Ag(I) Complex and Mixed-Ligand Complexes of Some Metal Ions Ni(II), Pd(II), Pt(II), Cu(II) and Zn(II) derived from 2-[4-(n-butyloxy phenyl)-5-(4-n-octyloxy phenyl)-1,3,4 oxadiazole and their Spectral and Biological Studies

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Abstract

The present work involves with the synthesis and characterization of mixed ligand complexes derived from 2-[4-(n-butyloxy phenyl)-5-(4-n-octyloxy phenyl)-1,3,4 oxadiazole as primary ligand and sodium (sodium benzyl)propan-2-ylcarbamodithioate as secondary ligand. The two ligands were used as Lewis bases for the preparation of metal complexes of nickel (II), copper(II), palladium(II), platinum(II) and zinc(II). Silver(I) complex was prepared through the reaction of two moles of the primary ligand of 1,3,4-oxadiazole with silver nitrate in dark medium. The prepared metal complexes were characterized after their purification with the help of micro-elemental analyses (CHNS), FT-IR , UV-Visible spectra, molar conductance , magnetic susceptibility and thermal analyses.

The results obtained from spectra and elemental analyses indicated the tetrahedral geometry around zinc(II) ion and square-planner for nickel(II), copper (II), palladium(II) and platinum(II) complexes. However, the linear geometry for Ag(I) complex was adopted. The thermal analyses (TG-DSC) were screened for some selected complexes and the observed data indicated their stability and the expected chemical formula. The biological activity of the prepared compounds in DMSO was tested against some negative and positive-Gram bacteria and the results obtained from inhibition zone diameters proved the greatest activity of silver(I), palladium(II) and platinum(II) complexes when compared with the other complexes and the free primary and secondary ligands.

Keywords: Mixed ligands of transition elements, complexes of 1,3,4-oxadiazole, biological activity, mixed-ligands of dithiocarbamate.

Introduction

Transition metal ions have played main roles in biological processes in the human body[1,2]. The nickel (II), copper (II) and zinc (II) ions are the most abundant transition metals in humans due to their great roles in the metabolism of human-beings[3,4]. The study of the coordination chemistry of biologically important metal ions with mixed ligands has been one of the recent developments in the field of bioinorganic chemistry. Pyridine derivatives play significant role in many biological systems as the component of several vitamins, nucleic acids, enzymes and proteins[5].

Other studies on the antimicrobial activities of their metal complexes are rare in literature. The metal chelates containing nitrogen and sulfur donors have been proved to be potential antibacterial and fungal agents[6] as well as component of several vitamins and drugs[7,8].The binding of metal ions to nicotine amide groups has been a subject of increasing interest, because many of these reactions provide simple models for much more complex metal peptide systems and enzymes. We report here the synthesis, characterization and biological activities of some new nickel (II), copper (II) and zinc (II) mixed-ligand complexes and carbamodithioate and containing oxadiazole as ligands. The synthesized complexes are characterized by elemental, IR, electronic spectroscopic analysis. Mixed ligand complexes are having at least two different kinds of ligands imported with the same metal ion in a complex.

The presence of two type of ligand in a complex increases chances of variation in properties. In recent years many publications are devoted to synthesis and characterization of mixed ligand complexes[1-6]. Present work is continuation of our previous research work on synthesis and characterization of mixed ligand complexes[9-12]. In this paper, we report preparation on study of a series of five mixed ligand complexes derived 2-[4-(n-butyloxy phenyl)-5-(4-n-octyloxy phenyl)-1,3,4 oxadiazole as primary ligand and sodium (4-methylbenzyl)propan-2-ylcarbamodithioate as secondary ligand with some transition elements.

Material and Methods

Instrumentation: The formation of 1,3,4 –oxadiazole derivatives as primary ligand and (S-bpth) as a secondary ligand by using the mass spectrum was acquired by GC mass spectroscopy technique on Shimadzu model GC MS QP 1000EX recorded at College of Science, Mustansiriyah University. The thermal analysis (TG-DSC) was recorded on Shimadzu STAPT-1000(Linesis) made in Germany. Ultra violet-visible spectrophotometer was used at 1800 nm on Shimadzu at Department of chemistry, College of Science University of Baghdad.

The electronic spectra of the prepared compounds were measured in the region (200–800) nm by using Varin Cary 100 Conc. UV–Vis. The ^{1}H and ^{13}C-NMR spectra were acquired in $CDCl_3$ solution using a 300 MHZ with tetra methyl silane (TMS) as an internal reference for ^{1}P-NMR. Melting points were obtained by using melting point apparatus on Gallen Kamp M, F, B 600-010f.TG at Department of Chemistry, College of Science, Mustansiriyah university.

The FT-IR spectra were carried out using Shimadzu FT-IR 8400S College of Sciences, University of Baghdad. The biological activities were evaluated by measuring the diameter of inhibition zones(mm) by using Division Laminar flow clean Bench at College of Education for Pure Sciences, Ibn Al-Haitham, Baghdad University. All reagents and chemicals were commercially used as received from suppliers. The starting materials like 4-hydroxyl benzoic acid, n-butyl bromide sodium bicarbonate (Fluka), hydrazine hydrate 99 %, $POCl_3$, $AgNO_3$, $CuCl_2.2H_2O$, $ZnCl_2$, $PdCl_2$, K_2PtCl_4 and $NiCl_2$. $6H_2O$ were purchased from Sigma-Aldrich.

