METAL COMPLEXES OF FORMAZANS

THESIS SUBMITTED TO THE UNIVERSITY OF CALICUT
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN CHEMISTRY

BY

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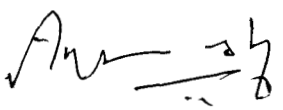
2000

DECLARATION

I hereby declare that the thesis bound herewith is an authentic record of the research work carried out by me under the supervision of Dr. K. Krishnankutty, Professor of Chemistry, University of Calicut in partial fulfilment of the requirements for the Degree of Doctor of Philosophy in Chemistry of the University of Calicut and further that no part thereof has been presented before for any other Degree.



Abdul Rahim A.K.

CERTIFICATE

This is to certify that the Thesis bound herewith is an authentic record of the research work carried out by Mr. Abdul Rahim A.K., under my supervision in partial fulfilment of the requirements for the Degree of Doctor of Philosophy in Chemistry of the University of Calicut and further that no part thereof has been presented before for any other Degree.

Dr. K. Krishnankutty

(Supervising Teacher)

AKNOWLEDGEMENT

This work would not have been as satisfying as it is now but for the guidance and help I received in ample measure from my Supervising Techer **Dr K.Krishnankutty**. *His perceptive comments and generous encouragement have made my work enjoyable.*

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Finally, I wish to thank everyone whose assistance, great or small, facilitated my efforts.

ABDUL RAHIM. A.K.

PREFACE

The study of metal complexes of organic ligand systems is one of the most dynamic field of coordination chemistry. A major application of these complexes is as dyes and pigments. Formazans, a class of synthetic organic dyestuff, and their metal complexes belongs to this category. Several biochemical applications exist for formazans and their metal complexes. However structural aspects of metallised formazans has received only scanty attention so far. The present investigation, therefore, has been so designed as to provide some advances in this direction.

Part I, Chapter 1 is a general introduction which highlights briefly some of the salient aspects of formazans and their metal complexes in order to provide perspective and appreciation of the continuing interest in the compounds. **Chapter 2** is a critical review of published work on metal complexes of formazans

In **Part II, Chapter 1**, synthesis and characterisationof typical bidentate and tridentate 1,5-diaryl-3-acetylformazans and their copper(II), nickel(II) and cobalt(II) complexes are presented. Electronic, ir, nmr, and mass spectral data clearly indicated the involvement of the formazyl hydrogen in intramolecular hydrogen bonding. In metal complexes, the metal ion replaces the formazyl proton with the formation of six membered chelate ring involving two formazyl nitrogens. The acetyl carbonyl group is not

involved in coordination with metal ion.. The spectral , and analytical data of metal complexes of the tridentate formazan, 1-phenyl-5-(2-carboxyphenyl)-3-acetyl formazan, are consistant with the M_2L_2 type complexes in which the carboxyl group act as bridging group. All other formazans form $[ML_2]$ type complexes.

The proton-ligand and metal -ligand stability constants of the compounds are also included

In **Chapter 2** the synthesis and characterisation of 1,5-diaryl-3-benzoylformazans and their copper(II), nickel(II) and cobalt(II) complexes are presented The analytical and spectral data are consistant with $[ML_2]$ stoichiometry of the bidentate formazan and M_2L_2 in the case of the tridentate, 1-phenyl-5-(2-carboxyphenyl)-3-benzoylformazan. The structure and nature of the bonding of the complexes are similar to those considered in **Chapter 1**

Synthesis, characterisation and nature of bonding of metal complexes of typical 1,5-diaryl-3-phenylformazans are given in **Chapter 3**.

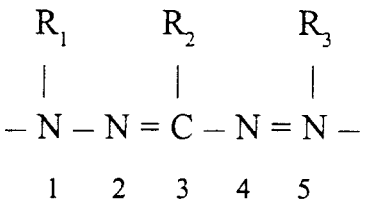
In **Chapter 4** details on the synthesis and characterisation of certain 1,5-diaryl-3-(2-hydroxyphenyl)formazans and their metal complexes are included. In all the complexes spectral data clearly suggest that the phenolic group is excluded from bonding with the metal ion. The structure and nature of bonding in the complex are established on the basis of ir, nmr and mass spectral data.

The results of biological studies of the various formazans and their metal complexes are presented in **Chapter 5**.

References in serial order are cited at the end of the Thesis.

NOMENCLATURE

Reaction of aryldiazonium salts with active methyl and methylene compound under specified conditions leads to the formation of a disazo type compounds. Such compounds are also formed by coupling of aryldiazonium salts with hydrazones. Von Pechmann in 1892 (Ber., 25, 3175, 1892) christened these compounds as formazyls. The characteristic structural feature of these compounds is the presence of the group



Later a more rational nomenclature based on calling the hypothetical parent compound of the above structure where $R_1 = R_2 = R_3 = H$, as formazan was accepted. This name still in use though not systematic and open to serious objections. In the present investigation also this terminology is adopted.

For the sake of brevity and better readability, abbreviations, instead of polysyllabic names have been freely used in this Thesis.

CONTENTS

Chapter 4

1,5-DIARYL-3-(2-HYDROXYPHENYL)FORMAZANS AND THEIR METAL COMPLEXES

Chapter 5

ANTIMICROBIAL STUDIES OF FORMAZANS AND THEIR METAL CHELATES

PART I
GENERAL INTRODUCTION

Abdul Rahim A.K. “Metal complexes of formazans ” Thesis. Department of Chemistry , University of Calicut, 2000

PART I

CHAPTER I

GENERAL INTRODUCTION

Coordination Chemistry of Formazans

In recent years coordination compounds have found increasing applications in diverse fields. This is particularly true in the case of metal complexes of organic compounds-both natural and synthetic. Their importance is well known in many fields such as in winning metals from their ores, in electroplating, in catalysing reactions and in obviating the effects of undesirable catalyses, in precipitating metallic ions and in preventing their precipitations, in the technology of dyes and pigments, in medicine and in diverse biochemical studies, and in many other ways[1-18]. Still other uses await study and exploration.

The bright colour of transition metal complexes of organic chelating agents have evoked considerable interest right from the time these compounds started becoming familiar. A large number of these intensily coloured complexes were in use as dyes and pigments long before they were recognised as coordination compounds[1-3]. Most of the colouring matters are synthetic organic compounds and their metal complexes.

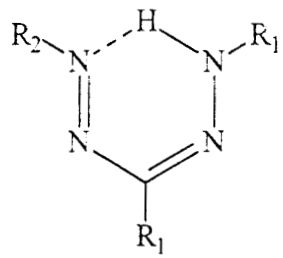
Thousands of synthetic dyes have been prepared purely by empirical experiments without any theoretical basis. Among the synthetic dyestuffs,

the most important are compounds containing —N=N— function in their structure. Of these the azo dyes form the largest and most versatile class[19-22]. Formazans are also a class of compounds containing the —N=N— groups. Azo dyes have a multitudes of uses depending their structures and method of application. Though formazans are intensily coloured and possess dyeing properties, their stability is less compared to azo compounds and as a result they have limited applications as dyestuffs. However in recent years a number of other uses have been developed using different formazans and their metal complexes.

Formazans and their metal complexes can be used together with disperse dyes in single step dyeing of cellulosic-polyester blends, for dyeing or printing of paper, leather and polyamide fibres, to detect the presence of trace elements in ores, in the development of new type of oxidative and reductive chromogenic reagents in clinical analysis, as biological redox indicator, as an indicator of cell viability with less cytotoxicity. Some formazans in tetrazolium slat form can be used reliably to measure metabolic activity of cell cultures in vitro for the assessment of growth characteristics and in various biological researches[23-40]. Though several such applications have been reported for metal complexes of formazans, structural aspects of these complexes have received only scanty attention. The present investigation is an attempt in this direcion.

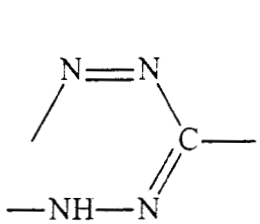
Structural aspects of formazans

Formazans are a class of synthetic organic compounds characterised by the linkage –N=N–C=N–NH– and were known[41-42] as early as in 1875. In general they can be represented by the structure **1**



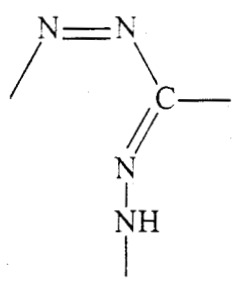
1

The following four different structures due to geometrical isomerism about the two double bonds are possible for formazans[43–46].



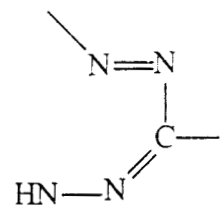
cis-syn

2



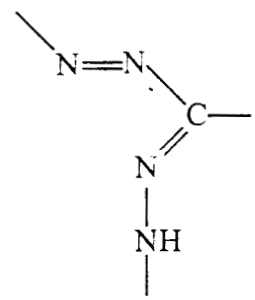
cis-anti

3



trans-syn

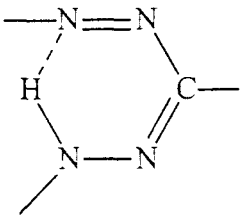
4



trans-anti

5

More structural possibilities exist if tautomerism is also considered. The *cis-syn* and *trans-syn* forms can readily involve in hydrogen bonding as in structures.



cis-syn

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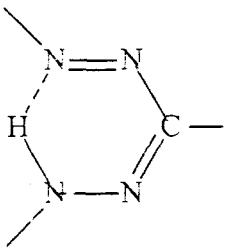
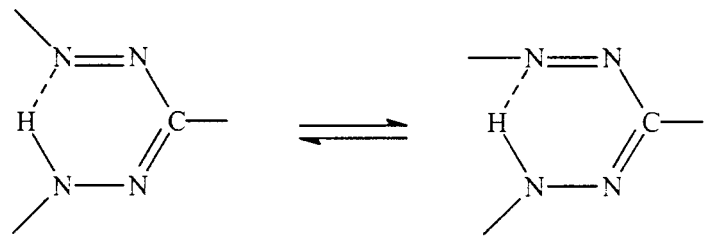


trans-syn

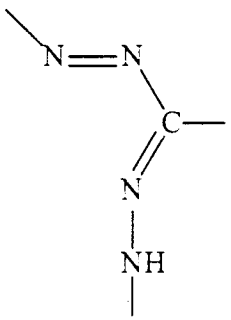
7

With the *trans* configuration about the C=N—, the *cis-anti* and *trans-anti* forms, the hydrogen bonding does not appear to be spatially possible. It has been noted[47-50] that irradiation of some formazan with visible light can convert the red formazan (λ_{mx} ~ 410 nm) into a yellow form (λ_{mx} ~ 455 nm) and that the reverse reaction occur in darkeness. This conversion involves the formation of different photochemical intermediate of very short half life. From detailed examination of this photochemical process Kuhn *et al* confirmed that the various species formed are the *cis-trans* and *syn-anti* isomers. These studies also concluded that the normal stable solid red formazan is the *trans-syn* form and the stable yellow form is the *trans- anti* form. These structure can be summarised as below in **scheme 1**

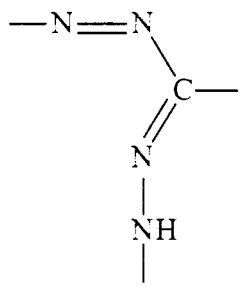


Red I
$\lambda_{max} \sim 495$ nm

Red II



Yellow I
$\lambda_{max} \sim 490$ nm

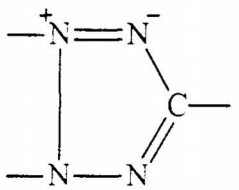


Yellow II

Scheme 1

In general only one form of the stable solid formazan is known, even when the two substituents attached to nitrogen are dissimilar. However in solution, depending on the presence or absence of light two forms are stable, one with hydrogen bonding and one without. It is to be pointed out that the effect of uv light on formazans is quite different from that of visible light. In uv light autoxidation can occur leading to the formation of tetrazolium salts.

Tetrazolium salts, basically analogus to formazans, containing one carbon and four nitrogen atoms in its structural unit, one of the four nitrogen atoms being quartenary, they possess salt like properties. They can be considered as quaternized tertrazoles with the following structures[51-55].



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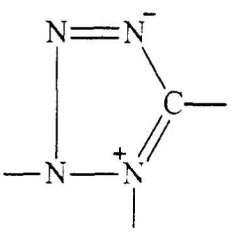

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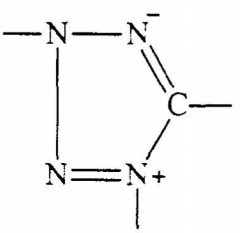
Or

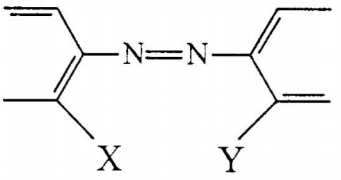


10

Metal complexes of formazans

In the basic structural unit of formazans consist of three important functional groups that can form stable metal complexes, namely the –N=N– (azo), C=N (azomethane) and –N–NH (hydrazo) groups. Thus it is to be expected that formazans can form metal complexes that exhibit diverse properties and applications.

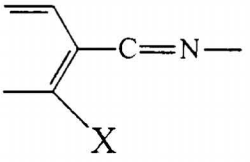
It is well known that the ability of azo nitrogens to form stable metal complexes is very limited[56]. Stable metal complexes are formed only if metal binding substituents such as OH, NH_2, COOH, etc. are present at suitable positions adjacent to the azo nitrogens as in structure **11**



11

X	Y
H	OH/ NH_2/ COOH/ SH
OH	OH/ NH_2/ COOH/ SH
NH_2	NH_2
COOH	COOH

The same is true in the case of azomethine, that is metal binding substituents are essential for the stability of such complex[57].

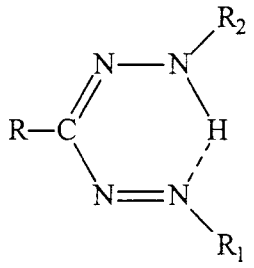


12

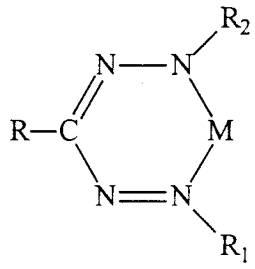
X = OH, NH_2, COOH

In these types of compounds the presence of suitable metal binding groups such as OH/ NH_2/ COOH/ etc. result in the formation of stable chelate rings involving the metal ion and the N=N, C=N or =N–NH groups.

However the spatial arrangement of formazans as in the structure **13** allows these compounds to form stable metal chelate rings, as in structure **14**.



13



14

Thus even without the presence of additional metal binding substituents on the R groups, formazans can form chelate ring with metal ions. On stereochemical ground it is evident that only one nitrogen atom of each N–N groups can coordinate to a metal ion. Presence of additional metal binding groups on R_1 and R_2 at suitable positions with respect to the N–N groups result in the formation of more stable metal chelates with more number of chelate rings.

Factors affecting the stability of metal complexes of formazan

The basicity of the ligand, chelate ring size, number of chelate rings per ligand and the nature of the metal ion are some of the factors that govern stability of metal complexes.

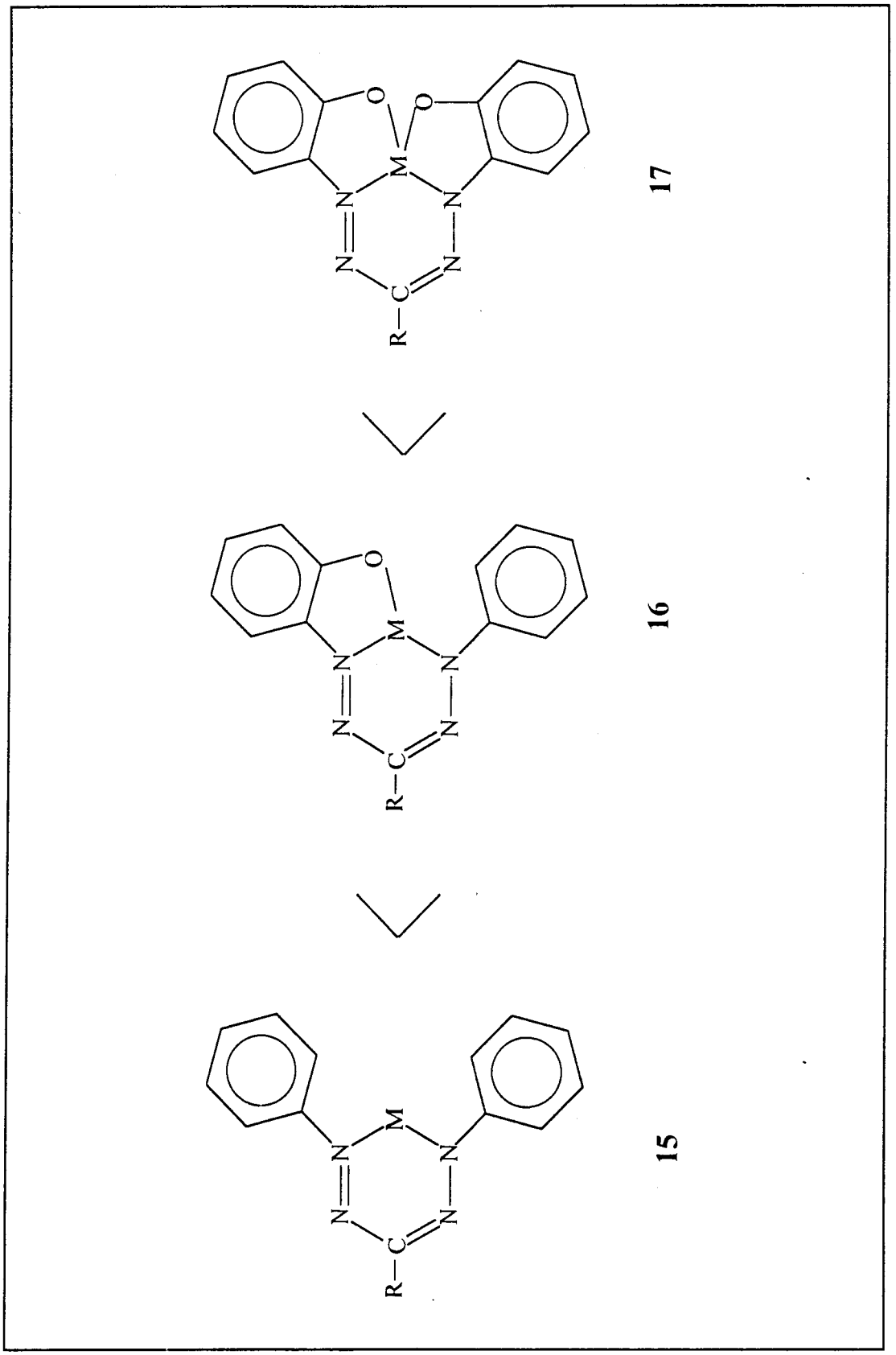
Internally H–bonded N=N / =N–N functions are potential metal chelating groups. Metal chelates result when the chelated hydrogen of the ligand is replaced by metal ion. Association of H^+ ion and metal ion to a

ligand anion are somewhat analogous and to a first approximation, strongly basic substances would be expected to have a large association constant with metal ions. Since the donor strength of the azo groups are weak, it form the weakest link with the metal ion. Therefore any substituent or structural effect that increase the electron density on the azo nitrogen (s) should and does increase stability of the resulting metal chelates. Thus substituents such as OH, COOH, NH_2, etc. adjacent to the azo groups form more stable complexes.

When donor functions of a chelating ligand are so placed as to form five or six membered chelate rings, the resulting complex is most stable. In general, stable metal chelate rings involving two double bonds are six membered structure. It is therefore, evident that why the metal binding groups are to be placed at *ortho* position with respect to the azo groups for effective metal chelation.

Thus bidentate formazan **15** form less stable complexes compared to the tridentate formazan **16** which in turn form less stable complex compared to the tetradentate formazan **17**.

Among tridentate and tetradentate formazans the stability of the complex varies with respect to metal binding groups. In conformity with this observations, the relative stabilities of metal complexes of the above formazans follow the general sequence as shown in **scheme 2**.


O
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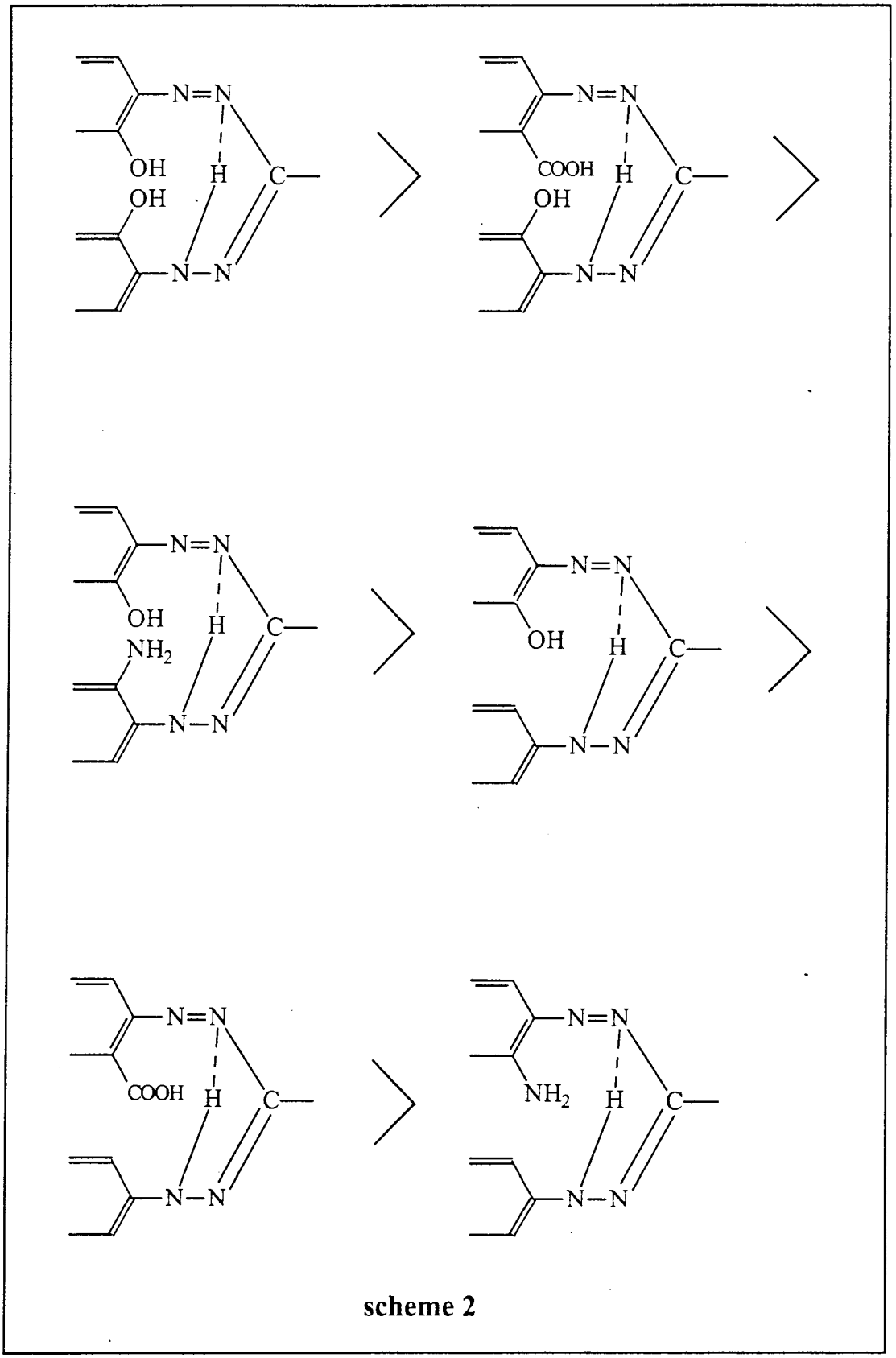


scheme 2

Metal complexes of certain formazan have been isolated particularly with copper(II), nickel(II) and cobalt(II). The stability of these complexes depends largely on the nature of the substituents on the aromatic rings. No systematic data available on the structure, stability and nature of bonding in these complexes. Reports available on these aspects are given in part II of this Thesis. **The present investigation is an attempt to study systematically using various spectral technique, the structure, nature of bonding and other relevant aspects of typical metal complex of some bi-and tridentate formazans.**

PART I
METAL COMPLEXES OF FORMAZANS - A REVIEW

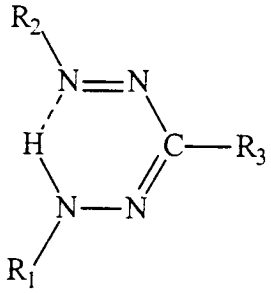
Abdul Rahim A.K. “Metal complexes of formazans ” Thesis. Department of Chemistry , University of Calicut, 2000

CHAPTER 2

METAL COMPLEXES OF FORMAZANS

A REVIEW

In general formazans used for complexation conform to the structure



1

where R_3 can be H, OH, SH, NH_2, NO_2, CI, Br, I, CN, COOH, alkyl, substituted alkyl, aryl ,substituted aryl, alkenyl, acyl, aroyl, hetroaryl, etc.[58-120]. R_1 and R_2 are usually aromatic carbocycles or heterocycles. The literature discloses seemingly endless permutations of these substituted formazans. It is not the purpose of this review to go into the details of the synthesis or properties of these compounds, since extensive literature is available on them and also since these details are not quite pertinent on synthesis and structural aspects of metal chelates of formazans considered in this study. Metal complexes of typical formazans, their synthesis and characterisation done will be reviewed. For brevity and to enable quick survey, much of the information is conveyed through tables. A convienient classification is based on the number of donor sites as bidentate, tridentate, tetradentate, etc.

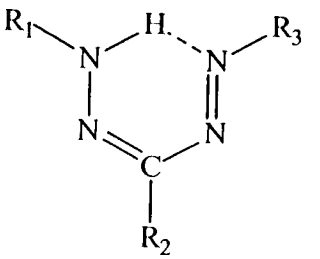
Metal chelates of bidentate formazans

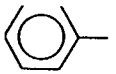
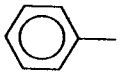
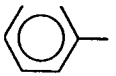
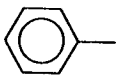
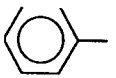
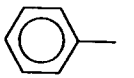
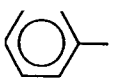
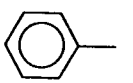
Synthesis

In general metal complexes of bidentate formazans were prepared by the interaction of formazans and the appropriate metal salts in methanol, and they are found to be of the [ML_2] type. Certain formazans (for example the formazan in which the 3-substituent is acetyl ,benzoyl etc.) were reported[121,127] to give copper complex of 1:1 stoichiometry, and a portion of the formazan was oxidised to 2,3-diaryl tetrazolium salts with simultaneous elimination of the 3-subsstituent. Formation of tetrazolium salts were also reported[122,127] when 1,3,5-triphenyl formazans on reaction with $CuCl_2$ and $CoCl_2$ in methanol. Reported typical metal complexes of the bidentate formazans are brought out in table **2.1**.

Table 2.1

Metal Complexes of the bidentate formazans



R_1	R_2	R_3	M	Ref
	CH_3CO-		Cu, Ce^{3+}, Th^{4+}, U^{6+}	123
	C_2H_5OCO-		Cu, Ni, Co	124
	C_6H_5CO-		Cu, Ni, Co	125
			Ni	126

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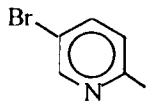
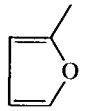
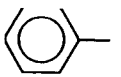
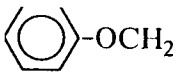
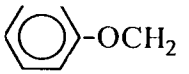
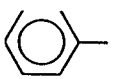
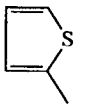
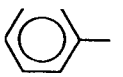
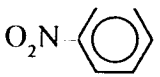
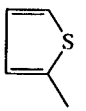
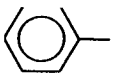
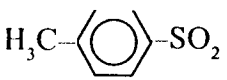
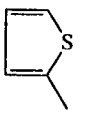
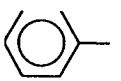
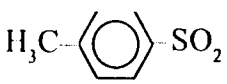
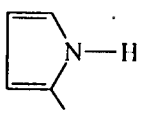
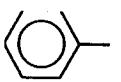
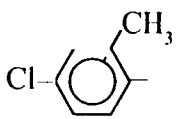
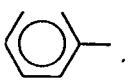
			Cd	127
	$C_2H_5CO_{.2}-$		Ni	128
			Ni, Cu, Pd	129
			Ni, Cu, Pd	129
			Ni, Cu, Pd	129
			Ni, Cu, Pd	129
			Cu	130

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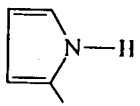
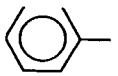
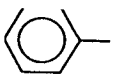
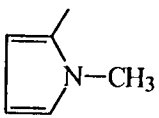
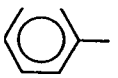
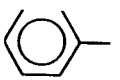
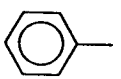
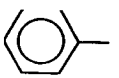
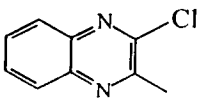
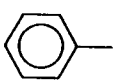
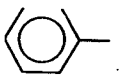
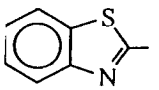
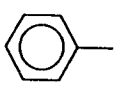
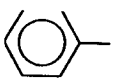
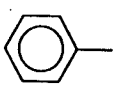
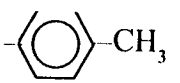
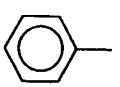
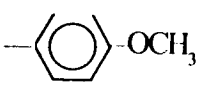
R_1	R_2	R_3	M	Ref
			Pd	131
			Pd	132
			Zn, Cd	133
			Zn, Cd	133
	CH_3		Ni,Co, Hg, Zn	134
	CH_3		Ni,Co, Hg, Zn	134
	CH_3		Ni,Co	134

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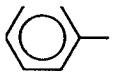
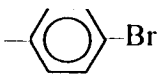
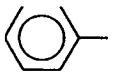
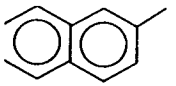
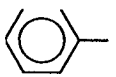
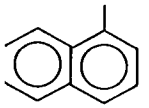
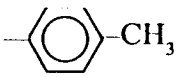
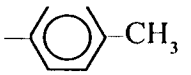
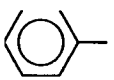
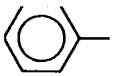
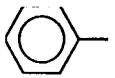
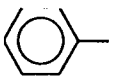
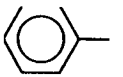
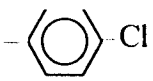
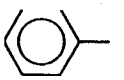
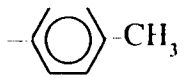
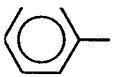
R_1	R_2	R_3	M	Ref
	CH_3–		Ni, Co	134
	CH_3–		Ni, Co	134
	CH_3–		Ni, Co	134
	CH_3–		Ni,Hg, Zn	134
	SH–		Ag,Hg, Cu, Co	134
			Ni,Cd, Tl, Zn	134
	CH_3CO–		Cu, Ni, CO	134
	CH_3CO–		Co, Ni	134

Metal chelates of tridentate formazans

Synthesis

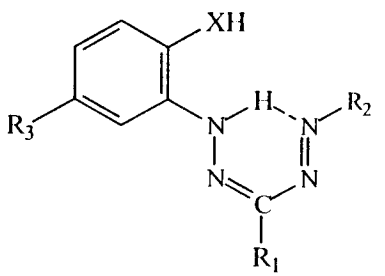
The tridentate formazans, when mixed with metal acetate in ethanol formed complexes with 1:1 stoichiometry .The fourth coordination position is occupied by other monodentate ligands such as Cl^- , py, etc., In this case also a part of the formazan was oxidised to tetrazolium salts. Striking difference exist between carboxy and hydroxy substituted formazan in their reaction with copper salts. Copper(I) chloride react with the formazan forming 1:1 copper(I) complex without the loss of imino nitrogen. Tridentate formazan also form $[ML_2]$ complex with Co (III) and Cr (III) salts. Typical complexes reported are given in table **2.2**.

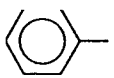
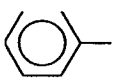
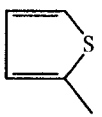
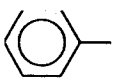
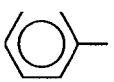
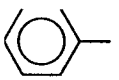
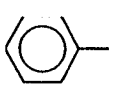
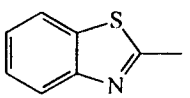
Tetradentate formazan

With tetradentate formazans 1:1 complexes were formed by the interaction of metal acetate in ethanol more readily than other formazans. Typical complexes are brought out in table **2.3**.

Table 2.2

Metal complexes of tridentate formazans



R_1	R_2	R_3	X	M	Ref
		H	O	Fe, Co, Cr, Cu	135
		H	O	Ni, Cu, Pd	129
		H	COO	Ni, Cu	136
		H	COO	Ni, Cu	137

contd.....

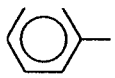
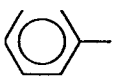
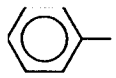
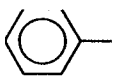
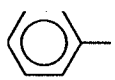
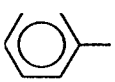
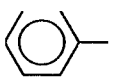
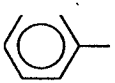
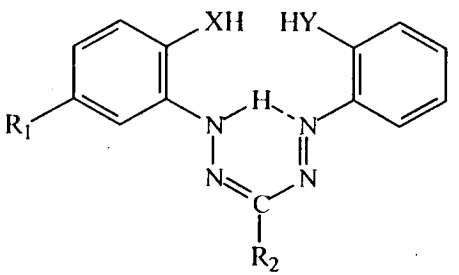
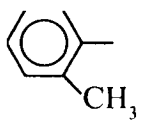
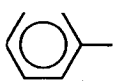
R_1	R_2	R_3	X	M	Ref
		Cl	O	Co	138
		SO_2CH_3	O	Co	138
		Cl	COO	Co	138
		SO_2CH_3	COO	Co	138

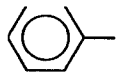
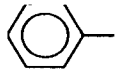
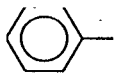
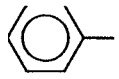
Table 2.3

Metal complexes of tetradentate formazans



R_1	R_2	R_3	X	Y	M	Ref
H		H	COO	COO	Ni, Co, Cu	139
H		H	COO	O	Cu	140
H	CN–	H	O	O	Ni, Cu, Co, Cr	141

contd.....

R_1	R_2	R_3	X	Y	M	Ref
H		H	O	O	Ni,Co,Cu,Cr	141
H	CN–	H	COO	COO	Cu	141
H		H	COO	COO	Ni,Co,Cu,Cr	141
H		H	COO	OH	Ni,Co,Cu,Cr	141
SO_3H		H	O	COO	Zn	142
NO_2	$COCH_3$	NO_2	O	O	Zn	143, 144

Characterisation of complexes

Most of the complexes represented have been formulated on meagre evidence,mainly from elemental analysis alone. In isolated instances, electronic, ir, nmr spectrometric data and magnetic moment data have been used sparingly for structural elucidation. To avoid repetition, these data will be quoted at appropriate places while discussing the results of the present investigation.

Formation constants of only very few formazan complex have been reported. Most of the stability data available are that of complex of dithiazone, a formazan analogue and their derivatives. The use of dithizone as reagent for the determination of many metal ions is well documented[145-149].

Recently biological activity of several formazans and their metal complexes have been reported. Metal complexes of formazans having antifertility, antiinflammatory, mutagenocity, vitrocytotoxicity, etc are known[149-152].

PART II
1,5-DIARYL-3-ACETYLFORMAZANS THEIR AND METAL COMPLEXES

Abdul Rahim A.K. “Metal complexes of formazans ” Thesis. Department of Chemistry , University of Calicut, 2000

PART II

MATERIALS, INSTRUMENTS AND METHODS

Materials

Chemicals used for synthesis were of C.P. grade. For analytical purposes, 'AnalaR' grade chemicals were employed. Commercial solvents were distilled and used for synthesis. Solvents purified by methods recommended by Weissberger[154] were employed for physical and physico-chemical measurements.

The following metal salts were used for the synthesis of metal complexes nickel(II) acetate, cobalt(II) acetate, copper(II) acetate and zinc(II) acetate.

Only compounds isolated analytically pure are reported in this Thesis. The metal complexes reported herein are stable and have good keeping qualities. Compounds for recording spectra were recrystallised from proper solvents several times till chromatographically pure (tlc-silica gel).

Instruments

Instruments used in this investigation are:

1. UV-1601 Schimadzu recording spectrophotometer
2. Schimadzu 8101 A FTIR spectrophotometer

3. Bruker WM-400 nmr spectrometer
4. Jeol 400 nmr spectrometer
5. JeolSX-102(FAB) mass spectrometer
6. Jeol D-300(EI/CI) mass spectrometer
7. Heraeus CHN-O-rapid analyser
8. Systronic pH-meter
9. Gouy type magnetic balance

Methods

Elemental analysis: Metal complexes were analysed by standard methods[155] after decomposing them with concentrated sulfuric–nitric acid mixture. Carbon and hydrogen percentages reported are by microanalyasis carried out at RSIC, Central Drug Research Institute, Lucknow.

Uv-visible spectra were recorded from solution (10^{-3}M) of compounds in ethanol unless otherwise mentioned.

Infrared spectra of compounds were recorded from discs with KBr. Bands were calibrated using the nearest polystyrene bands.

^{1}H and ^{13}C nmr spectra were recorded using $CDCl_3$ / dmso–d_6 as solvents and TMS as internal reference.

FAB mass spectra were recorded at room temperature using Argon

(6KV, 10 mA) as the FAB gas, and meta-nitrobenzyl alcohol (NBA) as the matrix.

EI mass spectra were recorded by imparting vapourised sample molecules with a beam of electrons at 70 eV.

pH measurements (accuracy $\pm$ 0.05) were made after calibrating with potassium hydrogen phthalate solution[156] at 28 $\pm$ 0.1°C.

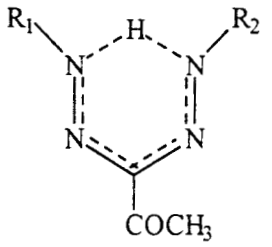
Magnetic susceptibility was determined at room temperature (28 $\pm$ 1°C) using $Hg[Co(NCS)_4]$ as standard[157].

Molecular weights of compounds reported were determined by Rast's method[158] using naphthalene /camphor as medium.

CHAPTER I

1, 5 - DIARYL-3-ACETYLFORMAZANS AND THEIR METAL COMPLEXES

Metal complexes of the following 1,5 -diaryl-3-acetylformazans were synthesised and characterised using electronic, ir, nmr and mass spectral data.



1.1

	R_1	R_2
1a	C_6H_5	C_6H_5
1b	$C_{10}H_7$	$C_{10}H_7$
1c	C_6H_5	C_6H_4 (COOH)
1d	C_6H_5	C_3H_2NS

Synthesis

The 3-acetyl formazans were prepared by coupling diazotised aromatic amines with acetylacetone as outlined below.

Synthesis of 1a & 1b

A solution of (0.05 mol) of acetylacetone in 400 ml of methanol was made alkaline with 500 ml of (0.5 mol) aqueous NaOH. The solution was cooled to below 5° C. Aniline / 1.naphthylamine (0.05 mol) was diazotised using sodium nitrite and hydrochloric acid. The clear diazonium chloride solution was, then added drop wise with stirring, to the above solution of acetylacetone. The precipitate formed was collected, washed with water and extracted with ether, dried with anhydrous $MgSO_4$. Ether was evaporated, the solid product obtained was recrystallised from n-hexane.

Synthesis of 1c

The compound was synthesised by coupling diazotized anthranilic acid with the phenylhydrazone of acetylacetone. The phenylhydrazone was prepared as follows.

Aniline (0.05 mol) was diazotised as reported[159] and kept below 0°C. The benzenediazonium chloride solution was added dropwise with stirring to a methanolic solution of acetylacetone (0.05 mol). The pH of the mixture was adjusted around 7 using sodium acetate. The precipitated phenylhydrazone was collected, washed with water.

Preparation of formazan: Anthranilic acid (14 g, 0.025 mol) was daizotised as reported[159] using nitrous acid. The diazonium salt solution was added with stirring to an aqueous methanolic (600 ml) solution of the phenylhydrazone (0.025 mol) containing sodium hydroxide (10.5 g) kept below 5°C. Stirring was continued for about 30 min. The precipitate formed was filtered, washed with water and extracted with ether. The ether extract was dried with anhydrous $MgSO_4$ and the ether was evaporated to get the formazan.

