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Synthesis and Spectral Characterization of Nickel (II) and Copper (II) Complexes of 4-Chlorobenzaldehydethiosemicarbazone (CBTSC) and Evaluation of Antioxidant Activity.

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ABSTRACT

Para-Chlorobenzaldehyde thiosemicarbazone was used as the bidentate ligand to synthesize nickel(II) and copper(II) complexes. The complexes are characterized by using different spectroscopic techniques like FT-IR, FT-Raman and electron paramagnetic spectroscopy. IR and Raman spectral analysis established the coordination of the donor groups of the free ligand with the metal ions. The thermal analysis of these complexes has shown different stages of decomposition with which the strength of bonding is estimated. Three resonance absorptions are found for the copper(II) complex in EPR spectrum. The g values found are as follows, $g_1 = 2.690$, $g_2 = 2.165$ and $g_3 = 2.030$ suggesting rhombic distortions of the molecule. Moderate antioxidant activity was found with the metal complexes when compared with the standard BHT.

Keywords: Thiosemicarbazones, Transition metal complexes, EPR spectra, Antioxidant activity.

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INTRODUCTION

Thiosemicarbazones emerged as the potential chelating ligands having bidentate donor groups well known for mixed hard-soft character which enabled them to coordinate with many of the transition metals both in neutral and ionic forms depending upon the conditions like pH. The appreciable part of the thiosemicarbazone ligand and their transition metal complexes was with their biological activity against various tumours [1,2], virus [3,4], malaria [5], bacteria [6], tuberculosis [7], diabetes [8], fungi [9], trypanosomal [10], plasmoidal and amoebic activities [11] etc. The vast literature survey has indicated that the biological activity of these compounds depends upon the parent aldehyde or ketone [12, 13]. Biologically active thiosemicarbazone ligands having iron chelators and their reactions with the ferrioxamine B and ferric EDTA is one of the best examples showing the importance of these chelating agents [14]. The coordination of the thiosemicarbazone ligands with the transition metal complexes has increased the lipophilicity and decreased some of the side effects [15].

In the present study, copper (II) and nickel (II) complexes of *para*-chlorobenzaldehyde thiosemicarbazone ligand are synthesized and characterized by using spectroscopic techniques like FT-IR, FT-Raman and EPR spectra. The synthesized compounds are then tested for the antioxidant activity by using the DPPH radical scavenging activity test.

MATERIALS AND METHODS

Chemicals

All the chemicals used in the present work are of AR grade unless reported. The organic chemicals *para*-chlorobenzaldehyde is purchased from Sigma Aldrich, thiosemicarbazide is purchased from Sd-Fine chemicals, $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$, $\text{Ni}(\text{CH}_3\text{COO})_2 \cdot 4\text{H}_2\text{O}$ and other organic solvents are purchased from different commercial sources and are used without further purification.

Physico-chemical studies

Infrared spectra are recorded as KBr pellets on FT-IR model ALPHA interferometer CECO-ATR, Bruker Ettlingen Kersruhe, Germany, in the range of $4000 - 400 \text{ cm}^{-1}$. EPR spectra of the copper(II) complex is recorded at 298°K on a Bruker-ER073 software provided by the manufacturer. Raman spectra are measured using a confocal Raman microscope (LabRam HR 800, Horiba JobinYvon SAS, France) equipped with a 432 nm He-Ne Laser and the Raman spectra are measured in the range of 400 to 1800 cm^{-1} . Thermal analyses of the complexes are performed on a TA Instruments SDT Q600 model using alumina crucibles of 70 L volume in an atmosphere of dry nitrogen with 50 mL min^{-1} flow rate and 5°C min^{-1} heating rate. The cyclic voltammogram of the complexes are studied using the $1 \times 10^{-3} \text{ M}$ DMSO solutions of nickel(II) and copper(II) complexes along with the 0.1 M solution of Tetrabutyl ammonium hexafluorophosphate (TBAHFP) as an electrolyte. Measurements are done by using a conventional three electrode system in a CH instrument model CHI600D.

