Supporting Information

for Highly Enantioselective Michael Addition of Silyl Nitronates to α,β -Unsaturated Aldehydes Catalyzed by Designer Chiral Ammonium Bifluorides: An Efficient Access to Optically Active γ -Nitro Aldehydes and Their Enol Silyl Ethers

Takashi Ooi, Kanae Doda, and Keiji Maruoka*

*Department of Chemistry, Graduate School of Science, Kyoto University
Sakyo, Kyoto 606-8502, Japan*

General Information. Infrared (IR) spectra were recorded on a Shimadzu FT-IR 8200A spectrometer. ^1H NMR spectra were measured on a JEOL JNM-FX400 (400 MHz) spectrometer. Chemical shifts were reported in ppm from tetramethylsilane as an internal standard. Data were reported as follows: chemical shift, integration, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, quint = quintet, m = multiplet, br = broad), coupling constants (Hz), and assignment. ^{13}C NMR spectra were recorded on a JEOL JNM-FX400 (100 MHz) spectrometer with complete proton decoupling. Chemical shifts are reported in ppm from the residual solvent as an internal standard. ^{19}F NMR spectra were recorded on a JEOL JNM-FX400 (376 MHz). Chemical shifts are reported in ppm from fluorobenzene resonance (–113 ppm) as an external standard. Analytical gas-liquid phase chromatography (GLC) was performed on Shimadzu GC-14B instruments equipped with a flame ionization detector using an Astec Chiradex Γ -TA (30 m x 0.25 mm) column or a GL Science CP-CHIRASIL-DEX CB (25 m x 0.25 mm) column. The high-resolution mass spectra (HRMS) were performed on Applied Biosystems Mariner 8295 API-TOF workstation. Optical rotations were measured on a JASCO DIP-1000 digital polarimeter.

All experiments were carried out under an atmosphere of dry argon. For thin layer chromatography (TLC) analysis throughout this work, Merck precoated TLC plates (silica gel 60 GF₂₅₄, 0.25 mm) were used. The products were purified by flash column chromatography on silica gel 60 (Merck 1.09386.9025, 230–400 mesh) or on silica gel 60 silanized (Merck 1.07719.0250, 0.063–0.200 mm). Tetrahydrofuran was distilled from sodium benzophenone ketyl and toluene was dried over sodium metal. Chiral quaternary ammonium bifluoride **1**¹ and silyl nitronate **2**² were prepared according to the literature procedures and **2** was purified by redistillation. α,β -Unsaturated aldehydes were distilled and stored under argon atmosphere at –17 °C. Other simple chemicals were purchased and used as such.

Characterization of the C₂-Symmetric Chiral Quaternary Ammonium Bifluoride (*R,R*)-1c**.** $[\alpha]_D^{27} -89.8^\circ$ (*c* 0.50, CH₃OH); ¹H NMR (400 MHz, CDCl₃) δ 8.33 (2H, s, Ar-H), 8.12 (4H, d, *J* = 8.4 Hz, Ar-H), 7.84 (2H, s, Ar-H), 7.77 (2H, d, *J* = 8.4 Hz, Ar-H), 7.63 (2H, t, *J* = 7.6 Hz, Ar-H), 7.48 (2H, t, *J* = 7.6 Hz, Ar-H), 7.33 (2H, t, *J* = 7.6 Hz, Ar-H), 7.27-7.05 (10H, m, Ar-H), 6.14 (2H, d, *J* = 8.4 Hz, Ar-H), 5.03 (2H, d, *J* = 13.6 Hz, ArCH₂), 4.27 (2H, d, *J* = 13.2 Hz, ArCH₂), 4.11 (2H, d, *J* = 13.6 Hz, Ar-CH₂), 3.54 (2H, d, *J* = 13.2 Hz, ArCH₂), 1.68 (18H, s, Bu'), 1.12 (18H, s, Bu'); ¹³C NMR (100 MHz, CDCl₃, at 50 °C) δ 139.87, 139.34, 138.55, 136.08, 135.68, 133.91, 133.39, 132.64, 130.91, 130.65, 129.32, 128.38, 128.34, 127.82, 127.65, 127.54, 127.41, 126.83, 126.38, 125.72, 124.76, 124.61, 122.89, 122.24, 62.26, 57.23, 31.87, 31.39; ¹⁹F NMR (376 MHz, CDCl₃) δ -152.63; IR (KBr) 3472, 3055, 2961, 2868, 1593, 1524, 1454, 1394, 1364, 1296, 1245, 1200, 1032, 883, 854, 812, 750, 721 cm⁻¹; HRMS (ESI-TOF) calcd for C₇₂H₇₂N (M⁺): 950.5659. Found: 950.5661 (M⁺).

