Pergamon

Tetrahedron: *Asymmetry* 13 (2002) 1509–1518

TETRAHEDRON: *ASYMMETRY*

Diastereoselective reaction of [1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthyl]methanimines via diastereomeric rotamers

Shuichi Nakamura, Hiroki Yasuda and Takeshi Toru*

Department of Applied Chemistry, Nagoya Institute of Technology, Gokiso, Showa-ku, Nagoya 466-8555, Japan

Received 13 June 2002; accepted 5 July 2002

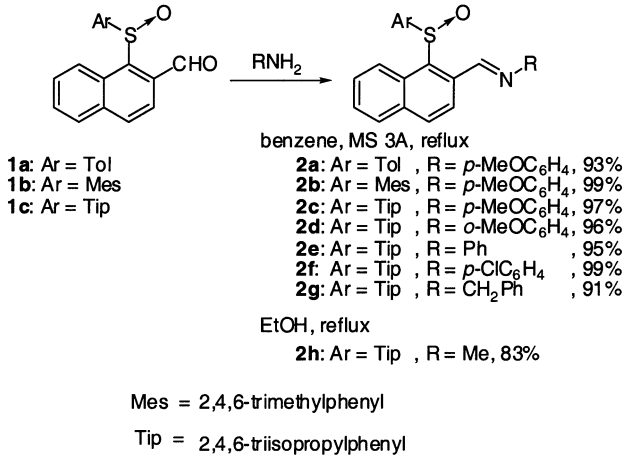
Abstract—The reactions of various (1-sulfinyl-2-naphthyl)methanimines with alkyllithium reagents were examined. Naphthylmethanimines bearing a 2,4,6-triisopropylphenylsulfinyl group gave the (R^*_S,S^*)-products as a single diastereomer, possibly derived from the predominant rotamer around the C–S bond axis. The reaction of chiral [1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthyl]methanimine with MeLi and subsequent elimination of the sulfinyl group afforded optically active 1-(2-naphthyl)ethylamine.

1. Introduction

Recently, high stereoselectivities have been achieved in asymmetric reactions of non-biaryl axially chiral compounds with high rotational barrier around the C–N[1,2] and C–C bond axes.[3] However, resolution of these compounds is always necessary prior to undertaking these reactions.[2c,e,g,h,4] We have reported diastereoselective nucleophilic reactions of 1-[(2,4,6-triisopropylphenyl)sulfinyl]-2-naphthaldehydes with Grignard reagents or with silyl enol ethers as well as the stereoselective reduction of 1-[(2,4,6-triisopropylphenyl)-sulfinyl]-2-naphthyl ketones. High stereoselectivities have been achieved in these reactions without prior resolution of axially chiral sulfinylnaphthalenes, and it has been demonstrated that the stereochemical outcome can be ascribed to the high population of a single diastereomer around the C_{naphth}–S bond axis, where one of the isopropyl groups efficiently blocks one face of the carbonyl group from nucleophilic attack.[5] In order to extend the scope and limitations of this new stereoselective reaction, we examined the nucleophilic reaction of (1-sulfinyl-2-naphthyl)methanimine with nucleophiles. We herein report on highly stereoselective reactions of [1-(arylsulfinyl)-2-naphthyl]methanimines with organolithium reagents.

2. Results and discussion

Scheme 1 summarizes the preparation of various racemic [1-(arylsulfinyl)-2-naphthyl]methanimines **2a**–**h** from 1-(arylsulfinyl)-2-naphthaldehydes[5] **1a**–**c**. Treatment of 1-(*p*-tolylsulfinyl)-, 1-(2,4,6-trimethylphenylsulfinyl)-, and 1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthaldehydes[5] **1a**–**c** with various amines in the presence of 3 Å molecular sieves in refluxing benzene gave the corresponding [1-(arylsulfinyl)-2-naphthyl]-



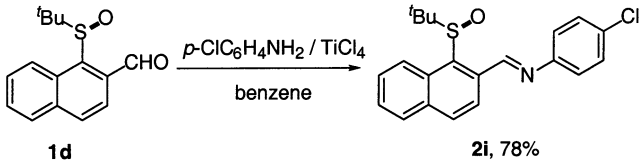
Scheme 1.

* Corresponding author. Tel./fax: (+)81-52-735-5217; e-mail: toru@ach.nitech.ac.jp

0957-4166/02/$ - see front matter
PII: S0957-4166(02)00379-8

methanimines, **2a**–**g** in high yields.[6] The *N*-methylimine **2h** was prepared on heating with methylamine under reflux in ethanol instead of benzene and in the absence of molecular sieves.[7]

[1-(*tert*-Butylsulfinyl)-2-naphthyl]methanimine **2i** was prepared in 78% yield by treatment of (*tert*-butylsulfinyl)naphthaldehyde[5] **1d** (Scheme 2) with *p*-chloroaniline in the presence of 0.6 equiv. of $TiCl_4$ in benzene at 0°C.[8] Heating the mixture in refluxing benzene in the presence of 3 Å molecular sieves failed to afford **2i** because of its thermal instability.



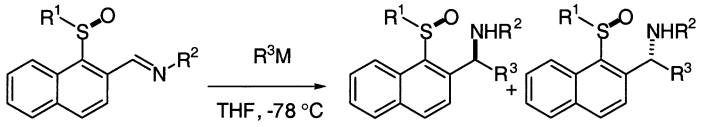
1d **2i**, 78%

Scheme 2.

Alkylation of the sulfinylimines **2** was first examined with Grignard reagents. However, alkylmagnesium halides such as methylmagnesium iodide failed to react, whereas alkyllithium reagents were found to afford the desired alkylated products. Thus, 1-sulfinylnaphthalen-2-imines **2a**–**i** were reacted with 1.1 equiv. of the appropriate organolithium reagent in THF at −78°C. The results are shown in Table 1.

The reaction of 1-(*p*-tolylsulfinyl)- and 1-(2,4,6-trimethylphenylsulfinyl)-2-naphthylmethanimines **2a**,**b** with MeLi resulted in the formation of a number of unidentified products and the desired products could not be isolated (entries 1 and 2). This is probably due to cleavage of the sulfinyl group caused by nucleophilic attack of MeLi on the sulfur center. On the other hand, the reaction of [1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthyl]methanimine **2c** with MeLi gave the (R_S^*,S^*)-(sulfinylnaphthyl)alkylamine **3** in high yield as a single diastereomer (entry 3). These results show that the sterically encumbered 2,4,6-triisopropylphenylsulfinyl group blocks the nucleophilic attack by MeLi on the sulfur center. The reaction of **2d**–**f** having various *N*-substituents with MeLi afforded the addition products **4**–**6** with diastereomeric ratio of >98:2 (entries 4–6), whereas similar treatment of the *N*-methyl and *N*-benzylimines **2g**,**h** with MeLi did not afford the desired products (entries 7 and 8). The highest yield was obtained in the reaction of the *N*-*p*-chlorophenylimine **2f** (entry 6). The reaction of **2f** with vinyllithium or phenyllithium also gave the products **7** and **8** with high stereoselectivity (entries 9 and 10).[9] In contrast to the highly stereoselective reaction of [1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthyl]methanimines **2c**–**f**, the naphthylmethanimine **2i** bearing a bulky *tert*-butylsulfinyl group gave the product **9** in a ratio of 61:39 (entry 11), showing that high stereoselectivity is not always obtained in the reaction of the naphthylmethanimines bearing a bulky sulfinyl group. The ^{1}H NMR spectrum of **2i** measured at −78°C in THF-d_8 showed three sets of two signals at 1.25 (major) and 1.26 (minor) ppm due to the *tert*-butyl protons, at 8.52 (major) and 9.65 (minor) ppm due to the *peri*-H(8) proton and at 9.26 (minor) and 10.3 (major) ppm due to the methanylylidene proton, which were obviously derived from the restricted rotation about the C_{naphth}–S bond. Thus, **2i** exists as two conformers, either having the sulfinyl oxygen close to the imino group (**A**) or close to the *peri*-H(8) of the naphthalene (**B**) as shown in Fig. 1.

Table 1. Stereoselective reaction of (1-sulfinyl-2-naphthyl)methanimines **2a**–**i** with organolithium reagents



2a-i (R_S^*,S^*) (R_S^*,R^*)

3-9

Entry	Substrate			R^3M	Product	Yield (%)	Diastereomer ratio[a] (R_S^*,S^*):(R_S^*,R^*)
		R^1	R^2				
1	**2a**	Tol	*p*-$MeOC_6H_4$	MeLi		–[b]	–
2	**2b**	Mes	*p*-$MeOC_6H_4$	MeLi		–[b]	–
3	**2c**	Tip	*p*-$MeOC_6H_4$	MeLi	**3**	72	>98:2
4	**2d**	Tip	*o*-$MeOC_6H_4$	MeLi	**4**	79	>98:2
5	**2e**	Tip	Ph	MeLi	**5**	89	>98:2
6	**2f**	Tip	*p*-ClC_6H_4	MeLi	**6**	98	>98:2
7	**2g**	Tip	CH_2Ph	MeLi		N.R.[c]	–
8	**2h**	Tip	Me	MeLi		–[b]	–
9	**2f**	Tip	*p*-ClC_6H_4	CH_2=CHLi	**7**	85	>98:2
10	**2f**	Tip	*p*-ClC_6H_4	PhLi	**8**	96	>98:2
11	**2i**	^{t}Bu	*p*-ClC_6H_4	MeLi	**9**	85	61:39

[a] Determined by ^{1}H NMR analysis.
[b] A number of unidentified products were obtained.
[c] **2g** was recovered.

