Electronic Supplementary Material (ESI) for Organic & Biomolecular Chemistry

Expeditious Diastereoselective Construction of a Thiochroman Skeleton via a Cinchona Alkaloid–Derived Catalyst

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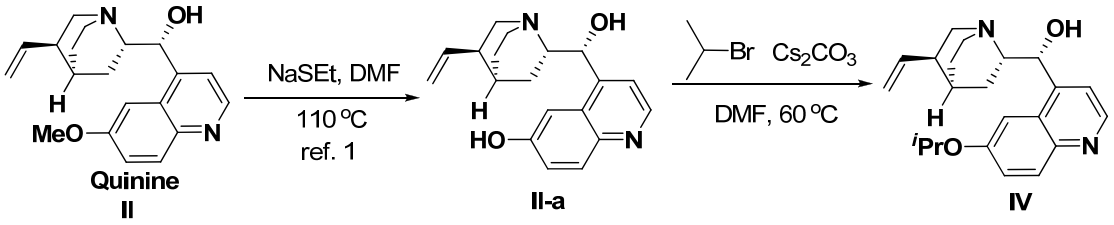
1. General information

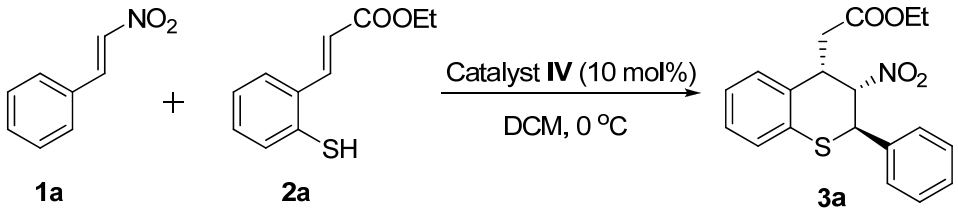
Chemicals and solvents were purchased from commercial suppliers and used as received. ^{1}H and ^{13}C NMR spectra were recorded on a Bruker ACF300 (300 MHz) or AMX500 (500 MHz) spectrometer. Chemical shifts were reported in parts per million (ppm), and the residual solvent peak was used as an internal reference: proton (chloroform δ 7.26), carbon (chloroform δ 77.0) or tetramethylsilane (TMS δ 0.00) was used as a reference. Multiplicity was indicated as follows: s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet), dd (doublet of doublet), bs (broad singlet). Coupling constants were reported in Hertz (Hz). Low resolution mass spectra were obtained on a Finnigan/MAT LCQ spectrometer in ESI mode, and a Finnigan/MAT 95XL-T mass spectrometer in EI mode. All high resolution mass spectra were obtained on a Finnigan/MAT 95XL-T mass spectrometer. For thin layer chromatography (TLC), Merck pre-coated TLC plates (Merck 60 F254) were used, and compounds were visualized with a UV light at 254 nm. Further visualization was achieved by staining with $KMnO_4$ solution, or ninhydrin followed by heating using a heat gun. Flash chromatography separations were performed on Merck 60 (0.040-0.063 mm) mesh silica gel. The enantiomeric excesses of products were determined by chiral phase HPLC analysis. Optical rotations were recorded on Jasco DIP-1000 polarimeter.

2. General procedure for preparation of the catalyst IV



(*R*)-(6-Isopropoxyquinolin-4-yl)((2*S*,4*R*,8*S*)-8-vinylquinuclidin-2-yl)methanol (IV). The intermediate compound **II-a** was prepared according to the literature reported[1]. Catalyst **IV** was then prepared using the similar procedure reported in the literature[2]. In brief, cesium carbonate (3.25 g, 10 mmol) and compound **II-a** (1.24 g, 4 mmol) was mixed in dry DMF (10 mL). The mixture was stirred at RT for 10 min, then 2-bromopropane (1.0 g, 8 mmol) was added, and the reaction mixture was stirred for 40 h at 60 ^{o}C. The solvent was removed under reduced pressure and the resulting residue was purified by flash chromatography (CH_2Cl_2/MeOH = 20:1). The desired product was obtained as a white solid (1.2 g, 85%). ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.41 (d, *J* = 4.6 Hz, 1H), 7.85 (d, *J* = 9.0 Hz, 1H), 7.43 (d, *J* = 4.6 Hz, 1H), 7.28-7.20 (m, 2H), 5.70 (ddd, *J* = 17.6, 10.2, 7.6 Hz, 1H), 5.49 (d, *J* = 3.5 Hz, 1H), 4.91 (t, *J* = 13.2 Hz, 2H), 4.69 (dt, *J* = 12.0, 6.0 Hz, 1H), 3.47 (d, *J* = 8.4 Hz, 1H), 3.04 (dd, *J* = 13.4, 10.1 Hz, 2H), 2.61 (dd, *J* = 12.6, 5.5 Hz, 2H), 2.24 (s, 1H), 1.78-1.72 (m, 3H), 1.45 (t, *J* = 9.3 Hz, 2H), 1.35 (t, *J* = 6.2 Hz, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 155.66, 148.10, 147.09, 143.62, 141.81, 131.10, 126.52, 122.47, 118.38, 114.23, 103.73, 71.74, 69.96, 59.98, 57.02, 43.18, 39.84, 27.81, 27.54, 22.03, 21.45; HRMS (ESI) calcd for $C_{22}H_{28}N_2O_2Na$ (M + Na^+) 375.2048, found 375.2043; $[\alpha]^{25}_{D}$ = –96.9 (*c* = 1.0 in $CHCl_3$).

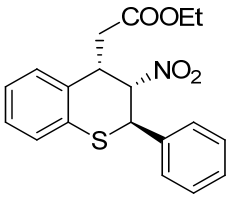
3. Representative procedure for Michael-Michael reaction



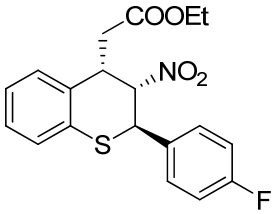
1a 2a 3a

General procedure: To a solution of (E)-ethyl 3-(2-mercaptophenyl)acrylate **2a** (25 mg, 0.12 mmol) in 0.45 mL DCM was added trans-β-nitrostyrene **1a** (15 mg, 0.1 mmol) at 0 °C, followed by adding of 50 μL of pre-cooled catalyst **IV** solution (3.5 mg in 50 μL DCM, 0.01 mmol). The mixture was stirred at 0 °C for 48 h. The crude product was purified by column chromatography on silica gel, eluted by hexane/EtOAc= 20:1 to afford 33 mg (92% yield) of the desired product **3a** as colorless oil.

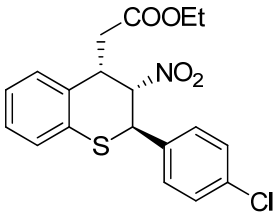
4. Analytical data of Michael-Michael reaction products



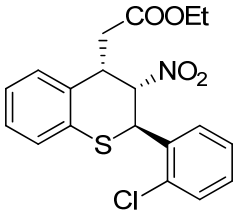
Ethyl 2-((2*R*,3*S*,4*S*)-3-nitro-2-phenylthiochroman-4-yl)acetate (3a) (Table 3 , entry 1). ^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.40 (dt, *J*=3.8, 2.2 Hz, 2H), 7.35-7.21 (m, 6H), 7.14 (ddd, *J*=7.6, 6.1, 2.7 Hz , 1H), 5.33 (dd, *J*=10.6, 3.6 Hz, 1H), 4.89 (d, *J*=10.4 Hz, 1H), 4.16-4.08 (m, 3H), 2.95 (qd, *J*=16.4, 6.9 Hz, 2H), 1.21 (t, *J*=7.1 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.54, 137.06, 134.13, 132.54, 129.06, 129.04, 128.84, 128.32, 128.14, 126.40, 125.64, 90.96, 60.99, 44.75, 40.65, 33.63, 14.04; HRMS (EI) calcd for $C_{19}H_{19}NO_4S$ 357.1035, found 357.1033; HPLC (Chiralpak IC, *i*-propanol/hexane = 10/90, flow rate 1.0 mL/min, λ = 254 nm): = t_{minor} = 7.7 min, t_{major} = 8.9 min, *ee* = 90%, d.r. = 25:1; $[\alpha]^{25}_{D}$ (major) = +162.3 (*c* = 1.0 in $CHCl_3$).



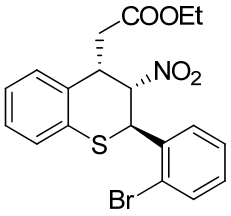
Ethyl 2-((2*R*,3*S*,4*S*)-2-(4-fluorophenyl)-3-nitrothiochroman-4-yl)acetate (3b) (Table 3 , entry 2). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.41-7.39 (m, 2H), 7.29-7.24 (m, 3H), 7.17-7.14 (m, 1H), 7.03 (dd, *J* = 11.8, 5.2 Hz, 2H), 5.27 (dd, *J* = 10.7, 3.5 Hz, 1H), 4.89 (d, *J* = 10.7 Hz, 1H), 4.18-4.08 (m, 3H), 2.95 (qd, *J* = 16.4, 7.1 Hz, 2H), 1.23 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.55, 161.82, 134.07, 132.89, 132.29, 130.11, 130.05, 129.18, 128.45, 126.42, 125.80, 116.21, 116.04, 91.07, 61.10, 44.06, 40.68, 33.66, 14.09; HRMS (EI) calcd for $C_{19}H_{18}FNO_4S$ 375.0941, found375.0938; HPLC (Chiralpak IC, *i*-propanol/hexane = 10/90, flow rate 1.0 mL/min, λ = 254 nm): t_{minor} = 7.1 min, t_{major} = 7.9 min, *ee* = 86%, d.r. = 29:1; $[\alpha]^{25}_{D}$ (major) = +175.9 (*c* = 1.17 in $CHCl_3$).



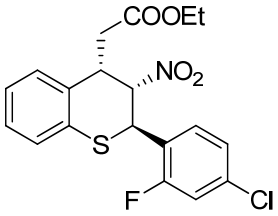
Ethyl 2-((2*R*,3*S*,4*S*)-2-(4-chlorophenyl)-3-nitrothiochroman-4-yl)acetate (3c) (Table 3 , entry 3). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.37-7.23 (m, 7H), 7.16 (ddd, *J* = 7.9, 5.0, 3.8 Hz, 1H), 5.26 (dd, *J* = 10.7, 3.5 Hz, 1H), 4.88 (d, *J* = 10.7 Hz, 1H), 4.18-4.07 (m, 3H), 2.99-2.89 (m, 2H), 1.22 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.51, 135.71, 134.86, 134.07, 132.14, 129.62, 129.32, 129.19, 128.48, 126.46, 125.87, 90.88, 61.11, 44.11, 40.68, 33.58, 14.08; HRMS (EI) calcd for $C_{19}H_{18}ClNO_4S$ 391.0645, found 391.0640; HPLC (Chiralpak IC, *i*-propanol/hexane = 10/90, flow rate 1.0 mL/min, λ = 254 nm): t_{minor} = 7.2 min, t_{major} = 8.3 min, *ee* = 86%, d.r. = 25:1; $[\alpha]^{25}_{D}$ (major) = +181.1 (*c* = 1.25 in $CHCl_3$).



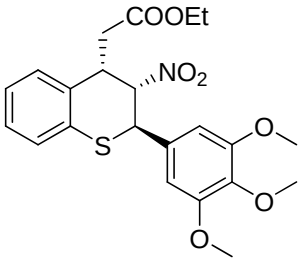
Ethyl 2-((2*R*,3*S*,4*S*)-2-(2-chlorophenyl)-3-nitrothiochroman-4-yl)acetate (3d) (Table 3 , entry 4). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.52 (dd, *J* = 7.7, 1.7 Hz, 1H), 7.41 (dd, *J* = 7.9, 1.6 Hz, 1H), 7.31-7.23 (m, 5H), 7.20-7.16 (m, 1H), 5.50 (p, *J* = 9.8 Hz, 2H), 4.18-4.10 (m, 3H), 2.99 (qd, *J* = 16.6, 6.9 Hz, 2H), 1.23 (t, *J* = 7.3 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.67, 134.80, 134.19, 134.10, 132.55, 130.40, 129.85, 128.73, 128.37, 127.77, 127.40, 126.86, 126.04, 89.66, 61.10, 41.51, 40.47, 33.59, 14.09; HRMS (EI) calcd for $C_{19}H_{18}ClNO_4S$ 391.0645, found 391.0639; HPLC (Chiralpak IC, *i*-propanol/hexane = 10/90, flow rate 1.0 mL/min, λ = 254 nm): t_{minor} = 7.0 min, t_{major} = 8.2 min, *ee* = 86%, d.r. = 15:1 ; $[\alpha]^{25}_{D}$ (major) = +131.2 (*c* = 0.95 in $CHCl_3$).



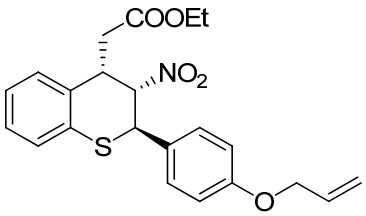
Ethyl 2-((2*R*,3*S*,4*S*)-2-(2-bromophenyl)-3-nitrothiochroman-4-yl)acetate (3e) (Table 3 , entry 5). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.60 (dd, *J* = 7.9, 0.9 Hz, 1H), 7.53 (dd, *J* = 7.7, 1.1 Hz, 1H), 7.34 (td, *J* = 7.7, 1.1 Hz, 1H), 7.28-7.24 (m, 3H), 7.18 (ddd, *J* = 7.6, 4.9, 1.6 Hz, 2H), 5.51 (s, 2H), 4.13 (ddd, *J* = 12.9, 8.8, 5.0 Hz, 3H), 2.99 (dd, *J* = 6.8, 5.8 Hz, 2H), 1.23 (t, *J* = 7.3 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 170.68, 136.47, 134.03, 133.72, 132.51, 130.11, 128.72, 128.43, 128.38, 128.01, 126.81, 126.01, 124.61, 89.71, 61.12, 43.95, 40.39, 33.73, 14.10; HRMS (ESI) calcd for $C_{19}H_{18}BrNO_4SNa$ (M + Na^+) 458.0038, found 458.0021; HPLC (Chiralpak IC, *i*-propanol/hexane = 10/90, flow rate 1.0 mL/min, λ = 254 nm): t_{minor} = 7.4 min, t_{major} = 8.9 min, *ee* = 84%, d.r. = 15:1; $[\alpha]^{25}_{D}$ (major) = +106.9 (*c* = 1.0 in $CHCl_3$).



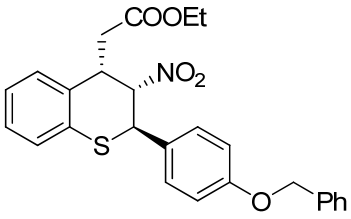
Ethyl 2-((2*R*,3*S*,4*S*)-2-(4-chloro-2-fluorophenyl)-3-nitrothiochroman-4-yl)acetate (3f) (Table 3 , entry 6). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.38 (t, *J* = 8.2 Hz, 1H), 7.29 (d, *J* = 7.6 Hz, 1H), 7.25 (dd, *J* = 4.1, 2.5 Hz, 2H), 7.19-7.11 (m, 3H), 5.39 (dd, *J* = 10.2, 3.6 Hz, 1H), 5.17 (d, *J* = 10.1 Hz, 1H), 4.17-4.09 (m, 3H), 2.99-2.89 (m, 2H), 1.23 (t, *J* = 7.3 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.51, 161.42, 159.40, 135.75, 135.67, 134.07, 131.99, 130.31, 130.28, 129.06, 128.48, 126.70, 126.10, 125.40, 125.37, 123.28, 123.18, 117.24, 117.04, 89.40, 61.13, 40.67, 38.15, 33.32, 14.07; HRMS (EI) calcd for $C_{19}H_{17}ClFNO_4S$ 409.0551, found 409.0548; HPLC (Chiralpak IC, *i*-propanol/hexane = 10/90, flow rate 1.0 mL/min, λ = 254 nm): t_{minor} = 6.6 min, t_{major} = 7.3 min, *ee* = 80%, d.r. = 15:1; $[\alpha]^{25}_{D}$ (major) = +134.8 (*c* = 1.25 in $CHCl_3$).



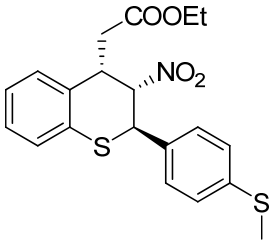
Ethyl 2-((2*R*,3*S*,4*S*)-3-nitro-2-(3,4,5-trimethoxyphenyl)thiochroman-4-yl)acetate (3g) (Table 3 , entry 7). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.28-7.23 (m, 3H), 7.18-7.15 (m, 1H), 6.62 (s, 2H), 5.37 (dd, *J* = 10.2, 3.6 Hz, 1H), 4.84 (d, *J* = 10.4 Hz, 1H), 3.84 (d, *J* = 9.1 Hz, 9H), 2.96 (qd, *J* = 16.4, 6.9 Hz, 2H), 1.23 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 170.62, 153.55, 138.39, 134.10, 132.78, 132.34, 128.85, 128.35, 126.61, 125.82, 105.23, 91.11, 61.08, 60.79, 56.21, 45.63, 40.67, 33.72, 14.09; HRMS (ESI) calcd for $C_{22}H_{25}NO_7SNa$ ($M + Na^+$) 470.1249, found 470.1244; HPLC (Chiralpak IC, *i* propanol/hexane = 20/80, flow rate 1.0 mL/min, λ = 254 nm): t_{minor} = 16.5 min, t_{major} = 21.3 min, *ee* = 82%, d.r. = 21:1; $[\alpha]^{25}_{D}$ (major) = +120.7 (*c* = 1.15 in $CHCl_3$).



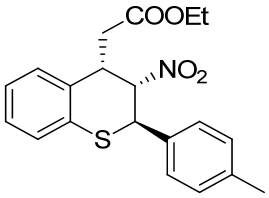
Ethyl 2-((2*R*,3*S*,4*S*)-2-(4-(allyloxy)phenyl)-3-nitrothiochroman-4-yl)acetate (3h) (Table 3 , entry 8). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.33-7.31 (m, 2H), 7.25 (dd, *J* = 18.3, 5.7 Hz, 3H), 7.15-7.13 (m, 1H), 6.88-6.86 (m, 2H), 6.03 (ddt, *J* = 17.3, 10.7, 5.4 Hz, 1H), 5.40 (ddd, *J* = 17.3, 3.0, 1.6 Hz, 1H), 5.30-5.27 (m, 2H), 4.86 (d, *J* = 10.4 Hz, 1H), 4.51 (dt, *J* = 5.4, 1.4 Hz, 2H), 4.18-4.07 (m, 3H), 2.95 (ddd, *J* = 25.2, 16.4, 6.9 Hz, 2H), 1.22 (t, *J* = 7.3 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.63, 158.97, 134.09, 132.96, 132.74, 129.42, 129.13, 128.86, 128.32, 126.34, 125.54, 117.84, 115.25, 91.07, 68.84, 61.03, 44.19, 40.71, 33.79, 14.09; HRMS (ESI) calcd for $C_{22}H_{23}NO_5SNa$ (M + Na^+) 436.1195, found 436.1184; HPLC (Chiralpak IB, *i*-propanol/hexane = 5/95, flow rate 1.0 mL/min, λ = 254 nm): t_{minor} = 9.0 min, t_{major} = 11.0 min, *ee* = 80%, d.r. = 72:1; $[\alpha]^{25}_{D}$ (major) = +169.8 (*c* = 1.35 in $CHCl_3$).



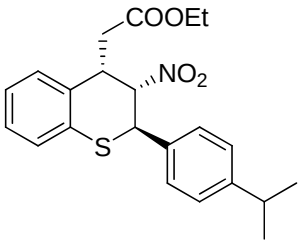
Ethyl 2-((2*R*,3*S*,4*S*)-2-(4-(benzyloxy)phenyl)-3-nitrothiochroman-4-yl)acetate (3i) (Table 3 , entry 9). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.42-7.32 (m, 7H), 7.27 (d, *J* = 8.5 Hz, 1H), 7.23 (d, *J* = 3.8 Hz, 2H), 7.14 (dd, *J* = 7.9, 4.4 Hz, 1H), 6.95-6.93 (m, 2H), 5.28 (dd, *J* = 10.7, 3.5 Hz, 1H), 5.04 (s, 2H), 4.86 (d, *J* = 10.4 Hz, 1H), 4.17-4.07 (m, 3H), 2.95 (ddd, *J* = 25.2, 16.4, 6.9 Hz, 2H), 1.22 (t, *J* = 7.3 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.64, 159.18, 136.65, 134.10, 132.73, 129.48, 129.14, 129.01, 128.62, 128.34, 128.07, 127.46, 126.36, 125.56, 115.38, 91.08, 70.10, 61.05, 44.21, 40.73, 33.79, 14.10; HRMS (ESI) calcd for $C_{26}H_{25}NO_5SNa$ (M + Na^+) 486.1351, found 486.1333; HPLC (Chiralpak IB, *i*-propanol/hexane = 5/95, flow rate 1.0 mL/min, λ = 254 nm): t_{minor} = 13.7 min, t_{major} = 18.2 min, *ee* = 88%, d.r. = 105:1; $[\alpha]^{25}_{D}$ (major) = +174.2 (*c* = 1.07 in $CHCl_3$).



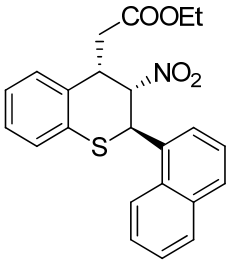
Ethyl 2-((2*R*,3*S*,4*S*)-2-(4-(methylthio)phenyl)-3-nitrothiochroman-4-yl)acetate (3j) (Table 3 , entry 10). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.32 (d, *J* = 8.2 Hz, 2H), 7.28-7.20 (m, 5H), 7.17-7.13 (m, 1H), 5.28 (dd, *J* = 10.7, 3.5 Hz, 1H), 4.87 (d, *J* = 10.7 Hz, 1H), 4.18-4.07 (m, 3H), 2.94 (qd, *J* = 16.4, 6.9 Hz, 2H), 2.46 (s, 3H), 1.22 (t, *J* = 7.3 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.58, 139.82, 134.09, 133.48, 132.49, 129.16, 128.62, 128.39, 126.74, 126.40, 125.68, 90.88, 61.07, 44.31, 40.71, 33.70, 15.46, 14.09; HRMS (ESI) calcd for $C_{20}H_{21}NO_4S_2Na$ (M + Na^+) 426.0810, found 426.0811; HPLC (Chiralpak IB, *i*-propanol/hexane = 5/95, flow rate 1.0 mL/min, λ = 254 nm): t_{minor} = 10.2 min, t_{major} = 12.1 min, *ee* = 83%, d.r. = 17:1; $[\alpha]^{25}_{D}$ (major) = +171.1 (*c* = 1.15 in $CHCl_3$).



