IHJPAS. 36(1)2023

Ibn Al-Haitham Journal for Pure and Applied Sciences

Journal homepage: jih.uobaghdad.edu.iq

Preparation, Structural Characterization and Biological Activities of Curcumin-Metal(II)-L-3,4-dihydroxyphenylalanin(L-dopa)complexes

Hala Mohammed Salh
Department of Chemstry , College of Education for Pure Sciences, Ibn Al – Haitham, University of Baghdad, Baghdad, Iraq.
hala.mohammed1205a@ihcoedu.uobaghdad.edu.iq

Taghreed H Al-Noor
Department of Chemstry , College of Education for Pure Sciences, Ibn Al – Haitham, University of Baghdad, Baghdad, Iraq.
drtaghreed2@gmail.com

Article history: Received 19 June 2022, Accepted 28 Augest 2022, Published in January 2023.

doi.org/10.30526/36.1.2899

Abstract

In the present work, a first-row divalent d-transition metal obtained from curcumin(Curc) and L-3,4-dihydroxyphenylalanin(L-dopa)have been synthesized which their complexes and characterized by C.H.N, conductance, spectral methods: FT-IR, Ultra–Visible. Magneto-chemical measurements, molar conductance ΛM (1×10^{-3} mol/L in DMSO):36- 0.84 $ohm^{-1}.cm^{2}.mol^{-1}$ (non-electrolyte).

The data shows that the complexes have the structure [M((II))-(Curc)-(L-dopa)] system. Electronic and magnetic data suggest an octahedral geometry for all complexes in which the (L-dopa) and curcumin act as bidentate ligands.

Curcumin coordinated to the metal ions M (II) through the lone pair of electrons of oxygen in 2(C=O) groups. The (L-dopa) coordinated to M (II) as a mono negative bidentate ligand through the oxygen atom of the carboxylate and the (N), atom of the ($-NH_2$) groups.

The general formula was given for the prepared mixed ligand complexes as [M (Cur)$(L\text{-dopa})_2$]. M= Mn (II), Fe (II),Co(II),Ni(II),Cu (II), Zn(II), Cd(II) and Hg(II).The ligands and their metal complexes were screened for their antimicrobial activity *klebsiella pneumonie,and Staphylococcus aureus,* and *Candida albicans*. Metal chelates showed very good antimicrobial activity than their parent curcumin-and (L- dopa).

Keywords: Curcumin, (L-Dopa), α -amino acid and *Antimicrobial activity*.

1.Introduction

α -amino - acid, L-3,4-dihydroxyphenylalanin(L- dopa) derivatives used as building blocks to generate protein [1,2] It also in humans, behaves like a hormone in the circulatory system with Alzheimer's and Parkinson's diseases. A tetradentate (N_2O_2) Schiff base (H2Ldfm) was successfully synthesized via condensation of curcumin / diferuloylmethane (dfm) and L-leucine amino acid (HL) [3]. The bacteriostatic effects `of L-dopa complexes shown to be more pitent than L-dopa .Brien et al. (2021), have been reported synthesis, cis-Bis(L-dopa -2N, O) Cu (II).H_2O [5]. Rama et al, chemical speciation of ternary complexes of L-dopa and1,10-phenanthroline as [(metal: (L-dopa): (phena)] [(metal: (L-dopa): 2 (phena)] molar ratios . metal: Co(II), Ni(II) and Cu(II) in 30% v/v, 2-propanediol–water mixtures [6].

Curcumin, is a yellow coloring and have many functional groups as a polyphenolic natural pigment, a powerful natural chelating agent by conjugated β-diketone moiety and shown to exhibit biological properties: anti-viral, anticancer, anti-inflammatory, anti-bacterial,anti-fungal, and anti-oxidant activities and the requirement to treat Alzheimer's diseases [6].
Curcumin ingreses the sencentivy cells to cisplatin through down-regulation of FEN1 [7].
Complexation of curcumin with metals ions Al(III), Ga(III), Se(II) and metal oxides of rare earth ions were synthesized, 1 : 1 and 1 : 2(metal/ion),respectively[8]. The Curcumin complexes of the Schiff Base [(Curc)- L-Tyrosine] with Pb(II) , Al(III), and Ag(I) Ions constitute an especially interesting series of compounds. [9]. Complexation of curcumin with transition metals were synthesized, characterized and evaluated for various biological activities [10].

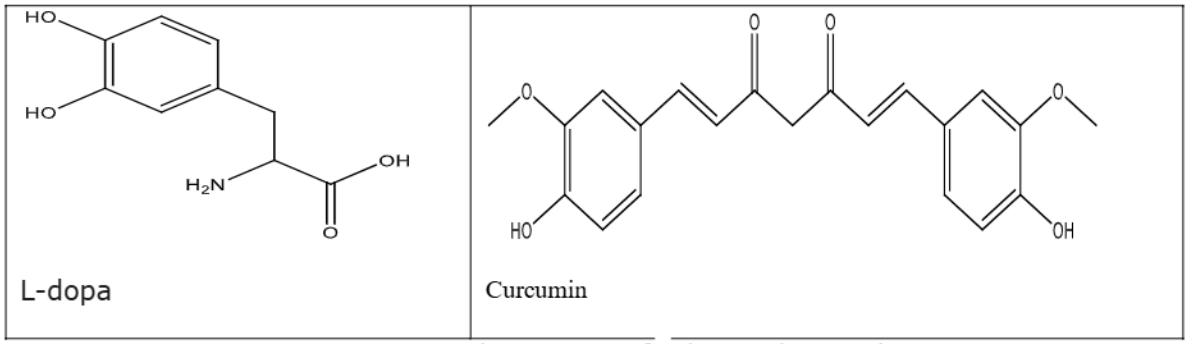


Figure1. The Structures of L-dopa and Curcumin

In this work, we synthetic and characterized of some complexes derives from Curcumin, as a primary ligand and (L- dopa)as a secondary ligand **Figure1.**

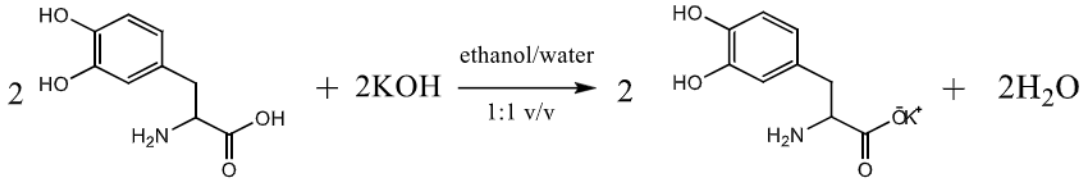
2.Experimental

2-1. Materials and physical measurements:

All solvents and reagents were obtained from Sigma-Aldrich and used without further purification. Metal salts [Zn(II), Cu(II), Ni(II), Co(II) Cd(II), and Mn(II)] as chlorides.The melting points using Stuart SRS –USA of the complexes . Ultraviolet-visible spectra were obtained using solvent(10^{-3}M-DMSO) between (200 to 1100) nm for comparison by U.V 160A - Shimadzu).The Fourier-transform infrared spectra were recorded using KBr pellets at range (400-4000 cm^{-1}).on FTIR 8400-S. Shimadzu spectrophotometry.The Conductivity measurements of the compounds (10^{-3}mol/L in DMSO) were obtained using digital Ino-Labro.720-conductivity.M% recorded by using atomic absorption spectrophotometer Shimadzu -A. A 620.

2-2. General Procedure for the Synthesis of Complexes 1–8 [11].

Preparation of potassium-2-aminohydroxytyrosine,Levodopa, 3-(3,4-dihydroxyphenyl)-L (L-dopa- K+): The amino acid L- 2-amino-3-(3,4-dihydroxyphenyl) propanoic-acid [0.394 g,2 m mol]was dissolved in 20 mL H2O/ethanol(50%) mixture containing KOH (0.112 g, 2 mmol) in a flask and stirred at (30 ℃), the solution of ligand (L-dopa) was deprotonated to L-dopalanilate ion by using (KOH)according to the **Scheme 1**



2-amino-3-(3,4-dihydroxyphenyl)-(S)propanoanoic acid

Potassium-2-amino-3-(3,4-dihydroxyphenyl)-(S)propanoate

Scheme 1. The Elucidation (L-dopa$^-$ K$^+$)

Preparation of Complexes: [11].

Molar ratio M: Cur: (L-dopa),[1 :1 : 2]. A mixture of (1 mmol)curcumine,and(2 mmol) (L-dopa- K+)in 50mL ethanol/water [1:1] v/v was added to the metal chloride (1 mmol) in the least amount of distilled water. The reaction mixture was prepared for 30 min with constant stirring to ensure complete formation of the complexes. The precipitated solid complexes were filtered, washed for several times with 50% (v/v) ethanol/water and recrystallized in ethanol, and dried in vacuum over anhydrous $CaCl_2$.

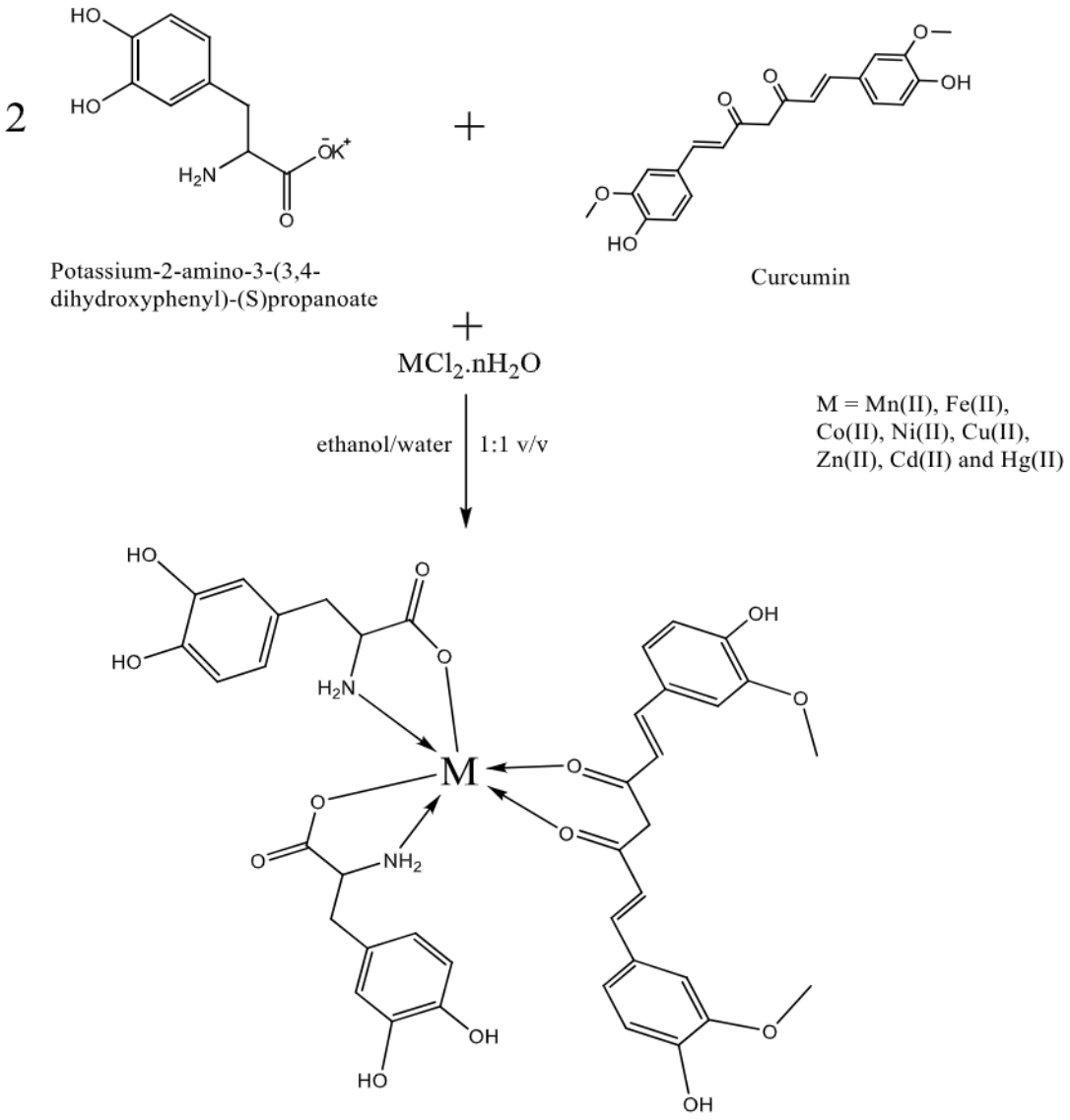
3.Results and Discussion

Generally, the complexes were prepared by reacting the respective metal salts with the ligands using [Cur:M: (L-dopa)$_2$] mole ratio, i.e. one mole of curcumin , one mole of metal salt and two mole of (L-dopa) [9] as the following equations:

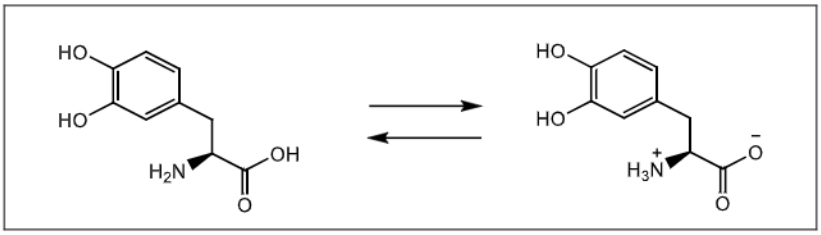
2(L-dopa) +2KOH→ 2 (L-dopa$^-$ K$^+$) + 2H_2O

2 (L-dopa$^-$ K$^+$) + Curc +MCl_2.nH_2O → [M(Curc) (L-dopa)$_2$] + nH_2O + 2KCl n= 0···6

{where (Curc) is Curcumin and [L-3,4-dihydroxyphenylalanin(L-dopa)]: as shown **Scheme 2.**



Scheme 2. Route the synthesis of [M(Curc)(L-dopa)$_2$] complexes



Scheme 3. Zwitterion of (L-dopa)

Table 1. Physico-chemical data of the [M (Curc)(L-Dopa)$_2$]complexes

	Compounds yield	Colour	m.p °C	Λ_m 1000 L/C ohm^{-1}-cm^2-mol^{-1} in DMSO1 0^{-3}M	Found (Calc.)%			
					C	H	N	M
1	[Mn(Curc)(L-dopa)$_2$]	Dark brown	185-187	0.60	57.43 (57.00)	3.43 (3.88)	6.74 (6.77)	6.74 (7.2)
2	[Fe(Curc)(L-dopa)$_2$]	bright brown	183-185	0.88	57.36 (57.00)	3.43 (4.00)	6.84 (6.70)	6.84 (7.7)
3	[Co(Curc)(L-dopa)$_2$]	yellow	182-184	0.56	57.15 (56.17)	3.42 (3.00)	7.19 (6.88)	7.19 (8.2)
4	[Ni(Curc)(L-dopa)$_2$]	Dark yellow	184-186	0.36	57.16 (58.61)	3.42 (3.00)	7.16 (6.08)	7.16 (8.2)
5	[Cu(Curc)(L-dopa)$_2$]	bright brown	185.5-188	0.55	56.83 (57.01)	3.40 (3.00)	7.71 (6.88)	7.71 (8.7)
6	[Zn(Curc)(L-dopa)$_2$]	yellow	188.7-190	0.84	56.70 (55.50)	3.39 (3.00)	7.92 (6.88)	7.92 (8.2)
7	[Cd(Curc)(L-dopa)$_2$]	yellow	220-222	1.80	53.65 (57.01)	3.21 (3.00)	12.87 (12.00)	12.87 (13.3)
8	[Hg(Curc)(L-dopa)$_2$]	yellowish brown	256	1.05	48.73 (47.31)	2.91 (3.00)	20.87 (20.00)	20.87 (…….)

The method of preparation of complexes to be reproducible, yielding 92-98% of products. recrystallization purified all complexes from ethanol and have yellow to orange. The physical and analytical data of complexes were listed in Table 1. The melting point range was between 182-256◦C. The melting points of the (L-dopa) ligand were higher than that of the metal complexes but

lower for (Curc). The results of elemental analyses (C.H.N) for complexes were found to be in agreement with the proposed molecular formulae of the complexes. Most of the compounds are soluble in water and most common organic solvents like DMF, DMSO and acetone.ΛM (1×10−3 M,DMSO): (Molar conductance 0.36- 0.84 (ohm-1.cm2.mol-1 - non-electrolyte nature). [10]. The test for chloride ion with AgNO3 solution was negative (Nil%) indicating that there is no (Cl^-) outside the coordination sphere of the central metal. Table 1, propose that the complexes are formed in 1:1:2 [M:Curc: (L-dopa)2)] ratio. [12-13].

IR spectra of [M (Curc)(L- dopa)$_2$] complexes (1-8)

IR spectrum of zwitterion of (L- dopa) as shown in scheme 3 is shows strong broad absorption 3432(br,-OH), 3112 (C-H stretching) , (3200 cm_{-1}) might be due to νOH - stretching and at 3066cm^{-1} due to the νas(+NH_3) and at stretching νs(+NH3)) 2927 cm^{-1}.The stretching of the –NH_2group of free L- doba were observed at 3387 cm^{-1} , and bending vibrations at 817 cm^{-1} ,The ν (CH_3) and ν (CH) groups appeard around (3000 - 2835) cm^{-1} overlap with the ν amino group. 1557 νC=C Phenyl ring stretching's, [14]. 1095 aromatic δνC-H bending, The (L-dopa) spectrum show two absorption at 1570 $cm^{-1}$and 1448 cm^{-1} belong to νasym (-COO^-) and νsym(-COO^-) respectively Figure 2.[15-16]. The energy difference Δ ν =200 cm^{-1},in complexes , indicates coordination between (-COO–) group of (L-dopa) and metal ions via oxygen atom. The spectrum of (Curc) Table 2. The were observed broad band in recovery (3059-3475) cm^{-1} corresponding to a (phenolic hydrogen -bonded compound) and at 1627 cm^{-1} due to ν (C=O). bands due to (C- O-C) at 1157Cm^{-1}. 3066 (Ar- C - H) and 1438 (Ar- C= C) [11]. and has two at (1626 and 1601)Cm^{-1} depicated to the whith CO group conjugated with C =C double bonds [16-17]

The (L-dopa) coordinated to M (II) as a mono negative bidentate ligand through the oxygen atom(O) of the (-COO^-)and the (N), atom of the amine(-NH2) group Table 2. The appearance of these bands supported the coordination of the (L-dopa) ligand to the metal ions through oxygen and nitrogen atoms. while (Curc) coordinates as a neutral bidentate through (O) in the (C=O) group. New bands at 428-497 cm^{-1} and 520-601 cm^{-1} were observed and assigned to ν(M-O) and ν (M-N), respectively, which are absent in both free ligands [16-20].