Synthesis of derivatives and ligands

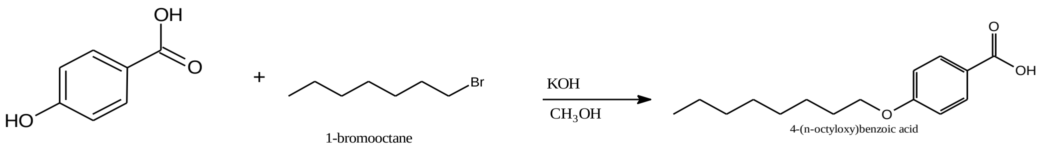
Synthesis of 4-(n-octyloxy) benzoic acid [H1]: To 13.6g, 0.098 mole of 4-hydroxyl benzoic acid dissolved in 100 mL of methanol in round flask, 25g of KOH dissolved in 20 mL of water was added with stirring for one hour. Then 18.34g, 0.098 mole of 1-bromo octane was added to the previous mixture and then heated under reflux for 24hrs. The excess of solvent was evaporated by rotary evaporator and allowed to be cooled and acidified with 10% dilute hydrochloric acid to afford the solid which was collected by filtration, washed with water and re-crystallized from ethanol to give 72% yield of precursor [H_1], M.P ^{o}C (191- 193).

Synthesis of 4-(n-butyoxy) benzo hydrazide[H2]: The solution of compound methyl 4-(n-butyloxy) benzoate (6.0 g, 0.028 mole) was dissolved in 35ml absolute ethanol and then hydrazine hydrate (99%) 0.32 mole,10mL was added to the mixture and heated under reflux (8hrs). Further the solvent was evaporated and the residue poured into ice cold water, filtered and washed with cold water, dried and re-crystallized from hot ethanol affording white crystals of H2 with % yield 75, M.P ^{o}C 155-157.

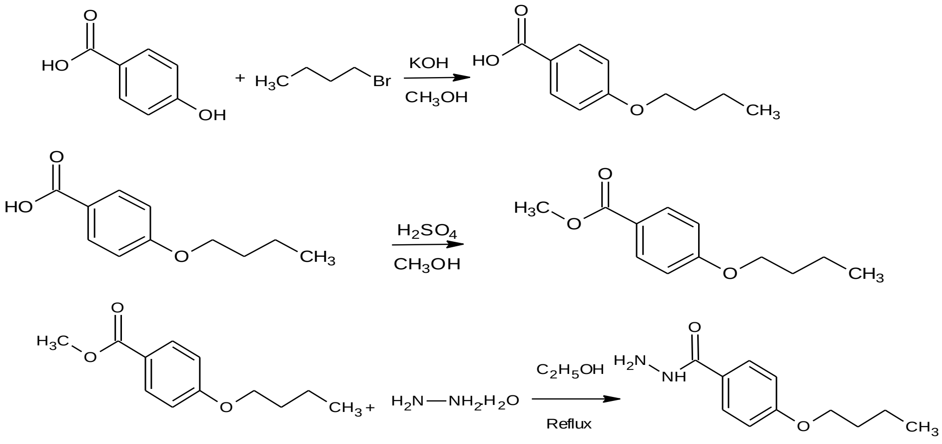
Synthesis of the ligand 2-[4-(n-butyloxy phenyl)-5-(4-n-octyloxy phenyl)-1,3,4 oxadiazole: 7g, 0.031mole of 4-(n-butyloxy) benzo hydrazide and 7.75g, 0.031mole of 8-(-n-octyloxy) benzoic acid are added to 5ml of $POCl_3$. The mixture was stirred for 2hrs.The precipitate formed was washed with sodium bi carbonate, filtered and dried to give a pure compound. The re crystallization from hot absolute ethanol yielded pale yellow crystals of the ligand, Yield:75 %; M.P^0 C: (116-118).

Synthesis of the secondary ligand sodium benzyl (propane-2-yl) carbamodithioate (S-bpth): The compound was synthesized according to the method published in literature[13] as in Scheme 4.

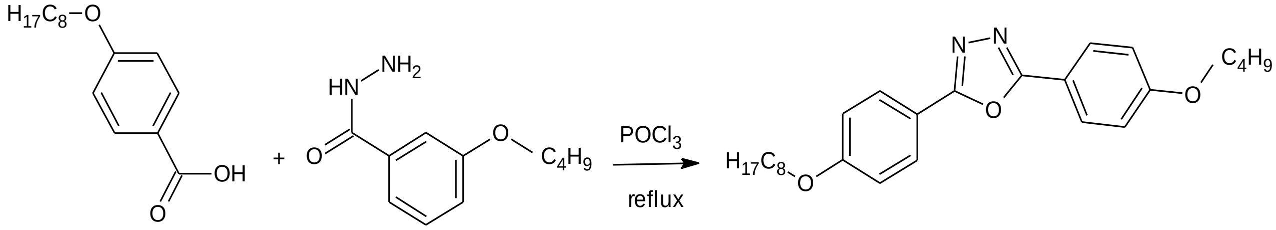
5 g,1mmole of pure Sodium hydroxide, 10ml of water and 16.2g, 1mmole of benzyl propyl amine were taken in the flask and heat the flask and contents to 90-95 ^{0}C, stir vigorously and run slowly about 1hr and then add CS_2. Then allow to cool, filter with suction and wash it with 25ml of saturated salt solution. The crude precipitate was dried on pellets of anhydrous $MgSO_4$ to afford 85% yield of sodium benzyl (propane-2-yl) carbamodithioate (S-bpth) with decomposition point 170-190^{o}C as in Scheme 4.



