Sudan University for Science and Technology

Faculty of Science

Scientific Laboratories Department of Chemistry

Schiff Bases and there complexes, syntheses Characterization, and there applications

A dissertation submitted for partial fulfillment requirement of B.Sc. degree (honors) in Chemistry

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OCT – 2015

الأية

قال تعالى :

﴿ قَالُواْ سُبْحَانَكَ لاَ عِلْمَ لَنَا إِلاَّ مَا عَلَّمْتَنَا إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيمُ ﴾

صدق الله العظيم

سورة البقرة الأية (32)

Dedication

To our mother.

Who gave us care our love.

To our father.

Who was the source of help fullness.

To our brothers.

To our teacher.

To people who stay beside us.

Acknowledgment

Thanks first and last to (ALLAH) who enabled we conduct this study by the grace of him and give we strength and patience, jewel immense debt and respect to our supervisor Ali EltayebJadAllah for hisguidance, helpful suggestion and solving problems.

Words can never help to express our feeling toward every one stand beside our to carry work, so we would like to thanks all those.

Abstract

Some Schiff bases were synthesized by condensation of two aldehydes(vanillin ,para-di methyl amino benzaldehyde) with two amines (Urea, Thiourea),and their complexes with two transition metals (Cu,Co) were also prepared.

These compounds were characterized by using IR spectrum,atomic absorption,UV/visible and their melting pointswere also determined .

The biological activity of these compounds were tested for bacteria(Ps.aeruyinosa,E.coli, S.aureus,E.faecalis).

الملخص

تم تحضير عدد من قواعد شيف من عدة امينات (يوريا ،ثيويوريا) ومركبات كربونيلية (الفانيلين ، بارا-داي ميثيل امين بنزالدهيد) ومن ثم تحضير معقداتها مع فلزات الكوبالت والنحاس.

ومن ثم تم تشخيص هذه المركبات باستخدام تقنية الاشعة تحت الحمراء وفوق البنفسجية والامتصاص الذري وحددت بعض الخواص الفيزيائية من درجة انصهار ولون

وتمت دراسة الفعالية البيولوجية لهذه المركبات لبعض انواع البكتيريا.

Table of Content

Introduction

1-1 Definition

Schiff bases was first reported by Hugo Schiff in 1948.

Chemist use this terminology to indicate the organic compounds which contain imine group , which is a carbon atom covalently bonded to a nitrogen atom =C=N-R. These compounds have different names such as aniles and benzaniles [1].

Schiff bases that are derived from ketones are known as “ketamines” and those which are derived from aldehyde and hydrazine are known as “aldimines” and “hydrazones" respectively .[2].

Hydrazones are special group compound in Schiff bases family and they are characterized by the presence of C=N-N=C=.The presence of tow inter-linked nitrogen atoms were separated from imine , Oximes…….etc.(see table 1-1)[2].

1.2-Preparation of Schiff bases:

Schiff bases can be prepared by condensing carbonyl compounds and amines in different condition and in different solvents with the elimination of water molecules. The common methods uses for preparation of Schiff bases are refluxing conditions. The presence of dehydrating agents like magnesium sulphate normally favors formation of Schiff bases [6].

$$R_2C{=}O \;+\; RNH_2 \Leftrightarrow R_2\text{-}COH(NH)\text{-}R \Leftrightarrow R_2\text{-}C{=}N\text{-}R \;+\; H_2O$$

Scheme(1):formation of schiff bases

Table (1-1) Reacted between primary amine with carbon

Carbonyl group	Ammonia derivative		Yield	
Structure	Name	Structure	Name	Structure
\ C=O /	Hydrazine	H_2N-NH_2	Hydrazone	\ C=N-NH2 /
\ C=O /	Seme-carbazide	H_2N-NH-CO-NH_2	Semi Cabazon	C=N-NH-C=O(NH2
\ C=O /	Thio semicarbazid	H_2N-NH-CS-NH_2	Thiosemi Cabazon	C=NNH-C=S(NH2)
\ C=O /	hydroxylaimne	H_2N-OH	Oxime	\ C=N-OH /
\ C=O /	phenylhydrazine	H_2N-NH-C_6H_5	Phenyl hydrazine	\ C=N-NH-C_6H_5 /

1-1-2 some properties of Schiff bases

1-aromatic or aliphatic Schiff bases that are derived from carbonyl and amines are very stable. [4].

2-schiff bases prepared from amines and amino acids and aromatic or aliphatic aldehydes are soilds.[4]

3-schiff baseswhich prepared fromaliphatic derivatives are liquids.

The stability of Schiff bases depending on the types of the aldehydes or ketones used in prepared. Schiff base which prepared from aromatic aldehydes and aromatic amines are stable.[7]

$$\mathbf{R\text{-}CO\text{-}H + R\text{-}NH_2 \xrightarrow[unstable]{} R\text{-}N{=}CH\text{-}R}$$

$$\text{Ar-CO-H} + \text{R-NH}_2 \xrightarrow[unstable]{} \text{R-N=CH (Ar)}$$

$$\text{R-C=OH} + \text{Ar-NH}_2 \xrightarrow[stable]{} \text{Ar-N=CH-R}$$

$$\text{Ar-CO-H} + \text{Ar-NH}_2 \xrightarrow[stable]{} \text{Ar-N=CH-Ar}$$

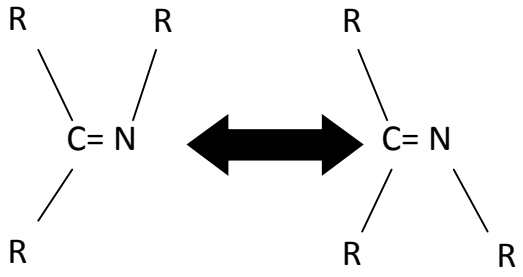
Scheme(2):stable and un stable Schiff bases

Aliphatic Schiff bases are unstable in aqueous solution , the first decomposition step involves addition of proton to nitrogen atom from iminum ion and in the presence of water carbonyl amine is formed which decompose to aldehydes and amine .[3]

$$\text{-C=N-R} \xrightarrow{H+} \text{[C=N}^{+}\text{HR} \Leftrightarrow \text{C}^{+}\text{H=N-R]} \xrightleftharpoons{\text{H2O/-H}} \text{-C=O+ R-NH}_2$$

The hydrolysis reaction is used to purify the carbonyle compound by converting it to oximes or other compound followed by the hydrolysis of thesederivatives.[8]

Schiff bases areinsolublein acidic ,basic or natural compounds.Schiff bases shows tautomersim (keto -enol) Shiff bases have two geometric isomers.



Hauser and coworker proved the presence of the isomer which is difficult to separate due to their rotation around each other.[8]

1-3 Applications of Schiff bases:

Schiff bases are widely applicable in analytical, biological and industrial

1-3-1 catalytic applications:

In Schiff metal complexes these environment at the coordination center can be modified by attaching different substitution to the ligand and useful range of steric and electronicProperties essential for the

fine –tuning of structure and reactivity can thus be provided.

The Schiff bases for metal complexes with p-Block and d-Block metal and these complexes have been Known to act as highly efficient catalyst in various syntheses and other useful reaction many Schiff base complexes of ruthenium and palladium are used as catalyst in the syntheses of quality polymers .[5]

Aromatic schiff bases or their metal complexes catalyze reactions on oxygenation ,hydrolysis , electro-reduction and decomposition.[1]

1-3-2 Coordination Chemistry:

Coordination chemistry has gained reputation the second half of last century and this was due to the progressive introduction of new coordination compounds complexes . [7]

Which finds a wide area of applications such as industry agriculture and medicine.

One of the most important class of three complexes is Schiff bases which involve transitional metal .

Schiff bases have been playing an important part in the development of coordination chemistry ,Schiff bases metal complexes have been studied extensively because of their attractive chemical and physical

properties and their wide range of applications in numerous scientific area .These types of complexes have been vigorously explored in recent years and such studies have been the subject of many papers and reviews .[8]

Many of them are centered on the catalytic activity of Schiff base complexes in a large number of homogenous and heterogeneous reactions.Schiff bases are common ligands in coordination chemistry the imine nitrogen is basic and exhibits pi- acceptor properties.

The ligands are typicallyderived alkyl di amines and aromatic aldehydes.[3]

1-3-3 Biological and medical application:

Many ligands have been designed to mimic the function of natural carriers in recognized and transporting specific metal ion.

Anionor nutrial moleculesand in understandingand reproducing the catalytic activity of metallo –enzymes and proteins.[1]

Schiff basecontain isomethane group which influence the enzymatic activity of biological system.[1]

A number of Schiff bases proved to have abiological activity against cancer and also against microorganisms ,influenza[1].

Many Schiff bases are Known to be medicinally important and used to be design medicinal compounds [3].

It was seen that the biological activity of Schiff bases either increase or decrease upon chelation with metal ions[7].

Copper(II) ,cobalt(II) complexes of Schiff bases derived from 3-substituted -4-amino-5-mercapto-1,2,4-triazole and 8-formyl-7-hydroxy-4-

methylcoumarin show potent antibacterial activity against Escherichia coli , staphylococcus aurous streptococcus piogenes, pseudomonasaeruginosa and salmonella typhi and antifungal a ctivities against Aspergillusnige , Aspergillusflavus and Cladosporium.[5]

1-3-4 Other applications:

Many Schiff bases compound are found to be good corrosion inhipitersemergal and atacolstudies the corrosion behavior of iron in 2M HCL solution at 298k with three Schiff basecompounds and found these compounds have the perfect inhibition efficiency.[6]

Schiff base are used to measure and extract Uranium and Thorium ions.

Experimental Section

2-1 Using material

Table (2-1) of using material

Name	Structure	Assay%
Ethanol	C_2H_6O	99.5
Vanillin	$C_8H_8O_3$	99
Para di methyl amino benzaldehyde	$C_9H_{11}ON$	98
Urea	$C_1H_4N_2O$	99
Thioria	$C_1H_4N_2S$	99

2-2 ApparatusandTools:

Sensitivebalance ,Beakers ,Round bottomed Flask ,

Condenser ,Glassrod ,Funnel ,

Filter Paper , IR Spectrometer ,

UV Spectrometer,

Meltingb Point measurement device, Cabilary Tubes.

2-3 Method:

2-3-1 preparation of ligands :

- **Preparation of N,N-Bis(di,para di methyl amino benzaldene)urea .(L_1):**

0.000033mmole of urea were weighed ,then dissolved with 30 ml of absolute ethanol ,also 0.0000671mmole of para di methyl amino benzaldehyde were weighed and dissolved with 30ml of absolute ethanol .the tow solution above mixed together and reflexed to about five hours at 70-80c^o.

The resultant solution was allowed to stand at room temperature for about three days .the crystals were filtered and washed with absolute ethanol ,dried and weighed .(the recrystalization will be done by using absolute ethanol)

- **Preparation of N,N-Bis (di,3-methoxy,4-hydroxy benzyledene)urea(L_2):**

0.000032mmole of urea were weighed ,then dissolved with 30 ml of absolute ethanol ,also 0.000066mmole of vanillin were weighed and dissolved with 30ml of absolute ethanol .the tow solution above mixed together and reflexed to about five hours at 70-80c^o

The resultant solution was allowed to stand at room temperature for about three days .the crystals were filtered and washed with absolute ethanol ,dried and weighed .(the recrystalization will be done by using absolute ethanol)

- **Preparation of N,N-Bis (dipara di methyl amino benzyledene) thiourea(L_3):**

0.000026mmole of thiourea were weighed ,then dissolved with 30 ml of absolute ethanol ,also 0.000067mmole of para di methyl amino

benzaldehyde were weighed and dissolved with 30ml of absolute ethanol .the tow solution above mixed together and reflexed to about five hours at 70-80c^{o}.

The resultant solution was allowed to stand at room temperature for about three days .the crystals were filtered and washed with absolute ethanol ,dried and weighed .(the recrystalization will be done by using absolute ethanol)

- **Preparation of N,N- Bis (di,3methoxy,4hydroxy benzyledene) thiourea (L_4):**

0.000026mmole of thiourea were weighed ,then dissolved with 30 ml of absolute ethanol ,also 0.000065mmole of vanillin were weighed and dissolved with 30ml of absolute ethanol .the tow solution above mixed together and reflexed to about five hours at 70-80c^{o}.

The resultant solution was allowed to stand at room temperature for about three days .the crystals were filtered and washed with absolute ethanol ,dried and weighed .(the recrystalization will be done by using absolute ethanol)

2-3-2 Preparation of complexes:

- **Preparation of N,N_Bis(di,para di methyl amino benzaldene)urea cobalt(III)chloride(L_1Co):**

0.000002682 mmole of the ligand were weighed and dissolved in about 10 ml of ethanol also0.000004439 mmole of cobalt chloride were dissolved in equal amount of ethanol and added to the solution of the ligand. The mixture transferred to a round bottomed flask ,and refluxed at 70-80C^{o} for 2 hours . The mixture allowed to cooled , until the precipitate was separated (48 hrs) . The crystals collected and weighed.

❖ **Preparation of N,N_Bis(di,para di methyl amino benzaldene)urea copper(3)chloride(L_1Cu):**

0.000002726 mmole of the ligand were weighed and dissolved in about 10 ml of ethanol also0.0000031 mmole of copper chloride were dissolved in equal amount of ethanol and added to the solution of the ligand. The mixture transferred to a round bottomed flask ,and refluxed at 70-80C^o for 2 hours . The mixture allowed to cooled , until the precipitate was separated(48 hrs) . The crystals collected and weighed.

