Preparation and ESR Study of the Complexes of Amino Acids with Calcium and Magnesium

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Summary: The preparations are reported of the complexes of calcium and magnesium with amino acids; Glycine, β-Alanine and L-Proline. The complexes have been characterized by elemental analyses. Esr spectra at both X- and Q-band are reported for manganese (II) ions doped in the lattices of these complexes, and the zero-field splitting parameters D and λ(= E/D) are deduced. The D value observed for $Ca(L\text{-}pro)_2Cl_2$ is consistent with a *trans*- CaO_4Cl_2 chromophore. Very small values of D observed for all the hydrated complexes suggest an MO_6^{2+} chromophore. Esr spectra of $Mg[(Gly)_2(H_2O)_4](NO_3)_2$ and $Mg[(\beta\text{-}Ala)(H_2O)_4]Cl_2$, closely resemble that of previously reported zinc complex, $Zn[(\beta\text{-}Ala)_2(H_2O)_4](NO_3)_2$, which contains octahedral structure with four water molecules and the β-Alanine molecules occupying the *trans*-positions.

Introduction

An understanding of the many differing roles played by the metal ions in biological processes can only be achieved through a detailed knowledge of the coordination spheres of the complexed metal ions in their active sites [1]. Marked progress has been made in biomimetic chemistry where the active site is modeled by relatively simple coordination compounds. As the proteins contain the same type of donor groups therefore, amino acids complexes act as models for the metal binding sites on proteins.

Although a large number of complexes of transition metals containing amino acids, as ligands, have been synthesized and x-ray crystal structures of most of them have been reported previously [2], those of alkaline earth metals have received very little attention. Only a few complexes of calcium and magnesium have been reported previously and some of them have been used as chemotherapeutic agents.

Here, we report the preparation of a number of complexes of calcium and magnesium with several amino acids, such as Glycine, β-Alanine and L-proline (Fig. 1). The structures of all these complexes are studied by means of the esr spectra of manganese (II) ions doped into their lattices.

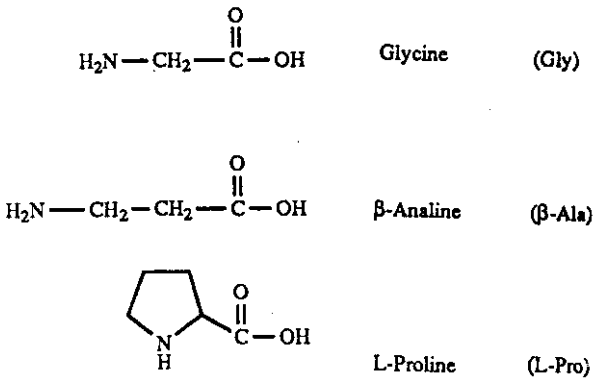

Fig. 1: Amino acids structures and abbreviations.

Results and Discussion

All the complexes of amino acids with calcium and magnesium, prepared in this work, are summarized in Table 1, together with their analytical data.

Esr spectra have been obtained at both X- and Q-band frequencies for manganese (II) ions doped at a nominal 1% into the lattices of compounds $Ca(L\text{-}pro)_2Cl_2$, $Ca(Gly)_4X_2$ (X = Cl or Br), $Ca[(Gly)_2(H_2O)_2]Cl_2$, $Mg(L\text{-}pro)_4Cl_2.5H_2O$, $Mg(L\text{-}pro)_4Br_2$, $4H_2O$, $Mg[(Gly)_2(H_2O)_2]X_2$ (X = Cl or Br), $Mg[(Gly)_2(H_2O)_4](NO_3)_2$, $Mg[(\beta\text{-}Ala)(H_2O)_4]Cl_2$ and $Zn[(\beta\text{-}Ala)_2(H_2O)_4](NO_3)_2$.

At X-band, all the complexes gave good quality but very complicated spectra and detailed interpretation was difficult. For the complexes $Ca(L\text{-}pro)_2Cl_2$ and $Ca(Gly)_4X_2$ (X=Cl or Br), the

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Table 1: Analytical data of the complexes of amino acids with Ca and Mg.

Complexes	%C Found (Calc.)	%H Found (Calc.)	%N Found) (Calc.)
$Ca(L\text{-pro})_2Cl_2$	35.47(35.19)	5.29(5.28)	7.51(8.21)
$Ca(Gly)_4Cl_2$	22.82 (23.36)	4.68 (4.87)	13.13(13.63)
$Ca(Gly)_4Br_2$	20.10(19.25)	4.13(4.00)	11.65(11.20)
$Ca[(Gly)_2(H_2O)_2]Cl_2$	16.12(16.16)	4.63(4.71)	9.52(9.43)
$Mg(L\text{-pro})_4Cl_2.5H_2O$	37.37(37.19)	7.29(7.13)	8.72(8.68)
$Mg(L\text{-pro})_4Br_2.H_2O$	33.45(33.51)	6.12(6.14)	7.82(7.82)
$Mg[(Gly)_2(H_2O)_2]Cl_2$	18.4(17.20)	5.03(4.98)	10.48(9.96)
$Mg[(Gly)_2(H_2O)_2]Br_2$	12.80(12.97)	3.74(3.78)	7.51(7.57)
$Mg[(Gly)_2(H_2O)_4](NO_3)_2$	13.27(12.96)	4.34(4.86)	15.42(15.42)
$Mg[(\beta\text{-Ala})(H_2O)_4]Cl_2$	13.91(14.05)	5.79(5.85)	5.40(5.46)

