Aluminum-Controlled Reactivity and Diastereoselectivity toward Radical Reactions of Optically Active Aldimines with Metallic Samarium

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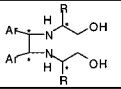
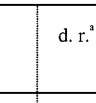
The intermolecular pinacol-type coupling reaction and allylation reaction of optically active imines bearing a β-hydroxy group were performed stereoselectively with metallic samarium after treatment of the imines with trimethylaluminum.

Recently, it has been shown that acyclic radicals can be used for highly stereoselective reactions.[1] The stereochemical aspect of these reactions has been particularly studied during the past decade. A new dimension was opened up by the use of Lewis acids, which have been employed for controlling the reactivity and diastereoselectivity.[2] The use of chiral auxiliaries in radical reactions in the presence of Lewis acids also has been reported recently.[3] Several chelation-controlled radical reactions of ketyl radicals generated by single electron reduction of ketones with samarium iodide are also reported.[4] Recently, we have reported the intermolecular pinacol-type dimerization of optically active imines **1** with metallic samarium (Sm) and a catalytic amount of iodine (Scheme 1, path A).[5] The observed stereochemistry can be predicted by assuming a radical intermediate on the basis of chelation to the Sm(III) cation generated during the reductive imine coupling reaction. We applied this reaction to the imines bearing β-hydroxy group **2**−**5** in order to obtain dimerization products **9**−**11** (N- and O-free) directly (Scheme 1, path B). These products are expected to become chiral ligands in stereoselective reactions. They also might possibly be changed to C_2-ethylenediamines **12**, which are used increasingly in several fields, for instance, stereoselective organic synthesis.[6] We would like to report here the novel effects of trimethylaluminum on reactivity and diastereoselectivity of the Sm-mediated radical dimerization and allylation reactions of optically active aldimines **2**−**5**. To the best of our knowledge, the stereoselective radical reactions with Sm on the basis of chelation control of Lewis acids, except for Sm^{3+}, has not been investigated.

Table 1. Reductive Dimerization of Imines

Imine	Coupling products yield, %			d. r.[a]	Amine yield, % 
2	83 **9** (*SRRS*)	7 *SRSS*	0 *SSSS*	92: 8	4
3	70 **10** (*SRRS*)	8 *SRSS*	0 *SSSS*	90:10	5
4	85 **11** (*RSSR*)	6 *RSRR*	0 *RRRR*	93: 7	2
5	complex mixture			—	—

[a] d. r.: diastereomeric ratio.

First, we attempted the reaction of imine **2** with Sm and a catalytic amount of iodine (the conditions of path A). Only the amine **13** was produced by the reduction of the C−N double bond. Then we tried a variety of methods. At last, we obtained the dimeric compounds bearing β-hydroxy group **9**−**11** stereoselectively. The general dimerization procedure is as follows. A mixture of the imine **2**, Sm (1 equiv) and Me_3Al (1.1 equiv) in hexane was stirred until the evolution of methane ceased. After hexane was removed, a catalytic amount of iodine in THF was added to the mixture, giving the desired coupling product **9** (*SRRS*)[5] in 83% yield. The same reaction of other imines **3** and **4** proceeded smoothly. Table 1 summarizes the results. The reductive coupling products **9**−**11** were obtained with high diastereoselectivity. Some amount of amines **13** were obtained as byproducts. Only the reaction employing **5** failed to give the expected product, but, instead, afforded a complex mixture which was not characterized. The diastereoselectivity of these reductive coupling reactions on the basis of the chelation control of Al^{3+} is slightly lower than that of the coupling reactions of the ether type imine **1** on the basis of the chelation control of Sm^{3+}.[5] We were able to obtain N- and O-free C_2-symmetric compounds **9**−**11** directly from imines **2**−**4** in high yield (Table 1).

The four types of C_2-symmetric compounds **6**−**11** (N-free, O-protected, O-free, N- and O-free) could be employed as chiral ligands for a variety of asymmetric

† Deceased on January 20, 2000.

(1) (a) Giese, B. *Angew. Chem., Int. Ed. Engl.* **1989**, *28*, 969−1146. (b) RajanBabu, T. V. *Acc. Chem. Res.* **1991**, *24*, 139−145. (c) Porter, N. A.; Giese, B.; Currn, D. P. *Acc. Chem. Res.* **1991**, *24*, 296−304. (d) Smadja, W. *Synlett* **1994**, 1−26.

