

Synthesis and Characterization of the Copper(II) Complex of a Nucleic Acid Constituent, Adenosine

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Copper(II)-adenosine complex has been synthesized in aqueous medium (pH 6) and characterized by elemental analysis, infrared, ^1H NMR electronic spectral and magnetic moment data and ESR study. From IR spectral analysis it is concluded that the $\text{C}_6\text{—NH}_2$ group and N_7 nitrogen of adenosine is involved in coordination with Cu(II) ion. This is most probable as it leads to formation of stable five-membered chelate ring. The formation of Cu—Cl bond is also evident from elemental analysis and the IR spectral data. The binding mode has also been confirmed from ^1H NMR studies. From electronic spectral analysis, it is proposed that the Cu(II) -adenosine complex assumes predominantly a square-planar geometry. This is also supported by magnetic moment measurements and EPR studies.

Key Words: Synthesis, Copper(II) complex, Adenosine.

INTRODUCTION

The establishment of the the structure of deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) and the discovery of their role as hereditary determinant in biological reproduction and growth, is one of the outstanding discoveries of this century. Although, many questions regarding the detailed structure and reactions of DNA and RNA are yet to be answered, structural studies indicate that nucleic acid and their derivatives are natural multisite ligands^{1–4}. So, studies concerning the interaction of these molecules with both natural and foreign metal species have been undertaken. One of the representative nucleosides is adenosine, in which the base is purine. It can act as a good ligand owing to the number of donor sites present in its structure. Copper is the third most abundant metallic element in the human body, following iron and zinc, and it is important in all other forms of life as well⁵. Considering these factors, complexation of adenosine with copper(II) has been studied in the isolated form.

EXPERIMENTAL

$\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ and adenosine were obtained from E. Merck, Germany. All other reagents and solvents used were analytical grade reagents, which were commercially available and were used without further purification.

Synthesis of Copper-adenosine Complex: 0.170 g (0.001 M) $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ was dissolved in 5 mL of triple-distilled water, 0.534 g (0.002 M) adenosine was taken in 10 mL of triple distilled water. The metal solution was added to it portionwise with constant stirring and the pH was adjusted to 4–5 in order to obtain a clear solution. Then the pH was gradually raised to *ca.* 6 by dropwise addition of NaOH solution while precipitation occurred in aqueous solution. It was kept in the refrigerator for *ca.* 30 min. The precipitate did not settle, it remained suspended in the solution. It was filtered through a gooch crucible, by transferring the precipitate from the beaker with a small quantity of distilled ethanol. The precipitate was washed with dry ethanol and finally with diethyl ether and was dried *in vacuo*. (Weight of the crude product = 0.341 g.)

The crude product was taken in *ca.* 10 mL of triple distilled water, pH was adjusted around 4 and the solution was stirred to dissolve the product. The solution was filtered and the pH of the filtrate was raised to 6 for precipitation of the product. The precipitate was kept in the refrigerator for *ca.* 30 min and then filtered through gooch crucible. It was washed with small amount of distilled ethanol and finally with diethyl ether. The precipitate was dried and then weighed. (Weight of the re-precipitated product = 0.324 g.)

C, H, N analysis was done microanalytically by Perkin-Elmer 240C elemental analyzer. IR spectra of the free ligands and the complex were taken on KBr pellets in a Perkin-Elmer IR spectrophotometer Model 597. UV-Vis spectra were recorded in Chemito UV-2100 spectrophotometer. The spectra of the free ligand and the complex were recorded in aqueous (triple-distilled water and the base-line was corrected with respect to triple distilled water). 10^{-5} M solution was taken for measuring the spectrum in the UV region (200–400 nm) and solution of concentration of the order of 10^{-2} M was used for measurement in the visible region (400–1000 nm). Magnetic susceptibility of the complex was measured by the Gouy method using the $\text{Hg}[\text{Co}(\text{NCS})_4]$ as the standard. EER of the polycrystalline sample was taken in Varian E-112 EPR spectrometer. NMR spectra were recorded in DMSO-d_6 with TMS as internal standard by Jeol JNM100 NMR spectrometer. TG analysis was done with a Shimadzu-DT-30 instrument.

