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Study of Zn(II)-salicylidene-4-(p-chlorophenyl)-2-aminothiazole Complex by Polarographic Method with Its Antibacterial activity

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ABSTRACT

Newly Zn(II)-salicylidene-4-(p-chlorophenyl)-2-aminothiazole (SCAT) ligand was synthesized and studied in DMF media by the polarographic method and produce a DC and DPP polarogram in KCl (supporting electrolyte) with Britton-Robinson buffer. The far FT-IR spectral study show signals at 465 and 412 cm^{-1} respectively which confirm the metal-ligand bonding. The serial tube dilution method (MIC) was used for investigating the antibacterial activity of this newly synthesized complex and ligand toward pathogenic bacteria, *B. subtilis*, and *E. coli*. The results concluded that the ligand enhanced the biological activity when it binds with Zn(II) ion.

Keywords: DCP, DPP, SCAT ligand, Zn(II) complex, Antibacterial activity, MIC.

INTRODUCTION

Schiff bases have received a lot of interest for their synthesis, structure, and reactivity due to their simplicity of synthesis and structural adaptability. However, Schiff bases have shown several clinical features, such as antifungal, antibacterial, and antioxidant, actions[1-5]. The derivatives of salicylaldehyde are coordinated with two donor sites, the O atom of the phenolic group (-OH) and the N atom of the azomethine group (>C=N-). Due to their ability to bind through N, O, and/or S atoms as either bidentate or tridentate chelators, which commonly form four- or six-coordinate complexes, Schiff bases are reported to be the most suitable chelating ligands in coordination chemistry[6,7]. Our interest in salicylidene-4-(p-chlorophenyl)-2-aminothiazole (SCAT) ligand is due to the presence of azomethine (>C=N-), -Cl and -OH moiety as they play an important role in chemotherapy and pharmaceutical perspective[8-10]. When employing the polarographic method, compound solution-mercury interactions[11], reflect their oxidation-reduction behavior, which can be useful for both physiological and biological objectives. In recent years, for the treatment of microbial disease, researcher has tried to increase the potentiality of the drug by the addition of a central metal atom[12]. So we have synthesized, and characterized, salicylidene-4-(p-chlorophenyl)-2-aminothiazole (SCAT) ligand and its Zn(II) complex for

their polarographic behavior and antibacterial activity.

MATERIALS AND METHODS

In this polarographic and antibacterial study, all organic compounds utilized were A.R. grade. 2-amino thiazole (AT) and p-chlorobenzaldehy de (Sigma Aldrich Chemicals Pvt Lt.). After double distillation, absolute methanol (E. Merck) was used, in the formation of the complex, Zn(II) acetate was used as received. Melting points of freshly synthesized chemicals were identified using the melting point apparatus. The purity of the chemicals was regularly examined using thin-layer chromatography. The KBr pellets method was used to record FT-IR spectra from the SHIMADZU FT-IR 01504 spectrophotometer. DC polarogram and DPP were recorded using the Elico DC Polarograph Model CL-362, and a systronic MK VI pH meter was used for pH measurements. A stock solution of the Schiff base and its Zn(II) complex has been synthesized in a DMF with Britton-Robinson (0.04 M) buffer. The polarogram of the (SCAT) ligand and its Zn(II) complex was taken after removing oxygen.

For antibacterial activity, the serial tube dilution method was used and the stock solution of the synthesized compounds under test was prepared by dissolving 15-20 mg/2.5 mL in an appropriate solvent DMF. For antibacterial activity, the solution was properly diluted with sterilized water to get 120, 60, 30, 15, 7.5, and 3.75 μg/mL 10 mL N. Broth was added to each of the glass tubes and autoclaved at 15 lbs/sq. inch pressure for 15 minutes. A properly diluted stock solution of the organic compound under test was added to the glass tubes to 120, 60, 30, 15, 7.5, and 3.75 μg/mL concentrations. Antimicrobial loopful of log phase cultures of *Bacillus subtilis* and *Escherichia coli* were inoculated and the tubes were incubated at 37°C. The MIC was determined after 24 hours.