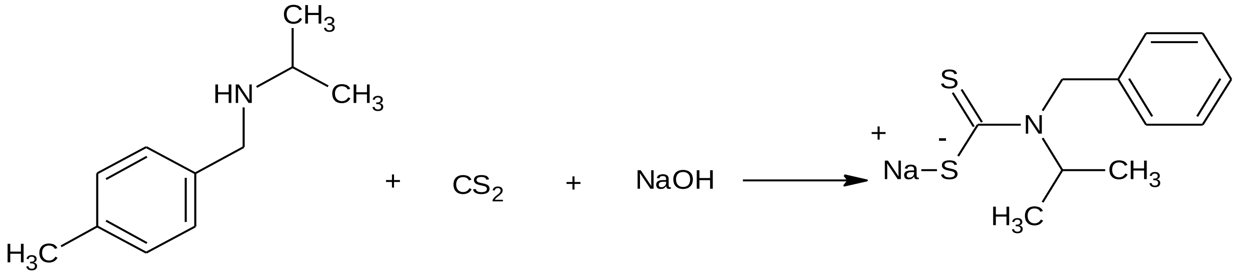
Scheme 1: Synthesis of [H_1] compound.



Scheme 2: Synthesis of 4-n(butoxy)benzo hydrazide [H_2]



Scheme 3: Synthesis of 2-[4-(n-butyloxy phenyl)-5-(4-n-octoxy phenyl)-1,3,4 oxadiazole



Scheme 4: Synthesis of the secondary Ligand sodium benzyl (propane-2-yl) carbamodithioate (S-bpth)

Synthesis of (L) complexes:

Synthesis of Ag [(L)$_2$]NO$_3$ complex: A solution of (LC$_4$-C$_8$),(2 mmoles,0.422 g) in dichloromethane (20ml) and Ag(I) nitrate (0.17g, 1mmol) was added .The mixture was stirred under dark and inert conditions at room temperature until the precipitate solid of $AgNO_3$ disappeared. The solvent was evaporated and the precipitate was collected and stored in desiccators. Solid product was washed with normal hexane and diethyl ether. Then dry to give white compound with melting point 165 ^{0}C, Yield 70%.

Synthesis of Mixed-ligand complexes with some metals ions:

Synthesis of[Cu (S-bpth)(L)$_2$]Cl Complex: Mix ligand metal complexes by using ligand (LC$_4$-C$_8$) as a primary ligand with sodium benzyl (propane-2-yl) carbamodithioate (S-bpth) as a secondary ligand with metal chlorides salts of Ni(II),Pd(II) Pt(II) ,Cu(II) and Zn (II).

A solution of (LC$_4$-C$_8$) (0.422 g,2mmole) in di chloromethane (20ml) and (S-bpth) (0.245g,0.001 mole) was stirred for 15 minutes, then $CuCl_2.2H_2O$ (0.171g ,1mmole) was added and heated under reflux for 2 hours. The colored precipitate of Cu(II) complex was filtered off and washed several times with hot distilled water and ethanol to remove the un-reacted materials of ligand and copper chloride, M.P ^{0}C (267-269) . %yield; 60%.

Synthesis of [Ni(S-bpth)(L)$_2$]Cl], [Pd(S-(bpth)(L)$_2$]Cl, [Pt(S-bpth)(L)$_2$]Cl,[Cu-(S-bpth)(L)$_2$] Cl and [Zn (S-(bpth)(L)$_2$ Cl complexes: The other complexes of Ni(II),Pd(II),Pt(II) and Zn(II) were isolated in their solid states according to the same procedure adopted for Cu(II) complex except that anionic $PtCl_4^{2-}$ and $PdCl_4^{2-}$ were spontaneously prepared by mixing $PdCl_2$ and $PtCl_2$ with saturated solution of NaCl and the periods times of reactions were 30, 60, 120 and 180 minutes for Pd(II),Pt(II),Zn(II) and Ni(II) complexes respectively.

Results and Discussion

FT-IR of the primary free ligand (L): The main feature of ring closure of hydrazide derivative [H2] with [H1] one is the disappearance of the broad band of –COOH carboxylic moiety around (3400-2800) cm^{-1}. However, the FT-IR spectrum, of ligand showed new bands at 2853- 2872 cm^{-1} as good evidence to alkylation reaction. The strong absorptions around 1608 and 1249-1070 cm^1 could be assigned to the vibration modes of υ (C=N) and (C-O-C) respectively[14,15]. The medium band at υ (835) cm^{-1} may be attributed to formation of 1,3,4-oxadiazole ring.

FT-IR spectra of metal complexes:

FT-IR spectral of Ag(I) complex: The remarkable changes in the spectrum of Ag(I) complex in CsI disc are through the shift of -C=N- vibrations[16] to 1558 cm^{-1} which supports the donation of lone pair of imine-C=N- to empty orbital of silver ion(I) as in figure 2.

FT-IR spectra of Mixed-ligand complexes:

FT-IR spectra of [Ni (S-bpth)](L)$_2$]Cl complex: The FT-IR absorption frequencies of the solid complexes with primary ligand are listed in table 3.The FT-IR spectrum of nickel(II) complex in CsI disc exhibited strong absorptions around 15540 and 1249 cm^{-1} confirming the shift of υ-C=N- and C-O-C functional groups respectively[17]. The weak bands in the Far-IR region (380-450) cm^{-1} are attributed to Ni-S and Ni-N bonds respectively.

FT-IR spectra of [Pd(S-bpth)(L)$_2$]Cl [Pt((S-bpth)(L)$_2$], [Cu(S-bpth)(L)$_2$]Cland [Zn(S-bpth)(L)$_2$]Cl complexes: The strong absorptions in the 1522-1570 cm^{-1} in the FT-IR spectra of copper(II), palladium(II), platinum(II) and zinc(II) complexes revealed the participation of nitrogen atom of –C=N- moiety in coordination with the metal ions[15,17]. The increasing of vibration modes of –C-O to the 1257-1260 cm^{-1} region supports the drift of lone pairs of ligand (L) to the empty orbital of metal ion. However, the remarkable changes in the stretching frequency of –C=S of dithiocarbamate secondary ligand would have given strong evidence for bonding of M-S observed as weak bands in the 350-397 cm^{-1} region[18], as in figure 2.