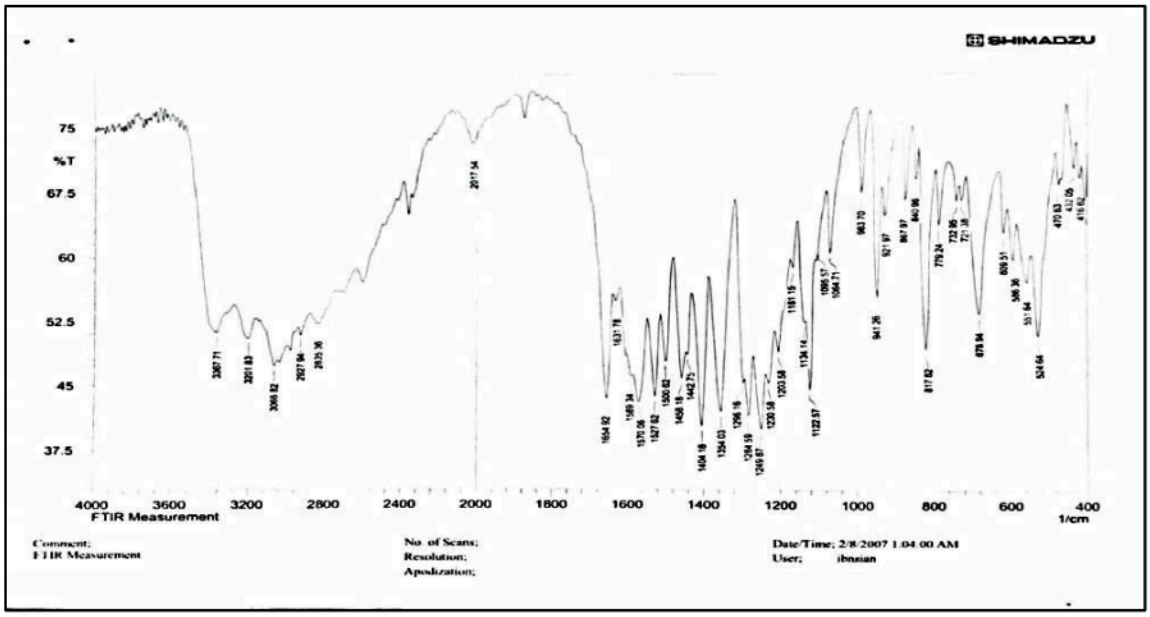


Figure 2. FT-IR spectrum of (L-dopa)

The geometry of all complexes were posted from the position of the bands in the electronic spectra and observed values of magnetic moments (μeff) which are summarized in Table 3. The (UV-Vis) spectrum of the (Curc) in DMSO Figure 3 exhibits two absorption peaks, (λmax 440 nm)(22727 cm^{-1}) and (λmax 270 nm,37037 cm^{-1}) can be due either to an n- π* transition or to a combination of π- π*,and n→π*transitions respectively, in the ketone
(C=O) group agree with data reported [19]. The (UV-Vis) spectrum for the (L-dopa) Figure 4 exhibits two absorption peaks, (λmax 451 nm, 22727 cm-1) and (λmax 277 nm.37037 cm-1) due to an n→π*transition [22,23].
In Zn ((II)), Hg ((II)),andCd ((II)) complexes, are (Dimegnetic) with octahedral environment., , d10 orbitals are completely filled exhibit charge transfer(C.T), [17-18].

Table 2. Characteristic IR (KBr) Vmax frequencies in (cm^{-1})of complexes

Compound	Phenol (Ar-OH)	ν(NH2)	ν(C-H) Aromatic	ν(C-H) Aliphatic	ν(C=O) Keton	ν(C=O) COO asy, sym	ν (C=C)	Δ ν COO^- sym-sym)	M-N)	M-O)
[Mn(Curc)(L-dopa)$_2$]	3506	3375	3012	2843	1508	1627 1427	1458	200	520	428
[Fe(Curc)(L-dopa)$_2$]	3502	3414	3012	2943	1508	1627 1427	1462	200	574	428
[Co(Curc)(L-dopa)$_2$]	3506	3417	3012	2974	1508	1627 1427	1458	200	574	428
[Ni(Curc)(L-dopa)$_2$]	3506	3300 3136	3016	2943	1508	1627 1427	1458	200	597	424
[Cu(Curc)(L-dopa)$_2$]	3506	-	3012	2943	1508	1627 1427	1458	200	597	497
[Zn(Curc)(L-dopa)$_2$]	3506	3275	3012	2843	1508	1627 1427	1458	200	543	466
[Cd(Curc)(L-dopa)$_2$]	3510	3406 3128	3016	2978	1508	1627 1427	1458	200	601	451
[Hg(Curc)(L-dopa)$_2$]	3510 3414	3290	3039	2920	1589	1627 1427	1450	216	597	451

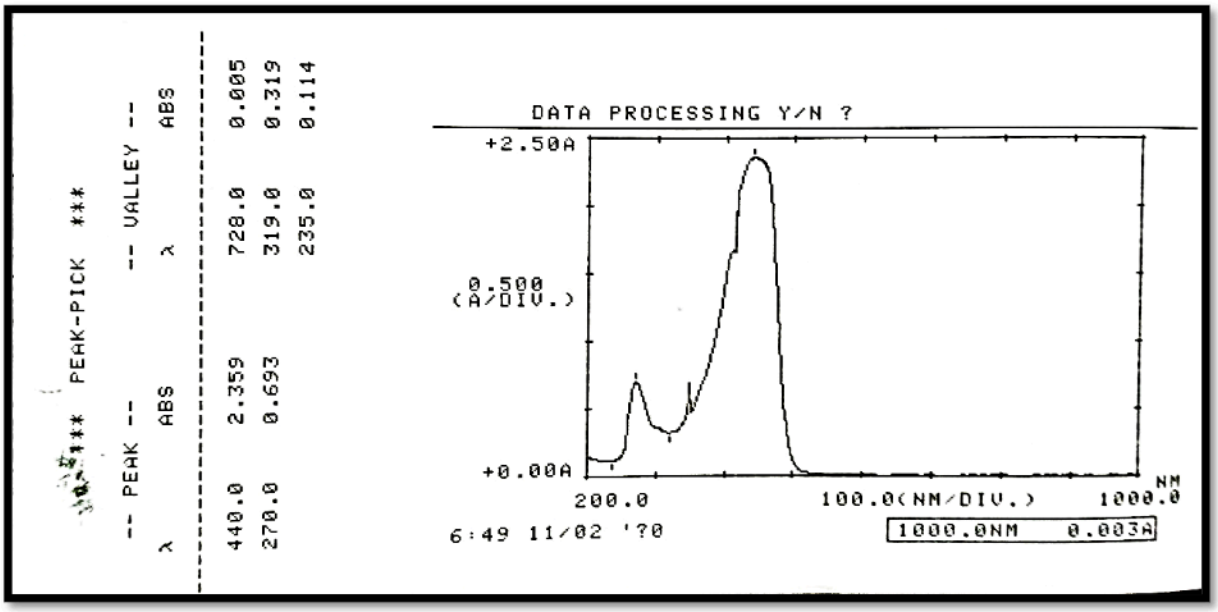


Figure 3. Electronic - Spectrum of the (Curc)

