Asymmetric Synthesis of Funtionalized 1,2,3,4-Tetrahydroquinolines

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SUPPORTING INFORMATION

General Methods. Reactions were carried out in oven- or flame-dried glassware under a nitrogen atmosphere, unless otherwise noted. All solvents used were reagent grade. Diethyl ether, hexanes and tetrahydofuran (THF) were freshly distilled from sodium/benzophenone. Dichloromethane and toluene were freshly distilled from calcium hydride. Triethylamine was distilled from calcium hydride and stored over potassium hydroxide. Acetonitrile was dried over silica, distilled from calcium hydride and stored over 4 Å molecular sieves. Pyridine was distilled and stored over potassium hydroxide. Acetic anhydride was azeotroped with toluene, distilled and stored over 4 Å molecular sieves. Anhydrous N,N-dimethylformamide was purchased from Fischer and used without purification. Acetone was dried over 4 Å molecular sieves for 2 hours prior to use. Except as otherwise indicated, all reactions were magnetically stirred and monitored by thin layer chromatography on E. Merck precoated (0.25 mm) silica gel 60 F_{254} plates.

Flash chromatography was conducted by using silica gel 40 (Scientific Adsorbents Incorporated, Microns Flash). Chiral gas chromatographic separations were accomplished using Chirasil *L*-Val on WCOT fused silica (25 m x 0.25 mm, 0.12 μm film thickness) capillary GC column purchased from Chromapack (column A). The settings were as follow: initial temperature, 185 °C; initial time, 25 min; rate, 1 °C/min; final temperature, 190°C; final time, 10 min. Other gas chromatographic (GC) analyses were performed on a HP-ultra-1 crosslinked methyl silicone capillary column (25 m lenght x 0.2 mm i.d) (column B). The settings were as follow: initial temperature, 150 °C; initial time, 10 min; rate, 10 °C/min; final temperature, 250°C; final time, 20 min. Yields, unless otherwise stated, refer to chromatographically and spectroscopically pure compounds. Melting points were determined on a Thomas Hoover uni-melt apparatus and are uncorrected. Infrared (IR) spectra were recorded on a Perkin-Elmer 1600 series FTIR. ^{1}H, ^{19}F and ^{13}C NMR spectra were recorded on a Bruker Aspect 200, 250, 400 or 500 MHz spectrometer. Chemical shift are reported relative to chloroform as standard at δ = 7.26 for ^{1}H and δ = 77.0 for ^{13}C. Coupling constants are reported in Hertz (Hz). Optical rotations were measured on a Perkin-Elmer 241 MC polarimeter. High-resolution mass spectra for **13**, **17**, **18** and **19** were recorded on a Kratos VG 70-250s at a ionization energy of 70 eV and for **12c** on the Micromas QTOF Electrospray mass spectrometer. Compounds for which exact mass is reported exhibited no significant *m/z* greater than the one of the parent peak. Microanalyses were performed by Atlantic Microlab, Inc.

4-Iodo-3-nitroanisole (5). A mixture of 4-methoxy-2-nitroaniline (10.0 g, 60 mmol) and concentrated hydrochloric acid (15 mL, 180 mmol, 3 equiv.) in 15 mL of water was heated to reflux for 15 minutes, then cooled to 0°C in an ice-salt bath. A cold solution of sodium nitrite (5.0 g, 72 mmol, 1.2 equiv.) in 15 mL of water was added dropwise over 30 minutes. The solution was stirred at 0°C for 30 minutes and then added dropwise to a cold solution of potassium iodide (14.5 g, 90 mmol, 1.5 equiv.) in 15 mL of water. The mixture was heated to reflux for 2 hours, taken in ethyl acetate (100 mL), washed with HCl 3 N (54 mL) and with dilute NaOH containing a small amount of sodium sulfite (2 x 20 mL), dried on $MgSO_4$ and concentrated to form a dark brown product. Purification by flash chromatography (SiO_2, eluent: hexane / ethyl acetate 5/1) gave a yellow crystalline product in 88% yield. m.p. 61-62°C; ^{1}H NMR ($CDCl_3$, 250 MHz): δ 7.86 (d, J = 8.8, 1 H), 7.40 (d, J = 2.9, 1 H), 6.86 (dd, J = 8.8, 2.9, 1 H), 3.86, (s, 3 H); ^{13}C NMR ($CDCl_3$, 63 MHz): δ 159.6, 142.0, 120.3, 110.9, 74.3, 55.9; IR (KBr): 1537, 1353, 1275 cm^{-1}.

Methyl 2-acetamido acrylate. A mixture of DL-serine methyl ester hydrochloride (13.52 g, 86.9 mmol), diisopropylethylamine (44.2 mL) and acetic anhydride (88.4 mL) were heated to reflux for 2 hours. The volatiles were distilled off under high vacuum and the residue was taken up in ether (500 mL) and washed with 1 N HCl (100 mL). Saturated aqueous sodium bicarbonate was added and the mixture was

stirred for 1 h. The ether layer was washed with water (50 mL) and was dried over magnesium sulfate. The solvent was removed at reduced pressure and the red residue was distilled at 90°C under 0.4 torr to afford 5 g of a mixture methyl-2-N-acetylamino acrylate and methyl-2-N,N'-diacetylamino acrylate. This mixture was taken in 25 mL of asolute methanol and was stirred with 1 equiv. of solid sodium bicarbonate overnight. Filtration and evaporation of the solvent afforded 5.1 g of the monoacetylated compound (38% yield). ^{1}H NMR ($CDCl_3$, 250 MHz): δ 7.85 (s, 1 H), 6.65 (s, 1 H), 5.90 (s, 1 H), 3.85 (s, 3 H), 2.15 (s, 3 H); ^{13}C NMR ($CDCl_3$, 63 MHz): δ 168.9, 130.9, 108.7, 52.9, 24.5; IR: 3406, 1721, 1692 cm^{-1}.

