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Characterization of mixed ligand Cu(II) complexes through mass spectral, thermal and biological studies

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ABSTRACT

A series of six mixed-ligand complexes of Cu(II) with 7-hydroxy-4-methoxy-10,11-dihydroindeno[5,4-c]chromene-6(9H)-one (A) and Schiff bases derived from quinazolinone (Qn1-Qn6) were synthesized and fully characterized. The structural features of the complexes were investigated using various spectroscopic techniques, including elemental analysis, infrared (IR) and proton nuclear magnetic resonance (¹H-NMR) spectroscopy, fast atom bombardment mass spectrometry (FAB-MS), magnetic measurement, and thermal studies. Furthermore, the biological activities of the ligands, complexes, and metal salt were assessed in vitro against both gram-positive and gram-negative microorganisms. The results showed that the newly synthesized metal complexes exhibited significantly higher biological activities compared to the free ligands and metal salt. These findings suggest that the mixed-ligand complexes have potential for further development as antimicrobial agents.

Keywords: Quinazolinone, Metal complex, FAB-MS spectroscopy, TGA, Biological activity

1. INTRODUCTION

Transition metal complexes with mixed ligands have attracted significant attention in coordination chemistry due to their diverse structures and potential applications in various fields

such as catalysis, medicine, and materials science. [1] Copper(II) complexes with mixed ligands have been particularly interesting due to the wide range of possible coordination geometries and ligand exchange reactions. [2]

In this study, we investigate the characterization of mixed ligand Cu(II) complexes using a combination of mass spectrometry, thermal analysis, and biological assays. Mass spectrometry is a powerful technique for identifying the molecular weight and chemical composition of metal complexes, [3] while thermal analysis provides information on the thermal stability and phase transitions of the complexes. [4] [5]

In addition, we evaluate the potential antimicrobial activity of the complexes using the zone of inhibition method [6] The gram-positive bacteria *E. coli* and *S. aureus*, and the gram-negative bacteria *S. marcescens* and *B. substills* were chosen as the test organisms. The results of the biological assays are compared between the ligand and metal complexes, and with standard drug. [7] [8]

The use of coumarin derivatives and quinazolinone Schiff base derivatives [9] as ligands for mixed ligand Cu(II) complexes has been of interest due to their structural diversity and potential applications in the development of new antimicrobial agents [10-13]. These ligands have been found to exhibit good coordination properties and form stable complexes with copper(II).

The goal of this study is to provide a comprehensive understanding of the structure, properties, and biological activity of mixed ligand Cu(II) complexes. We synthesized a series of Cu(II) complexes with mixed ligands and characterized them using mass spectrometry and thermal analysis. We also evaluated their antimicrobial activity against selected bacterial strains.

The results of this study provide insight into the structure-activity relationships of mixed ligand Cu(II) complexes and demonstrate their potential as antimicrobial agents. The combination of mass spectrometry, thermal analysis, and biological assays offers a powerful approach for the characterization of metal complexes with mixed ligands, and could be applied to the design and development of new metal-based drugs and materials.

2. EXPERIMENTAL

2. 1. Materials and Methods

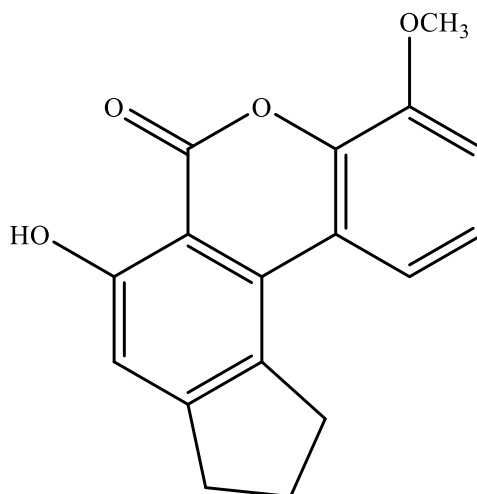
Analytical grade chemicals and reagents were exclusively utilized in this study. Salicylaldehyde, Ethylacetoacetate, piperidine, ether, chloroform, bromine, toluene, pyridine, cyclopentanone, benzaldehyde, 4-nitrobenzaldehyde, 4-methoxy-benzaldehyde, 4-dimethylamino benzaldehyde, furfural and Copper nitrate were purchased from the Sigma-Aldrich.

2. 2. Preparation of Ligands

- **7-hydroxy-4-methoxy-10,11-dihydroindeno[5,4-c]chromene-6(9H)-one(A)**

The desired compound, 8-methoxy-3-coumarinoyl methyl pyridinium, cyclopentanone, and sodium acetate were combined in acetic acid and refluxed for 8 hours to synthesize 7-hydroxy-4-methoxy-10,11-dihydroindeno[5,4-c]chromene-6(9H)-one (A). The resulting mixture was cooled to room temperature, and the solid product was obtained by extracting with

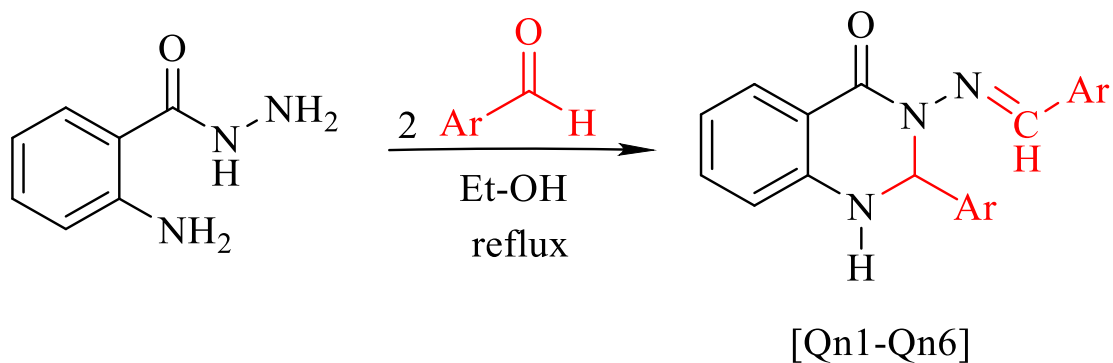
water and then chloroform. The white crystalline product was obtained by recrystallizing with chloroform-hexane. The ligand was synthesized using a modified literature procedure. [14] Yield, 62%, m.p., 227-230 °C. Found (%): C, 72.13, H, 4.82. $C_{17}H_{14}O_4$ (282.29) requires (%): C, 72.33, H, 5.00. 1H NMR (ppm): 11.71 (s, 1H, -OH proton), 7.81 (d, 1H, C_{11} proton), 7.18-7.30 (m, 3H, C_8, C_9, C_{10} proton), 6.86 (s, 1H, C_4 proton), 3.18 (t, 2H, C_3 proton), 2.78 (t, 2H, C_1 proton), 2.18 (2H m, C_2 proton), 3.90 (3H, s, -OCH₃). IR (cm⁻¹): 3419 ν (-OH stretching), 1610 and 3038 ν (aromatic C=C and C-H stretching), 2952 ν (aliphatic C-H stretching of cyclopentane ring), 1676 ν (C=O stretching).



A

- **Synthesis of Quinazolinone Schiff base ligands(Qn1-Qn6)**

The Quinazolinone Schiff bases Qn1-Qn6 presented in Table 1 were synthesized by modifying the method outlined in literature. [15] [16]. In Scheme 1, the reaction mixture of 2-amino benzoyl hydrazide and aromatic aldehyde in ethanol was stirred for 10 minutes and then refluxed for 2 hours. The resulting solid was isolated by filtration and washed with water.



