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Synthesis, Characterization & Antimicrobial activity of several Quinazolinone Schiff bases, 7-hydroxy-10,11-dihydroindeno[5,4-c]chromene-6(9H)-one & their Cu(II) complexes

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Abstract

The aim of this study was to synthesize mixed ligand complexes of copper(II) with a coumarin derivative,(1=7-hydroxy-10,11-dihydroindeno[5,4-c]chromene-6(9H)-one), and six Quinazolinone Schiff base derivatives, 2a-2f and characterize their structure using various spectroscopic techniques, including elemental analysis, , IR spectra, ^{1}H-NMR spectra, FAB mass spectra, magnetic measurement and thermal studies. In addition, the ligands, complexes, metal salt and control were tested in vitro for their biological activities against gram positive and gram negative micro organism. The results indicated that the metal complexes showed significantly higher activities compared to the free ligands and metal salt.

Keywords

Copper(II) complexes, TGA, Mass spectra, Magnetic measurement, Antibacterial activity.

Introduction

Nitrogen containing heterocyclic compounds are the part of thousand of molecules, active natural product as well as synthesized compounds. Quinazolinone is a kind of nitrogen containing heterocyclic compound comprising of benzene and a pyrimidine ring as fused ring(1). Plenty of work has been done which includes, the quinazolinone structural motifs containing imine(-C=N) functional group. Moreover it become one of the main areas of interest due to wide spectrum of biological activities for instance antibacterial, anticancer (2) anticytotoxicities (3), analgesic (4), diuretic (5), analgesic (4), antipyretic (6), antihistamine (7), anti- depressant (8) and vasodilating activities (9). Due to the importance of the biological activities exhibited by these compounds, there has been significance interest in the synthesis of quinazolinone schiff base and its derivatives.

The area of study involving the formation of coordination compounds by combining coumarin with a variety of metals has been extensively researched, with many researchers delving into the topic. Coumarin(2H-chromene 2-one) is an aromatic organic compound where fusion of phenyl ring with coumarin moiety at the third and fourth positions results in a formation of banzo[c] coumarin and it's derivatives. These are plant-derived natural products and also synthesized in laboratories comprising antidyslipidemic (10), anti-inflammatory (11), vasodilatory (12) anti-microbial (13) anti-thrombic, anti-mutagenic(14) antioxidant, antiallergic, antithrombotic, antiviral, anti-carcinogenic (15) and anti-tumourigenic (16)activities

Cu(II) ion is most studied metal ion among all the transition metal ion and one of the most important ion in human body. (17, 18) Cu(II) complexes are known to play a significant role either in naturally occurring biological system or as pharmacological agents, besides the complexes of Cu(II) with drugs are much more active in the presence of a nitrogen and oxygen donor heterocyclic ligand (19). Cu(II) complexes with coumarin derivatives can be used for the fluorescent sensor which extends its application in bioimaging and and can be commercialized as a solution for different problems. (20)

The condensation reaction of 2 -amino benzoyl hydrazide along with aromatic aldehydes give Quinazolinone schiff base derivative. The multifarious biological activities containing 7-hydroxy-10,11-dihydroindeno[5,4-c]chromene-6(9H) is the fusion of 2,3-dihydro-1H-indene-4-ol with third and fourth position of coumarin moiety. Various complexes formed by the complexation reaction between Copper salt with synthesized ligands.

In this experiment, the analytical and spectroscopic methods play a role in order to synthesize and characterize quinazolinone schiff base derivative, coumarin derivative and their Cu(II) complexes. Various spectroscopic techniques, incuding 1H-NMR spectroscopy, infrared spectroscopy, thermogravimetric analysis, and elemental analysis were used to examine the synthesized ligands and metal complexes. Magnetic properties of the complexes suggest the octahedral geometry and FAB mass spectra shows the molecular weight and stable fragments. The biological studies of synthesized ligand and complexes has also been tested on gram positive and gram negative micro-organism using agar plate diffusion method revealed that antimicrobial activity of complexes are higher than the ligands, drug and metal salt.