2-N-Acetyl-2-amino-3-(4-methoxy-2-nitrophenyl)acrylic acid methyl ester (7). *Via Heck reaction.* A mixture of 4-iodo-3-nitroanisole (500 mg, 1.79 mmol), methyl 2-acetamido acrylate (305 mg, 2.13 mmol, 1.2 equiv.), palladium acetate (46 mg, 0.20 mmol, 11.5 mol%), tetrabutyl ammonium chloride hydrate (587 mg, 2.15 mmol, 1.2 equiv.) and sodium bicarbonate (407 mg, 4.84 mmol, 2.7 equiv.) was flushed with nitrogen and heated in a sealed tube at 80°C. After 24 h of reaction, the tube was cooled to room temperature and the reaction mixture taken in 50 mL of dichloromethane and washed three times with 10 mL of water. The combined organic layers were dried on $MgSO_4$ and the solvent was removed by concentration under vacuum (no heat). The oily residue was purified by flash chromatography (SiO_2, eluent: hexane / ethyl acetate 2/1). The yellow product was a mixture of the *Z* and *E* isomers (84% yield, 86% *Z* and 14% *E*). The

isomers were separated by flash chromatography (SiO_2, eluent: hexane / ethyl acetate 3/1). ***Z* isomer**: m.p. 134-136°C; ^{1}H NMR ($CDCl_3$, 250 MHz): δ 7.65 (s, 1 H), 7.60 (d, J = 2.6, 1 H), 7.45 (s, 1 H), 7.35 (d, J = 8.6, 1 H), 7.10 (dd, J = 8.7, 2.6, 1 H), 3.88 (s, 3 H), 3.87 (s, 3 H), 1.97 (s, 3 H); ^{13}C NMR ($CDCl_3$, 63 MHz): δ 167.8, 165.1, 159.8, 148.1, 130.7, 125.0, 119.9, 109.2, 55.8, 52.9, 23.3; IR: 1698, 1531, 1348 cm^{-1}; Anal. found (calcd): C 52.96, (53.06); H 4.76, (4.80); N 9.50, (9.52); GC (column B: 200/5/5/220/25): t_R 16.8 min. ***E* isomer**: m.p. 113-115°C; ^{1}H NMR ($CDCl_3$, 250 MHz): δ 8.33 (s, 1 H), 7.70 (s, 1 H), 7.60 (d, J = 2.6, 1 H), 7.21 (d, J = 8.6, 1 H), 7.11 (dd, J = 8.6, 2.6, 1 H), 3.90 (s, 3 H), 3.55 (s, 3 H), 2.18 (s, 3 H); ^{13}C NMR ($CDCl_3$, 63 MHz): δ 168.7, 164.1, 159.0, 147.5, 132.1, 125.5, 124.1, 123.1, 119.3, 108.5, 55.7, 52.3, 26.4; IR: 1686, 1527, 1349 cm^{-1}; HRMS calcd for $C_{13}H_{14}N_2O_6$: $M^{\bullet+}$ = 294.0852, found 294.0866; GC (column B: 200/5/5/220/25): t_R 17.0 min.

(*S*)-2-N-acetyl-2-amino-3-(4-methoxy-2-nitrophenyl) propionic acid methyl ester (10a). In an inert atmosphere drybox, a Fisher-Porter apparatus was charged with (*Z*)-2-N-acetyl-2-amino-3-(4-methoxy-2-nitrophenyl) acrylic acid methyl ester (530 mg, 1.8 mmol), phenyl-[(4,6-*O*-benzylidene-2,3-*bis*-*O*-[(3,5-dimethylphenyl)phosphinol]-β-D-glucopyranoside)Rh(COD)]$^+$$SbF_6^-$ (5 mg, 0.004 mmol, 0.2 mol%)[10] and THF (8 mL). After sealing, the tube was removed from the drybox and placed behind proper shielding. With adequate stirring of the solution at room temperature, the tube was charged with 45 psi of H_2 gas and subsequently evacuated. This procedure was repeated twice. The tube

was charged with 45 psi of H_2 and recharged as necessary to maintain 45 psi. After 15 minutes, the tube was vented and the solution concentrated to give an orange oil that was purified by chromatography (SiO_2, hexane / ethyl acetate 1/2) to give a yellow solid in 98% yield. m.p. 109-111°C; ^{1}H NMR ($CDCl_3$, 250 MHz): δ 7.40 (d, J = 2.6, 1 H), 7.25 (d, J = 8.7, 1 H), 7.05 (dd, J = 8.6, 2.6, 1 H), 6.50 (d, J = 7.9, 1 H), 4.85 (dd, J = 13.8, 8.0, 1 H), 3.82 (s, 3 H), 3.65 (s, 3 H), 3.30 (ddd, J = 55.5, 13.9, 5.9, 2 H), 1.90 (s, 3 H); ^{13}C NMR ($CDCl_3$, 63 MHz): δ 171.9, 169.9, 158.8, 150.0, 133.5, 123.2, 119.6, 109.5, 55.7, 52.8, 52.4, 34.1, 22.8; IR: 1740, 1676, 1532 cm^{-1}; $[\alpha]_D^{21}$ +47° (*c* 2, $CHCl_3$); Anal. found (calcd): C 52.61, (52.70); H 5.44, (5.44); N 9.46, (9.76); GC (column B: 200/5/5/220/25): t_R 15.0 min; GC (column A: 190/30): t_R 22.9 min (0.6% R), t_R 25.2 min (99.4% S), 98.8 %ee. The product was recrystallized from ethyl acetate / petroleum ether 95/5; GC (column A: 190/30): t_R 22.9 min (0.2% R), t_R 25.2 min (99.8% S), 99.6 %ee.

(*R*)-2-N-acetyl-2-amino-3-(4-methoxy-2-nitrophenyl) propionic acid methyl ester. In an inert atmosphere drybox, a Fisher-Porter apparatus was charged with (*Z*)-2-N-acetyl-2-amino-3-(4-methoxy-2-nitrophenyl) acrylic acid methyl ester (46 mg, 0.15 mmol), [(methyl-2,6-di-*O*-benzoyl-3,4-bis-*O*-[bis-(3,5-dimethylphenyl)phosphino]-α-D-glucopyranoside)Rh(COD)]$^+SbF_6^-$ (0.5 mg, 0.003 mmol, 0.24 mol%)[10] and THF (1 mL). After sealing, the tube is removed from the drybox and placed behind proper shielding. With adequate stirring of the solution at room temperature, the tube was charged with 45 psi of H_2 gas and was subsequently evacuated. This procedure was repeated twice. The