Experimental Procedure for One-Pot Preparation of γ -Nitro Aldehyde **4a by the Asymmetric Michael Addition Catalyzed by **1c**.** To a solution of chiral quaternary ammonium bifluoride **1c** (5.6 mg, 0.006 mmol) in toluene (3 mL) was added *trans*-cinnamaldehyde (38 μ L, 0.3 mmol) at room temperature and the mixture was cooled to -78 °C with methanol-dry ice bath under argon atmosphere. Then, silyl nitronate **2a** (60 μ L, 0.36 mmol) was introduced. After being stirred for 1 h at that temperature, 1 N HCl (2 mL) and THF (6 mL) were added. The mixture was stirred vigorously at 0 °C for 0.5 h and the whole mixture was extracted with ether. The combined organic extracts were washed with brine and dried over Na₂SO₄. Removal of solvents and purification of the residue by column chromatography on silica gel (ether/hexane = 1:3) gave γ -nitro aldehyde **4a** [60 mg, 0.29 mmol, 97% yield, *anti/syn* = 82:18, 97% ee (*anti* isomer), 78% ee (*syn* isomer)].

***anti*-4-Nitro-3-phenylpentanal (*anti*-**4a**).** $[\alpha]_D^{24} -21.4^\circ$ (*c* 0.66, CHCl₃); ¹H NMR (400 MHz, CDCl₃) δ 9.65 (1H, s, CHO), 7.34-7.25 (3H, m, Ph), 7.18-7.16 (2H, m, Ph), 4.86 (1H, dq, *J* = 6.8, 6.8 Hz, CHNO₂), 3.81 (1H, ddd, *J* = 6.8, 6.8, 7.2 Hz, CHPh), 3.03-2.90 (2H, m, CH₂C=O), 1.52 (3H, d, *J* = 6.8 Hz, CH₃); ¹³C NMR (100 MHz, CDCl₃) δ 198.90, 137.30, 128.80, 127.97, 127.89, 86.28, 44.76, 43.50, 16.68; IR (liquid film) 3032, 2990, 2903, 2839, 2735, 1724, 1549, 1495, 1454, 1391, 1362, 1298, 1101, 1032, 868, 766, 704 cm⁻¹; HRMS (ESI-TOF) calcd for C₁₁H₁₃NNaO₃ ([M+Na]⁺): 230.0788. Found: 230.0784 ([M+Na]⁺). The enantiomeric excess was determined by GLC using an Astec Chiradex Γ -TA (30 m x 0.25 mm) column (150 °C isotherm), retention time; 25.5 min (major) and 29.2 min (minor).

General Procedure for the Preparation of Enol Silyl Ether **3 by the Asymmetric Michael Addition Catalyzed by **1c**.** To a solution of chiral quaternary ammonium bifluoride **1c** (5.6 mg, 0.006 mmol) in toluene (3 mL) was added α,β -unsaturated aldehyde (0.3 mmol) at room temperature and the mixture was cooled to -78 °C with methanol-dry ice bath under

argon atmosphere. Then, silyl nitronate **2** (0.36 mmol) was introduced. The mixture was stirred for 1 h at that temperature followed by additional stirring for 1 h at -40°C depending on α,β -unsaturated aldehyde employed. The resulting mixture was directly purified by column chromatography on silica gel 60 silanized (ether/hexane as eluant) to afford the corresponding enol silyl ether **3**. The optical purities of the enol silyl ethers were determined by GLC analysis using an Astec Chiradex Γ -TA (30 m x 0.25 mm) column or a GL Science CP-CHIRASIL-DEX CB (25 m x 0.25 mm) column.

Characterization of Enol Silyl Ethers.

