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Synthesis of Chiral Bitetralin-strapped "Twin Coronet" Porphyrins. Catalytic and Asymmetric Epoxidation of Styrene Derivatives

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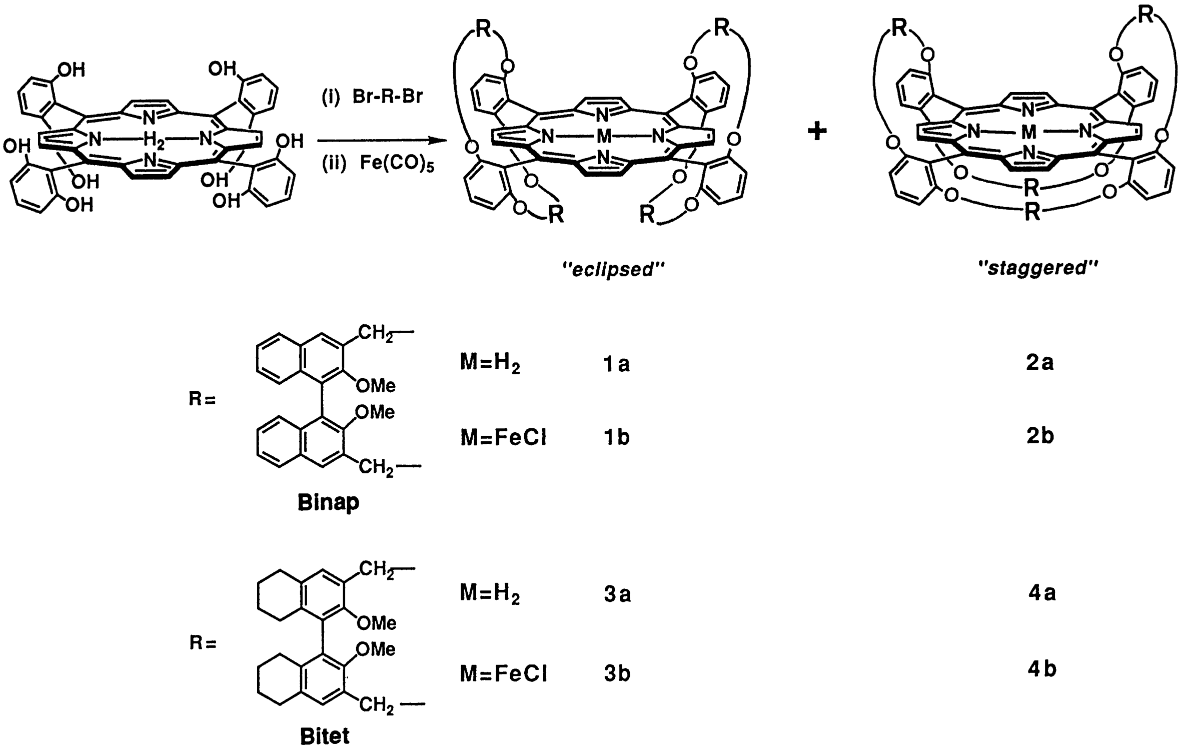
"Twin-coronet" porphyrins bearing optically active 1,1'-bitetrahydronaphthalene derivatives on the both faces of the porphyrin were prepared as enantioselective oxidation catalysts modeling on cytochrome P-450s. The eclipsed isomer of the corresponding iron(III) porphyrins catalyzed epoxidation of styrenes substituted with electron-withdrawing groups in high e.e. (61-89%) and high product selectivity.

Catalytic amplification of chirality is one of major topics in organic synthesis. In comparison with enantioselective hydrogenation and C-C bond formation, enantioselective oxidation of simple substrate is not fully exploited area for its difficulties:[1,2] (1) One can apply only a limited number of chiral auxiliaries or ligands which sustain oxidative degradation, and (2) one has to develop effective methodology for substrate prochiral-face recognition without bond formation including hydrogen bond between a catalyst and a substrate. To establish general methodology to solve the