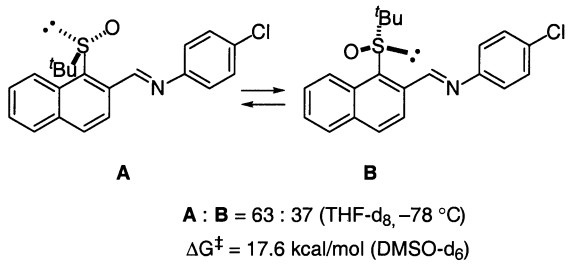


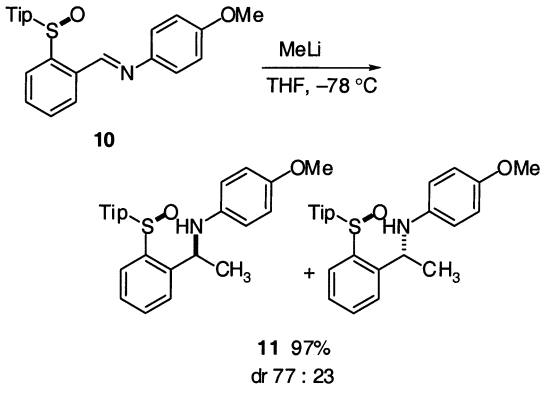
Figure 1. The diastereomeric ratio in THF-d_8 at −78°C and the rotational barrier in DMSO-d_6 of **2i** determined by the ^{1}H NMR spectral analysis.

The minor conformer was assigned to be the rotamer B on the basis of the downfield shift[10] of the *peri*-H(8) proton due to the anisotropy of the sulfinyl group. By ^{1}H NMR analysis, the ratio of the major and the minor isomers was estimated to be 63:37, which was essentially the same as the diastereomeric ratio of the products.[11] The rate constant for the rotation was found to be $k = 17$ s^{-1} at 58°C in DMSO-d_6 by line shape analysis of the broadened *tert*-butyl proton signal in the region of coalescence. From the rate constant, k, the activation energy ($\Delta G^{\ddagger}$) of rotation was calculated using Eyring's equation[12] to be 17.6 kcal/mol.[13]

On the other hand, each signal due to the *peri*-H(8) proton and the imino carbon of **2c–f** appeared as one conformer, and the rotamers of the sulfoxides **2c–f** originated from the rotational barrier around the C–S bond axis could not be detected in the ^{1}H NMR spectra. Since the reaction of **2c–f** shows high diastereoselectivity (Table 1), it can be reasonably assumed that the reaction of these imines with a nucleophile proceeds faster than the rotation process between rotamers. In the ^{1}H and ^{13}C NMR spectra of **2c** in $CDCl_3$, the *peri*-H(8) proton and the imino carbon appeared at 8.24 and 160.3 ppm, respectively, which are similar to the chemical shifts of the corresponding protons in the major rotamer (A) of **2i** (Fig. 2). These spectral data and the chemical behavior of **2c–f** and **2i** are quite similar to those of 1-sulfinyl-2-naphthaldehydes previously reported.[5,14]

The structure determined from the NMR data is in good accord with that obtained by X-ray crystallography; the sulfoxide oxygen is placed away from the *peri*-H(8), the imino group almost on the plane of the naphthalene ring, and the nitrogen away from the sulfoxide (Fig. 3). In this structure, one of the faces of the imino group is hindered by the 2,4,6-triisopropylphenyl group. Thus, the reaction with RLi would proceed through a non-chelated transition state, and the nucleophile approaches from the less hindered side to give (R_S^*,S^*)-**3** (Fig. 3).[15] It should be noted that the non-chelated mechanism of the [1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthyl]methanimine is in contrast to that reported by Clayden and co-workers, in which the reaction of the 2-imino-1-naphthamide with RLi proceeds through a chelated transition state.[3c,h]

Furthermore, the reaction of [2-(2,4,6-triisopropylphenylsulfinyl)benzyl]methanimine **10** (which apparently has a lower barrier to rotation than the naphthylmethanimines **2c–f**) with MeLi gave the product **11** with much lower stereoselectivity than that seen in the reactions of **2c–f** (Scheme 3). These results suggest that the stereochemical outcome in the reactions of **2c–f** is strongly related to the rotational barrier about the C_{naphth}–S bond, pointing to the significant role of the *peri*-H(8) proton.



Scheme 3.

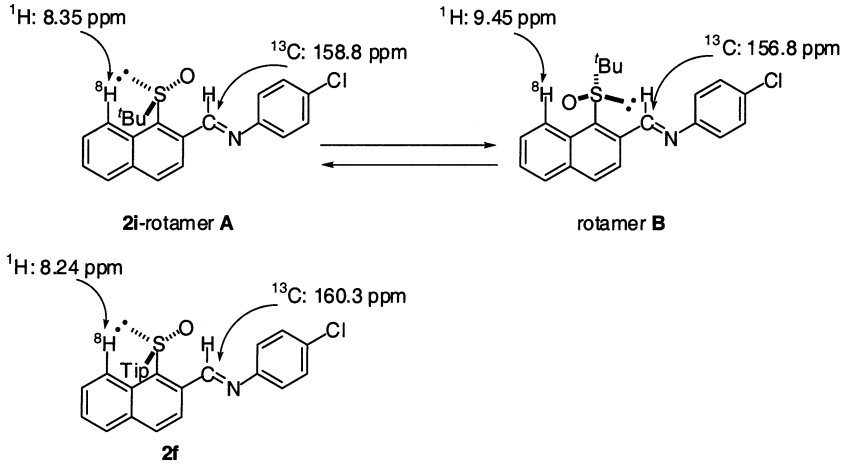


Figure 2. Significant ^{1}H and ^{13}C NMR chemical shifts for the (sulfinylnaphthyl)methanimines **2i** and **2f** in $CDCl_3$.

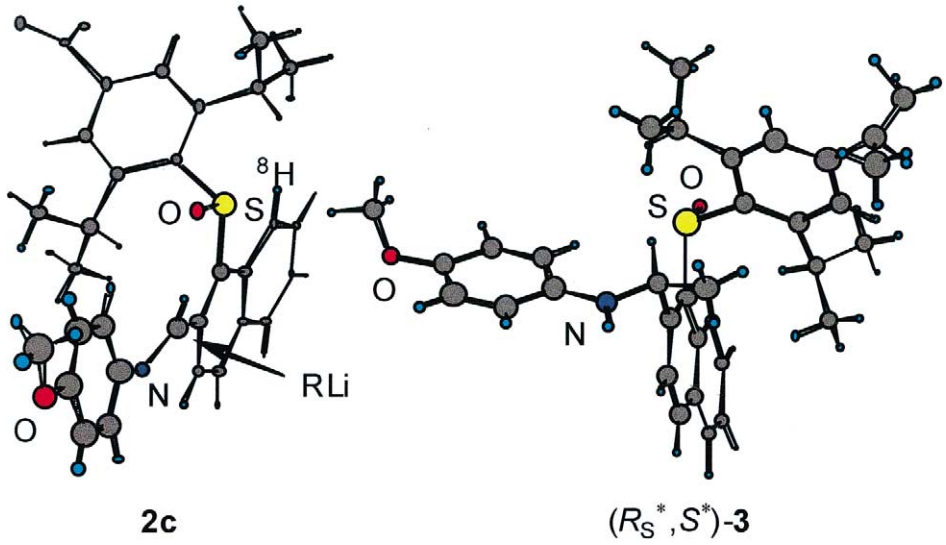


Figure 3. Chem 3D structure derived from the X-ray crystallography of **2c** and (R_S^*,S^*)-**3**.

Having established the high diastereoselectivity in the reaction of **2c**, we next applied this reaction to the preparation of an optically active 2-naphthylalkylamine derivative starting from the chiral [1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthyl]methanimine (*R*)-**2c**. When the sulfinylnaphthaldehyde (*R*)-**1c**[5b] was treated with *p*-methoxyaniline in the presence of 3 Å molecular sieves in refluxing benzene, racemization occurred, giving the imine **2c** with low enantiomeric purity. The optically active sulfoxide (*R*)-**2c** was obtained when (*R*)-**1c** was reacted with *p*-methoxyaniline in the presence of $TiCl_4$ at 0°C. The chiral (*R*)-**2c** was then reacted with MeLi at −78°C to give the product **3** in a diastereomer ratio of >98:2. Cleavage of the sulfinyl group with *n*-BuLi and HMPA gave the optically active amine **12** (Scheme 4),[16] which can be transformed to the amine by the oxidative cleavage of the 4-methoxyphenyl *N*-protecting group.[17]

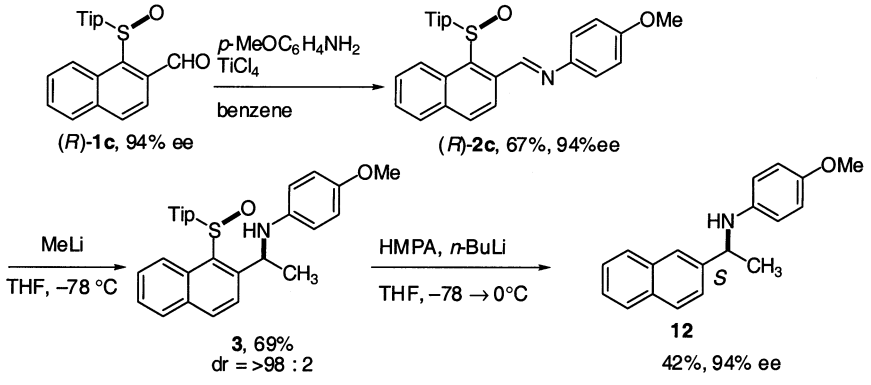
3. Conclusion

The highly enantioselective reaction of naphthylmethanimines bearing the bulky 2,4,6-triisopropylphenylsulfinyl group was achieved without isolation of the diastereomeric rotamers. We have demonstrated that the high diastereoselectivity is due to the restricted rotation about the C_{naphth}–S bond having the bulky 2,4,6-triisopropylphenylsulfinyl group. In addition, removal of the sulfinyl group from the products would provide a convenient and efficient method for the preparation of the optically active 2-naphthylalkylamine derivatives.

