Notes

Enantiopure Chiral Derivatives of the Fragrance Materials Majantol and Sila-majantol: A Bioisosteric Carbon/Silicon Switch with Drastic Effects on the Sensory Characteristics

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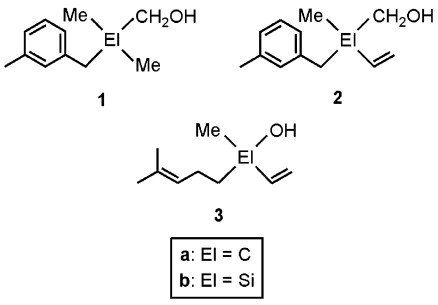
Received June 26, 2003

*Summary: The C/Si analogues 2-methyl-2-(3-methylbenzyl)but-3-en-1-ol (**2a**) and (hydroxymethyl)methyl(3-methylbenzyl)vinylsilane (**2b**) are chiral derivatives of the achiral fragrance materials majantol (**1a**) and sila-majantol (**1b**). Compounds **2a** and **2b** were synthesized as racemates, and the respective (+)- and (−)-enantiomers were obtained by chromatographic resolution (HPLC) of rac-**2a** and rac-**2b** using a chiral stationary phase. The enantiomerically pure compounds (+)-**2a**, (−)-**2a**, (+)-**2b**, and (−)-**2b** (optical rotations determined in methanol) were studied for their sensory properties. Both the odor character and the odor intensity of the silicon compounds (+)-**2b** and (−)-**2b** differ totally from those of the respective carbon analogues (+)-**2a** and (−)-**2a**.*

Introduction

In context with our systematic studies on C/Si bioisosterism,[1] we have recently investigated the sensory effects of C/Si exchange (sila-substitution) in the perfume ingredient majantol[2] (**1a**) (→ sila-majantol (**1b**)),[1e] a commercial synthetic product with a muguet-type fragrance.[3] In continuation of these studies, we have now prepared the (+)- and (−)-enantiomers of the chiral majantol and sila-majantol derivatives 2-methyl-2-(3-methylbenzyl)but-3-en-1-ol (**2a**) and (hydroxymethyl)-methyl(3-methylbenzyl)vinylsilane (**2b**) and have investigated their sensory properties. Compounds **2a** and **2b** formally derive from **1a** and **1b**, respectively, by replacement of one of the two geminal methyl groups by a vinyl moiety, which puts **2a** and **2b** in an additional structural relationship to the C/Si-analogous fragrances linalool (**3a**) and sila-linalool (**3b**).[1h,4] The aim of these studies was to extend our systematic investigations on "C/Si bioisosterism" and to contribute to the topic "chirality in bioorganosilicon chemistry".[1,5] We report here on the synthesis of *rac*-**2a** and *rac*-**2b**, the chromatographic separation of the enantiomers (+)-**2a**, (−)-**2a**, (+)-**2b**, and (−)-**2b**, and their sensory characterization. Preliminary results of these studies have been reported elsewhere.[6]



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(3) For muguet materials, see: Rossiter, K. J. In *Flavours and Fragrances*; Swift, K. A. D., Ed.; Royal Society of Chemistry: Cambridge, U.K., 1997; pp 21−35, and literature cited therein.

(4) Wrobel, D.; Wannagat, U. *Liebigs Ann. Chem.* **1982**, 734−738.

(5) Review dealing with chirality in bioorganosilicon chemistry: Tacke, R.; Wagner, S. A. In *The Chemistry of Organic Silicon Compounds*; Rappoport, Z., Apeloig, Y., Eds.; Wiley & Sons: Chichester, U.K., 1998; Vol. 2, Part 3, pp 2363−2400.