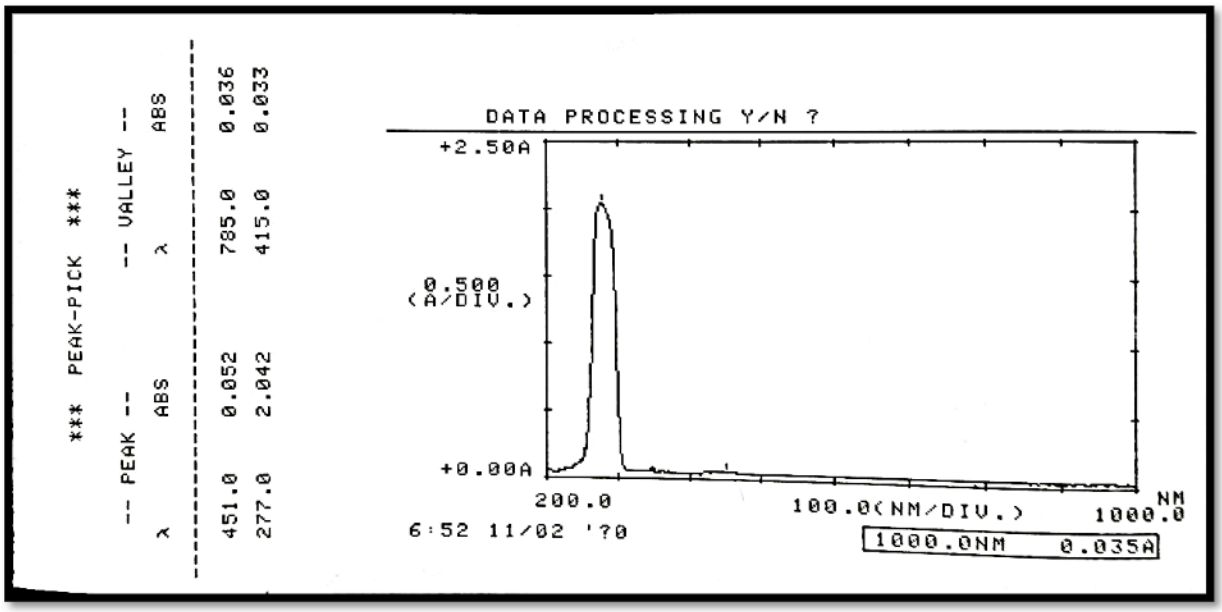


Figure 4. Electronic - Spectrum of the (L-dopa)

Table 3. Electronic spectral data of the (Curc - M- L-dopa) metal complexes

Complexes	λ nm	ν¯ Cm	ϵ Max	Assignments	*μB*
[Mn(Curc)(L-dopa)$_2$]	273 435 765	36630 22988 13071	376 1584 33	n→π* Charge transfer $^6A_1g^{(S)} \rightarrow {}^4T_1g$	5.4
[Fe(Curc)(L-dopa)$_2$]	270 436 795 843	37037 22935 12578 11862	580 2014 27 26	π →π* n →π* $A^1g \rightarrow {}_4T1g$ $A1g \rightarrow {}^4T2g$	4.11
[Co(Curc) (L-dopa)$_2$]	270 436 752 800 934	37037 22935 13297 12500 10706	362 1369 13 13 11	π→ π* 4T1g(F) → 4T2g(F), T1g(F) → 4T1g(P) T1g(F) → 4A2g(F)	4.62
[Ni(Curc)(L-dopa)$_2$]	270 437 809	37037 22883 123609.93	314 1260 15	n→π* Charge transfer $^3A_2g^{(F)} \rightarrow {}^3T_1g^{(p)}$	3.01
[Cu(Curc)(L-dopa)$_2$]	271 436 934	36900 22935 10706	350 1465 3	n→π* CT 2Eg → 2T2g	2.04
[Zn(Curc)(L-dopa)$_2$]	270 435	37037 22988	301 1251	π→π* Charge transfer	0.0
[Cd(Curc)(L-dopa)$_2$]	267 436	37453 22935 11350	596 2138 33	π→π* Charge transfer	0.0
[Hg (Curc)(L-dopa)$_2$]	267 435	37453 22988	659 2239	π→π* Charge transfer	0.0

4. Biological activities

The in-vitro biological activity of the the synthesized compunds in DMSO and all the plates were incubated at 37^{0}C and were tested against the bacterial [*Escherichia coli*,and *Staphylococcus aureus*] and *Candida albicans* by well diffusion method using nutrient agar as medium. The results were tabulated in Table 4,showed DMSO used as solvent negative control as it did not show any activity against bacteria,.Two ligands showed antimicrobial activity against gram-positive and gram negative bacteria and against Candida albicans. [26]

All complexes possess biological activity[20] and which have the same activities.

All tested of [M (Curc)(L-dopa)$_2$] mixed-ligand complexes were detected the same activities and good antimicrobial activity, displayed higher activities *candida albicans* fungus compared to bacteria.as show in **Table 4 Figure 5** and **Chart 1** [24-26],.Antifungal studies towards all tested fungi enhanced activity when coordinated with all metals, on chelation the polarity of the ion due to the overlap of the ligand orbital and partial sharing of the positive charge of the ion with donor groups reduced to a greater extent [27,28] .

