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Communications

A New Stereoisomer of Mn(II) Tris(2-Pyridylmethyl)amine Complex, $[TPA_2Mn](ClO_4)_2$

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To overcome unavoidable reactive oxygen species formation, nature has developed diverse defense mechanisms which mostly involve transition metal ions. Among the reactive oxygen species, hydrogen peroxide is scavenged by catalase and peroxidase. While peroxidase results in the oxidized product during the reaction, catalase specifically disproportionates hydrogen peroxide into water and oxygen molecules ($2H_2O_2 \rightarrow 2H_2O + O_2$). Although the majority of catalases harbor the heme group,[1] some microorganisms contain manganese catalase utilizing a dinuclear Mn center in the active site.[2] Because study of Mn catalase reaction mechanism could provide valuable scientific backgrounds for cancer therapy[3,4,5] and Mn-utilized green chemistry,[6,7] a plethora of Mn complexes have been synthesized and studied with a relevance to Mn catalase.[8,9]

We have recently reported synthesis of the dichloride-bridged $[TPA_2Mn_2(\mu\text{-}Cl)_2]^{2+}$ dimanganese complex (complex **I**), which mimics the chloride-inhibited Mn catalase core.[10] The complex **I** showed catalytic activity of hydrogen peroxide disproportionation, reminiscent of the reactivation of chloride-inhibited Mn catalase.[11] After termination of H_2O_2 disproportionation catalysis of the complex **I** in MeCN, the transparent rhombic crystalline products were isolated from the solution in few days. Here we report X-ray crystallographic structure, stereoisomerism, and catalytic activity of $[TPA_2Mn](ClO_4)_2$ (complex **II**).

Complex **II** was first reported by Gultneh, *et al.* and synthesized from the reaction between TPA and $Mn(ClO_4)_2$ in a high yield.[12] But we have isolated complex **II** from the complex **I** after disproportionation of excess H_2O_2.[13] The isolation of complex **II** provides the information about the catalytic fate of complex **I**, which should involve disintegration of the dinuclear core. The complex **I** is transformed to the unidentified active species in the presence of H_2O_2 and slowly the Mn(II) ion is leaching out, probably as an aqua species, during the catalysis. The free TPA ligand is then utilized by other mononuclear Mn·TPA species to form final product of complex **II** in almost quantitative yield. The original X-ray crystallographic structure of the $[TPA_2Mn](ClO_4)_2$ complex (**II**) has been reported with monoclinic crystal system and determined as a $P\,2_1/n$ space group.[12] The crystal of complex **II** we have collected X-ray data showed different cell parameters (Table 1), and it was determined as a hexagonal crystal system with $P\,3_121$ space group.[14] When the solid structure of **II** was scrutinized to understand the reason of different crystal system formation by the same complex, the bond distances and angles were not so different from the reported values with large variations in the Mn-N distances (Figure 1). The average $Mn\text{-}N_{pyridyl}$ and $Mn\text{-}N_{amine}$ distances of monoclinic crystal were 2.500 and 2.468 Å, respectively. The corresponding distances of hexagonal crystal were 2.48(5) and 2.446(3) Å, respectively. But when we aligned both structure side by side, immediately we were able to see the stereoisomerism between two structures (Figure 2). The pyridyl groups are tilted against $N_{amine}\text{-}Mn\text{-}N_{amine}$ axis of the complex and the helicity of the TPA pyridyl groups can be determined as Δ or Λ. The absolute configuration of complex **II**, isolated from the catalytic solution, was assigned as a ΔΔ stereoisomer while the same complex in monoclinic crystal

Table 1. Crystal data and structure refinement for $[TPA_2Mn](ClO_4)_2$ (**II**)

Empirical formula	$C_{36}H_{36}Cl_2MnN_8O_8$
Crystal system, space group	Hexagonal, $P\,3_121$
Unit cell dimensions	$a = b = 12.1714(4)$ Å, $c = 21.8446(16)$ Å
Volume	2802.6(2) Å^3
Z, Calculated density	3, 1.483 Mg/m^3
Absorption coefficient	0.560 mm^{-1}
F(000)	1412
R(int)	0.0561
Data / restraints / parameters	3939 / 0 / 258
Goodness-of-fit on F^2	0.904
Final R indices for I > 2sigma(I) (all data)	R1 = 0.0540 (0.0818), wR2 = 0.1222 (0.1330)
Absolute structure parameter	0.00(3)