tube was charged with 45 psi of H_2 and recharged as necessary to maintain 45 psi. After 15 minutes, the tube was vented and the solution concentrated to give an orange oil that was purified by chromatography (SiO_2, hexane / ethyl acetate 1/2) to give 46 mg of a yellow solid (99% yield). m.p. 109-111°C; ^{1}H NMR ($CDCl_3$, 250 MHz): δ 7.40 (d, J = 2.6, 1 H), 7.25 (d, J = 8.7, 1 H), 7.05 (dd, J = 8.6, 2.6, 1 H), 6.50 (d, J = 7.9, 1 H), 4.85 (dd, J = 13.8, 8.0, 1 H), 3.82 (s, 3 H), 3.65 (s, 3 H), 3.30 (ddd, J = 55.5, 13.9, 5.9, 2 H), 1.90 (s, 3 H); ^{13}C NMR ($CDCl_3$, 63 MHz): δ 171.9, 169.9, 158.8, 150.0, 133.5, 123.2, 119.6, 109.5, 55.7, 52.8, 52.4, 34.1, 22.8; IR: 1740, 1676, 1532 cm^{-1}; GC (column B: 200/5/5/220/25): t_R 15.0 min. The enantioselectivity as determined by GC analysis (column A, 190°C, 30 min) was 96.6%ee.

(*S*)-2-N-acetyl-2-amino-3-(4-methoxy-2-aminophenyl) propionic acid methyl ester (10b). This compound was prepared in quantitative yield by hydrogenation at rt of **10a** using 5% Pd/C (15 mol%) in THF/MeOH at 40 psi (40 min.). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 6.75 (d, J = 8.5, 1 H), 6.43 (b d, J = 6.0, 1 H), 6.22 (dd + d, 2 H), 4.65 (m, 1 H), 4.10 (b s, 2 H), 3.75 (s, 3 H), 3.68 (s, 3 H), 3.00 (dd, J = 15.4, 4.6, 1 H), 3.82 (dd, J = 14.5, 7.9, 1 H), 2.00 (s, 3 H).

(*S*)-N-(1-hydroxymethyl-2-(4-methoxy-2-nitrophenyl)-ethyl)-acetamide (11a). Super Hydride® (1.5 M in THF, 1.85 mL, 1.85 mmol, 2.2 equiv.), was added to a stirred solution of (*S*)-2-N-acetyl-2-amino-3-(4-methoxy-2-nitrophenyl) propionic acid methyl ester (**10a**, 250 mg, 0.84 mmol) in THF (10 mL) at 0°C. The reaction mixture was stirred at 0°C for 1 hour. The reaction was quenched with water (3 mL) and the aqueous

layer was extracted with CH_2Cl_2 (5 x 20 mL). The organic extracts were combined, washed with water, dried ($MgSO_4$) and concentrated to give an pink oil that was purified by chromatography (SiO_2, ethyl acetate / methanol 20/1) to give 190 mg (87%) of a pale yellow oil that solidified under vacuum. m.p. 105-108°C; ^{1}H NMR ($CDCl_3$, 200 MHz): δ 7.38 (d, J = 2.7, 1 H), 7.32 (d, J = 8.9, 1 H), 7.08 (dd, J = 8.6, 2.7, 1 H), 6.50 (d, J = 8.1, 1 H), 4.20 (m, 1 H), 3.82 (s, 3 H), 3.62 (m, 2 H), 3.05 (ddd, J = 23.0, 13.9, 6.0, 3 H), 1.88 (s, 3 H); ^{13}C NMR ($CDCl_3$, 50 MHz): δ 171.0, 158.6, 150.2, 133.5, 125.0, 119.9, 109.3, 64.3, 55.8, 53.0, 32.9, 23.2; IR: 3430, 1660, 1531, 1442, 1352, 1252 cm^{-1}; $[\alpha]_D^{21}$ -42.5° (*c* 0.8, $CHCl_3$); Anal. found (calcd): C 53.73, (53.64); H 6.01, (6.06); N 10.44, (10.30); GC (column B: 200/5/5/220/25): t_R 9.5 min; GC (column A: 160/10/5/190/20): t_R 11.2 min.

(*S*)-N-(1-methanesulfonyloxymethyl-2-(4-methoxy-2-nitrophenyl)-ethyl)-acetamide (11b). To a mixture of (*S*)-N-(1-hydroxymethyl-2-(4-methoxy-2-nitrophenyl)-ethyl)-acetamide (5 mg, 0.019 mmol), and triethylamine (2.9 μL, 0.020 mmol, 1.1 equiv.) in dichloromethane (1 mL) cooled to 0°C was added dropwise methylenesulfonyl chloride (1.7μL, 0.022 mmol, 1.2 equiv.). The mixture was stirred at 0°C for 30 minutes. The reaction was quenched with saturated solution of ammonium chloride (10 mL), the aqueous layer was washed with diethyl ether (4 x 10 mL), the combined organic layers were washed with brine (5 mL) and water (5 mL), dried ($MgSO_4$)

and concentrated. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.98 (bs, 1 H), 7.47 (d, J = 2.7, 1 H), 7.42 (d, J = 8.6, 1 H), 7.11 (dd, J = 8.6, 2.7, 1 H), 4.30 (dd, J = 12.1, 3.5, 1 H), 4.12 (dd, J = 12.2, 5.8, 1 H), 3.83 (m, 1 H), 3.82 (s, 3 H), 3.38 (dd, J = 8.7, 5.9, 1 H), 3.28 (dd, J = 14.0, 8.8, 1H), 2.71 (s, 3 H), 2.09 (s, 3 H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 171.0, 159.5, 149.8, 134.5, 122.5, 120.4, 110.3, 62.7, 56.0, 51.3, 39.5, 32.6, 20.8.