Preparation of 1d

The compound was prepared by coupling diazotised 2-aminothiazole with the phenylhydrozone of acetylacetone. 2 amino thiazole was diazotised as follows.

To a solution of 2-aminothiazole (0.025 mol) in H_2SO_4 (25 ml, 6N), an ice cold solution (12.5 ml) of $NaNO_2$ (1.75 g) was added drop wise with constant stirring. After cooling below 5°C urea was added to the diazonium sulphate solution to destroy the excess of HNO_2.

The diazonium sulphate solution was added in drop wise with stirring to the solution of phenylhydrazone of acetylacetone (0.025 mol). The precipitate formed, was collected, washed with water, extracted with ether and the ether was evaporated to get the compound.

Synthesis of metal chelates : Copper(II), nickel(II) and cobalt(II) chelates of the 1,5-diaryl-3-acetyleformazans were prepared by the following general methods.

A methanolic solution of (25 ml) the metal (II) acetate (0.01 mol) was added slowly with stirring to a solution (30 ml) of the ligand (0.002 mol) in 50% v/v ethanol-methanol mixture. The reaction mixture was gently refluxed for ~ 1 hr and the volume was reduced to half. The precipitated complex on cooling to room temperature was filtered, washed with ethanol and recrystallised from hot methanol.

RESULTS AND DISCUSSION

Characterisation of Ligand

All the formazans synthesised are crystalline solids, soluble in common organic solvents and show sharp melting points. Elemental analytical data (Table 1.1) of the compound correspond to their formulation as structure **1.1**.

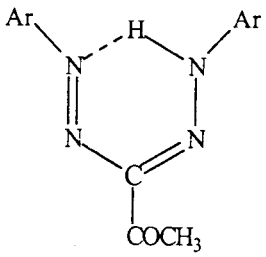
Formazans can in principle adopt structures corresponding to *syn-anti* isomerisation about the C=N bond and *s-cis/ s-trans* isomerisation about C-N bond. Thus four structures **1.2 - 1.5** are possible.

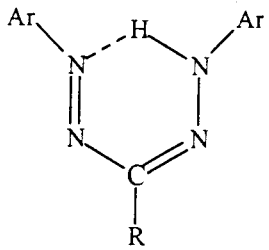
Based on X-ray crystal structure analysis, vibrational and nmr data, it has been shown[160-172] that in solid state several formazans crystallise as red or orange yellow solids; with *syn, s-cis* or *syn, s-trans* configuration if red and anti, *s-trams* configuration if orange-yellow. However in solution, the configuration depends on the nature of the solvent.

Table 1.1

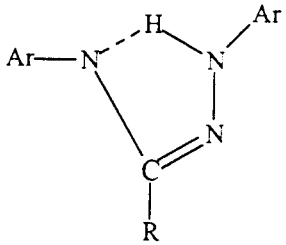
Physical, analytical and electronic spectral data of the 1,5–diaryl –3–acetylformazans

Compounds	Colour	M.P (°C)	Elemental analysis (%) Found/(Clacd)			λ_{max} (nm)
			C	H	N	
1,5 diphenyl-3-acetylformazan **1a**	dark red	135	66.1 (67.67)	5.06 (5.26)	20.92 (21.05)	494 308
1-phenyl-5-(1-naphthyl)-3-acetylformazan **1b**	violet	135	74.88 (75.40)	4.63 (4.92)	15.65 (15.3)	477 342 241
1-phenyl-5-(2-carboxyphenyl)-3-acetylformazan **1c**	red	168	60.93 (61.93)	4.92 (4.516)	17.91 (18.06)	445 309 275
1-phenyl-5-(2-thiazolyl)-3- acetylformazan **1d**	violet	125	39.1 (38.57)	2.64 (2.85)	29.54 (30.0)	448 310

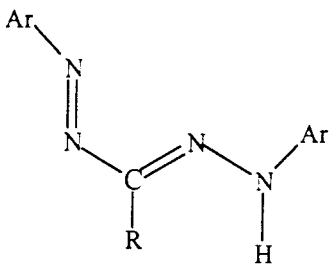




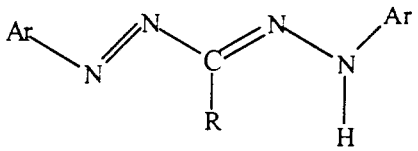
1.2
syn, s-cis



1.3
syn, s-trans



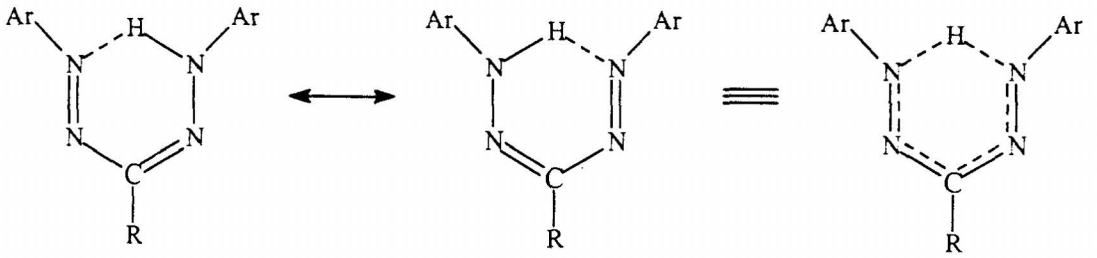
1.4
anti, s-cis



1.5
anti, s-trans

The *syn, s-cis* structure seems to be more stable since in this configuration the intramolecularly hydrogen bonded tautomers in equilibria are possible as in structure **1.6** and **1.7**. These structure may be represented by the mesomeric structure **1.8**.

However in the case of unsymmetrical formazans there may exist preference for structure **1.6** or **1.7** depending up on the nature of the Ar and R groups. Electronic, ir, nmr and mass spectral data of the compounds are discussed below with a view to establish their structure and tautomeric nature.



1.6 **1.7** **1.8**

Electronic spectra

All the formazans show two characteristic absorption maxima (table 1) above 300 nm. It has been reported[173-176] in the case of arylazo compounds that exhibit azo hydrazone tautomerism, that the hydrazone tautomer show characteristic absorptions above 400 nm and the azo form below 400 nm. Thus the longer wavelength absorption appear to be due to the hydrazone function and the short wavelength absorption to the azo group of the formazans.

Infrared spectra

Infrared spectroscopy is a powerful tool in determining the structural characteristics of organic compounds and metal complexes of organic ligands. The most useful functional groups for characterisation are the OH and NH in the X-H stretching region, and C=O, C=N, N=N and C=C in the double bond region. The compounds considered in this investigation possess many of these functional groups. Thus the problem of assigning the correct structural form of the compounds can be settled to a large extent by infrared spectra.

X - H Vibrations: The vibrations of X—H bonds provide one of the largest and most reliable set of group frequencies. The stretching vibration in particular show little sensitivity to mass effects. It follows that with certain reservations, the desired frequencies are an accurate measure of the force constants of the bonds, and their changes with structure might therefore be expected to run parallel to many chemical and physical properties.

The deformation modes of X—H are subject to coupling effects and are generally less useful. For example the OH and NH deformation frequency is strongly coupled with C=O stretch. Since both the stretching and deformation modes depend up on the electronic environment of the bond, a good deal of information can be derived from the systematic study of both.

Hydrogen bonds are formed in any XH·····Y system and its strength

depends on the nature of the X and Y atoms. It is easy to recognize hydrogen bond of moderate strength by ir spectra. Though it is very difficult to recognize the actual strength of the hydrogen bond and similar dielectric effects, the hydrogen bond formation is accompanied by an increase in intensity and broadening of the X—H band. Though several factors are to be considered, in general the band broadening and band shape vary with the strength of the hydrogen bond both in inter and intramolecular hydrogen bonding. However, in intermolecular hydrogen bonding the X and Y atoms come to that natural distance which maximise the hydrogen bond energy whereas in many intramolecular hydrogen bonds the X—Y distance are fixed by the molecular geometry and the dipole charges in the XH band may well be much smaller and the intensification of the band is reduced.

The X-H deformation modes occur in the finger print region where they are often strongly coupled with other vibrations and show an increase in breadth in hydrogen bonding. All deformation modes move to higher frequencies on hydrogen bonding.

The formazans considered here do not show absorption characteristics of free NH group in the region 2500 -3500 cm^{-1}. However the spectra of the compounds show a considerably broad band in the range 2900 - 3400cm^{-1}. From the observed breadth, intensity and position the band can be assigned to intramolecularly hydrogen bonded NH·····N function.

The double bond region : The stretching vibrations of C=N, C=C, N=N occur in this region. Many factors are involved in determining the precise frequency of these vibrations. These include inductive, resonance, vibrational coupling ,change in force constants of adjacent bonds, etc. Thus the positions and intensity of these vibrations are determined by the molecular structure in the immediate vicinity.

Normal acetyl carbonyl gives stretching band at about 1720cm^{-1}. Hydrogen bonding decreases the carbonyl stretching frequency. Further shift to lower values can be observed in compounds where C=O is a part of the conjugated system, that is the presence of C=C,C=N, N=N etc,. adjacent to the C=O group strongly influences the C=O stretching vibration[177-181].

In a non-conjugated system the C=N stretching normaly appears in the region 1690-1700 cm^{-1} and is shifted to lower value when conjugated with C=C and C=O. In the case of many hydrazones, Schiff's bases, oximes, etc. the C=N stretching frequency has been assigned[177-181] in the region 1600-1650 cm^{-1}.

The N=N group, because of its symmetry, ir spectral investigation seems to be rather difficult compared to Raman spectra. However in numerous azo compounds of practical importance, the azo group is unsymmetrically substituted thereby permit the study of vibration of the azo group for diagnostic purposes[177-181]. In general, the N=N stretch show

weaker absorption between 1400-1500 cm^{-1}. Unfortunately, this regions is rich in many aromatic vibrations, so N=N stretching offers only little support for characterisation in many cases.

The ir spectra of all the 1,5-diaryl-3-acetylformazans considered in this investigation show an intense band at about 1680 cm^{-1}. This band can be assigned to the stretching of the conjugated free acetyl carbonyl group[177,178]. Another intense band appeared at ~ 1620 cm^{-1}. in the spectra of all the compounds assignable to the stretching of C=N. Several medium intensity band observed near 1600 cm^{-1}. are due to the C=C stretches. A medium intensity band consistently present in the spectra of all the compounds at ~ 1450 cm^{-1}. The origin of this band may probably due to the stretching of the N=N bond. The observed $\nu_{C=N}$ frequency indicate that the C=N is a part of the conjugated system. Further the $\nu_{C=O}$ of the compounds suggest that the acetyl carbonyl remains free and not involved in intramolecular hydrogen bonding. The spectrum of **1d** shows an additional medium intensity band at 1615 cm^{-1}. Based on earlier reports[177,178] on related compound the band can be assigned to the stretching of $\nu_{C=N}$ of the thiazole ring.

The spectrum of **1c** displayed a very strong band at 1701 cm^{-1}. assignable to the stretching of carboxyl group. Thus the ir spectra strongly support the intramolecularly hydrogen bonded structure **1.8** of the compounds. Important bands an their assignments are given in table **1.2**.

Table 1.2

Characteristic ir bands of 1-5-diaryl-3-acetylformazans and their assignments

Compounds				Probable assignments
1a	**1b**	**1c**	**1d**	
1684	1660	1680	1680	$\nu_{C=O}$ Conjug
		1701		ν_{CO} carboxyl
1620	1610	1630	1625	$\nu_{C=N}$
			1615	$\nu_{C=N}$ (thiazole ring)
1596	1590	1603	1594	$\nu_{C=C}$
1588	1583	1598	1591	"
1578	1570	1592	1581	"
			1578	"
1456	1475	1454	1450	$\nu_{N=N}$
1280	1275	1270	1272	ν_{C-N}
1295	1292	1288	1296	

NMR Spectra

In ^{1}H nmr the most important function is the position of the NH proton signal. All the compounds show a low field one proton signal at the ~ δ14. This signal is undoubtedly caused by intramolecularly hydrogen bonded NH proton. The spectrum of **1c** exhibits another one proton signal at δ 15.532 presumably due to the carboxylic proton. The acetyl proton signal of all the compound appeared at δ **2.7** and aryl protons at between δ **7.2** and

δ **8.4**. Integrated intensities of these signals are as expected. The spectral data are given in table 1.3.

Table 1.3

Characteristic ^{1}H nmr data of the 1,5-diaryl-3-acetylformazans

	Chemical shift δ (ppm)		
Compounds	NH	Aryl	CH_3
1a	14.56	7.42-8.24	2.78
1b	14.68	7.40-8.48	2.82
1c	14.72	7.38-8.52	2.68
1d	14.48	6.82-8.32	2.54

^{13}C n m r

The ^{13}C nmr spectrum of **1a** is given in figure **1.1.** The spectrum clearly suggests the symmetrical structure for the compounds. The positions of the methyl carbon at 26.381 ppm and carbonyl carbon at 194.610 ppm are as expected. The signal at 146.751 ppm can be assigned to the formazyl carbon which is connected to two nitrogens. The identical electronic environment of the two phenyl groups is evident from the appearance of only four signals due to the phenyl groups. These signals can easily be assigned as indicated in figure **1.1**.

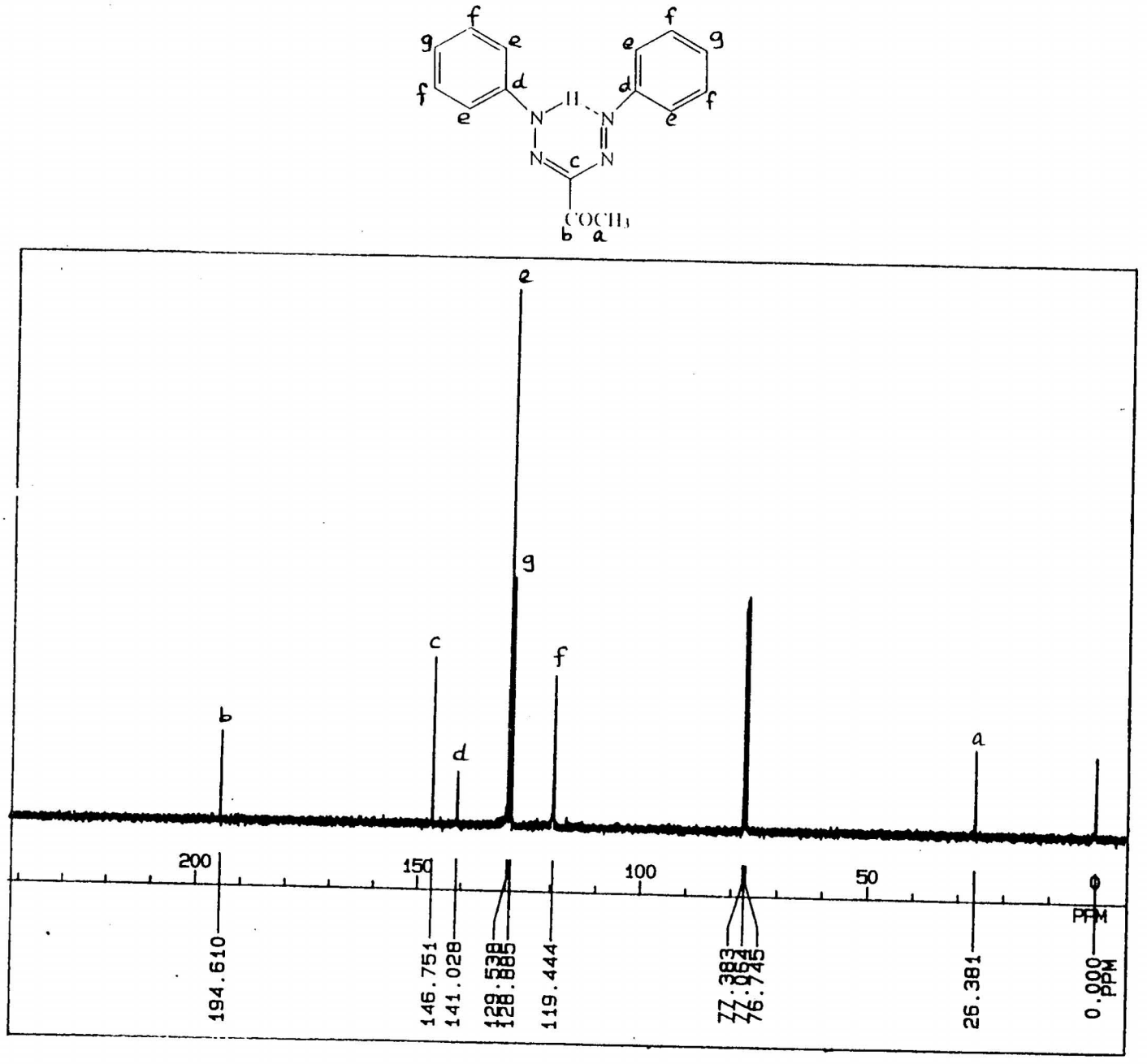
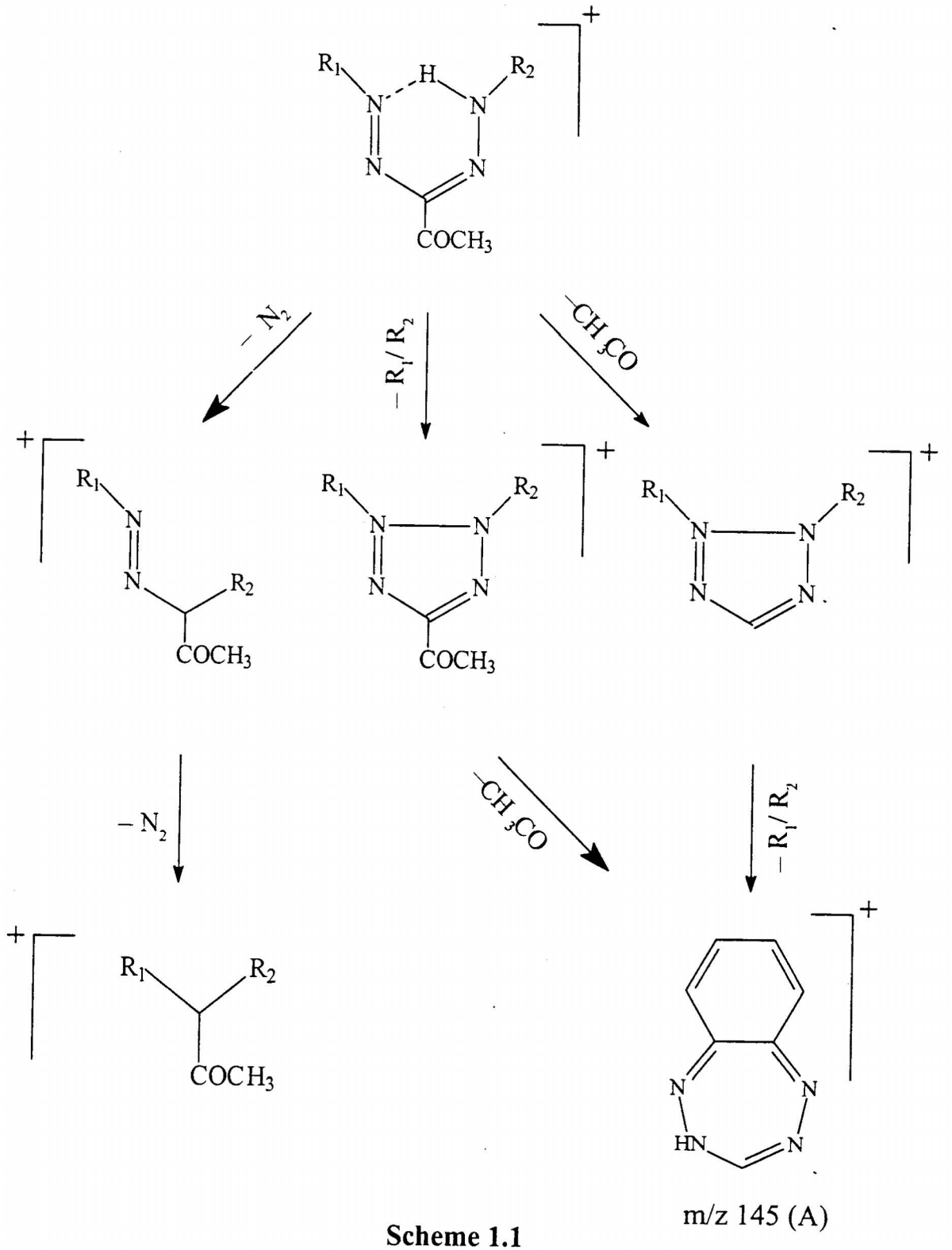


Figure 1.1 ^{13}C nmr spectrum of 1a

Mass spectra

Though the characteristic structural unit present in formazan is –C–N–N–C–N–N–C–, the mode of fragmentation under mass spectroscopic condition depends chiefly on the nature of the bonds between these atoms as well as on the nature of the terminal carbons[182-184]. In the case of azo compounds that can exhibit azo-hydrazone tautomerism, it has been reported that no tautomerisation occur on electron bombardment, so mass spectrum could reflect the true state of the molecule in the gaseous state[182-184]. The most important observation in the case of compounds having N = N group is the presence of peak due to the elimination of N_2, that is a $(P\text{-}N_2)^+$, from the parent ion $(P)^+$. In the case of compounds that possess, NH-N= group, appearance of a peak due to Ar NH^+ ion in the mass spetrum is also characteristic. Thus in the case of azo compounds cleavage occurs in both sides of the N=N function and for hydrazone at the -N -N = bond.

The observed mass spectra of the formazans considered in this investigation are reproduced in figures **1.2 - 1.5**. All the compounds show intense parent ion peak $P^+/(P+1)^+$. Other prominent peaks are due to $(P\text{-}CH_3CO)^+$, $(P\text{-}N_2)^+$, Ar^+, $ArNH^+$ and ArN_2^+. The formation of major peaks appeared in the spectra can be accounted by considering the fragmentation pattern given in scheme 1. A striking feature in the spectra of **1a** , **1c** and **1d** is the presence of a peak at m/z 145 and in the spectrum of **1b** at m/z 197. This fragment may be due to the formation of **species A** as indicated in scheme **1.1**


R1
H
R2
N
N
N
N
COCH3
+
– N2
– R1 / R2
– CH3CO
R1
N
N
R2
COCH3
– N2
– CH3CO
– R1 / R2
HN
m/z 145 (A)

Scheme 1.1

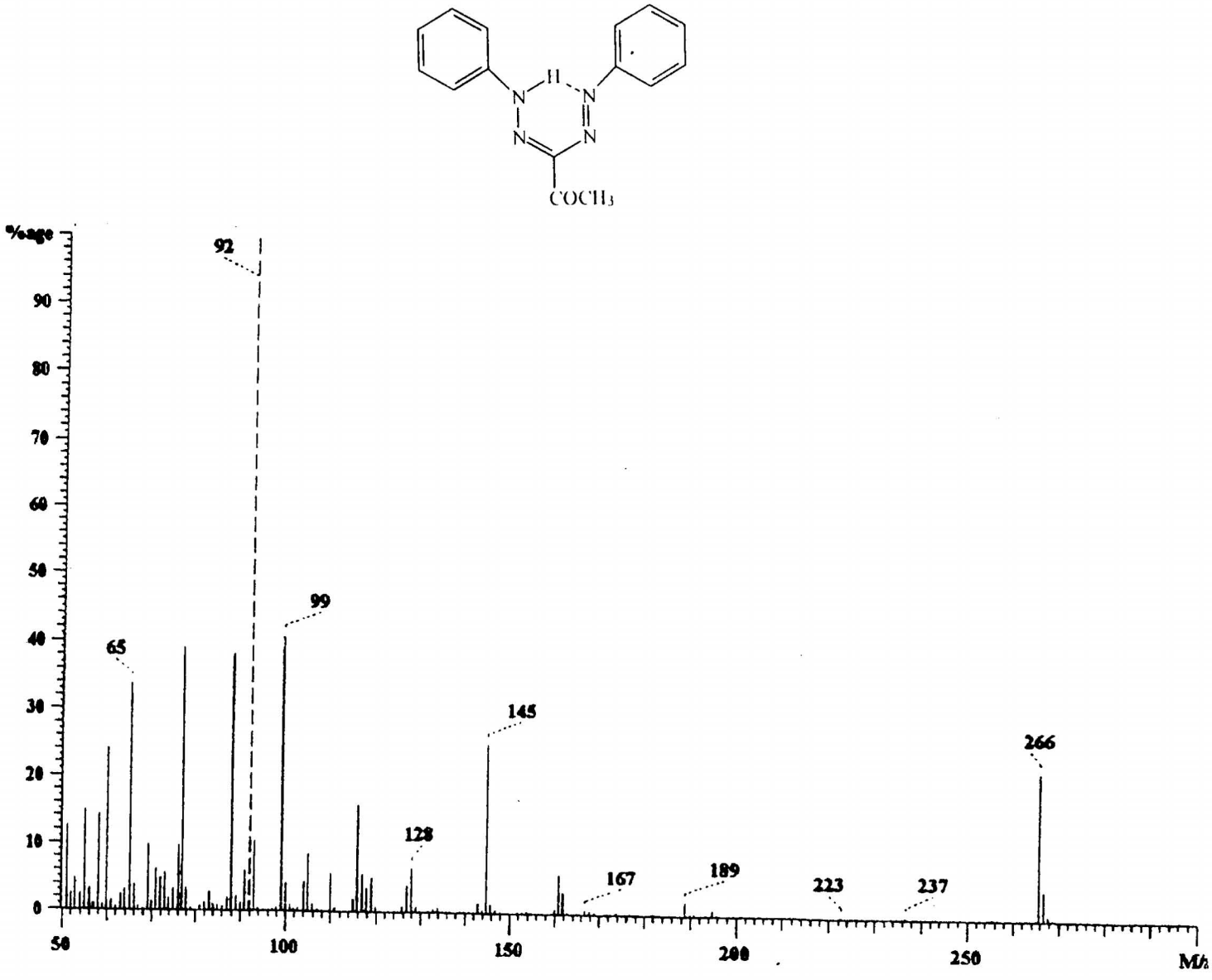


Figure 1.2 Mass spectrum of 1a

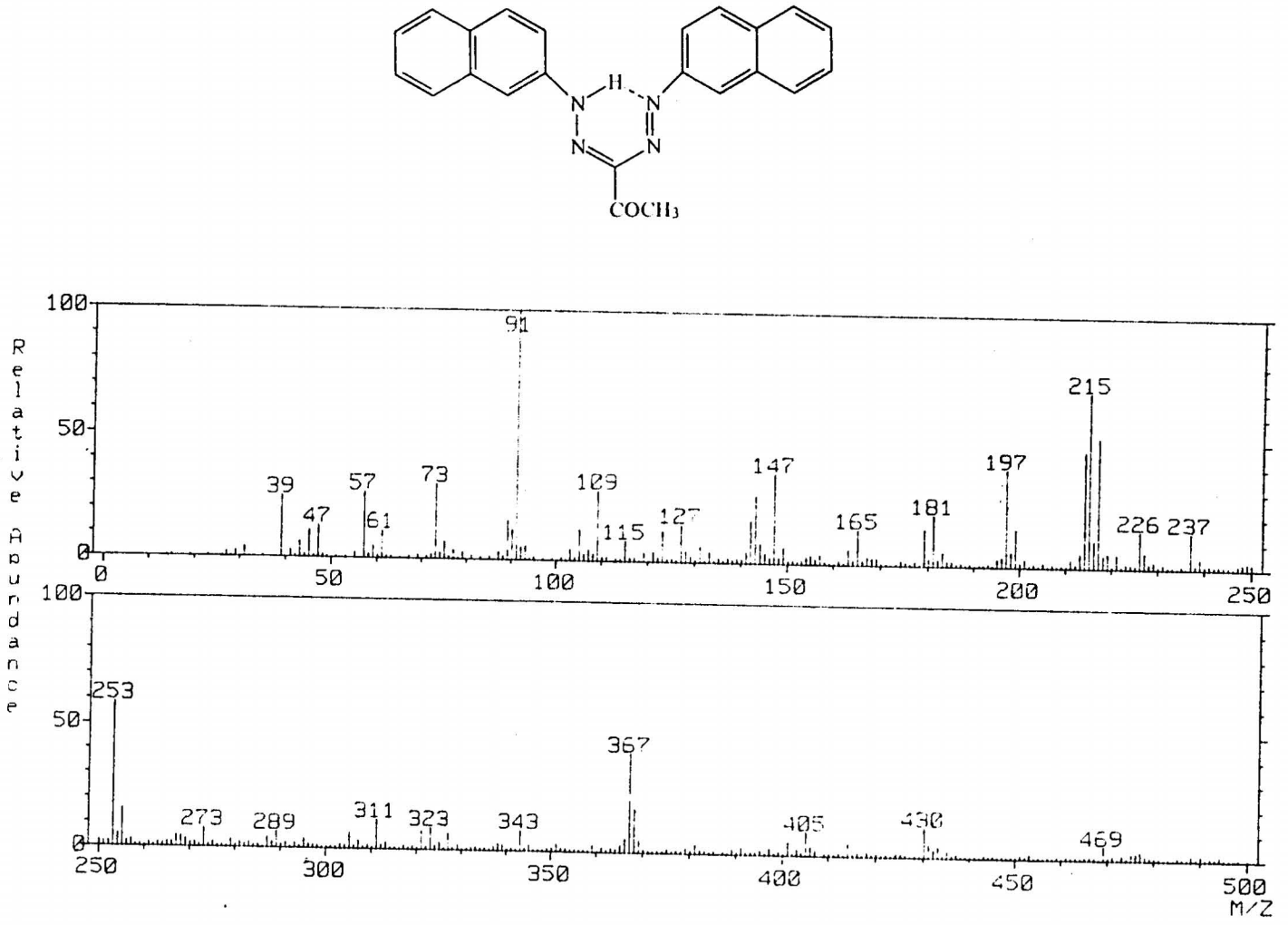


Figure 1.3 Mass spectrum of 1b

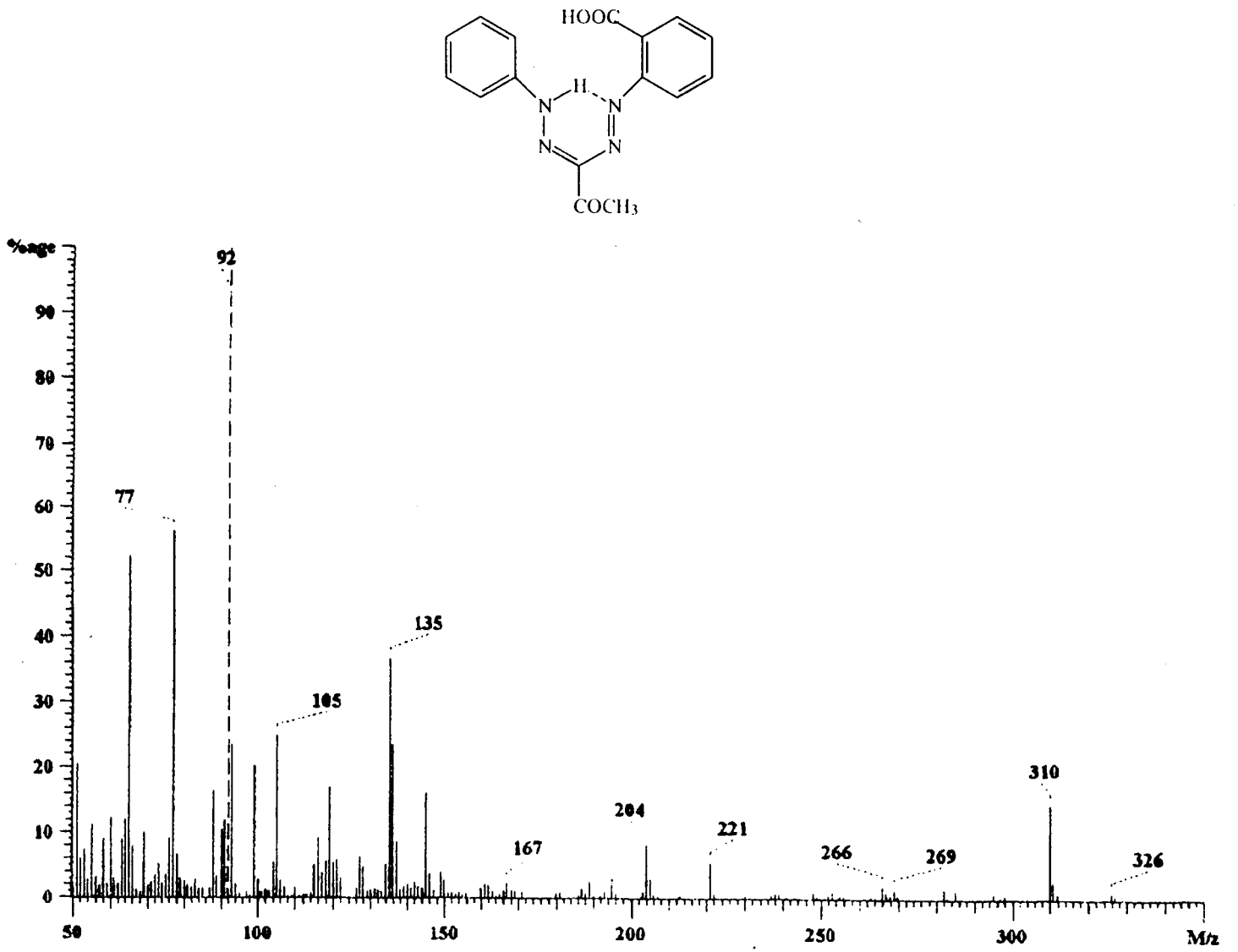


Figure 1.4 Mass spectrum of 1c

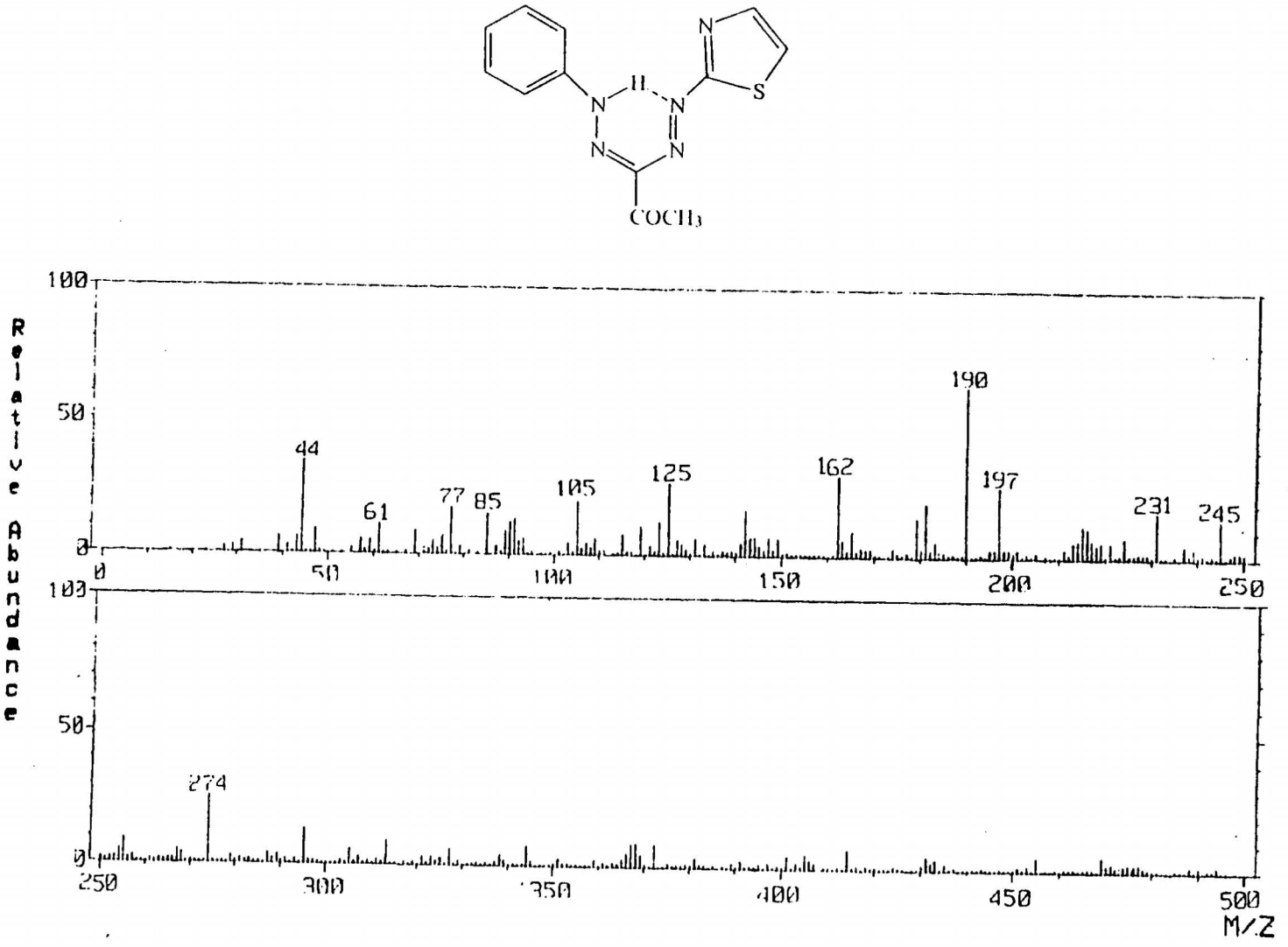


Figure 1.5 Mass spectrum of 1d.

Characterisation of metal Complexes

The formazans **1c** and **1d** contain additional metal binding groups adjacent to the formazyl group, whereas in the case of **1a** and **1b** no such groups are present. So the chelating power of the former will be different from that of the later. Steric factor prevents the simultaneous participation of the acetyl and formazyl group in coordination with same metal ion. Thus **1a** and **1b** can function only as a bidentate whereas **1c** and **1d** can behave as tridentate. So the spectra of the two sets of compounds are discussed separately.

Metal complexes of bidentate formazans

Copper(II), nickel(II) and cobalt(II) complexes of the formazans were obtained as crystalline solids. The elemental analysis data of complexes of **1a** and **1b** indicate their ML_2 stoichiometry. All the complexes behave as non electrolytes and do not contain the anion of the metal salt used for their preparation. Physical and analytical data of the complexes are given in table **1.4-1.5**. The compounds were characterised on the basis of the electronic, ir, nmr, and mass spectral data.

Ir Spectera: The broad absorption of the free ligands **1a** and **1b** in the region 2500-3500cm^{-1} cleared up in the spectra of all the complexes and only weak bands at about 3050 cm^{-1} (aromatic ν_{C-H}) and at about 2550 and 2850 cm^{-1} (asymmetric and symmetric aliphatic ν_{C-H}) appeared in this region.

Table 1.4

Physical, analytical and electronic spectral data of the metal chelates of 1,5 –diphenyl-3-acetylformazans (1a), HL

Compounds	M.P.°C	Elemental analysis found (calcd) %				λ_{max}
		C	H	N	metal	(nm)
$[CoL_2(H_2O)_2]$	300	59.11 (61.12)	4.72 (4.41)	18.12 (19.01)	9.05 (10.06)	610 309
$[CuL_2]$	300	57.83 (60.6)	4.26 (4.3)	18.98 (18.86)	8.76 (10.69)	416 310
$[NiL_2]$	300	62.37 (61.15)	4.79 (4.40)	17.33 (19.02)	9.08 (9.97)	688 309

Table 1.5

Physical, analytical and electronic spectral data of the metal chelates of 1-phenyl-5-(1-naphthyl)-3-acetylformazan (1b), HL

Compds.	M.P.°C	Elemental analysis found (calcd) in %				λmax (nm)
		C	H	N	Metal	
$[CoL_2(H_2O)_2]$	>300	66.86 (69.96)	4.13 (4.30)	13.28 (14.1)	6.823 (7.451)	487 342
$[CuL_2]$	>280	67.82 (69.56)	3.69 (4.28)	15.49 (14.11)	10.43 8.002	
$[NiL_2]$	>300	(69.98)	4.43 (4.3)	13.98 (14.2)	8.664 (7.44)	696, 390 339

This indicates that the hydrogen bonded NH proton of the free ligand is replaced by metal ion. The medium intensity band at ~1520 cm of the free ligand due to the deformation vibration of NH also absents in the spectra of the complexes.