(2) Renaud, P.; Gerster, M. *Angew. Chem., Int. Ed.* **1998**, *37*, 2562−2579.

(3) (a) Yamamoto, Y.; Onuki, S.; Yumoto, M.; Asao, N. *J. Am. Chem. Soc.* **1994**, *116*, 421−422. (b) Sibi, M. P.; Ji, J. *Angew. Chem., Int. Ed. Engl.* **1996**, *35*, 190−192. (c) Sibi, M. P.; Ji, J. G. *J. Am. Chem. Soc.* **1996**, *118*, 3063−3064. (d) Katsumata, A.; Iwaki, T.; Fukumoto, K.; Ihara, M. *Heterocycles* **1997**, *46*, 605−616. (e) Lee, E.; Jeong, J.-W.; Yu, Y. *Tetrahedron Lett.* **1997**, *38*, 7765−7768. (f) Kise, N.; Kumada, K.; Terao, Y.; Ueda, N. *Tetrahedron* **1998**, *54*, 2697−2708.

(4) (a) Matsuda, F. *J. Synth. Org. Chem. Jpn.* **1995**, *53*, 987−998. (b) Molander, G. A.; Harris, C. R. *Chem. Rev.* **1996**, *96*, 307−338. (c) Taniguchi, N.; Hata, T.; Uemura, M. *Angew. Chem., Int. Ed.* **1999**, *38*, 1232−1235.

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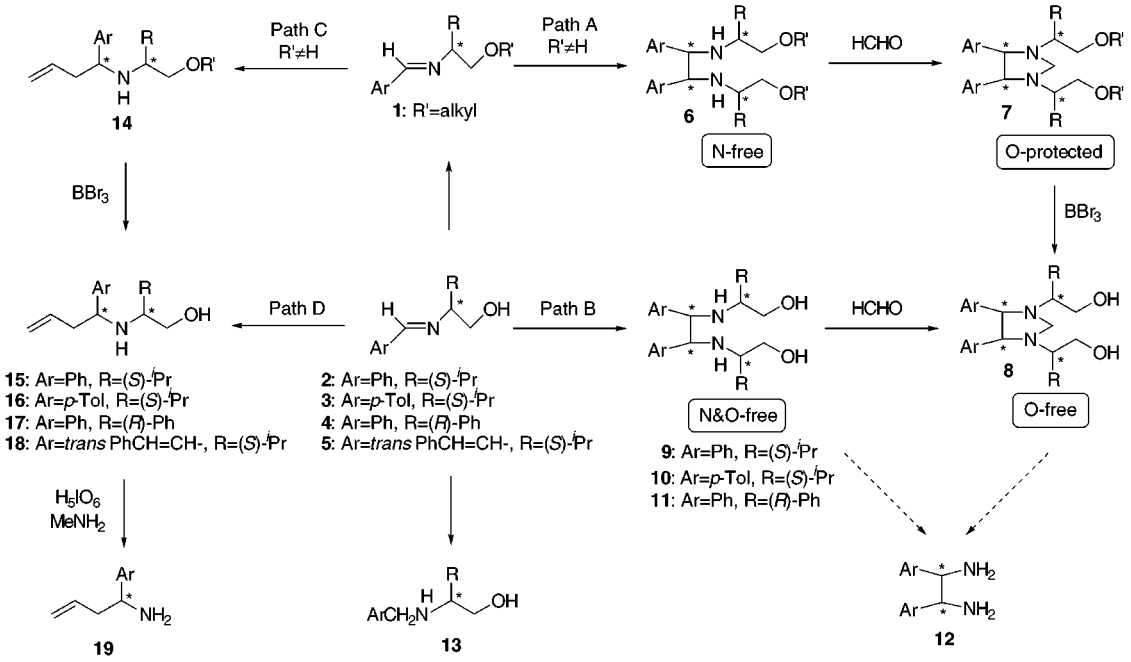
Scheme 1



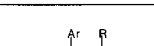
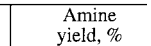
reactions. The diamines **6** and **9**−**11** were treated with formaldehyde to give the compounds **7** and **8** quantitatively (Scheme 1). The O-free compound **8** could be obtained from the dealkylation of the compound **7** by BBr_3, but this step gave low yield and was poorly reproducible. Now we can obtain C_2-symmetric ligands **6**−**11** in short steps, high yields, high diastereoselectivity by a combination of paths A and B. For example, as we expected, C_2-symmetric compound **8** gave high enantiomeric excess in the enantioselective addition of diethylzinc to several aldehydes.[7]

Next, we applied this method mentioned above to the allylation reaction of imines (**2**−**5**).

