rameters, anisotropic thermal parameters, hydrogen atom parameters, bond distances and angles, root-mean-square amplitudes of vibrations, and weighted least-squares planes and interplanar angles for $\mathbf{2}\cdot(PF_6)_2\cdot C_7H_8\cdot 1.5CH_2Cl_2$ (14 pages); listing of observed and calculated structure amplitudes for $\mathbf{2}\cdot(PF_6)_2\cdot C_7H_8\cdot 1.5CH_2Cl_2$ (39 pages). Ordering information is given on any current masthead page.

Synthetic Model for Dioxygen Binding Sites of Non-Heme Iron Proteins. X-ray Structure of Fe(OBz)(MeCN)(HB(3,5-iPr$_2$pz)$_3$) and Resonance Raman Evidence for Reversible Formation of a Peroxo Adduct

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Received January 16, 1990

The chemistry of dioxygen/porphyrin iron and related complexes continues to attract the attention of many chemists because of its relevance to biological systems.[1] On the contrary, little work has been done on the synthesis of dioxygen/non-porphyrin iron complexes,[2] although a family of non-heme iron containing oxygen carriers and oxygenases are now known. Among the proteins, the best characterized is hemerythrin, an oxygen carrier for some marine worms.[3] Although it contains a binuclear site, dioxygen binds only to one iron(II) center which is five-coordinate. The other non-heme proteins in this family, except methane monooxygenase, are known to contain a mononuclear iron site, and the coordination of multiple histidyl nitrogen atoms to iron has been suggested by analogy with hemerythrin. Our strategy for the development of a functional model for these non-heme iron proteins, therefore, lies in the synthesis of a mononuclear five-coordinate iron(II) complex by use of a hindered tris(pyrazolyl)borate ligand[4] which could allow us to see the binding of dioxygen at the open coordination site of the complex.[5] In this communication, we report the first success of such efforts.

The reaction of a tetrahedral iron(II) complex Fe(Cl)(HB(3,5-iPr$_2$pz)$_3$)[6] with an equimolar amount of NaOBz in toluene under argon gives a mononuclear complex, Fe(OBz)(HB(3,5-iPr$_2$pz)$_3$) (**1**).[7] Complex **1** is coordinatively unsaturated and accordingly reacts readily with MeCN or pyridine to yield the six-coordinate adduct. The crystal structure of Fe(OBz)(MeCN)(HB(3,5-iPr$_2$pz)$_3$) (**2**) was determined[8] and is shown in Figure 1. The benzoate group coordinates to the iron in a bidentate fashion, forming an octahedral coordination geometry.[9] The Fe–N bond lengths from the tris(pyrazolyl)borate ligand are similar to each other, with an average value of 2.14 Å, but significantly shorter than that of the MeCN ligand (2.28 Å). The

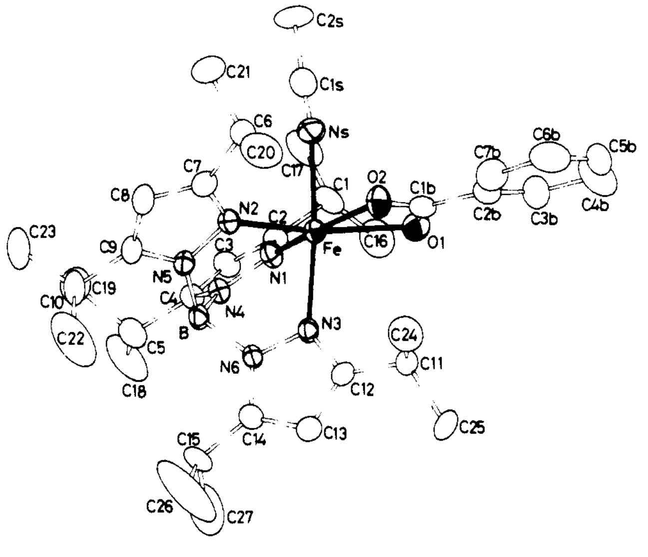

Figure 1. ORTEP view of **2**. Selected bond distances (Å) and angles (deg): Fe–O1, 2.252 (8); Fe–O2, 2.135 (8); Fe–Ns, 2.276 (9); Fe–N1, 2.116 (7); Fe–N2, 2.118 (7); Fe–N3, 2.196 (7); O1–C1b, 1.277 (16); O2–C1b, 1.215 (17); O1–Fe–O2, 59.2 (3); O1–C1b–O2, 121.0 (1.0); Ns–Fe–N1, 88.4 (3); Ns–Fe–N2, 90.2 (3); Ns–Fe–N3, 174.0 (3); Ns–Fe–O1, 86.1 (3); Ns–Fe–O2, 86.0 (3); Fe–Ns–C1s, 172.4 (9); N1–Fe–O1, 105.9 (3); N2–Fe–O2, 103.0 (3).

