Available online at www.sciencedirect.com
SCIENCE DIRECT®
Tetrahedron Letters 47 (2006) 4125–4128
Tetrahedron Letters

(*R*)-6,6′-Bis(trifluoromethanesulfonyl)-2,2′-dihydroxy-1,1′-binaphthyl: a new ligand for asymmetric synthesis

Omar Mouhtady, Hafida Gaspard-Iloughmane, André Laporterie and Christophe Le Roux*

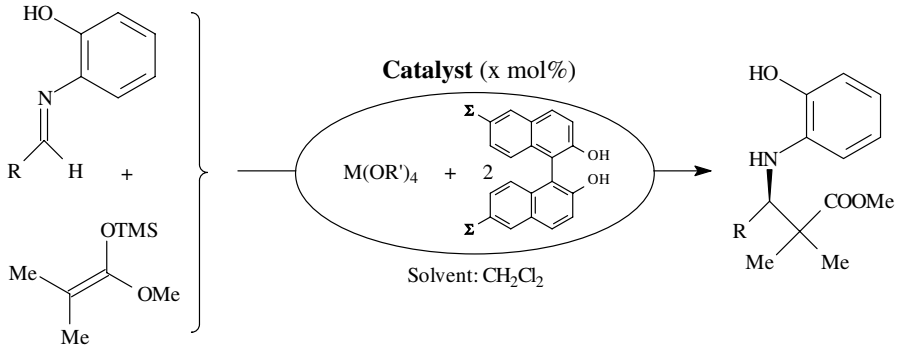
Hétérochimie Fondamentale et Appliquée (UMR-CNRS 5069), Université Paul-Sabatier, 118, route de Narbonne, 31062 Toulouse Cedex 09, France

Received 16 March 2006; revised 7 April 2006; accepted 18 April 2006
Available online 9 May 2006

Abstract—The new (*R*)-6,6′-bis(trifluoromethanesulfonyl)-2,2′-dihydroxy-1,1′-binaphthyl (**1**) has been synthesized and proved to generate highly active zirconium-based catalysts for asymmetric Mannich-type reactions.

(*R*)-2,2′-Dihydroxy-1,1′-binaphthyl ((*R*) Binol, **2**) has been known since 1979 to be an efficient ligand for the metal-mediated catalysis of asymmetric transformations.[1] As a result, it has been the subject of various modifications and one of these involves the introduction of electron withdrawing groups on to the aromatic rings.[2] Moreover, the introduction of bromine, trifluoromethyl or pentafluoroethyl groups in the 6,6′ positions of the binaphthol ring has served to increase the Lewis acidity as well as the enantioselectivity of zirconium-based catalysts as reported by Kobayashi.[3] The trifluoromethanesulfonyl group is one of the strongest electron withdrawing groups.[4] In light of these results, we decided to prepare the new 6,6′-bis(trifluoromethanesulfonyl)-2,2′-dihydroxy-1,1′-binaphthyl (**1**)[5] and we now wish to report our first results.