❖ **Preparation of of N,N-Bis(di,3-methoxy,4-hydroxy benzyledene)urea cobalt(III)chloride(L_2Co):**

0.000002639 mmole of the ligand were weighed and dissolved in about 10 ml of ethanol also0.000004365 mmole of cobalt chloride were dissolved in equal amount of ethanol and added to the solution of the ligand. The mixture transferred to a round bottomed flask ,and refluxed at 70-80C^o for 2 hours . The mixture allowed to cooled , until the precipitate was separated(48 hrs) . The crystals collected and weighed.

❖ **Preparation of N,N-Bis(di,3-methoxy,4-hydroxy benzyledene)urea copper(III)chloride(L_2Cu):**

0.000002564 mmole of the ligand were weighed and dissolved in about 10 ml of ethanol also0.000003044 mmole of copper chloride were dissolved in equal amount of ethanol and added to the solution of the ligand. The mixture transferred to a round bottomed flask ,and refluxed at 70-80C^o for 2 hours . The mixture allowed to cooled , until the precipitate was separated (48 hrs) . The crystals collected and weighed.

- **Preparation of N,N-Bis (di para di methyl amino benzyledene) thiourea cobalt(III)chloride(L_3Co):**

0.000002469 mmole of the ligand were weighed and dissolved in about 10 ml of ethanol also0.000004235 mmole of cobalt chloride were dissolved in equal amount of ethanol and added to the solution of the ligand. The mixture transferred to a round bottomed flask ,and refluxed at 70-80C^o for 2 hours . The mixture allowed to cooled , until the precipitate was separated(48 hrs) . The crystals collected and weighed.

- **Preparation of Preparation of N,N-Bis (di para di methyl amino benzyledene) thiourea copper(III)chloride(L_3Cu):**

0.000002519 mmole of the ligand were weighed and dissolved in about 10 ml of ethanol also0.000002950 mmole of copper chloride were dissolved in equal amount of ethanol and added to the solution of the ligand. The mixture transferred to a round bottomed flask ,and refluxed at 70-80C^o for 2 hours . The mixture allowed to cooled , until the precipitate was separated(48 hrs) . The crystals collected and weighed.

- **Preparation of N,N-Bis (di,3methoxy,4hydroxy benzyledene) thiourea cobalt(III)chloride(L_4Co):**

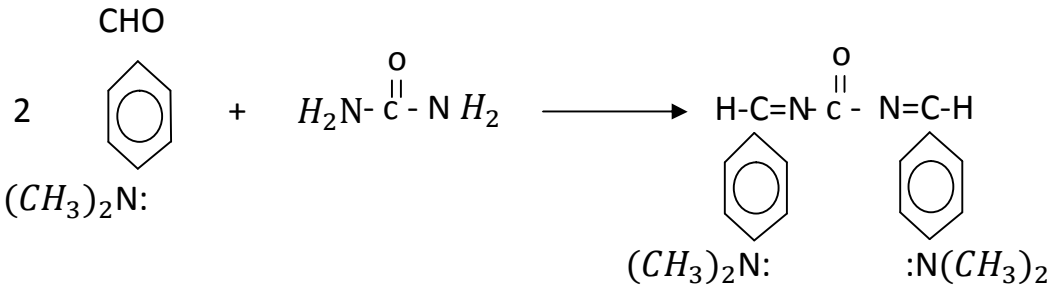
0.000002487 mmole of the ligand were weighed and dissolved in about 10 ml of ethanol also0.000004162 mmole of cobalt chloride were dissolved in equal amount of ethanol and added to the solution of the ligand. The mixture transferred to a round bottomed flask ,and refluxed at 70-80C^o for 2 hours . The mixture allowed to cooled , until the precipitate was separated(48 hrs) . The crystals collected and weighed.

❖ **Preparation of N,N-Bis (di,3methoxy,4hydroxy benzyledene) thiourea copper(III)chloride(L_4Cu):**

0.000002439 mmole of the ligand were weighed and dissolved in about 10 ml of ethanol also0.000002903 mmole of copper chloride were dissolved in equal amount of ethanol and added to the solution of the ligand. The mixture transferred to a round bottomed flask ,and refluxed at 70-80C^o for 2 hours . The mixture allowed to cooled , until the precipitate was separated (48 hrs) . The crystals collected and weighed.

Physical properties:

Complex	Molecular Formula	Molecular weight	Color	Yield%	Melting Point C
L1	$C_{19}H_{22}N_4O$	322.44	Color less	98.73	114
L2	$C_{17}H_{16}N_2O$	328.36	Off white	69.416	108
L3	$C_{19}H_{23}N_5S$	342.5	Yellow	79.55	109
L4	$C_{17}H_{17}N_3S$	344.3	Off white	85.66	106
L1+Cu	$C_{19}H_{22}N_4O$,Cu	385.94	Brown	77.10	98
L1+Co	$C_{19}H_{22}N_4O$,Co	381.34	Green	69.50	102
L2+Cu	$C_{17}H_{16}N_2O$,Cu	391.86	Brown	70.11	112
L2+Co	$C_{17}H_{16}N_2O$,Co	387.26	Blue	68.12	88
L3+Cu	$C_{19}H_{23}N_5S$,Cu	406	Brown	42.31	113
L3+Co	$C_{19}H_{23}N_5S$,Co	401.4	Blue	73.20	110
L4+Cu	$C_{17}C_{17}N_3S$,Cu	407.8	Brown	60.50	103
L4+Co	$C_{17}H_{17}N_3S$,Co	403.2	Blue	64.37	99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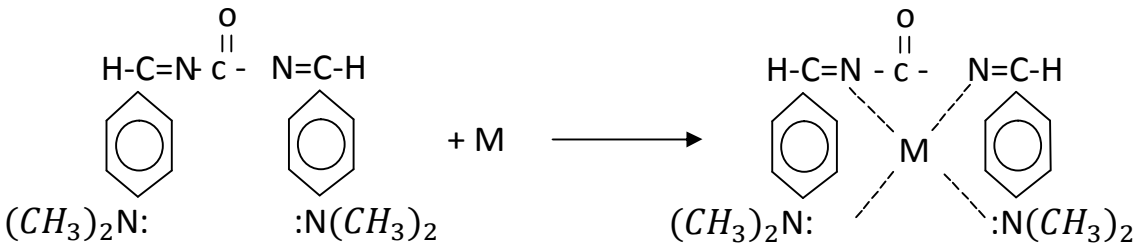
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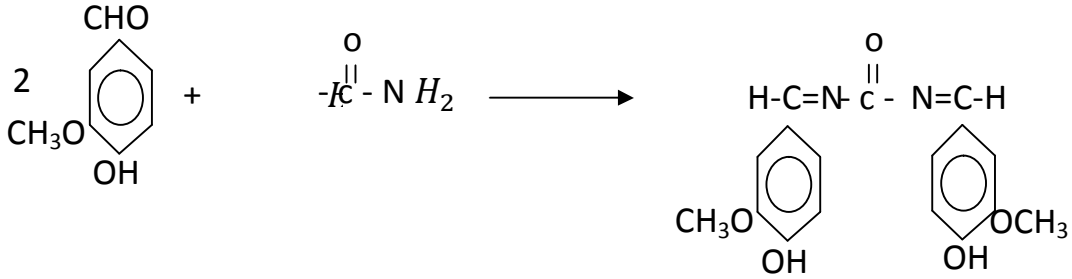
M ≡ Cu , Co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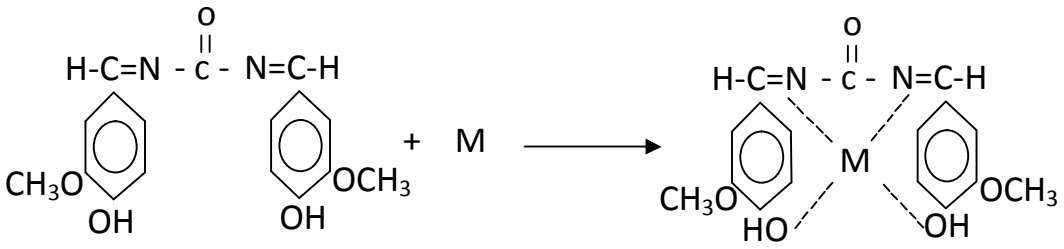
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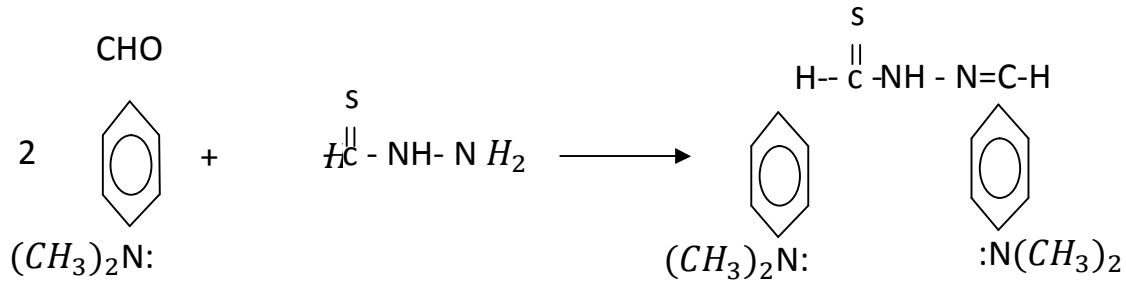
M ≡ Cu , Co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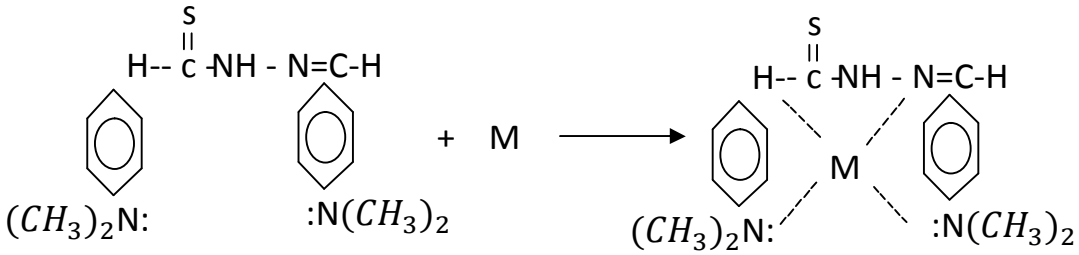
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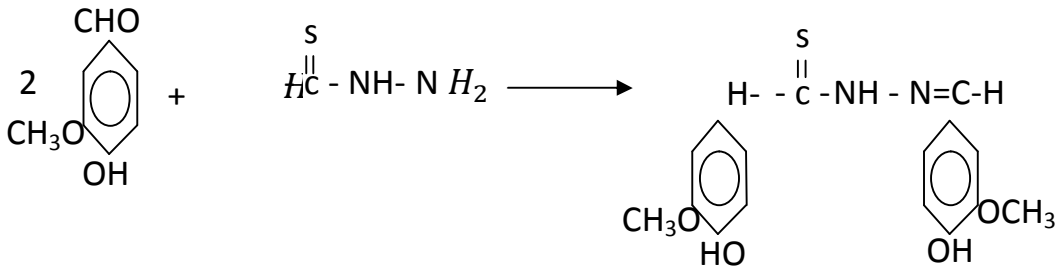
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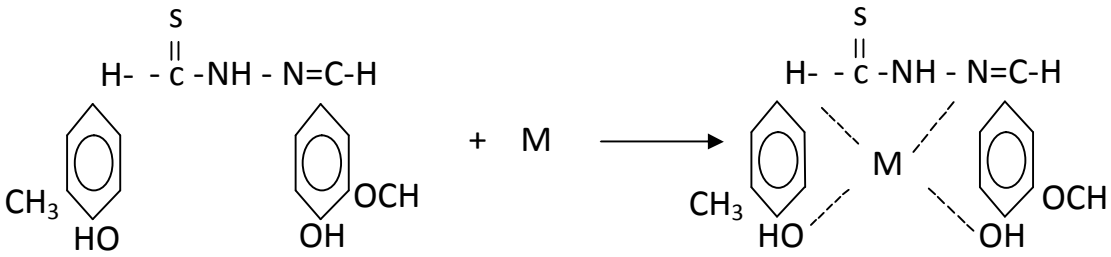
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OCH
OH

3-1 UV result:

Table (3-1) UV/ visble spectra data:

Compound	Absorption	Beak/nm
L1	0.744	210
L2	1.512	220
L3	1.494	220
L4	1.398	230
L1+Cu	1.180	210,220
L1+CO	0.713	210
L2+Cu	0.705	230,275
L2+Co	1.476	225,270,340
L3+Cu	1.247	215,260
L3+Co	1.489	220,270,380
L4+Cu	1.509	220,270,380
L4+Co	0.152	220,240

3-2 IR Result:

-The infrared spectrum of the ligands were recorded with in the 400-4000 cm^{-1} rang.

-The spectra of all complexes are alike with that of the free Schiff base,containing the absorption bonds which are assigned to the vibrations:(C=N),(CH_3),(C=O); that suggests the presence of a generally unaltered structure of this ligands.

