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A NOVEL AZO-SCHIFF BASE LIGAND AND ITS COBALT, COPPER, NICKEL COMPLEXES: SYNTHESIS, CHARACTERIZATION, ANTIMICROBIAL, CATALYTIC AND ELECTROCHEMICAL FEATURES

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ABSTRACT

A new azo containing Schiff base was synthesized using 3-amino-3-azabicyclo[3.3.0]octane hydrochloride, salicylaldehyde and aniline. The synthesized ligand were reacted with acetate salts of Cobalt (II), Copper (II) and Nickel (II). Synthesized compounds were characterized using spectral techniques. Metal coordination compounds gave good/moderate results as catalysts in the oxidation reactions of styrene and cyclohexene. Antimicrobial activities of the synthesized compounds showed good suppressor effects on a number of Gram (-) and Gram (+) bacteria. Electronic features of all the compounds were also reported.

Keywords: Azoimine, Coordination, Catalysis, Antimicrobial, Electronic

1. INTRODUCTION

Azoimine compounds are important ligands in coordination chemistry and have found extensively applications in different fields of science both chemically and biologically. These kind of compounds have previously been examined and are stil being examined for their various properties including dyeing textiles, optical switching, non-linear optical properties and preparation of photoactive materials[1-3]. Azo containing Schiff base ligands and their metal complexes shows interesting biological activities such as antibacterial, antifungal, anticonvulsant, antimalarial and anticancer [4-7]. So far, various azo containing Schiff base complexes have been used as catalysts in many organic reactions like oxidations or reductions on many chemical compounds both saturated and unsaturated [8-10]. Especially the catalysis of alkene oxidation by soluable transition metal complexes is of great interest in both biomimetic and synthetic chemistry [11]. This work, describes the synthesis of a new azo-imine ligand and its Cu(II), Cobalt(II) and Nickel (II) coordination compounds. The newly synthesized compounds were characterized using various spectral techniques. Catalytic activities of the complex compounds were tested in the oxidation reactions of both styrene and cyclohexene and good/moderate results were obtained. Antimicrobial and electronic features of all the synthesized compounds were also reported for the first time with this paper.

2. MATERIAL AND INSTRUMENTATION

Salicylaldehyde, aniline, 3-amino-3-azabicyclo[3.3.0]octane, $NaNO_2$, HCl, and other chemicals were purchased from Aldrich (USA) and Merck (Germany). $Cu(OAc)_2$, $Co(OAc)_2$, $Ni(OAc)_2$ metal salts were obtained from Fluka (Switzerland). All solvents were distilled before use. ^1H and ^{13}C NMR spectra were recorded on a Bruker AV 400 MHz spectrometer using $CDCl_3$ as a solvent. FTIR spectra (in KBr disc) were obtained on a Shimadzu 8300 FTIR spectrophotometer in the region of 400– 4000 cm^{-1}. UV-VIS absorption spectra were measured in ethanol using a Schimadzu UV-160A spectrophotometer in the range of 200–600 nm. Mass spectra were obtained on a VG Zab

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spectrometer. C, H, N elemental analyses were performed on a LECO CHNS 932 elemental analyzer. The metal contents of the complexes were determined on an Ati Unicam 929 Model AA Spectrometer in solutions prepared by decomposing the compounds in aqua regia and subsequently digesting them in conc. HCl.

Cyclic voltammetry was performed in CH_3CN (0.001–0.1 M NBu_4BF_4 as a supporting electrolyte) at 293 K using an Iviumstat electro-chemical workstation equipped with a low current module (BAS PA-1) recorder. The reaction products of the microwave experiments were analysed by using Perkin Elmer Clarus 600 GC equipped with MS detector fitted with Elite 5 MS and FID detector fitted with BPX5 capillary columns.

3. OXIDATION PROCESS

For the catalytic oxidation of cyclohexene and styrene, 0.02 mmol complex compound as the catalyst, 2 mmol cyclohexene or styrene and 4 mmol H_2O_2 were microwaved for 60 min. at 400 watt. A blank reaction was also carried out containing only the substrate (2 mmol cyclohexene/styrene) and the oxidant (4 mmol hydrogen peroxide) under the same conditions. The complexes and the substrate were dissolved in vessels with 5 cm^3 acetonitrile. Into this solution, cyclohexene or styrene and H_2O_2 were added. Then the closed vessels were placed inside the Berghof MWS3+microwave oven. The temperature was controlled automatically by the microwave instrument. Following the completion of microwaving, 1cm^3 H_2O was added into the vessels and the extraction of oxidized products was carried out with 10 cm^3 CH_2Cl_2. The extracts were then analysed with GC and GC-MS. During the oxidation process, the temperature and pressure were controlled at about 110 ^oC and 30 bar throughout the experiment.