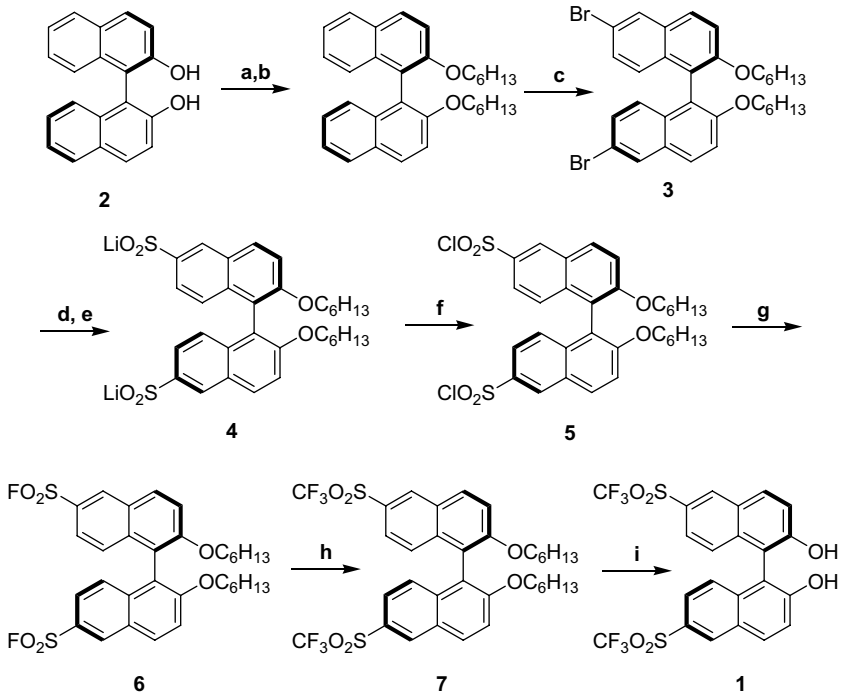
Since all previously reported synthesis of aryltrifluoromethylsulfones [6] failed in our case, the synthesis of **1** was achieved by an original route (Scheme 1). Our synthesis starts with the reaction of SO_2 with the lithiated derivative of the previously reported (*R*)-6,6′-dibromo-2,2′-bis(hexyloxy)-1,1′-binaphthyl (**3**).[7,8] The lithium sulfinate (**4**) produced was then treated with sulfuryl chloride to give the bis sulfonyl chloride intermediate (**5**), which was purified by column chromatography over silica gel.[9] Reaction with silver fluoride and filtration of AgCl gave pure bis sulfonyl fluoride intermediate (**6**),[10,11] which was trifluoromethylated to give the bis trifluoromethanesulfonyl intermediate (**7**).[12,13] Finally, enantiomerically pure **1** was obtained after dealkylation using BBr_3 in 51% overall yield starting from **2**.[14–16]



(1)

* Corresponding author. Fax: +33 (0)5 61 55 82 04; e-mail: leroux@chimie.ups-tlse.fr

0040-4039/$ - see front matter © 2006 Published by Elsevier Ltd.
doi:10.1016/j.tetlet.2006.04.069



Scheme 1. Reagents and conditions: (a) NaH (7 equiv), DMF, 0 °C; (b) $C_6H_{13}I$, rt, 1 h 30 min; (c) NBS (3 equiv), CH_3CN, rt, 16 h; (d) BuLi (2.1 equiv), THF, −60 °C; (e) SO_2 in excess; (f) SO_2Cl_2 (2 equiv); (g) AgF, CH_3CN, rt, 3 h; (h) $TMSCF_3$ (4 equiv), TASF (0.2 equiv), 5 °C; (i) BBr_3 (5 equiv), toluene, rt, 24 h.

We then decided to study the catalytic efficiency of **1** in asymmetric Mannich-type reactions involving zirconium-Binol based catalysts (Eq. 1). In order to compare the efficiency of this catalyst to that of other substituted Binol derived catalysts already reported,[3] we chose the reaction between the imine derived from 1-naphthalenecarboxaldehyde and the trimethylsilyl enolate derived from methyl isobutyrate as a model. Our results are summarized in Table 1.

Initially, we verified that none of the components of the catalytic system was active individually (Table 1, entries 1, 2). Our results clearly demonstrate that the introduction of the trifluoromethanesulfonyl group is strongly beneficial for catalyst turnover, since under our conditions **1** gave superior results to both **2** and (*R*)-dibromo Binol (Table 1, entries 3, 4 and 5). Using **1** the reaction even occurs at −95 °C (entries 7 and 8) or when catalyst loading is reduced to 0.5 mol % (entries 8, 11, and 13). The economically desirable replacement of $Zr(O^tBu)_4$ with a 30 wt % solution of $Zr(O^nPr)_4$ in ^nPrOH[17] did not adversely affect the reaction (Table 1, entries 5 and 9). The use of $Ti(O^iPr)_4$ instead of $Zr(O^tBu)_4$ led to a loss of both enantioselectivity (Table 1, entries 5 and 10) and isolated yield. Kobayashi reported the successful use of 6,6′-$(CF_3)_2$-Binol for the analogous reaction with

Table 1. Asymmetric catalysis of Mannich-type reactions using various 6,6′-Σ-substituted Binols

