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Supporting Information

Asymmetric synthesis of polysubstituted chiral chromans via an organocatalytic oxa-Michael-niotro-Michael domino reaction

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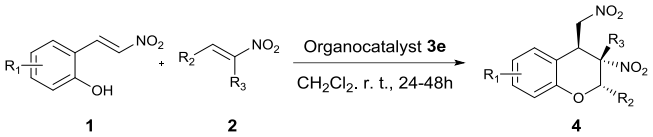
1. General information

NMR data were obtained on Bruker AVANCE III for ^{1}H at 500 MHz and for ^{13}C at 125 MHz with TMS as the internal standard. HRMS data were measured on Waters Premier GC/TOF-MS with EI source. In each case, enantiomeric ratio was determined on a chiral column in comparison with authentic racemates by chiral HPLC, using a JASCO LC-2000 Plus system consisting of MD-2010 HPLC diode array detector. GC-MS experiments were performed on an Agilent 6890N GC system with a 5973N mass selective detector. Column chromatography and flash chromatography experiments were conducted using silica gel GF254 (200-300mesh) eluting with ethyl ether and petroleum ether. TLC experiments were carried out on glass-backed silica plates. Chemicals were used without purification as commercially available.

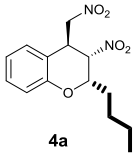
2. Typical experimental procedure for the oxa-Michael-nitro-Michael domino reaction and selected data for compounds 4a-5a



1 2 4

2-Hydroxynitrostyrenes **1** (0.02 mmol) and *trans-β*-nitroolefins **2** (0.024 mmol) were stirred under dichloromethane in the presence of catalyst **3e** (0.001 mmol) at room temperature, and the reaction was monitored by GC-MS. After completion, the reaction mixture was dried and concentrated. The residue was purified by flash chromatography to give the domino reaction products. The enantiomeric ratio was determined by HPLC analysis on a chiral column.

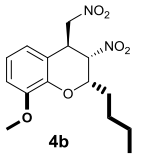
The 2-hydroxynitrostyrenes with different substituted groups [1] and aliphatic nitroolefins[2] were prepared according to the reported literature procedures.



4a

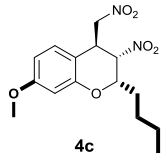
(2S,3S,4S)-2-butyl-3-nitro-4-(nitromethyl)chromane, white solid, mp 106-108 ℃, 78% yield, 92% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak OJ-H with hexane/*i*-PrOH (85:15) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22} = -99.000$ (c = 1 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.28-7.22 (m, 2H), 7.07-7.04 (m, 1H), 6.95 (dd, *J* = 8, 1.5 Hz, 1H), 5.02 (t, *J* = 2.5 Hz, 1H), 4.71 (dd, *J* = 14, 3.5 Hz, 1H), 4.60 (dd, *J* = 14, 4 Hz, 1H), 4.25-4.22 (m, 1H), 4.19-4.16 (m, 1H), 1.93-1.85 (m, 1H), 1.81-1.74 (m, 1H), 1.68-1.60 (m, 1H), 1.57-1.50 (m, 1H), 1.47-1.30 (m, 2H), 0.97 (t, *J* = 7.5 Hz, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 153.8, 129.5, 128.4, 122.4, 117.8, 116.4, 81.9, 78.2, 72.1, 36.6, 30.6, 27.6, 22.3, 13.9 ppm. HRMS (EI+) calcd for $[C_{14}H_{18}N_2O_5]^+$ m/z 294.1216, found 294.1231.

[1] D. B. Ramachary and R. Sakthidevi, *Org. Biomol. Chem*., 2010, **8**, 4259;
[2] D. Lucet, S. Sabelle, O. Kostelitz, T. L. Gall and C. Mioskowski, *Eur. J. Org. Chem.,* **1999**, 2583.