Scheme 1. Synthesis of Quinazolinone schiff base

Table 1. Aromatic aldehyde and identification of Quinazolinone Schiff bases Qn1-Qn6

Entry	Ar	Quinazolinone Schiff base	Yield (%)
1	C ₆ H ₅	Qn1	84
2	4-NO ₂ C ₆ H ₄	Qn2	82
3	4-CH ₃ OC ₆ H ₄	Qn3	79
4	4-(CH ₃) ₂ NC ₆ H ₄	Qn4	83
5	2-furyl	Qn5	85
6	4-ClC ₆ H ₄	Qn6	83

1) (E)-3-(benzylideneamino)-2-phenyl-2,3-dihydroquinazolin-4(1H)-one(Qn1):

Yield, 84%, m.p., 166-167 °C.

Found (%): C, 77.1, H, 5.17, N, 12.77. C₂₁H₁₇N₃O (327.39) requires (%) C, 77.04, H, 5.23, N, 12.84. ¹H NMR (ppm): 7.95 (s, -HC=N), 6.69-7.97 (m, Ar-H), 5.92 (s, C-H), 6.12 (s, -NH). IR (KBr, cm⁻¹): 3283 (-N-H str. vib.), 1660 (-C=O str. vib.), 1618 (-CH=N str. vib.), 3040 (aromatic C-H).

2) (E)-3-((4-nitrobenzylidene)amino)-2-(4-nitrophenyl)-2,3-dihydroquinazolin-4(1H)-one(Qn2):

Yield, 82%, m.p., 215-217 °C.

Found (%): C, 60.28, H, 3.55, N, 16.71. C₂₁H₁₅N₅O₅ (417.38) requires (%) C, 60.43, H, 3.62, N, 16.78. ¹H NMR (ppm): 8.12 (s, -HC=N), 6.52-8.12 (m, Ar-H), 5.96 (s, C-H), 6.18 (s, -NH). IR (KBr, cm⁻¹): 3284 (-N-H str. vib.), 1641 (-C=O str. vib.), 1612 (-CH=N str. vib.), 1561 (-C-N str. vib.), 3100 (aromatic C-H).

3) (E)-3-((4-methoxybenzylidene)amino)-2-(4-methoxyphenyl)-2,3-dihydroquinazolin-4(1H)-one(Qn3):

Yield, 79%, m.p., 223-234 °C.

Found (%): C, 71.17, H, 5.41, N, 10.79. C₂₃H₂₁N₃O₃ (387.44) requires (%) C, 71.30, H, 5.46, N, 10.85. ¹H NMR (ppm): 8.29 (s, -HC=N), 6.62-7.78 (m, Ar-H), 5.94 (s, C-H), 6.19 (s, -NH), 3.78 (s, -OCH₃). IR (KBr, cm⁻¹): 3335 (-N-H str. vib.), 1609 (-C=O str. vib.), 1572 (-CH=N str. vib.), 1251 (-C-O str. vib.), 2966 (aromatic C-H).

4) (E)-3-((4-(dimethylamino)benzylidene)amino)-2-(4-dimethylamino)phenyl)-2,3-dihydroquinazolin-4(1H)-one(Qn4):

Yield, 83%, m.p., 252-254 °C

Found (%): C, 72.48, H, 6.47, N, 16.82. C₂₅H₂₇N₅O (413.53) requires (%) C, 72.61, H, 6.58, N, 16.94. ¹H NMR (ppm): 8.29 (s, -HC=N), 6.45-7.32 (m, Ar-H), 5.96 (s, C-H), 6.18 (s, -NH), 2.96 (s, -NCH₃). IR (KBr, cm⁻¹): 3462 (-N-H str. vib.), 1714 (-C=O str. vib.), 1604 (-CH=N str. vib.), 1228 (-C-N str. vib.), 2915 (aromatic C-H).

5) (E)-2-(furan-2-yl)-3-((furan-2-ylmethylene)amino)-2,3-dihydroquinazolin-4(1H)-one(Qn5):

Yield, 85%, m.p., 170 – 172 °C.

Found (%): C, 66.32, H, 4.15, N, 13.61. C₁₇H₁₃N₃O₃ (301.31) requires (%) C, 66.44, H, 4.26, N, 13.67. ¹H NMR (ppm): 8.26 (s, -HC=N), 6.41-7.74 (m, Ar-H), 5.92 (s, C-H), 6.18 (s, -NH). IR (KBr, cm⁻¹): 3252 (-N-H str. vib.), 1655 (-C=O str. vib.), 1611 (-CH=N str. vib.), 3145 (aromatic C-H).

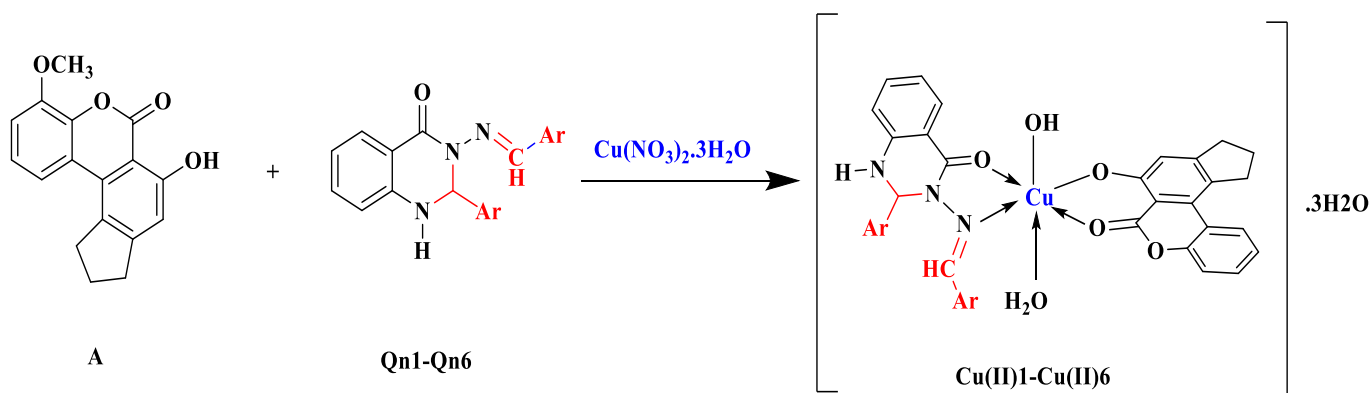
6) (E)-3-((4-chlorobenzylidene)amino)-2-(4-chlorophenyl)-2,3-dihydroquinazolin-4(1H)-one(Qn6):

Yield, 83%, m.p, 230 – 232 °C.

Found (%): C, 63.44, H, 3.74, N 10.53. C₂₁H₁₅Cl₂N₃O (396.27) requires: % C, 63.53, H, 3.82, N, 10.60. ¹H NMR (ppm): 8.32 (s, -HC=N), 6.52-7.92 (m, Ar-H), 5.21 (s, C-H), 6.17 (s, -NH). IR (KBr, cm⁻¹): 3435(-N-H str. vib.), 1625 (-C=O str. vib.), 1591 (-CH=N str. vib.), 810 (-C-Cl str. vib.), 3050 (aromatic C-H).

• **Synthesis of Cu(II) complexes(Cu(II)1-Cu(II)6)**

To synthesize these complexes, a general procedure was employed. Specifically, a solution of Cu(NO₃)₃·3H₂O (10 mmol) in water was added to a solution of ligand A (10 mmol) in dimethyl formamide, followed by addition of Schiff base ligand Qn1-Qn6 (10 mmol) in ethanol.



