

Catalytic enantioselective construction of quaternary stereocenter by direct vinylogous Michael addition of deconjugated butenolides to nitroolefins

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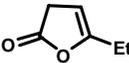
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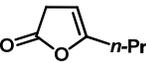
SUPPORTING INFORMATION: PART A

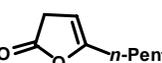
General: Unless stated otherwise, all reactions were carried out with distilled and dried solvents under an atmosphere of nitrogen or argon, oven (120 °C) dried glassware with standard vacuum-line techniques. Organic solvents used for carrying out reactions were dried using standard methods. All work up and purification were carried out with reagent grade solvents in air. Thin-layer chromatography was performed using Merck silica gel 60 F₂₅₄ pre-coated plates (0.25 mm). Column chromatography was performed using silica gel (230-400 or 100-200 mesh). Infrared (FT-IR) spectra were recorded on a Perkin Elmer Spectrum BX spectrophotometer in cm⁻¹ and the bands are characterized as broad (br), strong (s), medium (m), and weak (w). NMR spectra were recorded on Bruker Ultrashield spectrometer at 400 MHz (for ¹H-NMR) and 100 MHz (for ¹³C-NMR). Chemical shifts are reported in ppm from tetramethylsilane with the solvent resonance as internal standard (CDCl₃: δ 7.26, CD₃OD: δ 3.31, DMSO-d₆: δ 2.50 for ¹H-NMR and CDCl₃: δ 77.16, CD₃OD: δ 49.00, DMSO-d₆: δ 39.5 for ¹³C-NMR). For ¹H-NMR, data are reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, dd = double doublet, t = triplet, q = quartet, br = broad, m = multiplet), coupling constants (Hz) and integration. High resolution mass spectrometry was performed on Micromass Q-TOF Micro instrument. Optical rotations were measured on JASCO P-1020 polarimeter. Melting points were measured using ANALAB μ-Thermocal 10 melting point apparatus. All melting points were measured in open glass capillary and values are uncorrected. Enantiomeric ratios were determined by HPLC analysis using chiral columns in comparison with authentic racemic materials.

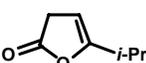
Preparation of β, γ-unsaturated butenolides:

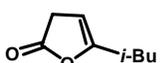
α-Angelica lactone **1a** was obtained from Alfa Aesar and used without any further purification. Other β, γ-unsaturated butenolides **1b-1g** were prepared according to the literature procedure.¹

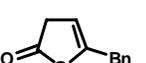

5-Ethylfuran-2(3H)-one (1b): $^1\text{H-NMR}$ (400 MHz, CDCl_3): δ 5.00 (br s, 1H), 3.07 (d, $J = 2.4$ Hz, 2H), 2.24-2.19 (m, 2H), 1.04 (t, $J = 7.4$ Hz, 3H); $^{13}\text{C-NMR}$ (100 MHz, CDCl_3): δ 177.1, 158.6, 97.4, 34.0, 21.6, 10.2; The spectral data is consistent with that reported in the literature.²


5-Propylfuran-2(3H)-one (1c): $^1\text{H-NMR}$ (400 MHz, CDCl_3): δ 5.10 (br s, 1H), 3.17 (d, $J = 2.4$ Hz, 2H), 2.26 (t, $J = 7.4$ Hz, 2H), 1.63-1.53 (m, 2H), 0.95 (t, $J = 7.4$ Hz, 3H); $^{13}\text{C-NMR}$ (100 MHz, CDCl_3): δ 177.2, 157.2, 98.4, 34.1, 30.3, 19.2, 13.6; The spectral data is consistent with that reported in the literature.³


5-Pentylfuran-2(3H)-one (1d): $^1\text{H-NMR}$ (400 MHz, CDCl_3): δ 5.10 (d, $J = 1.2$ Hz, 1H), 3.18-3.16 (m, 2H), 2.30-2.26 (m, 2H), 1.59-1.52 (m, 2H), 1.35-1.30 (m, 4H), 0.89 (t, $J = 6.8$ Hz, 3H); $^{13}\text{C-NMR}$ (100 MHz, CDCl_3): δ 177.2, 157.4, 98.3, 34.0, 31.3, 28.3, 25.5, 22.4, 14.0; The spectral data is consistent with that reported in the literature.¹


5-Isopropylfuran-2(3H)-one (1e): $^1\text{H-NMR}$ (400 MHz, CDCl_3): δ 5.07-5.06 (m, 1H), 3.17 (d, $J = 2.3$ Hz, 2H), 2.59-2.52 (m, 1H), 1.15 (d, $J = 6.8$ Hz, 6H); $^{13}\text{C-NMR}$ (100 MHz, CDCl_3): δ 177.2, 162.5, 96.3, 34.0, 27.9, 19.4; The spectral data is consistent with that reported in the literature.⁴


5-Isobutylfuran-2(3H)-one (1f): $^1\text{H-NMR}$ (400 MHz, CDCl_3): δ 5.12-5.11 (m, 1H), 3.19-3.18 (m, 2H), 2.16 (d, $J = 7.0$ Hz, 2H), 1.99-1.89 (m, 1H), 0.94 (d, $J = 6.7$ Hz, 6H); $^{13}\text{C-NMR}$ (100 MHz, CDCl_3): δ 177.2, 156.5, 99.5, 37.6, 34.1, 25.7, 22.4; The spectral data is consistent with that reported in the literature.⁴


5-Benzylfuran-2(3H)-one (1g): $^1\text{H-NMR}$ (400 MHz, CDCl_3): δ 7.35-7.31 (m, 2H), 7.28-7.25 (m, 3H), 5.06-5.05 (m, 1H), 3.61 (br s, 2H), 3.18-3.17 (m, 2H); $^{13}\text{C-NMR}$ (100 MHz, CDCl_3): δ 176.7, 156.1, 135.3, 129.2, 128.8, 127.2, 99.8, 35.0, 34.2.

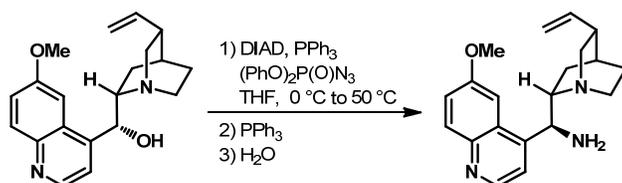
Preparation of nitroolefins:

Nitroolefins are prepared according to the literature procedure.⁵ The spectral data obtained are in accordance with those described in the literature.^{5,6}

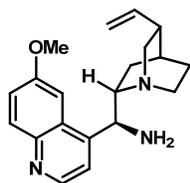
Synthesis of thiourea catalysts (VI-XII):

9-Amino(9-deoxy)epiquinine:

9-Amino(9-deoxy)epiquinine was prepared according to the modified literature procedure.⁷



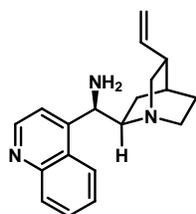
To a 50 mL 2-necked oven and vacuum-dried round-bottom flask, quinine (1.0 g, 3.08 mmol, 1.0 equiv.) and triphenylphosphine (1.05 g, 4.00 mmol, 1.3 equiv.) were taken under argon. To this mixture, was added 15.0 mL of dry THF and the resulting solution was cooled to 0 °C. Diisopropyl azodicarboxylate (DIAD) (0.8 mL, 4.00 mmol, 1.3 equiv.) was added at once and stirred for 15 min at 0 °C. A solution of diphenyl phosphoryl azide (0.86 mL, 4.00 mmol, 1.3 equiv.) in 6.0 mL of dry THF was added dropwise over 30 min at 0 °C. The resulting yellow solution was allowed to warm to r.t. After being stirred for 20 h at r.t., the solution was heated to 50 °C for 4 h. Another portion of triphenylphosphine (1.13 g, 4.31 mmol, 1.4 equiv.) was then added and heating was continued until the gas evolution has ceased (4 h). The reaction mixture was cooled to r.t. and 1.0 mL of distilled water was added and the resulting solution was stirred overnight at r.t. Solvents were removed under reduced pressure. The residue was dissolved in CH₂Cl₂ and 10% hydrochloric acid (1:1, 25 mL). The aqueous phase was washed with CH₂Cl₂ (3 × 10 mL). The organic extracts were discarded and the aqueous layer was made alkaline with excess aqueous ammonia (to pH ~9) and was extracted with CH₂Cl₂ (4 × 25 mL). The combined organic phase was washed with brine (2 × 25 mL), dried over anhydrous Na₂SO₄ and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel (100-200 mesh) with EtOAc/MeOH/aq. NH₄OH = 50/50/1 as eluent to afford the title compound as a yellowish viscous oil (767 mg, 2.37 mmol, 77%).



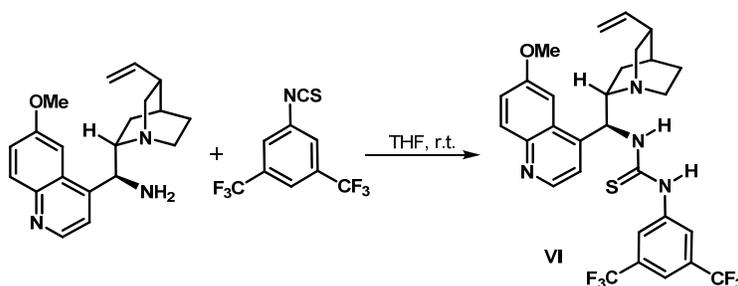
FT-IR (KBr): 2939 (s), 2864 (m), 1621 (s), 1589 (m), 1509 (m), 1475 (m), 1432 (m), 1261 (m), 1232 (s); **¹H-NMR (400 MHz, CD₃OD):** δ 8.61 (d, *J* = 4.7 Hz, 1H), 7.88 (d, *J* = 9.2 Hz, 1H), 7.59 (s, 1H), 7.53 (d, *J* = 4.7 Hz, 1H), 7.35 (dd, *J* = 9.2 Hz, 2.3 Hz, 1H), 5.83-5.74 (m, 1H), 5.00-4.91 (m, 2H), 4.71 (d, *J* = 9.8 Hz, 1H), 3.92 (s, 3H), 3.42-3.35 (m, 1H), 3.28-3.24 (m, 2H), 2.86-2.79 (m, 2H), 2.33 (br s, 1H), 1.61-1.54 (m, 3H), 1.46-1.40 (m, 1H), 0.71 (dd, *J* = 13.4 Hz, 7.2 Hz, 1H); **¹³C-NMR (100 MHz, CD₃OD):** δ 159.8, 148.5, 148.4, 145.1, 142.1, 131.5, 130.1, 123.4, 115.4, 102.8, 63.0, 56.5, 56.3, 41.7, 40.4, 28.7, 28.1, 26.6, 24.3; **HRMS (ESI+):** Calcd for C₂₀H₂₆N₃O ([M+H]⁺): 324.2076, Found: 324.2077.

9-Amino(9-deoxy)epicinchonine:

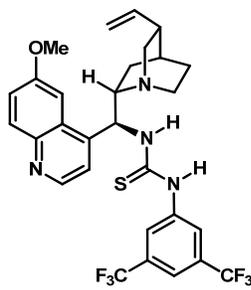
Same procedure as adopted for 9-amino(9-deoxy)epiquinine was followed to obtain 9-amino(9-deoxy)epicinchonine from cinchonine as a yellowish viscous oil (81%).



FT-IR (KBr): 2952 (s), 2867 (m), 1663 (m), 1635 (s), 1582 (m), 1574 (m), 1508 (m), 1465 (m), 1261 (m), 1232 (s); **¹H-NMR (400 MHz, CDCl₃):** δ 8.85 (d, *J* = 4.4 Hz, 1H), 8.29 (d, *J* = 5.8 Hz, 1H), 8.09 (d, *J* = 8.4 Hz, 1H), 7.67 (t, *J* = 7.6 Hz, 1H), 7.54 (t, *J* = 7.6 Hz, 2H), 5.84-5.76 (m, 1H), 5.06-5.01 (m, 2H), 4.74 (d, *J* = 7.4 Hz, 1H), 3.86 (br s, 2H), 3.05-2.90 (m, 5H), 2.25 (dd, *J* = 16 Hz, 7.9 Hz, 1H), 1.56-1.49 (m, 3H), 1.10-1.05 (m, 1H), 0.94-0.89 (m, 1H); **¹³C-NMR (100 MHz, CDCl₃):** δ 150.3, 148.8, 148.5, 140.3, 130.4, 129.1, 127.7, 126.5, 123.3, 119.7, 114.8, 62.3, 49.3, 47.1, 39.4, 27.6, 26.4, 24.9, 22.6. The spectral data is consistent with that reported in the literature.⁸

Synthesis of quinine derived thiourea alkaloid (VI):

To a solution of 9-amino(9-deoxy)epiquinine (457 mg, 1.41 mmol, 1.0 equiv.) in 4.0 mL of dry THF in a 25 mL round-bottom flask was slowly added a solution of 3,5-bis(trifluoromethyl)phenyl isothiocyanate (0.3 mL, 1.55 mmol, 1.1 equiv.) in 2.0 mL of dry THF at ambient temperature. The mixture was stirred for 14 h and the solvent was removed in *vacuo*. The residue was purified by column chromatography on silica gel (100-200 mesh) using CH₂Cl₂/MeOH/Et₃N 100/2/1 as eluent to afford thiourea VI (638 mg, 1.07 mmol, 76%) as a white amorphous solid (76%).

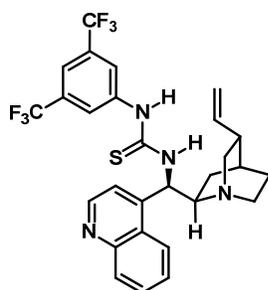


m.p. 109-110 °C; **FT-IR (KBr):** 2932 (m), 2865 (m), 1639 (m), 1623 (m), 1592 (m), 1474 (m), 1385 (s), 1278 (s), 1178 (m), 1134 (s); **¹H-NMR (400 MHz, CD₃OD):** δ 8.70 (d, *J* = 4.7 Hz, 1H), 8.12 (s, 2H), 8.10 (s, 1H), 7.95 (d, *J* = 9.2 Hz, 1H), 7.61 (s, 1H), 7.59 (d, *J* = 4.8 Hz, 1H), 7.44 (dd, *J* = 9.2 Hz, 2.5 Hz, 1H), 6.48 (d, *J* = 10.9 Hz, 1H), 5.93-5.84 (m, 1H), 5.11-5.02 (m, 2H), 4.02 (s, 3H), 3.68-3.61 (m, 1H), 3.42-3.36 (m, 1H), 3.30 (br s, 1H), 2.99-2.92 (m, 2H), 2.47 (br s, 1H), 1.77-1.75 (m, 2H), 1.71 (m,

1H), 1.60-1.54 (m, 1H), 0.94 (dd, $J = 13.4$ Hz, 6.7 Hz, 1H); $^{13}\text{C-NMR}$ (100 MHz, CD_3OD): δ 182.6, 159.7, 148.3, 146.7, 145.2, 143.0, 141.6, 132.6 (q, $J = 33$ Hz), 131.3, 130.0, 124.6 (q, $J = 271$ Hz), 123.9, 123.7, 121.3, 117.9 (q, $J = 3.4$ Hz), 115.6, 104.1, 61.4, 56.6, 56.2, 55.6, 43.2, 40.0, 28.5, 27.7, 26.5; **HRMS (ESI+)**: Calcd for $\text{C}_{29}\text{H}_{29}\text{F}_6\text{N}_4\text{OS}$ ($[\text{M}+\text{H}]^+$): 595.1966, Found: 595.1962; **Optical rotation**: $[\alpha]_{\text{D}}^{24} -134.4$ (c 0.8, CHCl_3) [lit⁷ -135.0]. The spectral data is consistent with that reported in the literature.⁹

Synthesis of cinchonine derived thiourea alkaloid (VII):

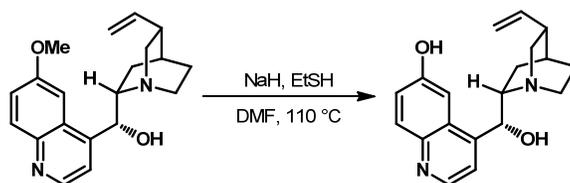
Same procedure as adopted for thiourea VI was followed to obtain thiourea VII from 9-amino(9-deoxy)epicinchonine as a white amorphous solid (78%).



m.p. 172-173 °C; **FT-IR (KBr)**: 2933 (m), 2870 (m), 1645 (m), 1602 (m), 1385 (s), 1278 (s), 1178 (m), 1135 (m); $^1\text{H-NMR}$ (400 MHz, CD_3OD): δ 8.84 (d, $J = 4.7$ Hz, 1H), 8.65 (d, $J = 8.4$ Hz, 1H), 8.13 (s, 2H), 8.06 (d, $J = 8.4$ Hz, 1H), 7.82-7.78 (m, 1H), 7.72-7.68 (m, 1H), 7.63 (d, $J = 4.7$ Hz, 1H), 7.60 (s, 1H), 6.37 (d, $J = 10.2$ Hz, 1H), 6.00-5.91 (m, 1H), 5.25-5.19 (m, 2H), 3.40-3.35 (m, 1H), 3.11-3.02 (m, 3H), 2.43-2.39 (m, 1H), 1.64-1.63 (m, 3H), 1.29-1.25 (m, 3H), 0.97-0.87 (m, 2H); $^{13}\text{C-NMR}$ (100 MHz, CD_3OD): δ 182.6, 150.9, 148.9, 143.0, 141.2, 132.6 (q, $J = 33$ Hz), 131.0, 130.0, 129.9, 128.9, 128.0, 125.9, 124.6 (q, $J = 271$ Hz), 123.4, 120.9, 117.7 (q, $J = 3.4$ Hz), 115.5, 61.8, 50.1, 48.4, 40.1, 30.7, 28.7, 27.0, 26.0; **HRMS (ESI+)**: Calcd for $\text{C}_{28}\text{H}_{27}\text{F}_6\text{N}_4\text{S}$ ($[\text{M}+\text{H}]^+$): 565.1861, Found: 565.1858; **Optical rotation**: $[\alpha]_{\text{D}}^{24} +161.9$ (c 0.8, CHCl_3) (lit⁸ +168.2). The spectral data is consistent with that reported in the literature.¹⁰

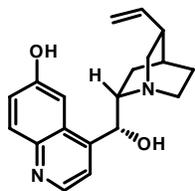
Procedure for the preparation of cupreine:

Cupreine was prepared according to the modified literature procedure.¹¹



To a 50 mL 2-necked round-bottom flask, equipped with reflux condenser, quinine (500 mg, 1.54 mmol, 1.0 equiv.) and NaH (60% suspension in oil, 246.5 mg, 6.16 mmol, 4.0 equiv.) were taken under argon. Freshly distilled DMF (10.0 mL) was added to it followed by EtSH (0.44 mL, 6.06 mmol, 4.0 equiv.). The resulting solution was then stirred at 110 °C under argon

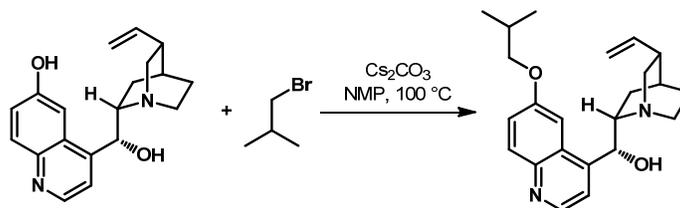
until a TLC analysis (100:5:1 CH₂Cl₂, MeOH, Et₃N) showed complete consumption of starting material (20-24 h). The reaction mixture was cooled to r.t. and carefully quenched with sat. aqueous NH₄Cl solution (10 mL). To this solution, EtOAc (20 mL) was added and organic phase was separated. Aqueous phase was extracted with 10 ml of EtOAc. Combine organic layers were washed with brine (2 × 20 mL), dried over anh. Na₂SO₄ and concentrated to obtain a yellowish solid. It was further dried by keeping in oil bath at 60 °C under high-vac for 6 h and the crude was found to be pure enough for further application (475 mg, 1.53 mmol, 99%).