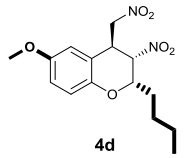
4b

(2S,3S,4S)-2-butyl-8-methoxy-3-nitro-4-(nitromethyl)chromane, white solid, mp 158-160 ℃, 82% yield, 98% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak AS-H with hexane/*i*-PrOH (70:30) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22}$ = -93.939 (c = 0.66 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.00 (t, *J* = 8 Hz, 1H), 6.86-6.82 (m, 2H), 5.05 (t, *J* = 2 Hz, 1H), 4.82 (dd, *J* = 14, 4 Hz, 1H), 4.59 (dd, *J* = 14, 10.5 Hz, 1H), 4.27-4.23 (m, 1H), 4.22-4.19 (m, 1H), 3.87 (s, 3H), 2.02-1.95 (m, 1H), 1.83-1.76 (m, 1H), 1.67-1.50 (m, 2H), 1.47-1.40 (m, 2H), 0.97 (t, *J* = 7.5 Hz, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 148.8, 143.6, 122.2, 119.6, 117.3, 111.3, 81.5, 78.1, 72.6, 56.1, 36.4, 30.3, 27.5, 22.3, 13.8 ppm. HRMS (EI+) calcd for $[C_{15}H_{20}N_2O_6]^+$ m/z 324.1321, found 324.1315.



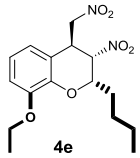
4c

(2S,3S,4S)-2-butyl-7-methoxy-3-nitro-4-(nitromethyl)chromane, white solid, mp 161-163 ℃, 75% yield, >99% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak AS-H with hexane/*i*-PrOH (90:10) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22}$ = -100.000 (c = 0.28 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.12 (d, *J* = 8 Hz, 1H), 6.64 (dd, *J* = 8.5, 2.5 Hz, 1H), 6.48 (d, *J* = 2.5 Hz, 1H), 5.00 (s, 1H), 4.77 (dd, *J* = 13.5, 3.5 Hz, 1H), 4.57 (t, *J* = 10.5 Hz, 1H), 4.18-4.16 (m, 2H), 3.80 (s, 3H), 1.92-1.85 (m, 1H), 1.80-1.73 (m, 1H), 1.66-1.59 (m, 1H), 1.55-1.51 (m, 1H), 1.47-1.40 (m, 2H), 0.98 (t, *J* = 7 Hz, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 160.5, 154.8, 129.1, 110.0, 108.1, 102.1, 81.8, 78.2, 72.2, 55.4, 36.2, 30.6, 27.6, 22.3, 13.9 ppm. HRMS (EI+) calcd for $[C_{15}H_{20}N_2O_6]^+$ m/z 324.1321, found 324.1320.



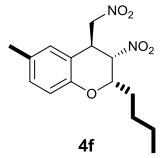
4d

(2S,3S,4S)-2-butyl-6-methoxy-3-nitro-4-(nitromethyl)chromane, white solid, mp 152-154 ℃, 76% yield, 98% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak AS-H with hexane/*i*-PrOH (90:10) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22}$ = -97.623 (c = 0.53 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 6.88 (t, *J* = 9 Hz, 1H), 6.85-6.82 (m, 1H), 6.72-6.72 (d, *J* = 3 Hz, 1H), 4.98 (t, *J* = 2.5 Hz, 1H), 4.82 (dd, *J* = 14, 4 Hz, 1H), 4.59 (d, *J* = 14, 10.5 Hz, 1H), 4.23-4.19 (m, 1H), 4.13-4.10 (m, 1H), 3.79 (s, 3H), 1.91-1.83 (m, 1H), 1.79-1.72 (m, 1H), 1.66-1.60 (m, 1H), 1.56-1.48 (m, 1H), 1.47-1.40 (m, 2H), 0.97 (s, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 154.7, 147.8, 118.6, 116.8, 115.8, 112.6, 81.9, 78.1, 72.2, 55.8, 36.8, 30.6, 27.6, 22.3, 13.9 ppm. HRMS (EI+) calcd for $[C_{15}H_{20}N_2O_6]^+$ m/z 324.1321, found 324.1304.