4. PREPARATION OF MICROORGANISM CULTURE

The growth inhibitory activity of the synthesized compounds was tested against 5 gram negative, 4 Gram positive bacteria (*Pseudomonas aeruginosa* 9027, *Klebsiella pneumoniae* FMC 5, *Escherichia coli* DM, and *Enterobacter faecium* (Clinic isolate), *Enterobacter aerogenes* ATCC 13048, *Bacillus subtilis* IMG 22 *Bacillus megaterium* DSM 32*, Staphylococcus aureus* ATCC 25923*, Streptococcus faecalis* and 3 yeasts (*Candida albicans* ATCC 1023, *Candida utilis* and *Saccharomyces cerevisiae* WET 136). These microorganisms were provided from Microbiology Laboratory Culture Collection, Department of Biology, Kahramanmaras Sütçü İmam University, Turkey.

Antimicrobial activities of the compounds were determined using the hollow agar, as will be described below. The bacteria were first incubated at 37±0.1 °C for 24 h in nutrient broth (Difco), and the yeasts were incubated in sabouraud dextrose broth (Difco) at 25±0.1 °C for 24 h. The cultures of the bacteria and yeast were injected into the Petri dishes (9 cm) in the amount of 0.1 cm^3 (Mc Farland OD:0.5, $1.5x10^8$ bacteria/cm^3 and $1.5x10^6$ yeast/cm^3). Then, Mueller Hinton agar and sabouraud dextrose agar (sterilized in a flask and cooled to 45-50 °C) were homogeneously distributed onto the sterilized Petri dishes in the amount of 25 cm^3. Finally, 2 mg of each chemical compound dissolved in ethanol was placed inside the sterilised antibiotic discs. The prepared antibiotic discs were then placed in the bacterial medium. Afterwards, the plates combined with the disks were left at 4 °C for 2 h, the plates injected with yeast were incubated at 25±0.1 °C for 24 h, and ones injected with bacteria were incubated at 37±0.1 °C for 24 h. After 24 h, inhibition zones appearing around the disks were measured and recorded in mm.

5. EXPERIMENTAL

5.1. Synthesis of 2-((E)-(hexahydrocyclopenta[c]pyrrol-2(1H)-ylimino)methyl)-4-((E)-phenyldiazenyl) phenol [L]

Aniline was first dissolved in hydrochloric acid (2 M, 10 mL) and the solution was kept in a salt/ice bath at -5°C followed by slow addition of sodium nitrite (0.7 g) in distilled water (7 mL). The resulting mixture was stirred at -5 °C for 2.5 hours. Over this mixture, a solution of salicylaldehyde in 2 M 6 mL sodium hydroxide was added slowly keeping the pH at around 6. After stirring 3 hours, the precipitate was collected and crystallized from methanol [12,13]. The obtained azo compound and 3-amino-3-azabicyclo[3.3.0]octane hydrochloride were then mixed in sufficient amount of ethanol in equal amounts. The mixture were stirred under reflux for 24 hours. Obtained precipitate was recrystallized from ethanol. Synthesis scheme can be seen in Figure 1.

Chemical formula: $C_{20}H_{22}N_4O$.Yield: 70%, m.p.: 195-210°C, Elemental Analysis found % (calculated %): C 71.51(71.83); H 6.94(6.63); N 16.91(16.75). UV-Vis (ethanol) (λ_{max}, nm): 226, 294, 355. FT-IR (KBr, cm^{-1}): 3350 (Ar-OH); 2948, 2920, 2865 (Ar-H,C-H), 1575 (Ar-C-C); 1621(CH=N), 1490 (N=N). Mass spectrum (LC/MS APCI): m/z 335 $[M+H]^+$. ^1H NMR(400MHz,$CDCl_3$): 11.9 (OH); 7.05 (H-2, d, J= 8.6 Hz); 7.84 (H-3, dd, J= 8.6 Hz & 2.3 Hz); 7.8 (H-5, d, J=2.3 Hz); 7.9 (H-7, s); 3.4 (2H-8, t, J= 9.3 Hz); 3.07 (2H-12, dd, J= 9.6 Hz & 3.4 Hz); 2.77 (H-13 & H-14); 1.4-2.0 (2H-9 & 2H-10 & 2H-11); 7.4-7.6 (2H-2' & 2H-3' & 2H-4'). ^{13}C NMR(400MHz,$CDCl_3$): 152.8 (C-1); 119.9 (C-2); 130.3 (C-3); 138.5 (C-4); 124.3 (C-5); 123.5 (C-6); 160.0 (C-7); 58.2 (C-8 & C-12); 40.4 (C-13 & C-14); 33.4 (C-9 & C-11); 26.09 (C-10); 145.9 (C-1'); 117.06 (C-2'); 129.06 (C-3'); 122.5 (C-4')

5.2. Synthesis of Coordination Compounds

Acetate salts of Nickel (II), Copper (II) and Cobalt (II) metals were dissolved in ethanol and added into the ethanol solution of our ligand. Ligand and the metal mole ratio was taken as 2:1. Mixture was refluxed for 24 hours and the resulting complex compounds were filtered, washed with ethanol and recrystallised from ethanol-methanol solvent mixture.

