Pergamon

Tetrahedron: *Asymmetry* 9 (1998) 3985–3989

TETRAHEDRON:
ASYMMETRY

A simple, convenient preparation for enantiomerically pure 1,1′-bi-2-naphthols

Zixing Shan,* Ying Xiong, Weizhong Li and Dejie Zhao
Department of Chemistry, Wuhan University, Wuhan 430072, China

Received 26 August 1998; accepted 25 September 1998

Abstract

A new preparative method for enantiomerically pure 1,1′-bi-2-naphthols is described. 1,1′-Bi-2-naphtholboric anhydride generated from the reaction of racemic 1,1′-bi-2-naphthol and boric acid in toluene is reacted with (*S*)-proline to produce 1,1′-bi-2-naphtholboric proline anhydride. Its two diastereomers were efficiently separated in THF. After treating successively with NaOH, HCl, and recrystallizing from benzene, enantiomerically pure (*S*)- and (*R*)-1,1′-bi-2-naphthol were obtained in 71–79% yield and in 62–74% yield, respectively. © 1998 Elsevier Science Ltd. All rights reserved.

---

1. Introduction

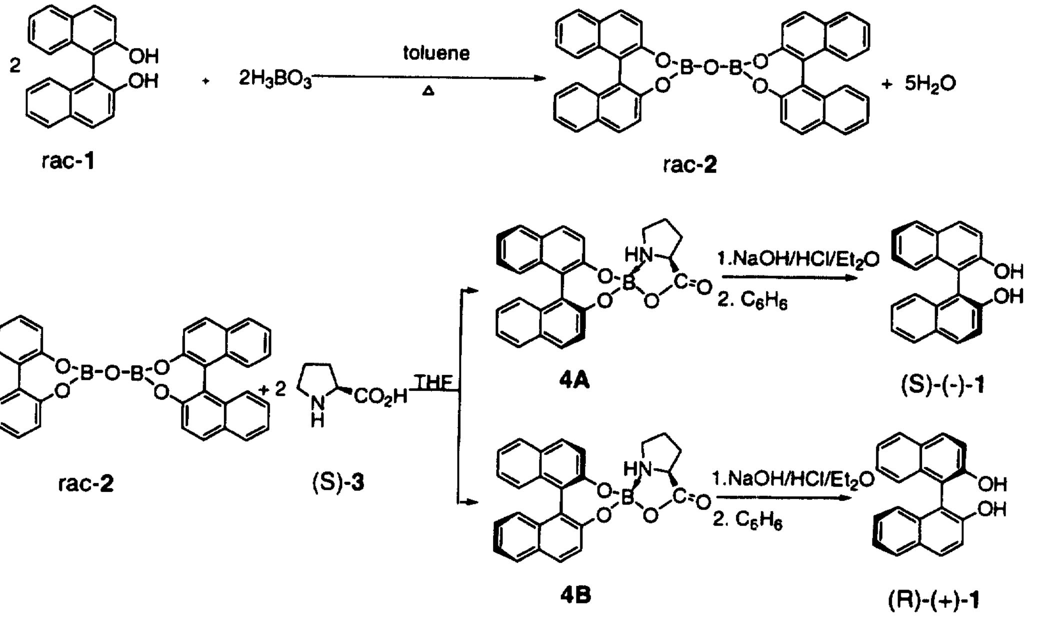
It has been demonstrated that 1,1′-bi-2-naphthyl compounds possessing C_2 chirality are very useful chiral inducers in stoichiometric and catalytic asymmetric reactions. Specifically, many chiral auxiliaries developed from enantiomerically pure 1,1′-bi-2-naphthols exhibited an excellent chiral induction ability in asymmetric reductions,[1] asymmetric Diels–Alder reactions,[2] asymmetric aza Diels–Alder reactions,[3] asymmetric ene reactions,[4] asymmetric Michael additions,[5] asymmetric hydroformylations,[6] asymmetric alkylations,[7] asymmetric oxidations,[8] asymmetric epoxidations[9] and asymmetric nitroaldol reactions.[10] As for the preparation of enantiomerically pure 1,1′-bi-2-naphthols, a number of approaches have been reported. However, most preparative methods need expensive homochiral materials, and they either have a long period for preparation, or are not easy to carry out, or have lower yields. To our knowledge, only one research group[11] has reported the resolution of racemic 1,1′-bi-2-naphthol using a naturally inexpensive amino acid via an inclusion complexation. Unfortunately, they merely obtained 65% ee (*S*)-(−)- and 44% ee (*R*)-(+)-1,1′-bi-2-naphthol from the reaction of racemic 1,1′-bi-2-naphthol and (*S*)-proline in benzene under refluxing conditions for 24 h. In order to obtain essentially enantiomerically pure 1,1′-bi-2-naphthols, they either did three successive repetitions of the above procedure, or enriched