RESULTS AND DISCUSSION

The elemental analytical data indicate that the formula of the complex is $[\text{Cu}(\text{adenosine})\text{Cl}_2]$ (Table-1).

IR spectrum shows a band at 1680 cm^{-1} corresponding to $\nu(\text{C—N})$ vibration of adenosine. The otherwise sharp and strong band of adenosine is broadened and shifted to 1660 cm^{-1} in case of the complex. This indicates the involvement of ring N_7 nitrogen in coordination with the metal ion^{2,3,6}. The $\delta(\text{NH}_2)$ vibration of adenosine appears at 1610 cm^{-1} as a strong band. This is shifted to 1580 cm^{-1} with serious loss of intensity indicating the involvement of the $\text{C}_6\text{—NH}_2$ group in complexation. Another vibrational mode of NH_2 at 1305 cm^{-1} is modified by getting split into two components which further supports the claim of involvement of $\text{C}_6\text{—NH}_2$ in coordination with the $\text{Cu}(\text{II})$ ion. This is also very much likely in view of the coordination of N_7 nitrogen to the metal ion, as it leads to the formation of a stable five-membered chelate ring. The formation of Cu—Cl bond is also

evidenced by the presence of a split (two components suggests *cis*- geometry) band in the 340–320 cm^{-1} range⁷. Evidently, C₆—NH₂ and N₇ mutually engage the *cis*- positions, the other two *cis*- positions of the square-planar Cu(II) are occupied by two Cl ligands (*vide infra*). The relevant data are given in Table-1.

TABLE-1
ANALYTICAL AND SPECTRAL DATA OF ADENOSINE AND
Cu(II) ADENOSINE COMPLEX

Molecule (Colour)	Elemental analysis (%): Found (Calcd.)	μ_{eff} (BM)	IR spectral data (cm^{-1})	Electronic spectral data
Adenosine			$\nu(\text{C}\equiv\text{N})$ 1680 (s) $\delta(\text{NH}_2)$ 1610 (s) 1305 (s)	$\lambda_{\text{max}} = 260$ (nm) $\epsilon = 34950$
Copper-adenosine complex [Cu(adenosine)Cl ₂] (Light green)	C 30.12 (29.80) H 3.41 (3.25) N 17.50 (17.41) Cl 17.87 (17.70)	1.86	$\nu(\text{C}\equiv\text{N})$ 1660 $\delta(\text{NH}_2)$ 1580 (w) 1280–1310 (s, b) $\delta(\text{Cu—Cl})$ 320–340	(a) $\lambda_{\text{max}} = 260$ (nm) $\epsilon = 21079$ ($\text{L mol}^{-1} \text{cm}^{-1}$) (b) $\lambda_{\text{max}} = 810$ nm $\epsilon = 9.5$ ($\text{L mol}^{-1} \text{cm}^{-1}$)

The metal binding by adenosine has further been confirmed by ¹H NMR spectroscopy⁸. The C₆—NH₂ proton signal appears at 7.40 ppm. This C₆—NH₂ signal is down shifted to 7.75 ppm upon complexation. This happens because of the participation of the lone pair of electrons in coordination with copper(II). Another ¹H proton signal for C₈—H is again downshifted from 8.60 to 8.80 ppm, which clearly indicates that this shift occurs because of the involvement of the vicinal N₇ in coordination. No other remarkable changes, other than a minor broadening of the peaks, in the NMR spectra are observed as such. So, the above findings clearly demonstrate that copper(II) binds the C₆—NH₂ and N₇ of adenosine. This has also been suggested by the IR studies.

The electronic spectrum of the complex was taken in aqueous solution and wavelength maxima with corresponding molar extinction coefficients of ligand and the complex are presented in Table-1. In the ligand there appears a very strong absorption band in the UV region centered at 261 nm. This is attributed to the intraligand $\pi \rightarrow \pi^*$ transition. The intensity of the intra-ligand transition is substantially reduced on complexation, because of change in the electronic environment within the ligand.