Experimental

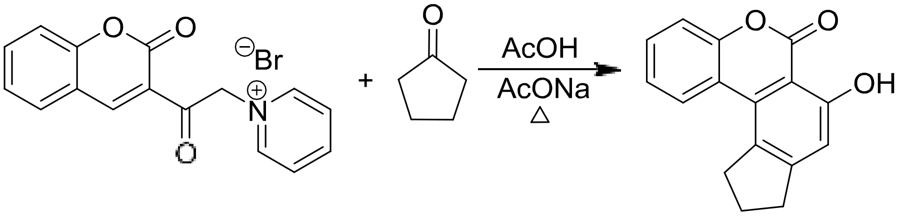
Materials and Methods

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

Preparation of Ligands

- **7-hydroxy-10,11-dihydroindeno[5,4-c]chromene-6(9H)-one(1)**

7-hydroxy-10,11-dihydroindeno[5,4-c]chromene-6(9H)-one(1) was synthesized using a modified literature procedure. (21) To synthesize the desired compound, 3-coumarinoyl methyl pyridinium, cyclopentanone and sodium acetate were combined in acetic acid and refluxed for 8 hours. The resulting mixture was subsequently cooled to room temperature, and the solid product was obtained by extracting with water followed by chloroform. Chloroform-hexane was used to recrystalize and obtained the white crystalline products. Yield, 72%, m.p.,179-183˚C. Found (%): C, 76.05, H, 4.56. $C_{16}H_{12}O_3$ (252.27) requires (%) C,76.18, H, 4.79. ^1H NMR (ppm): 11.69 (s, 1H, -OH proton), 8.06 (d, 1H, C_{11} proton), 7.20-7.37(m, 3H, C_8, C_9, C_{10} proton), 6.76 (s,1H, C_4 proton), 3.35 (t,2H, C_3 proton), 2.98 (t, 2H, C_1 proton), 3.03 (2H m, C_2 proton). IR (cm^{-1}): 3422 ν(-OH stretching), 1613 and 3040 ν(aromatic C=C and C-H stretching), 2950 ν(aliphatic C-H stretching of cyclopentane ring), 1671 ν(C=O stretching).



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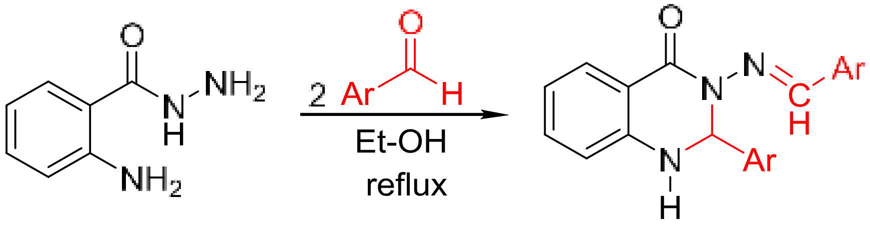
Scheme 1 Synthesis of Ligand 1

- **Synthesis of Quinazolinone Schiff base ligands(2a-2f)**

All of the Schiff bases 2a-2f showed in table-1 were prepared by adopting and modifying the method described in literature (22) (23). In scheme 2 the reaction mixture of 2 amino benzoyl hyrdrazide(1 mmol) and aromatic aldehyde(2 mmol) in ethanol (20ml) was stirred for 10 min and then refluxed for 2 h. The resulting solid was isolated by filteration and washed with water.



[2a-2f]

Scheme 2 Synthesis of Quinazolinone schiff base

Table-1 Aromatic aldehyde and identification of Quinazolinone Schiff bases 2a-2f.

Entry	Ar	Quinazolinone Schiff base	Yield(%)
1	C_6H_5	2a	85
2	$4\text{-}NO_2C_6H_4$	2b	83
3	$4\text{-}CH_3OC_6H_4$	2c	81
4	$4\text{-}(CH_3)_2NC_6H_4$	2d	85
5	2-furyl	2e	86
6	$4\text{-}ClC_6H_4$	2f	84

1. **(E)-3-(benzylideneamino)-2-phenyl-2,3-dihydroquinazolin-4(1H)-one(2a):**

Yield, 85%, m.p.,166-167˚C.

Found(%): C, 77.1, H, 5.17, N, 12.77. $C_{21}H_{17}N_3O$(327.39) requires(%)C,77.04, H, 5.23, N, 12.84.^{1}H 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(2b):**

   Yield, 83%, m.p., 215-217˚C.
   Found(%):C, 60.28, H, 3.55, N, 16.71. $C_{21}H_{15}N_5O_5$(417.38) requires(%)C, 60.43, H, 3.62, N, 16.78. ^{1}H 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(2c):**

   Yield, 81%, m.p., 223-234˚C.
   Found(%):C,71.17, H, 5.41, N, 10.79. $C_{23}H_{21}N_3O_3$(387.44) requires (%)C, 71.30, H, 5.46, N,10.85. ^{1}H 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,-OCH_3).
   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(2d):**

   Yield,85%,m.p.,252-254 ˚C
   Found(%):C,72.48,H,6.47,N,16.82.$C_{25}H_{27}N_5O$(413.53)requires(%)C,72.61,H,6.58,N,16.94.
   ^{1}H 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,-NCH_3)
   IR(KBr,cm^{-1}): 3462 (-N-H str. vib.),1714(-C=Ostr.vib.),1604(-CH=Nstr.vib.),1228(-C-Nstr.vib.)2915(aromatic C-H).

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

   Yield,86%, m.p., 170 - 172 ˚C.
   Found(%):C,66.32,H,4.15,N,13.61. $C_{17}H_{13}N_3O_3$(301.31)requires(%)C,66.44,H,4.26,N,13.67.
   ^{1}H 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).