-The bands that occur in the low wavenumbers rang were assigned to the stretching vibrations v (M-O)

Table (3-2) IR spectra (cm^{-1})

***L1~~ N,N_Bis(di,para di methyl amino benzaldene)urea:**

	CH_3	C=O	C=N	CH(Ar)	M-O	M-N
L1	2904	1545	1600	3166	_	_
L1Cu	2909	1375	1594	3452	816	750
L1Co	2914	1374	1593	3183	810	590

Table (3-3) IR spectra(cm^{-1})

L2~~N,N-Bis (di,3methoxy , 4 hydroxy benzyldene) urea

	OH	CH_3	CH(Ar)	OCH_3	C=O	C=N	M-O	M-N
L2	3463	2969	3315	1161	1517	1671	_	_
L2Cu	3380	2920	3130	1160	1495	1582	530	580
L3Co	3230	1590	3190	1161	1506	1594	722	739

Table (3-4) IR spectra (cm^{-1})

L3~~~ N,N-Bis (dipara di methyl amino benzyldene)thiourea

	CH_3	CH(Ar)	NH(alphatic)	C=S	C=N	M-O	M-N
L3	3172	3172	3391	1200	1600	_	_
L3Cu	2915	3260	3435	1161	1589.04	530	816
L3Co	2920	3200	3424	1167	1600	723	816

Table (3-5)IR spectra(cm^{-1})

L4~~N,N-Bis (di,3methoxy,4hydroxy benzyldene) thiourea

	CH_3	CH(Ar)	OH	OCH_3	C=S	C=N	NH(alpha)	M-O	M-N
L4	2969	3167	3390	1035	1161	1660	3391	_	_
L4Cu	2854	3130	3580	1150	1150	1600	3468	635	720
L4Co	2953	3189	3390	1150	1150	1594.52	3280	723	816

3-3 Results of atomic absorption

Sample	Cu%		Co%	
	practical	Theoirtical	practical	Theoritical
L1Cu	10.724	16.4533	_____	_____
L1Co	_____	_____	9.972	15.2614
L2Cu	3.928	16.2047	____	____
L2Co	____	____	6.948	15.2094
L3Cu	11.724	15.640	____	____
L3Co	____	____	7.01	14.6736
L4Cu	9.736	15.5713	____	____
L4Co	___	____	4.742	14.6081

3-4 Result of biologicalactivity:

Type of bacteria	C	L_1 (0.05)	L_4(0.05)	L_4(0.1)
Ps.aeruyinosa	15	18	22	18
E.coli	6	20	18	25
S.aureus	6	15	17	20
E.faecalis	10	6	11	14

Type of bacteria	L_3(C)	L_3(0.05)	L_3(0.1)	L_2(C)	L_2(0.05)	L_2(0.1)
Ps.aeruyinosa	7	10	12	19	14	13
E.coli	6	14	14	5	10	13
S.aureus	5	18	16	6	7	10
E.faecalis	6	9	17	6	9	12

3-5 Discussion of IR Results:

*In ligand1 C=N 1600 schiffted to 1594and 1593 in L_1Cu and L_1Co respectively .this change due to complexation.

*In ligand2 C=N 1671 schiffted to 1582 and 1594 in L_2Cu and L_2Co respectively.this change due to complexation

In ligand3 C=N 1600 Schiffted to 1589.04 and 1600in L_3Cu andL_3Co Respectively. This change due to complexation.

*in ligand 4C=N 1660 schiffted to 1600 and 1594 in L_4Cu and L_4Co Respectively. This chang due to complexation.

Discussion of UV Results:

The beaks in UV results explained lamda max of ligands and there complexes

Discussion of biological activity:

After testing the ligands found it efficient for types of bacteria which utilized in medical and pharmaceutical fields

3-6 Refernces:

1.Marinescu, D., Badea,M., Olar, R., and Nicolae, A., (1996)Anal. Univ. Buc., V, 3-8

2.Marinescu, D.,Badea,M., Olar, R., and Nicolae,A.,(1994-1995) Bul. I.P.B.-seriachimie, 56-57,(1-4) 3-10.

3.Marinescu, D., Badea,M.,Cristurean, E., Olar, R. and Nicolea , A., (1994-1995) Bul. I. P.B. 56-57, (1-4) 11-18.

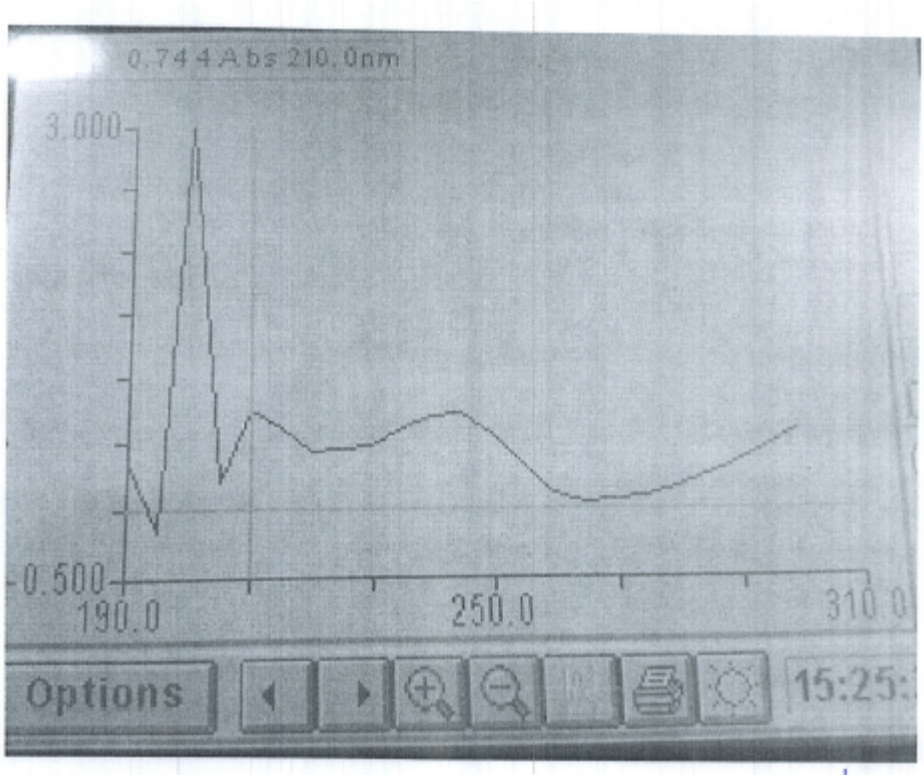
4.Balaban, A.T., Banciu , M. and Pogany, I., (1983) Aplicatii ale metodelorfizice in chimiaorganica, Ed. Stiintificasienciclopedica , Bucuresti, 20-36

5.Nakamoto , K., (1986) Infrared and Raman spectra of Inorganic and coordination compounds , Wiley , New york , 227-231.

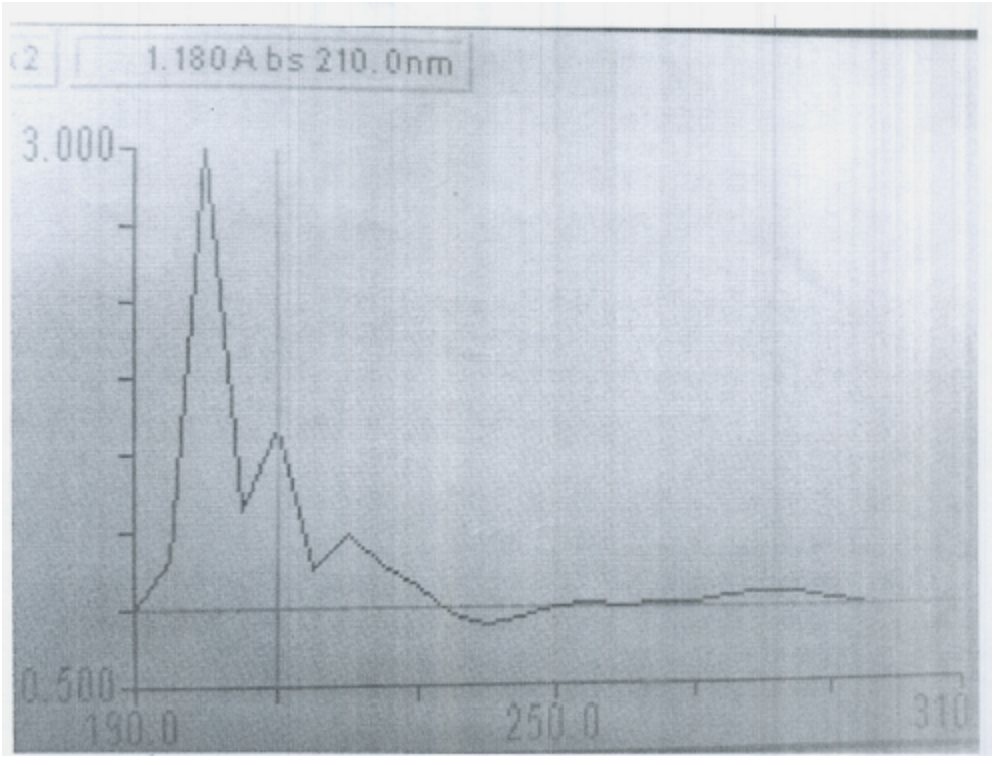
6.Lever , A. B. P., (1984), Inorganic Electronic spectroscopy ,Elsevier Publ. comp., Amsterdam , London , New york, 440-444 ,458-472 , 554-572.

7. Hathaway, B. J. and Billing, D.E., (1970) Coord. Chem. Rev., 5, 143-167.

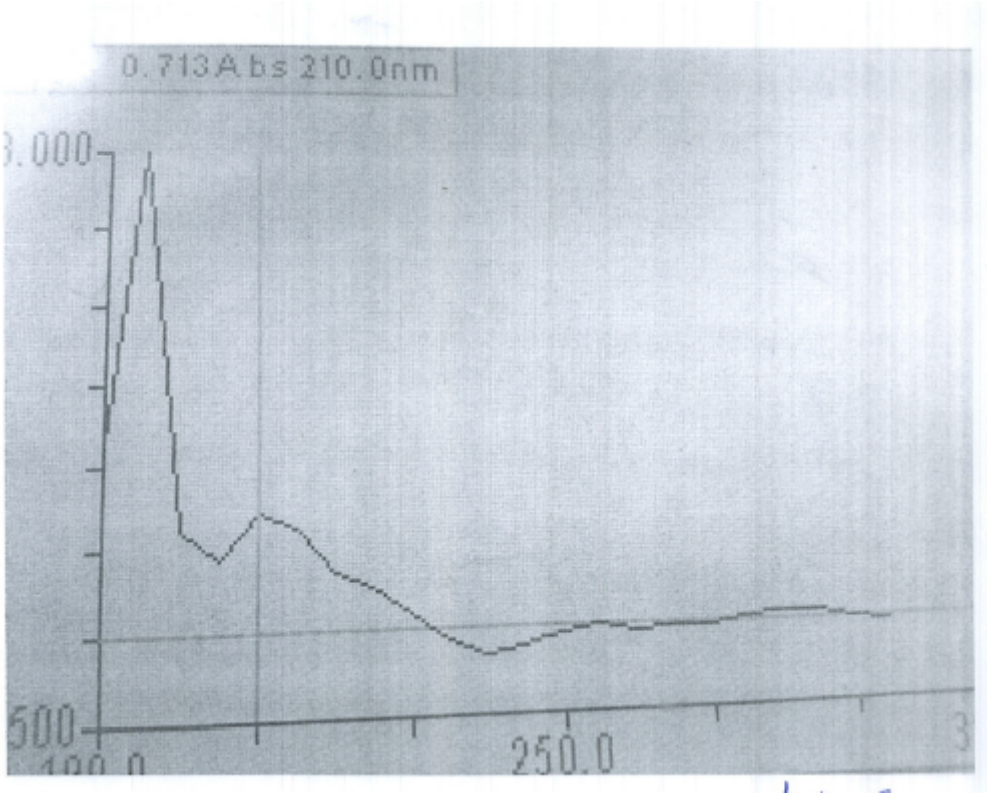
8. Hathaway,B.J. (1988) Electron spin resonance spectroscopy in comprehensive Coordination Chemistry , vol . 5, 662