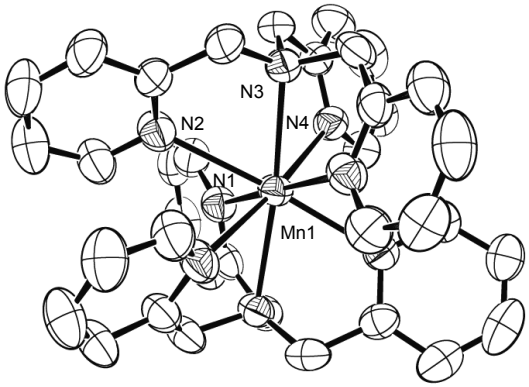

Figure 1. Crystallographic structure of $[TPA_2Mn](ClO_4)_2$ (**II**) with thermal ellipsoids (50% probability); hydrogen atoms were omitted for clarity. Mn(1)-N(1); 2.519(3) Å, Mn(1)-N(2); 2.537(4) Å, Mn(1)-N(3); 2.446(3) Å, Mn(1)-N(4); 2.369(3) Å, N(1)#1-Mn(1)-N(1); 176.98(17)°, N(2)#1-Mn(1)-N(2); 69.49(18)°, N(3)#1-Mn(1)-N(3); 173.92(16)°, N(4)#1-Mn(1)-N(4); 80.50(15)°, N(4)-Mn(1)-N(3); 68.22 (11)°, N(4)-Mn(1)-N(1); 71.68(11)°, N(3)-Mn(1)-N(1); 113.30(11)°, N(4)-Mn(1)-N(2); 105.01(11)°, N(3)-Mn(1)-N(2); 65.92(12)°, N(1)-Mn(1)-N(2); 76.33(11)°. Symmetry code #1: x-y, -y, -z+5/3.

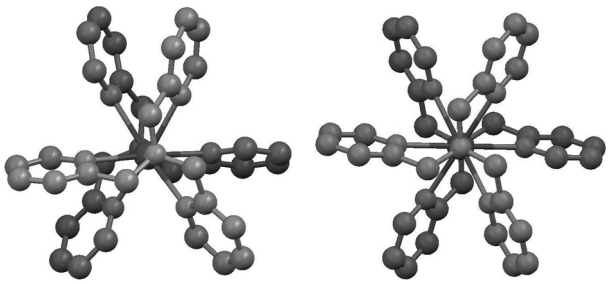

Figure 2. Two different crystallographic structures of $[TPA_2Mn](ClO_4)_2$ (**II**). The left structure reported in this work was assigned as ΔΔ stereoisomer and the right one generated from the deposited structure was assigned as ΔΛ stereoisomer.

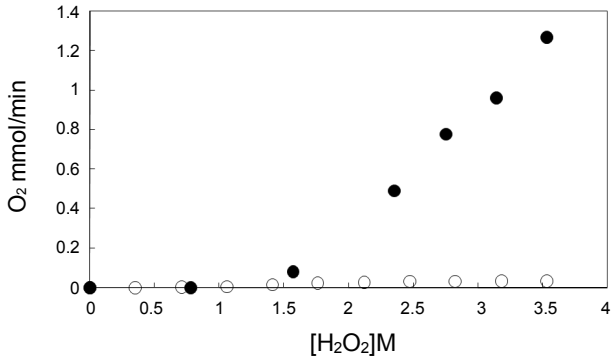

Figure 3. Substrate-dependent catalytic activity of $[TPA_2Mn_2(\mu\text{-}Cl)_2]^{2+}$ (**I**, ●) and $[TPA_2Mn](ClO_4)_2$ (**II**, ○). The catalytic activity of the complexes was measured under the experimental conditions described previously.[10]

system was identified as a ΔΛ stereoisomer. The chiral space group of $P3_121$ excluded the possibility of racemic mixture. Even though the ΔΔ stereoisomer of complex **II** could be refined as its enantiomer, the absolute configuration parameter of Flack x was 0.00(3). It is interesting the TPA ligand, even it is symmetrical, can form stereoisomers due to the puckering of the metal-containing pentagons.[15] Presently, we are not sure how the different stereoisomer of the $[TPA_2Mn](ClO_4)_2$ complex was crystallized from the catalysis solution. Besides, the solution of complex **II** didn't show any chiral properties.

Finally, we have checked the H_2O_2 disproportionation activity of complex **II** to make sure the $[TPA_2Mn](ClO_4)_2$ complex (**II**) is the catalytical end-complex. As shown in Figure 3, the complex **II** didn't show significant H_2O_2 disproportionation activity when it is compared to the complex **I**. In summary, we have reported the structure of a new ΔΔ stereoisomer of the $[TPA_2Mn](ClO_4)_2$ complex, as well as its H_2O_2 disproportionation property.

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Supplementary Data. Crystallographic data for the structure reported here have been deposited with Cambridge Crystallographic Data Center (Deposition No. CCDC 690348). The data can be obtained free of charge *via* www.ccdc.cam.ac.uk/conts/retrieving.html (or from the CCDC, 12 Union Road, Cambridge CB2 1EZ, UK; fax: +44 1223 336033; e-mail: deposit@ccdc.cam.ac.uk).

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13. FT-IR (KBr, cm^{-1}) 3070(w), 3024(w), 2924(w), 2852(w), 1599(s), 1573(m), 1481(m), 1438(s), 1373(m), 1307(m), 1267(m), 1157(m), 1089(vs), 1006(m), 906(m), 758(s), 733(m), 621(s).
14. Colorless rhombic crystals of $[TPA_2Mn](ClO_4)_2$ (**II**) were used for the data collection. The diffraction data for **II** was collected at 293(2) K, using a Bruker SMART area diffractometer equipped with a monochromator in the Mo Kα (λ = 0.71073 Å) incident beam. The CCD data were integrated and scaled using the Bruker-SAINT software package, and the structure was solved and refined using SHEXTL V5.10. The structure for compound **II** was solved by direct methods to locate heavy atoms, and the non-hydrogen atoms were located through subsequent difference Fourier syntheses. Structural refinement was carried out by full-matrix least squares on F^2. All non-hydrogen atoms were refined with anisotropic thermal parameters. Hydrogen atoms were located in the calculated positions.
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