Hydration and Structure of Copper(II) Complexes of DL-Methionine and other Thiocarboxylates in Aqueous Solution

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Summary Magnetic resonance of protons in methionine and water bound to copper(II) has shown that, in solution, as in the solid, the methionine is co-ordinated *via* N and O and not *via* S; the complexes are $CuA(H_2O)_4^+$ and $CuA_2(H_2O)_2$: however, Cu^{II} is bound by S in many other potentially bidentate and tridentate thiocarboxylates.

Veidis and Palenik's recent communication[1] of the crystal structure of bis(methioninato)copper(II) prompts us to report our studies of this and related complexes in solution. Analysis of the line-width of the ^1H n.m.r. signal of water in the presence of *ca.* 0·04M-Cu^{II} as a function of degree of complexation,[2] $\bar{n}$, by DL-methionine using the method described recently[3] shows that the predominant complex in solution is $CuA(H_2O)_4^+$, with a mean $Cu–OH_2$ bond length of $2{\cdot}2_1$ Å (see Table 1). The bis complex is clearly $CuA_2(H_2O)_2$, but the Cu–O bond length cannot be quoted, as $\bar{n} < 0{\cdot}7$ at the necessary high Cu^{II} concentration. Differential proton relaxation[4] in Cu^{II} methionine solutions (with $\bar{n} = 2$) indicates that the co-ordination sites are N and O, but not S. The visible absorption spectra ($\bar{\nu}_{max}$ 16·1 kK) are also consistent with this binding pattern. Hence, in solution as in the solid state, there are glycinato-copper(II) rings with unco-ordinated methylthio-groups. Indeed, the p*K*'s of methionine and the stability constants of its copper(II) complexes[5] are almost identical to the corresponding values for glycine.

Table 1

^1H *Reciprocal spin–spin relaxation times and* Cu–O *bond lengths for* H_2O *in* $CuA_n(H_2O)_x$

$CuA_n(H_2O)_x$	$(1/T_n) \times 10^{-3}\,sec^{-1}$	Cu–O, Å
$[Cu(C_2H_5CO_2)(H_2O)_5]^+$	$7{\cdot}2_8$	$2{\cdot}1_2$
$[Cu(Me_2NCH_2CO_2)(H_2O)_4]^+$	$6{\cdot}6_5$	$2{\cdot}2_1$
$[Cu(MeSC_2H_4NH_2CHCO_2)(H_2O)_4]^+$ ..	$6{\cdot}8_5$	$2{\cdot}2_1$
$[Cu(O_2CCH_2NH_2CHCO_2)(H_2O)_3]^+$ ..	$6{\cdot}3_7$	$2{\cdot}1_6$[a]

[a] The aspartate system provides a further warning against the danger of guessing structures from thermodynamic data. Aspartate really is tridentate towards Cu^{II} in solution, as in the crystal structure of its Zn^{II} complex, although the overall stability constant for Cu^{II} bis(methioninate) is little more than that of the bis(glycinate).

Notwithstanding, we have found copper(II) to be chelated *via* S by other thiocarboxylates. We have examined some 12 other systems to date. Our n.m.r. studies indicate cyclic–acyclic equilibria with approximately complete, half, and no chelation by 2-, 3-, and by both 4- and 5- thio-substituted monocarboxylates respectively in solution. *X*-Ray studies of crystal and molecular structures in the solid state and magnetic studies are in progress.[6] Both the n.m.r. and visible spectra[7] show that in solution copper(II) is bound by the carboxylate group in the acyclic forms and that the S is not co-ordinated. The position of chelated thiocarboxylates in the spectrochemical series approaches that of the aminocarboxylates (see Table 2). Thermodynamically, the 2-thiocarboxylates alone are stabilised by comparison with their O-analogues. *Pace* Prue,[9] both ΔH (determined by isothermal titration calorimetry) and ΔS

Table 2

$\bar{\nu}_{max}$ *for tetragonally distorted* Cu^{II} *chromophores*

	$\bar{\nu}_{max}$, kK[a]
CuO_6	12·6
CuO_5S	*ca.* 13·4
CuO_4S_2	*ca.* 14·5
CuO_4N_2	*ca.* 16

[a] 1 kK = $10^3\,cm^{-1}$.

are associated to varying degrees with the enhanced stability of the several 2-thiocarboxylates.

Some potentially tridentate S-ligands other than methionine have also been examined.[10] Our n.m.r. studies show thiodiacetate to be only bidentate towards copper(II), but thiodipropionate to be tridentate, although the former complex is thermodynamically more stable. Models indicate that closure of the second five-membered ring with the thiodiacetate would result in severe strain. However, the thiodibutyrate copper(II) complex appears to be acyclic.

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