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3,3'-Dinitro-octahydrobinaphthol: A New Chiral Ligand for Metal-Catalyzed Enantioselective Reactions

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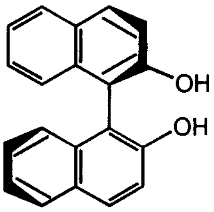
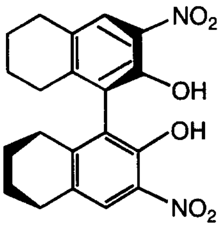
Abstract: Starting from *R*-configurated binaphthol the *R*-form of the title compound was readily prepared in two steps and characterized by X-ray structural analysis. It was used as the chiral ligand in the Ti-catalyzed asymmetric oxidation of methyl-p-tolylsulfide, the *S*-enantiomeric form of the sulfoxide being formed preferentially (ee = 86%).

Binaphthol **1** is a commercially available chiral compound which has played a pivotal role in stoichiometric[1,2] and catalytic[3-9] metal-mediated asymmetric reactions. For example, binaphtholtitanium dichloride, first prepared and characterized by our group in 1986,[3] is a chiral Lewis acidic catalyst which leads to mediocre enantioselectivity in most Diels-Alder cycloadditions,[3] but to unusually high stereoselection in ene-reactions.[4] Ligand **1** has also been used with other metals,[6] e. g., in the form of lanthanide ate-complexes to catalyze a variety of other enantioselective C-C bond forming reactions,[7] and as Ti-complexes to catalyze the ROOH-induced enantioselective oxidation of sulfides to sulfoxides.[8] Surprisingly, only a limited number of derivatives of **1** have been tested in asymmetric synthesis.[4-9] In this letter we describe the synthesis and first application of the dinitrooctahydro-derivative **2**, a compound which may be expected to be an interesting chiral Brönsted acid and/or a useful ligand in metal catalysis.

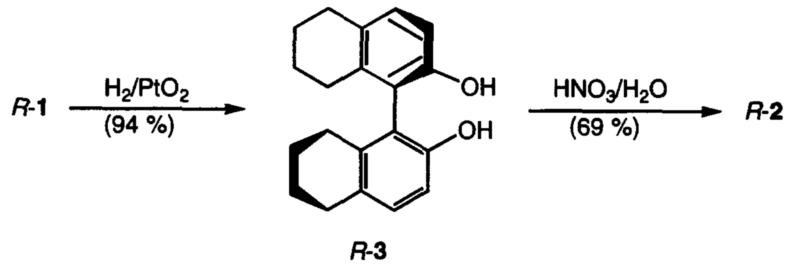


R-**1**

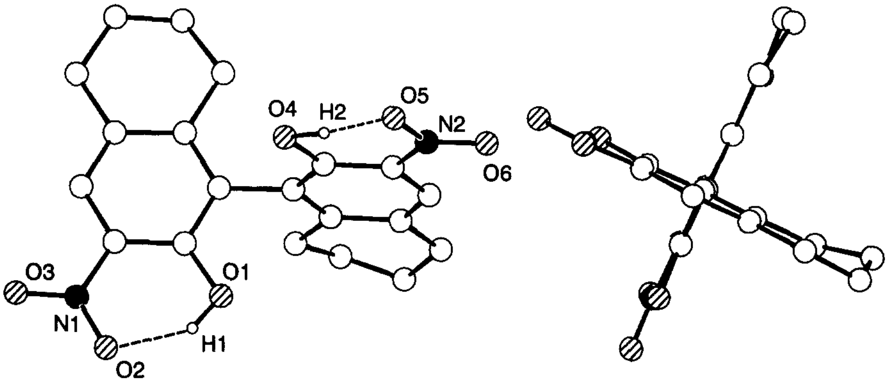


R-**2**

Using the protocol of Cram,[10] *R*-**1** was first reduced to the known octahydro-derivative *R*-**3**, which was then nitrated to form the title compound **2** having the *R*-configuration.[11] Direct nitration of *R*-**1** caused problems.



The enantiomeric purity (ee) of **2** as determined by HPLC (Chiralpak OP, Okomoto; mobile phase 100 % methanol) was found to be > 99 %. Its crystal structure reveals several interesting features (Fig. 1).[12] Both phenolic hydroxy functions participate in H-bonding with the α-nitro groups (Fig 1a), and the two aromatic π-systems are approximately perpendicular to one another (Fig. 1b).