FT-IR (KBr): 3403 (m), 3197 (m), 2926 (s), 2855 (m), 1616 (m), 1596 (m), 1468 (m), 1240 (m), 1227 (m), 1094 (w); **¹H-NMR (400 MHz, CD₃OD):** δ 8.58 (d, *J* = 4.6 Hz, 1H), 7.88 (d, *J* = 8.9 Hz, 1H), 7.62 (d, *J* = 4.6 Hz, 1H), 7.33-7.29 (m, 2H), 5.77-5.67 (m, 1H), 5.62 (br d, *J* = 2.1 Hz, 1H), 4.99 (d, *J* = 17.1 Hz, 1H), 4.92 (d, *J* = 10.4 Hz, 1H), 3.89-3.84 (m, 1H), 2.92-2.82 (m, 2H), 2.48 (br s, 1H), 1.98-1.90 (m, 3H), 1.87-1.86 (m, 1H), 1.70-1.66 (m, 1H), 1.47-1.41 (m, 1H); **¹³C-NMR (100 MHz, CD₃OD):** δ 157.9, 148.6, 147.5, 143.9, 141.4, 131.5, 128.1, 123.3, 119.9, 115.8, 105.1, 70.7, 61.0, 56.7, 44.6, 39.9, 28.8, 27.0, 20.8; **HRMS (ESI+):** Calcd for C₁₉H₂₃N₂O₂ ([M+H]⁺): 311.1760, Found: 311.1756. The spectral data is consistent with that reported in the literature.¹²

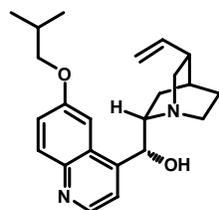
Preparation of 6'-isobutoxy-cinchonidine:

6'-Isobutoxy-cinchonidine was prepared according to a modified literature procedure.¹³



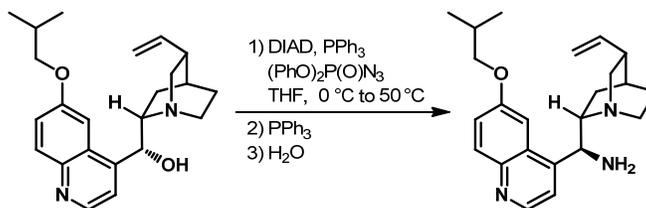
In an oven-dried 50 mL 2-necked round-bottom flask, Cs₂CO₃ (1.51g, 4.62 mmol, 1.5 equiv.) was taken and heated at 150 °C under high vacuum for 6 h. It was cooled to r.t. under high vacuum, purged with argon and cupreine (953 mg, 3.08 mmol, 1.0 equiv.) was added. Freshly distilled *N*-methylpyrrolidone (10.0 ml) was added and stirred for 10 min at r.t. Isobutyl bromide (0.4 ml, 3.69 mmol, 1.2 equiv.) was then added and the resulting solution was stirred at 100 °C under argon for 36 h. Solvent was removed by high vacuum distillation at 100 °C. The residue was dissolved in EtOAc (20 ml), filtered through a Buchner funnel, washed with EtOAc. The filtrate was concentrated to obtain a deep brown gel. Purification by silica-gel (230-400

mesh) column chromatography (2-5% MeOH in CH₂Cl₂) afforded an off-white solid (495 mg, 1.35 mmol, 44%).



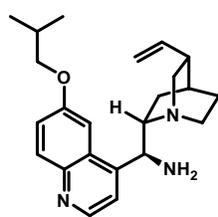
FT-IR (KBr): 3182 (w), 2932 (s), 2872 (m), 1620 (m), 1591 (m), 1509 (m), 1460 (m), 1240 (s), 1227 (s), 1027 (m); **¹H-NMR (400 MHz, CDCl₃):** δ 8.64 (d, *J* = 4.5 Hz, 1H), 7.96 (d, *J* = 9.2 Hz, 1H), 7.48 (d, *J* = 4.5 Hz, 1H), 7.33 (dd, *J* = 9.2, 2.7 Hz, 1H), 7.21 (d, *J* = 2.6 Hz, 1H), 5.79-5.71 (m, 1H), 5.53 (d, *J* = 4.2 Hz, 1H), 4.99-4.90 (m, 2H), 3.79 (d, *J* = 6.5 Hz, 2H), 3.45-3.41 (m, 1H), 3.18-3.07 (m, 2H), 2.70-2.64 (m, 2H), 2.28 (br s, 1H), 2.17-2.07 (m, 1H), 1.82 (br s, 1H), 1.76-1.68 (m, 2H), 1.60-1.47 (m, 2H), 1.05 (d, *J* = 6.7 Hz, 6H); **¹³C-NMR (100 MHz, CDCl₃):** δ 157.6, 147.6, 147.3, 144.4, 142.0, 131.7, 126.8, 122.0, 118.5, 114.5, 102.2, 74.9, 72.3, 60.0, 57.1, 43.4, 40.1, 28.4, 28.0, 27.8, 22.2, 19.4; **HRMS (ESI+):** Calcd for C₂₃H₃₁N₂O₂ ([M+H]⁺): 367.2386, Found: 367.2386.

Preparation of 6'-isobutoxy-9-amino(9-deoxy)epicinchonidine:



To a 25 mL 2-necked round-bottom flask, 6'-isobutoxy-cinchonidine (450 mg, 1.23 mmol, 1.0 equiv.) and triphenylphosphine (483 mg, 1.84 mmol, 1.5 equiv.) were taken under argon. Dry THF (6.5 mL) was added and the resulting solution was cooled to 0 °C. Diisopropyl azodicarboxylate (0.36 mL, 1.84 mmol, 1.5 equiv.) was added at once and stirred for 15 min at 0 °C. A solution of diphenyl phosphoryl azide (0.40 mL, 1.84 mmol, 1.5 equiv.) in 2.5 mL of dry THF was added dropwise over 20 min at 0 °C. The resulting yellow mixture was allowed to warm to r.t. After being stirred for 20 h, the solution was heated to 50 °C for 4 h. Triphenylphosphine (805 mg, 3.07 mmol, 2.5 equiv.) was then added and heating was continued until the gas evolution ceased (4 h). The solution was cooled to r.t., and 1.0 mL of distilled water was added and the solution was stirred overnight. Solvents were removed *in vacuo* and the residue was dissolved in CH₂Cl₂ and 10% hydrochloric acid (1:1, 15 mL). The aqueous phase was washed with CH₂Cl₂ (3 × 5 mL). The organic layer was discarded and the aqueous layer was made alkaline with excess aqueous ammonia and was extracted with CH₂Cl₂ (3 × 15 mL). The combined organic layers were dried over anh. Na₂SO₄ and concentrated under reduce pressure to a residue. Purification by column chromatography on silica gel (100-200 mesh) with 40-60%

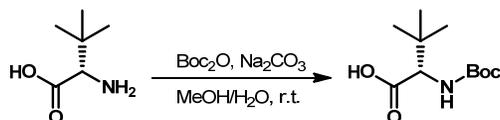
MeOH in EtOAc as eluent afforded the title compound as yellowish viscous oil (245 mg, 0.67 mmol, 54%).



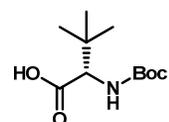
FT-IR (thin film): 3373 (m), 2953 (m), 2928 (m), 1636 (m), 1619 (m), 1591 (m), 1508 (w), 1458 (w), 1229 (s), 1019 (s); **¹H-NMR (400 MHz, CDCl₃):** δ 8.73 (d, *J* = 4.4 Hz, 1H), 8.02 (d, *J* = 9.2 Hz, 1H), 7.58 (br s, 1H), 7.44 (br s, 1H), 7.39 (dd, *J* = 9.2, 2.4 Hz, 1H), 5.84-5.75 (m, 1H), 5.03-4.97 (m, 2H), 4.59 (d, *J* = 8.5 Hz, 1H), 3.91-3.84 (m, 2H), 3.37-3.22 (m, 2H), 3.15-3.13 (m, 1H), 2.88-2.81 (m, 4H), 2.31 (br s, 1H), 2.21-2.14 (m, 1H), 1.65-1.57 (m, 3H), 1.48-1.42 (m, 1H), 1.09 (d, *J* = 6.7 Hz, 6H), 0.77 (dd, *J* = 13.5, 7.1 Hz, 1H); **¹³C-NMR (100 MHz, CDCl₃):** δ 157.5, 147.8, 146.9, 144.8, 141.6, 131.8, 128.9, 121.8, 119.9, 114.6, 102.8, 74.9, 61.9, 56.2, 41.0, 39.8, 28.4, 28.1, 27.7, 26.1, 22.6, 19.5; **HRMS (ESI⁺):** Calcd for C₂₃H₃₂N₃O ([M+H]⁺): 366.2545, Found: 366.2549.

Preparation of *N*-Boc-(*S*)-*tert*-leucine:

N-Boc-(*S*)-*tert*-leucine was prepared according to the modified literature procedure.¹⁴



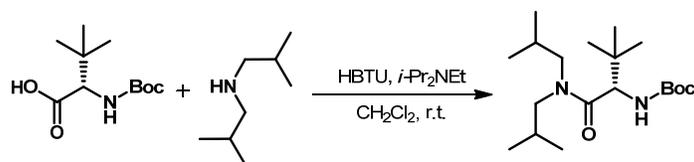
To a solution of (*S*)-*tert*-leucine (1.50 g, 11.43 mmol, 1.0 equiv) and Na₂CO₃ (1.33 g, 12.57 mmol, 1.1 equiv.) in 45 mL MeOH/H₂O (1:1), was added di-*tert*-butyl dicarbonate (2.70 g, 12.57 mmol, 1.1 equiv.) and the resulting mixture was stirred at r.t. for 20 h. Methanol was removed *in vacuo*. The aqueous solution was acidified with sat. citric acid solution (pH~4) and extracted with CH₂Cl₂ (4 × 30 mL) and Et₂O (2 × 20 mL). The combined layer was washed with brine (2 × 25 mL), dried over anh. Na₂SO₄ and concentrated to obtain a colorless amorphous solid (2.6 g, 11.24 mmol, 98%). This was used in the next step without any further purification.



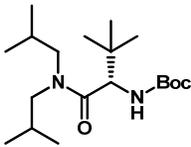
¹H-NMR (400 MHz, CD₃OD): δ 3.95 (s, 1H), 1.45 (s, 9H), 1.00 (s, 9H); **¹³C-NMR (100 MHz, CD₃OD):** δ 174.9, 158.0, 80.5, 63.4, 34.9, 28.7, 27.1.

Synthesis of (*S*)-*tert*-butyl (1-(diisobutylamino)-3,3-dimethyl-1-oxobutan-2-yl)carbamate:

(*S*)-*tert*-Butyl (1-(diisobutylamino)-3,3-dimethyl-1-oxobutan-2-yl)carbamate was prepared according to the modified literature procedure.¹⁵

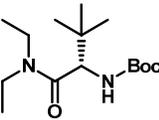


In an oven-dried 25 mL 2-necked round-bottom flask, *N*-Boc-(*S*)-*tert*-leucine (200 mg, 0.865 mmol, 1.0 equiv.) and HBTU (361 mg, 0.951 mmol, 1.1 equiv.) were taken with 10.0 ml of dry CH₂Cl₂ under argon. Diisopropylethylamine (0.2 mL, 1.038 mmol, 1.2 equiv.), followed by diisobutylamine (0.17 mL, 0.951 mmol, 1.1 equiv.) were added and the mixture was stirred at r.t. for 18 h. The reaction mixture was diluted with Et₂O (15 ml), washed with 1 M aqueous HCl (2 × 25 mL), sat. NaHCO₃ (2 × 20 mL) and brine (2 × 20 mL). The organic phase was dried over anh. Na₂SO₄ and concentrated to get a pale yellow gel (295 mg, 0.861 mmol, >99%). This was used in the next step without any further purification.

 **¹H-NMR (400 MHz, CDCl₃):** δ 5.36 (d, *J* = 9.5 Hz, 1H), 4.52 (d, *J* = 9.5 Hz, 1H), 3.77 (dd, *J* = 13.3, 6.6 Hz, 1H), 3.42 (dd, *J* = 14.6, 9.4 Hz, 1H), 3.01 (dd, *J* = 14.6, 6.0 Hz, 1H), 2.54 (dd, *J* = 13.2, 7.9 Hz, 1H), 2.04-1.89 (m, 2H), 1.39 (s, 9H), 0.97 (s, 9H), 0.92-0.90 (m, 6H), 0.87-0.83 (m, 6H). **¹³C-NMR (100 MHz, CDCl₃):** δ 172.3, 155.5, 79.3, 56.6, 56.3, 53.7, 36.3, 28.4, 27.7, 26.8, 26.7, 20.8, 20.6, 20.3, 19.1.

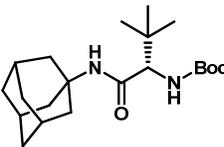
Synthesis of (*S*)-*tert*-butyl (1-(diethylamino)-3,3-dimethyl-1-oxobutan-2-yl)carbamate:

Same procedure as adopted above was followed to obtain (*S*)-*tert*-butyl (1-(diethylamino)-3,3-dimethyl-1-oxobutan-2-yl)carbamate as a yellow oil (>99%):

 **¹H-NMR (400 MHz, CDCl₃):** δ 5.26 (d, *J* = 9.9 Hz, 1H), 4.41 (d, *J* = 9.9 Hz, 1H), 3.75-3.66 (m, 1H), 3.65-3.55 (m, 1H), 3.24-3.15 (m, 1H), 3.01-2.93 (m, 1H), 1.37 (s, 9H), 1.16 (t, *J* = 7.1 Hz, 3H), 1.07 (t, *J* = 7.1 Hz, 3H), 0.93 (s, 9H), **¹³C-NMR (100 MHz, CDCl₃):** δ 171.0, 155.7, 79.4, 55.8, 42.8, 40.3, 35.8, 28.4, 26.5, 14.5, 13.0.

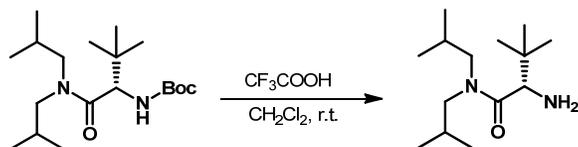
Synthesis of (*S*)-*tert*-butyl-(1-adamantanylamino)-3,3-dimethyl-1-oxobutan-2-yl)carbamate:

Same procedure as adopted above was followed to obtain *tert*-butyl ((*2S*)-1-((*1S,3R*)-adamantan-1-ylamino)-3,3-dimethyl-1-oxobutan-2-yl)carbamate as a white crystalline solid (>99%):

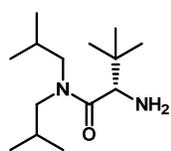
 **¹H-NMR (400 MHz, CDCl₃):** δ 5.27 (br s, 2H), 3.63 (d, *J* = 9.2 Hz, 1H), 2.05 (br s, 3H), 1.98 (s, 6H), 1.65 (s, 6H), 1.42 (s, 9H), 0.96 (s, 9H); **¹³C-NMR (100 MHz, CDCl₃):** δ 169.8, 156.0, 79.6, 62.7, 52.4, 41.7, 36.4, 34.8, 29.5, 28.5, 26.8.

Preparation of (S)-2-amino-N,N-diisobutyl-3,3-dimethylbutanamide:

(S)-2-Amino-N,N-diisobutyl-3,3-dimethylbutanamide was prepared according to the modified literature procedure.¹⁵



In an oven-dried 25 mL round-bottom flask, (*S*)-*tert*-butyl (1-(diisobutylamino)-3,3-dimethyl-1-oxobutan-2-yl)carbamate (740 mg, 2.16 mmol, 1.0 equiv.) was taken with 9.0 mL of dry CH₂Cl₂ under argon. Trifluoroacetic acid (1.7 mL, 21.62 mmol, 10.0 equiv.) was added to it and the resulting solution was stirred at r.t. for 1h. The reaction was cooled to 0 °C and carefully quenched with 20% aqueous Na₂CO₃ solution (10 mL). Chloroform (20.0 mL) was added to it and the organic phase was separated from aqueous phase. Organic phase was washed with 20% aqueous Na₂CO₃ solution (2 × 15 mL), brine (2 × 15 mL), dried over anh. Na₂SO₄ and concentrated to get a brown oil (497 mg, 2.05 mmol, 95%). This was used in the next step without any further purification.