Synthesis of *para*-chlorobenzaldehyde thiosemicarbazone (CBTSC)

The free ligand *para*-chlorobenzaldehyde thiosemicarbazone is prepared freshly by refluxing a mixture of *para*-chlorobenzaldehyde (0.01 moles, 1.8150 g) and thiosemicarbazide (0.01 moles, 0.9102 g) as reported earlier [16, 17].

Synthesis of copper (II) and nickel(II) complexes of CBTSC

To 10.0 mL solution of the ligand in ethanol (0.002 moles, 0.6132 gm), aqueous ethanolic solution of corresponding metal salt (0.001 moles) is added slowly under constant stirring in nitrogen atmosphere. The contents of the flask are then stirred at room temperature for 48 hours to collect the dark coloured solution. The coloured solution is then allowed to evaporate at room temperature to obtain the coloured precipitate.

Antioxidant activity

To evaluate the radical scavenging activity of these compounds, a valid and standard method is employed using DPPH [18]. In DPPH method, the principle involved in evaluation of antioxidant activity is based on the conversion of DPPH into 1, 1-diphenyl-2-picrylhydrazine. First preliminary analysis is carried out in order to check whether the compounds are active or not. A qualitative procedure is employed in which the sample compound (approximately 100 $\mu\text{g/mL}$) is applied as a spot on TLC plate and after the development of chromatogram using MeOH:CH₃CN (7:1) mobile phase, 0.2 percent DPPH (w/v) solution is sprayed on the plate. A yellow spot on the purple background indicates the antioxidant activity. For the quantitative estimation of scavenging activity, compounds are dissolved in 1% DMSO solution to give the 10.0 mL of stock solution (1.0 mg/mL). The stock is further diluted to get the sample solutions containing 25-100 $\mu\text{g/mL}$. To each sample solution containing the concentrations of 25-100 $\mu\text{g/mL}$, 3.0 mL of 0.004% methanolic DPPH(w/v) is added. After 30 minutes of incubation, the colour change is measured by taking the absorbance value at 517 nm using a Shimadzu UV-vis-2450 instrument. The absorbance values are compared with BHT (standard) concentrations of 25-100 $\mu\text{g/mL}$. The percent of scavenging activity was evaluated by using the formula

$$\% \text{ Scavenging activity} = (A_0 - A_i / A_0) \times 100$$

Where, A_0 is the absorbance of the control and A_i is the absorbance of the sample.

RESULTS AND DISCUSSION

Fourier-Transform Infrared spectra

Infrared spectra stood as the important tool in identifying the nature of bonding and structure of both inorganic and organic compounds in the absence of the single crystal X-ray diffraction studies. The FT-IR spectra of the nickel(II) and copper(II) complexes are carried out in the range of 400-4000 cm^{-1} by using ALPHA interferometer CECO-ATR, Bruker make. The characteristic vibration bands for the complexes are studied and compared with the spectrum of the free ligand [19, 20]. The ligand formation was confirmed by the appearance of the stretching band at 1648 cm^{-1} for C=N, and 872 cm^{-1} for C=S functions. The same donor functions after coordination, has shown negative shift of the bands around 1580 cm^{-1} and 848 cm^{-1} for the nickel(II) complex and 1648 cm^{-1} and 848 cm^{-1} for the copper(II) complexes for C=N and C=S functions respectively. In both the complexes the imine function stretching band is found to be coupled with the aromatic C=C stretching band making the band appear as broad one. The information thus suggests the involvement of the azomethine and thione functions in coordination to the metal ion. Appearance of the broad band at around 3400 cm^{-1} indicates the presence of the NH₂ groups without involving in the bonding. Fig. 1 shows the FT-IR spectra of the free ligand, its nickel(II) and copper(II) complexes respectively.