4. Experimental

4.1. *N*-(*p*-Methoxyphenyl)-[1-(*p*-tolylsulfinyl)-2-naphthyl]methanimine, 2a

A mixture of (*p*-tolylsulfinyl)-2-naphthaldehyde **1a** (150 mg, 0.486 mmol), *p*-methoxyaniline (90 mg, 0.729 mmol) and 3 Å molecular sieves in benzene (5.0 mL) was heated under reflux for 12 h. The mixture was filtered through Celite® and the filtrate was concentrated under reduced pressure to leave a residue, which was purified by column chromatography (silica gel 25 g, hexane/ethyl acetate = 80:20) to afford **2a** (206 mg, 99%): mp 39.1–40.0°C; R_f = 0.64 (hexane/ethyl acetate = 50:50); ^{1}H NMR: δ 2.30 (s, 3H, CH_3), 3.84 (s,



Scheme 4.

3H, OCH_3), 6.94 (d, 2H, $J=8.9$ Hz, Ar), 7.18 (d, 2H, $J=8.0$ Hz, Ar), 7.29 (d, 2H, $J=8.9$ Hz, Ar), 7.42 (d, 2H, $J=8.0$ Hz, Ar), 7.45–7.56 (m, 2H, Ar), 7.86–7.91 (m, 1H, Ar), 8.00–8.04 (m, 1H, Ar), 8.39–8.43 (m, 1H, Ar), 8.75–8.80 (m, 1H, Ar), 9.61 (s, 1H, CH=); ^{13}C NMR: δ 21.2, 55.5, 114.4, 122.8, 124.3, 124.4, 124.9, 127.7, 127.9, 128.9, 129.9, 130.9, 132.6, 135.1, 136.7, 139.5, 140.3, 141.5, 144.2, 153.9, 159.0; IR (KBr): 2960, 1610, 1500, 1460, 1290, 1250, 1080, 1040, 850, 750 cm^{-1}; EIMS m/z (rel. intensity): 400 (M^+, 1.2), 383 (48), 382 (100), 213 (33). Anal. calcd for $C_{25}H_{21}NO_2S$: C, 75.16; H, 5.30; N, 3.51. Found: C, 75.11; H, 5.36; N, 3.50%.

4.2. *N*-(*p*-Methoxyphenyl)-[1-(2,4,6-trimethylphenylsulfinyl)-2-naphthyl]methanimine, 2b

The reaction was carried out as described above except using **1b** (157 mg, 0.486 mmol) and *p*-methoxyaniline (90 mg, 0.729 mmol). Standard work-up gave the crude product which was purified by column chromatography (silica gel 25 g, hexane/ethyl acetate = 80:10) to afford **2b** (206 mg, 99%): mp 54.5–55.0°C; $R_f=0.36$ (hexane/ethyl acetate = 80:20); ^1H NMR: δ 2.18 (s, 3H, CH_3), 2.42 (s, 6H, $CH_3\times2$), 3.82 (s, 3H, OCH_3), 6.77 (s, 2H, Mes), 6.92 (d, 2H, $J=6.6$ Hz, Ar), 7.31 (d, 2H, $J=6.6$ Hz, Ar), 7.39–7.52 (m, 2H, Ar), 7.81–7.86 (m, 1H, Ar), 7.93–7.97 (m, 1H, Ar), 8.12–8.16 (m, 1H, Ar), 8.26–8.30 (m, 1H, Ar), 9.89 (s, 1H, CH=); ^{13}C NMR: δ 19.9, 20.9, 55.4, 114.2, 122.8, 123.6, 125.7, 127.0, 127.1, 128.8, 129.5, 131.1, 131.3, 134.2, 137.2, 138.2, 138.3, 138.5, 141.8, 145.0, 156.7, 158.5; IR (KBr): 2860, 1610, 1510, 1440, 1290, 1250, 1150, 1060, 1030, 850, 740 cm^{-1}; EIMS m/z (rel. intensity): 428 (M^+, 3), 411 (66), 410 (100), 241 (31). Anal. calcd for $C_{27}H_{25}NO_2S$: C, 75.85; H, 5.89; N, 3.28. Found: C, 75.85; H, 6.02; N, 3.23%.

4.3. *N*-(*p*-Methoxyphenyl)-[1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthyl]methanimine, 2c

The reaction was carried out as described above except using **1c** (108 mg, 0.266 mmol) and *p*-methoxyaniline (66 mg, 0.532 mmol). Standard work-up gave the crude product which was purified by column chromatography (silica gel 15 g, hexane/Et_3N = 90:10) to afford **2c** (132 mg, 97%): mp 147.0–148.0°C; $R_f=0.31$ (hexane/ethyl acetate = 80:20); ^1H NMR: δ 0.82 (d, 6H, $J=6.9$ Hz, $CH_3\times2$), 1.18 (d, 6H, $J=6.9$ Hz, $CH_3\times2$), 1.28 (d, 6H, $J=6.8$ Hz, $CH_3\times2$), 2.82 (sept., 1H, $J=6.9$ Hz, $CHMe_2$), 3.83 (s, 3H, OCH_3), 4.10 (sept., 2H, $J=6.8$ Hz, $CHMe_2\times2$), 6.89–6.96 (m, 2H, Ar), 7.01 (s, 2H, Tip), 7.29–7.49 (m, 4H, Ar), 7.80–8.09 (m, 3H, Ar), 8.31 (d, 1H, $J=8.6$ Hz, Ar), 10.1 (s, 1H, CH=); ^{13}C NMR: δ 25.0, 26.3, 30.6, 35.8, 57.0, 115.8, 124.3, 124.9, 125.4, 128.0, 128.1, 128.4, 130.3, 130.8, 132.0, 135.7, 138.7, 139.3, 141.2, 147.1, 151.5, 155.0, 158.9, 159.9; IR (KBr): 2960, 1620, 1590, 1510, 1480, 1290, 1250, 1150, 1030, 830, 740 cm^{-1}; EIMS m/z (rel. intensity): 511 (M^+, 4), 452 (82), 292 (63), 122 (54), 28 (100). Anal. calcd for $C_{33}H_{37}NO_2S$: C, 77.46; H, 7.29; N, 2.74; Found: C, 77.35; H, 7.45; N, 2.69%.

4.4. *N*-(*o*-Methoxyphenyl)-[1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthyl]methanimine, 2d

The reaction was carried out as described above, using **1c** (204 mg, 0.503 mmol) and *o*-methoxyaniline (124 mg, 1.01 mmol). Usual work-up gave the crude product which was purified by column chromatography (silica gel 4 g, hexane/ethyl acetate/Et_3N = 95:3:2) to afford **2d** (223 mg, 96%): mp 54.2–54.9°C; $R_f=0.26$ (hexane/ethyl acetate = 80:20); ^1H NMR: δ 0.81 (d, 6H, $J=6.9$ Hz, $CH_3\times2$), 1.18 (d, 6H, $J=6.9$ Hz, $CH_3\times2$), 1.29 (d, 6H, $J=6.8$ Hz, $CH_3\times2$), 2.82 (sept., 1H, $J=6.9$ Hz, $CHMe_2$), 3.92 (s, 3H, OCH_3), 4.10 (sept., 2H, $J=6.8$ Hz, $CHMe_2\times2$), 6.89–6.96 (m, 2H, Ar), 7.01 (s, 2H, Tip), 7.13–7.52 (m, 4H, Ar), 7.80–8.09 (m, 3H, Ar), 8.36 (d, 1H, $J=8.7$ Hz, Ar), 9.99 (s, 1H, CH=); ^{13}C NMR: δ 23.4, 24.7, 29.0, 34.2, 55.8, 111.2, 120.5, 121.2, 123.2, 123.9, 126.5, 126.7, 126.9, 127.0, 128.7, 129.1, 130.4, 134.2, 136.9, 137.8, 140.0, 142.3, 150.0, 152.5, 153.4, 159.8; IR (KBr): 2940, 1600, 1490, 1460, 1250, 1120, 1050, 1030, 740 cm^{-1}; EIMS m/z (rel. intensity): 511 (M^+, 4.8), 495 (33), 495 (46), 494 (74), 453 (34), 452 (100). Anal. calcd for $C_{33}H_{37}NO_2S$: C, 77.46; H, 7.29; N, 2.74. Found: C, 77.33; H, 7.46 N, 2.71%.