Entry	Imine (R)	Catalytic system $M(OR')_4/\Sigma$[a]	Cat. (mol %)	Temperature (°C)	Time (h)	Product yield[b] (%)	Ee (%) *R* isomer
1	Np	Zr/no ligand	2	−78	16	0	—
2	Np	No metal/Tf	2	−78	16	0	—
3	Np	Zr/H	2	−78	2	6	nd
4	Np	Zr/Br	2	−78	2	65	68
5	Np	Zr/Tf	2	−78	2	99	66
6[3a]	Np	Zr/Br	10	−45	30	99	92
7	Np	Zr/H	0.5	−95	4	0	—
8	Np	Zr/Tf	0.5	−95	4	50	80
9[c]	Np	Zr/Tf	2	−78	2	99	62
10[d]	Np	Ti/Tf	0.5	−78	16	50	14
11	Np	Zr/Tf	0.5	−78	16	67	66
12[3a]	4-Cl–Ph	Zr/CF_3	2	−78	16	>99	83
13	4-Cl–Ph	Zr/Tf	2	−78	16	85	66
14	4-Cl–Ph	Zr/Tf	0.5	−78	16	41	65

[a] Molar ratio Zr/Binol = 1/2.
[b] Isolated yields.
[c] In this experiment $Zr(O^tBu)_4$ was replaced by $Zr(^nOPr)_4$.
[d] $Ti(O^iPr)_4$ was used as the titanium source.

the imine derived from 4-chlorobenzaldehyde (Table 1, entry 12).[3a] In preliminary experiments we have found that **1** is also effective for this reaction, although further optimization is required (Table 1, entries 13 and 14). Interestingly, when racemic 3,3′-trifluoromethanesulfonyl-2,2′-dihydroxy-1,1′-binaphthyl[5] was used in place of **1** (same conditions in entry 5) the reaction proceeded in only 17% yield.

In conclusion, we have shown that the introduction of trifluoromethanesulfonyl groups in the 6,6′ positions on the chiral backbone generates highly active zirconium-based catalyst for Mannich-type reactions. The catalysis of other reactions with this ligand and its derivatives is currently under investigation in our laboratory.

Acknowledgement

We wish to thank Chantal Zedde for the HPLC analysis and Magnus Bebbington for his kind contribution to the preparation of the manuscript.

