Electronic Supplementary Material (ESI) for Dalton Transactions.

SUPPORTING INFORMATION

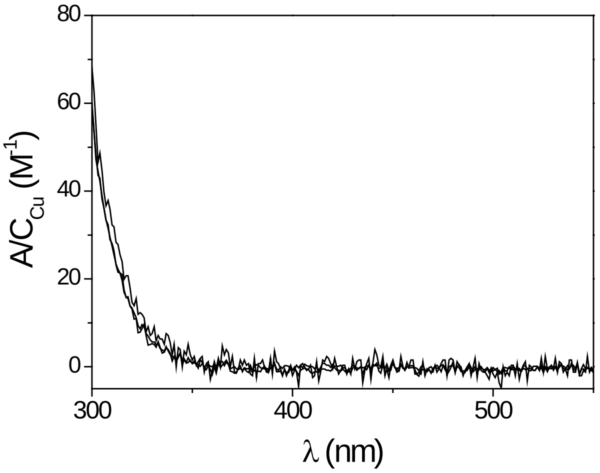

Figure 1S: *Absorbance spectra recorded for the Cu(II))/Alaha system at pH = 3.0 for a titration experiment where increasing amounts of the metal are added to the ligand.* $C_L = 2.5 \cdot 10^{-4}$ *M,* C_M *from 0 to* $1.3 \cdot 10^{-2}$ *M; I = 0.1 M and T = 25°C. The superimposition of the spectra shows that no interaction between Cu(II)) and Alaha does occur at pH=3.0*