overlapping of transitions were observed over a wide range of magnetic field. The highest band observed around 825 mT, in the spectrum of $Ca(L\text{-pro})_2Cl_2$, suggested D value of about 0.120 cm^{-1}. Like its acetamide analogue [3], in the X-band spectrum of $Ca(Gly)_4Cl_2$, many more lines were observed than can be accounted for by a single set of zero-field splitting parameters, D and λ, suggesting the presence of Mn(II) in more than one environment.

In contrast, the X-band spectra of all the hydrated complexes were of the same general type, with the strongest bands appearing in the $g_{eff} = 2$ region, indicating much lower D values for them.

The Q-band spectra of all these amino acids complexes were very well resolved, and therefore, were used to determine the precise values of zero-field splitting parameters, D and λ (= E/D), in the Spin Hamiltonian (I).

$$\mathcal{H} = g\,\beta\,BS + D\,(Sz^2 - 1/3S(S+1)) + E(Sx^2 - Sy^2) \quad (I)$$

Experimental resonance fields fitted very well with those calculated, using the program ESRS [4], by exact diagonalization of the matrix derived from (I) with $g_{iso} = 2.00$. The results are given in Table 2.

In the Q-band spectrum of $Ca(Gly)_4Cl_2$, at least four pairs of transitions were observed at the extremities of the spectrum. The positions and intensities of these transitions suggested unequal distribution of Mn(II) between two lattice sites characterized by the zero-field splitting parameters

$D = 0.082\ cm^{-1}$, $\lambda = 0.178$ and $D = 0.086\ cm^{-1}$ $\lambda = 0.144$.

Table 2: Q-band ESR spectrum(mT) of $Mg(Mn)(L\text{-pro})_4Br_2.2H_2O$.

Observed (v = 33.900 GHz)		Calculated for $D = 0.053\ cm^{-1}$, $\lambda = 0.150$. B.	T.P Direction	Field	Levels.
419.3	W				
613.6	W				
640.3	W				
986.9	W	986.4	5.15	Z	2--1.
1050.8	W	1050.2	4.60	Y	6--5.
1096.1	M	1098.3	8.13	Z	3--2.
1129.2	M	1127.5	7.64	Y	5--4.
		1152.8	4.48	X	6--5.
1175.0	M/S	1176.0	7.55	X	5--4.
1205.3	S	1204.1	8.95	X	4--3.
1207.7	S	1207.3	8.94	Y	4--3.
1211.0	S	1210.5	9.02	Z	4--3.
		1237.3	8.40	X	3--2.
Region.		1276.0	5.55	X	2--1.
1289.2	S/M	1289.8	8.27	Y	3--2.
1325.8	M	1323.1	7.91	Z	5--4.
1375.9	M/W	1375.6	5.39	Y	2--1.
1436.7	W	1436.1	4.87	Z	6--5.

Like diacetamide complexes [5], at Q-band frequency, a difference was observed between the mean hyperfine spacing of the sextets for the extreme Z-axis transitions, for the complex $Ca(L\text{-pro})_2Cl_2$. The spacing was greater on the highest field than on the lowest field, so D is positive.

Values of D and λ for all these amino acids complexes of calcium and magnesium are listed in Table 3. The observed values of $D = 0.118\ cm^{-1}$ and $\lambda = 0.087$, for $Ca(Mn)(L\text{-pro})_2Cl_2$, are consistent with a trans-CaO_4Cl_2 chromophore. These values are closely similar to the values previously found for manganese (II) ions in the analogous biuret complex,

Table 3: Zfs parameters of Mn(II) in amino acids complexes.

Complex	D (cm^{-1})	λ
$Ca(L\text{-pro})_2Cl_2$	+ 0.118	0.087
$Ca(Gly)_4Cl_2$	0.082	0.178
	0.086	0.144
$Ca(Gly)_4Br_2$	0.240	0.007
$Ca[(Gly)_2(H_2O)_2]Cl_2$	0.035	0.285
$Mg(L\text{-pro})_4Cl_2.5H_2O$	0.053	0.150
$Mg(L\text{-pro})_4Br_2.4H_2O$	0.053	0.150
$Mg[(Gly)_2(H_2O)_2]Cl_2$	0.043	0.215
$Mg[(Gly)_2(H_2O)_2]Br_2$	0.033	0.200
$Mg[(Gly)_2(H_2O)_4](NO_3)_2$	0.026	0.200
$Mg[(\beta\text{-Ala})(H_2O)_4]Cl_2$	0.025	0.180
$Zn[(\beta\text{-Ala})_2(H_2O)_4](NO_3)_2$*	< 0.02	--

*Too small to evaluate.