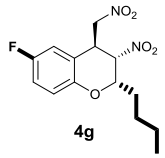
4e

(2S,3S,4S)-2-butyl-8-ethoxy-3-nitro-4-(nitromethyl)chromane, white solid, mp 159-162 ℃, 77% yield, >99% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak AS-H with hexane/*i*-PrOH (70:30) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22}$ = -110.610 (c = 0.66 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 6.98 (t, *J* = 8 Hz, 1H), 6.86-6.81 (m, 2H), 5.04 (t, *J* = 2.5 Hz, 1H), 4.82 (dd, *J* = 14, 4 Hz, 1H), 4.60 (dd, *J* = 14, 10 Hz, 1H), 4.27-4.20 (m, 2H), 4.11-4.04 (m, 2H), 2.00-1.93 (m, 1H), 1.82-1.75 (m, 1H), 1.67-1.60 (m, 1H), 1.57-1.51 (m, 1H), 1.48-1.41 (m, 5H), 0.97 (t, *J* = 7.5 Hz, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 148.2, 144.0, 122.1, 119.7, 117.4, 113.1, 81.8, 78.1, 72.6, 64.8, 36.5, 30.2, 27.6, 22.3, 14.8, 13.9 ppm. HRMS (EI+) calcd for $[C_{16}H_{22}N_2O_6]^+$ m/z 338.1478, found 338.1467.



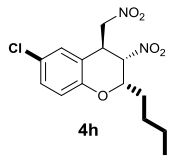
4f

(2S,3S,4S)-2-butyl-6-methyl-3-nitro-4-(nitromethyl)chromane, white solid, mp 154-156 ℃, 71% yield, >99% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak AS-H with hexane/*i*-PrOH (90:10) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22} = -81.250$ (c = 0.16 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.07-7.02 (m, 2H), 6.84 (d, *J* = 8.5 Hz, 1H), 4.99 (t, *J* = 2.5 Hz, 1H), 4.81 (dd, *J* = 13.5, 3.5 Hz, 1H), 4.58 (dd, *J* = 14, 10.5 Hz, 1H), 4.21-4.18 (m, 1H), 4.15-4.12 (m, 1H), 2.32 (s, 3H), 1.92-1.85 (m, 1H), 1.80-1.73 (m, 1H), 1.67-1.59 (m, 1H), 1.55-1.49 (m, 1H), 1.48-1.39 (m, 2H), 0.97 (t, *J* = 7 Hz, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 151.7, 131.9, 130.3, 128.6, 117.5, 115.9, 81.9, 78.2, 72.1, 36.6, 30.6, 27.6, 22.4, 20.6, 13.9 ppm. HRMS (EI+) calcd for $[C_{15}H_{20}N_2O_5]^+$ m/z 308.1372, found 308.1356.



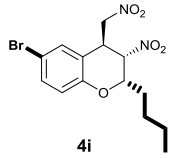
4g

(2S,3S,4S)-2-butyl-6-fluoro-3-nitro-4-(nitromethyl)chromane, white solid, mp 118-120 ℃, 77% yield, 71% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak IC with hexane/*i*-PrOH (99:1) as the eluent, flow = 1.0 mL/min, UV = 212 nm. $[\alpha]_D^{22} = -94.000$ (c = 0.5 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.01-6.91 (m, 3H), 5.00 (t, *J* = 2.5 Hz, 1H), 4.79 (dd, *J* = 9, 4 Hz, 1H), 4.61 (dd, *J* = 14, 10 Hz, 1H), 4.24-4.20 (m, 1H), 4.15-4.12 (m, 1H). 1.89-1.84 (m, 1H), 1.80-1.73 (m, 1H), 1.64-1.51 (m, 2H), 1.45-1.40 (m, 2H), 0.99-0.96 (t, *J* = 7.5 Hz, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 156.7 (d, $^1J_{C\text{-}F}$ = 240.3 Hz), 149.9 (d, $^4J_{C\text{-}F}$ = 2.3 Hz), 119.1 (d, $^3J_{C\text{-}F}$ = 8.1 Hz), 117.4 (d, $^3J_{C\text{-}F}$ = 7.4 Hz), 116.8 (d, $^2J_{C\text{-}F}$ = 23.1 Hz), 114.4 (d, $^2J_{C\text{-}F}$ = 24.1 Hz), 81.5, 77.9, 72.4, 36.6, 30.5, 27.5, 22.3, 13.9 ppm. HRMS (EI+) calcd for $[C_{14}H_{17}FN_2O_5]^+$ m/z 312.1122, found 312.1123.