Scheme 2. Synthesis of Complexes

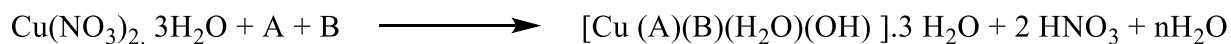
The resulting mixture was refluxed on a water bath for 7 hours. The dark green precipitate obtained was filtered, washed with ethanol and hot water, and subsequently dried in a vacuum at room temperature. [17] The general reaction scheme is shown in Scheme 2. Whereas analytical and physical data are shown in Table 2.

Table 2. Analytical and physical data of Cu(II) complexes.

Compound	Color	Yield (%)	Molecular weight	Melting Point (°C)	Compound	% found (required)			
						C	H	N	Cu
Cu(II)-1	Dark green	64	761.24	>350	Cu(II)-1	64.11 (64.53)	4.48 (4.70)	5.78 (5.94)	8.68 (8.99)
Cu(II)-2	Dark green	62	851.24	>350	Cu(II)-2	56.84 (57.25)	3.78 (3.92)	8.56 (8.78)	7.78 (7.97)
Cu(II)-3	Dark green	63	821.29	>350	Cu(II)-3	62.44 (62.61)	4.25 (4.86)	5.22 (5.48)	8.09 (8.28)
Cu(II)-4	Dark green	61	847.38	>350	Cu(II)-4	63.21 (63.58)	5.13 (5.46)	8.38 (8.83)	7.89 (8.01)
Cu(II)-5	Dark green	65	741.16	>350	Cu(II)-5	59.18 (59.43)	4.05 (4.25)	6.01 (6.12)	9.11 (9.25)

3. RESULT & DISCUSSION

Table 2 presents the physical data and elemental results for synthesized mixed ligand copper(II) complexes. The reaction below outlines the process by which the complexes were formed.



where A = Ligand A & B = Ligand Qn1 – Qn6

All of the synthesized copper(II) complexes were found to be insoluble in nearly all organic solvents, but they exhibited slightly greater solubility in dimethyl sulfoxide.

3. 1. Magnetic Properties of Cu(II) Complexes.

The electronic spectral data and magnetic moment measurements presented in Table 3 provided valuable information about the geometry of the mixed ligand complexes. The complexes displayed two broad bands at around 10,500 and 14,500 cm^{-1} , corresponding to $d_{z^2} \rightarrow d_{x^2-y^2}$ and $dxz, dyz \rightarrow d_{x^2-y^2}$, respectively. The magnetic moment values of the copper(II) complexes ranged from 1.79 to 1.85 B.M., which is close to the spin allowed value of 1.73 B.M.

Based on the electronic spectral and magnetic moment data, it is suggested that the copper(II) ion in the complexes may have an octahedral geometry. [18] [19]

Table 3. Electronic spectroscopy and magnetic measurement data of metal complexes

Complexes	d-d transition in cm^{-1}	Assignment	μ_{eff}
Cu(II)-1	14,100-10,700	$d_{z^2} \rightarrow d_{x^2-y^2}, d_{xz}, d_{yz} \rightarrow d_{x^2-y^2}$.	1.82
Cu(II)-2	14,200-10,600	$d_{z^2} \rightarrow d_{x^2-y^2}, d_{xz}, d_{yz} \rightarrow d_{x^2-y^2}$.	1.84
Cu(II)-3	14,000-10,500	$d_{z^2} \rightarrow d_{x^2-y^2}, d_{xz}, d_{yz} \rightarrow d_{x^2-y^2}$.	1.79
Cu(II)-4	14,600-10,800	$d_{z^2} \rightarrow d_{x^2-y^2}, d_{xz}, d_{yz} \rightarrow d_{x^2-y^2}$.	1.83
Cu(II)-5	14300-10,700	$d_{z^2} \rightarrow d_{x^2-y^2}, d_{xz}, d_{yz} \rightarrow d_{x^2-y^2}$.	1.81
Cu(II)-6	14,400-10900	$d_{z^2} \rightarrow d_{x^2-y^2}, d_{xz}, d_{yz} \rightarrow d_{x^2-y^2}$.	1.85

3. 2. IR spectra

Table 4 displays the crucial infrared spectral bands recorded using KBr disks and their corresponding assignments for the synthesized complexes. The $\text{V}(\text{C}=\text{O})$ vibration band of the ligand (A) at 1670 cm^{-1} corresponding to lactone carbonyl ketone was observed, and this band shifted to a lower frequency of 1625 cm^{-1} upon complexation, suggesting coordination of the carbonyl oxygen atom.

The $\text{V}(\text{C}=\text{N})$ band in quinazolinone Schiff bases was observed within the $1572\text{-}1618 \text{ cm}^{-1}$ range, and it shifted towards lower frequencies in all mixed ligand complexes, suggesting that the imine nitrogen coordinated with the copper ion. [20]

Several new weak bands in the far IR region appeared at $505\text{-}508 \text{ cm}^{-1}$ and $538\text{-}544 \text{ cm}^{-1}$ in the complexes, and these were attributed to $\text{V}(\text{Cu-O})$ and $\text{V}(\text{Cu-N})$ modes. [21] Moreover IR spectra shows a weak and broad band at 3060 cm^{-1} with a sharp band at 2920 cm^{-1} due to aromatic C-H stretching and methyl group C-H stretching respectively.

The broad band spectra of mixed ligand complexes in the region $3200\text{-}3400 \text{ cm}^{-1}$ were attributed to the coordination of water in the complex, and other bands at 860 cm^{-1} and 716 cm^{-1} were due to the rocking and wagging mode of the $-\text{OH}$ group. [22]

Table 4. Selected IR data (cm^{-1}) for the Cu(II) complexes.

Complexes	$\text{V}(\text{CH}=\text{N})$ cm^{-1}	$\text{V}(\text{CH}=\text{O})$ cm^{-1} [Qn]	$\text{V}(\text{N-H}) \text{ cm}^{-1}$	$\text{V}(\text{Cu-O})$ cm^{-1} [A]	$\text{V}(\text{Cu-N})$ cm^{-1} [Qn]
Cu(II)-1	1605(w)	1650(s)	3275	508	541
Cu(II)-2	1594(w)	1635(s)	3278	507	544

Cu(II)-3	1552(w)	1595(s)	3324	503	540
Cu(II)-4	1589(w)	1692(s)	3476	504	538
Cu(II)-5	1590(w)	1638(s)	3245	507	539
Cu(II)-6	1572(w)	1620(s)	3427	505	543

3. 3. Thermal behavior of synthesized complexes

Thermo gravimetric analysis is a powerful technique used to investigate the thermal properties of materials [23]. In this study, mixed-ligand complexes were analyzed through thermo gravimetric analysis to determine their thermal stability and decomposition pathways. The analysis was carried out under a N₂ atmosphere, with a heating rate of 10 °C per minute, over a temperature range of 10 to 900 °C.

The primary objective of the study was to determine the compositional differences of the mixed-ligand complexes and identify the nature of associated water molecules. [24] The results showed that the [Cu(A)(Qn1)H₂O OH]·3H₂O complex undergoes four decomposition stages upon heating. The first stage occurs between 75 and 125 °C, and it corresponds to the loss of three water molecules, which indicates water of crystallization. The second stage occurs between 125 and 210 °C and is associated with the decomposition of one coordinated hydroxyl and water molecules. In the third stage, which occurs between 210 and 325 °C, ligand A is removed, and in the last stage, between 325 and 750 °C, ligand Qn1 is removed. The final residue was estimated as copper oxide.

