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Supplementary Information

Acid-Catalyzed Chirality-Transferring Intramolecular Friedel-Crafts Cyclization of α-Hydroxy-α-alkenylsilanes

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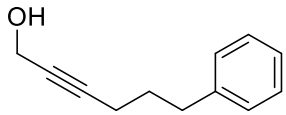
1. General information

All reagents and solvents were purchased from either Aldrich Chemical Company, Inc., Merck & Co., Inc., Nacalai Tesque Co., Ltd., Tokyo Kasei, Kogyo Co., Ltd., Kanto Chemical Co., Ltd., Wako Pure Chemical Industries, Ltd., and used without further purification unless otherwise indicated. Optical rotations ($[\alpha]_D$) were taken on a JASCO P-2200 polarimeter with a sodium lamp (D line). FT-IR spectra were measured on a JASCO FT/IR-4200 infrared spectrophotometer. ^{1}H NMR spectra were recorded on an either Bruker Biospin Avance 300 nanobay (300 MHz), JEOL JNM-ECZ400S or Bruker Biospin Avance III HD 400 (400 MHz). Chemical shifts of ^{1}H NMR were reported in parts per million (ppm, δ) relative to $CHCl_3$ (δ = 7.26) in $CDCl_3$ or C_6H_6 (δ = 7.16) in C_6D_6. ^{13}C NMR spectra were recorded on an either Bruker Biospin Avance 300 nanobay (75 MHz), JEOL JNM-ECZ400S or Bruker Biospin Avance III HD 400 (100 MHz). Chemical shifts of ^{13}C NMR were reported in ppm (δ) relative to $CDCl_3$ (δ = 77.0) or C_6D_6 (δ = 128.06). The following abbreviations are used; s, singlet: d, doublet: t, triplet: q, quartet: quint, quintet: sext, sextet: m, multiplet: br, broad. High resolution mass spectra (HRMS) were obtained on an either JEOL AccuTOF LC-plus 4G for electrospray ionization (ESI), JEOL AccuTOF LC-plus 4G for direct analysis in real time (DART), JEOL JMS-AX500 for electron ionization (EI), JEOL JMS-AX500 for chemical ionization (CI), or JEOL JMS-AX500 for fast atom bombardment ionization (FAB). All reactions were monitored by thin layer chromatography (TLC), which was performed with precoated plates (silica gel 60 F-254, 0.25 mm layer thickness, manufactured by Merck). TLC visualization was accomplished using UV lamp (254 nm) or a charring solution (ethanoic phosphomolybdic acid or $KMnO_4$ *aq*.). Either Wakogel® 60N (particle size 38–100 μm) or Daisogel® IR-60 1002W (particle size 40–63 μm) was used for flash column chromatography on silica gel. Wakogel® B-5F (particle size pass 45 μm) was used for preparative thin-layer chromatography. Activation of powdered 3Å molecular sieves (3Å MS) involved heating in a vacuum oven at 130 °C for at least 3 h.

2. Experimental

Compound 5

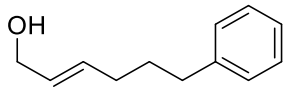


To a solution of 5-Phenyl-1-pentyne (1.01 g, 6.98 mmol) in anhydrous THF (25 mL) was added dropwise *n*-BuLi (1.55 *M* in *n*-hexane, 5.0 mL, 7.8 mmol) at –78 °C under a nitrogen atmosphere. To the mixture was added paraformaldehyde (0.229 g, 7.64 mmol), and the reaction mixture was stirred at 0 °C for 1.5 h, quenched with saturated NH_4Cl, and extracted with AcOEt (x 2). The combined organic layers were washed with brine, dried over $MgSO_4$, and filtered. The filtrate was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (*n*-hexane/AcOEt = 10/1) to give **5** (1.14 g, 94%) as a colorless oil:

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32 (t, *J* = 7.6 Hz, 2 H), 7.27-7.23 (m, 3 H), 4.32 (t, *J* = 2.0 Hz, 2 H), 2.78 (t, *J* = 7.6 Hz, 2 H), 2.30 (tt, *J* = 7.6, 2.0 Hz, 2 H), 1.90 (quint., *J* = 7.6 Hz, 2 H).

^{1}H NMR spectral data of **5** was identical with the authentic data.[1)]

Compound 6

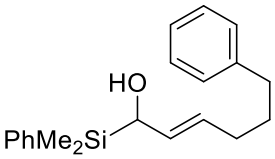


To a stirred suspension of $LiAlH_4$ (0.591 g, 15.6 mmol) in anhydrous THF (10 mL) was added dropwise **5** (0.904 g, 5.19 mmol) at 0 °C under a nitrogen atmosphere. The reaction mixture was stirred under reflux for 5 h. The reaction mixture was cooled to 0 °C and quenched with 1N NaOH. The mixture was filtered through a thin Celite-pad. The filtrate was concentrated under reduced pressure. The residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt = 10/1) to give **6** as a colorless oil (0.557 g, 61%):

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.27 (t, *J* = 7.8 Hz, 2 H), 7.20-7.17 (m, 3 H), 5.75-5.61 (m, 2 H), 4.09 (d, *J* = 4.8 Hz, 2 H), 2.63 (t, *J* = 7.6 Hz, 2 H), 2.10 (brq, *J* = 7.6 Hz, 2 H), 1.73 (quint, *J* = 7.6 Hz, 2 H), 1.26 (t, *J* = 7.6 Hz, 1 H).

^{1}H NMR spectral data of **6** was identical with the authentic data.[1)]

Compound 3a

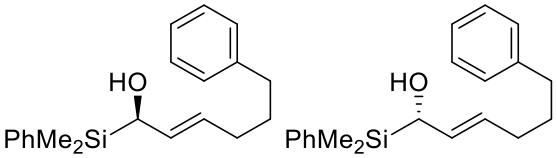


To a solution of **6** (4.36 g, 24.7 mmol) in anhydrous THF (73 mL) was added dropwise *n*-BuLi (1.55 *M* in *n*-hexane, 18.0 mL, 27.9 mmol) at –78 °C under a nitrogen atmosphere. The mixture was stirred at 0 °C for 30 min. $PhMe_2SiCl$ (4.85 g, 28.4 mmol) was added to the mixture at 0 °C. After stirring at room temperature for 18 h, *tert*-BuLi (1.55 *M* in *n*-pentane, 20.0 mL, 31.0 mmol) was added dropwise to the mixture at –78 °C. The reaction mixture was stirred at –45 °C for 4 h, quenched with saturated NH_4Cl at –45 °C, and extracted with Et_2O (x 2). The combined organic layers were washed with saturated $NaHCO_3$, brine, dried over Na_2SO_4, and filtered. The filtrate was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (*n*-hexane/AcOEt = 7/1 with 3% triethylamine) to give **3a** (4.68 mg, 61%) as a colorless oil:

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58-7.55 (m, 2 H), 7.38-7.34 (m, 3 H), 7.28 (t, *J* = 7.2 Hz, 2 H), 7.20-7.16 (m, 3 H), 5.60 (dd, *J* = 15.6, 6.4 Hz, 1 H), 5.18 (dt, *J* = 15.6, 7.2 Hz, 1 H), 4.13 (m, 1 H), 2.59 (t, *J* = 7.2 Hz, 2 H), 2.08 (q, *J* = 7.2 Hz, 2 H), 1.67 (quint., *J* = 7.2 Hz, 2 H), 0.34 (s, 3 H), 0.32 (s, 3H).

^{1}H NMR spectral data of **3a** was identical with the authentic data.[1)]

Compounds (*R*)-3a and (*S*)-3a



Conditions of optical resolution by HPLC using a chiral stationary phase column were as follows:

Column: CHIRALPAK AD-H

Column size: 30 cm × 3 cm

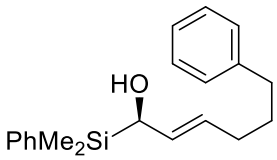
Eluent: *n*-hexane/EtOH = 70/1

Flow rate: 8 mL/min

Detect: 254 nm

Time: (*R*)-**3a**, 19 min, (*S*)-**3a**, 24 min.

Compound (*R*)-3a

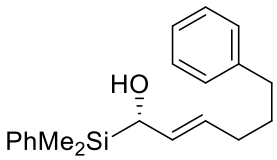


$[\alpha]^{25}_{D}$ +26 (*c* 1.00, $CHCl_3$, >99% ee);

The optical purity of (*R*)-**3a** was determined by the chiral HPLC analysis.

[chiral HPLC data of (*R*)-**3a** (>99% ee): see appendix]

Compound (*S*)-3a



$[\alpha]^{25}_{D}$ –25 (*c* 1.14, $CHCl_3$, >99% ee);

The optical purity of (*S*)-**3a** was determined by the chiral HPLC analysis.

[chiral HPLC data of (*S*)-**3a** (>99% ee): see appendix]

The absolute configuration of **3a** was determined by comparing the sign of the specific rotation with the authentic data.[1)]

General procedure A: Acid-catalyzed reaction of α-hydroxy silanes or their carbon-substituted analogs

To a solution of α-hydroxy silanes in anhydrous CH_2Cl_2 (0.1 *M*) was added powdered molecular sieves 3Å (100 mg/1 mL CH_2Cl_2). The reaction mixture was stirred at –78 °C under a nitrogen atmosphere. Lewis or Brønsted acid (0.3 *M* CH_2Cl_2 solution) was added dropwise to the reaction mixture. The reaction mixture was stirred at –78 °C for 21 h, and the reaction mixture was quenched with saturated $NaHCO_3$ at –78 °C. The reaction mixture was filtered through a celite pad at room temperature. The filtrate was extracted with AcOEt (x 2). The combined organic layers were washed with brine, dried over anhydrous Na_2SO_4, and filtered. The filtrate was concentrated under reduced pressure. The residue was purified by column chromatography on silica gel.

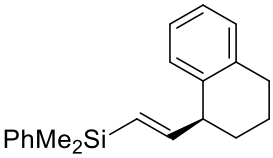
General procedure B: Synthesis of the MTPA ester

To a solution of α-hydroxy silanes (1.0 equiv), triethylamine (5.0 equiv) and *N*,*N*'-dimethylaminopyridine (DMAP, 0.1 equiv) in anhydrous CH_2Cl_2 (0.02 *M*) was added (*R*)-(–)- or (*S*)-(+)-MTPA chloride (2.0 equiv) at room temperature under a nitrogen atmosphere. The reaction mixture was stirred at room temperature for 15 h, quenched with saturated NH_4Cl, and extracted with AcOEt (x 2). The combined organic layers were washed with brine, dried over anhydrous Na_2SO_4, and filtered. The filtrate was concentrated under reduced pressure. The residue was purified by preparative thin-layer chromatography on silica gel.

Reaction of (*S*)-3a

According to the general procedure A, the reaction of (*S*)-**3a** (302 mg, 0.972 mmol) with Me_3SiOTf (43.0 mg, 0.193 mmol) followed by purification by flash column chromatography on silica gel (*n*-hexane/AcOEt = 10/1) afforded (*S*)-**4a** (231 mg, 82%) as a colorless oil and (*R*)-**7a** (45.7 mg, 15%) as a colorless oil.

Compound (*S*)-4a



$[\alpha]^{23}_D$ +49 (*c* 0.98, $CHCl_3$, 98% ee);

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.57–7.52 (m, 2H), 7.38–7.34 (m, 3H), 7.15–7.09 (m, 4H), 6.18 (dd, *J* = 18.5, 7.5 Hz, 1H), 5.79 (dd, *J* = 18.5, 1.2 Hz, 1H), 3.54 (m, 1H), 2.79 (t, *J* = 5.1 Hz, 2H), 2.02–1.83 (m, 2H), 1.80–1.67 (m, 2H), 0.34 (s, 6H);

^{13}C NMR (100 MHz, $CDCl_3$) δ 152.8, 139.2, 138.0, 137.1, 133.8, 129.6, 129.1, 128.8, 128.1, 127.7, 125.9, 125.5, 46.3, 29.8, 29.7, 20.7, –2.3;

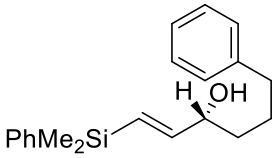
FTIR (neat) 3067, 3017, 2952, 2931, 2859, 1697, 1609, 1489, 1449, 1427, 1248, 1114, 988 cm^{-1};

HRMS (DART) *m*/*z* calcd for $C_{20}H_{25}Si$ $(M+H)^+$ 293.1726, found 293.1724.

The optical purity of (*S*)-**4a** was determined by the chiral HPLC analysis.