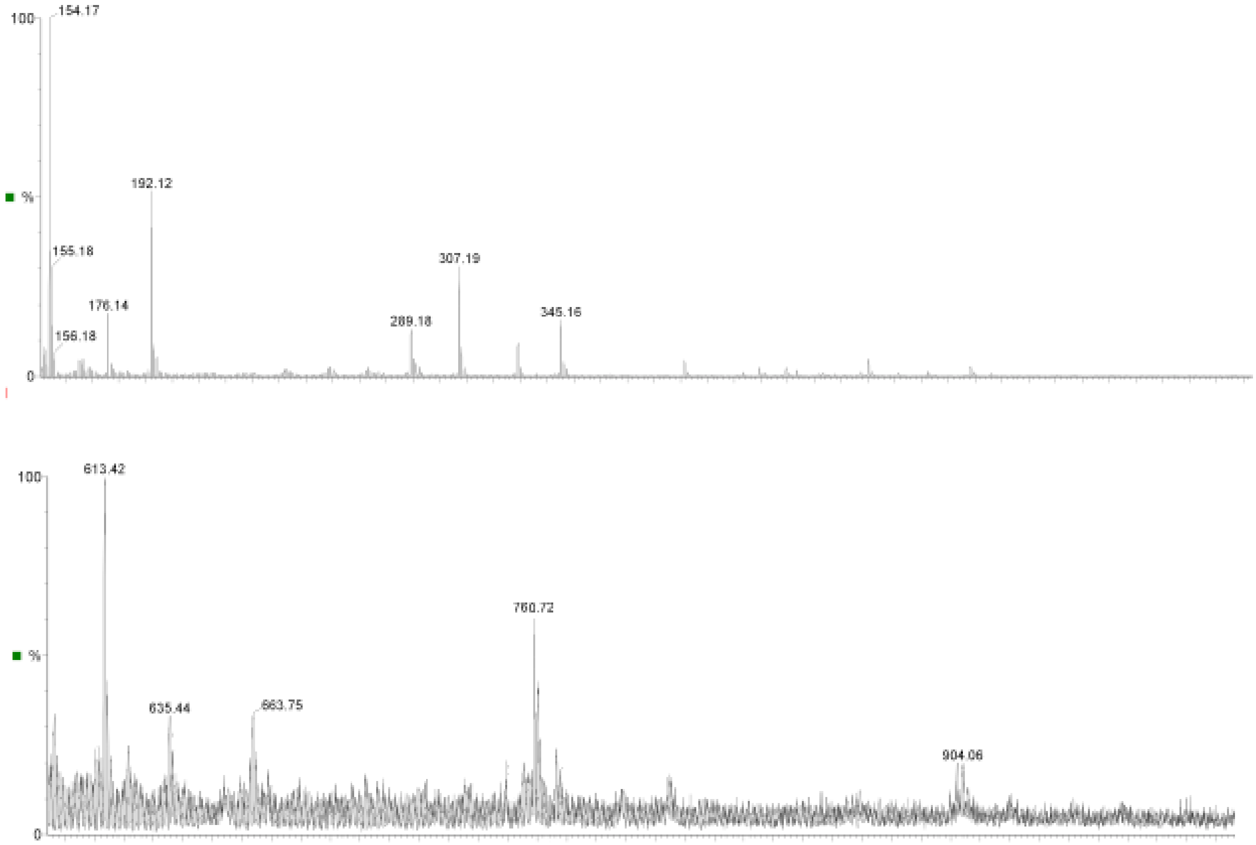

Figure 2S . *FAB-MS spectra of a Cu(II)/Alaha solution. Cu:L=5:4,* $[CuCl_2]=1.25\times10^{-2}$ *M, pH = 4.5 (acetic buffer), I = 0.1 M (KCl)*

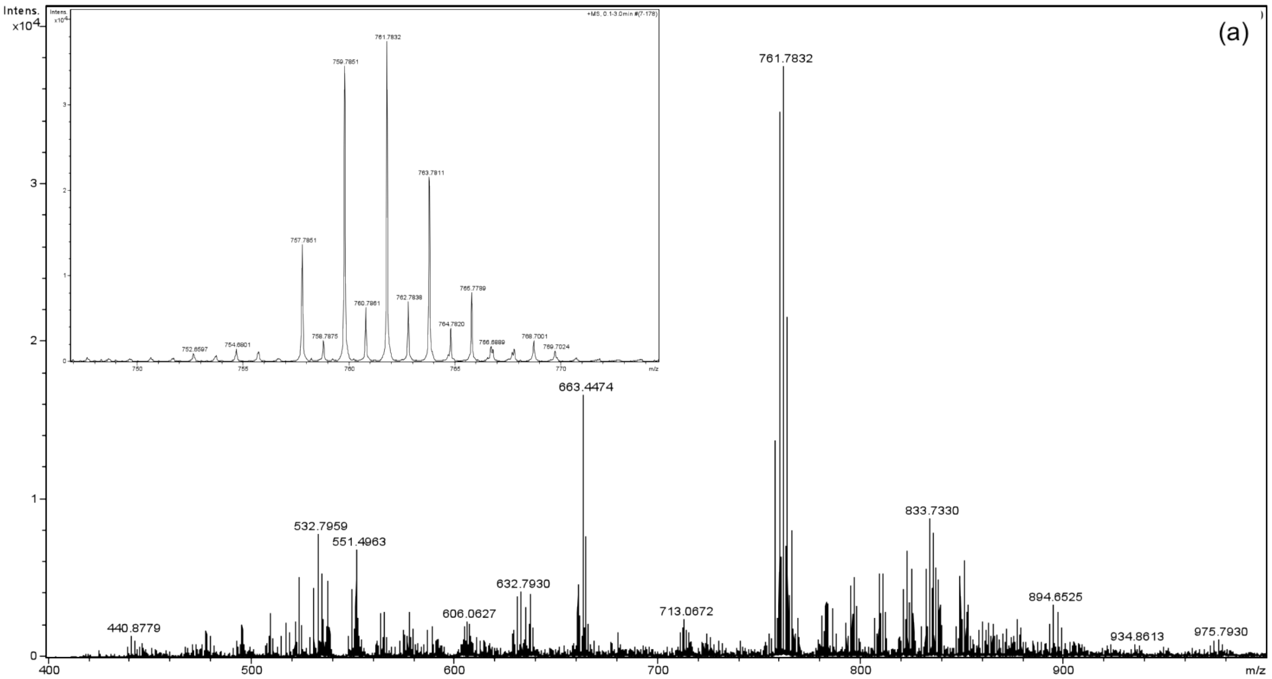

Figure 3S. *ESI-MS spectra of a Cu(II)/Alaha solution recorded before heating. Inset: isotopic profile of the peak corresponding to* $[Cu_5L_4]Cl^+$*. Cu:L=5:4,* $[CuCl_2]=1\times10^{-3}$ *M, pH = 4.5 (acetic buffer).*