Figures 1 and 2 display the TG curves for the Cu(II) complexes, and Table 5 presents the thermal data obtained from the thermal curves, which are consistent with other investigations. The analysis of mixed-ligand complexes through thermo gravimetric analysis can provide valuable information about the thermal stability and thermal decomposition of such complexes.

This information can be useful for understanding the mechanisms involved in the decomposition process and for optimizing the conditions under which these complexes are synthesized and stored.

Table 5. Thermal decomposition analytical data of complexes

Compounds	TG range (°C)	DTG max (°C)	Mass loss (%) Obs. (cal.)	Assignment
Cu(II)-1	75-125	90	6.93 (7.09)	Loss of three lattice water molecules
	125-210	-	4.41(4.59)	Loss of coordinated water and hydroxyl molecules
	210-325	280	36.98(37.08)	Removal of ligand A
	325-750	460	42.98(43.01)	Removal of ligand Qn1

Cu(II)-2	70-110	-	6.22(6.34)	Loss of three lattice water molecules
	110-210	145	4.08(4.11)	Loss of coordinated water and hydroxyl molecules
	210-320	270	33.08(33.16)	Removal of ligand A
	320-750	440	48.98(49.03)	Removal of ligand Qn2
Cu(II)-3	65-115	80	6.41(6.57)	Loss of three lattice water molecules
	115-210	140	4.11(4.26)	Loss of coordinated water and hydroxyl molecules
	210-330	255	34.22(34.37)	Removal of ligand A
	330-750	425	47.08(47.17)	Removal of ligand Qn3
Cu(II)-4	80-120	95	6.28(6.37)	Loss of three lattice water molecules
	120-200	160	4.05(4.13)	Loss of coordinated water and hydroxyl molecules
	200-310	285	33.18(33.31)	Removal of ligand A
	310-750	475	48.65(48.80)	Removal of ligand Qn4
Cu(II)-5	85-140	-	7.14(7.28)	Loss of three lattice water molecules
	140-230	160	4.65(4.72)	Loss of coordinated water and hydroxyl molecules
	230-310	282	38.01(38.08)	Removal of ligand A
	310-750	472	41.12(41.43)	Removal of ligand Qn5
Cu(II)-6	65-105	78	6.41(6.50)	Loss of three lattice water molecules
	105-205	136	4.11(4.21)	Loss of coordinated water and hydroxyl molecules
	205-300	252	33.89(34.01)	Removal of ligand A
	300-750	410	47.63(47.73)	Removal of ligand Qn6

3. 4. Mass spectra

The molecular ion peaks of the complexes $[\text{Cu}(\text{A})(\text{Qn1})\cdot\text{H}_2\text{O}\cdot\text{OH}]\cdot 3\text{H}_2\text{O}$, $[\text{Cu}(\text{A})(\text{Qn2})\text{H}_2\text{O}\cdot\text{OH}]\cdot 3\text{H}_2\text{O}$, $[\text{Cu}(\text{A})(\text{Qn3})\text{H}_2\text{O}\cdot\text{OH}]\cdot 3\text{H}_2\text{O}$, $[\text{Cu}(\text{A})(\text{Qn4})\cdot\text{H}_2\text{O}\cdot\text{OH}]\cdot 3\text{H}_2\text{O}$, $[\text{Cu}(\text{A})(\text{Qn5})\text{H}_2\text{O}\cdot\text{OH}]\cdot 3\text{H}_2\text{O}$, and $[\text{Cu}(\text{A})(\text{Qn6})\text{H}_2\text{O}\cdot\text{OH}]\cdot 3\text{H}_2\text{O}$ appear at $m/z = 761, 851, 821, 847, 741,$ and 830 in the mass spectra. These molecular ion peaks have been used, along with the recorded mass spectra shown in Figure 3, to confirm the molecular formula of the complexes (without water of crystallization).

The fragmentation pattern of the complexes can be found in Scheme 3. Furthermore, the fragmentation pattern in Scheme 3 provides insight into the structural details of the complexes. The observed fragmentation products can be used to determine the positions of the ligands on the copper atom, as well as the relative strengths of the metal-ligand bonds. Additionally, by analyzing the relative intensities of the fragmentation products, it is possible to gain information about the stability of the complexes and the energetics of the fragmentation process. These details can help to further understand the behavior and properties of the complexes in various applications. [25]