Previously, we have reported the allylation of ether-type imine **1** with Sm (2 equiv) and iodine (0.1 equiv) (Scheme 1, path C).[8] The allylation of imine **2** bearing a free hydroxy group by the same method gave the allylated diastereomers **15**[9] [(*SS*): (*SR*) = 62:38] in 47% yield. The protection of the free hydroxy group of **2** by Me_3Al, prior to the Sm-mediated allylation, increased the reactivity and diastereoselectivity to give the allylated amines **15** [(*SS*): (*SR*) = 99:1] in 97% yield (Scheme 1, path D), (Table 2).[10] Other imines **3**−**5** also gave allylated products **16**−**18**, which were versatile compounds for synthesizing optically active homoallylamines **19**. For an example, the optically active amine **15** was used for the synthesis of β-amino acid derivative (*R*)-**21** (Scheme 2, 78% overall yield, >99% (*R*)-enantiomer).[11]

In conclusion, we have achieved highly diastereoselective intermolecular coupling reactions of optically active imines bearing a β-hydroxy group with a combination of a Lewis acid (Me_3Al) and the single-electron reduction system (Sm/I_2). This method represents the first example of the dimerization of imines with Sm based on the chelation control of aluminum for the *N*-benzylideneamino alcohol radical. Optically active amino alcohols have been extensively used as catalysts in alkylation of aldehyde with alkyllithium[12] or dialkylzinc,[13] reduction of ketones with borane or borates,[14] and dihydroxylation of a double bond with osmium tetraoxide.[15] We are trying now to use our C_2-chiral compounds for these reactions as asymmetric ligands.

Table 2. Allylation of Imines

Imine	Allyl compounds yield, %		d. r.[a]	Amine yield, % 
2	96 **15** (*SS*)	trace *SR*	>99	trace
3	94 **16** (*SS*)	trace *SR*	>99	trace
4	93 **17** (*RR*)	—	>99	trace
5	70 **18** (*SS*)	—	> 99	—

[a] d. r.: diastereomeric ratio.

Experimental Section

All reactions were carried out under a positive pressure of argon or nitrogen. ^1H NMR spectra were recorded on a JEOL JNM-EX-270 spectrometer using tetramethylsilane (TMS) as an internal standard. ^{13}C NMR spectra were recorded on a

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(10) This allylation reaction proceeded without iodine (0.1 equiv).

(11) Determined by HPLC analysis using Chiralcel OD (hexane: AcOEt = 20:1).

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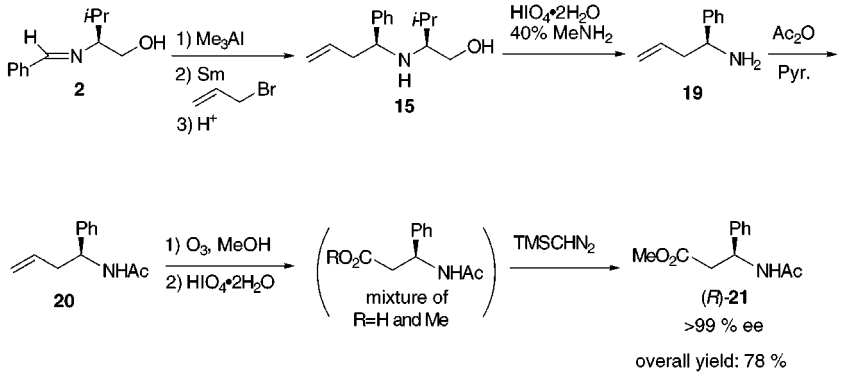
Scheme 2



JEOL JNM-EX-270 (67.8 MHz) spectrometer. Optical rotations were measured with a JASCO DIP-360 digital polarimeter. Nominal (LRMS) and exact mass (HRMS) spectra were recorded on a JEOL JMS-HX/HX-110A instrument. Metallic samarium was purchased from Kojundo Chemical Laboratory Co., Ltd. For flash chromatography, silica gel FL60D (Fuji Silysia Chemical Ltd.) was employed.

