Regio- and Stereoselective Reductions of *gem*-Difluorinated Vinyloxiranes.

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List of content

Experimental Section , General Methods	S2
Experimental Section , Physical properties for 2a	S2
Experimental Section , Physical properties for 2b	S2
Experimental Section , Physical properties for 3a	S3
Experimental Section , Physical properties for 3b	S3
Experimental Section , Physical properties for 3d	S3

General Methods. Unless otherwise noted, materials were obtained from commercial suppliers and were used without further purification. All manipulations involving air-sensitive materials were performed under argon, with such materials being exposed only to thoroughly dried and degassed solvents. Anhydrous ether, THF and CH₂Cl₂ were purchased and were used without further purification.

¹H NMR and ¹³C NMR spectra were recorded with a Varian Mercury (300 and 75 MHz) and a VXR-500 (500 MHz: for ¹H) in CDCl₃ unless otherwise noted. Chemical shifts were reported in parts per million (ppm) downfield from internal tetramethylsilane (Me₄Si). ¹⁹F NMR spectra were recorded with a Varian Mercury (282 MHz) and a VXFR-500 (470 MHz) in CDCl₃ unless otherwise noted. Chemical shifts were reported in ppm downfield from internal hexafluorobenzene (C₆F₆). Data were tabulated in the following order: multiplicity (s, singlet; d, doublet; t, triplet; q, quartet; quint, quintet; sex, sextet; m, multiplet), number of protons, coupling constants (in hertz). Infrared (IR) spectra were obtained on a JASCO FT/IR-5000 spectrometer as thin films on NaCl plates, and all spectra were reported in wave numbers (cm⁻¹). Column chromatography was conducted with silica gel (BW-200) by using a mixture of *n*-hexane and AcOEt (v/v), and before starting separation, it is recommended to “wash” silica gel by passing AcOEt for removing the chance of decomposition of epoxy-containing products, which makes the isolation easier.

Typical procedure for the reduction of **1** with LiAlH₄.

The reaction of **1a** is described as a representative example. To a solution of **1a** (0.10 g, 0.45 mmol) in 5 mL of dry THF, 0.5 equiv of LiAlH₄ THF solution (0.23 mmol) was added at 0 °C under argon. After 2.0 h stirring at 80 °C, the reaction was quenched with 3 *N* HCl aq, and the organic layer was extracted with Et₂O three times and dried over anhydrous MgSO₄. Removal of the solvents and purification with silica gel column chromatography (*n*-hexane:AcOEt = 4:1) afforded pure **2a** in 78% yield.

Typical procedure for the reduction of **1** with DIBAL-H.

The reaction of **1a** in CH₂Cl₂ is described as a representative example. To a solution of **1a** (0.10 g, 0.45 mmol) in 5 mL of dry CH₂Cl₂, 2.0 equiv of DIBAL-H (0.89 mmol) was added at -78 °C under argon. After 1.0 h stirring, the reaction was quenched with 3 *N* HCl aq, and the organic layer was extracted with CH₂Cl₂ three times and dried over anhydrous MgSO₄. Removal of the solvents and purification with silica gel column chromatography (*n*-hexane:AcOEt = 4:1) afforded pure *E*-**3a** in 66% yield.

Typical procedure for the reduction of **1** with BH₃·THF.

The reaction of **1a** is described as a representative example. To a solution of **1a** (0.10 g, 0.45 mmol) in 5 mL of dry THF, 0.75 equiv of BH₃·THF THF solution (0.33 mmol) was added under argon. After 1.0 h stirring at rt, the reaction was quenched with 3 *N* NaOH aq, and the organic layer was extracted with Et₂O three times, washed with brine, and dried over anhydrous MgSO₄. Removal of the solvents and purification with silica gel column chromatography (*n*-hexane:AcOEt = 4:1) afforded pure *Z*-**3a** in 95% yield.

5-Difluoromethylene-1-phenylhexan-3-ol (2a): ¹H NMR δ 1.59 (3 H, m), 1.76 (1 H, dddd, *J* = 13.9, 9.34, 7.93, 6.32 Hz), 1.80 (1 H, dddd, *J* = 13.8, 9.15, 7.14, 4.67 Hz), 2.08 (1 H, ddt, *J* = 14.3, 5.22, 2.47 Hz), 2.18 (1 H, dddd, *J* = 14.0, 8.24, 2.20, 1.10 Hz), 2.68 (1 H, m), 2.82 (1 H, ddd, *J* = 13.7, 9.34, 6.60 Hz), 3.74 (1 H, ddd, *J* = 12.6, 7.97, 4.94 Hz), 7.15-7.33 (5 H, m). ¹⁹F NMR δ 66.6 (1 F, dsex, *J* = 54.7, 3.02 Hz), 67.3 (1 F, dq, *J* = 55.1, 3.01 Hz). ¹³C NMR δ 12.5 (dd, *J* = 2.29, 1.44 Hz), 32.1, 36.6 (d, *J* = 3.29 Hz), 38.7, 68.9 (dd, *J* = 3.44, 2.30 Hz), 82.0 (dd, *J* = 19.2, 18.9 Hz), 125.8, 128.3, 128.3, 141.6, 153.7 (dd, *J* = 283.1, 280.7 Hz). IR (neat) ν 700, 746, 856, 926, 1030, 1052, 1082, 1119, 1204, 1268, 1454, 1496, 1604, 1758, 1944, 2344, 2362, 2864, 2927, 3028, 3063, 3086, 3374 cm⁻¹. Anal. Calcd for C₁₃H₁₆F₂O: C, 69.01; H, 7.13. Found: C, 68.86; H, 6.97.