References and notes

1. Noyori, R.; Tomino, I.; Tanimoto, Y. *J. Am. Chem. Soc.* **1979**, *101*, 3129–3131.
2. (a) Chen, Y.; Yekta, S.; Yudin, A. K. *Chem. Rev.* **2003**, *103*, 3155–3211; (b) Cook, G. R.; Kargbo, R.; Maity, B. *Org. Lett.* **2005**, *7*, 2767–2770.
3. (a) Ishitani, H.; Ueno, M.; Kobayashi, S. *J. Am. Chem. Soc.* **2000**, *122*, 8180–8186; (b) Ueno, M.; Ishitani, H.; Kobayashi, S. *Org. Lett.* **2002**, *4*, 3395–3397.
4. (a) Goumont, R.; Kizilian, E.; Buncel, E.; Terrier, F. *Org. Biomol. Chem.* **2003**, *1*, 1741–1748; (b) Goumont, R.; Faucher, N.; Moutiers, G.; Tordeux, M.; Wakselman, C. *Synthesis* **1997**, 691–695.
5. The synthesis of racemic 3,3′-trifluoromethanesulfonyl-2,2′-dihydroxy-1,1′-binaphthyl has been recently reported using the anionic thia-Fries rearrangement of 1,1′-bi-2,2′-naphthol bis(trifluoromethanesulfonate): Charmant, J. P. H.; Dyke, A. M.; Lloyd-Jones, G. C. *J. Chem. Soc. Chem. Commun.* **2003**, 380–381.
6. (a) Hendrickson, J. B.; Bair, K. W. *J. Org. Chem.* **1977**, *42*, 3875–3878; (b) Singh, R. P.; Cao, G.; Kirchmeier, R. L.; Shreeve, J. M. *J. Org. Chem.* **1999**, *64*, 2873–2876; (c) Creary, X. *J. Org. Chem.* **1980**, *45*, 2727–2729; (d) Pevere, V.; Quiclet-Sire, B.; Zard, S.; Bertrand F. PCT Int. WO 00/00467.
7. Hamada, T.; Yonemitsu, O. *Synthesis* **1986**, 852–854.
8. Hu, Q. S.; Vitharana, D.; Liu, G.; Jain, V.; Wagaman, M. W.; Zhang, L.; Lee, T.; Pu, L. *Macromolecules* **1996**, *29*, 1082–1084.
9. Synthesis of compound **5**. To a vigorously stirred solution of sulfur dioxide (20 mL) in THF (230 mL) cooled to −70 °C was gradually added through a teflon canula a solution of the aryllithium prepared from **3** (10.65 g, 17.4 mmol) in THF (120 mL) and 1.6 M *n*-butyllithium in hexanes (22 mL) at −60 °C under argon. The addition was complete in 5 min and the reaction mixture was allowed to warm to room temperature over 5 min. After removal of the solvents in vacuo, the residual crude lithium sulfinate **4** was washed with ether and used in the next reaction without further purification. Following the procedure previously reported,[7] compound **5a** (9.07 g) was isolated by column chromatography on silica gel (eluent: pentane/AcOEt: 90/10) as a green yellow oil contaminated by approximately 30% (^{1}H NMR determination) of (*R*)-6,6′-bromochlorosulfonyl-2,2′-bis(hexyloxy)-1,1′-binaphthyl (**5b**) as shown by mass spectrometry. The mixture of compounds **5** was used in the next reaction without further purification and gave the following NMR signals. ^{1}H NMR (300 MHz, $CDCl_3$) δ 0.61–0.65 (m, 3H, Me), 0.80–1.15 (m, 6H, CH_2), 1.37 (q, $J = 6$ Hz, 2H, OCH_2CH_2), 3.98 (m, 2H, OCH_2CH_2), 7.18 (d, $J = 9$ Hz, 1H), 7.17 (d, $J = 9$ Hz, 1H), 7.52 (d, $J = 12$ Hz, 1H), 7.62 (dd, $J = 9$, 3 Hz, 1H), 8.10 (d, $J = 9$ Hz, 1H), 8.49 (d, $J = 2$ Hz, 1H), 8.55 (d, $J = 2$ Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 13.8, 22.4, 25.3, 28.9, 31.1, 69.2, 116.5, 116.6, 118.8, 118.9, 121.6, 121.9, 126.6, 126.7, 126.8, 126.9, 128.8, 129.5, 132.3, 132.4, 136.6, 136.7, 138.7, 141.6, 158.1, 158.2.
10. Garlyauskajte, R. Y.; Sereda, S. V.; Yagupolskii, L. M. *Tetrahedron* **1994**, *50*, 6891–6906.
11. Synthesis of compound **6**. Into a 250 mL round bottomed flask was placed **5** (6 g, 9.2 mmol) in 100 mL of anhydrous acetonitrile. Then, AgF (2.8 g, 22.07 mmol) was added under argon and the resulting suspension was stirred for 4 h at rt. After this time, the suspension was filtered over celite and the solvents were evaporated under reduced pressure. Compound **6** (5.43 g, 95% yield) was obtained as a brown orange oil and was pure enough to be used in the next step without purification. $[\alpha]_D^{20}$ +56.7 (*c* 2.38, CH_2Cl_2); IR (KBr pellet) 3474, 1611, 1498, 1465, 1356, 1281, 1216, 1131, 1084, 1069, 898, 848, 666, 631 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ 0.69–0.75 (m, 3H, Me), 0.80–1.15 (m, 6H, CH_2), 1.45 (m, 2H, OCH_2CH_2), 4.06 (m, 2H, OCH_2CH_2), 7.26 (d, $J = 9$ Hz, 1H), 7.60 (d, $J = 11$ Hz, 1H), 7.65 (dd, $J = 9$, 2 Hz, 1H), 8.18 (d, $J = 9$ Hz, 1H), 8.65 (d, $J = 1.8$ Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 13.8, 22.4, 25.3, 28.9, 31.1, 69.2, 116.4, 118.7, 122.7, 126.7, 126.9, 127.0, 127.2, 131.4, 131.9, 136.9, 158.0; ^{19}F NMR (188 MHz, $CDCl_3$) δ 103.3.
12. Movchun, V. N.; Kolomeitsev, A. A.; Yagupolskii, Y. L. *J. Fluorine Chem.* **1995**, *70*, 255–257.
13. Synthesis of compound **7**. Into a 100 mL flask were added successively under argon TASF (472 mg, 1.713 mmol) and 35 mL of dry pentane, and the suspension was cooled to +5 °C. Then, a solution of **6** (5.3 g, 8.56 mmol) in 20 mL of dry THF was added. A solution of $TMSCF_3$ (4.87 g, 34.24 mmol) in 20 mL of dry pentane was added dropwise and the suspension was stirred for 24 h. After this time, water (50 mL) was added and the organic materials were extracted with dichloromethane. Compound **7** (4.92 g, 80% yield) was isolated by column chromatography on silica gel (eluent: pentane/AcOEt: 95/5) as an orange viscous oil; . $[\alpha]_D^{20}$ +45.5 (*c* 0.85, CH_2Cl_2); ^{1}H NMR (300 MHz, $CDCl_3$) δ 0.59–0.63 (m, 3H, Me), 0.80–1.15 (m, 6H, CH_2), 1.35 (m, 2H, OCH_2CH_2), 3.98 (m, 2H, OCH_2CH_2), 7.23 (d, $J = 9$ Hz, 1H), 7.53 (d, $J = 9$ Hz, 1H), 7.58 (dd, $J = 9$, 3 Hz, 1H), 8.13 (d, $J = 9$ Hz, 1H), 8.60 (d, $J = 3$ Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 13.7, 22.3, 25.2, 28.9, 31.1, 69.2, 116.4, 118.6, 120.0 (q, $J = 326$ Hz, CF_3), 125.1, 127.3, 132.3, 137.5, 158.4; ^{19}F NMR (188 MHz, $CDCl_3$) δ −2.86.
14. Bhatt, M. V.; Kulkarni, S. U. *Synthesis* **1983**, 249–282, and references cited.
15. Synthesis of compound **1**. Into a 250 mL flask were added **7** (4.65 g, 6.47 mmol) and toluene (130 mL). Then BBr_3 (8.1 g, 32.35 mmol) was added dropwise and the solution was stirred at RT for 24 h. Water (50 mL) was added followed by a saturated aqueous solution of sodium bicarbonate (50 mL) and the organic materials were extracted with ether (100 mL). After removal of the solvents under reduced pressure, compound **1** (3.1 g,