4-Nitro-3-phenyl-1-trimethylsiloxy-1-pentene (3a; Table 2, entry 1). ^1H NMR (400 MHz, CDCl_3) δ 7.34-7.15 (5H, m, Ph), 6.36 (0.83H, d, $J = 11.6$ Hz, $\text{C}=\text{CHOSi}$, *anti* isomer), 6.29 (0.17H, d, $J = 12.0$ Hz, $\text{C}=\text{CHOSi}$, *syn* isomer), 5.22 (0.17H, dd, $J = 10.2, 12.0$ Hz, $\text{CH}=\text{COSi}$, *syn* isomer), 5.16 (0.83H, dd, $J = 9.8, 11.6$ Hz, $\text{CH}=\text{COSi}$, *anti* isomer), 4.82-4.70 (1H, m, CHNO_2), 3.78 (0.83H, dd, $J = 9.8, 9.8$ Hz, CHPh , *anti* isomer), 3.54 (0.17H, dd, $J = 10.2, 10.2$ Hz, CHPh , *syn* isomer), 1.52 (2.49H, d, $J = 6.8$ Hz, CH_3 , *anti* isomer), 1.31 (0.51H, d, $J = 6.4$ Hz, CH_3 , *syn* isomer), 0.18 (7.47H, s, SiCH_3 , *anti* isomer), 0.15 (1.53H, s, SiCH_3 , *syn* isomer); ^{13}C NMR (100 MHz, CDCl_3) δ 143.37, 142.83, 140.27, 139.60, 129.33, 129.08, 128.01, 127.71, 127.61, 127.61, 110.04, 108.16, 88.89, 87.98, 50.49, 49.73, 18.25, 17.15, 0.00, -0.05; IR (liquid film) 3032, 2961, 2901, 1661, 1551, 1497, 1452, 1389, 1360, 1298, 1256, 1173, 1032, 932, 876, 847, 758, 700 cm^{-1} ; HRMS (ESI-TOF) calcd for $\text{C}_{14}\text{H}_{21}\text{NNaO}_3\text{Si}$: 302.1183 ($[\text{M}+\text{Na}]^+$). Found: 302.1167 ($[\text{M}+\text{Na}]^+$).

4-Nitro-3-propyl-1-trimethylsiloxy-1-pentene (3b; Table 2, entry 2). ^1H NMR (400 MHz, CDCl_3) δ 6.20 (0.81H, d, $J = 12.0$ Hz, $\text{C}=\text{CHOSi}$, *anti* isomer), 6.17 (0.19H, d, $J = 12.2$ Hz, $\text{C}=\text{CHOSi}$, *syn* isomer), 4.69 (0.19H, dd, $J = 10.2, 12.2$ Hz, $\text{CH}=\text{COSi}$, *syn* isomer), 4.60 (0.81H, dd, $J = 10.4, 12.0$ Hz, $\text{CH}=\text{COSi}$, *anti* isomer), 4.43-4.36 (1H, m, CHNO_2), 2.53-2.45 (0.81H, m, $\text{CHC}=\text{COSi}$, *anti* isomer), 2.35-2.27 (0.19H, m, $\text{CHC}=\text{COSi}$, *syn* isomer), 1.48 (0.57H, d, $J = 6.4$ Hz, CH_3CNO_2 , *syn* isomer), 1.42 (2.43H, d, $J = 6.4$ Hz, CH_3CNO_2 , *anti* isomer), 1.39-1.09 (4H, m, 2CH_2), 0.87 (2.43H, t, $J = 7.2$ Hz, CH_3 , *anti* isomer), 0.85 (0.57H, t, $J = 6.8$ Hz, CH_3 , *syn* isomer), 0.17 (7.29H, s, SiCH_3 , *anti* isomer), 0.16 (1.71H, s, SiCH_3 , *syn* isomer); ^{13}C NMR (100 MHz, CDCl_3) δ 143.18, 142.94, 110.09, 109.15, 88.21, 87.54, 43.68, 43.64, 34.70, 33.30, 30.21, 20.64, 17.21, 16.47, 14.27, 14.21, 0.00, 0.00; IR (liquid film) 2961, 2876, 1663, 1549, 1454, 1389, 1360, 1256, 1175, 1132, 912, 847, 733 cm^{-1} ; HRMS (ESI-TOF) calcd for $\text{C}_{11}\text{H}_{23}\text{NNaO}_3\text{Si}$: 268.1339 ($[\text{M}+\text{Na}]^+$). Found: 268.1352 ($[\text{M}+\text{Na}]^+$).