General Procedure for the Dimerization of Imines. To a stirred solution of the imine **2** (95.5 mg, 0.5 mmol) and Sm (75 mg, 0.5 mmol) in hexane (1 mL) were added 1 M Me_3Al in hexane (0.55 mL, 0.55 mmol) at 0 °C under argon atmosphere. The mixture was stirred until the evolution of methane ceased. Hexane was removed under reduced pressure. A catalytic amount of iodine (13 mg, 0.05 mmol) in THF (1 mL) was added to the residue at 0 °C under argon. The color changes of the mixture during the reaction served as indicator of the progress of the reaction. After a short induction period, the color of the solution turned to black-purple and then dark blue-green. The reaction mixture was stirred vigorously for 1 h. After the reaction was quenched with 1 N hydrochloric acid, and the resulting mixture was made basic with 10% NaOH aq, the product was extracted with diethyl ether, washed with brine, dried over anhydrous potassium carbonate, and concentrated under reduced pressure. Flash silica gel column chromatography with hexanes−EtOAc (5:1) afforded the title compound **9** (*SRRS*) (79.5 mg, 83%).

Synthesis of (*R*,*R*)-1,2-Diphenyl-*N*,*N*′-bis((*S*)-1-(hydroxymethyl)-2-methylpropyl)ethylenediamine (9), (*SRRS*). Colorless prisms; mp 149 °C (hexane−$CHCl_3$); $[\alpha]^{30}_D$ −58.2 (*c* 1.14, $CHCl_3$). ^{1}H NMR ($CDCl_3$) δ: 0.69 (d, J = 6.6 Hz, 6H), 0.72 (d, J = 6.6 Hz, 6H), 1.57 (ddd, J = 6.6, 6.6, 6.6 Hz, 2H), 2.51 (ddd, J = 3.6, 6.6, 7.3 Hz, 2H), 3.69 (dd, J = 7.3, 11.4 Hz, 2H), 3.77 (dd, J = 3.6, 11.4 Hz, 2H), 3.94 (s, 2H), 7.03−7.16 (m, 10H). ^{13}C NMR ($CDCl_3$) δ: 19.0, 19.3, 29.9, 64.2, 64.7, 69.3, 127.0, 127.0, 128.4, 142.1. LRMS (CI) *m*/*z*, 385 (MH^+), 367, 282, 192. HRMS Calcd for $C_{24}H_{37}N_2O_2$ (MH^+): 385.2857. Found: 385.2859. Anal. Calcd for $C_{24}H_{36}N_2O_2$: C, 74.96; H, 9.44; N, 7.29%. Found: C, 74.84; H, 9.51; N, 7.14%.

(*R*,*S*)-1,2-Diphenyl-*N*,*N*′-bis((*S*)-1-(hydroxymethyl)-2-methylpropyl)ethylenediamine (9), (*SRSS*). Colorless needles; mp 130−132 °C (hexane−$CHCl_3$); $[\alpha]^{26}_D$ 30.2 (*c* 1.00, $CHCl_3$). ^{1}H NMR ($CDCl_3$) δ: 0.43 (d, J = 6.9 Hz, 3H), 0.64 (dd, J = 6.9, 6.9 Hz, 6H), 0.69 (d, J = 6.9 Hz, 3H), 1.46 (qq, J = 6.9, 6.9 Hz, 1H), 1.10−1.70 (br s, 3H), 1.73 (qq, J = 6.9, 6.9 Hz, 1H), 1.95−1.99 (m, 1H), 2.21−2.25 (m, 1H), 2.50−2.70 (br s, 1H), 2.98 (dd, J = 8.6, 10.2 Hz, 1H), 3.17−3.22 (m, 2H), 3.32 (dd, J = 3.6, 11.2 Hz, 1H), 3.68 (d, J = 8.8 Hz, 1H), 3.80 (d, J = 8.8 Hz, 1H), 7.29−7.40 (m, 10H). ^{13}C NMR ($CDCl_3$) δ: 16.5, 18.9, 19.0, 19.3, 27.5, 29.1, 59.6, 60.4, 60.9, 61.6, 66.5, 66.7, 127.9, 128.0, 128.1, 128.4, 128.6, 128.7, 141.6, 142.1. Anal. Calcd for $C_{24}H_{36}N_2O_2$: C, 74.96; H, 9.44; N, 7.29%. Found: C, 74.94; H, 9.24; N, 7.32%.