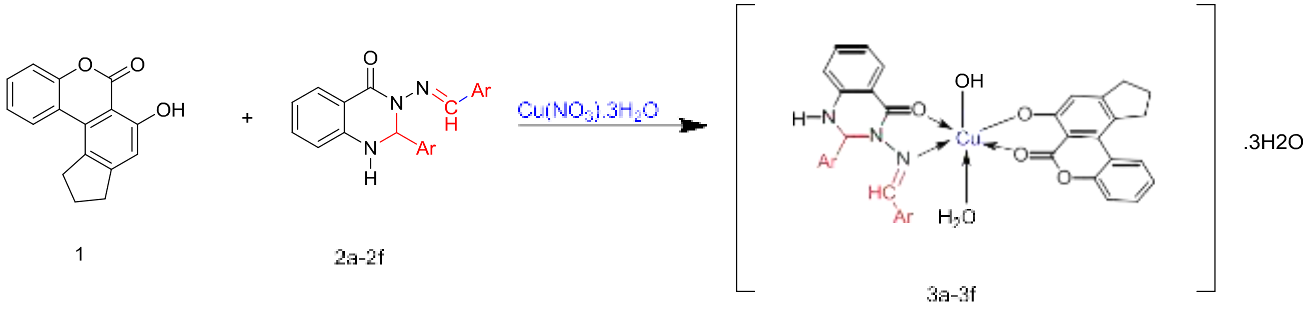
6. **(E)-3-((4-chlorobenzylidene)amino-2-(4-chlorophenyl)-2,3-dihydroquinazolin-4(1H)-one(2f):**

   Yield,84%, m.p, 230 – 232 ˚C.

Found(%): C,63.44, H, 3.74, N 10.53. $C_{21}H_{15}Cl_2N_3O$ (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(3a-3f)**

A general procedure was followed to synthesize these complexes. In scheme 3 the water solution of $CuNO_3.3H_2O$ (10 mmol) was added to dimethyl formamide solution of ligand 1 (10 mmol), followed by addition of Schiff base ligand 2a-2f (10 mmol) in ethanol. The resultant mixture was refluxed for 7 hrs on a water bath. The obtained dark green precipitate was filtered, washed with ethanol and hot water further dried in vacuum at room temperature (24). The general reaction scheme is shown in Scheme 3. Whereas analytical and physical data are shown in Table-2.



Scheme 3 Synthesis of Complexes

Table-2 Elemental analysis and physical data of the ligand 1,2a-2f and it's metal complexes.

Compound	Color	Yield(%)	Molecular weight	Melting Point (˚C)	% found (required)				μ$_{eff}$(B.M.)
					C	H	N	Cu	
1/$C_{16}H_{12}O_3$	White	72	252.27	180-182	76.01 (76.18)	4.68 (4.79)	-	-	-
2a/ $C_{21}H_{17}N_3O$	Yellow	85	327.39	166-167	77.01 (77.04)	5.17 (5.23)	12.77 (12.84)	-	-
2b/ $C_{21}H_{15}N_5O_5$	Yellow	83	417.38	215-217	60.28 (60.43)	3.55 (3.62)	16.71 (16.78)	-	-
2c/ $C_{23}H_{21}N_3O_3$	Yellow	81	387.44	223-234	71.17 (71.30)	5.41 (5.46)	10.79 (10.85)	-	-
2d/ $C_{25}H_{27}N_5O$	Yellow	85	413.53	252-254	72.48 (72.61)	6.47 (6.58)	16.82 (16.94)	-	-
2e/ $C_{17}H_{13}N_3O_3$	Yellow	86	307.31	170-172	66.32 (66.44)	4.15 (4.26)	13.61 (13.67)	-	-
2f/$C_{21}H_{15}Cl_2N_3O$	Yellow	84	396.27	230-232	63.44 (63.65)	3.74 (3.82)	10.53 (10.60)	-	-
[Cu(1)(2a)H_2O.OH]. 3H_2O/$C_{37}H_{37}CuN_3O_6$	Dark green	63	731.22	366 (Decomposed)	65.35 (65.62)	4.58 (4.61)	6.17 (6.20)	9.34 (9.38)	1.78
[Cu(1)(2b)H_2O.OH]. 3H_2O/ $C_{38}H_{37}CuN_5O_{14}$	Dark green	60	821.21	352 (Decomposed)	57.87 (57.93)	3.80 (3.81)	9.07 (9.13)	8.21 (8.28)	1.86
[Cu(1)(2c)H_2O.OH]. 3H_2O/ $C_{40}H_{43}CuN_3O_{12}$	Dark green	65	791.27	376 (Decomposed)	63.45 (63.54)	4.75 (4.79)	5.68 (5.70)	8.77 (8.62)	1.76
[Cu(1)(2d)H_2O.OH]. 3H_2O/ $C_{41}H_{47}CuN_5O_9$	Dark green	61	817.35	373 (Decomposed)	64.41 (64.51)	5.36 (5.41)	9.10 (9.17)	8.29 (8.32)	1.84
[Cu(1)(2e)H_2O.OH]. 3H_2O/ $C_{33}H_{33}CuN_3O_{11}$	Dark green	64	711.14	362 (Decomposed)	60.24 (60.32)	4.05 (4.14)	6.31 (6.39)	9.56 (9.67)	1.82
[Cu(1)(2f)H_2O.OH]. 3H_2O/ $C_{37}H_{35}Cl_2CuN_3O_9$	Dark green	61	800.1	360 (Decomposed)	59.22 (59.56)	3.78 (3.92)	5.48 (5.63)	8.44 (8.52)	1.85