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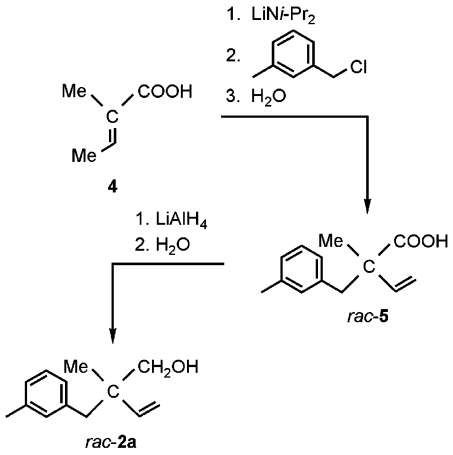
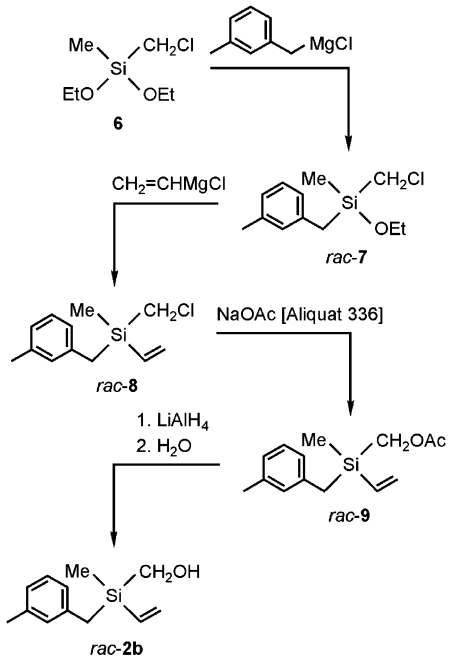
10.1021/om0304964 CCC: $25.00
Publication on Web 09/19/2003

Scheme 1



Scheme 2



Results and Discussion

Syntheses. Compound *rac*-**2a** was prepared by a two-step synthesis, starting from (2*E*)-2-methylbut-2-enoic acid (**4**) (Scheme 1). Treatment of **4** with lithium diisopropylamide in tetrahydrofuran and subsequent reaction with 3-methylbenzyl chloride in tetrahydrofuran/*n*-pentane, followed by hydrolysis, afforded *rac*-2-methyl-2-(3-methylbenzyl)but-3-enoic acid (*rac*-**5**) (yield 55%). Reduction of *rac*-**5** with lithium aluminum hydride in diethyl ether, followed by hydrolysis, finally gave *rac*-**2a** (yield 89%).

Compound *rac*-**2b** was prepared by a four-step synthesis, starting from (chloromethyl)diethoxy(methyl)-silane (**6**) (Scheme 2). Treatment of **6** with 3-methylbenzylmagnesium chloride in diethyl ether gave *rac*-(chloromethyl)ethoxy(methyl)(3-methylbenzyl)silane (*rac*-**7**) (yield 51%), which on reaction with vinylmagnesium chloride in tetrahydrofuran afforded *rac*-(chloromethyl)-methyl(3-methylbenzyl)vinylsilane (*rac*-**8**) (yield 85%). Reaction of *rac*-**8** with sodium acetate in dimethylformamide, in the presence of methyltrioctylammonium chloride (Aliquat 336), afforded *rac*-(acetoxymethyl)-methyl(3-methylbenzyl)vinylsilane (*rac*-**9**) (yield 55%), which on reduction with lithium aluminum hydride in diethyl ether, followed by hydrolysis, finally gave *rac*-**2b** (yield 83%).

Compounds *rac*-**2a**, *rac*-**2b**, *rac*-**5**, *rac*-**7**, *rac*-**8**, and *rac*-**9** were isolated as colorless liquids. Their identities were established by elemental analyses (C, H) and solution NMR studies (^{1}H, ^{13}C, ^{29}Si).

Chromatographic Resolution. The (+)- and (−)-enantiomers of the C/Si analogues **2a** and **2b** were separated by preparative liquid chromatography (HPLC) on a chiral stationary phase, starting from the respective racemates *rac*-**2a** and *rac*-**2b**. The enantiomerically pure (≥99% ee) compounds (+)-**2a**, (−)-**2a**, (+)-**2b**, and (−)-**2b** (optical rotations determined in methanol) were obtained as colorless liquids, and their identities were established by elemental analyses (C, H) and solution NMR studies (^{1}H, ^{13}C, ^{29}Si). Compounds (+)-**2a** and (+)-**2b** were isolated from the first eluate, and the corresponding antipodes (−)-**2a** and (−)-**2b** were isolated from the second eluate. Provided that the identically configurated enantiomers of the C/Si analogues **2a** and **2b** undergo the same kind of interaction with the chiral stationary phase (→ analogous diastereomeric discrimination), information about the absolute configurations of the separated enantiomers can be obtained by comparison of their order of elution. On the basis of this comparison, compounds (+)-**2a** and (+)-**2b** have the same absolute configuration, and their antipodes (−)-**2a** and (−)-**2b** are also characterized by an identical absolute configuration.[7,8]

Determination of the Enantiomeric Purities. The enantiomeric purities of compounds (+)-**2a**, (−)-**2a**, (+)-**2b**, and (−)-**2b** were determined by analytical liquid chromatography (HPLC) on a chiral stationary phase using a UV diode array detector. According to this method, the enantiomeric purities of all enantiomers were determined to be ≥99% ee. This is demonstrated for the enantiomers of **2b** in Figure 1.