The position of the acetyl carbonyl band of the free ligand remained almost unaffected in the spectra of the complexes. This indicate that the carbonyl group is not involved in bonding with the metal ion. Similarly the $\nu_{C=N}$ band is only marginally altered in the spectra of complexes. whereas the $\nu_{N=N}$ band is shifted appreciably to lower value in complexes. Important stretching bands and probable assignments are given in tables **1.6** and **1.7.**

Table – 1.6

Characteristic ir stretching bands (cm^{-1}) of chelates of 1,5-diphenyl -3-acetylformazan **1a**, HL

Compd	C=O	C=N	N=N	C – N	M – N
$[CuL_2]$	1680	1615	1422	1280 , 1268	555 ,542
$[CoL_2]$	1678	1602	1420	1275 ,1265	560 ,545
$[NiL_2]$	1685	1618	1428	1278 ,1264	558 ,548

Spectra of the cobalt complexes displays additional bands in the region 3500 – 3400 cm^{-1} presemably due to coordinated water.

Table 1.7

Characteristic ir stretching bands (cm^{-1}) of chelates of 1-phenyl-5-(1-naphthyl)-3-acetylformazan 1b,HL

Compd	C=O	C=N	N=N	C-N	M-N
$[CuL_2]$	1658	1602	1455	1285, 1262	558, 545
$[CoL_2(H_2O)_2]$	1660	1598	1452	1280 , 1265	560, 552
$[NiL_2]$	1655	1601	1458	1285, 1280	550, 542

The spectra of all the complexes showed two medium intensity bands at ~ 550 cm^{-1} not found in the spectra of the free ligands. These bands can be assigned to the stretching of M-N vibration. Thus the ir spectra support the structure **1.9** of the complexes of **1a** and **1b**.

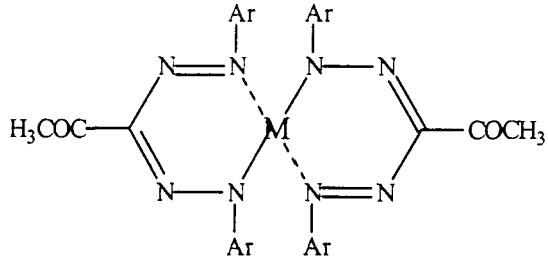
Nmr Spectra

In the ^1H nmr spectra of the diamagnetic nickel(II) omplexes, the low field signal due to the NH proton disappeared. The methyl proton signal remained almost unaffected indicating that the acetyl carbonyl is not involved in complex formation (table **1.8**). The integrated intensities of the methyl and aryl protons are as expected of structure **1.9.**

Table 1.8

^{1}H Nmr data of nickel(II) complexes of **1a** and **1b**

	^{1}H Chemical shift (ppm)	
Nickel (II) complexes of	**Aryl**	**CH_3**
1a	7.62 – 8.45	2.76
1b	7.852 – 8.62	2.78



1.9

Mass Spectra

The FAB mass spectra of the copper (II) complexes shows peak corresponds to $[CuL_2]^+$ species. However the most intense peak is due to the $[L]^+$ion. Other prominent peaks are due to $[CuL]^+$ and fragments of $[L]^+$. The spectrum of the copper (II) complex of **1b** is reproduced in figure **1.6**

Metal complexes of tridentate formazans

Elemental analytical data of the copper(II) and nickel(II) complexes of **1c** indicate their 1:1 stoichometry (table 1.9). The observed magnetic moment data, electronic and ir spectral data are in conformity with the binuclear structure **1.10** of the complexes. The NH and COOH protons of the ligand are replaced by the metal ion is clearly indicated in the ir spectra

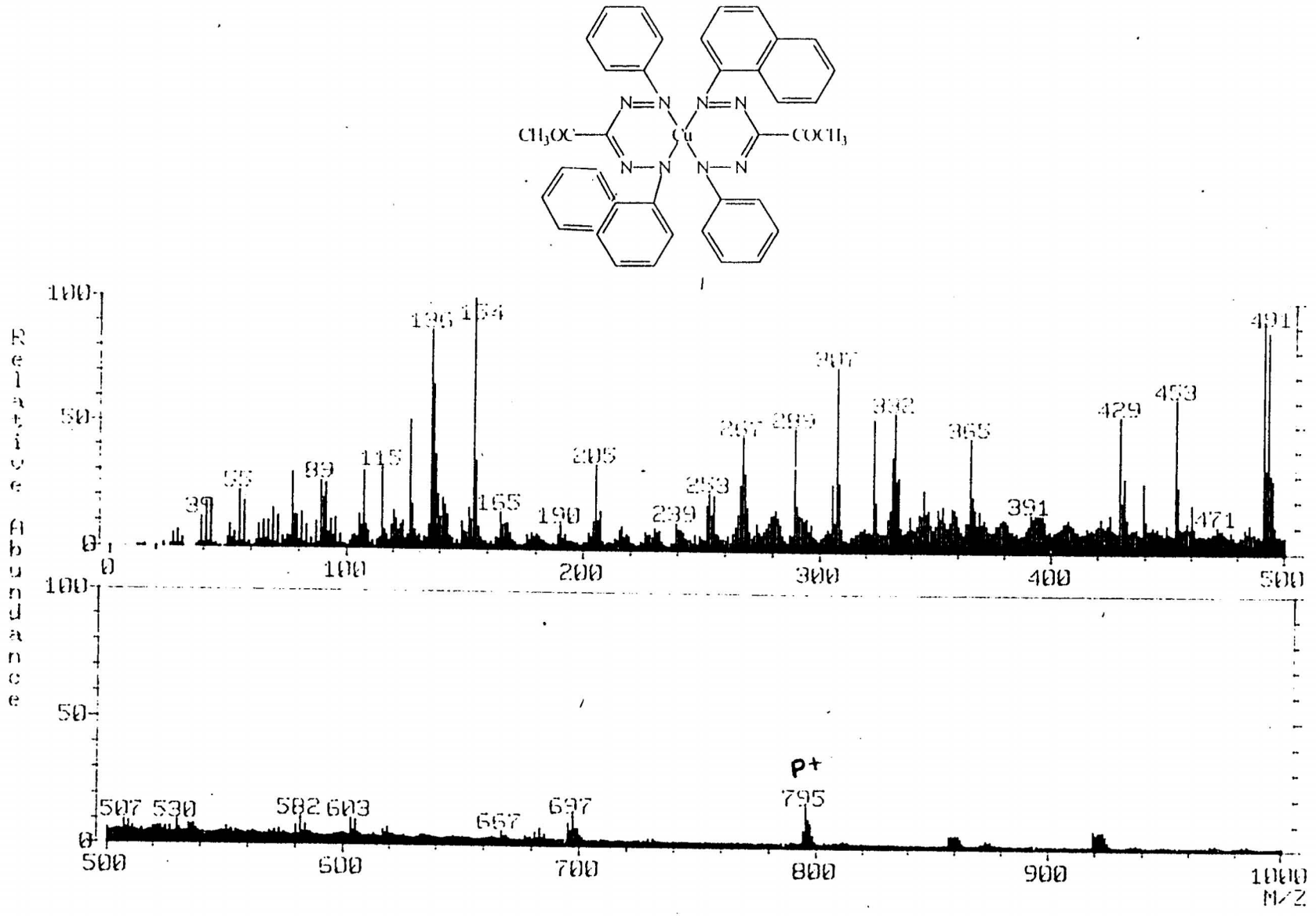


Figure 1.6 Mass spectrum of Cu(II) complex of **1b**

Table 1.9

Physical, analytical and electronic spectral data of the metal chelates of

1-phenyl-5-(2-carboxyphenyl)-3-acetylformazan (1c),HL

Compds.	M.P.°C	Elemental analysis found (calcd) in %				λmax (nm)
		C	H	N	Metal	
$[Cu_2L_2]$	>250	50 46 (51.41)	3.91 (3.74)	15.75 (15.03)	16.60 (17.00)	498 253
$[Ni_2L_2]$	>280	51. 93 (52.03)	3.64 (3.79)	15.57 (15.17)	15.38 (15.98)	830, 663, 491, 376, 310

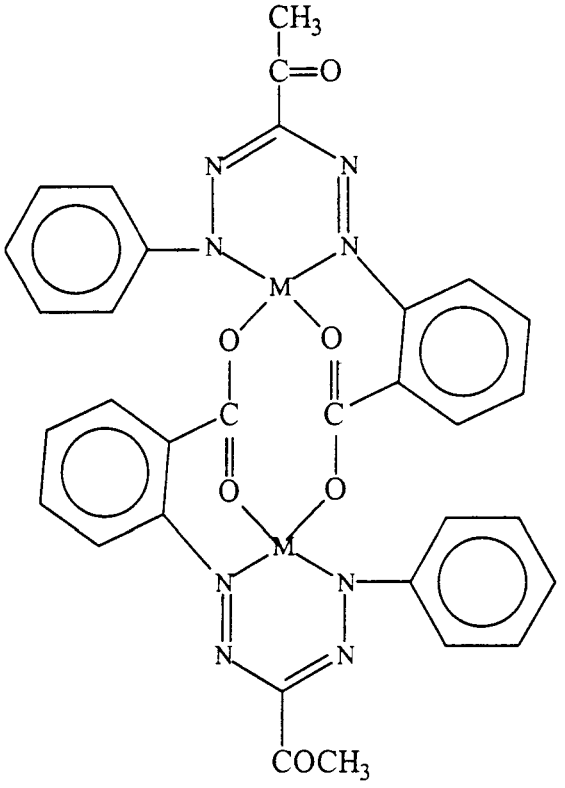
of the complexes. Thus the broad band in the region 2500 - 3500 cm^{-1} in the ir spectrum of the ligand disappeared in the spectra of all the chelates. Instead well defined medium intensity band appeared in the region due to aliphatic and aromtic ν_{C-H} vibrations.

In the double bond region a strong band observed approximately at 1670 cm^{-1} due to free acetyl carbonyl stretching. The stretching bands due to the C=N and N=N group of the free ligand is shifted considerably to low value in complexes, indicating its strong involvment in complex formation. A striking feature in the spectra of the complexes is the disappearance of the carboxylate stretching band from the region above 1600 cm^{-1}. It is well established that infrared spectra can easily distinguish unidentate, bidentate and bridging modes of coordination of carboxylate group. When COO function as a bridging group, the assymetric stretching of COO appears below 1600 cm^{-1} and the symmetric stretch around 1600 cm^{-1}. Spectra of all the complexes showed well defined medium intensity band at ~1550 cm^{-1} and at ~1400 cm^{-1} assignable respectively to ν_a and ν_s of the bridging carboxylate group as in structure **1.10**. Spectra of all the complexes below 600 cm^{-1} displayed several bands not found in the spectra of the ligand. The origin of these band can be attributed to the various M-O and M-N stretching vibrations of the dimeric structure. Important bands and their probable assignment are given in table **1.10.**

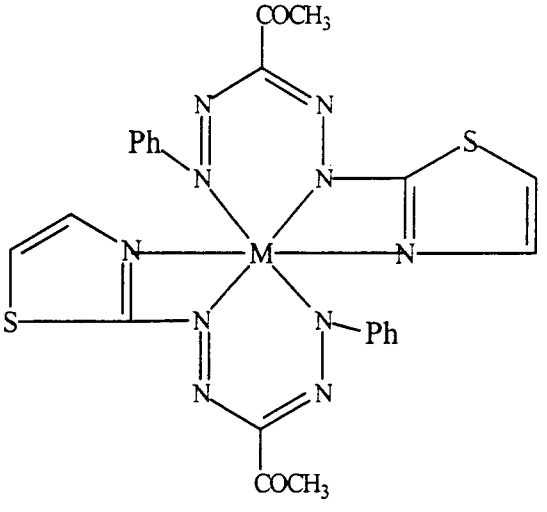
Table 1.10

Characteristic ir stretching bands (cm^{-1}) of the metal chelates of 1-phenyl-5-(2-carboxyphenyl)-3- acetylformazan 1c H_2L

Compounds	C=O(acetyl)	C=N	C=O(Carboxylate)		N=N	C-N	M-N	M-O
			$\nu_{a\ (COO)}$	$\nu_{S\ (COO)}$				
$[Cu_2L_2]$	1675	1610	1562 1554	1408 1396	1428	1275 1260	545 528	445 438
$[Ni_2L_2]$	1675	1610	1560 1548	1405 1395	1430	1272 1262	565 532	440 432


CH3
C=O
N
N
N
N
M
O
O
C
C
O
O
M
N
N
N
N
COCH3

1.10


COCH3
N
N
Ph
N
N
S
N
M
N
S
N
N
N
Ph
N
N
COCH3

1.11

The measured magnetic moment and visible spectra of the complexes also support the dimeric structure **1.10**. The observed magnetic moment of the copper(II) complexes is 1.35 B.M. The very low value indicate appreciable antiferromagnetic interaction between the two metal ions. This together with the appearance of band at in the visible spectrum of the complex table **1.11** suggest planar coordination around the metal ions.

The presence of broad band in the region 550 – 650 nm of the diamagnetic nickel(II) complex suggests the planar coordination environment of the metal ion.

Table 1.11

Magnetic moment and visible spectral data of Co(II), Ni(II) and Cu(II) chelates of 1-phenyl-5-(2-carboxyphenyl)-3- acetylformazan **1c**

Compound	μeff B.M	λ_{max} (cm^{-1})
$[Ni_2L_2]$	--	12048, 15082, 20366, 26595, 32258
$[Cu_2L_2]$	1.35	20080, 39525

Metal complexes of 1 d

Analytical and physical data of Cu(II), Ni(II) and Co(II) complexes of **1d** are in agreement with the $[ML_2]$ stoichiometry (table **1.12**). All the complexes are paramagnetic and show magnetic moment very close to the spin only value. The paramagnetic nature of the nickel(II) complex indicate the octahedral environment for the metal ion. Since the complexes do not contain the anion used for the preparation of the complexes, the hexacoordination can only be attained through the nitrogen of thiazole ring. The octahedral / distorted octahedral geometry of the complexes are also evident[185] from the number and position of the electronic spectral bands in the visible region (table **1.13**).

The observed ir spectra of the complex can also be explained on the basis of the proposed structure **1.11.** Thus the acetyl carbonyl stretching frequency of the free ligand shifted only marginally in complexes whereas the $\nu_{C=N}$ and $\nu_{N=N}$ bands shifted appreciably to lower value. The $\nu_{C=N}$ band of the thiazole ring of the free ligand observed at 1610 cm^{-1} shifted by about 10 - 15 cm^{-1} suggest the participation of the thiazole nitrogen in bonding with the metal. That the N - H proton are replaced by metal ion is evident from the spectra of complexes in the region 2500 - 3500 cm^{-1}. Important ir bands and their assignment are given in table **1.14.**

Table 1.12

Physical analytical and electronic spectral data of the metal chelates of 1-phenyl-5-(2-thiazolyl)-3-acetyl formazan (1d)

Compds.	M.P.°C	Elemental analysis found (calcd) in %				λmax (nm)
		C	H	N	Metal	
$[Co_2L_2H_2O_2]$	>300	45.83 (47.76)	3.81 (3.31)	24.33 (23.2	9.88 (9.77)	710 310
$[Cu_2L_2]$	180	44.99 (47.40)	2.87 (3.22)	24.64 (23.04)	11.38 (10.45)	610 445 308
$[Ni_2L_2]$	>300	45.22 (47.78)	3.01 (3.31)	24.61 (23.22)	18..94 (19.74)	616 446 310

Table. 1.13

Magnetic moment and visible spectral data of Co(II), Ni(II) and Cu(II) chelates of 1-phenyl-5-(2-thiazolyl)-3-acetylformazan **1d**

Compound	**μeff**, B.M	**λmax(cm^{-1})**
$[CoL_2]$	4.3	1404, 32258
$[NiL_2]$	3.46	16233, 22421, 32258
$[CuL_2]$	1.72	16393, 22471, 32467

Table 1.14

Characteristic ir stretching bands (cm^{-1}) of the metal chelates of 1d [HL]

Compound	**C=O (acetyl)**	**C=N**	**C=N (Thiazolyl)**	**N=N**	**C-N**	**M-N**
$[CuL_2]$	1678	1605	1595	1415	1280	560
					1255	545
$[CoL_2]$	1675	1602	1602	1408	1275	555
					1262	542
$[NiL_2]$	1675	1600	1594	1418	1280	548
					1260	540

Potentiomeric studies on acidity and chelation of 1,5-diaryl-3-acetylformazans

The complex forming properties of various compounds and the relation between their acidic strength and stability constants are well established[186,187]. The behaviour of metal chelates in solution invariably depends on their stability constants (K)[188]. Since K refers to a system in equilibrium, it may be used to calculate free energy change (ΔG) and other various thermodynamic parameters of the reaction by means of the equation **1.1.**

$$\Delta G = \Delta H - T\Delta S = -RT \ln K \qquad \textbf{1.1}$$

where ΔH is the change in enthalpy, ΔS is the change in entropy at tempereture T. A knoweldge of these parameters are equally important in the study of the role of these metal cheletes in different biological systems.

Different experimental methods and computational techniques for the determination of stability constants are well described[187-191]. The proton-ligand and metal-ligand stability constants of the title compounds were examined by pHmetric titration technique of Irving and Rossotti[187] in 50% v/v dioxane medium.

For pH measureements the ligand solutions, ($1x\ 10^{-3}$) were prepared in 1,4-dioxane and all other solutions in double distilled CO_2 free water. The following sets of pH titrations were done using a standard carbonate free 0.01 M NaOH solution at constant ionic strength (0.01 M KCl). The strength of the hydrochloric acid solution used was $1x10^{-3}$ M.

(i) 6mL HCl + 2mL H2O + 10 mL 1,4-dioxane + 2 mL KCl.

(ii) 6 mL HCl + 2mL H2O + 9 mL 1,4-dioxane + 1 mL ligand solution + 2 mL KCl.

(iii) 6 mL HCl + 1.8 mL H2O +9mL 1,4-dioxane+1 mL ligand solution +0.2 mL metal(II) chloride solution (1x10-4 M) + 2mL KCl.

Duplicate titrations were performed in each case under identical conditions. The pH reading was noted after every addition of 0.1 mL alkali and the titrations curves were plotted as pH vs volume of alkali added. The calculation method adopted were given below.

The acid dissociation constants

The average proton-ligand formation number, $\overline{n}_A$, were calculated at various pH values from the titration curves uasing Irving and Rossotti's expression[187] **1.2.**

$$\overline{n}_A = yT^{\circ}_{CL} + \frac{(V_1 - V_2)(N+E^{\circ})}{T^{\circ}_{CL}(V_0+V_1)} \qquad \textbf{1.2}$$

where V_2 and V_1 denote the volume of alkali added to reach the same pH in the titration of the ligand and free acid (solution sets ii and i) respectively, T°_{CL} is the total concentration of the chelating ligand, V_o is the total volume of the mixture, N is the normality of the alkali and E° is the initial concentration of the free acid.

From the proton-ligand formation curves (pH vs $\overline{n}_A$), the acid dissociation constants were calculated by half-integral and midpoint

computational methods[187]. The mean values are presented in table **1.15**. The proton-ligand formation curves are given in figure **1.7**.

Table 1.15

The acid dissociation constants of 1,5-diaryl-3-acetylformazans

Compounds	pK
1a	9.27
1b	9.20
1c	9.24 6.20
1d	9.26

From the table **1.15** it follows that pK values of **1b** and **1c** are smaller than **1a** and **1d**. This indicate that the NH proton of formazans having 1-naphthyl group and 2-carboxyphenyl group dissociates prior to the formazans having simple phenyl or thiazolyl groups. The difference may be attributed to the extended conjugation of the anion of formazans **1b** and **1c**. In the case of **1c**, carboxyl proton is released more readily than NH proton as evident from the pK value in the table **1.15**.

Metal-ligand stability constants

The stepwise metal-ligand formation constants are given by equation **1.3**

$$K_n = \frac{[ML_n]}{[ML_{n-1}][L]}, \quad (n = 1, 2, 3, \ldots.) \qquad \textbf{1.3}$$

where K_n is the nth metal-ligand stability constant. In the present case the stability constants were obtained by plotting $\bar{n}$ against pL, where $\bar{n}$ is the average number of ligands attached per metal ion and pL, the free ligand exponent. The equation **1.4** is used for calculating $\bar{n}$

$$\bar{n} = \frac{(V_3 - V_2)(N + E^o)}{(V_o + V_1)\,\bar{n}_A\,T^o_{CM}} \qquad \textbf{1.4}$$

where T^o_{CM} denotes the total concentration of the metal ions present in the solultion and V_3, the volulme of alkali required to reach a particular pH in the presence of metal lion (solution set iii). The other terms have the same meaning as above.

Equation **1.5** is used to calculate pL.

$$pL = \log_{10}\left[\frac{\sum_{n=0}^{n=j} \beta_n^H \left[\frac{1}{\text{antilog pH}}\right]^n X \frac{V_0 + V_3}{V_0}}{[T^o_{CL} - nT^o_{CM}]}\right] \qquad \textbf{1.5}$$

where β_n^H is the overall proton – ligand stability constant.

The formation curves ($\bar{n}$ *vs* pL) of metal complexes with respect to ligands **1a - 1d** are shown in figures **1.7 - 1.11**. The $\bar{n}$ values extend upto 2.0 indicating the formation of [ML] and [ML_2] complexes in all cases studied. From the formation curves, the stepwise stability constant were computed by the half-integral and midpoint methods[187]. The mean values and the overall stability constants calculated are broght out in table **1.16**.

Table 1.16
Metal-ligand stability constants of 1,5-diaryl-3-acetylformazans

Metal(II) Ions	Stability constants	Ligands			
		1a	1b	1c	1d
Cu^{2+}	$logK_1$	9.03	9.05	9.08	9.06
	$logK_2$	7.05	6.98	7.1	7.12
Ni^{2+}	$logK_1$	8.1	8.05	8.02	8.08
	$logK_2$	6.72	6.93	7.08	7.1
Co^{2+}	$logK_1$	7.12	7.3	7.26	7.18
	$logK_2$	6.32	6.18	6.48	6.4
Zn^{2+}	$logK_1$	7.89	7.85	7.92	7.92
	$logK_2$	6.48	6.68	6.98	6.7

The stability constants of the cobalt(II), nickel(II), copper(II) and zinc(II) complexes agree with the Irving-Williams natural order of stability[192]. The log K_n values show an increasing trend when electron withdrawing groups are present in the aryl ring. Since log K_1 > logK_2, indicates a decrease in the bond strength with successive attachment of the ligand molecules. However, the observed small differences between the two values suggest the planar geometry of the chelates.

Fig. 1.7 Proton-ligand formation curves for 1,5-diaryl-3-acetylformazan

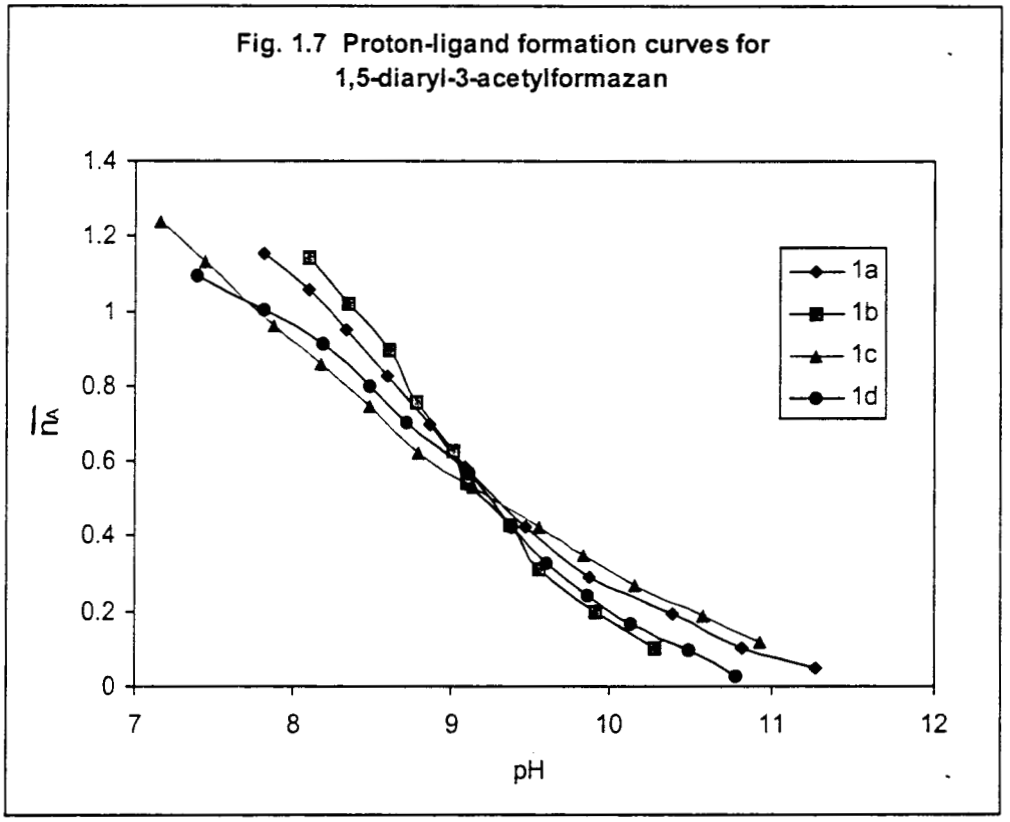


Fig. 1.8 Metal-ligand formation curves for 1a

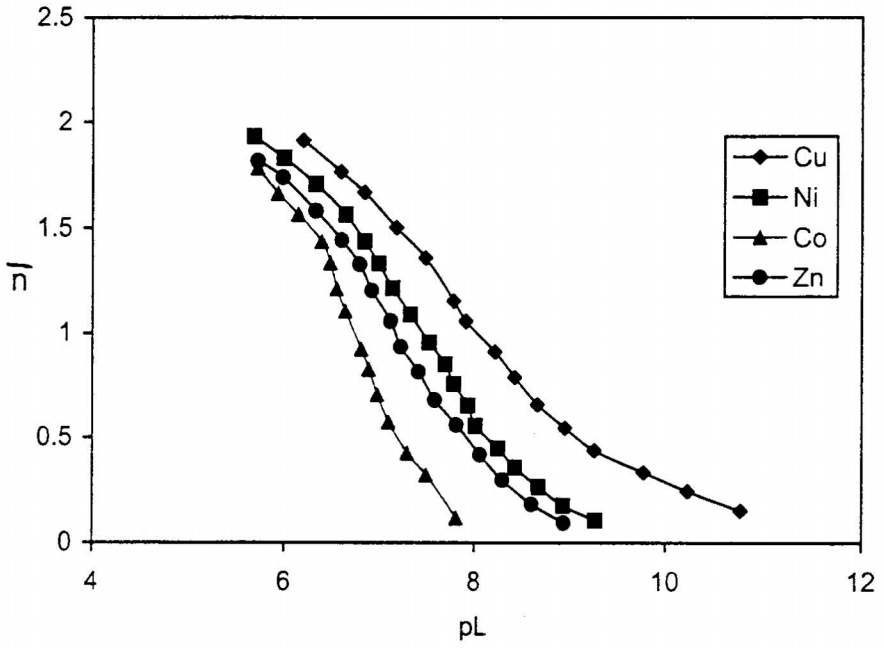


Fig. 1.9 Metal-ligand formation curves for 1b

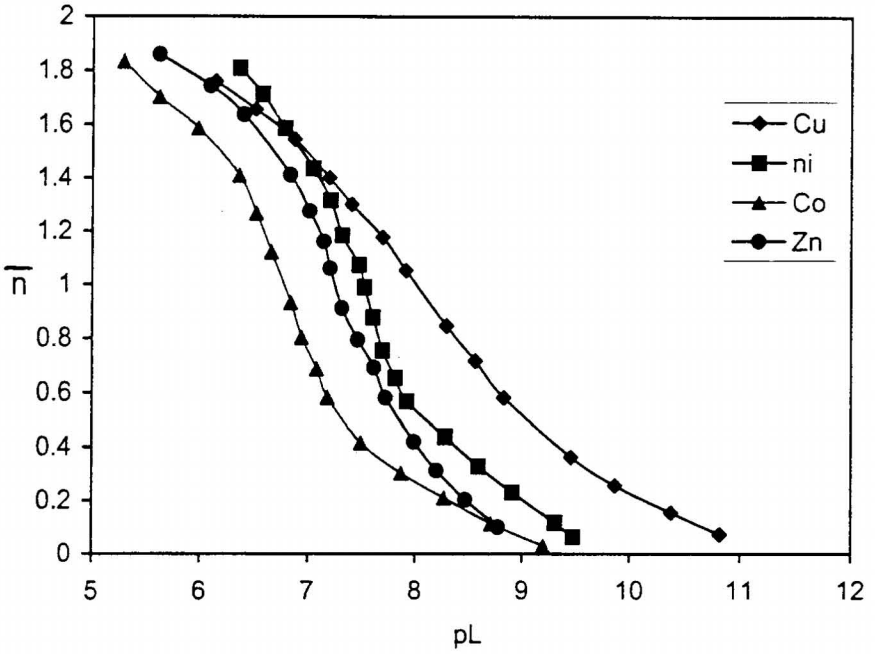


Fig. 1.10 Metal-ligand formation curves for 1c

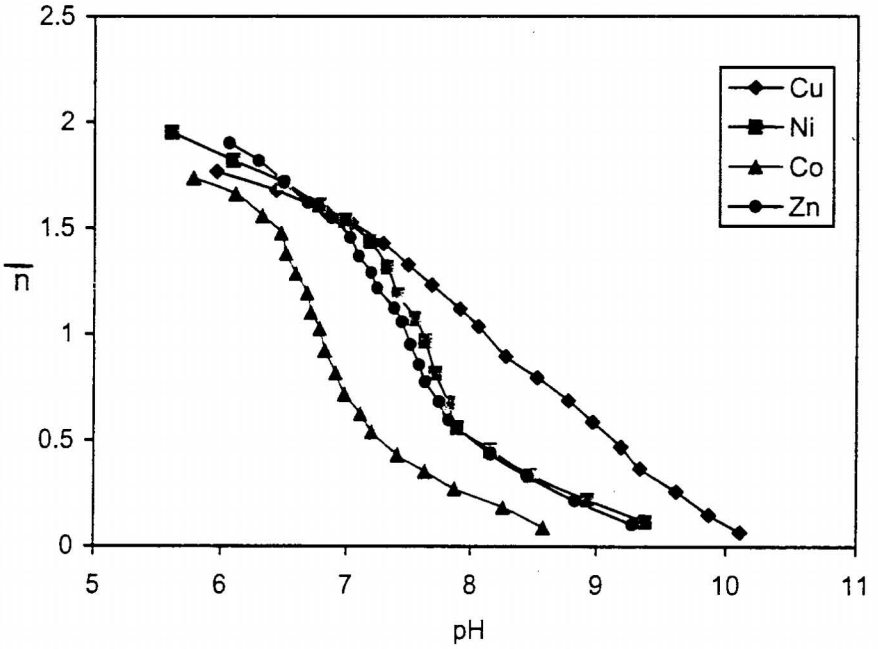
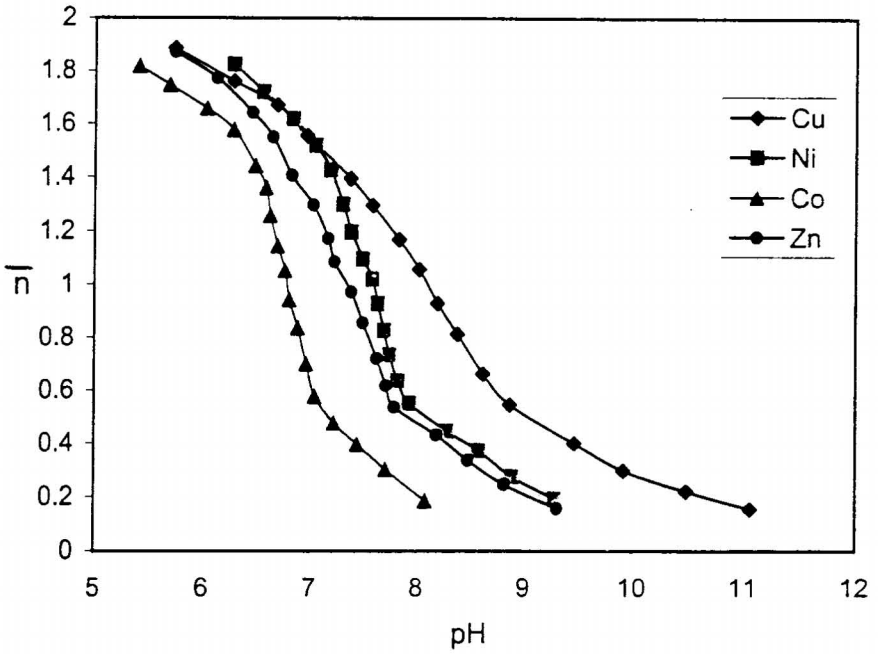


Fig. 1.11 Metal-ligand formation curves for 1d



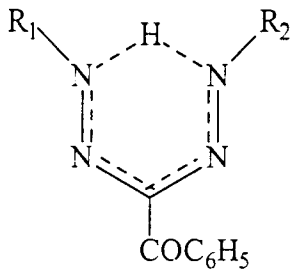
PART II
1,5 DIARYL -3 BENZOYLFORMAZANS AND THEIR METAL COMPLEXES

Abdul Rahim A.K. “Metal complexes of formazans ” Thesis. Department of Chemistry , University of Calicut, 2000

CHAPTER 2

1, 5 - DIARYL -3 - BENZOYLFORMAZANS AND THEIR METAL COMPLEXES

Reaction of two equivalents of aryldiazonium salt with benzoylacetone in strongly basic medium results 1,5-diaryl-3-benzoylformazans in good yield with the elimination of the acetyl group. The same products are also formed by coupling arylhydrazone of benzoylacetone with aryldiazonium salt in strong alkaline medium. Both the methods are employed for the synthesis of the 1,5-diaryl-3-benzoylformazans, **2a** – **2d**, considered in this investigation.



2.1

	R_1	R_2
2a	C_6H_5	C_6H_5
2b	C_6H_5	$C_{10}H_7$
2c	C_6H_5	$C_6H_4(COOH)$
2d	C_6H_5	C_3H_2NS

Synthesis

Preparation of 2a and 2b

A methanolic solution (400 ml) of benzoylacetone (0.05 mol) was mixed with 500 ml of aqueous NaOH and was cooled to below 5 °C. A diazonium chloride solution prepared from 0.05 mol of aniline/ naphthylamine was then added dropwise with stirring to the above solution. The precipitate formed was collected, washed with water and extracted with ether, dried with anhydrous $MgSO_4$. Ether was evaporated and the solid product obtained was recrystallised from n-hexane.

Preparation of 2c

The compound was prepared by coupling the phenyl hydrazone of benzoylacetone with diazotised anthranilic acid. Phenylhydrazone of benzoylacetone was prepared as reported[193].

Anthranilic acid (0.025 mol) was diazotised as reported[159]. The clear diazonium salt solution was added drop wise with stirring to a methanolic solution (0.025 mol, 400ml) of phenylhydrazone of benzoylacetone containing 200 ml of aqueous NaOH kept below 5°C. The mixed solution was stirred for ~ 30 minutes. The precipitate formed was filtered, washed with water and extracted with ether, dried with anhydrous MgSO4. Ether was evaporated, to get the formazans and recrystallised from hot methanol.

Preparation of 2d

The formazan was prepared by coupling diazotised 2-aminothiazole with the phenylhydrazonee of acetylacetone.

2-aminothiazole was diazotised as reported[194]. The diazonium sulphate solution so obtained was added in dropwise with stirring to a methanolic solution of the phenylhydrazone of benzoylacetone (0.025 mol, 400 ml), containing also aqueous NaOH solution (0.05 mol, 200 ml), kept below 5°C. The precipitate formed, was collected, washed with water, extracted with ether and the ether was evaporated to get the compound.The compound was purified by recrystallisation from hot methanol.

Synthesis of metal chelates

Copper(II), nickel(II) and cobalt(II) chelates of 1,5-diaryl-3-benzoylformazans were prepared by the following general method.

To a solution of the formazan (0.025 mol) in methanol (100ml) was added with stirring a solution of metal acetate (0.012mol). The mixture was refluxed on a boiling water bath for ~ 1h, and the volume was reduced to half. The precipitated complex on cooling to room temp was filtered, washed with ethanol and recrystallised from hot methanol

Results and Discussion

Characterisation of the formazans: Physical and analytical data of the compounds are given in table **2.1**. Electronic, ir, nmr and mass spectral data of the compounds are in accord with structure **2.1**.

Table 2.1

Physical, analytical and electronic spectral data of 1,5-diaryl-3-benzoylformazans

Compound	M.P	Elemental analysis found, (calcd) %			λ_{max}
	°C	C	H	N	(nm)
2a	128	74.25	4.95	17.27	446
		(73.17)	(4.87)	(17.07)	314
2b	145	77.02	4.45	15.01	419
		(76.4)	(4.8)	(14.8)	308
					246
2c	135	68.34	3.95	16.02	438
		(67.74)	(4.30)	(15.05)	314
2d	155	61.5	3 .89	21.01	384
		(60.7)	(4.16)	(20.8)	258

Uv spectra

The uv spectra of the compounds consist of two broad bands (table **2.1**). The high frequency band is due to the azo function and the low frequency band to the hydrazone group.

Infrared spectra

The carbonyl stretching frequency of free benzoyl group usually appear at ~ 1650 cm^{-1}. Hydrogen bonding decreases the ν_{CO} frequency. Spectra of all the formazan show an intense band at ~ 1650 cm^{-1} indicating that the benzoyl carbonyl group remains free and not involved in intramolecular hydrogen bonding. Other prominent bands in the region 1400 -1700 cm^{-1} and their assignments are given in table **2.2**. The assignments were made by comparing the spectra with the spectra of compounds considered in chapter 1 and also with the spectra of arylhydrazones of 1,3 dicarbonyls[174,175,193,195-197].

The region 2500 - 3500 cm^{-1} of the compounds show a very broad band in agreement with the intramolecularly hydrogen bonded structure **2.1**

NMR spectra

The ^1H nmr spectra of the compounds are reproduced in figures **2.1-2.3**. The low field signal appeared at ~ δ 14 in the spectra of all compounds is due to the strong intramolecularly hydrogen bonded NH

Table 2.2

Characteristic ir stretching bands (cm^{-1}) of the 1,5-diaryl –3-benzoylformazans

Compounds				Probable
2a	**2b**	**2c**	**2d**	assignments
1655	1652	1645	1660	C=O(free)
		1705		C=O(carboxyl)
598	1618	1617	1619	C=N
			1625	C=N (thiazolyl)
1453	1446	1456	1460	N=N
1285	1280	1275	1290	C–N
1272	1268	1266	1274	"

proton. Spectra of **2c** show an additional signal at δ 15.297 ppm for the carboxylic proton. This very low value indicate that this proton is also engaged in intramolecular hydrogen bonding.

The position of the resonance signals of the aryl proton of the benzoyl group is clearly separated from other aryl protons. Integrated intensities of all the signals agree well with the structure **2.1**.

The ^{13}C nmr spectrum of **2a** (figure **2.4**) shows the carbonyl carbon signal at 189.45 ppm and the formazyl carbon signal at 146.766 ppm. The number of aryl carbon signals suggest that the two phenyl rings of the formazyl group are slightly in different electronic environment, probably these rings are coplanar with formazyl group.