---

* Corresponding author.

PII: S0957-4166(98)00396-6

the excess enantiomer from the product with a lower ee in a system consisting of boric acid and tetramethylethylenediamine. Even so, the overall yields of (*S*)-(−)- and (*R*)-(+)-isomer were only 43.7% and 31.5% (calcd. from racemic 1,1′-bi-2-naphthol), respectively. Although the authors utilized a cheaper amino acid as the resolving agent in those preparations, owing to a long preparative period and a complicated reaction, these methods still are not economical from the preparative point of view. In the course of looking for a practical preparation of enantiomerically pure (*S*)-(−)- and (*R*)-(+)-1,1′-bi-2-naphthol, we invented a cyclic borate ester method[12] on the basis of examining, extensively, the reactions of racemic 1,1′-bi-2-naphthol with boron compounds and chiral auxiliaries. Recently, we published the resolution of racemic 1,1′-bi-2-naphthol utilizing an alkaloid as the resolving agent via the formation of a cyclic borate ester.[13] We wish to report herein the preparative method for enantiomerically pure (*S*)-(−)- and (*R*)-(+)-1,1′-bi-2-naphthol from racemic 1,1′-bi-2-naphthol, boric acid and (*S*)-proline (Scheme 1).



Scheme 1.

2. Results and discussion

Racemic 1,1′-bi-2-naphthol **1** was allowed to react with boric acid in toluene under reflux for several hours. The resulting water during the course of the reaction was removed by azeotropic distillation. The reaction mixture was cooled to room temperature and filtered. The solid was washed successively with freshly dried toluene and diethyl ether and dried under reduced pressure to give 1,1′-bi-2-naphtholboric anhydride **2**. **2** was allowed to reflux with (*S*)-proline **3** in a 1:2–2.3 molar ratio in tetrahydrofuran for 3 h to produce, almost quantitatively, a white precipitate of (*S*)-1,1′-bi-2-naphtholboric acid (*S*)-proline anhydride **4A**. The precipitate was filtered, and the filtrate was evaporated to dryness to give solid (*R*)-1,1′-bi-2-naphtholboric acid (*S*)-proline anhydride **4B**. **4A** and **4B**, thus obtained, were separately dissolved in a dilute NaOH, and, followed by the treatment with a dilute HCl and diethyl ether, offered (*R*)-(+)- and (*S*)-(−)-1,1′-bi-2-naphthol of over 90% ee from the corresponding organic phase. After 'kinetic' crystallization[14] from benzene, enantiomerically pure (*S*)-(−)- and (*R*)-(+)-1,1′-bi-2-naphthol were obtained in ca. 80% overall yield, respectively.

1,1′-Bi-2-naphtholboric anhydride **2** generated from the reaction of racemic 1,1′-bi-2-naphthol and boric acid in toluene did not need to be separated. To the reaction system was directly added with constant stirring solid (*S*)-proline **3** in a 1:2–2.3 molar ratio ('one pot' reaction), then heated for an additional 3 h under reflux. The reaction mixture was cooled to room temperature and filtered. The solid was washed successively with toluene and diethyl ether and dried under reduced pressure. Tetrahydrofuran was then added, and stirred for 2 h at room temperature. The solid and the mother liquor were separated, from which **4A′** and **4B′** were obtained. This was followed by working up by the basification, the acidification and 'kinetic' crystallization as with the above procedure, obtaining (*S*)-(−)- and (*R*)-(+)-1,1′-bi-2-naphthol with enantiomeric purity in 71% and 62% yield, respectively.