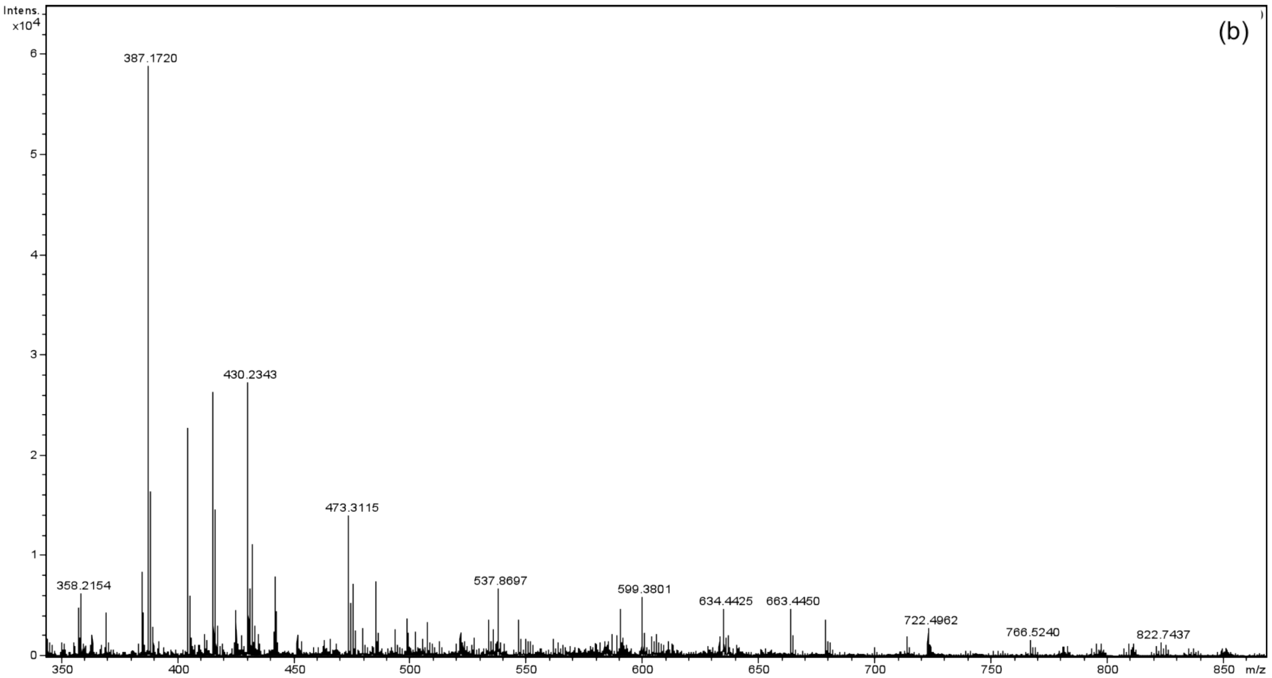

Figure 4S. *ESI-MS spectra of a Cu(II)/Alaha solution recorded after heating (90 °C, 3 hours). Cu:L=5:4,* $[CuCl_2]=1\times10^{-3}$ *M, pH = 4.5 (acetic buffer).*

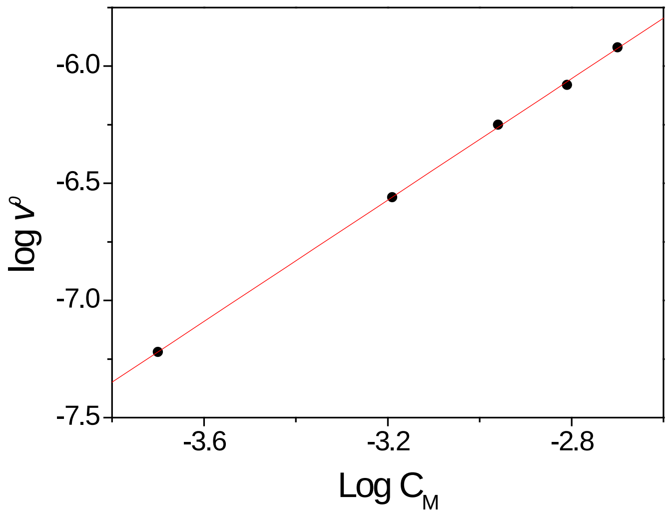

Figure 5S: *Logarithmic dependence of the initial rate, v°, on the metal concentration for the Cu(II)/Alaha system;* $C_L = 2.0\cdot10^{-2}$ *M, pH = 4.5, I = 0.1 M and T = 25°C.*