[chiral HPLC data of (*S*)-**4a** (98% ee): see appendix]

Compound (*R*)-7a



$[\alpha]^{22}_{D}$ –5 (*c* 0.47, $CHCl_3$, >99% ee);

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.53–7.48 (m, 2H), 7.38–7.33 (m, 3H), 7.31–7.25 (m, 2H), 7.21–7.16 (m, 3H), 6.12 (dd, *J* = 18.8, 5.1 Hz, 1H), 5.97 (dd, *J* = 18.8, 1.2 Hz, 1H), 4.15 (q, *J* = 6.0 Hz, 1H), 2.64 (t, *J* = 7.2 Hz, 2H), 1.82–1.55 (m, 5H), 0.35 (s, 6H);

^{13}C NMR (100 MHz, $CDCl_3$) δ 150.3, 142.3, 138.5, 133.8, 129.0, 128.4, 128.3, 127.8, 127.1, 125.7, 74.5, 36.3, 35.7, 27.1, –2.6;

FTIR (neat) 3359, 3025, 2936, 2858, 1691, 1454, 1428, 1334, 1250, 1113, 992, 843, 735 cm^{-1};

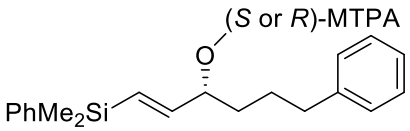
HRMS (ESI+) *m*/*z* calcd for $C_{20}H_{26}NaOSi$ $(M+Na)^+$ 333.16506, found 333.16555.

The absolute configuration of (*R*)-**7a** was determined by the modified Mosher method.[2)]

The optical purity of (*R*)-**7a** was determined by the chiral HPLC analysis.

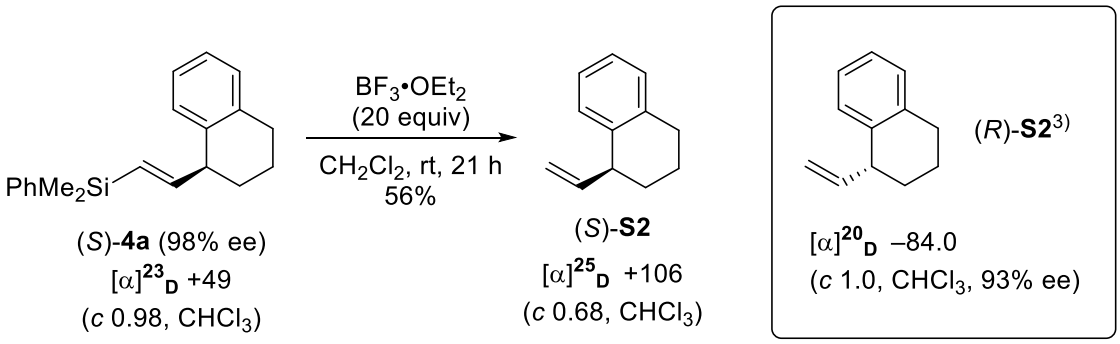
[chiral HPLC data of (*R*)-**7a** (>99% ee): see appendix]

MTPA ester of (*R*)-7a (S1)



According to the general procedure B, the reaction of (*R*)-**7a** (6.0 mg, 0.019 mmol) with triethylamine (13.5 μL, 0.0963 mmol), DMAP (0.2 mg, 0.002 mmol), and (*R*)-MTPA chloride (7.2 μL, 0.039 mmol) followed by purification by preparative thin-layer chromatography on silica gel (*n*-hexane/AcOEt = 10/1) afforded (*S*)-MTPA ester **S1** (5.7 mg, 56%) as a colorless oil. The corresponding (*R*)-MTPA ester **S1'** (8.2 mg, 45%) was synthesized by using (*S*)-MTPA chloride instead of (*R*)-MTPA chloride [^{1}H NMR spectrum of the (*S*)-MTPA ester **S1** and (*R*)-MTPA ester **S1'**: see appendix].

Conversion of (*S*)-4a into the known compound S2[3)]



To a solution of (*S*)-**4a** (50.3 mg, 0.172 mmol, 98% ee) in anhydrous CH_2Cl_2 (1.1 mL) was added dropwise BF_3•OEt_2 (0.43 mL, 3.42 mmol) at room temperature. The reaction mixture was stirred at room temperature for 3 h, quenched with saturated $NaHCO_3$, and extracted with Et_2O (x 2). The combined organic layers were washed with brine, dried over $MgSO_4$, and filtered. The filtrate was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (*n*-hexane only) to give (*S*)-**S2**[3)] (15.2 mg, 56%) as a colorless oil:

$[\alpha]^{25}_D$ +106 (*c* 0.68, $CHCl_3$);

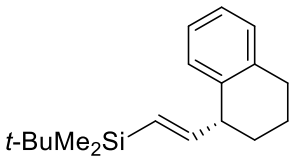
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.24-7.13 (m, 4 H), 5.95 (ddd, *J* = 17.2, 10.1, 8.1 Hz, 1 H), 5.17-5.07 (m, 2 H), 3.52 (m, 1 H), 2.89-2.80 (m, 2 H), 2.05-1.94 (m, 2 H), 1.85-1.73 (m, 2 H);

^{13}C NMR (100 MHz, $CDCl_3$) δ 143.1, 138.1, 136.9, 129.4, 129.1, 125.9, 125.5, 114.9, 43.6, 30.0, 29.6, 20.7;

FTIR (neat) 3074, 3017, 2931, 2856, 1638, 1488, 1450, 1000, 990, 913, 828, 768, 742, 665 cm^{-1};

HRMS (EI) *m/z* calcd for $C_{12}H_{14}$ $(M)^+$ 158.1096, found 158.1077.

Compound (*R*)-4b



According to the general procedure A, the reaction of (*R*)-**3b**[1)] (>99% ee, 58.3 mg, 0.201 mmol) with Me_3SiOTf (0.5 *M* in CH_2Cl_2, 80 μL, 0.04 mmol) followed by purification by flash column chromatography on silica gel (*n*-hexane/AcOEt = 10/1) afforded (*R*)-**4b**

(33.6 mg, 61%) as a colorless oil:

$[\alpha]^{22}_{D}$ –48 (*c* 1.50, $CHCl_3$, 96% ee);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.12-7.10 (4 H), 6.07 (dd, *J* = 18.4, 7.6 Hz, 1 H), 5.64 (dd, *J* = 18.4, 1.0 Hz, 1 H), 3.49 (m, 1 H), 2.78 (t, *J* = 6.2 Hz, 2 H), 1.99-1.86 (m, 2 H), 1.75-1.66 (m, 2 H), 0.88 (s, 9 H), 0.02 (s, 3 H), 0.01 (s, 3 H);

^{13}C NMR (75 MHz, $CDCl_3$) δ 152.2, 138.2, 137.0, 129.5, 129.1, 127.5, 125.9, 125.5, 46.6, 30.0, 29.7, 26.5, 20.9, 16.6, -6.02, -6.04;

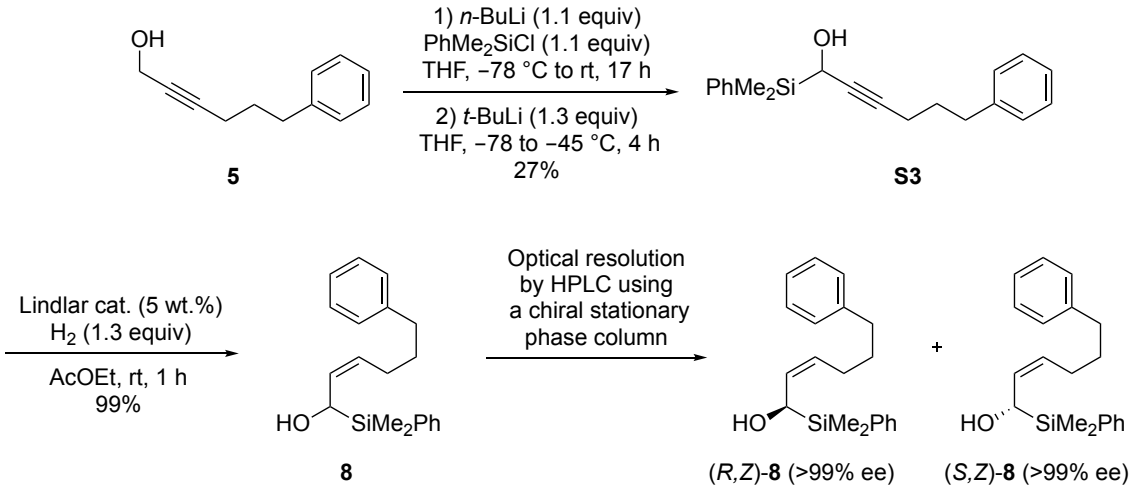
FTIR (neat) 2951, 2927, 2881, 2855, 1609, 1489, 1470, 1462, 1448, 1361, 1254, 1247, 988, 841, 829, 747, 661 cm^{-1};

HRMS (EI) *m/z* calcd for $C_{18}H_{28}Si$ $(M)^+$ 272.1960, found 272.1974;

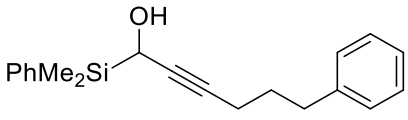
The optical purity of (*R*)-**4b** was determined by the chiral HPLC analysis.

[chiral HPLC data of (*R*)-**4b** (96% ee): see appendix]

Synthesis of (*R, Z*)-8 and (*S, Z*)-8



Compound S3



To a solution of **5** (1.20 g, 6.92 mmol) in anhydrous THF (23 mL) was added dropwise *n*-BuLi (1.6 *M* in *n*-hexane, 4.8 mL, 7.7 mmol) at –78 ℃ under a nitrogen atmosphere. The mixture was stirred at 0 ℃ for 40 min. $PhMe_2SiCl$ (1.37 g, 8.00 mmol) was added to the mixture at 0 ℃. After stirring at room temperature for 17 h, *tert*-BuLi (1.55 *M* in *n*-

pentane, 5.8 mL, 9.0 mmol) was added dropwise to the mixture at –78 ℃. The reaction mixture was stirred at –45 ℃ for 4 h, quenched with saturated NH_4Cl at –45 ℃, and extracted with Et_2O (x 2). The combined organic layers were washed with saturated $NaHCO_3$, brine, dried over Na_2SO_4, and filtered. The filtrate was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (*n*-hexane/AcOEt = 10/1 with 3% triethylamine) to give **S3** (573.9 mg, 27%) as a colorless oil:

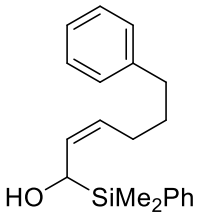
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.65–7.62 (m, 2H), 7.40–7.36 (m, 3H), 7.31–7.26 (m, 2H), 7.21–7.14 (m, 3H), 4.28 (dt, *J* = 4.5, 2.4 Hz, 1H), 2.92 (brs, 1H), 2.68 (t, *J* = 7.8 Hz, 2H), 2.26 (td, *J* = 7.1, 2.4 Hz, 2H), 1.80 (quint, *J* = 6.9 Hz 2H) 0.45 (s, 3H), 0.44 (s, 3H);

^{13}C NMR (100 MHz, $CDCl_3$) δ 141.6, 135.4, 134.3, 129.6, 128.5, 128.3, 127.8, 125.8, 88.4, 80.6, 56.2, 34.8, 30.5, 18.5, –5.5, –5.8;

FTIR (neat) 3416, 3026, 2941, 2858, 1453, 1428, 1251, 1114, 983, 835, 785, 738, 701 cm^{-1};

HRMS (ESI+) *m*/*z* calcd for $C_{20}H_{24}NaOSi$ $(M+Na)^+$ 331.14941, found 331.15007.

Compound 8



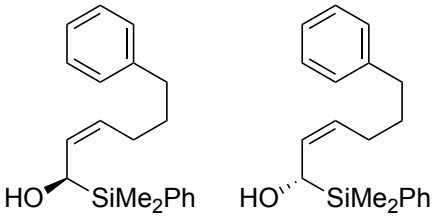
A suspension of **S3** (245.5 mg, 0.800 mmol) and Lindlar catalyst (12.5 mg, 5 wt%) in AcOEt (6 mL) was stirred at room temperature for 1 h under a hydrogen atmosphere. The mixture was filtered and the filtrate was concentrated under reduced pressure to give **8** (245.0 mg, 99%) as a colorless oil:

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.58–7.55 (m, 2H), 7.38–7.34 (m, 3H), 7.27–7.24 (m, 2H), 7.20–7.12 (m, 3H), 5.51–5.32 (m, 2H), 4.39 (d, *J* = 9.9 Hz, 1H), 2.55 (td, *J* = 7.5, 3.6 Hz, 2H), 2.01 (sext, *J* = 7.5 Hz, 1H), 1.81 (sext, *J* = 7.5 Hz, 1H), 1.62–1.53 (m, 3H), 0.34 (s, 3H), 0.31 (s, 3H);

^{13}C NMR (100 MHz, $CDCl_3$) δ 142.2, 136.2, 134.2, 130.4, 129.4, 129.3, 128.4, 128.2, 127.8, 125.7, 63.6, 35.4, 31.3, 27.4, –5.5, –6.0;

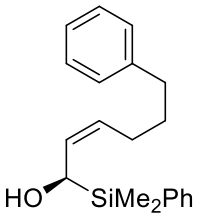
FTIR (neat) 3394, 3025, 2931, 2857, 1692, 1428, 1251, 1115, 836, 736, 700 cm^{-1};
HRMS (ESI+) *m*/*z* calcd for $C_{20}H_{26}NaOSi$ $(M+Na)^+$ 333.16506, found 333.16408.