5.2.1. Bis[2-((E)-(hexahydrocyclopenta[c]pyrrol-2(1H)-ylimino)methyl)-4-((E)-phenyldiazenyl) phenolato] Copper (II) $[(L)_2Cu]$

Chemical formula: $C_{40}H_{42}CuN_8O_2$.Yield: 65%, m.p.: 228-231°C, Elemental Analysis found % (calculated %): C 66.01(65.78); H 6.15(5.80); N 15.12(15.34); Cu 8.91(8.70). UV-Vis (ethanol) (λ_{max}, nm): 239, 370, 530. FT-IR (KBr, cm^{-1}): 2955, 2930, 2872 (Ar-H,C-H), 1572 (Ar-C-C); 1615(CH=N), 1491 (N=N). 480 (M-N), 626 (M-O). Mass spectrum (LC/MS APCI): m/z 730.3 $[M+H]^+$. μ_{eff} (B.M.): 1.80.

5.2.2. Bis[2-((E)-(hexahydrocyclopenta[c]pyrrol-2(1H)-ylimino)methyl)-4-((E)-phenyldiazenyl) phenolato] Cobalt (II) $[(L)_2Co]$

Chemical formula: $C_{40}H_{42}CoN_8O_2$.Yield: 67%, m.p.: 231-244°C, Elemental Analysis found % (calculated %): C 66.30(66.20); H 6.05(5.83); N 15.31(15.44); Co 8.10(8.12). UV-Vis (ethanol) (λ_{max}, nm): 242, 375, 516. FT-IR (KBr, cm^{-1}): 2958, 2920, 2871 (Ar-H,C-H), 1576 (Ar-C-C); 1617(CH=N), 1493 (N=N). 482 (M-N), 623 (M-O). Mass spectrum (LC/MS APCI): m/z 725.1 $[M]^+$. μ_{eff} (B.M.): 2.62.

5.2.3.Bis[2-((E)-(hexahydrocyclopenta[c]pyrrol-2(1H)-ylimino)methyl)-4-((E)-phenyldiazenyl)phenolato]Nickel (II) [(L)$_2$Ni]

Chemical formula: $C_{40}H_{42}NiN_8O_2$.Yield: 72%, m.p.: 225-239 -C, Elemental Analysis found % (calculated %): C 66.42(66.22); H 5.96(5.84); N 15.40(15.44); Ni 8.17(8.09). UV-Vis (ethanol) (λ_{max}, nm): 244, 378, 520. FT-IR (KBr, cm^{-1}): 2955, 2924, 2871 (Ar-H,C-H), 1577 (Ar-C-C); 1618(CH=N), 1492 (N=N). 483 (M-N), 626 (M-O). Mass spectrum (LC/MS APCI): m/z 725.2 $[M]^+$. μ_{eff} (B.M.): 0.0.