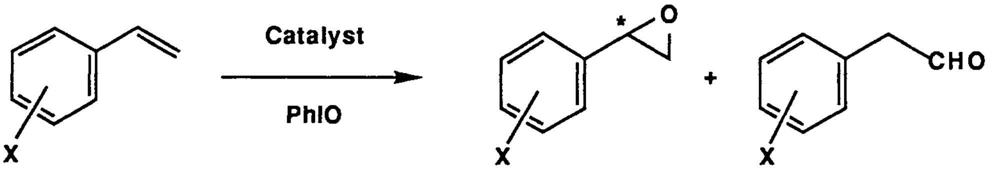


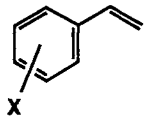
problem, we have studied on catalytic oxidation of olefins$^{3)}$ and sulfides$^{4)}$ with iron "twin coronet" porphyrins (Binap, **1b** and **2b**) which bear optically-active binaphthalene auxiliaries on their both faces. These catalysts exhibited moderate to high e.e. (11-80%) in enantioselective epoxidation of styrene derivatives. Remarkably, the *eclipsed* catalyst epoxidized styrenes substituted with electron-deficient group(s), e.g. 2-nitrostyrene, in up to 80% e.e. From detailed mechanistic analysis, we concluded that the frontier orbital (π-π^*) interaction between the appended π system (a donor) on the catalyst and the π^* level of a substrate aromatic ring (an acceptor) works properly to fix substrate on the catalyst in the oxo transfer stage.$^{3b)}$ According to our conclusion, a higher e.e. could be attained, if we use more electron-donating auxiliaries on the catalyst. To confirm this assumption, we designed and synthesized analogous twin-coronet porphyrins (Bitet) bearing bi(tetrahydronaphthalene) derivatives. Except the saturation of the binaphthalene distal ring, the other part of the catalyst was left unchanged. This will be favorable for the evaluation of the stereoelectronic effect of the auxiliary on the product enantioselectivity. Their synthesis was similarly performed by the similar method as the corresponding Binap derivatives by means of the coupling reaction between 5,10,15,20-tetrakis(2,6-dihydroxyphenyl)porphyrin and optically pure [1,1'-bi-5,6,7,8-tetrahydronaphthalene]-3,3'-bis(bromomethyl)-2,2'-diol dimethyl ether in the presence of K_2CO_3.$^{5,6)}$ The two isomeric porphyrins, eclipsed (**3a**) and staggered (**3b**), were converted to the corresponding iron (III) derivatives, **4a** and **4b**, respectively.$^{6)}$

Catalytic epoxidation of styrene derivatives was performed under standard conditions: the catalyst (1 μmol), an olefin (500 μmol) , and a GLC standard were dissolved in deaerated dry CH_2Cl_2. Reaction was initiated by the addition of PhIO (100 μmol) and stirring at a constant speed under an Ar atmosphere at 0 °C in the dark. At appropriate intervals, aliquots taken from the reaction mixture were quenched by PPh_3 and analyzed by GLC. After confirming the cessation of product increase, the products were isolated by silica-gel flash chromatography. Results are summarized in Table 1. In the most cases examined, the corresponding epoxides were obtained in reasonable yields.$^{7)}$ The e.e. values of the obtained epoxides are compared with those obtained in the reaction with the corresponding Binap catalysts. Among two isomeric catalysts **3b** and **4b**, the eclipsed form **3b** gave higher e.e. values of epoxide than **4b**. The highest e.e. (89%) was attained in the oxidation of 2-nitrostyrene. Other styrene derivatives with electron-withdrawing group(s) were also converted to the corresponding epoxide in high e.e. (61-83%) with the catalyst **3b**.

Three characteristic features are observed: (1) In the oxidation of styrenes with electron-deficient group(s), the Bitet catalyst **3b** gave the epoxides in higher e.e. than the corresponding Binap **1b**, (2) a good correlation of the epoxide e.e. values between the Binap and the Bitet catalyzed reaction, and (3) for styrene derivatives except to 2-methoxystyrene, the Bitet catalyst did not give a detectable amount of the corresponding arylacetaldehyde by means of GLC and ^1H NMR, whereas the Binap gave the aldehyde in ≈10% of overall oxidized products. The observed linear correlation in epoxide e.e. between the two types of the twin-coronet porphyrins suggests that the prochiral-face recognition of the substrates is governed by a similar mechanism. Between the two different auxiliaries, the major difference is their electron density of the proximal aromatic rings to the porphyrin ring: The Bitet appendage is more electron-rich than the Binap moiety owing to the

Table 1. Asymmetric oxidation of substituted styrene derivatives with Bitet "twin-coronet" porphyrin catalysts.



		Reaction	Turnover no.a)		Epoxide e.e.,%b)		Confign.e)
X	Catalyst	time / h	Epoxide	Aldehyde	With Bitetc)	With Binapd)	
H	(*S*)-**3b**	3	28	0	56	20	*R*
H	(*R*)-**4b**	7	44	0	28	-f)	*S*
2-NO_2	(*R*)-**3b**g)	7	42	0	89	80	(*S*)
2-NO_2	(*R*)-**4b**	3	10	0	43	54	(*S*)
3-NO_2	(*R*)-**3b**	2	26	0	74	60	(*S*)
4-NO_2	(*R*)-**3b**	3	21	0	67	54	(*S*)
2,4-(NO_2)	(*R*)-**3b**h)	12	13	0	61	68	(*S*)
3,5-(NO_2)	(*R*)-**3b**	3	30	0	82	74	(*S*)
F_5	(*S*)-**3b**	3	10	0	83	74	*R*
2-MeO	(*S*)-**3b**	3	0	35	-	0	-
3-MeO	(*R*)-**3b**	2	33	0	73	45	(*S*)