Compounds (*R*,*Z*)-8 and (*S*,*Z*)-8



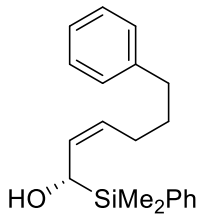
Conditions of optical resolution by HPLC using a chiral stationary phase column were as follows:
Column : CHIRALPAK AD-H
Column size : 30 cm × 3 cm
Eluent : *n*-hexane/EtOH = 70/1
Flow rate : 8 mL/min
Detect : 254 nm
Time : (*R*,*Z*)-**8**, 29 min, (*S*,*Z*)-**8**, 26 min

Compound (*R*,*Z*)-8



$[\alpha]^{27}_D$ +93 (*c* 0.53, $CHCl_3$, >99% ee);
^1H NMR spectral data was identical with that of **8**.
The absolute configuration of (*R*,*Z*)-**8** was determined by the modified Mosher method.[2)]
The optical purity of (*R*,*Z*)-**8** was determined by the chiral HPLC analysis.
[chiral HPLC data of (*R*,*Z*)-**8** (>99% ee): see appendix]

Compound (*S*,*Z*)-8



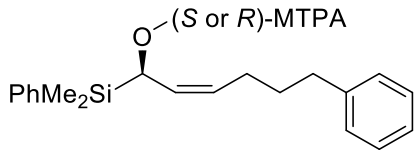
$[\alpha]^{27}_{D}$ –91 (*c* 0.51, $CHCl_3$, >99% ee);

The absolute configuration of (*S*,*Z*)-**8** was determined by the modified Mosher method.[2)]

The optical purity of (*S*,*Z*)-**8** was determined by the chiral HPLC analysis.

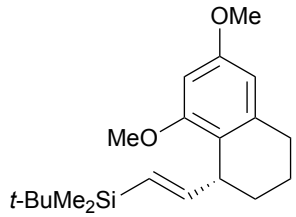
[chiral HPLC data of (*S*,*Z*)-**8** (>99% ee): see appendix]

MTPA ester of (*R*,*Z*)-8 (S4)



According to the general procedure B, the reaction of (*R*,*Z*)-**8** (10.1 mg, 0.0326 mmol) with triethylamine (23.0 μL, 0.164 mmol), DMAP (0.4 mg, 0.003 mmol), and (*R*)-MTPA chloride (12.0 μL, 0.0641 mmol) followed by purification by preparative thin-layer chromatography on silica gel (*n*-hexane/AcOEt = 10/1) afforded (*S*)-MTPA ester **S4** (16.4 mg, 96%) as a colorless oil. The corresponding (*R*)-MTPA ester **S4'** (13.3 mg, 77%) was synthesized by using (*S*)-MTPA chloride instead of (*R*)-MTPA chloride [^{1}H NMR spectrum of the (*S*)-MTPA ester **S4** and (*R*)-MTPA ester **S4'**: see appendix].

Compound 4c



According to the general procedure A, the reaction of (*R*)-**3c** (>99% ee, 29.1 mg, 0.0830 mmol) with Me_3SiOTf (3.8 mg, 0.017 mmol) followed by purification by flash column chromatography on silica gel (*n*-hexane/AcOEt = 10/1) afforded **4c** (72% ee, 7.2 mg, 26%) as a colorless oil:

$[\alpha]^{25.1}_{D}$ -17 (*c* 1.80, $CHCl_3$, 72% ee);

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.28 (d, *J* = 2.4 Hz, 1 H), 6.25 (d, *J* = 2.4 Hz, 1 H), 6.10 (dd, *J* = 18.7, 5.5 Hz, 1 H), 5.27 (dd, *J* = 18.7, 1.5 Hz, 1 H), 3.79 (s, 3 H), 3.71 (s, 3 H), 3.66 (m, 1 H), 2.74-2.69 (m, 2 H), 1.88 (m, 1 H), 1.81-1.63 (m, 3 H), 0.82 (s, 9 H), -0.02 (s, 3 H), -0.04 (s, 3 H);

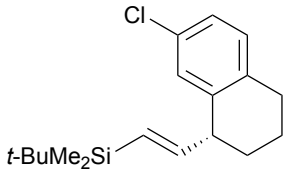
^{13}C NMR (100 MHz, $CDCl_3$) δ 158.9, 158.7, 151.7, 139.3, 125.0, 119.8, 104.4, 96.2, 55.33, 55.26, 38.2, 30.2, 28.6, 26.6, 18.5, 16.8, -5.8, -6.0;

FTIR (neat) 2932, 2853, 1607, 1489, 1463, 1359, 1277, 1247, 1198, 1155, 1140, 1107, 1051, 987, 945, 847, 830 cm^{-1};

HRMS (FAB) *m/z* calcd for $C_{20}H_{33}O_2Si$ $(M+H)^+$ 333.2244, found 333.2242.

[chiral HPLC data of **4c** (72% ee): see appendix]

Compound 4d



According to the general procedure A, the reaction of (*S*)-**3d** (49% ee, 48.5 mg, 0.149 mmol) with Me_3SiOTf (6.67 mg, 0.030 mmol) followed by purification by flash column chromatography on silica gel (*n*-hexane/AcOEt = 10/1) afforded **4d** (27% ee, 4.5 mg, 10%) as a colorless oil:

$[\alpha]^{28}_{D}$ –4 (*c* 0.13, $CHCl_3$, 27% ee);

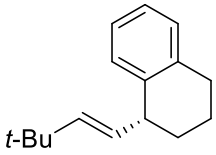
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.09-7.06 (m, 2 H), 7.00 (d, *J* = 8.0 Hz, 1 H), 6.01 (dd, *J* = 18.4, 7.0 Hz, 1 H), 5.65 (dd, *J* = 18.4, 0.8 Hz, 1 H), 3.44 (q, *J* = 7.0 Hz, 1 H), 2.72 (t, *J* = 5.8 Hz, 2 H), 1.95-1.84 (m, 2 H), 1.75-1.65 (m, 2 H), 0.88 (s, 9 H), 0.03 (s, 3 H), 0.02 (s, 3 H);

^{13}C NMR (100 MHz, $CDCl_3$) δ151.2, 140.1, 135.4, 131.0, 130.4, 129.3, 128.4, 126.0, 46.5, 29.6, 29.1, 26.5, 20.6, 16.6, –6.1, –6.1;

HRMS (DART) *m/z* calcd for $C_{18}H_{28}ClSi$ $(M+H)^+$ 307.1649, found 307.1633.

[chiral HPLC data of **4d** (27% ee): see appendix]

Compound 10



According to the general procedure A, the reaction of (*S*)-**9**[1)] (90% ee, 21.8 mg, 0.094 mmol) with Me_3SiOTf (21.0 mg, 0.094 mmol) followed by purification by flash column chromatography on silica gel (*n*-hexane/AcOEt = 10/1) afforded **10** (15% ee, 14.6 mg, 73%) as a colorless oil:

$[\alpha]^{24}_{D}$ –7 (*c* 0.35, $CHCl_3$, 15% ee);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.16-7.06 (m, 4 H), 5.52 (d, *J* = 15.6 Hz, 1 H), 5.36 (dd, *J* = 15.6, 8.3 Hz, 1 H), 3.35 (td, *J* = 8.6, 3.5 Hz, 1 H), 2.80-2.77 (m, 2 H), 1.96-1.86 (m, 2 H), 1.77-1.59 (m, 2 H), 1.03 (s, 9 H);

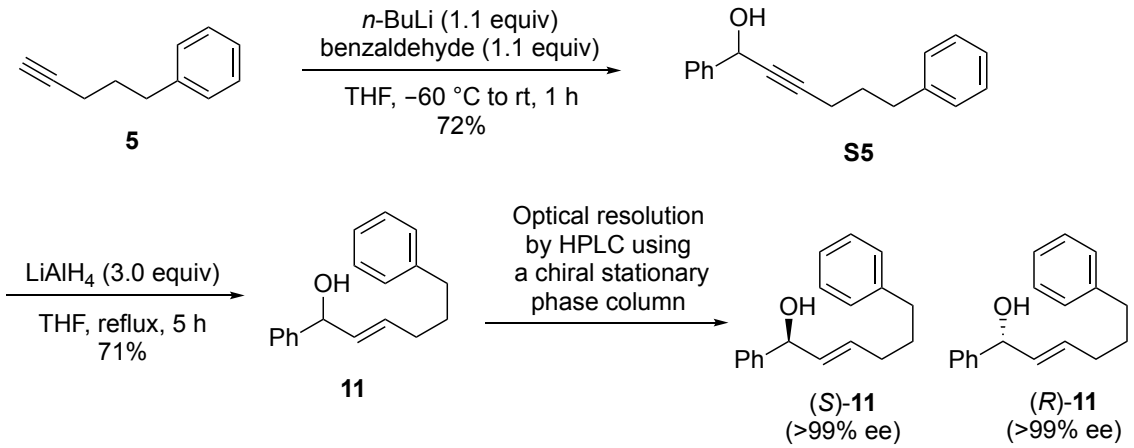
^{13}C NMR (100 MHz, $CDCl_3$) δ 142.6, 139.6, 137.1, 129.5, 129.4, 129.1, 125.8, 125.6, 42.7, 33.0, 31.0, 29.99, 29.97, 21.3;

FTIR (neat) 3407, 3060, 3017, 2954, 2865, 1478, 1452, 1363, 971, 769, 755, 736 cm^{-1};

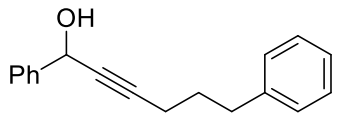
HRMS (EI) *m/z* calcd for $C_{16}H_{22}$ $(M)^+$ 214.1722, found 214.1722.

[chiral HPLC data of **10** (15% ee): see appendix]

Synthesis of (*R*)-11 and (*S*)-11



Compound S5

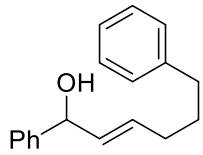


To a solution of 5-phenyl-1-pentyne (**5**, 2.04 g, 14.2 mmol) in anhydrous THF (47 mL) was added dropwise *n*-BuLi (1.6 *M* in *n*-hexane, 9.75 mL, 15.6 mmol) at –60 ℃ under a nitrogen atmosphere. The mixture was stirred at –60 ℃ for 10 min. Benzaldehyde (1.07 g, 15.6 mmol) was added dropwise to the mixture at –60 ℃. The reaction mixture was stirred at room temperature for 1 h, quenched with saturated NH_4Cl at room temperature, and extracted with AcOEt (x 2). The combined organic layers were washed with brine, dried over Na_2SO_4, and filtered. The filtrate was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (*n*-hexane/AcOEt = 8/1) to give **S5** (2.58 g, 72%) as a colorless oil:

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58–7.54 (m, 2H), 7.42–7.26 (m, 5H), 7.21–7.17 (m, 3H), 5.47 (d, *J* = 8.0 Hz, 1H), 2.73 (t, *J* = 10.0 Hz, 2H), 2.30 (td, *J* = 9.4, 2.8 Hz, 2H), 2.07 (d, *J* = 8.0 Hz, 1H), 1.87 (quint, *J* = 9.6 Hz, 2H).

^{1}H NMR spectral data of **S5** was identical with the authentic data.[4)]

Compound 11

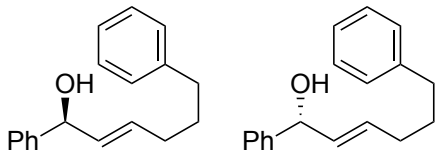


To a stirred suspension of $LiAlH_4$ (460 mg, 12.1 mmol) in anhydrous THF (8 mL) was added dropwise **S5** (1.01 g, 4.05 mmol) at 0 ℃ under a nitrogen atmosphere. The reaction mixture was stirred under reflux for 5 h. The reaction mixture was cooled to 0 ℃ and quenched with 1N NaOH. The mixture was filtered through a thin Celite-pad. The filtrate was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (*n*-hexane/AcOEt = 8/1) to give (±)-**11** (725.4 mg, 71%) as a colorless oil:

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41–7.36 (m, 4H), 7.32–7.28 (m, 3H), 7.23–7.18 (m, 3H), 5.80 (dt, *J* = 15.6, 6.0 Hz, 1H), 5.70 (dd, *J* = 15.2, 6.4 Hz, 1H), 5.19 (d, *J* = 6.4 Hz, 1H), 2.65 (t, *J* = 7.6 Hz, 2H), 2.13 (q, *J* = 7.2 Hz, 2H), 2.01 (brs, 1H), 1.76 (quint, *J* = 7.6 Hz 2H);

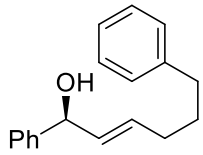
^{13}C NMR (100 MHz, $CDCl_3$) δ 143.3, 142.2, 132.7, 132.0, 128.4 (x 2), 128.2, 127.4, 126.1, 125.7, 75.1, 35.3, 31.6, 30.7;
FTIR (neat) 3330, 3027, 2930, 2855, 1602, 1494, 1452, 1029, 1007, 748, 699 cm^{-1};
HRMS (ESI+) *m*/*z* calcd for $C_{20}H_{20}NaOSi$ $(M+Na)^+$ 275.14118, found 275.13917.