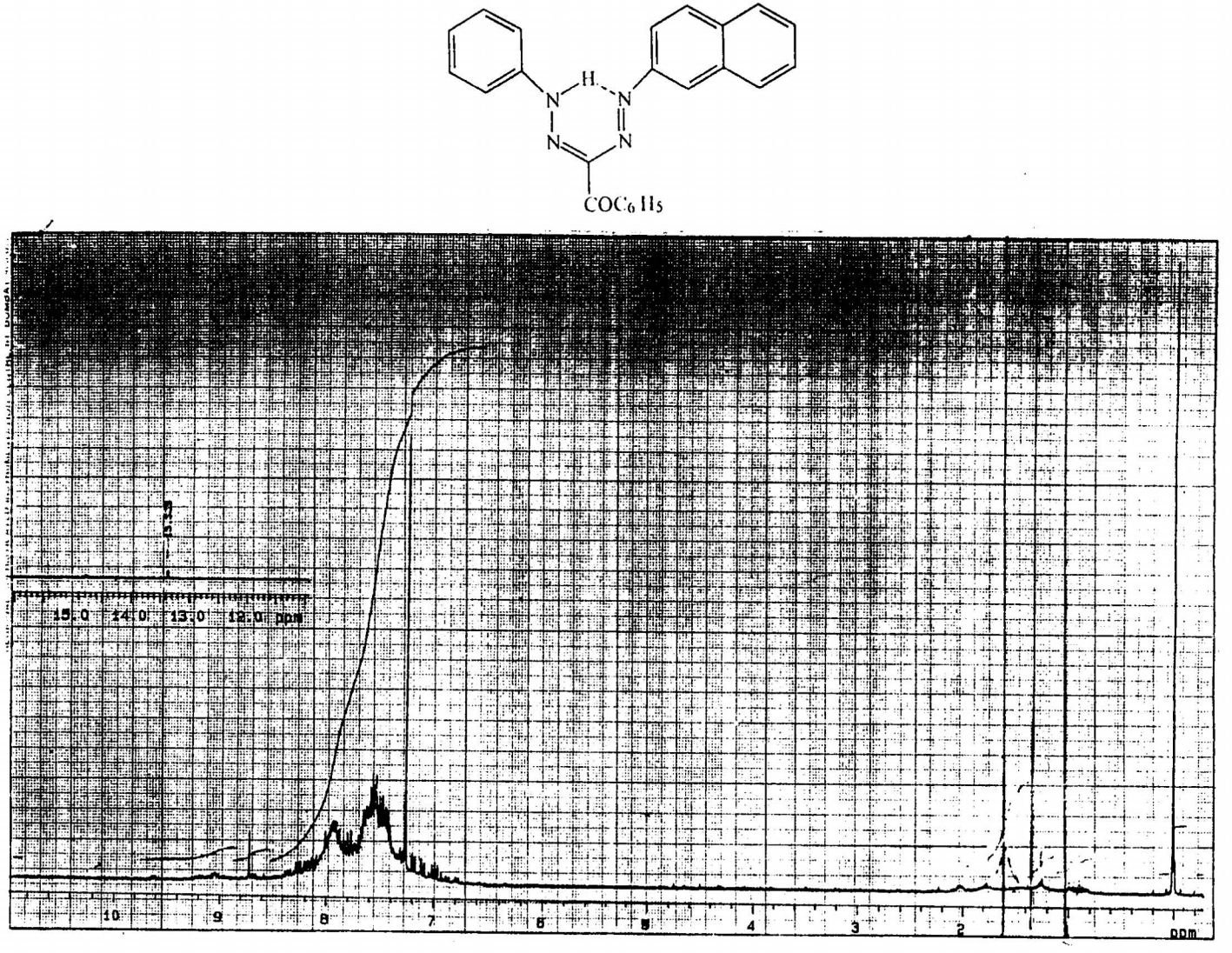
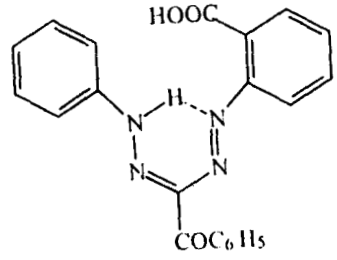


Figure 2.1 ^{1}H **nmr spectrum of 2b**



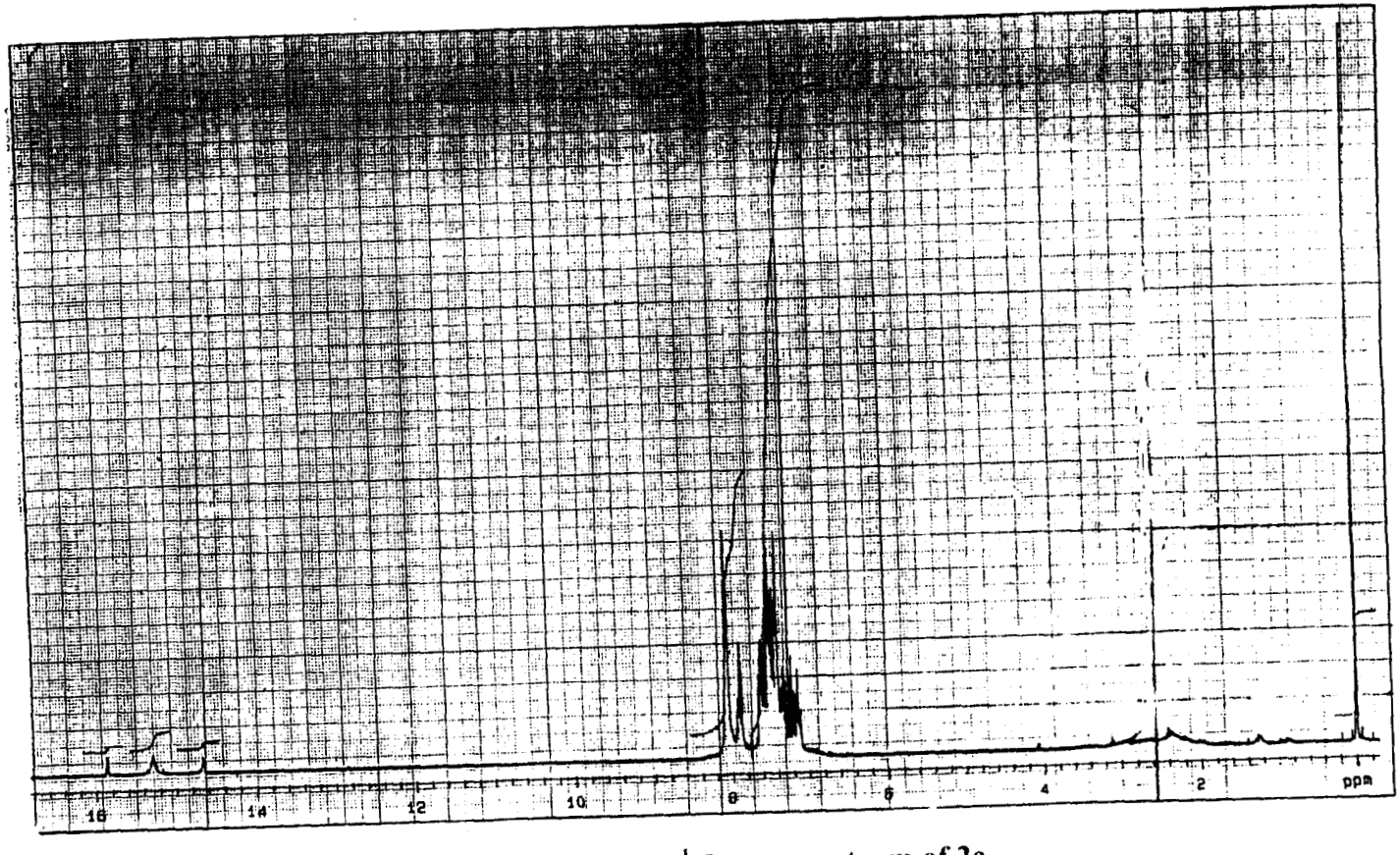
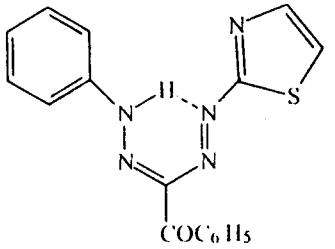


Figure 2.2 ^{1}H nmr spectrum of 2c



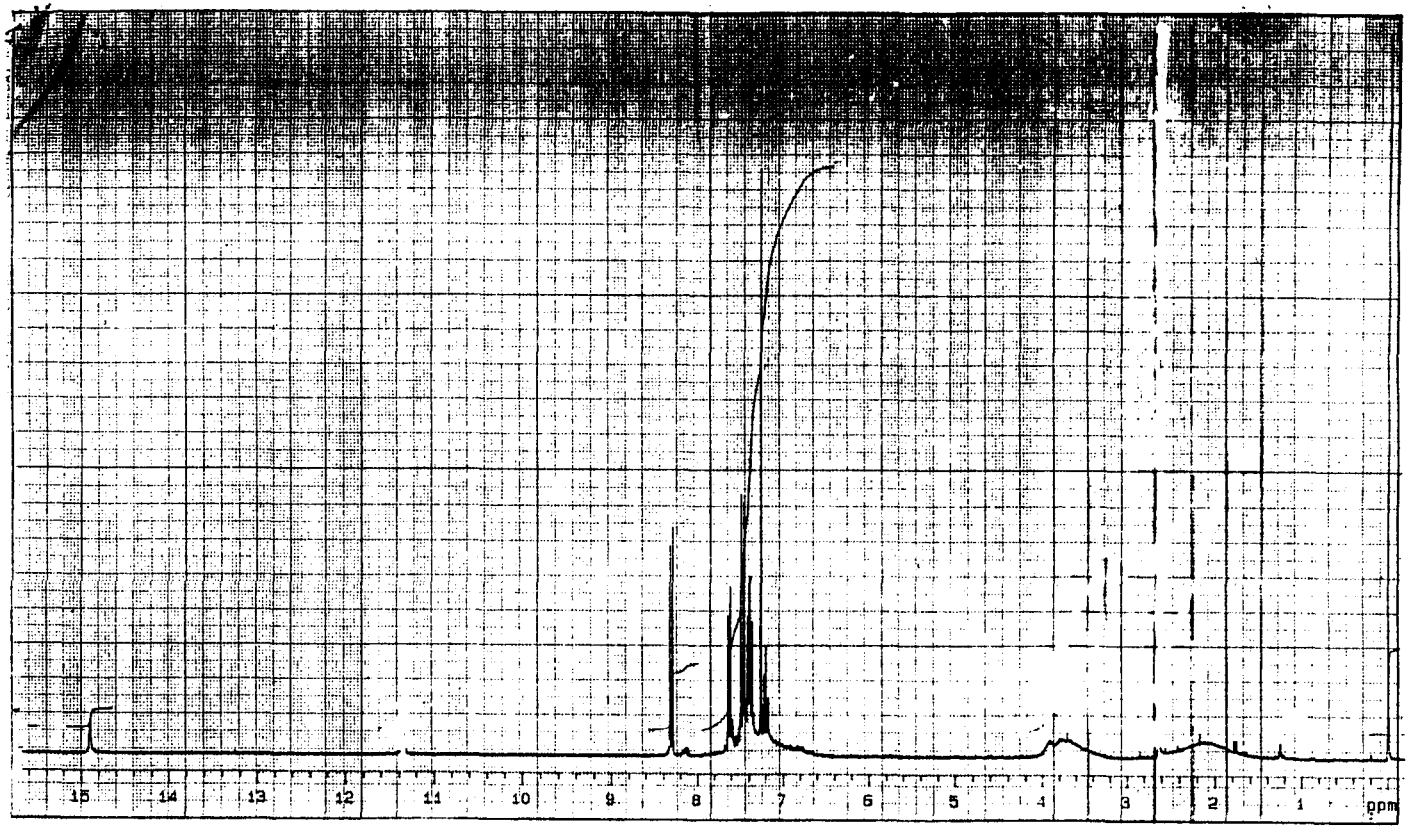


Figure 2.3 ^{1}H nmr spectrum of 2d

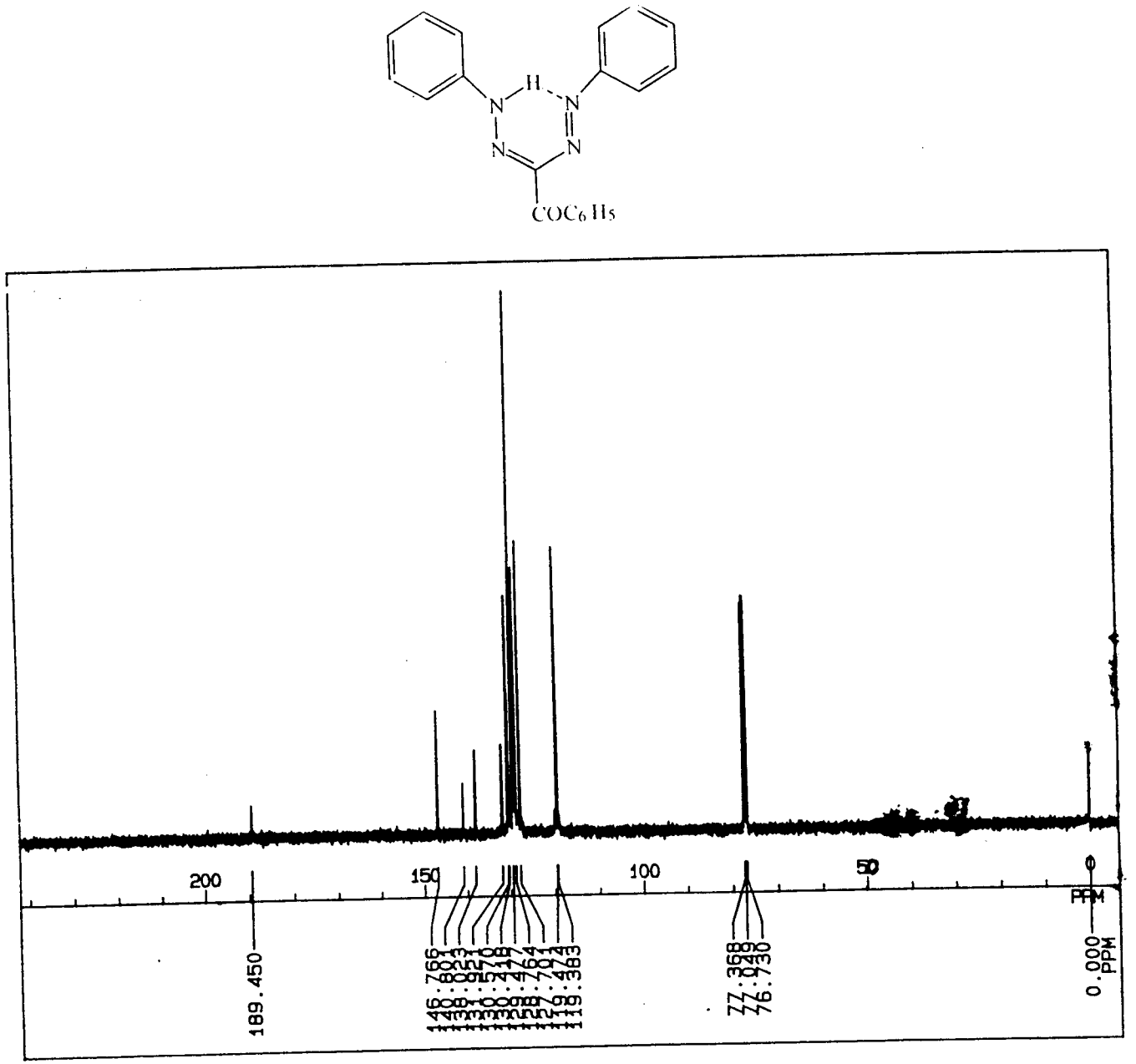


Figure 2.4 ^{13}C **nmr spectrum of 2a**

Mass spectra

The mass spectra of the compounds are given in figures **2.5 - 2.8**. The presence of the parent P^+ / $(P+1)^+$ ion peak is one of the characteristic of all the spectra. Other prominent peaks are due to the elimination of N_2, C_6H_5CO, aryl group from the parent ion and also peaks due to $C_6H_5CO^+$, $ArNH^+$, ArN_2^+, etc., The observed spectra can be conveniently explained by the fragmentation pattern similar to that given in scheme **1.1** for the 3-acetylformazans considered in chapter 1.

Characterisation of metal complexes

The C, H, N and metal percentages of the Cu(II), Ni(II) and Co(II) complex of **2a** , **2b** and **2d** (tables, **2.3**, **2.4** and **2.5**) suggest the 1:2 metal ligand stoichiometry while 1:1 in the case of complex of **2c** (table **2.6**). All the complex are non-conducting and do not contain the anion of the metal salt used for their preparation. Spectral data of the complexes of **2a** and **2b** are in conformity with structure **2.2**, that of **2c** as in structure **2.3** and **2d** as in structure **2.4.**

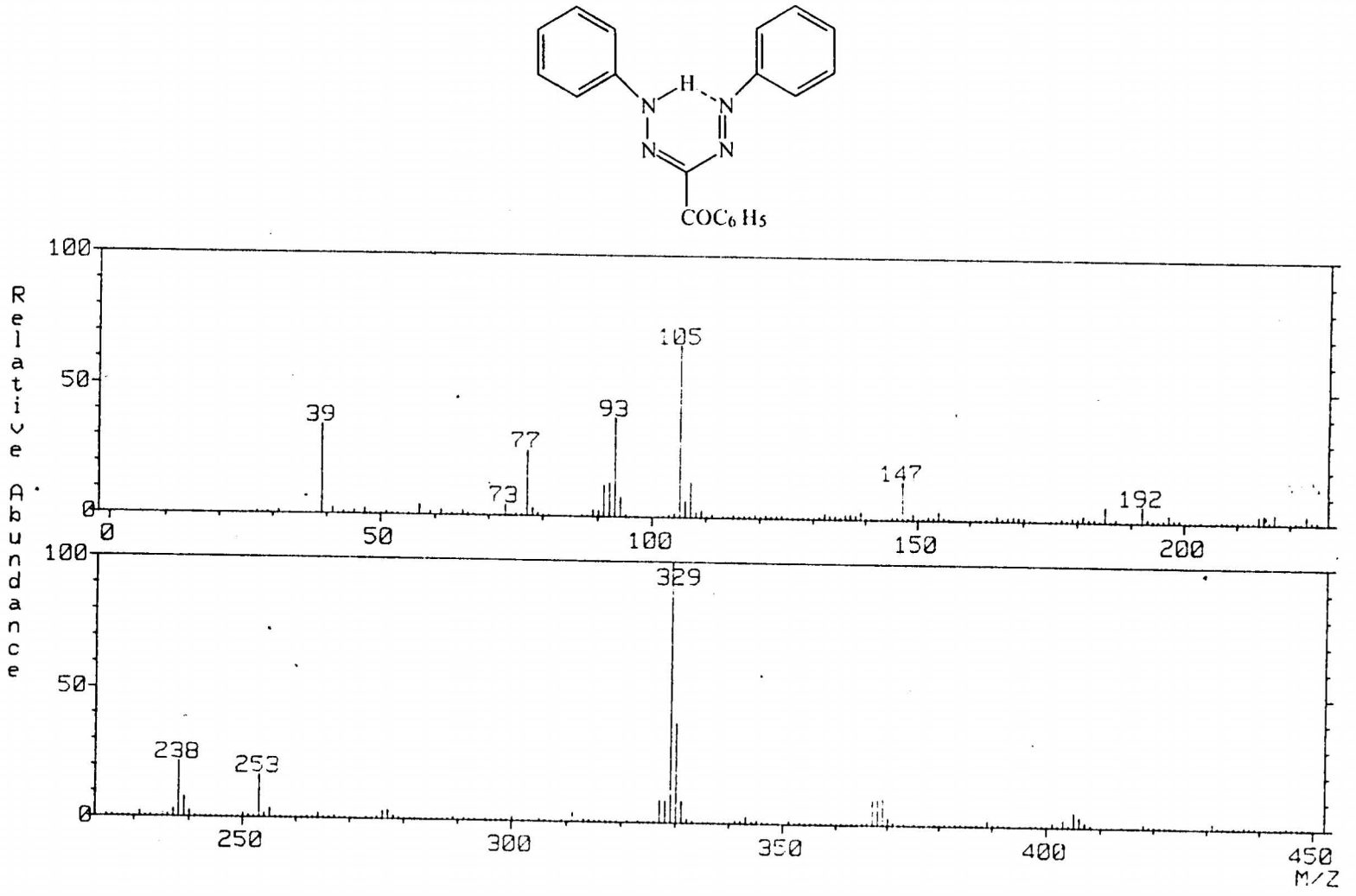


Figure 2.5 Mass spectrum of 2a

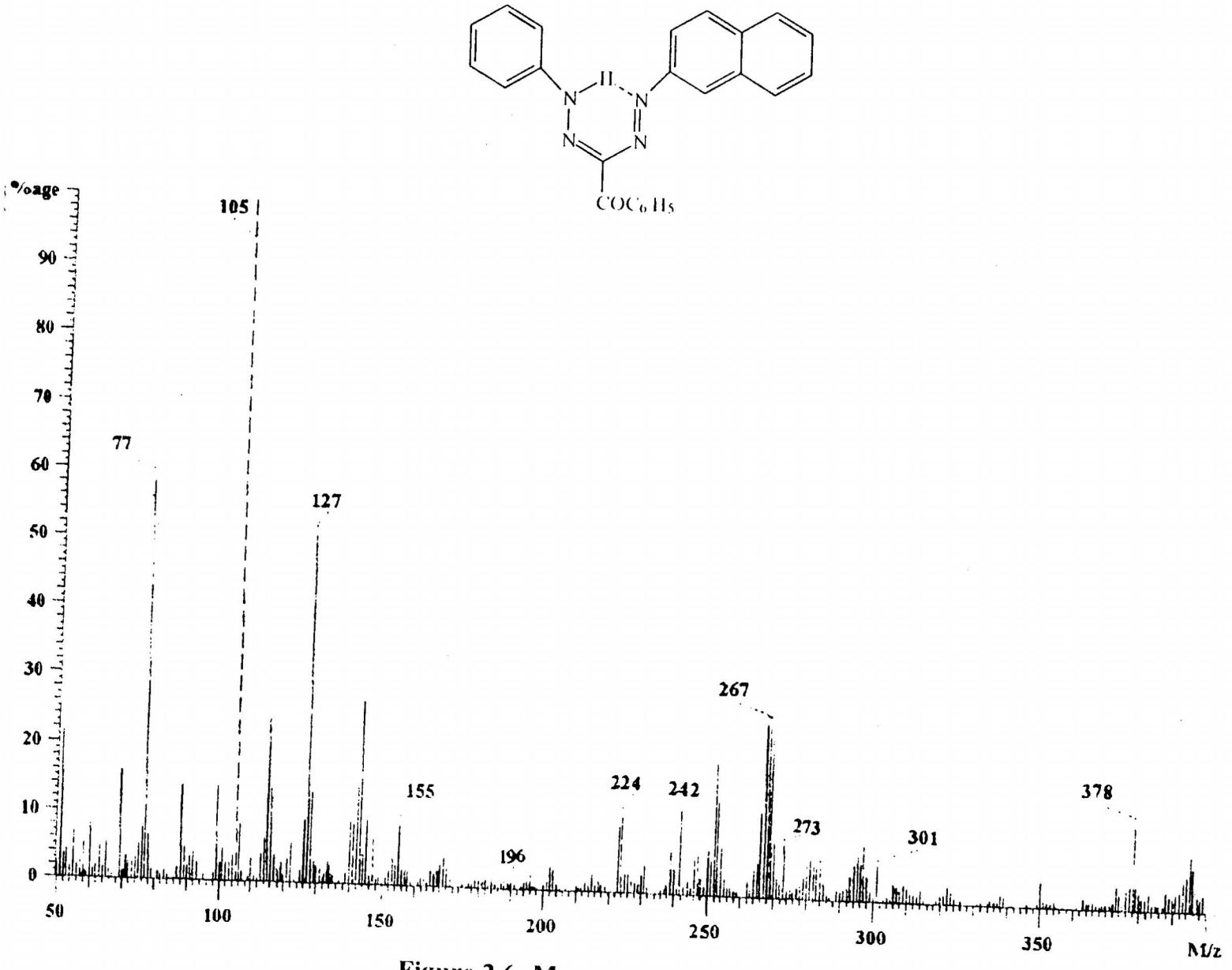


Figure 2.6 Mass spectrum of 2b

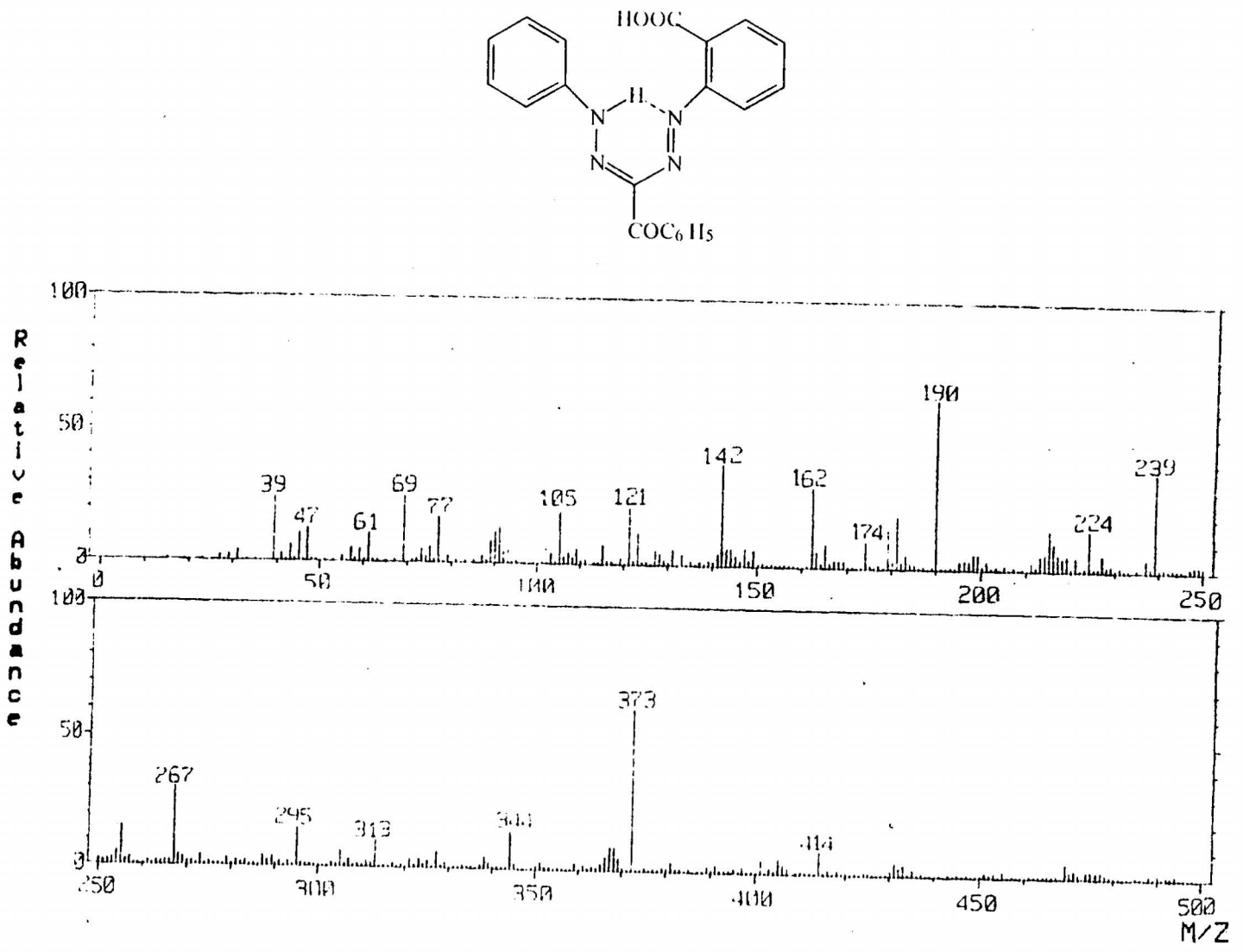


Figure 2.7 Mass spectrum of 2c

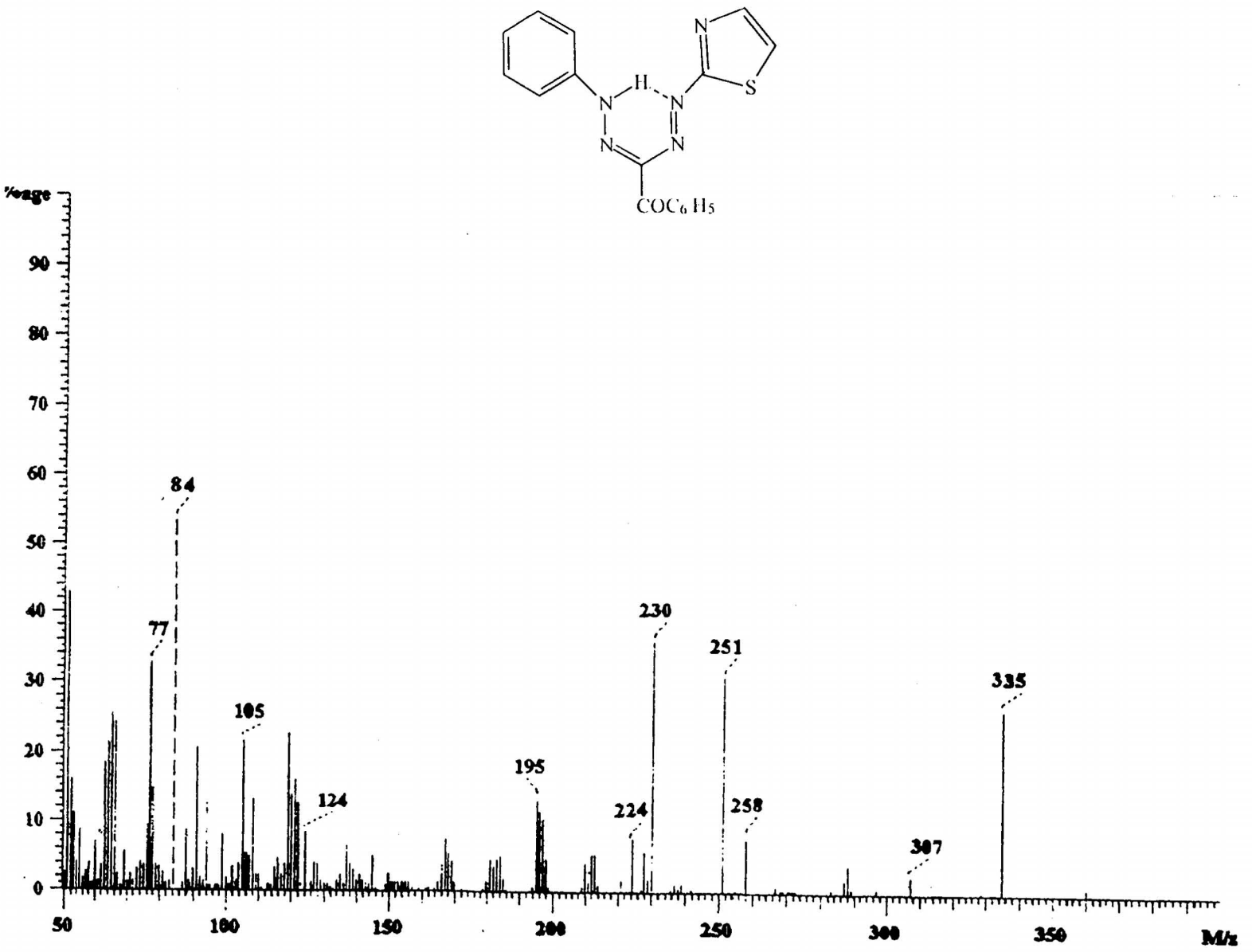


Figure 2.8 Mass spectrum of 2d

Table 2.3

Physical, analytical and electronic spectral data of metal chelates of 1,5-di phenyl-3-benzoylformazan (2a) HL

Compound	M.P °C	Elemental analysis found (cacld.) (%)				λ_{max} (nm)
		C	H	N	Metal	
$[CoL_2(H_2O)_2]$	> 300	67.92 (67.33)	4.431 (4.48)	14.32 (14.28)	8.372 (8.25)	311 439
$[NiL_2]$	> 300	68.24 (67.3)	4.63 (4.48)	14.50 (15.7)	8.85 (8.2)	310 442
$[CuL_2]$	185	67.95 (66.89)	4.08 (4.40)	14.20 (15.60)	8.32 (8.85)	394 310

Table 2.4

Physical, analytical and electronic spectral data of metal chelates of 1-phenyl-5-(1-naphthyl)-3-benzoylformazan (2b) HL

Compound	M.P ^{o}C	Elemental analysis found (cacld.) (%)				λ_{max} (nm)
		C	H	N	Metal	
$[CoL_2(H_2O)_2]$	> 280	69.4 (70.85)	4.89 (4.42)	13.50 (13.7)	8.02 (7.24)	441 307
$[NiL_2]$	> 280	69.54 (70.87)	4.84 (4.42)	13.45 (13.78)	7.01 (7.22)	440 309
$[CuL_2]$	230	69.81 (70.45)	4.51 (4.40)	12.01 (13.70)	6.96 (7.77)	428 310

Table 2.5

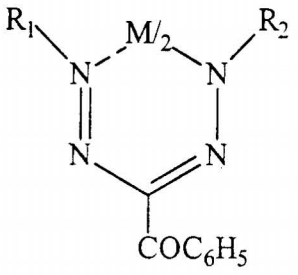
Physical, analytical and electronic spectral data of metal chelates of 1-phenyl-5-(thiazolyl)-3-benzoylformazan, (2d) HL

Compound	M.P.°C	Elemental analysis found (Calcd) in %				λ_{max} (nm)
		C	H	N	Metal	
$[CoL_2]$	>270	56.89 (56.12)	3.81 (3.57)	18.01 (19.25)	8.5 (8.12)	720 310
$[NiL_2]$	> 250	56.01 (56.14)	3.89 (3.57)	18.07 (19.2)	8.2 (8.07)	60 5 310
$[Cu\ L_2]$	190	55.89 (55.77)	4.01 (3.55)	18.01 (19.13)	9.72 (8.68)	610 327

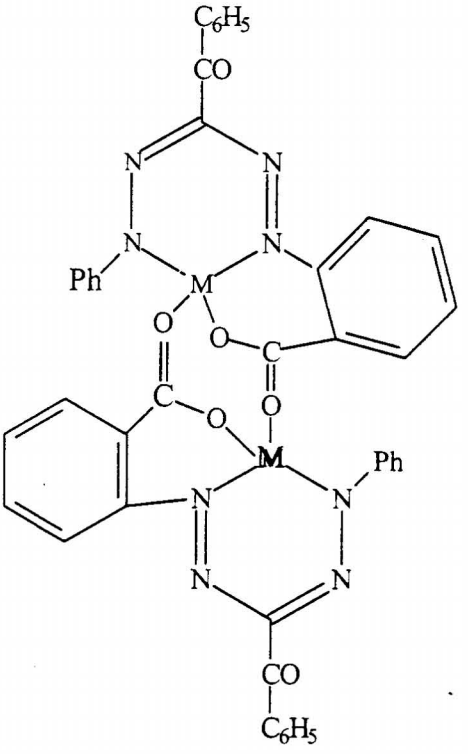
Table 2.6

Physical, analytical and electronic spectral data of metal chelates of 1-phenyl-5-(2-carboxy phenyl)-3-benzoylformazan (2 c) HL

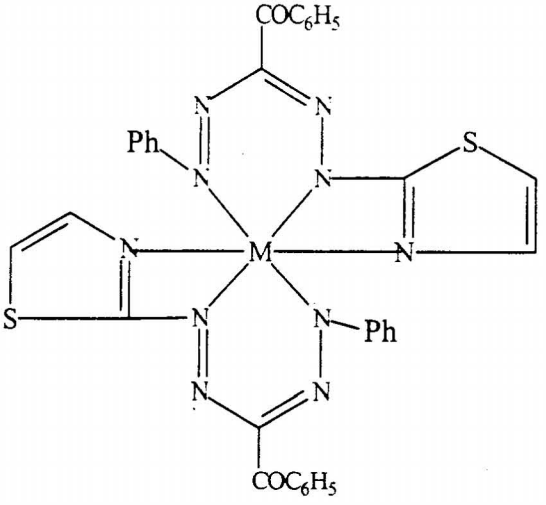
Compound	M.P. °C	Elemental analysis found (Calcd) %				λ_{max} (nm)
		C	H	N	Metal	
$[Ni_2L_2]$	> 300	59.00 (58.6)	3.02 (3.72)	12.01 (13.03)	14.01 (13.66)	636, 376 204
$[Cu_2L_2]$	>250	58.05 (57.99)	4.02 (3.68)	12.00 (12.88)	14.20 (14.62)	764, 493 310, 254


R1
M/2
R2
N
N
N
N
COC6H5

2.2


C6H5
CO
N
N
N
N
Ph
M
O
O
C
C
O
O
M
Ph
N
N
N
N
CO
C6H5

2.3


COC6H5
N
N
Ph
N
N
S
N
M
N
S
N
N
N
Ph
N
N
COC6H5

2.4

Ir spectra

The ir spectra of all the complexes are characterised by the presence of a strong band at ~1650 cm^{-1} assignable to free benzoyl carbonyl stretching. That chelated NH proton is replaced by metal ion is evident from the disappearance of the broad band in the region 2500 - 3500 cm^{-1} in the spectra of all the complexes. Only bands due to aromatic C-H appeared in this region. The N=N, C=N, stretches of the free ligand shifted appreciably to lower wave number in the spectra of the complexes indicating the involvement of the formazan function in metal chelation. Important bands and their probable assignments are given in tables, **2.7– 2.10**.

The formazan **2c** function as dibasic tridentate is clearly indicated in their spectra of its complexes. The observed shift in stretching vibration of the carboxyl function suggest the involvement of both oxygen in bonding with the metal ions as in the case of the 3-acetylformazans (chapter1) The magnetic moment data and visble absorption spectra support the dimeric nature of the complexes of **2c**.

The presence of a broad band in the region 550 – 600 nm in the visible spectrum of the diamagnetic nickel(II) complex indicate its planar configuration. The measured magnetic moment of the copper(II) complex of **2c** is 1.42 B.M. This value suggest appreciable antiferromagnetic interaction

Table 2.7

Characteristic ir stretching frequencies (cm^{-1}) of metal chelates of 1,5-diphenyl-3-benzoylformazan 2a, HL

Compound	Probable assignments			
	C=O	C=N	N=N	M-N
$[CuL_2]$	1652	1580	1440	540, 538
$[NiL_2]$	1650	1586	1445	535, 526
$[CoL_2]$	1645	1584	1438	545, 532

Table 2.8

Characteristic ir stretching frequencies (cm^{-1}) of metal chelates of 1-phenyl-5-(1-naphthyl)-3-benzoylformazan 2b, (HL)

Compounds	Probable assignments			
	C=O	C=N	N=N	M-N
$[CuL_2]$	1648	1605	1415	526, 548
$[NiL_2]$	1650	1612	1420	528, 542
$[CoL_2]$	1655	1605	1425	520, 538

Table 2.9

Characteristic ir stretching frequencies (cm^{-1}) of

1-phenyl-5-(2-carboxyphenyl1)-3-benzoylformazan 2C, H_2L

Compounds	Probable assignments						
	C=O benzoyl	νa (COO)	νs (COO)	C=N	N=N	M–N	M–O
$[Cu_2 L_2]$	1648	1560 1552	1402 1398	1605	1420	565 528	436 425
$[Ni_2 L_2]$	1642	1535 1548	1408 1402	1600	1435	540 532	432 422

Table 2.10

Characteristic ir data (cm^{-1}) of

1-phenyl-5-thiazolyl-3-benzoylformazan 2d, HL

Compounds	Probable assignments				
	C=O	C=N	C=N thiazolyl	N=N	M–N
$[Cu L_2]$	1650	1630	1605	1445	568
$[NiL_2]$	1655	1645	1610	1450	575
$[CoL_2]$	1665	1640	1605	1455	580

between the two copper atoms. The planar nature of the copper (II) complex is also evident from the presence of visible absorption bands at ~650 nm

NMR spectra

The ^1H nmr spectra of nickel(II) complexes fully agree with the proposed structure of the complexes. Thus the low field signals of the ligands due to the hydrogen bonded NH proton is absent in the spectra of the complexes. In the spectra of the complexes of **2c**, the signal due to the carboxyl proton disappeared indicating the replacement of the proton by metal ion. Integrated intensities of the aryl proton signal agree with their formulation.

Potentiometric studies on acidity and chelation of 1,5-diaryl-3-benzoylformazans

The proton-ligand and metal-ligand stability constants of Co(II), Ni(II), Cu(II), and Zn(II) complexes of the title compounds were determined in 50% v/v aqueous dioxane medium, the experimental are similar tothat employed for 1,5-diaryl-3-acetylformazans (chapter1).

The proton-ligand formation number $\overline{n}_A$ were calculated at various pH values from the titration curves. The pK values were calculated by half -integral and midpoint methods from the pH *vs* $\overline{n}_A$ plots (fig **2.9**). The mean values are presented in table **2.11**.

Table 2.11

The acid dissociation constants of 1,5-diaryl-3-benzoylformazans.

Compounds	pK
2a	9.15
2b	9.05
2c	9.18
	6.16
2d	9.16

The pK values of **2b** and **2c** are lower than that of **2a** and **2d** . This can be attributed to electron withdrawing tendencies of naphthyl ring and the carboxyphenyl group. The extended conjgation in their structure stabilises the anionic form and this is evidensed by the magnitude of their pK values which are significantly lower than that of **2a** and **2d**.