In summary, a novel convenient method to prepare enantiomerically pure (*R*)-(+)- and (*S*)-(−)-1,1′-bi-2-naphthol through the reaction of racemic 1,1′-bi-2-naphthol, boric acid and (*S*)-proline has been developed. The above results indicate that by using isolated 1,1′-bi-2-naphtholboric anhydride in the preparative reaction, products with high enantiomeric excess and high yield are obtained; a 'one-pot' method is easier to carry out, although it gave products with slightly lower ee and yield. Our methods presented here not only made use of a readily available chiral pool material, but are also operationally simple. We believe this route is one of the most practical approaches for preparing enantiomerically pure 1,1′-bi-2-naphthols in high yield at present.

3. Experimental

3.1. Reaction of the separated 1,1′-bi-2-naphtholboric anhydride with (S)-proline

5.72 g (20 mmol) racemic 1,1′-bi-2-naphthol refluxed with 1.40 g (22.58 mmol) boric acid in 120 ml toluene with the liberation of water to give 5.92 g of powdery white solid of 1,1′-bi-2-naphtholboric anhydride **2**, yield, 98%. It does not melt at up to 300°C. Elemental analysis: found (%), B, 3.36; C, 78.86; H, 3.90. Calcd for $B_2C_{40}H_{24}O_5$: B, 3.51; C, 79.25; H, 3.99. IR (KBr, cm^{-1}): 1620 m, 1594 m, 1509 m, 1466 ms (naphthalene ring framework); 1360 s ($\nu^{as}_{B\text{–}O}$); 1307 vvs ($\nu_{B\text{–}O\text{–}B}$); 1228 s ($\nu^{as}_{C\text{–}O}$); 818 vs, 751 vs ($\delta_{C\text{–}H}$).

3.0 g (5 mmol) 1,1′-bi-2-naphtholboric anhydride **2** prepared as stated above was allowed to mix with 1.15 g (10 mmol) (*S*)-proline **3** in 50 ml dried tetrahydrofuran and was refluxed for 3 h; a great deal of white solid precipitated out of the reaction system. After the reaction mixture was cooled to room temperature, the solid was filtered out, washed successively with tetrahydrofuran and diethyl ether and dried under reduced pressure to afford 2.33 g 1,1′-bi-2-naphtholboric acid (*S*)-proline derivative **4A**, yield, 96% (based on $C_{25}H_{20}BNO_4\cdot C_4H_8O$). It does not melt at up to 260°C. IR (KBr, cm^{-1}): 1750 sh, 1742 ms ($\nu^{as}_{C=O}$); 1619 m, 1593 m, 1506 m, 1467 m (naphthalene ring framework); 1368 m, 1333 ms ($\nu^{as}_{B\text{–}O}$); 1251 vs ($\nu^{as}_{Naph\text{–}O\text{–}B}$)†; 1230 sh, ms ($\nu^{as}_{N\rightarrow B}$); 1080 vs ($\nu^{s}_{B\text{–}O}$); 1050 s ($\nu^{s}_{Naph\text{–}O\text{–}B}$); 1020 vs ($\nu^{s}_{C\text{–}O}$); 824 ms, 754 s ($\delta_{Naph\text{–}H}$). After recrystallization from acetonitrile, it lost the associated tetrahydrofuran. ^1H NMR (DMSO-d_6+MeCN-d_3, ppm, TMS=0): 1.66–2.30 (4H, m, CH_2CH_2); 2.75–3.38 (3H, m, $NHCH_2$); 4.54 (1H, t, NCHCOO); 6.97–7.53 (8H, m, 8×Binaph-H);‡ 7.80–8.04 (4H, m, 4×Binaph-H). MS (EI, 70 ev): m/z, 409 (44.3, M^+), 364 (2.8), 312 (13.2), 297 (5.7), 268 (15.1), 239 (14.2), 70 (100), 44 (3.3). The solid **4A** was treated successively with 30 ml 2N NaOH and 30 ml 2 N HCl at room temperature with stirring, followed by the addition of 30 ml diethyl ether

---

† 'Naph' is an abbreviation of naphthalene ring.