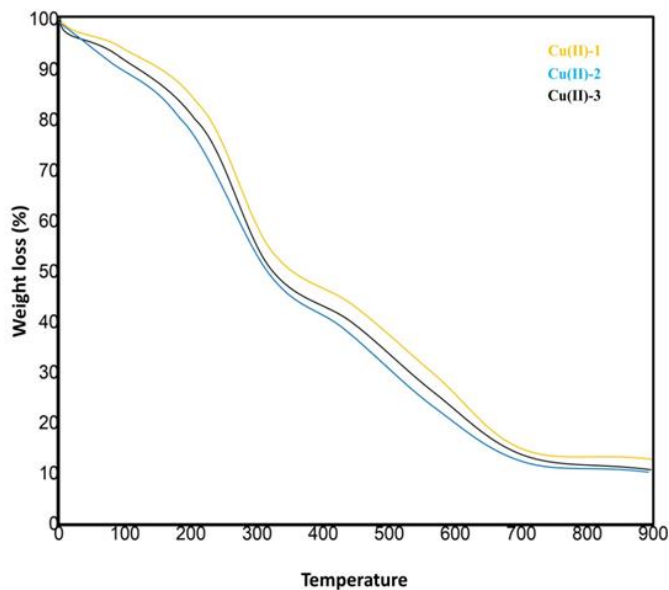


Fig. 1. TGA curve for complexes Cu(II)-1 to Cu(II)-3

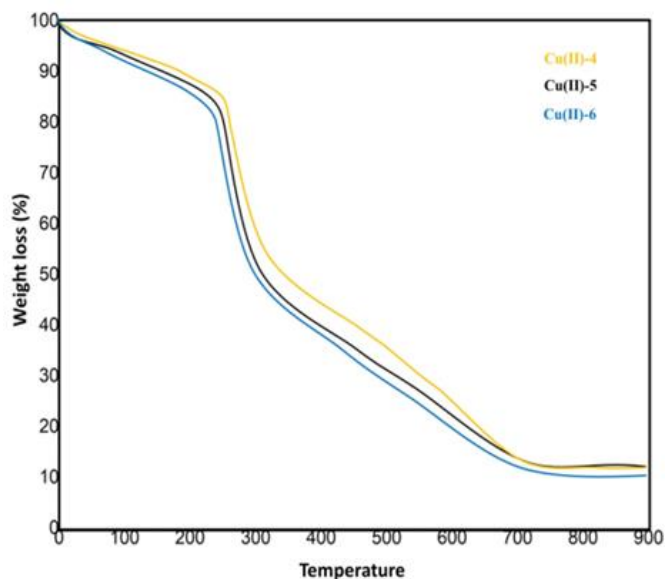
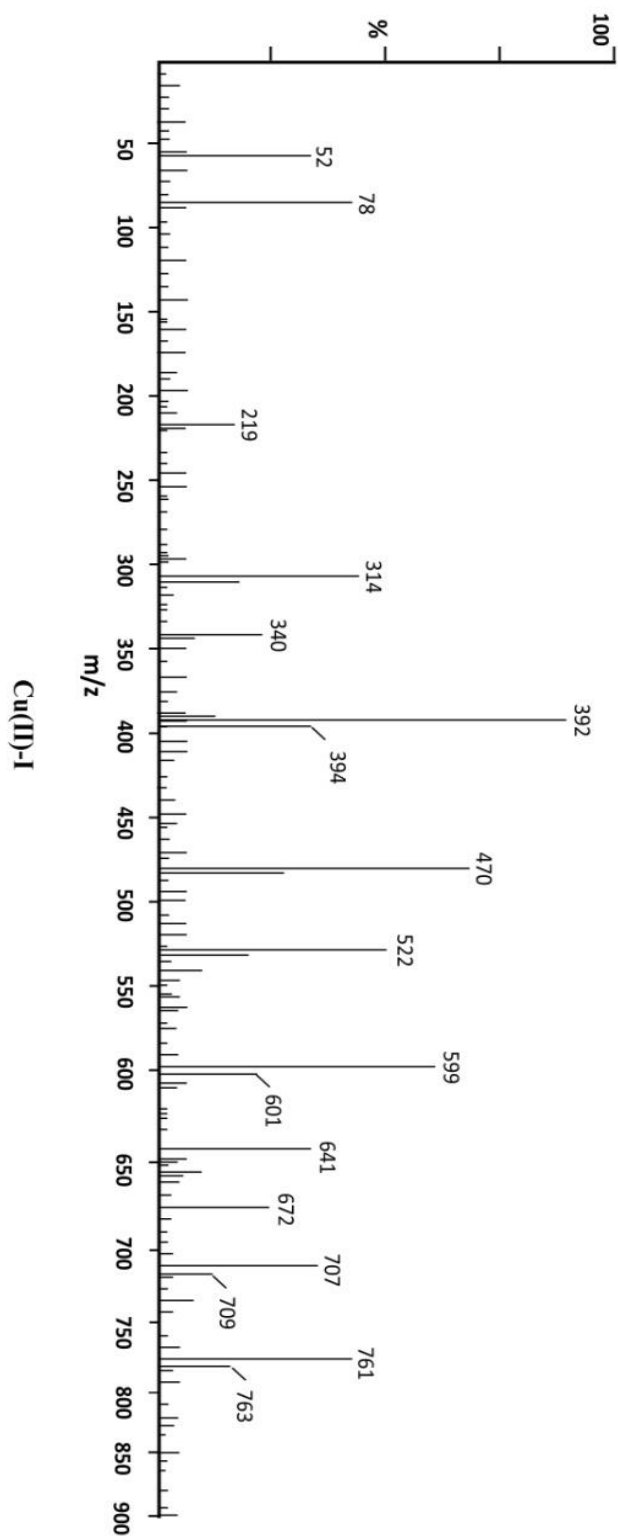
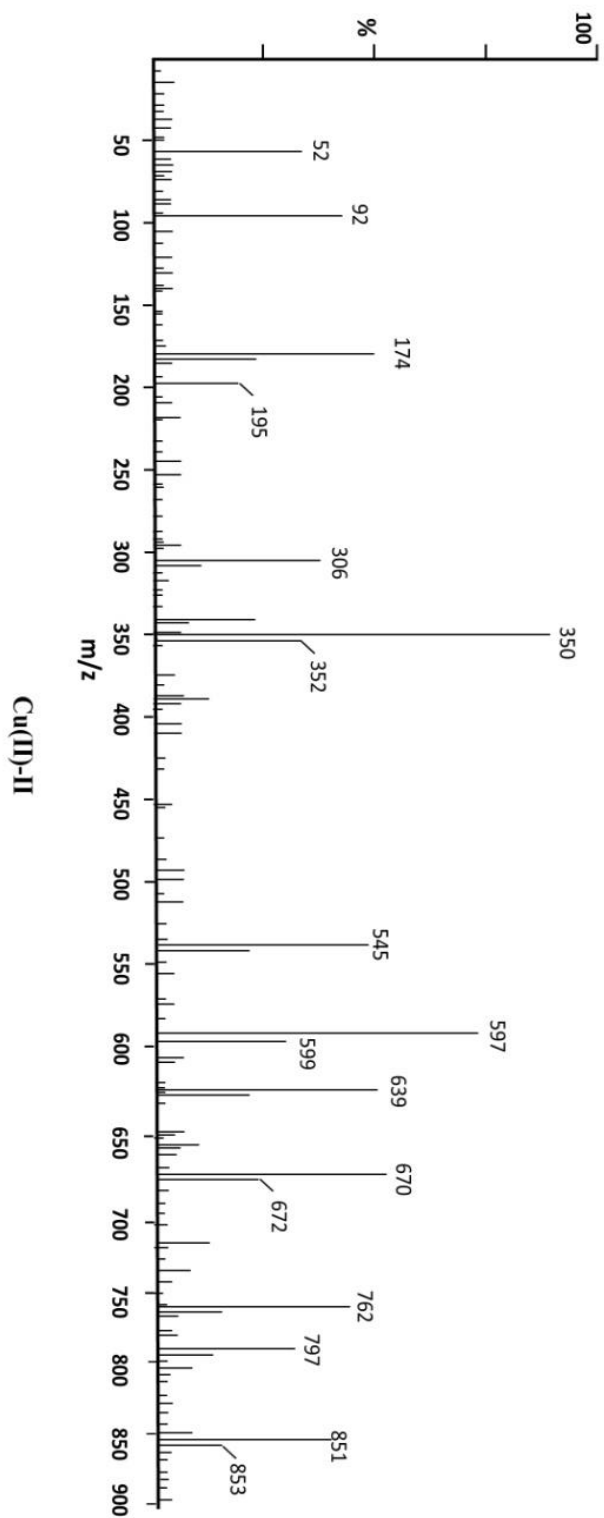


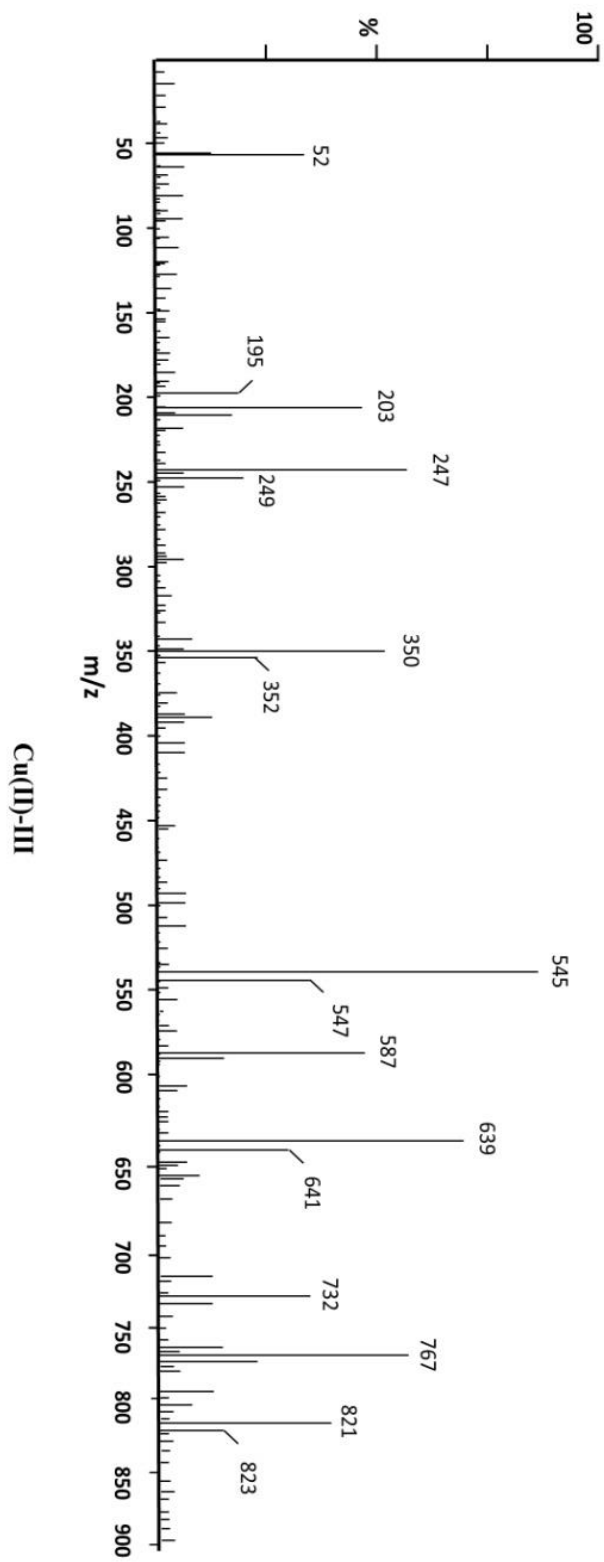
Fig. 2. TGA curve for complexes Cu(II)-4 to Cu(II)-6