Mass Spectrum of [2-4(-4-n-butyloxyphenyl)-5-(-4-n-octyloxy phenyl)-1,3,4-oxadiazo (L): The mass spectrum of the primary ligand (L) showed molecular ion at *m/z*=422 with 48 % relative abundance conforming the expected molecular formula of the isolated free ligand (L). The other peaks around 366, 310 and 254 are mainly assigned to the cleavage of long chain of butoxy, octyl and breaking of oxadiazole ring respectively[19] as in figure 3.

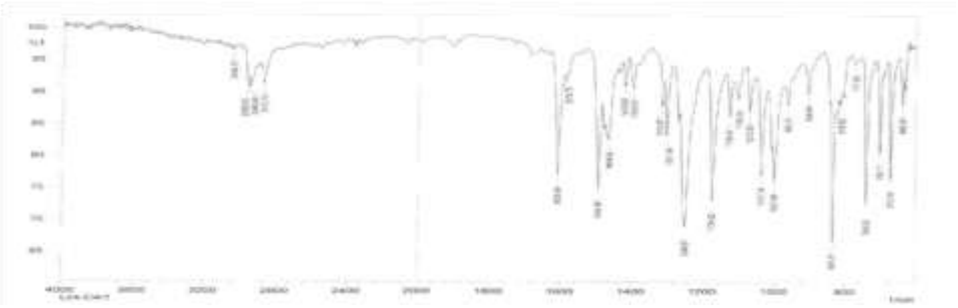


Figure 1: F-TIR spectrum of ligand in KBr disc.

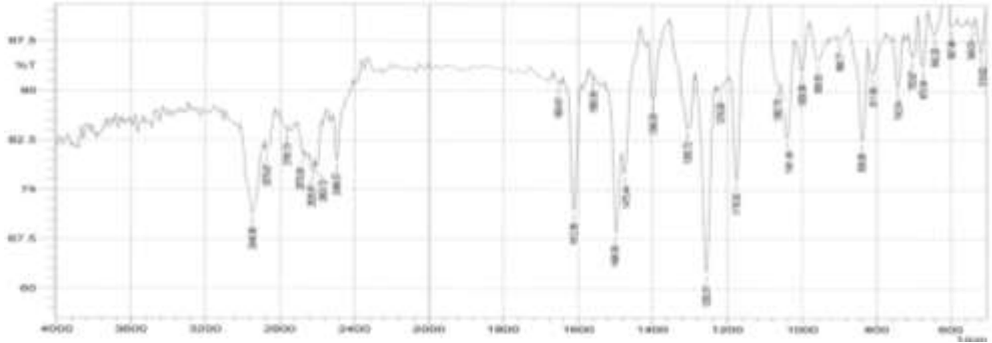


Figure 2: F-TIR spectrum of Pt(II) complex in CsI disc

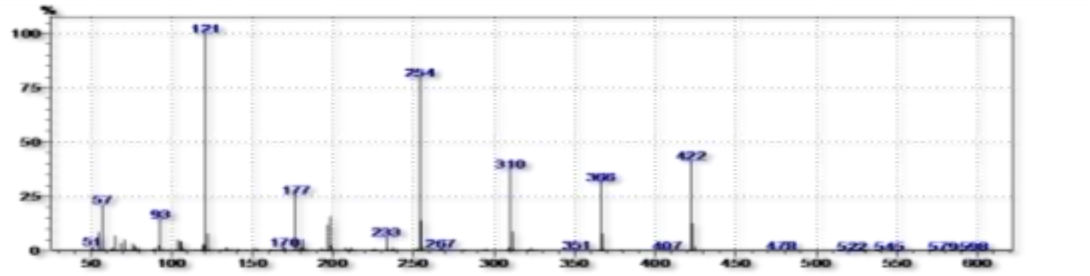


Figure 3: Mass spectra of (L)

Table 2
FT-IR spectral data (υ $^{-1}$) cm^{-1}for the mixed ligand [(L)-(S-bpth)] metal complexes

Compound	υ C=N	υ C=C	υ(C-O-C)	υ(C-H)	υ(C-S)	υ(M-S)	υ (M-N)
L	1610		1249	1471	-	-	-
[Ag((L)$_2$] NO$_3$	1558(s)	1604(sh)	1257	1498	1062 939	-	450(w)
[Ni(S-bpth)(L)$_2$]Cl	1530(s)	1610(sh)	1257	1469	1072 906	350(w)	470(m)
[Pd(S-bpth)(L)$_2$]Cl	1570(s)	1600(s)	1255(m)	1498	1062(s) 956(w)	358(w)	480(w)
[Pt(S-bpth)(L)$_2$]Cl	1552(s)	1610	1253(s)	1496	1068(s), 904(w)	354(w)	490(m)
[Cu(S-bpth)(L)$_2$]Cl	1556(s)	1604(s)	1255(s)	1496	1057 966(w)	358(w)	450(w)
[Zn(S-bpth)(L)$_2$]Cl	1554(s)	1615(s)	1265(s)	1494	955(w)	397(m)	410(m)