(*S*)-3-Acetamido-7-methoxy-1-ethoxy-1,2,3,4-tetrahydroquinoline (12c). To a mixture of (*S*)-N-(1-hydroxymethyl-2-(4-methoxy-2-nitrophenyl)-ethyl)-acetamide (10 mg, 0.038 mmol), and triethylamine (5.8 μL, 0.040 mmol, 1.1 equiv.) in dichloromethane (1 mL) cooled to 0°C was added dropwise methylenesulfonyl chloride (3.4μL, 0.044 mmol, 1.2 equiv.). The mixture was stirred at 0°C for 30 minutes. The reaction was quenched with saturated solution of ammonium chloride (10 mL), the aqueous layer was washed with diethyl ether (4 x 10 mL), the combined organic layers were washed with brine (5 mL) and water (5 mL), dried ($MgSO_4$) and concentrated. The crude yellow oil was diluted in absolute ethanol (1 mL) and transferred to a Fisher-Porter tube containing Pd/C (10%, about 10 mol%) in absolute ethanol (1 mL). After sealing, the tube was placed behind proper shielding. With adequate stirring of the solution at room temperature, the tube was charged with 45 psi of H_2 gas and vented. This procedure was repeated twice. The tube was charged with 45 psi of H_2 and recharged as necessary to maintain 45 psi. After 2 hours, the tube was vented and the solution filtrated on silica gel and concentrated to give a colorless oil that purified by preparative column chromatography (eluent: ethyl

acetate) to give 9 mg (90% yield) of a white solid. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 6.85 (d, J = 8.1, 1 H), 6.20 (d, J = 2.1, 1 H), 6.19 (dd, J = 8.1, 2.1, 1 H), 5.75 (bd, J = 5.4, 1 H), 4.44 (m, 1 H), 3.76 (s, 3 H), 3.40 (m, 1 H) overlapping 3.39 (dd, J = 10.0, 1.6, 1 H), 3.20 (hex, J = 7.2, 1 H), 3.09 (dt, J = 11.5, 2.6, 1 H), 2.95 (dd, J = 17.4, 4.5, 1 H), 2.62 (m, 1 H), 1.90 (s, 3 H), 1.11 (t, J = 7.0, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 168.6, 158.6, 144.0, 129.9, 110.5, 99.9, 96.7, 54.2, 50.7, 44.3, 41.0, 31.7, 22.5, 9.6; HRMS calcd for $C_{14}H_{20}N_2O_3$: $M^{\bullet+}$ = 264.1474, found 264.1438.

(*S*)-3-Acetamido-7-methoxy-1-(4-toluenesulfonyl)-1,2,3,4-tetrahydroquinoline (12b). *Synthesis of the intermediate: (S)-3-Acetamido-7-methoxy-1,2,3,4-tetrahydro-quinoline (12a).* To a mixture of (*S*)-N-(1-hydroxymethyl-2-(4-methoxy-2-nitrophenyl)-ethyl)-acetamide (100 mg, 0.37 mmol), and triethylamine (57 μL, 0.41 mmol, 1.1 equiv.) in dichloromethane (1 mL) cooled to 0°C was added dropwise methanesulfonyl chloride (35μL, 0.45 mmol, 1.2 equiv.). The mixture was stirred at 0°C for 30 minutes. The reaction was quenched with saturated solution of ammonium chloride (10 mL), the aqueous layer was washed with diethyl ether (4 x 10 mL), the combined organic layers were washed with brine (5 mL) and water (5 mL), dried ($MgSO_4$) and concentrated. The crude yellow oil was diluted in THF (2 mL) and transferred to a Fisher-Porter tube containing Pd/C (10%, 40 mg, 10 mol%) in THF (1 mL). After sealing, the tube was placed behind proper shielding. With adequate stirring of the solution at room temperature, the tube was charged with 45 psi of H_2 gas and vented. This

procedure was repeated twice. The tube was charged with 45 psi of H_2 and recharged as necessary to maintain 45 psi. After 1 hour, the tube was vented and the solution filtrated on silica gel and concentrated to give a colorless oil that would not even permit purification by preparative column chromatography (eluent: ethyl acetate). The following data has been deciphered from the crude compound obtained. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 6.86 (d, J = 5.1, 1 H), 6.35 (d, J = 6.8, 1 H), 6.24 (dd, J = 10.6, 2.5, 1 H), 6.22 (bd, J = 2.3, 1 H), 4.01 (m, 1 H), 3.73 (s, 3+1 H), 3.56 (m, 1 H), 2.72 (m, 1 H), 2.59 (m, 1 H), 1.98 (s, 3 H), 1.83 (m, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 170.9, 159.5, 146.2, 131.7, 115.1, 104.0, 101.8, 62.3, 55.1, 51.8, 32.1, 23.3.

Crude (*S*)-3-Acetamido-7-methoxy-1,2,3,4-tetrahydroquinoline was diluted in CH_2Cl_2 (2 mL), Et_3N (57 µL, 0.41 mmol, 1.1 equiv.) and TsCl (71 mg, 0.37 mmol, 1.0 equiv.) were added at 0°C. The mixture was stirred at that temperature for 15 minutes, let to warm up at room temperature and stirred overnight. The reaction mixture was taken in 10 mL of water, the organic layer was extracted 5 times with 20 mL of ether, dried over magnesium sulfate and concentrated. The crude compound was purified by column chromatography (SiO_2, eluent: hexane / ethyl acetate 3/1) to give the expected product (12b) in 46% yield (3 steps). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 10.38 (bs, 1H), 7.64 (d, J = 8.3, 2 H), 7.18 (d, J = 7.9, 2 H), 7.00 (d, J = 2.6, 1 H), 6.86 (d, J = 8.4, 1H), 6.56 (dd, J = 8.4, 2.6, 1H), 4.33 (dd, J = 9.6, 8.6, 1 H), 4.08 (qm, J = 8.7, 1 H), 3.78 (dd seen as t, J = 8.6, 1 H), 3.72 (s, 3 H), 2.44 (dd, J = 14.4, 2.6, 1 H), 2.35 (s, 3H), 2.23 (dd, J = 14.3, 8.9, 1 H), 2.02 (s, 3 H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 166.9, 159.2, 143.1,

138.3, 137.5, 131.9, 129.5, 129.2, 126.9, 123.4, 111.2, 109.5, 72.0, 67.6, 55.3, 50.8, 37.2, 21.5, 13.9; IR: 2924, 1734, 1508, 1157 cm^{-1}; $[\alpha]_D^{21}$ -10° (*c* 1.5, $CHCl_3$); HRMS calcd for $C_{19}H_{22}N_2O_4SNa$: $M^{\bullet+}$ = 397.1198, found 397.1183.