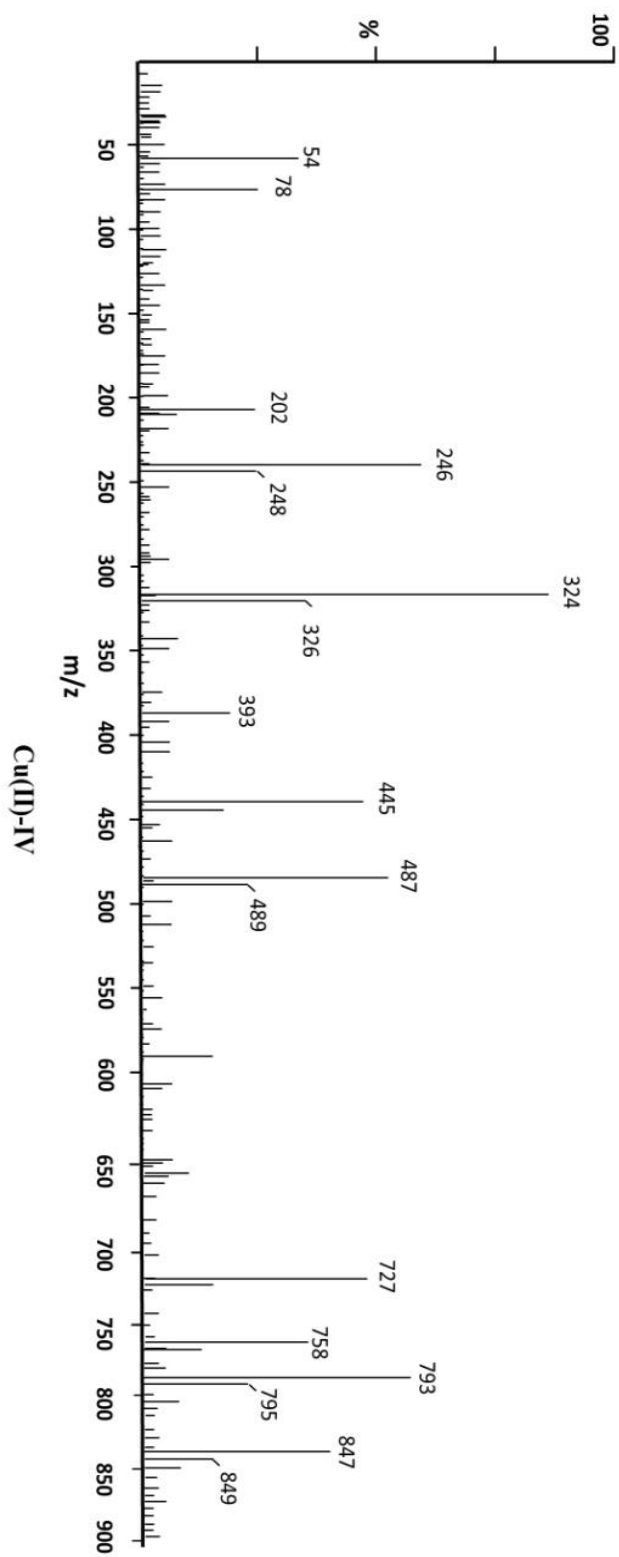
(a)



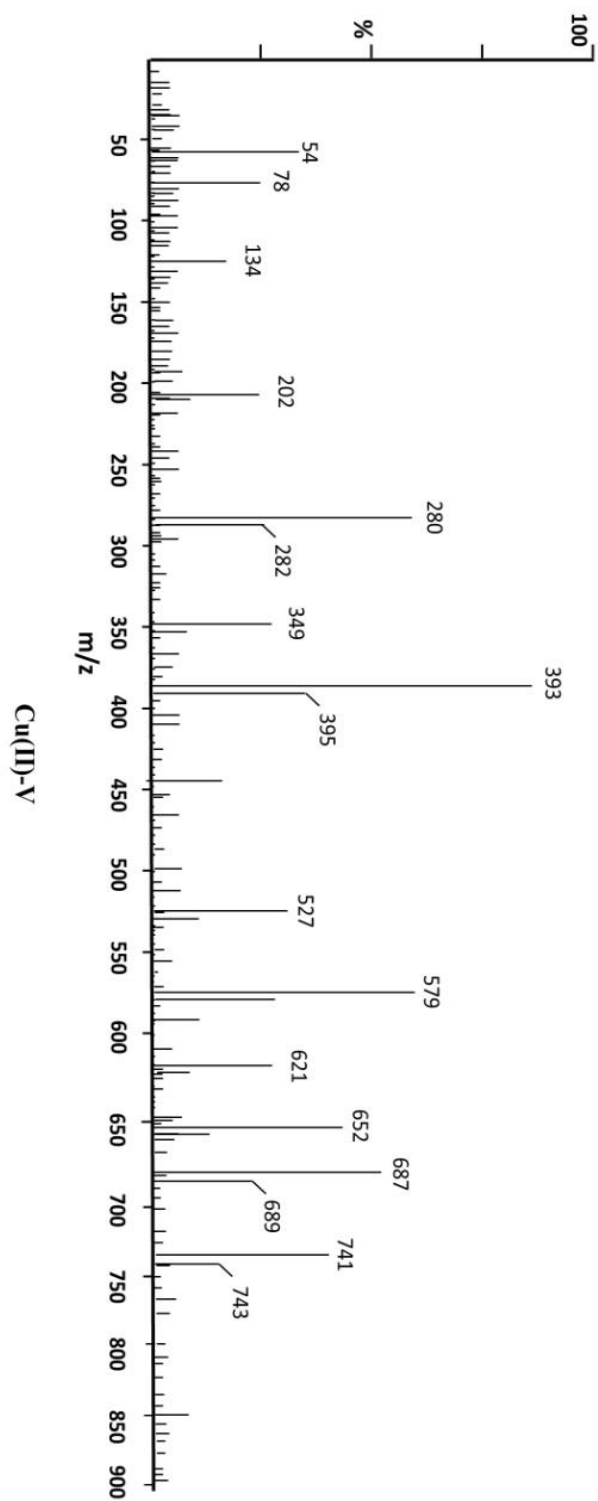
(b)