(3*S*,4*S*)-2-Methyl-4-nitro-3-phenyl-1-trimethylsiloxy-1-pentene

(3*c*; Table 2, entry 3). ¹H NMR (400 MHz, CDCl₃) δ 7.34-7.15 (5H, m, Ph), 6.30 (1H, s, C=CHOSi), 5.18 (1H, dq, *J* = 6.4, 11.6 Hz, CHNO₂), 3.60 (1H, d, *J* = 11.6 Hz, CHPh), 1.50 (3H, s, CH₃C=CO₂Si), 1.39 (3H, d, *J* = 6.4 Hz, CH₃CNO₂), 0.15 (9H, s, SiCH₃); ¹³C NMR (100 MHz, CDCl₃) δ 138.38, 136.46, 129.11, 128.64, 127.64, 117.29, 85.40, 55.57, 19.12, 10.55, 0.00; IR (liquid film) 3030, 2961, 1665, 1553, 1495, 1452, 1389, 1360, 1302, 1254, 1171, 886, 849, 754, 702 cm⁻¹; HRMS (ESI-TOF) calcd for C₁₅H₂₃NNaO₃Si: 316.1339 ([M+Na]⁺). Found: 316.1339 ([M+Na]⁺). Olefin geometry of **3c** was confirmed by a NOE experiment (See the Table in page S5).

***anti*-1-(Trimethylsiloxyethylidene)-2-(1'-nitroethyl)cyclohexane**

(*anti*-3*d*; Table 2, entry 4). ¹H NMR (400 MHz, CDCl₃) δ 5.95 (1H, s, CHOSi), 4.90 (1H, dq, *J* = 6.4, 11.0 Hz, CHNO₂), 2.68-2.64 (1H, m, NO₂CCHC=C), 2.45-2.41 (1H, m, CH₂), 1.87-1.73 (3H, m, CH₂), 1.63-1.55 (2H, m, CH₂), 1.52 (3H, d, *J* = 6.4 Hz, CH₃), 1.40-1.20 (2H, m, CH₂), 0.12 (9H, s, SiCH₃); ¹³C NMR (100 MHz, CDCl₃) δ 134.58, 119.72, 85.27, 44.69, 28.84, 27.05, 22.48, 21.83, 18.14, 0.00; IR (liquid film) 2934, 2860, 1668, 1553, 1448, 1389, 1364, 1306, 1254, 1217, 1171, 1150, 1109, 1072, 924, 847, 754, 694 cm⁻¹; HRMS (ESI-TOF) calcd for C₁₂H₂₃NNaO₃Si: 280.1339 ([M+Na]⁺). Found: 280.1330 ([M+Na]⁺). GLC condition: Astec Chiradex Γ-TA (30 m x 0.25 mm) column (130 °C isotherm), retention time; 16.6 min (minor) and 17.1 min (major).

4-Nitro-3-phenyl-1-trimethylsiloxy-1-hexene (3*e*; Table 2, entry 5).