(*S*)-3-*tert*-Butoxycarbonyl-7-methoxy-1-(4-toluenesulfonyl)-1,2,3,4-tetrahydroquinoline (13). (*S*)-3-Acetamido-7-methoxy-1-(4-toluenesulfonyl)-1,2,3,4-tetrahydroquinoline (30 mg, 0.080 mmol) and DMAP (2 mg, 0.016mmol, 0.2 equiv.) were dissolved in THF (1 mL). Di-*tert*-butoxy dicarbonate (35 mg, 0.160 mmol, 2 equiv.) was added and the mixture was heated to reflux for 4 hours. After cooling to room temperature, methanol (1ml) and hydrazine (10 µL, 0.320 mmol, 4 equiv.) were added and the mixture was stirred at room temperature for 4 hours. The reaction was poured into dichloromethane and washed with 1 N HCl , $CuSO_4$ and $NaHCO_3$ saturated, dried ($MgSO_4$) and evaporated. The crude was purified by column chromatography (SiO_2, eluent: hexane / ethyl acetate 3/1) to give 9 mg of the pure expected compound (26% yield in 2 steps). ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.68 (d, J = 8.3, 2 H), 7.23 (d, J = 8.1, 2 H), 7.17 (d, J = 2.5, 1 H), 6.97 (d, J = 8.4, 1H), 6.67 (dd, J = 8.4, 2.5, 1H), 5.04 (bs, 1 H), 3.82 (s, 3 H), 3.62 (dd, J = 10.8, 3.3, 1 H), 3.47 (dd overlapping a m, 1 H + 1 H), 2.45 (m, 2 H), 2.42 (s, 3 H), 1.53(s, 9 H); ^{13}C NMR ($CDCl_3$, 75 MHz): δ 193.1, 160.5, 159.0, 143.3, 136.9, 131.5, 129.4, 127.1, 122.2, 111.9, 109.5, 80.3, 61.8, 55.4, 53.3, 31.6, 28.4, 21.5; IR: 3434, 1731, 1509, 1374 cm^{-1}; $[\alpha]_D^{21}$ -2° (*c* 5, $CHCl_3$).

4-Methoxy-2-nitrophenyl nitrile. A mixture of 4-methoxy-2-nitroaniline (166 μL, 200 mg, 1.19 mmol) and concentrated hydrochloric acid (0.30 mL, 3.6 mmol, 3 equiv.) in water (0.30 mL) was heated to reflux for 20 minutes, then cooled to 0°C in an ice-salt bath. A cold solution of sodium nitrite (255 mg, 3.7 mmol, 3.1 equiv.) in water (1 mL) was added dropwise over 15 minutes while stirring. The solution was stirred for 15 minutes and was then added dropwise below the surface of a mechanically stirred cold solution of potassium cyanide (444 mg, 6.8 mmol, 5.7 equiv.) and copper cyanide (306 mg, 3.4 mmol, 2.8 equiv.) in water (2.5 mL). The mixture was heated to reflux for 2 hours, then taken in diethyl ether, washed with a saturated solution of sodium bicarbonate and hydrochloric acid 10%, dried ($MgSO_4$) and concentrated to form dark red crystals in 78% yield; m.p. 129-131°C; ^{1}H NMR ($CDCl_3$, 200 MHz): δ 7.80 (d, J = 8.5, 1 H), 7.78 (d, J = 3.1, 1 H), 7.27 (dd, J = 8.7, 2.5, 1 H), 4.00 (s, 3 H); ^{13}C NMR ($CDCl_3$, 63 MHz): δ 163.3, 136.7, 136.5, 119.7, 115.2, 111.4, 111.1, 56.6; IR: 2231, 1621, 1546, 1503, 1351, 1320, 1286 cm^{-1}; GC (column B: 150/10/10/250/10): t_R 14.3 min.

4-Methoxy-2-nitrobenzaldehyde. A cold (-78°C), magnetically stirred solution of 4-methoxy-2-nitrophenyl nitrile (360 mg, 2 mmol) in toluene (10 ml) and ether (10 ml) was treated with DIBAL (2.7 ml of 1.5 M in toluene, 4 mmol, 2 equiv.) and allowed to warm to 0°C after 30 min. After 20 min at 0°C, the reaction mixture was quenched with methanol (10mL) and triethylamine (14 mL). The intermediate imine was hydrolyzed with silica gel. The mixture was filtered through a short column of silica gel (elution with

5% ethyl acetate in petroleum ether), and the eluate was concentrated in vacuo to provide 365 mg (99%) of the aldehyde as a yellow solid. Another procedure was to add DIBAL (400 μL of a 1.5 M solution in toluene, 0.59 mmol, 1.05 equiv.) to a cold (0°C) solution of 4-methoxy-2-nitrophenyl nitrile (100 mg, 0.56 mmol) in toluene (2 mL) and ether (1 mL). The reaction mixture was stirred at 0°C for 1 hour then quenched with methanol (1 mL) and HCl 1 M (1 mL). The reaction mixture was let to warm to room temperature and more HCl 1 M (10 mL) is added. The mixture was extracted with diethyl ether (4 x 10 mL) and washed with water (10 mL), dried ($MgSO_4$) and concentrated. The crude compound was purified by flash chromatography (SiO_2, eluent: hexane / ethyl acetate 1/1) and gave 86 mg (85%) of yellow crystals. m.p. 84-86°C; ^1H NMR ($CDCl_3$, 200 MHz): δ 10.2 (s, 1 H), 7.90 (d, J = 8.7, 1 H), 7.45 (d, J = 2.5, 1H), 7.15 (dd, J = 9.7, 1.9, 1 H), 3.90 (s, 3 H); ^{13}C NMR ($CDCl_3$, 50 MHz): δ 187.0, 163.7, 151.4, 131.5, 123.2, 118.9, 109.7, 56.5; IR: 1692, 1615, 1537, 1499, 1352, 1244 cm^{-1}; GC (column B: 150/10/10/250/10): t_R 11.2 min.

(*Z*)-2-N-Acetyl-3-(4-methoxy-2-nitrophenyl)acrylic acid methyl ester (7). *Via Wadsworth-Emmons reaction.* To a solution of methyl-2-acetylamino-2-(dimethoxyphosphinyl)-acetate (220 mg, 0.91 mmol)[14] in dichloromethane (1.7 mL) was added DBU (0.13 mL, 132 mg, 0.97 mmol, 1..05 equiv). After 10 minutes, 4-methoxy-2-nitrobenzaldehyde was added. The mixture was stirred at room temperature for 2 h. The solution was then diluted in ethyl acetate (20 mL) and washed with 1 M sulfuric acid (5