Table 4. Zone of inhibition, (ZI) diameter in mm of the[M (Curc)(L-dopa)$_2$] complexes

Comp.		*staphylococus aureus*	*klebsiella pneumonie*	*candida albicans*
Curc ($C_{21}H_{20}O_6$)		12	17	25
(L-dopa) ($C_3H_7NO_2$)		16	18	20
DMSO		0	0	0
1	[Mn(Curc)(L-dopa)$_2$]	12	20	19
2	[Fe(Curc)(L-dopa)$_2$]	13	20	13
3	[Co(Curc)(L-dopa)$_2$]	14	20	20
4	[Ni(Curc)(L-dopa)$_2$]	13	20	11
5	[Cu(Curc)(L-dopa)$_2$]	14	20	27
6	[Zn(Curc)(L-dopa)$_2$]	16	20	20
7	[Cd(Curc)(L-dopa)$_2$]	16	15	30
8	[Hg (Curc)(L-dopa)$_2$]	15	15	30

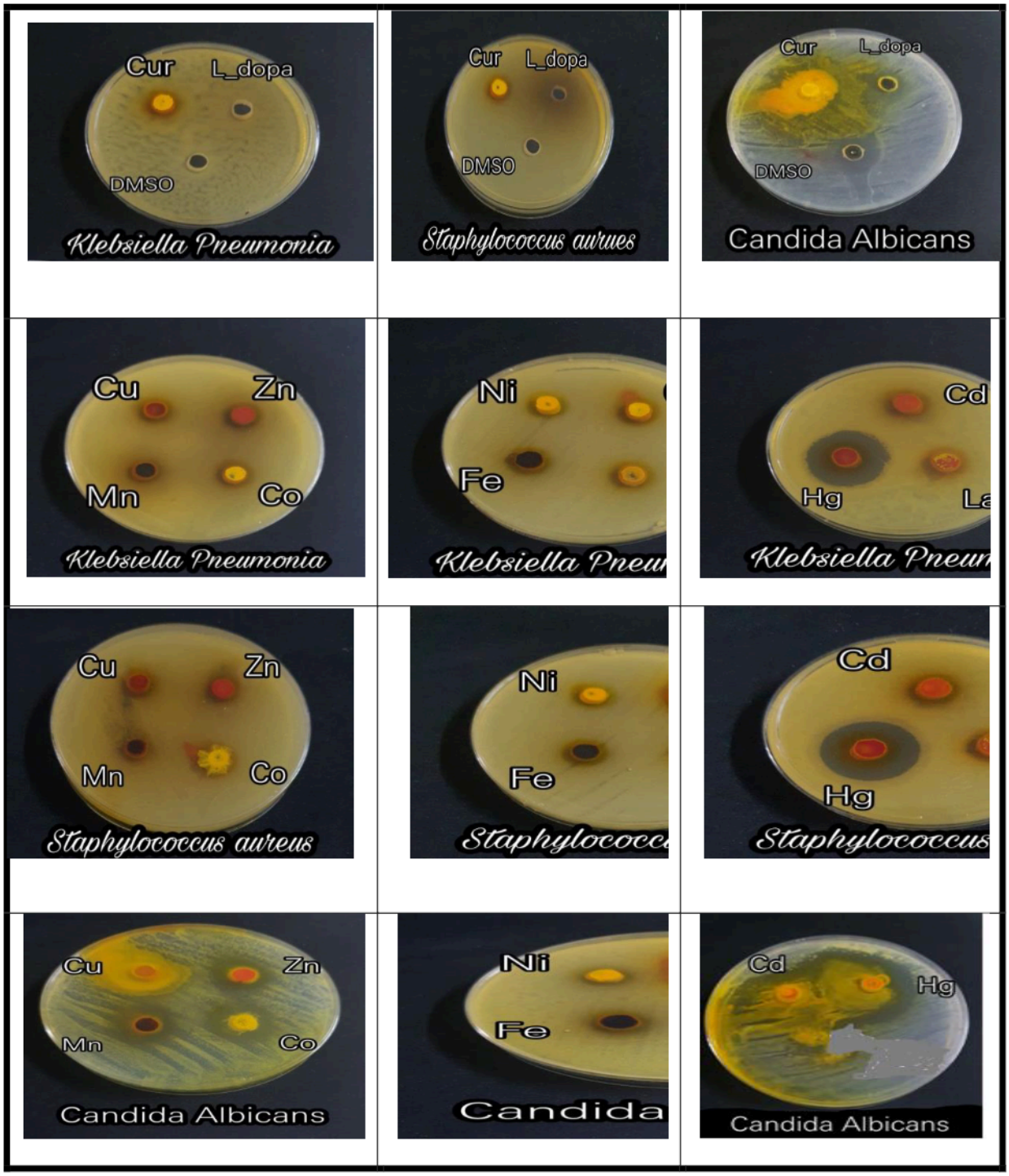


Figure 5. The Inhibition zone (ZI) of compounds

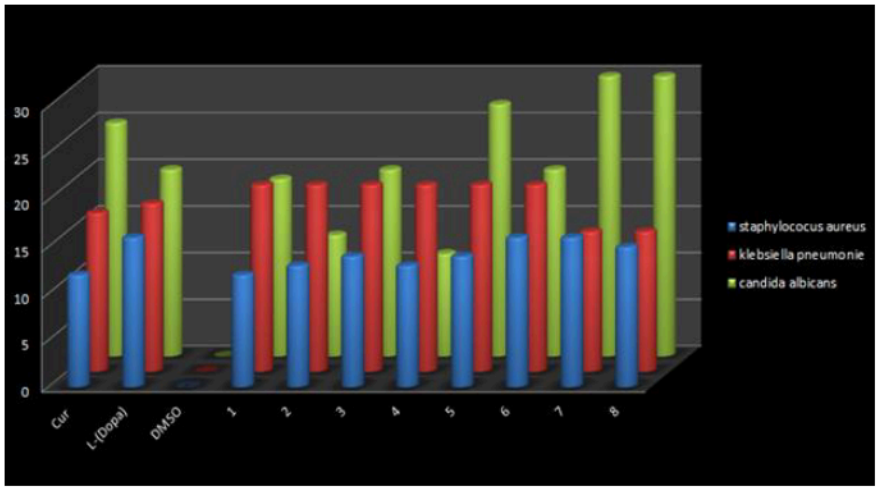


Chart 1. The (ZI) mm of ligands and [M (Curc)(L-dopa)$_2$] complexes (1-8)

5. Proposed molecular structure

Examining complexes based on the above analysis, the data indicated the existence of (Hexa-coordinate - an octahedral geometry around M(II). The proposed structures of [M(II)-(Curc)-(L-dopa)] are shown in **Figure 6**.