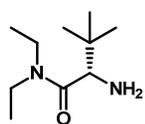


¹H-NMR (400 MHz, CDCl₃): δ 3.79 (dd, *J* = 13.2, 6.3 Hz, 1H), 3.43-3.37 (m, 2H), 2.89 (dd, *J* = 14.8, 6.8 Hz, 1H), 2.50 (dd, *J* = 13.2, 8.1 Hz, 1H), 2.03-1.96 (m, 1H), 1.92-1.85 (m, 1H), 1.66 (br s, 2H), 0.96 (s, 9H), 0.92-0.84 (m, 12H).

¹³C-NMR (100 MHz, CDCl₃): δ 175.3, 58.1, 56.7, 54.7, 35.4, 28.4, 27.0, 26.7, 20.8, 20.6, 20.4, 19.9.

Synthesis of (S)-2-amino-N,N-diethyl-3,3-dimethylbutanamide:

Same procedure as adopted above was followed to obtain (*S*)-2-amino-N,N-diethyl-3,3-dimethylbutanamide as a yellow oil (96%):

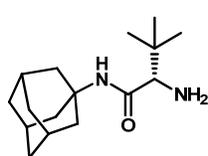


¹H-NMR (400 MHz, CDCl₃): δ 3.71-3.62 (m, 1H), 3.60-3.51 (m, 1H), 3.35 (s, 1H), 3.20-3.11 (m, 1H), 3.07-2.99 (m, 1H), 1.67 (br s, 2H), 1.15 (t, *J* = 7.1 Hz, 3H), 1.08 (t, *J* = 7.1 Hz, 3H), 0.94 (s, 9H); **¹³C-NMR (100 MHz, CDCl₃):** δ 173.9, 57.8,

42.5, 40.4, 35.2, 26.5, 14.8, 13.1.

Synthesis of (S)-2-amino-(1-adamantanyl)-3,3-dimethylbutanamide:

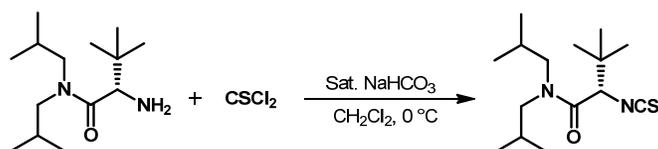
Same procedure as adopted above was followed to obtain (*S*)-*N*-((1*S*,3*R*)-adamantan-1-yl)-2-amino-3,3-dimethylbutanamide as an off-white solid (>99%):



$^1\text{H-NMR}$ (400 MHz, CDCl_3): δ 6.27 (s, 1H), 2.92 (s, 1H), 2.06 (br s, 3H), 2.00 (s, 6H), 1.67 (s, 6H), 1.51 (br s, 2H), 0.97 (s, 9H). **$^{13}\text{C-NMR}$ (100 MHz, CDCl_3):** δ 172.7, 65.1, 51.5, 41.8, 36.5, 34.1, 29.6, 26.9.

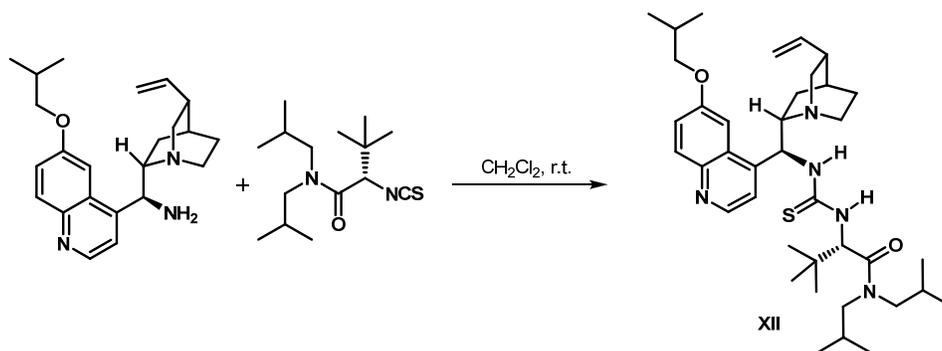
Preparation of (*S*)-*N,N*-diisobutyl-2-isothiocyanato-3,3-dimethylbutanamide:

(*S*)-*N,N*-Diisobutyl-2-isothiocyanato-3,3-dimethylbutanamide was prepared according to the modified literature procedure.¹⁵



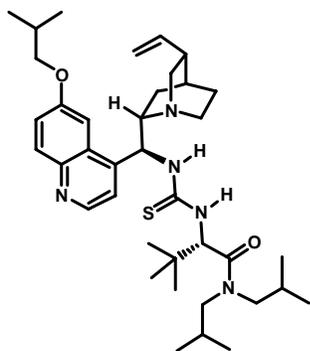
In a 50 mL round bottom-flask (*S*)-2-amino-*N,N*-diisobutyl-3,3-dimethylbutanamide (205 mg, 0.846 mmol, 1.0 equiv.) was taken with 5.0 mL CH_2Cl_2 and 5.0 mL of sat. aqueous NaHCO_3 solution and cooled to 0 °C. The stirring was stopped and thiophosgene (78 μL , 1.015 mmol, 1.2 equiv.) was added to the organic phase by a syringe to the organic layer. The resulting orange mixture was vigorously stirred at 0 °C for 30 min. The reaction mixture was then diluted with CH_2Cl_2 (10 mL) and the organic phase was separated from aqueous phase. Aqueous phase was again extracted with CH_2Cl_2 (2×10 mL). Combined organic phase was dried over anh. Na_2SO_4 and concentrated to get an off-white solid (240 mg, 0.843 mmol, 99%). This was used immediately for the thiourea formation without further purification or characterization.

Preparation of (*S*)-2-(3-((*S*)-(6-isobutoxyquinolin-4-yl)((1*S*,2*S*,4*S*,5*R*)-5-vinylquinuclidin-2-yl)methyl)thioureido)-*N,N*-diisobutyl-3,3-dimethylbutanamide (XII):

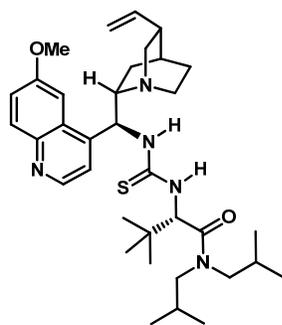


In an oven-dried 25 mL round-bottom flask 6'-isobutoxy-9-amino(9-deoxy)epicinchonidine (225 mg, 0.615 mmol, 1.0 equiv.) was taken with 1.5 mL of dry CH_2Cl_2 under argon. A solution of (*S*)-*N,N*-diisobutyl-2-isothiocyanato-3,3-dimethylbutanamide (210 mg, 0.739 mmol, 1.2 equiv.) in 1.0 mL of dry CH_2Cl_2 was added slowly and the resulting

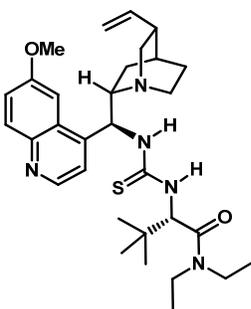
mixture was stirred at r.t. for 16h. Solvent was removed *in vacuo* and the residue was purified by silica-gel (100-200 mesh) column chromatography using 100:2:1 CH₂Cl₂/MeOH/Et₃N as eluent to afford an off-white amorphous solid (321 mg, 0.494 mmol, 80%).



¹H-NMR (400 MHz, DMSO-d₆): δ 8.69 (br s, 1H), 8.40 (br s, 1H), 7.91-7.89 (m, 2H), 7.63-7.62 (m, 1H), 7.39 (d, *J* = 8.7 Hz, 2H), 5.86-5.76 (m, 1H), 5.35 (d, *J* = 9.2 Hz, 1H), 5.00-4.91 (m, 2H), 3.95 (d, *J* = 4.1 Hz, 2H), 3.37-3.13 (m, 7H), 2.63-2.58 (m, 2H), 2.23 (br s, 1H), 2.18-2.10 (m, 1H), 1.85-1.80 (m, 2H), 1.54 (br s, 3H), 1.25-0.87 (m, 16H), 0.75-0.68 (m, 9H), 0.49 (br s, 3H); **¹³C-NMR (100 MHz, DMSO-d₆):** δ 182.3, 171.1, 156.4, 147.4, 145.9, 144.0, 141.9, 141.4, 131.0, 127.9, 121.7, 114.2, 103.8, 79.3, 78.9, 78.6, 74.2, 58.5, 55.3, 55.1, 54.8, 52.5, 36.5, 27.5, 27.3, 27.1, 26.7, 25.9, 25.5, 20.1, 19.7, 19.1, 19.0, 18.8; **HRMS (ESI⁺):** Calcd for C₃₈H₆₀N₅O₂S ([M+H]⁺): 650.4468, Found: 650.4468; **Optical rotation:** [α]_D²³ -89.4 (*c* 0.8, CHCl₃).

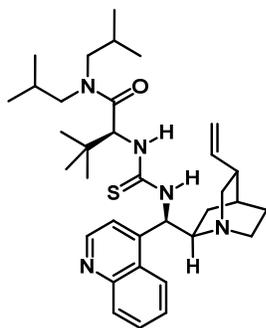


Catalyst IX: Off-white amorphous solid, **m.p.** 111-112 °C; **FT-IR (KBr):** 2959 (s), 2926 (s), 2871 (m), 1637 (m), 1623 (m), 1534 (m), 1434 (m), 1365 (s), 1241 (m), 1230 (m), 1140 (w); **¹H-NMR (400 MHz, DMSO-d₆):** δ 8.74 (s, 1H), 8.04 (br s, 1H), 7.92 (d, *J* = 8.9 Hz, 1H), 7.76 (br s, 1H), 7.60 (br s, 1H), 7.41 (d, *J* = 8.9 Hz, 1H), 5.89-5.85 (m, 1H), 5.33 (d, *J* = 9.1 Hz, 1H), 5.14-5.05 (m, 2H), 3.96 (s, 3H), 3.50-3.37 (m, 4H), 3.24-3.19 (m, 1H), 3.09-3.02 (m, 3H), 2.56-2.53 (m, 1H), 1.97-1.77 (m, 5H), 1.55 (br s, 1H), 1.34-1.32 (m, 1H), 1.21-1.18 (m, 3H), 0.97 (s, 9H), 0.90-0.83 (m, 1H), 0.68-0.66 (m, 8H), 0.46 (m, 3H); **¹³C-NMR (100 MHz, DMSO-d₆):** δ 182.2, 170.7, 157.3, 147.5, 144.2, 143.8, 139.3, 138.8, 131.1, 127.5, 121.7, 115.6, 103.3, 58.9, 55.7, 55.1, 52.6, 45.2, 41.3, 36.6, 28.9, 27.3, 26.8, 25.9, 20.1, 20.0, 19.6, 18.7; **HRMS (ESI⁺):** Calcd for C₃₅H₅₄N₅O₂S ([M+H]⁺): 608.3998, Found: 608.3997; **Optical rotation:** [α]_D²⁴ -102.6 (*c* 0.8, CHCl₃).

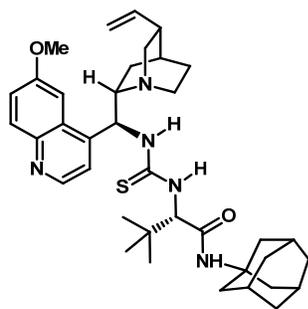


Catalyst X: Off-white amorphous solid, **m.p.** 121-122 °C; **FT-IR (KBr):** 2955 (s), 2931 (s), 2872 (m), 1772 (m), 1622 (s), 1532 (m), 1464 (m), 1366 (m), 1320 (m), 1228 (m), 1133 (m); **¹H-NMR (400 MHz, DMSO-d₆):** δ 8.75 (s, 1H), 8.56 (br s, 1H), 7.93 (d, *J* = 9.0 Hz, 2H), 7.71 (br s, 1H), 7.52 (br s, 1H), 7.42 (d, *J* = 9.0 Hz, 1H), 5.92-5.82 (m, 1H), 5.35 (d, *J* = 11.0 Hz, 1H), 5.11-4.91 (m, 2H), 3.94 (s, 3H), 3.50-3.45 (m, 2H), 3.39-3.36 (m, 3H), 3.29-3.22 (m, 2H), 3.06-3.01 (m, 1H), 2.86-2.81

(m, 1H), 1.83-1.61 (m, 3H), 1.35-1.33 (m, 1H), 1.24-1.17 (m, 4H), 1.03 (t, $J = 6.3$ Hz, 3H), 0.94-0.82 (m, 11H); $^{13}\text{C-NMR}$ (100 MHz, DMSO-d_6): δ 182.1, 169.4, 157.2, 153.4, 147.6, 144.1, 140.1, 138.7, 131.1, 127.7, 121.4, 115.6, 103.2, 58.6, 55.7, 52.0, 45.2, 41.9, 36.0, 31.5, 29.4, 28.9, 26.8, 26.5, 26.3, 14.4, 12.5; **HRMS (ESI+)**: Calcd for $\text{C}_{31}\text{H}_{46}\text{N}_5\text{O}_2\text{S}$ ($[\text{M}+\text{H}]^+$): 552.3372, Found: 552.3371; **Optical rotation**: $[\alpha]_{\text{D}}^{24} -113.5$ (c 0.8, CHCl_3).

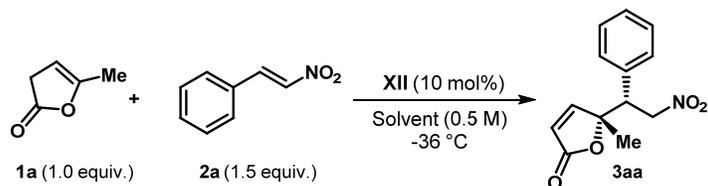


Catalyst VIII: Off-white amorphous solid, **m.p.** 119-120 °C; **FT-IR (KBr)**: 2959 (s), 2935 (s), 2872 (m), 1633 (m), 1537 (m), 1466 (m), 1365 (s), 1241 (m), 1140 (m); $^1\text{H-NMR}$ (400 MHz, DMSO-d_6): δ 8.88 (d, $J = 4.3$ Hz, 1H), 8.71 (br s, 1H), 8.50 (d, $J = 8.3$ Hz, 1H), 8.01 (d, $J = 8.3$ Hz, 1H), 7.83 (d, $J = 9.0$ Hz, 1H), 7.74 (t, $J = 7.5$ Hz, 1H), 7.63 (t, $J = 7.5$ Hz, 1H), 7.49 (br s, 1H), 5.96-5.88 (m, 1H), 5.36 (d, $J = 9.5$ Hz, 1H), 5.17 (d, $J = 12.1$ Hz, 2H), 3.61-3.57 (m, 1H), 3.40-3.34 (m, 3H), 3.18-3.13 (m, 1H), 3.05-2.88 (m, 4H), 2.66 (dd, $J = 12.4, 7.6$ Hz, 1H), 2.33 (br s, 1H), 2.09-2.06 (m, 1H), 1.95-1.88 (m, 1H), 1.57-1.52 (m, 3H), 1.24-1.11 (m, 2H), 0.87-0.85 (m, 6H), 0.83-0.80 (m, 15H); $^{13}\text{C-NMR}$ (100 MHz, DMSO-d_6): δ 182.0, 171.1, 150.1, 147.8, 140.1, 136.7, 129.5, 128.9, 126.9, 126.1, 124.5, 119.7, 114.9, 60.0, 58.5, 55.3, 52.8, 46.4, 36.4, 27.6, 26.8, 26.6, 26.0, 20.3, 20.2, 20.0, 19.3; **HRMS (ESI+)**: Calcd for $\text{C}_{34}\text{H}_{52}\text{N}_5\text{OS}$ ($[\text{M}+\text{H}]^+$): 578.3893, Found: 578.3890; **Optical rotation**: $[\alpha]_{\text{D}}^{24} +171.7$ (c 0.8, CHCl_3).



Catalyst XI: Off-white amorphous solid, **m.p.** 143-144 °C **FT-IR (KBr)**: 2910 (s), 2852 (m), 1770 (br), 1661 (m), 1622 (m), 1537 (m), 1511 (m), 1475 (m), 1361 (m), 1312 (m), 1228 (m); $^1\text{H-NMR}$ (400 MHz, DMSO-d_6): δ 8.74 (s, 1H), 8.50 (br s, 1H), 7.93 (d, $J = 9.1$ Hz, 2H), 7.69-7.46 (br m, 2H), 7.42-7.40 (m, 1H), 7.29 (s, 1H), 5.92-5.77 (m, 1H), 5.16-4.97 (m, 2H), 4.63 (d, $J = 9.1$ Hz, 1H), 3.95 (s, 3H), 3.39-3.18 (m, 4H), 2.78-2.66 (m, 1H), 2.35-2.08 (m, 1H), 1.90 (s, 3H), 1.78 (s, 6H), 1.53 (m, 8H), 1.35-1.33 (m, 1H), 1.24-1.13 (m, 3H), 0.92 (s, 9H); $^{13}\text{C-NMR}$ (100 MHz, DMSO-d_6): δ 182.3, 169.0, 157.1, 153.3, 147.5, 144.2, 139.4, 138.7, 131.1, 127.8, 121.3, 114.5, 103.3, 59.3, 55.7, 52.0, 51.0, 45.3, 41.1, 35.9, 34.9, 31.4, 31.2, 29.5, 29.4, 28.9, 28.7, 26.8; **HRMS (ESI+)**: Calcd for $\text{C}_{37}\text{H}_{52}\text{N}_5\text{O}_2\text{S}$ ($[\text{M}+\text{H}]^+$): 630.3842, Found: 630.3846; **Optical rotation**: $[\alpha]_{\text{D}}^{24} -87.7$ (c 0.8, CHCl_3).