(*R*,*R*)-1,2-Di-*p*-tolyl-*N*,*N*′-bis((*S*)-1-(hydroxymethyl)-2-methylpropyl)ethylenediamine (10), (*SRRS*). Colorless prisms; mp 133−135 °C (hexane−$CHCl_3$); $[\alpha]^{26}_D$ −33.2 (*c* 2.00, $CHCl_3$). ^{1}H NMR ($CDCl_3$) δ: 0.58 (d, J = 6.6 Hz, 6H), 0.62 (d, J = 6.6 Hz, 6H), 0.75−0.85 (br s, 2H), 1.10−1.25 (br s, 2H), 1.41−1.49 (q, J = 6.6 Hz, 2H), 2.11 (s, 6H), 2.35−2.48 (br s, 2H), 3.54−3.67 (m, 4H), 3.80 (s, 2H), 6.75−6.95 (br s, 8H). ^{13}C NMR ($CDCl_3$) δ: 19.0, 19.3, 21.0, 29.9, 64.2, 64.6, 68.8, 126.8, 129.1, 136.4, 139.2. Anal. Calcd for $C_{26}H_{40}N_2O_2$: C, 75.68; H, 9.77; N, 6.79%. Found: C, 75.41; H, 9.80; N, 6.71%.

(*R*,*S*)-1,2-Di-*p*-tolyl-*N*,*N*′-bis((*S*)-1-(hydroxymethyl)-2-methylpropyl)ethylenediamine (10), (*SRSS*). Colorless oil; $[\alpha]^{28}_D$ 29.2 (*c* 2.00, $CHCl_3$). ^{1}H NMR ($CDCl_3$) δ: 0.44 (d, J = 6.9 Hz, 3H), 0.61−0.71 (m, 9H), 1.42−1.50 (m, 1H), 1.67−1.97 (m, 6H), 2.18−2.25 (m, 1H), 2.34 (s, 3H), 2.36 (s, 3H), 2.97 (dd, J = 9.2, 9.9 Hz, 1H), 3.19 (dd, J = 3.6, 10.7 Hz, 2H), 3.34 (dd, J = 3.6, 11.2 Hz, 1H), 3.64 (d, J = 8.6 Hz, 1H), 3.74 (d, J = 8.6 Hz, 1H), 7.15−7.28 (m, 8H). ^{13}C NMR ($CDCl_3$) δ: 16.6, 18.9, 19.1, 19.4, 21.0, 21.1, 27.5, 29.0, 59.4, 60.2, 60.6, 61.3, 65.9, 66.2, 127.6, 127.8, 128.0, 129.3, 137.4, 137.5, 138.4, 138.9. Anal. Calcd for $C_{26}H_{40}N_2O_2$: C, 75.68; H, 9.77; N, 6.79%. Found: C, 75.63; H, 9.49; N, 6.57%.

(*S*,*S*)-1,2-Diphenyl-*N*,*N*′-bis((*R*)-1-(hydroxymethyl)-2-phenylmethyl)ethylenediamine (11), (*RSSR*). Colorless oil; $[\alpha]^{28}_D$ −81.1 (*c* 2.00, $CHCl_3$). ^{1}H NMR ($CDCl_3$) δ: 3.73−3.93 (m, 8H), 4.05 (br s, 4H), 6.93−7.26 (m, 20H). ^{13}C NMR ($CDCl_3$) δ: 63.2, 66.6, 67.8, 127.1, 127.2, 127.5, 127.7, 128.1, 128.5, 141.0, 141.2. LRMS (FAB) *m*/*z*, 453 (MH^+), 316, 226, 106. HRMS Calcd for $C_{30}H_{33}N_2O_2$ (MH^+): 453.2544. Found: 453.2548.

(*S*,*R*)-1,2-diphenyl-*N*,*N*′-bis((*R*)-1-(hydroxymethyl)-2-phenylmethyl)ethylenediamine (11), (*RSRR*). Colorless oil; $[\alpha]^{28}_D$ −75.9 (*c* 2.00, $CHCl_3$). ^{1}H NMR ($CDCl_3$) δ: 2.03−2.40 (br s, 4H), 3.23−3.51 (m, 6H), 3.64 (d, J = 7.6 Hz, 1H), 3.72 (d, J = 7.6 Hz, 1H), 6.80−7.35 (m, 20H). ^{13}C NMR ($CDCl_3$) δ: 60.8, 61.6, 64.0, 65.2, 66.1, 66.5, 126.6, 127.0, 127.2, 127.2, 127.4, 127.6, 127.7, 128.0, 128.2, 128.3, 128.4, 128.4, 139.9, 140.7, 140.8, 141.0. LRMS (FAB) *m*/*z*, 453 (MH^+), 316, 226, 196, 106. HRMS Calcd for $C_{30}H_{33}N_2O_2$ (MH^+): 453.2544. Found: 453.2547. Anal. Calcd for $C_{30}H_{32}N_2O_2$: C, 79.60; H, 7.13; N, 6.19%. Found: C, 79.67; H, 7.10; N, 5.92%.