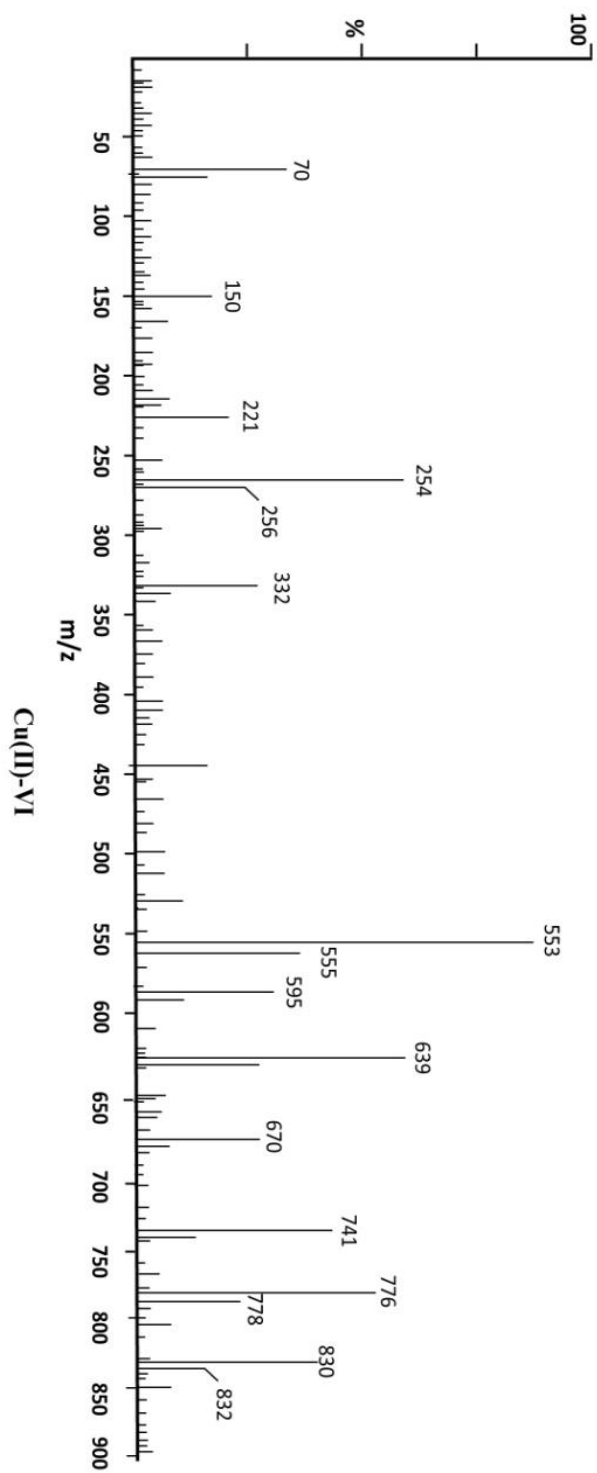
(c)



(d)

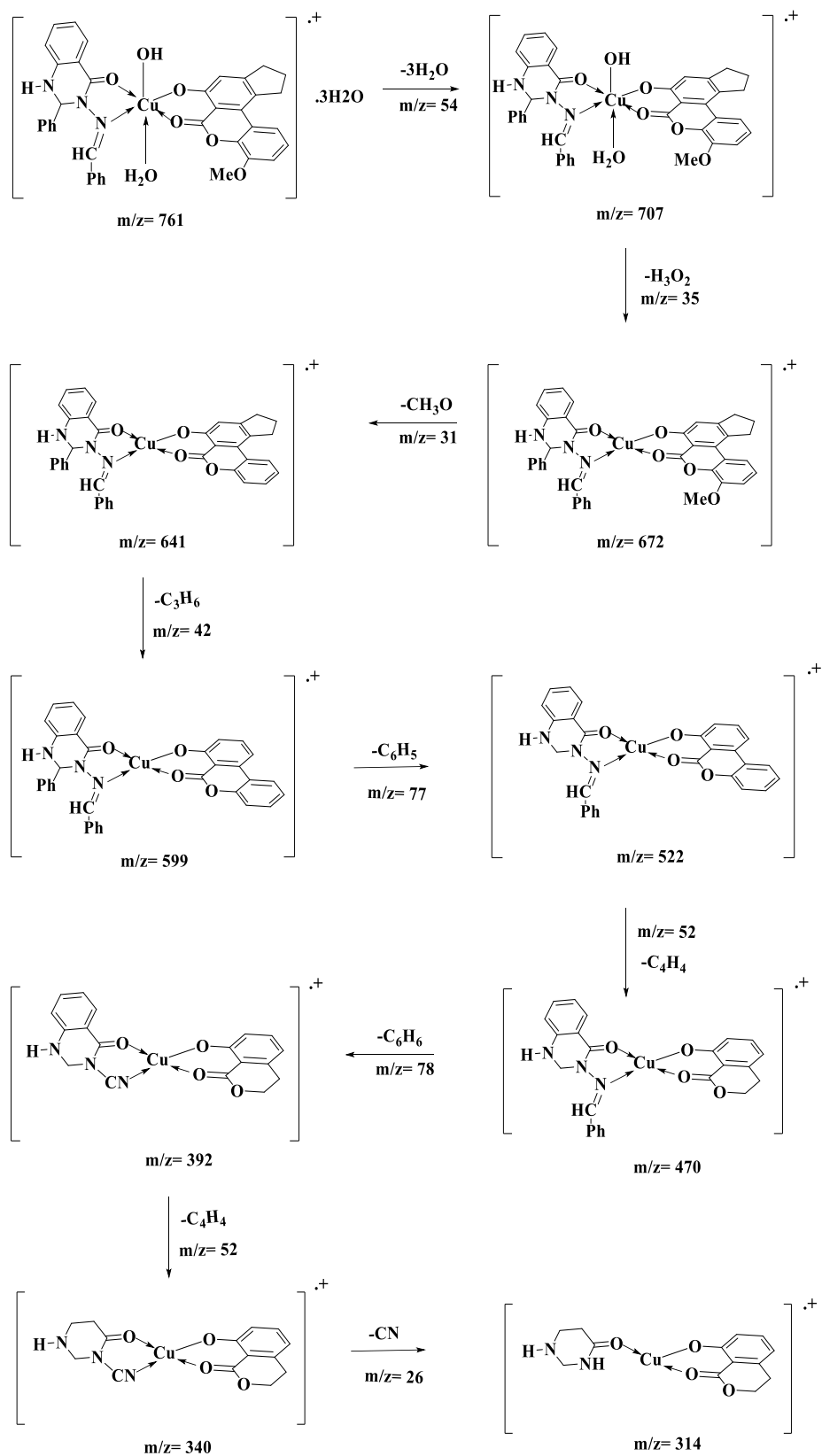


(e)



(f)