Sensory Characterization. The sensory properties of compounds (+)-**2a**, (−)-**2a**, (+)-**2b**, and (−)-**2b** were determined using 10% solutions of the respective compounds in diethyl ether applied to a blotter.

The odor of the carbon compound (+)-**2a** was found to be strong floral linalool-like with only a very weak muguet majantol-like character and turned out to be much more intense than that of its antipode (−)-**2a**, which, on the other hand, is also floral, but more muguet-like and closer to that of majantol but has surprisingly no linalool character. This result clearly demonstrates that replacement of one of the two geminal methyl groups of majantol by a vinyl moiety leads to significant changes in the sensory properties, with very strong differences in the odor of the enantiomers (+)-**2a** and (−)-**2a**.

The odor of the silicon compound (+)-**2b** was found to be more intense than that of its carbon analogue (+)-**2a** but has a totally different sensory character. It is not floral but strongly mushroom-like, similar to that of (*R*)-oct-1-en-3-ol and shows also some earthy

(7) As a matter of principle, the signs of the optical rotations of the enantiomers of **2a** and **2b** cannot be used to assign the absolute configurations. In this context, see ref 1d.

(8) Attempts to establish the absolute configurations by crystal structure analyses of crystalline derivatives failed so far.

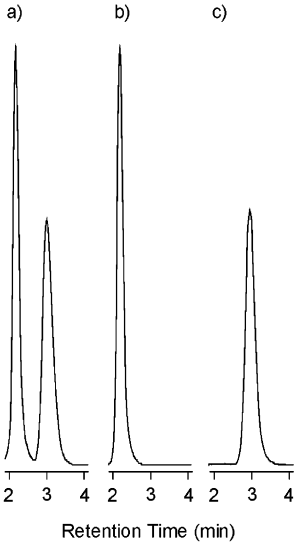


Figure 1. Quantitative HPLC determination of the enantiomeric purities of the enantiomers (+)-**2b** and (−)-**2b**: (a) chromatogram of *rac*-**2b**; (b) chromatogram of enantiomerically pure (≥99% ee) (+)-**2b** obtained by preparative HPLC separation; (c) chromatogram of enantiomerically pure (≥99% ee) (−)-**2b** obtained by preparative HPLC separation. For details, see Experimental Section.

and musty nuances. The odor of the silicon compound (−)-**2b** has a very low intensity and lacks the strong mushroom note. It has only a very weak slightly rosy muguet-like character.

In conclusion, replacement of one of the two methyl groups of majantol by a vinyl moiety leads to a chiral compound with totally different odors of the two enantiomers. The sensory evaluation clearly shows that the character of majantol (**2a**) is only preserved in the (−)-enantiomer, whereas the (+)-enantiomer has a totally different note. Quite remarkably, the odor intensities also differ considerably. Sila-substitution of the stereogenic carbon center changes the sensory properties of both enantiomers drastically. Both the odor character and the odor intensity of the silicon compounds (+)-**2b** and (−)-**2b** differ totally from those of the respective carbon analogues (+)-**2a** and (−)-**2a**. Compound (+)-**2b** has a much stronger odor intensity than its carbon analogue (+)-**2a** and displays a totally different odor character. It also strongly differs in its sensory properties from the antipode (−)-**2b**, which has only a weak odor. An explanation for these drastic biological sila-substitution effects cannot be given yet.