Result & Discussion

Table2 presents the physical data and elemental results for ligands 1, 2a-2f, and their corresponding copper(II) complexes. The reaction below outlines the process by which the complexes were formed.

$$Cu(NO_3)_2.\ 3H_2O + A + B \longrightarrow [Cu\ (A)(B)(H_2O)(OH)\ ].3\ H_2O + 2\ HNO_3 + nH_2O$$

Where A = Ligand1 & B = Ligand 2a-2f

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.

Magnetic Properties of Cu(II) Complexes.

The fruitful information about the geometry of mixed ligand complexes was prevailing by UV spectral data and magnetic moment. Table 3 provides the electronic spectral data and magnetic susceptibility ($\mu_{eff.)}$ values for several Cu(II) complexes. The complexes displayed two broad band at approximately 10,500 and 14,500 cm^{-} corresponding to $dz^2 \rightarrow dx^2{}_{-}y^2$ and dxz, $dyz \rightarrow dx^2\ y^2_{-}$ respectively. The mixed-ligand complexes 3a-3f demonstrated $\mu_{eff.}$ values that ranged from 1.76 to 1.86 B.M., which closely approximated the spin allowed value of 1.73 B.M. Based on the electronic spectral and magnetic measurement data, an octahedral geometry around the copper(II) ion appears possible.

Table-3 electronic spectral and magnetic measurement of metal complexes

Complex	d-d transition in cm^{-}	Assignment	μ_{eff}
3a	14,000-10,600	$d_{z2} \longrightarrow d_{x2-y2,}\ d_{xz}, d_{yz} \longrightarrow d_{x2-y2.}$	1.78
3b	14,200-10700	$d_{z2} \longrightarrow d_{x2-y2,}\ d_{xz}, d_{yz} \longrightarrow d_{x2-y2.}$	1.86
3c	14000-10500	$d_{z2} \longrightarrow d_{x2-y2,}\ d_{xz}, d_{yz} \longrightarrow d_{x2-y2.}$	1.76
3d	14100-10800	$d_{z2} \longrightarrow d_{x2-y2,}\ d_{xz}, d_{yz} \longrightarrow d_{x2-y2.}$	1.84
3e	14300-10700	$d_{z2} \longrightarrow d_{x2-y2,}\ d_{xz}, d_{yz} \longrightarrow d_{x2-y2.}$	1.82
3f	14400-10900	$d_{z2} \longrightarrow d_{x2-y2,}\ d_{xz}, d_{yz} \longrightarrow d_{x2-y2.}$	1.85

IR Spectra

Table 4 summarizes the tentative assignment of the synthesized ligand and complexes important infrared spectral bands, which were recorded as KBr discs.

The differences in IR spectra of ligand and its complexes was found as one medium intensity of lactone carbonyl ketone at 1671 cm^- was shifted to lower frequency at 1656cm^-, indicating that co-ordination to the Cu(II) ion occurs via the carbonyl oxygen.

Moreover, imine functional group of the ligand [2a-2f] evident to coordinate with metal ion by shifting of V_{CN} stretching vibrations in the range of 1572-1618 cm^- to lower frequency[table-3] stipulate the coordination of imine nitrogen to the metal ion Cu(II).

The several new weak band appear in the region 400-600 cm^- in the complexes were attributed to the V(Cu-O) and V(Cu-N) stretching frequency. (25)-(26)