Synthesis of Salicylidene-4-(p-chlorophenyl)-2-aminothiazole (SCAT) Ligand

The salicylidene-4-(p-chlorophenyl)-2-aminothiazole (SCAT) ligand was synthesized, according to reports in the literature[13]. To prepare a reaction solution of p-chlorophenyl-2- aminothiazole (4.3 g, 20 mmol) and salicylaldehyde (2.5 g, 20 mmol) in ethanol. The reaction solution was stirred and heated gently for 2 and a half hours, and an orange crystalline precipitate could be observed. The resultant precipitate was recovered from the ethanol and dried at 55°C which was carefully confirmed by silica gel thin layer chromatography (TLC).

Color: orange; Yield: 88%; m.p.^{0}C: 159; Elemental analysis (%): Anal. Calc. for $C_{16}H_{11}N_2OSCl$: C, 61.85; H, 3.55; N, 8.93; S, 10.16 and found: C, 61.83; H, 3.49; N, 8.91; S, 10.16; IR [(KBr) υmax/ cm^{-1}]: 3547 cm^{-1} (OH); 3041 cm^{-1} (C-H)$_{aromatic}$; 1681 cm^{-1} (C=N)$_{thiazole\ ring}$; 1639 cm^{-1} (C=N)$_{azomethine}$; 1371 cm^{-1} (C=C)$_{phenyl}$; 1214 cm^{-1} (C-O); 822 cm^{-1} (C-S-C) str; 766 cm^{-1} (C-Cl).

The synthesis of the SCAT ligand is represented in Scheme 1.

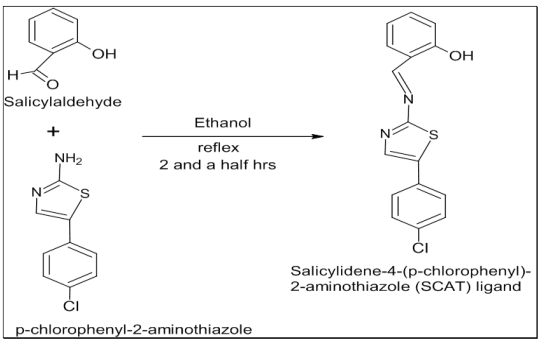

Fig. 1. Synthesis of salicylidene-4-(p-chlorophenyl)-2-aminothiazole (SCAT) ligand

Synthesis of Zn(II) complex

Zn(II)-salicylidene-4-(p-chlorophenyl)-2-aminothiazole (SCAT) complex was created by refluxing the required metal acetate in a 1:2 (M: L) molar ratio in the presence of methanol for 3 hours. The final product undergoes recrystallization, filtering, washing with water and methanol, and drying under a vacuum.

Color: Light brown; Yield: 71%; m.p.^{0}C: 274; Elemental analysis (%): Anal. Calc. for $C_{32}H_{26}Cl_2ZnN_4O_4S_2$: C, 50.38. ; H, 3.33; N, 7.44; S, 8.95; Zn 8.81 and found: C, 50.38; H, 3.32; N, 7.43; S, 8.94; Zn 8.79; IR [(KBr) υ max/cm^{-1}]: 3041 cm^{-1} (C-H)aromatic; 1679 cm^{-1} (C=N)$_{thiazole\ ring}$; 1613 cm^{-1} (C=N)$_{azomethine}$; 1334 cm^{-1} (C=C)$_{phenyl}$; 1208 cm^{-1} (C-O); 818 cm^{-1} (C-S-C); 465 cm^{-1} (Zn-O); 412 cm^{-1} (Zn-N).

The synthesis of the Zn(II) complex is represented in scheme 2.