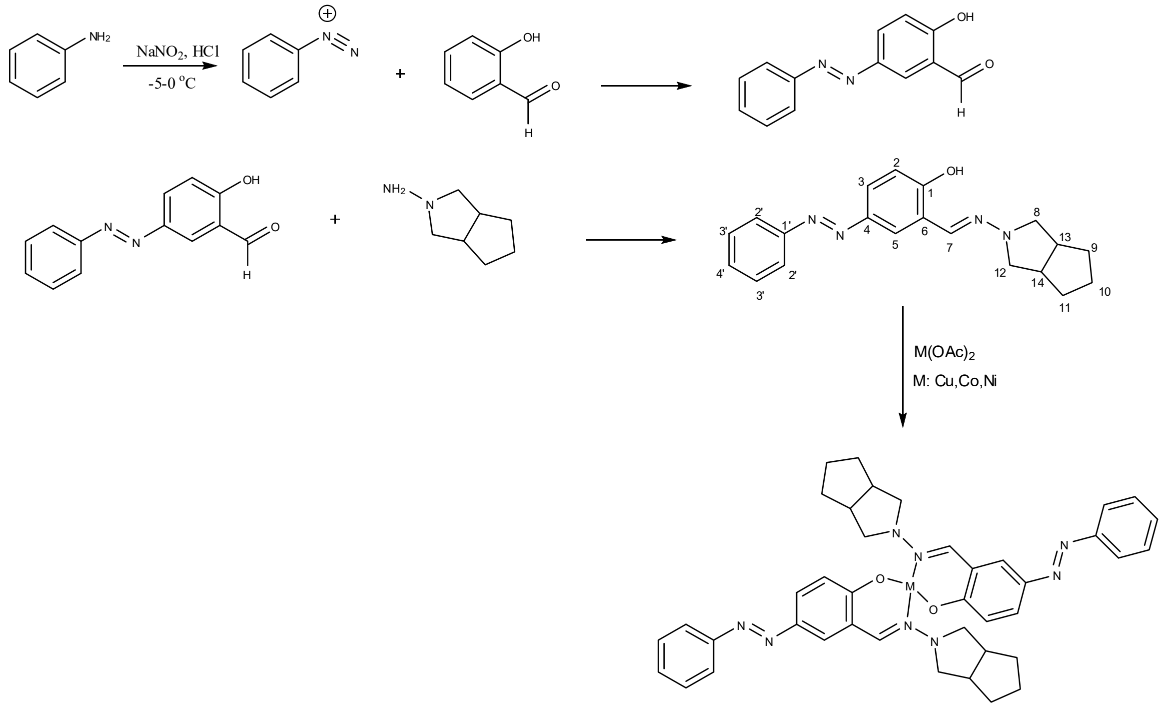

Figure 1. Reaction scheme and proposed structures for the synthesized compounds

6. RESULTS AND DISCUSSION

6.1. Spectral Analysis

^{1}H NMR spectrum (Figure 2) of our ligand revealed the imine proton at 7.9 ppm. Sharp singlet seen at 11.9 ppm belonged to the hydroxyl proton. The three hydrogens on the phenolic ring were clearly observed in the proton NMR spectrum. H-2 seen at 7.05 as a doublet (J= 8.6 Hz) was coupling with H-3 at 7.84 as dd (J= 8.6 Hz & 2.3 Hz). The last proton H-5 belonging to this ring gave a doublet at 7.8 with a coupling constant of 2.3 Hz (coupling with only H-3). The other aromatic ring protons in our compound were seen between 7.4 ppm and 7.6 ppm as overlapped with each other. As for the Azabicyclo[3.3.0]octane ring, the four hydrogens adjacent to the nitrogen were observed at 3.4 ppm (2H-8, t, J= 9.3 Hz) and at 3.07 (2H-12, dd, J= 9.6 Hz & 3.4 Hz). Two hydrogens present on the joint of the rings gave a broad multiplet at 2.77 ppm. The rest of the protons on the azabicyclo ring (2H-9, 2H-10, 2H-11) were seen between 1.4 ppm and 2.0 ppm as multiplets. ^{13}C NMR spectrum of our ligand (Figure 3) showed fifteen carbon signals and among them the one seen at 160.08 ppm belonged to imine carbon (C-7), the three aromatic carbons 2C-2', 2C-3' and C-4' were observed at 117.06 ppm, 129.06 ppm and 122.5 ppm respectively. The rest of the aromatic carbons wee between 115 ppm and 155 ppm. Azabicyclo[3.3.0]octane ring, on the other hand, gave four signals in the ^{13}C NMR spectrum and the methylene carbons C-8 and C-12, adjacent to the nitrogen, were seen at 58.19 ppm. The methine carbons at the ring joints were at 40.4.

The IR spectra of all the complexes showed a red shift in their imine stretching frequencies compared to that of the ligand itself, which proves that the complexation took place on the nitrogens in the imine groups. Also, the OH streching frequency seen for our ligand were absent in the IR spectra of our coordination compounds, showing the coordination between the metals and the phenolic oxygens. Among the aromatic ring stretchings, C-C streching frequencies were observed between 1572 cm^{-1} and 1577 cm^{-1}. If we examine the substitution patterns of the benzene rings, we can say that one meta disubstituted strong aryl-H vibrations at around 816 cm^{-1} were present in the IR spectra of our ligand and its complexes.

UV spectra of the coordination compounds gave d-d* transitions between 516 nm and 530 nm and the other absorbtions were seen between 226 nm and 378 nm. Apart from their parent ions, mass spectra of the synthesized compounds gave suitable fragments to the proposed structures. For example, the two aromatic rings connected with the azo group ($C_{13}H_9N_2O$) were seen at around 210 m/z and at 410 m/z. The azobicyclo fragment ($C_6H_5N_2$) were also observed at around 125 m/z. The magnetic susceptibilities of all comlexes were measured at room temperature and according to their B.M.values, all the coordination compounds exhibited square planar geometries [8,14].