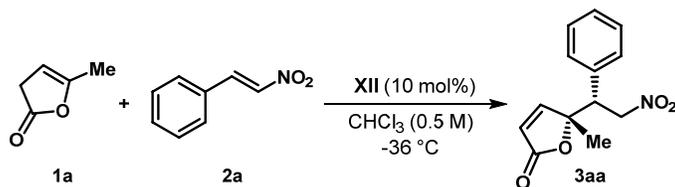
Optimization of reaction media:



Entry	Solvent	t (h) ^a	<i>dr</i> ^b	<i>er</i> ^c
1	CH ₂ Cl ₂	9	>20:1	88:12
2	Toluene	24	>20:1	91:9
3	TBME	28	>20:1	83.5:16.5
4	(CH ₂) ₂ Cl ₂	18	>20:1	91.5:8.5
5	PhCl	25	>20:1	85:15
6	CHCl ₃	34	>20:1	94.5:5.5

^a Time required for the complete consumption of **1a**. ^b Determined from the ¹H-NMR analysis of the crude reaction mixture. ^c Determined by chiral HPLC.

Optimization of reaction conditions:



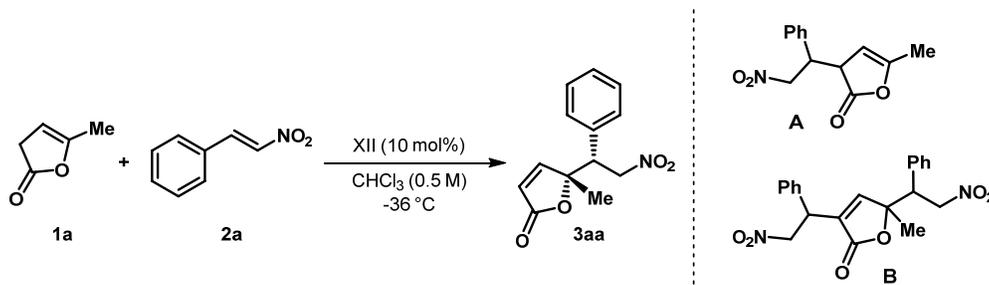
Entry	Ratio of 1a/2a	Conc. (M) ^a	t (h) ^b	<i>dr</i> ^c	<i>er</i> ^d
1	1:1.2	0.5	40	>20:1	94.5:5.5
2	1:1.5	0.5	34	>20:1	94.5:5.5
3	1:2.0	0.5	28	>20:1	94:6
4	1:1.5	0.25	45	>20:1	94.5:5.5
5	1:1.5	1.0	22	>20:1	93.5:6.5
6 ^e	1:1.5	0.5	36	>20:1	94.5:5.5
7 ^f	1:1.5	0.5	50	>20:1	94.5:5.5

^a Conc. with respect to **1a**. ^b Time required for the complete consumption of **1a**.

^c Determined from the ¹H-NMR of the crude reaction mixture. ^d Determined by chiral HPLC.

^e Using 5 Å MS. ^f Reaction with 5 mol% catalyst loading.

Typical procedure for the asymmetric direct vinylogous Michael addition of Angelica lactone **1a to ω -nitrostyrene **2a**:**

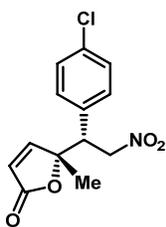


A Schlenk tube was heated to $150\text{ }^\circ\text{C}$ under vacuum for 30 min, cooled to r.t. under vacuum and purged with argon. Nitroolefin **2a** (62.6 mg, 0.42 mmol, 1.5 equiv.) and catalyst **XII** (18.2 mg, 0.028 mmol, 0.1 equiv.) were introduced under an argon flow. Freshly distilled CHCl_3 (0.3 mL) was added to it and the mixture was cooled to $-36\text{ }^\circ\text{C}$. A solution of α -Angelica lactone **1a** (25 μL , 0.28 mmol, 1.0 equiv.) in 0.25 ml of CHCl_3 was added to it and the resulting solution was stirred at $-36\text{ }^\circ\text{C}$ until TLC (30% EtOAc in Pet ether) revealed that conversion of the starting material **1a** was complete (34 h). The reaction mixture was brought to r.t., solvent was removed *in vacuo* and the residue was purified by column chromatography on silica gel (100-200 mesh) using 20-25% EtOAc in petroleum ether to afford a colorless liquid which solidified upon standing in the refrigerator (63.7 mg, 0.26 mmol, 92%). No trace of normal Michael adduct **A** and double Michael adduct **B** could be detected by $^1\text{H-NMR}$ analysis of the crude reaction mixture.

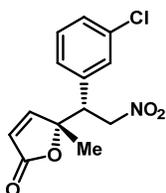
Compound 3aa: Colorless solid; **m.p.** $92\text{--}94\text{ }^\circ\text{C}$; **FT-IR (KBr):** 2922 (w), 1761(s), 1715 (w), 1557 (s), 1435 (w), 1380 (m), 1200 (w), 1139 (w), 1106 (m); **$^1\text{H-NMR}$ (400 MHz, CDCl_3):** δ 7.34-7.28 (m, 4H), 7.16 (d, $J = 6.7\text{ Hz}$, 2H), 5.90 (d, $J = 5.7\text{ Hz}$, 1H), 4.87 (dd, $J = 13.3, 5.1\text{ Hz}$, 1H), 4.76 (dd, $J = 13.3, 9.9\text{ Hz}$, 1H), 4.00 (dd, $J = 9.9, 5.1\text{ Hz}$, 1H), 1.53 (s, 3H); **$^{13}\text{C-NMR}$ (100 MHz, CDCl_3):** δ 171.3, 158.0, 134.4, 129.3, 128.9, 128.4, 121.7, 88.4, 75.5, 50.7, 23.8; **HRMS (ESI+):** Calcd for $\text{C}_{13}\text{H}_{13}\text{NNaO}_4$ ($[\text{M}+\text{Na}]^+$): 270.0742, Found: 270.0741; **Optical rotation:** $[\alpha]_{\text{D}}^{23} +183.5$ (c 2.0, CHCl_3) for an enantiomerically enriched sample of 89%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak IC column (75:25 *n*-Hexane/EtOH, 1.0 mL/min, $20\text{ }^\circ\text{C}$, 210 nm, $\tau_{\text{minor}} = 16.0\text{ min}$, $\tau_{\text{major}} = 19.9\text{ min}$). See Supporting Information: Part B for HPLC chromatograms.

Compound 3ab: Colorless solid, 85% yield; eluent for column chromatography: 1/4 EtOAc/pet ether; **m.p.** $115\text{--}116\text{ }^\circ\text{C}$; **FT-IR (KBr):** 2986 (w), 1761 (s), 1555 (s), 1493 (m), 1379 (m), 1200 (w); **$^1\text{H-NMR}$ (400 MHz, CDCl_3):** δ 7.31-7.27 (m, 3H), 7.11 (d, $J = 8.3\text{ Hz}$, 2H), 5.90 (d, $J = 5.7\text{ Hz}$, 1H), 4.90 (dd, $J = 13.5, 4.9\text{ Hz}$, 1H), 4.76 (dd, $J = 13.5, 10.2\text{ Hz}$, 1H), 3.97 (dd, $J = 10.2,$

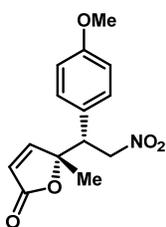
4.9 Hz, 1H), 1.55 (s, 3H); **¹³C-NMR (100 MHz, CDCl₃):** δ 171.1, 157.9, 134.9, 132.9, 129.7, 129.5, 121.8, 88.0, 75.4, 50.0, 23.5 **HRMS (ESI+):** Calcd for C₁₃H₁₂ClNNaO₄ ([M+Na]⁺): 304.0353, Found: 304.0353; **Optical rotation:** [α]_D²³ +150.1 (*c* 1.0, CHCl₃) for an enantiomerically enriched sample of 82%. The enantiomeric ratio was determined by HPLC analysis using Daicel Chiralpak AD-H column (90:10 *n*-Hexane/EtOH, 1.0 mL/min, 20 °C, 210 nm, τ_{major} = 40.7 min, τ_{minor} = 47.8 min). See Supporting Information: Part B for HPLC chromatograms.



Compound 3ac: Colorless thick oil, 86% yield; eluent for column chromatography: 1/4 EtOAc/pet ether; **FT-IR (thin film):** 2923 (w), 1762 (s), 1596 (w), 1557 (s), 1478 (w), 1436 (m), 1379 (m), 1200 (m), 1138 (w), 1107 (m); **¹H-NMR (400 MHz, CDCl₃):** δ 7.30-7.25 (m, 3H), 7.16 (s, 1H), 7.08 (d, *J* = 6.2 Hz, 1H), 5.92 (d, *J* = 5.6 Hz, 1H), 4.88 (dd, *J* = 13.4, 4.9 Hz, 1H), 4.76 (dd, *J* = 13.4, 10.0 Hz, 1H), 3.96 (dd, *J* = 10.0, 4.9 Hz, 1H), 1.54 (s, 3H); **¹³C-NMR (100 MHz, CDCl₃):** δ 171.1, 157.8, 136.4, 135.1, 130.6, 129.2, 128.9, 126.3, 121.9, 87.9, 75.2, 50.3, 23.6; **HRMS (ESI+):** Calcd for C₁₃H₁₂ClNNaO₄ ([M+Na]⁺): 304.0353, Found: 304.0355; **Optical rotation:** [α]_D²⁴ +130.6 (*c* 2.0, CHCl₃) for an enantiomerically enriched sample of 84%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak IC column (75:25 *n*-Hexane/EtOH, 1.0 mL/min, 20 °C, 210 nm, τ_{minor} = 12.1 min, τ_{major} = 14.9 min). See Supporting Information: Part B for HPLC chromatograms.

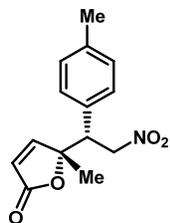


Compound 3af: Light yellowish thick oil, 94% yield; eluent for column chromatography: 1/4 EtOAc/pet ether; **FT-IR (thin film):** 2935 (m), 2841 (m), 1763 (s), 1612 (m), 1557 (s), 1515 (m), 1438 (m), 1380 (m), 1306 (w), 1254 (m), 1183 (m), 1139 (m) 1106 (m); **¹H-NMR (400 MHz, CDCl₃):** δ 7.28 (d, *J* = 5.7 Hz, 1H), 7.07 (d, *J* = 8.6 Hz, 2H), 6.82 (d, *J* = 8.6 Hz, 2H), 5.89 (d, *J* = 5.7 Hz, 1H), 4.83 (dd, *J* = 13.0, 5.0 Hz, 1H), 4.71 (dd, *J* = 13.0, 10.1 Hz, 1H), 3.93 (dd, *J* = 10.1, 5.0 Hz, 1H), 3.75 (s, 3H), 1.50 (s, 3H); **¹³C-NMR (100 MHz, CDCl₃):** δ 171.4, 159.8, 158.2, 129.5, 126.1, 121.6, 114.6, 88.6, 75.7, 55.3, 50.0, 23.6; **HRMS (ESI+):** Calcd for C₁₄H₁₅NNaO₅ ([M+Na]⁺): 300.0848, Found: 300.0843; **Optical rotation:** [α]_D²⁴ +167.8 (*c* 2.0, CHCl₃) for an enantiomerically enriched sample of 91%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak IC column (75:25 *n*-Hexane/EtOH, 1.0 mL/min, 20 °C, 210 nm, τ_{minor} = 20.6 min, τ_{major} = 26.1 min). See Supporting Information: Part B for HPLC chromatograms.

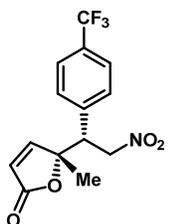


Compound 3ag: Colorless thick oil, 90% yield; eluent for column chromatography: 1/4 EtOAc/pet ether; **FT-IR (thin film):** 2985 (m), 2924 (m), 1763 (s), 1604 (m), 1557 (s), 1517

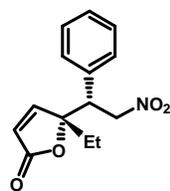
(m), 1438 (m), 1380 (m), 1298 (w), 1279 (w), 1240 (w), 1195 (m), 1139 (m) 1106 (m); **¹H-NMR (400 MHz, CDCl₃):** δ 7.29 (d, *J* = 5.7 Hz, 1H), 7.11 (d, *J* = 7.8 Hz, 2H), 7.03 (d, *J* = 7.8 Hz, 2H), 5.89 (d, *J* = 5.7 Hz, 1H), 4.83 (dd, *J* = 13.2, 5.1 Hz, 1H), 4.73 (dd, *J* = 13.2, 10.1 Hz, 1H), 3.95 (dd, *J* = 10.1, 5.1 Hz, 1H), 2.29 (s, 3H), 1.50 (s, 3H); **¹³C-NMR (100 MHz, CDCl₃):** δ 171.4, 158.2, 138.7, 131.2, 129.9, 128.3, 121.6, 88.6, 75.5, 50.4, 23.7, 21.1; **HRMS (ESI+):** Calcd for C₁₄H₁₅NNaO₄ ([M+Na]⁺): 284.0899, Found: 284.0899; **Optical rotation:** [α]_D²⁵ +198.3 (*c* 2.0, CHCl₃) for an enantiomerically enriched sample of 90%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak IC column (75:25 *n*-Hexane/EtOH, 1.0 mL/min, 20 °C, 210 nm, τ_{minor} = 17.8 min, τ_{major} = 23.0 min). See Supporting Information: Part B for HPLC chromatograms.



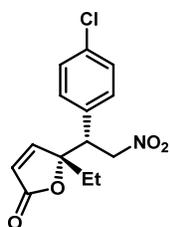
Compound 3an: Yellowish thick oil, 88% yield; eluent for column chromatography: 1/49 EtOAc/toluene; **FT-IR (thin film):** 3088 (w), 2987 (m), 2926 (m), 1765 (s), 1604 (m), 1558 (s), 1425 (m), 1380 (m), 1327 (s), 1241 (w), 1168 (m), 1119 (m); **¹H-NMR (400 MHz, CDCl₃):** δ 7.60 (d, *J* = 8.0 Hz, 2H), 7.31 (d, *J* = 8.0 Hz, 2H), 7.27 (d, *J* = 5.3 Hz, 1H), 5.90 (d, *J* = 5.7 Hz, 1H), 4.95 (dd, *J* = 13.6, 4.8 Hz, 1H), 4.83 (dd, *J* = 13.6, 10.1 Hz, 1H), 4.05 (dd, *J* = 10.1, 4.8 Hz, 1H), 1.58 (s, 3H); **¹³C-NMR (100 MHz, CDCl₃):** δ 171.0, 157.8, 138.5, 128.9, 126.3 (q, *J* = 4 Hz), 123.7 (q, *J* = 271.7 Hz), 122.0, 119.7, 87.8, 75.3, 50.4, 23.6; **HRMS (ESI+):** Calcd for C₁₄H₁₂F₃NNaO₄ ([M+Na]⁺): 338.0616, Found: 338.0614; **Optical rotation:** [α]_D²³ +136.9 (*c* 2.0, CHCl₃) for an enantiomerically enriched sample of 80%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak IC column (75:25 *n*-Hexane/EtOH, 1.0 mL/min, 20 °C, 210 nm, τ_{minor} = 8.4 min, τ_{major} = 9.7 min). See Supporting Information: Part B for HPLC chromatograms.



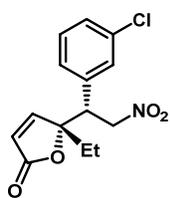
Compound 3ba: Colorless thick oil, yield 94%; eluent for column chromatography: 1/3 EtOAc/pet ether; **FT-IR (thin film):** 2924 (w), 1767 (s), 1557 (s), 1457 (w), 1381 (w), 1202 (w), 1123 (w); **¹H-NMR (400 MHz, CDCl₃):** δ 7.34-7.28 (m, 3H), 7.22-7.20 (m, 1H), 7.17-7.15 (m, 2H), 5.96 (d, *J* = 5.7 Hz, 1H), 4.83 (dd, *J* = 13.3, 5.0 Hz, 1H), 4.74 (dd, *J* = 13.2, 9.9 Hz, 1H), 4.06 (dd, *J* = 9.9, 5.1 Hz, 1H), 2.02-1.93 (m, 1H), 1.81-1.72 (m, 1H), 0.82 (t, *J* = 7.4 Hz, 3H); **¹³C-NMR (100 MHz, CDCl₃):** δ 171.6, 156.6, 134.4, 129.2, 128.8, 128.5, 122.8, 91.3, 75.5, 49.7, 28.8, 7.5. **HRMS (ESI+):** Calcd for C₁₄H₁₅NNaO₄ ([M+Na]⁺): 284.0899, Found: 284.0896; **Optical rotation:** [α]_D²³ +126.1 (*c* 1, CHCl₃) for an enantiomerically enriched sample of 91%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak AD-H column (75:25



n-Hexane/EtOH, 1.0 mL/min, 20 °C, 210 nm, $\tau_{\text{minor}} = 13.1$ min, $\tau_{\text{major}} = 14.9$ min). See Supporting Information: Part B for HPLC chromatograms.