‡ 'Binaph-H' represents a proton of binaphthyl group.

to give a clear two-phase solution. The organic layer was collected and the water layer was extracted with diethyl ether (10 ml×2). The organic phases were then combined and washed with saturated brine, dried over anhydrous sodium sulfate, filtered and the filtrate was evaporated to dryness. (*S*)-(−)-1,1′-Bi-2-naphthol (1.22 g) was obtained, yield, 85.3%, m.p. 206–208°C, $[\alpha]_D^{25}=-33.73$ (*c*=1, THF), 94% ee. After 'kinetic' crystallization from benzene, 1.13 g massy crystals of (*S*)-(−)-isomer was obtained, m.p. 206–207°C, $[\alpha]_D^{25}=-35.3$ (*c*=1, THF), 100% ee, overall yield, 79%.

The mother liquor removed **4A** was evaporated to dryness to give a yellowish solid residue which was washed with a small amount of benzene and dried under vacuum, to afford 2.45 g solid **4B**, yield, 101%. It did not melt at up to 260°C. Its IR and MS resembled those of **4A** in shape. **4B** was worked up by the basification, the acidification and 'kinetic' crystallization according to the same procedure as above; 1.06 g (*R*)-(+)-1,1′-bi-2-naphthol was afforded, m.p. 206–207°C, $[\alpha]_D^{25}=+35.2$ (*c*=1, THF), 100% ee, overall yield, 74%.

3.2. *'One-pot' preparation of enantiomerically pure 1,1′-bi-2-naphthols*

2.86 g (10 mmol) racemic 1,1′-bi-2-naphthol and 0.70 g (11.3 mmol) boric acid were allowed to mix in 70 ml toluene and reflux with constant stirring for several hours. The liberated water was distilled off to produce a white solid precipitate. The reaction mixture was cooled to about 50°C; 1.30 g (11.3 mmol) (*S*)-proline was added and reflux was continued, with stirring, for an additional 3 h. The mixture was then cooled to room temperature. The resulting large amount of white solid was separated by filtration, washed successively with fresh toluene and diethyl ether, and dried under reduced pressure to give 4.0 g product. The product was transferred to a 100 ml flask and 50 ml tetrahydrofuran was added. The mixture was stirred magnetically for 2 h at ambient temperature, filtered, the solid was washed with fresh tetrahydrofuran and then dried under reduced pressure; 2.1 g **4A′** was obtained. It did not melt at up to 295°C. After recrystallization from acetonitrile, its IR, ^{1}H NMR and MS were the same as those of **4A**. The mother liquor removed **4A′** was evaporated to dryness to give 2.45 g yellowish solid residue **4B′**. It did not melt at up to 260°C. IR (KBr, cm^{-1}): 1756 ms, br ($\nu^{as}_{C=O}$); 1619 m, 1592 m, 1506 m, 1467 m (naphthalene ring framework); 1339 ms (ν^{as}_{B-O}); 1248 s ($\nu^{as}_{Naph-O-B}$); 1232 s ($\nu^{as}_{N\rightarrow B}$): 1079 s ($\nu^{s}_{B-O}$); 1019 vs ($\nu^{s}_{C-O}$); 821 ms, 752 ms ($\delta_{Naph-H}$). **4A′** and **4B′**, thus obtained, were treated separately by the basification, the acidification and 'kinetic' crystallization as per the above procedure, and afforded 1.02 g transparent massy crystals of (*S*)-(−)-1,1′-bi-2-naphthol, m.p. 206–207°C, $[\alpha]_D^{25}=-35.5$ (*c*=1, THF), 100% ee, overall yield, 71.3%, and 0.90 g transparent massy crystals of (*R*)-(+)-1,1′-bi-2-naphthol, m.p. 206–207°C, $[\alpha]_D^{20}=+35.4$ (*c*=1, THF), 100% ee, overall yield, 62%, respectively. Additionally, in the course of 'kinetic' crystallization from benzene for (*R*)-(+)-isomer with lower ee, 0.3 g light white solid was separated, m.p. 216–218°C, $[\alpha]_D^{20}=+0.6$ (*c*=1, THF), 2% ee. It is obvious that this was racemic 1,1′-bi-2-naphthol contaminated by (*R*)-isomer.

Acknowledgements

Financial support by the National Natural Science Foundation of China and the Natural Science Foundation of Hubei Province are gratefully acknowledged.