a) mol product/mol catalyst. b) Enantiomeric excesses were determined by ^{1}H NMR spectroscopy performed in the presence of a chiral shift reagent, tris[3-((heptafluoropropyl)hydroxymethylene)-(+)-camphorato]europium (III), $Eu(hfc)_3$. c)This work. d) Epoxides obtained in the reaction with the corresponding Binap modified catalysts **1b** or **2b** Taken from ref. 3b. d) Major configurations of styrene and perfuruorostyrene oxides were determined by comparison with the authentic optically pure epoxides. Others in parentheses were determined from analogy with the spectroscopic behavior of (*R*)-styrene oxide. f) Not examined. g) 0.73 µmol catalyst was used. h) 0.37 µmol catalyst was used.

saturation of its distal six-membered ring. Thus, the Bitet favors the CT interaction with electron-deficient aromatic rings. Moreover, from CNDO/2 MO calculation of the Bitet group, the electron density profile of its HOMO is similar to that of the Binap. Therefore, the magnitude of the assumed π-π^* interaction between the host and electron-deficient guests will be larger in the Bitet catalyst than the Binap one, and electron-deficient substrates will be fixed more tightly at the oxo transfer stage in the chiral cavity. Steric factor is another controlling one of the enantioselectivity. The Bitet catalyst has more crowded cavities than·the Binap. From CPK model study, the tetramethylene chains of the Bitet auxiliary will make steric hindrance as *a canopy* over the porphyrins and the molecular motion of substrate olefins incorporated into the chiral cavity will be considerably restricted. This steric effect will effectively work to fix the substrates inside the cavity and to enhance the catalyst enantioselectivity. More detailed analysis of enantioselectivity including oxidation mechanism is under way.

References

1) Review: *Chem. Br.*, **1989**, 259.

2) With enzymes: G. L. Foureman, C. Harris, F. P. Guengerich, and J. R. Beno, *J. Pharm. Exp. Ther.*, **248**, 492 (1989); P. R. Ortiz de Montellano, J. A. Frutel, J. R. Collins, D. L. Camper, and G. H. Loew, *J. Am. Chem. Soc.*, **113**, 3195 (1991). With metalloporphyrins: J. T. Groves and R. S. Myers, *ibid.*, **105**, 5791 (1983); D. Mansuy, P. Battioni, and J. -P. Renaud, and P. Guerin, *J. Chem. Soc., Chem. Commun.*, **1985**, 155; S. O'Malley and T. Kodadek, *J. Am. Chem. Soc.*, **111**, 9116 (1989); J. T. Groves and P. Viski, *J. Org. Chem.*, **55**, 3628 (1990). With nonheme metal complexes; K. Tani, M. Hanafusa, and S. Otsuka, *Tetrahedron Lett.*, 3017 (1979); R. Curci, M. Fioreutino, and M. R. Serio, *J. Chem. Soc., Chem. Commun.*, **1984**, 155; R. Sinigalia, R. A. Michelin, F. Pinna, G. Strukul, *Organomettalics*, **6**, 728 (1987); W. Zhang, J. L. Loebach, S. R. Wilson, E. N. Jacobsen, *J. Am. Chem. Soc.*, **112**, 2801 (1990); R.Irie, K. Noda, Y. Ito, N. Matsumoto, and T. Katsuki, *Tetrahedron Lett.*, **31**, 7345 (1990); R. Irie, K. Noda, Y. Ito, and T. Katsuki, *ibid.*, **32**, 1055 (1991).

3) a) Y. Naruta, F. Tani, and K. Maruyama, *Chem. Lett.*, **1989**, 1269. b) Y. Naruta, F. Tani, N. Ishihara, and K. Maruyama, *J. Am. Chem. Soc.*, in press.

4) Y. Naruta, F. Tani, and K. Maruyama, *J. Chem. Soc., Chem. Commun.*, **1990**, 1378; Y. Naruta, F. Tani, and K. Maruyama, *Tetrahedron: Asymmetry*, **2**, 533 (1991).

5) A THF-acetone solution (75 ml, 1:1) of the octahydroxyporphyrin (120 mg) and the bi(bromomethyltetraline) (394 mg) was heated in an autoclave with K_2CO_3 (1.0 g) under high-purity Ar at 180 °C for 6 days. The Bitet porphyrins **3a** and **4a** were obtained in 3 and 8% yields, respectively. Detailed synthetic procedure will be published elsewhere.

6) All new compounds afforded satisfactory ^{1}H NMR and/or high resolution FAB-MS data.

7) Turnover numbers correspond to the product yield based on PhIO applied. For the electron-deficient olefins, these yields were low. This is attributed to the presence of the competitive disproportionation pathway of PhIO to PhI and $PhIO_2$ in the presence of a metal catalyst.

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