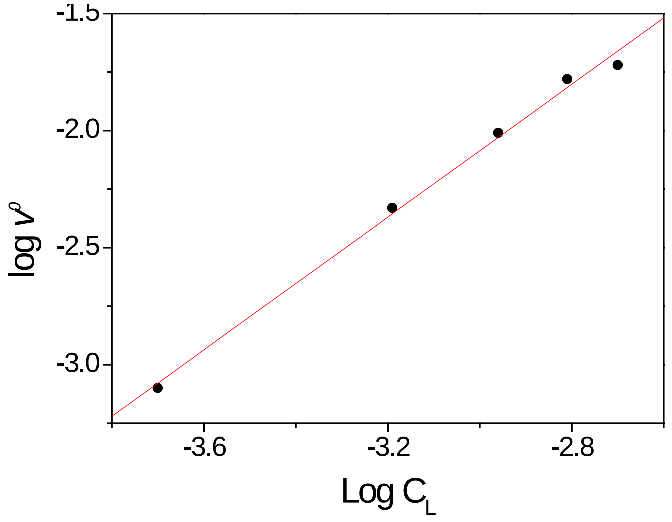

Figure 6S: *Logarithmic dependence of the initial rate, v°, on the ligand concentration for the Cu(II)/Alaha system;* $C_M = 2.0\cdot10^{-2}$*M; pH = 4.5, I = 0.1 M and T = 25°C.*

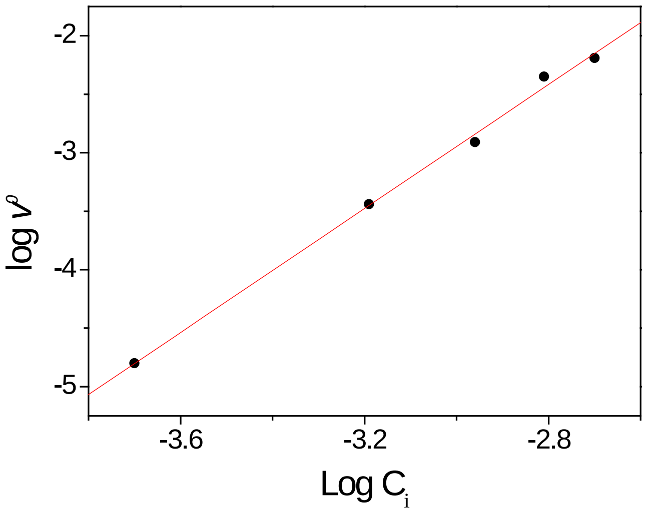

Figure 7S: *Logarithmic dependence of the initial rate, v°, on reactant concentration for the Cu(II)/Alaha system. The concentration of metal and ligand are the same in each experiment* ($C_i = C_M = C_L$)*; pH = 4.5, I = 0.1 M and T = 25°C.*

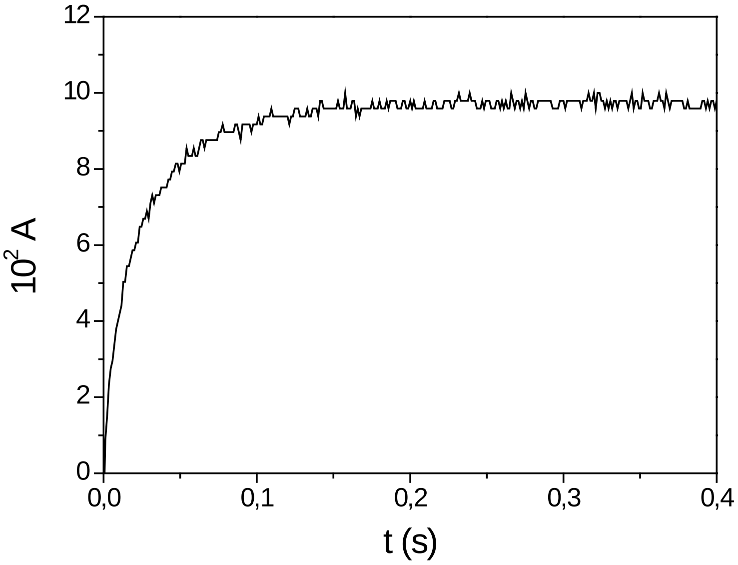

Figure 8S: *Kinetic curve for the Cu(II))/Alaha system;* $C_L = 5.0\times10^{-4}$ *M,* $C_M = 5.0\times10^{-3}$ *M, pH = 4.5, I = 0.1 M, λ = 340 nm and T =25°C.*