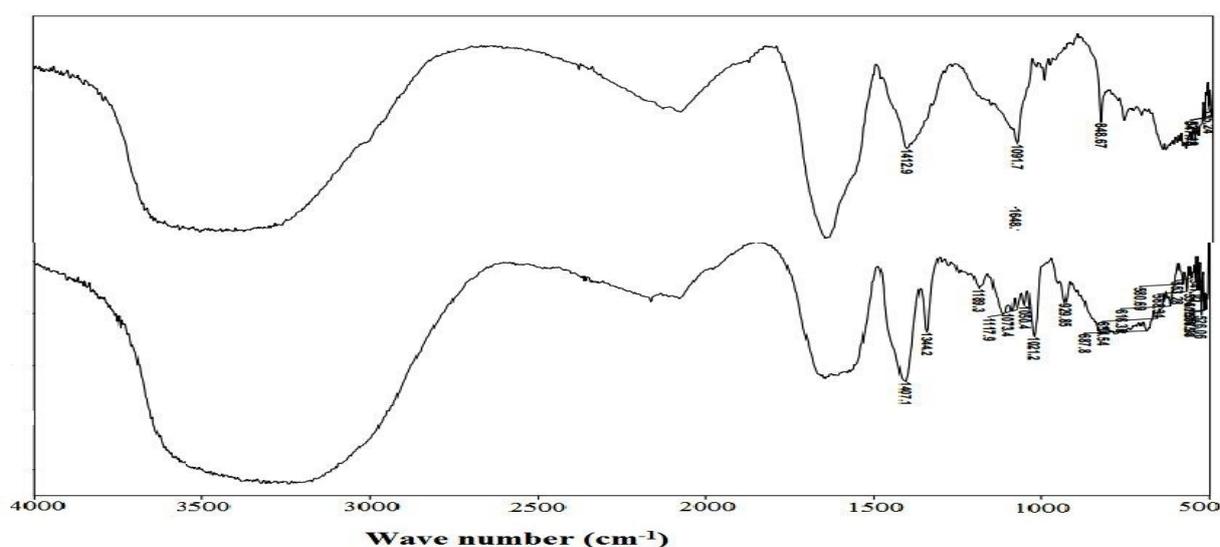


Figure 1: FT-IR spectra of nickel(II) and copper(II) complexes of CBTSC.

Fourier-Transform Raman spectra

The Raman scattering of these molecules has resulted in the peaks corresponding to the important functions that can be correlated with the FT-infrared spectra. The compounds have shown the bands of C=N at 1578, 1592 cm^{-1} for the nickel(II) and copper(II) complexes respectively. The bands at 840 and 859 cm^{-1} for the nickel(II) and copper(II) complexes in a row has indicated the thione function (C=S) of the ligand. The appearance of the short peak at this frequency in the nickel(II) complex is suggesting the strong involvement of the thione in coordination with the metal ion whereas in the case of the copper(II) complex the same peak is seen as a broad band indicating weaker coordination with the copper(II) ion. Fig. 2 shows the FT-Raman spectra of both the complexes.

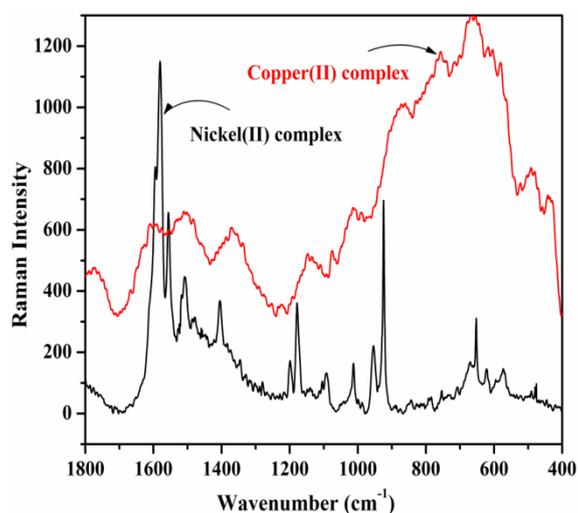


Figure 2: FT-Raman spectra of nickel(II) and copper(II) complexes of CBTSC recorded from 400 to 1800 cm^{-1} .