4.5. *N*-Phenyl-[1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthyl]methanimine, 2e

The reaction was carried out as described above except using **1c** (202 mg, 0.497 mmol) and aniline (0.068 mL, 0.746 mmol). Standard work-up gave the crude product which was purified by column chromatography (silica gel 20 g, hexane/ethyl acetate/Et_3N = 95:3:2) to afford **2e** (228 mg, 95%): mp 54–55°C; $R_f=0.46$ (hexane/ethyl acetate = 80:20); ^1H NMR: δ 0.81 (d, 6H, $J=6.7$ Hz, $CH_3\times2$), 1.18 (d, 6H, $J=6.9$ Hz, $CH_3\times2$), 1.28 (d, 6H, $J=6.7$ Hz, $CH_3\times2$), 2.81 (sept., 1H, $J=6.9$ Hz, $CHMe_2$), 4.09 (sept., 2H, $J=6.7$ Hz, $CHMe_2\times2$), 7.01 (s, 2H, Tip), 7.18–7.50 (m, 7H, Ar), 7.80–8.10 (m, 3H, Ar), 8.28 (d, 1H, $J=8.6$ Hz, Ar), 9.99 (s, 1H, CH=); ^{13}C NMR: δ 23.3, 23.5, 24.7, 29.0, 34.1, 121.3, 123.2, 123.8, 125.9, 126.5, 126.9, 128.7, 129.0, 130.4, 134.1, 136.7, 137.7, 140.0, 149.9, 152.4, 153.4, 159.5; IR (KBr): 2960, 1610, 1590, 1460, 1150, 1030, 820, 740, 700 cm^{-1}; EIMS m/z (rel. intensity): 481 (M^+, 21), 466 (66), 465 (99), 423 (100), 421 (46), 420 (37), 295 (36), 278 (41), 262 (38), 247 (87), 187 (45). Anal. calcd for $C_{32}H_{35}NOS$: C, 79.79; H, 7.32; N, 2.91. Found: C, 79.72; H, 7.46; N, 2.84%.

4.6. *N*-(*p*-Chlorophenyl)-[1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthyl]methanimine, 2f

The reaction was carried out as described above except using **1c** (314 mg, 0.773 mmol) and *p*-chloroaniline (198 mg, 1.55 mmol). Standard work-up gave the crude product which was purified by column chromatography (silica gel 18 g, hexane/ethyl acetate/Et_3N = 95:3:2) to afford **2f** (132 mg, 99%): mp 170.0–170.5°C; $R_f=0.53$ (hexane/ethyl acetate = 80:20); ^1H NMR: δ 0.81 (d, 6H, $J=6.9$ Hz, $CH_3\times2$), 1.18 (d, 6H, $J=6.9$ Hz, $CH_3\times2$), 1.29 (d, 6H, $J=6.8$ Hz, $CH_3\times2$), 2.82 (sept., 1H, $J=6.9$ Hz, $CHMe_2$), 4.07 (sept., 2H, $J=6.8$ Hz, $CHMe_2\times2$), 7.01 (s, 2H, Tip), 7.23–7.51 (m, 6H, Ar), 7.82–7.84 (m,

1H, Ar), 7.94 (d, 2H, $J=8.5$ Hz, Ar), 8.24 (d, 1H, $J=8.5$ Hz, Ar), 10.0 (s, 1H, CH=); ^{13}C NMR: δ 23.4, 24.8, 29.0, 34.2, 122.7, 123.3, 123.8, 126.6, 127.1, 127.8, 128.8, 128.9, 129.1, 130.5, 131.4, 134.2, 136.7, 137.6, 140.3, 150.0, 150.9, 153.6, 160.3; IR (KBr): 2960, 1610, 1490, 1480, 1050, 840, 740 cm^{-1}; EIMS m/z (rel. intensity): 515 (M^+, 0.1), 497 (39), 453 (100), 293 (55), 184 (47), 112 (39). Anal. calcd for $C_{32}H_{34}ClNOS$: C, 74.47; H, 6.64; N, 2.71. Found: C, 74.35; H, 6.72; N, 2.76%.

4.7. *N*-Benzyl-[1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthyl]methanimine, 2g

The reaction was carried out as described above except using **1c** (517 mg, 1.27 mmol) and benzylamine (205 mg, 1.91 mmol). Standard work-up gave the crude product which was purified by recrystallization to afford **2g** (573 mg, 91%): mp 58–59°C; $R_f=0.42$ (hexane/ethyl acetate = 80:20); ^{1}H NMR: δ 0.79 (d, 6H, $J=6.7$ Hz, $CH_3\times2$), 1.18 (d, 6H, $J=6.9$ Hz, $CH_3\times2$), 1.28 (d, 6H, $J=6.7$ Hz, $CH_3\times2$), 2.82 (sept., 1H, $J=6.9$ Hz, $CHMe_2$), 4.07 (sept., 2H, $J=6.7$ Hz, $CHMe_2\times2$), 4.84 (s, 2H, CH_2Ph), 7.01 (s, 2H, Tip), 7.25–7.49 (m, 6H, Ar), 7.78–7.89 (m, 2H, Ar), 7.98–8.02 (m, 2H, Ar), 8.10–8.17 (m, 1H, Ar), 9.84 (s, 1H, CH=); ^{13}C NMR: δ 23.5, 24.7, 29.0, 34.2, 65.5, 123.2, 123.9, 126.4, 126.7, 126.9, 127.1, 128.2, 128.4, 128.7, 129.1, 130.3, 134.1, 136.5, 137.8, 139.4, 149.9, 153.3, 160.7; IR (KBr): 2960, 1640, 1600, 1460, 1040, 820, 770, 730, 700 cm^{-1}; EIMS m/z (rel. intensity): 495 (M^+, 9.8), 479 (46), 478 (100), 261 (40). Anal. calcd for $C_{33}H_{37}NOS$: C, 79.96; H, 7.52; N, 2.83. Found: C, 79.84; H, 7.68; N, 2.79%.

4.8. *N*-Methyl-[1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthyl]methanimine, 2h

A solution of **1c** (517 mg, 1.27 mmol) and methylamine (200 mg, 40% aqueous solution, 2.58 mmol) in EtOH (10 mL) was stirred under reflux for 12 h. The mixture was purified by recrystallization to afford **2h** (470 mg, 87%): mp 54–55°C; $R_f=0.35$ (hexane/ethyl acetate = 80:20); ^{1}H NMR: δ 0.81 (d, 6H, $J=6.7$ Hz, $CH_3\times2$), 1.19 (d, 6H, $J=6.9$ Hz, $CH_3\times2$), 1.30 (d, 6H, $J=6.8$ Hz, $CH_3\times2$), 2.83 (sept., 1H, $J=6.9$ Hz, $CHMe_2$), 3.51 (s, 3H, CH_3), 4.05 (sept., 2H, $J=6.8$ Hz, $CHMe_2\times2$), 7.02 (s, 2H, Tip), 7.28–7.49 (m, 2H, Ar), 7.78–7.79 (m, 2H, Ar), 7.94–8.01 (m, 1H, Ar), 8.11–8.18 (m, 1H, Ar), 9.48 (s, 1H, CH=); ^{13}C NMR: δ 23.4, 24.5, 28.9, 34.1, 48.2, 123.0, 123.8, 126.3, 126.4, 126.6, 128.5, 129.3, 130.3, 133.9, 136.2, 137.7, 138.8, 149.7, 153.1, 160.9; IR (KBr): 2960, 1630, 1600, 1460, 1060, 880, 820, 740 cm^{-1}; EIMS m/z (rel. intensity): 419 (M^+, 26), 402 (100), 361 (36), 185 (59). Anal. calcd for $C_{27}H_{33}NOS$: C, 77.28; H, 7.93; N, 3.34. Found: C, 77.18; H, 7.97; N, 3.39%.

4.9. *N*-(*p*-Chlorophenyl)-[1-(*tert*-butylsulfinyl)-2-naphthyl]methanimine, 2i

To a solution of **1d** (366 mg, 1.40 mmol) and *p*-chloroaniline (1.79 g, 14.0 mmol) in benzene (14 mL) was added $TiCl_4$ (1.41 mol L^{-1} in CH_2Cl_2, 0.60 mL, 0.84 mmol) at 0°C. After stirred for 30 min, the mixture was filtered through Celite® and the filtrate was concentrated under reduced pressure to leave a residue which was purified by column chromatography (silica gel 50 g, hexane/ethyl acetate/Et_3N = 80:18:2) to afford **2i** (402 mg, 78%). The atropisomer ratio was determined to be 63:37 by the ^{1}H NMR analysis of the product in THF-d_8 at −78°C: $R_f=0.66$ (hexane/ethyl acetate = 50:50); ^{1}H NMR: δ 1.25 (s, 5.7H, ^{t}Bu, major isomer), 1.26 (s, 3.3H, ^{t}Bu, minor isomer), 7.18–7.43 (m, 2H, Ar), 7.56–7.64 (m, 3H, Ar), 7.86–7.94 (m, 5H, Ar), 8.01 (d, 2H, $J=8.8$ Hz, Ar), 8.28 (d, 2H, $J=8.8$ Hz, Ar), 8.41–8.44 (m, 1H, Ar), 8.52 (d, 1.3H, $J=8.8$ Hz, Ar, major isomer), 9.26 (s, 0.7H, CH=, minor isomer), 9.63–9.69 (m, 0.7H, Ar, minor isomer), 10.3 (s, 1.3H, CH=, major isomer); ^{13}C NMR: δ 24.3, 25.0, 60.4, 61.2, 122.2, 122.7, 123.4, 124.7, 125.0, 127.0, 127.3, 127.5, 127.9, 128.4, 128.6, 129.1, 129.4, 131.3, 131.8, 132.3, 132.6, 133.2, 133.8, 134.9, 135.2, 136.7, 138.5, 149.8, 150.0, 156.8, 158.8; IR (KBr): 2960, 1610, 1480, 1200, 1160, 1100, 1050, 840 cm^{-1}; EIMS m/z (rel. intensity): 369 (M^+, 2), 297 (42), 296 (38), 295 (100), 294 (38). Anal. calcd for $C_{21}H_{20}ClNOS$: C, 68.19; H, 5.45; N, 3.79; Found: C, 68.18; H, 5.51; N, 3.74%.