mL), dried ($MgSO_4$) and concentrated under vacuum. The residue was filtered through silica gel (eluent: hexane / ethyl acetate 1/1) to remove excess phosphorylglycine ester. The ratio *E/Z* of the product (yield 90 %) was determined by ^{1}H NMR to be 10/90. An attempt was made to isomerize the product in benzene containing thiophenol and AIBN at 80 °C for 4 hours. The resulting product unfortunatly showed a *E/Z* ratio 18/81. ***Z* isomer**: m.p. 134-136°C; ^{1}H NMR ($CDCl_3$, 250 MHz): δ 7.65 (s, 1 H), 7.60 (d, J = 2.6, 1 H), 7.45 (s, 1 H), 7.35 (d, J = 8.6, 1 H), 7.10 (dd, J = 8.7, 2.6, 1 H), 3.88 (s, 3 H), 3.87 (s, 3 H), 1.97 (s, 3 H); ^{13}C NMR ($CDCl_3$, 63 MHz): δ 167.8, 165.1, 159.8, 148.1, 130.7, 125.0, 119.9, 109.2, 55.8, 52.9, 23.3; IR: 1698, 1619, 1531, 1496, 1439, 1348 cm^{-1}; GC (column B: 200/5/5/220/25): t_R 16.8 min. ***E* isomer**: m.p. 113-115°C; ^{1}H NMR ($CDCl_3$, 250 MHz): δ 8.33 (s, 1 H), 7.70 (s, 1 H), 7.60 (d, J = 2.6, 1 H), 7.21 (d, J = 8.6, 1 H), 7.11 (dd, J = 8.6, 2.6, 1 H), 3.90 (s, 3 H), 3.55 (s, 3 H), 2.18 (s, 3 H); ^{13}C NMR ($CDCl_3$, 63 MHz): δ 168.7, 164.1, 159.0, 147.5, 132.1, 125.5, 124.1, 123.1, 119.3, 108.5, 55.7, 52.3, 26.4; IR: 1686, 1619, 1527, 1438, 1349 cm^{-1}; GC (column B: 200/5/5/220/25): t_R 17.0 min.

(*E*)-Methyl 4-methoxy-2-nitrocinnamate (14). A solution of 4-iodo-3-nitroanisole (1.29 g, 4.6 mmol), methyl acrylate (0.51 mL, 5.6 mmol, 1.2 equiv.), triethylamine (0.85 mL, 6.10 mmol, 1.3 equiv.) and palladium acetate (10.3 mg, 46 μmol, 0.01 equiv.) in acetonitrile (3 mL) was stirred at 100 °C in a sealed tube for 48 hours. After cooling, the reaction mixture was stirred with 10% aqueous hydrochloric acid (50

mL). The aqueous solution was then extracted with dichloromethane. The combined organic layers were washed with water, dried (magnesium sulfate) and concentrated. The resulting yellow solid was purified by chromatography (SiO_2, hexanes / ethyl acetate, 10/1 $\rightarrow$ 5/1) to give 1.05 g (96%) of a bright yellow solid. An analytical sample was obtained by recrystallization from 95% ethanol. m. p. 87-88 °C; ^{1}H NMR ($CDCl_3$, 250 MHz): δ 8.05 (d, J = 15.7, 1 H), 7.58 (d, J = 8.7, 1 H), 7.51 (d, J = 2.6, 1 H), 7.17 (dd, J = 8.7, 2.7, 1 H), 6.31 (d, J = 15.8, 1 H), 3.91 (s, 3 H), 3.82 (s, 3 H); ^{13}C NMR ($CDCl_3$, 62.9 MHz): δ 166.4, 160.9, 139.4, 129.9, 122.4, 121.0, 119.9, 109.4, 56.0, 51.8; IR: 1722, 1530, 1348 cm^{-1}; Anal. found (calcd): C, 55.64 (55.70); H, 4.65 (4.67); N, 5.91 (5.90).

(E)-4-Methoxy-2-nitrocinnamyl alcohol (15). At 0 °C, to a solution of (E)-methyl 4-methoxy-2-nitrocinnamate (7.34 g, 30.9 mmol) in dry toluene, was added, dropwise and over 30 minutes, a solution of DIBAL (46 mL of a 1.5 M solution in toluene, 69 mmol, 2.2 equiv.). After stirring for an additional 30 minutes at 0 °C, the reaction was quenched with methanol (30 mL) and 1 N HCl (30 mL). The solution was allowed to warm up to room temperature and an additional 300 mL of 1 N HCl was added. The reaction mixture was extracted with ethyl acetate and the combined organic extracts were washed with brine, dried (magnesium sulfate) and concentrated. The crude product was purified by chromatography (SiO_2, hexanes / ethyl acetate, 3/1) to give 4.84 g (75%) of a yellow solid. An analytical sample was obtained by recrystallization from

ethyl acetate/petroleum ether. m. p. 65-66 °C; ^{1}H NMR: ($CDCl_3$, 250 MHz): δ 7.50 (d, J = 8.7, 1 H), 7.40 (d, J = 2.7, 1 H), 7.10 (dd, J = 8.7, 2.7, 1 H), 6.99 (d, J = 15.7, 1 H), 6.23 (dt, J = 15.8, 5.5, 1 H), 4.35-4.31 (m, 2 H), 3.86 (s, 3 H); ^{13}C NMR ($CDCl_3$, 62.9 MHz): δ 159.1, 148.3, 132.3, 129.6, 125.7, 124.9, 120.0, 108.7, 63.3, 55.8; IR: 3340, 1526, 1348 cm^{-1}; Anal. found (calcd): C, 57.45 (57.41); H, 5.26 (5.30); N, 6.69 (6.70). GC analysis showed several peaks, with one major at 18.9 min. After derivation with bis(trimethylsilylacetamide), GC analysis showed one peak at 20.5 min.

(2*S*, 3*S*)-3-(4-Methoxy-2-nitrophenyl)-2,3-epoxypropanol (16). To a solution of (*E*)-4-methoxy-2-nitrocinnamyl alcohol (104 mg, 0.50 mmol) and a suspension of powdered, activated 4 Å molecular sieves (150 mg) in dry dichloromethane (2 mL) at -20 °C was added (*L*)-(+)-diethyl tartrate (12 μL, 0.07 mmol, 0.14 equiv.) followed by Ti(O*i*-Pr)$_4$ (14 μL, 0.047 mmol, 9.5 mol%). After 15 minutes, the solution was cooled to -30 °C and a solution of t-BuOOH (200 μL of a 5 M solution in decane, 1 mmol, 2 equiv.) was added. After stirring for 30 minutes at -40 °C, the solution was allowed to warm up to -30 °C. After 6 days, a solution of triethanolamine (14 mg) in dichloromethane (1 mL) was added and the solution was stirred for 30 minutes at 0 °C. The solution was filtered through a pad of silica gel and concentrated. The resulting yellow oil was purified by chromatography (SiO_2, hexanes / ethyl acetate, 5/1) to give 89.1 mg of a mixture of epoxide and starting material. The ratio was determined by ^{1}H NMR to be 85% of the

epoxy alcohol and 15% of the allylic alcohol. The enantiomeric excess was determined as higher than 90% by conversion of the epoxide into the corresponding Mosher ester.