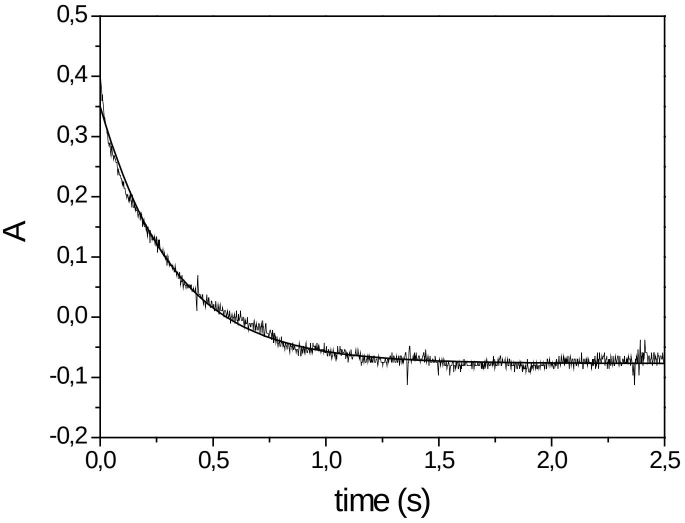

Figure 9S: *Kinetic relaxation curve for the dissociation reaction of the Cu(II))/Alaha system;* $C_{12\text{-}MC\text{-}4} = 1.0\times10^{-4}$ *M, pH = 3.5 (after mixing), I = 0.1 M, λ = 340 nm and T =25°C.*