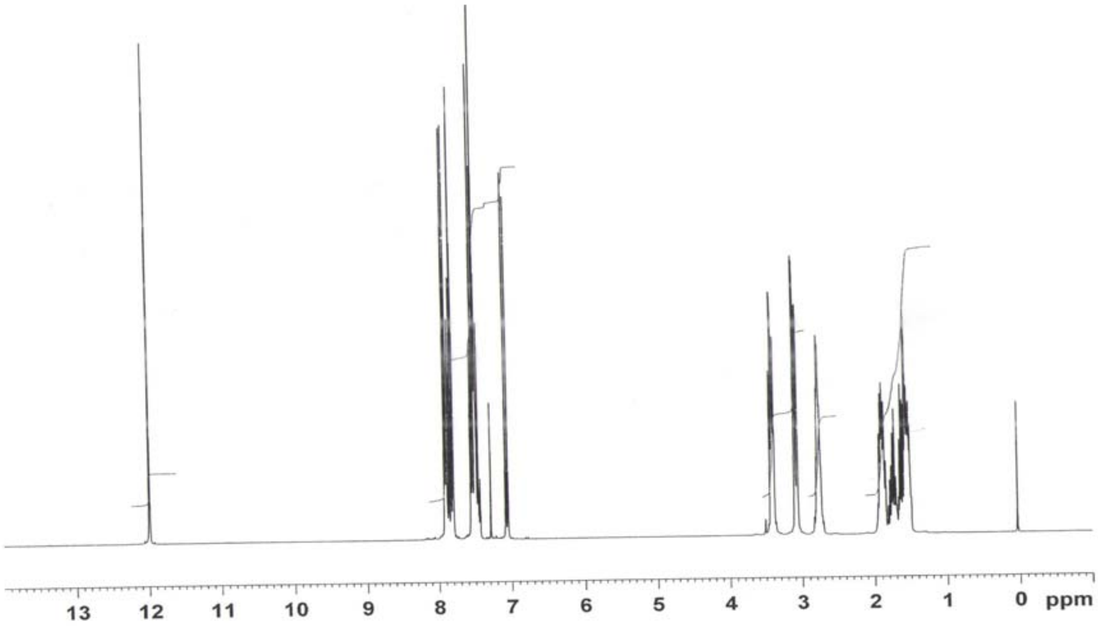

Figure 2. ^{1}H NMR spectrum of the ligand

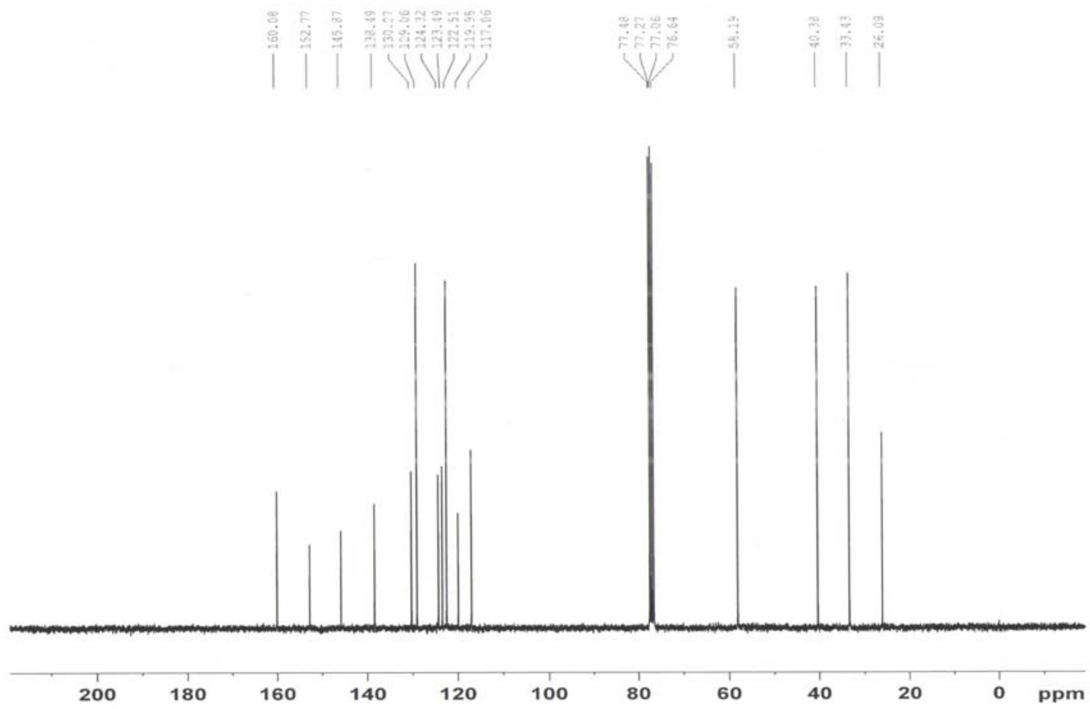

Figure 3. ^{13}C NMR spectrum of the ligand

6.2. Antimicrobial and Minimal Inhibitory Concentration (MIC) Analysis

The examination of antimicrobial activity, including both antibacterial and antifungal, of the synthesized compounds revealed that the ligand compound were quite effective both as antimicrobial and as antifungal. The Ligand created larger inhibition zones than 10 mm, which is considered as the limit inhibition zone for being reasonable antibiotic [15]. Our Ligand did not create any zones for gram negative bacterias *P. aeroginosa* and *E. fecium* and for gram positive bacteria *B. megaterium* and *S. faecalis*.

The ligand and its Cobalt(II) and Copper(II) complexes have higher effect on the bacteria and some of the fungi. The Ligand itself shows antifungal activity for all the fungi and the most effective compound both as antimicrobial and antifungal was the copper complex of this ligand creating inhibition zones between 12 mm and 20 mm for both gram negative and gram positive bacteria. The biggest inhibition zone with 23 mm of this complex is observed for *S. Cerevisiae* among the fungi. The rest of the results can be seen in Table 2. In the literature, many different Schiff base ligands and their coordination compounds exhibit different activities against various microorganisms [16,17] The antimicrobial results of our compounds revealed similar antimicrobial activities as presented in the literature. As for the MIC (minimal inhibitory concentration) determination, we can see from Table 3 that most of the microorganisms are vulnerable against our ligand L and its complexes, giving MIC values varying from 100 μg/cm^3 to 1000 μg/cm^3.