4.10. Reaction of (1-sulfinyl-2-naphthyl)methanimines with alkyllithium. (R_S^*,S^*)-*N*-(*p*-Methoxyphenyl)-1-[1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthyl]ethylamine, (R_S^*,S^*)-3

To a solution of **2c** (102 mg, 0.220 mmol) in THF (2.2 mL) was added MeLi (1.14 mol L^{-1} THF solution, 0.29 mL, 0.33 mmol) at −78°C and the mixture was stirred for 15 min. Saturated aq. NH_4Cl was added and the mixture was extracted with CH_2Cl_2. The combined organic extracts were washed with brine, dried over Na_2SO_4, and concentrated under reduced pressure to leave a residue which was purified by column chromatography (silica gel 12 g, hexane/ethyl acetate = 90:10) to afford (R_S^*,S^*)-**3** (84 mg, 73%). The diastereomer ratio was determined to be >98:2 by the ^{1}H NMR analysis of the crude product: mp 76.1–76.9°C; $R_f=0.15$ (hexane/ethyl acetate = 80:20); ^{1}H NMR: δ 0.65 (d, 3H, $J=6.4$ Hz, CH_3), 0.74 (d, 6H, $J=6.9$ Hz, $CH_3\times2$), 1.15 (d, 6H, $J=6.8$ Hz, $CH_3\times2$), 1.21 (d, 6H, $J=6.9$ Hz, $CH_3\times2$), 2.83 (sept., 1H, $J=6.9$ Hz, $CHMe_2$), 3.65 (s, 3H, OCH_3), 3.70–3.98 (br, 1H, NH), 4.20 (sept., 2H, $J=6.8$ Hz, $CHMe_2\times2$), 4.81 (q, 1H, $J=6.4$ Hz, CH), 6.38–6.42 (m, 2H, Ar), 6.60–6.64 (m, 2H, Ar), 7.06 (s, 2H, Tip), 7.26–7.60 (m, 3H, Ar), 7.73–7.81 (m, 2H, Ar), 9.84 (d, 1H, $J=8.0$ Hz, Ar); ^{13}C NMR: δ 22.4, 23.7, 24.4, 29.1, 34.3, 48.5, 55.6, 114.3, 114.8, 122.8, 123.3, 123.8, 125.8, 126.6, 126.7, 127.5, 128.4, 131.9, 133.2, 133.7, 134.6, 138.7, 140.6, 142.5, 150.0, 152.1, 153.3; IR (KBr): 3360, 2960, 1600, 1510, 1460, 1240, 1040, 820, 760 cm^{-1}; EIMS m/z (rel. intensity): 527 (M^+, 0.1), 509 (72), 304 (69), 121 (48), 28 (100). Anal. calcd for $C_{34}H_{41}NO_2S$: C, 77.38; H, 7.83; N, 2.65; Found: C, 77.34; H, 7.75; N, 2.87%.

4.11. (R^*_S,S*)-*N*-(*o*-Methoxyphenyl)-1-[1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthyl]ethylamine, (R^*_S,S*)-4

The reaction was carried out as described above except using **2d** (72.5 mg, 0.142 mmol) and MeLi (1.14 mol L^{-1}, 0.14 mL, 0.160 mmol). Standard work-up gave the crude product which was purified column chromatography (silica gel 20 g, hexane/ethyl acetate = 95:5) to afford (R^*_S,S*)-**4** (65 mg, 87%). The diastereomeric ratio was determined to be >98:2 by the ^{1}H NMR analysis of the crude product: mp 39–40°C; R_f = 0.48 (hexane/ethyl acetate = 80:20); ^{1}H NMR: δ 0.71 (d, 9H, J = 6.5 Hz, $(CH_3)_2CH$, CH_3), 1.14 (d, 6H, J = 6.6 Hz, CH_3×2), 1.21 (d, 6H, J = 7.0 Hz, CH_3×2), 2.87 (sept., 1H, J = 6.6 Hz, $CHMe_2$), 3.84 (s, 3H, OCH_3), 4.21 (sept., 2H, J = 7.0 Hz, $CHMe_2$×2), 4.52–4.72 (m, 1H, NH), 4.89 (q, 1H, J = 6.5 Hz, CH), 6.25–6.35 (m, 1H, Ar), 6.49–6.79 (m, 3H, Ar), 7.07 (s, 2H, Tip), 7.32–7.61 (m, 3H, Ar), 7.69–7.83 (m, 2H, Ar), 9.79–9.84 (m, 1H, Ar); ^{13}C NMR: δ 22.4, 23.6, 23.7, 24.4, 29.1, 34.3, 47.5, 55.4, 109.1, 110.7, 116.5, 121.6, 122.8, 123.3, 123.8, 125.8, 126.7, 128.4, 131.9, 133.1, 133.7, 134.5, 136.2, 138.6, 146.3, 150.0, 153.2; IR (KBr): 3360, 2960, 1600, 1510, 1460, 1240, 1040, 820, 760 cm^{-1}; EIMS m/z (rel. intensity): 514 (M^+, 1), 512 (43), 511 (100), 306 (32). Anal. calcd for $C_{34}H_{41}NO_2S$: C, 77.38; H, 7.83; N, 2.65. Found: C, 77.17; H, 7.94; N, 2.75%.

4.12. (R^*_S,S*)-*N*-Phenyl-1-[1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthyl]ethylamine, (R^*_S,S*)-5

The reaction was carried out as described above except using **2e** (63 mg, 1.30 mmol) and MeLi (1.14 mol L^{-1}, 0.170 mL, 0.194 mmol). Standard work-up gave the crude product which was purified column chromatography (silica gel 10 g, hexane/ethyl acetate = 95:5) to afford (R^*_S,S*)-**5** (58 mg, 89%). The diastereomer ratio was determined to be >98:2 by the ^{1}H NMR analysis of the crude product: mp 201–202°C; R_f = 0.30 (hexane/ethyl acetate = 80:20); ^{1}H NMR: δ 0.67–0.92 (m, 9H, $(CH_3)_2CH$, CH_3), 1.15 (d, 6H, J = 6.7 Hz, CH_3×2), 1.20 (d, 6H, J = 6.9 Hz, CH_3×2), 2.87 (sept., 1H, J = 6.9 Hz, $CHMe_2$), 4.05–4.35 (m, 3H, $CHMe_2$×2, NH), 4.91 (q, 1H, J = 6.5 Hz, CH), 6.40–6.67 (m, 3H, Ar), 6.95–7.15 (m, 4H, Tip, Ar), 7.41–7.62 (m, 3H, Ar), 7.69–7.87 (m, 2H, Ar), 9.81 (d, 1H, J = 8.5 Hz, Ar); ^{13}C NMR: δ 22.5, 23.6, 23.8, 29.1, 34.3, 47.8, 112.9, 117.5, 122.8, 123.4, 123.8, 125.8, 126.8, 128.4, 129.2, 131.9, 133.1, 133.7, 134.6, 138.6, 142.3, 146.4, 150.0, 153.3; IR (KBr): 3340, 2960, 1600, 1500, 1460, 1320, 1170, 1040, 1020, 850, 750, 700 cm^{-1}; EIMS m/z (rel. intensity): 497 (M^+, 100), 405 (36). Anal. calcd for $C_{33}H_{39}NOS$: C, 79.63; H, 7.90; N, 2.81. Found: C, 79.56; H, 8.06; N, 2.71%.

4.13. (R^*_S,S*)-*N*-(*p*-Chlorophenyl)-1-[1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthyl]ethylamine, (R^*_S,S*)-6

The reaction was carried out as described above except using **2f** (21 mg, 0.041 mmol) and MeLi (1.14 mol L^{-1}, 0.040 mL, 0.046 mmol). Standard work-up gave the crude product which was purified column chromatography (silica gel 4 g, hexane/ethyl acetate/Et_3N = 95:3:2) to afford (R^*_S,S*)-**6** (21 mg, 98%). The diastereomer ratio was determined to be >98:2 by the ^{1}H NMR analysis of the crude product: mp 153–154°C; R_f = 0.22 (hexane/ethyl acetate = 80:20); ^{1}H NMR: δ 0.77 (d, 6H, J = 6.5 Hz, CH_3×2), 1.19 (d, 6H, J = 6.7 Hz, CH_3×2), 1.20 (d, 6H, J = 6.9 Hz, CH_3×2), 1.27 (d, 3H, J = 6.1 Hz, CH_3), 2.87 (sept., 1H, J = 6.5 Hz, $CHMe_2$), 4.05–4.28 (m, 3H, $CHMe_2$×2, NH), 4.95 (q, 1H, J = 6.1 Hz, CH), 6.31 (d, 2H, J = 8.9 Hz, Ar), 6.94 (d, 2H, J = 8.9 Hz, Ar), 7.06 (s, 2H, Tip), 7.48–7.61 (m, 3H, Ar), 7.75–7.83 (m, 2H, Ar), 9.63–9.72 (m, 1H, Ar); ^{13}C NMR: δ 22.6, 23.7, 24.2, 28.9, 34.2, 47.9, 113.9, 122.0, 122.7, 123.4, 123.7, 125.9, 126.9, 128.4, 129.0, 132.1, 132.8, 133.6, 134.8, 138.0, 142.1, 144.9, 150.0, 153.3; IR (KBr): 3290, 2960, 1600, 1490, 1460, 1320, 1040, 1020, 820, 750 cm^{-1}; EIMS m/z (rel. intensity): 531 (M^+, 100), 515 (32), 405 (69), 347 (69), 312 (53), 205 (73), 128 (58). Anal. calcd for $C_{33}H_{38}ClNOS$: C, 74.48; H, 7.20; N, 2.63. Found: C, 74.47; H, 7.36; N, 2.48%.