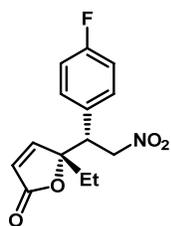
Compound 3bb: Colorless thick oil, 94% yield; eluent for column chromatography: 1/3 EtOAc/pet ether; **FT-IR (thin film):** 3091 (m), 3032 (w), 2978 (s), 2941 (s), 2884 (m), 2747 (w), 2255 (m), 1911 (w), 1812 (m), 1773 (s), 1764 (s), 1758 (s), 1752 (s), 1597 (m), 1559 (s), 1492 (m), 1459 (w), 1438 (m), 1415 (m), 1379 (m), 1313 (w), 1199 (m), 1122 (m), 1115 (m); **$^1\text{H-NMR}$ (400 MHz, CDCl_3):** δ 7.29 (d, $J = 8.3$ Hz, 2H), 7.16 (d, $J = 5.7$ Hz, 1H), 7.10 (d, $J = 8.3$ Hz, 2H), 5.96 (d, $J = 5.7$ Hz, 1H), 4.85 (dd, $J = 13.4, 4.8$ Hz, 1H), 4.73 (dd, $J = 13.2, 10.3$ Hz, 1H), 4.01 (dd, $J = 10.3, 4.8$ Hz, 1H), 2.01-1.92 (m, 1H), 1.84-1.75 (m, 1H), 0.83 (t, $J = 7.2$ Hz, 3H); **$^{13}\text{C-NMR}$ (100 MHz, CDCl_3):** δ 171.4, 156.4, 134.8, 132.9, 129.8, 129.5, 123.0, 90.9, 75.4, 49.1, 28.8, 7.6. **HRMS (ESI+):** Calcd for $\text{C}_{14}\text{H}_{14}\text{ClNNaO}_4$ ($[\text{M}+\text{Na}]^+$): 318.0509, Found: 318.0508; **Optical rotation:** $[\alpha]_{\text{D}}^{25} +156.5$ (c 2.0, CHCl_3) for an enantiomerically enriched sample of 92%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak IC column (90:10 *n*-Hexane/EtOH, 1.5 mL/min, 20 °C, 210 nm, $\tau_{\text{major}} = 19.4$ min, $\tau_{\text{minor}} = 21.3$ min). See Supporting Information: Part B for HPLC chromatograms.



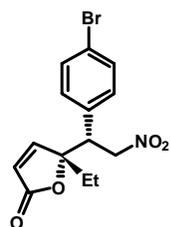
Compound 3bc: Colorless thick oil, 92% yield; eluent for column chromatography: 1/3 EtOAc/pet ether; **FT-IR (thin film):** 3092 (w), 3021 (w), 2978 (m), 2927 (m), 2852 (m), 2574 (w), 1998 (w), 1831 (w), 1773 (s), 1764 (s), 1596 (m), 1559 (s), 1508 (w), 1458 (w), 1438 (m), 1379 (m), 1309 (w), 1199 (m), 1162 (m), 1124 (m); **$^1\text{H-NMR}$ (400 MHz, CDCl_3):** δ 7.31-7.28 (m, 2H), 7.22 (d, $J = 5.7$ Hz, 1H), 7.17 (s, 1H), 7.10-7.08 (m, 1H), 6.01 (d, $J = 5.7$ Hz, 1H), 4.86 (dd, $J = 13.5, 4.8$ Hz, 1H), 4.73 (dd, $J = 13.3, 10.2$ Hz, 1H), 4.04 (dd, $J = 10.1, 4.8$ Hz, 1H), 2.04-1.95 (m, 1H), 1.86-1.77 (m, 1H), 0.85 (t, $J = 7.4$ Hz, 3H); **$^{13}\text{C-NMR}$ (100 MHz, CDCl_3):** δ 171.3, 156.3, 136.5, 135.1, 130.6, 129.1, 128.9, 126.4, 123.1, 90.8, 75.3, 49.3, 28.8, 7.6; **HRMS (ESI+):** Calcd for $\text{C}_{14}\text{H}_{14}\text{ClNNaO}_4$ ($[\text{M}+\text{Na}]^+$): 318.0509, Found: 318.0504; **Optical rotation:** $[\alpha]_{\text{D}}^{25} +112.6$ (c 2.0, CHCl_3) for an enantiomerically enriched sample of 90%. The enantiomeric ratio was determined by HPLC with a Phenomenex Amylose-2 column (95:5 *n*-Hexane/EtOH, 1.5 mL/min, 20 °C, 210 nm, $\tau_{\text{major}} = 30.5$ min, $\tau_{\text{minor}} = 33.7$ min). See Supporting Information: Part B for HPLC chromatograms.

Compound 3bd: Light yellowish thick oil, 87% yield; eluent for column chromatography: 1/4 EtOAc/pet ether; **FT-IR (thin film):** 2977 (m), 2926 (m), 1764 (s), 1557 (s), 1513 (m), 1380 (m), 1229 (m), 1164 (m), 1123 (m); **$^1\text{H-NMR}$ (400 MHz, CDCl_3):** δ 7.18-7.13 (m, 3H), 7.03-6.98 (m, 2H), 5.96 (d, $J = 5.6$ Hz, 1H), 4.85 (dd, $J = 13.0, 4.5$ Hz, 1H), 4.73 (dd, $J = 13.0, 9.9$ Hz,

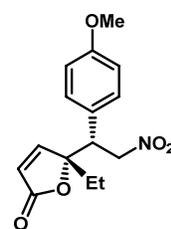
1H), 4.03 (dd, $J = 9.9, 4.5$ Hz, 1H), 2.01-1.92 (m, 1H), 1.84-1.75 (m, 1H), 0.83 (t, $J = 7.4$ Hz, 3H); **$^{13}\text{C-NMR}$ (100 MHz, CDCl_3):** δ 171.5, 162.7 (d, $J = 249$ Hz), 156.5, 130.2 (d, $J = 8$ Hz), 122.9, 116.3 (d, $J = 22$ Hz), 91.1, 75.6, 49.0, 28.7, 7.6; **HRMS (ESI+):** Calcd for $\text{C}_{14}\text{H}_{14}\text{FNNaO}_4$ ($[\text{M}+\text{Na}]^+$): 302.0805, Found: 302.0806; **Optical rotation:** $[\alpha]_{\text{D}}^{26} +121.6$ (c 2.0, CHCl_3) for an enantiomerically enriched sample of 90%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak IC column (90:10 *n*-Hexane/EtOH, 1.5 mL/min, 20 °C, 210 nm, $\tau_{\text{major}} = 19.5$ min, $\tau_{\text{minor}} = 21.3$ min). See Supporting Information: Part B for HPLC chromatograms.

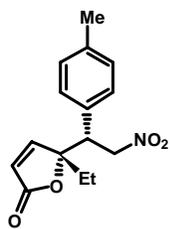


Compound 3be: Light yellowish thick oil, yield 90%; eluent for column chromatography: 1/49 EtOAc/toluene; **FT-IR (thin film):** 2927 (w), 1763 (s), 1557 (s), 1491 (w), 1380 (w), 1202 (w), 1124 (w); **$^1\text{H-NMR}$ (400 MHz, CDCl_3):** δ 7.45 (d, $J = 8.3$ Hz, 2H), 7.16 (d, $J = 5.8$ Hz, 1H), 7.04 (d, $J = 8.3$ Hz, 2H), 5.97 (d, $J = 5.8$ Hz, 1H), 4.85 (dd, $J = 13.3, 4.8$ Hz, 1H), 4.73 (dd, $J = 13.2, 10.4$ Hz, 1H), 4.01 (dd, $J = 10.3, 4.8$ Hz, 1H), 2.02-1.93 (m, 1H), 1.85-1.76 (m, 1H), 0.84 (t, $J = 7.4$ Hz, 3H); **$^{13}\text{C-NMR}$ (100 MHz, CDCl_3):** δ 171.4, 156.4, 134.4, 132.5, 130.1, 123.1, 123.0, 90.9, 75.4, 49.2, 28.8, 7.7. **HRMS (ESI+):** Calcd for $\text{C}_{14}\text{H}_{14}\text{BrNNaO}_4$ ($[\text{M}+\text{Na}]^+$): 362.0004, Found: 362.0006; **Optical rotation:** $[\alpha]_{\text{D}}^{23} +126.4$ (c 0.5, CHCl_3) for an enantiomerically enriched sample of 88%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak AD-H column (75:25 *n*-Hexane: EtOH, 1.0 mL/min, 20 °C, 210 nm, $\tau_{\text{major}} = 15.2$ min, $\tau_{\text{minor}} = 18.1$ min). See Supporting Information: Part B for HPLC chromatograms.

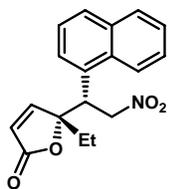


Compound 3bf: Light yellowish oil, 97% yield; eluent for column chromatography: 1/4 EtOAc/pet ether; **FT-IR (thin film):** 3083 (w), 2975 (m), 2938 (m), 2840 (m), 1763 (s), 1611 (m), 1583 (w), 1556 (s), 1515 (m), 1458 (w), 1438 (w), 1380 (m), 1298 (w), 1252 (m), 1183 (m), 1120 (m); **$^1\text{H-NMR}$ (400 MHz, CDCl_3):** δ 7.19 (d, $J = 5.7$ Hz, 1H), 7.07 (d, $J = 8.6$ Hz, 2H), 6.82 (d, $J = 8.6$ Hz, 2H), 5.97 (d, $J = 5.7$ Hz, 1H), 4.80 (dd, $J = 13.1, 4.9$ Hz, 1H), 4.69 (dd, $J = 12.7, 10.3$ Hz, 1H), 3.99 (dd, $J = 10.3, 4.9$ Hz, 1H), 3.75 (s, 3H), 2.00-1.90 (m, 1H), 1.81-1.72 (m, 1H), 0.81 (t, $J = 7.3$ Hz, 3H); **$^{13}\text{C-NMR}$ (100 MHz, CDCl_3):** δ 171.7, 159.7, 156.7, 129.6, 126.1, 122.8, 114.6, 91.5, 75.7, 55.3, 49.0, 28.8, 7.6; **HRMS (ESI+):** Calcd for $\text{C}_{15}\text{H}_{17}\text{NNaO}_5$ ($[\text{M}+\text{Na}]^+$): 314.1004, Found: 314.1003; **Optical rotation:** $[\alpha]_{\text{D}}^{23} +183.5$ (c 2.0, CHCl_3) for an enantiomerically enriched sample of 93%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak AD-H column (75:25 *n*-Hexane/EtOH, 1.0 mL/min, 20 °C, 210 nm, $\tau_{\text{major}} = 18.8$ min, $\tau_{\text{minor}} = 22.3$ min). See Supporting Information: Part B for HPLC chromatograms.

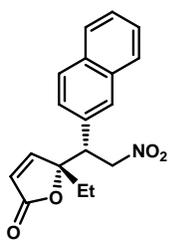




Compound 3bg: Light yellowish thick oil, yield 91%; eluent for column chromatography: 1/49 EtOAc/toluene; **FT-IR (thin film):** 2921 (w), 1762 (s), 1557 (s), 1436 (w), 1380 (w), 1194 (w), 1122 (w); **¹H-NMR (400 MHz, CDCl₃):** δ 7.21 (d, *J* = 5.7 Hz, 1H), 7.12 (d, *J* = 8.0 Hz, 2H), 7.04 (d, *J* = 8.0 Hz, 2H), 5.98 (d, *J* = 5.7 Hz, 1H), 4.80 (dd, *J* = 13.2, 5.1 Hz, 1H), 4.71 (dd, *J* = 13.1, 10.2 Hz, 1H), 4.02 (dd, *J* = 10.1, 5.0 Hz, 1H), 2.29 (s, 3H), 2.01-1.92 (m, 1H), 1.81-1.72 (m, 1H), 0.82 (t, *J* = 7.4 Hz, 3H); **¹³C-NMR (100 MHz, CDCl₃):** δ 171.7, 156.7, 138.7, 131.3, 129.9, 128.4, 122.8, 91.4, 75.6, 49.4, 28.8, 21.1, 7.5. **HRMS (ESI⁺):** Calcd for C₁₅H₁₇NNaO₄ ([M+Na]⁺): 298.1055, Found: 298.1058; **Optical rotation:** [α]_D²³ +154.5 (*c* 1.0, CHCl₃) for an enantiomerically enriched sample of 92%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak AD-H column (75:25 *n*-Hexane/EtOH, 1.0 mL/min, 20 °C, 210 nm, τ_{major} = 11.3 min, τ_{minor} = 12.2 min). See Supporting Information: Part B for HPLC chromatograms.

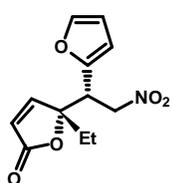


Compound 3bh: Colorless foam, 90% yield; eluent for column chromatography: 1/49 EtOAc/toluene; **FT-IR (thin film):** 3050 (w), 2954 (m), 2924 (s), 2854 (m), 1762 (s), 1618 (w), 1577 (w), 1598 (w), 1553 (s), 1458 (m), 1378 (m), 1341 (w), 1265 (m), 1195 (m), 1170 (m), 1122 (m); **¹H-NMR (400 MHz, CDCl₃):** δ 8.14 (d, *J* = 8.5 Hz, 1H), 7.86 (d, *J* = 8.1 Hz, 1H), 7.79 (d, *J* = 8.1 Hz, 1H), 7.62 (t, *J* = 7.1 Hz, 1H), 7.52 (t, *J* = 7.7 Hz, 1H), 7.44 (t, *J* = 7.7 Hz, 1H), 7.35 (d, *J* = 7.2 Hz, 1H), 7.12 (d, *J* = 5.7 Hz, 1H), 5.75 (d, *J* = 5.7 Hz, 1H), 5.13-5.05 (m, 2H), 4.97 (dd, *J* = 13.1, 9.4 Hz, 1H), 2.17-2.07 (m, 1H), 1.95-1.87 (m, 1H), 0.86 (t, *J* = 7.3 Hz, 3H); **¹³C-NMR (100 MHz, CDCl₃):** δ 171.7, 156.0, 134.2, 131.9, 130.8, 129.5, 129.3, 127.3, 126.2, 125.4, 124.9, 122.7, 122.2, 91.8, 76.1, 42.3, 28.9, 7.8; **HRMS (ESI⁺):** Calcd for C₁₈H₁₇NNaO₄ ([M+Na]⁺): 334.1055, Found: 334.1056; **Optical rotation:** [α]_D²⁶ +93.5 (*c* 2.0, CHCl₃) for an enantiomerically enriched sample of 90%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak AD-H column (75:25 *n*-Hexane/EtOH, 1.0 mL/min, 20 °C, 210 nm, τ_{major} = 8.6 min, τ_{minor} = 11.5 min). See Supporting Information: Part B for HPLC chromatograms.

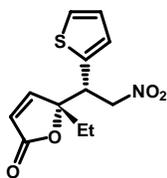


Compound 3bi: Colorless foam, 96% yield; eluent for column chromatography: 1/49 EtOAc/toluene; **FT-IR (thin film):** 3056 (w), 2975 (m), 2923 (m), 2852 (w), 1765 (s), 1601 (w), 1557 (s), 1598 (w), 1506 (s), 1435 (m), 1379 (m), 1341 (w), 1206 (m), 1121 (m); **¹H-NMR (400 MHz, CDCl₃):** δ 7.82-7.78 (m, 3H), 7.64 (s, 1H), 7.51-7.48 (m, 2H), 7.27-7.23 (m, 2H), 5.94 (d, *J* = 5.7 Hz, 1H), 4.94-4.83 (m, 2H), 4.22 (dd, *J* = 9.6, 5.4 Hz, 1H), 2.07-1.98 (m, 1H), 1.86-1.77 (m, 1H), 0.84 (t, *J* = 7.4 Hz, 3H); **¹³C-NMR (100 MHz, CDCl₃):** δ 171.6, 156.5, 133.3, 133.2, 131.9, 129.3, 128.2, 128.0, 127.8, 126.9, 126.8, 125.5, 122.9, 91.4, 75.7, 49.9, 29.0, 7.6; **HRMS**

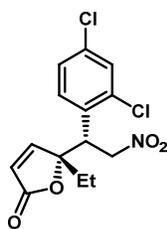
(ESI+): Calcd for $C_{18}H_{17}NNaO_4$ ($[M+Na]^+$): 334.1055, Found: 334.1049; **Optical rotation:** $[\alpha]_D^{23} +179.5$ (c 2.0, $CHCl_3$) for an enantiomerically enriched sample of 91%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak IC column (75:25 *n*-Hexane/EtOH, 1.0 mL/min, 20 °C, 210 nm, $\tau_{major} = 12.3$ min, $\tau_{minor} = 15.4$ min). See Supporting Information: Part B for HPLC chromatograms.



Compound 3bj: Colorless oil, yield 97%; eluent for column chromatography: 1/49 EtOAc/toluene; **FT-IR (thin film):** 2924 (s), 1770 (s), 1557 (s), 1463 (w), 1378 (m), 1206 (w), 1120 (w); **1H -NMR (400 MHz, $CDCl_3$):** δ 7.44 (d, $J = 5.7$ Hz, 1H), 7.38 (br s, 1H), 6.33-6.30 (m, 2H), 6.12 (d, $J = 5.7$ Hz, 1H), 4.56 (d, $J = 7.4$ Hz, 2H), 4.23 (t, $J = 7.4$ Hz, 1H), 1.94-1.85 (m, 1H), 1.70-1.61 (m, 1H), 0.84 (t, $J = 7.4$ Hz, 3H); **^{13}C -NMR (100 MHz, $CDCl_3$):** δ 171.4, 156.8, 147.8, 143.4, 122.8, 110.9, 110.6, 90.5, 73.9, 43.5, 29.1, 7.3. **HRMS (ESI+):** Calcd for $C_{12}H_{13}NNaO_5$ ($[M+Na]^+$): 274.0691, Found: 274.0691; **Optical rotation:** $[\alpha]_D^{23} +139.6$ (c 2, $CHCl_3$) for an enantiomerically enriched sample of 87%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak AD-H column (75:25 *n*-Hexane/EtOH, 1.0 mL/min, 20 °C, 210 nm, $\tau_{minor} = 10.5$ min, $\tau_{major} = 14.8$ min). See Supporting Information: Part B for HPLC chromatograms.