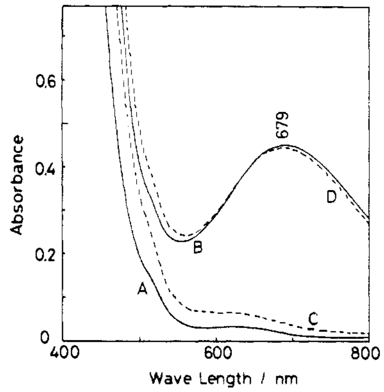

Figure 2. Electronic spectral changes of **1** in toluene under argon and dioxygen at −20 °C: (A) **1** in toluene under argon (concentration, 1.1 mM); (B) dioxygen is bubbled for 2 min in solution A; (C) argon is bubbled for 15 min in B; (D) dioxygen is bubbled for 2 min in C.

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[5] As an accurate hemerythrin model, an asymmetric binuclear iron(II) complex which contains a five-coordinate iron was recently reported: Tolman, W. B.; Bino, A.; Lippard, S. J. *J. Am. Chem. Soc.* **1989**, *111*, 8522.

[6] Fe(Cl)(HB(3,5-iPr$_2$pz)$_3$) was synthesized by the reaction of $FeCl_2$ and KHB(3,5-iPr$_2$pz)$_3$ in CH_2Cl_2: Kitajima, N.; Fukui, H.; Moro-oka, Y. *Inorg. Chim. Acta*, submitted for publication.

[7] Abbreviations used: HB(3,5-iPr$_2$pz)$_3$, hydrotris(3,5-diisopropyl-1-pyrazolyl)borate; OBz, benzoate. Anal. Calcd for $C_{34}H_{51}N_6O_2BFe$: C, 63.56; H, 8.00; N, 13.08. Found for **1**: C, 62.83; H, 8.20; N, 12.84. IR (KBr, cm^{-1}): ν(HB), 2533; ν_a(COO). 1538; ν_s(COO), 1418.

[8] Recrystallization of **1** from MeCN at −20 °C yielded **2** as slightly yellow needles. Anal. Calcd for $C_{36}H_{54}N_7O_2BFe$: C, 63.26; H, 7.96; N, 14.34. Found for **3**: C, 63.18; H, 8.17; N, 14.75. IR (KBr, cm^{-1}): ν(BH), 2531; ν(CN), 2281; ν_a(COO), 1537; ν_s(COO), 1418. Magnetic susceptibility, solid state at 25 °C, 5.35 μ_B. **2** (FW, 683.53) crystallizes in the monoclinic space group $P21/n$ with $a = 26.007$ (10) Å, $b = 15.320$ (3) Å, $c = 9.936$ (3) Å, $\beta = 93.93$ (2)°, $V = 3950$ (2) Å^3, $Z = 4$. The structure was solved by direct methods and refined by full-matrix least squares with anisotropic thermal parameters for all non-hydrogen atoms. Hydrogen atoms except the ones on the methyl groups were calculated and fixed in the final refinements with d(C–H), 1.0 Å. The final R and R_w values are 8.97 and 9.15%, respectively, for 4075 independent reflections ($2° < 2\theta < 55°$, $F_o > 3\sigma(F_o)$).

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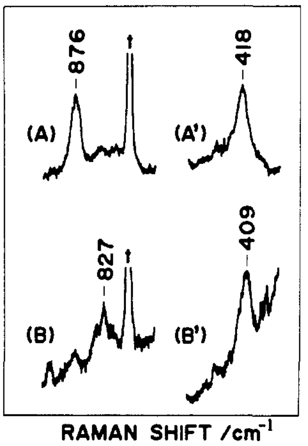

Figure 3. Resonance Raman spectra in the 1000–800 and 500–350-cm^{-1} regions of the O_2 adduct of **1** at −80 °C in a spinning cell: (A and A′) $^{16}O_2$ adduct; (B and B′) $^{18}O_2$ adduct. Excitation, 676 nm, 20 mW. Exposure time, 3.2 s. Number of scans, 100. The spectra were observed with a Kr$^+$ ion laser and an OMA-III system. Peaks marked by a dagger are due to solvent (toluene).

removal of the MeCN molecule in **2** to recover **1** is effected upon the evacuation of the solid sample under vacuum. Thus, **1** is a five-coordinate species (a N_3O_2 ligand donor set) having one open coordination site.

Figure 2 explores the interaction between **1** and dioxygen. A solution of **1** in toluene (trace A) shows no characteristic absorption band in the visible region under an argon atmosphere. Bubbling of dioxygen into the solution at −20 °C causes an immediate color change from pale yellow to dark green, giving rise to a strong band at 679 nm (trace B), which disappears upon bubbling with argon (trace C). A second treatment with dioxygen reproduces the characteristic band at 679 nm, whose intensity is almost the same as that of the initial one (trace D). These results clearly demonstrate reversible binding of dioxygen to **1**.