Table 2. Antimicrobial activity of synthesized compounds

Microorganisms	Compounds			
Gram (-)	L	$(L)_2Cu$	$(L)_2Co$	$(L)_2Ni$
E.coli	10[1]	12	11	9
K.pneumoniae	9	12	9	11
E.aerogenes	11	12	9	15
P.aeroginosa	-[2]	-	-	-
E.faecium	-	13	12	9
Gram (+)				
B. subtilis	12	17	11	12
B.megaterium	-	17	12	12
S.aureus	13	20	9	13
S.faecalis	-	15	-	-
Fungi				
C.albicans	13	15	8	15
C.utilis	15	18	10	16
S.cerevisiae	17	23	7	19

[1]: Inhibition zone, mm
[2]: Undetermined inhibition zone

Table 3. MIC values of the ligand and its complexes

Microorganisms	Compounds			
Gram (-)	L	$(L)_2Cu$	$(L)_2Co$	$(L)_2Ni$
E.coli	750	1000	1000	1000
K.pneumoniae	1000	750	1000	750
E.aerogenes	1000	1000	1000	750
P.aeroginosa	>2500	>2500	>2500	>2500
E.faecium	>2500	1000	750	>2500
Gram (+)				
B. subtilis	750	500	1000	500
B.megaterium	>2500	500	750	750
Table continued…				
S.aureus	750	500	1000	500
S.faecalis	>2500	750	>2500	>2500
Fungi				
C.albicans	750	750	1000	750
C.utilis	500	500	1000	>2500
S.cerevisiae	500	100	1000	500

All tests were performed in Mueller Hinton broth (MHB). Test tubes were incubated under normal atmospheric conditions at 37 °C for 24 h for bacteria and at 30 °C for 48 h for the yeasts and the microbial growth was determined by turbidimetric methods.

6.3. Catalytic Activity

The optimum conditions for the oxidation reactions of cyclohexene and styrene were obtained as catalyst: substrate:oxidant ratio of 1:100:200 in acetonitrile under 400 W microwave power for 60 min. The temperature and pressure were controlled at about 110 ^{o}C and 30 bar by the instrument. The possible oxidation reactions are given in Figure 4. Unlike classical thermal oxidation techniques, microwave power is easy to use and clean for organic and inorganic synthesis. Classical thermal oxidation techniques, however, require longer times and the control of reaction conditions is very difficult.

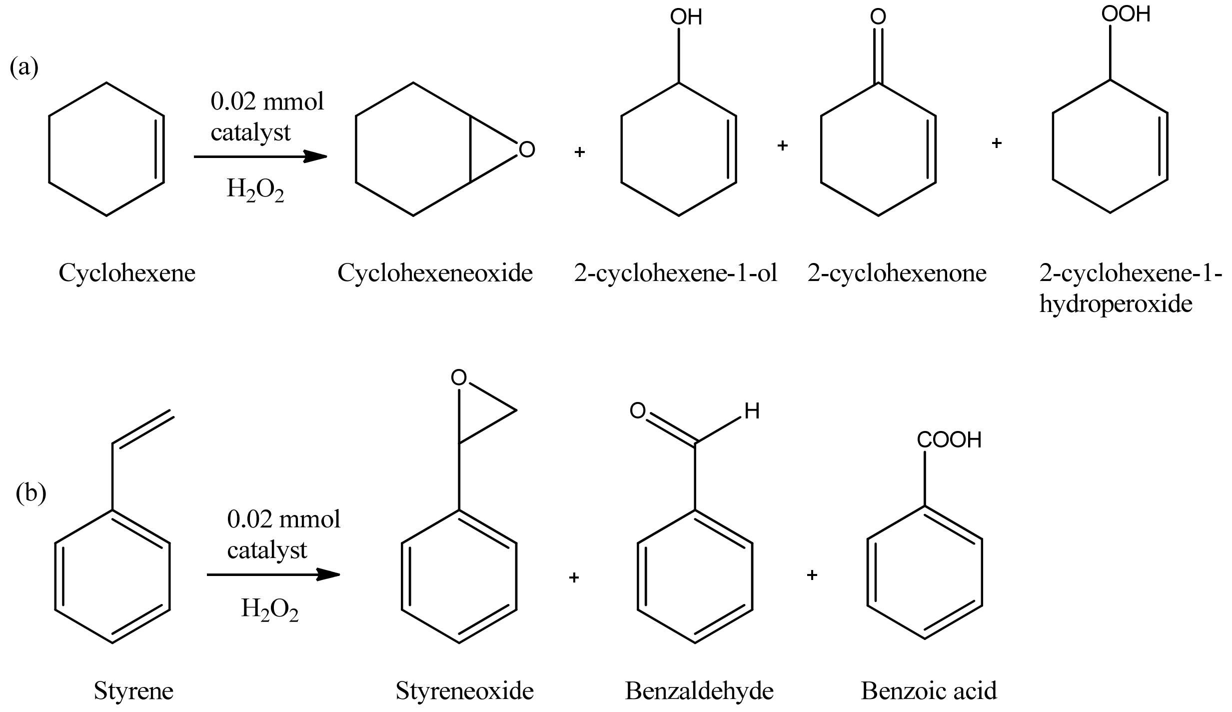

Figure 4. Various oxidation products of cyclohexene (a) and styrene (b)