Experimental Section

General Procedures. All reactions were carried out under dry nitrogen. Dimethylformamide (DMF), tetrahydrofuran (THF), *n*-pentane, and diethyl ether were dried and purified according to standard procedures and stored under nitrogen. ^{1}H, ^{13}C, and ^{29}Si NMR spectra were recorded at 22 °C on a Bruker DRX-300 NMR spectrometer (^{1}H, 300.1 MHz; ^{13}C, 75.5 MHz; ^{29}Si, 59.6 MHz) using $CDCl_3$ as the solvent. Chemical shifts (ppm) were determined relative to internal $CHCl_3$ (^{1}H, δ 7.24), internal $CDCl_3$ (^{13}C, δ 77.0), or external TMS (^{29}Si, δ 0). Assignment of the ^{1}H NMR data was partially supported by simulations using the WIN-DAISY software package (version 4.05, Bruker). Assignment of the ^{13}C NMR data was supported by DEPT 135 and ^{13}C HMQC experiments. Optical rotations were measured at 20 °C with a JASCO polarimeter P-1030; CH_3OH (purified by drying over Mg and subsequent distillation) served as the solvent.

Preparation of *rac*-2-Methyl-2-(3-methylbenzyl)but-3-en-1-ol (*rac*-2a). A solution of *rac*-**5** (2.67 g, 13.1 mmol) in diethyl ether (85 mL) was added dropwise at 0 °C over a period of 30 min to a stirred suspension of lithium aluminum hydride (LAH) (990 mg, 26.1 mmol) in diethyl ether (30 mL). The resulting mixture was stirred for 1 h at 0 °C and then added to 2 M hydrochloric acid (90 mL) at 0 °C. The organic phase was separated and the aqueous layer extracted with diethyl ether (3 × 100 mL). The combined organic solutions were dried over anhydrous sodium sulfate, the solvent was removed under reduced pressure, and the residue was distilled in vacuo to give *rac*-**2a** in 89% yield as a colorless liquid (2.22 g, 11.7 mmol); bp 55 °C/0.01 mbar. ^{1}H NMR ($CDCl_3$): δ 0.98 (s, 3 H, OCH_2CCH_3), 1.8 (br s, 1 H, O*H*), 2.33 (s, 3 H, $C_6H_4CH_3$), 2.61 (δ_A) and 2.68 (δ_B) (2 H, $C_6H_4CH_AH_B$, $^2J_{AB}$ = 13.1 Hz), 3.37 (δ_A) and 3.42 (δ_B) (2 H, CH_AH_BO, $^2J_{AB}$ = 11.0 Hz), 5.02 (δ_A), 5.16 (δ_M), and 5.84 (δ_X) (3 H, $CH_X{=}CH_AH_M$, $^3J_{AX}$ = 17.6 Hz, $^2J_{AM}$ = 1.2 Hz, $^3J_{MX}$ = 10.9 Hz), 6.92−7.06 (m, 3 H, *H*-2/*H*-4/*H*-6, C_6H_4), 7.13−7.19 (m, 1 H, *H*-5, C_6H_4). ^{13}C NMR ($CDCl_3$): δ 20.1 (OCH_2CCH_3), 21.4 ($C_6H_4CH_3$) 43.0 (CC_4), 43.1 ($C_6H_4CH_2$), 68.9 (CH_2O), 114.5 ($CH{=}CH_2$), 126.8 (*C*-4 or *C*-6, C_6H_4), 127.6 (2 C) (*C*-4 or *C*-6, and *C*-5, C_6H_4), 131.3 (*C*-2, C_6H_4), 137.1 (*C*-1 or *C*-3, C_6H_4), 137.6 (*C*-1 or *C*-3, C_6H_4), 143.9 ($CH{=}CH_2$). Anal. Calcd for $C_{13}H_{18}O$: C, 82.06; H, 9.53. Found: C, 81.5; H, 9.3.