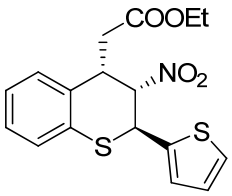
Ethyl 2-((2*R*,3*S*,4*S*)-3-nitro-2-*p*-tolylthiochroman-4-yl)acetate (3k) (Table 3, entry 11). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.30-7.23 (m, 5H), 7.16-7.13 (m, 3H), 5.31 (dd, *J* = 10.6, 3.6 Hz, 1H), 4.87 (t, *J* = 7.3 Hz, 1H), 4.16-4.07 (m, 3H), 2.95 (qd, *J* = 16.4, 6.9 Hz, 2H), 2.33 (s, 3H), 1.22 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.63, 153.24, 138.85, 134.14, 133.94, 132.71, 129.77, 129.12, 128.33, 128.05, 126.39, 125.58, 91.00, 61.03, 44.47, 40.70, 33.76, 21.12, 14.09; HRMS (EI) calcd for $C_{20}H_{21}NO_4S$ 371.1191, found 371.1190; HPLC (Chiralpak IB, *i*-propanol/hexane = 5/95, flow rate 1.0 mL/min, λ = 254 nm): t_{minor} = 6.8 min, t_{major} = 8.5 min, *ee* = 82%, d.r. = 26:1; $[\alpha]^{25}_{D}$ (major) = +158.7 (*c* = 1.25 in $CHCl_3$).



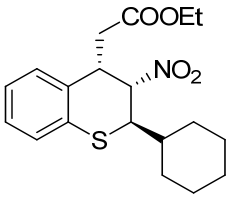
Ethyl 2-((2*R*,3*S*,4*S*)-2-(4-isopropylphenyl)-3-nitrothiochroman-4-yl)acetate (3l) (Table 3, entry 12). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.33-7.13 (m, 8H), 5.33 (dd, J = 10.4, 3.5 Hz, 1H), 4.88 (d, J = 10.4 Hz, 1H), 4.17-4.09 (m, 3H), 3.00-2.85 (m, 3H), 1.22 (dt, J = 6.9, 3.6 Hz, 9H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.64, 149.68, 134.22, 134.16, 132.77, 129.09, 128.33, 128.10, 127.17, 126.42, 125.59, 90.99, 61.04, 44.49, 40.76, 33.80, 33.74, 23.80, 23.78, 14.09; HRMS (ESI) calcd for $C_{22}H_{25}NNaO_4S$ (M + Na^+) 422.1402, found 422.1388; HPLC (Chiralpak IB, *i*-propanol/hexane = 5/95, flow rate 1.0 mL/min, λ = 254 nm): t_{minor} = 6.1 min, t_{major} = 7.3 min, *ee* = 90%, d.r. = 26:1; $[\alpha]^{25}_{D}$ (major) = +160.8 (*c* = 1.23 in $CHCl_3$).



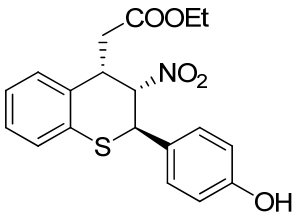
Ethyl 2-((2*R*,3*S*,4*S*)-2-(naphthalen-1-yl)-3-nitrothiochroman-4-yl)acetate (3m) (Table 3, entry 13). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.15 (d, J = 8.5 Hz, 1H), 7.86 (dd, J = 28.1, 7.9 Hz, 2H), 7.67 (s, 1H), 7.57-7.44 (m, 3H), 7.32-7.20 (m, 4H), 5.78 (d, J = 6.0 Hz, 1H), 5.71 (s, 1H), 4.23-4.20 (m, 1H), 4.18-4.09 (m, 2H), 3.06 (ddd, J = 22.7, 16.6, 7.3 Hz, 2H), 1.22 (t, J = 7.3 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.69, 134.38, 134.15, 133.61, 130.96, 129.51, 129.26, 128.43, 128.31, 127.92, 127.16, 126.95, 126.47, 126.23, 126.19, 125.51, 122.69, 90.85, 61.12, 40.72, 33.59, 33.57, 14.09; HRMS (ESI) calcd for $C_{23}H_{21}NNaO_4S$ (M + Na^+) 430.1089, found 430.1079; HPLC (Chiralpak IC, *i* propanol/hexane = 5/95, flow rate 1.0 mL/min, λ = 254 nm): t_{minor} = 9.5 min, t_{major} = 12.3 min, *ee* = 90%, d.r. = 60:1; $[\alpha]^{25}_{D}$ (major) = +144.4 (*c* = 1.17 in $CHCl_3$).



Ethyl 2-((2*S*,3*S*,4*S*)-3-nitro-2-(thiophen-2-yl)thiochroman-4-yl)acetate (3n) (Table 3, entry 14). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.27 (ddd, *J* = 13.3, 5.5, 2.3 Hz, 4H), 7.16 (ddd, *J* = 7.3, 6.5, 2.6 Hz, 1H), 7.11 (dd, *J* = 3.6, 1.0 Hz, 1H), 6.94 (dd, *J* = 5.0, 3.7 Hz, 1H), 5.31-5.25 (m, 2H), 4.17-4.07 (m, 3H), 3.00-2.90 (m, 2H), 1.22 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.50, 140.33, 133.91, 132.30, 128.84, 128.39, 127.39, 127.14, 126.55, 125.96, 91.86, 77.20, 61.08, 40.61, 33.43, 14.08; HRMS (EI) calcd for $C_{17}H_{17}NO_4S_2$, 363.0599 found 363.0592; HPLC (Chiralpak IB, *i* propanol/hexane = 5/95, flow rate 1.0 mL/min, λ = 254 nm): t_{minor} = 9.2 min, t_{major} = 12.4 min, *ee* = 86%, d.r. = 19:1; $[\alpha]^{25}_{D}$ (major) = +164.6 (*c* = 1.13 in $CHCl_3$).

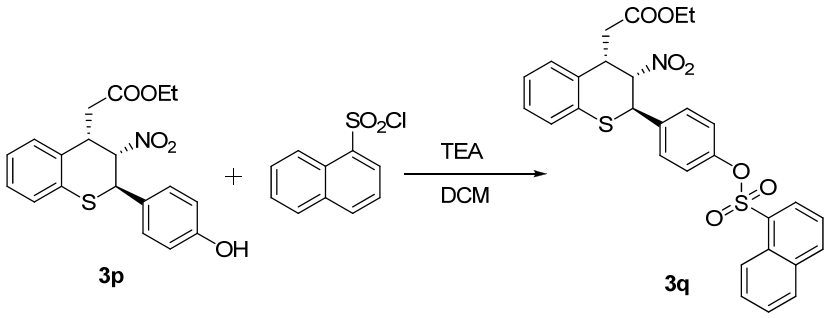


Ethyl 2-((2*R*,3*S*,4*S*)-2-cyclohexyl-3-nitrothiochroman-4-yl)acetate (3o) (Table 3, entry 15). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.33 (d, *J* = 7.6 Hz, 1H), 7.23-7.15 (m, 3H), 5.13 (dd, *J* = 8.9, 3.9 Hz, 1H), 4.19-4.09 (m, 2H), 3.85 (ddd, *J* = 8.0, 6.4, 3.9 Hz, 1H), 3.72 (dd, *J* = 8.8, 4.2 Hz, 1H), 2.94 (ddd, *J* = 22.9, 16.7, 7.2 Hz, 2H), 1.78-1.66 (m, 5H), 1.32-1.17 (m, 9H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 170.99, 135.40, 133.36, 128.14, 128.04, 127.73, 126.11, 89.13, 60.96, 48.80, 40.92, 40.82, 32.42, 30.59, 27.78, 26.19, 26.02, 25.83, 14.12; HRMS (EI) calcd for $C_{19}H_{25}NO_4S$ 363.1504, found 363.1500; HPLC (Chiralpak IB, *i*-propanol/hexane = 2/98, flow rate 0.5 mL/min, λ = 254 nm, t_{minor} = 13.2 min, t_{major} = 14.6 min, *ee* = 84%, d.r. = 15:1; $[\alpha]^{25}_{D}$ (major) = +67.2 (*c* = 1.0 in $CHCl_3$).



Ethyl 2-((2*R*,3*S*,4*S*)-2-(4-hydroxyphenyl)-3-nitrothiochroman-4-yl)acetate (3p). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.28-7.10 (m, 6H), 6.78 (d, *J* = 8.5 Hz, 2H), 5.67 (s, 1H), 5.28 (dd, *J* = 10.6, 3.4 Hz, 1H), 4.84 (d, *J* = 10.7 Hz, 1H), 4.17-4.07 (m, 3H), 2.95 (ddd, *J* = 25.0, 15.9, 6.5 Hz, 2H), 1.22 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.85, 156.22, 133.99, 132.71, 129.65, 129.08, 128.63, 128.34, 126.34, 125.55, 115.95, 91.09, 61.16, 44.19, 40.67, 33.85, 14.06; HRMS (ESI) calcd for $C_{19}H_{19}NO_5SNa$ ($M + Na^+$) 396.0882, found 396.0880; HPLC (Chiralpak IB, *i* propanol/hexane = 10/90, flow rate 1.0 mL/min, λ = 254 nm): t_{minor} = min, t_{major} = min, *ee* = 66%, d.r. = 1:2; $[\alpha]^{25}_{D}$ (major) = +155.3 (*c* = 1.0 in $CHCl_3$).

5. Preparation of the Compound for X-ray Analysis



Ethyl 2-((2*R*,3*S*,4*S*)-2-(4-(naphthalen-1-ylsulfonyloxy)phenyl)-3-nitrothiochroman-4-yl)acetate (3q). TEA (0.3g, 3 mmol) was added into a solution of **3p** (56 mg, 0.15 mmol) and naphthalene-1-sulfonyl chloride (68 mg, 3 mmol) in DCM (2 mL), the mixture was stirred at r.t. for 5h. The crude mixture was purified by column chromatography on silica gel to afford product **3q** (50 mg, 60%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.79 (dd, *J* = 23.0, 8.8 Hz, 1H), 8.16-7.97 (m, 3H), 7.82-7.65 (m, 3H), 7.50-7.47 (m, 1H), 7.26-7.06 (m, 5H), 6.85 (d, *J* = 8.5 Hz, 2H), 5.15 (dd, *J* = 10.4, 3.5 Hz, 1H), 4.80 (d, *J* = 10.4 Hz, 1H), 4.09 (dddd, *J* = 27.4, 12.9, 6.9, 3.8 Hz, 3H), 2.90 (d, *J* = 6.6 Hz, 2H), 1.21 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 170.47, 149.77, 136.27, 136.10, 135.84, 134.08, 134.05, 131.33, 131.21, 130.72, 129.59, 129.10, 129.03, 128.47, 127.39, 126.50, 125.94, 124.97, 124.05, 122.73, 122.71, 90.97, 61.10,

44.09, 40.68, 33.43, 14.07; HRMS (ESI) calcd for $C_{29}H_{25}NO_7S_2Na$ ($M + Na^+$) 586.0970, found 586.0950.

Computational Section:

The DFT/GGA calculations were performed using the Perdew and Wang[5a,5b] (PW91) exchange-correlation functional as implemented in DMol^3 package[5c,5d]. A double numerical basis set augmented with polarization functions was used to describe both core and valence electrons. The tolerances for SCF and total energy convergence were set to be 1.0×10^{-5} Ha and 2.0×10^{-5} Ha, respectively. Structural relaxation and transition state (TS) search/optimization were performed without symmetry constraints. The TS research was done with the LST/QST algorithm[5e] and the obtained TS structures were verified via normal mode analysis that yields only one imaginary frequency.

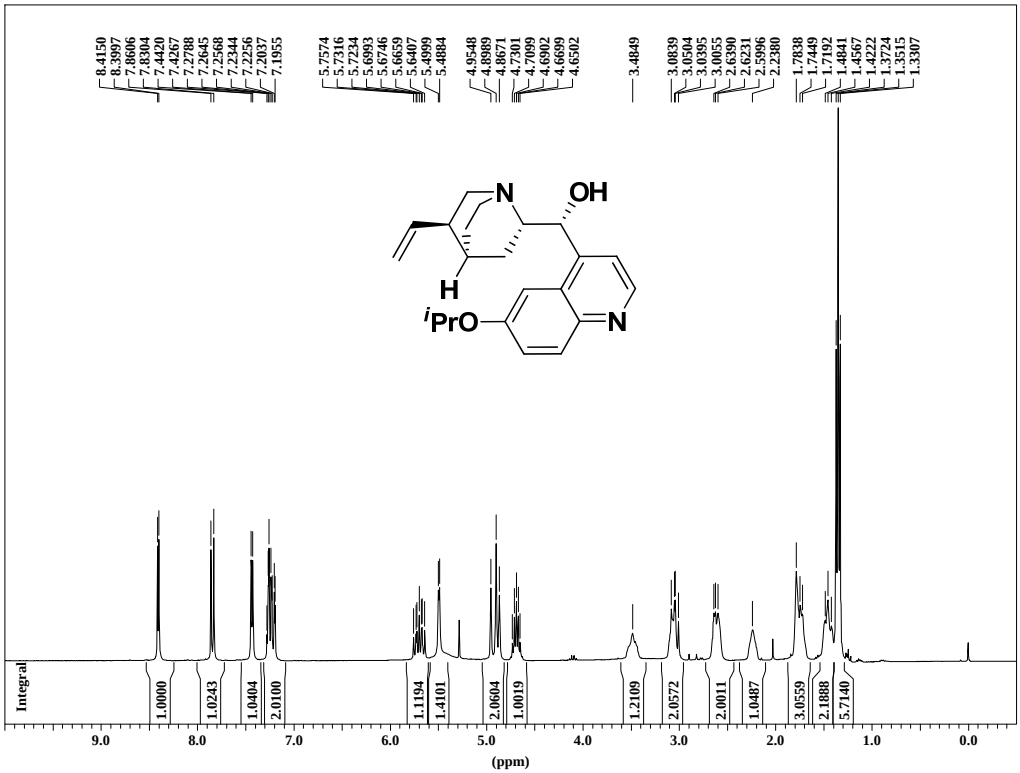
Reference:

[1] H. Li, Y. Wang, L. Tang, *J. Am. Chem. Soc.*, **2004**, *126*, 9906.

[2] A. Berkessel, M. Guixà, F. Schmidt, J. M. Neudöfl, J. Lex, *Chem. –Eur. J.* **2007**, *13*, 4483.

[3] (a). J. P. Perdew, Y. Wang, *Phys. Rev. B.* **1992**, 45, 13244; (b). J. P. Perdew, K. Burke, M. Ernzerhof, *Phys. Rev. Lett.* **1996**, 77, 3865; (c).B. Delley, *J. Phys. Chem.* **1996**, 100, 6107; (d). B. Delley, *J. Chem. Phys.* **2000**, 113, 7756; (e). T. A. Halgren, W. N. Lipscomb, *Chem. Phys. Lett.* **1977**, 49, 225.

Catalyst **IV**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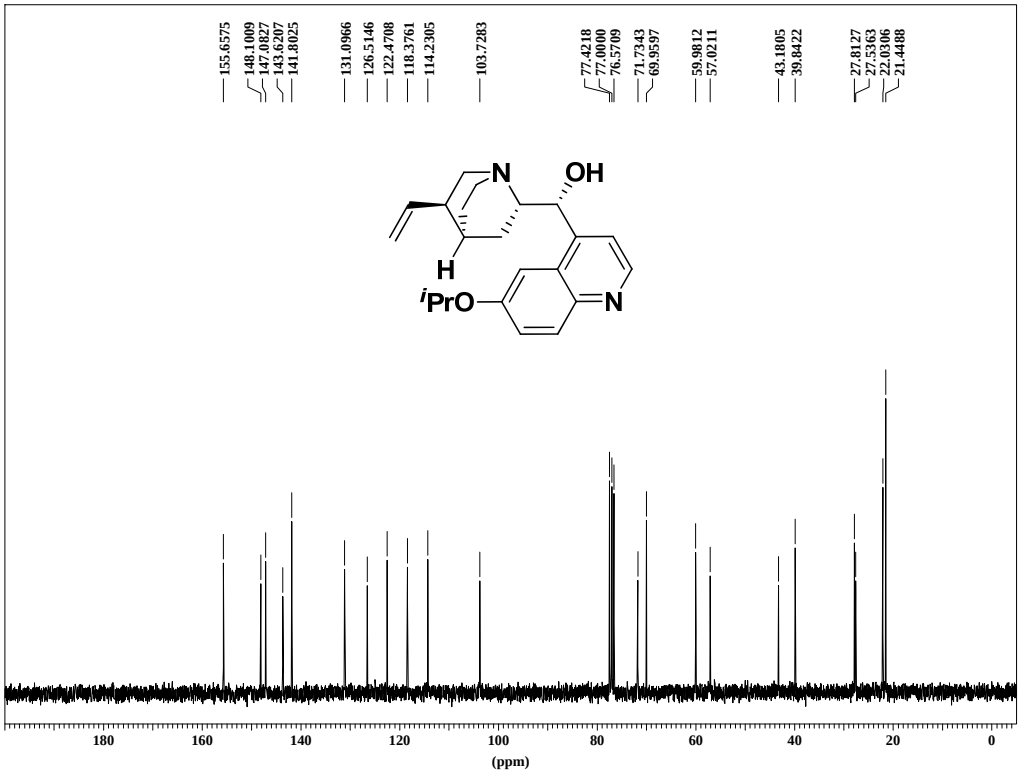
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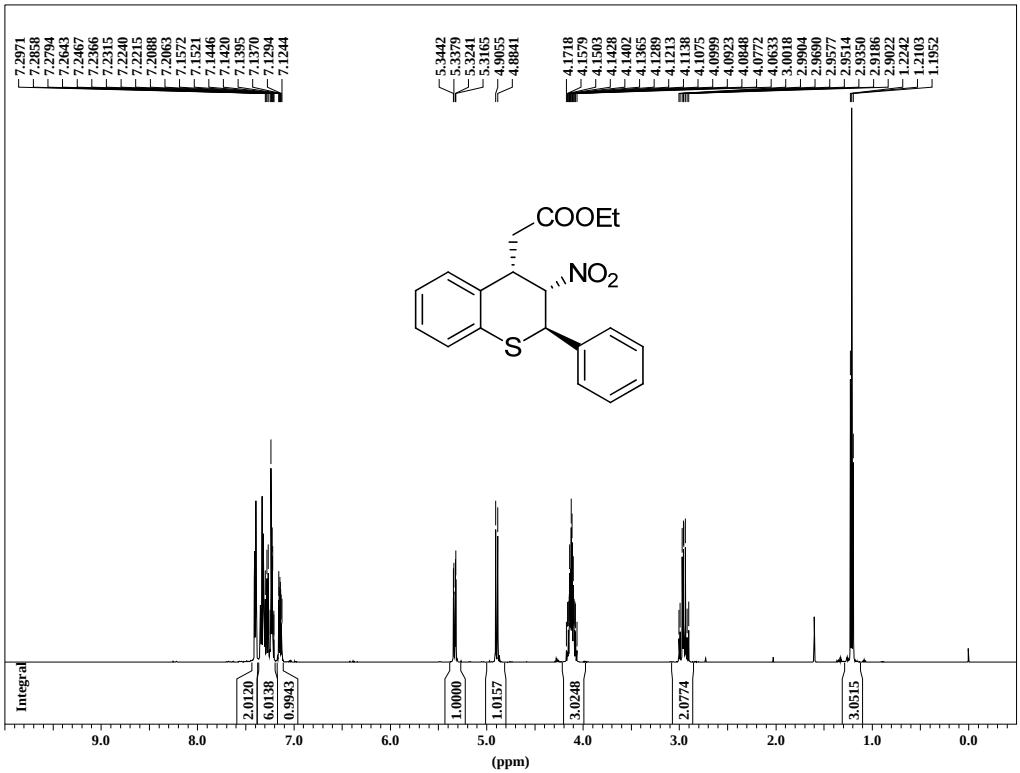
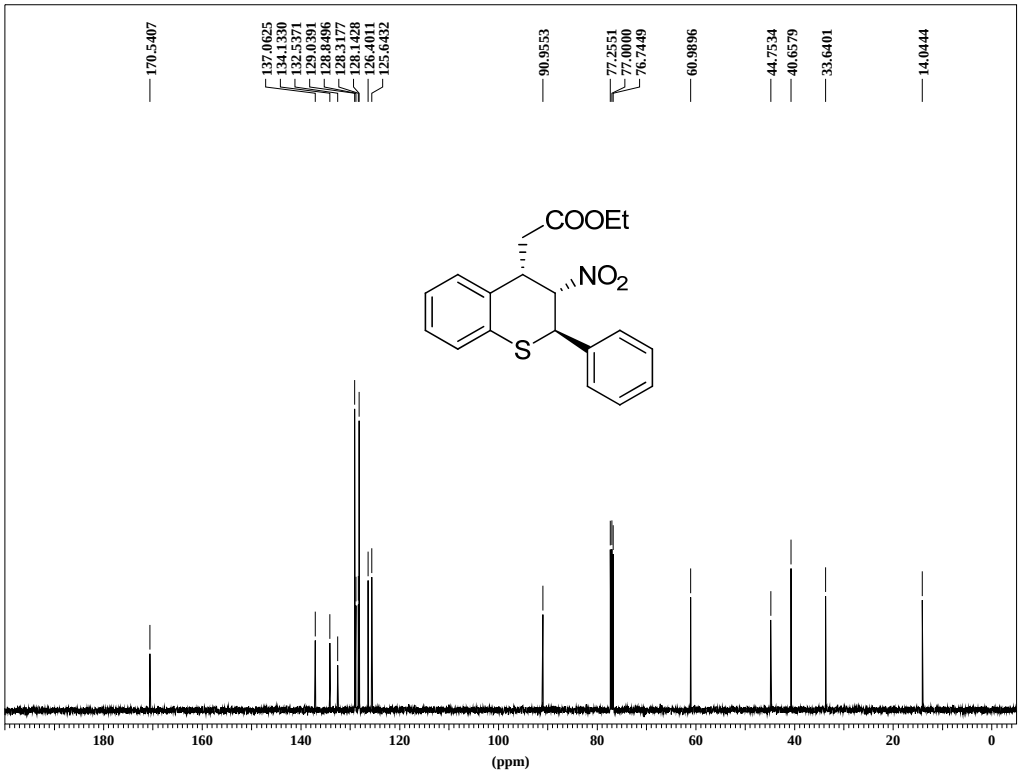
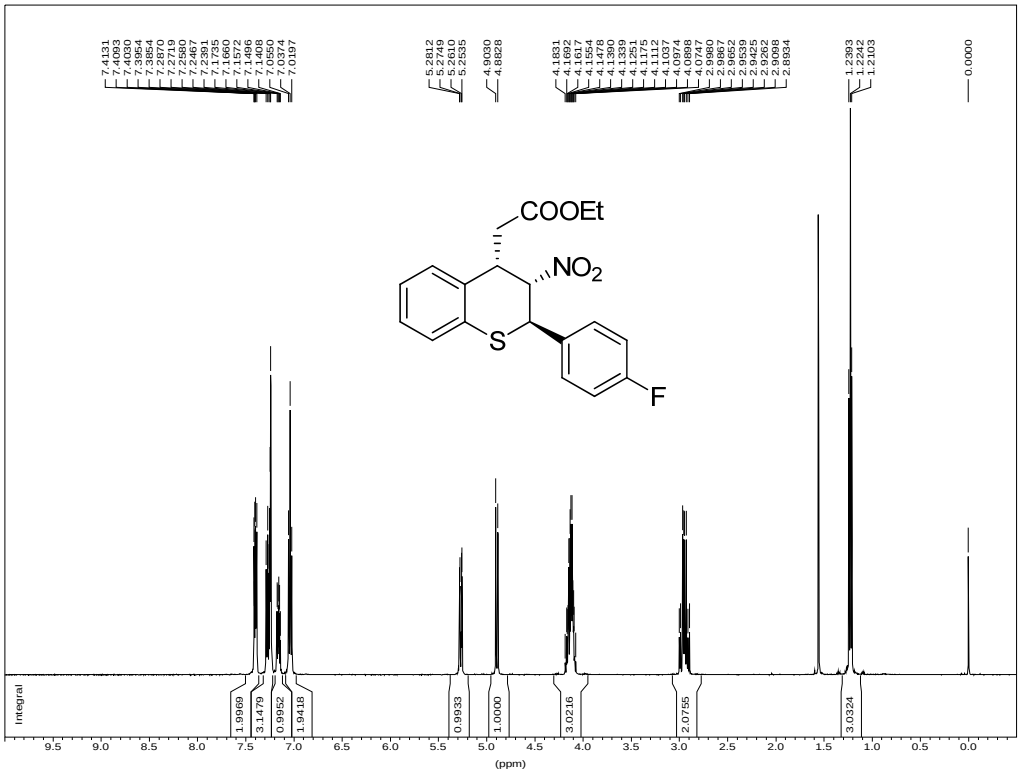
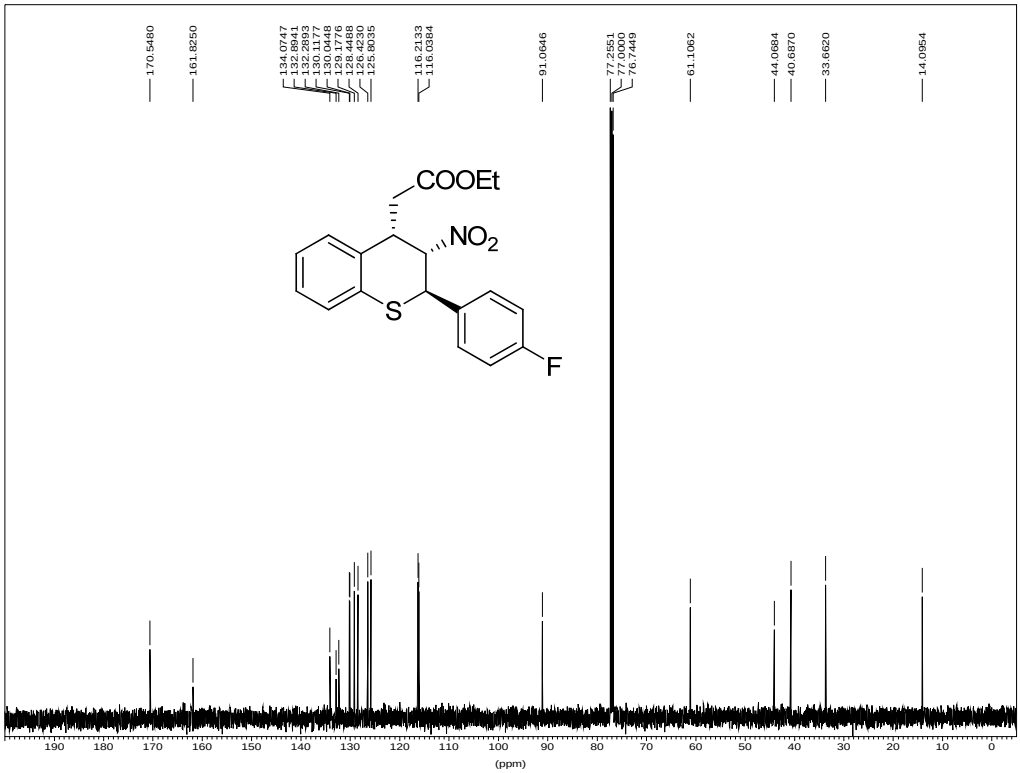
Compound 3a