Electron paramagnetic spectra

The Electron paramagnetic spectra of the copper(II) complex is recorded as polycrystalline samples at 298°K using JEOL, FE-IX ESR equipped with the X-band microwave frequency with a 100 KHz modulation. The copper(II) complex has produced three resonance sets with increase in the field between 2200 G and 4200 G. The three resonance sets are assigned for g_1 , g_2 and g_3 respectively. From the g values, $g_1 = 2.690$, $g_2 = 2.165$ and $g_3 = 2.030$, the copper(II) complex is found to be with rhombic distortions. Fig. 3 shows the EPR spectrum of the polycrystalline copper(II) complex recorded at room temperature.

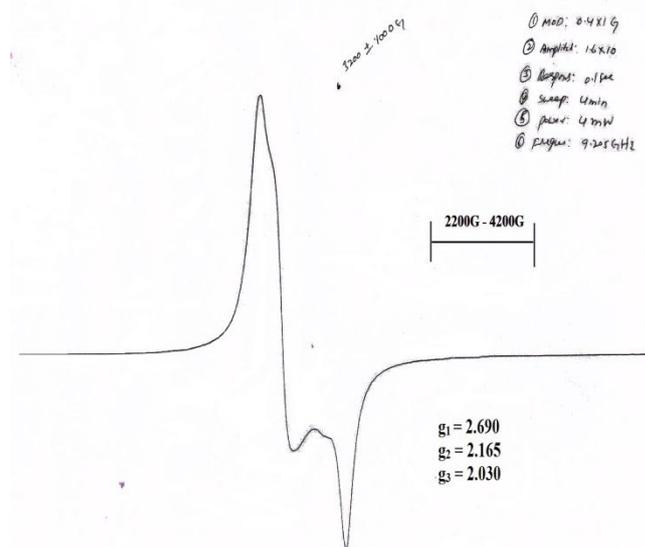


Figure 3: EPR spectrum of the copper (II) CBTSC complex recorded from 2200 to 4200G.