¹H NMR (400 MHz, CDCl₃) δ 7.37-7.15 (5H, m, Ph), 6.36 (0.90H, d, *J* = 11.6 Hz, C=CHOSi, *anti* isomer), 6.27 (0.10H, d, *J* = 12.0 Hz, C=CHOSi, *syn* isomer), 5.20 (0.10H, dd, *J* = 10.0, 12.0 Hz, CH=CO₂Si, *syn* isomer), 5.11 (0.90H, dd, *J* = 10.4, 11.6 Hz, CH=CO₂Si, *anti* isomer), 4.64-4.53 (1H, m, CHNO₂), 3.68 (0.90H, dd, *J* = 10.4, 10.4 Hz, CHPh, *anti* isomer), 3.53 (0.10H, dd, *J* = 10.0, 10.0 Hz, CHPh, *syn* isomer), 2.03-1.75 (2H, m, CH₂), 0.95 (2.70H, t, *J* = 7.4 Hz, CH₃, *anti* isomer), 0.84 (0.30H, t, *J* = 7.4 Hz, CH₃, *syn* isomer), 0.17 (8.10H, s, SiCH₃, *anti* isomer), 0.15 (0.90H, s, SiCH₃, *syn* isomer); ¹³C NMR (100 MHz, CDCl₃) δ 143.00, 142.74, 140.39, 139.90, 129.34, 129.06, 127.93, 127.64, 127.58, 127.53, 110.13, 109.40, 95.89, 94.96, 49.65, 49.31, 25.86, 25.65, 10.95, 10.85, 0.00, -0.07; IR (liquid film) 3032, 2963, 1661, 1551, 1497, 1456, 1373, 1286, 1256, 1217, 1171, 930, 874, 849, 808, 758, 700 cm⁻¹; HRMS (ESI-TOF) calcd for C₁₇H₂₂NNaO₃Si: 316.1364 ([M+Na]⁺). Found: 316.1339 ([M+Na]⁺). Olefin geometry of **3e** was confirmed by a NOE experiment (See the Table in page S5).

4-Nitro-3-propyl-1-trimethylsiloxy-1-hexene (3f; Table 2, entry 6). ^1H NMR (400 MHz, CDCl_3) δ 6.22 (0.74H, d, $J = 12.0$ Hz, $\text{C}=\text{CHOSi}$, *anti* isomer), 6.15 (0.24H, d, $J = 12.4$ Hz, $\text{C}=\text{CHOSi}$, *syn* isomer), 4.73 (0.24H, dd, $J = 10.6, 12.4$ Hz, $\text{CH}=\text{COSi}$, *syn* isomer), 4.57 (0.76H, dd, $J = 10.8, 12.0$ Hz, $\text{CH}=\text{COSi}$, *anti* isomer), 4.25 (0.24H, m, CHNO_2 , *syn* isomer), 4.18 (0.76H, dt, $J = 6.0, 8.4$ Hz, CHNO_2 , *anti* isomer), 2.43-2.35 (0.76H, m, $\text{CHC}=\text{COSi}$, *anti* isomer), 2.32-2.23 (0.24H, m, $\text{CHC}=\text{COSi}$, *syn* isomer), 2.01-1.73 (2H, m, CH_2), 1.47-1.12 (4H, m, 2CH_2), 0.95-0.83 (6H, m, 2CH_3), 0.19 (6.84H, s, SiCH_3 , *anti* isomer), 0.17 (2.16H, s, SiCH_3 , *syn* isomer); ^{13}C NMR (100 MHz, CDCl_3) δ 142.98, 142.73, 110.09, 109.98, 95.26, 95.02, 43.09, 42.58, 34.62, 33.86, 25.42, 25.16, 20.61, 20.41, 14.26, 14.15, 11.00, 10.95, 0.00, -0.03; IR (liquid film) 2960, 2876, 1663, 1551, 1460, 1375, 1254, 1217, 1175, 931, 874, 849, 808, 758 cm^{-1} ; HRMS (ESI-TOF) calcd for $\text{C}_{12}\text{H}_{25}\text{NNaO}_3\text{Si}$: 282.1496 ($[\text{M}+\text{Na}]^+$). Found: 282.1478 ($[\text{M}+\text{Na}]^+$).

Summary of the NOE Data for Enol Silyl Ether 3

<p>3c</p>				<p>3e</p>			
NOE (saturated/observed, %)				NOE (saturated/observed, %)			
H^a/H^b	H^a/H^c	H^b/H^a	H^c/H^a	H^a/H^b	H^a/H^c	H^b/H^a	H^c/H^a
-2	-16	0.2	-13	1	-9	-2	-13

General Procedure for the Preparation of γ -Nitro Aldehyde 4 from the Corresponding Enol Silyl Ether 3. To a stirred solution of **3** (0.3 mmol) in THF (3 mL) was added 1 N HCl (1 mL) at 0 $^\circ\text{C}$. After vigorous stirring at 0 $^\circ\text{C}$ for 0.5 h, the whole mixture was extracted with ether. The combined organic extracts were washed with brine and dried over Na_2SO_4 . Evaporation of solvents and purification of the residue by column chromatography on silica gel (ether/hexane as eluant) afforded γ -nitro aldehyde **4**. The optical purities of the γ -nitro aldehydes were determined by GLC analysis using an Astec Chiradex Γ -TA (30 m x 0.25 mm) column or a GL Science CP-CHIRASIL-DEX CB (25 m x 0.25 mm) column.