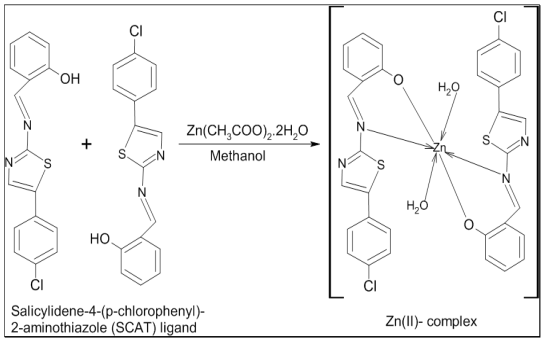

Fig. 2. Synthesis of Zn(II)- salicylidene-4-(p-chlorophenyl)-2-aminothiazole (SCAT) complex

RESULTS AND DISCUSSION

Polarographic study of salicylidene-4-chlorophenyl-2-aminothiazole (SCAT) Ligand

The polarogram of salicylidene-4-(p-chlorophenyl)-2-aminothiazole (SCAT) ligand in 40% DMF with B-R buffer at pH 7.4±0.01. The polarogram was recorded after the removal of oxygen from the analyte solution. The cathodic reduction wave/peak with $E_{1/2}$/Ep = -1.14 V/-1.16 V was apparent in the DC and DPP polarogram (Fig. 3), and it can be due to the azomethine (>C=N-) functional group[14-17].

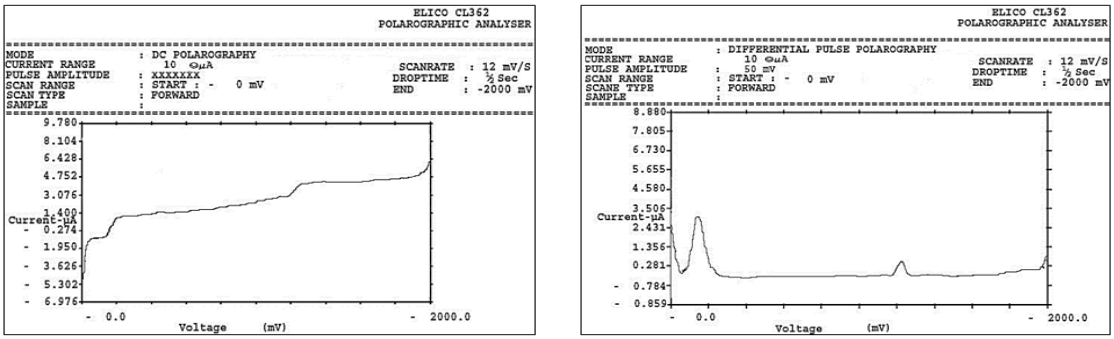

Fig. 3. DC Polarogram and DPP Polarogram of salicylidene-4-(p-chlorophenyl)-2-aminothiazole (SCAT) ligand in B-R buffer at pH 7.4±0.01

Polarographic Study of Zn(II) Complex

Zn(II) and its complex with SCAT ligand both occur in a two-electron reduction wave in 40% DMF with B-R buffer at pH 6.5±0.01 (Fig. 4). In the polarographic study when the progressive increase in the concentration of Schiff base (depolarizer), changes in the potential to a more negative value and a decrease in the height of the diffusion current, indicated complexes formation[18].