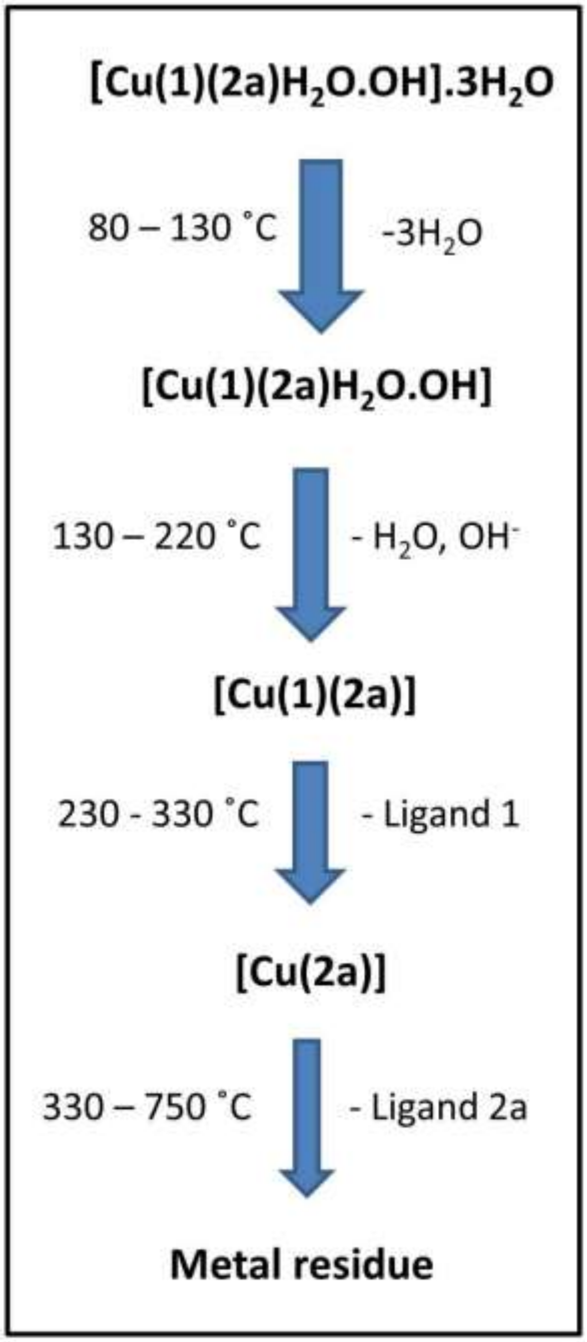
The broad band at ~3400 cm^- which indicates that the coordination of water in complex. This was further supported by bands at ~1295, ~865 and ~716 cm^- due to V(-OH) bending, rocking and wagging mode of vibrations respectively. (27) The coordination of water in complexes was further supported by Thermal analysis.

Table-4 Selected IR data (cm^-) for the Cu(II) complexes 3a-3f

Complex	$V_{(CH=N)}$	$V_{(CH=O)}$	$V_{(N-H)}$
3a	1606	1651	3273
3b	1599	1634	3275
3c	1559	1591	3322
3d	1593	1694	3457
3e	1599	1642	3242
3f	1577	1617	3425

Thermal behavior of synthesized complexes

The graphical representation of % weight loss with respect to temperature shows the thermal behavior of complexes. (28) Thermo gravimetrical data of complexes are given in table 5. The typical thermo gravimetric curves of the complex $[Cu(1)(2a)H_2O.OH].3H_2O$ is represented in figure **1**. The scheme 4 shows a thermal fragmentation for $[Cu(1)(2a)H_2O.OH].3H_2O$ complex.



Scheme 4 The suggested fragmentation pattern of [Cu(1)(2a)H_2O.OH].3H_2O.

TABLE 5 Thermal decomposition analytical data of complexes

Compound	Temp. range (˚C)	Mass loss (%) Obs.(cal.)	Assignment
[Cu(1)(2a)H_2O.OH].3H_2O	80 – 130 ˚C	7.22 (7.38)	Loss of three lattice water molecules
	130 – 220 ˚C	4.65(4.78)	Loss of coordinated water and hydroxyl molecules
	230 - 330 ˚C	34.44(34.56)	Removal of 1 ligand
	330 – 750 ˚C	44.77(44.61)	Removal of 2a ligand
[Cu(1)(2b)H_2O.OH].3H_2O	65-115 ˚C	6.35(6.57)	Loss of three lattice water molecules
	115-205 ˚C	4.11(4.26)	Loss of coordinated water and hydroxyl molecules
	205-310 ˚C	30.09(30.72)	Removal of 1 ligand
	310-750 ˚C	48.32(48.87)	Removal of 2b ligand
[Cu(1)(2c)H_2O.OH].3H_2O	70-120 ˚C	6.22(6.82)	Loss of three lattice water molecules
	120-220 ˚C	4.09(4.42)	Loss of coordinated water and hydroxyl molecules
	220-340 ˚C	31.65(31.88)	Removal of 1 ligand
	340-750 ˚C	50.61(50.72)	Removal of 2c ligand
[Cu(1)(2d)H_2O.OH].3H_2O	85-125 ˚C	6.44(6.60)	Loss of three lattice water molecules
	125-210 ˚C	4.10(4.28)	Loss of coordinated water and hydroxyl molecules
	210-305 ˚C	30.47(30.86)	Removal of 1 ligand
	305-750 ˚C	48.32(48.63)	Removal of 2d ligand
[Cu(1)(2e)H_2O.OH].3H_2O	80-150 ˚C	7.25(7.59)	Loss of three lattice water molecules
	150-245 ˚C	4.77(4.94)	Loss of coordinated water and hydroxyl molecules
	245-340 ˚C	35.10(35.47)	Removal of 1 ligand
	340-750 ˚C	40.12(40.96)	Removal of 2e ligand
[Cu(1)(2f)H_2O.OH].3H_2O	60-100 ˚C	6.28(6.57)	Loss of three lattice water molecules
	100-190 ˚C	4.11(4.37)	Loss of coordinated water and hydroxyl molecules
	190-300 ˚C	31.23(31.52)	Removal of 1 ligand
	300-750 ˚C	47.14(47.52)	Removal of 2e ligand