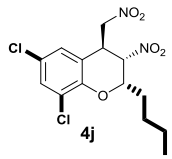
4h

(2S,3S,4S)-2-butyl-6-chloro-3-nitro-4-(nitromethyl)chromane, yellow solid, mp 125-127 ℃, 68% yield, 98% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak AS-H with hexane/*i*-PrOH (80:20) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22} = -103.850$ (c = 0.26 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.24-7.22 (m, 2H), 6.90 (d, *J* = 9.5 Hz, 1H), 5.00 (t, *J* = 2.5 Hz, 1H), 4.80 (dd, *J* = 14, 4 Hz, 1H), 4.59 (dd, *J* = 14, 10.5 Hz, 1H), 4.23-4.19 (m, 1H), 4.16-4.13 (m, 1H), 1.92-1.84 (m, 1H), 1.81-1.74 (m, 1H), 1.65-1.58 (m, 1H), 1.55-1.49 (m, 1H), 1.45-1.40 (m, 2H), 0.97 (t, *J* = 7 Hz, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 152.5, 129.7, 128.1, 127.3, 119.2, 117.9, 81.4, 77.3, 72.3, 36.4, 30.6, 27.5, 22.3, 13.9 ppm. HRMS (EI+) calcd for $[C_{14}H_{17}ClN_2O_5]^+$ m/z 328.0826, found 328.0805.



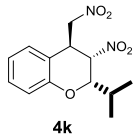
4i

(2S,3S,4S)-6-bromo-2-butyl-3-nitro-4-(nitromethyl)chromane, yellow solid, mp 105-107 ℃, 68% yield, >99% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak AS-H with hexane/*i*-PrOH (95:5) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22} = -98.124$ (c = 0.5 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.37-7.34 (m, 2H), 6.84 (d, *J* = 8.5 Hz, 1H), 4.99 (t, *J* = 2 Hz, 1H), 4.79 (dd, *J* = 14, 4 Hz, 1H), 4.58 (dd, *J* = 14, 10.5 Hz, 1H), 4.22-4.19 (m, 1H), 4.15-4.12 (m, 1H), 1.91-1.84 (m, 1H), 1.81-1.74 (m, 1H), 1.65-1.57 (m, 1H), 1.55-1.48 (m, 1H), 1.46-1.39 (m, 2H), 0.97 (t, *J* = 7 Hz, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 153.0, 132.6, 131.1, 119.6, 118.4, 114.4, 81.4, 77.8, 72.2, 36.4, 30.6, 27.5, 22.3, 13.8 ppm. HRMS (EI+) calcd for $[C_{14}H_{17}BrN_2O_5]^+$ m/z 372.0321, found 372.0338.



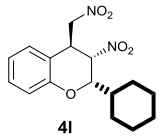
4j

(2S,3S,4S)-2-butyl-6,8-dichloro-3-nitro-4-(nitromethyl)chromane, yellow solid, mp 135-137 ℃, 65% yield, 88% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak AS-H with hexane/*i*-PrOH (90:10) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22} = -108.713$ (c = 0.28 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.37 (d, *J* = 2.5 Hz, 1H), 7.16 (dd, *J* = 2.5, 1 Hz, 1H), 5.03 (t, *J* = 4 Hz, 1H), 4.78 (dd, *J* = 14, 4 Hz, 1H), 4.56 (dd, *J* = 14.5, 10.5 Hz, 1H), 4.25-4.20 (m, 2H), 1.96-1.89 (m, 1H), 1.84-1.77 (m, 1H), 1.72-1.63 (m, 1H), 1.58-1.50 (m, 1H), 1.48-1.41 (m, 2H), 0.98 (t, *J* = 7 Hz, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 148.5, 130.0, 127.0, 126.5, 123.9, 119.2, 81.3, 77.6, 73.0, 36.5, 30.4, 27.4, 22.2, 13.9 ppm. HRMS (EI+) calcd for $[C_{14}H_{16}Cl_2N_2O_5]^+$ m/z 362.0436, found 362.0416.