0.744 Abs 210.0nm
3.000
0.500
190.0
250.0
310.0
Options
15:25:

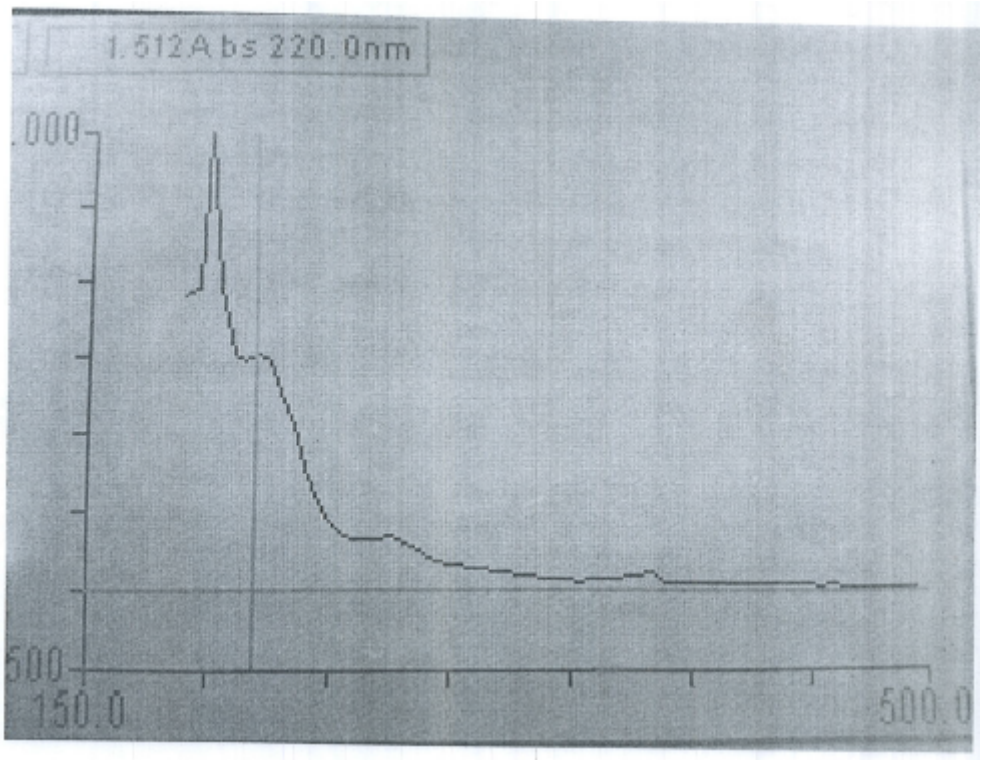
L1


(2
1.180 Abs 210.0nm
3.000
0.500
190.0
250.0
310

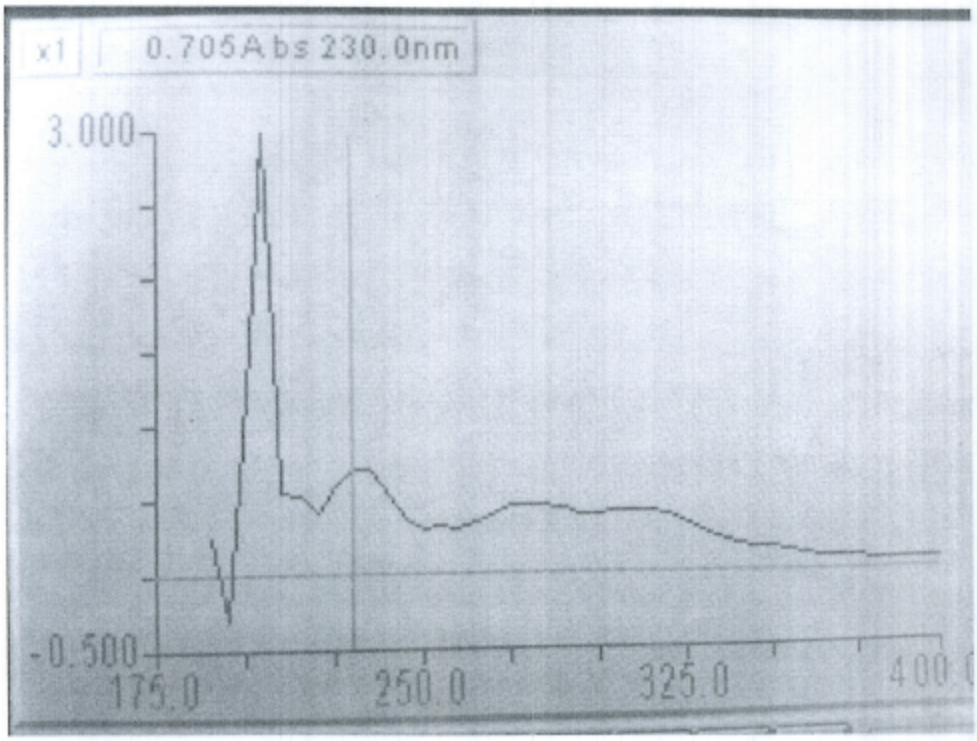
L1 + Cu


0.713Abs 210.0nm
3.000
500
250.0

L1 + Co


1.512Abs 220.0nm
.000
500
150.0
500.0

L2


x1
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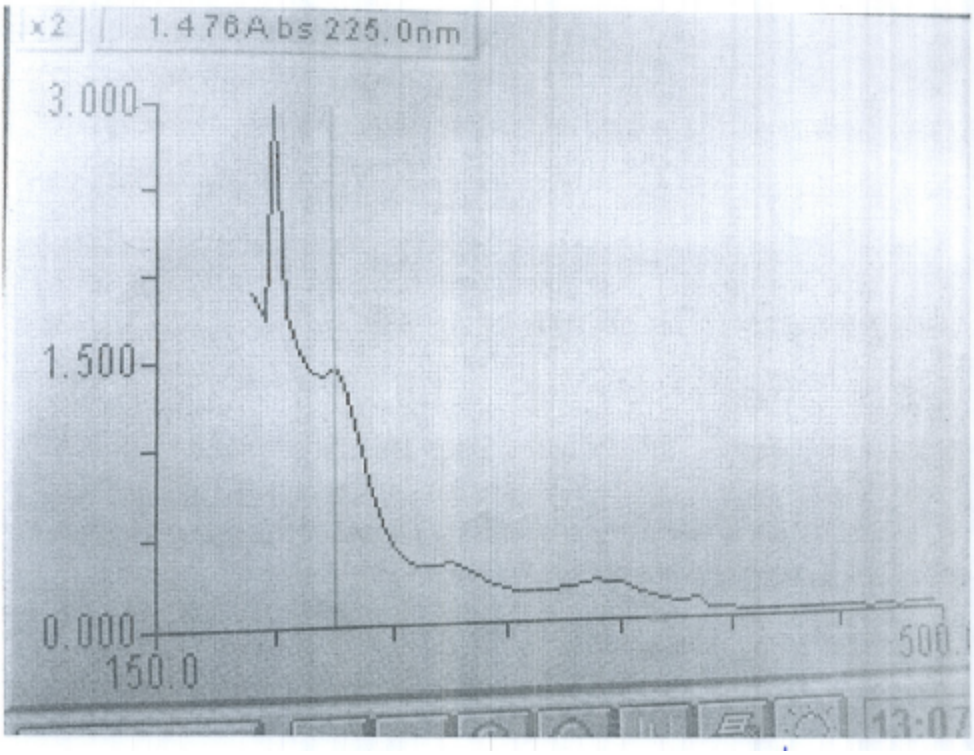
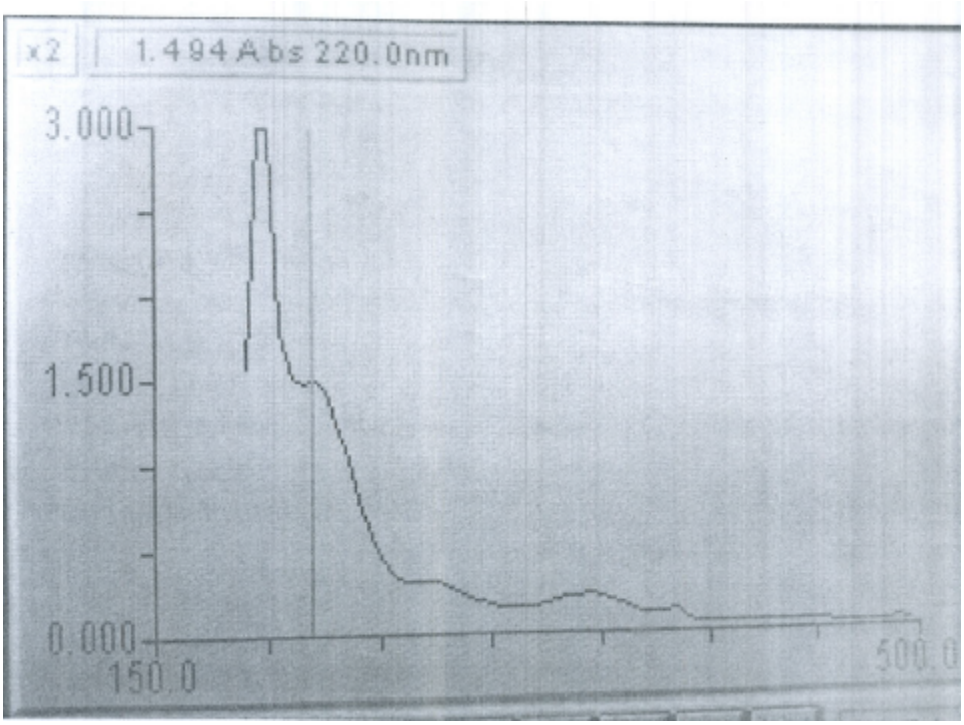
3.000
-0.500
175.0
250.0
325.0