4-Difluoromethylene-1-phenylbutan-1-ol (2b): ¹H NMR δ 1.59 (3 H, t, *J* = 3.17 Hz), 2.29 (1 H, ddt, *J* = 14.2, 5.37, 2.57 Hz), 2.50 (1 H, dddd, *J* = 14.2, 8.55, 1.10, 0.98 Hz), 4.80 (1 H, m), 7.27-7.38 (5 H, m). ¹⁹F NMR δ 66.9 (1 F,

dsex, $J = 53.4, 3.05$ Hz), 67.3 (1 F, dqint, $J = 53.4, 3.05$ Hz). ^{13}C NMR δ 12.5 (dd, $J = 2.15, 1.56$ Hz), 38.2 (d, $J = 2.58$ Hz), 72.3 (dd, $J = 3.44, 2.29$ Hz), 81.9 (t, $J = 18.9$ Hz), 125.6, 127.7, 128.4, 143.5, 153.7 (dd, $J = 283.1, 282.1$ Hz). IR (neat) ν 513, 702, 741, 760, 833, 872, 914, 968, 1003, 1030, 1053, 1123, 1204, 1219, 1273, 1331, 1389, 1454, 1492, 1755, 2955, 3032, 3063, 3383 cm^{-1} . Anal. Calcd for $\text{C}_{11}\text{H}_{12}\text{F}_2\text{O}$: C, 66.66; H, 6.10. Found: C, 66.72; H, 6.57.

6,6-Difluoro-5-methyl-1-phenylhex-4-en-3-ol (3a): IR (neat) ν 509, 698, 748, 822, 841, 883, 918, 1018, 1092, 1153, 1207, 1339, 1362, 1396, 1454, 1497, 1524, 1585, 1605, 1655, 1674, 1686, 1717, 1751, 1802, 1871, 1948, 2862, 2928, 3028, 3063, 3086, 3368, 3530, 3568, 3588 cm^{-1} . Anal. Calcd for $\text{C}_{13}\text{H}_{16}\text{F}_2\text{O}$: C, 69.01; H, 7.13. Found: C, 69.28; H, 6.92. **E Isomer:** ^1H NMR δ 1.71 (3 H, dd, $J = 1.48, 0.38$ Hz), 1.80 (1 H, dddd, $J = 13.7, 9.61, 6.87, 5.77$ Hz), 1.95 (1 H, dddd, $J = 13.7, 8.79, 7.42, 6.32$ Hz), 2.67 (1 H, ddd, $J = 13.7, 8.79, 6.60$ Hz), 2.74 (1 H, ddd, $J = 14.0, 9.34, 6.32$ Hz), 4.44 (1 H, m), 5.74 (1 H, m), 5.92 (1 H, t, $J = 56.2$ Hz), 7.10-7.35 (5 H, m). ^{19}F NMR δ 45.8 (1 F, dd, $J = 299.0, 56.0$ Hz), 46.9 (1 F, dd, $J = 299.0, 56.0$ Hz). ^{13}C NMR δ 9.66 (dd, $J = 2.29, 2.01$ Hz), 31.4, 38.3 (t, $J = 1.72$ Hz), 67.0, 117.1 (t, $J = 236.8$ Hz), 125.9, 128.2, 128.3, 131.1 (dd, $J = 21.8, 21.5$ Hz), 135.2 (dd, $J = 10.0, 9.73$ Hz), 141.1. **Z Isomer:** ^1H NMR δ 1.81 (1 H, dddd, $J = 12.7, 9.15, 6.96, 5.83$ Hz), 1.83 (3 H, m), 1.95 (1 H, dddd, $J = 13.7, 8.91, 7.32, 6.38$ Hz), 2.67 (1 H, ddd, $J = 13.9, 8.91, 6.96$ Hz), 2.70 (1 H, ddd, $J = 14.0, 9.16, 6.47$ Hz), 4.44 (1 H, m), 5.63 (1 H, m), 6.42 (1 H, t, $J = 55.7$ Hz), 7.16-7.32 (5 H, m). ^{19}F NMR δ 44.8 (2 F, d, $J = 55.6$ Hz). ^{13}C NMR δ 15.7 (t, $J = 3.01$ Hz), 31.4, 38.9 (t, $J = 1.14$ Hz), 66.5 (t, $J = 0.86$ Hz), 112.0 (t, $J = 233.9$ Hz), 125.9, 128.2, 128.3, 131.2 (t, $J = 22.5$ Hz), 136.3 (t, $J = 8.88$ Hz), 141.0.