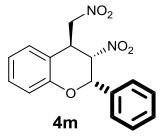
4k

(2S,3S,4S)-2-isopropyl-3-nitro-4-(nitromethyl)chromane, white solid, mp 104-106 ℃, 65% yield, >99% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak AS-H with hexane/*i*-PrOH (90:10) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22} = -105.000$ (c = 0.08 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.29-7.23 (m, 2H), 7.08-7.05 (m, 1H), 6.97 (dd, *J* = 8, 1 Hz, 1H), 5.15 (t, *J* = 1.5 Hz, 1H), 4.82 (dd, *J* = 13.5, 4 Hz, 1H), 4.55 (dd, *J* = 13, 1 Hz, 1H), 4.25 (dd, *J* = 11, 4 Hz, 1H), 3.60 (dd, *J* = 10, 1.5 Hz, 1H), 2.17-2.10 (m, 1H), 1.25 (d, *J* = 6.5 Hz, 3H), 1.18 (d, *J* = 7 Hz, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 154.4, 129.5, 128.6, 122.5, 117.7, 116.3, 79.4, 78.6, 76.8, 37.2, 29.4, 19.6, 18.3 ppm. HRMS (EI+) calcd for $[C_{13}H_{16}N_2O_5]^+$ m/z 280.1059, found 280.1056.



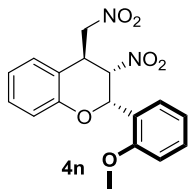
4l

(2S,3S,4S)-2-cyclohexyl-3-nitro-4-(nitromethyl)chromane, white solid, mp 162-164 ℃, 70% yield, 89% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak AS-H with hexane/*i*-PrOH (90:10) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22} = 101.761$ (c = 1 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.28-7.22 (m, 2H), 7.05 (t, *J* = 7.5 Hz, 1H), 6.95 (d, *J* = 8.5 Hz, 1H), 5.15 (s, 1H), 4.81 (dd, *J* = 13.5, 4 Hz, 1H), 4.53 (dd, *J* = 12, 11 Hz, 1H), 4.23 (dd, *J* = 11, 5 Hz, 1H), 3.70 (d, *J* = 10 Hz, 1H), 2.38 (d, *J* = 12.5 Hz, 1H), 2.10-2.06 (m, 1H), 1.88-1.81 (m, 3H), 1.78-1.74 (m, 1H), 1.42-1.20 (m, 3H), 1.17-1.01 (m, 2H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 154.5, 129.5, 128.7, 122.4, 117.7, 116.4, 78.9, 78.6, 76.5, 38.1, 37.2, 29.8, 28.3, 26.1, 25.4, 25.3 ppm. HRMS (EI+) calcd for $[C_{16}H_{20}N_2O_5]^+$ m/z 320.1372, found 320.1354.

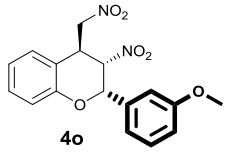


4m

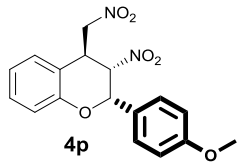
(2S,3S,4S)-3-nitro-4-(nitromethyl)-2-phenylchromane, white solid, mp 165-168 ℃, 60% yield, 94% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak OD-H with hexane/*i*-PrOH (70:30) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22} = 103.125$ (c = 0.33 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.48-7.41 (m, 5H), 7.36-7.29 (m, 1H), 7.14-7.32 (m, 1H), 7.31-7.29 (m, 2H), 5.36 (d, *J* = 4 Hz, 1H), 5.24 (t, *J* = 4 Hz, 1H), 4.92 (dd, *J* = 14, 4 Hz, 1H), 4.79 (dd, *J* = 13.5, 10.5 Hz, 1H), 4.29-4.25 (m, 1H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 154.0, 134.5, 129.8, 129.3, 128.9 (×2), 128.5, 125.6 (×2), 122.8, 118.1, 115.8, 84.1, 78.4, 73.3, 37.0 ppm; HRMS (EI+) calcd for $[C_{16}H_{14}N_2O_5]^+$ m/z 314.0903, found 314.0910.