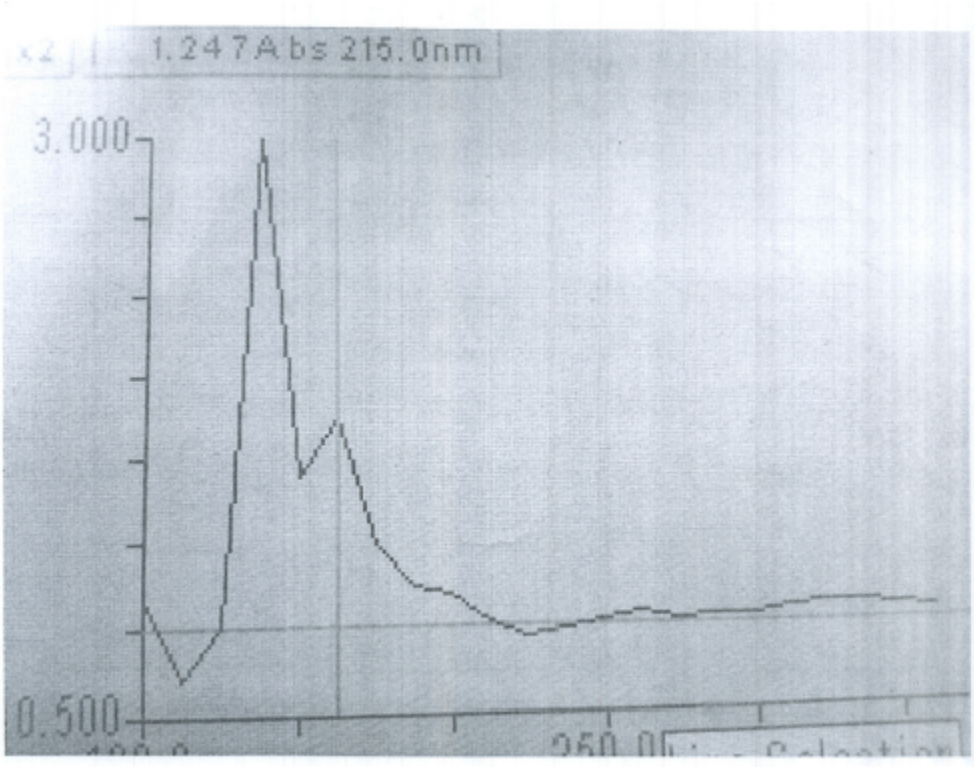
L2 + Cu


x2
1.476Abs 225.0nm
3.000
1.500
0.000
150.0

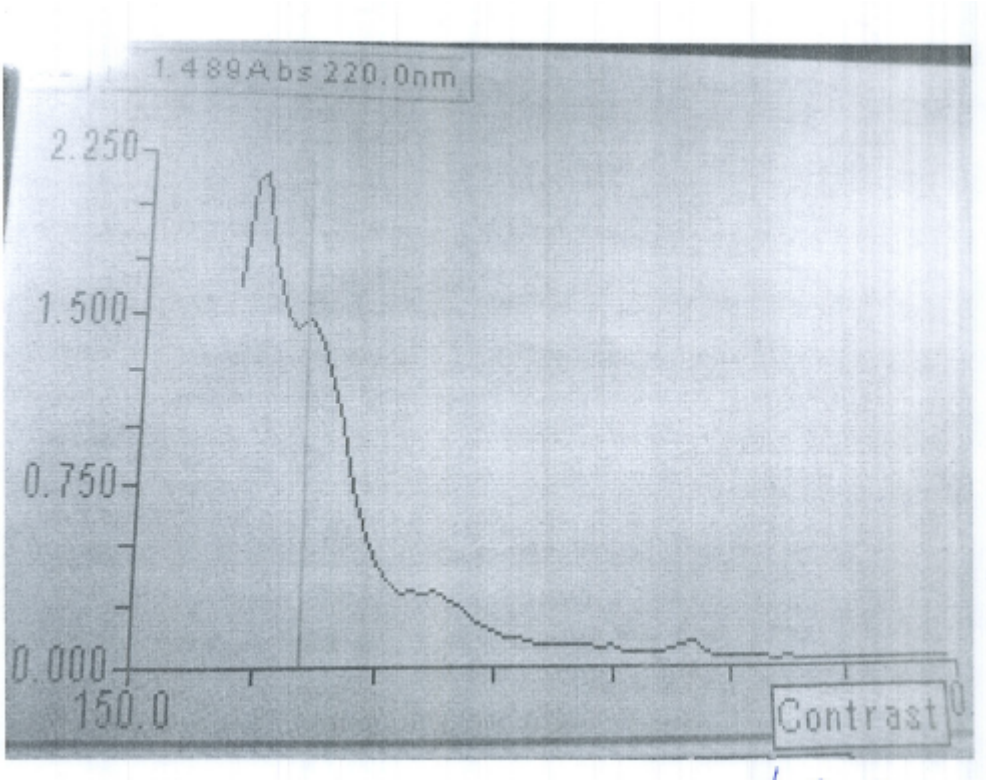
L2 + Co


x2
1.494Abs 220.0nm
3.000
1.500
0.000
150.0
500.0

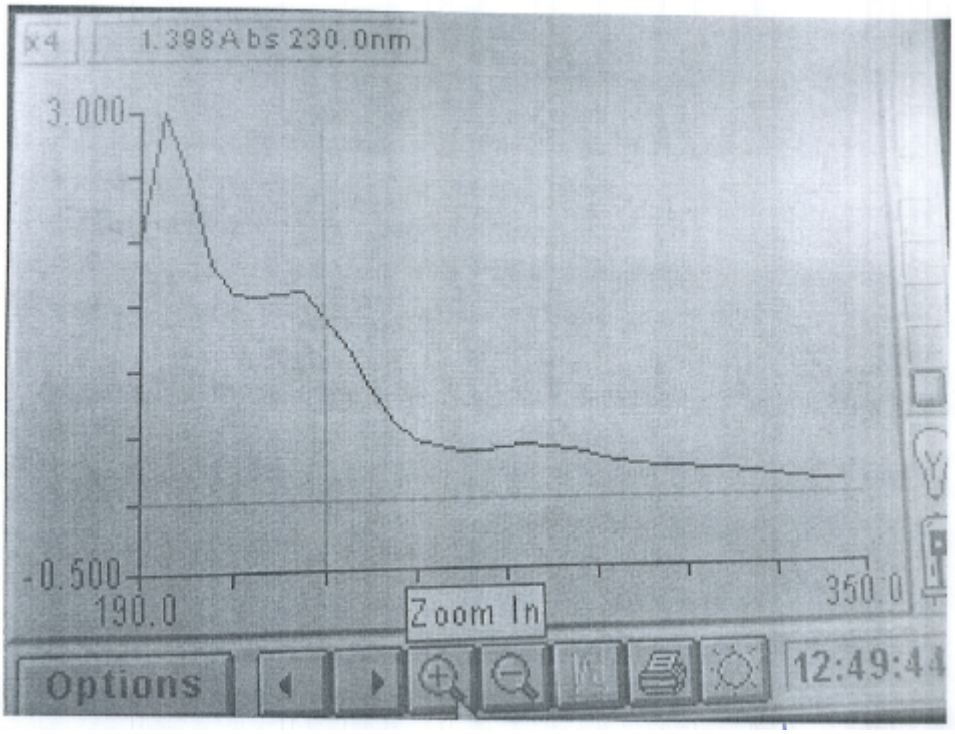
L3


1.247Abs 215.0nm
3.000
0.500

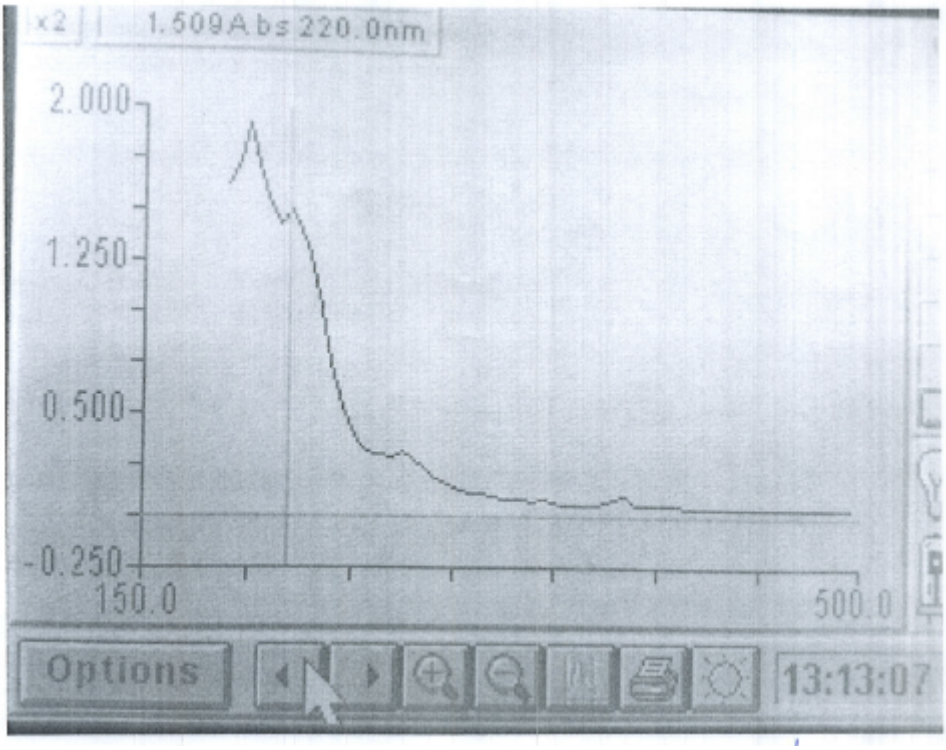
L3 + Cu


1.489Abs 220.0nm
2.250
1.500
0.750
0.000
150.0
Contrast

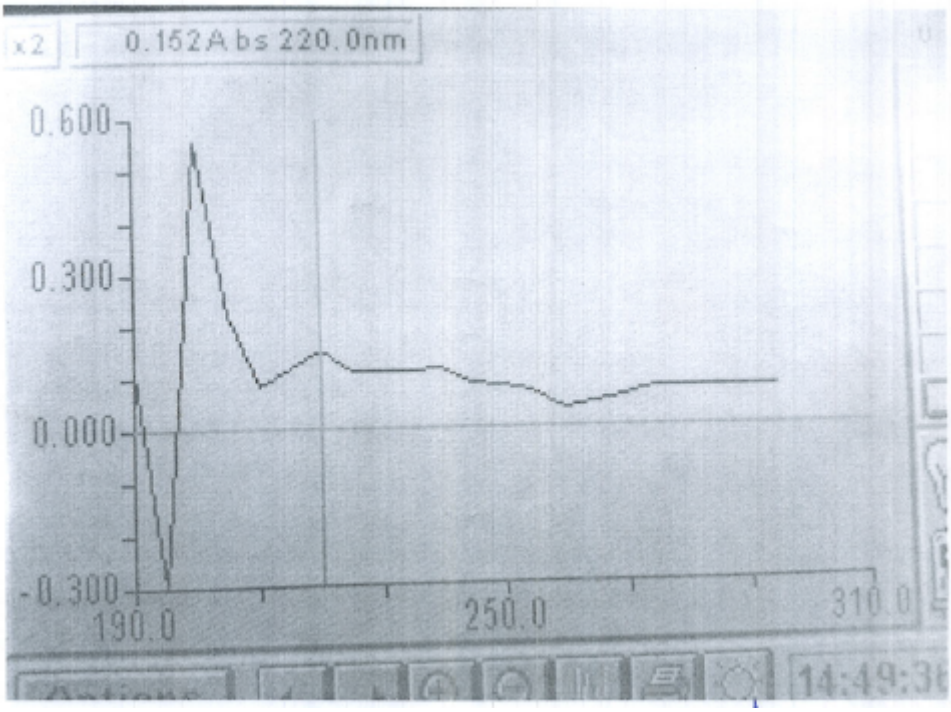
L3 + Co


x4
1.398Abs 230.0nm
3.000
-0.500
190.0
350.0
Zoom In
Options
12:49:44

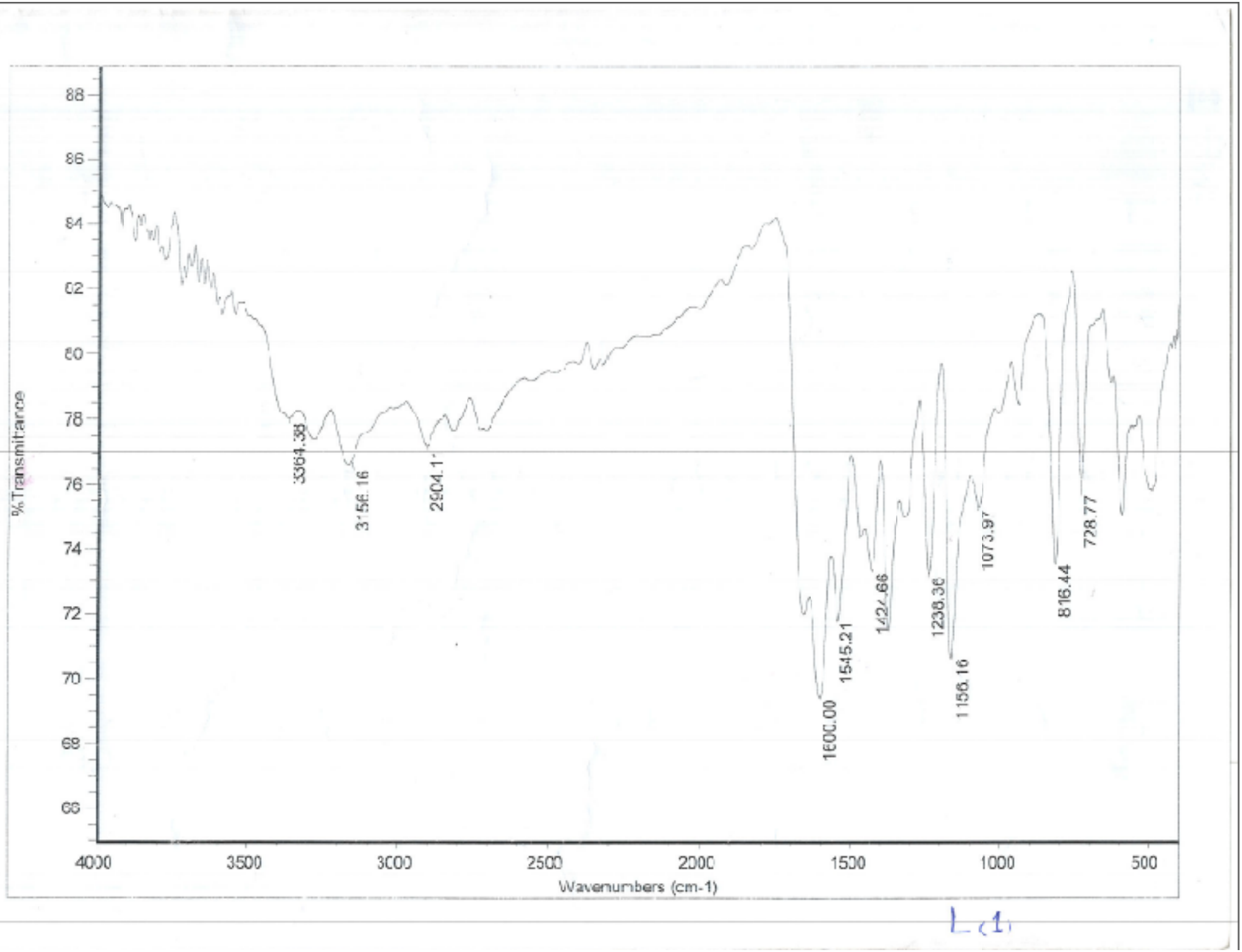
L4


x2
1.509Abs 220.0nm
2.000
1.250
0.500
-0.250
150.0
500.0
Options
13:13:07

L4 + Cu


x2
0.152Abs 220.0nm
0.600
0.300
0.000
-0.300
190.0
250.0
310.0

L4 + Co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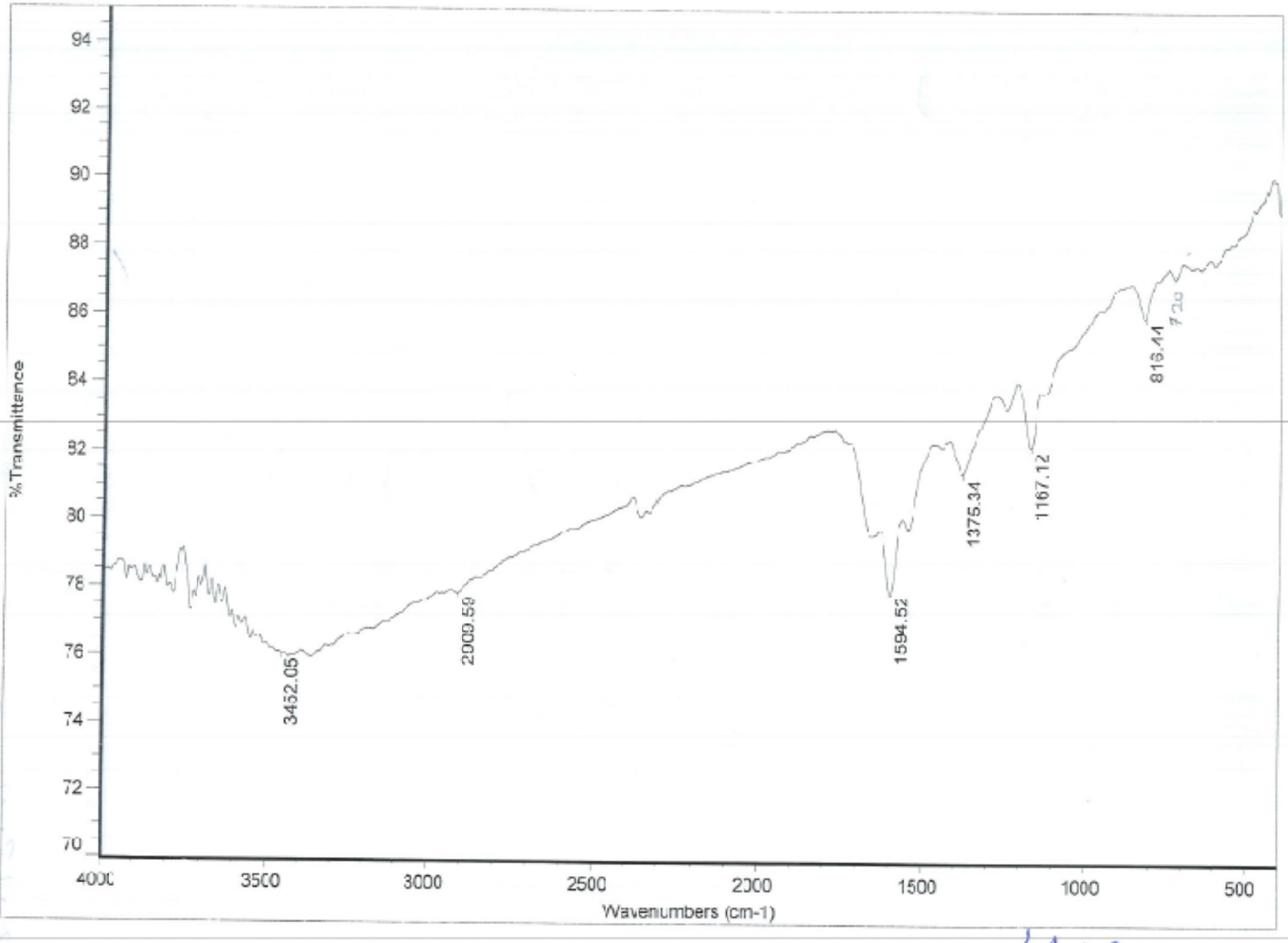
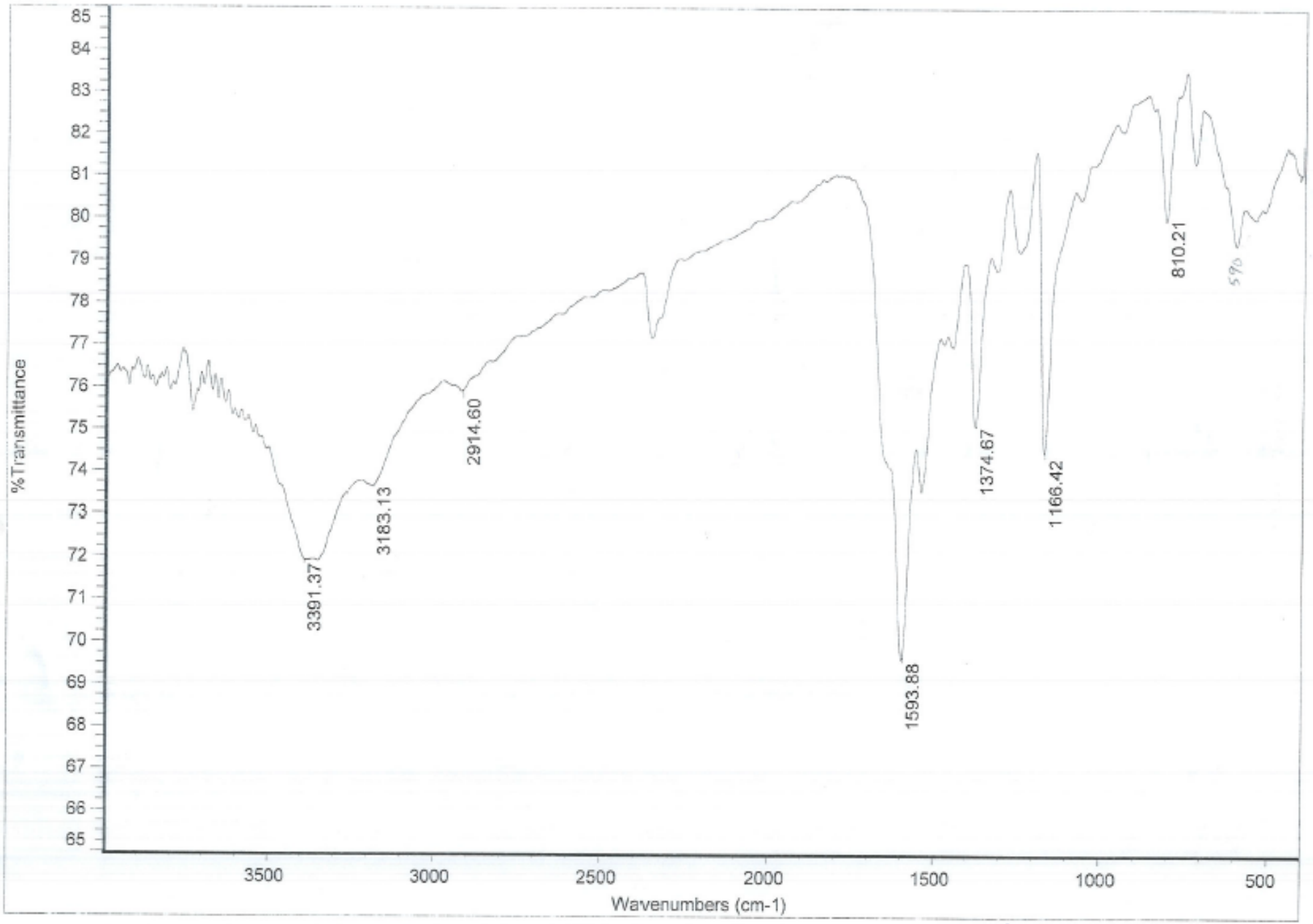
86
84
82
80
78
76
74
72
70
68
66
3364.38
3156.16
2904.1
1600.00
1545.21
1424.66
1238.36
1156.16
1073.97
816.44
728.77
4000
3500
3000
2500
2000
1500
1000
500
Wavenumbers (cm-1)