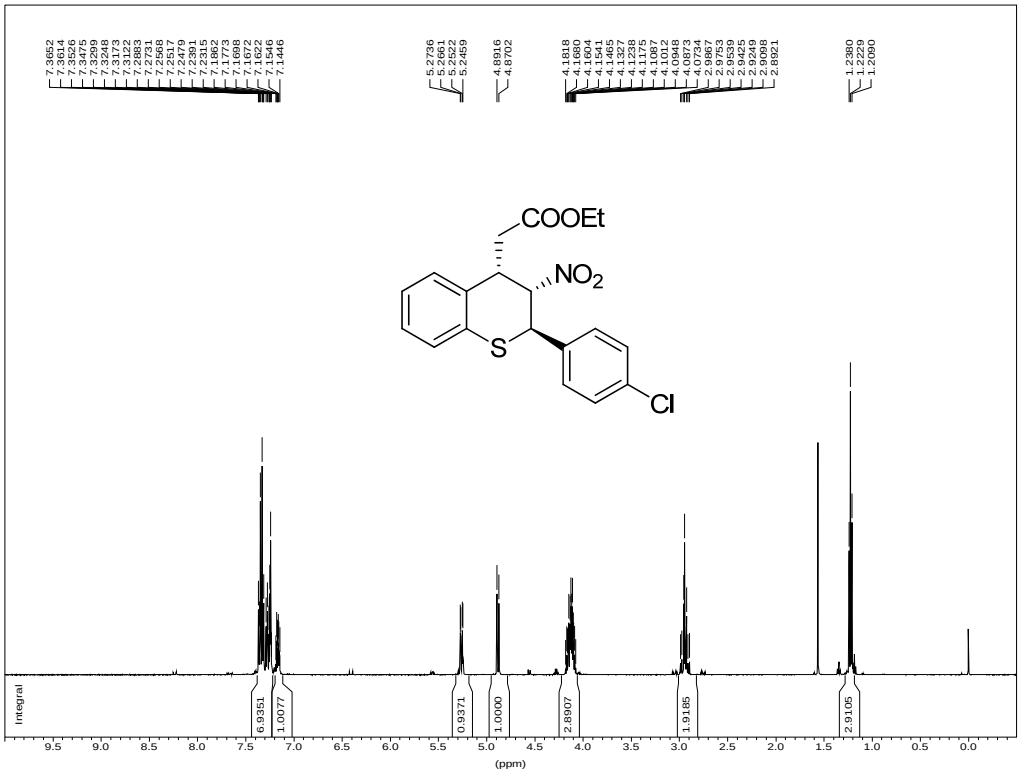


Compound 3b





Compound 3c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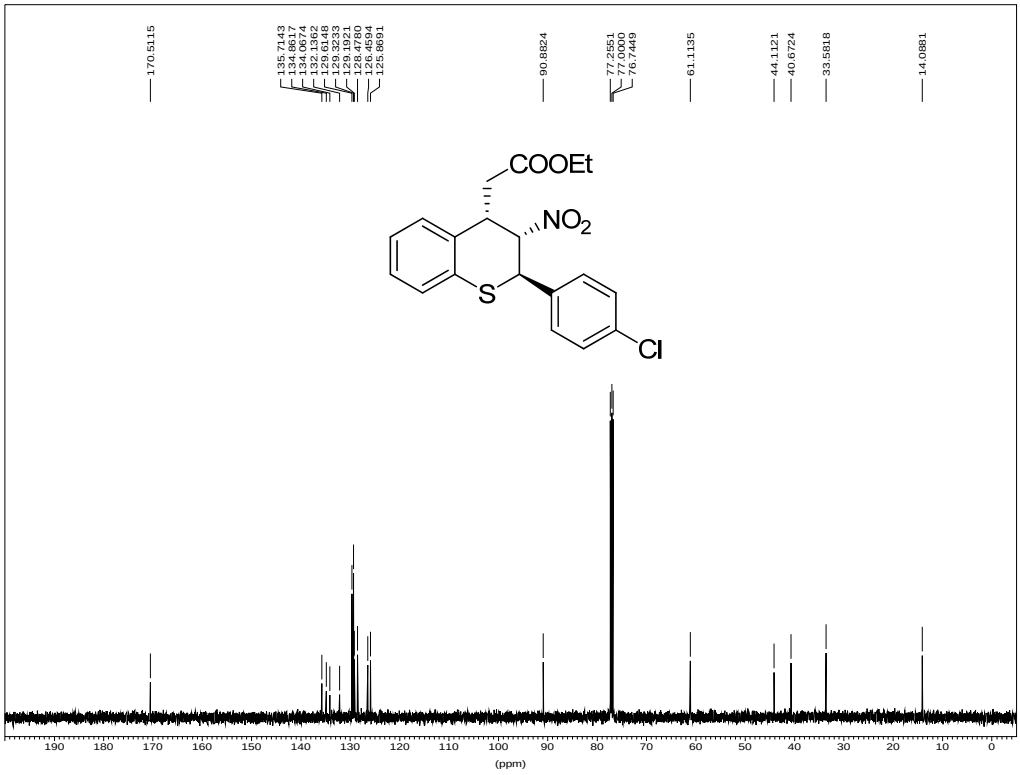
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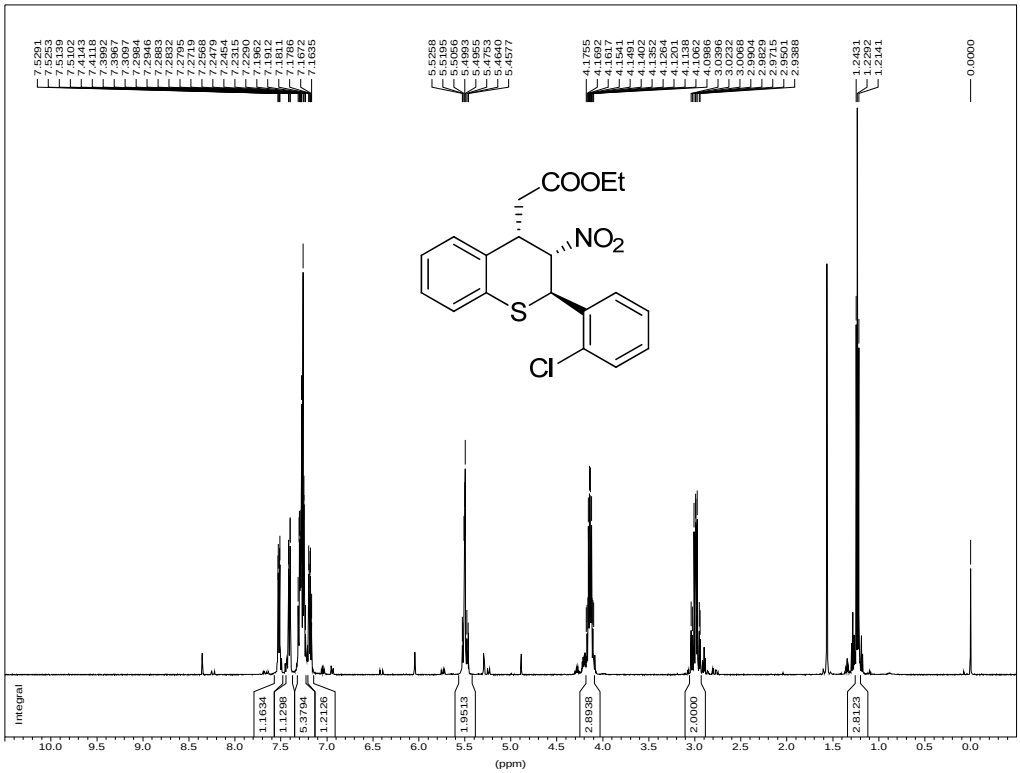
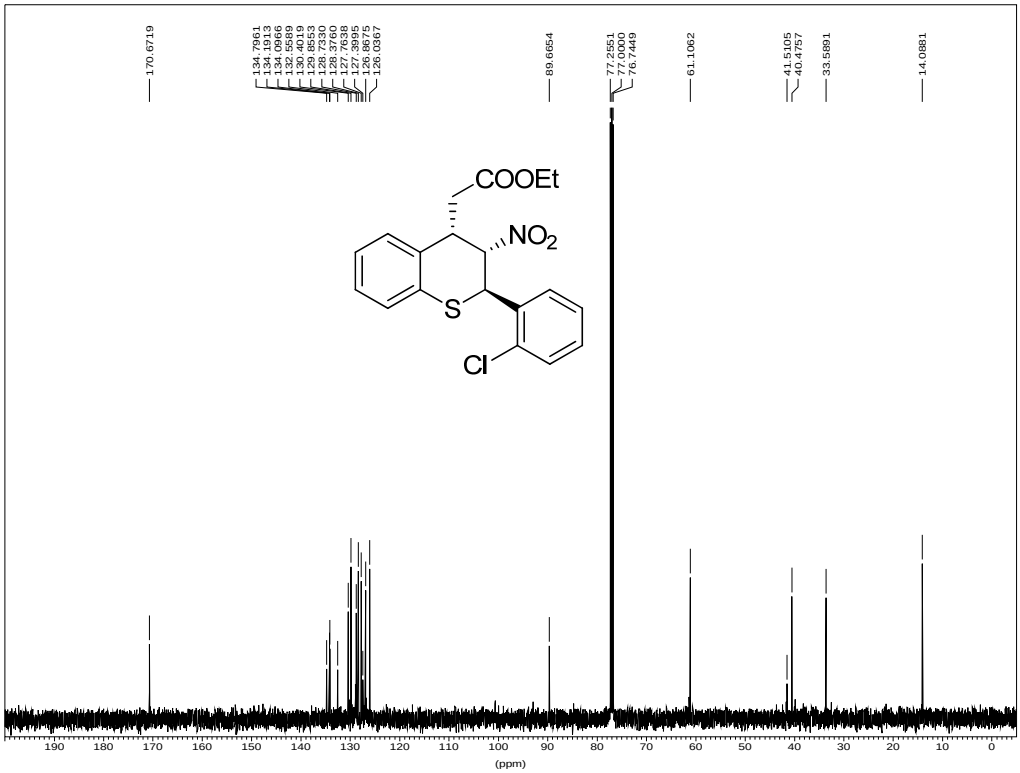
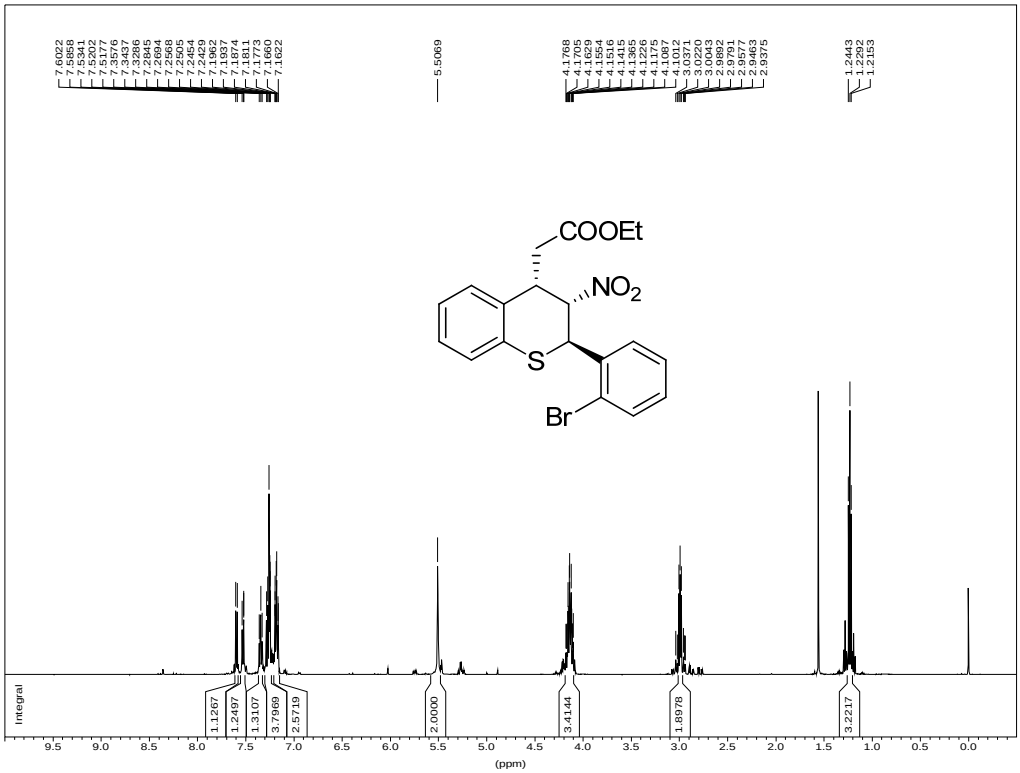
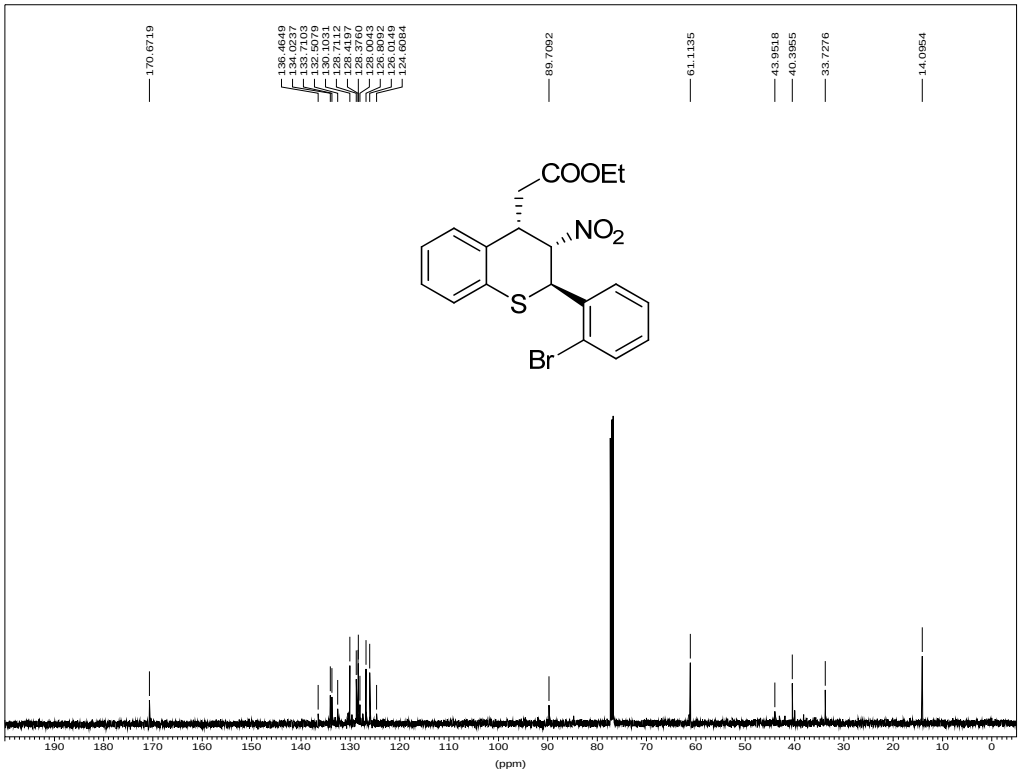
Compound 3d





