Synthesis of a tetradentate piperazine ligand and a structural study of its coordination compounds." *Polyhedron* 18, no. 17 (1999): 2265-2273.