The results of cyclohexene and styrene oxidations catalyzed by tetradentate Schiff-base metal complexes under microwave radiation using hydrogen peroxide are listed in Table 4 and Table 5. All the metal complexes have moderate catalytic activity over the oxidation of both cyclohexene and styrene. For the cyclohexene oxidation, among the oxidation products, 2-cyclohexene-1-ol and 2-cyclohexenone showed the highest percentages. Our tetradentate Schiff base complexes revealed good results as catalysts over styrene oxidation. The highest catalytic activity for this oxidation reaction was obtained for Copper coordination compound with 18 % styreneoxide selectivity. The oxidation experiments without the catalysts under microwave irradiation gave poor yields towards the oxidation products.

Table 4. Cyclohexene oxidation results

		Selectivity of products (%)			
Catalyst	Conversition (%)	Epoxy	1-ol	1-one	1-hydroperoxide
Blank[a]	10.5	1.9	3.7	-	6.85
$(L)_2Cu$[b]	65	15	21	56	8
$(L)_2Co$[b]	38	8	16	66	10
$(L)_2Ni$[b]	50	10	26	56.5	7.5

For all the experiments 400 W power was applied for 60 min. The reaction temperature and pressure were held at around 110°C and 30 bar in closed DAP60 vessels.

[a] 2 mmol cyclohexene:4 mmol hydrogen peroxide and 5 mL acetonitrile were used without catalyst.

[b] 0.02 mmol catalyst:2 mmol cyclohexene:4 mmol hydrogen peroxide (1:100:200) and 5 mL acetonitrile were used.

Table 5. Styrene oxidation results

		Selectivity of products (%)		
Catalyst	Conversion (%)	Styreneoxide	Benzaldehyde	Benzoic acid
Blank[a]	7.8	1.1	2.12	3.7
$(L)_2Cu$[b]	68.7	18	31	51
$(L)_2Co$[b]	29.6	10.4	27.8	61.8
$(L)_2Ni$[b]	55.3	13.5	44.6	41.9

For all the experiments 400 W power was applied for 60 min. The reaction temperature and pressure were held at around 110◦C and 30 bar in closed DAP60 vessels.

[a] 2 mmol styrene:4 mmol hydrogen peroxide and 5 mL acetonitrile were used without catalyst.

[b] 0.02 mmol catalyst:2 mmol styrene:4 mmol hydrogen peroxide (1:100:200) and 5 mL acetonitrile were used.

6.4. Cyclic Voltammetry

The ligand and its coordination compouds were examined electrochemically at scan rates (v) of 100 mVs^{-1}, 150 mVs^{-1}, 200 mVs^{-1}, 250 mVs^{-1}, 500 mVs^{-1}, 750 mVs^{-1}, and 1000 mVs^{-1} and against an internal ferrocene–ferrocenium standard.

Our ligand and its complexes generally showed irreversible redox processes in most of their scan rates. Nickel (II) complex of our ligand showed reversible processes at 100 mVs^{-1} and 150 mVs^{-1} scan rates with anodic potentials of 0.38 V, 0.35 V and cathodic potentials of 0.32 V and 0.33 V. The values for anodic and cathodic ratios ($I_{pa}:I_{pc}$) for these potentials were calculated around 1. In the CV spectra of Copper coordination compound, generally the pseudo-reversible redoxes were recorded. For example, for 100 mVs^{-1}, forward scan gave a potential of 0.42 V and the reverse scan revealed 0.52 V cathodic potential, their anodic to cathodic ratios ($I_{pa}:I_{pc}$) were around 0.8, which is generally considered to be semi-reversible redox values [18]. All the rest of the recorded potentials are given in Table 6, Figures 5 and 6 shows the CV spectra of our ligand and Copper (II) complex of it.