The ^{1}H-NMR of (L): The ^{1}H-NMR of (LC_4-C_8) as in figure 4 showed multiple peak at 0.96ppm, (6H) assigned to the C_{14} and C_{18} equivalent to 6 protons in the chemical shift at (δ=1.33 ppm) (4H,m) assigned to C_{13} and C_{17} equivalent to 4 protons. Another signal at (δ=1.29ppm) (8H,m) is attributed to (C_{16}, C_{15}, C_{14} and C_{13}) equivalent 8proton signal at (δ=3.94ppm(2H,m)) which is assigned to (C_{12} and C_{12}) equivalent to 2 protons the chemical shift at (δ=1.71ppm (4H,t) attributed to the ($C_{11}$and C_{11}) equivalent 4 protons The protons of aromatic ring show two doublet signals at (δ=6.8ppm,2H) and (δ=7.5ppm,2H) bonded to (C_6 ,C_7,C_9 , C_{10}) atoms. The two doublet signals at(δ=7.08,2H), (δ=6.70,2H) are attributed to C_6 and C_{10}), ($C_7$and C_9) a single peak at (δ=7.0) attributed to the proton of N - H supporting the structure of the 1,3,4-oxadiazole ligand (L).

^{13}C-NMR spectrum of (L): The ^{13}C- NMR spectrum for the ligand(L) in *d6*-DMSO is displayed in figure 6. The chemical shifts appeared around 13.830, 19.21 and 31,17 ppm which may be assigned to aliphatic C12, C13 and C14 respectively. The peaks at 67.949 ppm are already attributed to the $C_{11}$and C_{12} carbon atoms. However, the chemical shift shown at 161.815 is attributed to the carbon of (C_3=N-N=C_3). The peaks observed around (114.932 161.128) ppm region may result from the nuclear spin of aromatic carbon atoms as in table 3.

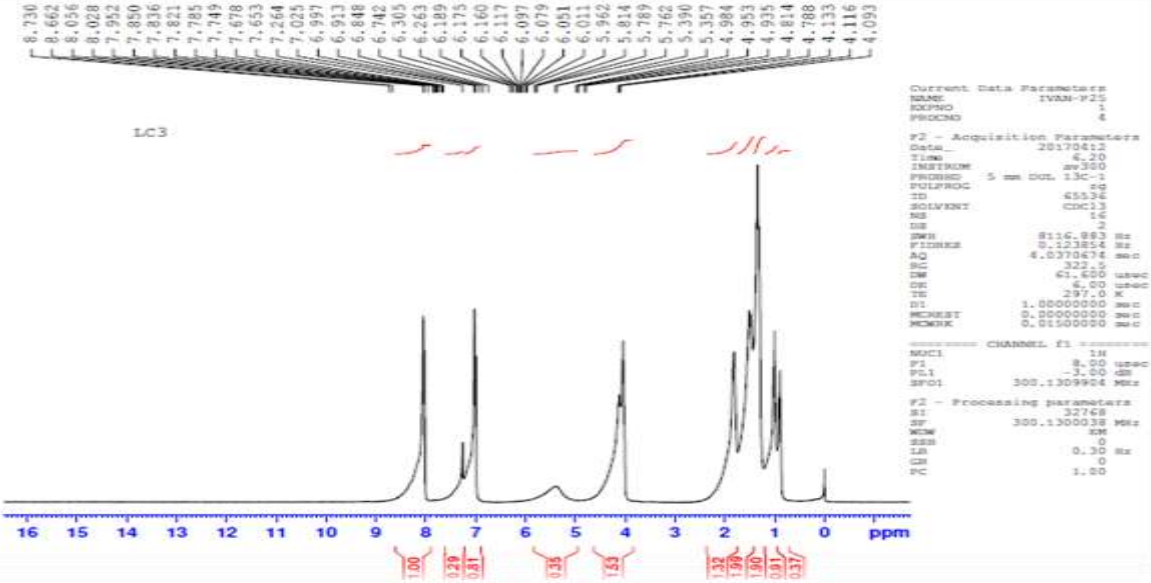


Figure 4: ^{1}H-NMR of (L) ligand in d6-DMSO solvent

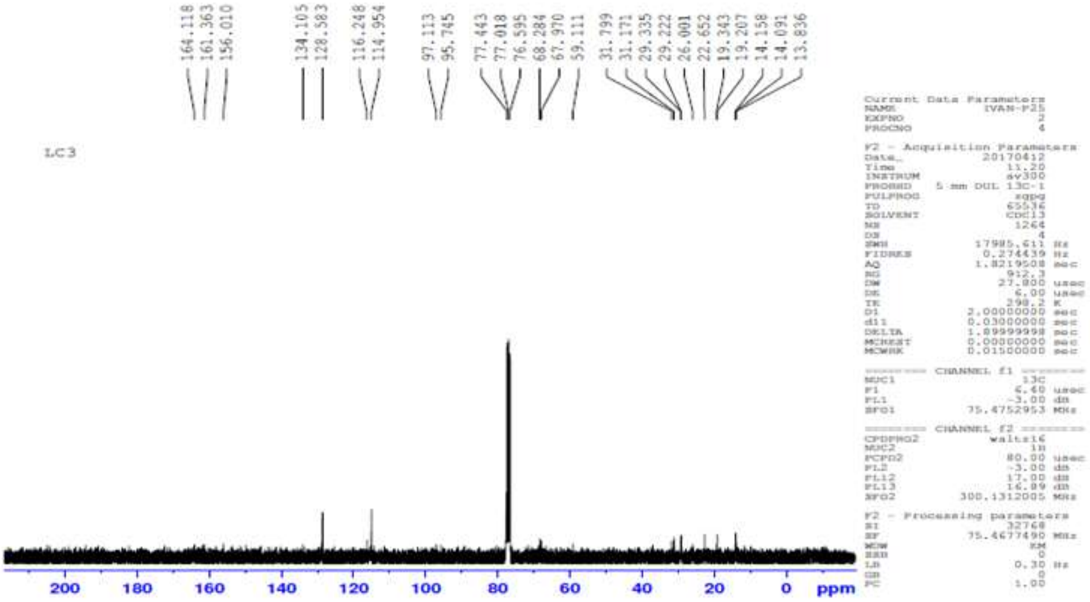


Figure 5: ^{13}C-NMR spectrum of (L) in ^{6}d-DMSO

UV-Vis Spectra of metal complex:

UV-Vis Spectra of Ni(II),Pd(II) and Pt(II) complexes: The UV-Visible spectrum of Ni(II) complex showed peaks at 260 nm (38461 cm^{-1}) ,305 nm (32786cm-^{1}) and at 546 nm (18315 cm^{-1}) assigned to π →π* , LMCT and $^{1}A_{1}g \rightarrow {}^{1}A_{2}g$ respectively, then confirmed the square-planner environment around nickel(II) ion[20,21]. The electronic spectrum for the complexes of Pd (II) complex showed the absorption peaks at 246 nm (40650 cm^{-1}) (901 molar^{-1} cm^{-1}) 305 nm (32786 cm^{-1}) and 376 nm(26595 cm^{-1}). These transitions belonged to intra-ligand charge transfer, LMCT and$^{1}A_{1g} \rightarrow {}^{1}A_{2}g$ of 4d^{8} configuration of Pd(II) ion[22]. The electronic spectrum for the Pt(II) complex exhibited the absorption peaks at 258 nm(38759 cm^{-1}) ,305 nm (32786 cm^{-1}) and 540 nm (18518 cm^{-1}) indicating the (π →π*) of chromophores; -C=N-, -C=S, while the second peak is attributed to MLCT respectively[22].

Ni(II),Pd(II) and Pt(II) were in well-agreement of electronic spectra to confirm their square-planner symmetry as in table 3. In addition to above data, the copper(II) complex recorded high energy bands around 429 nm (21929 cm^{-1}) , 282(35460cm^{-1}) and 250 nm (40000 cm^{-1}) which are associated with $^{2}B_{1}g \rightarrow {}^{2}B_{2}g$, $^{2}B_{1}g \rightarrow {}^{2}Eg$ and π →π* respectively. The lowering in the value of magnetic moment for copper(II) complex to 1.65 BM indicated the square-planner geometry.

TG-DSC of [Zn(S-bpth)(L]Cl complex: The thermo gram of Ligand is shown in figure 6 .The TGA peak recorded at 594.82^{o}C is assigned to the loss of C_{40} H_{59} and 3O (det.=8.30mg,55.52%,calc.8.32mg). The differences between the observed and calculated may be related to sublimation process. The final residue of the complex recorded above 600 ^{o}C attributed to the [C_{15} H_{7} Cl $N_{5}O_{3}$ S_{2} and Zn] (obs.=6.7 mg, 44.48 %, calc.=6.77 mg). The DSC curve indicated exothermic decomposition processes at temperature 283.8^{o}C. The exothermic peak may indicate combustion of the organic ligand in an argon atmosphere[23-26].

Biological Activity: The anti-bacterial activity for the mixed-ligand complexes was studied against four types of bacteria like *Staphylococcus auera, Bcillus* Sub., *E. Coli* and *Eterobactern.* The results indicated that Ag 10^{-4} ppm and Cu 10^{-4} ppm complexes were more active against all kinds of bacteria and Cu 10-4 ppm was inactive against three kinds of bacteria[22,27]. The mixed ligand complexes are generally stable in the DMSO solvent used as a biological solvent media because of the stability of compounds in this solvent and its negative effect against studied bacteria, DMSO was selected as solvent media for the biological tests. Ampicillin and Ciprofloxacin were used in the antibacterial study as standard drugs.

Table 3
Electronic spectral data and magnetic moments of metals complexes

Compound	nm	υ cm-1	E max Molar-1cm	Assignment	Suggested Structure	*μeff* B.M
L	304 258 241	32894 38759 41493	1318 665 594	n →π* π →π* n →π*	-	
[Ag((L)$_{2}$] NO$_{3}$	245 248 304	40816 32786 18315	478 503 1333	n →π* π →π* INCT	Linear	0.0
[Ni(S-bpth)(L)$_{2}$]Cl	260 305 546	38461 32786 18315	148 631 5811	π →π* LMCT $^{1}A_{1}g \rightarrow {}^{1}B_{1}g$	Square planner	0.0
[Pd(S-bpth)(L)$_{2}$]Cl	246 305 376	40650 32786 26595	901 631 389	π →π* n →π* MLCT	Square planar	0.0
[Pt(S-bpth)(L)$_{2}$]Cl	258 305 540	38759 32786 18518	702 1490 115	π → π* n →π* $^{1}A_{1}g$.→ $^{1}B_{2}g$	Square planar	0.0
[Cu(S-bpth)(L)$_{2}$]Cl	250 282 456	40000 35460 21929	437 1119 290	π →π* π →π* MLCT	Square planar	1.65
[Zn(S-bpth)(L)$_{2}$]Cl	259 306 378	38610 32679 26455	719 1540 119	π →π* n →π* LMCT	Tetrahedral	0.0

INCT=Intra-ligand charge transfer, LMCT=Ligand-metal charge transfer and MLCT=Metal-ligand charge transfer

The data of the mixed ligand complexes is shown at concentration of 20 ppm against *Bacillus subtilis*, *Staphylococcus aureus*, *Escherichia Coli* and *Eterobactern*. The antibacterial activity of mixed (L) complexes showed the order: $[Zn(L)_2(s\text{-}bpth)Cl] > [Pd((L)_2(s\text{-}bpth)Cl] > [Cu((L))_2(s\text{-}bpth)Cl] > [Ag(L)_2](NO_3)_2$. Zinc complex showed more biological activity than other complexes against *Bacillus Sub.*, *Staphylococcus aureus*, *E.Coli* and *Eterobactern.* $[Ag(L)_2](NO_3)_2$ had the best effect on it against *Bacillus Sub.*, *Staphylococcus aureus*, *E. Coli* and *Eterobactern* as in figures 8 and 9.