4.14. (R^*_S,S*)-*N*-(*p*-Chlorophenyl)-1-[1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthyl]prop-2-enylamine, (R^*_S,S*)-7

The reaction was carried out as described above except using **2f** (105 mg, 0.203 mmol) and MeLi (0.74 mol L^{-1}, 0.30 mL, 0.222 mmol). Standard work-up gave the crude product which was purified column chromatography (silica gel 20 g, hexane/ethyl acetate = 95:5) to afford (R^*_S,S*)-**7** (94 mg, 85%). The diastereomer ratio was determined to be >98:2 by ^{1}H NMR analysis of the crude product: mp 200–201°C; R_f = 0.42 (hexane/ethyl acetate = 80:20); ^{1}H NMR: δ 0.76 (d, 6H, J = 6.8 Hz, CH_3×2), 1.16 (d, 12H, J = 6.9 Hz, CH_3×4), 2.85 (sept., 1H, J = 6.9 Hz, $CHMe_2$), 4.01–4.22 (m, 3H, $CHMe_2$×2, NH), 4.91 (d, 1H, J = 10.3 Hz, CH_2=), 4.98 (d, 1H, J = 16.1 Hz, CH_2=), 5.39 (ddd, 1H, J = 4.1, 10.3, 16.1 Hz, CH=), 6.15–6.26 (m, 1H, CH), 6.53 (d, 2H, J = 8.8 Hz, Ar), 7.03 (s, 2H, Tip), 7.05 (d, 2H, J = 8.8 Hz, Ar), 7.40–7.54 (m, 3H, Ar), 7.73–7.88 (m, 2H, Ar), 9.03–9.15 (m, 1H, Ar); ^{13}C NMR: δ 23.6, 24.5, 29.1, 34.2, 52.5, 114.4, 115.0, 122.2, 123.3, 123.6, 124.6, 126.2, 126.7, 128.5, 129.0, 131.6, 133.3, 135.5, 137.2, 138.3, 139.2, 145.1, 149.9, 153.2; IR (KBr): 3320, 2960, 1600, 1500, 1460, 1320, 1040, 1020, 930, 820 cm^{-1}; EIMS m/z (rel. intensity): 543 (M^+, 9), 418 (35), 417 (100). Anal. calcd for $C_{34}H_{38}ClNOS$: C, 75.04; H, 7.04; N, 2.57. Found: C, 74.95; H, 7.12; N, 2.58%.

4.15. (R^*_S,S*)-*N*-(*p*-Chlorophenyl)-1-phenyl-1-[1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthyl]methylamine, (R^*_S,S*)-8

The reaction was carried out as described above except using **2f** (63 mg, 0.130 mmol) and PhLi (1.14 mol L^{-1}, 0.170 mL, 0.194 mmol). Standard work-up gave the crude product which was purified column chromatography (silica gel 10 g, hexane/ethyl acetate = 95:5) to afford (R^*_S,S*)-**8** (58 mg, 89%). The diastereomer ratio was determined to be >98:2 by the ^{1}H NMR analysis of the crude product: mp 177–178°C; R_f = 0.32 (hexane/ethyl acetate = 80:20); ^{1}H NMR: δ 0.80 (d, 6H, J = 6.8 Hz, CH_3×2), 1.13 (d, 6H, J = 6.8 Hz, CH_3×2), 1.18 (d, 6H, J = 6.9 Hz, CH_3×2), 2.81 (sept., 1H, J = 6.8 Hz, $CHMe_2$), 3.99–4.18 (m, 3H, $CHMe_2$×2, NH), 4.21–4.29 (br, 1H, CH), 6.55 (d, 2H, J = 8.9 Hz, Ar), 6.98 (s, 2H, Tip), 7.06

(d, 2H, $J=8.9$ Hz, Ar), 7.19–7.49 (m, 7H, Ar), 7.71–7.83 (m, 3H, Ar), 8.58–8.62 (m, 1H, Ar); ^{13}C NMR: δ 23.6, 24.7, 29.2, 34.2, 53.5, 114.5, 122.2, 123.3, 123.7, 126.2, 126.3, 126.6, 127.0, 127.1, 127.2, 128.5, 129.0, 130.6, 131.8, 132.9, 135.7, 138.0, 141.1, 141.8, 145.4, 149.7, 153.1; IR (KBr): 3360, 2960, 1600, 1500, 1460, 1320, 1040, 1020, 820, 740, 700 cm^{-1}; EIMS m/z (rel. intensity): 593 (M$^+$, 5), 466 (35), 390 (30), 388 (73), 372 (61), 359 (36), 358 (30), 357 (100), 263 (41), 203 (72). Anal. calcd for $C_{38}H_{40}ClNOS$: C, 76.81; H, 6.78; N, 2.36. Found: C, 76.83; H, 6.95; N, 2.16%.

4.16. (R^*_S,S*)- and (R^*_S,R*)-*N*-(*p*-Chlorophenyl)-1-[1-(*tert*-butylsulfinyl)-2-naphthyl)]ethylamine, (R^*_S,S*)- and (R^*_S,R*)-9

The reaction was carried out as described above except using **2i** (101 mg, 0.273 mmol) and MeLi (1.14 mol L^{-1}, 0.26 mL, 0.300 mmol). Standard work-up gave the crude product which was purified column chromatography (silica gel 20 g, hexane/ethyl acetate = 80:20) to afford a diastereomeric mixture of **9** (89 mg, 85%). The diastereomer ratio a:b:c was determined to be 34:27:39 by the ^{1}H NMR analysis of the crude product. Since the diastereomers a and b were determined to be the atropisomeric products by variable temperature ^{1}H NMR; the ratio of (R^*_S,S*)/(R^*_S,R*) turned to be 61:39: $R_f=0.40$ (hexane/ethyl acetate = 50:50); ^{1}H NMR: δ 1.26 (s, 2.4H, ^{t}Bu, b), 1.33 (s, 3.5H, ^{t}Bu, c), 1.38 (s, 3.1H, ^{t}Bu, a), 1.52 (d, 0.8H, $J=6.1$ Hz, -CH$_3$, b), 1.62 (d, 1.0H, $J=6.3$ Hz, -CH$_3$, a), 1.63 (d, 1.2H, $J=6.6$ Hz, -CH$_3$, c), 3.52–4.18 (m, 1.3H, NH, CHMe$_2$, b+c), 5.33–5.53 (m, 0.7H, NH, CHMe$_2$, a), 6.49–6.73 (m, 2H, Ar, a+b+c), 7.02–7.18 (m, 2H, Ar, a+b+c), 7.45–8.07 (m, 5H, Ar, a+b+c), 8.41–8.46 (m, 0.7H, Ar, a+c), 9.47–9.51 (m, 0.3H, Ar, b); ^{13}C NMR: δ 22.9, 23.7, 24.5, 25.0, 25.6, 26.0, 46.5, 47.7, 50.1, 60.0, 60.1, 60.3, 114.5, 114.6, 114.7, 121.8, 122.2, 122.7, 124.1, 124.6, 126.4, 126.6, 126.7, 127.0, 127.2, 128.2, 128.3, 128.5, 129.2, 132.2, 132.4, 132.6, 133.0, 133.2, 133.4, 133.4, 133.5, 133.6, 144.9, 145.2, 145.5, 145.7, 146.4; IR (KBr): 3290, 2960, 1600, 1500, 1040, 820, 760 cm^{-1}; EIMS m/z (rel. intensity): 385 (M+, 6), 314 (38), 312 (100). Anal. calcd for $C_{22}H_{24}ClNOS$: C, 68.46; H, 6.27; N, 3.63. Found: C, 68.46; H, 6.35; N, 3.55%.

4.17. *N*-(*p*-Methoxyphenyl)-[2-(2,4,6-triisopropylphenylsulfinyl)phenyl]methanimine, 10

A mixture of 2-(2,4,6-triisopropylphenyl)sulfinylbenzaldehyde (601 mg, 1.69 mmol) and *p*-methoxyaniline (313 mg, 2.54 mmol) in the presence of 3 Å molecular sieves in benzene was heated under reflux for 12 h. The mixture was filtered through Celite® and the filtrate was concentrated under reduced pressure to leave a residue which was purified by column chromatography (silica gel 40 g, hexane/ethyl acetate/Et$_3$N = 98:2:8) to afford **10** (748 mg, 96%): mp 142–143°C; $R_f=0.32$ (hexane/ethyl acetate = 80:20); ^{1}H NMR: δ 0.97 (d, 6H, $J=6.6$ Hz, CH$_3$×2), 1.12 (d, 6H, $J=6.7$ Hz, CH$_3$×2), 1.25 (d, 6H, $J=6.9$ Hz, CH$_3$×2), 2.89 (sept., 1H, $J=6.7$ Hz, CHMe$_2$), 3.71 (sept., 2H, $J=6.9$ Hz, CHMe$_2$×2), 3.82 (s, 3H, OCH$_3$), 6.81–6.96 (m, 4H, Ar), 7.07 (s, 2H, Tip), 7.45–7.60 (m, 2H, Ar), 7.72–7.80 (m, 1H, Ar), 8.15–8.24 (m, 1H, Ar), 8.64 (s, 1H, CH=); ^{13}C NMR: δ 23.6, 23.8, 24.2, 29.2, 34.4, 55.4, 114.1, 122.5, 123.3, 126.0, 128.3, 130.0, 130.5, 134.3, 135.2, 144.6, 145.6, 150.9, 153.6, 154.2, 158.5; IR (KBr): 2960, 1620, 1590, 1510, 1460, 1250, 1040, 1020, 840, 770 cm^{-1}; EIMS m/z (rel. intensity): 446 (M$^+$, 16), 446 (53), 444 (100), 402 (90), 401 (43), 291 (92), 242 (48), 149 (32). Anal. calcd for $C_{29}H_{35}NO_2S$: C, 75.30; H, 7.22; N, 3.14; Found: C, 75.04; H, 7.71; N, 2.91%.