Compound 3e





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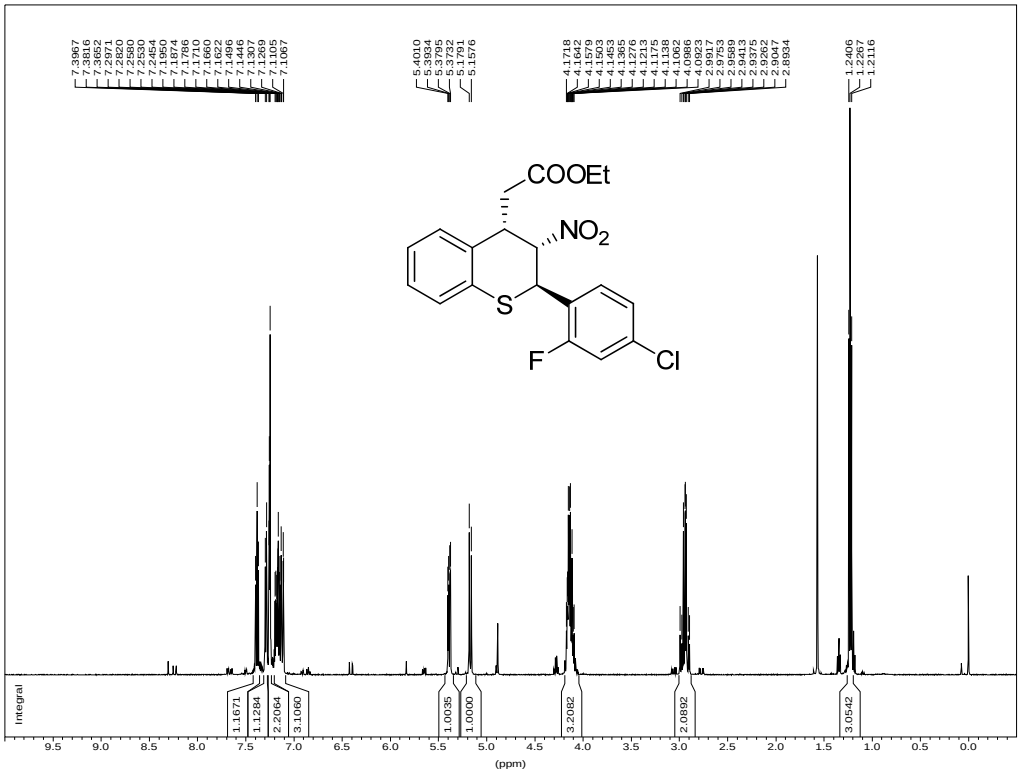
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NO2
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F
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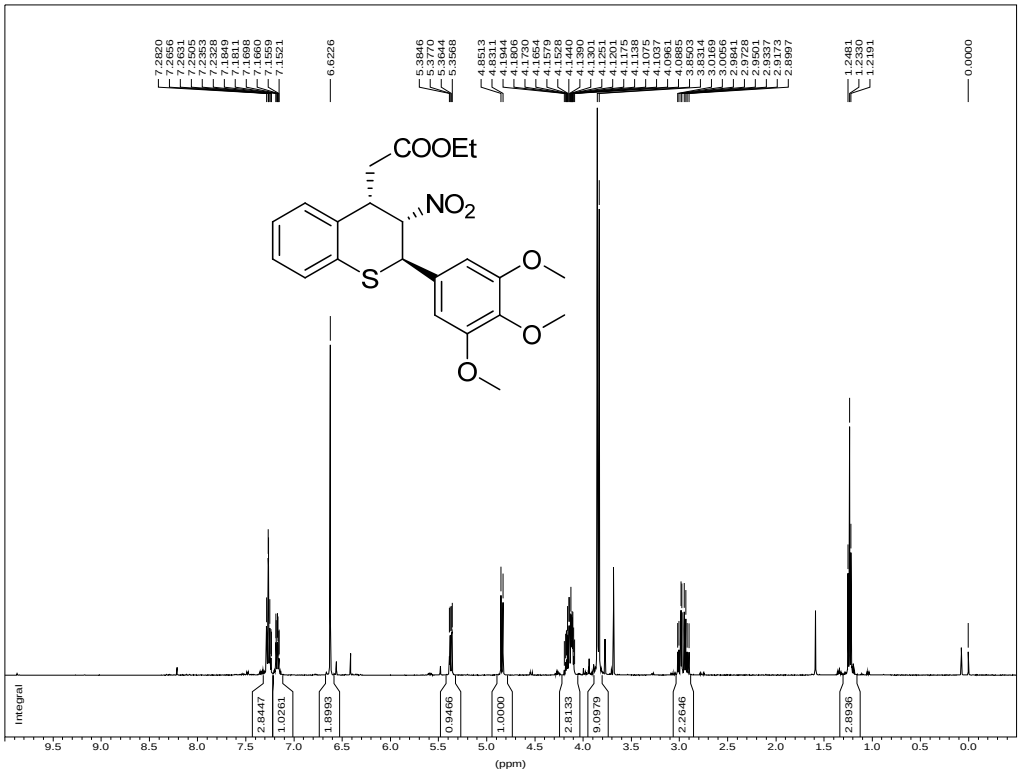
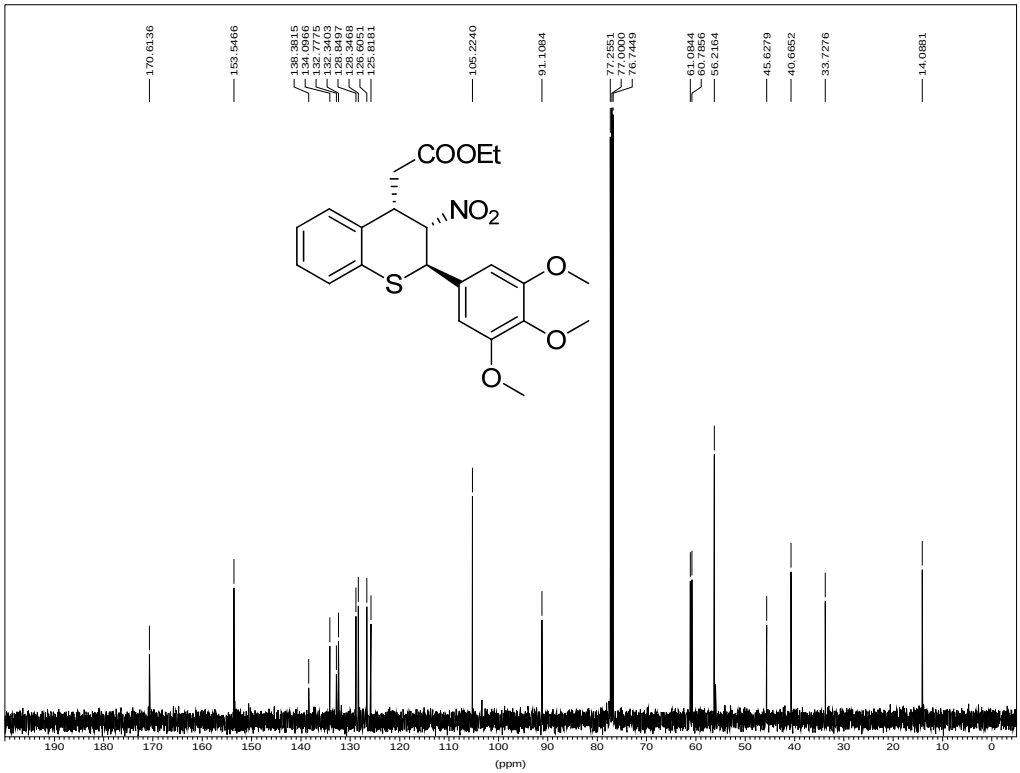
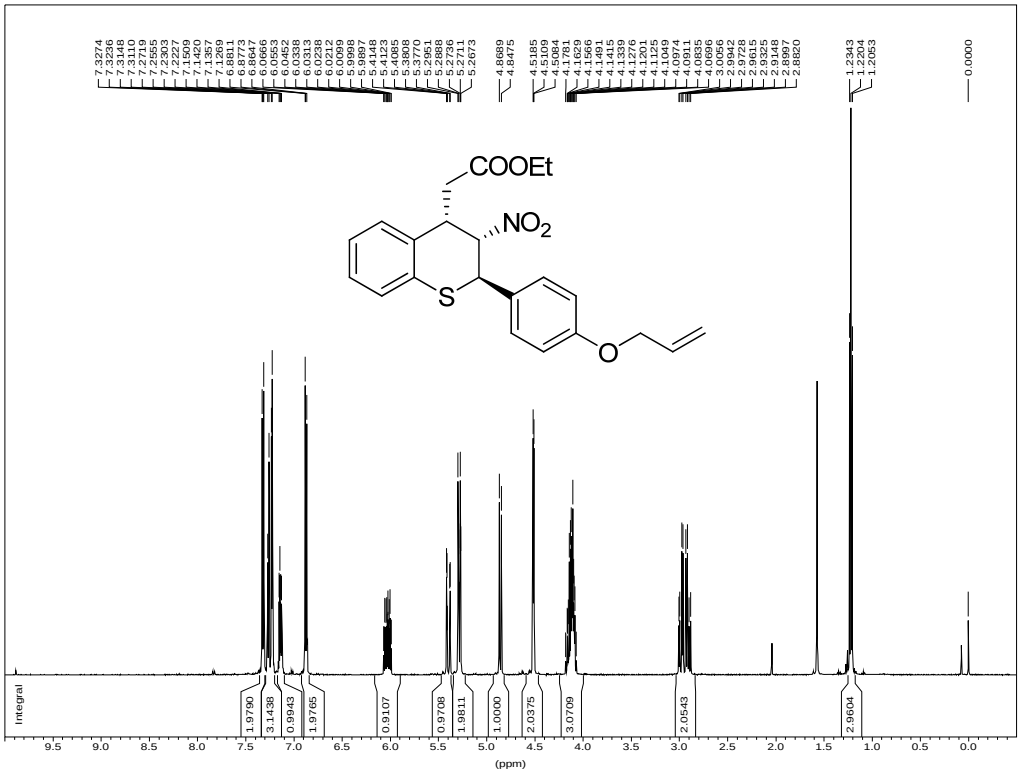
130.2780
129.0610
128.4769
126.7077
126.1023
125.4027
125.3736
123.2831
123.1801
117.2409
117.0368
89.3958
77.2551
77.0000
76.7449
61.1281
40.6724
38.1510
33.3195
14.0735
COOEt
NO2
S
F
Cl
(ppm)