Synthesis of the corresponding Mosher ester: Oxalyl chloride (2 mL, 22 mmol, 419 equiv) was added to a solution of (*R*)-(+)-MTPA (12.8 mg, 0.05 mmol, 1 equiv) and DMF (4.2 μL, 0.05 mmol, 1 equiv) in hexane (2.4 mL) at room temperature. A white precipitate formed immediately. After one hour, the mixture was filtered and concentrated (water aspirator). A solution of (2*S*, 3*S*)-3-(4-Methoxy-2-nitrophenyl)-2,3-epoxypropanol (11 mg, 0.05 mmol), triethylamine (10 μL, 0.07 mmol, 1.4 equiv.) and DMAP (catalytic amount) in $CDCl_3$ (1 mL) was added to the residue and the solution was stirred overnight. ^{19}F NMR of the crude shows the OCF_3 peak due to the major isomer at δ -72.873 and the minor isomer at δ -72.911. Since there is some overlap between the peaks, the ee was estimated by determination of areas under the peaks. The selectivity was greater than >90% ee. The absolute configuration was tentatively assigned by comparison with those from other Sharpless epoxidation of cinnamyl alcohols.[19]

Racemic series, (2*S, 3*S**)-3-(4-Methoxy-2-nitrophenyl)-2,3-epoxypropanol (*rac*-16).** A solution of m-CPBA (131 mg, 70% by weight, 0.52 mmol, 1.1 equiv.) in dichloromethane (2 mL) was added to a cold solution (0 °C) of (*E*)-4-methoxy-2-nitrocinnamyl alcohol (99 mg, 0.47 mmol, 1 equiv.) and Na_2CO_3 (58 mg, 0.55 mmol, 1.5

equiv.) in dichloromethane (2 mL). The reaction was allowed to warm up to room temperature. After 5 hours, water (2 mL) was added. The layers were separated, and the aqueous phase was extracted with dichloromethane (emulsions have a tendency to form), dried (magnesium sulfate) and concentrated to give a yellow solid that was purified by chromatography (SiO_2, hexanes / ethyl acetate, 5/1) to give 120 mg (97%) of a pale yellow solid. An analytical sample was obtained by recrystallization from ethyl acetate / petroleum ether. m. p. 110-111 °C; ^{1}H NMR ($CDCl_3$, 250 MHz): δ 7.65 (d, J = 2.4, 1 H), 7.51 (d, J = 8.6, 1 H), 7.19 (dd, J = 8.6, 2.4, 1 H), 4.38 (d, J = 1.1, 1 H), 3.97 (dd, J = 12.7, 2.6, 1 H), 3.88 (s, 3 H overlapping 1 H), 3.05 (d, J = 1.3, 1 H), 2.03-1.98 (m, 1 H); ^{13}C NMR ($CDCl_3$, 62.9 Mhz): δ 159.4, 148.0, 128.2, 125.8, 120.8, 109.2, 61.8, 61.5, 55.9, 54.1; IR: 3249, 1533, 1348 cm^{-1}; Anal. found (calcd): C, 53.40 (53.33); H, 4.93 (4.92); N, 6.17 (6.22).

Synthesis of the corresponding Mosher ester: At 0 °C, to a solution of (2*S**, 3*S**)-3-(4-methoxy-2-nitrophenyl)-2,3-epoxypropanol and (*E*)-4-methoxy-2-nitrocinnamyl alcohol (52 mg, 0.21 mmol) in CH_2Cl_2 (3 mL) was sequentially added pyridine (24 μL, 0.29 mmol,1.4 equiv.), DMAP (catalytic amount) and (*R*)- MTPA-Cl (41 μL, 0.22 mmol, 1.05 equiv). The solution was allowed to warm up to room temperature and stirred overnight. The reaction mixture was washed with 5% aqueous HCl, saturated $NaHCO_3$ and brine. It was then dried (magnesium sulfate) and concentrated to give a yellow oil that was purified by chromatography (SiO_2, hexanes / ethyl acetate,20/1) to give 37 mg of a yellow oil. ^{19}F NMR shows 3 peaks: -72.7079

(Mosher ester of the cinnamic alcohol), -72.8468 (one enantiomer, 52.4%), -72.8869 (the other enantiomer, 47.6%) (see attached chromatogram).

1-(4-Methoxy-2-nitrophenyl)-1,2-epoxy-3-(4-toluenesulfonyloxy)-propane (17). A solution of freshly recrystallized TsCl (3.78 g, 19.8 mmol, 1.05 equiv.) in dichloromethane (60 mL) was added to a cold (0 °C) solution of 3-(4-methoxy-2-nitrophenyl)-2,3-epoxypropanol (4.25 g, 18.9 mmol), freshly distilled triethylamine (5.26 mL, 37.7 mmol, 2 equiv.) and DMAP (50 mg, 0.41 mmol, 2 mol%) in dichloromethane (120 mL) at 0 °C. The reaction was cooled down to -10 °C and kept at this temperature for 6 hours. Then, water (90 mL) was added, and the mixture was extracted with dichloromethane. The organic phase was washed with water and dried (magnesium sulfate). The resulting orange oil was purified by chromatography (SiO_2, hexanes / ethyl acetate, 3/1) to give 5.70 g (80%) of a golden oil that crystallized at room temperature. m. p. 77-78 °C; ^{1}H NMR ($CDCl_3$, 250 MHz): δ 7.84 (d, J = 8.1, 2 H), 7.66 (d, J = 2.6, 1 H), 7.45 (d, J = 8.7, 1 H), 7.37 (d, J = 8.2, 2 H), 7.18 (dd, J = 8.7, 2.6, 1 H), 4.56 (dd, J = 11.6, 2.5, 1 H), 4.26 (d, J = 1.8, 1 H), 4.06 (dd, J = 11.6, 6.6, 1 H), 3.88 (s, 3 H), 3.15-3.10 (m, 1 H), 2.46 (s, 3 H); ^{13}C NMR ($CDCl_3$, 62.9 MHz): δ 159.7, 147.9, 145.1, 132.6, 129.6, 128.2, 128.0, 124.6, 120.8, 109.4, 69.7, 58.1, 55.9, 54.2, 21.6; IR (film): 1528, 1350 cm^{-1}; HRMS calcd for $C_{10}H_{10}NO_4$: M^+ - $C_7H_7O_3S$ = 208.0609, found 208.0575.

