

A CORRELATION OF SIGNED CHARGE-TRANSFER COTTON EFFECTS WITH ABSOLUTE CONFIGURATION OF α -AMINO ACIDS IN COPPER(II) COMPLEXES

K.M. Wellman, S. Bogdansky, W. Mungall, T.G. Mecca, and C.R. Hare

Chemistry Department, State University of New York at Buffalo
Buffalo, New York 14214

(Received in USA 26 May 1967)

An early and often-used application of optical rotatory dispersion (ORD) has been the determination of the absolute configuration of an α -amino acid by analysis of the visible-region ORD curve of the copper(II)-amino acid complex (1). However, the utility of this correlation has been shown to have severe limitations (2a). More recently it has been amply demonstrated (2b) that the visible-region ORD curves of these complexes depend upon chelate ring conformation which in turn is influenced by subtle structural details. In the mean time a number of correlations have been made utilizing α -amino acid derivatives and their ORD spectra (3). On the other hand, with the advent of spectropolarimeters capable of penetrating through the region of the carbonyl chromophore, several studies have reported direct measurements on the parent amino acids (4). Inherent in these inquiries, however, is the implicit assumption that all of the amino acids, or their derivatives, take up similar conformations such that the measured chromophoric transition is "perturbed" in a similar manner by the extrachromophoric framework. Such an assumption is tenuous at best with these acyclic molecules and anomalies have been noted (3e, 4a).

Because of the above-mentioned difficulties, we present here a theoretically intriguing and chemically useful correlation observed in our laboratories. It is stated simply as follows: complexation of L- α -amino

acids with copper(II) at pH 8-10 leads to a charge-transfer (C.T.) band centered at 250-270 μ exhibiting a negative Cotton effect. The value of this observation is enhanced by the experimental simplicity of the determination. Thus, the method (5) requires a small sample (less than 1 mg is suitable in most cases), involves an experimentally convenient ultraviolet region of the spectrum, and necessitates a minimum of time for sample preparation since the complexes are synthesized in situ simply by dissolving a 2:1 molar ratio of amino acid to copper(II) in aqueous solution. The Cotton effect amplitudes expressed as molecular rotation are large varying from a few thousand for simple amino acids to ca. -30,000 for the complex of L-2,4-diaminobutanoic acid.

The potential correlative value is indicated by the following list of L-amino acids whose Cu(II) complexes exhibit negative C.T. Cotton effects: α -alanine, α -aminobutyric acid, norvaline, valine, isoleucine, leucine, threonine, N-methylalanine, ornithine, lysine, serine, homoserine, aspartic acid, asparagine, arginine, proline, picolinic acid, hydroxyproline, 2-carboxyazetidine, 2,3-diaminopropionic acid, 2,4-diaminobutanoic acid, histidine, and 3-methylhistidine. This configurational criterion for amino acids may not be applicable to the phenyl-containing acids because of interfering phenyl transitions.

Curves of some representative examples are shown in the Fig. 1. The copper complexes of L-asparagine (I) and L-valine (II) at pH 8.4 exhibit negative Cotton effects in the vicinity of 600 μ in agreement with the correlation of earlier workers (1, 2a). However, the L-proline complex (III) behaves in an anomalous fashion in the visible region exhibiting a positive Cotton effect (2). In contrast, the L-proline copper (II) complex

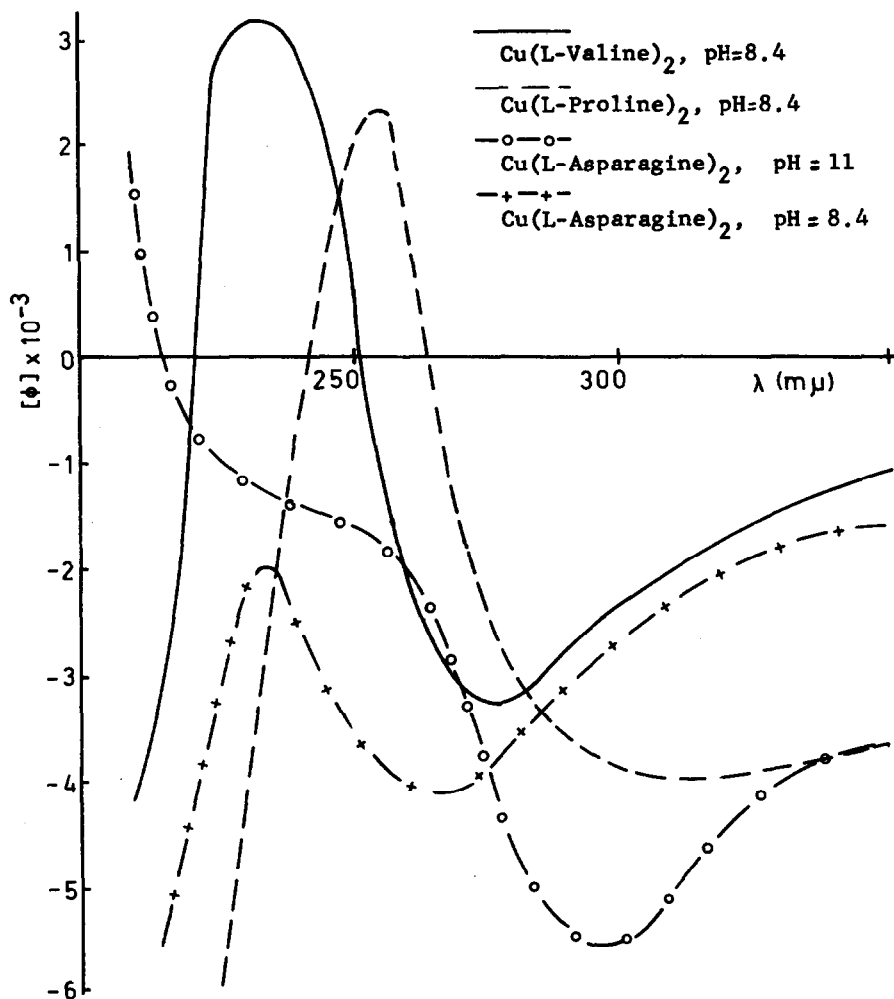
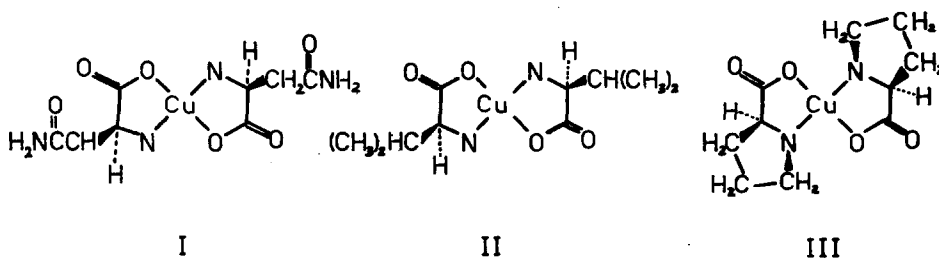