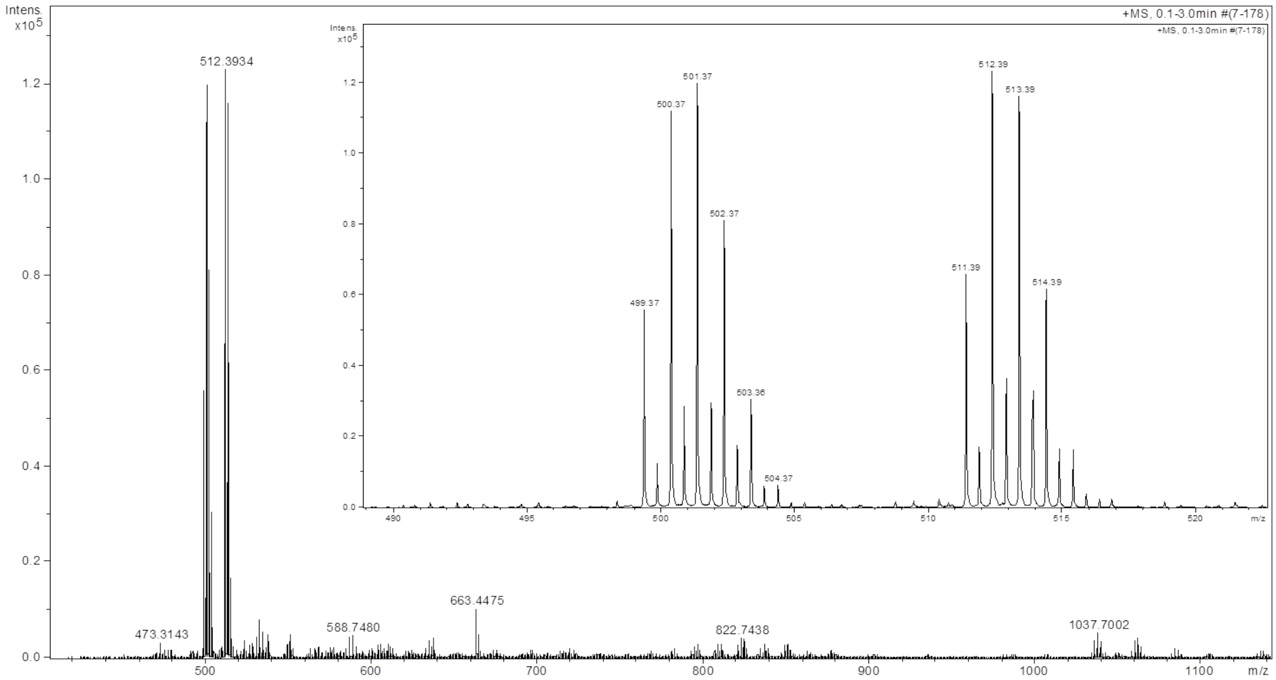

Figure 10S. *ESI-MS spectrum of a La(III)/Cu(II)/Alaha solution. Inset: isotopic profile of the peaks corresponding to* $[LaCu_5L_5]Cl^{2+}$ *and* $[LaCu_5L_5]AcO^{2+}$*. Cu:L=5:4,* $[CuCl_2]=1\times10^{-3}$ *M, pH = 4.5 (acetic buffer).*

***DERIVATION OF EQUATION (6) of the text* - Initial rate expression for the fast phase**

The fast process is represented by reactions (1S) and (2S)

$$Cu^{2+} + H_3L^+ \overset{K_1}{\rightleftarrows} CuHL^+ + 2H^{2+} \tag{1S}$$

$$2\ CuHL^+ \xrightarrow{k_2} \text{products} \tag{2S}$$

where reaction (1S) is much faster than reaction (2S).
Note that the derivation is aimed to find the expression for the initial rates, so the reverse step of reaction (2S) has been neglected, since the amount of products is negligible.
The equilibrium constant of reaction (1S) is

$$\mathrm{K}_1^{'} = \frac{\mathrm{K}_1}{[\mathrm{H}^+]^2} = \frac{[\mathrm{CuHL}^+]}{[\mathrm{Cu}^{2+}][\mathrm{H}_3\mathrm{L}^+]} \tag{3S}$$

The mass conservation equations for the above (1S)-(2S) system are

$$C_{Cu} = [Cu^{2+}] + [CuHL^+] \tag{4S}$$
$$C_L = [H_3L]^+ + [CuHL^+] \tag{5S}$$

where C_M and C_L denote the total concentrations of the metal and the ligand respectively.
Introduction of equation (3S) in equations (4S) and (5S) yields

$$C_{Cu}C_L = [CuHL^+]^2\ \{1+1/(K_1'\times[H_3L^+])\}\{1+1/(K_1'\times[Cu^{2+}])\} \tag{6S}$$

The initial rate of reaction is

$$V^{\circ}_{fast} = k_2[CuHL^+]^2 \tag{7S}$$

Introduction of equation (6S) in equation (7S) yields

$$V^{\circ}_{fast} = \frac{k_2 C_{Cu} C_L}{\left(1+\frac{1}{K_1^{'}[Cu^{2+}]}\right)\left(1+\frac{1}{K_1^{'}[H_3L^+]}\right)} = \frac{k_2 C_{Cu} C_L}{\left(1+\frac{[H^+]^2}{K_1\,[Cu^{2+}]}\right)\left(1+\frac{[H^+]^2}{K_1\,[H_3L^+]}\right)} \tag{8S}$$

which corresponds to equation (6) of the text.

For the limiting case where $1/K_1'[H_3L^+]$ and $1/K_1'[Cu^{2+}] << 1$ the reaction order is one with respect to each of the reactants. For $1/K_1'[H_3L^+]$ and $1/K_1'[Cu^{2+}] >> 1$ the reaction order is two with respect to each of the reactants. For intermediate values the reaction orders are fractional, as experimentally observed.