Cyclic voltammetry

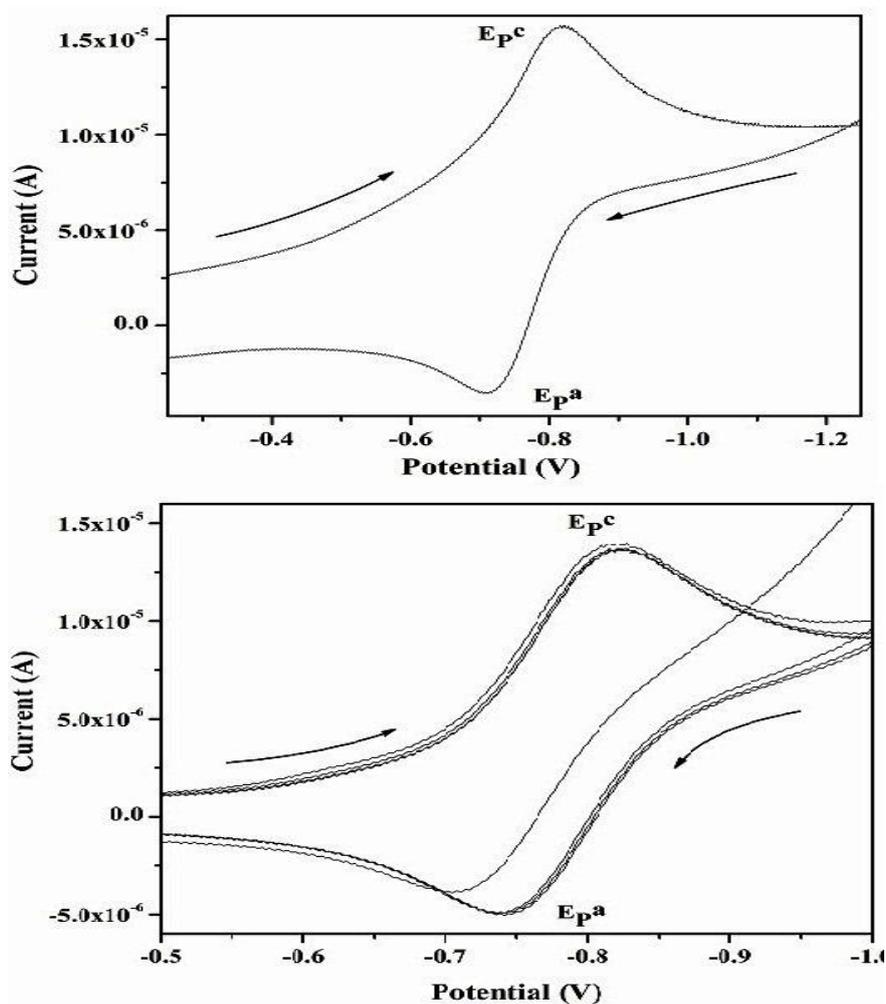


Figure 4: Cyclic voltammogram of the complexes swept between 0.0 V to 1.2 V.

A conventional three electrode system is used after purging the sample solution with the nitrogen atmosphere. The synthesized complexes are studied as 1×10^{-3} M DMSO solutions at 25 ± 1 °C by sweeping the voltammogram from -1.4 V to +1.4 V at a scan rate of 0.06 V/sec. The redox potentials of the nickel(II) complex with the glassy carbon electrode has produced a reversible peak at with E_{p^a} value of -0.711 V and the E_{p^c} value is found at -0.816 V. The planar structure of the nickel(II) complex is suggestive of the redox peaks observed at this potential. When the copper(II) complex is studied by using the glassy carbon electrode, on sweeping the voltage from -1.0 to 0.0 V, a similar pattern of cyclic voltammogram is observed. The E_{p^a} of -0.699 V and -0.820 V. Fig. 4 shows the electrochemical behavior of the nickel and copper complexes of *para*-chlorobenzaldehyde thiosemicarbazone ligand.

Thermogravimetry

Thermal analysis of the complexes is carried out using TA Instruments SDT Q600 model. The thermal data obtained for the nickel (II) and copper(II) complexes has is found informative with regard to the strength of bonding between the ligand and the metal ions. The step wise degradation of the complexes is calculated and compared with the observed data. Fig. 5 shows the thermograms obtained for the nickel(II) and the copper(II) complexes.

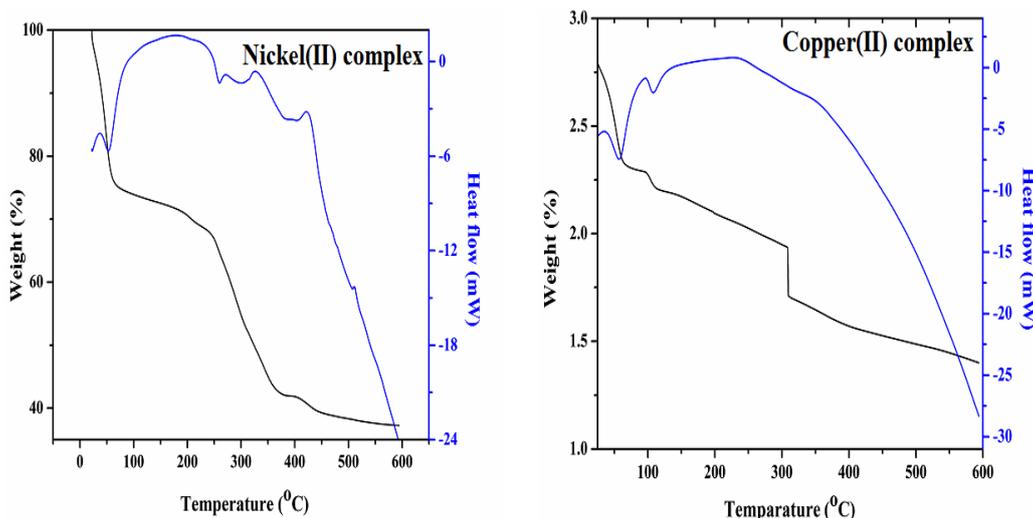


Figure 5: Thermograms of the nickel (II) and copper(II) complexes showing the decomposition of the complex molecules with respect to the temperature.

