# Metalloporphyrin as an Efficient Catalyst in the Regioselective Isomerization of Epoxides to Carbonyl Compounds

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(Received August 22, 1996)

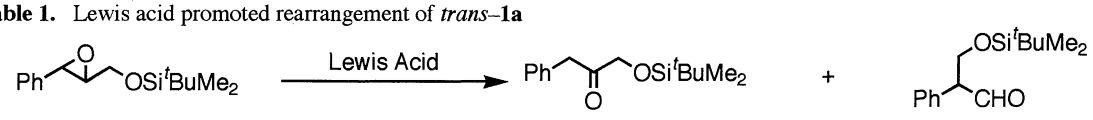
Regioselective ring-opening isomerization of epoxides to carbonyl compounds can effectively be catalyzed by iron (III) tetraphenylporphyrin, Fe(tpp)$ClO_4$.

Brϕnsted or Lewis acid-promoted conversion of epoxides to carbonyl compounds is a well known but still challenging topic in organic synthesis.[1–3] Despite a number of methods in this field, only a few *catalytic* conversion systems have been appeared.[2] Most of the reactions being reported so far required more than a stoichiometric amount of reagents, *e.g.*, $BF_3$ and its etherate, lithium and magnesium halides, *etc.*[1–3] In addition, the ring opening with these reagents frequently lacks regioselectivity, giving a mixture of products, unless any structural and streochemical bias is present in the substrates.[1,3] Recently, we have reported that manganese (III) tetraphenylporphyrin, Mn(tpp)Cl, is a regio- and stereoselective catalyst for the rearrangement of *N*–arylspirooxaziridins into lactams.[4] We now report here that high valent metalloporphyrins, especially iron (III) tetraphenylporphyrin, Fe(tpp)$ClO_4$, work as a mild and characteristic Lewis acid catalyst for the regioselective isomerization of di- and trisubstituted epoxides (**1**) into the corresponding ketones (**2**).

As a model substrate for the catalytic isomerization, *trans*-2-(*t*-butyldimethylsiloxy)methyl-3-phenyloxirane (*trans*-**1a**) was chosen, and the catalytic isomerization with various tetraphenylporphyrin complexes was investigated. The reaction of *trans*-**1a** was carried out in 1, 2-dichloroethane at 80 °C with 2 mol% of a tetraphenylporphyrin complex. As shown in Table 1, Fe(tpp)$ClO_4$ was the most effective catalyst examined, and the total yield and the ratio of ketone **2a** and aldehyde **3a** were in the order: Mn(tpp)Cl (0%) ≈ Fe(tpp)Cl (0%) ≪ Mn(tpp)$ClO_4$ (98%, **2a**:**3a**=54:46) < Fe(tpp)$ClO_4$ (~100%, **2a**:**3a**=67:33) (runs 1–4).[5] In the Fe(tpp)$ClO_4$ catalyzed rearrangement, the selectivity between **2a** and **3a** was dramatically changed with the solvents used. For example, highly regioselective trans-formation of *trans*-**1a** to **2a** *via* a hydride shift occurred in dioxane at 80 °C (**2a**:**3a**=99:1) (run 5). In contrast to this catalytic system, the use of an equimolar amount of $BF_3$ etherate, which is one of the most widely employed reagents for the epoxides ring opening, could not take place the isomerization, only the starting material *trans*-**1a** being decomposed (run 6).