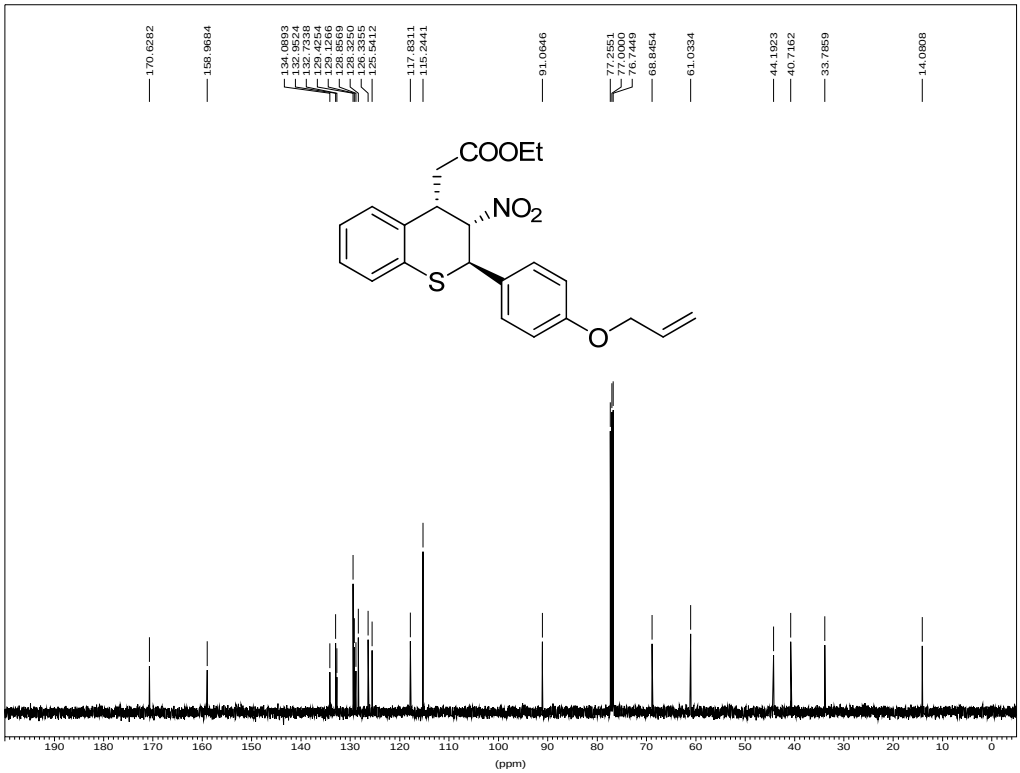
Compound 3g



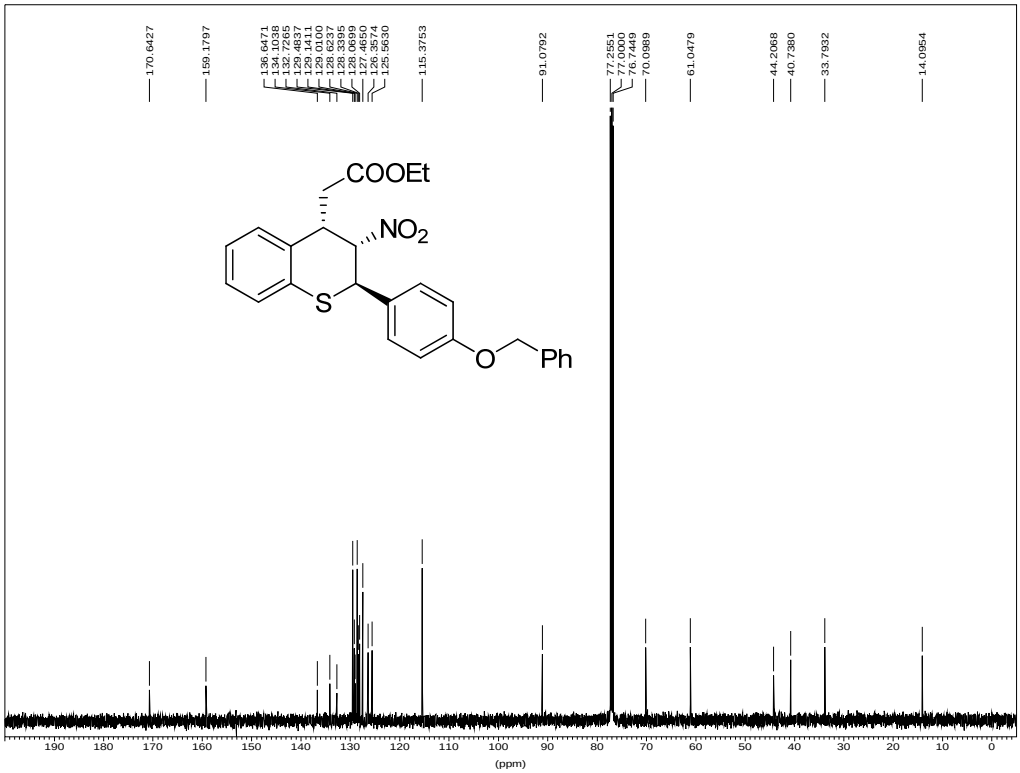


Compound 3h

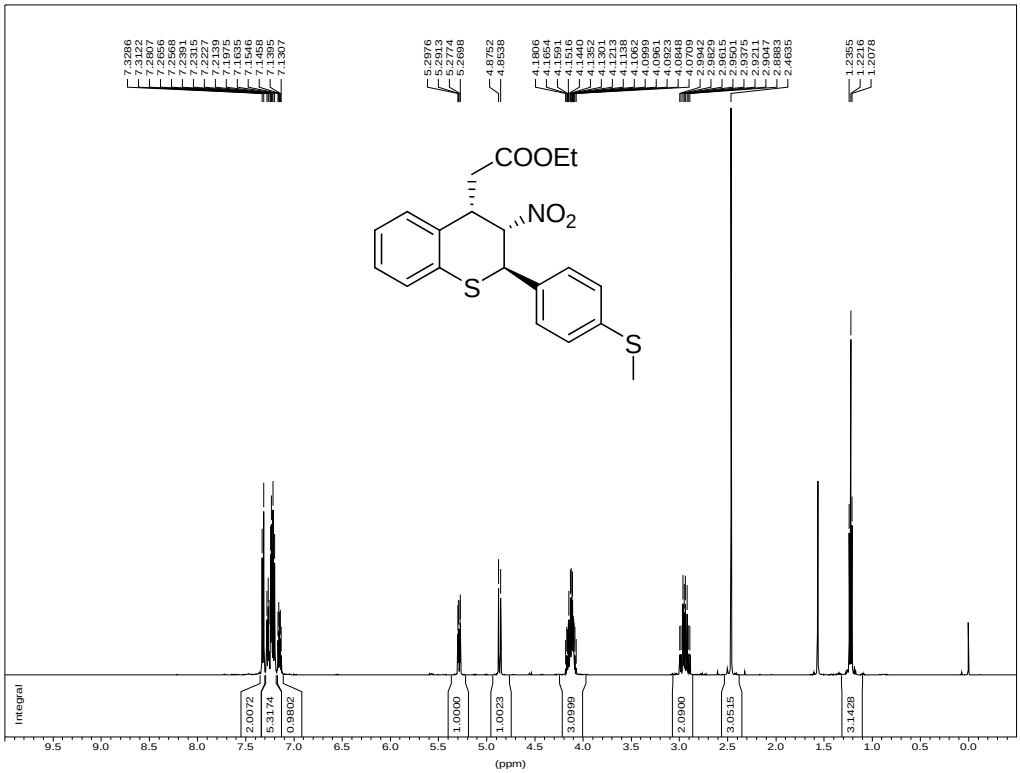


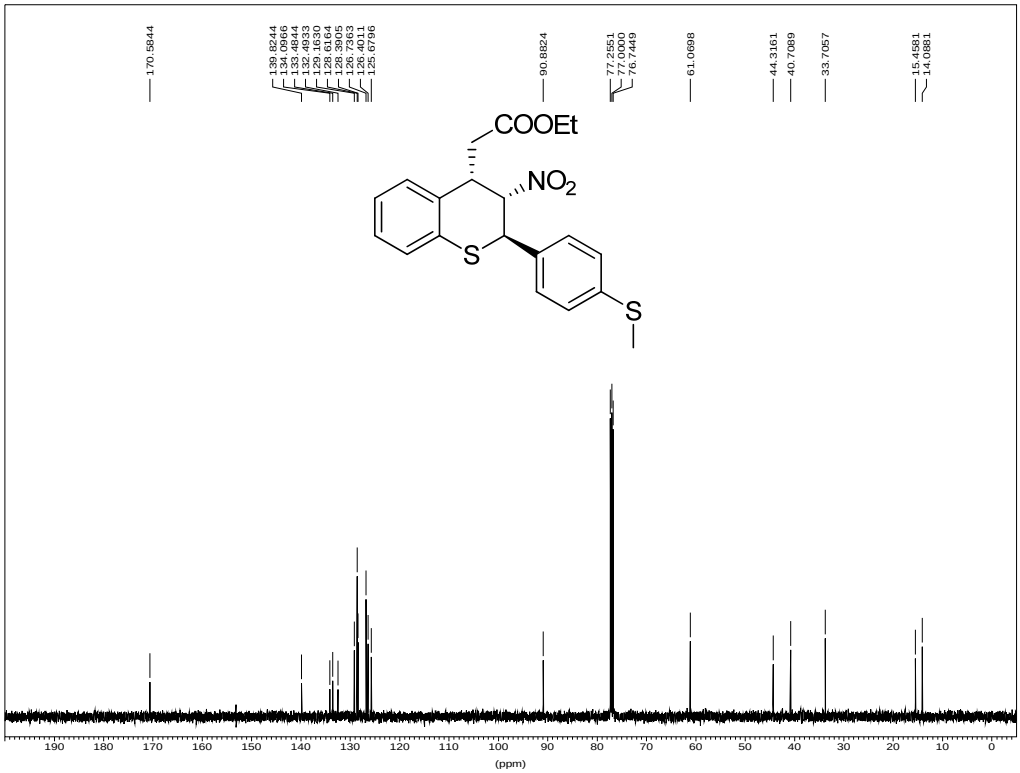


Compound 3i

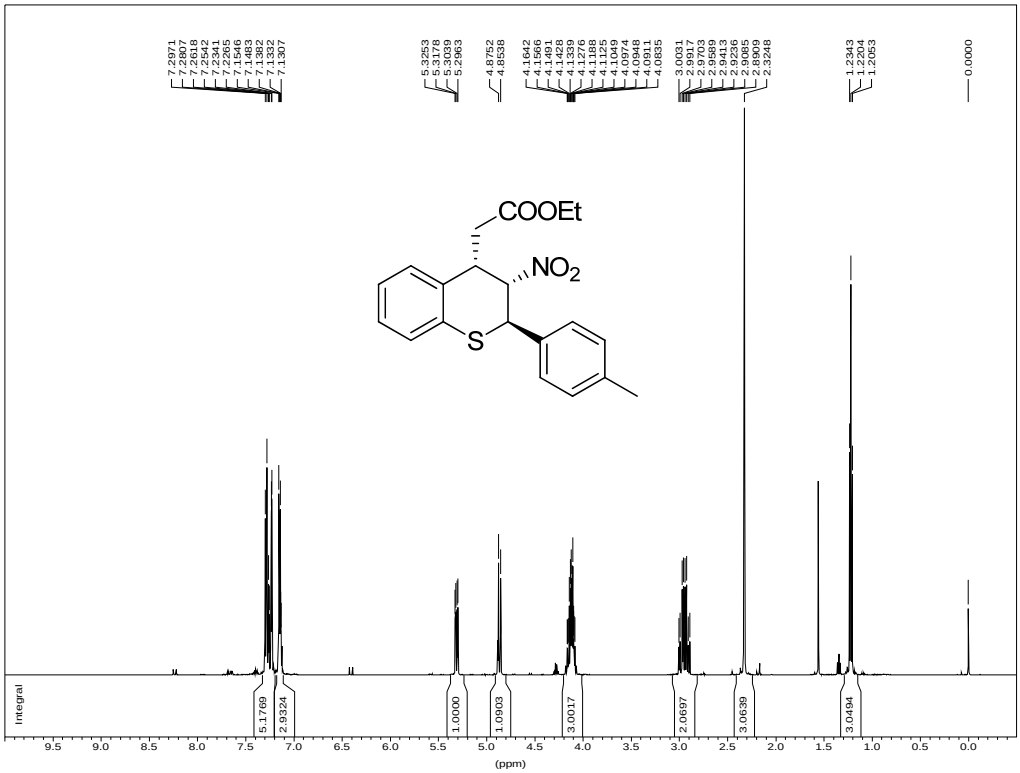


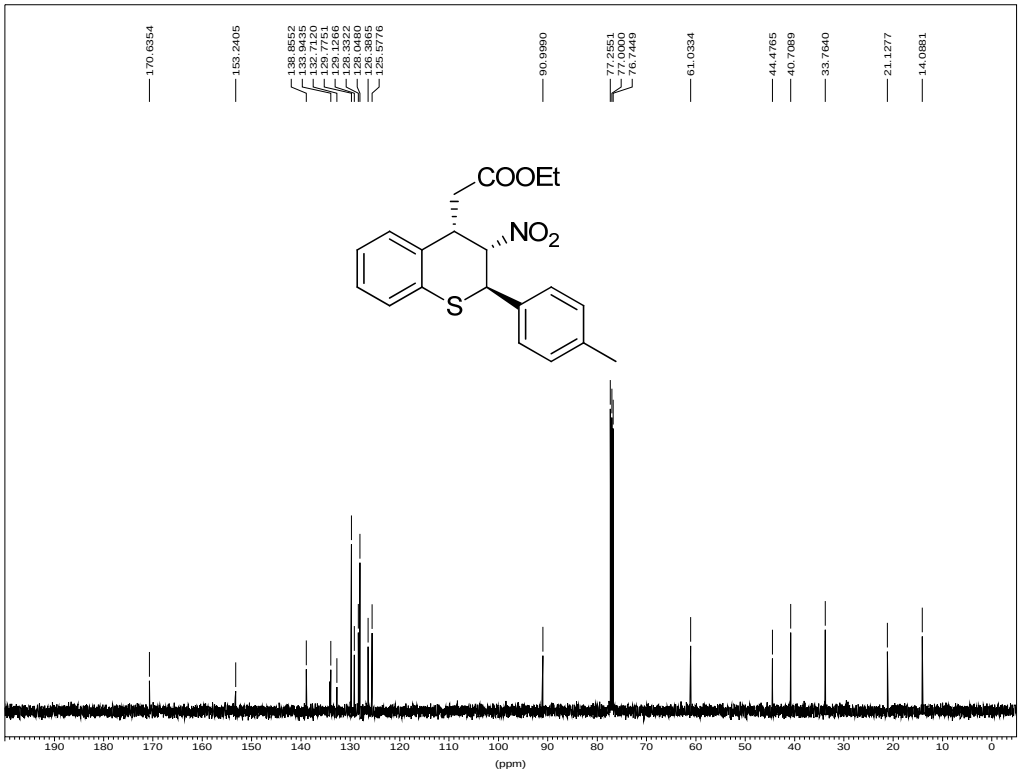
Compound 3j





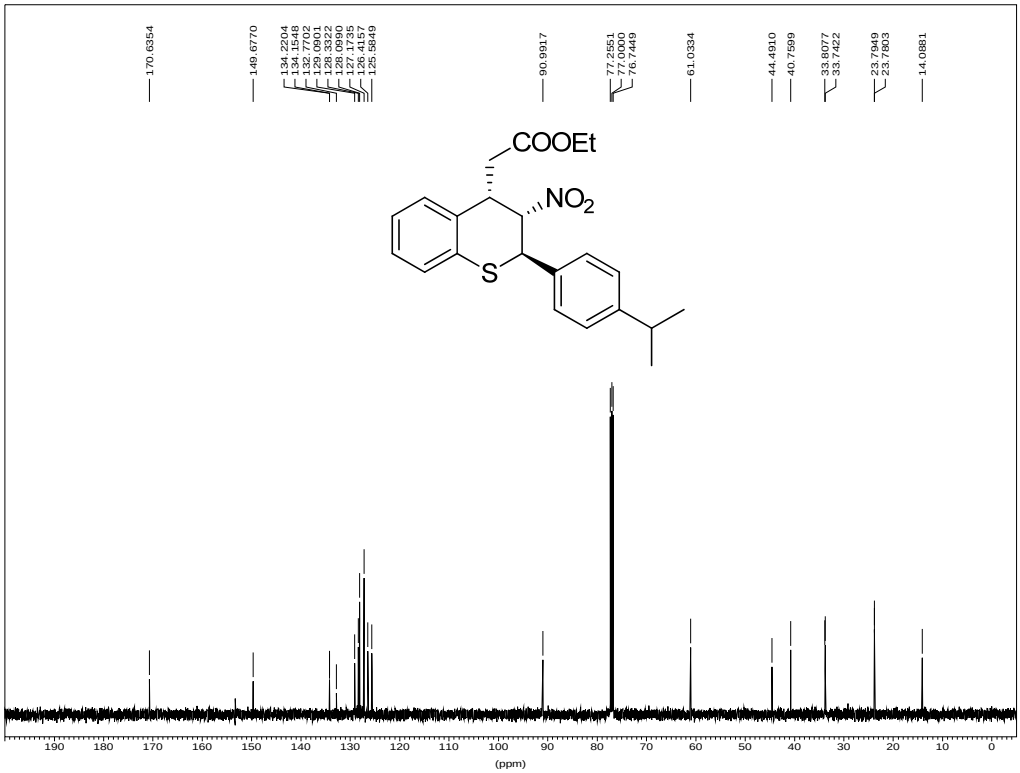
Compound 3k



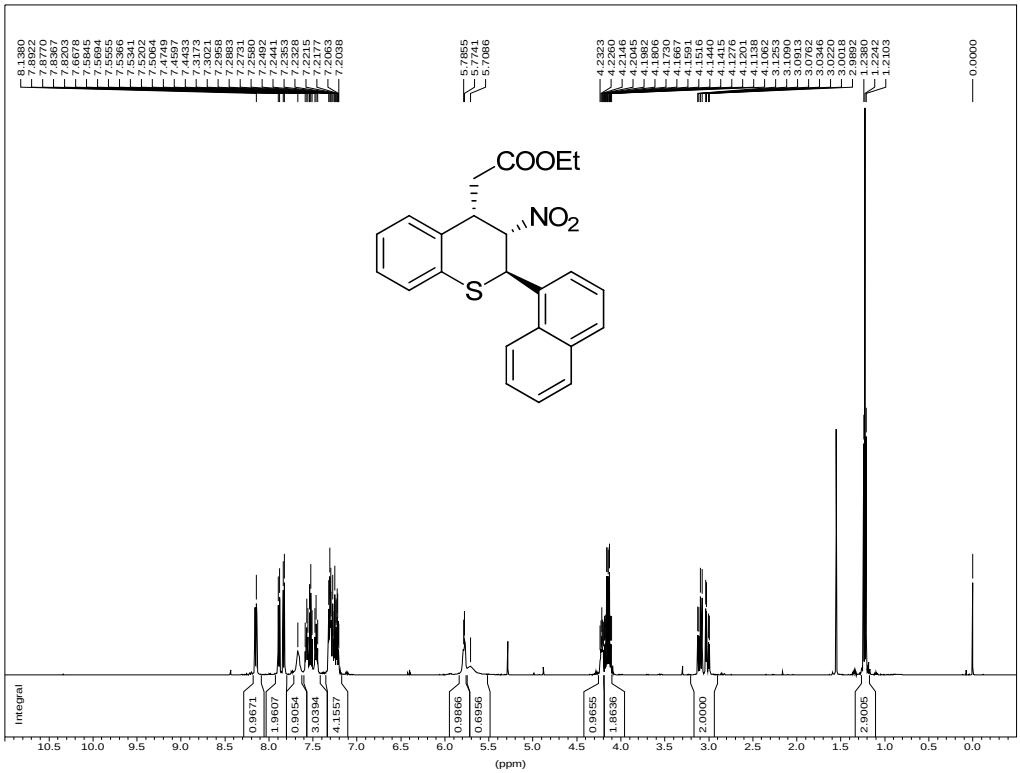


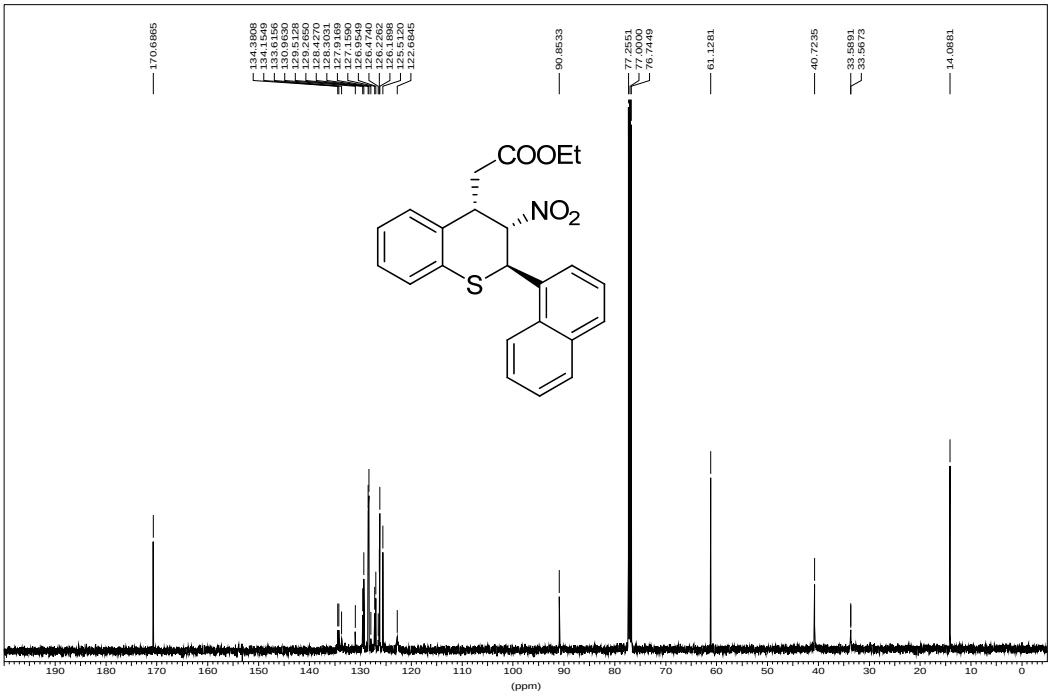
Compound 3l


COOEt
NO2
S
Integral
1.0000
1.0744
3.1661
3.1625
9.4039
(ppm)

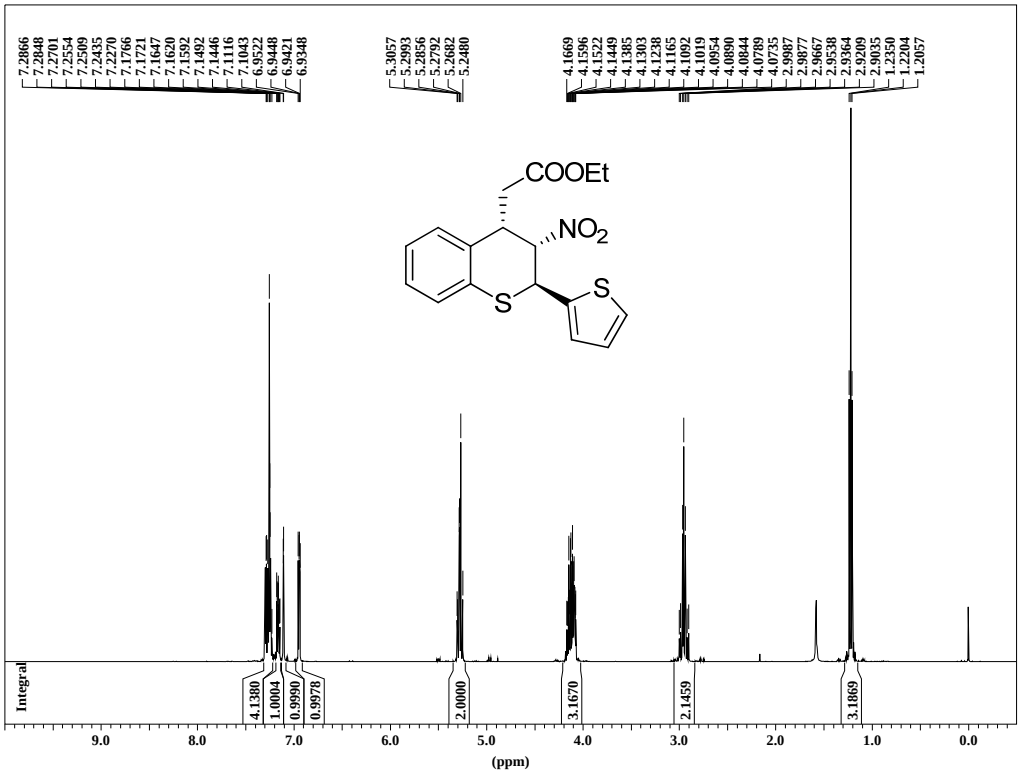

COOEt
NO2
S
(ppm)

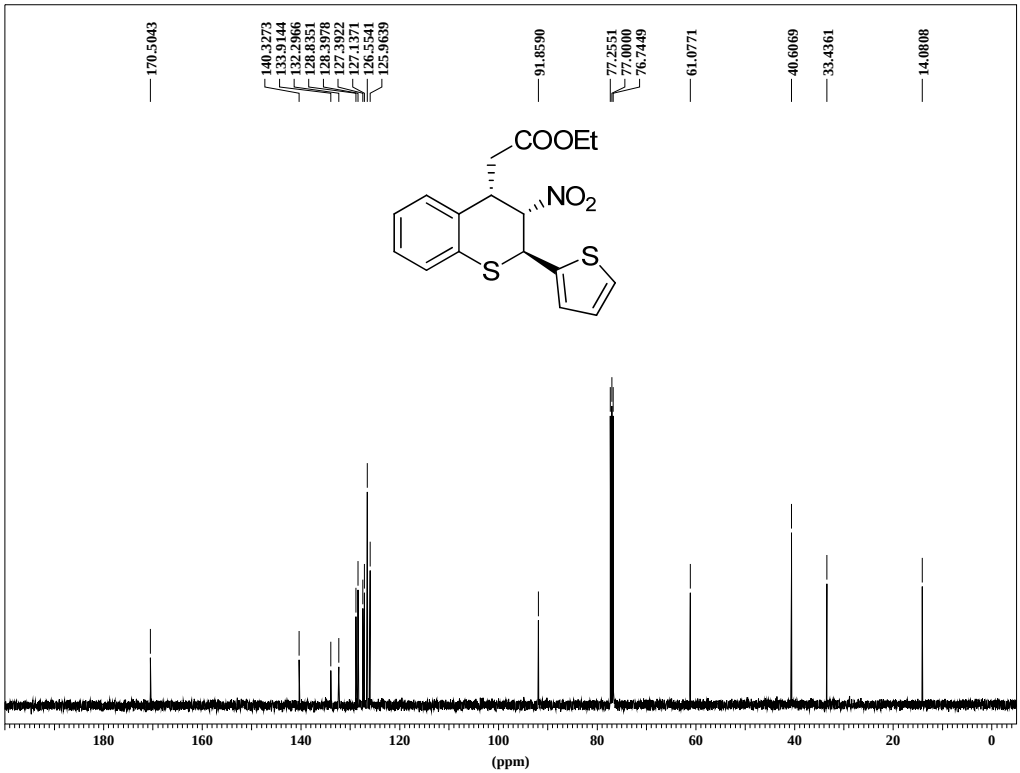
Compound 3m





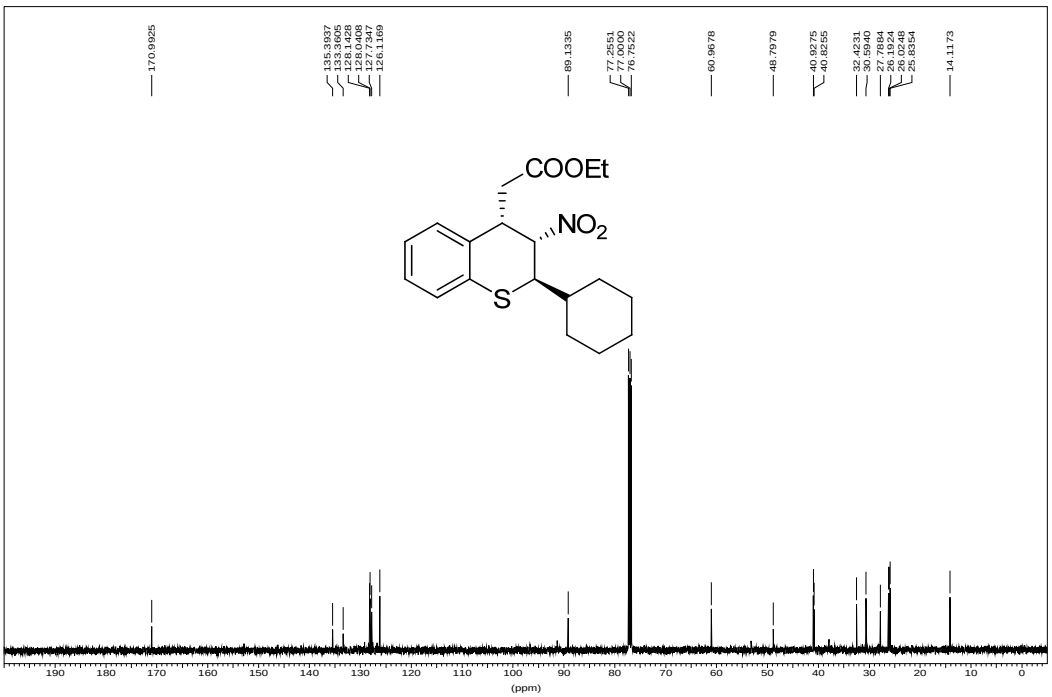
Compound 3n


7.2866
7.2848
7.2701
7.2554
7.2509
7.2435
7.2270
7.1766
7.1721
7.1647
7.1620
7.1592
7.1492
7.1446
7.1116
7.1043
6.9522
6.9448
6.9421
6.9348
5.3057
5.2993
5.2856
5.2792
5.2682
5.2480
4.1669
4.1596
4.1522
4.1449
4.1385
4.1303
4.1238
4.1165
4.1092
4.1019
4.0954
4.0890
4.0844
4.0789
4.0735
2.9987
2.9877
2.9667
2.9538
2.9364
2.9209
2.9035
1.2350
1.2204
1.2057
COOEt
NO2
S
S
Integral
4.1380
1.0004
0.9990
0.9978
2.0000
3.1670
2.1459
3.1869
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
(ppm)

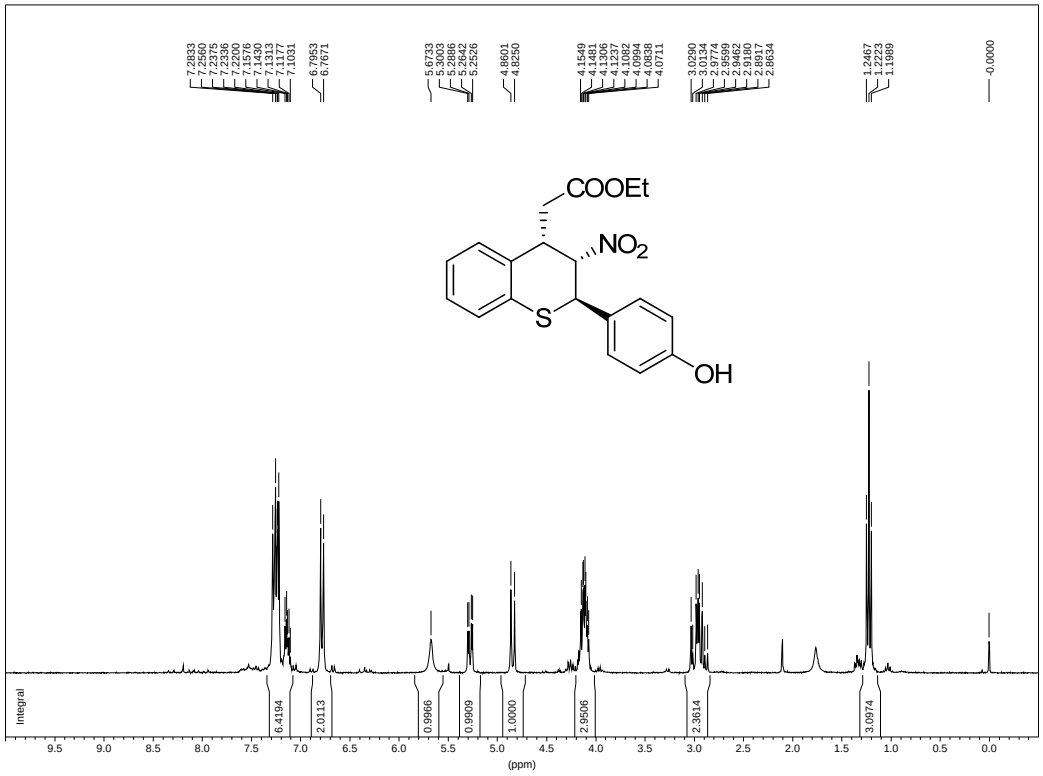

170.5043
140.3273
133.9144
132.2966
128.8351
128.3978
127.3922
127.1371
126.5541
125.9639
91.8590
77.2551
77.0000
76.7449
61.0771
40.6069
33.4361
14.0808
COOEt
NO2
S
S
180
160
140
120
100
80
60
40
20
0
(ppm)

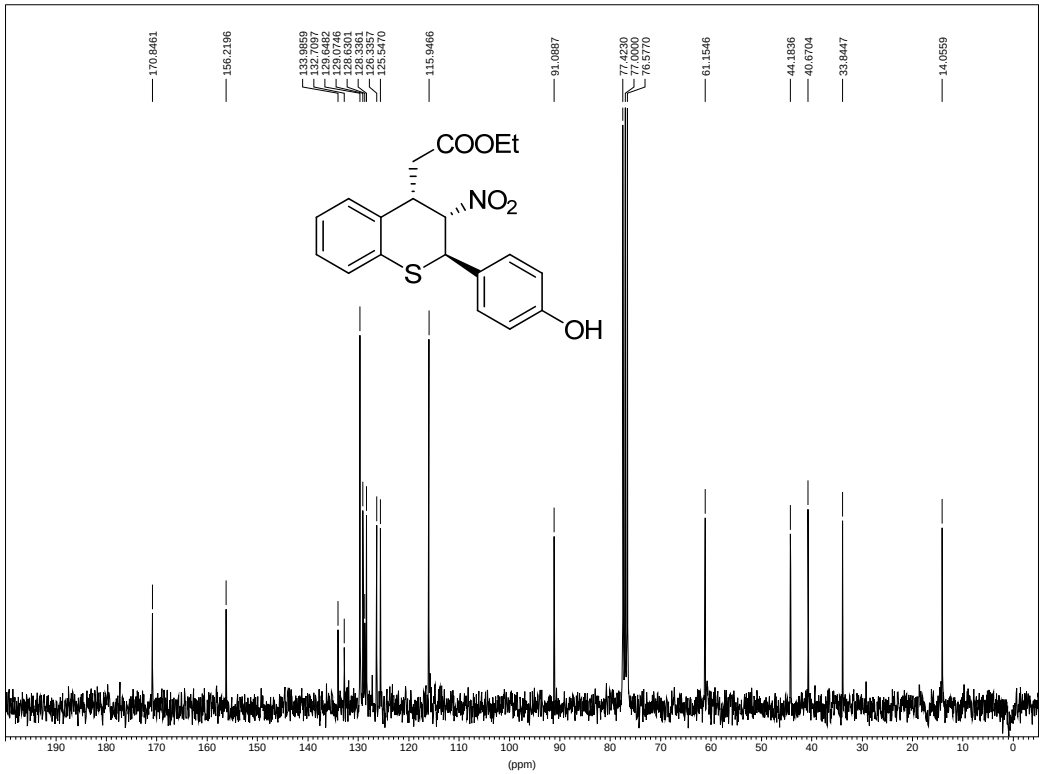
Compound 3o


COOEt
NO2
S
Integral
1.1310
3.4559
0.9917
2.3030
0.9831
1.0000
2.2272
5.4786
9.2239
(ppm)