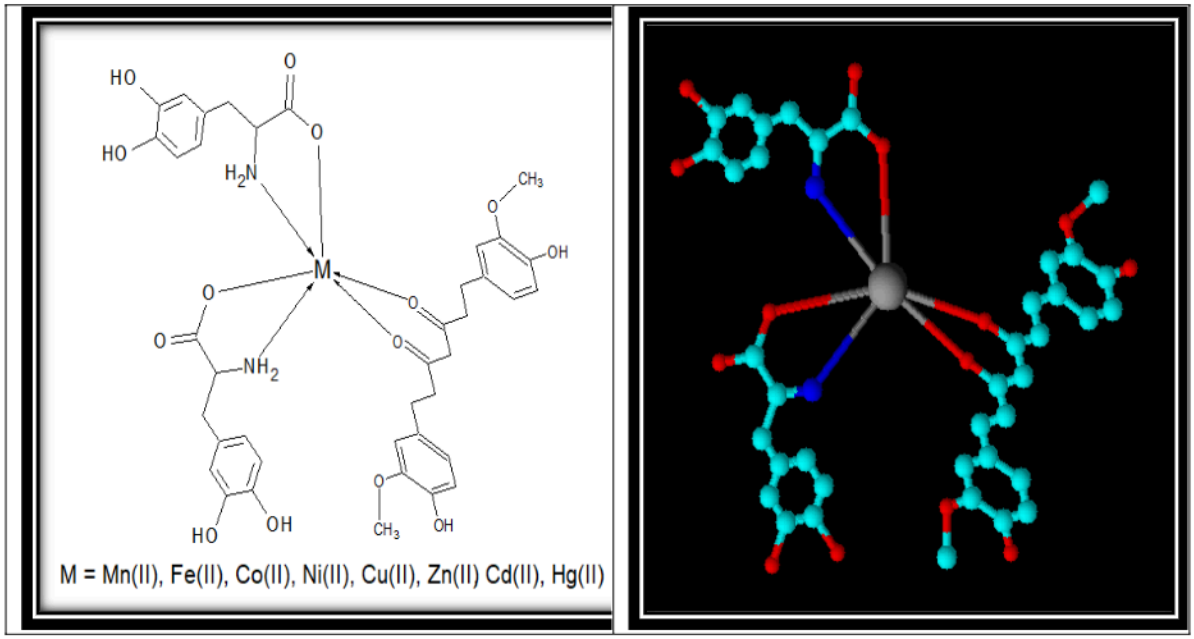


Figure 6. Probable 3-D structure of the complexes

6.Conclusion

The synthetic direction adopted for the synthesis of new complexes was very simple with good yield.

Eight new mixed ligand metal(II) coordination compounds have been prepared by using curcumin,L-dopa and appropriate metal chloride, in 1:1:2 Curc:M:2 L-dopa molar ratio , M= Mn (II), Fe (II),Co(II) ,Ni(II),Cu (II), Zn(II), Cd(II) and Hg(II). The results suggest that octahedral symmetry for the all complexes which the curcumin and L-dopa may act as bidentate ligands. L-dopa probably binds to the metal ions in the mono-deprotonated. The antibacterial activity studies were done using agar well diffusion technique and the result shows that the complexes have higher antibacterial activity than the free ligand.
The ligands and their corresponding metal complexes were evaluated for biologically active, the complexes show better activity than the free ligands.

Acknowledgements
This project is supported by the office of university of Baghdad.Iraq. The authors are grateful to the authorities of the university of Baghdad

References

1.Kiss, T.; Gergely. A. Copper (II) and nickel (II) ternary complexes of L-dopa and related compounds. Journal of inorganic biochemistry, **1985**, *25*, 247-259, https://doi.org/10.1016/0162-0134(85)80024-6
2.Ostrov, D. A.; Alkanani,A.; McDaniel, K. A.; Case, S.; Baschal, E. E.; Pyle, L.; Michels, A. W. Methyldopa blocks MHC class II binding to disease-specific antigens in autoimmune diabetes. The Journal of clinical investigation, **2018**, *128*, 1888-1902, https://doi.org/10.1172/JCI97739
3.Ali, A. M.; Al-Noor, T. H. Synthesis, spectroscopic study, biological activity and dyeing application of curcumin-Schiff base with various metal ions complexes. IOP Conf. Ser.: Mater. Sci. Eng, **2021**, 1046, 012006, 10.1088/1757-899X/1046/1/012006
4.Tosato, M.; Di Marco, V. Metal chelation therapy and Parkinson's disease: A critical review on the thermodynamics of complex formation between relevant metal ions and promising or established drugs. Biomolecules, **2019**, 9, 269 https://doi.org/10.3390/biom9070269
5.O'Brien, P.; Poyner, E. A.; Alraddadi,T. S.; Hursthouse, M. B.; Foxman, B. M. cis-Bis (l-DOPA-κ2N, O) copper (II) monohydrate: synthesis, crystal structure, and approaches to the analysis of pseudosymmetry. Acta Crystallographica Section C: Structural Chemistry, **2021**, 77, 383-390, https://doi.org/10.1107/S2053229621006082.
6.Raju Bendi, R.; Santhee Devi Karri, V.; Rao Gollapalli, N. Chemical speciation of ternary complexes of L-dopa and 1,10-phenanthroline with Co(II), Ni(II) and Cu(II) in low dielectric media. Chemical Speciation and Bioavailability, **2012**, *24*, 10.3184/095422912X13324388533472
7.Hussain, Y.; Islam, L.; Khan, H.; Filosa, R.; Aschner, M.; Javed, S. Curcumin-cisplatin chemotherapy: A novel strategy in promoting chemotherapy efficacy and reducing side effects. Phytother. Res, **2021**, *35*, 6514–6529. https://doi.org/10.1002/ptr.7225
8.Barik, A.; Mishra, B.; Kunwar, A.; Kadam, R. M.; Shen, L.; Dutta,S.; Priyadarsini,K. I. Comparative study of copper(II)ecurcumin complexes as superoxide dismutase mimics and free radical scavengers. European journal of medicinal chemistry, **2007**, *42*, 431-439, https://doi.org/10.1016/j.ejmech.2006.11.012
9.Ali, A. M.; Al-Noor, T. H.; Abdalrazaq, E.; Jbarah, A. A. Q. Synthesis and DFT Study of the Complexation of Schiff Base Derived Curcumin and L-Tyrosine with Al