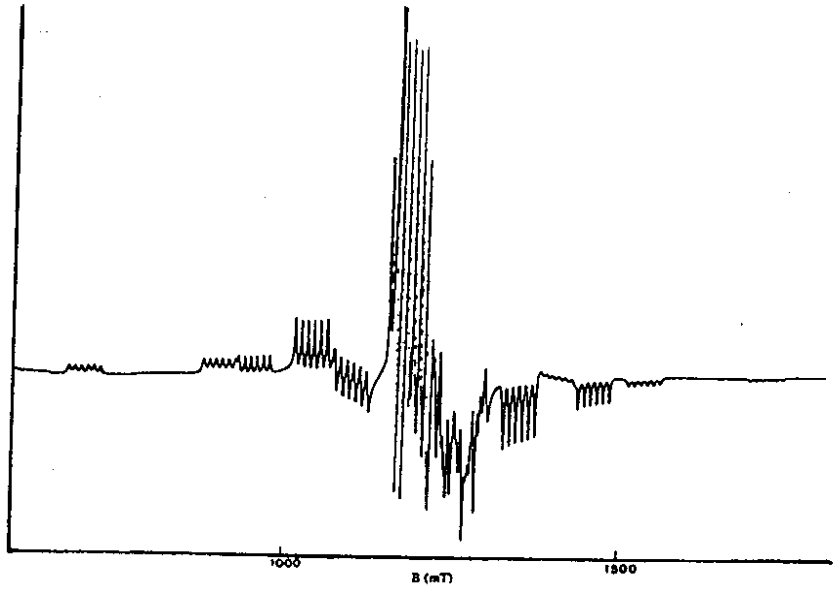

Fig. 2: Q-band ESR spectrum of $Ca(Mn)(L\text{-pro})_2Cl_2$.

$Ca(Mn)(biuret)_2Cl_2$, for which D = 0.121 cm^{-1} and λ = 0.023 [6]. It confirms that, like $Ca(Mn)(biuret)_2Cl_2$, this complex also has an octahedral structure, with each calcium ion surrounded by four oxygen atoms and chlorides occupying the *trans*-positions. Comparatively higher λ value for L-pro complex suggests considerable asymmetry in the X/Y plane.

For $Ca(Mn)(Gly)_4X_2$ (X = Cl or Br) the values of zero-field splitting parameters D and λ suggest octahedral structures, with coordinated halide ions. The D value of bromide is higher than for chloride analogue, as expected. The very small value of λ observed for bromide complex suggests D_{4h} symmetry but the higher value of λ for chloride imply quite considerable rhombic distortion.

Further, D values observed for $M(Mn)[(Gly)_2(H_2O)_2]X_2$ (M = Ca and Mg ; X = Cl, M = Mg; X = Br) are close to one another, but very different from those of analogous anhydrous calcium complexes. The low values of D for these hydrated complexes are consistent with a coordination sphere of six oxygens and suggest the formulation of these compounds as dihydrates, with water molecules replacing the halide ions in the coordination sphere.

For complexes $Mg(Mn)(L\text{-pro})_4Cl_2.5H_2O$ and $Mg(Mn)(L\text{-pro})_4Br_2.4H_2O$, identical values of D eliminate the possibility of halide coordination and the low values of D are consistent with an MgO_6^{2+} chromophore, but it was not possible to find the exact number of L-pro and water molecules coordinated with magnesium ions.

The zero-field splitting parameters, for $Mg(Mn)(Gly)_2(NO_3)_2.4H_2O$ and $Mg(Mn)(\beta\text{-Ala})Cl_2.4H_2O$, are close to one another, indicating identical structures for both of them. A similar complex of zinc, with formula $Zn[(\beta\text{-Ala})_2(H_2O)_4](NO_3)_2$, has previously been reported and its crystal structure has been determined [7]. In this complex each zinc ion was octahedrally coordinated by four water molecules and the β-Ala molecules were occupying trans-positions, coordinating through their carboxyl oxygen atoms. This zinc complex was also made doped with 1% of Mn(II) ions and its esr spectrum suggested a very low value for D. The observed D values for both of these hydrated magnesium complexes are also very small and suggest that, like zinc complex, probably all the four water molecules are coordinated to magnesium ion and these complexes can correctly be formulated as $Mg[(Gly)_2(H_2O)_4](NO_3)_2$ and $Mg[(\beta\text{-Ala})(H_2O)_4]Cl_2$.

Experimental

Preparation of complexes

All the chemicals used in the present work were pure analytical grade and were used without further purificatior

All the amino acids complexes of calcium and magnesium were prepared by the same general method. The hot aqueous solutions of metal salt and corresponding amino acid, in stoichiometric quantities, were prepared separately in minimum of water. The solutions were mixed together and the resulting solution was filtered off. The mixture was allowed to evaporate slowly at room temperature for several days. The white precipitates thus formed were washed with ether and dried in vacuo over P_2O_5.

Analysis for % compositions of C, H and N were carried out by the Microanalytical Laboratory, Imperial College of Science, Technology and Medicine, London.

For the esr study the normal doping level was 1% of manganese in all cases. Esr spectra were obtained as described previously [8], using polycrystalline samples at room temperatures.

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