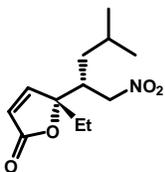


Compound 3bk: Colorless oil, yield 92%; eluent for column chromatography: 1/49 EtOAc/toluene; **FT-IR (thin film):** 2922 (w), 1766 (s), 1557 (s), 1457 (w), 1379 (w), 1205 (w), 1123 (w); **1H -NMR (400 MHz, $CDCl_3$):** δ 7.34 (d, $J = 5.8$ Hz, 1H), 7.25-7.23 (m, 1H), 6.96-6.93 (m, 2H), 6.05 (d, $J = 5.8$ Hz, 1H), 4.79 (dd, $J = 13.1, 4.6$ Hz, 1H), 4.62 (dd, $J = 12.9, 10.2$ Hz, 1H), 4.39 (dd, $J = 10.2, 4.6$ Hz, 1H), 2.02-1.93 (m, 1H), 1.86-1.77 (m, 1H), 0.86 (t, $J = 7.4$ Hz, 3H); **^{13}C -NMR (100 MHz, $CDCl_3$):** δ 171.5, 156.2, 136.2, 127.8, 127.4, 126.2, 123.1, 90.9, 76.7, 44.9, 28.8, 7.6. **HRMS (ESI+):** Calcd for $C_{12}H_{13}NNaO_4S$ ($[M+Na]^+$): 290.0463, Found: 290.0466; **Optical rotation:** $[\alpha]_D^{23} +115.1$ (c 2, $CHCl_3$) for an enantiomerically enriched sample of 92%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak ID column (75:25 *n*-hexane/EtOH, 1.0 mL/min, 20 °C, 210 nm, $\tau_{major} = 8.1$ min, $\tau_{minor} = 9.2$ min). See Supporting Information: Part B for HPLC chromatograms.

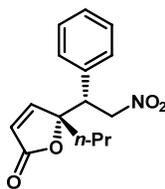


Compound 3bl: Light yellowish thick oil, 96% yield; eluent for column chromatography: 1/4 EtOAc/pet ether; **FT-IR (thin film):** 3092 (w), 2976 (m), 2923 (m), 2852 (w), 1766 (s), 1589 (m), 1557 (s), 1476 (m), 1379 (m), 1351 (w), 1219 (m), 1193 (m), 1123 (m); **1H -NMR (400 MHz, $CDCl_3$):** δ 7.38 (d, $J = 1.8$ Hz, 1H), 7.31 (d, $J = 5.7$ Hz, 1H), 7.23-7.16 (m, 2H), 5.83 (d, $J = 5.7$ Hz, 1H), 5.00 (dd, $J = 13.7, 4.7$ Hz, 1H), 4.88 (dd, $J = 13.7, 10.3$ Hz, 1H), 4.72 (dd, $J =$

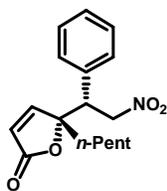
10.3, 4.7 Hz, 1H), 2.08-1.94 (m, 2H), 0.90 (t, $J = 7.4$ Hz, 3H); $^{13}\text{C-NMR}$ (100 MHz, CDCl_3): δ 171.4, 156.0, 135.3, 135.2, 131.0, 130.1, 128.7, 128.1, 123.0, 91.0, 75.1, 43.5, 28.5, 8.0; **HRMS (ESI+)**: Calcd for $\text{C}_{14}\text{H}_{13}\text{Cl}_2\text{NNaO}_4$ ($[\text{M}+\text{Na}]^+$): 352.0119, Found: 352.0119; **Optical rotation**: $[\alpha]_{\text{D}}^{22} +153.4$ (c 2.0, CHCl_3) for an enantiomerically enriched sample of 94%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak AD-H column (75:25 *n*-Hexane/EtOH, 1.0 mL/min, 20 °C, 210 nm, $\tau_{\text{major}} = 7.4$ min, $\tau_{\text{minor}} = 12.8$ min). See Supporting Information: Part B for HPLC chromatograms.



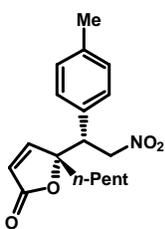
Compound 3bm: Colorless oil, yield 59%; eluent for column chromatography: 1/49 EtOAc/toluene; **FT-IR (thin film)**: 2925 (w), 1766 (s), 1557 (s), 1463 (w), 1380 (w), 1206 (w), 1126 (w); $^1\text{H-NMR}$ (400 MHz, CDCl_3): δ 7.28 (d, $J = 5.7$ Hz, 1H), 6.20 (d, $J = 5.7$ Hz, 1H), 4.41 (dd, $J = 13.7, 6.6$ Hz, 1H), 4.21 (dd, $J = 13.7, 4.8$ Hz, 1H), 2.94-2.87 (m, 1H), 2.00-1.93 (m, 1H), 1.90-1.83 (m, 1H), 1.62-1.55 (m, 1H), 1.30-1.18 (m, 2H), 0.94 (d, $J = 2.3$ Hz, 3H), 0.93 (d, $J = 2.4$ Hz, 3H), 0.84 (t, $J = 7.3$ Hz, 3H); $^{13}\text{C-NMR}$ (100 MHz, CDCl_3): δ 171.6, 156.4, 123.3, 92.3, 75.5, 41.4, 37.6, 28.2, 26.0, 23.4, 21.5, 7.5. **HRMS (ESI+)**: Calcd for $\text{C}_{12}\text{H}_{19}\text{NNaO}_4$ ($[\text{M}+\text{Na}]^+$): 264.1212, Found: 264.1213; **Optical rotation**: $[\alpha]_{\text{D}}^{23} -4.2$ (c 0.5, CHCl_3) for an enantiomerically enriched sample of 91%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak IC column (75:25 hexane/EtOH, 1.0 mL/min, 20 °C, 210 nm, $\tau_{\text{major}} = 9.6$ min, $\tau_{\text{minor}} = 10.4$ min). See Supporting Information: Part B for HPLC chromatograms.



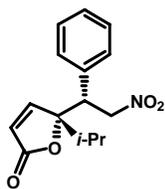
Compound 3ca: Colorless thick oil, 92% yield; eluent for column chromatography: 1/4 EtOAc/pet ether; **FT-IR (thin film)**: 3089 (w), 3034 (w), 2964 (m), 2933 (m), 2875 (m), 1761 (s), 1604 (m), 1557 (s), 1496 (m), 1456 (m), 1435 (m), 1380 (m), 1313 (w), 1294 (m), 1196 (m), 1130 (m); $^1\text{H-NMR}$ (400 MHz, CDCl_3): δ 7.35-7.29 (m, 3H), 7.21 (d, $J = 5.7$ Hz, 1H), 7.17-7.14 (m, 2H), 5.94 (d, $J = 5.7$ Hz, 1H), 4.84 (dd, $J = 13.3, 5.1$ Hz, 1H), 4.75 (dd, $J = 13.3, 10.1$ Hz, 1H), 4.04 (dd, $J = 10.1, 5.1$ Hz, 1H), 1.93-1.85 (m, 1H), 1.77-1.69 (m, 1H), 1.35-1.22 (m, 1H), 1.21-1.11 (m, 1H), 0.89 (t, $J = 7.3$ Hz, 3H); $^{13}\text{C-NMR}$ (100 MHz, CDCl_3): δ 171.6, 156.9, 134.4, 129.3, 128.8, 128.6, 122.5, 91.0, 75.6, 50.0, 37.8, 16.7, 14.0; **HRMS (ESI+)**: Calcd for $\text{C}_{15}\text{H}_{17}\text{NNaO}_4$ ($[\text{M}+\text{Na}]^+$): 298.1055, Found: 298.1056; **Optical rotation**: $[\alpha]_{\text{D}}^{26} +135.2$ (c 1.0, CHCl_3) for an enantiomerically enriched sample of 94%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak IC column (75:25 *n*-Hexane/EtOH, 1.0 mL/min, 20 °C, 210 nm, $\tau_{\text{major}} = 13.3$ min, $\tau_{\text{minor}} = 16.0$ min). See Supporting Information: Part B for HPLC chromatograms.



Compound 3da: Colorless thick oil, yield 91%; eluent for column chromatography: 1/49 EtOAc/toluene; **FT-IR (thin film):** 2929 (m), 1771 (s), 1557 (s), 1456 (w), 1380 (m), 1188 (w), 1130 (w); **¹H-NMR (400 MHz, CDCl₃):** δ 7.34-7.27 (m, 3H), 7.21 (d, *J* = 5.8 Hz, 1H), 7.16-7.14 (m, 2H), 5.94 (d, *J* = 5.7 Hz, 1H), 4.84 (dd, *J* = 13.3, 5.0 Hz, 1H), 4.75 (dd, *J* = 13.0, 10.1 Hz, 1H), 4.05 (dd, *J* = 10.0, 5.0 Hz, 1H), 1.93-1.85 (m, 1H), 1.76-1.69 (m, 1H), 1.28-1.10 (m, 6H), 0.85 (t, *J* = 7.0 Hz, 3H); **¹³C-NMR (100 MHz, CDCl₃):** δ 171.6, 156.9, 134.4, 129.3, 128.8, 128.5, 122.5, 91.0, 75.6, 49.9, 35.8, 31.7, 22.9, 22.4, 14.0; **HRMS (ESI+):** Calcd for C₁₇H₂₁NNaO₄ ([M+Na]⁺): 326.1368, Found: 326.1364; **Optical rotation:** [α]_D²³ +87.8 (*c* 0.5, CHCl₃) for an enantiomerically enriched sample of 94%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak ID column (95:5 *n*-hexane: EtOH, 1.5 mL/min, 20 °C, 210 nm, τ_{minor} = 11.2 min, τ_{major} = 12.9 min). See Supporting Information: Part B for HPLC chromatograms.

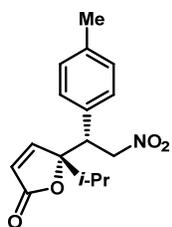


Compound 3dg: Light yellowish thick oil, yield 95%; eluent for column chromatography: 1/49 EtOAc/toluene; **FT-IR (thin film):** 2928 (m), 1765 (s), 1557 (s), 1435 (w), 1379 (m), 1188 (w), 1124 (w); **¹H-NMR (400 MHz, CDCl₃):** δ 7.21 (d, *J* = 5.7 Hz, 1H), 7.12 (d, *J* = 7.7 Hz, 2H), 7.03 (d, *J* = 7.9 Hz, 2H), 5.96 (d, *J* = 5.7 Hz, 1H), 4.82 (dd, *J* = 13.2, 4.9 Hz, 1H), 4.72 (dd, *J* = 12.6, 10.2 Hz, 1H), 4.01 (dd, *J* = 10.1, 4.9 Hz, 1H), 2.31 (s, 3H), 1.92-1.85 (m, 1H), 1.75-1.69 (m, 1H), 1.28-1.09 (m, 6H), 0.85 (t, *J* = 6.9 Hz, 3H); **¹³C-NMR (100 MHz, CDCl₃):** δ 171.7, 157.0, 138.7, 131.3, 129.9, 128.4, 122.5, 91.2, 75.7, 49.7, 35.8, 31.7, 23.0, 22.5, 21.2, 14.0. **HRMS (ESI+):** Calcd for C₁₈H₂₃NNaO₄ ([M+Na]⁺): 340.1525, Found: 340.1523; **Optical rotation:** [α]_D²³ +107.7 (*c* 0.5, CHCl₃) for an enantiomerically enriched sample of 93%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak AD-H column (75:25 *n*-hexane: EtOH, 1.0 mL/min, 20 °C, 210 nm, τ_{major} = 7.2 min, τ_{minor} = 15.6 min). See Supporting Information: Part B for HPLC chromatograms.

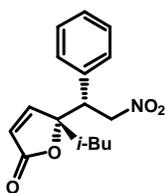


Compound 3ea: Colorless oil, yield 90%; eluent for column chromatography: 1/49 EtOAc/toluene; **FT-IR (thin film):** 2973 (m), 2923 (m), 1760 (s), 1556 (m), 1455 (w), 1380 (w), 1200 (w), 1132 (w); **¹H-NMR (400 MHz, CDCl₃):** δ 7.32-7.27 (m, 3H), 7.20-7.15 (m, 3H), 5.91 (d, *J* = 5.8 Hz, 1H), 4.85-4.80 (m, 2H), 4.24 (dd, *J* = 9.2, 5.8 Hz, 1H), 2.23-2.13 (m, 1H), 1.03 (d, *J* = 6.9 Hz, 3H), 0.95 (d, *J* = 6.7 Hz, 3H); **¹³C-NMR (100 MHz, CDCl₃):** δ 171.7, 156.7, 134.4, 129.3, 128.8, 128.6, 123.1, 93.6, 75.8, 47.4, 31.9, 17.9, 16.9. **HRMS (ESI+):** Calcd for C₁₅H₁₇NNaO₄ ([M+Na]⁺): 298.1055, Found: 298.1058; **Optical rotation:** [α]_D²³ +120.8 (*c* 2.0, CHCl₃) for an enantiomerically enriched sample of 96%. The enantiomeric ratio was determined by HPLC with

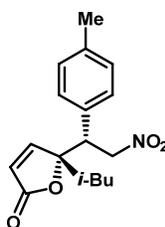
a Daicel Chiralpak IC column (90:10 *n*-hexane: EtOH, 1.5 mL/min, 20 °C, 210 nm, $\tau_{\text{major}} = 17.1$ min, $\tau_{\text{minor}} = 18.9$ min). See Supporting Information: Part B for HPLC chromatograms.



Compound 3eg: Colorless thick oil, yield 92%; eluent for column chromatography: 1/49 EtOAc/toluene; **FT-IR (thin film):** 2970 (m), 2924 (m), 1762 (s), 1556 (s), 1465 (w), 1380 (m), 1195 (w), 1132 (w); **$^1\text{H-NMR}$ (400 MHz, CDCl_3):** δ 7.19 (d, $J = 5.8$ Hz, 1H), 7.11 (d, $J = 7.9$ Hz, 2H), 7.04 (d, $J = 8.0$ Hz, 2H), 5.93 (d, $J = 5.8$ Hz, 1H), 4.83-4.74 (m, 2H), 4.20 (dd, $J = 9.6, 5.4$ Hz, 1H), 2.29 (s, 3H), 2.20-2.14 (m, 1H), 1.02 (d, $J = 6.9$ Hz, 3H), 0.96 (d, $J = 6.6$ Hz, 3H); **$^{13}\text{C-NMR}$ (100 MHz, CDCl_3):** δ 171.8, 155.8, 138.6, 131.3, 129.9, 128.5, 123.1, 93.7, 75.9, 47.1, 31.9, 21.2, 17.9, 16.9. **HRMS (ESI+):** Calcd for $\text{C}_{16}\text{H}_{19}\text{NNaO}_4$ ($[\text{M}+\text{Na}]^+$): 312.1212, Found: 312.1214; **Optical rotation:** $[\alpha]_{\text{D}}^{23} +120.7$ (c 2.0, CHCl_3) for an enantiomerically enriched sample of 96%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak AD-H column (75:25 *n*-hexane: EtOH, 1.0 mL/min, 20 °C, 210 nm, $\tau_{\text{major}} = 7.0$ min, $\tau_{\text{minor}} = 9.2$ min). See Supporting Information: Part B for HPLC chromatograms.

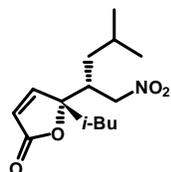


Compound 3fa: Colorless oil, yield 93%; eluent for column chromatography: 1/49 EtOAc/toluene; **FT-IR (thin film):** 2924 (m), 1761 (s), 1557 (s), 1436 (w), 1379 (w), 1197 (w), 1127 (w); **$^1\text{H-NMR}$ (400 MHz, CDCl_3):** δ 7.35-7.29 (m, 3H), 7.25 (d, $J = 5.8$ Hz, 1H), 7.16-7.14 (m, 2H), 5.94 (d, $J = 5.7$ Hz, 1H), 4.85 (dd, $J = 13.3, 4.9$ Hz, 1H), 4.76 (dd, $J = 13.2, 10.1$ Hz, 1H), 4.02 (dd, $J = 10.1, 4.9$ Hz, 1H), 1.88 (dd, $J = 14.6, 6.2$ Hz, 1H), 1.69 (dd, $J = 14.6, 5.7$ Hz, 1H), 1.59-1.49 (m, 1H), 0.91 (d, $J = 6.6$ Hz, 3H), 0.87 (d, $J = 6.6$ Hz, 3H); **$^{13}\text{C-NMR}$ (100 MHz, CDCl_3):** δ 171.6, 157.2, 134.4, 129.3, 128.8, 128.6, 122.4, 91.2, 75.7, 50.7, 44.4, 24.5, 24.0, 23.8. **HRMS (ESI+):** Calcd for $\text{C}_{16}\text{H}_{19}\text{NNaO}_4$ ($[\text{M}+\text{Na}]^+$): 312.1212, Found: 312.1211; **Optical rotation:** $[\alpha]_{\text{D}}^{23} +114.4$ (c 0.5, CHCl_3) for an enantiomerically enriched sample of 94%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak IC column (75:25 *n*-hexane/EtOH, 1.0 mL/min, 20 °C, 210 nm, $\tau_{\text{major}} = 10.5$ min, $\tau_{\text{minor}} = 13.5$ min). See Supporting Information: Part B for HPLC chromatograms.

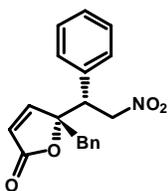


Compound 3fg: Colorless oil, yield 96%; eluent for column chromatography: 1/49 EtOAc/toluene; **FT-IR (thin film):** 2925 (w), 1765 (s), 1557 (s), 1466 (w), 1379 (w), 1192 (w), 1127 (w); **$^1\text{H-NMR}$ (400 MHz, CDCl_3):** δ 7.26-7.25 (m, 1H), 7.12 (d, $J = 7.9$ Hz, 2H), 7.03 (d, $J = 8.0$ Hz, 2H), 5.96 (d, $J = 5.7$ Hz, 1H), 4.82 (dd, $J = 13.2, 4.9$ Hz, 1H), 4.72 (dd, $J = 13.1, 10.2$ Hz, 1H), 3.98 (dd, $J = 10.2, 4.9$ Hz, 1H), 2.31 (s, 3H), 1.86 (dd, $J = 14.6, 6.1$ Hz, 1H), 1.68 (dd, $J = 14.6, 5.8$ Hz, 1H), 1.60-1.50 (m, 1H), 0.91 (d, $J = 6.6$ Hz, 3H), 0.87 (d, $J = 6.6$ Hz, 3H);

¹³C-NMR (100 MHz, CDCl₃): δ 171.7, 157.3, 138.7, 131.3, 129.9, 128.4, 122.4, 91.4, 75.8, 50.4, 44.4, 24.5, 24.0, 23.8, 21.2. **HRMS (ESI+):** Calcd for C₁₇H₂₁NNaO₄ ([M+Na]⁺): 326.1368, Found: 326.1366; **Optical rotation:** $[\alpha]_D^{23}$ +121.0 (*c* 0.2, CHCl₃) for an enantiomerically enriched sample of 94%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak AD-H column (75:25 *n*-hexane: EtOH, 1.0 mL/min, 20 °C, 210 nm, τ_{major} = 6.6 min, τ_{minor} = 9.5 min). See Supporting Information: Part B for HPLC chromatograms.