Conclusion

The structural characterization of the complexes was established on the basis of the techniques: IR spectra, UV-Vis spectroscopic and some of complexes by TG-DSC analyses and the square-planner geometry was concluded for all complexes except that zinc(II) and silver(I) complexes were tetrahedral and of linear symmetry as in Scheme 5 . The FT-IR spectra showed that the N atom and S-atom of thion group are coordinated to the metal in all cases.

The data observed from elemental analyses confirmed that all metal complexes were formed in 2:1:1 mole ratio of (L) primary ligand, dithiocarbamate secondary ligand to one mole of the metal ions whereas the silver complex was formed by optimizing the L: M ratio to 1:1 respectively. The complexes showed biological activity against bacteria strains *Staphylococcus aureus*, *Bacillus Sub*, *E.Coli* and *Eterobactern*

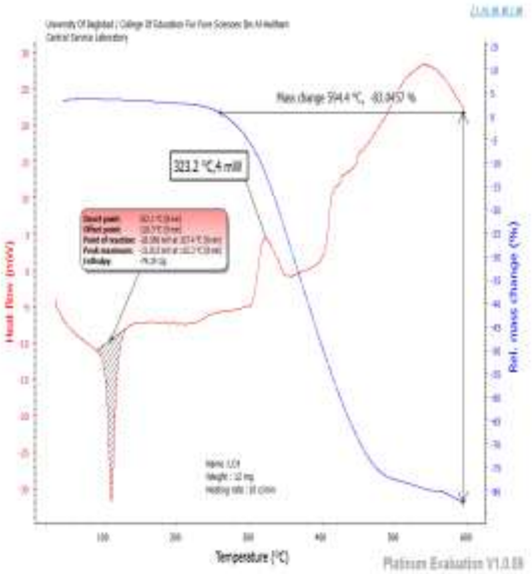


Figure 6: (TG/DTG and DSC) Thermo gram of $(L)_2$] in argon atmosphere

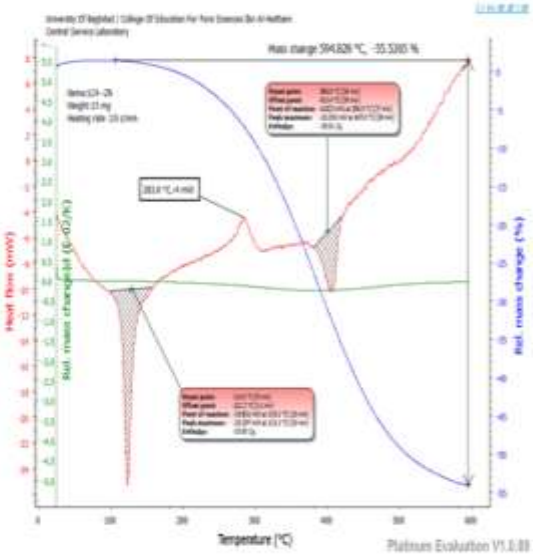


Figure 7: (TG/DTG and DSC) Thermo gram of [Zn(S-bpth)$(L)_2$]Cl in argon atmosphere

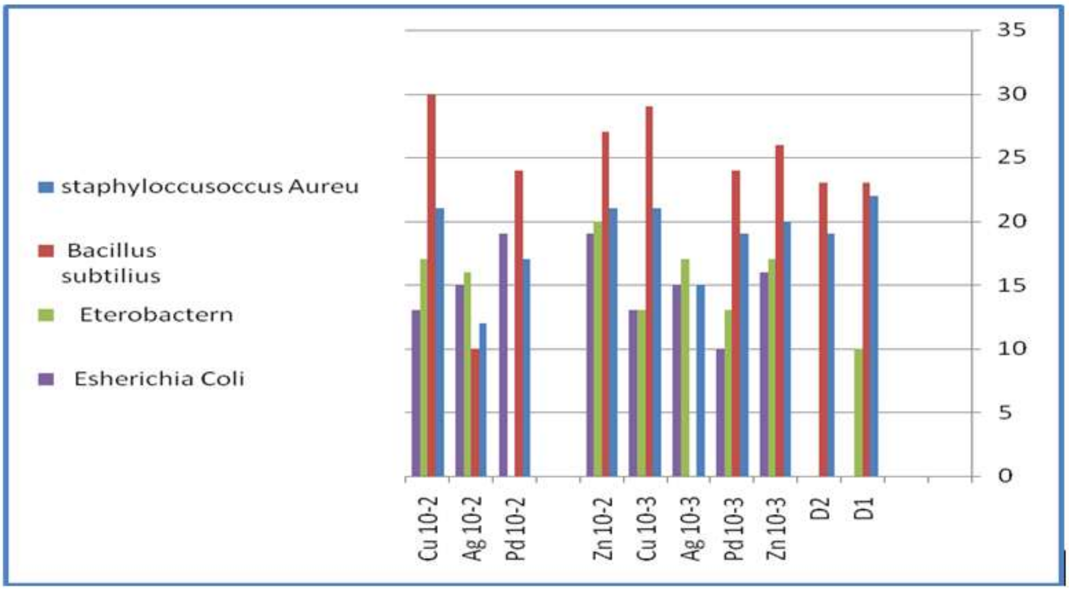


Figure 8: Evolution of diameter zone(mm) of inhibition of (L) complexes against growth of bacterial strains