The observed stability constants of the metal ions considered are in agreement with the Irving-William natural order of stability[192]. The log K_n values follow an increasing trend as seen from the table **2.12** which can be correlated with the electron withdrawing effect of aryl substituents in the ligand molecules. The order of formation constants log K_1 > log K_2 is in agreement with the weakening of metal - ligand bond strength by the successive attachement of ligand molecules.

Table 2.12
Metal-ligand stability constants of 1,5-diaryl-3-benzoylformazans

Ions	Stability constants	Ligands			
		2a	2b	2c	2d
Cu^{2+}	$logK_1$	8.93	8.82	8.95	8.98
	$logK_2$	6.85	6.78	6.82	6.9
Ni^{2+}	$logK_1$	7.92	7.86	7.94	7.96
	$logK_2$	6.48	6.52	6.62	6.78
Co^{2+}	$logK_1$	6.98	6.9	6.96	6.98
	$logK_2$	6.17	6.22	6.2	6.25
Zn^{2+}	$logK_1$	7.62	7.6	7.68	7.7
	$logK_2$	6.53	6.48	6.52	6.58

Fig. 2.9 Proton-ligand formation curves for 1,5-diaryl-3-benzoylformazan

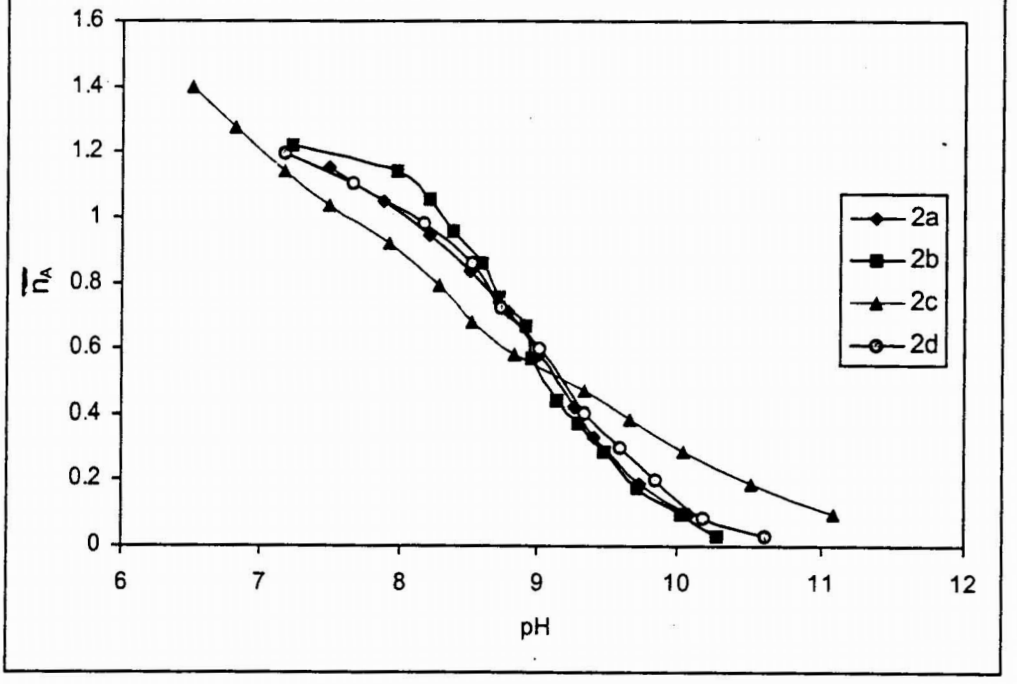


Fig. 2.10 Metal-ligand formation curves for 2a

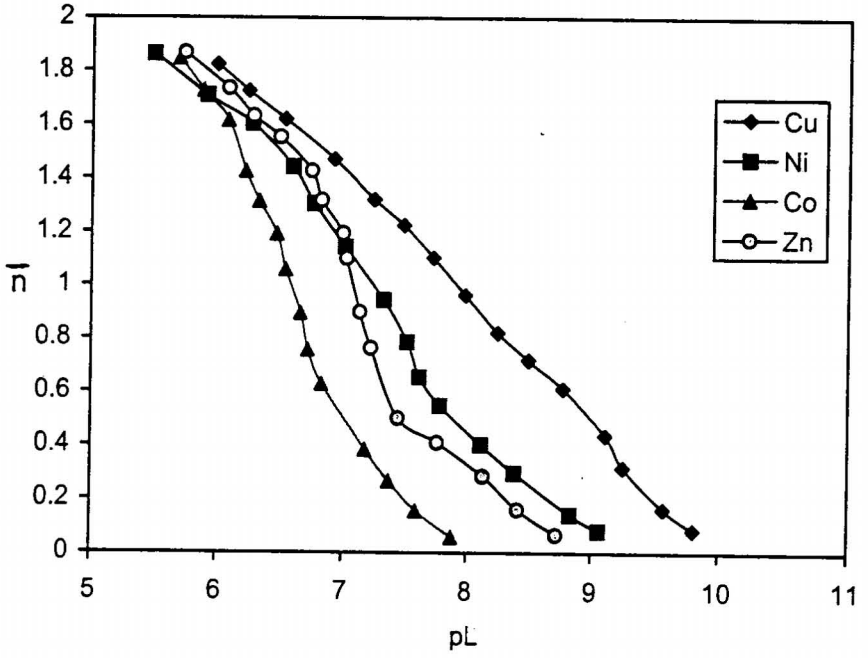


Fig. 2.11 Metal-ligand formation curves for 2b

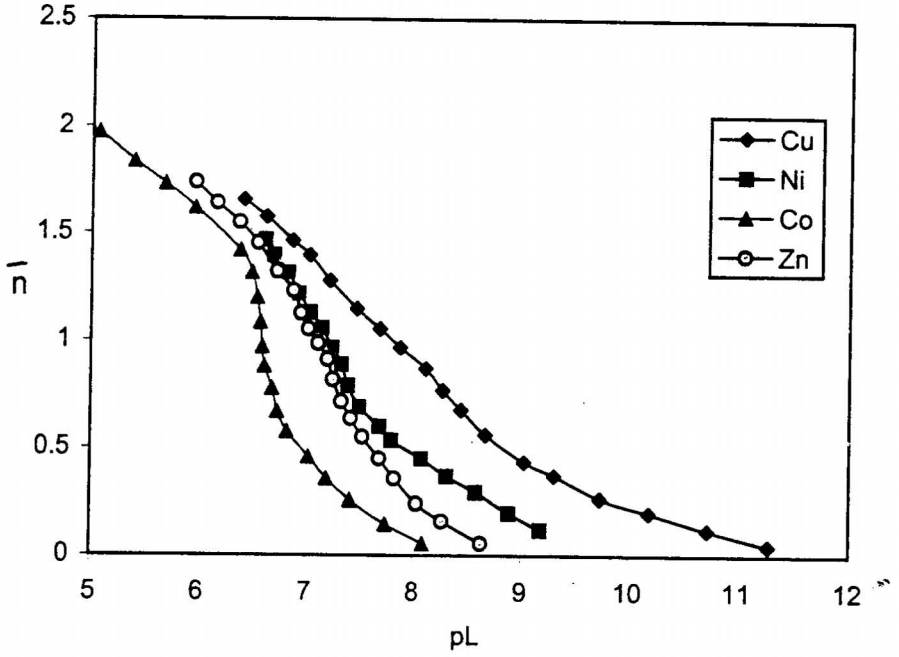


Fig. 2.12 Metal-ligand formation curves for 2c

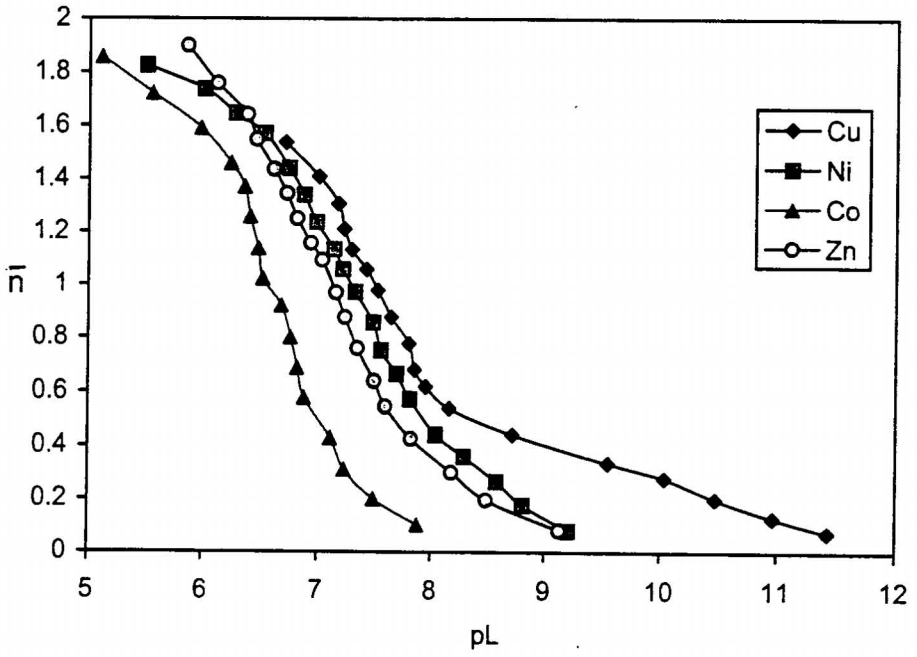
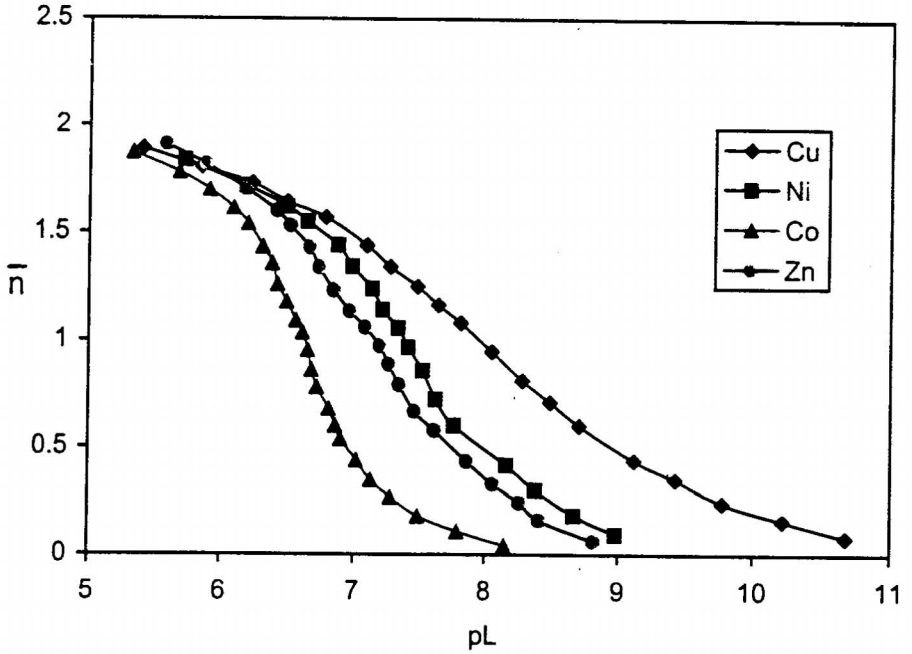


Fig. 2.13 Metal-ligand formation curves for 2d



PART II
1,5 DIARYL -3-PHENYLFORMAZANS AND THEIR METAL COMPLEXES

Abdul Rahim A.K. “Metal complexes of formazans ” Thesis. Department of Chemistry , University of Calicut, 2000

CHAPTER 3

1,5 - DIARYL -3-PHENYLFORMAZANS AND THEIR METAL COMPLEXES

Synthesis

The 1,5-diaryl-3-phenylformazans were synthesised by the reaction of aryldiazonium salt with benzaldehyde phenylhydrazone in alkaline media. Details of the synthesis are given below.

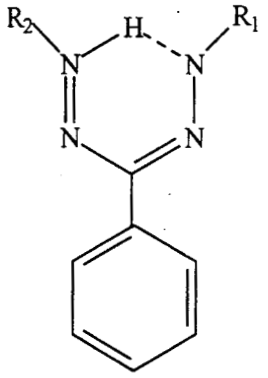
Preparation of benzaldehyde phenylhydrazone

To a solution (250 ml) of benzaldehyde (10.6 g, 0.1 mol) in aqueous ethanol (1:4) was added an ethanolic solution of phenylhydrazine (10.8 g, 0.1 mol) and the mixed solution was refluxed on a boiling water bath for about 3 h. The precipitate formed on cooling to room temperature was filtered, washed with water and recrystallised from ethanol to get pure benzaldehyde phenylhydrazone. M.P:160°C (M.P.reported[159]: 158°C).

Preparation of the formazans

The benzaldehyde phenylhydrazone (4.9g, 0.025 mol) was dissolved in methanol (400ml) and made alkaline with aqueous sodium hydroxide (0.05 N, 200 ml) and kept cooled below 5°C. To this a solution of (0.025 mol) aryldiazonium salt prepared as reported[159,194] was added slowly with stirring. The stirring was continued for about 30 min. The precipitated compound was filtered, washed with water. The product was then extracted with ether (150 ml), the ether extract was dried by anhydrous magnesium

sulphate. The ether extract on evaporation resulted pure solid formazan The following 1,5-diaryl-3-phenylformazans were synthesised



3.1

3a	C_6H_5	C_6H_5
3b	C_6H_5	$C_{10}H_7$
3c	C_6H_5	$C_6H_4(COOH)$
3d	C_6H_5	C_3H_2NS

Synthesis of metal chelates

Copper(II), nickel(II) and cobalt(II) chelates of 1,5-diaryl-3-phenylformazans were prepared by the following general method

A methanolic solution of (25 ml) the metal(II) acetate (0,01 mol) was added slowly with stirring to a solution (30ml) of the ligand (0.01 mol) in 50% v/v ethanol-methanol mixture. The mixed solution was refluxed

for ~1 hr and the volume was reduced to half. The precipitated complex on cooling to room temperature was filtered, washed with ethanol and recrystallised from hot methanol.

Results and Discussion

Characterisation of the 1,5-diaryl-3-phenylformazans

Elemental analytical data of the compounds are given in table **3.1**. All the compounds are crystalline, insoluble in water and soluble in common organic solvents. The compounds are characterised on the basis of the uv, ir, nmr, and mass spectral data.

UV spectra

Important uv absorption bands of the compounds are given in table 3.1. Based on the spectra of the compounds considered in chapter 1 and 2, these absorptions can be assigned as due to the N=NH and C=N-N groups of the formazyl structure.

Ir spectra

Ir spectra of all the compounds show a broad band in the region 2500 – 3500 cm^{-1} presumably due to the intramolecularly hydrogen bonded NH proton as in structure **3.1**.

A medium intensity band is observed at ~ 1650 cm^{-1} in the spectra of all the compounds can be assigned as due to the C=N group . Several bands appeared in the region 1550-1610 cm^{-1} are due to the aromatic C=C stretching

Table 3.1

Physical, analytical and electronic spectral data of 1,5-diaryl-3-phenylformazans

Compounds	M.P. °C	Elemental analysis found (calcd.) %.			λmax (nm)
		C	H	N	
3a	155	76.89 (76.00)	5.89 (5.33)	19.01 (18.33)	485 348 277
3b	168	79.23 (78.85)	4.89 (5.14)	16.05 (16.09)	513 295 262
3c	180	70.01 (69.76)	5.01 (4.65)	17.01 (16.27)	481 289
3d	136	64.01 (62.54)	4.81 (4.23)	23.1 (22.80)	443 310

vibrations. From a comparison of the spectra of compound considered in chapter 1 and chapter 2 the band observed at ~1440 cm^{-1} can be assigned to $\nu_{N=N}$. The spectrum of **3c** shows a strong band at 1698 cm^{-1} due to its stretching of carboxyl group. In the case of **3d** an additional band appeared at 1620cm^{-1} assignable to the $\nu_{C=N}$ of the thiazole ring. Important ir bands and their assignments are give in table **3.2.**

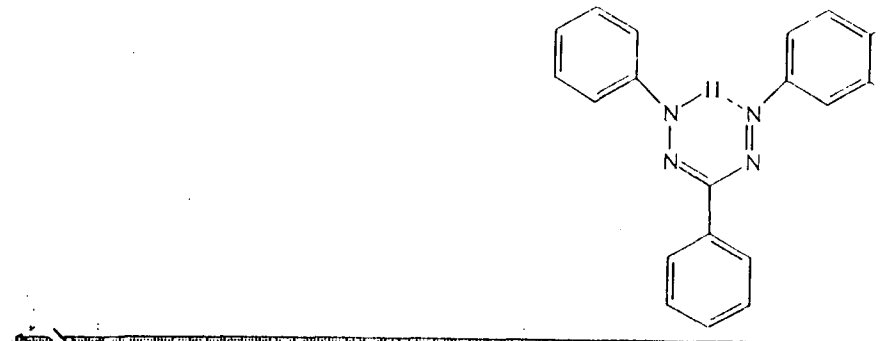
Table 3.2

Ir stretching bands (cm^{-1}) of 1,5- diaryl-3-phenyl formazans

Compounds				Probable
3a	**3b**	**3c**	**3d**	Assignments
1598,1592	1600,1590	1605,1598	1598,1593	C=C
1585	1588	1592,1588	1588,1585	
1440	1430	1458	1450	N=N
1620	1626	1630	1635 1620	C=N
		1698		C=O (carboxyl)

NMR Spectra

The proton nmr spectra of the compounds are brought out in figures **3.1-3.4**. The involvement of the NH proton in strong intramolecular hydrogen bonding is evident from the position of the low field signal above



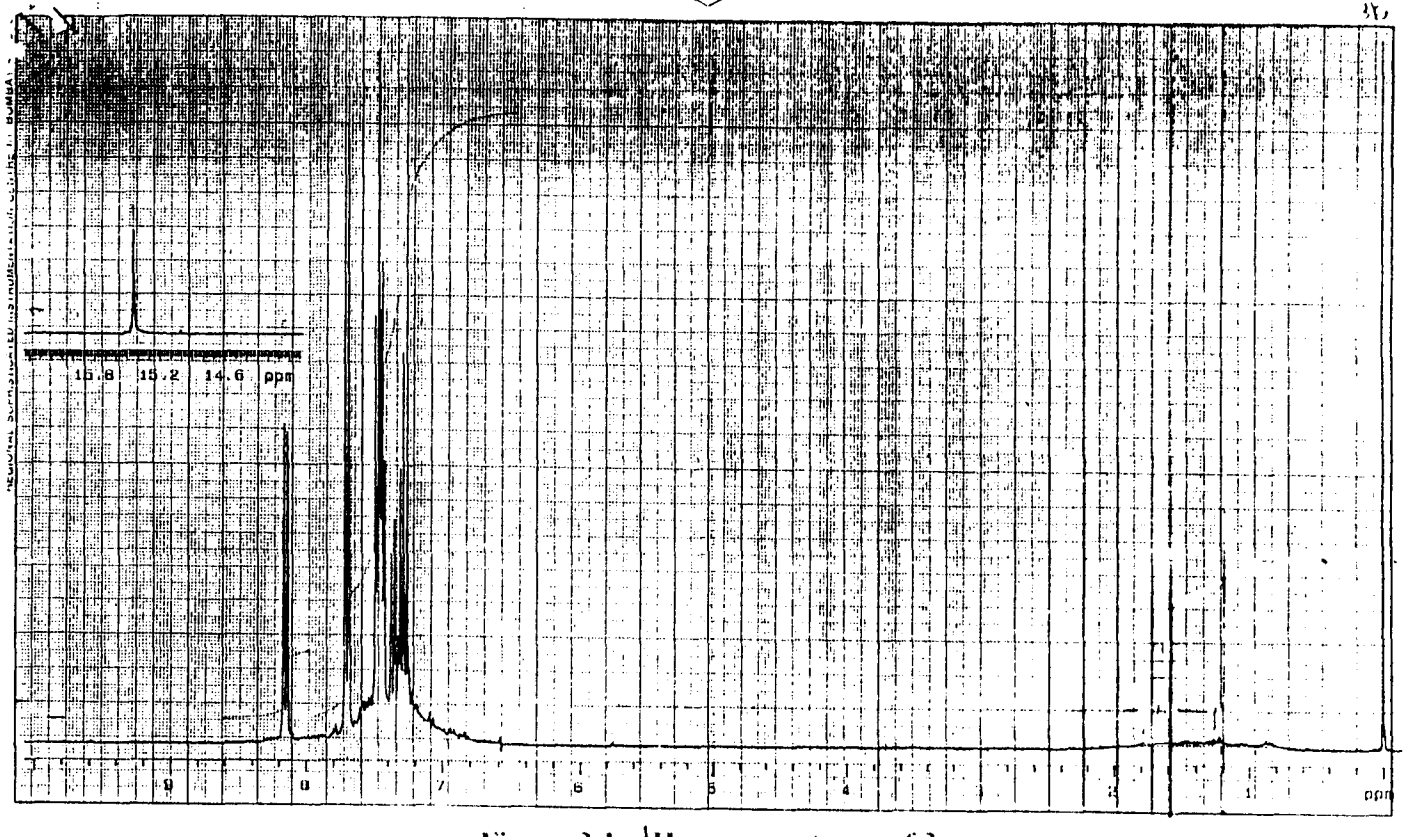
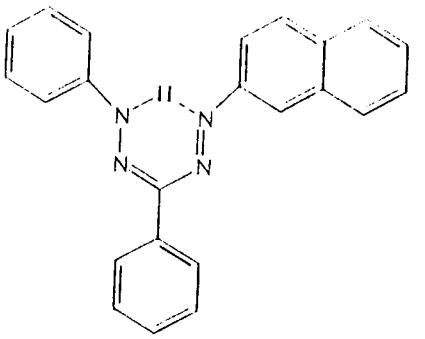


Figure 3.1 ^{1}H nmr spectrum of 3a



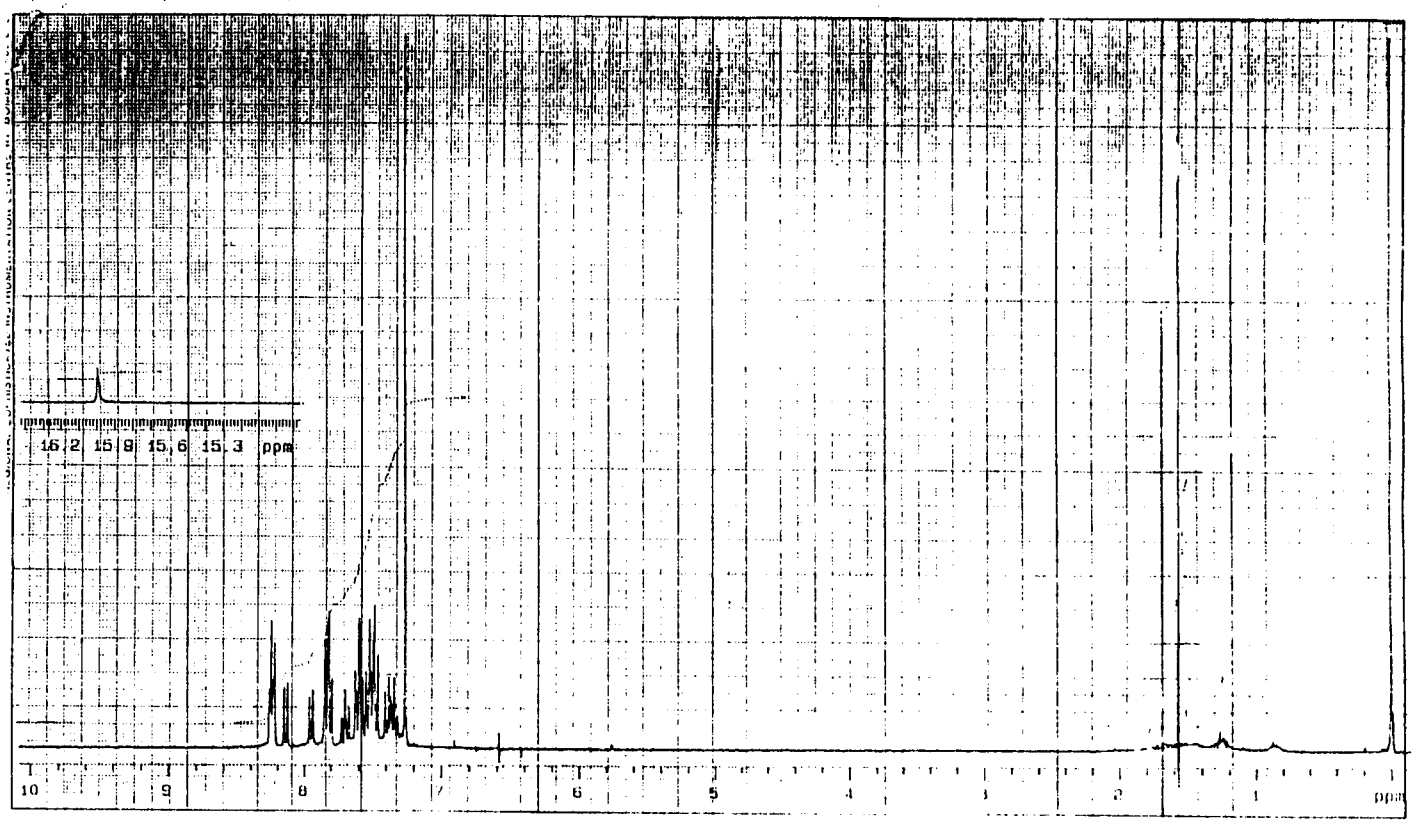


Figure 3.2 ^{1}H nmr spectrum of 3b

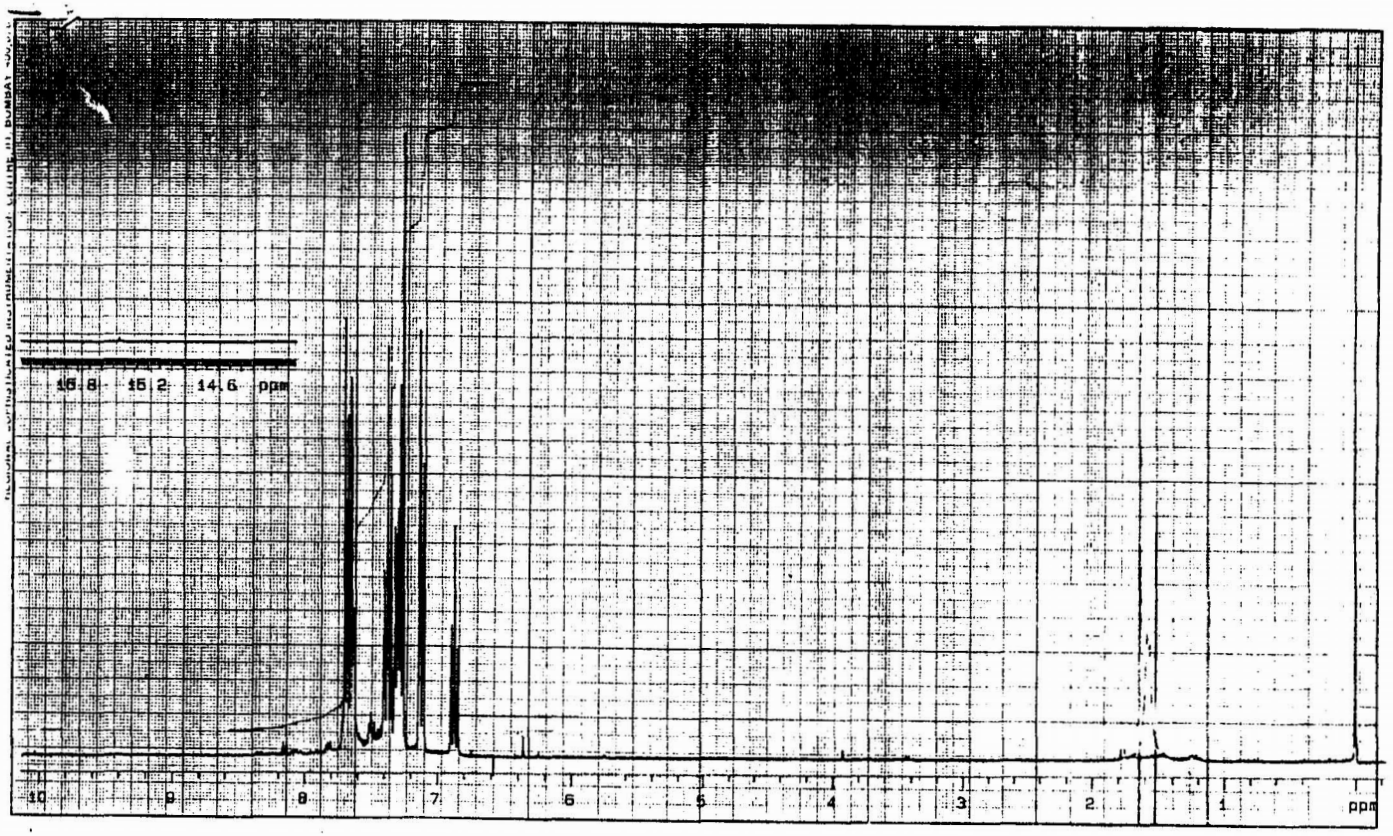
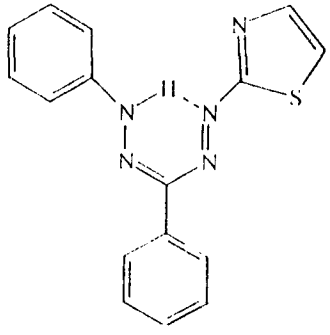


Figure 3.3 ^{1}H nmr spectrum of 3c



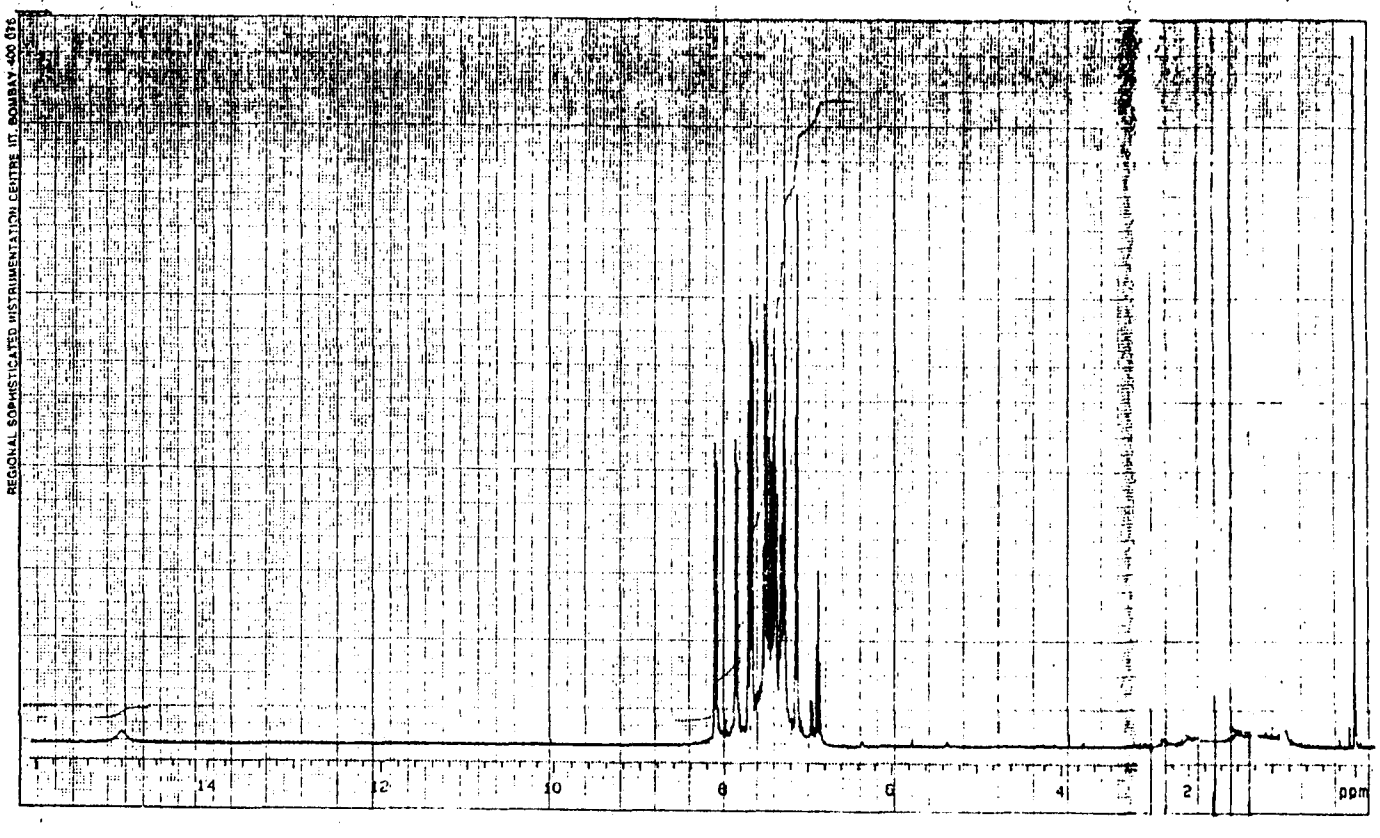


Figure 3.4 ^{1}H nmr spectrum of 3d

15 δ in all the compounds. Spectra of **3c** shows two low field one proton signal due to the hydrogen bonded NH and COOH proton.

In the ^{13}C nmr spectrum of **3a** is given in figure **3.5**. The number and positions of the signals are as expected of the structure **3.1**.

Mass Spectra

Mass spectra of all the compounds (figure **3.6-3.9)** show peaks due to the parent ion P^+ / $(P + 1)^+$. Other characteristic peaks are due to the elimination of phenyl, aryl groups, N_2 from the molecular ion and C_6H_5NH, $C_6H_5N_2$, C_6H_5. The origin of the prominent peaks can be explained by considering the fragmentation pattern as in scheme **3.1**.

Characterisation of metal complexes

Physical and analytical data of the complexes are given in tables **3.3 - 3.6**. The data show that **3a** and **3b** behaves as monobasic bidentate while **3c** as dibasic tridentate and **3d** as monobasic tridentate. The observed eletronic, ir, nmr and mass spectral data are in accord with the structure **3.2-3.3**. The spectral data are discussed below.