Compounds (*S*)-11 and (*R*)-11



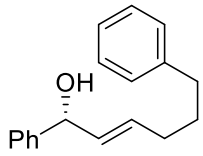
Conditions of optical resolution by HPLC using a chiral stationary phase column were as follows:
Column: CHIRALPAK AD-H
Column size: 30 cm × 3 cm
Eluent: *n*-hexane/EtOH = 50/1
Flow rate: 8 mL/min
Detect: 254 nm
Time: (*R*)-**11**, 47 min, (*S*)-**11**, 39 min.

Compound (*S*)-**11**



$[\alpha]^{26}_D$ +25 (*c* 0.93, $CHCl_3$, >99% ee);
The absolute configuration of (*S*)-**11** was determined by the modified Mosher method.[2)]
The optical purity of (*S*)-**11** was determined by the chiral HPLC analysis.
[chiral HPLC data of (*S*)-**11** (>99% ee): see appendix]

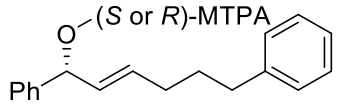
Compound (*R*)-**11**



$[\alpha]^{26}_D$ –25 (*c* 0.87, $CHCl_3$, >99% ee);
The absolute configuration of (*R*)-**11** was determined by the modified Mosher method.[2)]

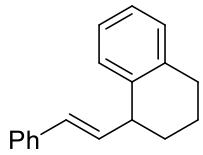
The optical purity of (*R*)-**11** was determined by the chiral HPLC analysis.
[chiral HPLC data of (*R*)-**11** (>99% ee): see appendix]

MTPA ester of (*R*)-11 (S6)



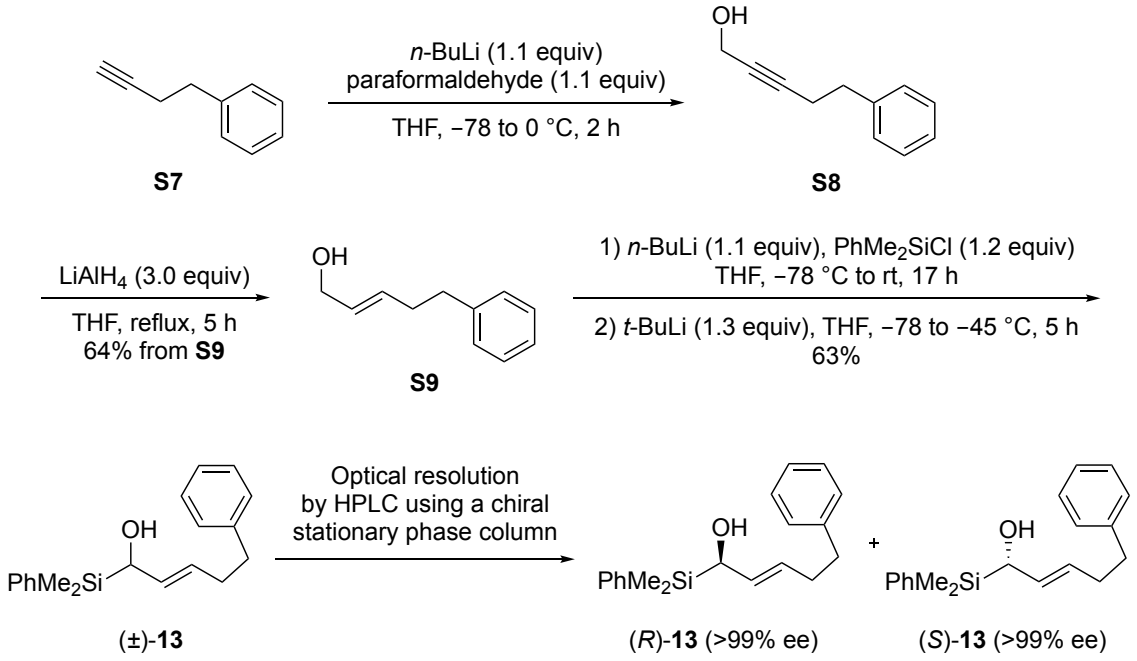
According to the general procedure B, the reaction of (*R*)-**11** (11.3 mg, 0.0448 mmol) with triethylamine (31.0 μL, 0.223 mmol), DMAP (0.6 mg, 0.005 mmol), and (*R*)-MTPA chloride (17.0 μL, 0.0908 mmol) afforded (*S*)-MTPA ester **S6** (24.6 mg, quant) as a pale yellow oil. The corresponding (*R*)-MTPA ester **S6'** (25.0 mg, quant) was synthesized by using (*S*)-MTPA chloride instead of (*R*)-MTPA chloride [^{1}H NMR spectrum of the (*S*)-MTPA ester **S6** and (*R*)-MTPA ester **S6'**: see appendix].

Compound 12

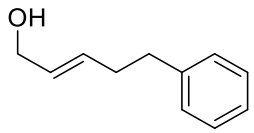


According to the general Procedure A, the reaction of (*S*)-**11** (>99% ee, 48.3 mg, 0.191 mmol) with Me_3SiOTf (8.5 mg, 0.038 mmol) followed by purification by flash column chromatography on silica gel (*n*-hexane/AcOEt = 20/1) afforded **12** (0% ee, 40.0 mg, 89%) as a colorless oil:
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40–7.38 (m, 2H), 7.33–7.30 (m, 2H), 7.24–7.20 (m, 2H), 7.16–7.11 (m, 2H), 6.44 (d, *J* = 15.6, 1H), 6.30 (dd, *J* = 15.6, 8.4 Hz, 1H), 2.86–2.82 (m, 2H), 2.08–1.94 (m, 2H), 1.83–1.77 (m, 2H).
^{1}H NMR spectral data of **12** was identical with the authentic data.[5)]
[chiral HPLC data of **12** (0% ee): see appendix]

Synthesis of (*R*)-13 and (*S*)-13



Compound S9



To a solution of **S7** (3.97 g, 30.5 mmol) in anhydrous THF (99 mL) was added dropwise *n*-BuLi (1.6 *M* in *n*-hexane, 21.0 mL, 33.6 mmol) at –78 ℃ under a nitrogen atmosphere. The mixture was stirred at –78 ℃ for 30 min. Paraformaldehyde (1.01 g, 33.7 mmol) was added to the mixture at –78 ℃. The reaction mixture was stirred at 0 °C for 2 h, quenched with saturated NH_4Cl at 0 °C, and extracted with AcOEt (x 2). The combined organic layers were washed with brine, dried over Na_2SO_4, and filtered. The filtrate was concentrated under reduced pressure to give the crude **S8** (4.91 g), which was used to the next reaction without further purification.

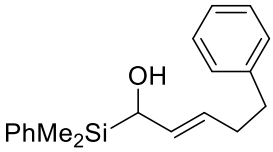
To a stirred suspension of $LiAlH_4$ (3.20 g, 84.4 mmol) in anhydrous THF (55 mL) was added dropwise **S8** (4.55 g) at 0 ℃ under a nitrogen atmosphere. The reaction mixture was stirred under reflux for 5 h. The reaction mixture was cooled to 0 ℃ and quenched with 1N NaOH. The mixture was filtered through a thin Celite-pad. The filtrate was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (*n*-hexane/AcOEt = 10/1) to give **S9** (2.93 g, 64% from **7**)

as a colorless oil:

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31–7.26 (m, 2H), 7.21–7.17 (m, 3H), 5.77–5.62 (m, 2H), 4.09 (d, J = 6.4 Hz, 2H), 2.71 (t, J = 9.2 Hz, 2H), 2.42–2.34 (m, 2H), 1.43 (brs, 1H).

^{1}H NMR spectral data of **S9** was identical with the authentic data.[6)]

Compound 13



To a solution of **S9** (2.00 g, 12.3 mmol) in anhydrous THF (40 mL) was added dropwise *n*-BuLi (1.6 *M* in *n*-hexane, 8.5 mL, 13.6 mmol) at –78 ℃ under a nitrogen atmosphere. The mixture was stirred at 0 ℃ for 30 min. $PhMe_2SiCl$ (2.41 g, 14.1 mmol) was added to the mixture at 0 ℃. After stirring at room temperature for 17 h, *tert*-BuLi (1.55 *M* in *n*-pentane, 10.3 mL, 16.0 mmol) was added dropwise to the mixture at –78 ℃. The reaction mixture was stirred at –45 ℃ for 5 h, quenched with saturated NH_4Cl at –45 ℃, and extracted with Et_2O (x 2). The combined organic layers were washed with saturated $NaHCO_3$, brine, dried over Na_2SO_4, and filtered. The filtrate was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (*n*-hexane/AcOEt = 10/1 with 3% triethylamine) to give (±)-**13** (2.3 g, 63%) as a colorless oil:

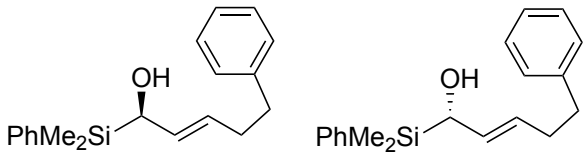
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.54–7.51 (m, 2H), 7.40–7.35 (m, 3H), 7.31–7.25 (m, 2H), 7.21–7.15 (m, 3H), 5.60 (dd, J = 15.5, 6.3 Hz, 1H), 5.49 (dtd, J = 15.3, 6.5, 1.2 Hz, 1H), 4.10 (dd, J = 6.0, 1.2 Hz, 1H), 2.67 (t, J = 7.2 Hz, 2H), 2.37 (quint, J = 6.9, 6.9 Hz, 2H), 1.45 (brs, 1H), 0.30 (s, 3H), 0.27 (s, 3H);

^{13}C NMR (100 MHz, $CDCl_3$) δ 141.8, 136.2, 134.2, 131.5, 129.3, 128.4, 128.3, 127.8, 127.0, 125.8, 67.7, 36.0, 34.2, –5.6, –6.0;

FTIR (neat) 3428, 3026, 2956, 2926, 2850, 1495, 1452, 1428, 1250, 1114, 969, 836, 816, 736 cm^{-1};

HRMS (ESI+) *m*/*z* calcd for $C_{19}H_{24}NaOSi$ $(M+Na)^+$ 319.14941, found 319.14765.

Compounds (*R*)-13 and (*S*)-13



Conditions of optical resolution by HPLC using a chiral stationary phase column were as follows:

Column: CHIRALPAK AD-H

Column size: 30 cm × 3 cm

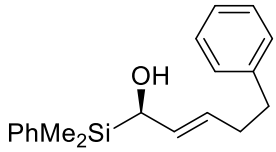
Eluent: *n*-hexane/EtOH = 50/1

Flow rate: 8 mL/min

Detect: 254 nm

Time: (*R*)-**13**, 19 min, (*S*)-**13**, 23 min.

Compound (*R*)-13



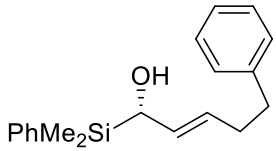
$[\alpha]^{22}_{D}$ +32 (*c* 1.04, $CHCl_3$, >99% ee);

The absolute configuration of (*R*)-**13** was determined by the modified Mosher method.[2)]

The optical purity of (*R*)-**13** was determined by the chiral HPLC analysis.

[chiral HPLC data of (*R*)-**13** (>99% ee): see appendix]

Compound (*S*)-13



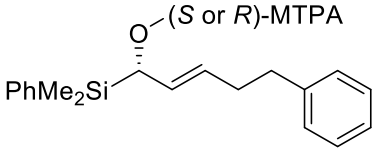
$[\alpha]^{22}_{D}$ –30 (*c* 1.06, $CHCl_3$, >99% ee);

The absolute configuration of (*S*)-**13** was determined by the modified Mosher method.[2)]

The optical purity of (*S*)-**13** was determined by the chiral HPLC analysis.

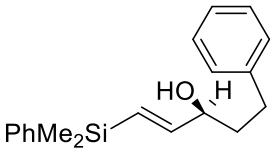
[chiral HPLC data of (*S*)-**13** (>99% ee): see appendix]

MTPA ester of (*S*)-13 (S10)



According to the general procedure B, the reaction of (*S*)-**13** (16.4 mg, 0.0553 mmol) with triethylamine (38.5 μL, 0.274 mmol), DMAP (0.7 mg, 0.006 mmol), and (*R*)-MTPA chloride (20.5 μL, 0.110 mmol) followed by purification by preparative thin-layer chromatography on silica gel (*n*-hexane/AcOEt = 20/1) afforded (*S*)-MTPA ester **S10** (25.3 mg, 89%) as a colorless oil. The corresponding (*R*)-MTPA ester **S10'** (22.0 mg, 83%) was synthesized by using (*S*)-MTPA chloride instead of (*R*)-MTPA chloride [^{1}H NMR spectrum of the (*S*)-MTPA ester **S10** and (*R*)-MTPA ester **S10'**: see appendix].