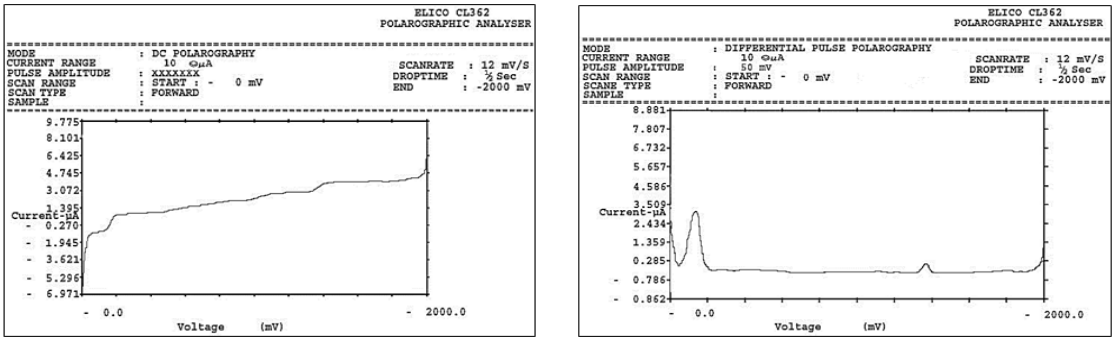

Fig. 4. DC Polarogram and DPP Polarogram of Zn(II) Complex of salicylidene-4-(p-chlorophenyl)-2-aminothiazole (SCAT) ligand in B-R buffer at pH 6.5±0.01.

A linear straight line (Fig. 5) was obtained by plotting $E_{1/2}$ against log Cx (concentration of the Schiff base in logarithmic form) indicating the formation of the most stable complex in solution[19]. The stability constant of the complex was calculated using the difference in $E_{1/2}$/Ep between the free metal ion and the complex ion[20-23]. The polarographic data was treated with Lingane equation[24] to produce a stoichiometric 1:2 (M:L) ratio with a stability constant log β_2=4.4 of the Zn(II) complex.

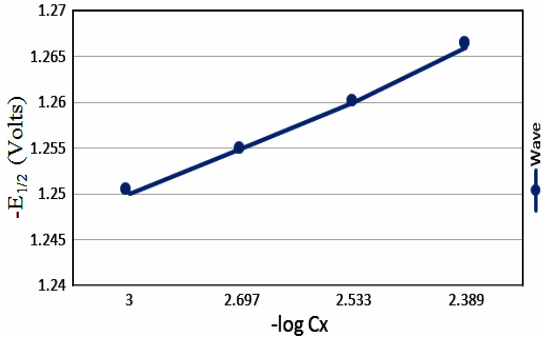

Fig. 5. Zn(II) complex

IR Spectroscopic Characterization Salicylidene-4-(p-chlorophenyl)-2-aminothiazole (SCAT) ligand and its Zn (II) Complex

The signal at 3547 cm^{-1} in the FT-IR spectra of the SCAT ligand is due to the phenolic OH group25. This signal is disappearing in Zn(II) complex indicating the phenolic OH involved in coordination[26]. The medium signal seen in the complex 1613 cm^{-1} frequency range was characterized as corresponding to the (C=N) mode and lower frequency indicates that the azomethine nitrogen atom is involved in the complexation[25]. The lower (C=N) frequency indicates stronger Zn–N bonding. In the IR spectra of the complex, a signal was observed at 465 and 412 cm^{-1} which is due to the (Zn–O) and (Zn–N) stretching vibrations, respectively[27,28]. Confirmed the metal-ligand bonding.

Antibacterial activity

The synthesized SCAT ligand and its Zn(II) complex were investigated for their in vitro antibacterial activity against the specified microorganisms *Gram-positive (B. subtilis)* and *Gram-negative (E. coli)* by the serial tube dilution method[29-31]. The results of the antimicrobial studies were presented in Fig. 6 and Fig. 7 (A, B, C, and D). The novel salicylidene-4-(p-chlorophenyl)-2-aminothiazole (SCAT) ligand and its Zn(II) complex were tested for their efficacy in inhibiting microorganisms at a minimum concentration (μg/mL). The antibacterial activity of SCAT against *B. subtilis* and *E. coli* were found to be good, with MIC values revealed to be 60 and 65 μg/mL (Fig. 6 and Fig. 7 (A), (B)), which is advantageous from a clinical and pharmaceutical viewpoint. In the newly synthesized Zn(II) complex, MIC values were found to be 20 μg/mL and 25 μg/mL (Fig. 6 and Fig. 7 (C), (D)), against pathogenic bacteria *B. subtilis* and *E. coli*. The antibacterial activity of SCAT ligand and its Zn(II) complex have been compared with streptomycin (standard drug) and we obtained enough results when Zn(II) ion have been binding with SCAT, through oxygen and nitrogen donor sites. The SCAT ligand enhanced the antimicrobial activity when binding with the metal ion.