Characterization of γ -Nitro Aldehydes.

4-Nitro-3-propylpentanal (4b, *syn* and *anti* mixture). ^1H NMR (400 MHz, CDCl_3) δ 9.77 (1H, s, CHO), 4.72-4.66 (1H, m, CHNO_2), 2.69-2.45 (3H, m, $\text{CHCH}_2\text{C}=\text{O}$), 1.50 (3H, d, $J = 6.8$ Hz, CH_3CNO_2), 1.43-1.19 (4H, m, 2CH_2), 0.92 (3H, t, $J = 6.8$ Hz, CH_3); ^{13}C NMR (100 MHz, CDCl_3) δ 199.85, 199.69, 84.88, 84.63, 44.14, 44.04, 36.56, 36.39, 32.61, 32.46, 20.13, 19.82, 16.26, 15.22, 14.01, 13.92; IR (liquid film) 2963, 2936, 2876, 2731, 1726, 1549, 1458, 1393, 1362, 1300, 1115, 1099, 1028, 1009, 868, 741, 687 cm^{-1} ; HRMS (ESI-TOF) calcd for $\text{C}_8\text{H}_{15}\text{NNaO}_3$ ($[\text{M}+\text{Na}]^+$):

196.0944. Found: 196.0928 ($[M+Na]^+$). GLC condition: Astec Chiradex Γ -TA (30 m x 0.25 mm) column (140 °C isotherm), retention time; *anti* isomer: 9.9 min (major) and 14.4 min (minor), *syn* isomer: 9.6 min (major) and 12.5 min (minor).

2-Methyl-4-nitro-3-phenylpentanal [4c ; mixture of *rel*-(2*S*,3*S*,4*S*) and *rel*-(2*R*,3*R*,4*S*) in a ratio of 95:5].

1H NMR (400 MHz, $CDCl_3$) δ 9.60 (0.95H, d, J = 1.6 Hz, CHO), 9.59 (0.05H, d, J = 1.6 Hz, CHO), 7.36-7.28 (3H, m, Ph), 7.13-7.11 (2H, m, Ph), 5.32-5.24 (0.95H, m, $CHNO_2$), 5.07-4.99 (0.05H, m, $CHNO_2$), 3.84 (0.05H, dd, J = 6.2, 9.6 Hz, $CHPh$), 3.47 (0.95H, dd, J = 6.6, 9.4 Hz, $CHPh$), 2.76-2.63 (1H, m, $CHC=O$), 1.39 (0.15H, d, J = 6.8 Hz, CH_3), 1.35 (2.85H, d, J = 6.8 Hz, CH_3), 1.14 (2.85H, d, J = 7.2 Hz, CH_3), 1.08 (0.15H, d, J = 7.2 Hz, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 202.31, 201.57, 135.17, 135.16, 129.13, 129.02, 128.93, 128.85, 128.19, 128.07, 84.63, 84.44, 52.30, 49.35, 47.79, 47.31, 17.72, 17.46, 12.92, 12.72; IR (liquid film) 2980, 2829, 2735, 1724, 1556, 1540, 1495, 1454, 1389, 1356, 1298, 1084, 868, 803, 768, 710 cm^{-1} ; HRMS (ESI-TOF) calcd for $C_{12}H_{15}NNaO_3$ ($[M+Na]^+$): 244.0944. Found: 244.0944 ($[M+Na]^+$). GLC condition: GL Science CP-CHIRASIL-DEX CB (25 m x 0.25 mm) column (140 °C isotherm), retention time; 42.6 min (2*S*,3*S*,4*S*), 43.2 min (2*R*,3*R*,4*R*), 44.1 min and 47.1 min.