DERIVATION OF EQUATION (8) of the text

Kinetic equation for the fast phase under $C_M >> C_L$ conditions

Being given the following (1S')-(2S') system

$$Cu^{2+} + H_3L^{+} \overset{K_1}{\rightleftarrows} CuHL^{+} + 2H^{+} \qquad (1S')$$

$$Cu^{2+} + CuHL^{+} \underset{k'_{-2}}{\overset{k'_2}{\rightleftarrows}} Cu_2L^{2+} + H^{+} \qquad (2S')$$

The following equations yield

$$K_1' = K_1/ [H^+]^2 = [CuHL^+]/([Cu^{2+}]\times[H_3L^+]) \qquad (3S')$$

$$\frac{d[Cu_2L]}{dt} = k_2^{'}[CuHL^{+}]\times[Cu^{2+}] - k_{-2}^{'}[Cu_2L] \qquad (4S')$$

The total analytical concentration of the ligand is given by

$$C_L = [H_3L^+] + [CuHL^+] + [Cu_2L] \qquad (5S')$$

That, in the differential form, gives

$$0 = \delta[H_3L^+] + \delta[CuHL^+] + \delta[Cu_2L] \qquad (6S')$$

If the metal is in excess $[Cu^{2+}] \sim C_M$ and we have

$$K_1'C_{Cu} = \delta[CuHL^+]/\delta[H_3L^+] \qquad (7S')$$

Then, from (7S') and (6S')

$$\delta[CuHL^{+}]\left(1+\frac{1}{K_1^{'}C_M}\right) = -\delta[Cu_2L] \qquad (8S')$$

Thus, differentiating equation (4S'), using (8S') and taking into account $[Cu^{2+}] \sim C_M$ we have

$$\frac{d\delta[Cu_2L]}{dt} = k_2^{'}[Cu^{2+}]\times\delta[CuHL^{+}] - k_{-2}^{'}\delta[Cu_2L] \qquad (9S')$$

$$-\frac{d\delta[Cu_2L]}{dt} = \left(k_2^{'}\frac{K_1^{'}C_{Cu}^2}{1+K_1^{'}C_{Cu}} + k_{-2}^{'}\right)\delta[Cu_2L] \qquad (10S')$$

So that, finally we obtain equation (11S') that corresponds to equation (8) of the text.

$$\frac{1}{\tau_f} = k_2^{'}\frac{K_1^{'}C_{Cu}^2}{1+K_1^{'}C_{Cu}} + k_{-2}^{'} \qquad (11S')$$

DERIVATION OF EQUATION (16) of the text

Kinetic equation for the fast effect. C_{La}, C_{Cu}>> $C_{Cu[2MC4]}$ in buffered solution

The fast phase (eq 14) is composed of two series steps. The first step, corresponding to $K_1'$is fast compared to the second one.

Fast phase:

$$\mathrm{Cu[12MC4] + La} \overset{K_1'}{\rightleftarrows} \mathrm{Cu[12MC4]La} \underset{k_{-1}}{\overset{k_1}{\rightleftarrows}} \mathrm{La[12MC4]+ Cu} \qquad (14)$$

Since when the fast phase is equilibrated the slow phase is not yet started (i.e. the final product La[15MC5] is not present), the mass conservation equation with respect to the metallacrown, is expressed by eq (1.3S)

$$\delta\mathrm{Cu[12MC4]} + \delta\mathrm{Cu[12MC4]La} + \delta\mathrm{La[12MC4]} = 0 \qquad (1.3S)$$

Since C_{La} >> $C_{12MC4Cu}$**,** the relationship between the reactants involved in the equilibrium step corresponding to K_1' can be written as :

$$\delta Cu[12MC4]La \times \left(\frac{1}{K_1' \times C_{La}} \right) = \delta Cu[12MC4] \qquad (2.3S)$$

Introduction of eq (2.3S) in eq (1.3S) yields

$$\delta Cu[12MC4]La \times \left(1 + \frac{1}{K_1' \times C_{La}} \right) = -\delta La[12MC4] \qquad (3.3S)$$

The rate law of the sequence 17 is given bye eq (3.4S)

$$\frac{d\delta La[12MC4]}{dt} = k_1 \times \delta Cu[12MC4]La] - k_{-1}' \times \delta La[12MC4] \qquad (3.4S)$$

Introduction of eq (3.3S) in eq (3.4S) yields eq (3.5S)

$$-\frac{d\delta La[12MC4]}{dt} = \left(k_1 \frac{K_1' C_{La}}{1 + K_1' C_{La}} + k_{-1}' C_{Cu} \right) \delta La[12MC4] \qquad (3.5S)$$

Integration of eq (3.5S) provides the expression for the time constant of the fast reacting system in the form of eq (3.6S), which corresponds to the eq 16 of the text.