Ir Spectra

A striking difference between the spectra of the metal complexes and the spectra of the ligands is the absence of the broad band in the region 2500-3500 cm^{-1} in the former spectra. This indicate the replacement of the NH proton by metal ion (in the case of **3c** the carboxylic proton also replaced by

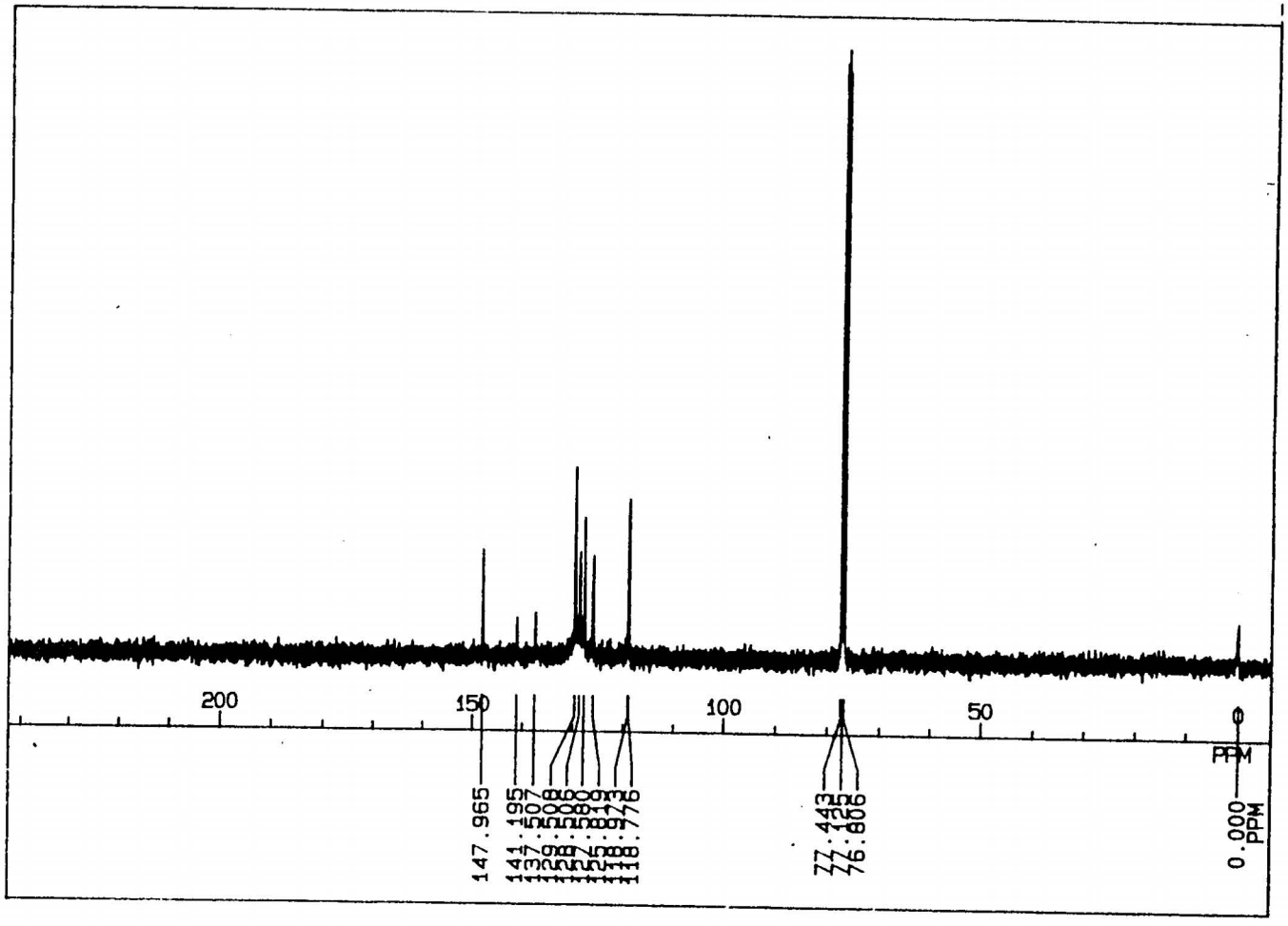
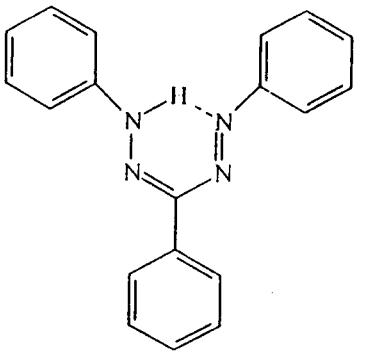


Figure 3.5 ^{13}C nmr spectrum of 3a



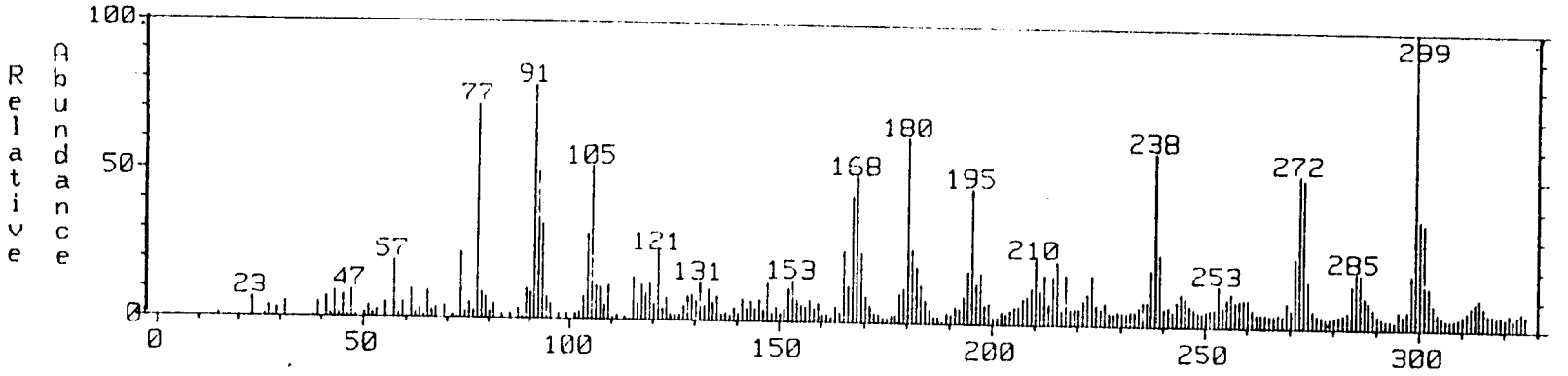


Figure 3.6 Mass spectrum of 3a

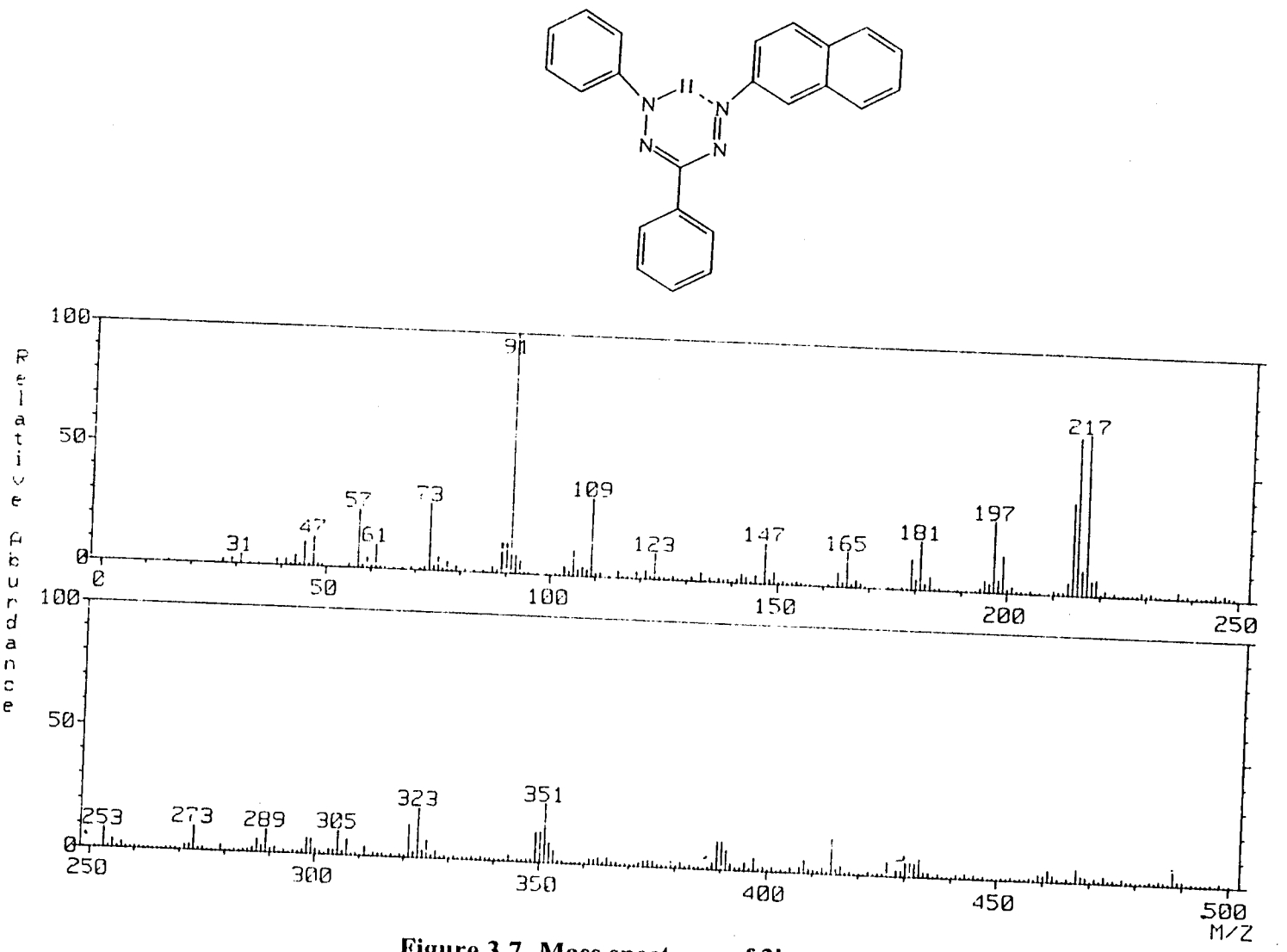


Figure 3.7 Mass spectrum of 3b

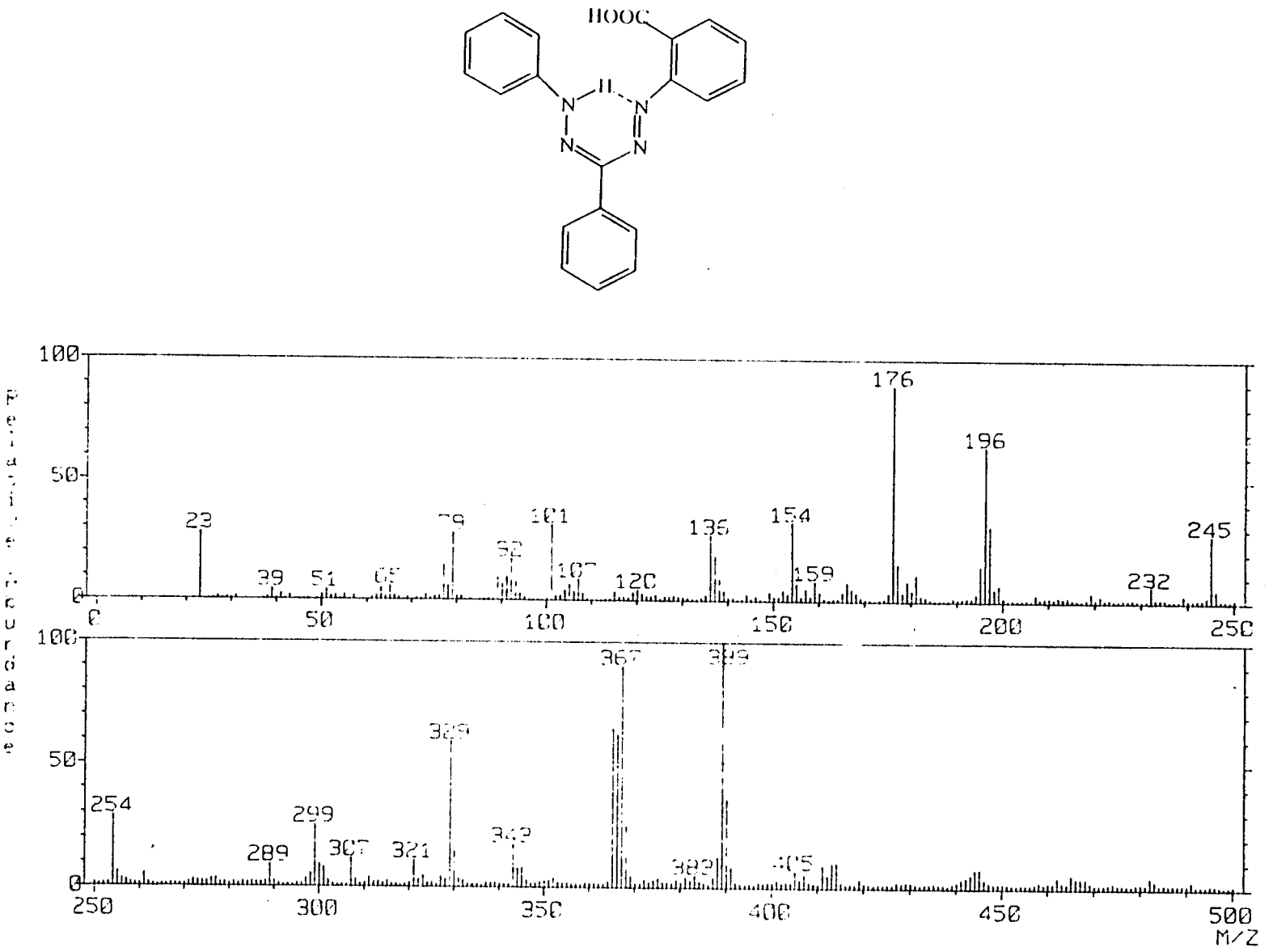


Figure 3.8 Mass spectrum of 3c

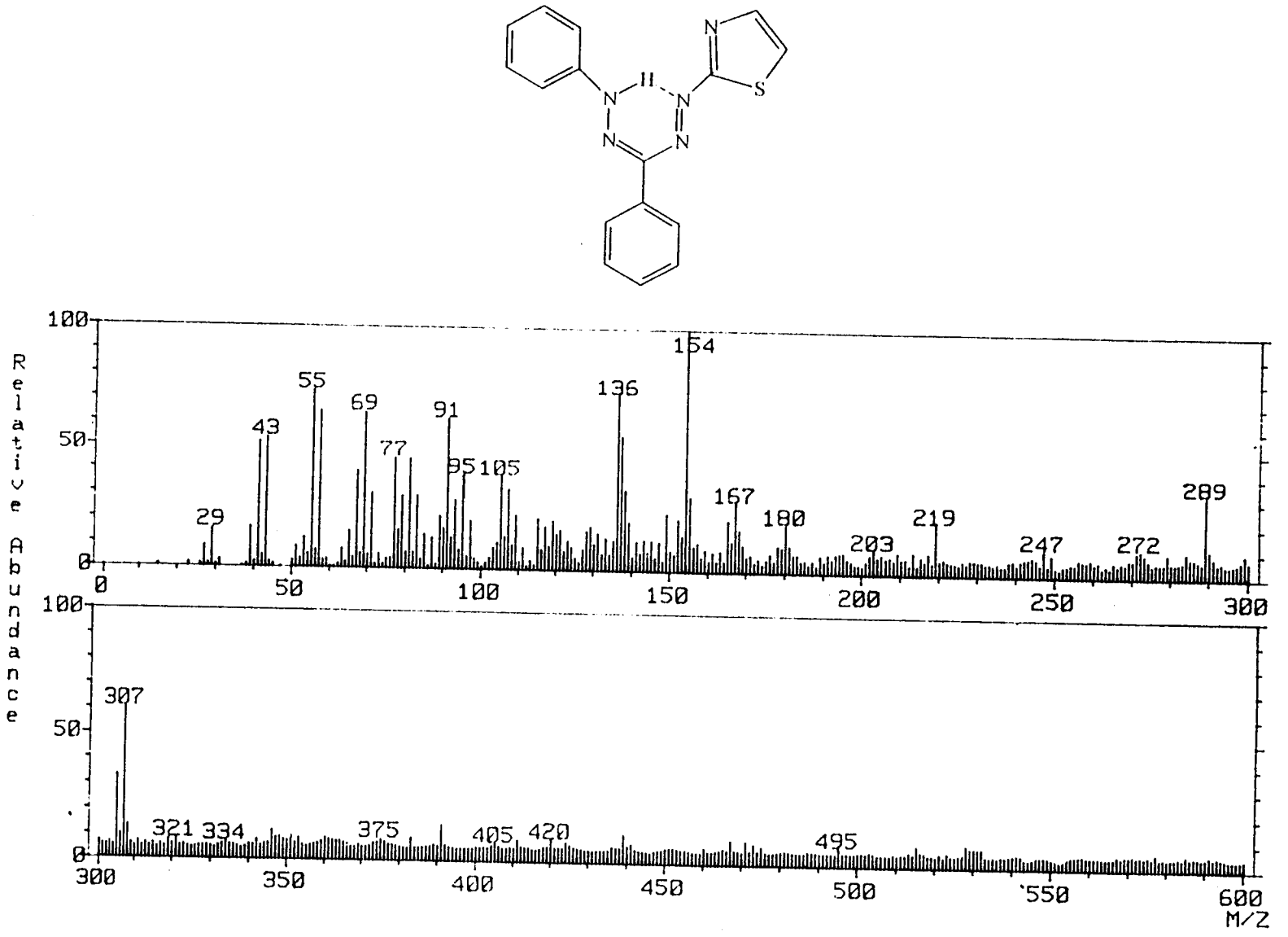
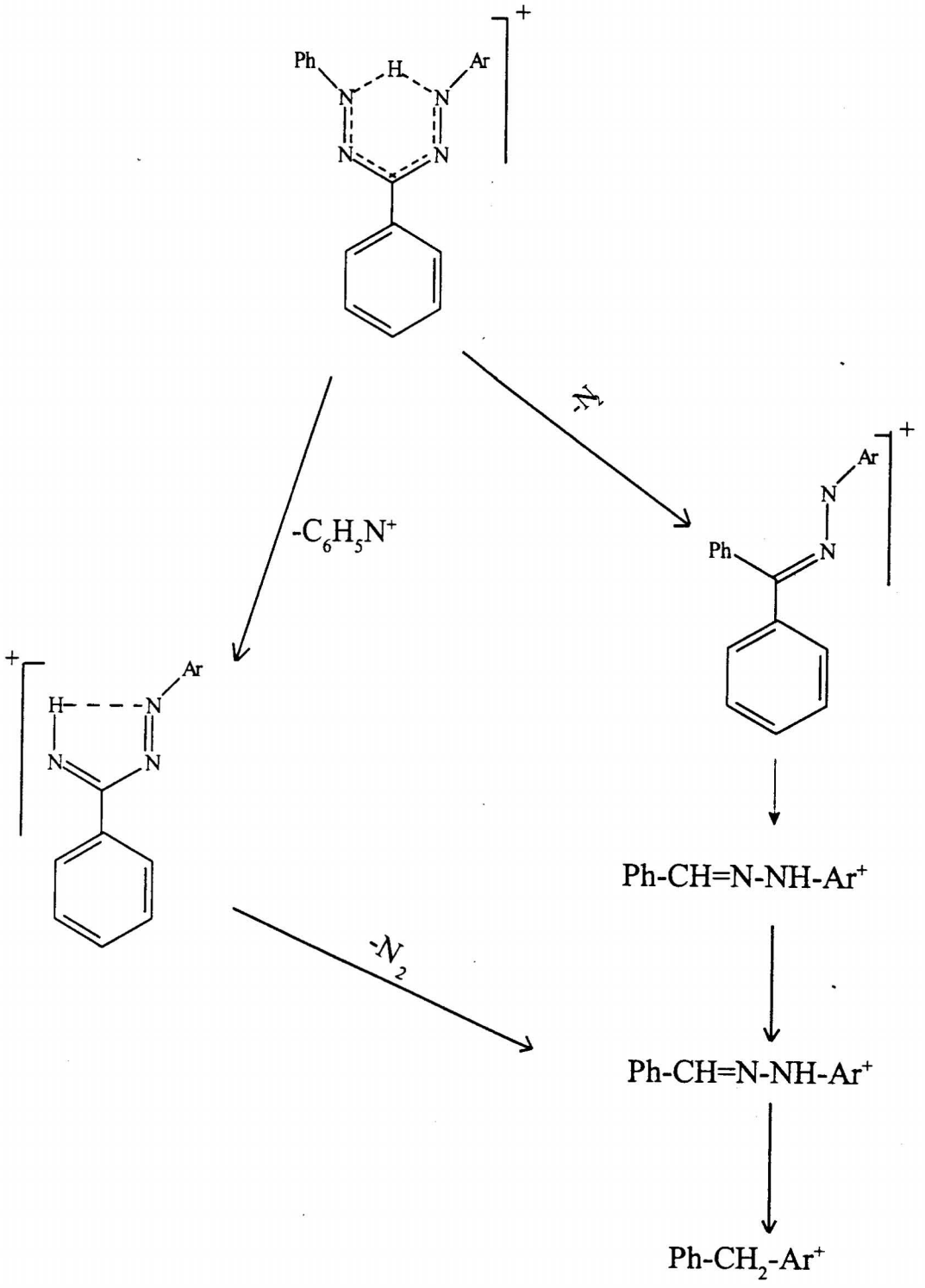


Figure 3.9 Mass spectrum of 3d


Ph
H
Ar
N
N
N
N
+
-N2
-C6H5N+
Ar
N
Ph
N
+
H
N
N
N
Ar
+
Ph-CH=N-NH-Ar+
-N2
Ph-CH=N-NH-Ar+
Ph-CH2-Ar+

Schemed 3.1

Table 3.3

Physical, analytical and electronic spectral data of metal chelates of 1,5-diphenyl-3-phenylformazan (3a) HL

	M.P °C	Elemental analysis found (calcd) %				λmax nm
		C	H	N	Metal	
$[CoL_2(H_2O)_2]$	>300	68.9 (69.41)	4.81 (4.566)	16.95 (17.4)	8.25 (8.96)	500 341
$[NiL_2]$	>270	68.65 (69.43)	4.81 (4.56)	16.84 (17.05)	8.26 (8.93)	786 322
$[CuL_2]$	>280	67.94 (68.93)	4.75 (4.53)	16.20 (16.93)	8.95 (9.60)	351 310

Table 3.4

Physical, analytical and electronic spectral data of metal chelates of 1-phenyl-5- (1- naphtyl) 3-phenylformazan (3b) HL

Compounds	M.P °C	Elemental analysis found (calcd) %				λmax nm
		C	H	N	Metal	
$[CoL_2(H_2O)_2]$	>300	58.54 (59.71)	3.54 (3.73)	14.01 (13.99)	15.41 (14.65)	500 341
$[NiL_2]$	>300	58.94 (59.74)	3.85 (3.73)	14.52 (13.94)	15.82 (14.61)	658 282
$[CuL_2]$	>300	58.94 (59.03)	4.01 (3.68)	14.89 (13.77)	14.91 (15.62)	603 383 289

Table 3.5
Physical, analytical and electronic spectral data of metal chelates of 1phenyl-5-(2-carboxy phenyl) -3-phenylformazan (3c) H_2L

Compounds	M.P. °C	Elemental analysis found (calcd) %				λmax nm
		C	H	N	Metal	
$[Ni_2 L_2]$	≥250	71.84 (72.94)	(5.01) (4.49)	15.41 (14.8)	8.41 (7.75)	452 309 260
$[Cu_2 L_2]$	>300	71.94 (72.48)	4.31 (4.46)	15.54 (14.70)	9.12 (8.34)	498 295 261

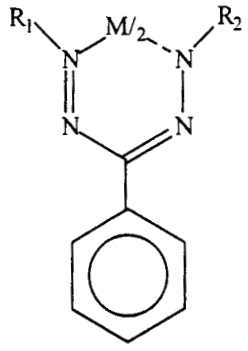
Table 3.6
Physical, analytical and electronic spectral data of metal chelates of 1-phenyl-5(2-thiazolyl)-3-phenylformazan (3d) HL

Compounds	M.P °C	Elemental analysis found/ (calcd) %					λ_{max} nm
		C	H	N	Metal	S	
$[CoL_2(H_2O)]$	200	58.9 (57.23)	3.48 (3.57)	21.04 (20.86)	9.01 (8.77)	19.84 (9.53)	721 310
$[NiL_2]$	210	58.45 (57.25)	4.01 (3.57)	21.45 20.87	9.45 (8.75)	9.41 (9.54)	616 310
$[CuL_2]$	180	55.41 (56.84)	3.21 (3.55)	21.54 (20.72)	8.54 (9.40)	8.56 (9.47)	643 327

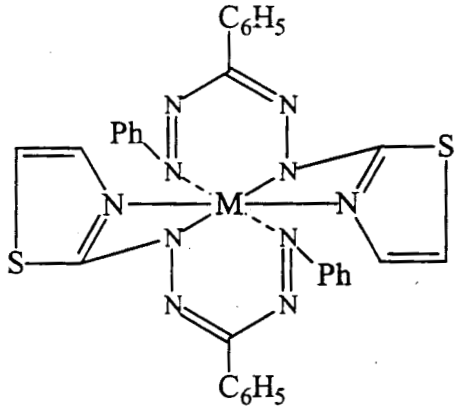
metal ion). In the double bond region the $\nu_{C=N}$ $\nu_{N=N}$ bands shifted significantly to lower values (~20-50 cm) in the spectra of complexes compared to that of the ligands. However the spectra of complexes of **3c**, suggest the involvement of both the oxygen in complexation as in structure. Spectra of all the complexes displayed band assignable to M-N in the far ir region. Important bands and their assignments are given in tables **3.7-3.10.**

Nmr Specra

The low field signal in ^1H nmr of the free ligands disappeared in the spectra of the diamagnetic Nickel(II) complexes of **3a** and **3b** thereby confirming the replacement of the NH proton by metal. The carboxyl proton of **3c** also absent in the spectrum of the complex. The aryl proton signals are shifted to low field (figure **3.10 - 3.12**).



3.2



3.3

The FAB mass spectrum of the Cu^{2+} complexes of 3a is in full agreement with the CuL_2 formulation of the compound (figure **3.13**)

Table 3.7

Characteristic ir stretching bants (cm^{-1}) of metal chelates of 3a HL

Compound	Probable assignments			
	C=N	C=C	N=N	M-N
$[CuL_2]$	1600	1570	1410	540
$[NiL_2]$	1610	1545	1400	530
$[CoL_2 (H_2O)_2]$	1615	1550	1420	545

Table 3.8

Characteristic ir stretching bands (cm^{-1}) of metal chelates of 3b, HL

Compounds	Probable assignments			
	C=N	N=N	C=C	M-N
$[CuL_2]$	1565	1420	1480	590
$[NiL_2]$	1585	1480	1470	588
$[CoL_2]$	1590	1410	1485	570

Table 3.9

Characteristic ir stretching bands (cm^{-1}) of metal chelates of 3C, H_2L

Compounds	Probable assignments			
	C=O carboxyl	C=N	N=N	M-N
$[Cu_2 L_2]$	1660	1625	1425	565
$[Ni_2 L_2]$	1665	1620	1430	580

Table 3.10

Characteristic ir stretching bands (cm^{-1}) of metal chelates of 3d, HL

Compounds	Probable assignments			
	C=N	C=N thiazolyl	N=N	M-N
$[Cu L_2]$	1610	1605	1430	568
$[NiL_2]$	1615	1610	1435	585
$[CoL_2]$	1620	1605	1430	580

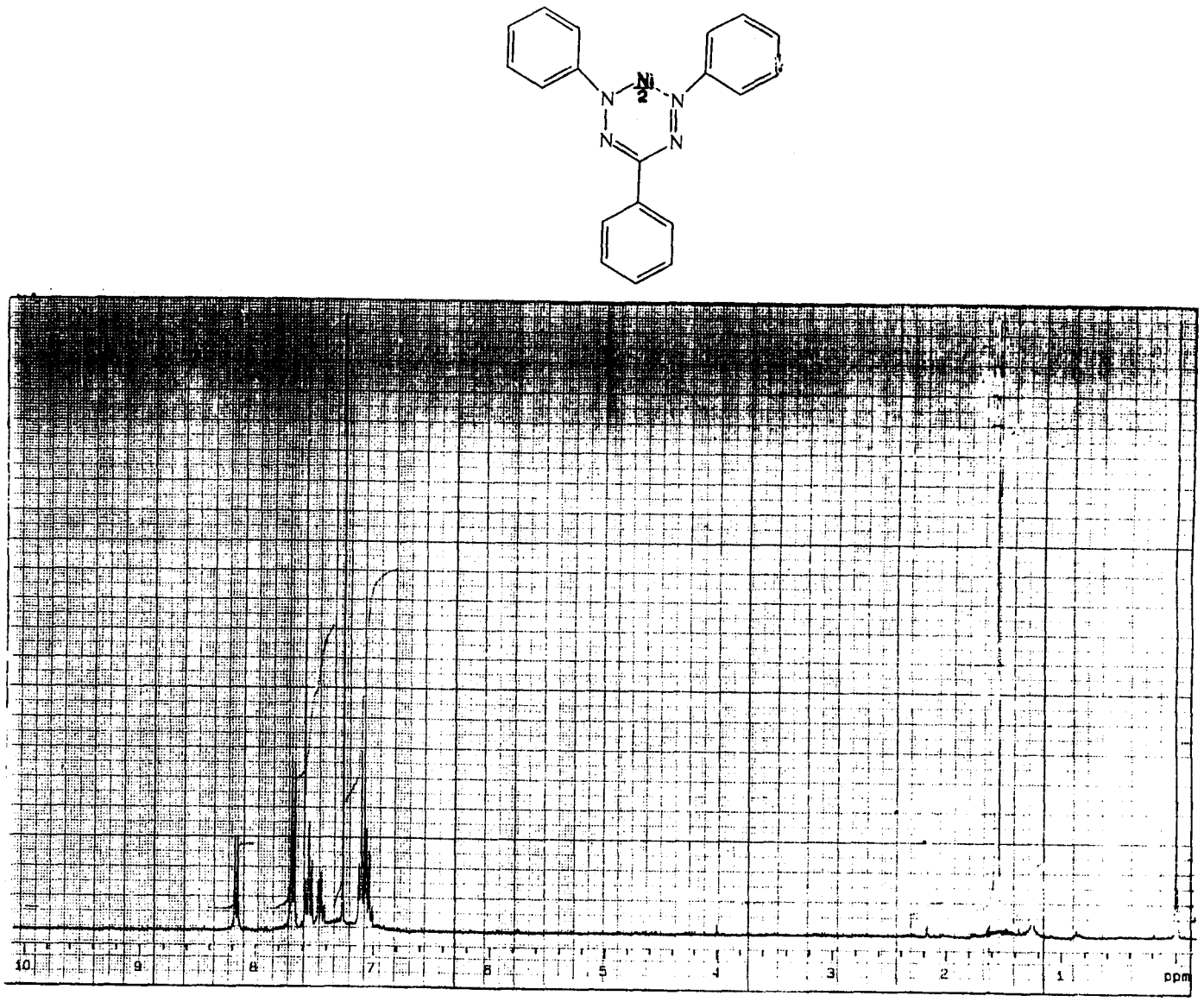


Figure 3.10 ^{1}H nmr spectrum of Nickel(II) complex of 3a

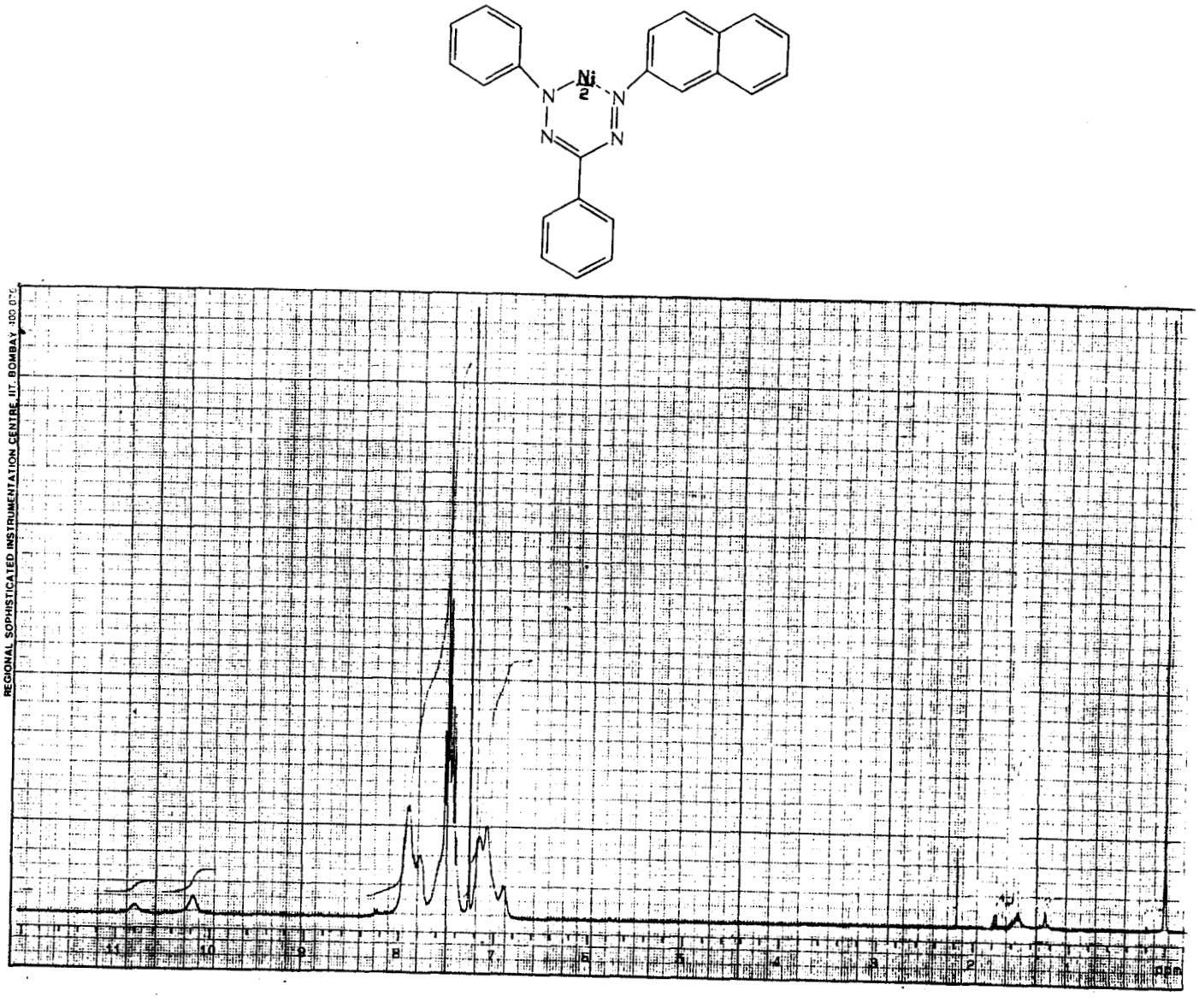


Figure 3.11 ^{1}H nmr spectrum of Nickel(II) complex of 3b

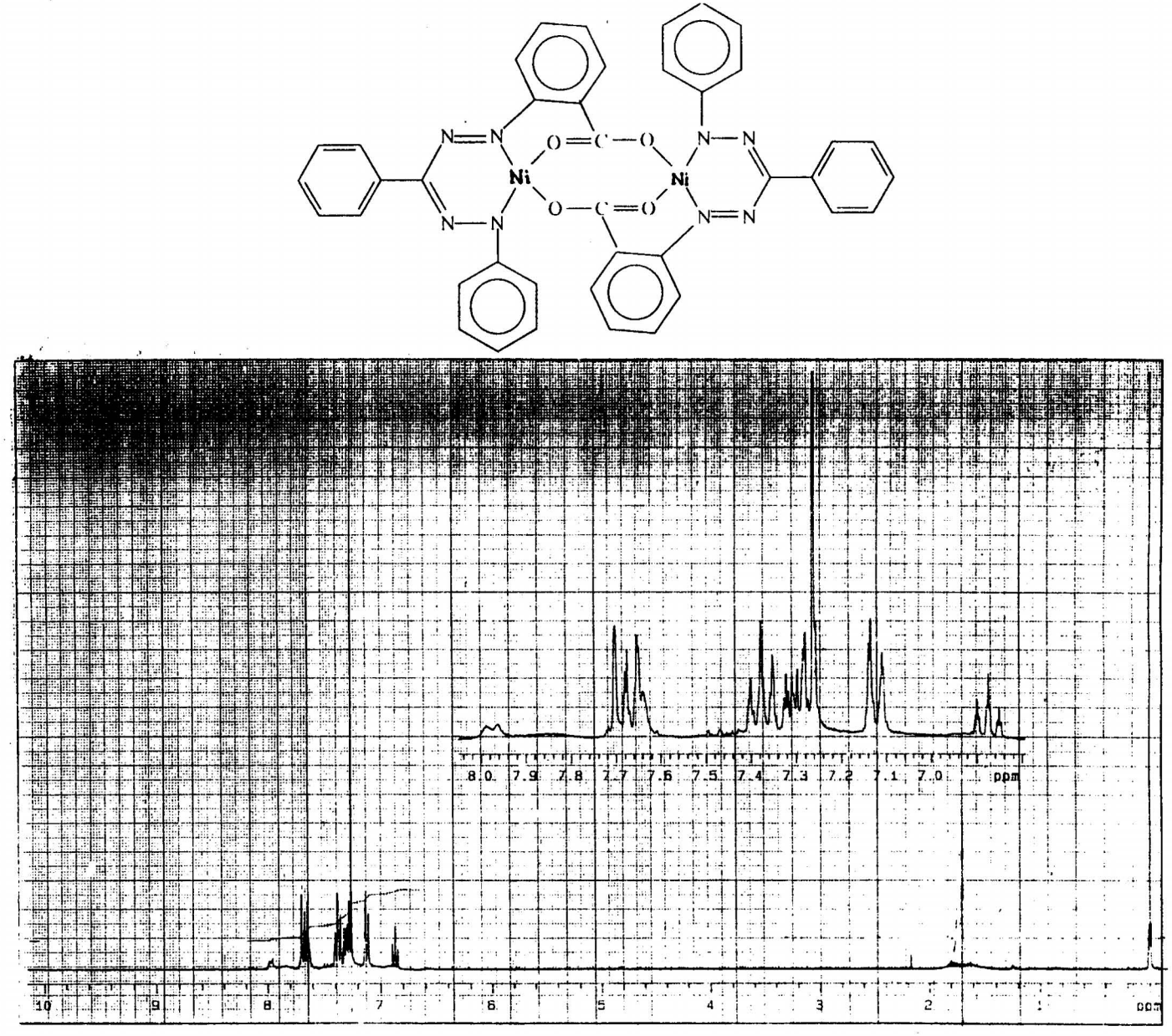


Figure 3.12 ^{1}H nmr spectrum of Nickel(II) complex of 3c

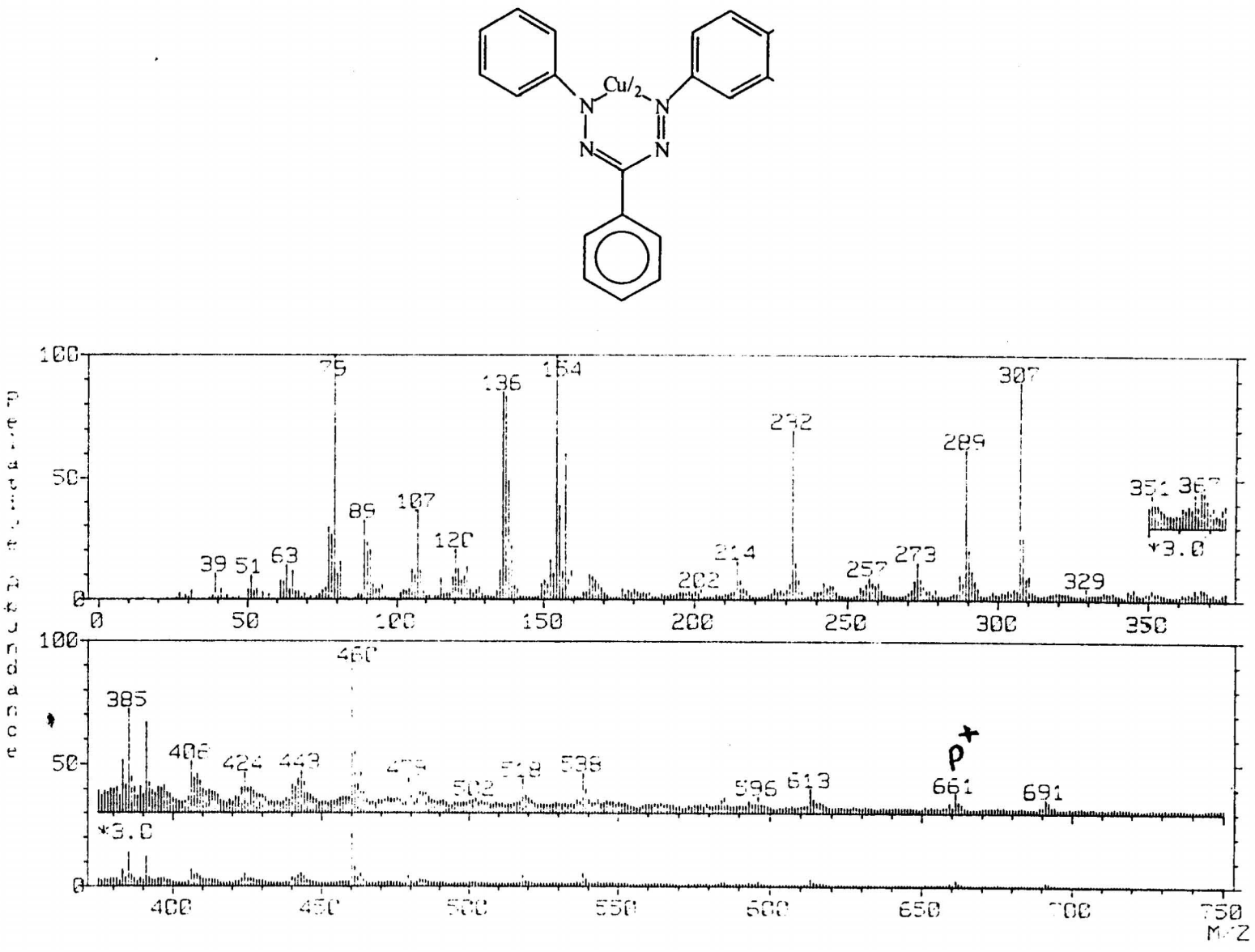


Figure 3.13 Mass spectrum of Cu(II) complex of 3a

Potentiomeric studies on acidity and chelation of 1,3-diaryl-3-phenylformazan

The proton-ligand and metal-ligand stability constants of 1,5-diaryl-3-phenylformazan with Co^{+2}, Ni^{2} and Cu^{+2} ions in 50% v/v aqueous dioxane medium were determined by the pHmetric titration technique as reported by Irving and Rossotti[191]. The experimental details are as given in chapter 1.

The proton-ligand formation number n_A were calculated at various pH values from the titration curves obtained by plotting vs volume of alkali added. The acid dissociation constant (pK) were calculated by half-integral and mid-point calculation methods from the pH vs n_A plots fig **3.14** and the average values are presented in table **3.11**.

The pK values of **3b** and **3c** are lower than **3a** and **3d** indicates greater acidity of **3b** and **3c** which can be correlated with the electronic effects exerted by the aryl substituents.

The observed stability constants follow the Irving-William natural order[180]. The magnitude of $\log K_n$ values of **3b** and **3c** show an increasing trend and this can also be attributted to the elecron withdrawing tendenicies of the substitutuents in the aryl ring. The observed order of formation constants $\log K_1 > \log K_2$ (table **3.12**) suggest a decrease in bond strength

due to sterric effect associated with the successive attachement of ligand molecules.