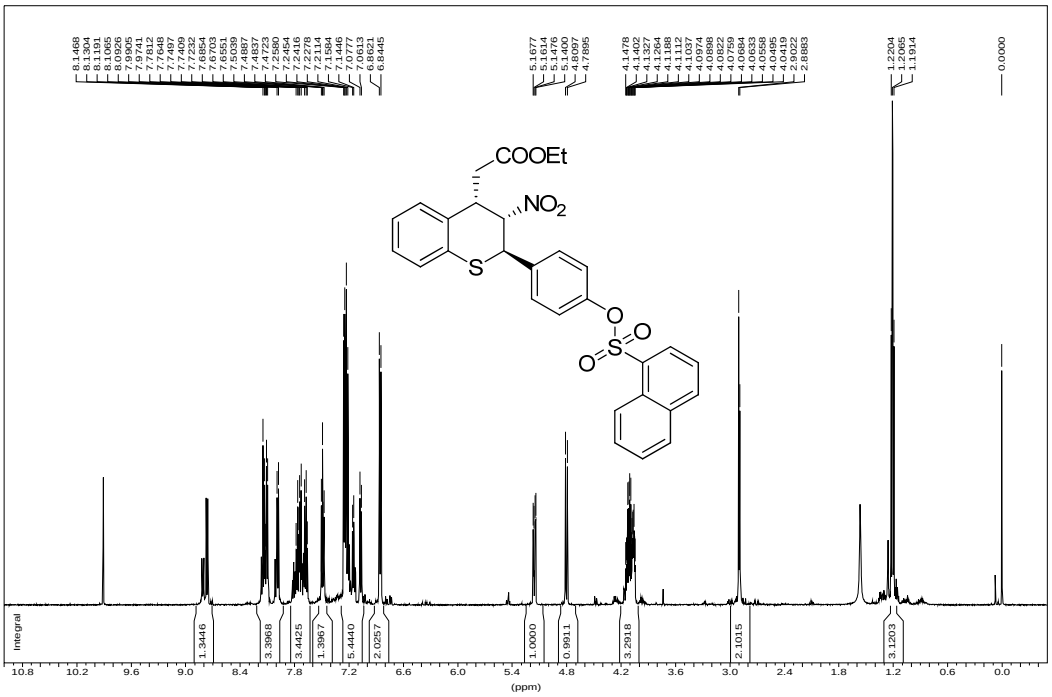

170.9925
135.3937
133.3605
131.4738
128.0408
127.7347
126.1169
89.1335
77.2551
77.0000
76.7522
60.9678
48.7979
40.9275
40.8255
32.4231
30.5940
27.7084
26.1924
26.0248
25.8354
14.1173
COOEt
NO2
S
(ppm)

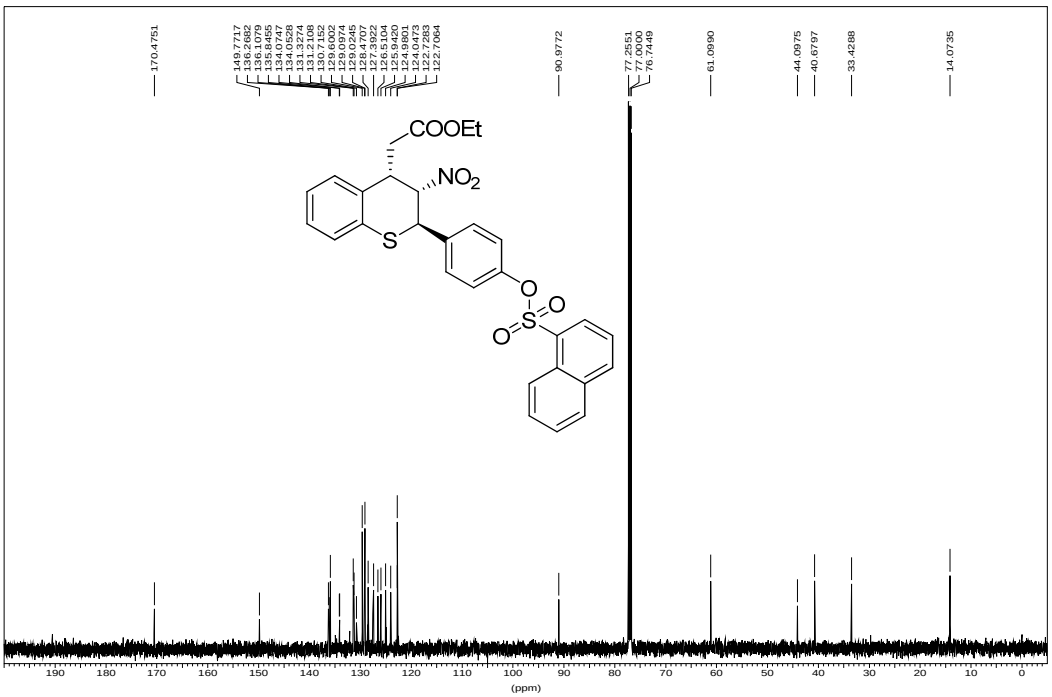
Compound 3p


7.2833
7.2560
7.2375
7.2336
7.2290
7.1570
7.1430
7.1313
7.1177
7.1031
6.7953
6.7671
5.6733
5.3003
5.2886
5.2642
5.2526
4.8601
4.8250
4.1549
4.1481
4.1306
4.1237
4.1092
4.0994
4.0838
4.0711
3.0290
3.0134
2.9774
2.9659
2.9482
2.9180
2.8917
2.8634
1.2467
1.2233
1.1989
-0.0000
COOEt
NO2
S
OH
Integral
6.4194
2.0113
0.9966
0.9909
1.0000
2.9506
2.3614
3.0974
(ppm)


170.8461
156.2196
133.9859
132.7097
129.6482
129.0746
128.8361
128.3361
126.3357
125.5470
115.9466
91.0887
77.4230
77.0000
76.5770
61.1546
44.1836
40.6704
33.8447
14.0559
COOEt
NO2
S
OH
(ppm)

Compound 3q

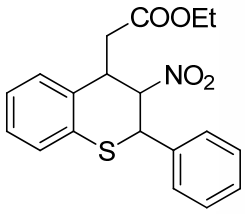

COOEt
NO2
S
O
S
O
O
Integral
1.3446
3.3968
3.4425
1.3967
5.4440
2.0257
1.0000
0.9911
3.2918
2.1015
3.1203
(ppm)


COOEt
NO2
S
O
S
O
O
(ppm)

Racemic **3a**

==== Shimadzu LCsolution Analysis Report ====

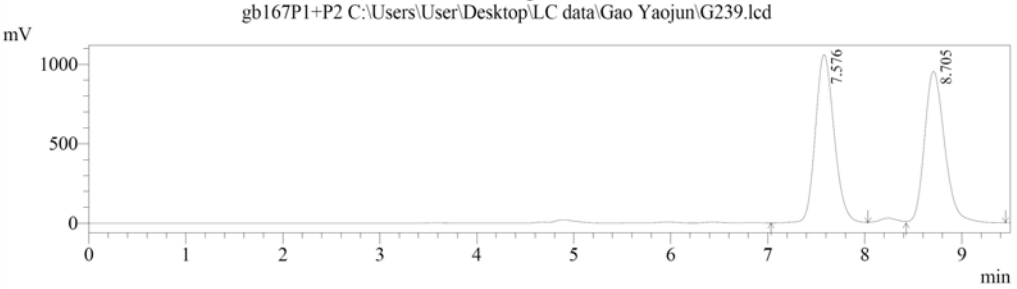
C:\Users\User\Desktop\LC data\Gao Yaojun\G239.lcd



Acquired by : Admin
Sample Name : gb167P1+P2
Sample ID : gyj
Data File Name : G239.lcd
Method File Name : 10%IPA, 1ml-min, 40min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IC column with guard column,10%IPA

Chromatogram

gb167P1+P2 C:\Users\User\Desktop\LC data\Gao Yaojun\G239.lcd



PeakTable

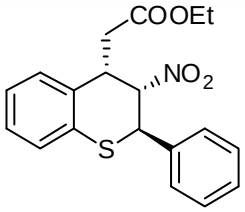
SPD-20A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	7.576	14264209	1059469	50.915	52.603
2	8.705	13751628	954623	49.085	47.397
Total		28015836	2014092	100.000	100.000

Enantiomeric enriched **3a**

==== Shimadzu LCsolution Analysis Report ====

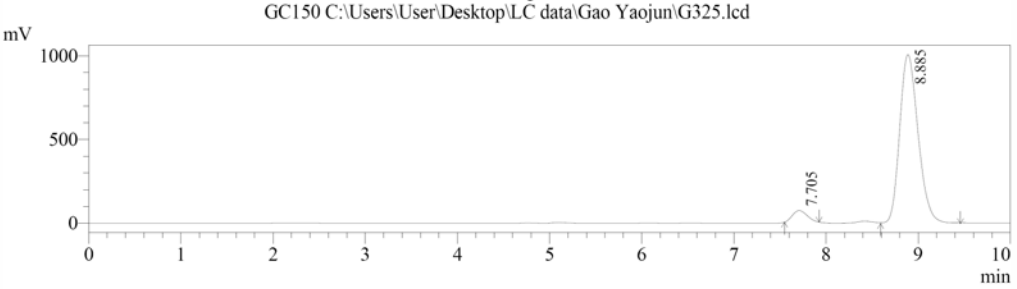
C:\Users\User\Desktop\LC data\Gao Yaojun\G325.lcd



Acquired by : Admin
Sample Name : GC150
Sample ID : GC
Data File Name : G325.lcd
Method File Name : 10%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IC column with guard column,10%IPA

Chromatogram

GC150 C:\Users\User\Desktop\LC data\Gao Yaojun\G325.lcd



PeakTable

SPD-20A Ch1 254nm

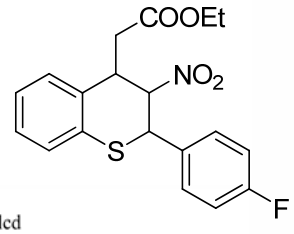
Peak#	Ret. Time	Area	Height	Area %	Height %
1	7.705	769464	69791	5.173	6.464
2	8.885	14105205	1009885	94.827	93.536
Total		14874669	1079676	100.000	100.000

Racemic **3b**

==== Shimadzu LCsolution Analysis Report ====

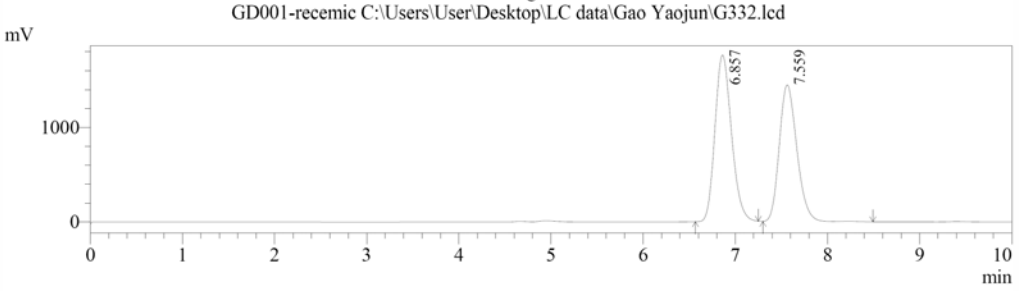
C:\Users\User\Desktop\LC data\Gao Yaojun\G332.lcd

Acquired by : Admin
Sample Name : GD001-recemic
Sample ID : GC
Data File Name : G332.lcd
Method File Name : 10%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IC column with guard column,10%IPA



Chromatogram

GD001-recemic C:\Users\User\Desktop\LC data\Gao Yaojun\G332.lcd



PeakTable

SPD-20A Ch1 254nm

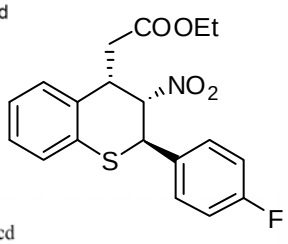
Peak#	Ret. Time	Area	Height	Area %	Height %
1	6.857	21932199	1760568	53.369	54.960
2	7.559	19163404	1442792	46.631	45.040
Total		41095603	3203359	100.000	100.000

Enantiomeric enriched **3b**

==== Shimadzu LCsolution Analysis Report ====

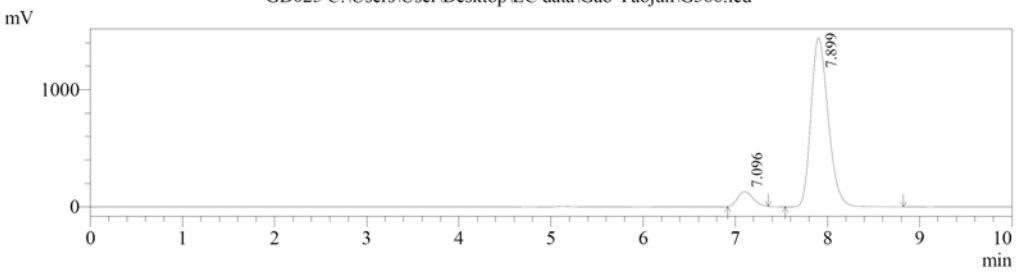
C:\Users\User\Desktop\LC data\Gao Yaojun\G386.lcd

Acquired by : Admin
Sample Name : GD023
Sample ID : GYJ
Data File Name : G386.lcd
Method File Name : 10%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IC column with guard column,10%IPA



Chromatogram

GD023 C:\Users\User\Desktop\LC data\Gao Yaojun\G386.lcd



PeakTable

SPD-20A Ch1 254nm

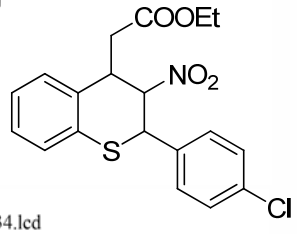
Peak#	Ret. Time	Area	Height	Area %	Height %
1	7.096	1452666	128165	7.202	8.171
2	7.899	18717077	1440371	92.798	91.829
Total		20169742	1568536	100.000	100.000

Racemic **3c**

==== Shimadzu LCsolution Analysis Report ====

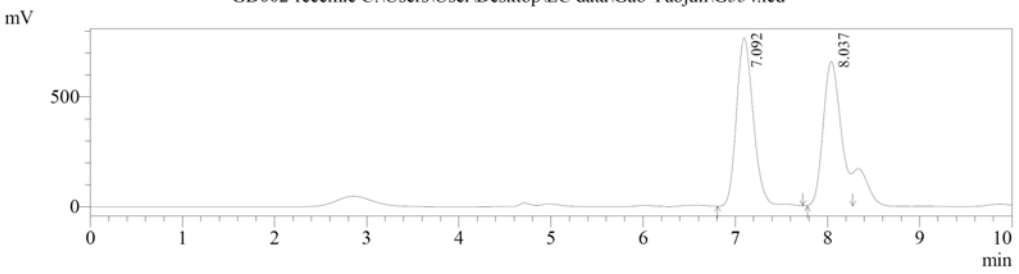
C:\Users\User\Desktop\LC data\Gao Yaojun\G334.lcd

Acquired by : Admin
Sample Name : GD002-recemic
Sample ID : GC
Data File Name : G334.lcd
Method File Name : 10%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IC column with guard column,10%IPA



Chromatogram

GD002-recemic C:\Users\User\Desktop\LC data\Gao Yaojun\G334.lcd



PeakTable

SPD-20A Ch1 254nm

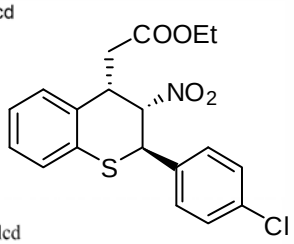
Peak#	Ret. Time	Area	Height	Area %	Height %
1	7.092	9733021	765706	52.015	53.745
2	8.037	8978923	658985	47.985	46.255
Total		18711944	1424690	100.000	100.000

Enantiomeric enriched **3c**

==== Shimadzu LCsolution Analysis Report ====

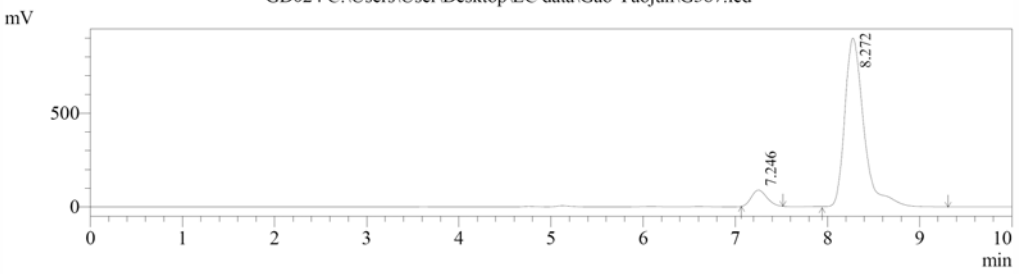
C:\Users\User\Desktop\LC data\Gao Yaojun\G387.lcd

Acquired by : Admin
Sample Name : GD024
Sample ID : GYJ
Data File Name : G387.lcd
Method File Name : 10%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IC column with guard column,10%IPA



Chromatogram

GD024 C:\Users\User\Desktop\LC data\Gao Yaojun\G387.lcd



PeakTable

SPD-20A Ch1 254nm

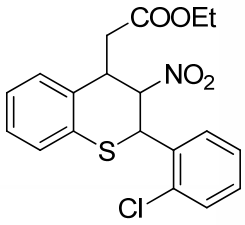
Peak#	Ret. Time	Area	Height	Area %	Height %
1	7.246	1005140	86645	7.057	8.748
2	8.272	13237942	903844	92.943	91.252
Total		14243082	990489	100.000	100.000

Racemic **3d**

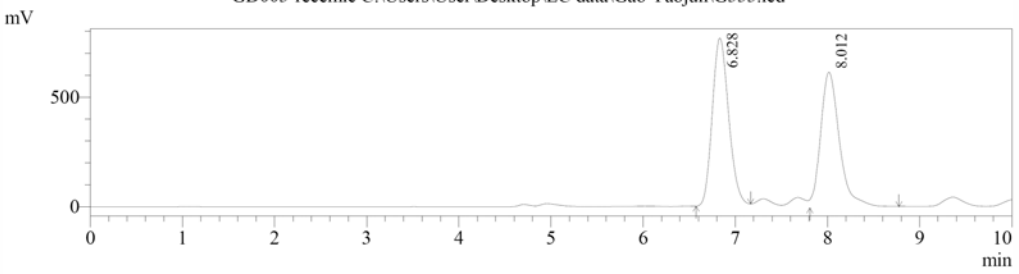
==== Shimadzu LCsolution Analysis Report ====

C:\Users\User\Desktop\LC data\Gao Yaojun\G333.lcd

Acquired by : Admin
Sample Name : GD003-recemic
Sample ID : GC
Data File Name : G333.lcd
Method File Name : 10%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IC column with guard column,10%IPA



Chromatogram
GD003-recemic C:\Users\User\Desktop\LC data\Gao Yaojun\G333.lcd



PeakTable

SPD-20A Ch1 254nm

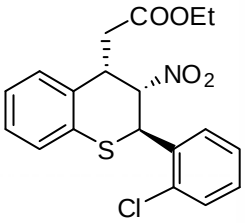
Peak#	Ret. Time	Area	Height	Area %	Height %
1	6.828	9373308	762774	51.483	55.223
2	8.012	8833222	618484	48.517	44.777
Total		18206530	1381258	100.000	100.000

Enantiomeric enriched **3d**

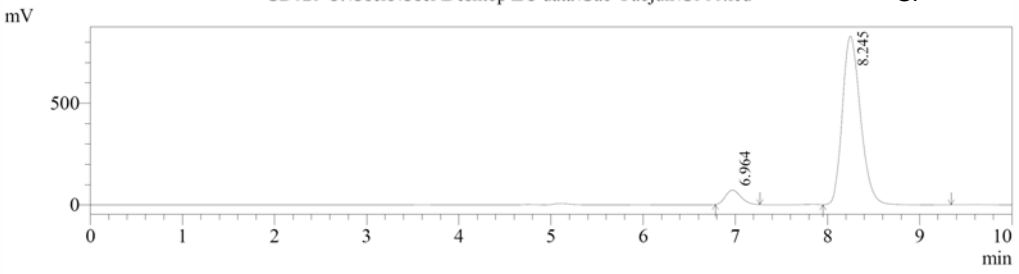
==== Shimadzu LCsolution Analysis Report ====

C:\Users\User\Desktop\LC data\Gao Yaojun\G388.lcd

Acquired by : Admin
Sample Name : GD025
Sample ID : GYJ
Data File Name : G388.lcd
Method File Name : 10%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IC column with guard column,10%IPA



Chromatogram
GD025 C:\Users\User\Desktop\LC data\Gao Yaojun\G388.lcd



PeakTable

SPD-20A Ch1 254nm

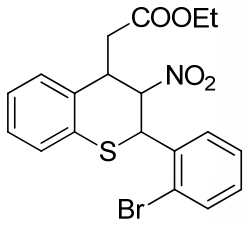
Peak#	Ret. Time	Area	Height	Area %	Height %
1	6.964	826394	71271	6.774	7.908
2	8.245	11373811	830018	93.226	92.092
Total		12200205	901289	100.000	100.000