Compound (*S*)-14



According to the general Procedure A, the reaction of (*R*)-**13** (>99% ee, 322 mg, 1.09 mmol) with Me_3SiOTf (242 mg, 1.09 mmol) followed by purification by flash column chromatography on silica gel (*n*-hexane/AcOEt = 10/1) afforded (*S*)-**14** (99% ee, 56.4 mg, 18%) as a colorless oil:

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.53–7.50 (m, 2H), 7.37–7.34 (m, 3H), 7.30–7.26 (m, 2H), 7.20–7.15 (m, 3H), 6.15 (dd, *J* = 19.0, 5.1 Hz, 1H), 6.00 (dd, *J* = 18.8, 1.2 Hz, 1H), 4.16 (q, *J* = 5.2 Hz, 1H), 2.80–2.65 (m, 2H), 1.89–1.83 (m, 2H), 1.53 (brs, 1H) 0.35 (s, 6H);

^{13}C NMR (75 MHz, $CDCl_3$) δ 150.1, 141.8, 138,4 133.8, 129.0, 128.5, 128.4, 127.8, 127.2, 125.8, 73.8, 38.4, 31.7, –2.6;

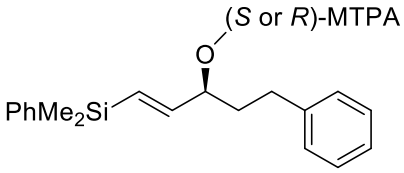
FTIR (neat) 3353, 3023, 2953, 1620, 1452, 1427, 1250, 1114, 992, 779 cm^{-1};

HRMS (ESI+) *m*/*z* calcd for $C_{19}H_{24}NaOSi$ $(M+Na)^+$ 319.14941, found 319.14940.

[chiral HPLC data of (*S*)-**14** (99% ee): see appendix]

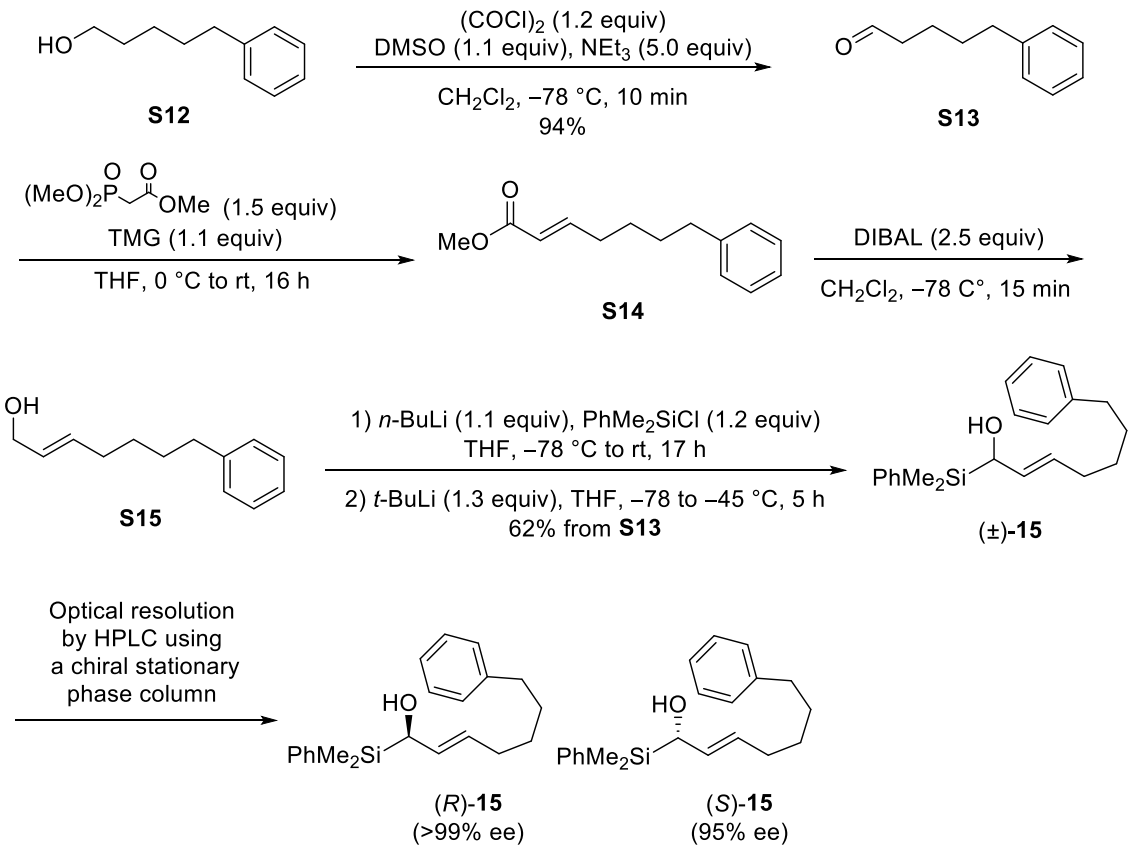
The absolute configuration of (*S*)-**14** was determined by the modified Mosher method.[2)]

MTPA ester of (*S*)-14 (S11)

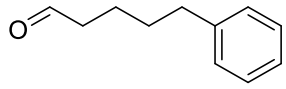


According to the general procedure B, the reaction of (*S*)-**14** (5.5 mg, 0.019 mmol) with triethylamine (13.0 μL, 0.0934 mmol), DMAP (0.2 mg, 0.002 mmol), and (*R*)-MTPA chloride (7.0 μL, 0.037 mmol) followed by purification by preparative thin-layer chromatography on silica gel (*n*-hexane/AcOEt = 10/1) afforded (*S*)-MTPA ester **S11** (5.7 mg, 60%) as a colorless oil. The corresponding (*R*)-MTPA ester **S11'** (5.9 mg, 61%) was synthesized by using (*S*)-MTPA chloride instead of (*R*)-MTPA chloride [^{1}H NMR spectrum of the (*S*)-MTPA ester **S11** and (*R*)-MTPA ester **S11'**: see appendix].

Synthesis of (*R*)-15 and (*S*)-15



Compound S13

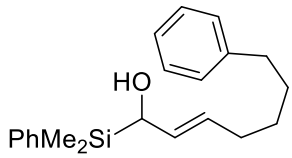


To a solution of oxalyl chloride (96 μL, 1.1 mmol) in anhydrous CH_2Cl_2 (1.4 mL) was added dropwise DMSO (73 μL, 1.0 mmol) at –78 ℃ under a nitrogen atmosphere. The mixture was stirred at –78 ℃ for 5 min. A solution of **S12** (1.0 M in CH_2Cl_2, 0.93 mL, 0.93 mmol) was added to the mixture at –78 ℃. After stirring at –78 ℃ for 15 min, TEA (0.64 mL, 4.6 mmol) was added to the mixture at –78 ℃. The reaction mixture was stirred at –78 ℃ for 10 min, CH_2Cl_2 (4.6 mL) was added to the mixture at room temperature. The reaction mixture was quenched with saturated NH_4Cl at room temperature and extracted with CH_2Cl_2 (x 2). The combined organic layers were washed with brine, dried over Na_2SO_4, and filtered. The filtrate was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (*n*-hexane/AcOEt = 10/1) to give **S13** (142 mg, 94%) as a colorless oil:

^{1}H NMR (300 MHz, $CDCl_3$) δ 9.76 (t, J = 2.1 Hz, 1H), 7.31–7.26 (m, 2H), 7.21–7.16 (m, 3H), 2.67–2.62 (m, 2H), 2.48–2.42 (m, 2H), 1.70–1.65 (m, 4H).

^{1}H NMR spectral data of **S13** was identical with the authentic data.[7)]

Compound 15



To a solution of trimethyl phosphonoacetate (2.42 g, 13.3 mmol) in anhydrous THF (4.9 mL) was added dropwise tetramethylguanidine (1.64 mL, 13.1 mmol) at 0 ℃ under a nitrogen atmosphere. The mixture was stirred at 0 ℃ for 30 min. A solution of **S13** (15 *M* in CH_2Cl_2, 0.80 mL, 12 mmol) was added to the mixture at –78 ℃. After stirring at room temperature for 16 h, the reaction mixture was quenched with water at room temperature and extracted with Et_2O (x 3). The combined organic layers were washed with 1 *M* HCl aq. and brine, then dried over Na_2SO_4, and filtered. The filtrate was concentrated under reduced pressure to give the crude **S14** (2.48 g), which was used to the next reaction without further purification.

To a solution of **S14** (2.20 g) in anhydrous CH_2Cl_2 (100 mL) was added dropwise DIBAL (1.0 *M* in *n*-hexane, 25.3 mL, 25.3 mmol) at –78 ℃ under a nitrogen atmosphere. The

mixture was stirred at –78 ℃ for 15 min. The reaction mixture was quenched with MeOH at –78 ℃, then saturated Rochelle salts at 0 ℃. The reaction mixture was extracted with CH_2Cl_2 (x 3). The combined organic layers were washed with brine, dried over Na_2SO_4, and filtered. The filtrate was concentrated under reduced pressure to give the crude **S15** (1.91 g), which was used to the next reaction without further purification.

To a solution of **S15** (1.91 g) in anhydrous THF (33 mL) was added dropwise *n*-BuLi (1.6 *M* in *n*-hexane, 6.9 mL, 11.0 mmol) at –78 ℃ under a nitrogen atmosphere. The mixture was stirred at 0 ℃ for 30 min. $PhMe_2SiCl$ (2.06 g, 12.1 mmol) was added to the mixture at 0 ℃. After stirring at room temperature for 17 h, *tert*-BuLi (1.56 *M* in *n*-pentane, 8.4 mL, 13.1 mmol) was added dropwise to the mixture at –78 ℃. The reaction mixture was stirred at –45 ℃ for 5 h, quenched with saturated NH_4Cl at –45 ℃, and extracted with Et_2O (x 2). The combined organic layers were washed with saturated $NaHCO_3$, brine, dried over Na_2SO_4, and filtered. The filtrate was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (*n*-hexane/AcOEt = 10/1 with 3% TEA) to give (±)-**15** (2.12 g, 62% from **S13**) as a colorless oil:

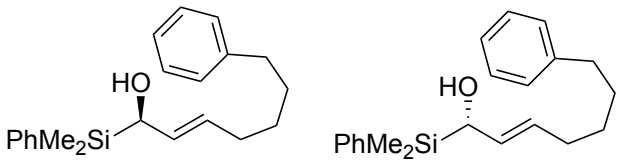
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.57–7.54 (m, 2H), 7.42–7.26 (m, 3H), 7.31–7.25 (m, 2H), 7.21–7.16 (m, 3H), 5.58 (dd, *J* = 15.3, 6.3 Hz, 1H), 5.46 (dtd, *J* = 15.3, 6.5, 0.9 Hz, 1H), 4.12 (dd, *J* = 6.3, 0.9 Hz, 1H), 2.61 (t, *J* = 7.8 Hz, 2H), 2.07 (quint, *J* = 7.5 Hz, 2H), 1.61 (m, 2H), 1.40 (m, 2H), 1.26 (brs, 1H), 0.34 (s, 3H), 0.32 (s, 3H);

^{13}C NMR (75 MHz, $CDCl_3$) δ 142.7, 136.3, 134.2, 130.9, 129.3, 128.4, 128.2, 128.0, 127.8, 125.6, 67.8, 35.8, 32.3, 30.9, 29.3, –5.5, –6.0;

FTIR (neat) 3435, 3065, 3025, 2929, 2854, 1692, 1494, 1455, 1429, 1250, 1115, 1082, 969, 834, 817, 778, 737 cm^{-1};

HRMS (ESI+) *m*/*z* calcd for $C_{21}H_{28}NaOSi$ $(M+Na)^+$ 347.18071, found 347.17914.

Compounds (*R*)-15 and (*S*)-15



Conditions of optical resolution by HPLC using a chiral stationary phase column were as follows:

Column: CHIRALPAK AD-H

Column size: 30 cm × 3 cm

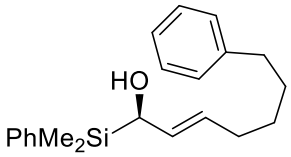
Eluent: *n*-hexane/EtOH = 50/1

Flow rate: 8 mL/min

Detect: 254 nm

Time: (*R*)-**15**, 19 min, (*S*)-**15**, 26 min.

Compound (*R*)-15



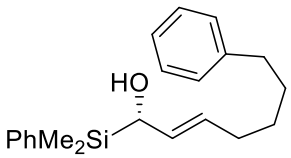
$[\alpha]^{19}_{D}$ +24 (*c* 1.24, $CHCl_3$, >99% ee);

The absolute configuration of (*R*)-**15** was determined by the modified Mosher method.[2)]

The optical purity of (*R*)-**15** was determined by the chiral HPLC analysis.