4.18. (R^*_S,S*)- and (R^*_S,R*)-*N*-(*p*-Methoxyphenyl)-1-[2-(2,4,6-triisopropylphenylsulfinyl)phenyl]ethylamine, (R^*_S,S*)- and (R^*_S,R*)-11

The reaction was carried out as described above except using **10** (101 mg, 0.226 mmol) and MeLi (1.14 mol L^{-1}, 0.30 mL, 0.339 mmol). Standard work-up gave the crude product which was purified column chromatography (silica gel 12 g, hexane/ethyl acetate = 85:15) to afford a diastereomeric mixture of **11** (105 mg, 97%). The diastereomer ratio a:b was determined to be 77:23 by the ^{1}H NMR analysis of the crude product: $R_f=0.17$ (hexane/ethyl acetate = 80:20); ^{1}H NMR: δ 0.60 (d, 0.7H, $J=6.3$ Hz, CH$_3$, minor isomer), 0.80–1.03 (m, 6H, CH$_3$×2), 1.22 (d, 6H, $J=6.6$ Hz, CH$_3$×2), 1.25 (d, 1.4H, $J=6.6$ Hz, CH$_3$×2, minor isomer), 1.27 (d, 4.6H, $J=6.8$ Hz, CH$_3$×2, major isomer), 1.52 (d, 2.3H, $J=6.6$ Hz, CH$_3$, major isomer), 2.89 (sept., 1H, $J=6.8$ Hz, CHMe$_2$), 3.47–3.52 (m, 0.2H, NH, minor isomer), 3.60 (s, 2.3H, OCH$_3$, major isomer), 3.69 (s, 0.7H, OCH$_3$, minor isomer), 3.72–3.81 (m, 0.8H, NH, major), 3.92 (sept., 2H, $J=6.6$ Hz, CHMe$_2$×2), 4.12 (q, 0.2H, $J=6.3$ Hz, CH, minor isomer), 4.48 (q, 0.8H, $J=6.6$ Hz, CH, major isomer), 5.67 (d, 1.5H, $J=9.0$ Hz, Ar, major isomer), 6.37 (d, 1.5H, $J=9.0$ Hz, Ar, major isomer), 6.44 (d, 0.5H, $J=8.9$ Hz, Ar, minor isomer), 6.67 (d, 0.5H, $J=8.9$ Hz, Ar, minor isomer), 7.07 (s, 0.5H, Tip, minor isomer), 7.13 (s, 1.5H, Tip, major isomer), 7.30–7.48 (m, 3H, Ar), 7.91–7.98 (m, 0.2H, Ar, minor isomer), 8.01–8.09 (d, 0.8H, Ar, major isomer); ^{13}C NMR: δ 22.5, 23.5, 23.7, 24.4, 24.6, 24.9, 28.3, 28.7, 34.4, 48.9, 49.8, 55.5, 114.0, 114.2, 114.4, 114.7, 123.3, 125.0, 125.3, 125.4, 126.0, 127.1, 127.3, 130.5, 130.6, 133.5, 135.2 140.1, 140.7, 141.2, 141.3, 143.1, 143.2, 151.4, 151.5, 152.0, 153.6; IR (KBr): 3340, 2960, 1600, 1510, 1460, 1240, 1040, 1020, 820, 760 cm^{-1}; EIMS m/z (rel. intensity): 477 (M$^+$, 17), 462 (95), 461 (100), 256 (77). Anal. calcd for $C_{30}H_{39}NO_2S$: C, 75.43; H, 8.23; N, 2.93. Found: C, 75.32; H, 8.30; N, 2.97%.

4.19. Preparation of the chiral sulfoxides. (*R*)-*N*-(*p*-Methoxyphenyl)-[1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthyl]methanimine, (*R*)-2c

The reaction was carried out as described in the preparation of racemic **2i** except using (*R*)-**1c** (43 mg, 0.106 mmol), *p*-methoxyphenylamine (131 mg, 1.06 mmol) and $TiCl_4$ (1.41 mol L^{-1}, 0.045 mL, 0.064 mmol). Standard work-up gave the crude product which was purified by column chromatography (silica gel 50 g, hexane/Et$_3$N = 90:10) to afford (*R*)-**2c** (51 mg, 94%).

HPLC (Daicel Chiralcel OD-H, hexane/^{i}PrOH = 95:5, flow rate 0.5 mL/min) t_R 17.9 (*S*) and 21.2 min (*R*); $[\alpha]_D^{20} = -589.5$ (*c* 0.23, $CHCl_3$).

4.20. Reaction of (*R*)-2c with MeLi. (R_S,*S*)-*N*-(*p*-Methoxyphenyl)-1-[1-(2,4,6-triisopropylphenylsulfinyl)-2-naphthyl]ethylamine, (R_S,*S*)-3

The reaction was carried out as described in the preparation of racemic **3** except using (*R*)-**2c** (49 mg, 0.095 mmol) and MeLi (1.14 mol L^{-1}, 0.095 mL, 0.108 mmol). Standard work-up gave the crude product which was purified by column chromatography (silica gel 10 g, hexane/ethyl acetate = 90:10) to afford (R_S,*S*)-**3**. The diastereomer ratio was determined to be >98:2 by the ^{1}H NMR analysis of the crude product. column chromatography (silica gel 10 g, hexane/ethyl acetate = 90:10) to afford a mixture of (R_S,*S*)-**3**. The enantiomer excess was determined to be 93% ee by the HPLC analysis. HPLC (Daicel Chiralpak AD, hexane/^{i}PrOH = 80:20, flow rate 0.5 mL/min) t_R 19.5 (*R*) and 26.2 min (*S*).

4.21. Preparation of (*S*)-*N*-(4-methoxyphenyl)-1-(2-naphthyl)ethylamine, (*S*)-12

To a solution of (R_S,*S*)-**3** (18.2 mg, 0.031 mmol) and HMPA (0.030 mL, 0.172 mmol) in THF (0.3 mL) was added *n*-BuLi (0.10 mL, 1.54 mol L^{-1} in hexane, 0.155 mmol) at −78°C. Then the reaction mixture was allowed to warm to 0°C and stirred for 60 min. Standard work-up gave the crude product which was purified by column chromatography (silica gel 15 g, hexane/ethyl acetate = 95:5) to afforded (*S*)-**12** (4.4 mg, 42%). The enantiomer excess was determined to be 94% ee by the HPLC analysis: HPLC (Daicel Chiralcel OD-H, hexane/^{i}PrOH = 90:10, flow rate 0.5 mL/min) t_R 18.1 (*R*) and 21.3 (*S*) min; $[\alpha]_D^{20} = +15.6$ (*c* 0.194, $CHCl_3$, 94% ee).

Acknowledgements

We thank Dr. Shinya Kusuda, Ono Pharmaceutical Co., Ltd., for X-ray crystallographic analyses. This work was partly supported by a Grant-in-Aid for Scientific Research (no. 11650890) from the Ministry of Education, Science, Sports and Culture of Japan.