Racemic **3e**

==== Shimadzu LCsolution Analysis Report ====

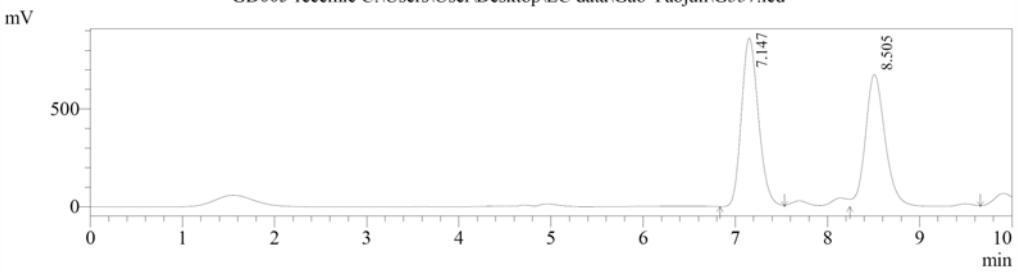
C:\Users\User\Desktop\LC data\Gao Yaojun\G337.lcd

Acquired by : Admin
Sample Name : GD005-recemic
Sample ID : GC
Data File Name : G337.lcd
Method File Name : 10%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IC column with guard column,10%IPA



Chromatogram

GD005-recemic C:\Users\User\Desktop\LC data\Gao Yaojun\G337.lcd



PeakTable

SPD-20A Ch1 254nm

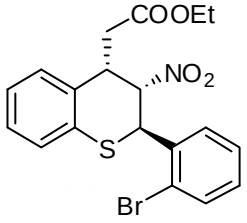
Peak#	Ret. Time	Area	Height	Area %	Height %
1	7.147	11110043	862821	52.225	56.062
2	8.505	10163483	676233	47.775	43.938
Total		21273525	1539054	100.000	100.000

Enantiomeric enriched **3e**

==== Shimadzu LCsolution Analysis Report ====

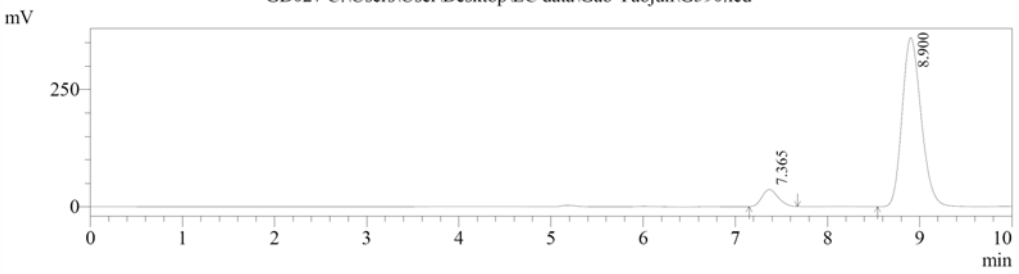
C:\Users\User\Desktop\LC data\Gao Yaojun\G390.lcd

Acquired by : Admin
Sample Name : GD027
Sample ID : GYJ
Data File Name : G390.lcd
Method File Name : 10%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IC column with guard column,10%IPA



Chromatogram

GD027 C:\Users\User\Desktop\LC data\Gao Yaojun\G390.lcd



PeakTable

SPD-20A Ch1 254nm

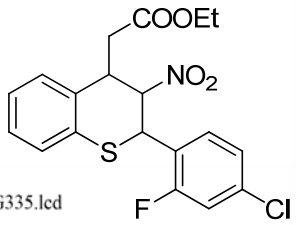
Peak#	Ret. Time	Area	Height	Area %	Height %
1	7.365	443347	36582	7.844	9.197
2	8.900	5208351	361195	92.156	90.803
Total		5651698	397776	100.000	100.000

Racemic **3f**

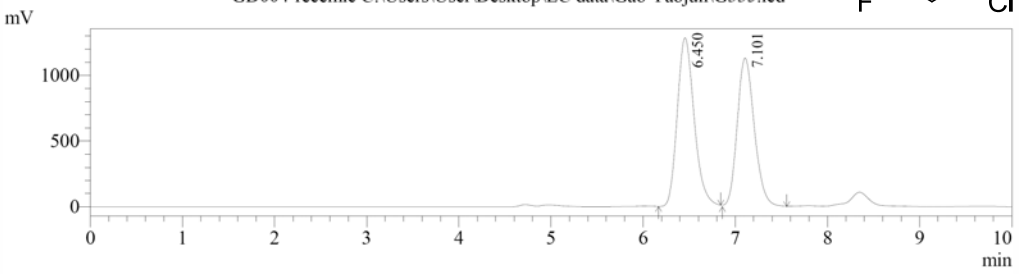
==== Shimadzu LCsolution Analysis Report ====

C:\Users\User\Desktop\LC data\Gao Yaojun\G335.lcd

Acquired by : Admin
Sample Name : GD004-recemic
Sample ID : GC
Data File Name : G335.lcd
Method File Name : 10%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IC column with guard column,10%IPA



Chromatogram
GD004-recemic C:\Users\User\Desktop\LC data\Gao Yaojun\G335.lcd



PeakTable

SPD-20A Ch1 254nm

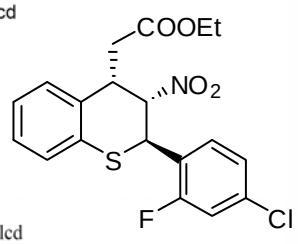
Peak#	Ret. Time	Area	Height	Area %	Height %
1	6.450	16227056	1277700	52.524	53.029
2	7.101	14667638	1131729	47.476	46.971
Total		30894694	2409429	100.000	100.000

Enantiomeric enriched **3f**

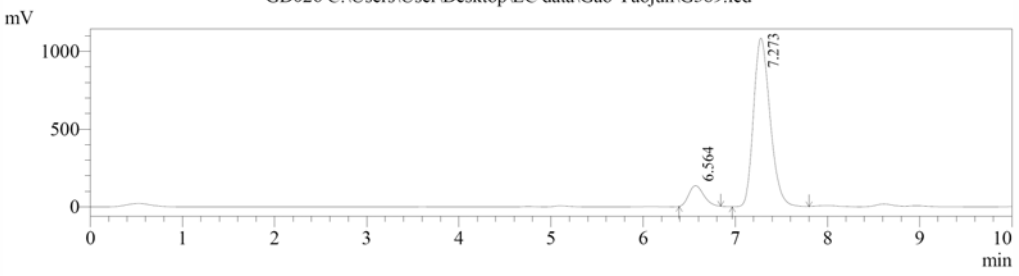
==== Shimadzu LCsolution Analysis Report ====

C:\Users\User\Desktop\LC data\Gao Yaojun\G389.lcd

Acquired by : Admin
Sample Name : GD026
Sample ID : GYJ
Data File Name : G389.lcd
Method File Name : 10%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IC column with guard column,10%IPA



Chromatogram
GD026 C:\Users\User\Desktop\LC data\Gao Yaojun\G389.lcd



PeakTable

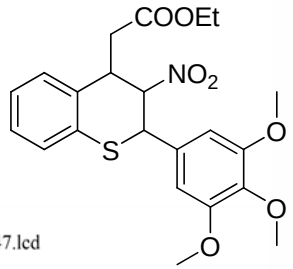
SPD-20A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	6.564	1493596	133179	9.875	10.929
2	7.273	13631721	1085454	90.125	89.071
Total		15125317	1218634	100.000	100.000

Racemic **3g**

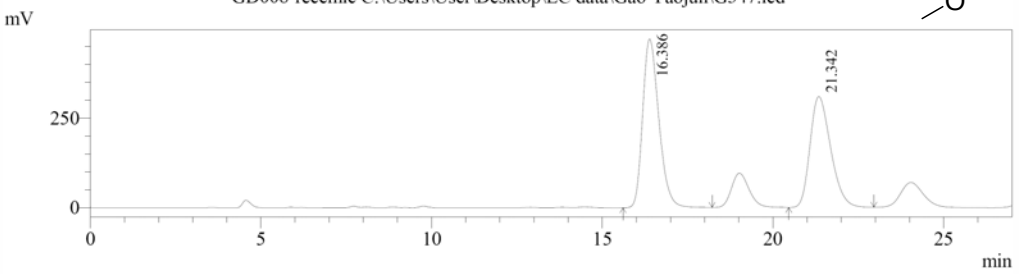
==== Shimadzu LCsolution Analysis Report ====

C:\Users\User\Desktop\LC data\Gao Yaojun\G347.lcd



Acquired by : Admin
Sample Name : GD008-recemic
Sample ID : GYJ
Data File Name : G347.lcd
Method File Name : 20%IPA, 1ml-min, 40min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IC column with guard column,20%IPA

Chromatogram
GD008-recemic C:\Users\User\Desktop\LC data\Gao Yaojun\G347.lcd



PeakTable

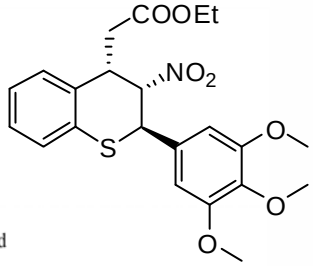
SPD-20A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	16.386	15505454	471139	54.327	60.330
2	21.342	13035443	309801	45.673	39.670
Total		28540898	780940	100.000	100.000

Enantiomeric enriched **3g**

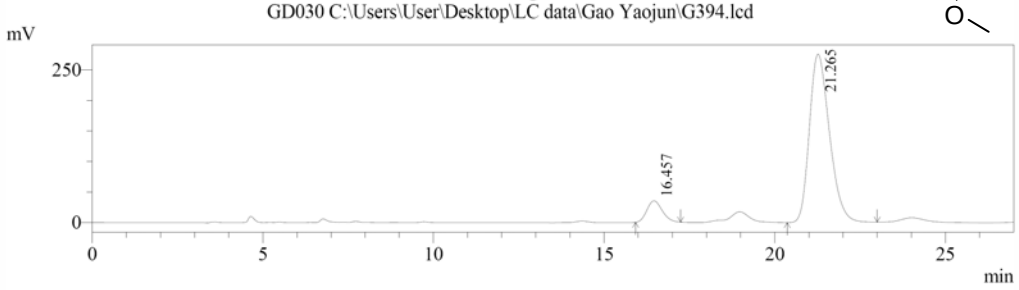
==== Shimadzu LCsolution Analysis Report ====

C:\Users\User\Desktop\LC data\Gao Yaojun\G394.lcd



Acquired by : Admin
Sample Name : GD030
Sample ID : GYJ
Data File Name : G394.lcd
Method File Name : 20%IPA, 1ml-min, 40min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IC column with guard column,20%IPA

Chromatogram
GD030 C:\Users\User\Desktop\LC data\Gao Yaojun\G394.lcd



PeakTable

SPD-20A Ch1 254nm

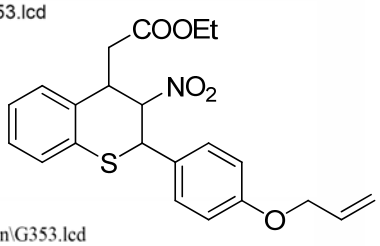
Peak#	Ret. Time	Area	Height	Area %	Height %
1	16.457	1097697	35200	8.860	11.311
2	21.265	11292290	276006	91.140	88.689
Total		12389987	311206	100.000	100.000

Racemic **3h**

==== Shimadzu LCsolution Analysis Report ====

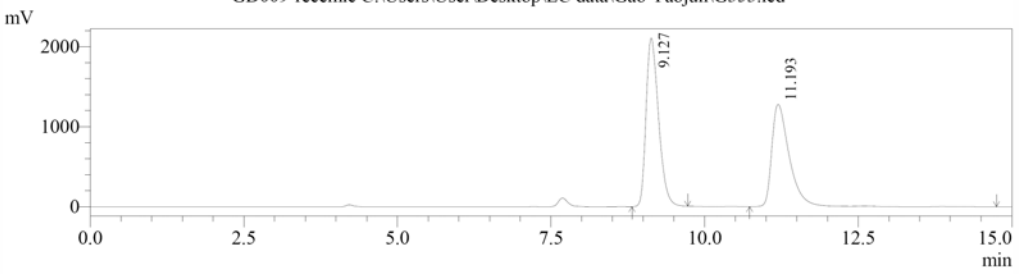
C:\Users\User\Desktop\LC data\Gao Yaojun\G353.lcd

Acquired by : Admin
Sample Name : GD009-recemic
Sample ID : GYJ
Data File Name : G353.lcd
Method File Name : 5%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IB column with guard column,5%IPA



Chromatogram

GD009-recemic C:\Users\User\Desktop\LC data\Gao Yaojun\G353.lcd



PeakTable

SPD-20A Ch1 254nm

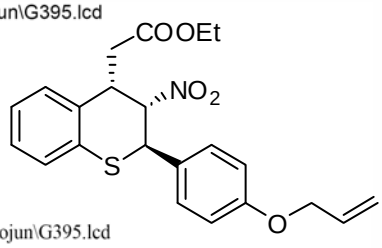
Peak#	Ret. Time	Area	Height	Area %	Height %
1	9.127	29761918	2104954	54.056	62.228
2	11.193	25295302	1277704	45.944	37.772
Total		55057220	3382658	100.000	100.000

Enantiomeric enriched **3h**

==== Shimadzu LCsolution Analysis Report ====

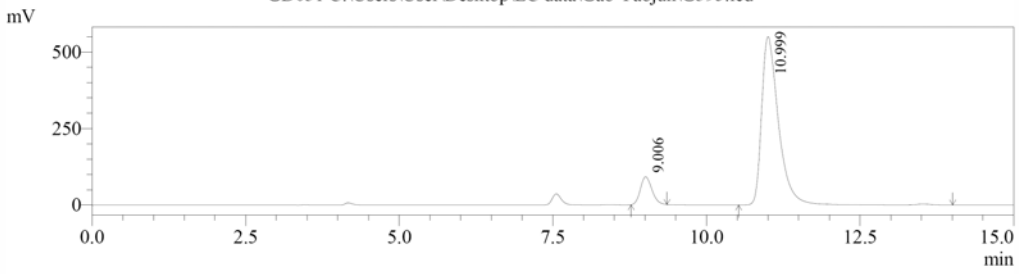
C:\Users\User\Desktop\LC data\Gao Yaojun\G395.lcd

Acquired by : Admin
Sample Name : GD031
Sample ID : GYJ
Data File Name : G395.lcd
Method File Name : 5%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IB column with guard column,5%IPA



Chromatogram

GD031 C:\Users\User\Desktop\LC data\Gao Yaojun\G395.lcd



PeakTable

SPD-20A Ch1 254nm

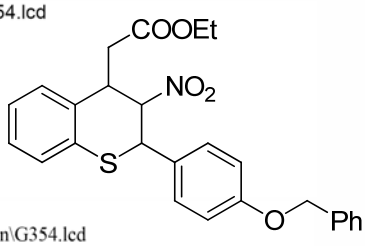
Peak#	Ret. Time	Area	Height	Area %	Height %
1	9.006	1182257	91101	10.094	14.203
2	10.999	10530258	550299	89.906	85.797
Total		11712515	641400	100.000	100.000

Racemic **3i**

==== Shimadzu LCsolution Analysis Report ====

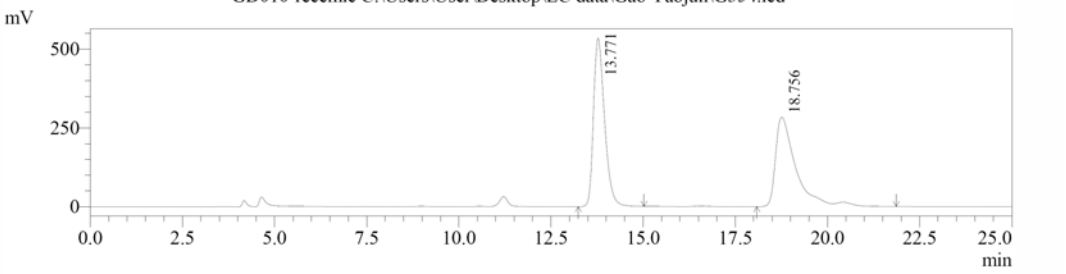
C:\Users\User\Desktop\LC data\Gao Yaojun\G354.lcd

Acquired by : Admin
Sample Name : GD010-recemic
Sample ID : GYJ
Data File Name : G354.lcd
Method File Name : 5%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IB column with guard column,5%IPA



Chromatogram

GD010-recemic C:\Users\User\Desktop\LC data\Gao Yaojun\G354.lcd



PeakTable

SPD-20A Ch1 254nm

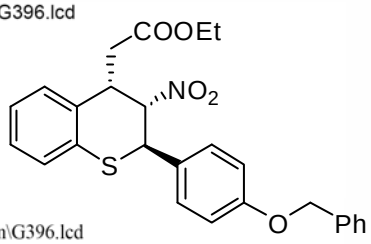
Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.771	11126254	534623	50.861	65.296
2	18.756	10749612	284145	49.139	34.704
Total		21875866	818768	100.000	100.000

Enantiomeric enriched **3i**

==== Shimadzu LCsolution Analysis Report ====

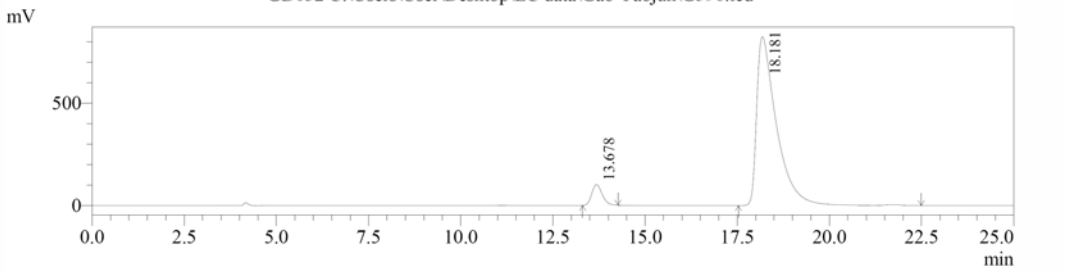
C:\Users\User\Desktop\LC data\Gao Yaojun\G396.lcd

Acquired by : Admin
Sample Name : GD032
Sample ID : GYJ
Data File Name : G396.lcd
Method File Name : 5%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IB column with guard column,5%IPA



Chromatogram

GD032 C:\Users\User\Desktop\LC data\Gao Yaojun\G396.lcd



PeakTable

SPD-20A Ch1 254nm

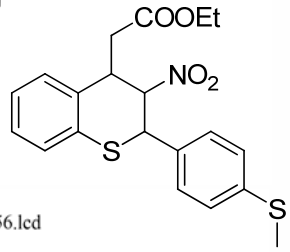
Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.678	1989893	101707	6.089	10.980
2	18.181	30691400	824622	93.911	89.020
Total		32681293	926329	100.000	100.000

Racemic **3j**

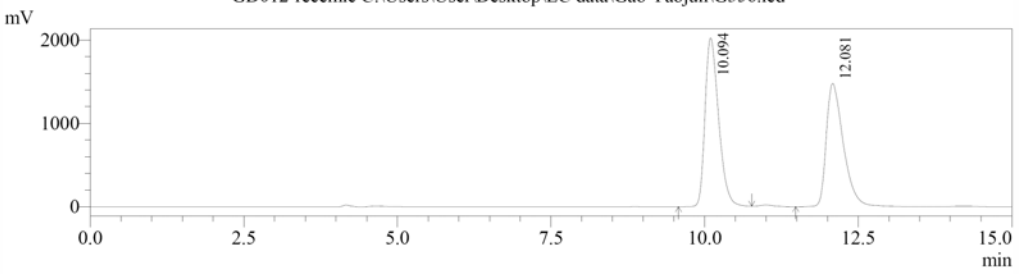
==== Shimadzu LCsolution Analysis Report ====

C:\Users\User\Desktop\LC data\Gao Yaojun\G356.lcd

Acquired by : Admin
Sample Name : GD012-recemic
Sample ID : GYJ
Data File Name : G356.lcd
Method File Name : 5%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IB column with guard column,5%IPA



Chromatogram
GD012-recemic C:\Users\User\Desktop\LC data\Gao Yaojun\G356.lcd



PeakTable

SPD-20A Ch1 254nm

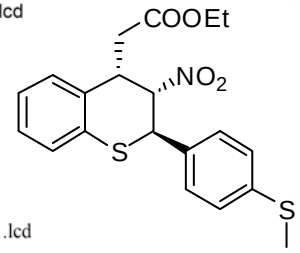
Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.094	30992647	2020806	52.008	57.759
2	12.081	28599290	1477908	47.992	42.241
Total		59591937	3498714	100.000	100.000

Enantiomeric enriched **3j**

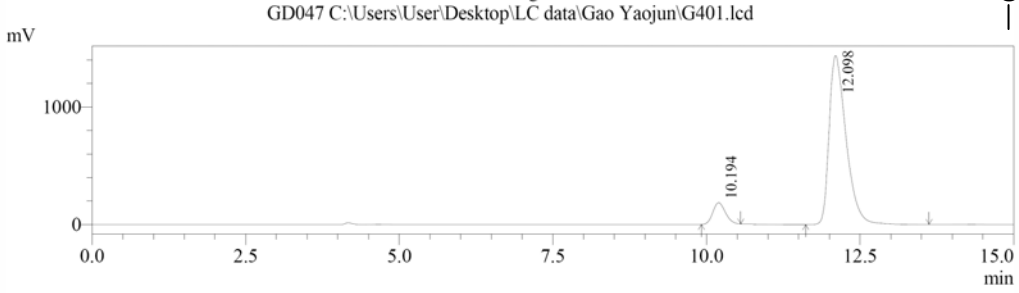
==== Shimadzu LCsolution Analysis Report ====

C:\Users\User\Desktop\LC data\Gao Yaojun\G401.lcd

Acquired by : Admin
Sample Name : GD047
Sample ID : GYJ
Data File Name : G401.lcd
Method File Name : 5%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IB column with guard column,5%IPA



Chromatogram
GD047 C:\Users\User\Desktop\LC data\Gao Yaojun\G401.lcd



PeakTable

SPD-20A Ch1 254nm

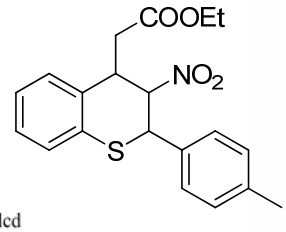
Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.194	2605876	183094	8.615	11.295
2	12.098	27641439	1437891	91.385	88.705
Total		30247315	1620986	100.000	100.000