Preparation of *rac*-(Hydroxymethyl)methyl(3-methylbenzyl)vinylsilane (*rac*-2b). A solution of *rac*-**9** (2.46 g, 9.90 mmol) in diethyl ether (30 mL) was added dropwise at −30 °C over a period of 30 min to a stirred suspension of LAH (790 mg, 20.8 mmol) in diethyl ether (10 mL). The resulting mixture was stirred for 1 h at 20 °C and then added to a mixture of 2 M hydrochloric acid (30 mL) and diethyl ether (20 mL) at 0 °C. The organic phase was separated and the aqueous layer extracted with diethyl ether (3 × 25 mL). The combined organic solutions were dried over anhydrous sodium sulfate, the solvent was removed under reduced pressure, and the residue was purified by Kugelrohr distillation (oven temperature 80 °C, 0.01 mbar) to give *rac*-**2b** in 83% yield as a colorless liquid (1.70 g, 8.24 mmol). ^{1}H NMR ($CDCl_3$): δ 0.10 (s, 3 H, $SiCH_3$), 1.0 (br s, 1 H, O*H*), 2.20 (δ_A) and 2.23 (δ_B) (2 H, $C_6H_4CH_AH_B$, $^2J_{AB}$ = 14.0 Hz), 2.29 (s, 3 H, $C_6H_4CH_3$), 3.42 (s, 2 H, CH_2O), 5.79 (δ_A), 6.08 (δ_M), and 6.11 (δ_X) (3 H, $CH_X{=}CH_AH_M$, $^3J_{AX}$ = 20.9 Hz, $^2J_{AM}$ = 3.1 Hz, $^3J_{MX}$ = 14.9 Hz), 6.82−6.91 (m, 3 H, *H*-2/*H*-4/*H*-6, C_6H_4), 7.05−7.13 (m, 1 H, *H*-5, C_6H_4). ^{13}C NMR ($CDCl_3$): δ −7.2 ($SiCH_3$), 21.4 ($C_6H_4CH_3$), 22.2 ($C_6H_4CH_2$), 53.5 (CH_2O), 125.1 (*C*-4 or *C*-6, C_6H_4), 125.2 (*C*-4 or *C*-6, C_6H_4), 128.2 (*C*-5, C_6H_4), 129.0 (*C*-2, C_6H_4), 134.5 ($CH{=}CH_2$), 134.7 ($CH{=}CH_2$), 137.9 (*C*-1 or *C*-3, C_6H_4), 138.9 (*C*-1 or *C*-3, C_6H_4). ^{29}Si NMR ($CDCl_3$): δ −8.6. Anal. Calcd for $C_{12}H_{18}OSi$: C, 69.84; H, 8.79. Found: C, 69.8; H, 8.8.

(2*E*)-2-Methylbut-2-enoic Acid (4). This compound was commercially available (ABCR).

Preparation of *rac*-2-Methyl-2-(3-methylbenzyl)but-3-enoic Acid (*rac*-5). A 1.6 M solution of *n*-butyllithium in *n*-hexane (44.7 mL, 71.5 mmol of *n*-BuLi) was added dropwise at 0 °C over a period of 30 min to a stirred solution of diisopropylamine (7.20 g, 71.2 mmol) in THF (9 mL), and the resulting mixture was stirred for 30 min at 0 °C and then cooled to −78 °C. A solution of **4** (3.56 g, 35.6 mmol) in THF/*n*-pentane (1:5 (v/v)) (20 mL) was added dropwise at −78 °C over a period of 30 min and the resulting mixture then stirred for 30 min at 0 °C. The mixture was again cooled to −78 °C, and a solution of 3-methylbenzyl chloride (5.00 g, 35.6 mmol) in THF/*n*-pentane (1:5 (v/v)) (20 mL) was added dropwise within a period of 30 min. The resulting mixture was stirred for 30 min at −78 °C and then warmed to 20 °C, followed by addition of water (100 mL). The organic phase was separated and discarded, and the aqueous layer was washed with diethyl ether (40 mL), followed by addition of 12 M hydrochloric acid (1.5 mL → pH ca. 3) and diethyl ether (50 mL). The aqueous layer was separated and extracted with diethyl ether (2 × 50 mL). The combined organic extracts were dried over anhydrous