Resonance Raman spectra of the oxygenated complex in toluene excited at 676 nm were observed at −80 °C with a spinning cell (1800 rpm). The results are shown in Figure 3, where the spectra of $^{16}O_2$ (A and A′) and $^{18}O_2$ derivatives (B and B′) are displayed. The 876- and 418-cm^{-1} bands of the $^{16}O_2$ derivative are downshifted to 827 and 409 cm^{-1}, respectively, in the $^{18}O_2$ derivative, although a small amount of the $^{16}O_2$ derivative is present as a contaminant in spectrum B. The magnitude of the frequency shifts is in reasonable agreement with the values expected on the basis of diatomic approximation (50 and 15 cm^{-1}, respectively). Accordingly, the 876- and 418-cm^{-1} bands are assigned to the O–O and Fe–O_2 stretching vibrations, respectively. These Raman bands were not observed upon blue and green excitation, implicating that the 679-nm absorption arises from a charge-transfer transition between dioxygen and iron. Although the O–O stretching is slightly higher than that of oxyhemerythrin (845 cm^{-1}),[10] it is located in a frequency region typical for peroxo transition-metal complexes.[11,12] In fact, the manometric measurement of the O_2 uptake at −78 °C is 0.5 mol/mol of **1**,[13] implying the formation of a peroxo-bridged binuclear iron(III) complex.[14]

One of the striking features of **1** is its inertness toward CO. The toluene solution of **1** saturated with CO does not give any IR absorption band ascribed to a coordinated CO at room temperature. This is in contrast to the CO binding ability of the iron(II) porphyrin complexes. However, this is consistent with hemerythrin, which yields no stable CO adduct. Consequently, **1** can mimic, at least in part, the structure and function of nonheme iron containing oxygen transport proteins.

Acknowledgment. We thank Prof. Y. Ishimura and Dr. R. Makino of Keio University for low-temperature measurements of electronic spectra and Prof. Y. Fukuda of Ochanomizu University for magnetic susceptibility measurements. We appreciate the kind editing of this manuscript by Dr. J. K. Bashkin of Monsanto. Supports for this research from the Ministry of Education, Science and Culture, Japan (62430018 and 01607003), are gratefully acknowledged. N.K. is also grateful to Kawakami Memorial Foundation for financial support.

Supplementary Material Available: Tables S-I–S-V of crystallographic details, atomic coordinates including hydrogens and isotropic thermal parameters, anisotropic thermal parameters, and bond distances and angles for **2** (10 pages); Table S-VI of observed and calculated structure factors for **2** (12 pages). Ordering information is given on any current masthead page.

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[12] A few peroxo iron complexes whose structures were confirmed by resonance Raman spectroscopy are as follows. (a) Fe–(O_2): Ahmad, S.; McCallum, J. D.; Shiemke, A. K.; Appelman, E. H.; Loehr, T. M.; Sanders-Loehr, J. *Inorg. Chem.* **1988**, *27*, 2230 (ν(O–O), 815 cm^{-1}). (b) Fe–(O_2)–Fe: Sawyer, D. T.; McDowell, M. S.; Spencer, L.; Tsang, P. K. S. *Ibid.* **1989**, *28*, 1166 (ν(O–O), 882 cm^{-1}). (c) Fe_2–(O_2)–Fe_2: Micklitz, W.; Bott, S. G.; Bentsen, J. G.; Lippard, S. J. *J. Am. Chem. Soc.* **1989**, *111*, 372 (ν(O–O), 853 cm^{-1}).

[13] The consumed amount of dioxygen was determined with a closed vacuum system equipped with a manometer. The measurements were performed with cooling of the solution at −78 °C. Comparison of the pressure decrease with blank experiments showed that 0.666 mmol of **1** in 20 mL of toluene reacts with 0.314 mmol of dioxygen.

[14] The other possibilities that the adduct is a mononuclear peroxo iron complex or an asymmetric binuclear complex, in which the peroxide ion coordinates to one side iron, are not excluded at the present stage.

Macrolactams: A New Class of Antifungal Agents

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Received March 5, 1990

Various structural classes of compounds such as macrolides, peptides, nucleosides, polyenes, heterocycles, etc. exhibit antifungal activity. Recently, during our efforts to pursue novel antifungals,[2] we have isolated members of a new class of potent antifungal agents[3,4] which comprise a 14-membered macrocyclic lactam ring attached to a sugar. Structure elucidation of members of this novel class of compounds proved difficult owing to the absence of similar compounds in the literature as well as to the presence of a multiple number of saturated carbon atoms. Sch 38516 (**1**), produced by *Actinomadura vulgaris* subsp. *lanata*,[5,6] is a representative member

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[1] (a) Microbial Products Department. (b) Chemical Research Department. (c) Molecular Spectroscopy Department.

[2] Detailed assay procedures were presented at the 1987 Annual SIM meeting held at Baltimore, MD, Aug 8–14, 1987: Lotvin, J. A.; Smith, E. B.; Shaw, K. J.; Ryan, M. J., PS #12.

[3] Four papers on these macrolactams were presented at the 28th ICAAC meeting held at Los Angeles, CA: Paper No. 305–308, Oct 1988.

[4] Manuscripts detailing taxonomy, fermentation, isolation, and structures are in preparation.

[5] The producing microorganism was obtained from a soil sample collected in Missouri.

[6] A manuscript detailing the taxonomy, fermentation, and isolation is in preparation.

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