Under the conditions adopted in run 5, we next examined the rearrangement of various epoxides **1**. The catalytic transformation of **1a–f** was carried out in dioxane at 80 °C with a catalytic amount of Fe(tpp)$ClO_4$ (2 mol%).[6] The results are summarized in Table 2. In the reactions of phenylepoxides, *trans*-**1a** and *cis*-**1a**, both substrates were regioselectively converted to the corresponding ketone **2a** in quantitative yields, regardless of their stereochemistry. Other phenyl derivatives **1b** and **1c** also gave ketones **2b** and **2c**, respectively, in excellent yields. The ring opening of cyclic epoxides **1d–f** are noteworthy. The reactions of cyclic epoxides with conventional Lewis acids, such as $ZnBr_2$, $BF_3$, *etc.*, have been reported to give a mixture of the corresponding cyclic ketones and the ring contracted aldehydes.[1] However, the present catalytic transformation of **1d–f** was completely regioselective, providing the corresponding cyclic ketones **2d–f** as the sole products without any ring contraction. Based on the results obtained, the present catalytic transformation of epoxides is rationalized as follows:

**Table 1.** Lewis acid promoted rearrangement of *trans*–**1a**

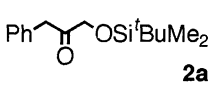
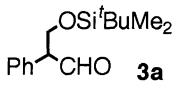
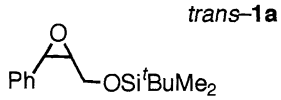
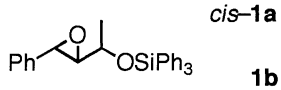
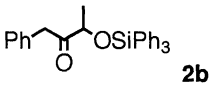
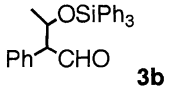
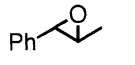
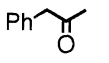
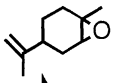
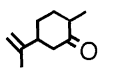
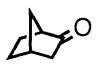



*trans*–**1a** **2a** **3a**

| Run | Lewis Acid (mol%) | Conditions: solvent / time / temp | Yield (%)[a] | Ratio (**2a**:**3a**)[b] |
|---|---|---|---|---|
| 1 | Mn(tpp)Cl (2) | $(CH_2)_2Cl_2$ / 48 h / 80 °C | no reaction | |
| 2 | Fe(tpp)Cl (2) | $(CH_2)_2Cl_2$ / 48 h / 80 °C | no reaction | |
| 3 | Mn(tpp)$ClO_4$ (2) | $(CH_2)_2Cl_2$ / 1 h / 80 °C | 98 | 54:46 |
| 4 | Fe(tpp)$ClO_4$ (2) | $(CH_2)_2Cl_2$ / 1 h / 80 °C | 100 | 67:33 |
| 5 | Fe(tpp)$ClO_4$ (2) | dioxane / 0.5 h / 80 °C | 100 | 99:1 |
| 6 | $BF_3$•$OEt_2$ (100) | $(CH_2)_2Cl_2$ / 48 h / 80 °C | decompd. | |

[a] Isolated yield. [b] Determined by 270 MHz $^1$H-NMR analysis of the crude reaction mixture.

**Table 2.** Fe(tpp)$ClO_4$ catalyzed isomerization of epoxides **1** to ketones **2**

| Run | Substrate | Time (h) | Products | Yield (%)[a] |
|---|---|---|---|---|
| 1 |  *trans*-**1a** | 0.5 |  **2a** +  **3a** | 100 (**2a**:**3a**=99:1)[b] |
| 2 |  *cis*-**1a** | 0.5 | **2a** + **3a** | 100 (**2a**:**3a**=96:4)[b] |
| 3 |  **1b** | 1.0 |  **2b** +  **3b** | 91 (**2b**:**3b**=96:4)[b] |
| 4 |  **1c** | 2.5 |  **2c** | 90 |
| 5 |  **1d** | 5.5 |  **2d** | 83 |
| 6 |  **1e**[c] | 8.0 |  **2e**[c] | 73 |
| 7 |  **1f** | 3.0 |  **2f** | 77 |

[a] Isolated yield. [b] The isomer ratios were determined by 270MHz $^1$H-NMR analysis of the crude reaction mixture. [c] A 1:1 mixture of *cis* and *trans* isomers.

Coordination of the metalloporphyrin, Fe(tpp)$ClO_4$, to the epoxide oxygen is followed by the regioselective cleavage of the C–O bond to give the most stable carbocation which is transformed into the ketone *via* 1, 2-shift of the hydride.