sodium sulfate, the solvent was removed under reduced pressure, and the residue was distilled in vacuo to give *rac*-**5** in 55% yield as a colorless liquid (3.96 g, 19.4 mmol); bp 115 °C/0.01 mbar. ^{1}H NMR ($CDCl_3$): δ 1.25 (s, 3 H, C(O)CCH_3), 2.30 (s, 3 H, $C_6H_4CH_3$), 2.86 (δ_A) and 3.06 (δ_B) (2 H, $C_6H_4CH_AH_B$, $^2J_{AB}$ = 13.2 Hz), 5.13 (δ_A), 5.18 (δ_M), and 6.10 (δ_X) (3 H, CH_X=CH_AH_M, $^3J_{AX}$ = 17.5 Hz, $^2J_{AM}$ = 0.7 Hz, $^3J_{MX}$ = 10.7 Hz), 6.93−7.08 (m, 3 H, *H*-2/*H*-4/*H*-6, C_6H_4), 7.13−7.19 (m, 1 H, *H*-5, C_6H_4), 11.0 (br s, 1 H, O*H*). ^{13}C NMR ($CDCl_3$): δ 19.6 (C(O)-CCH_3), 21.4 ($C_6H_4CH_3$), 45.1 ($C_6H_4CH_2$), 49.7 (*C*C_4), 114.6 (CH=*C*H_2), 127.37 (*C*-4 or *C*-6, C_6H_4), 127.39 (*C*-4 or *C*-6, C_6H_4), 127.8 (*C*-5, C_6H_4), 131.2 (*C*-2, C_6H_4), 136.7 (*C*-1 or *C*-3, C_6H_4), 137.4 (*C*-1 or *C*-3, C_6H_4), 140.7 (*C*H=CH_2), 182.0 (*C*=O). Anal. Calcd for $C_{13}H_{16}O_2$: C, 76.44; H, 7.90. Found: C, 76.7; H 8.0.

(Chloromethyl)diethoxy(methyl)silane (6). This compound was commercially available (Aldrich).

Preparation of *rac*-(Chloromethyl)ethoxy(methyl)(3-methylbenzyl)silane (*rac*-7). A solution of 3-methylbenzyl chloride (14.3 g, 102 mmol) in diethyl ether (35 mL) was added dropwise at −10 °C over a period of 30 min to a stirred suspension of magnesium turnings (2.95 g, 121 mmol) in diethyl ether (5 mL). The mixture was stirred for 1 h at −10 °C and then added at 20 °C within 30 min to a stirred solution of **6** (18.6 g, 102 mmol) in diethyl ether (80 mL). After the resulting mixture was heated under reflux for 60 h, it was cooled to 20 °C and filtrated, and the filter cake was washed with diethyl ether (30 mL). The filtrate and the wash solutions were combined, the solvent was removed under reduced pressure, and the residue was distilled in vacuo to give *rac*-**7** in 51% yield as a colorless liquid (12.6 g, 51.9 mmol); bp 92 °C/1 mbar. ^{1}H NMR ($CDCl_3$): δ 0.19 (s, 3 H, SiCH_3), 1.18 (t, $^3J_{HH}$ = 7.0 Hz, 3 H, CH_2CH_3), 2.26 (δ_A) and 2.29 (δ_B) (2 H, $C_6H_4CH_AH_B$, $^2J_{AB}$ = 14.3 Hz), 2.30 (s, 3 H, $C_6H_4CH_3$), 2.76 (δ_A) and 2.78 (δ_B) (2 H, CH_AH_BCl, $^2J_{AB}$ = 13.9 Hz), 3.72 (q, $^3J_{HH}$ = 7.0 Hz, 2 H, CH_2CH$_3$), 6.84−6.95 (m, 3 H, *H*-2/*H*-4/*H*-6, C_6H_4), 7.08−7.15 (m, 1 H, *H*-5, C_6H_4). ^{13}C NMR ($CDCl_3$): δ −5.4 (SiCH_3), 18.4 (CH_2CH_3), 21.4 ($C_6H_4CH_3$), 23.2 ($C_6H_4CH_2$), 28.1 (CH_2Cl), 59.4 (CH_2CH_3), 125.36 (*C*-4 or *C*-6, C_6H_4), 125.41 (*C*-4 or *C*-6, C_6H_4), 128.3 (*C*-5, C_6H_4), 129.2 (*C*-2, C_6H_4), 137.6 (*C*-1 or *C*-3, C_6H_4), 137.9 (*C*-1 or *C*-3, C_6H_4). ^{29}Si NMR ($CDCl_3$): δ 7.0. Anal. Calcd for $C_{12}H_{19}ClOSi$: C, 59.36; H, 7.89. Found: C, 59.0; H, 7.6.