Results also show that Zn(II) complex has strong antibacterial properties due to the presence of electron-withdrawing[32] (azomethine) groups connected to the aromatic system. The fact that when N and O atoms are present in the SCAT ligand provides extra support with enhanced biological activity[33,34]. As reported previously, chelation[35,36] enhances the ligand's antibacterial potency and effectiveness compared to either metal ions or uncoordinated ligands.

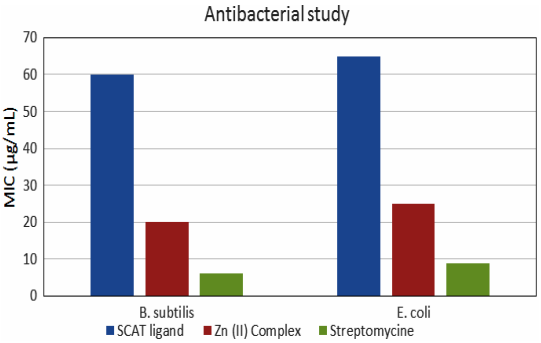

Fig. 6 Minimum inhibitory concentration (MIC) μg/mL of salicylidene-4-(p-chlorophenyl)-2-aminothiazole (SCAT) ligand and its Zn(II) complex

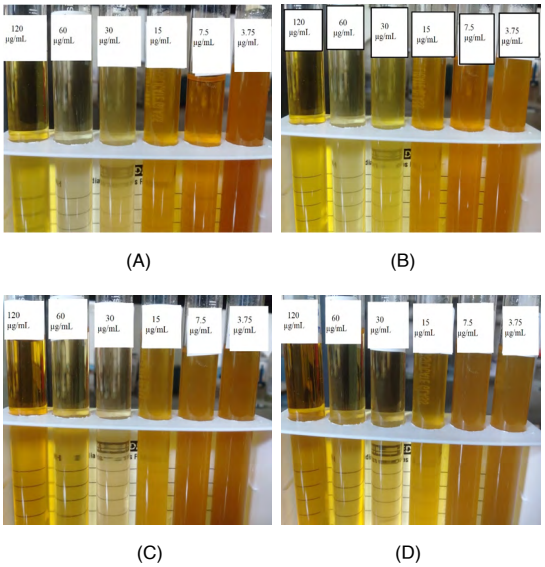

Fig. 7. Images of Minimum inhibitory concentration (MIC) μg/mL, (A) and (B) of SCAT ligand against *B. subtillis* and *E. coli* and (C) and (D) of Zn(II) complex against *B. subtillis* and *E. coli*

CONCLUSION

In the present research work, the polarographic and antibacterial activity of the salicylidene-4-(p-chlorophenyl)-2-aminothiazole (SCAT) ligand and its Zn(II) complex were studied. The formation of the complex between Zn(II) ion and SCAT ligand was confirmed by stability constant (log β_2) with stoichiometric 1:2 (M:L) ratio and FT-IR Spectroscopy. The polarographic method is used for the calculation of stability constants of complex, which is useful in the drug industry for the treatment of toxic metals[37] and the binding mechanism of Zn(II) ion in biological systems[38]. The antibacterial activity results exhibited that the SCAT ligand enhanced its bacterial activity when binding with Zn(II) ion and formed a complex.

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Conflict of Interests

No conflicts of interest exist, according to the authors, with the publishing of this paper.

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