Antioxidant activity

The synthesized copper(II) (CBTSC) and nickel(II) (CBTSC) complexes are subjected to antioxidant activity test by using DPPH radical scavenging method [21]. In which the diphenylpicryl hydrazyl radical is reduced to diphenyl picryl hydrazide with donation of an electron or hydrogen by the complex molecules. The compounds are first subjected to a preliminary test by dissolving them in methanol and a spot is made on the TLC plate. After the development of chromatogram using MeOH:CH₃CN (7:1) mobile phase, 0.2% DPPH (w/v) solution is sprayed on the plate. Appearance of a yellow spot on the purple background of the TLC plate indicates the activity of the compounds in scavenging the radical. Among the two complexes, the nickel(II) complex is only found to show the yellow spot and therefore, it is chosen for further testing. The complex is then dissolved in 1% DMSO solution to prepare 10.0 mL of stock solution which represents 1.0 mg/mL and then diluted to get sample solutions of 25, 50, 75 and 100 µg/mL. After incubation of 2.0 mL sample + 3.0 ml of 0.004% (w/v) methanolic DPPH solution, the colour change is measured by taking the absorbance value at 517 nm and the percent of scavenging activity in comparison with the standard BHT is presented in Fig. 6. The free ligand has shown better antioxidant activity than the nickel(II) CBTSC.

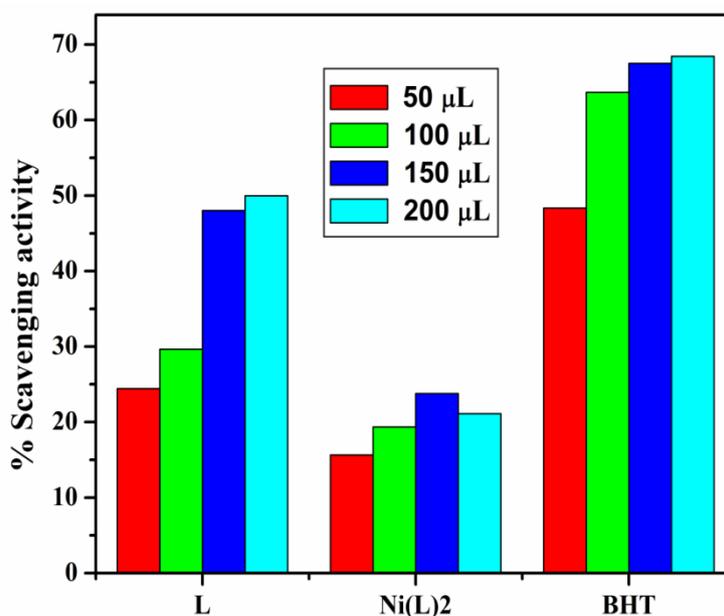


Figure 6: Percent of scavenging activity for the compounds against the standard BHT.

CONCLUSIONS

Finally, it is to conclude that the nickel(II) and copper(II) complexes of bidentate *para*-chlorobenzaldehyde thiosemicarbazone were prepared and characterized. The FT-IR and FT-Raman spectra of the complex have suggested the strong bonding interactions of the imine and thione functions of the free ligand with the metal ion. The copper(II) complex is found to have rhombic distortions. Free ligand *para*-chlorobenzaldehyde thiosemicarbazone is found to be better antioxidant agent than the nickel(II) and copper(II) complexes.

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