Preparation of *rac*-(Chloromethyl)methyl(3-methylbenzyl)vinylsilane (*rac*-8). A 1.7 M solution of vinylmagnesium chloride in THF (25.4 mL, 43.2 mmol of CH_2=CHMgCl) was added at 20 °C within 30 min to a stirred solution of *rac*-**7** (10.5 g, 43.2 mmol) in diethyl ether (30 mL). After the mixture was stirred for 20 h at 20 °C, diethyl ether (80 mL) and 3 M hydrochloric acid (50 mL) were added. The organic phase was separated and the aqueous layer extracted with diethyl ether (3 × 30 mL). The combined organic solutions were dried over anhydrous sodium sulfate, the solvent was removed under reduced pressure, and the residue was distilled in vacuo to give *rac*-**8** in 85% yield as a colorless liquid (8.23 g, 36.6 mmol); bp 66 °C/0.01 mbar. ^{1}H NMR ($CDCl_3$): δ 0.18 (s, 3 H, SiCH_3), 2.26 (δ_A) and 2.28 (δ_B) (2 H, $C_6H_4CH_AH_B$, $^2J_{AB}$ = 13.9 Hz), 2.30 (s, 3 H, $C_6H_4CH_3$), 2.79 (s, 2 H, CH_2Cl), 5.78 (δ_A), 6.09 (δ_M), and 6.11 (δ_X) (3 H, CH_X=CH_AH_M, $^3J_{AX}$ = 20.4 Hz, $^2J_{AM}$ = 3.5 Hz, $^3J_{MX}$ = 14.9 Hz), 6.83−6.94 (m, 3 H, *H*-2/*H*-4/*H*-6, C_6H_4), 7.07−7.15 (m, 1 H, *H*-5, C_6H_4). ^{13}C NMR ($CDCl_3$): δ −6.9 (SiCH_3), 21.4 ($C_6H_4CH_3$), 22.0 ($C_6H_4CH_2$), 28.3 (CH_2Cl), 125.26 (*C*-4 or *C*-6, C_6H_4), 125.32 (*C*-4 or *C*-6, C_6H_4), 128.2 (*C*-5, C_6H_4), 129.1 (*C*-2, C_6H_4), 133.9 (*C*H=CH_2), 134.8 (CH=*C*H_2), 137.9 (*C*-1 or *C*-3, C_6H_4), 138.2 (*C*-1 or *C*-3, C_6H_4). ^{29}Si NMR ($CDCl_3$): δ −6.4. Anal. Calcd for $C_{12}H_{17}ClSi$: C, 64.11; H, 7.62. Found: C, 64.2; H, 7.7.

Preparation of *rac*-(Acetoxymethyl)methyl(3-methylbenzyl)vinylsilane (*rac*-9). A mixture of sodium acetate (4.38 g, 53.4 mmol), *rac*-**8** (5.00 g, 22.2 mmol), Aliquat 336 (450 mg, 1.11 mmol), and DMF (100 mL) was stirred for 2 days at 50 °C. After the mixture was cooled to room temperature, water (70 mL) and diethyl ether (80 mL) were added. The organic phase was separated and extracted with water (3 × 15 mL) and then dried over anhydrous sodium sulfate. The solvent was removed under reduced pressure and the residue distilled in vacuo to give *rac*-**9** in 55% yield as a colorless liquid (3.05 g, 12.3 mmol); bp 80 °C/0.01 mbar. ^{1}H NMR ($CDCl_3$): δ 0.10 (s, 3 H, SiCH_3), 2.01 (s, 3 H, C(O)CH_3), 2.20 (s, 2 H, $C_6H_4CH_2$), 2.27 (s, 3 H, $C_6H_4CH_3$), 3.79 (s, 2 H, CH_2O), 5.74 (δ_A), 6.04 (δ_M), and 6.06 (δ_X) (3 H, CH_X=CH_AH_M, $^3J_{AX}$ = 20.0 Hz, $^2J_{AM}$ = 3.9 Hz, $^3J_{MX}$ = 14.8 Hz), 6.76−6.89 (m, 3 H, *H*-2/*H*-4/*H*-6, C_6H_4), 7.05−7.13 (m, 1 H, *H*-5, C_6H_4). ^{13}C NMR ($CDCl_3$): δ −6.9 (SiCH_3), 20.8 (C(O)CH_3), 21.4 ($C_6H_4CH_3$), 22.4 ($C_6H_4CH_2$), 55.0 (CH_2O), 125.2 (*C*-4 or *C*-6, C_6H_4), 125.3 (*C*-4 or *C*-6, C_6H_4), 128.2 (*C*-5, C_6H_4), 129.1 (*C*-2, C_6H_4), 134.1 (*C*H=CH_2), 134.5 (CH=*C*H_2), 137.8 (*C*-1 or *C*-3, C_6H_4), 138.3 (*C*-1 or *C*-3, C_6H_4), 171.7 (*C*=O). ^{29}Si NMR ($CDCl_3$): δ −8.8. Anal. Calcd for $C_{14}H_{20}O_2Si$: C, 67.70; H, 8.12. Found: C, 67.5; H, 8.3.