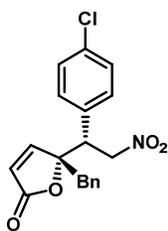
Compound 3fm: Colorless oil, yield 89%; eluent for column chromatography: 1/3 EtOAc/pet ether; **FT-IR (KBr):** 2960 (s), 2926 (m), 1756 (s), 1562 (m), 1464 (w), 1379 (w), 1197 (w), 1126 (w); **¹H-NMR (400 MHz, CDCl₃):** δ 7.31 (d, *J* = 5.7 Hz, 1H), 6.18 (d, *J* = 5.7 Hz, 1H), 4.36 (dd, *J* = 13.7, 6.6 Hz, 1H), 4.17 (dd, *J* = 13.7, 4.8 Hz, 1H), 2.89-2.83 (m, 1H), 1.86 (dd, *J* = 14.6, 5.7 Hz, 1H), 1.66 (dd, *J* = 14.7, 6.2 Hz, 1H), 1.57-1.49 (m, 2H), 1.28-1.13 (m, 2H), 0.93-0.88 (m, 12H); **¹³C-NMR (100 MHz, CDCl₃):** δ 171.6, 156.8, 123.0, 92.2, 75.5, 43.8, 42.3, 37.8, 26.1, 24.3, 24.1, 23.7, 23.5, 21.5; **HRMS (ESI+):** Calcd for C₁₄H₂₃NNaO₄ ([M+Na]⁺): 292.1525, Found: 292.1521; **Optical rotation:** $[\alpha]_D^{23}$ +1.1 (*c* 2, CHCl₃) for an enantiomerically enriched sample of 88%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak AD-H column (90:10 *n*-hexane/EtOH, 1.5 mL/min, 20 °C, 210 nm, τ_{major} = 4.6 min, τ_{minor} = 4.9 min). See Supporting Information: Part B for HPLC chromatograms.



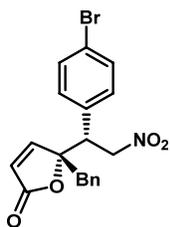
Compound 3ga: White solid, yield 95%; eluent for column chromatography: 1/3 EtOAc/Pet ether; **m.p.** 145-147 °C; **FT-IR (thin film):** 2923 (w), 1753 (s), 1552 (s), 1456 (w), 1380 (m), 1183 (w), 1098 (w); **¹H-NMR (400 MHz, CDCl₃):** δ 7.36-7.31 (m, 3H), 7.26-7.24 (m, 3H), 7.19-7.15 (m, 3H), 7.06-7.05 (m, 2H), 5.69 (d, *J* = 5.7 Hz, 1H), 4.95 (dd, *J* = 13.3, 4.8 Hz, 1H), 4.82 (dd, *J* = 13.0, 10.2 Hz, 1H), 4.16 (dd, *J* = 10.1, 4.8 Hz, 1H), 3.26 (d, *J* = 14.0 Hz, 1H), 3.04 (d, *J* = 14.0 Hz, 1H); **¹³C-NMR (100 MHz, CDCl₃):** δ 171.1, 156.2, 134.4, 133.1, 130.4, 129.4, 129.0, 128.7, 128.6, 127.7, 122.9, 90.5, 75.7, 50.0, 42.6; **HRMS (ESI+):** Calcd for C₁₉H₁₇NNaO₄ ([M+Na]⁺): 346.1055, Found: 346.1057; **Optical rotation:** $[\alpha]_D^{23}$ +45.8 (*c* 1.00, CHCl₃) for an enantiomerically enriched sample of 94%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak AD-H column (75:25 *n*-hexane: EtOH, 1.0 mL/min, 20 °C, 210 nm, τ_{minor} = 11.0 min, τ_{major} = 15.2 min). See Supporting Information: Part B for HPLC chromatograms.

Compound 3gb: White powder, 97% yield; eluent for column chromatography: 1/4 EtOAc/pet ether; **m.p.** 202-203 °C; **FT-IR (KBr):** 3105 (w), 2920 (m), 2641 (br), 1773 (m), 1752 (s), 1735 (m), 1653 (br), 1546 (m), 1379 (m), 1228 (w), 1183 (m); **¹H-NMR (400 MHz, CDCl₃):** δ 7.33-7.26 (m, 5H), 7.13-7.07 (m, 5H), 5.70 (d, *J* = 5.7 Hz, 1H), 4.99 (dd, *J* = 13.1, 4.5 Hz, 1H), 4.82

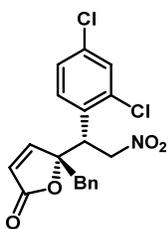
(dd, $J=13.1, 10.5$ Hz, 1H), 4.12 (dd, $J=10.5, 4.5$ Hz, 1H), 3.25 (d, $J=14.0$ Hz, 1H), 3.07 (d, $J=14.0$ Hz, 1H); $^{13}\text{C-NMR}$ (100 MHz, CDCl_3): δ 170.9, 156.2, 135.1, 132.9, 132.8, 130.4, 129.9, 129.7, 128.8, 127.9, 123.0, 91.1, 75.6, 49.2, 42.5; **HRMS (ESI+)**: Calcd for $\text{C}_{19}\text{H}_{16}\text{ClNNaO}_4$ ($[\text{M}+\text{Na}]^+$): 380.0666, Found: 380.0669; **Optical rotation**: $[\alpha]_{\text{D}}^{23} +62.7$ (c 1.0 CHCl_3) for an enantiomerically enriched sample of 96%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak ID column (95:5 *n*-Hexane/EtOH, 1.5 mL/min, 20 °C, 210 nm, $\tau_{\text{minor}} = 20.2$ min, $\tau_{\text{major}} = 21.9$ min). See Supporting Information: Part B for HPLC chromatograms.

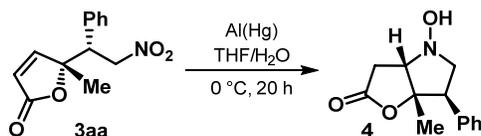


Compound 3ge: White powder, 98% yield; eluent for column chromatography: 1/4 EtOAc/pet ether; **m.p.** 205-206 °C; **FT-IR (KBr)**: 3106 (w), 2922 (m), 1752 (s), 1590 (m), 1547 (m), 1379 (m), 1181 (m), 1115 (m); $^1\text{H-NMR}$ (400 MHz, CDCl_3): δ 7.46 (d, $J=8.3$ Hz, 2H), 7.28-7.22 (m, 3H), 7.10 (d, $J=5.7$ Hz, 1H), 7.07-7.04 (m, 4H), 5.69 (d, $J=5.7$ Hz, 1H), 4.98 (dd, $J=13.4, 4.6$ Hz, 1H), 4.81 (dd, $J=13.4, 10.5$ Hz; 1H), 4.10 (dd, $J=10.5, 4.6$ Hz, 1H), 3.24 (d, $J=13.9$ Hz; 1H), 3.06 (d, $J=13.9$ Hz, 1H); $^{13}\text{C-NMR}$ (100 MHz, CDCl_3): δ 170.9, 156.2, 133.4, 132.8, 132.6, 130.3, 130.2, 128.8, 127.9, 123.2, 123.0, 90.0, 75.5, 49.3, 42.5; **HRMS (ESI+)**: Calcd for $\text{C}_{19}\text{H}_{16}\text{BrNNaO}_4$ ($[\text{M}+\text{Na}]^+$): 424.0160, Found: 424.0160; **Optical rotation**: $[\alpha]_{\text{D}}^{23} +59.5$ (c 1.0, CHCl_3) for an enantiomerically enriched sample of 95%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak AD-H column (90:10 *n*-Hexane/EtOH, 1.5 mL/min, 20 °C, 210 nm, $\tau_{\text{minor}} = 28.1$ min, $\tau_{\text{major}} = 29.7$ min). See Supporting Information: Part B for HPLC chromatograms.

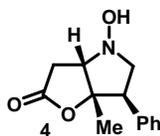


Compound 3gl: White powder, 99% yield; eluent for column chromatography: 1/4 EtOAc/pet ether; **m.p.** 147-148 °C; **FT-IR (KBr)**: 3102 (w), 2927 (m), 2855 (w), 1756 (s), 1587 (m), 1554 (s), 1475 (m), 1380 (m), 1184 (m); $^1\text{H-NMR}$ (400 MHz, CDCl_3): δ 7.37 (d, $J=1.5$ Hz, 1H), 7.31-7.26 (m, 3H), 7.21-7.19 (m, 3H), 7.12 (d, $J=6.5$ Hz, 2H), 5.57 (d, $J=5.7$ Hz, 1H), 5.14 (dd, $J=13.6, 4.4$ Hz, 1H), 4.98 (dd, $J=13.6, 10.5$ Hz, 1H), 4.83 (dd, $J=10.5, 4.4$ Hz, 1H), 3.32 (d, $J=13.9$ Hz, 1H), 3.20 (d, $J=13.9$ Hz, 1H); $^{13}\text{C-NMR}$ (100 MHz, CDCl_3): δ 171.0, 156.0, 135.3, 135.2, 132.9, 131.0, 130.2, 128.9, 128.6, 128.2, 127.9, 122.8, 90.2, 75.2, 43.6, 42.2; **HRMS (ESI+)**: Calcd for $\text{C}_{19}\text{H}_{15}\text{Cl}_2\text{NNaO}_4$ ($[\text{M}+\text{Na}]^+$): 414.0276, Found: 414.0275; **Optical rotation**: $[\alpha]_{\text{D}}^{23} +63.0$ (c 2.0, CHCl_3) for an enantiomerically enriched sample of 98%. The enantiomeric ratio was determined by HPLC with a Daicel Chiralpak AD-H column (90:10 *n*-Hexane/EtOH, 1.5 mL/min, 20 °C, 210 nm, $\tau_{\text{major}} = 11.8$ min, $\tau_{\text{minor}} = 12.9$ min). See Supporting Information: Part B for HPLC chromatograms.



Procedure for the reductive aza-Michael cyclization of compound 3aa:

In a 25 ml round-bottom flask, compound **3aa** (62 mg, 0.251 mmol) was taken with 11 mL of THF-H₂O (20:1) and the resulting mixture was cooled to 0 °C. Aluminium foil (135 mg, 5.015 mmol) was cut into small pieces, washed with diethyl ether and dipped into 2% aqueous HgCl₂ and again washed with methanol and diethyl ether. The resulting aluminium amalgam was added to the above solution at 0 °C and the resulting mixture allowed to stir vigorously at the same temperature for 20 h. Reaction mixture was then filtered through celite pad, washed with 1:1 THF and methanol. The filtrate was concentrated under reduced pressure to obtain a pale yellow residue. Purification by column chromatography on silica gel (100-200 mesh) afforded compound **4** (43 mg, 0.18 mmol, 73%).



FT-IR (KBr): 3401 (br), 2928 (w), 1775 (s), 1454 (w), 1242 (m), 1147 (w), 1098 (w); **¹H-NMR (400 MHz, CDCl₃):** δ 7.37-7.22 (m, 5H), 6.41 (br s, 1H), 3.69 (dd, *J* = 12.1, 6.6 Hz, 1H), 3.63-3.59 (m, 1H), 3.40 (d, *J* = 6.6 Hz, 1H), 3.33 (dd, *J* = 12.1, 9.5 Hz, 1H), 2.91-2.78 (m, 2H), 1.02 (s, 3H); **¹³C-NMR (100 MHz, CDCl₃):** δ 175.6, 135.9, 128.8, 128.7, 127.7, 92.2, 72.9, 60.4, 51.2, 34.4, 22.7; **HRMS (ESI+):** Calcd for C₁₃H₁₅NNaO₃ ([M+Na]⁺): 256.0950, Found: 256.0950; **Optical rotation:** [α]_D²³ -31.3 (*c* 2.0, CHCl₃).

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Single crystal X-ray diffraction analysis of **3aa**:

A single crystal of **3aa** was mounted and the diffraction data were collected at 296 K on a Bruker SMART APEX CCD diffractometer using SMART/SAINT software. Intensity data were collected using graphite-monochromatized Mo-K α radiation (0.71073 Å) at 296 K. The structures were solved by direct methods using the SHELX-97 and refined by full-matrix least-squares on F^2 . Empirical absorption corrections were applied with SADABS. All Non-hydrogen atoms were refined anisotropically, and hydrogen atoms were included in geometric positions. Structure was drawn using ORTEP-3. The crystallographic refinement parameters are given below:

Crystal data and structure refinement for **3aa**

Identification code	3aa	
Empirical formula	C ₁₃ H ₁₃ NO ₄	
Formula weight	247.24	
Temperature	296(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group	C2	
Unit cell dimensions	a = 14.8379(12) Å	$\alpha = 90^\circ$
	b = 6.4738(6) Å	$\beta = 98.932(6)^\circ$
	c = 13.3730(11) Å	$\gamma = 90^\circ$
Volume	1269.00(19) Å ³	
Z	4	
Density (calculated)	1.294 Mg/m ³	
Absorption coefficient	0.097 mm ⁻¹	
F(000)	520	
Crystal size	0.42 x 0.12 x 0.11 mm ³	
Theta range for data collection	1.54 to 25.50°	

Index ranges	$-17 \leq h \leq 17, -7 \leq k \leq 7, -16 \leq l \leq 16$
Reflections collected	19698
Independent reflections	2360 [$R_{\text{int}} = 0.0401$]
Completeness to $\Theta = 25.50^\circ$	100.0 %
Absorption correction	Empirical
Max. and min. transmission	0.989 and 0.986
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	2360 / 1 / 169
Goodness-of-fit on F^2	1.044
Final R indices [$I > 2\sigma(I)$]	$R1 = 0.0416, \omega R2 = 0.0918$
R indices (all data)	$R1 = 0.0668, \omega R2 = 0.1013$
Absolute structure parameter	0.6(5)
Extinction coefficient	0.011(2)
Largest diff. peak and hole	0.127 and $-0.127 \text{ e.}\text{\AA}^{-3}$

Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for 3aa. $U(\text{eq})$ is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	$U(\text{eq})$
O(1)	3491(2)	13055(4)	2553(3)	86(1)
O(2)	2951(1)	10275(3)	1663(2)	52(1)
C(2)	4052(2)	9657(5)	3022(3)	52(1)
O(4)	697(3)	4307(8)	1268(3)	119(1)
C(4)	3083(2)	8050(4)	1753(2)	41(1)
C(1)	3506(2)	11213(5)	2437(3)	54(1)
C(5)	2162(2)	7047(5)	1907(2)	47(1)
C(8)	1845(2)	7691(5)	2886(2)	47(1)
C(9)	1928(2)	6280(6)	3676(3)	66(1)
C(10)	1630(3)	6758(10)	4578(3)	90(1)
C(11)	1235(3)	8595(10)	4691(3)	91(2)
C(3)	3797(2)	7842(5)	2653(2)	47(1)
C(6)	1432(2)	7426(7)	1001(2)	65(1)
N(1)	597(2)	6176(9)	1135(2)	85(1)
O(3)	-105(2)	7080(8)	1101(2)	115(1)
C(12)	1146(3)	10037(8)	3927(4)	87(1)
C(13)	1449(2)	9574(6)	3010(3)	67(1)

C(7) 3419(2) 7246(6) 808(3) 63(1)

Bond lengths [Å] and angles [°] for 3aa

O(1)-C(1)	1.203(4)
O(2)-C(1)	1.361(4)
O(2)-C(4)	1.457(4)
C(2)-C(3)	1.308(4)
C(2)-C(1)	1.445(5)
C(2)-H(1)	0.96(4)
O(4)-N(1)	1.229(6)
C(4)-C(3)	1.481(4)
C(4)-C(7)	1.520(4)
C(4)-C(5)	1.555(3)
C(5)-C(6)	1.515(4)
C(5)-C(8)	1.517(4)
C(5)-H(2)	0.9800
C(8)-C(13)	1.374(5)
C(8)-C(9)	1.388(5)
C(9)-C(10)	1.382(6)
C(9)-H(4)	0.9300
C(10)-C(11)	1.345(8)
C(10)-H(5)	0.9300
C(11)-C(12)	1.375(8)
C(11)-H(6)	0.9300
C(3)-H(7)	0.9300
C(6)-N(1)	1.514(5)
C(6)-H(8A)	0.9700
C(6)-H(8B)	0.9700
N(1)-O(3)	1.189(6)
C(12)-C(13)	1.403(6)
C(12)-H(11)	0.9300
C(13)-H(12)	0.9300
C(7)-H(13A)	0.9600
C(7)-H(13B)	0.9600
C(7)-H(13C)	0.9600

C(1)-O(2)-C(4)	108.7(2)
C(3)-C(2)-C(1)	108.5(3)
C(3)-C(2)-H(1)	131(2)
C(1)-C(2)-H(1)	121(2)
O(2)-C(4)-C(3)	103.1(2)
O(2)-C(4)-C(7)	109.2(2)
C(3)-C(4)-C(7)	111.1(2)
O(2)-C(4)-C(5)	108.3(2)
C(3)-C(4)-C(5)	112.7(2)
C(7)-C(4)-C(5)	112.0(2)
O(1)-C(1)-O(2)	121.3(3)
O(1)-C(1)-C(2)	129.9(3)
O(2)-C(1)-C(2)	108.8(2)
C(6)-C(5)-C(8)	111.5(2)
C(6)-C(5)-C(4)	111.1(2)
C(8)-C(5)-C(4)	113.4(2)
C(6)-C(5)-H(2)	106.8
C(8)-C(5)-H(2)	106.8
C(4)-C(5)-H(2)	106.8
C(13)-C(8)-C(9)	118.8(3)
C(13)-C(8)-C(5)	122.9(3)
C(9)-C(8)-C(5)	118.2(3)
C(10)-C(9)-C(8)	121.0(4)
C(10)-C(9)-H(4)	119.5
C(8)-C(9)-H(4)	119.5
C(11)-C(10)-C(9)	120.0(4)
C(11)-C(10)-H(5)	120.0
C(9)-C(10)-H(5)	120.0
C(10)-C(11)-C(12)	120.7(4)
C(10)-C(11)-H(6)	119.7
C(12)-C(11)-H(6)	119.7
C(2)-C(3)-C(4)	110.7(3)
C(2)-C(3)-H(7)	124.6
C(4)-C(3)-H(7)	124.6
N(1)-C(6)-C(5)	108.4(3)
N(1)-C(6)-H(8A)	110.0