[chiral HPLC data of (*R*)-**13** (>99% ee): see appendix]

Compound (*S*)-15



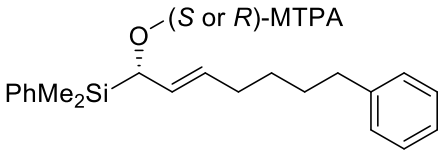
$[\alpha]^{19}_{D}$ –24 (*c* 1.05, $CHCl_3$, 95% ee);

The absolute configuration of (*S*)-**15** was determined by the modified Mosher method.[2)]

The optical purity of (*S*)-**15** was determined by the chiral HPLC analysis.

[chiral HPLC data of (*S*)-**13** (95% ee): see appendix]

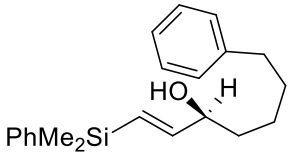
MTPA ester of (*S*)-15 (S16)



According to the general procedure B, the reaction of (*S*)-**15** (9.8 mg, 0.030 mmol) with TEA (21.0 μL, 0.151 mmol), DMAP (0.4 mg, 0.003 mmol), and (*R*)-MTPA chloride (11.5 μL, 0.0615 mmol) followed by purification by preparative thin-layer chromatography on silica gel (*n*-hexane/AcOEt = 20/1) afforded (*S*)-MTPA ester **S16** (11.4 mg, 70%) as a colorless oil. The corresponding (*R*)-MTPA ester **S16'** (11.1 mg, 69%) was synthesized

by using (*S*)-MTPA chloride instead of (*R*)-MTPA chloride [^{1}H NMR spectrum of the (*S*)-MTPA ester **S16** and (*R*)-MTPA ester **S16'**: see appendix].

Compound of (*S*)-16



According to the general procedure A, the reaction of (*R*)-**15** (>99% ee, 354 mg, 1.09 mmol) with Me_3SiOTf (242 mg, 1.09 mmol) followed by purification by flash column chromatography on silica gel (*n*-hexane/AcOEt = 10/1) afforded (*S*)-**16** (70% ee, 149 mg, 42%) as a colorless oil:

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.52–7.48 (m, 2H), 7.37–7.34 (m, 3H), 7.27–7.25 (m, 2H), 7.19–7.15 (m, 3H), 6.12 (dd, *J* = 18.6, 5.1 Hz, 1H), 5.96 (dd, *J* = 18.8, 1.2 Hz, 1H), 4.12 (q, *J* = 5.4 Hz, 1H), 2.62 (t, *J* = 7.5 Hz, 2H), 1.70–1.33 (m, 7H), 0.35 (s, 6H);

^{13}C NMR (75 MHz, $CDCl_3$) δ 150.4, 142.5, 138.5, 133.8, 129.0, 128.4, 128.2, 127.8, 126.9, 125.6, 74.5, 36.7, 35.8, 31.4, 25.0, –2.6;

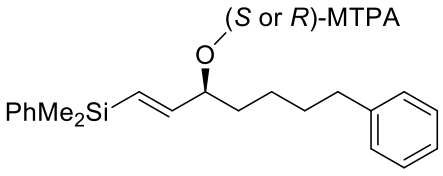
FTIR (neat) 3340, 3025, 2932, 2856, 1619, 1455, 1428, 1250, 1113, 992, 845 cm^{-1};

HRMS (ESI+) *m*/*z* calcd for $C_{21}H_{28}NaOSi$ $(M+Na)^+$ 347.18071, found 347.18342.

[chiral HPLC data of (*S*)-**16** (70% ee): see appendix]

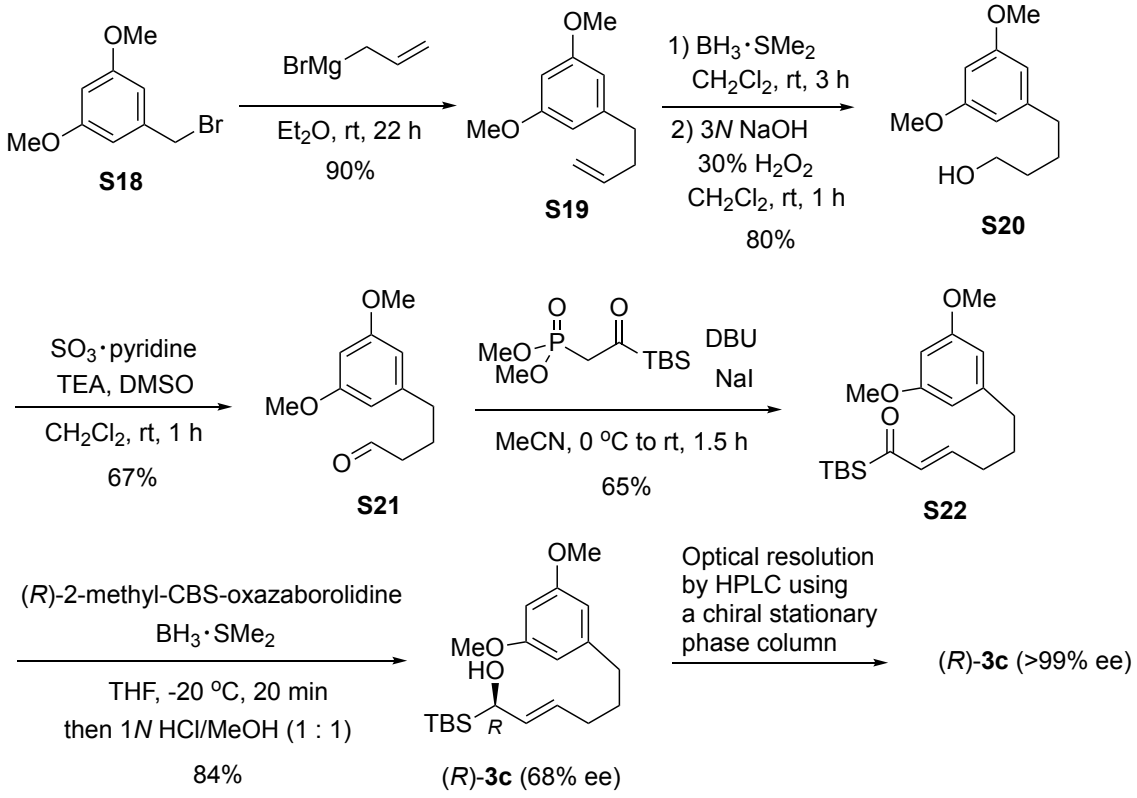
The absolute configuration of (*S*)-**16** was determined by the modified Mosher method.[2)]

MTPA ester of (*S*)-16 (S17)

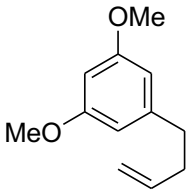


According to the general procedure B, the reaction of (*S*)-**16** (10.5 mg, 0.0324 mmol) with TEA (22.5 μL, 0.162 mmol), DMAP (0.4 mg, 0.003 mmol), and (*R*)-MTPA chloride (12.1 μL, 0.0647 mmol) followed by purification by preparative thin-layer chromatography on silica gel (*n*-hexane/AcOEt = 20/1) afforded (*S*)-MTPA ester **S17** (11.7 mg, 67%) as a colorless oil. The corresponding (*R*)-MTPA ester **S17'** (13.3 mg, 76%) was synthesized by using (*S*)-MTPA chloride instead of (*R*)-MTPA chloride [^{1}H NMR spectrum of the (*S*)-MTPA ester **S17** and (*R*)-MTPA ester **S17'**: see appendix].

Synthesis of α-hydroxysilane 3c



Compound S19

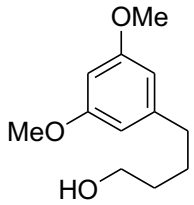


To allylmagnesium bromide (1M in Et_2O, 86.5 mL, 86.5 mmol) was added a solution of 3,5-dimethoxybenzyl bromide (**S18**, 10.0 g, 43.3 mmol) in Et_2O (62 mL) at 0 °C under argon atmosphere. The reaction mixture was stirred at room temperature for 22 h and quenched by saturated NH_4Cl. The mixture was extracted with Et_2O (x 3). The combined organic layers were washed with brine and dried over $MgSO_4$, and filtered. The solvent was evaporated *in vacuo*. The residue was purified by flash column chromatography on silica gel (*n*-hexane/AcOEt = 60/1) to give **S19** (7.44 g, 90%) as colorless oil:

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.40 (d, *J* = 2.2 Hz, 2 H), 6.35 (t, *J* = 2.2 Hz, 1 H), 5.90 (ddt, *J* = 17.1, 9.9, 7.4 Hz, 1 H), 5.09 (brd, *J* = 17.1 Hz, 1 H), 5.02 (brd, *J* = 9.9 Hz, 1 H),

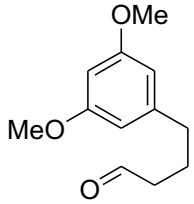
3.80 (s, 6 H), 2.69 (t, J = 7.4 Hz, 2 H), 2.40 (q, J = 7.4 Hz, 2 H);
^{13}C NMR (100 MHz, $CDCl_3$) δ 160.8, 144.4, 138.1, 115.0, 106.6, 97.9, 55.2, 35.8, 35.3;
FTIR (neat) 2937, 1595, 1462, 1348, 1294, 1203, 1147, 1061, 914, 829, 754, 694 cm^{-1};
HRMS (EI) *m/z* calcd for $C_{12}H_{16}O_2$ $(M)^+$ 192.1150, found 192.1149.

Compound S20



To a solution of **S19** (47.6 g, 248 mmol) in CH_2Cl_2 (82.5 mL) was added dropwise $BH_3 \cdot SMe_2$ (8.45 mL, 89.1 mmol) at 0 °C under argon atmosphere. The reaction mixture was stirred for at room temperature 2 h and then evaporated *in vacuo*. CH_2Cl_2 (82.5 mL), EtOH (82.5 mL) and 3 *N* NaOH (30.5 mL, 91.6 mmol) were added to the residue, and the mixture was cooled to 0 °C. 30% H_2O_2 aq. (30.5 mL) was added to the mixture, and the mixture was stirred under reflux for 1 h. The mixture was cooled to room temperature and then poured into 1000 mL of ice-water. The mixture was extracted with Et_2O (x 3). The combined organic layers were washed with brine and dried over $MgSO_4$, and filtered. The solvent was evaporated *in vacuo*. The residue was purified by flash column chromatography on silica gel (*n*-hexane/AcOEt = 5/1) to give **S20** (41.8 g, 80%) as colorless oil:
^{1}H NMR (400 MHz, $CDCl_3$) δ 6.35 (d, J = 2.2 Hz, 2 H), 6.30 (t, J = 2.2 Hz, 1 H), 3.75 (s, 6 H), 3.61 (t, J = 6.4 Hz, 2 H), 2.57 (t, J = 7.2 Hz, 2 H), 2.39 (brs, 1 H), 1.67 (m, 2 H), 1.57 (m, 2 H);
^{13}C NMR (100 MHz, $CDCl_3$) δ 160.7, 144.8, 106.5, 97.7, 62.5, 55.2, 35.9, 32.3, 27.3;
FTIR (neat) 3381, 2939, 1595, 1462, 1429, 1205, 1149, 1057, 906, 727, 694, 648 cm^{-1};
HRMS (EI) *m/z* calcd for $C_{12}H_{18}O_3$ $(M)^+$ 210.1256, found 210.1260.

Compound S21



To a solution of **S20** (2.00 g, 9.51 mmol) in CH_2Cl_2 (32 mL) were added DMSO (3.40 mL, 47.6 mmol), Et_3N (6.60 mL, 47.6 mmol) and sulfur trioxide pyridine complex (5.00 g, 31.4 mmol) at 0 ^oC under argon atmosphere, and the reaction mixture was stirred at room temperature for 1.5 h. After addition of *n*-hexane (32 mL), the mixture was filtered on silica gel (*n*-hexane/AcOEt = 2/1), and the filtrate was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (*n*-hexane/AcOEt = 20/1) to give **S21** (1.33 g, 67%) as colorless oil:

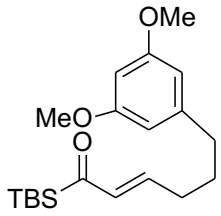
^1H NMR (400 MHz, C_6D_6) δ 9.29 (t, *J* = 1.5 Hz, 1 H), 6.41 (t, *J* = 2.2 Hz, 1 H), 6.34 (d, *J* = 2.2 Hz, 2 H), 3.40 (s, 6 H), 2.31 (t, *J* = 7.6 Hz, 2 H), 1.87 (dt, *J* = 7.6, 1.5 Hz, 2 H), 1.64 (quint, *J* = 7.6 Hz, 2 H);

^{13}C NMR (100 MHz, C_6D_6) δ 200.2, 161.6, 144.1, 107.0, 98.5, 54.9, 43.1, 35.5, 23.7;

FTIR (neat) 2944, 2839, 2726, 1722, 1597, 1464, 1430, 1351, 1205, 1152, 1059, 835, 697 cm^{-1};

HRMS (CI) *m/z* calcd for $C_{12}H_{17}O_3$ $(M+H)^+$ 209.1178, found 209.1175.