4,4-Difluoro-3-methyl-1-phenylbut-2-en-1-ol (3b): IR (neat) ν 700, 761, 845, 890, 917, 1020, 1091, 1192, 1249, 1340, 1396, 1420, 1437, 1453, 1473, 1493, 2855, 2927, 2957, 2988, 3031, 3064, 3351 cm^{-1} . Anal. Calcd for $\text{C}_{11}\text{H}_{12}\text{F}_2\text{O}$: C, 66.66; H, 6.10. Found: C, 66.10; H, 6.12. **E Isomer:** ^1H NMR δ 1.86 (3 H, m), 5.54 (1 H, ddt, $J = 8.43, 3.41, 1.47$ Hz), 5.95 (1 H, t, $J = 55.7$ Hz), 5.96 (1 H, m), 7.31-7.42 (5 H, m). ^{19}F NMR δ 45.8 (1 F, dd, $J = 300.6, 54.9$ Hz), 46.5 (1 F, dd, $J = 300.6, 54.9$ Hz). ^{13}C NMR δ 9.85 (t, $J = 2.15$ Hz), 69.9, 117.0 (t, $J = 237.2$ Hz), 125.8, 128.0, 128.7, 130.9 (t, $J = 21.8$ Hz), 134.7 (t, $J = 9.74$ Hz), 142.0 (t, $J = 1.58$ Hz). **Z Isomer:** ^1H NMR δ 1.83 (3 H, s), 5.54 (1 H, d, $J = 8.79$ Hz), 5.76 (1 H, d, $J = 8.79$ Hz), 6.67 (1 H, t, $J = 55.5$ Hz), 7.25-7.41 (5H, m). ^{19}F NMR δ 44.3 (1 F, dd, $J = 56.5, 294.3$ Hz), 45.4 (1 F, dd, $J = 56.5, 314.3$ Hz). ^{13}C NMR δ 15.9 (t, $J = 3.14$ Hz), 69.5 (m), 112.1 (t, $J = 234.5$ Hz), 125.7, 127.9, 128.7, 130.8 (dd, $J = 22.3, 21.8$ Hz), 135.4 (t, $J = 8.74$ Hz), 142.1 (t, $J = 2.57$ Hz).

4,4-Difluoro-1,3-diphenylbut-2-en-1-ol (3d): IR (neat) ν 509, 702, 760, 806, 841, 903, 1026, 1096, 1123, 1196, 1234, 1281, 1358, 1393, 1450, 1493, 1601, 1732, 1813, 1890, 1956, 2854, 2928, 3028, 3059, 3364 cm^{-1} . Anal. Calcd for $\text{C}_{16}\text{H}_{14}\text{F}_2\text{O}$: C, 73.83; H, 5.42. Found: C, 73.78; H, 5.81. **E Isomer:** ^1H NMR δ 5.22 (1 H, dd, $J = 9.10, 3.36$ Hz), 6.21 (1 H, t, $J = 55.7$ Hz), 6.29 (1 H, dt, $J = 9.27, 2.32$ Hz), 7.05-7.50 (10 H, m). ^{19}F NMR δ 49.0 (d, $J = 56.0$ Hz). ^{13}C NMR δ 70.2, 115.6 (t, $J = 222.9$ Hz), 126.0, 128.0, 128.4, 128.4, 128.6, 129.3, 132.3 (t, $J = 1.00$ Hz), 135.9 (t, $J = 20.6$ Hz), 136.0 (t, $J = 9.02$ Hz), 141.9 (t, $J = 1.29$ Hz). **Z Isomer:** ^1H NMR δ 5.82 (1 H, m), 6.19 (1 H, d, $J = 8.52$ Hz), 6.90 (1 H, t, $J = 54.7$ Hz), 7.15-7.60 (10 H, m). ^{19}F NMR δ 50.9 (2F, dd, $J = 54.7, 6.03$ Hz). ^{13}C NMR δ 69.8, 112.9 (t, $J = 237.6$ Hz), 125.9, 127.5, 128.0, 128.1, 128.3, 128.7, 134.7 (t, $J = 21.0$ Hz), 135.8 (t, $J = 1.71$ Hz), 138.6 (t, $J = 6.87$ Hz), 141.7 (t, $J = 1.43$ Hz).