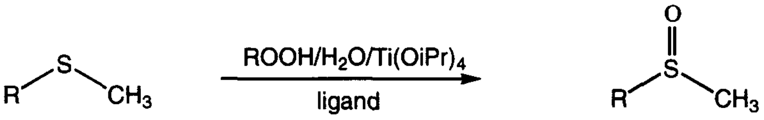


a) b)

Fig. 1. Crystal structure of **2**: a) sideview; b) view along the 1,1'-bond

In exploratory experiments directed toward testing *R*-**2** as a chiral ligand in metal catalyzed reactions, the enantioselective oxidation of sulfide **4** was studied. Using *tert*-butylhydroperoxide (TBHP) or cumene hydroperoxide (CHP), the Ti-catalyzed oxidation was performed in the presence of *R*-**2**, a process which had previously been carried out using *R*-binaphthol **1** with preferential formation of the *R*-configurated sulfoxide **5** (ee = 99 % under optimized conditions employing TBHP).[8] Surprisingly, in our case the preferential formation of the *S*-configurated product *S*-**5** was consistently observed (ee = 86 % using CHP in toluene,[13] ee = 60 % using TBHP in toluene; ee = 83 % using CHP in CCl_4; ee = 46 % using TBHP in

CCl_4). Under the latter conditions (CHP in CCl_4) the parent ligand **1** affords *R*-**5** with an ee-value of 42 %. Interestingly, ligand **3** behaves poorly under these conditions (*R*-**5** with ee ~ 10 %).



4 (R = tolyl)

5

The results show that chemical modification of binaphthol **1** results in drastic changes in the direction and degree of enantioselectivity in the above oxidation reactions. In particular, the presence of the ortho-nitro groups leads to the reversal of enantioselectivity (*S*- instead of *R*-product). Although the reason for this unexpected switch is currently unclear, our initial observations demonstrate the profound role of these electron-withdrawing groups, which may also be important in other metal-catalyzed reactions based on ligand **2**.

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REFERENCES AND NOTES

1. Cram, D. J.; Cram, J. M. *Acc. Chem. Res.* **1978**, *11*, 8.
2. Examples: Noyori, R.; Tomino, I.; Tanimoto, Y. *J. Am. Chem. Soc.* **1979**, *101*, 3129; Seebach, D.; Beck, A. K.; Imwinkelried, R.; Roggo, S.; Wonnacott, A. *Helv. Chim. Acta* **1987**, *70*, 954.
3. Reetz, M. T.; Kyung, S.-H.; Bolm, C.; Zierke, T. *Chem. Ind. (London)* **1986**, 824.
4. Mikami, K.; Terada, M.; Nakai, T. *J. Am. Chem. Soc.* **1989**, *111*, 1940; Mikami, K.; Terada, M. *Tetrahedron* **1992**, *48*, 5671; Motoyama, Y.; Terada, M.; Mikami, K. *Synlett* **1995**, 967; Terada, M.; Matsumoto, Y.; Nakamura, Y.; Mikami, K. *Chem. Commun. (Cambridge)* **1997**, 281; see also: Keck, G. E.; Geraci, L. S. *Tetrahedron Lett.* **1993**, *34*, 7827; Gauthier, D. R., Jr.; Carreira, E. M. *Angew. Chem.* **1996**, *108*, 2521; *Angew. Chem., Int. Ed. Engl.* **1996**, *35*, 2363.
5. Reviews of chiral Lewis acids: Narasaka, K. *Synthesis* **1991**, 1; Maruoka, K.; Yamamoto, H. In *Catalytic Asymmetric Synthesis*; Ojima, I. Ed.; VCH: Weinheim, 1993; p 413.
6. See for example: Hattori, K.; Yamamoto, H. *J. Org. Chem.* **1992**, *57*, 3264; Maruoka, K.; Murase, N.; Yamamoto, H. *J. Org. Chem.* **1993**, *58*, 2938; Kobayashi, S.; Ishitani, H. *J. Am. Chem. Soc.* **1994**, *116*, 4083; Kaufmann, D.; Boese, R. *Angew. Chem.* **1990**, *102*, 568; *Angew. Chem., Int. Ed. Engl.* **1990**, *29*, 545; Bedeschi, P.; Casolari, S.; Costa, A. L.; Tagliavini, E.; Umani-Ronchi, A. *Tetrahedron Lett.* **1995**, *36*, 7897; Kitajima, H.; Ito, K.; Aoki, Y.; Katsuki, T. *Bull. Chem. Soc. Jpn.* **1997**, *70*, 207.
7. Sasai, H.; Arai, T.; Satow, Y.; Houk, K. N.; Shibasaki, M. *J. Am. Chem. Soc.* **1995**, *117*, 6194; Shibasaki, M.; Sasai, H. *Pure Appl. Chem.* **1996**, *68*, 523.