Racemic **3k**

==== Shimadzu LCsolution Analysis Report ====

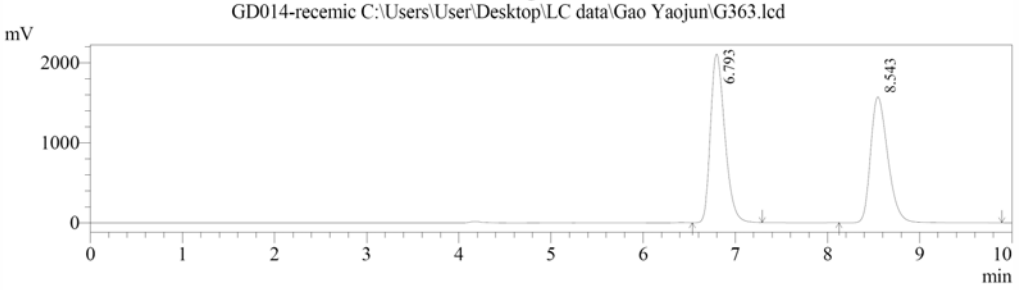
C:\Users\User\Desktop\LC data\Gao Yaojun\G363.lcd

Acquired by : Admin
Sample Name : GD014-recemic
Sample ID : GYJ
Data File Name : G363.lcd
Method File Name : 5%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IB column with guard column,5%IPA



Chromatogram

GD014-recemic C:\Users\User\Desktop\LC data\Gao Yaojun\G363.lcd



PeakTable

SPD-20A Ch1 254nm

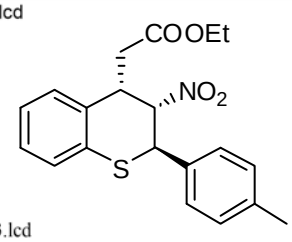
Peak#	Ret. Time	Area	Height	Area %	Height %
1	6.793	22815058	2105886	52.742	57.271
2	8.543	20442560	1571149	47.258	42.729
Total		43257618	3677034	100.000	100.000

Enantiomeric enriched **3k**

==== Shimadzu LCsolution Analysis Report ====

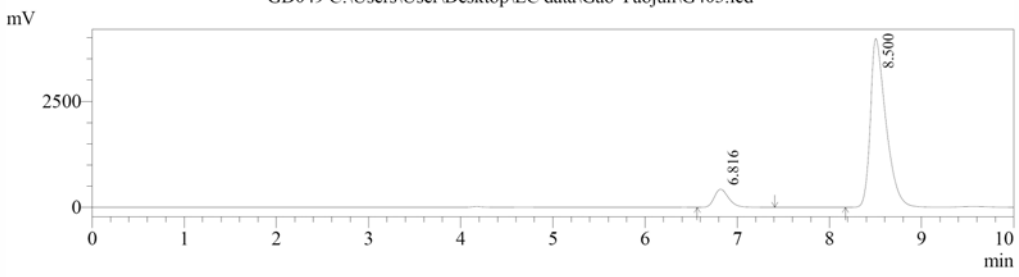
C:\Users\User\Desktop\LC data\Gao Yaojun\G403.lcd

Acquired by : Admin
Sample Name : GD049
Sample ID : GYJ
Data File Name : G403.lcd
Method File Name : 5%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IB column with guard column,5%IPA



Chromatogram

GD049 C:\Users\User\Desktop\LC data\Gao Yaojun\G403.lcd



PeakTable

SPD-20A Ch1 254nm

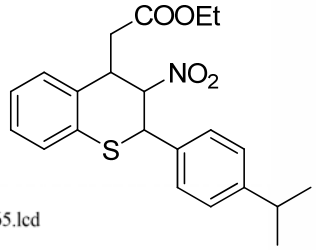
Peak#	Ret. Time	Area	Height	Area %	Height %
1	6.816	4639530	427295	9.004	9.703
2	8.500	46889145	3976429	90.996	90.297
Total		51528675	4403724	100.000	100.000

Racemic **3l**

==== Shimadzu LCsolution Analysis Report ====

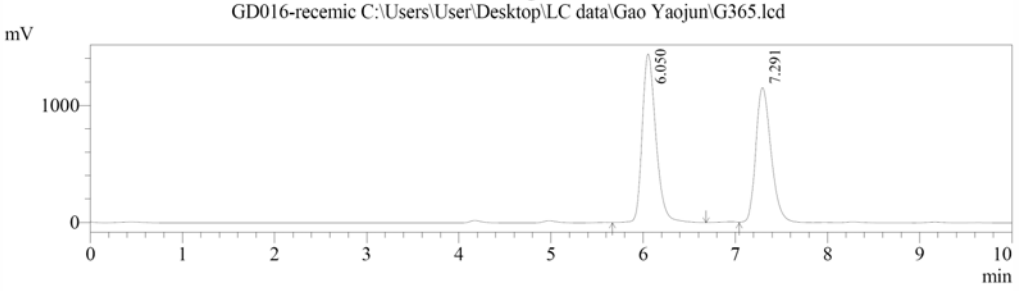
C:\Users\User\Desktop\LC data\Gao Yaojun\G365.lcd

Acquired by : Admin
Sample Name : GD016-recemic
Sample ID : GYJ
Data File Name : G365.lcd
Method File Name : 5%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IB column with guard column,5%IPA



Chromatogram

GD016-recemic C:\Users\User\Desktop\LC data\Gao Yaojun\G365.lcd



PeakTable

SPD-20A Ch1 254nm

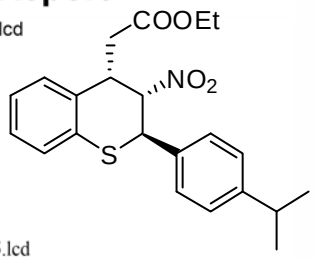
Peak#	Ret. Time	Area	Height	Area %	Height %
1	6.050	15085855	1443226	52.807	55.493
2	7.291	13481905	1157530	47.193	44.507
Total		28567760	2600756	100.000	100.000

Enantiomeric enriched **3l**

==== Shimadzu LCsolution Analysis Report ====

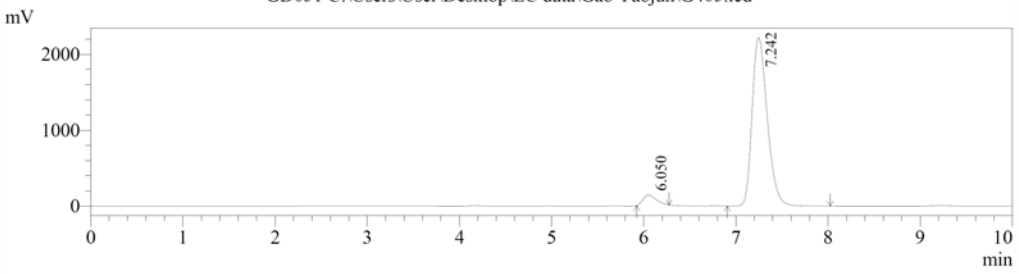
C:\Users\User\Desktop\LC data\Gao Yaojun\G405.lcd

Acquired by : Admin
Sample Name : GD051
Sample ID : GYJ
Data File Name : G405.lcd
Method File Name : 5%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IB column with guard column,5%IPA



Chromatogram

GD051 C:\Users\User\Desktop\LC data\Gao Yaojun\G405.lcd



PeakTable

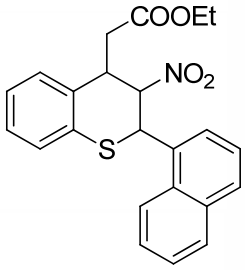
SPD-20A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	6.050	1303691	134367	4.899	5.708
2	7.242	25309627	2219567	95.101	94.292
Total		26613318	2353934	100.000	100.000

Racemic **3m**

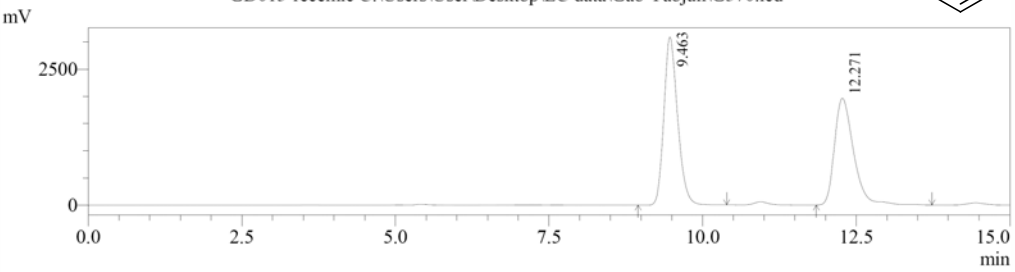
==== Shimadzu LCsolution Analysis Report ====

C:\Users\User\Desktop\LC data\Gao Yaojun\G370.lcd



Acquired by : Admin
Sample Name : GD013-recemic
Sample ID : GYJ
Data File Name : G370.lcd
Method File Name : 5%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :Ic column with guard column,5%IPA

Chromatogram
GD013-recemic C:\Users\User\Desktop\LC data\Gao Yaojun\G370.lcd



PeakTable

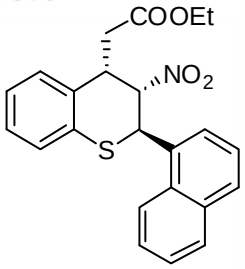
SPD-20A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	9.463	47924537	3092314	53.060	61.163
2	12.271	42396050	1963519	46.940	38.837
Total		90320587	5055833	100.000	100.000

Enantiomeric enriched **3m**

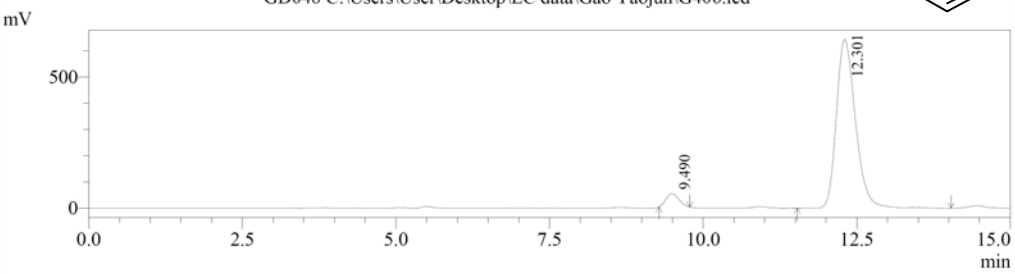
==== Shimadzu LCsolution Analysis Report ====

C:\Users\User\Desktop\LC data\Gao Yaojun\G406.lcd



Acquired by : Admin
Sample Name : GD048
Sample ID : GYJ
Data File Name : G406.lcd
Method File Name : 5%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IC column with guard column,5%IPA

Chromatogram
GD048 C:\Users\User\Desktop\LC data\Gao Yaojun\G406.lcd



PeakTable

SPD-20A Ch1 254nm

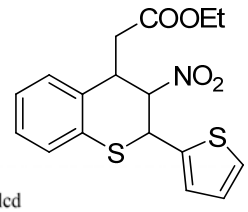
Peak#	Ret. Time	Area	Height	Area %	Height %
1	9.490	738730	50377	5.046	7.252
2	12.301	13901969	644306	94.954	92.748
Total		14640699	694683	100.000	100.000

Racemic **3n**

==== Shimadzu LCsolution Analysis Report ====

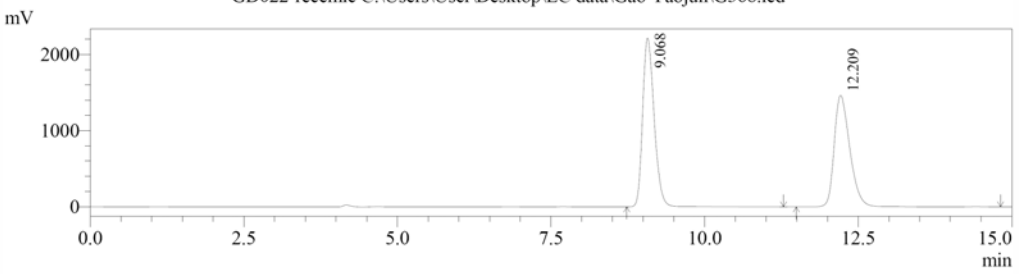
C:\Users\User\Desktop\LC data\Gao Yaojun\G368.lcd

Acquired by : Admin
Sample Name : GD022-recemic
Sample ID : GYJ
Data File Name : G368.lcd
Method File Name : 5%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IB column with guard column,5%IPA



Chromatogram

GD022-recemic C:\Users\User\Desktop\LC data\Gao Yaojun\G368.lcd



PeakTable

SPD-20A Ch1 254nm

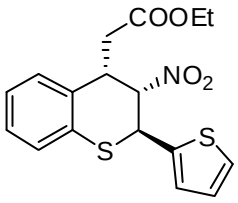
Peak#	Ret. Time	Area	Height	Area %	Height %
1	9.068	29007305	2217787	52.852	60.230
2	12.209	25876465	1464385	47.148	39.770
Total		54883770	3682173	100.000	100.000

Enantiomeric enriched **3n**

==== Shimadzu LCsolution Analysis Report ====

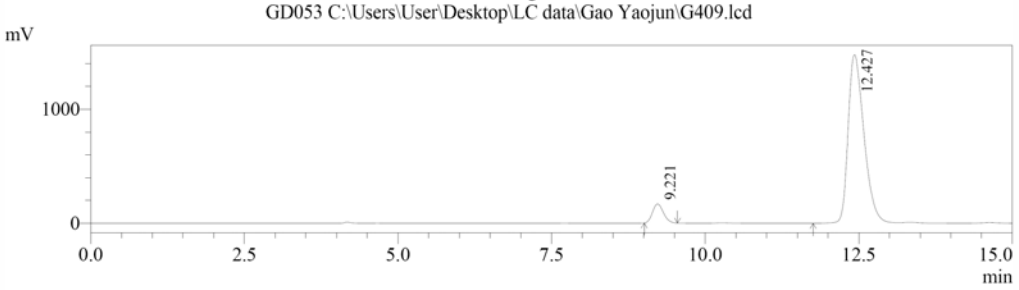
C:\Users\User\Desktop\LC data\Gao Yaojun\G409.lcd

Acquired by : Admin
Sample Name : GD053
Sample ID : GYJ
Data File Name : G409.lcd
Method File Name : 5%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :Ib column with guard column,5%IPA



Chromatogram

GD053 C:\Users\User\Desktop\LC data\Gao Yaojun\G409.lcd



PeakTable

SPD-20A Ch1 254nm

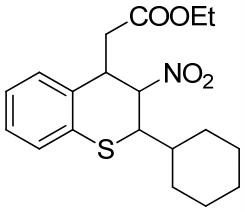
Peak#	Ret. Time	Area	Height	Area %	Height %
1	9.221	2071648	168086	7.208	10.214
2	12.427	26669683	1477619	92.792	89.786
Total		28741331	1645705	100.000	100.000

Racemic **3o**

==== Shimadzu LCsolution Analysis Report ====

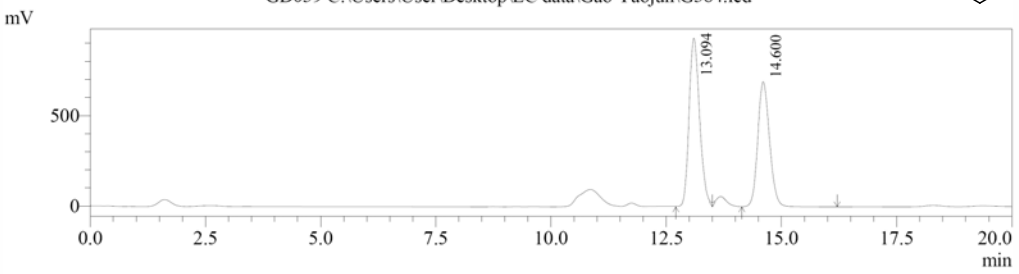
C:\Users\User\Desktop\LC data\Gao Yaojun\G384.lcd

Acquired by : Admin
Sample Name : GD039
Sample ID : GYJ
Data File Name : G384.lcd
Method File Name : 2%IPA, 0.5ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IB column with guard column,2%IPA,0.5ml/min



Chromatogram

GD039 C:\Users\User\Desktop\LC data\Gao Yaojun\G384.lcd



PeakTable

SPD-20A Ch1 254nm

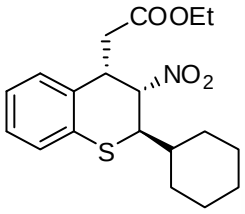
Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.094	14919912	933264	54.726	57.419
2	14.600	12342838	692093	45.274	42.581
Total		27262750	1625357	100.000	100.000

Enantiomeric enriched **3o**

==== Shimadzu LCsolution Analysis Report ====

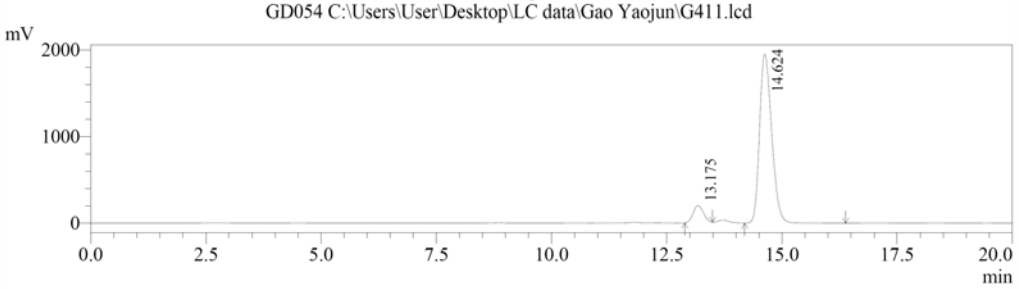
C:\Users\User\Desktop\LC data\Gao Yaojun\G411.lcd

Acquired by : Admin
Sample Name : GD054
Sample ID : GYJ
Data File Name : G411.lcd
Method File Name : 2%IPA, 0.5ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :Ib column with guard column,2%IPA, 0.5ml/min



Chromatogram

GD054 C:\Users\User\Desktop\LC data\Gao Yaojun\G411.lcd



PeakTable

SPD-20A Ch1 254nm

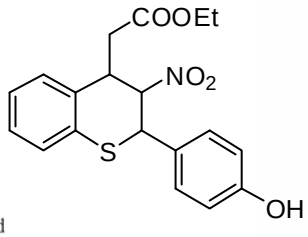
Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.175	3008813	196018	7.757	9.128
2	14.624	35779747	1951403	92.243	90.872
Total		38788560	2147421	100.000	100.000

Racemic **3p**

==== Shimadzu LCsolution Analysis Report ====

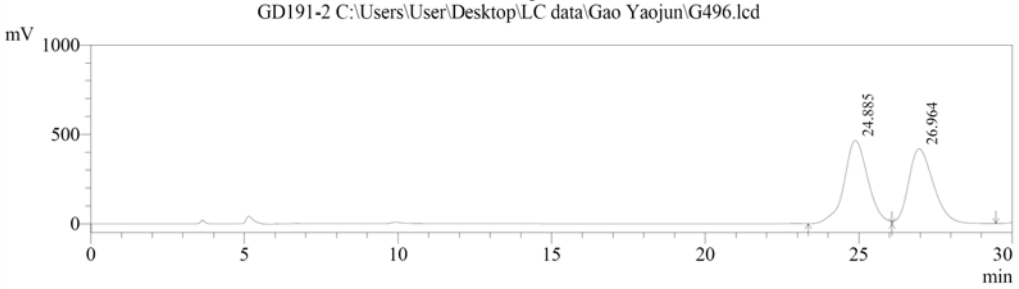
C:\Users\User\Desktop\LC data\Gao Yaojun\G496.lcd

Acquired by : Admin
Sample Name : GD191-2
Sample ID : GYJ
Data File Name : G496.lcd
Method File Name : 5%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IC column with guard column 5%IPA, spot 2



Chromatogram

GD191-2 C:\Users\User\Desktop\LC data\Gao Yaojun\G496.lcd



PeakTable

SPD-20A Ch1 254nm

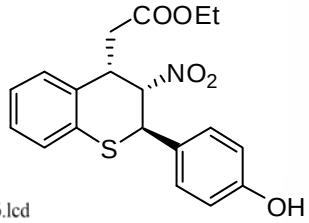
Peak#	Ret. Time	Area	Height	Area %	Height %
1	24.885	25073194	466172	51.707	52.695
2	26.964	23418174	418496	48.293	47.305
Total		48491369	884668	100.000	100.000

Enantiomeric enriched **3p**

==== Shimadzu LCsolution Analysis Report ====

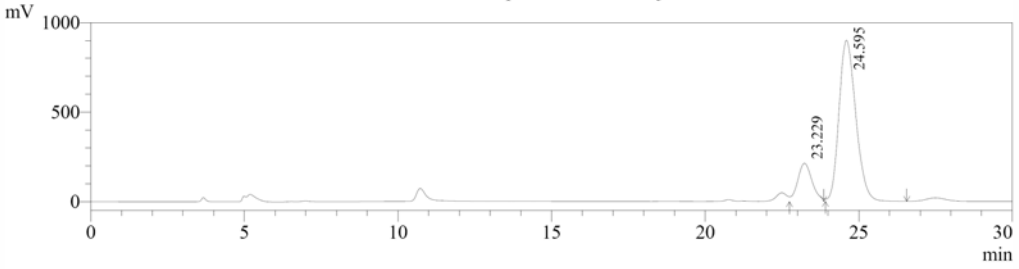
C:\Users\User\Desktop\LC data\Gao Yaojun\G506.lcd

Acquired by : Admin
Sample Name : GD192-2
Sample ID : GYJ
Data File Name : G506.lcd
Method File Name : 5%IPA, 1ml-min, 60min.lcm
Batch File Name :
Report File Name : Default.lcr
Description :IC column with guard column 5%IPA



Chromatogram

GD192-2 C:\Users\User\Desktop\LC data\Gao Yaojun\G506.lcd



PeakTable

SPD-20A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	23.229	6998356	214308	16.957	19.228
2	24.595	34271767	900283	83.043	80.772
Total		41270123	1114591	100.000	100.000