In summary, Fe(tpp)$ClO_4$ is an efficient and highly regioselective catalyst for the isomerization of various epoxides to carbonyl compounds. Generalization and application of this unique catalytic system utilizing high valent metalloporphyrins are a matter of continuing concern in this laboratory.

This research was supported in part by a Grant-in-Aid for Scientific Research (C) (No. 08672454) from the Ministry of Education, Science, Sports, and Culture, Japan, and The Science Research Promotion Fund from Japan Private School Promotion Foundation.

## References and Notes

1 a) B. Rickborn, in "*Comprehensive Organic Synthesis*," ed by B. M. Trost and I. Fleming, Pergamon Press, New York (1991), Vol. 3, p. 733. b) J. G. Smith, *Synthesis*, **1984**, 629, and references cited therein.

2 Following Lewis and none-Lewis acid catalyzed reactions have been reported. a) [Pd(0) complexes] S. Kulasegaram, and R. Kulawiec, *J. Org. Chem.*, **59**, 7195 (1994). b) [Tris-(pentafluorophenyl)boron] K. Ishihara, N. Hanaki, and H. Yamamoto, *Synlett*, **1995**, 721. c) [EGA (electrogenerated acid)] K. Uneyama, A. Ishimura, K. Fujii, and S. Torii, *Tetrahedron Lett.*, **24**, 2857 (1983). d) [$Ph_3SiClO_4$] T. Inokuchi, M. Kusumoto, S. Matsumoto, H. Okada, and S. Torii, *Chem. Lett.*, **1991**, 2009. e) [TCNE (tetracyanoethylene)] Y. Masaki, T. Miura, and M. Ochiai, *Chem. Lett.*, **1993**, 17, and references cited therein.

3 Several Lewis-acid reagents have been reported for the regioselective isomerization of epoxides. a) [Organoboron reagents] see Ref. 2b. b) [Organoaluminum reagents] K. Maruoka, N. Murase, R. Bureau, T. Ooi, and H. Yamamoto, *Tetrahedron*, **50**, 3663 (1994). c) [5M $LiClO_4$ in ether] R. Sudha, K. M. Narasimhan, V. G. Saraswathy, and S. Sankararaman, *J. Org. Chem.*, **61**, 1877 (1996), and references cited therein.

4 K. Suda, M. Sashima, M. Izutsu, and F. Hino, *J. Chem. Soc., Chem. Commun.*, **1994**, 949.

5 Fe(tpp)$ClO_4$ and Mn(tpp)$ClO_4$ were prepared from Fe(tpp)Cl and Mn(tpp)Cl, respectively, by the axial ligand exchange with $AgClO_4$ in THF followed by recrystallization (hexane-$CH_2Cl_2$). These complexes were characterized by UV–VIS spectroscopy, cyclic voltammetry and elemental analysis.

6 General procedure: An epoxide **1** (1 mmol) was heated at 80 °C with 0.02 mmol of Fe(tpp)$ClO_4$ in dioxane (3 ml). After completion of the reaction (monitored by TLC), the mixture was directly passed through a silica gel short column (1:1 hexane–ethyl acetate) to remove the catalyst. The eluate was concentrated under a reduced pressure, and the residue was then chromatographed on silica gel (1:1 hexane–ethyl acetate) to afford the corresponding ketones **2**. All the products gave satisfactory IR, NMR, and high resolution mass spectra. For example, $^1$H-NMR (270 MHz, $CDCl_3$) data of **2a** and **2b** are as follows. **2a**: δ 0.12 (6H, s), 0.97 (9H, s), 3.86 (2H, s), 4.29 (2H, s), 7.25–7.41 (5H, m); **2b**: δ 1.33 (3H, d, $J$ = 6.6 Hz), 3.75 and 3.90 (each 1H, d, $J$ = 16.5 Hz), 4.47 (1H, q, $J$ = 6.6 Hz), 6.97–7.67 (20H, m).