The Asymmetrically-selective Oxidation Reaction of 3,4-Dihydroxyphenylalanine Catalyzed by the Poly-L-lysine-copper(II) Complex

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Many polymer-metal complexes[1,2] have been found to exhibit high catalytic efficiencies in comparison with the low molecular analogs. However, no polymer-metal complex showing an asymmetrically selective catalysis has been reported. In this communication we wish to report that the oxidation reaction of 3,4-dihydroxyphenylalanine (DOPA) can be catalyzed by the poly-L-lysine-copper(II) complex (PLL-Cu(II)) with an appreciable asymmetric selectivity. This is the first example of a synthetic polymer-metal complex used to catalyze a reaction with an asymmetric selectivity. Most of the experimental details have been reported elsewhere.[1] At several temperatures from 25 to 10°C, the circular dichroism of the catalyst and the rate of the oxidation reaction were measured. These kinetic and circular dichroism results are collected in Table 1, which indicates that the initial oxidation rate of D-DOPA (V_D) is greater than that of L-DOPA (V_L) and that the ratio of the rate of D-DOPA to that of L-DOPA (V_D/V_L) increases with a decrease in the reaction temperature measured, reaching 1.5 at 10°C. These observations seem to be of great interest by analogy with the catalytic behavior of enzymes. It has been reported that the asymmetric induction in the oxidation reaction may be attributed to the selective formation of the substrate-catalyst complex.[1] It is evident from Table 1 that, at a constant T_{Cu}/T_N[*1] (0.13), the asymmetric selectivity ratio in the reaction increased with an increase in the α-helix content in the catalyst. However, when the T_{Cu}/T_N was varied, the selectivity did not increase with the α-helix content. That is, the catalyst prepared at $T_{Cu}/T_N=0.05$ exhibited almost no selectivity, though it had a much higher α-helix content than the catalyst prepared at $T_{Cu}/T_N=0.13$. These results mean that the α-helix structure in the catalyst may be necessary, but may not be sufficient to show an appreciable selectivity. The chief difference, other than the α-helix content, between the catalyst prepared at $T_{Cu}/T_N=0.05$ and that prepared at $T_{Cu}/T_N=0.13$ may be the distances between the cupric complex units along the polymer chain,[*2] because the asymmetric structure in a cupric complex unit did not differ very much, judging from the fact that the molar ellipticity in the wave length of 240—650 mμ changed little with the variation in the T_{Cu}/T_N ratio.[1] Therefore, the selectivity in the catalysis can not be correlated with the separated cupric complex unit only, but two or more cupric complex units may act cooperatively in the selective catalysis. Consequently, it seems that the results can be explained by the assumption that the helix structure in the catalyst serves to hold the two or more cupric complex units in a special steric configuration, thus forming a site which can bind D-DOPA selectively.

Table 1. Oxidation rate of DOPA catalyzed by PLL-Cu(II)[a]

T_{Cu}/T_N	Temp. (°C)	V_D ×10⁻⁵ mol/l min	V_L ×10⁻⁵ mol/l min	V_D/V_L	α-Helix content (%)
0.13	25	2.9_3	2.7_4	1.0_7	$15._6$
0.13	20	2.2_0	1.9_0	1.1_6	$17._2$
0.13	15	1.8_5	1.3_0	1.4_2	$24._0$
0.13	10	1.4_3	0.9_3	1.5_3	$27._6$
0.15	20	2.8_2	2.7_9	1.0_2	$6._3$
0.13	20	3.5_0	2.7_9	1.2_5	$17._2$
0.10	20	2.9_5	2.7_6	1.0_7	$25._6$
0.05	20	2.7_7	2.6_8	1.0_3	$57._6$

a) The kinetic experiments were carried out at pH 10.5 at the condition of $T_{Cu}=2.0\times10^{-4}$M. The initial concentration of DOPA was 1.0×10^{-4}M in the upper four runs and 2.1×10^{-4}M in the lower four runs.

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[1] M. Hatano, T. Nozawa, S. Ikeda and T. Yamamoto, *Kogyo Kagaku Zasshi*, **72**, 474 (1969); *Makromol. Chem.*, to be published.

[2] H. Sigel, *Angew. Chem.*, **81**, 161 (1969).

[*1] T_{Cu} and T_N represent the total analytical concentration of the cupric ion and that of lysine residue of PLL in the solution, respectively.

[*2] From the results of various experiments, it may be considered that a cupric complex unit is made of a cupric ion coordinated by four amino nitrogens in a plane and one peptide nitrogen at the apical position and that PLL-Cu(II), as a whole, takes a certain helical structure in all T_{Cu}/T_N of 0.05—0.15. These results will be reported elsewhere.