General Procedure for the Preparation of Allylated Amines. To a stirred solution of the imine **2** (95.5 mg, 0.5 mmol) and Sm (75 mg, 0.5 mmol) in hexane (1 mL) were added 1 M Me_3Al in hexane (0.55 mL, 0.55 mmol) at 0 °C under argon atmosphere. The mixture was stirred until the evolution of methane ceased. Hexane was removed under reduced pressure. Allyl bromide (121 mg, 1 mmol) in THF (4 mL) was added to the residue at 0 °C under argon. The color changed to black-purple and then dark blue-green. The reaction mixture was stirred vigorously for 30 min. After the reaction was quenched with 1 N hydrochloric acid, the resulting mixture was made basic with 10% NaOH aq, the product was extracted with diethyl ether, washed with brine, dried over anhydrous potassium carbonate, and concentrated under reduced pressure. Usual workup followed by flash silica gel column chromatography with $CHCl_3$ gave the title compound **15** (112.1 mg, 96%).

Synthesis of (2*S*)-3-Methyl-2-(1*S*)-1-phenylbut-3-enylamino)butan-1-ol (15). Colorless oil; $[\alpha]^{24}_D$ −32.4 (*c* 2.00, $CHCl_3$). ^{1}H NMR ($CDCl_3$) δ: 0.81 (d, J = 6.6 Hz, 3H), 0.86 (d, J = 6.9 Hz, 3H), 1.69 (dd, J = 6.6, 6.9 Hz, 1H), 1.80−2.60 (br s, 1H), 2.21−2.28 (m, 1H), 2.34−2.52 (br s, 1H), 2.43 (ddd, J

= 6.6, 6.9, 7.3 Hz, 2H), 3.38 (dd, *J* = 4.2, 10.9 Hz, 1H), 3.61 (dd, *J* = 4.2, 10.9 Hz, 1H), 3.72 (dd, *J* = 6.6, 6.9 Hz, 1H), 4.99−5.09 (m, 2H), 5.62−5.78 (m, 1H), 7.20−7.36 (m, 5H). ^{13}C NMR ($CDCl_3$) *δ*: 18.9, 19.4, 29.3, 42.6, 59.7, 59.9, 61.0, 117.2, 126.9, 127.0, 127.1, 128.0, 128.3, 135.3, 143.8. Anal. Calcd for $C_{15}H_{23}NO$: C, 77.21; H, 9.93; N, 6.00%. Found: C, 77.27; H, 10.06; N, 5.88%.

(2*S*)-3-Methyl-2-(1*S*)-1-*p*-tolylbut-3-enylamino)butan-1-ol (16). Colorless oil; $[\alpha]^{29}_D$ −26.3 (*c* 1.00, $CHCl_3$). ^{1}H NMR ($CDCl_3$) *δ*: 0.81 (d, *J* = 6.6 Hz, 3H), 0.86 (d, *J* = 6.9 Hz, 3H), 1.68 (qq, *J* = 6.6, 6.9 Hz, 1H), 2.09−2.15 (br s, 1H), 2.22−2.29 (m, 1H), 2.33 (s, 3H), 2.37−2.49 (m, 3H), 3.36 (dd, *J* = 4.6, 10.9 Hz, 1H), 3.60 (dd, *J* = 4.1, 10.9 Hz, 1H), 3.69 (t, *J* = 6.9 Hz, 1H), 4.98−5.08 (m, 2H), 5.61 (m, 1H), 7.13 (s, 4H). ^{13}C NMR ($CDCl_3$) *δ*: 19.4, 19.5, 21.0, 29.4, 42.6, 59.7, 61.0, 117.1, 126.9, 129.1, 135.4, 136.7, 140.7. Anal. Calcd for $C_{16}H_{25}NO$: C, 77.63; H, 10.19; N, 5.66%. Found: C, 77.36; H, 10.06; N, 5.37%.