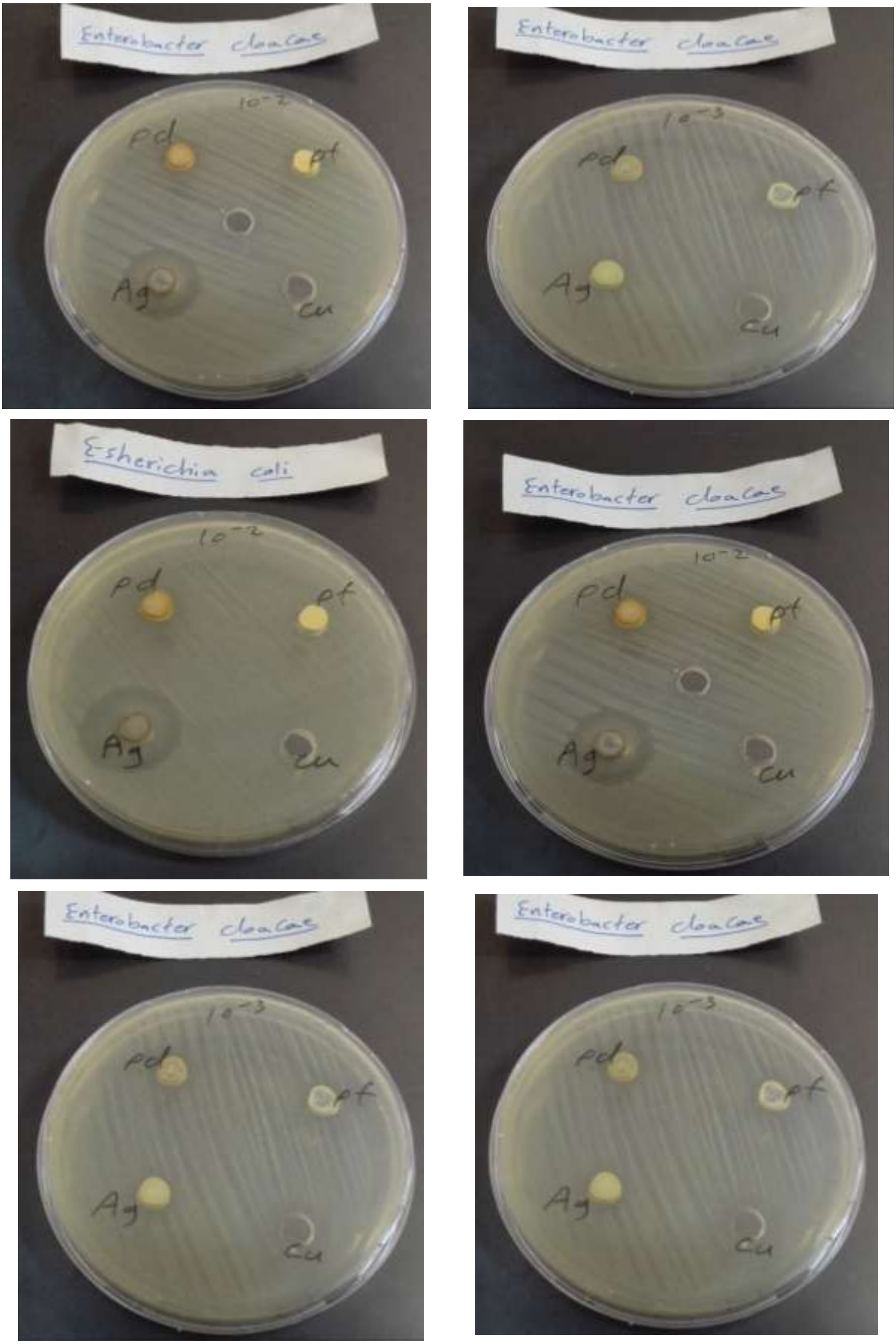
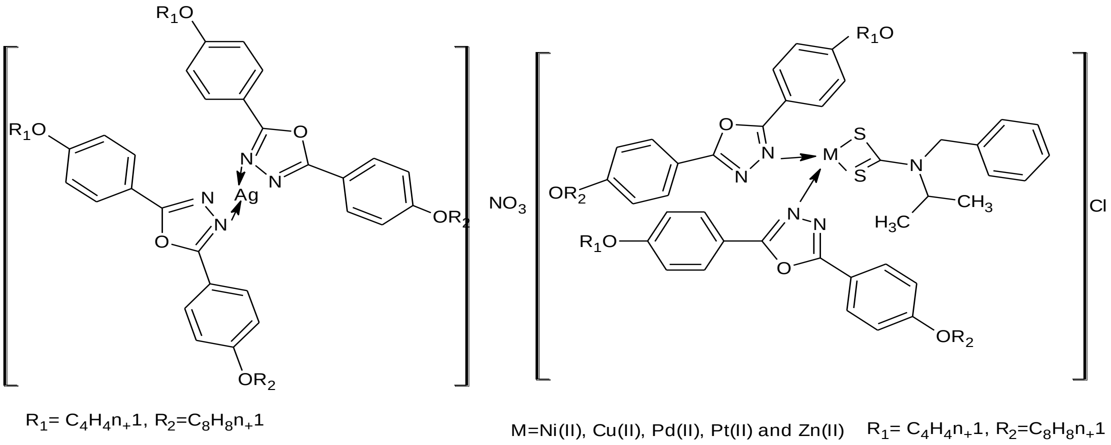


Figure 9: The effect of (L) complexes against bacterial strains



Scheme 5: Geometrical structures of metal complexes

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