L(1)

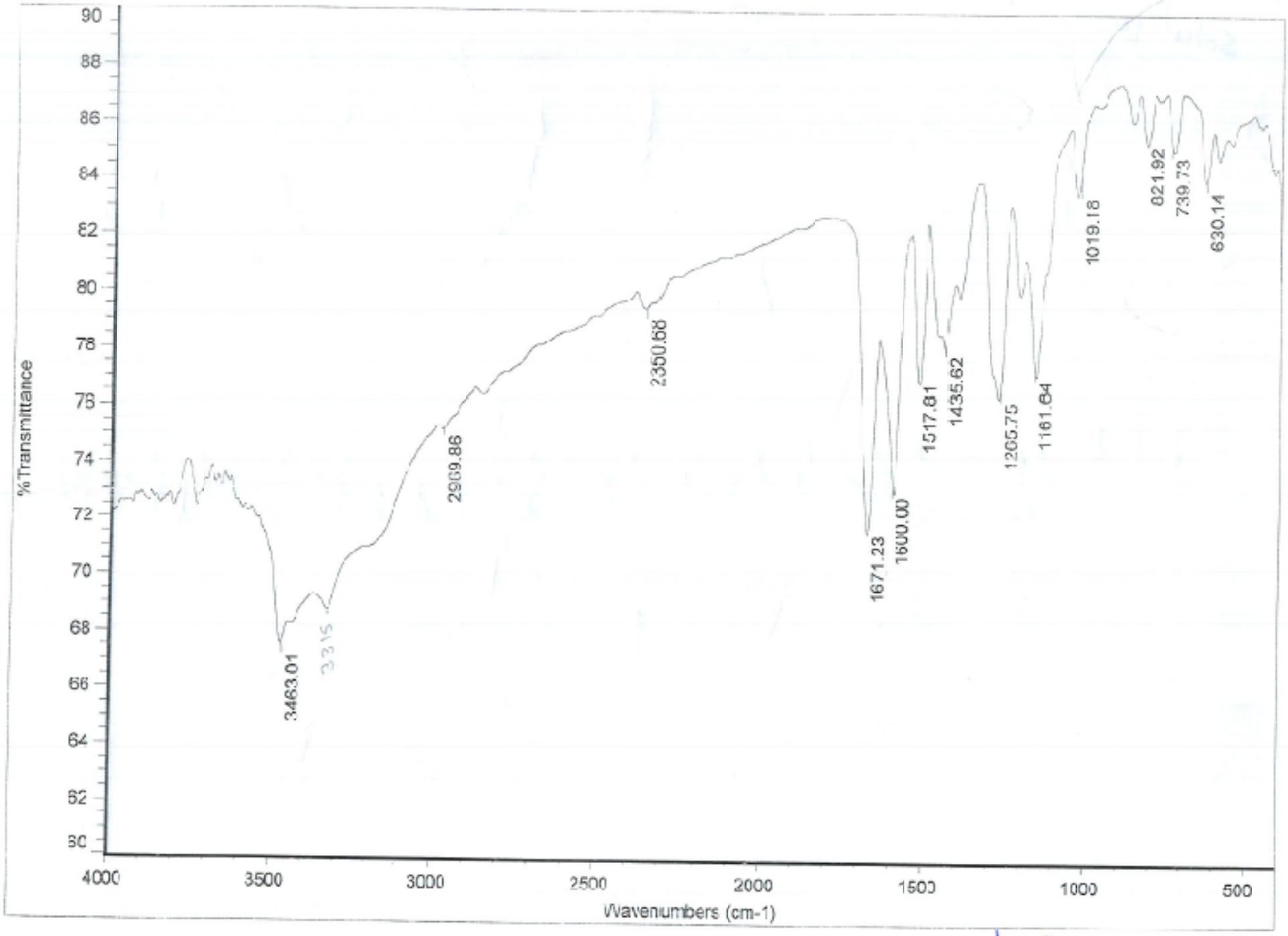

%Transmittance
94
92
90
88
86
84
82
80
78
76
74
72
70
4000
3500
3000
2500
2000
1500
1000
500
Wavenumbers (cm-1)
3452.05
2909.59
1594.52
1375.34
1167.12
813.41
720