Figure 1. Optical rotatory dispersion curves in the charge-transfer region of the copper(II) complexes of L-valine, L-proline and L-asparagine



is normal by the present criterion as shown in the Figure. Bis-(L-asparaginato)copper(II) is a particularly instructive example because of its pH dependence. Recent results from our laboratories (6b) have demonstrated that at pH 8 this complex behaves normally in the visible region, but undergoes a sign inversion resulting in an anomalous, positive Cotton effect at $\text{pH} > 9$. Such Cotton effect inversions are indicative of deep-seated conformational changes in the 5-membered, amino acid-Cu(II) ring systems (2b). This conformational change appears to be reflected in the background curves of the asparagine complex which are of opposite sign at $\text{pH} 8.4$ and 11 (see Figure); however, under both conditions the C.T. Cotton Effect remains negative. The shift in the C.T. band position is probably associated in part with the chelate ring conformational change and will be discussed elsewhere.

The transition centered at ca. 250-270 $\text{m}\mu$ in these complexes is charge transfer in nature (6) and involves the promotion of an electron formally associated with the ligand to the copper(II) ion. Apparently, the generality and, hence, the utility of the correlation presented here is due to two favorable circumstances: first, the 5-membered chelate ring is largely restricted to two limiting conformations (2b); and, secondly, it appears that both conformations give rise to negative C.T. Cotton effects for Cu(II) complexes of L-amino acids. These conclusions will be discussed at length elsewhere.

References

1. P. Pfeiffer and W. Christeleit, Z. Physiol. Chem., 245, 197 (1937), 247, 262 (1937); P. Karrer and J. Mayer, Helv. Chim. Acta., 20, 407 (1937).
2. (a) N. Izumiya, M. Winitz, S.M. Birnbaum and J.P. Greenstein, J. Am. Chem. Soc., 78, 1602 (1956); (b) K.M. Wellman, T.G. Mecca, W. Mungall, and C.R. Hare, J. Am. Chem. Soc., 89, 000 (1967).
3. (a) B. Sjoberg, A. Fredga, and C. Djerassi, J. Am. Chem. Soc., 81, 5002 (1959); (b) C. Djerassi, K. Undheim, R.C. Sheppard, W.G. Terry and B. Sjoberg, Acta. Chem. Scand., 15, 903 (1951); (c) C. Djerassi, H. Wolf, and E. Bunnenberg, J. Am. Chem. Soc., 84, 4552 (1962); (d) B. Sjoberg, B. Karlen, and R. Dahlbom, Acta. Chem. Scand., 16, 1071 (1962); (e) G.C. Barrett, J. Chem. Soc., 2825 (1965).
4. (a) J.P. Jennings, W. Klyne, P.M. Scopes, J. Chem. Soc., 294 (1965); (b) J.C. Craig and S.K. Roy, Tetrahedron, 21, 391 (1965); (c) M. Legrand and R. Viennet, Bull. Soc. Chim., France, 679 (1965); (d) W. Gaffield, Chem. Ind., 1460 (1964).
5. Instrumentation: Cary 60 spectropolarimeter; slit width programmed at a band width between 10-20 Å; full range of 0.02° or 0.04°; cell path of 0.01 dcm. Solutions: 2:1 molar ratios of amino acid to $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ were used giving 10^{-3}M Bis-complex. A pH of 8.4 was generally used.
6. (a) S.F. Mason, Quart Rev., 17, 20 (1963); (b) Unpublished results.