There appears another very weak intensity band in the visible region at 810 nm. This is attributed to the *d-d* transition. The appearance of the *d-d* band around this region signifies the formation of a four-coordinated metal complex in case of copper(II)^{9,10}.

It has also been suggested that a red-shift of the band towards 900 nm occurs in case of tetrahedral copper complex. On the other hand, bands produced by

square-planar Cu(II) complexes are found to be blue-shifted towards 750 nm^{11,12}. In the present case, as the *d-d* band is found to occur at 810 nm, which is close to 750 nm, it is proposed that Cu(II)-adenosine complex assumes a predominantly square-planar geometry. This type of observation has also been confirmed by X-ray crystallographic studies by others in different situations¹³.

The magnetic moment for copper(II)-adenosine complex is found to be 1.86 BM. The magnetic moment thus found is very much in conformity with square-planar geometry of the complex¹⁴.

EPR spectrum of the complex was recorded in the polycrystalline state at room temperature. The spectrum shows two peaks (Fig. 1) only. The $g_{\text{I}} = 2.15$, $g_{\text{II}} = 2.03$ and $g_{\text{av}} = 2.07$ are observed for the complex and it obeys the trend of $g_{\text{I}} > g_{\text{II}} > 2.0023$ or $g_{\text{av}} > 2.0023$, which indicates that the probability of finding the unpaired electron in the d_{z^2} orbital is maximum. It has been proposed that the value of g_{II} can be utilized to assess the covalency in the molecule¹⁵. The value of $g_{\text{II}} < 2.3$ indicates a covalent M-L environment. In the present case, the g_{II} value is much less than 2.3 and hence a fair degree of covalency in the Cu—L bonding is indicated.

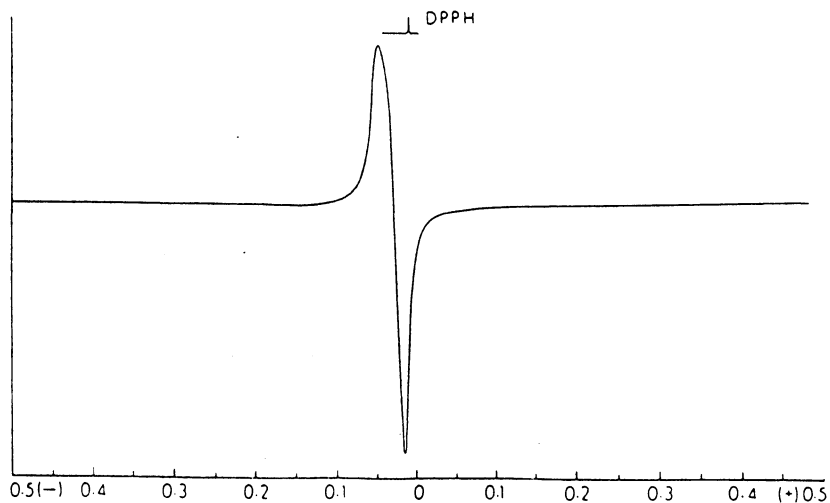


Fig. 1. EPR spectra of Cu(II)-adenosine complex

TG analysis does not show any weight loss up to 180°.

Conclusion

The elemental analytical data indicate that the formula of the complex is [Cu(adenosine)Cl₂]. It is suggested from IR and NMR data that the C₆—NH₂ group and N₇ of nitrogen of the ligand, adenosine, is involved in complexation. Two chloride ions are linked with the copper centre occupying two *cis*- positions (this is also apparent from the IR data). From electronic spectral data, it is proposed that the complex assumes a predominately square-planar geometry (Fig. 2), which is also supported by magnetic moment measurements and EPR study.

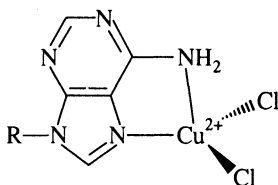


Fig. 2. Proposed model of [Cu(adenosine)Cl₂]

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