87% yield) was isolated by column chromatography on silica gel (eluent: CH_2Cl_2/AcOEt: 90/10) as an off-white solid. Mp: 147 °C; $[\alpha]_D^{20}$ −131.2 (*c* 0.91, CH_2Cl_2); IR (KBr pellet) 3474, 1611, 1498, 1465, 1356, 1281, 1216, 1131, 1084, 1069, 898, 848, 666, 631 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 5.98 (br s, 1H), 7.30 (d, $J = 9$ Hz), 7.62 (d, $J = 9$ Hz, 1H), 7.74 (dd, $J = 9$, 1.5 Hz, 1H), 8.23 (d, $J = 9$ Hz, 1H), 8.68 (d, $J = 1.5$ Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 111.2, 119.9 (q, $J = 326$ Hz, CF_3), 120.7, 125.8, 125.9, 126.0, 128.1, 133.8, 134.4, 137.5, 157.0; ^{19}F NMR (188 MHz, $CDCl_3$) δ −2.58.

16. The enantiomeric purity of **1** (>99% ee) was determined by analytical HPLC using a chiralpak AD column (eluant: hexane/isopropanol: 80/20). The absolute structure of **1** was definitively established by X-ray diffraction (structure not shown).
17. Yamashita, Y.; Ishitani, H.; Shimizu, H.; Kobayashi, S. *J. Am. Chem. Soc.* **2002**, *124*, 3292–3302.