***anti*-4-Nitro-3-phenylhexanal (*anti*-4e).** $[\alpha]_D^{29} -7.87^\circ$ (c 1.00, $CHCl_3$);

1H NMR (400 MHz, $CDCl_3$) δ 9.63 (1H, s, CHO), 7.32-7.24 (3H, m, Ph), 7.17-7.15 (2H, m, Ph), 4.72-4.66 (1H, m, $CHNO_2$), 3.81-3.76 (1H, m, $CHPh$), 2.99 (1H, dd, J = 5.6, 18.1 Hz, $CH_2C=O$), 2.89 (1H, dd, J = 8.6, 18.1 Hz, $CH_2C=O$), 2.00-1.77 (2H, m, CH_2), 0.96 (3H, t, J = 7.6 Hz, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.88, 137.56, 128.71, 127.90, 127.86, 93.42, 45.31, 42.75, 24.52, 10.44; IR (KBr) 3067, 2972, 2932, 2856, 2745, 1720, 1543, 1495, 1456, 1437, 1414, 1391, 1339, 1317, 1285, 1259, 1088, 810, 770, 702 cm^{-1} ; HRMS (ESI-TOF) calcd for $C_{12}H_{15}NNaO_3$ ($[M+Na]^+$): 244.0944. Found: 244.0935 ($[M+Na]^+$). GLC condition: Astec Chiradex Γ -TA (30 m x 0.25 mm) column (160 °C isotherm), retention time; 17.4 min (major) and 18.3 min (minor).

***anti*-4-Nitro-3-propylhexanal (*anti*-4f).** $[\alpha]_D^{29} -22.16^\circ$ (c 1.00, $CHCl_3$);

1H NMR (400 MHz, $CDCl_3$) δ 9.78 (1H, t, J = 1.2 Hz, CHO), 4.50 (1H, ddd, J = 3.6, 5.2, 10.8 Hz, $CHNO_2$), 2.71-2.65 (1H, m, $CH_2C=O$), 2.57-2.48 (2H, m, $CHCHC=O$), 2.10-1.98 (1H, m, CH_2), 1.78-1.65 (1H, m, CH_2), 1.46-1.32 (2H, m, CH_2), 1.28-1.21 (2H, m, CH_2), 0.97 (3H, t, J = 3.6 Hz, CH_3), 0.91 (3H, t, J = 3.0 Hz, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 199.98, 92.21, 44.37, 35.80, 32.20, 23.56, 20.22, 14.01, 10.79; IR (liquid film) 2963, 2937, 2876, 2729, 1726, 1549, 1464, 1373, 1313, 1263, 1028, 808 cm^{-1} ; HRMS (ESI-TOF) calcd for $C_9H_{17}NNaO_3$ ($[M+Na]^+$): 210.1101. Found: 210.1106 ($[M+Na]^+$). GLC condition: Astec Chiradex Γ -TA (30 m x 0.25 mm) column (160 °C isotherm), retention time; 5.1 min (major) and 5.7 min (minor).

Assignment of the Absolute Configuration of γ -Nitro Aldehyde **4c.** Treatment of **4c** (66 mg, 0.3 mmol) with triethyl orthoformate (55 μ L, 0.33 mmol), (2*R*,4*R*)-pentanediol (35 mg, 0.33 mmol) and a catalytic amount of *p*-TsOH in benzene (3 mL) at room temperature for 12 h gave the corresponding acetal **6** (89 mg, 0.29 mmol, 97% yield). The X-ray crystallographic analysis of **6** confirmed that the absolute configuration of γ -nitro aldehyde **4c** was (2*S*,3*S*,4*S*).