Fig. 3(a-f). Mass spectra of synthesized complexes



Scheme 3. The proposed fragmentation pattern of Cu(II)-1 complex

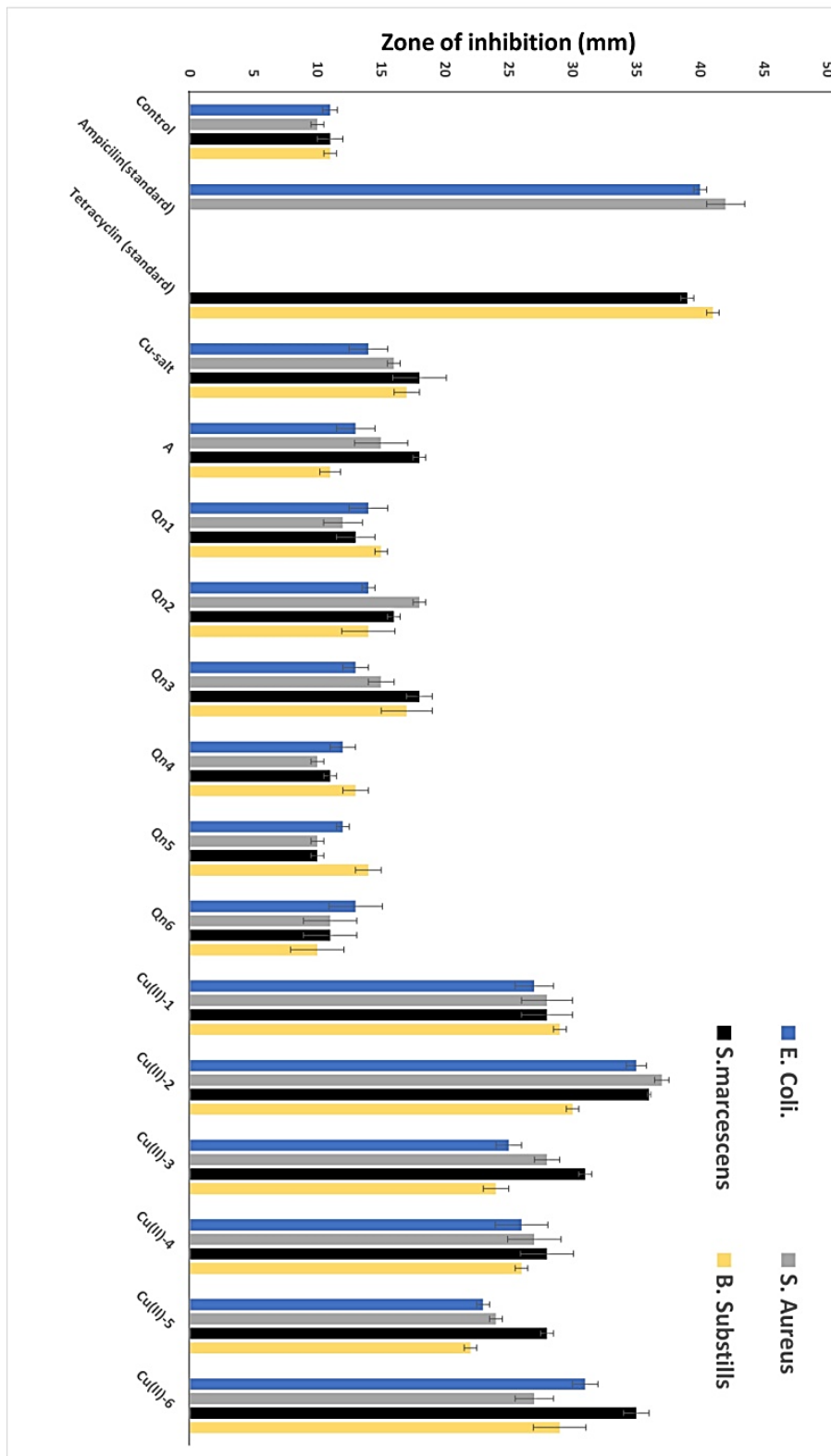


Fig. 4. Comparative analysis for biological activity

3. 5. Antibacterial Activity of complexes

A stock solution of 10 mg/mL was prepared by dissolving the compound in DMSO, which was subsequently diluted to the desired volume with double distilled water. Agar plates were prepared by dissolving bacteriological agar and Luria broth in distilled water, which was then sterilized by autoclaving. The target microorganisms were activated in liquid LB medium and incubated with two 10 mm wells. The agar plate was inoculated with the activated strain, and then sterilized stock solutions were added to the wells. Following incubation, the zone of inhibition was measured. Control experiments were carried out using solvents without any test compounds added. The results were reported as the zone of inhibition and compared to the standard drug.

The biological activity of ligands and their corresponding metal complexes was assessed by testing them against the gram-positive bacteria *E. coli* and *S. aureus*, as well as the gram-negative bacteria *S. marcescens* and *B. substilis*. The metal complexes showed greater potency than the ligands, as evidenced by the zone of inhibition measurements [27-30]. In particular, the Cu(II)-2 complex exhibited the highest activity against both gram-positive bacteria, particularly *S. aureus*, as well as gram-negative *S. marcescens*. These findings highlight the potential of coordination compounds for use in biological applications.

The results are presented in Table 6, and Figure 4 provides a graphical representation of the findings for *S. aureus*.

Table 6. Antibacterial activity data of ligands and complexes

	Zone of inhibition (mm)			
	Gram +ve		Gram -ve	
	<i>E. coli.</i>	<i>S. aureus</i>	<i>S. marcescens</i>	<i>B. substilis</i>
Control	11 ± 0.58	10 ± 0.5	11 ± 1	11 ± 0.5
Ampicillin	40 ± 0.5	42 ± 1.5	-	-
Tetracyclin	-	-	39 ± 0.5	41 ± 0.5
Cu-salt	14 ± 1.55	16 ± 0.5	18 ± 2.1	17 ± 1
A	14 ± 1.5	15 ± 2.01	18 ± 0.5	11 ± 0.8
Qn1	14 ± 1.55	12 ± 1.53	13 ± 1.53	15 ± 0.5
Qn2	14 ± 0.5	18 ± 0.6	16 ± 0.5	14 ± 2.08
Qn3	13 ± 1	15 ± 1.1	18 ± 1.2	17 ± 1.8
Qn4	12 ± 1	10 ± 0.5	11 ± 0.5	13 ± 0.8
Qn5	12 ± 0.5	10 ± 0.8	10 ± 0.5	14 ± 1
Qn6	13 ± 2.1	11 ± 2.06	11 ± 2.1	10 ± 2.06

Cu(II)-1	27 ± 1.5	28 ± 1.5	28 ± 2	29 ± 0.5
Cu(II)-2	35 ± 0.28	37 ± 0.5	36 ± 0.13	30 ± 0.5
Cu(II)-3	25 ± 1	28 ± 0.5	31 ± 0.5	24 ± 1
Cu(II)-4	26 ± 2.06	27 ± 2.06	28 ± 2.06	26 ± 0.5
Cu(II)-5	23 ± 0.5	24 ± 1	28 ± 0.5	22 ± 1
Cu(II)-6	31 ± 1	27 ± 1.5	35 ± 1	29 ± 2.06

E. coli = *Escherichia coli*, *S. aureus* = *Staphylococcus aureus*, *S. marcescens* = *Serratia marcescens*, *B. substills* = *Bacillus subtilis* (n = 3) ± standard deviation of three replicates.

4. CONCLUSIONS

- The ligands utilized in this study have demonstrated the ability to act as strong electron donors, serving as Lewis base to form complexes with octahedral geometry. This assertion is supported by the magnetic properties of the complexes, which indicate that the complexes exhibit an octahedral structure.
- The mass fragmentation pattern with molecular ion peak is the unique properties for any compounds. Here, we had used these unique patterns to find the molecular mass and the structural information of different complexes.
- The thermal studies revealed the degradation pattern of the different complexes and show the degradation rate of organic moiety with residual inorganic composition.
- The synthesized ligands and complexes were evaluated for their potential as antibacterial agents through a screening process. The results demonstrated significant antibacterial activity against both gram positive and gram negative bacteria for both the compounds. Notably, the complexes exhibited better activity than the ligands, and metal salts. These findings suggest that these complexes have potential for further development as antibacterial agents.

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