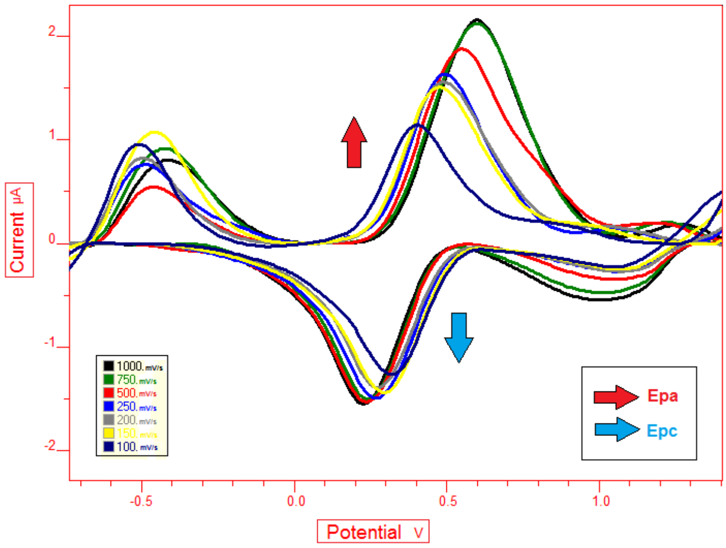

Figure 5. CV spectrum of the ligand L

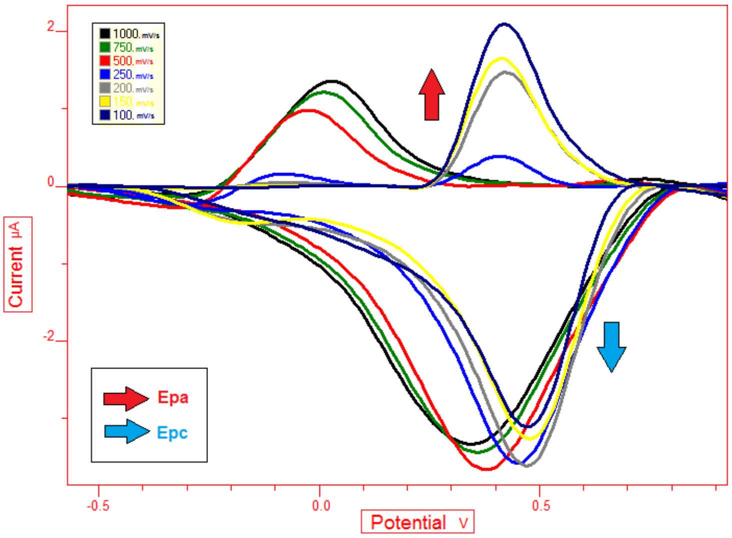

Figure 6. CV spectrum of Copper (II) coordination compound

Table 6. Cyclic voltammogram data of synthesized compounds

Compound	Scan Rate (mV/s)	E_{pa}(V)	E_{pc}(V)	$E_{1/2}$(V)	I_{pa}/I_{pc}	ΔE_p(V)
L	100	-0.49, 0.38	0.27	0.3	1.4	0.11
	150	-0.4, 0.45	0.25	0.35	1.8	0.2
	200	0.45, 0.50	1.1, 0.31	0.38, 0.4	1.4, 1.6	0.14, 0.19
	250	-0.53, 0.48	0.98, 0.31	0.4	1.5	0.17
	500	-0.52, 0.51	0.97, 0.28	0.4	1.8	0.23
	750	-0.48, 0.58	0.98, 0.27	0.4	2.1	0.31
	1000	-0.45, 0.58	0.97, 0.25	0.4	2.3	0.33
$(L)_2Co$	100	0.42	0.31	0.36	1.3	0.1
	150	0.44	0.28	0.36	1.5	0.16
	200	0.45	0.33	0.39	1.4	0.12
	250	-0.15, 0.42	0.17	0.29	2.4	0.25
	500	-0.04, 0.45	0.16	0.3	2.8	0.29
	750	-0.02, 0.44	0.16	0.3	2.7	0.28
	1000	-0.01, 0.47	0.1, -0.48	0.3, -0.24	4.7, -0.02	0.37, 0.47
$(L)_2Cu$	100	0.42	0.52	0.47	0.8	-0.1
	150	0.38	0.53	0.45	0.7	-0.15
	200	0.38	0.45	0.4	0.8	-0.07
	250	0.37	0.48	0.4	0.7	-0.11
	500	-0.28	0.41	-	-	-
	750	0.015	0.37	0.19	0.04	-0.35
	1000	0.017	0.38	0.19	0.04	-0.36
$(L)_2Ni$	100	0.38	0.32	0.35	1.1	0.06
	150	0.35	0.33	0.34	1	0.02
	200	0.41	0.29	0.35	1.4	0.12
	250	0.45	0.31	0.38	1.4	0.14
	500	0.43	0.98, 0.26	0.7, 0.34	0.4, 1.6	-0.55, 0.17
	750	0.48	1.03, 0.22	0.75, 0.35	0.5, 2.1	-0.55, 0.26
	1000	0.52	1.01, 0.2	0.76, 0.36	0.5, 2.6	-0.49, 0.32

All the potentials are referenced to $Ag^+/AgCl$; where E_{pa} and E_{pc} are anodic and cathodic potentials, respectively. $\Delta E_p = E_{pa} - E_{pc}$. $E_{1/2} = 0.5 \times (E_{pa} + E_{pc})$

7. CONCLUSION

This work explains the synthesis and structural elucidation of azoimine compound and its Copper, Cobalt and Nickel complexes. Characterized complex compounds were subjected to oxidation reactions of styrene and cyclohexene as catalysts. Among the complex compounds, copper coordination compound revealed slightly higher catalytic activity in these reactions. Antimicrobial activities of the compounds were generally high, especially the coordination compounds showed higher activities compared to ligand itself. Electronic features of all the synthesized compouds were examined and explained in various scan rates.

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