L1 + Cu

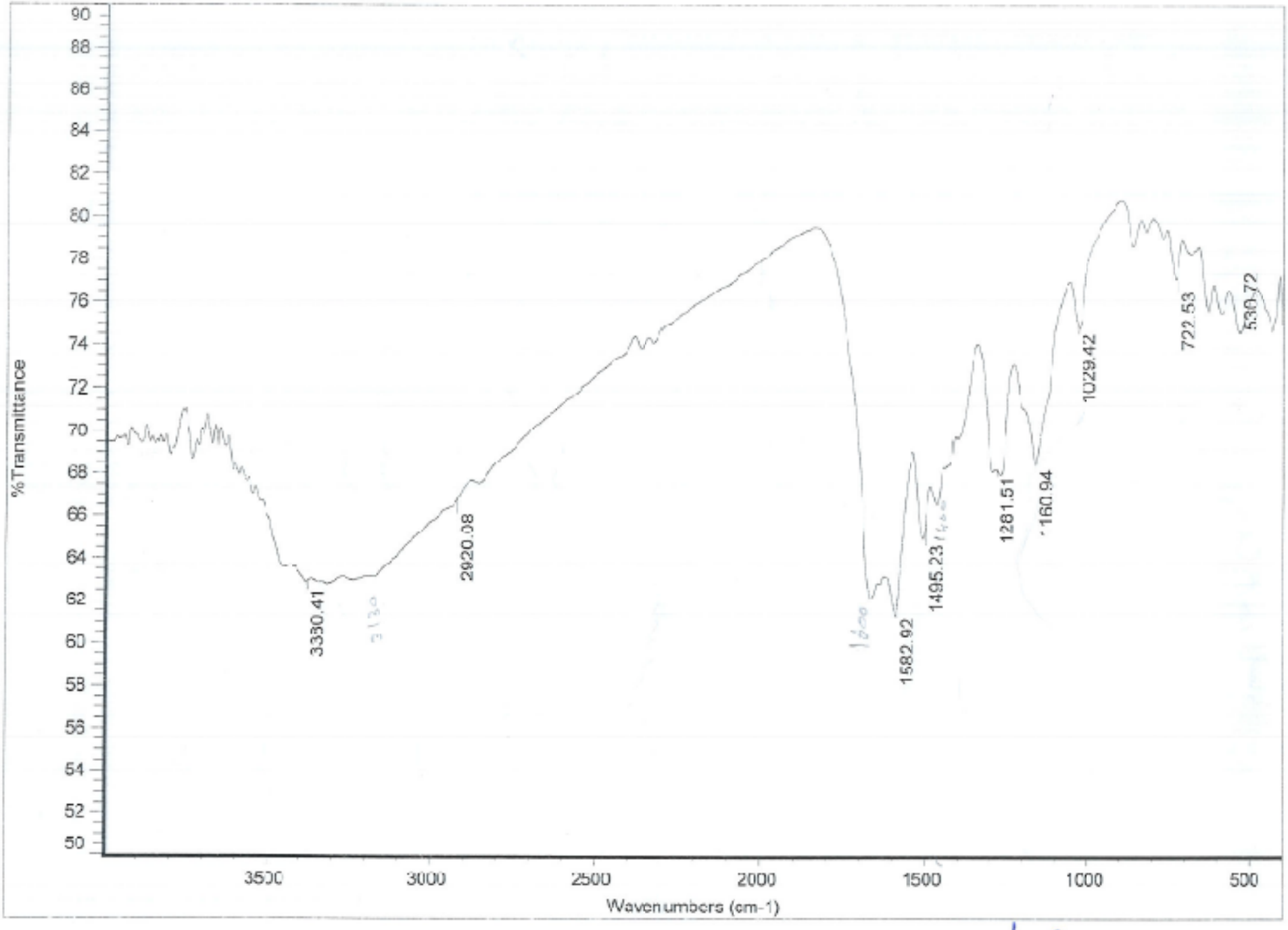


L1 + CO

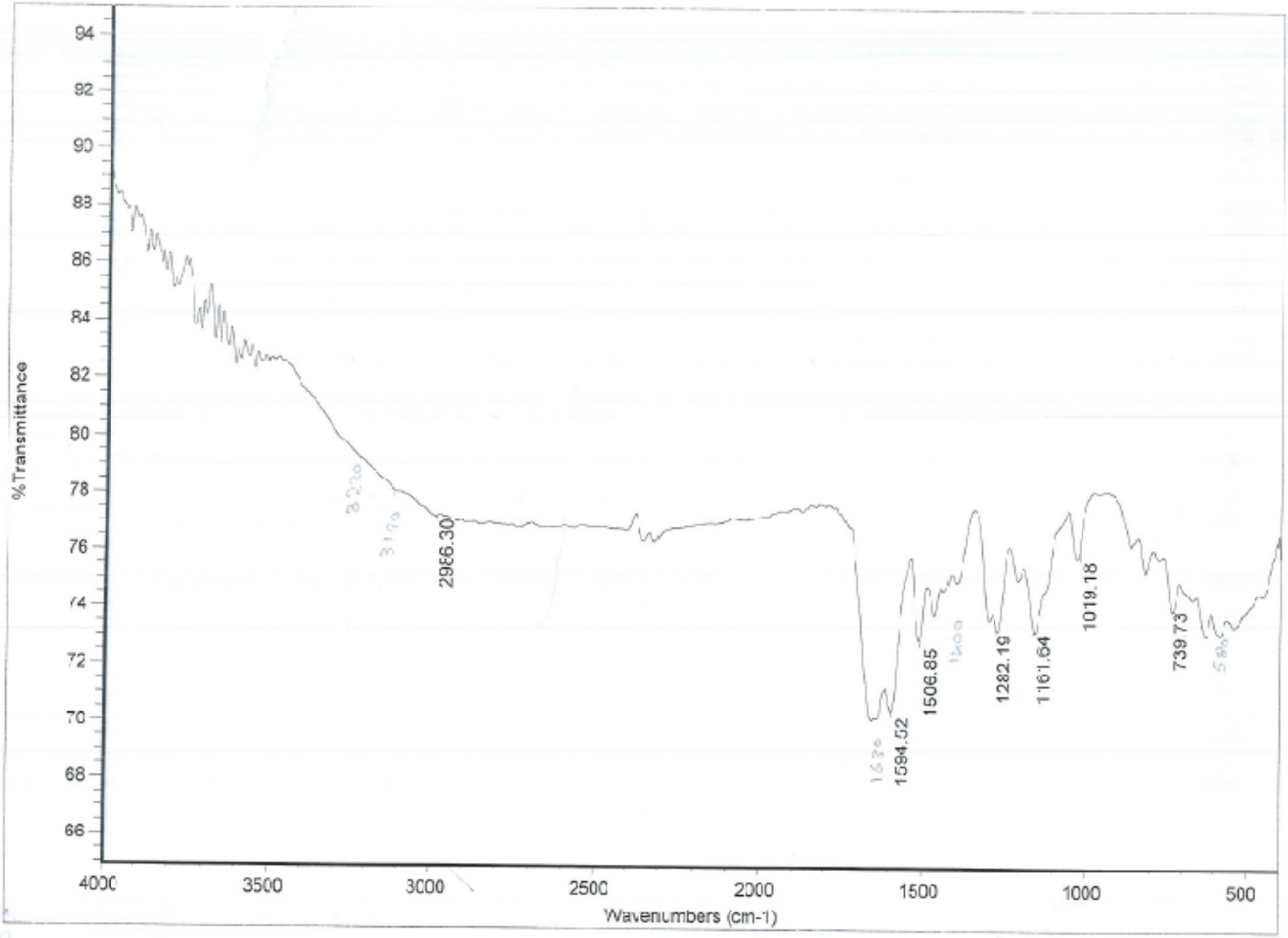
shifts + CO


%Transmittance
Wavenumbers (cm-1)
3463.01
3315
2909.86
2350.68
1671.23
1600.00
1517.81
1435.62
1265.75
1161.84
1019.18
821.92
739.73
630.14

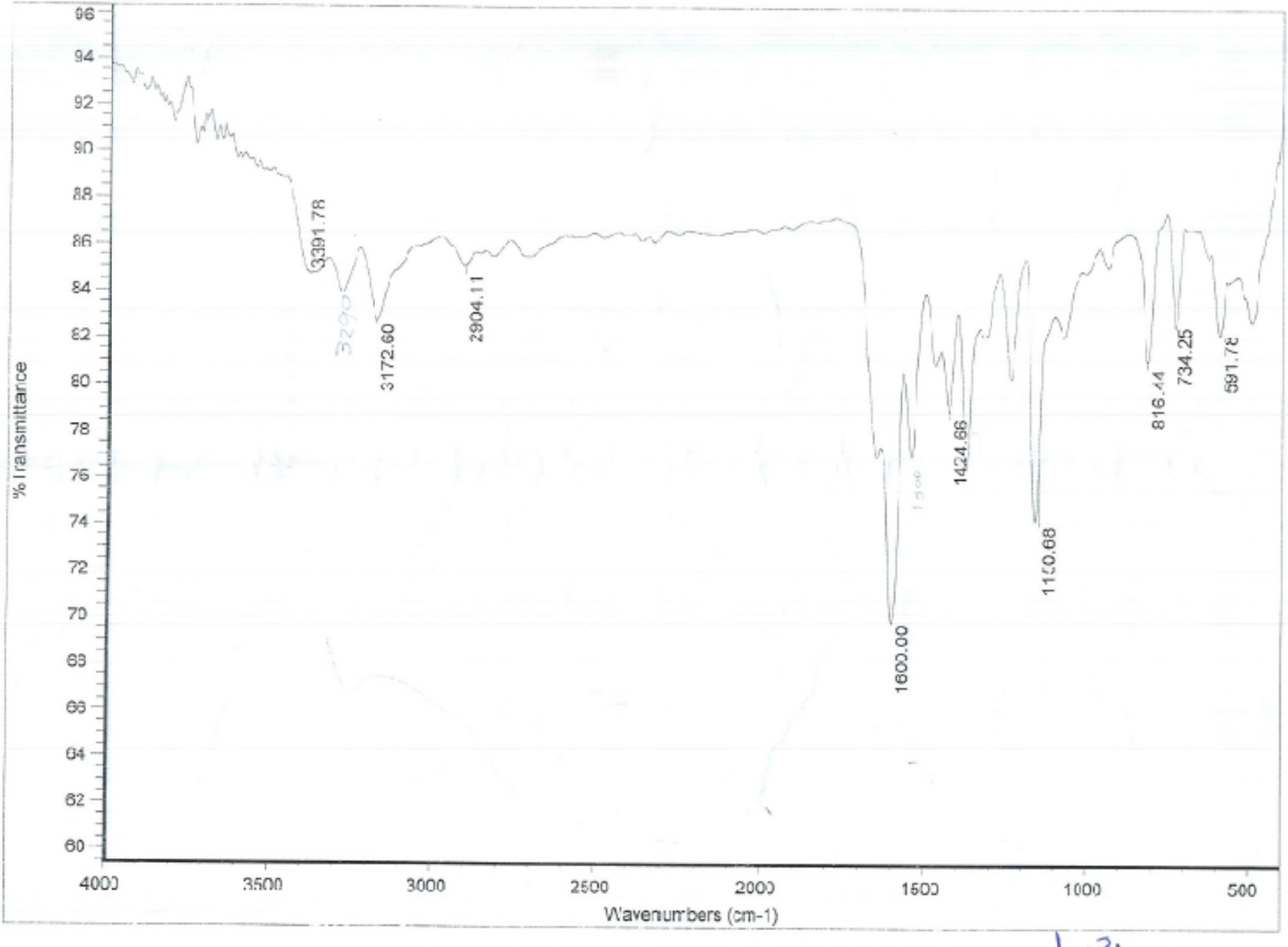
L(2)


%Transmittance
90
88
86
84
82
80
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
3500
3000
2500
2000
1500
1000
500
Wavenumbers (cm-1)
3330.41
2920.08
1582.92
1495.23
1281.51
1160.94
1029.42
722.53
530.72

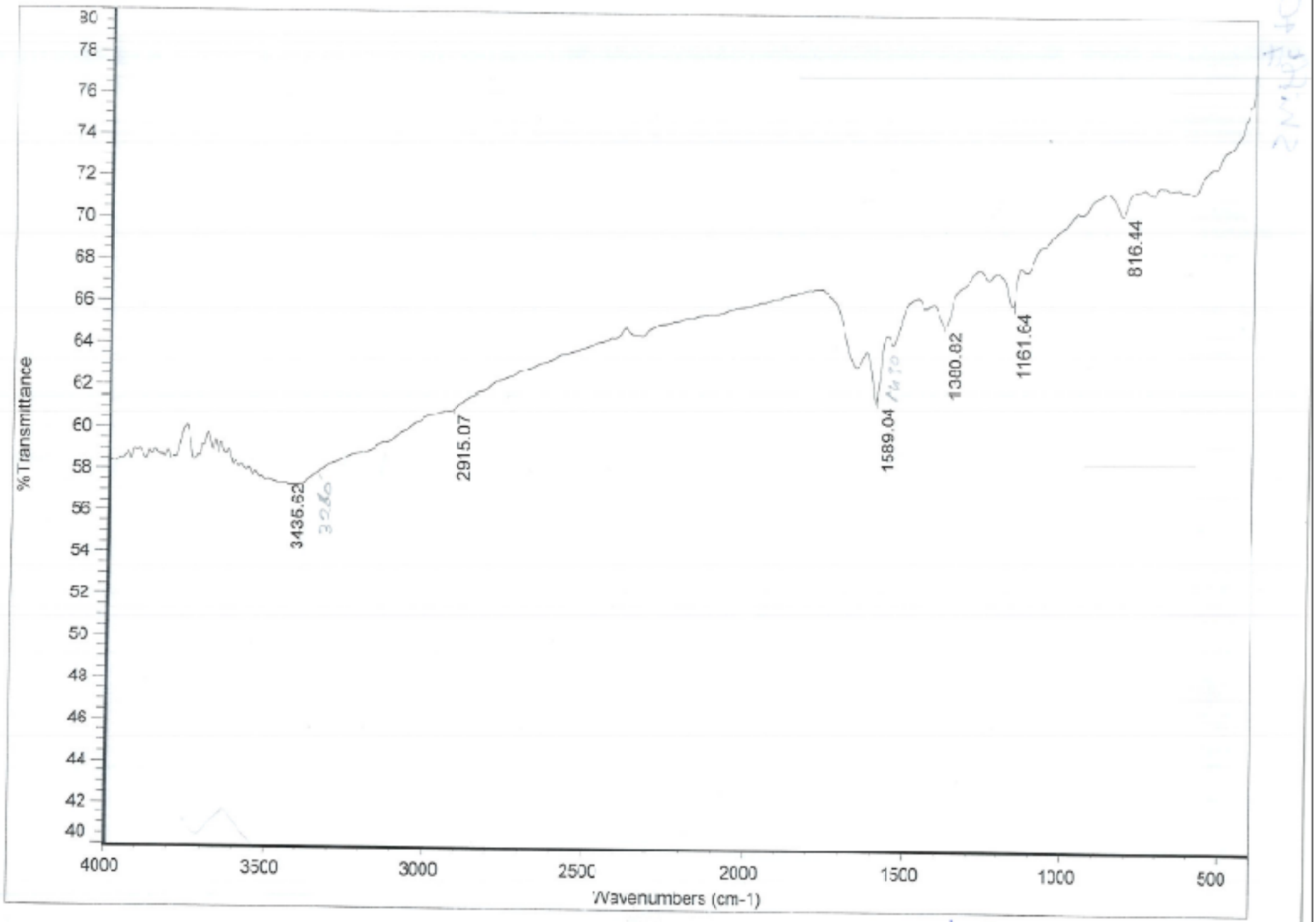
L 2 + cu


%Transmittance
94
92
90
88
86
84
82
80
78
76
74
72
70
68
66
4000
3500
3000
2500
2000
1500
1000
500
Wavenumbers (cm-1)
2966.30
1594.52
1506.85
1282.19
1161.64
1019.18
739.73

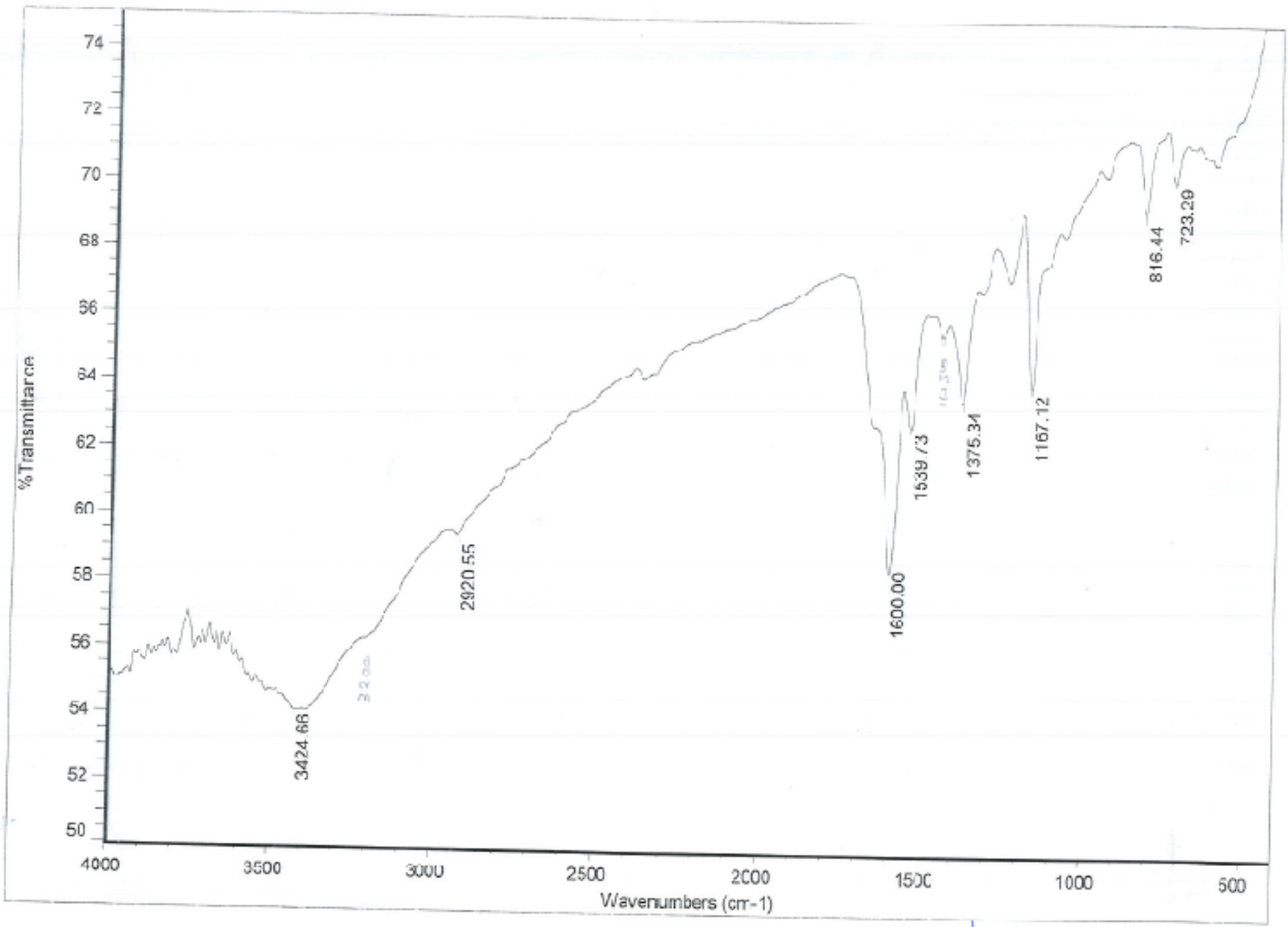
L2+Co


% Transmittance
96
94
92
90
88
86
84
82
80
78
76
74
72
70
68
66
64
62
60
3391.78
3290
3172.60
2904.11
1600.00
1506
1424.66
1150.68
816.44
734.25
591.78
4000
3500
3000
2500
2000
1500
1000
500
Wavenumbers (cm-1)