(2*R*)-2-Phenyl-2-(1*R*)-1-phenylbut-3-enylamino)ethanol (17). Colorless oil; $[\alpha]^{29}_D$ −42.3 (*c* 4.00, $CHCl_3$). ^{1}H NMR ($CDCl_3$) *δ*: 2.40 (br s, 2H), 2.35−2.57 (m, 2H), 3.46−3.56 (m, 1H), 3.69−3.87 (m, 3H), 4.97−5.06 (m, 2H), 5.57−5.76 (m, 1H), 7.15−7.35 (10H, m). ^{13}C NMR ($CDCl_3$) *δ*: 41.3, 60.0, 61.2, 65.5, 117.4, 127.1, 127.1, 127.3, 127.4, 128.3, 128.5, 134.9, 141.0, 143.5. Anal. Calcd for $C_{18}H_{21}NO$: C, 80.86; H, 7.92; N, 5.24%. Found: C, 80.98; H, 8.02; N, 4.95%.

(2*S*)-3-Methyl-2-[(1*S*)-1-(4-styrylphenyl)but-3-enylamino]butan-1-ol (18). Colorless oil; $[\alpha]^{29}_D$ −46.1 (*c* 2.00, $CHCl_3$). ^{1}H NMR ($CDCl_3$) *δ*:0.85 (d, *J* = 6.9, 3H), 0.94 (d, *J* = 6.6 Hz, 3H), 1.77 (qq, *J* = 6.6, 6.9 Hz, 1H), 2.10−2.40 (m, 4H), 2.43−2.49 (m, 1H), 3.26−3.35 (m, 1H), 3.42 (dd, *J* = 3.6, 10.7 Hz, 1H), 3.58 (dd, *J* = 4.1, 10.7 Hz, 1H), 5.07−5.16 (m, 2H), 5.78−5.89 (m, 1H), 5.98 (dd, *J* = 8.6, 15.8 Hz, 1H), 6.43 (d, *J* = 15.8 Hz, 1H), 7.23−7.39 (m, 5H). ^{13}C NMR ($CDCl_3$) *δ*: 18.9, 19.6, 29.4, 40.8, 58.2, 60.1, 60.9, 117.5, 126.2, 127.4, 128.5, 131.0, 132.4, 134.9, 136.8. Anal. Calcd for $C_{17}H_{25}O$: C, 78.72; H, 9.71; N, 5.40%. Found: C, 78.81; H, 9.51; N, 5.14%.

***N*-((*S*)-1-Phenylbut-3-enyl)acetamide (20).** Colorless needles; mp 68.0−69.5 °C (hexane−AcOEt).^{1}H NMR ($CDCl_3$) *δ*:1.94 (s, 3H), 2.53 (dd, *J* = 6.9, 6.9 Hz, 2H), 5.00−5.12 (m, 3H), 5.59−5.75 (m, 1H), 6.34 (br d, *J* = 7.6 Hz, 1H), 7.20−7.34 (m, 5H). ^{13}C NMR ($CDCl_3$) *δ*: 23.1, 40.4, 52.5, 117.9, 126.4, 127.2, 128.4, 134.0, 141.7, 169.4. Anal. Calcd for $C_{12}H_{15}NO$: C, 76.16; H, 7.99; N, 7.40%. Found: C, 75.84; H, 8.01; N, 7.35%.

3-Acetylamino-(*R*)-3-phenylpropionic Acid Methyl Ester (21). Colorless prisms; mp 78.0 °C (decomp) (Et_2O).^{1}H NMR ($CDCl_3$) *δ*:1.99 (s, 3H), 2.81 (dd, *J* = 6.1, 15.7 Hz, 1H), 2.92 (dd, *J* = 6.1, 15.7 Hz, 1H), 3.60 (s, 3H), 5.42 (dd, *J* = 6.1, 6.1 Hz), 6.80 (br d, *J* = 7.9 Hz, 1H), 7.24−7.35 (m, 5H). ^{13}C NMR ($CDCl_3$) *δ*: 23.2, 39.7, 49.5, 51.7, 126.2, 127.5, 128.6, 140.5, 169.3, 171.6. Anal. Calcd for $C_{12}H_{15}NO_3$: C, 65.14; H, 6.83; N, 6.33%. Found: C, 65.06; H, 6.86; N, 6.38%.

Supporting Information Available: ^{1}H and ^{13}C NMR spectra and spectral data for **11**. This material is available free of charge via the Internet at http://pubs.acs.org.

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