$$\frac{1}{\tau_{fast}} = \left(k_1 \frac{K_1' C_{La}}{1 + K_1' C_{La}} + k_{-1} C_{Cu} \right) \qquad (3.6S)$$

DERIVATION OF EQUATION (17) of the text
Kinetic equation for the slow effect. C_L>> C_{La} >> $C_{Cu[2MC4]}$ in buffered solution

Fast phase $$\mathrm{Cu[12MC4] + La \overset{K_1'}{\rightleftarrows} Cu[12MC4]La \overset{K_1}{\rightleftarrows} La[12MC4] + Cu} \tag{14}$$

Slow phase $$\mathrm{Cu[12MC4]La + L \overset{K_2'}{\rightleftarrows} CuL[12MC4]La \underset{k_{-2}}{\overset{k_2}{\rightleftarrows}} [15MC5]La} \tag{15}$$

The rate determining step is associated to the rate constant k_2 and k_{-2}, other steps being fast equilibria.

The intermediate Cu[12MC4]La, formed in the fast phase, reacts in the slow phase with the ligand present in excess, according to the sequence (19).

The mass equation concerning MC, written in differential form, is eq (1.4S)

$$\delta Cu[12MC4] + \delta Cu[12MC4]La + \delta La[12MC4] + CuL[12MC4]La + 15MC5La = 0 \tag{1.4S}$$

Under the conditions C_L>>C_{12MC4} and C_{La}>>C_{12MC4} , from reactions 17 one obtains eq (2.4S)

$$\delta Cu[12MC4]La \times \left(\frac{1}{K_1^{'} \times C_{La}} \right) = \delta Cu[12MC4] \tag{2.4S}$$

and eq (3.4S).

$$\delta Cu[12MC4]La \times \left(\frac{1}{K_1 \times C_{Cu}} \right) = \delta La[12MC4] \tag{3.4S}$$

From the fast phase (eq 14) one obtains eq (4.4S).

$$\delta Cu[12MC4]La \times \left(K_2^{'} C_L \right) = \delta CuL[12MC4]La \tag{4.4S}$$

Introduction of eqs (2.4S), (3.4S) and (4.4S) in eq ((1.4S) yields eq (5.4S).

$$\delta Cu[12MC4]La \times \left(1 + \frac{1}{K_1^{'} \times C_{La}} + \frac{1}{K_1 \times C_{Cu}} + K'_2\, C_L \right) = -\delta La[15MC5] \tag{5.4S}$$

The rate law for the fast phase is given by eq (6.4S)

$$\frac{d\delta La[15MC5]}{dt} = k_2 \times \delta CuL[12MC4]La - k_{-2} \times \delta La[15MC5] \tag{6.4S}$$

Introduction of eqs (4.4S) and (5.4S) in eq (6.4S) yields eq (7.4S).

$$-\frac{d\delta[15MC5La]}{dt}=\left(k_2\frac{K_2^{'}C_L}{1+K_2^{'}C_L+\frac{K_1^{'}}{C_{La}}+\frac{K_1}{C_{Cu}}}+k_{-2}C_{Cu}\right)\delta[12MC4La] \qquad (7.4S)$$

Which, upon integration, yields eq (8.4S), the expression for the time constant of the slow reacting system.

$$\frac{1}{\tau_{slow}}=\left(k_2\frac{K_2^{'}C_L}{1+K_2^{'}C_L+\frac{K_1^{'}}{C_{La}}+\frac{K_1}{C_{Cu}}}+k_{-2}\right) \qquad (8.4S)$$

Eq (8.4S) can be rearranged to give eq (17) of the text

$$\frac{1}{\tau_{slow}}=\frac{K_2{}'k_2C_{La}C_L}{(1+\frac{K_1}{C_{Cu}}+K_2{}'C_L)C_{La}+K'_1}+k_{-2} \qquad (17)$$

or to give eq (17’), not reported in the text, which directly shows the dependence of the slow effect on C_L.

$$\frac{1}{\tau_{slow}}=\frac{K_2{}'k_2C_L}{(1+\frac{K_1}{C_{Cu}}+\frac{K'_1}{C_{La}})+K_2{}'C_L}+k_{-2} \qquad (17’)$$