Compound S22



To a solution of NaI (10.6 g, 70.4 mmol) in CH_3CN (70 mL) were added a solution of dimethyl 2-(*tert*-butyldimethylsilyl)-2-oxoethylphosphonate[8)] (18.7 g, 70.4 mmol) and DBU (11.7 g, 76.8 mmol) at room temperature under argon atmosphere. After the reaction mixture was stirred for 30 min, a solution of **S21** (13.3 g, 64.0 mmol) in CH_3CN (130 mL) was added at 0 ^oC. The reaction mixture was stirred for 2 h and quenched by saturated NH_4Cl. The mixture was extracted with AcOEt (x 3). The combined organic layers were washed with brine and dried over $MgSO_4$, and filtered. The solvent was evaporated *in*

vacuo. The residue was purified by flash column chromatography on silica gel (*n*-hexane/AcOEt = 30/1) to give **S22** (14.5 g, 65%) as yellow oil:

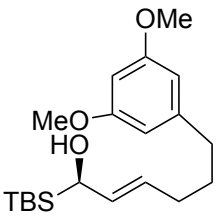
^{1}H NMR (400 MHz, C_6D_6) δ 6.66 (dt, *J* = 15.9, 6.9 Hz, 1 H), 6.45-6.41 (m, 4 H), 3.37 (s, 6 H), 2.38 (t, *J* = 7.5 Hz, 2 H), 1.90 (q, *J* = 7.5 Hz, 2 H), 1.54 (quint, *J* = 7.5 Hz, 2 H), 0.95 (s, 9 H), 0.17 (s, 6 H);

^{13}C NMR (100 MHz, C_6D_6) δ 233.3, 161.7, 145.2, 144.3, 136.8, 107.1, 98.4, 54.8, 35.9, 32.1, 30.1, 26.8, 16.8, -5.9;

FTIR (neat) 2931, 2857, 1645, 1595, 1463, 1429, 1347, 1313, 1293, 1250, 1205, 1151, 1066, 977, 832, 776, 694 cm^{-1};

HRMS (FAB) *m/z* calcd for $C_{20}H_{32}O_3Si$ $(M)^+$ 348.2121, found 348.2125.

Compound (*R*)-3c



To a solution of **S22** (1.91 g, 5.48 mmol) in THF (23 mL) was added (*R*)-2-methyl-CBS-oxazaborolidine (1.52 g, 5.48 mmol) at room temperature under argon atmosphere. After the reaction mixture was stirred for 30 min, $BH_3 \cdot SMe_2$ (0.78 mL, 8.22 mmol) was added dropwise at -20 ^oC. The reaction mixture was stirred for 15 min and quenched by 1N HCl (26 mL) in MeOH (26 mL). The mixture was added saturated $NaHCO_3$ and extracted with AcOEt (x 3). The combined organic layers were washed with brine and dried over $MgSO_4$, and filtered. The solvent was evaporated *in vacuo*. The residue was purified by flash column chromatography on silica gel (*n*-hexane/AcOEt = 25/1) to give (*R*)-**3c** (68% ee, 1.61 g, 84%) as pale yellow oil:

$[\alpha]^{27.7}_D$ +12.9 (*c* 1.22, $CHCl_3$, 68% ee);

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.34 (d, *J* = 2.2 Hz, 2 H), 6.30 (t, *J* = 2.2 Hz, 1 H), 5.67 (ddt, *J* = 15.4, 6.7, 1.2 Hz, 1 H), 5.51 (dtd, *J* = 15.4, 6.7, 1.5 Hz, 1 H), 4.08 (dd, *J* = 6.7, 1.5 Hz, 1 H), 3.78 (s, 6 H), 2.56 (t, *J* = 7.8 Hz, 2 H), 2.10 (brq, *J* = 7.8 Hz, 2 H), 1.69 (quint, *J* = 7.8 Hz, 2 H), 1.50 (brs, 1 H), 0.95 (s, 9 H), 0.01 (s, 3 H), -0.05 (s, 3 H);

^{13}C NMR (100 MHz, $CDCl_3$) δ 160.8, 145.1, 132.8, 127.1, 106.7, 97.8, 67.0, 55.3, 35.9, 32.2, 31.3, 27.1, 17.1, -7.4, -8.8;

FTIR (neat) 3510, 2929, 2855, 1596, 1462, 1428, 1351, 1247, 1205, 1149, 1061, 968, 826, 808, 771, 694 cm^{-1};
HRMS (CI) *m/z* calcd for $C_{20}H_{35}O_3Si$ $(M+H)^+$ 351.2355, found 351.2361.

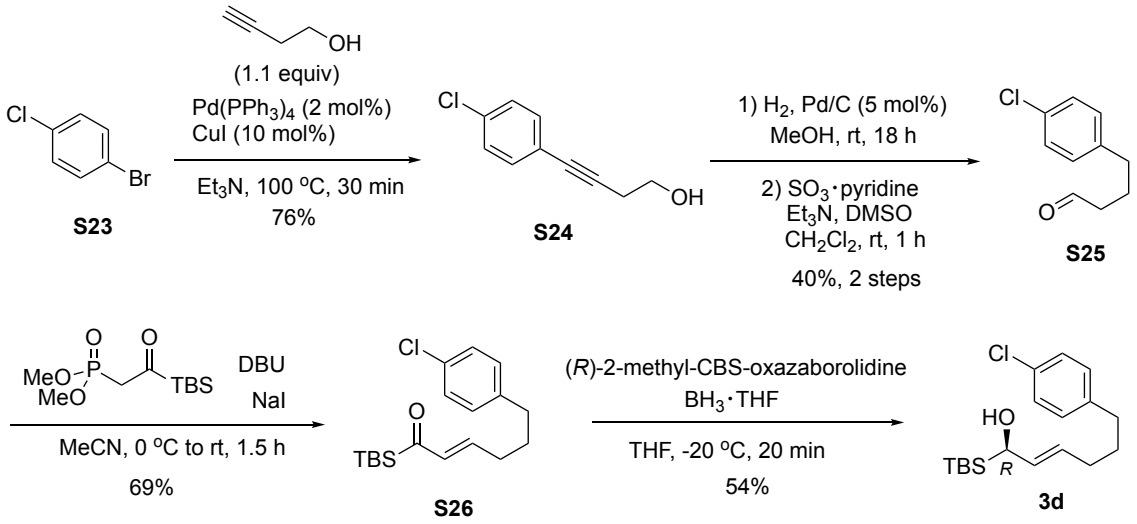
The absolute configuration of (*R*)-**3c** were determined by the modified Mosher method[2] [^{1}H NMR spectrum of the (*R*)-MTPA ester derived from (*R*)-**3c** (68% ee): see appendix].

To obtain a pure enantiomer of **3c**, optical resolution of the resulting **3c** were performed by HPLC using a chiral stationary phase column.
Conditions:
Column: CHIRALPAK AD-H
Column size: 30 cm × 3 cm
Eluent: *n*-hexane/EtOH = 40/1
Flow rate: 8 mL/min
Detect: 254 nm
Time: (*R*)-**3c**, 22 min, (*S*)-**3c**, 34 min.

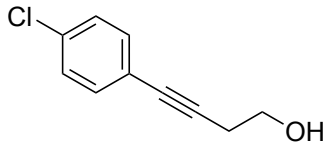
Compound (*R*)-3c
$[\alpha]^{27}_D$ +21 (*c* 0.74, $CHCl_3$, >99% ee);
The optical purity of (*R*)-**3c** was determined by the chiral HPLC analysis.
[chiral HPLC data of (*R*)-**3c** (>99% ee): see appendix]

Compound (*S*)-3c
$[\alpha]^{27}_D$ -21 (*c* 1.16, $CHCl_3$, >99% ee);
The optical purity of (*S*)-**3c** was determined by the chiral HPLC analysis.
[chiral HPLC data of (*S*)-**3c** (>99% ee): see appendix]

Synthesis of α-hydroxysilane 3d



Compound S24



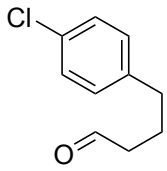
To a mixture of 1-bromo-4-chlorobenzene **S23** (6.75 g, 30 mmol), 3-butyn-1-ol (2.31 g, 33 mmol), $Pd(PPh_3)_4$ (0.75 g, 0.65 mmol) and Et_3N (150 mL) was added CuI (0.57 g, 3 mmol) at 0 °C under nitrogen atmosphere. The reaction mixture was stirred at 95 °C for 30 min. The mixture was filtered on celite, and the filtrate was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (*n*-hexane/AcOEt = 3/1) to give **S24** (4.11 g, 76%) as colorless oil:

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.33 (d, *J* = 8.0 Hz, 2 H), 7.25 (d, *J* = 8.0 Hz, 2 H), 3.81 (t, *J* = 6.4 Hz, 2 H), 2.68 (t, *J* = 6.4 Hz, 2 H), 1.87 (s, 1 H);

^{13}C NMR (100 MHz, $CDCl_3$) δ 133.9, 132.9, 128.6, 121.8, 87.5, 81.3, 61.0, 23.8;

HRMS (DART) *m/z* calcd for $C_{10}H_{10}OCl$ $(M+H)^+$ 181.0420, found 181.0411.

Compound S25



A suspension of 1-bromo-4-chlorobenzene **S24** (4.10 g, 22.8 mmol) and 10% Pd/C (1.20 g, 1.13 mmol) in MeOH (60 mL) was stirred under H_2 for 15 h. The mixture was filtered on celite, and the filtrate was concentrated under reduced pressure to give 4-(4-chlorophenyl)-1-butanol (2.60 g), which was used to the next reaction without further purification.

4-(4-chlorophenyl)-1-butanol: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23 (d, *J* = 8.4 Hz, 2 H), 7.11 (d, *J* = 8.4 Hz, 2 H), 3.66 (t, *J* = 6.0 Hz, 2 H), 2.61 (t, *J* = 7.6 Hz, 2 H), 1.72–1.56 (m, 5 H).

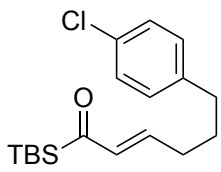
To a solution of the obtained 4-(4-chlorophenyl)-1-butanol (2.60 g), DMSO (10 mL), Et_3N (12 mL) in CH_2Cl_2 (43 mL) was added pyridine-sulfur trioxide complex (6.1 g, 38 mmol) at room temperature under a nitrogen atmosphere. The mixture was stirred for 1 h. The reaction mixture was quenched with saturated NH_4Cl, and extracted with Et_2O (x 2). The combined organic layers were washed with brine and dried over $MgSO_4$, and filtered. The solvent was evaporated *in vacuo*. The residue was purified by flash column chromatography on silica gel (*n*-hexane/AcOEt = 5/1) to give **S25** (1.22 g, 40% from **S24**) as a colorless oil:

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.76 (t, *J* = 1.2 Hz, 1 H), 7.25 (d, *J* = 8.4 Hz, 2 H), 7.10 (d, *J* = 8.4 Hz, 2 H), 2.62 (t, *J* = 7.2 Hz, 2 H), 2.45 (td, *J* = 7.2, 1.6 Hz, 2 H), 1.93 (quint, *J* = 7.2 Hz, 2 H);

^{13}C NMR (100 MHz, $CDCl_3$) δ 202.0, 139.6, 131.8, 129.8, 128.5, 43.0, 34.3, 23.5;

HRMS (ESI+) *m/z* calcd for $C_{10}H_{11}ClNaO$ $(M+Na)^+$ 205.0396, found 2015.0361.

Compound S26



To a solution of NaI (990 mg, 6.6 mmol) in CH_3CN (7 mL) were added a solution of

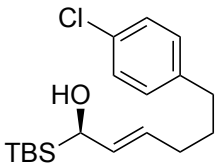
dimethyl 2-(*tert*-butyldimethylsilyl)-2-oxoethylphosphonate[8] (1.7 g, 6.4 mmol) in CH_3CN (10 mL) and DBU (1.1 g, 7.2 mmol) at 0 °C. After the reaction mixture was stirred for 30 min, a solution of **S25** (1.1 g, 6.0 mmol) in CH_3CN (13 mL) was added at 0 °C. The reaction mixture was stirred for 2 h at 0 °C and quenched by saturated NH_4Cl. The mixture was extracted with AcOEt (x 3). The combined organic layers were washed with brine and dried over $MgSO_4$, and filtered. The solvent was evaporated *in vacuo*. The residue was purified by flash column chromatography on silica gel (*n*-hexane/AcOEt = 10/1) to give **S26** (1.3 g, 69%) as yellow oil:

^{1}H NMR (400 MHz, C_6D_6) δ 7.27 (d, *J* = 8.4 Hz, 2 H), 7.10 (d, *J* = 8.4 Hz, 2 H), 6.67 (dt, *J* = 15.6, 6.8 Hz, 1 H), 6.38 (dt, *J* = 15.6, 1.2 Hz, 1 H), 2.62 (t, *J* = 7.2 Hz, 2 H), 2.24 (qd, *J* = 7.2, 1.2 Hz, 2 H), 1.78 (quint, *J* = 7.2 Hz, 2 H), 0.94 (s, 9 H), 0.23 (s, 6 H);

^{13}C NMR (100 MHz, C_6D_6) δ 235.6, 157.8, 145.5, 140.0, 136.6, 129.7, 128.5, 34.5, 31.9, 29.7, 26.7, 16.6, -6.1;

HRMS (ESI+) *m/z* calcd for $C_{18}H_{27}ClNaOSi$ $(M+Na)^+$ 345.1417, found 345.1364.