(III), Ag (I), and Pb (II) Metal Ions. *Indonesian Journal of Chemistry*, **2021**, *21*, 708-724, https://doi.org/10.22146/ijc.62188

10.Baira, K.; Ounissi, A.; Merouani, H.; Alam, M.; Ouddai, N.; Erto, A.; Yadav, K. K.; Islam, S.; Cheon, J.-K.; Jeon, B.-H. Multitask Quantum Study of the Curcumin-Based Complex Physicochemical and Biological Properties. *J. Mol.Sci*, **2022**, *23*, https://doi.org/10.3390/ijms23052832

11.Alkhafagi, Z. H.; Al-Noor,T. H. Synthesis, characterization and antimicrobial studies of mixed ligand from phthalic acid and 1, 10-phenanthroline with their complexes. AIP Conference Proceedings, **2020**, 2290, https://doi.org/10.1063/5.0028226

12.Geary, W. J. The Use of Conductivity Measurements in Organic Solvents for the Characterisation of Coordination Compounds. *Coordination Chemistry Reviews*, **1971**, *7*, 81-122, https://doi.org/10.1016/S0010-8545(00)80009-0

13.Abu-Dief, A. M.; Nassr, L. A. Tailoring, physicochemical characterization, antibacterial and DNA binding mode studies of Cu (II) Schiff bases amino acid bioactive agents incorporating 5-bromo-2-hydroxybenzaldehyde. *Journal of the Iranian Chemical Society*, **2015**, *12*, 943-955, DOI 10.1007/s13738-014-0557-9

14.Cotton, F. A.; Wilkinson, G.; Murillo, C. A.; Bochmann, M. Advanced Inorganic Chemistry; John Wiley and Sons, Inc: **1999**, http://repository.vnu.edu.vn/handle/VNU_123/85212

15.Nakamoto, K. Infrared and Raman spectra of inorganic and coordination compounds, part B: applications in coordination, organometallic, and bioinorganic chemistry; *John Wiley & Sons*, **2009**.

16.Vlad, M.; Labadi, L.; Sasca, V.; Saity, L.; Costisor, O. Synthesis and thermal decomposition of the coordination polymer of 4, 4'-bipyridine and oxalate anion with Cu (II) and VO (IV). Chem. Bull. Chem. Bull. Politechnica Univ. Timisoara, **2006**, *51*, 17-19.

17.Calatayud, M. L.; Castro, I.; Sletten, J.; Lloret, F.; Julve, M. Syntheses, crystal structures and magnetic properties of chromato-, sulfato-, and oxalato-bridged dinuclear copper (II) complexes. Inorganica Chimica Acta, **2000**, *300*, 846-854, https://doi.org/10.1016/S0020-1693(99)00590-3

18.Barthes, M.; Vik, A. F.; Spire, A.; Bordallo, H. N.; Eckert, J. Breathers or structural instability in solid L-alanine: a new IR and inelastic neutron scattering vibrational spectroscopic study. The Journal of Physical Chemistry A, **2002**, *106*, 5230-5241, https://doi.org/10.1021/jp015615c

19.Bodkhe. A. S.; Patil. S. S.; Shaikh. M. M. Synthesis, characterization and antibacterial studies on mixed ligand copper complexes with polydentate ligands. Acta Poloniae Pharmaceutica, **2012**, *69*, 871-877, ISSN 0001-6837.

20.Deka, B.; Bhattacharyya, A.; Mukherjee, S.; Sarkar, T.; Soni, K.; Banerjee, S.; Hussain, A. Ferrocene conjugated copper (II) complexes of terpyridine and traditional Chinese medicine (TCM) anticancer ligands showing selective toxicity towards cancer cells. Applied Organometallic Chemistry, **2018**, 32, e4287 https://doi.org/10.1002/aoc.4287

21.Lever, A. B. P., Inorganic Electronic Spectroscopy; Netherlands, **1984**, ISSN 0167-6881.

22.Singh, P.D; Jha, N.K.; Mishra, L. K. Complexes of 2, 4-dimercapto-s-triazolo-[4, 3-b]-1, 3, 4-thiadiazole with some bivalent metal ions—I. Journal of Inorganic and Nuclear Chemistry, **1980**, *42*, 282-285, https://doi.org/10.1016/0022-1902(80)80258-2.

23.Shriver, D. W., ; Atkins, P. W., Inorganic chemistry, electronic spectra of TM complexes: Freeman; New York; **2006**.

24.Patel, K. S.; Patel, J. C.; Dholariya, H. R.; Patel, V. K.; Patel, K. D. Synthesis of Cu (II), Ni (II), Co (II), and Mn (II) complexes with ciprofloxacin and their evaluation of antimicrobial,

antioxidant and anti-tubercular activity. Open Journal of Metal, **2012**, 2, DOI:10.4236/ojmetal.2012.23008

25.Reiss, A.; Florea, S.; Caproiu,T.; Stanica, N. Synthesis, characterization, and antibacterial activity of some transition metals with the Schiff base N-(2-furanylmethylene)-3-aminodibenzofuran. Turkish Journal of Chemistry, **2009**, *33*, 775-783 doi:10.3906/kim-0807-31

26.Mohapatra, R. K.; El-ajaily, M. M.; Alassbaly,F. S.; Sarangi, A. K.; Das, D.; Maihub,A. A.; Al-Noor. T. H. DFT, anticancer, antioxidant and molecular docking investigations of some ternary Ni (II) complexes with 2-[(E)-[4-(dimethylamino) phenyl] methyleneamino] phenol. Chemical Papers, **2021**, *75*, 1005-1019, https://doi.org/10.1007/s11696-020-01342-8

27.Singh, K.; Kumar, Y.; Puri, P.; Sharma, C.; Aneja, K. R. Antimicrobial, spectral and thermal studies of divalent cobalt, nickel, copper and zinc complexes with triazole Schiff bases. *Arabian Journal of Chemistry*, **2017**, *10*, S978-S987, https://doi.org/10.1016/j.arabjc.2012.12.038

28.abdul karem, Lekaa K.; Al-Noor,T.H. Synthesis, Spectral and Bacterial Studies of Mixed Ligand Complexes of Schiff Base Derived from Methyldopa and Anthranilic Acid with Some Metal Ions. *Ibn Al-Haitham Journal for Pure and Applied scienc*, **2017**, 235-247, https://doi.org/ 10.30526/2017.IHSCICONF.1797.