Table 3.11

The acid dissociation constants of 1,5-diaryl-3-phenylformazans

compounds	pK
3a	9.38
3b	9.30
3c	9.25
	6.18
3d	9.32

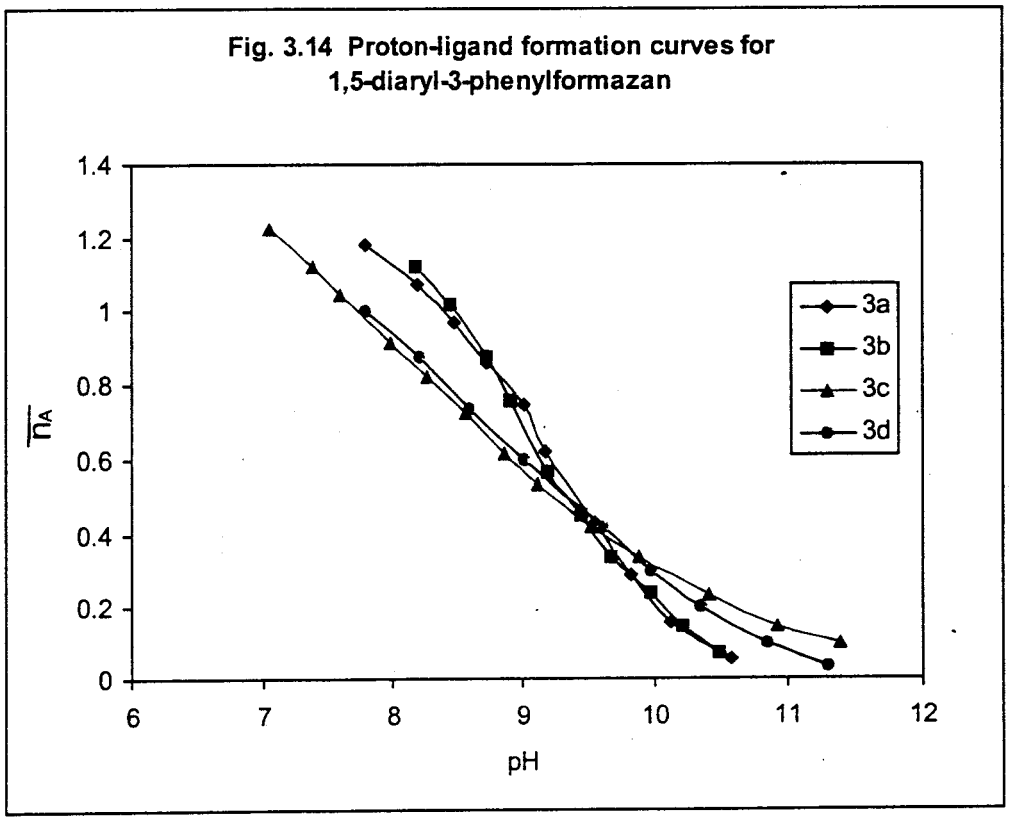


Fig. 3.14 Proton-ligand formation curves for 1,5-diaryl-3-phenylformazan

Fig. 3.15 Metal-ligand formation curves for 3a

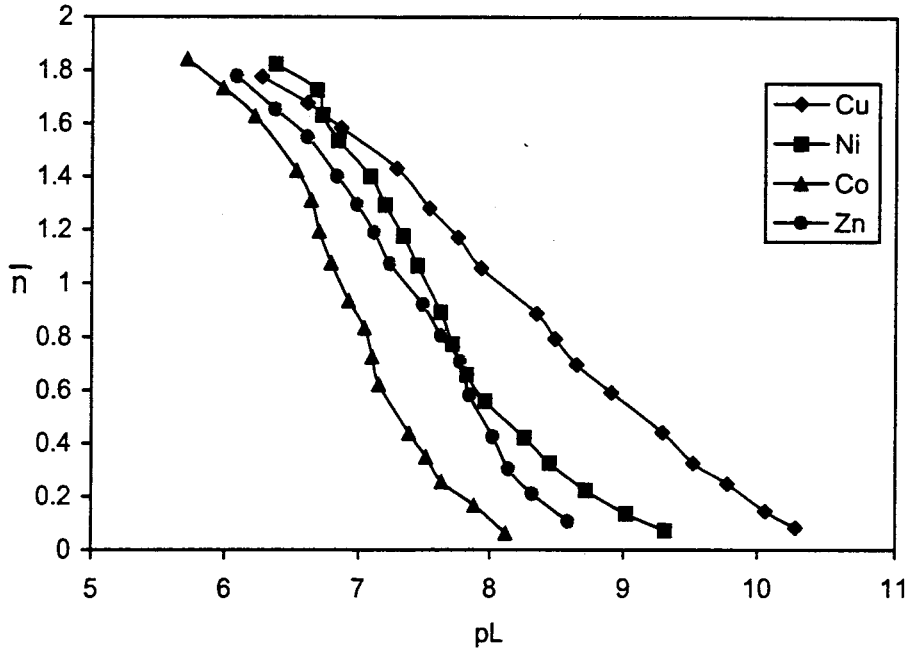


Fig. 3.16 Metal-ligand formation curves for 3b

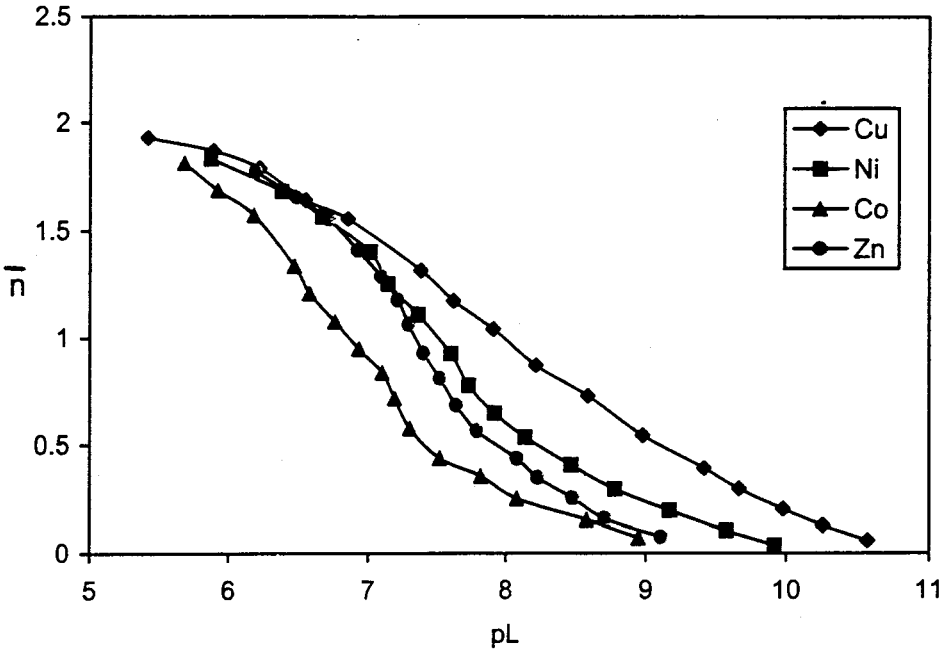


Fig. 3.17 Metal-ligand formation curves for 3c

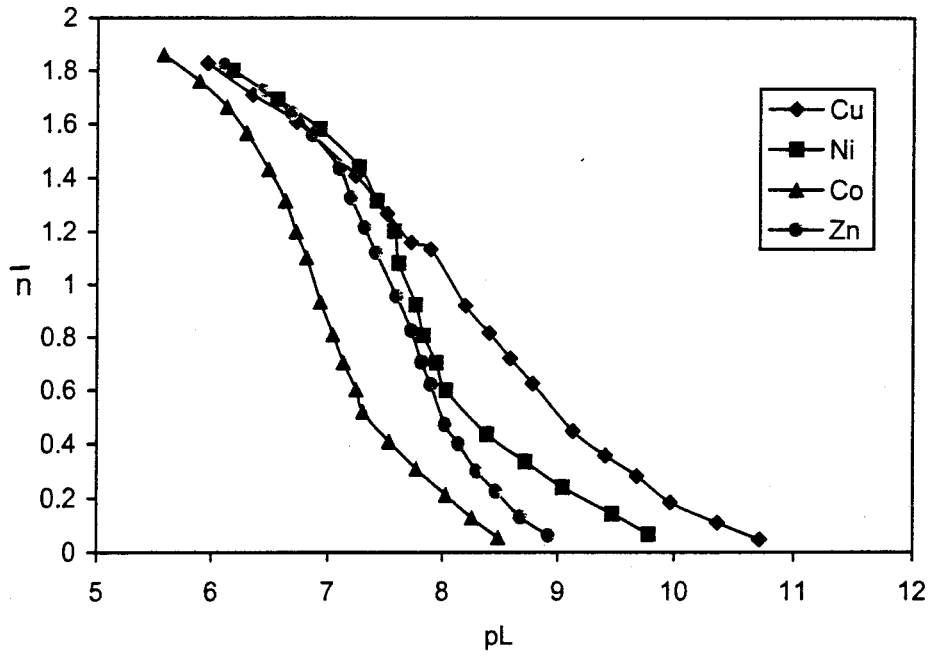


Fig. 3.18 Metal-ligand formation curves for 3d

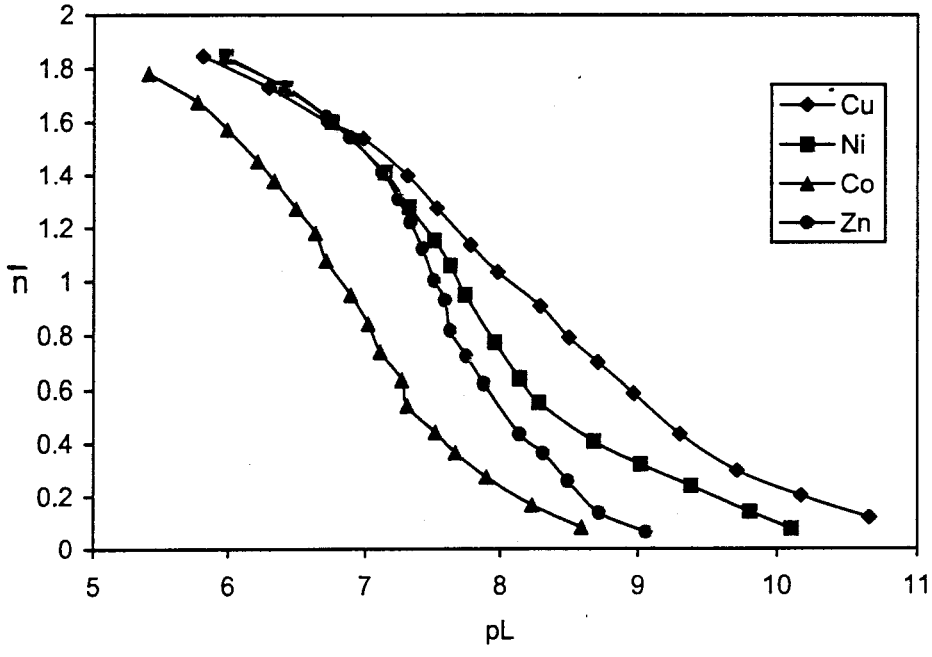


Table 3.12

Metal-ligand stability constants of 1,5-diaryl-3-phenylormazans

Metal(ii) ions	Stability constants	Ligands			
		3a	3b	3c	3d
Cu^{2+}	$logK_1$	9.12	9.1	9.05	9.12
	$logK_2$	7.1	6.95	7.01	7.14
Ni^{2+}	$logK_1$	8.08	8.21	8.2	8.42
	$lofK_2$	6.9	6.84	7.12	6.95
Co^{2+}	$logK_1$	7.27	7.4	7.35	7.4
	$logK_2$	6.42	6.28	6.4	6.18
Zn^{2+}	$logK_1$	7.9	7.95	7.96	8.05
	$logK_2$	6.72	6.8	6.95	7.01

PART II
1,5-DIARYL-3-(2-HYDROXYPHENYL) FORMAZANS AND THEIR METAL COMPLEXES

Abdul Rahim A.K. “Metal complexes of formazans ” Thesis. Department of Chemistry , University of Calicut, 2000

CHAPTER 4

1,5-DIARYL-3-(2-HYDROXYPHENYL) FORMAZANS AND THEIR METAL COMPLEXES

Synthesis

The compounds were synthesised by the reaction of phenylhydrazone of salicylaldehyde with aryldiazonium salts.

Preparation of salicylaldehydephenylhydrazone

A solution of salicylaldehyde (12 g, 0.1mol) in 75%v/v ethanol-water mixture (250ml) was mixed with an ethanolic solution (250 ml) of phenyl hydrazine (12.2g, 0.1 mol) and refluxed on boiling water bath for about 3 h. The precipitate formed on cooling to room temperature was filtered, washed with water, recrystallised from ethanol. MP:144 °C (reported[159] 142 °C).

Preparation of the formazan

The aryldiazonium salts of aniline, 1-aminonaphthalene, anthranilic acid and 2-aminothiazole were prepared as reported[159,194].

The diazonium salt solution (0.025mol) was added slowly with stirring to an ice cooled aqueous methanolic solution of the salicylaldehyde phenylhydrazone (400ml) containing also sodium hydroxide (10.5 g). Stirring was continued for about 1 h. The precipitate formed was filtered, washed with water and extracted into ether. The ether extract was dried

using anhydrous magnesium sulphate. On evaporation of ether, pure formazan was obtained.

Synthesis of metal chelates

The 1,5-diaryl-3-(2-hydroxyphenyl) formazan (0.025 mol) was extracted into a boiling methanolic solution (150 ml) of metal(II) acetate (0.05mol) and glacial acetic acid (1 ml). When the extraction was complete, the precipitated metal complex was separated, washed with the boiling methanol and dried. Recrystallised from methanol.

Results and Discussion

Characterisation of 1,5-diaryl-3-(2-hydroxyphenyl)formazans

The C, H, N percentages of the compounds along with other physical data are given in table **4.1**. Uv, ir, nmr and mass spectral data of the compounds are consistent with structure **4.1.**

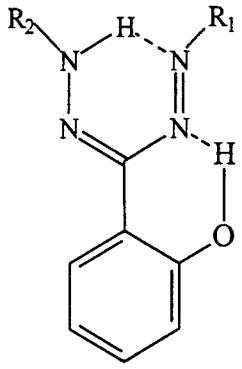
The uv spectra of all the compounds show broad absorption maxima at about 380 and 300 nm due to the various chromophoric groups present in the compounds.

The ir spectra of the compounds display a broad band extending the range 2400 – 3800 cm^{-1}. The observed breadth and intensity of the band indicate the involvement of the phenolic OH group also in hydrogen bonding in addition to the N-H···N hydrogen bonded system of the formazans as in structure **4.1**.

Table 4.1

Physical, analytical and electronic spectral data of the 1,5-diaryl-3-(2-hydroxyphenyl)formazans

Compounds	M.P °C	Elemental analysis found/ (calcd) %			λmax (nm)
		C	H	N	
4a	110	73.54 (72.15)	5.65 (5.63)	18.01 (17.72)	381 262
4b	140	78.01 (76.66)	5.01 (4.91)	16.85 (15.30)	309 244
4c	135	65.41 (66.66)	4.01 (4.44)	16.41 (15.55)	380 310
4d	125	60.51 (59.44)	3.98 (4.02)	20.58 (21.67)	386 242



4.1

Compound	R_1	R_2
4a	C_6H_5	C_6H_5
4b	C_6H_5	$C_{10}H_7$
4c	C_6H_5	$C_6H_4(COOH)$
4d	C_6H_5	C_3H_2NS

Presence of an OH group on the phenyl ring brought out only marginal shift in the stretching frequency of C=C and N=N as evidenced from a comparison of the spectra with the spectra of compounds discussed in chapter 3. However the C=N frequency shifted considerably to lower value, presumably due to the involvement of its nitrogen in hydrogen bonding with the phenolic OH group (table **4.2**).

Table 4.2

Characteristic ir stretching bands of of

1,5-diaryl-3-(2-hydroxyphenyl) formazans

Compounds				Probable
4a	**4b**	**4c**	**4d**	assignments
1454	1459	1454	1456	N=N
1565	1602	1610	1612	C=N

N M R spectra

The ^{1}H nmr spectra unequivocally support the structure **4.1** of the compounds. In the low field region two well resolved one proton signals exist in all the spectra. The signal at about δ 15 ppm is due to the N–H····N proton. The slightly broadened signal at δ 11 ppm can confidently be assigned to the phenolic proton which is involved in strong internal hydrogen bonding with the adjacent N atom of the formazan structure. The spectrum of **4c** shows an additional one proton signal in the low field at δ 15.5 ppm for the carboxylic proton. The position and intensity of the aryl proton signals are as expected. The spectra are reproduced in figures **4.1 - 4.4**.

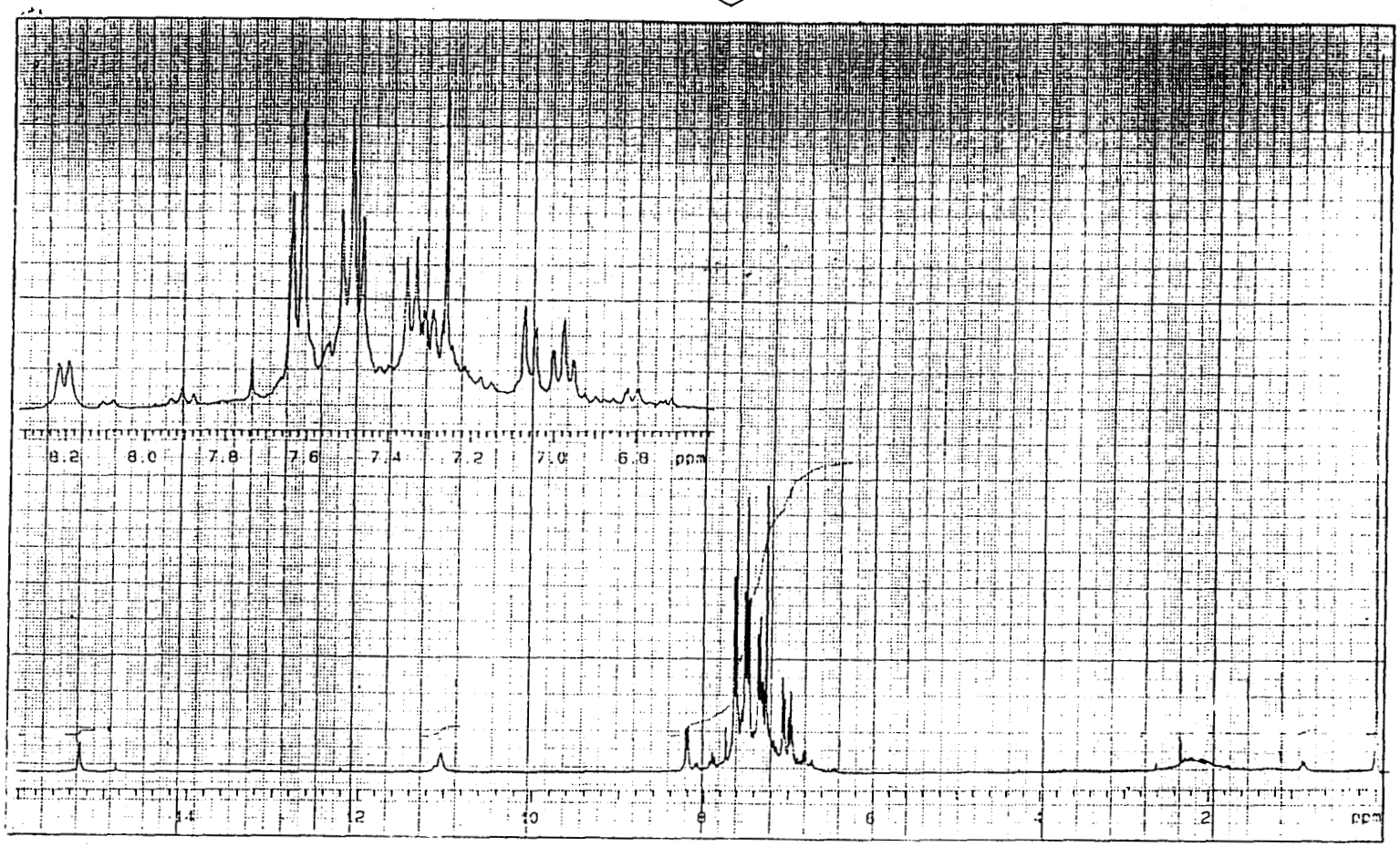
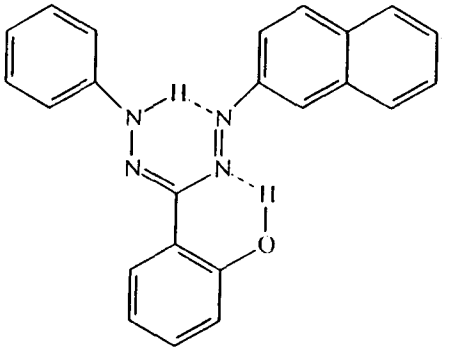


Figure 4.1 ^{1}H nmr spectrum of 4a



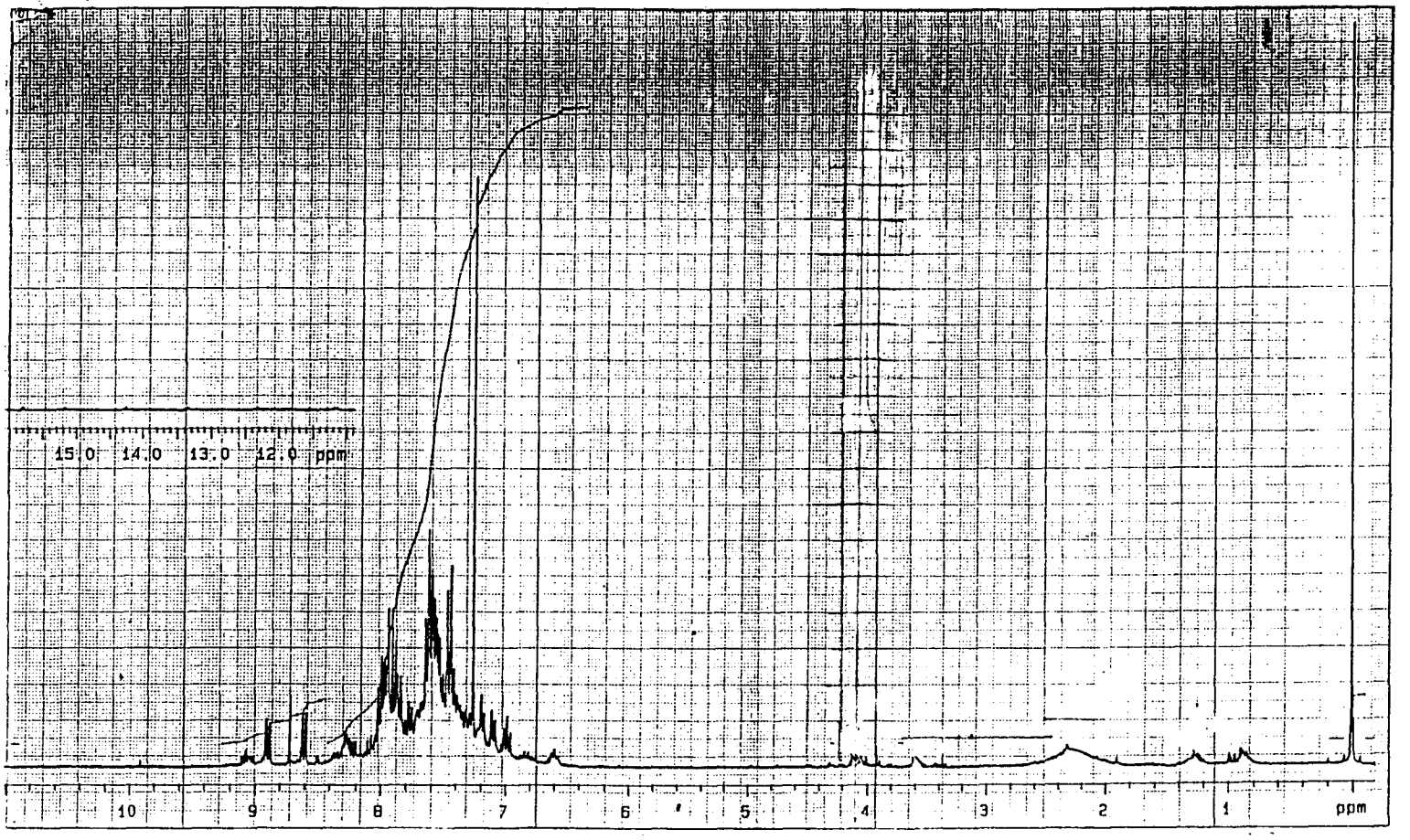


Figure 4.2 ^{1}H nmr spectrum of 4b ,

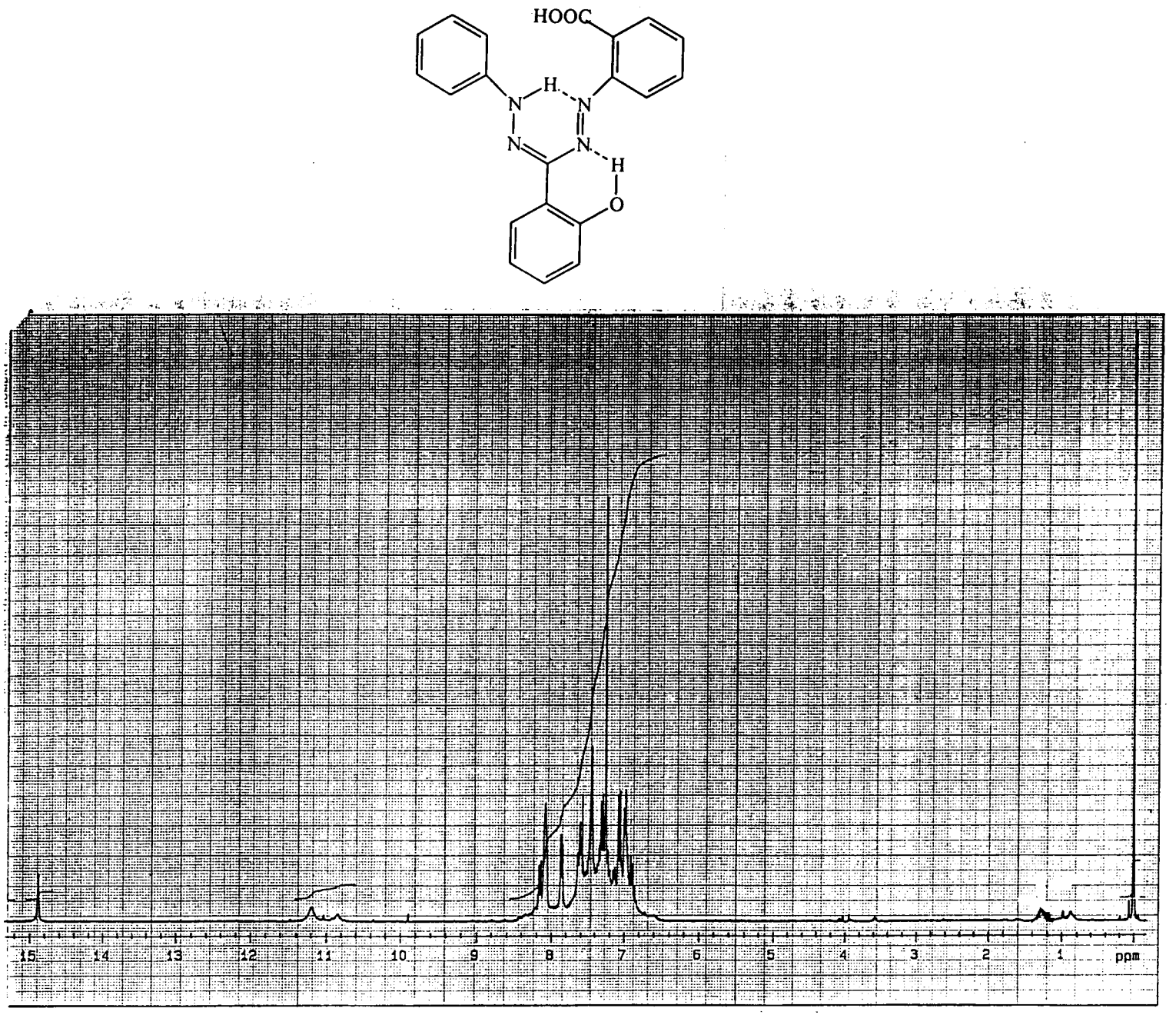
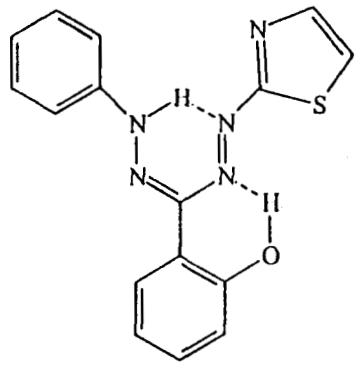


Figure 4.3 ^{1}H nmr spectrum of 4c



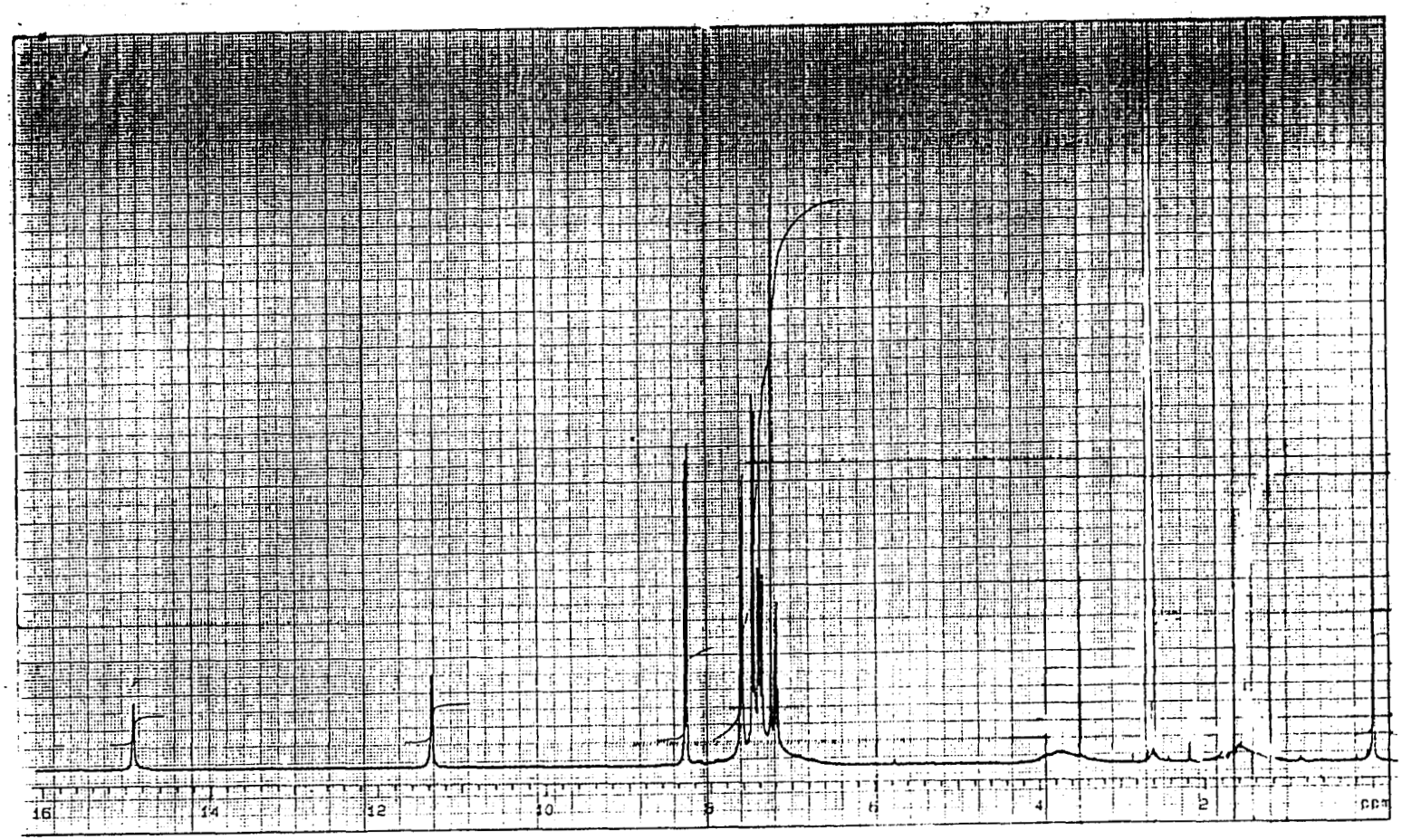


Figure 4.4 ^{1}H nmr spectrum of 4d

Mass spectra

Mass spectra of all the compounds show the molecular ion peak, P^+ / $(P+1)^+$. Elimination of N_2 from the parent ion is characteristic of all spectra. The observed peaks can be explained by the fragmentation pattern given in scheme **4.1.** The spectra are given in figures **4.5 - 4.8.**

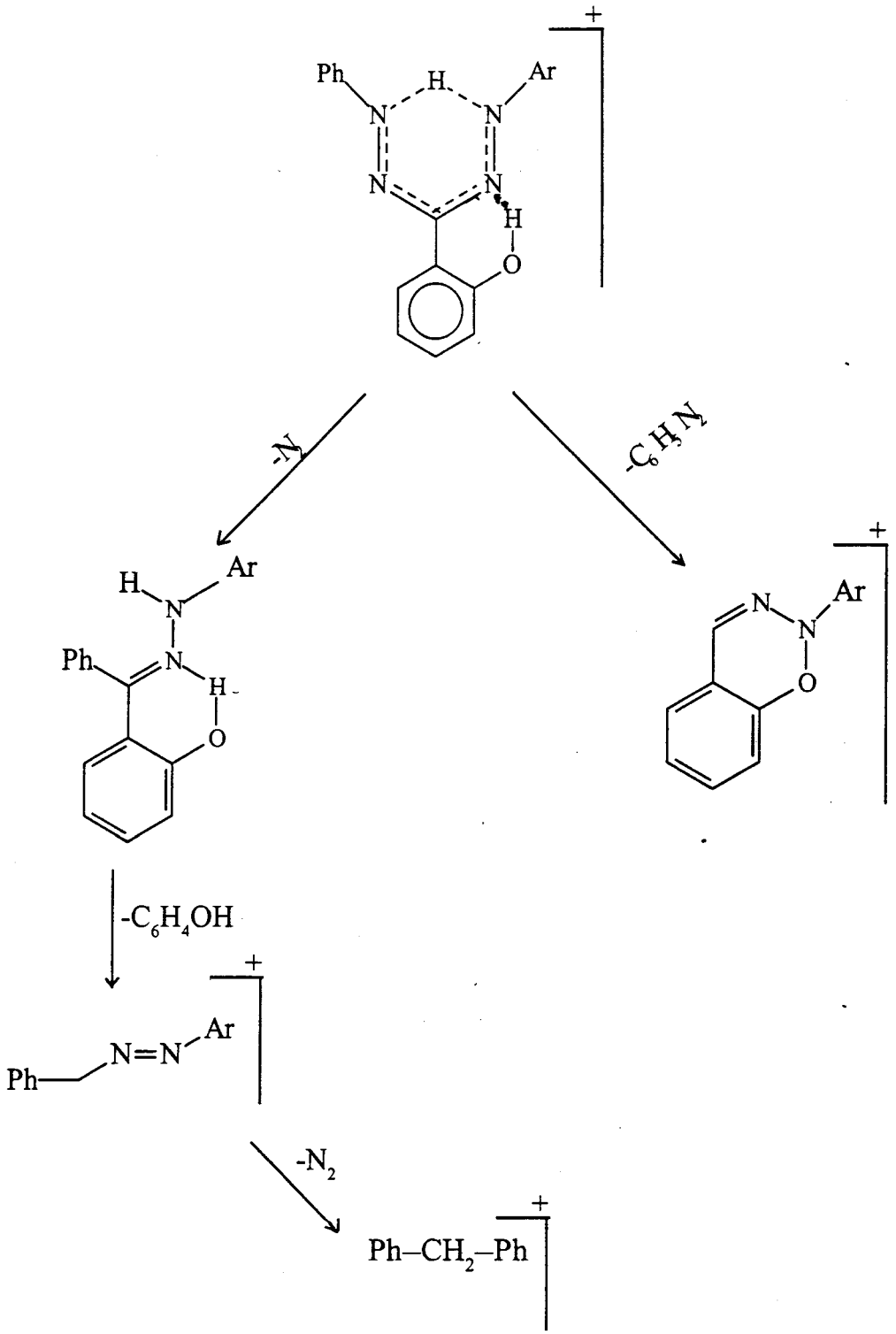
Characterisation of metal complexes

The C, H, N and metal percentages of the complexes are given in tables **4.3 - 4.6.**

Ir spectra

The intensity of the broad band of the free ligand in the region 2400 – 3800 cm^{-1} has decreased considerably and confined to the region 2800 –3200 cm^{-1} in the spectra of all complexes. This indicate the existence of internal hydrogen bonding in the complexes also probably the phenolic O –H ····N hydrogen bonding.