Compound 3d



To a solution of **S26** (177 mg, 0.548 mmol) in THF (1.0 mL) was added (*R*)-2-methyl-CBS-oxazaborolidine (0.50 mL, 0.50 mmol, 1.0 M toluene solution) at room temperature under nitrogen atmosphere. Then, BH_3·THF (0.85 mL, 0.800 mmol, THF solution) was added dropwise at -38 °C. The reaction mixture was stirred for 30 min and quenched by 1*N* HCl (1.0 mL) in MeOH (1.0 mL). The mixture was added saturated $NaHCO_3$ and extracted with Et_2O (x 3). The combined organic layers were washed with brine and dried over $MgSO_4$, and filtered. The solvent was evaporated *in vacuo*. The residue was purified by preparative thin-layer chromatography on silica gel (*n*-hexane/AcOEt = 10/1) to give (*R*)-**3d** (95.6 mg, 54%) as pale yellow oil:

$[\alpha]^{27}_D$ +16 (*c* 0.70, $CHCl_3$, 49% ee);

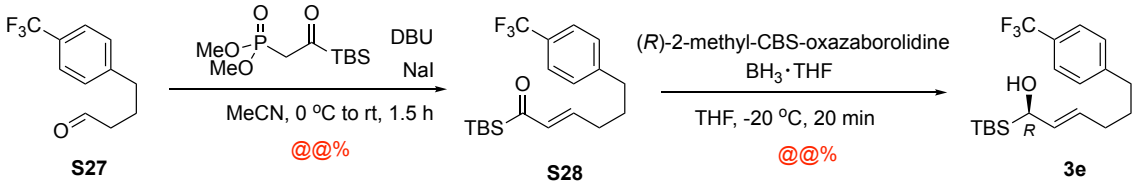
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.26 (d, *J* = 8.4 Hz, 2 H), 7.12 (d, *J* = 8.4 Hz, 2 H), 5.68 (dd, *J* = 14.8, 6.4 Hz, 1 H), 5.52 (dtd, *J* = 14.8, 8.4, 1.6 Hz, 1 H), 4.11 (dd, *J* = 6.4, 0.8 Hz, 1 H), 2.61 (t, *J* = 7.6 Hz, 2 H), 2.24 (q, *J* = 7.6 Hz, 2 H), 1.70 (quint, *J* = 7.6 Hz, 2 H),

0.98 (s, 9 H), 0.04 (s, 3 H), -0.02 (s, 3 H);

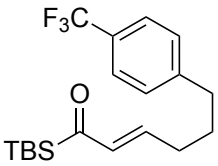
^{13}C NMR (100 MHz, $CDCl_3$) δ 140.9, 132.8, 129.7, 128.34, 128.31, 126.7, 66.8, 34.7, 31.9, 31.3, 27.0, 17.0, -7.6, -8.9;

HRMS (ESI-) *m/z* calcd for $C_{18}H_{28}ClOSi$ $(M-H)^+$ 323.1598, found 323.1586.

Synthesis of α-hydroxysilane 3e



Compound S28



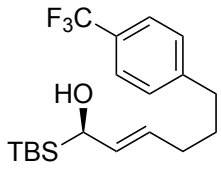
To a solution of NaI (1.65 g, 11.0 mmol) in CH_3CN (11 mL) were added a solution of dimethyl 2-(*tert*-butyldimethylsilyl)-2-oxoethylphosphonate[8] (2.93 g, 11.0 mmol) in CH_3CN (16 mL) and DBU (1.83 g, 12.0 mmol) at 0 °C. After the reaction mixture was stirred for 30 min, a solution of **S27**[9] (2.16 g, 10.0 mmol) in CH_3CN (20 mL) was added at 0 °C. The reaction mixture was stirred for 1.5 h at 0 °C and quenched by saturated NH_4Cl. The mixture was extracted with AcOEt (x 2). The combined organic layers were washed with brine and dried over Na_2SO_4, and filtered. The solvent was evaporated *in vacuo*. The residue was purified by flash column chromatography on silica gel (*n*-hexane/AcOEt = 20/1) to give **S28** (2.90 g, 81%) as yellow oil:

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.53 (d, J = 7.8 Hz, 2 H), 7.27 (d, J = 7.8 Hz, 2 H), 6.66 (dt, J = 16.0, 7.3 Hz, 1 H), 6.38 (dt, J = 16.0, 1.4 Hz, 1 H), 2.70 (t, J = 7.3 Hz, 2 H), 2.25 (q, J = 7.3 Hz, 2 H), 1.81 (quint, J = 7.3 Hz, 2 H), 0.93 (s, 9 H), 0.22 (s, 6 H);

^{13}C NMR (100 MHz, $CDCl_3$) δ 235.5, 145.8, 145.2, 136.6, 128.7, 128.3 (q, J = 32 Hz), 125.3 (q, J = 3 Hz), 124.3 (q, J = 272 Hz), 35.1, 31.8, 29.5, 26.5, 16.6, –6.1;

HRMS (ESI+) *m/z* calcd for $C_{19}H_{27}F_3NaOSi$ $(M+Na)^+$ 379.1681, found 379.1707.

Compound 3e



To a solution of **S28** (175 mg, 0.491 mmol) in THF (1.0 mL) was added (*R*)-2-methyl-CBS-oxazaborolidine (0.50 mL, 0.50 mmol, 1.0 M toluene solution) at room temperature under nitrogen atmosphere. Then, $BH_3 \cdot THF$ (0.78 mL, 0.737 mmol, 0.94 M THF solution) was added dropwise at -38 °C. The reaction mixture was stirred for 30 min and quenched by 1*N* HCl (1.0 mL) in MeOH (1.0 mL). The mixture was added saturated $NaHCO_3$ and extracted with Et_2O (x 3). The combined organic layers were washed with brine and dried over $MgSO_4$, and filtered. The solvent was evaporated *in vacuo*. The residue was purified by preparative thin-layer chromatography on silica gel (*n*-hexane/AcOEt = 10/1) to give (*R*)-**3e** (115 mg, 65%) as pale yellow oil:

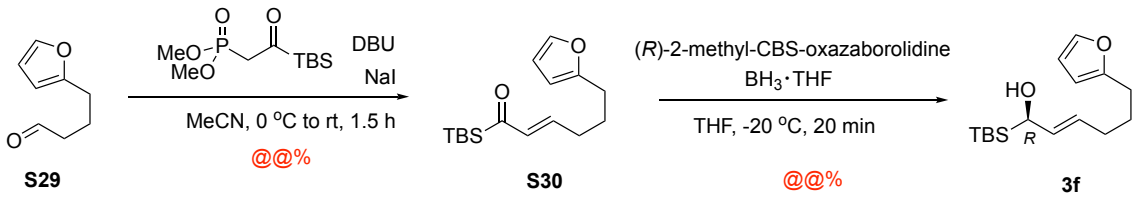
$[\alpha]^{28}_D$ +24 (*c* 0.87, $CHCl_3$, 78% ee);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 (d, *J* = 7.8 Hz, 2 H), 7.27 (d, *J* = 7.8 Hz, 2 H), 5.67 (dd, *J* = 15.4, 6.5 Hz, 1 H), 5.51 (dtd, *J* = 15.4, 7.3, 1.6 Hz, 1 H), 4.09 (dd, *J* = 6.5, 1.6 Hz, 1 H), 2.67 (t, *J* = 7.3 Hz, 2 H), 2.10 (q, *J* = 7.3 Hz, 2 H), 1.71 (quint, *J* = 7.3 Hz, 2 H), 1.4 (brs, 1 H), 0.95 (s, 9 H), 0.01 (s, 3 H), -0.05 (s, 3 H);

^{13}C NMR (100 MHz, $CDCl_3$) δ 146.6, 133.0, 128.7, 128.1 (q, *J* = 33 Hz), 126.5, 125.2 (q, *J* = 4 Hz), 124.4 (q, *J* = 272 Hz), 66.8, 35.2, 31.9, 31.1, 26.9, 17.0, -7.6, -8.9;

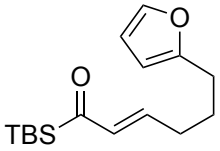
HRMS (ESI-) *m/z* calcd for $C_{19}H_{28}F_3OSi$ $(M-H)^+$ 357.1862, found 357.1842.

Synthesis of α-hydroxysilane 3f



S29 **S30** **3f**

Compound S30



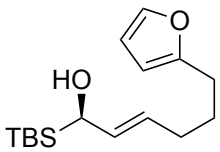
To a solution of NaI (1.44 g, 9.61 mmol) in MeCN (9.3 mL) were added a solution of dimethyl 2-(*tert*-butyldimethylsilyl)-2-oxoethylphosphonate (2.55 g, 9.57 mmol) and DBU (1.63 g, 10.7 mmol) at 0 °C under nitrogen atmosphere. After the reaction mixture was stirred for 30 min, a solution of **S29**[10] (1.15 g, 8.32 mmol) in MeCN (17.6 mL) was added at 0 °C. The reaction mixture was stirred for 2 h and quenched by saturated NH_4Cl. The mixture was extracted with AcOEt (x 3). The combined organic layers were washed with brine and dried over $MgSO_4$, and filtered. The solvent was evaporated *in vacuo*. The residue was purified by flash column chromatography on silica gel (*n*-hexane/AcOEt = 5/1) to give **S30** (2.08 g, 90%) as yellow oil:

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31 (d, *J* = 1.8 Hz, 1 H), 6.66 (dt, *J* = 16.0, 7.2 Hz, 1 H), 6.37 (dt, *J* = 16.0, 1.4 Hz, 1 H), 6.28 (dd, *J* = 2.8, 1.8 Hz 1 H), 5.99 (d, *J* = 2.8 Hz 1 H), 2.66 (t, *J* = 7.2 Hz, 2 H), 2.25 (brq, *J* = 7.2 Hz, 2 H), 1.82 (quint, *J* = 7.2 Hz, 2 H), 0.93 (s, 9 H), 0.22 (s, 6 H);

^{13}C NMR (100 MHz, $CDCl_3$) δ 235.5, 155.2, 145.4, 140.9, 136.6, 110.0, 105.1, 31.8, 27.3, 26.5 (×2), 16.6, –6.1;

HRMS (ESI+) *m/z* calcd for $C_{16}H_{26}NaO_2Si$ $(M+Na)^+$ 301.1600, found 301.1561.

Compound 3f



To a solution of **S30** (304 mg, 1.09 mmol) in THF (2.2 mL) was added (*R*)-2-methyl-CBS-oxazaborolidine (1.0 mL, 1.00 mmol, 1.0 M toluene solution) at room temperature under nitrogen atmosphere. Then, BH_3·THF (1.7 mL, 1.60 mmol, 0.94 M THF solution) was added dropwise at -38 °C. The reaction mixture was stirred for 30 min and quenched by 1N HCl (4.2 mL) in MeOH (4.2 mL). The mixture was added saturated $NaHCO_3$ and extracted with Et_2O (x 3). The combined organic layers were dried over $MgSO_4$, and filtered. The solvent was evaporated *in vacuo*. The residue was purified by flash column chromatography on silica gel (*n*-hexane/AcOEt = 30/1) to give (*R*)-**3f** (241 mg, 79%) as

pale yellow oil:

$[\alpha]^{28}_{D}$ +19 (*c* 0.93, $CHCl_3$, 80% ee);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.30 (d, *J* = 1.6 Hz, 1 H), 6.28 (dd, *J* = 2.8, 1.6 Hz, 1 H), 5.98 (d, *J* = 2.8 Hz, 1 H), 5.57 (dd, *J* = 15.1, 6.6 Hz 1 H), 5.48 (dtd, *J* = 15.1, 7.4, 1.5 Hz 1 H), 4.08 (dd, *J* = 6.6, 1.5 Hz, 1 H), 2.63 (t, *J* = 7.4 Hz, 2 H), 2.11 (q, *J* = 7.4 Hz, 2 H), 1.72 (quint, *J* = 7.4 Hz, 2 H), 1.4-1.1 (brs, 1H), 0.95 (s, 9 H), 0.01 (s, 3 H), –0.05 (s, 3 H);

^{13}C NMR (100 MHz, $CDCl_3$) δ 156.1, 140.7, 132.9, 126.6, 110.0, 104.7, 66.8, 31.9, 28.0, 27.4, 27.0, 17.0, –7.6, –9.0;

HRMS (ESI+) *m/z* calcd for $C_{16}H_{28}NaO_2Si$ $(M+Na)^+$ 303.1756, found 303.1723.

3. References

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