(4-Methoxy-2-nitrophenyl)2-hydroxy-3-(4-toluenesulfonyloxy)-propane (18). *Synthesis of the intermediate: (4-Methoxy-2-nitrophenyl)1-iodo-2-hydroxy-3-(4-toluenesulfonyloxy)-propane***.** A solution of 1-(4-methoxy-2-nitrophenyl)1,2-epoxy-3-(4-toluenesulfonyloxy)-propane (99 mg, 0.26 mmol) in toluene (2.5 mL) was cooled down to -55 °C. To this solution was added, under vigorous stirring, a solution of magnesium iodide (79 mg, 0.28 mmol, 1.1 equiv.) in ether (250 μL). After 12 hours at -55 °C, the mixture was allowed to warm up to room temperature and was then quenched with saturated Na_2SO_3 (2 mL). It was then extracted with ethyl acetate and the combined organic extracts were washed with brine, dried (magnesium sulfate) and concentrated. The product was used rapidly in the next step without any further purification.

A solution of crude (4-methoxy-2-nitrophenyl)-1-iodo-2-hydroxy-3-(4-toluenesulfonyloxy)-propane, Et_3N (42 μL, 0.30 mmol, 1.1 equiv.) and PtO_2 (2.1 mg, 0.009 mmol, 0.03 equiv) in THF (5 mL) was hydrogenated at 6 psi for 10 min at room temperature. White needles, that appeared to be a salt of triethylamine, separated. The catalyst and the salt were removed by filtration over Celite using diethyl ether as the eluent. The solution was concentrated and the resulting orange oil was purified by chromatography (SiO_2, hexanes / ethyl acetate, 4/1) to give 76.7 mg (77% on two steps) of a yellow oil. ^{1}H NMR ($CDCl_3$, 250 MHz): δ 7.81 (d, J = 8.0, 2 H), 7.45 (d, J = 2.4, 1 H), 7.36 (d, J = 8.0, 2 H), 7.09 (dd, J = 8.5, 2.5, 1 H), 4.20-4.00 (m, 2H), 4.01 (dd, J = 10.6, 7.0, 1 H), 3.85 (s, 3 H), 3.06 (dd, J = 14.0, 4.0, 1 H), 2.90 (dd, J = 13.9, 7.9, 1 H), 2.46 (s, 3 H), 2.32 (d, J = 4.9, 1 H), 1.26 (s, 1 H); ^{13}C NMR ($CDCl_3$, 62.9 MHz): δ

158.8, 149.9, 145.1, 134.0, 129.9, 127.9, 124.0, 119.7, 109.6, 72.9, 69.7, 55.8, 35.6, 29.6, 21.6; IR (film): 3533, 1529, 1355 cm^{-1}; HRMS calcd for $C_9H_{11}O_4S$: M^+ - $C_8H_8NO_3$ = 215.0378, found 215.0387.

1-(4-Toluenesulfonyl)-7-methoxy-1, 2, 3, 4-tetrahydroquinolin-3-ol (19b). *Synthesis of the intermediate: 7-Methoxy-1, 2, 3, 4-tetrahydro-quinolin-3-ol (19a).* A solution of 1-(4-methoxy-2-nitrophenyl)-2-hydroxy-3-(4-toluenesulfonyloxy)-propane (75 mg, 0.19 mmol) in DMF (600 μL), water (84 μl) and concentrated HCl (28 μL, 0.34 mmol, 1.7 equiv.) was warmed to 40 °C, and iron (56 mg, 1.01 mmol, 5.1 equiv.) was added. After heating at 70 °C for one hour, the solution was allowed to cool down to room temperature and concentrated ammonium hydroxide (1 ml) was added. The red solution was filtered through Celite using diethyl ether as eluent, the solvent was removed *in vacuo* and the resulting oil was taken in ether (10 mL) and water (10 mL). The aqueous phase was extracted with ether. The combined organic phases were washed with brine, dried (magnesium sulfate) and concentrated to give a redish oil that was rapidly used, without any further purification.

The crude 7-methoxy-1, 2, 3, 4-tetrahydroquinolin-3-ol was taken in dichloromethane (1 mL), and to this solution, was added, at 0 °C, Et_3N (28 μL, 0.20 mmol, 1 equiv.) and TsCl (37 mg, 0.19 mmol, 1 equiv.). The solution was allowed to warm up to room temperature over one hour and then refluxed for 4 hours. To the cooled

solution, water (2 mL) was added and the aqueous phase was extracted with dichloromethane. The combined organic extracts were washed with water, dried (magnesium sulfate) and concentrated to give a yellow oil that was purified by chromatography (SiO_2, hexanes/ethyl acetate, 3/1) to give 39 mg (66% on two steps) of a colourless oil. ^{1}H NMR ($CDCl_3$, 250 MHz): δ 7.60 (d, J = 8.3, 2 H), 7.31 (d, J = 2.5, 1 H), 7.22 (d, J = 8.1, 2 H), 6.92 (d, J = 8.4, 1 H), 6.65 (dd, J = 8.4, 2.5, 1 H), 4.07-3.39 (m, 1 H), 3.78 (s, 3 H), 3.61 (dd, J = 14.2, 8.0, 1 H), 2.71 (dd, J = 16.0, 5.4, 1 H), 2.46 (dd, 6.6, 6.0, 1 H), 1.99 (d, J = 5, 1 H); ^{13}C NMR ($CDCl_3$, 62.9 MHz): δ 158.3, 143.8, 136.8, 136.7, 130.2, 129.6, 127.1, 119.1, 111.8, 108.4, 64.1, 55.4, 52.1, 35.2, 21.5; IR (film): 3442 cm^{-1}; Anal. found (calcd): C, 60.54 (61.24); H, 5.66 (5.74); N, 4.14 (4.20); HRMS calcd for $C_{17}H_{19}NO_4S$: $M^{\bullet+}$ = 333.1035, found 333.1023.