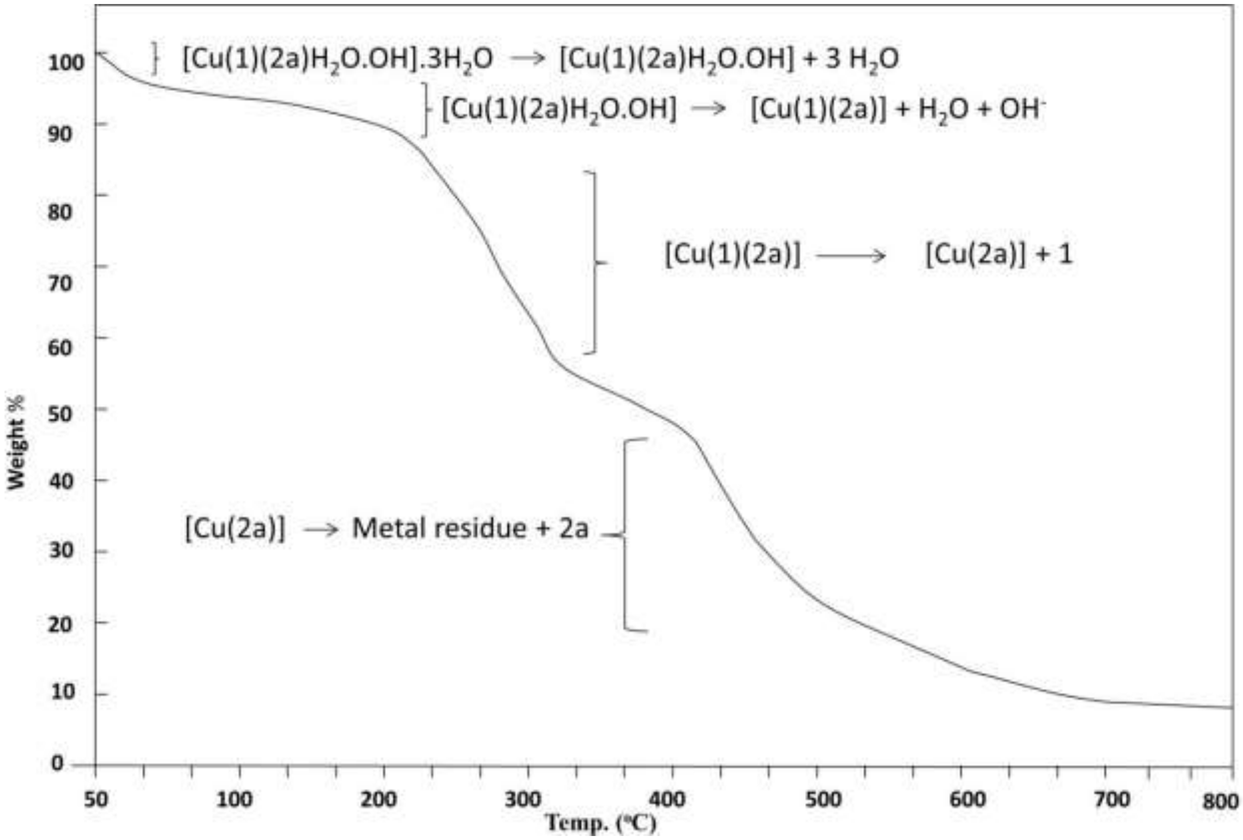


FIG.1 TGA curve of $[Cu(1)(2a)H_2O.OH].3H_2O$.

Mass Spectra

Using a high resolution mass spectrometer, the mass spectra of $[Cu(1)(2a)H_2O.OH].3H_2O$ were obtained. The recorded mass spectra indicated a peak at m/z = 731, which suggests the molecular ion peak of the complex (without water of crystallization) (see figure 2). The confirmed molecular formula of the complex was further supported by the obtained mass spectra and molecular ion peak.