8. Hassner, A.; Maurya, R.; Friedman, O.; Gottlieb, H. E.; Padwa, A.; Austin, D. . *J. Org. Chem.* **1993**, *58*, 4539; Komatsu, N.; Hashizume, M.; Sugita, T.; Uemura, S. *J. Org. Chem.* **1993**, *58*, 7624; previous Ti-catalyzed oxidations of sulfides using other ligands: Pitchen, P.; Duñach, E.; Deshmukh, M. N.; Kagan, H. B.; *J. Am. Chem. Soc.* **1984**, *106*, 8188; Brunel, J.-M.; Kagan, H. B. *Bull. Soc. Chim. Fr.* **1996**, *133*, 1109; Di Furia, F.; Modena, G.; Seraglia, R. *Synthesis* **1984**, 325; see also Bolm, C.; Bienewald, F. *Angew. Chem.* **1995**, *107*, 2883; *Angew. Chem., Int. Ed. Engl.* **1995**, *34*, 2883, and lit. cited therein.
9. Sasai, H.; Tokunaga, T.; Watanabe, S.; Suzuki, T.; Itoh, N.; Shibasaki, M. *J. Org. Chem.* **1995**, *60*, 7388; Green, J.; Woodword, S. *Synlett* **1995**, 155; Lipshutz, B. H.; James, B.; Vance, S.; Carrico, I. *Tetrahedron Lett.* **1997**, *38*, 753.
10. Agbossou, F.; Carpentier, J.-F.; Mortreux, A. *Chem. Rev.* **1995**, *95*, 2485, Cram, D. J.; Helgeson, R. C.; Peacock, S. C.; Kaplan, L. J.; Domeier, L. A.; Moreau, P.; Koga, K.; Mayer, J. M.; Chao, Y.; Siegel, M. G.; Hoffman, D. H.; Sogah, G. D. Y. *J. Org. Chem.* **1978**, *43*, 1930.
11. Preparation of *R*-(-)-2,2'-dihydroxy-5,5', 6,6', 7,7', 8,8'-octahydro-3,3'-dinitro-1,1'-binaphthyl (**2**): To the rapidly stirred solution of *R*-**3** (3 g; 10.2 mmol) in 24 ml of CH_2Cl_2 is added dropwise 12 ml of the mixture of 65 % HNO_3 and H_2O (5 : 3 ratio). The mixture is carefully heated to about 45 °C (dark orange color formation), and after 10 min, the phases are separated. The org. phase is washed twice with H_2O and once with sat. $NaHCO_3$ solution and dried over $MgSO_4$. Further purification is brought about by chromatography over SiO_2 (pentane/ether 5 : 1) to afford 2.7 g (69 %) of *R*-**2** having a corrrect elemental analysis (± 0.2); ^{13}C-NMR ($CDCl_3$) δ = 21.8, 21.9, 27.2, 28.3, 124.1, 125.7, 129.4, 133.1, 145.9, 148.2; $[\alpha]_{589}^{25} = -15.3$ (c = 4.66 g / 100 ml $CHCl_3$).
12. X-ray analysis of **2** (racemate): $C_{20}H_{20}N_2O_6$, $M_r = 384.4$ g mol^{-1}, yellow crystals, crystal size 0.46 × 0.56 × 0.63 mm, orthorhombic, *Pbca* [No. 61], $a = 12.640(1)$, $b = 21.783(1)$, $c = 13.194(1)$ Å, V = 3632.8(6) Å^3, T = 293 K, Z = 8, $d_{cal} = 1.41$ g cm^{-3}, $\mu = 0.11$ mm^{-1}, Enraf-Nonius CAD4 diffractometer, $\lambda = 0.71069$ Å, ω-2θ-scan, 3687 independent reflections, 1937 observed $[I > 2\sigma(I)]$, $[(\sin\theta)/\lambda]_{max} = 0.62$ Å^{-1}, no absorption correction, direct methods (SHELXS-86, Sheldrick, G. M. *Acta Cryst.* **1990**, *A46*, 467), least-squares refinement (on F_o^2, SHELXL-93, Sheldrick, G. M., University of Göttingen, 1993), H riding, 261 refined parameters [$w = 1/(\sigma^2(F_o^2) + (0.1015P)^2 + 2.9613P)$, where $P = (F_o^2+2F_c^2)/3$], $R_1 = 0.067$ (obs. data), $wR_2 = 0.182$, final shift/error 0.001, residual electron density +0.323 eÅ^{-3}. O1···O2 2.572(4) Å, O4···O5 2.554(5) Å. Atomic coordinates and e.s.d.'s have been deposited at the Cambridge Crystallographic Data Centre.
13. Oxidation of **4**: The ligand *R*-**2** (38.4 mg; 0.1 mmol) is placed in a Schlenk-tube under argon and dissolved in 2 ml of dry toluene. Then $Ti(OiPr)_4$ (14.7 µl; 0.05 mmol) is added which leads to a red coloration, followed by the addition of 18 µl (1.0 mmol) of distilled H_2O. After 1 h sulfide **4** (0.5 mmol) is added to the stirred (milky) mixture followed by cumene hydroperoxide (CHP) (185 µl of an 80 % solution in cumene; 1.0 mmol). After 45 min the mixture is worked up in the usual way,[8] affording 52 % of *S*-**5** having an ee-value of 86 %.

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