References

1. (a) Noyori, R. *Chem. Soc. Rev.* **1989**, *18*, 187. (b) Suzuki, M.; Morite, Y.; Koyano, H.; Koga, M.; Noyori, R. *Tetrahedron* **1990**, *46*, 4809.
2. (a) Kagan, H. B.; Riant, O. *Chem. Rev.* **1992**, *92*, 1007. (b) Kobayashi, M.; Araki, M.; Hachiya, I. *J Org. Chem.* **1994**, *59*, 3758. (c) Ishihama, K.; Yamamoto, H. *J. Am. Chem. Soc.* **1994**, *116*, 1561.
3. (a) Ishitani, H.; Kobayashi, S. *Tetrahedron Lett.* **1996**, *37*(41), 7357. (b) Hattori, K.; Yamamoto, H. *J. Org. Chem.* **1992**, *57*, 3264.
4. (a) Mikami, K.; Matsukawa, S.; Sawa, E.; Harada, A.; Koga, N. *Tetrahedron Lett.* **1997**, *38*(11), 1951. (b) Mikami, K.; Terada, M. *Tetrahedron* **1992**, *48*, 5671. (c) Corey, E. J.; Barnes-Seeman, D.; Lee, T. W.; Goodman, S. N. *Tetrahedron Lett.* **1997**, *38*(37), 6513.
5. Kobayashi, S.; Suda, S.; Yamada, M.; Mukaiyama, T. *Chem. Lett.* **1994**, *97*, 1.
6. (a) Sakai, N.; Mano, S.; Nozaki, K.; Takaya, H. *J. Am. Chem. Soc.* **1993**, *115*, 7033. (b) Nozaki, H.; Sakai, N.; Nanno, T.; Higashijima, T.; Mano, S.; Horiuchi, T.; Takaya, H. *J. Am. Chem. Soc.* **1997**, *119*, 4413. (c) Horiuchi, T. *Tetrahedron* **1997**, *53*(23), 7795.
7. Chan, A. S. C.; Zhang, F. Y.; Yip, C. W. *J. Am. Chem. Soc.* **1997**, *119*, 4080.
8. (a) Komatsu, N.; Hashizuma, M.; Sugita, T.; Uemura, S. *J. Org. Chem.* **1993**, *58*, 4529. (b) Reetz, M. T.; Merk, C.; Naberfeld, G.; Rudolph, J.; Griebenow, N.; Goddard, R. *Tetrahedron Lett.* **1997**, *38*(30), 5273.
9. Bougauchi, M.; Watanabe, S.; Arai, T.; Sasai, H.; Shibasaki, M. *J. Am. Chem. Soc.* **1997**, *119*, 2329.
10. (a) Shibasaki, M.; Sasai H. *Pure Appl. Chem.* **1996**, *68*(3), 523. (b) Sasai, H.; Suzuki, T.; Arai, T.; Shibasaki, M. *J. Am. Chem. Soc.* **1992**, *114*, 4418.
11. (a) Periasamy, M. *Pure Appl. Chem.* **1996**, *68*, 663. (b) Periasamy, M.; Bhanu Prasad, A. S.; Bhaskar Kanth, J. V.; Kishan Reddy, Ch. *Tetrahedron: Asymmetry* **1995**, *6*(2), 341. (c) Periasamy, M.; Venkatraman, L.; Thomas, K. R. J. *J. Org. Chem.* **1997**, *62*(13), 4302.
12. Shan, Z. X.; Wang, G. P.; Duan, B.; Zhao, D. J. *Faming Zhuanli Shenqing Gongkai Shuomingshu* CN1097728, 25 January 1995. Appl. No: CN93103325, 1993.
13. (a) Shan, Z. X.; Wang, G. P.; Duan, B.; Zhao, D. J. *Tetrahedron: Asymmetry* **1996**, *7*(10), 2647. (b) Shan, Z. X.; Cheng, F. Y.; Huang, S. W.; Zhao, D. J.; Jing, Z. Z. *Tetrahedron: Asymmetry* **1997**, *8*(8), 1175.
14. Smrcina, M.; Lorene, M.; Hanus, V.; Sedmera, P.; Kocovsky, P. *J. Org. Chem.* **1992**, *57*(6), 1917.