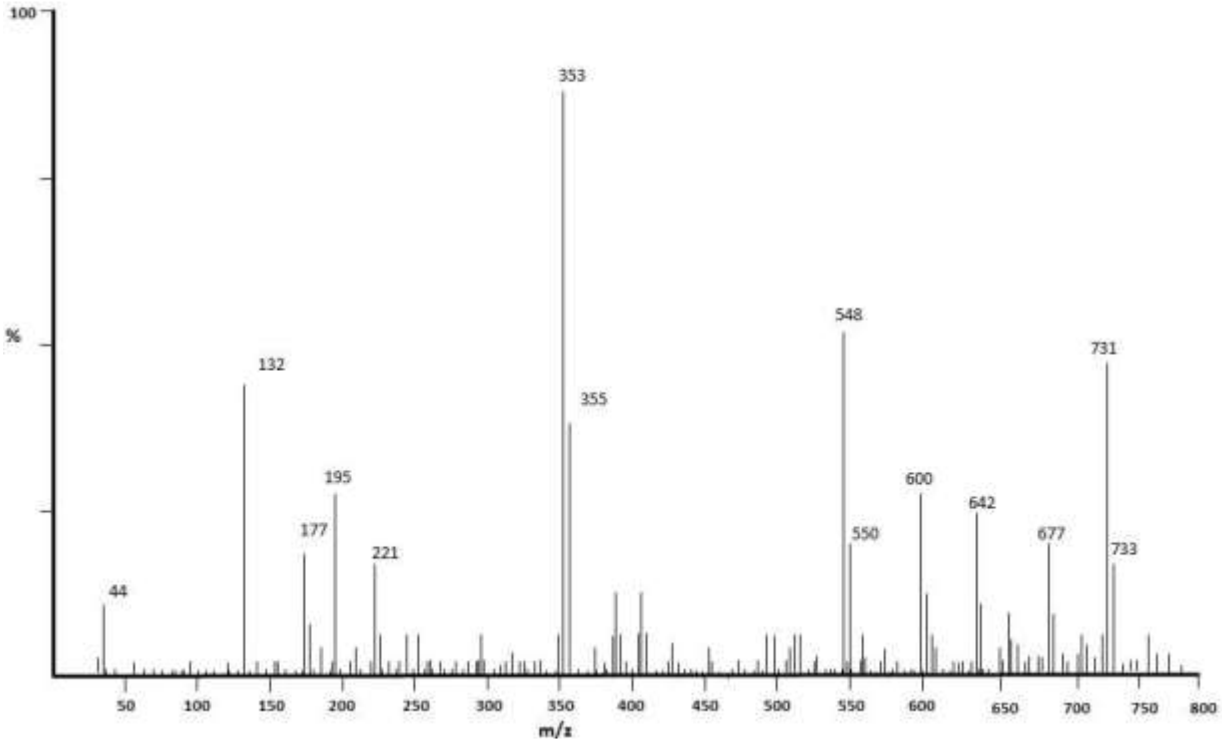


FIG.2 Mass spectra of the $[Cu(1)(2a)H_2O.OH].3H_2O$ complex

Antibacterial Activity of complexes

In this study, we screened all free ligands and complexes for their activity against Staphylococcus aureus, Escherichia coli, and S.marcescens B. substills using the disc diffusion method, (29) with the agar diffusion test method employed for this purpose. To perform this test, we dissolved the chemically synthesized compound (5 mg) in 250 µl of DMSO as a solvent and introduced 100 µl of a known concentration of the test compounds onto 10mm disks. We then saturated the disks with the test compound and introduced them onto the upper layer of the medium with the bacteria. After adding 100 µl of solvent (DMSO) onto blank disks and implanting them as negative controls on each plate, along with standard drugs, we incubated the plates at 30°C for gram-positive bacteria and 37°C for gram-negative bacteria for 24 hours and measured the zone of inhibition (in mm) around the disk. We then measured in triplicate and compared the inhibition zones with the standard drugs.

Our results showed that the synthesized ligands and their corresponding metal complexes exhibited promising biocidal properties against gram-positive and gram-negative bacteria. Interestingly, the metal complexes were found to have greater potency compared to the ligands, as demonstrated by the larger zone of inhibition measurements. The values obtained are presented in Table 6. Notably, among the metal complexes, complex 3b exhibited the highest activity against both gram-positive bacteria, particularly S. aureus, as shown in Figure 3. The in vitro assay results revealed that complex 3b (38 ± 0.57 mm) exhibited greater activity against S. aureus than the other compounds tested. Furthermore, complex 3b (32 ± 0.5 mm) displayed the most potent activity against gram-negative B. substilis. These findings demonstrate the potential of coordination compounds for biological applications.

TABLE 6 Antibacterial activity data of ligands and complexes

Zone of inhibition (mm)

	Gram +ve		Gram –ve	
	E. Coli.	S. aureus	S.marcescens	B. substilis
Control(DMSO)	11 ± 0.5774	10 ± 0.5	11 ± 1	11 ± 0.5
Ampicillin	40 ± 0.5	42 ± 1.5	-	-
Tetracyclin	-	-	39 ± 0.5	41 ± 0.5
$Cu(NO_3)_2.3H_2O$	14 ± 1.52	16 ± 0.5	18 ± 2.08	17 ± 1
1	13 ± 1	16 ± 2.08	11 ± 0.5	13 ± 0.5
2a	14 ± 1.52	12 ± 1.52	13 ± 1.5	15 ± 0.5
2b	14 ± 0.5	18 ± 0.5	16 ± 0.5	14 ± 2.08
2c	13 ± 1	15 ± 1	18 ± 1	17 ± 2
2d	12 ± 0.5	10 ± 0.5	11 ± 0.5	13 ± 1
2e	12 ± 0.5	10 ± 0.5	10 ± 0.5	14 ± 1
2f	13 ± 2.08	11 ± 2.08	11 ± 2.08	10 ± 2.08
3a	26 ± 2	28 ± 2	24 ± 2	29 ± 0.5
3b	34 ± 0.32	38 ± 0.57	30 ± 0.12	32 ± 0.5
3c	24 ± 1	29 ± 1	28 ± 1	26 ± 1
3d	25 ± 2.08	28 ± 2.08	24 ± 2.08	29 ± 0.5
3e	22 ± 0.5	24 ± 0.5	21 ± 0.5	24 ± 0.5
3f	30 ± 1.5	28 ± 1.5	34 ± 1.5	30 ± 2.08