References

1. For the reaction of (*o*-*tert*-butylphenyl)maleimide, see: (a) Kishikawa, K.; Tsuru, I.; Kohmoto, S.; Yamamoto, M.; Yamada, K. *Chem. Lett*. **1994**, 1605–1606; (b) Curran, D. P.; Qi, H.; Geib, S. J.; DeMello, N. C. *J. Am. Chem. Soc*. **1994**, *116*, 3131–3132; (c) Curran, D. P.; Geib, S.; DeMello, N. *Tetrahedron* **1999**, *55*, 5681–5704.
2. For the reaction of *N*-acyl-*o*-*tert*-butylanilides, see: (a) Hughes, A. D.; Price, D. A.; Shishkin, O.; Simpkins, N. S. *Tetrahedron Lett*. **1996**, *37*, 7607–7610; (b) Kitagawa, O.; Izawa, H.; Taguchi, T.; Shiro, M. *Tetrahedron Lett*. **1997**, *38*, 4447–4450; (c) Kitagawa, O.; Izawa, H.; Sato, K.; Dobashi, A.; Taguchi, T.; Shiro, M. *J. Org. Chem*. **1998**, *63*, 2634–2640; (d) Hughes, A. D.; Simpkins, N. S. *Synlett* **1998**, 967–968; (e) Hughes, A. D.; Price, D. A.; Simpkins, N. S. *J. Chem. Soc., Perkin Trans. 1* **1999**, 1295–1304; (f) Fujita, M.; Kitagawa, O.; Izawa, H.; Dobashi, A.; Fukaya, H.; Taguchi, T. *Tetrahedron Lett*. **1999**, *40*, 1949–1952; (g) Kitagawa, O.; Momose, S.; Fushimi, Y.; Taguchi, T. *Tetrahedron Lett*. **1999**, *40*, 8827–8831; (h) Bach, T.; Schröder, J.; Harms, K. *Tetrahedron Lett*. **1999**, *40*, 9003–9004; (i) Curran, D. P.; Liu, W.; Chen, C. H. *J. Am. Chem. Soc*. **1999**, *121*, 11012–11013; (j) Fujita, M.; Kitagawa, O.; Yamada, Y.; Izawa, H.; Hasegawa, H; Taguchi, T. *J. Org. Chem*. **2000**, *65*, 1108–1114; (k) Kitagawa, O.; Fujita, M.; Kohriyama, M.; Hasegawa, H.; Taguchi, T. *Tetrahedron Lett*. **2000**, *41*, 8539–8544.
3. For the reaction of *N*,*N*-diisopropylnaphthamide, see: (a) Clayden, J.; Westlund, N.; Wilson, F. X.; *Tetrahedron Lett*. **1996**, *37*, 5577–5580; (b) Clayden, J. *Angew. Chem., Int. Ed. Engl*. **1997**, *36*, 949–951; (c) Clayden, J.; Westlund, N.; Wilson, F. X. *Tetrahedron Lett*. **1999**, *40*, 3329–3330; (d) Bragg, R. A.; Clayden, J. *Tetrahedron Lett*. **1999**, *40*, 8323–8326; (e) Bragg, R. A.; Clayden, J. *Tetrahedron Lett*. **1999**, *40*, 8327–8331; (f) Clayden, J.; Westlund, N.; Wilson, F. X. *Tetrahedron Lett*. **1999**, *40*, 7883–7887; (g) Clayden, J.; Westlund, N.; Beddoes, R. L.; Helliwell, M. *J. Chem. Soc., Perkin Trans. 1* **2000**, 1351–1361; (h) Clayden, J.; McCarthy, C.; Westlund, N.; Frampton, C. S. *J. Chem. Soc., Perkin Trans. 1* **2000**, 1363–1378; (i) Clayden, J.; Westlund, N.; Frampton, C. S. *J. Chem. Soc., Perkin Trans. 1* **2000**, 1379–1385; (j) Clayden, J.; McCarthy, C.; Cumming, J. G. *Tetrahedron Lett*. **2000**, *41*, 3279–3283; (k) Clayden, J.; Helliwell, M.; McCarthy, C.; Westlund, N. *J. Chem. Soc., Perkin Trans. 1* **2000**, 3232–3249; (l) Clayden, J.; Johnson, P.; Pink, J. H.; Helliwell, M. *J. Org. Chem*. **2000**, *65*, 7033–7040; (m) Dai, W.; Lau, C. W. *Tetrahedron Lett*. **2001**, *42*, 2541–2544.
4. (a) Thayumanavan, S.; Beak, P.; Curran, D. P. *Tetrahedron Lett*. **1996**, *37*, 2899–2902; (b) Cass, Q. B.; Degani, A. L. G.; Tiritan, M. E.; Matlin, S. A.; Curran, D. P.; Balog, A. *Chirality* **1997**, *9*, 109–112; (c) Koide, H.; Uemura, M. *Chem. Commun*. **1998**, 2483–2484; (d) Curran, D. P.; Hale, G. R.; Geib, S. J.; Balog, A.; Cass, Q. B.; Degani, A. L. G.; Hernandes, M. Z.; Freitas, L. C. G. *Tetrahedron: Asymmetry* **1997**, *8*, 3955–3975; (e) Clayden, J.; Lai, L. W. *Angew. Chem., Int. Ed*. **1999**, *38*, 2556–2557; (f) Godfrey, C. R. A.; Simpkins, N. S.; Walker, M. D. *Synlett* **2000**, 388–390; (g) Hata, T.; Koide, H.; Uemura, M. *Synlett* **2000**, 1145–1147; (h) Shimizu, K. D.; Freyer, O. H.; Adams, R. D. *Tetrahedron Lett*. **2000**, *40*, 5431–5434; (i) Kondo, K.; Iida, T.; Fujita, H.; Suzuki, T.; Yamaguchi, K.; Murakami, Y. *Tetrahedron* **2000**, *56*, 8883–8891; (j) Hata, T.; Koide, H.; Taniguchi, N.; Uemura, M. *Org. Lett*. **2000**, *2*, 1907–1910; (k) Clayden, J.; Lai, L. W. *Tetrahedron Lett*. **2001**, *42*, 3163–3166; (l) Clayden, J.; Johnson, P.; Pink, J. H. *J. Chem. Soc., Perkin Trans. 1* **2001**, 371–375; (m) Dai, W.; Yeung, K. K. Y.; Chow, C. W.; Williams, I. D. *Tetrahedron: Asymmetry* **2001**, *12*, 1603–1613; (n) Ates, A.; Curran, D. P. *J. Am. Chem. Soc*. **2001**, *123*, 5130–5131.

5. (a) Nakamura, S.; Yasuda, H.; Watanabe, Y.; Toru, T. *Tetrahedron Lett*. **2000**, *41*, 4157–4160; (b) Nakamura, S.; Yasuda, H.; Watanabe, Y.; Toru, T. *J. Org. Chem*. **2000**, *65*, 8640–8650.
6. Castellano, J. A.; Goldmacher, J. E.; Barton, L. A.; Kane, J. S. *J. Org. Chem*. **1968**, *33*, 3501–3504.
7. Cromwell, N. H.; Hoeksema, H. *J. Am. Chem. Soc*. **1945**, *67*, 1658–1660.
8. Moretti, I.; Torre, G. *Synthesis* **1970**, 141–144.
9. Reaction of **2f** with *n*-BuLi gave the diastereomeric product in a ratio of 63:37. The reason why *n*-BuLi showed low stereoselectivity is not clear; the stereoselectivity was not improved by the addition of $LiClO_4$, LiBr or HMPA.
10. The stereochemical outcome for the reaction of **2i** was assumed to be the same as that in the reaction of 1-(*tert*-butylsulfinyl)naphthaldehyde in comparison with the ^1H NMR and variable temperature ^1H NMR spectral data. See Ref. 5.
11. Lett, R.; Marquet, A. *Tetrahedron* **1974**, *30*, 3379–3392.
12. Eyring, H. *Chem. Rev*. **1935**, *17*, 65–77.
13. We have obtained a similar result in the reaction of 1-(*tert*-butylsulfinyl)naphthaldehyde (which has somewhat higher activation energy of rotation (17.9 kcal/mol) than that of **2i**) with a Grignard reagent giving a 68:32 mixture of the product. The stereochemistry of the product **9** was assumed to be the same as the product from the reaction of 1-(*tert*-butylsulfinyl)naphthaldehyde. See Ref. 5.
14. 2-Fluoro, 2-chloro, 2-bromo, 2-methoxy, 2-isopropoxycarbonyl- and 2-methyl-substituted, 1-(alkylsulfinyl)naphthalenes are known to preferentially exist as the isomer having the sulfinyl oxygen close to the *peri*-H(8) proton. See: (a) Casarini, D.; Foresti, E.; Gasparrini, F.; Lunazzi, L.; Macciantelli, D.; Misiti, D.; Villani, C. *J. Org. Chem*. **1993**, *58*, 5674–5682; (b) Casarini, D.; Lunazzi, L.; Gasparrini, F.; Villani, C.; Cirilli, M.; Gavuzzo, E. *J. Org. Chem*. **1995**, *50*, 97–102; (c) Baker, R. W.; Kyasnoor, R. V.; Sargent, M. V. *J. Chem. Soc., Perkin Trans. 2* **1998**, 1333–1337; (d) Stephens, P. J.; Aamouche, A.; Devlin, F. J.; Superchi, S.; Donnoli, M. I.; Rosini, C. *J. Org. Chem*. **2001**, *66*, 3671–3677. On the other hand, we recently found that 1-[(2,4,6-triisopropylphenyl)sulfinyl]-2-naphthaldehydes preferentially exist as the isomer having the sulfinyl oxygen close to the formyl group. See Ref. 5.
15. The stereochemistry of other products **4**–**8** was assumed to be the same as that of **3**.
16. Attempts for desulfinylation with Raney Ni did not give the desired product. Successful desulfinylation of the optically active amine **3** with *n*-BuLi has been achieved only in the presence of HMPA. For desulfinylation using *n*-BuLi, see: (a) Lockard, J. P.; Schroeck, C. W.; Johnson, C. R. *Synthesis* **1973**, 485–486; (b) Durst, T.; LeBelle, M. J.; Van den Elzen, R.; Tin, K.-C. *Can. J. Chem*. **1974**, *52*, 761–766; (c) Satoh, T.; Kaneko, Y.; Yamakawa, K. *Tetrahedron Lett*. **1986**, *27*, 2379–2382; (d) Furukawa, N.; Ogawa, S.; Matsumura, K.; Fujihara, H. *J. Org. Chem*. **1991**, *56*, 6341–6348; (e) Nakamura, S.; Oda, M.; Yasuda, H.; Toru, T. *Tetrahedron* **2001**, *57*, 8469–8480. See also Ref. 5.
17. (a) Aspinall, H. C.; Bissett, J. S.; Greeves, N.; Levin, D. *Tetrahedron Lett*. **2002**, *43*, 323–325; (b) Denmark, S. E.; Nakajima, N.; Nicaise, O. J.-C. *J. Am. Chem. Soc*. **1994**, *116*, 8797–8798.