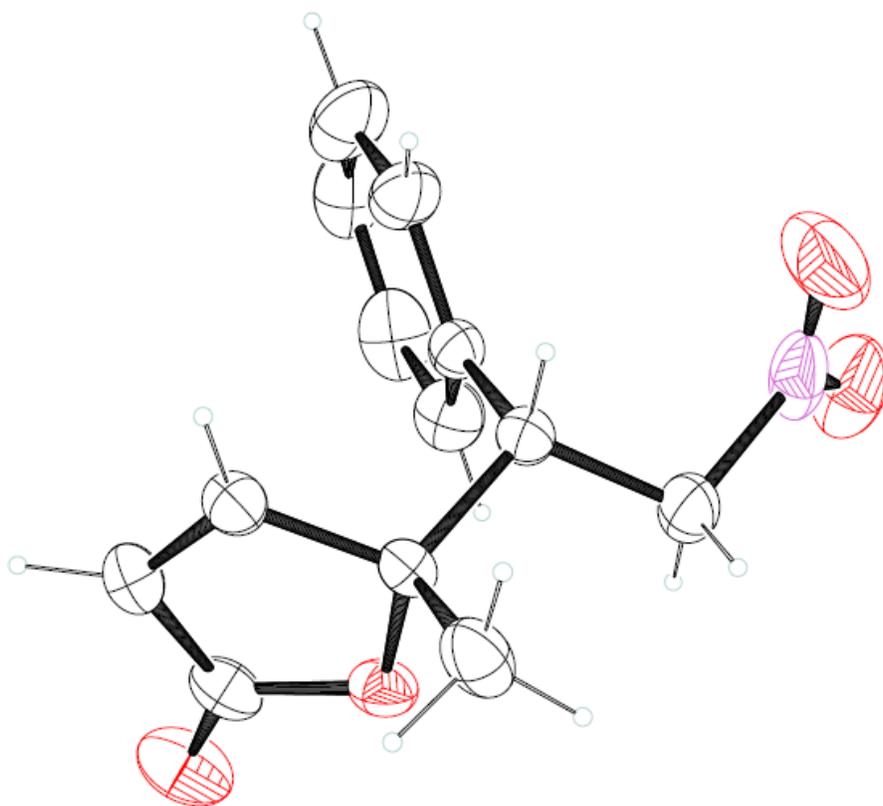
C(5)-C(6)-H(8A)	110.0
N(1)-C(6)-H(8B)	110.0
C(5)-C(6)-H(8B)	110.0
H(8A)-C(6)-H(8B)	108.4
O(3)-N(1)-O(4)	125.1(4)
O(3)-N(1)-C(6)	117.4(5)
O(4)-N(1)-C(6)	117.4(4)
C(11)-C(12)-C(13)	119.8(5)
C(11)-C(12)-H(11)	120.1
C(13)-C(12)-H(11)	120.1
C(8)-C(13)-C(12)	119.7(4)
C(8)-C(13)-H(12)	120.1
C(12)-C(13)-H(12)	120.1
C(4)-C(7)-H(13A)	109.5
C(4)-C(7)-H(13B)	109.5
H(13A)-C(7)-H(13B)	109.5
C(4)-C(7)-H(13C)	109.5
H(13A)-C(7)-H(13C)	109.5
H(13B)-C(7)-H(13C)	109.5

Symmetry transformations used to generate equivalent atoms:

Anisotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for 3aa. The anisotropic displacement factor exponent takes the form: $-2\pi^2 [h^2 a^{*2} U^{11} + \dots + 2 h k a^* b^* U^{12}]$

	U11	U22	U33	U23	U13	U12
O(1)	97(2)	40(2)	128(2)	-6(1)	38(2)	-1(1)
O(2)	48(1)	45(1)	64(1)	13(1)	12(1)	1(1)
C(2)	47(2)	50(2)	58(2)	-10(1)	6(1)	-9(1)
O(4)	99(3)	133(4)	127(3)	-8(3)	22(2)	-61(3)
C(4)	38(1)	40(1)	47(2)	-1(1)	9(1)	-5(1)
C(1)	54(2)	37(2)	74(2)	-5(1)	22(2)	-6(1)
C(5)	42(1)	57(2)	42(1)	1(1)	7(1)	-9(1)
C(8)	40(1)	58(2)	43(2)	2(1)	7(1)	-4(1)
C(9)	60(2)	83(2)	55(2)	12(2)	12(2)	-2(2)

C(10)	78(3)	141(4)	52(2)	16(2)	19(2)	-1(3)
C(11)	66(2)	152(5)	59(2)	-18(3)	24(2)	-12(3)
C(3)	42(1)	42(2)	57(2)	2(1)	6(1)	2(1)
C(6)	42(1)	101(3)	51(2)	8(2)	4(1)	-19(2)
N(1)	43(2)	163(4)	48(2)	-8(2)	6(1)	-25(2)
O(3)	49(2)	219(4)	79(2)	-4(2)	13(1)	-14(2)
C(12)	63(2)	110(3)	91(3)	-32(3)	23(2)	6(2)
C(13)	59(2)	73(2)	72(2)	-2(2)	18(2)	6(2)
C(7)	54(2)	74(2)	64(2)	-17(2)	22(1)	-19(2)



ORTEP representation of the X-ray structure of enantiopure 3aa (thermal ellipsoids at 30% probability)

Single crystal X-ray diffraction analysis of **3ab**

A single crystal of **3ab** (recrystallized from 1:1 hexane/EtOAc at 0 °C) was mounted and the diffraction data were collected at 100 K on a Bruker SMART APEX CCD diffractometer using SMART/SAINT software. Intensity data were collected using graphite-monochromatized Mo-K α radiation (71.073 pm) at 100 K. The structures were solved by direct methods using the SHELX-97 and refined by full-matrix least-squares on F^2 . Empirical absorption corrections were applied with SADABS. All Non-hydrogen atoms were refined anisotropically, and hydrogen atoms were included in geometric positions. Structure was drawn using Olex-2 and ORTEP-3. The crystallographic refinement parameters are given below:

Crystal data and structure refinement for **3ab**

Identification code	3ab	
Empirical formula	C ₁₃ H ₁₂ ClNO ₄	
Formula weight	281.69	
Temperature	100(2) K	
Wavelength	71.073 pm	
Crystal system	orthorhombic	
Space group	P2 ₁ 2 ₁ 2 ₁	
Unit cell dimensions	a = 786.64(5) pm	$\alpha = 90^\circ$
	b = 1242.42(9) pm	$\beta = 90^\circ$
	c = 1285.41(9) pm	$\gamma = 90^\circ$
Volume	1.25628(15) nm ³	
Z	4	
Density (calculated)	1.489 Mg/m ³	
Absorption coefficient	0.313 mm ⁻¹	
F(000)	584	
Crystal size	0.45 × 0.15 × 0.12 mm ³	
Θ range for data collection	3.036 to 27.546°	
Index ranges	-10 ≤ h ≤ 10, -16 ≤ k ≤ 16, -16 ≤ l ≤ 16	
Reflections collected	31554	
Independent reflections	2900 [$R_{\text{int}} = 0.0471$]	
Completeness to $\Theta = 25.50^\circ$	99.9 %	
Absorption correction	Empirical	
Max. and min. transmission	0.963 and 0.945	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	2900 / 0 / 173	
Goodness-of-fit on F^2	1.072	

Final R indices [$I > 2\sigma(I)$]	$R1 = 0.0302, \omega R2 = 0.0769$
R indices (all data)	$R1 = 0.0325, \omega R2 = 0.0787$
Absolute structure parameter	0.006(15)
Extinction coefficient	0.012(2)
Largest diff. peak and hole	0.298 and $-0.182 \text{ e.}\text{\AA}^{-3}$

Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement parameters ($\text{pm}^2 \times 10^{-1}$) for 3ab. $U(\text{eq})$ is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	$U(\text{eq})$
Cl(1)	9312(1)	2781(1)	4824(1)	30(1)
O(1)	-1032(2)	3981(1)	294(1)	27(1)
O(2)	1434(2)	3196(1)	722(1)	18(1)
C(10)	4499(3)	4588(2)	893(2)	20(1)
O(4)	4183(2)	4244(1)	-878(1)	30(1)
O(3)	2374(2)	5331(1)	-161(1)	26(1)
C(1)	74(3)	3845(2)	922(2)	20(1)
C(2)	2513(3)	3121(2)	1642(2)	16(1)
C(3)	4342(3)	3438(2)	1306(2)	15(1)
C(4)	5591(3)	3293(2)	2198(2)	16(1)
C(5)	5723(3)	4038(2)	3004(2)	18(1)
C(6)	6854(2)	3885(2)	3820(2)	19(1)
C(7)	7855(3)	2973(2)	3823(2)	20(1)
C(8)	6625(3)	2381(2)	2223(2)	19(1)
C(9)	7752(3)	2212(2)	3037(2)	21(1)
N(1)	3607(2)	4730(1)	-127(1)	19(1)
C(11)	272(3)	4277(2)	1981(2)	21(1)
C(12)	1676(3)	3875(2)	2394(2)	18(1)
C(13)	2444(3)	1959(2)	2033(2)	22(1)

Bond lengths [pm] and angles [°] for 3ab.

Cl(1)-C(7)	173.9(2)
O(1)-C(1)	120.0(3)
O(2)-C(1)	136.4(3)
O(2)-C(2)	145.9(2)
C(10)-N(1)	149.7(3)
C(10)-C(3)	153.0(3)
C(10)-H(10A)	97.00
C(10)-H(10B)	97.00
O(4)-N(1)	122.4(2)
O(3)-N(1)	122.5(2)
C(1)-C(11)	147.1(3)
C(2)-C(12)	149.9(3)
C(2)-C(13)	153.0(3)
C(2)-C(3)	155.2(3)
C(3)-C(4)	152.1(3)
C(3)-H(3)	98.00
C(4)-C(5)	139.4(3)
C(4)-C(8)	139.5(3)
C(5)-C(6)	138.9(3)
C(5)-H(9)	93.00
C(6)-C(7)	138.0(3)
C(6)-H(10)	93.00
C(7)-C(9)	138.6(3)
C(8)-C(9)	138.7(3)
C(8)-H(2)	93.00
C(9)-H(1)	93.00
C(11)-C(12)	132.3(3)
C(11)-H(4)	93.00
C(12)-H(5)	93.00
C(13)-H(6)	96.00
C(13)-H(8)	96.00
C(13)-H(7)	96.00
C(1)-O(2)-C(2)	109.91(15)

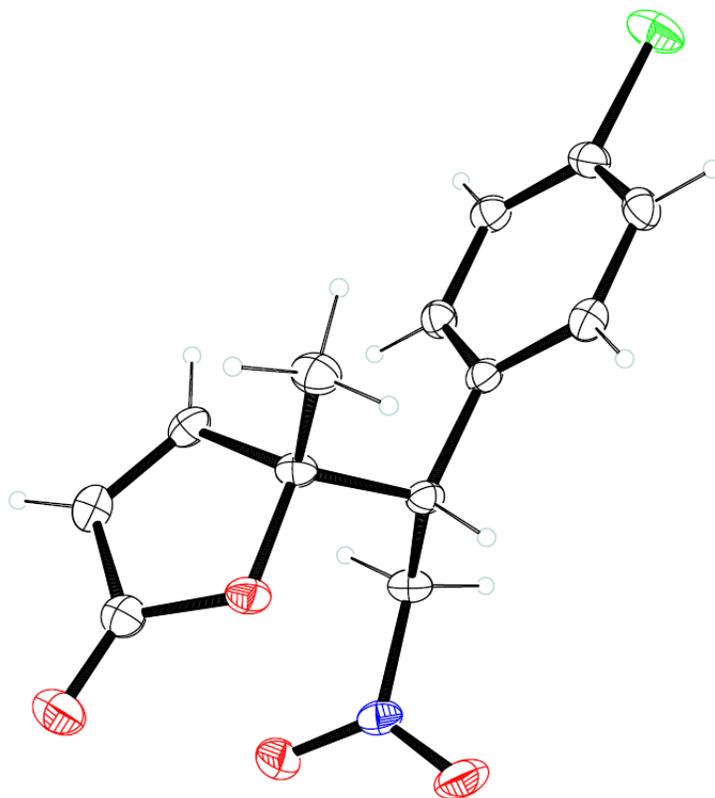
N(1)-C(10)-C(3)	112.08(16)
N(1)-C(10)-H(10A)	109.2
C(3)-C(10)-H(10A)	109.2
N(1)-C(10)-H(10B)	109.2
C(3)-C(10)-H(10B)	109.2
H(10A)-C(10)-H(10B)	107.9
O(1)-C(1)-O(2)	121.7(2)
O(1)-C(1)-C(11)	130.4(2)
O(2)-C(1)-C(11)	107.95(18)
O(2)-C(2)-C(12)	103.13(16)
O(2)-C(2)-C(13)	107.79(15)
C(12)-C(2)-C(13)	111.25(17)
O(2)-C(2)-C(3)	107.32(15)
C(12)-C(2)-C(3)	115.33(16)
C(13)-C(2)-C(3)	111.35(17)
C(4)-C(3)-C(10)	108.71(16)
C(4)-C(3)-C(2)	111.03(15)
C(10)-C(3)-C(2)	114.11(17)
C(4)-C(3)-H(3)	107.6
C(10)-C(3)-H(3)	107.6
C(2)-C(3)-H(3)	107.6
C(5)-C(4)-C(8)	118.65(19)
C(5)-C(4)-C(3)	121.96(18)
C(8)-C(4)-C(3)	119.38(18)
C(6)-C(5)-C(4)	121.17(19)
C(6)-C(5)-H(9)	119.4
C(4)-C(5)-H(9)	119.4
C(7)-C(6)-C(5)	118.73(19)
C(7)-C(6)-H(10)	120.6
C(5)-C(6)-H(10)	120.6
C(6)-C(7)-C(9)	121.65(19)
C(6)-C(7)-Cl(1)	119.36(17)
C(9)-C(7)-Cl(1)	118.98(16)
C(9)-C(8)-C(4)	120.84(19)
C(9)-C(8)-H(2)	119.6
C(4)-C(8)-H(2)	119.6

C(7)-C(9)-C(8)	118.96(19)
C(7)-C(9)-H(1)	120.5
C(8)-C(9)-H(1)	120.5
O(4)-N(1)-O(3)	124.42(19)
O(4)-N(1)-C(10)	117.31(17)
O(3)-N(1)-C(10)	118.25(18)
C(12)-C(11)-C(1)	108.73(19)
C(12)-C(11)-H(4)	125.6
C(1)-C(11)-H(4)	125.6
C(11)-C(12)-C(2)	110.13(19)
C(11)-C(12)-H(5)	124.9
C(2)-C(12)-H(5)	124.9
C(2)-C(13)-H(6)	109.5
C(2)-C(13)-H(8)	109.5
H(6)-C(13)-H(8)	109.5
C(2)-C(13)-H(7)	109.5
H(6)-C(13)-H(7)	109.5
H(8)-C(13)-H(7)	109.5

Symmetry transformations used to generate equivalent atoms:

Anisotropic displacement parameters ($\text{pm}^2 \times 10^{-1}$) for 3ab. The anisotropic displacement factor exponent takes the form: $-2\pi^2 [h^2 a^{*2} U^{11} + \dots + 2 h k a^* b^* U^{12}]$

	U^{11}	U^{22}	U^{33}	U^{23}	U^{13}	U^{12}
Cl(1)	28(1)	29(1)	33(1)	8(1)	-15(1)	-3(1)
O(1)	25(1)	30(1)	27(1)	5(1)	-7(1)	0(1)
O(2)	22(1)	20(1)	14(1)	-2(1)	-4(1)	0(1)
C(10)	24(1)	20(1)	15(1)	3(1)	-2(1)	-1(1)
O(4)	42(1)	32(1)	14(1)	1(1)	5(1)	5(1)
O(3)	25(1)	28(1)	26(1)	8(1)	0(1)	5(1)
C(1)	20(1)	17(1)	22(1)	3(1)	0(1)	-4(1)
C(2)	18(1)	16(1)	13(1)	1(1)	-2(1)	-2(1)
C(3)	19(1)	15(1)	12(1)	-1(1)	0(1)	2(1)
C(4)	16(1)	18(1)	14(1)	2(1)	2(1)	-1(1)
C(5)	17(1)	17(1)	19(1)	1(1)	2(1)	2(1)
C(6)	19(1)	21(1)	16(1)	0(1)	0(1)	-4(1)
C(7)	16(1)	23(1)	20(1)	7(1)	-3(1)	-4(1)
C(8)	20(1)	17(1)	20(1)	-1(1)	4(1)	0(1)
C(9)	17(1)	19(1)	27(1)	6(1)	2(1)	2(1)
N(1)	24(1)	19(1)	16(1)	5(1)	1(1)	-2(1)
C(11)	20(1)	20(1)	23(1)	-2(1)	4(1)	-1(1)
C(12)	21(1)	20(1)	14(1)	-3(1)	3(1)	-4(1)
C(13)	24(1)	19(1)	23(1)	5(1)	-2(1)	-3(1)



ORTEP representation of the X-ray structure of enantiopure 3ab (thermal ellipsoids at 50% probability)