The Metal-ion Catalysed Hydrolysis of Cysteine Methyl Ester

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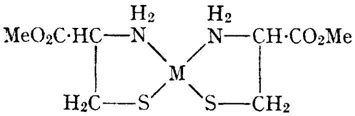
WE have recently isolated a number of bis-metal complexes of methyl cysteineate (I),[1] where M = Ni^{II}, Zn^{II}, Cd^{II}, Pb^{II}, and Hg^{II}. We now report the results of some kinetic measurements on the base hydrolysis of the ester function in these bis-complexes at 25° and I = 0·1M.


(I) ["ME₂"]

The kinetics of base hydrolysis in the pH range 9—11 followed by a pH-stat, are consistent with a kinetic scheme involving two consecutive second-order processes (*pseudo*-first-order at constant pH)

$$ME_2 + OH^- \xrightarrow{k_1} MEA^- + MeOH$$
$$MEA^- + OH^- \longrightarrow MA_2^{2-} + MeOH$$

where E⁻ is the methyl cysteineate anion and A^{2-} the cysteineate anion. The kinetic scheme is therefore similar to that observed for the base hydrolysis of the bis-copper(II) complex of histidine methyl ester.[2,3] Conley and Martin[4] studied the nickel(II)-, zinc(II)-, and cadmium(II)-catalysed base hydrolysis of cysteine ethyl ester and considered the reaction scheme to be,

$$ME_2 + OH^- \rightarrow MEA^- + EtOH$$
$$2MEA^- \underset{}{\overset{\text{fast}}{\rightleftharpoons}} ME_2 + MA_2^{2-}$$

This scheme implies that strict *pseudo*-first-order kinetics should be obtained throughout the reaction at constant pH, but this behaviour is not in fact observed. The relevant data for the hydrolysis of the bis-complexes are given in the Table. The "catalytic power" of the metal ions based on k_1 is Ni > Pb > Zn > Cd > Hg, while for k_2 the series Ni > Zn > Pb > Hg ∼ Cd is obtained. The order of reactivity based on k_1 (bis-complexes) correlates quite well with that previously found for the order of metal–nitrogen bond strengths obtained from infrared-spectral measurements on these complexes,[1] Ni > Zn > Pb > Cd > Hg. This correlation of hydrolytic reactivity with metal–nitrogen bond strength probably implies that the metal's catalytic effect is primarily due, in these charge-neutral complexes, to the inductive effect of the metal ion

TABLE

Metal ion	k_1 (mole^{-1} min.$^{-1}$)[a]	k_2 (mole^{-1} min.$^{-1}$)[b]
Nickel(II)	650	215
Zinc(II)	280	83
Lead(II)	340	54
Cadmium(II) ..	210	42
Mercury(II)	140	46

Reactions studied at a ligand–metal ratio of 2 : 1.
Kinetic data analysed by computer calculated time ratios.

[a] For the process $ME_2 + OH^- \rightarrow MEA^- + MeOH$.
[b] For the process $MEA^- + OH^- \rightarrow MA_2^{2-} + MeOH$.

All measurements at 25° and I = 0·1M.

For the process $^-SCH_2{\cdot}CH(NH_2)CO_2Me + OH^- \rightarrow$ $^-SCH_2{\cdot}CH(NH_2)CO_2^- + MeOH$ k = 4·4 mole^{-1} min.$^{-1}$ at 25° and I = 0·1M. For the base hydrolysis of *S*-methyl methylcysteinate under these conditions k = 64 mole^{-1} min.$^{-1}$.

acting through the amino-nitrogen. This effect tends to withdraw electrons from the acyl carbon atom and therefore facilitates nucleophilic attack by the hydroxide ion. It is significant that the carbonyl stretching frequency of the protonated α-amino-acid esters occurs at a higher frequency (*ca.* 25 cm.$^{-1}$) than that observed in the unprotonated esters.[1]

Infrared-spectral measurements give no evidence of bonding between the metal ion and the ester function of methyl cysteineate in both the solid state[1] and in aqueous solution.[5] Such bonding has been postulated to account for the catalytic effect of copper(II) in the base hydrolysis of α-amino-acid esters.[6] Whereas such interaction may occasionally occur[7,8] there is no evidence for it in the metal ion-catalysed base hydrolysis of cysteine methyl ester.

(*Received, May 22nd,* 1967; *Com.* 500.)

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