L(3)


%Transmittance
Wavenumbers (cm-1)
4000
3500
3000
2500
2000
1500
1000
500
3436.62
2915.07
1589.04
1300.82
1161.64
816.44

L3+Cu


%Transmittance
74
72
70
68
66
64
62
60
58
56
54
52
50
4000
3500
3000
2500
2000
1500
1000
500
Wavenumbers (cm-1)
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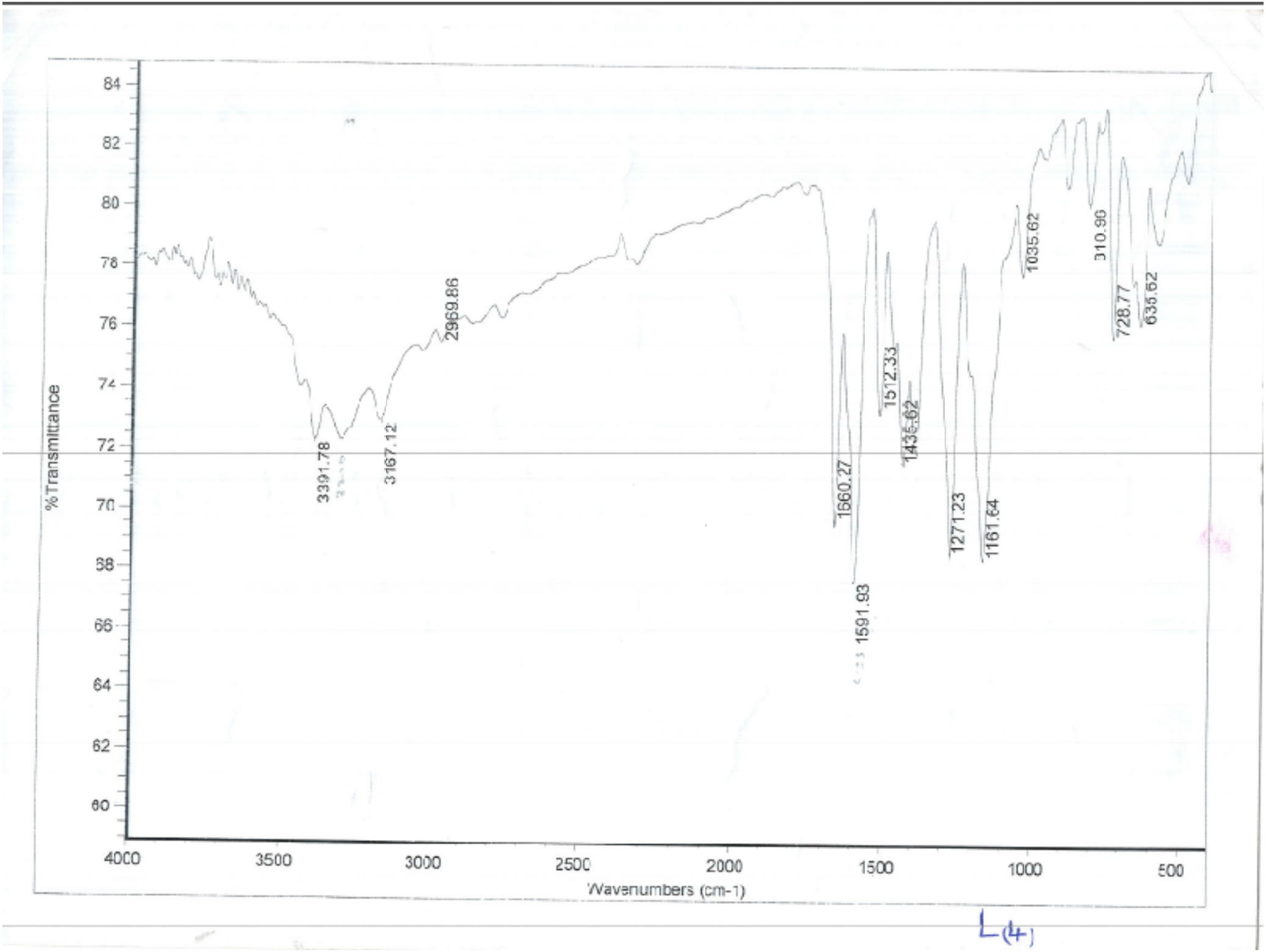
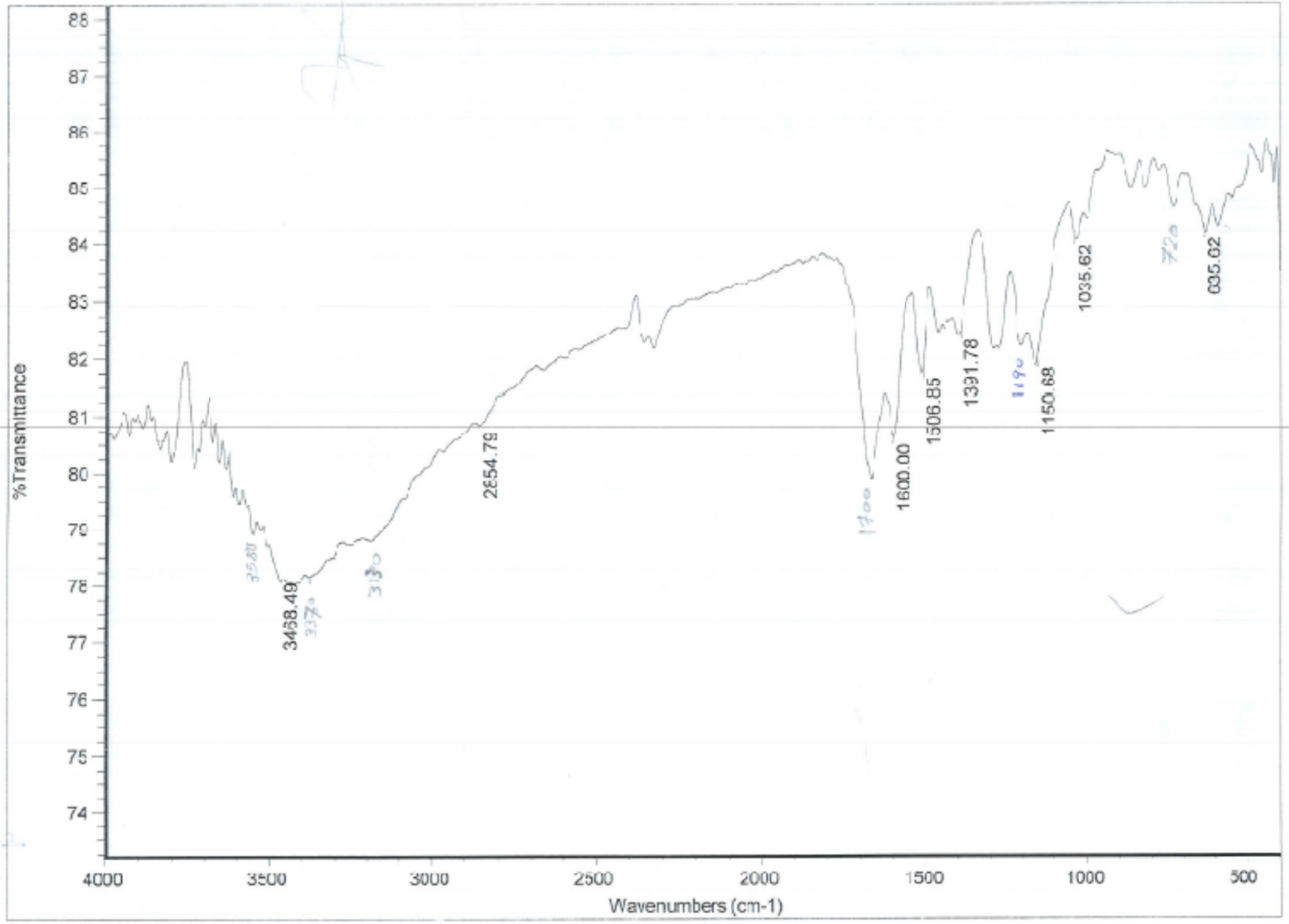
1539.73
1375.34
1167.12
816.44
723.29

L 3+Co


% Transmittance
Wavenumbers (cm-1)
84
82
80
78
76
74
72
70
68
66
64
62
60
4000
3500
3000
2500
2000
1500
1000
500
3391.78
3167.12
2969.86
1660.27
1591.93
1512.33
1435.62
1271.23
1161.64
1035.62
910.96
728.77
635.62

L(4)


%Transmittance
88
87
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85
84
83
82
81
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79
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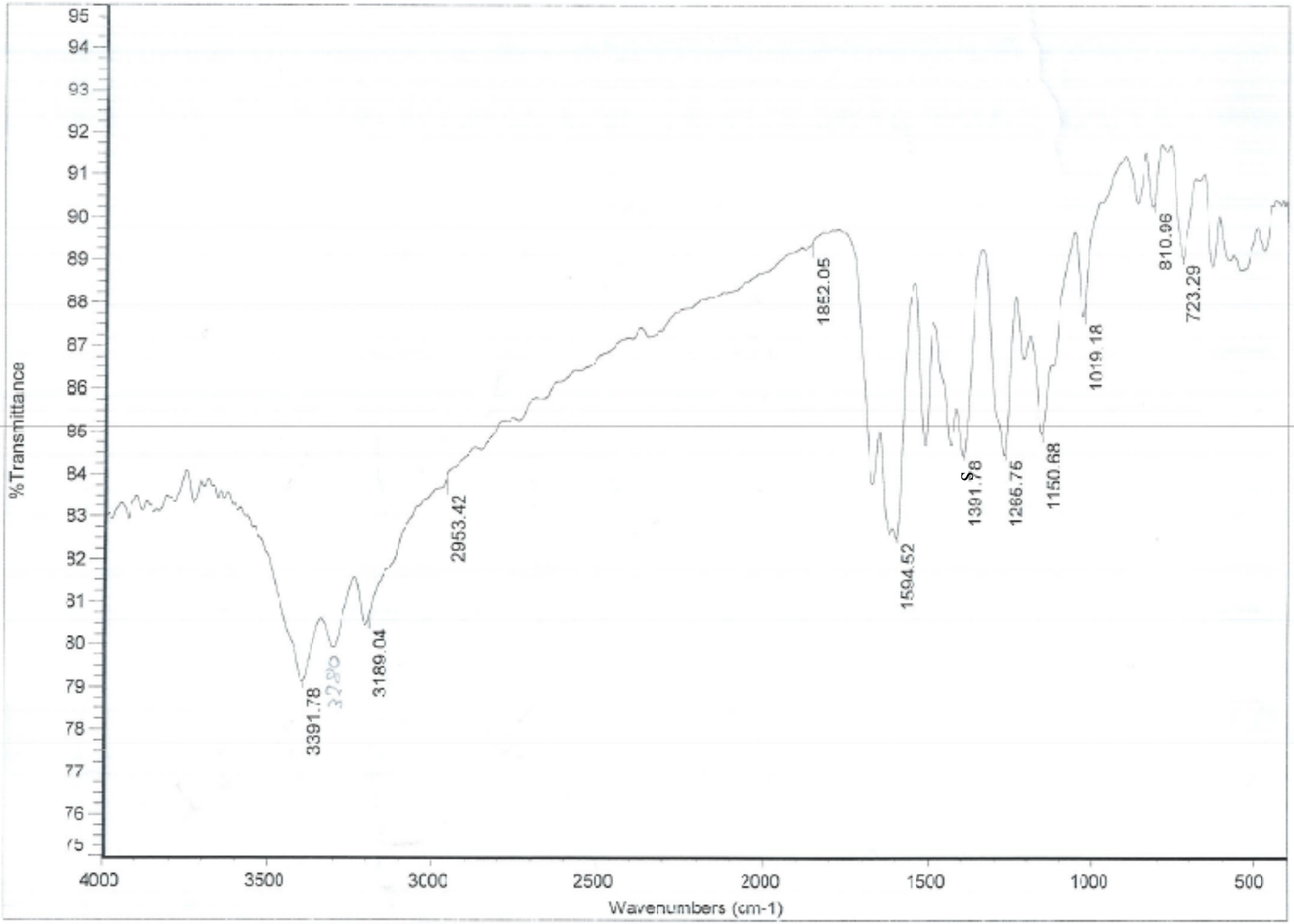
77
76
75
74
3458.49
2654.79
1600.00
1506.85
1391.78
1150.68
1035.62
635.62
4000
3500
3000
2500
2000
1500
1000
500
Wavenumbers (cm-1)

L + Cu


%Transmittance
Wavenumbers (cm-1)
4000
3500
3000
2500
2000
1500
1000
500
95
94
93
92
91
90
89
88
87
86
85
84
83
82
81
80
79
78
77
76
75
3391.78
3189.04
2953.42
1852.05
1594.52
1391.78
1266.76
1150.68
1019.18
810.96
723.29

L4+Co