The two formazan nitrogens are involved in the metal coordination is evident from the shift in C=N and N=N stretching frequency of the ligand to lower values in the spectra of complexes. Further two prominent medium intensity bands appeared in the spectra of metal complex in the region 520-550 cm^{-1} assignable to ν_{M-N} also support the nature of bonding in the complex as in structure **4.2.** Important ir bands of the complexes are given in tables **4.7 - 4.10.**


Ph
H
Ar
N
N
N
N
H
O
+
-N2
-C6H5N
H
N
Ar
Ph
N
H
O
N
N
Ar
O
+
-C6H4OH
Ph
N=N
Ar
+
-N2
Ph–CH2–Ph
+

Scheme 4.1

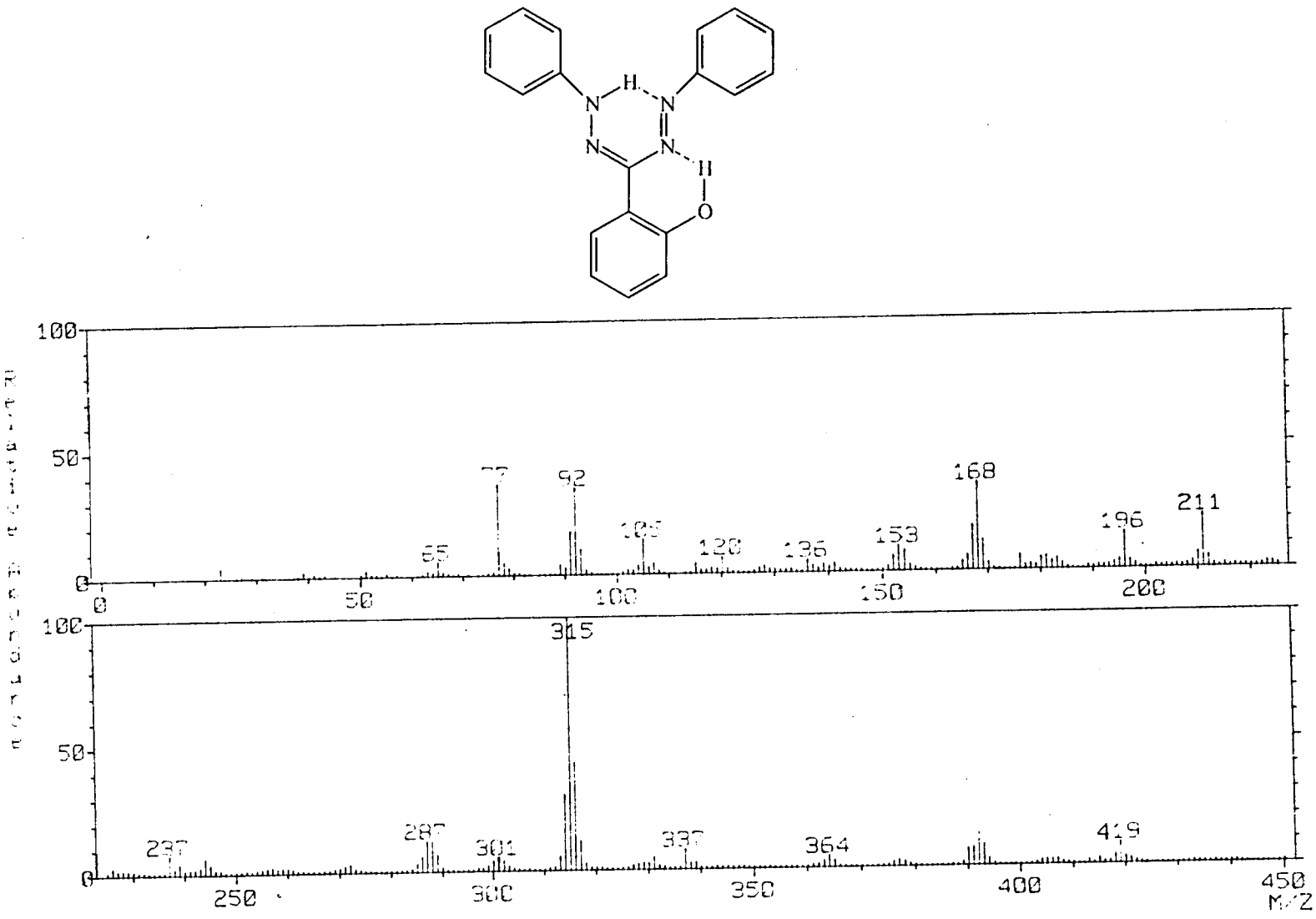


Figure 4.5 Mass spectrum of 4a

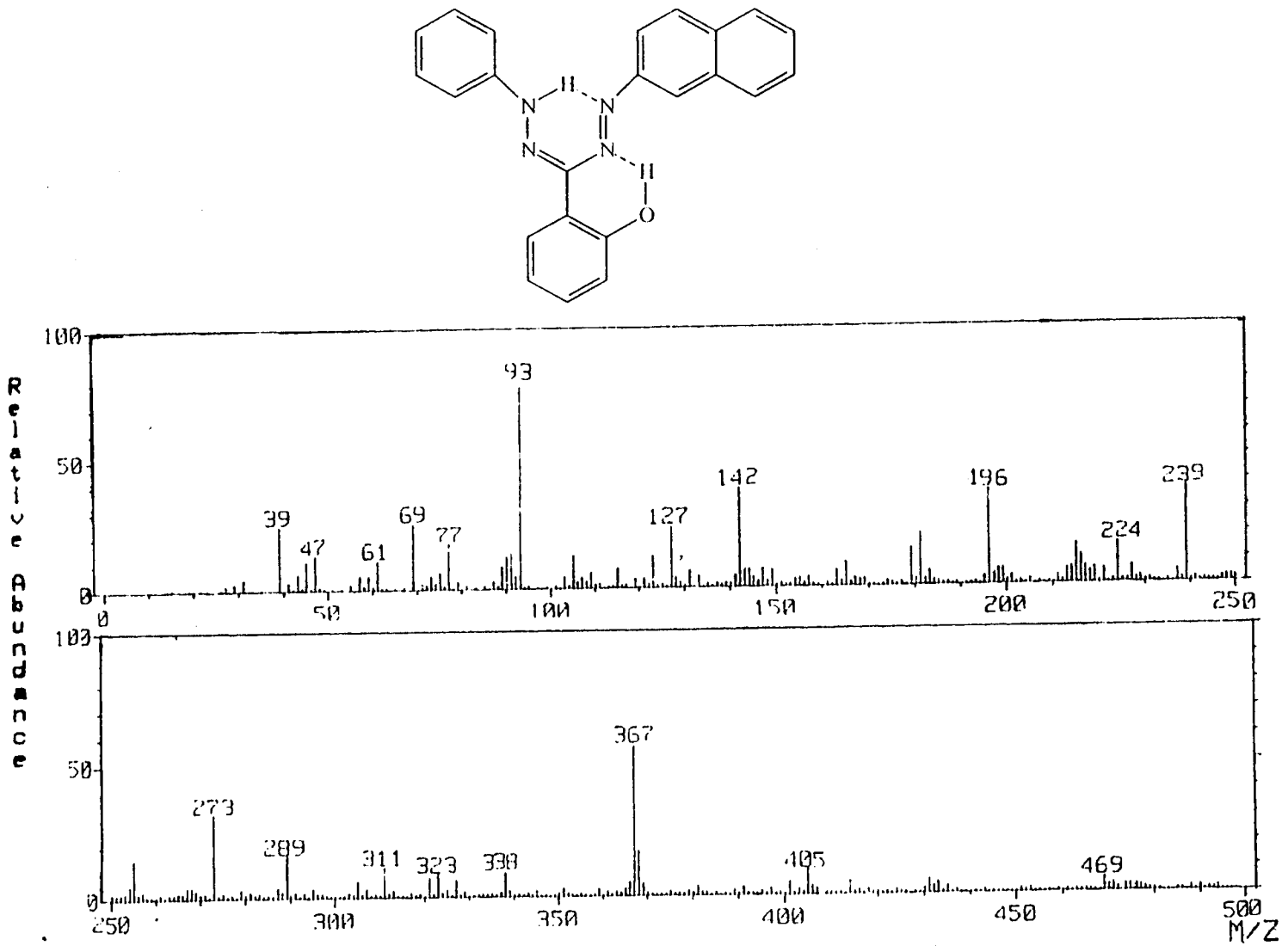


Figure 4.6 Mass spectrum of 4b

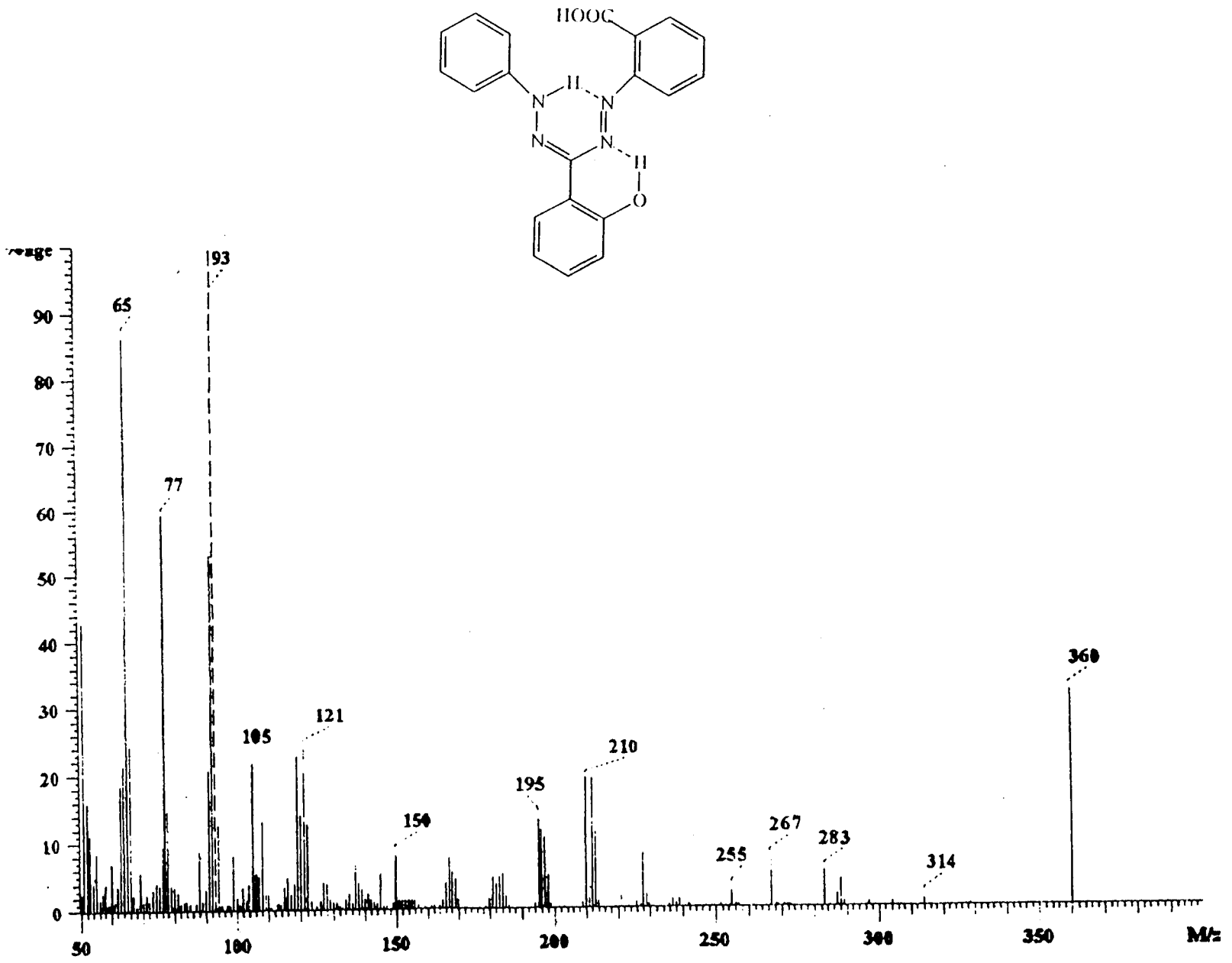


Figure 4.7 Mass spectrum of 4c

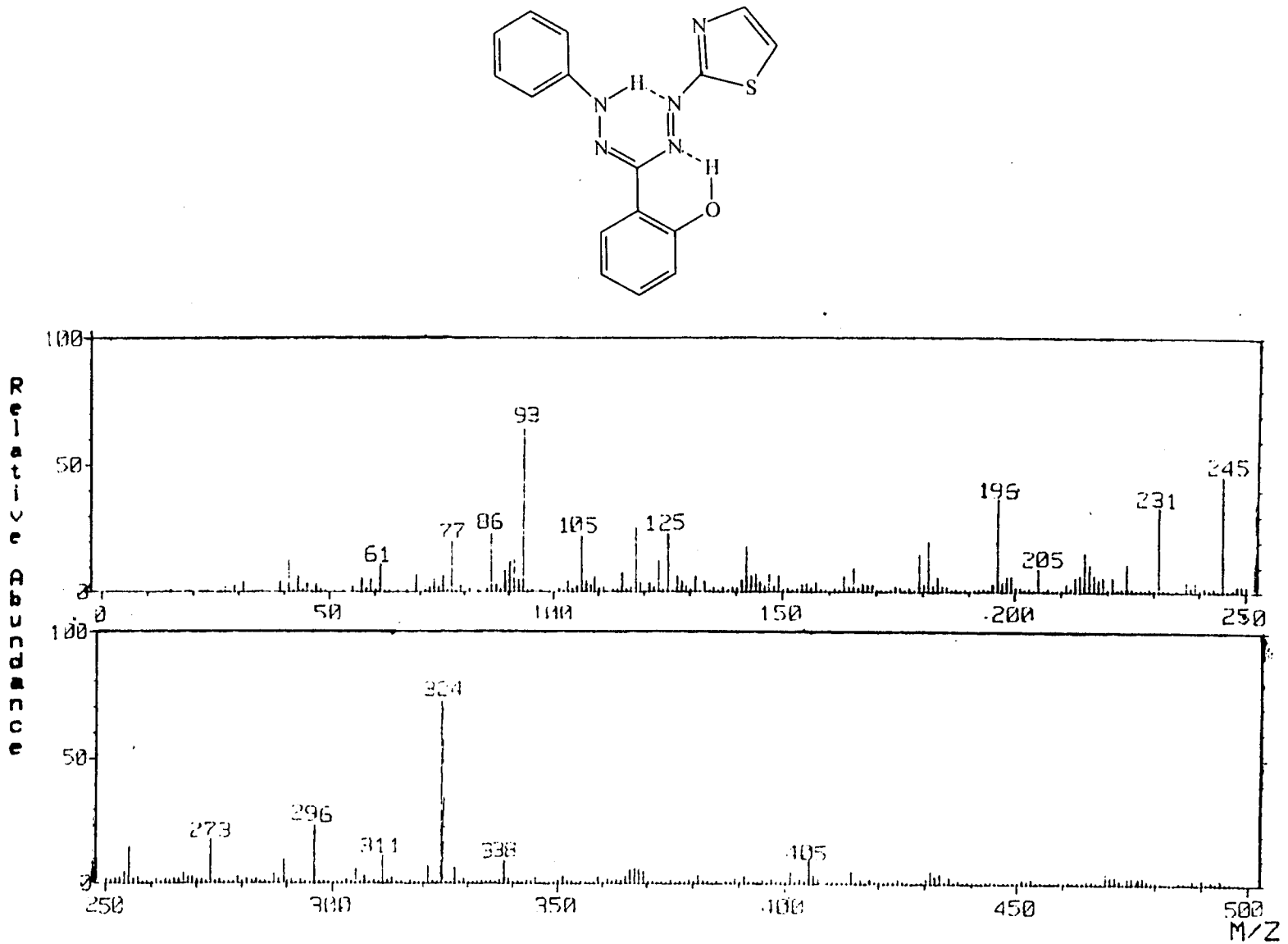


Figure 4.8 Mass spectrum of 4d

Table - 4.3

Physical, analytical and electronic spectral data of metal chelates of 1,5-diphenyl-3-(2-hydroxyphenyl)formazan, 4a, HL

Compds.	M.P. °C	Elemental analysis found (calcd.) %				λmax (nm)
		C	H	N	metal	
$[CuL_2]$	> 300	66.54 (65.74)	4.54 (4.32)	15.84 (16.16)	8.95 (9.16)	296 261
$[CoL_2H_2O]$	> 300	65.87 (66.18)	3.85 (4.06)	15.82 (16.25)	8.68 (8.53)	295 261
$[NiL_2]$	>300	69.45 (69.98)	4.34 (4.35)	16.87 (16.26)	8.532 (8.52)	804 306 262

Table 4.4

Physical, analytical, electronic spectral data of metal chelates of 1-phenyl–5-(1-naphthyl)-3-(2-hydroxyphenyl)formazan (4b) HL

Compds.	M.P. °C	Elemental analysis found (calcd.) %				λmax (nm)
		C	H	N	metal	
$[CuL_2]$	> 300	69.2 (69.56)	4.62 (4.28)	14.81 (14.2)	7.92 (8.01)	429 310
$[CoL_2H_2O]$	> 300	69.25 (69.95)	3.95 (4.31)	14.50 (16.17)	8.2 (7.46)	429 310
$[NiL_2]$	>300	68.92 (69.98)	3.85 (4.36)	14.54 (14.2)	8.23 (7.44)	433 309

Table 4.5

Physical, analytical and electronic spectral data of metal chelates of 1-phenyl-5-(2-carboxyphenyl)-3-(2-hydroxyphenyl)formazan (4c) H_2L

Compds.	M.P. °C	Elemental analysis found (calcd.) %				λmax (nm)
		C	H	N	metal	
$[CuL_2]$	> 280	55.48 (56.79)	3.37 (3.31)	13.68 (13.25)	15.01 (15.03)	730, 470 310, 285
$[NiL_2]$	>300	55.3 (57.59)	3.54 (3.35)	13.68 (13.43)	15.5 (14.08)	630 315 204

Table 4.6

Physical, analytical and electronic spectral data of 1-phenyl-5-thiazolyl-3-(2-hydroxyphenyl)formazan (4d) HL

Compds.	M.P. °C	Elemental analysis found (calcd.) %				λmax (nm)
		C	H	N	metal	
$[CuL_2]$	> 280	54.85 (54.27)	4.01 (3.39)	19.25 (19.78)	8.25 (8.98)	640 360
$[CoL_2]$	>290	54.7 (54.62)	3.50 (3.41)	19.28 (19.91)	7.96 (8.38)	730 310 255
$[NiL_2]$	>300	54.25 (54.64)	3.51 (3.13)	19.2 (19.92)	8.9 (8.35)	615 310

Table 4.7

Characteristic ir stretching bands (cm^{-1})of the metal chelates of 4a

Compounds	**C=N**	**N=N**	**M-N**
$[CuL_2]$	1580	1425	540 528
$[CoL_2(H_2O)_2]$	1565	1440	545 530
$[NiL_2]$	1570	1430	535 522

Table 4.8

Characteristic ir stretching bands (cm^{-1}) of the metal chelates of 4b

Compounds	C=N	N=N	M–N
$[CuL_2]$	1565	1430	545 520
$[CoL_2(H_2O)_2]$	1576	1435	548 532
$[NiL_2]$	1558	1442	525 520

Table 4.9

Characteristic ir stretching bands (cm^{-1}) of metal chelates of 4c H_2L

Compounds	C=N	N=N	N-N	M-N
$[Cu_2L_2]$	1556	1435	1355	540 532
$[Ni_2L_2]$	1575	1445	1360	545 527

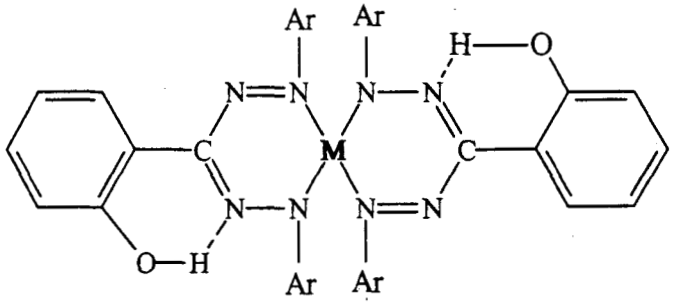
Table 4.10

Characteristic ir stretching bands (cm^{-1}) of metal chelates of 4d HL

Compounds	C=N	N=N	N-N	M-N
$[CuL_2]$	1560	1412	1362	560 538
$[CoL_2]$	1570	1445	1355	565 532
$[NiL_2]$	1565	1442	1365	555 520

N.M.R spectra

In these types of ligands in which two acidic protons are present and only one of them is replaced by metal ion during complex formation, the best method available to study these systems is the proton nmr spectra. The proton nmr spectra of typical complex are given in figure **4.9**. The spectra clearly demonstrate that in complex the phenolic proton is not eliminated and is involved in intramolecular hydrogen bonding with one of the azo nitrogen as in the free ligand. This conclusion is based on the fact that the phenolic proton signal of the free ligand at ~ δ11 ppm also observed in the spectra of the diamagnetic nickel(II) complexes with slight shift in position. The integrated intensities of the aryl protons agree well with the formulation of the complex.



4.2

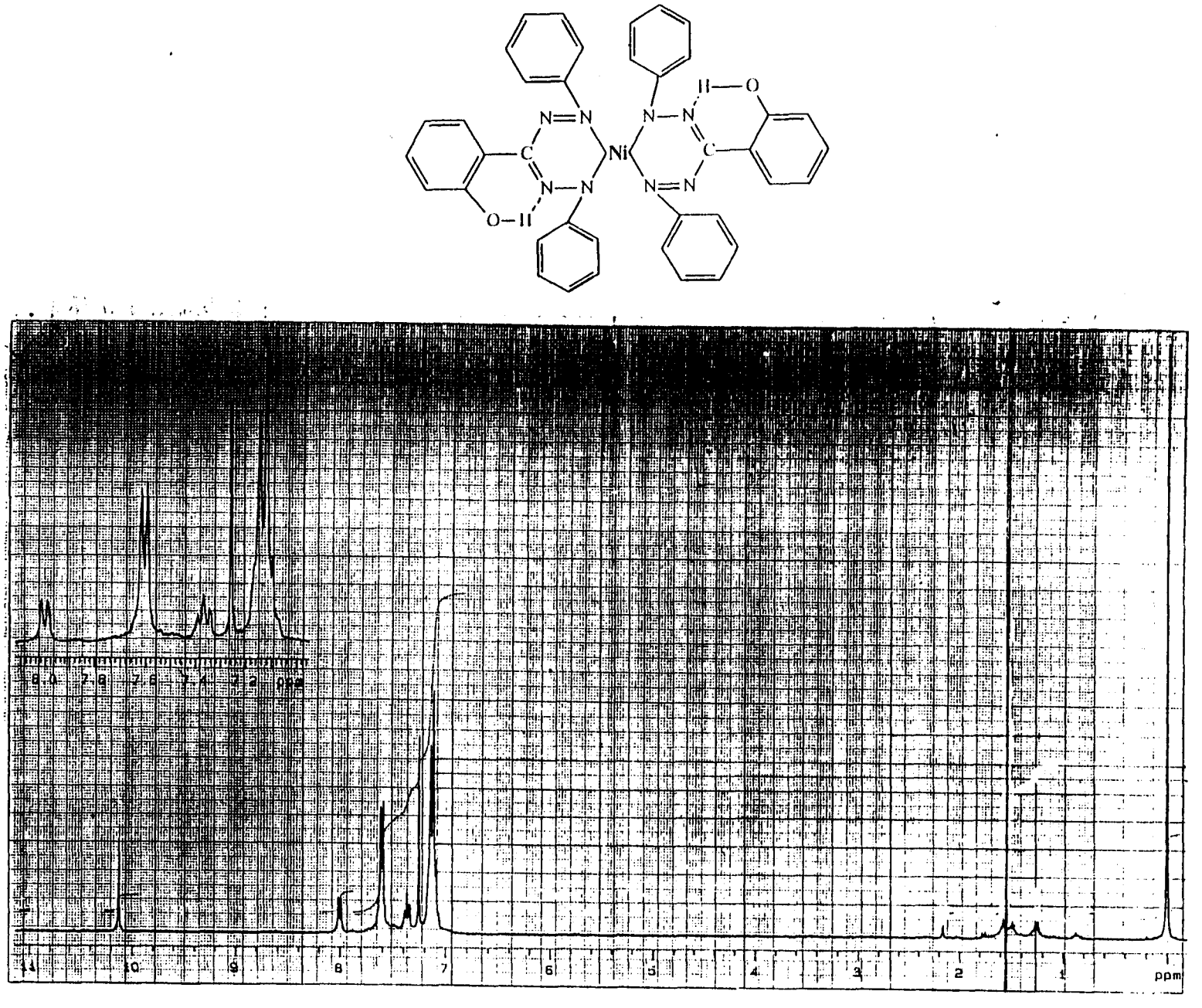


Figure 4.9 ^{1}H nmr spectrum of Nickel(II) complex of 4a

Potenntionmetric studies on acidity and chelation of 1,5-diaryl-3-(2-hydroxy phenyl)formazan

The proton-ligand and metal-ligand stability constants of Co^{II}, Ni^{II}, Cu^{II}, and Zn^{II} complexes of 1,5-diaryl-3-(2-hydroxy phenyl)formazan were determined in 50% v/v aqueous dioxane medium. The experimental detials are similar to that described in previous chapters.

The proton-ligand formation number n_A calculated by half-intergel and mid-point methodes from the pH *vs* n_A plots fig. **4.10**. The mean values are presented in table **4.11**.

Table 4.11

The acid dissociation constans of 1,5-diaryl-3-(2-hydroxy phenyl)formazan

Compounds	pK
4a	9.30
	7.52
4b	9.22
	7.48
4c	9.20
	7.50
	6.10
4d	9.24
	7.54

From the table **4.11** it follows that pK phenolic proton dissociates prior to the NH function. The decreasing trend in pK values from **4a** through **4d** can be attributed to electron withdrawing effects of the aryl substituents.

The stability constants for the cobalt(II), nickel(II), copper(II) and Zinc(II) complexes agrees with the Irvin-william natural order of stability[192]. The log K_n values (table **4.12**) show an increasing trend when electron withdrawing groups are presnt in the ring. Since log K_1 > log K_2 indicate a decrease in the bond strengh with successive attachement of the ligand molecules. However, the observed differences between the two values suggest the essentially planner geometry of the chelates.

Fig. 4.10 Proton-ligand formation curves for 1,5-diaryl-3-(2-hydroxyphenyl)formazan

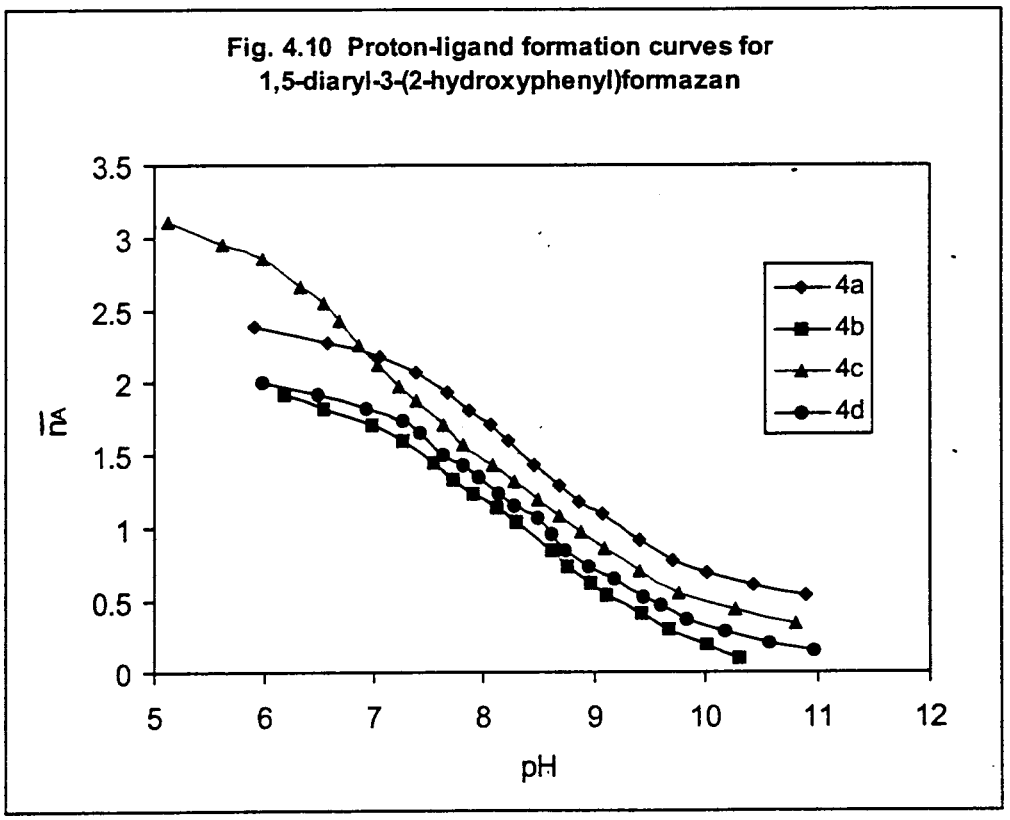


Fig. 4.11 Metal-ligand formation curves for 4a

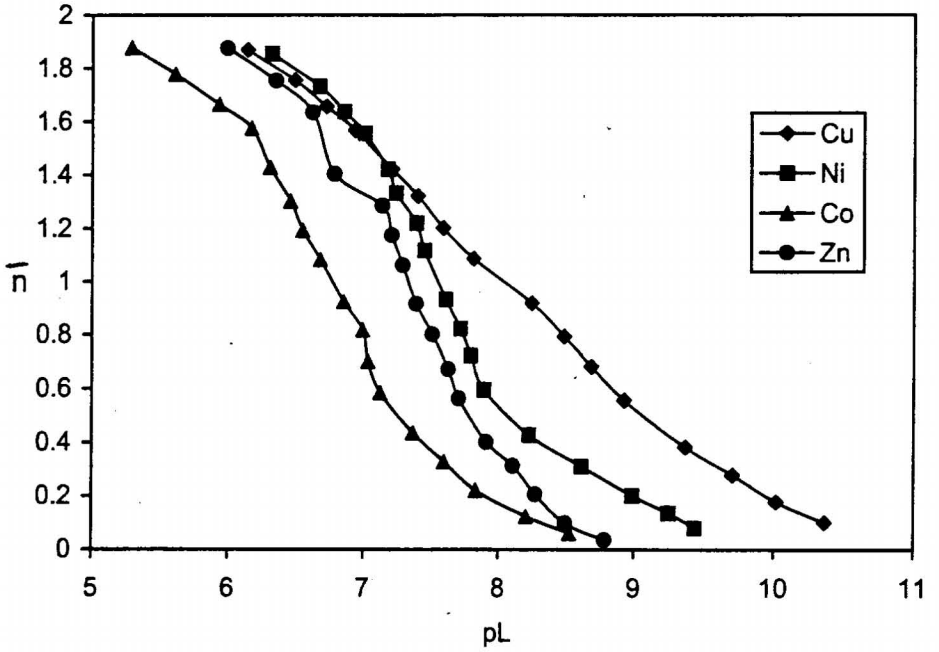


Fig. 4.12 Metal-ligand formation curves for 4b

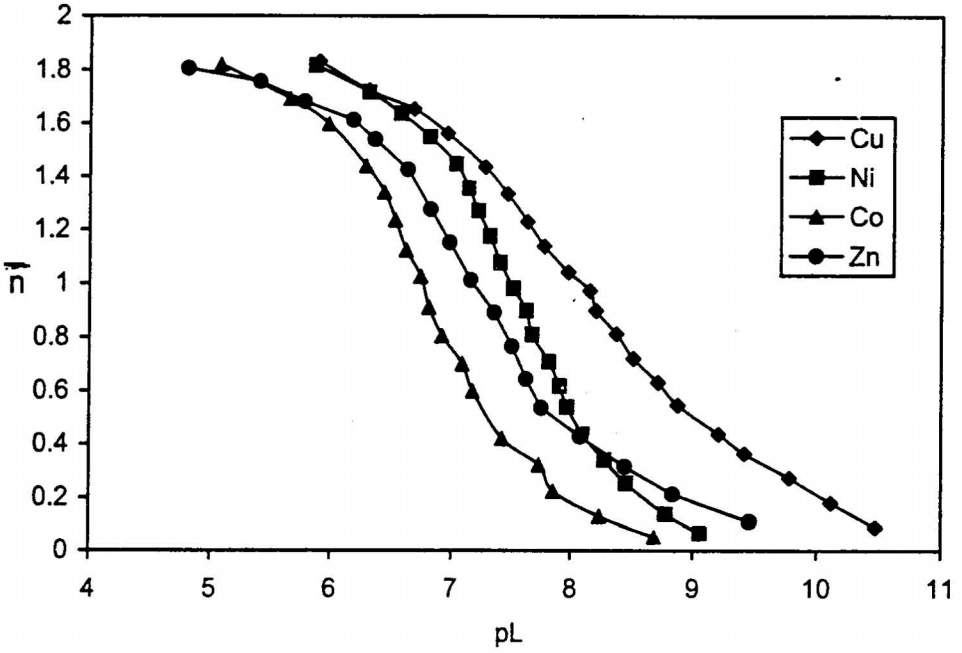


Fig. 4.13 Metal-ligand formation curves for 4c

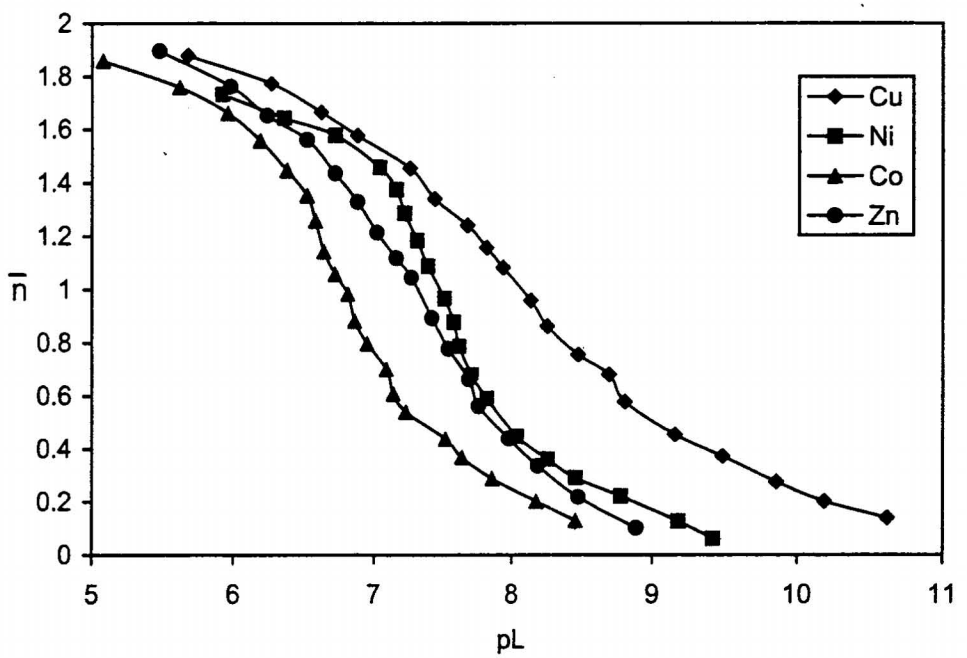


Fig. 4.14 Metal-ligand formation curves for 4d

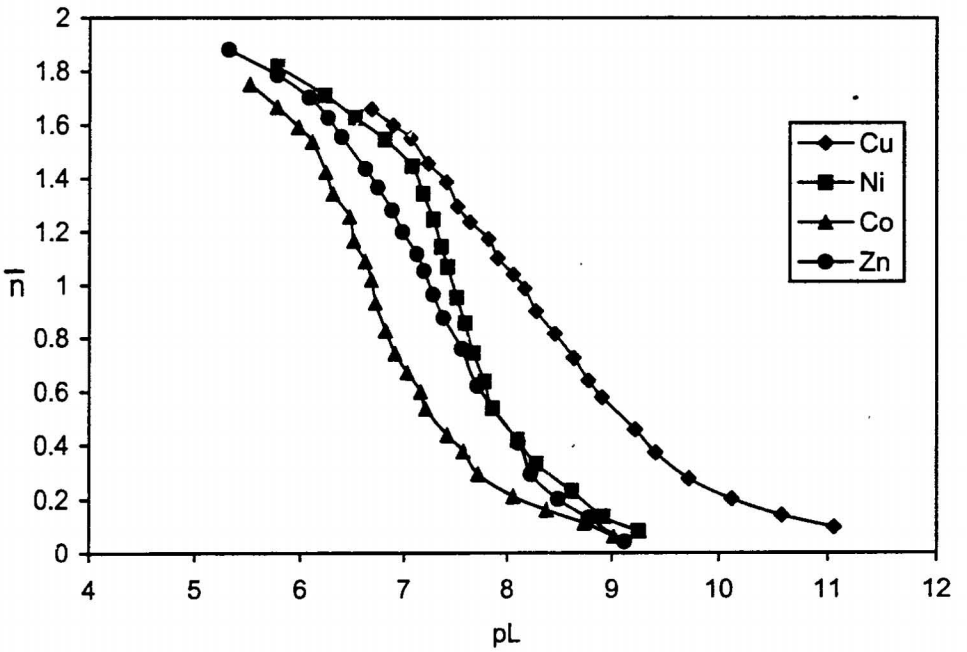


Table 4.12

Metal-ligand stability constants of 1,5-diaryl-3-(2-hydroxyphenyl)formozans

Metal(ii) ions	Stability constants	Ligands			
		4a	**4b**	**4c**	**4d**
Cu^{2+}	$logK_1$	9.1	9.02	9	9.05
	$lokK_2$	7.03	7.12	7.1	7.13
Ni^{2+}	$logK_1$	8.03	8	7.95	7.98
	$logK_2$	7.05	6.92	6.96	6.9
Co^{2+}	$logK_1$	7.21	7.3	7.35	7.28
	$logK_2$	6.27	6.18	6.28	6.14
Zn^{2+}	$logK_1$	7.74	7.81	7.88	7.92
	$logK_2$	6.82	6.48	6.61	6.56

PART II
ANTIMICROBIAL STUDIES OF FORMAZANS AND THEIR METAL CHELATES

Abdul Rahim A.K. “Metal complexes of formazans ” Thesis. Department of Chemistry , University of Calicut, 2000

CHAPTER 5

ANTIMICROBIAL STUDIES OF FORMAZANS AND THEIR METAL CHELATES

Recently inorganic coordination compounds have come to the forefront of interest from the biological point of view. The role of metal ions and their chelates in various biological activities are well documented[198-200]. Microorganisms such as yeast, moulds, bacteria, etc, have nutritional requirements similar to our own and, infact,many foodstuffs are ideal carriers of pathogenic bacteria as well as ideal substrate for the growth of bacteria and fungi which secrets toxins.

In many instances it has been shown that metal chelates are more potent than the metals and the chelating agents themselves[201-204,213-214]. The activity of any compound is a complex combination of steric,electronic, and pharmokinetic factors.

Formazans are reported to be used[205] for the cytochemical study of the dehydrogenases of mitochondria and mitochondrial particulates. The role of formazans[206] in cell metabolism, in skin carcinogenisis, histoenzymic studies of arteries in high salt hypertension[207,208] like genotoxicity, aquatic

toxicity[209], antifertility and anti inflammatory activity are also reported[150-153]. Thus the wide range of biological activities exhibited by the formazans and its chelates, led to the present investigation on the bactericidal and fungicidal activities of the formazans and their chelates.

Fungi had been recognized as causative agents of human disease earlier than bacteria, and are extremely common and some of them are serious and even fatal. Therefore the study of fungal infections and their control have greater importance.

Aspergillus niger and *pencillium species*, the two fungal strains choosed for the study are commonest moulds seen on damp bread or almost any other organic matter. Even within brief span of life of the human race, action of bacteria were observed for thousands of years before they were understood. In the apparently peaceful ecological relationship with the human host it may produce small and slightly discomforting boils or it may produce fulminating *septicemia* and death.

The bacteria selected for the study are *staphylococcus aureus* and *escherichia coli. Staphylococus* grow on a variety of media and are frequent contaminants of other cultures. *Escherichia coli* organism are normal inhabitants of animal intestinal tracts, they usually grown well on common laboratory media, is faculatively anaerobic. They are the organism most

widely used in genetic studies. Although *e.coli* is usually considered as nonpathogenic and beneficial organism in the intestinal tracts infections of the appendix, gallbladder, kidney, urinary bladder, and peritoneal cavity may be severe.

Experimental

1. Antifungal activity

Materials and methods

Analar grade chemicals were used in the experiments. DMSO was used as the solvent for preparing different concentrations of the formazans and its complexes. Microorganisms Aspergillus niger and Pencillium species were maintained on nutrient agar slant. The composition of nutrient agar was: peptone – 1g, meatextract – 0.5g, NaCl– 0.5g, and agar –2.5g in distilled water (100 ml) and adjusting the pH of the medium to 7.2 – 7.4 using 10% NaOH.

The antifungal activity of the compounds under study against the two selected fungal strains were done using cup-plate technique. The medium used for demonstration of the antifungal activity was Sabourauds glucose agar. Composition of it was: Peptone – 1g, D-glucose – 4g, agar – 2g, distilled water – 100 ml and the pH has been adjusted to 5.7 using 10%

HCl. The medium after autoclaving at 120 °C for 20 min. was poured into petriplates and allowed to cool.

Detection of antifungal activity

The petri plates were sealed with the two fungi under study. The suspension of spores were prepared in normal saline (0.9%). For this each fungi were grown on Sabourauds glucose agar slants till they get sporulated. These spores were scrapped and suspended in about 3 to ml of normal saline.

To prepare a mat growth of fungi on the petri plates this spore suspension was poured on the surface of the plates. After swirling the plates properly for the uniform distribution of the spores on the surface, the excess suspension was decanted. Plates were allowed to dry in an incubator at 37 °C for 1 h. Using an agar punch, wells (10 mm) were made on these plates. In each well **75mL 4000 ppm** of the compounds in dmso were added. Each plate was having a well for the control, the solvent dmso. The wells were properly labelled and the plates were prepared in triplicate and incubated at room temperature for 4- 5 days. The antimicrobial activity was detected by measuring the diameter of the inhibitory zone around each well[212-215]. The results observed are presented in the table **5.1.**

Table 5.1

Results of studies on antifungal activity

Compounds	Average diameter (mm) of the zone inhibition Strains	
	A.niger	*Pencilium.spec.*
1a	21 (10.5)	20 (9.5)
1b	20 (10)	20 (9)
1c	24 (11)	22 (11)
1d	30 (12)	32 (12.5)
2a	19 (10)	20 (9)
2b	24 (12)	22 (9.5)
2c	22 (10.5)	20 (10.)
2d	31 (12.5)	33 (12)
3a	20 (11)	20 (10.5)
3b	19 (11.5)	21 (10)
3c	24 (9.5)	22 (9.5)
3d	30 (12.5)	32 (12.5)
4a	18 (9)	19 (9.5)
4b	20 (10.5)	22 (9)
4c	21 (11)	21 (10)
4d	32 (12)	34 (12.5)
dmso	7	7

(Values in parantheses indicate the value observed for the corresponding copper(II) chelate)

1. Antibacterial activity

A. Materials and method

Nutrient agar slants were used for maintaining the stock culture of test bacteria. Nutrient agar slants were prepared as reported[212]. A loopful of bacteria was transferred in to 5ml. of nutrient broth (sterilized) and was incubated at 37 °Cfor 6-8 h. From this culture, 200 μL of suspension was transferred to petriplates containing nutrient agar and spreaded evenly on the medium with the help of a glass spreader to get a uniform lawn of bacteria.

Using an agar punch, wells were made on these seeded plates and 75μL (4000ppm) of test compounds as a solution in **dmso** were added to the wells and each well were labelled. The petriplate were prepared in triplicate and inoculated at 37°C overnight. A control was prepared for each plate in the same way using the solvent **dmso**.The antibacterial activity was determined by measuring the diameter of the zone of inhibtion (mm) The results observed are given in the table 5.2

Table 5.2

Results of studies on antibacterial activity

Compounds	Average diameter (mm) of the zone inhibition Strains	
	S.aures	*E.coli.*
1a	16 (8)	18 (9)
1b	14 (9)	18 (10)
1c	18 (7.5)	20 (8)
1d	26 (11)	28 (10.5)
2a	14 (6.5)	14 (9)
2b	16 (7)	16 (9.5)
2c	15 (8)	17 (11)
2d	25 (11.5)	28 (11.5)
3a	16 (7.5)	14 (8)
3b	17 (8)	18 (7.5)
3c	18 (9)	19 (9.5)
3d	26 (11.5)	26 (11)
4a	16 (8.5)	15 (9)
4b	14 (9)	11 (9.5)
4c	18 (9.5)	11 (8.5)
4d	26 (11)	28 (12)
dmso	7	6

(Values in parantheses indicate the value observed for the corresponding copper(II) chelate)

B. Results and discussion

The average diameter of the zone of inhibition observed for the compounds are brought out in tables **5.1** and **5.2**. These qualitative results show that formazans are effective against all tested organisms. From a comparison of the data obtained formazans containing the thiazole ring showed maximum activity. Eventhough many derivatives of thiazole are subjected to antimicrobial studies, the role of thiazole ring in inhibition of microbial growth is not known.

All the metal complexes studies did not show any significant activity against any of the tested organism. In metal complexes, the bactericidal and fungicidal activity of formazans diminished to a great extent.

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