Preparative HPLC Separation of *rac*-2a and *rac*-2b. To prepare the enantiomers (+)-**2a**, (−)-**2a**, (+)-**2b**, and (−)-**2b**, compounds *rac*-**2a** and *rac*-**2b** were resolved by preparative liquid chromatography (HPLC) on a chiral stationary phase. The experimental conditions were as follows: LC pump, SunChrom SunFlow 100; detector, SunChrom SpectraFlow 600 (λ = 264 nm); column thermostat, Spark Mistral; column temperature, 10 °C; column (25 cm, i.d. 4.6 mm), Chiral Technologies Europe CHIRALPAK 50801 (particle size, 20 μm); injection volumes, 70 μL (*rac*-**2a**: stock solution, 280 mg of the sample material dissolved in 4.0 mL of acetonitrile; sample loop, 200 μL) or 17 μL (*rac*-**2b**: stock solution, 80 mg of the sample material dissolved in 1.0 mL of acetonitrile; sample loop, 20 μL); flow rate, 1.0 mL/min; solvent, acetonitrile (100%). The solvent of the respective fractions obtained ((+)-**2a** and (+)-**2b**, first fractions; (−)-**2a** and (−)-**2b**, second fractions) was removed (rotary evaporator), and the enantiomerically pure products were finally purified by Kugelrohr distillation (**2a**: 55 °C, 0.01 mbar; **2b**: 80 °C, 0.01 mbar). Yields: (+)-**2a**, 127 mg; (−)-**2a**, 93 mg; (+)-**2b**, 39 mg; (−)-**2b**, 31 mg. The NMR data of the products were identical with those obtained for *rac*-**2a** and *rac*-**2b**, respectively. Data for (+)-**2a**: Anal. Calcd for $C_{13}H_{18}O$: C, 82.06; H, 9.53. Found: C, 81.5; H, 9.9; $[\alpha]_{365}^{20}$ +47.1 (*c* 1.00, MeOH). Data for (−)-**2a**: Anal. Calcd for $C_{13}H_{18}O$: C, 82.06; H, 9.53. Found: C, 82.4; H, 9.9; $[\alpha]_{365}^{20}$ −47.1 (*c* 1.00, MeOH). Data for (+)-**2b**: Anal. Calcd for $C_{12}H_{18}OSi$: C, 69.84; H, 8.79. Found: C, 69.8; H, 8.7; $[\alpha]_{365}^{20}$ +2.8 (*c* 1.00, MeOH). Data for (−)-**2b**: Anal. Calcd for $C_{12}H_{18}OSi$: C, 69.84; H, 8.79. Found: C, 69.7; H, 8.8; $[\alpha]_{365}^{20}$ −2.8 (*c* 1.00, MeOH).

Determination of the Enantiomeric Purities by Analytical HPLC. The enantiomers (+)-**2a**, (−)-**2a**, (+)-**2b**, and (−)-**2b** were investigated for their enantiomeric purities by analytical liquid chromatography (HPLC) using a chiral stationary phase. Except for the concentrations of the stock solutions (1 mg of the respective sample material dissolved in 250 μL of acetonitrile), the injection volumes (20 μL), and the flow rate (2 mL/min), the experimental conditions were identical with those used for the preparative resolution of *rac*-**2a** and *rac*-**2b** (see above). The enantiomeric purities were determined to be ≥99% ee for all compounds.

Sensory Characterization. The sensory properties of (+)-**2a**, (−)-**2a**, (+)-**2b**, and (−)-**2b** were determined using 10% solutions of the respective freshly distilled (Kugelrohr apparatus) samples in diethyl ether applied to a blotter.

Acknowledgment. Financial support of this work by the Fonds der Chemischen Industrie is gratefully acknowledged.

OM0304964