X-ray Structure Determination

Characterization of **6.** $[\alpha]_D^{29} -35.15^\circ$ (*c* 1.00, CHCl₃); ¹H NMR (400 MHz, CDCl₃) δ 7.33-7.25 (3H, m, Ph), 7.13-7.11 (2H, m, Ph), 5.14 (1H, dq, *J* = 6.8, 7.6 Hz, CHNO₂), 4.33 (1H, d, *J* = 4.4 Hz, OCHO), 4.21-4.15 (1H, m, OCHCH₃), 3.81-3.73 (1H, m, OCHCH₃), 3.41 (1H, dd, *J* = 7.6, 7.6 Hz, CHPh), 2.11-2.02 (1H, m, CH₂), 1.80-1.72 (1H, m, CH₂), 1.34 (3H, d, *J* = 6.8 Hz, CH₃), 1.22 (1H, m, CHCH₃), 1.20 (3H, d, *J* = 6.4 Hz, CH₃), 1.05 (3H, d, *J* = 6.8 Hz, CH₃), 0.95 (3H, d, *J* = 7.2 Hz, CH₃); ¹³C NMR (100 MHz, CDCl₃) δ 136.09, 129.38, 128.30, 127.43, 93.81, 85.04, 67.66, 67.31, 52.13, 38.89, 36.73, 21.93, 16.63, 15.74, 12.37; IR (KBr) 2972, 2947, 2918, 1549, 1493, 1452, 1408, 1389, 1371, 1337, 1302, 1236, 1173, 1155, 1134, 1111, 1065, 1020, 993, 953, 905, 768, 733, 708, 687 cm⁻¹; HRMS (ESI-TOF) calcd for C₁₇H₂₅NNaO₄ ([M+Na]⁺): 330.1676. Found: 330.1686 ([M+Na]⁺). The single crystal of **6** (recrystallization from ether/hexane) was mounted on a glass capillary. Data of X-ray diffraction were collected by a Rigaku RAXIS-RAPID Imaging Plate two-dimensional area detector using graphite-monochromated MoK α radiation (λ = 0.71069 Å) to a maximum 2θ value of 55°. All of the crystallographic calculations were performed using teXsan software package of the Molecular Structure Corp. The crystal structure was solved by the direct methods and refined by the full-matrix least squares using SIR-92. All non-hydrogen atoms and hydrogen atoms were refined anisotropically and isotropically, respectively. The crystallographic data were summarized in the following table.

Experimental Details

empirical formula	C ₁₇ H ₂₅ NO ₃
formula weight	307.39
crystal system	orthorhombic
space group	P2 ₁ 2 ₁ 2 ₁ (No. 19)
<i>a</i> , Å	6.004(2)
<i>b</i> , Å	14.986(5)
<i>c</i> , Å	19.108(7)
<i>V</i> , Å ³	1719.3(9)
<i>Z</i>	4
<i>D</i> _{calc} , g/cm ³	1.187
<i>T</i> , °C	23
<i>μ</i> (MoKα), cm ⁻¹	0.84
no. of rflns meased	13884
no. of rflns obsd	2254
no. of variable	200
<i>R</i> <i>I</i>	0.059
<i>R</i> _w	0.138
goodness of fit	1.35
max shift/error in final cycle	0.001

References

- (1) (a) Ando, A.; Miura, T.; Tatematsu, T.; Shioiri, T. *Tetrahedron Lett.* **1993**, *34*, 1507. (b) Shioiri, T.; Bohsako, A.; Ando, A. *Heterocycles* **1996**, *42*, 93. (c) Horikawa, M; Busch-Petersen, J.; Corey, E. J. *Tetrahedron Lett.* **1999**, *40*, 3843.
- (2) Seebach, D.; Beck, A. K.; Mukhopadhyay, T; Thomas, E. *Helv. Chim. Acta.* **1982**, *65*, 1101.

¹H and ¹³C NMRs of New Compounds

3a-1H (CDCl₃,rt)

3a-13C (CDCl₃,rt)

3b-1H (CDCl₃,rt)

3b-13C (CDCl₃,rt)

3c-1H (CDCl₃,rt)

3c-13C (CDCl₃,rt)

3d-1H (CDCl₃,rt)

3d-13C (CDCl₃,rt)

3e-1H (CDCl₃)

3e-13C (CDCl₃)

3f-1H (CDCl₃,rt)

3f-13C (CDCl₃,rt)

4a-1H (CDCl₃,rt)

4a-13C (CDCl₃,rt)

4b-1H (CDCl₃,rt)

4b-13C (CDCl₃,rt)

4c-1H (CDCl₃,rt)

4c-13C (CDCl₃,rt)

4e-1H (CDCl₃,rt)

4e-13C (CDCl₃,rt)

4f-1H (CDCl₃,rt)

4f-13C (CDCl₃,rt)

6-1H (CDCl₃, rt)

6-13C (CDCl₃, rt)