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

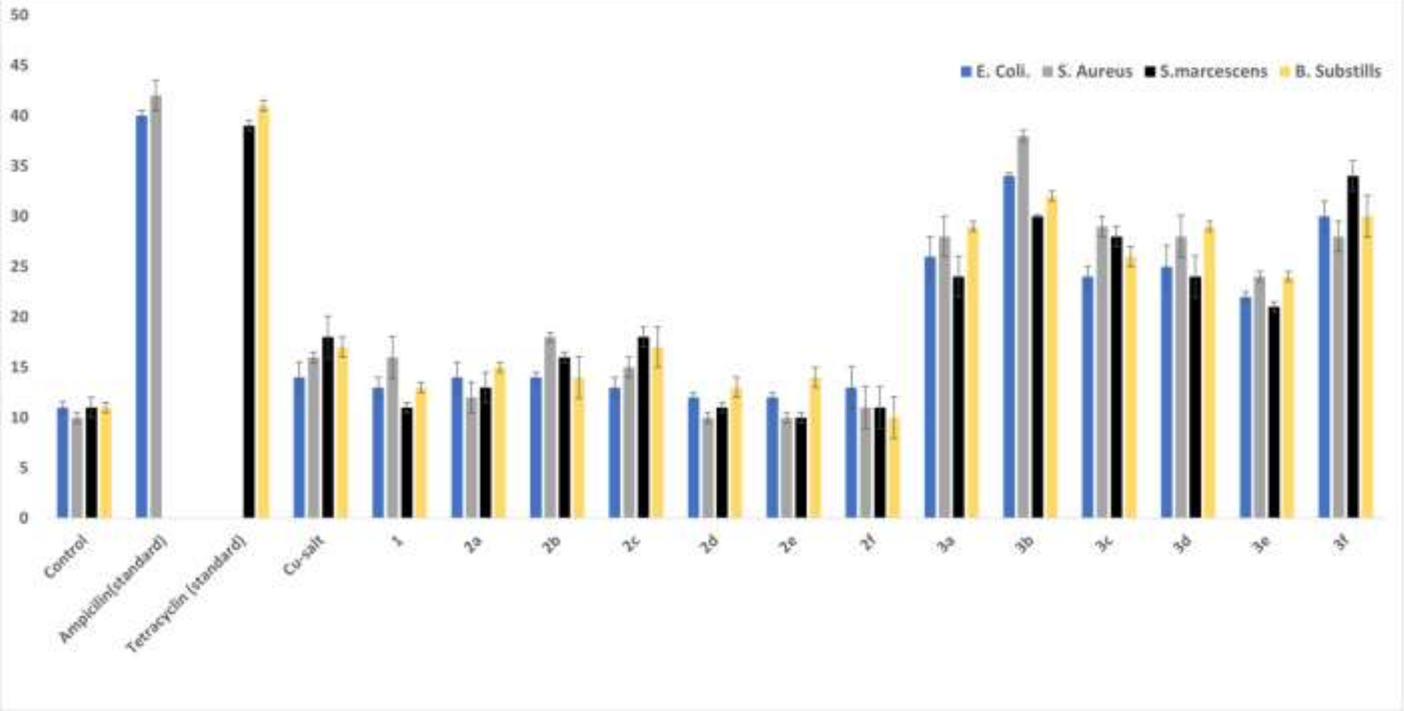


FIG3 . – Comparative analysis for biological activity

Conclusion

- Various spectroscopic techniques, including elemental analysis, IR and NMR(1H) spectra, magnetic measurement, FAB mass spectra and thermo gravimetric analysis were utilized to verify the structure of the synthesized compounds.
- The magnetic moment values of the metal complexes were used to gather information about their geometry. Specifically, the values obtained (ranging from 1.76 to 1.92) indicate that the copper(II) complexes are high spin, with no exchange interactions present. As a result of this study, it has been revealed that the central metal ion is surrounded by an octahedral geometry, which can be seen in scheme 2.
- In order to evaluate their potential as antibacterial agents, both the ligands and complexes that were synthesized were subjected to a screening process. The results of this screening indicated that the compounds showed significant antibacterial activity against both gram positive and gram negative bacteria. Interestingly, the complexes demonstrated even greater activity when compared to the ligands and metal salts.

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