(2S,3S,4S)-2-(2-methoxyphenyl)-3-nitro-4-(nitromethyl)chromane, white solid, mp 190-192 ℃, 63% yield, 95% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak OD-H with hexane/*i*-PrOH (80:20) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22} = 166.667$ (c = 0.12 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.58-7.56 (m, 1H), 7.43-7.39 (m, 1H), 7.34-7.28 (m, 2H), 7.13-7.07 (m, 3H), 6.98 (dd, *J* = 8.5, 1.5 Hz, 1H), 5.57 (s, 1H), 5.39-5.38 (m, 1H), 4.91 (dd, *J* = 13.5, 4 Hz, 1H), 4.79 (dd, *J* = 14, 11.5 Hz, 1H), 4.48 (dd, *J* = 11, 4 Hz, 1H), 3.93 (s, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 155.0, 154.6, 129.9, 129.5, 128.9, 126.5, 122.8, 122.7, 121.1, 118.0, 116.7, 109.9, 81.0, 78.6, 69.3, 55.4, 37.4 ppm; HRMS (EI+) calcd for $[C_{17}H_{16}N_2O_6]^+$ m/z 348.1008, found 348.1008.

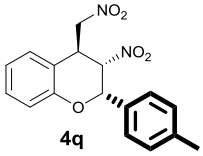


(2S,3S,4S)-2-(3-methoxyphenyl)-3-nitro-4-(nitromethyl)chromane, white solid, mp 193-195 ℃, 66% yield, >99% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak OD-H with hexane/*i*-PrOH (70:30) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22} = 153.274$ (c = 0.18 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.39-7.32 (m, 2H), 7.30-7.28 (m, 1H), 7.17-7.10 (m, 2H), 7.01-6.94 (m, 3H), 5.33 (d, *J* = 2.5, 1H), 5.24 (dd, *J* = 2.5, 1.5 Hz, 1H), 4.91 (dd, *J* = 13.5, 4 Hz, 1H), 4.79 (dd, *J* = 14, 10 Hz, 1H), 4.28-4.25 (m, 1H), 3.84 (s, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 160.0, 154.0, 136.0, 130.0, 129.8, 128.5, 122.8, 118.1, 117.8, 115.9, 114.6, 111.5, 84.0, 78.4, 73.1, 55.4, 37.0 ppm; HRMS (EI+) calcd for $[C_{17}H_{16}N_2O_6]^+$ m/z 348.1008, found 348.1006.



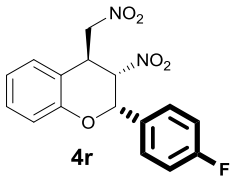
4p

(2S,3S,4S)-2-(4-methoxyphenyl)-3-nitro-4-(nitromethyl)chromane, white solid, mp 198-190 ℃, 67% yield, >99% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak OD-H with hexane/*i*-PrOH (80:20) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22} = 147.513$ (c = 0.22 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.35-7.29 (m, 4H), 7.13-7.08 (m, 2H), 6.98-6.95 (m, 2H), 5.33 (d, *J* = 3.5 Hz, 1H), 5.20 (t, *J* = 2.5 Hz, 1H), 4.91 (dd, *J* = 13.5, 4 Hz, 1H), 4.79 (dd, *J* = 14, 10 Hz, 1H), 4.27-4.23 (m, 1H), 3.85 (s, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 154.2, 129.8, 128.5, 127.0 (×2), 126.4, 122.7, 118.1, 115.9, 114.4 (×2), 84.5, 78.4, 73.2, 55.3, 37.0, 29.7 ppm; HRMS (EI+) calcd for $[C_{17}H_{16}N_2O_6]^+$ m/z 348.1008, found 348.1008.



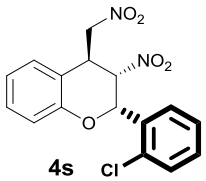
4q

(2S,3S,4S)-3-nitro-4-(nitromethyl)-2-(p-tolyl)chromane, white solid, mp 166-168 ℃, 58% yield, >99% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak OD-H with hexane/*i*-PrOH (80:20) as the eluent, flow = 1.0 mL/min, UV = 230 nm, $[\alpha]_D^{22} = 124.763$ (c = 0.16 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.35-7.25 (m, 6H), 7.13-7.09 (m, 2H), 5.34 (d, *J* = 2 Hz, 1H), 5.21 (t, *J* = 2 Hz, 1H), 4.91 (dd, *J* = 13.5, 4 Hz, 1H), 4.79 (dd, *J* = 14, 10 Hz, 1H), 4.27-4.24 (m, 1H), 2.40 (s, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 154.1, 139.2, 131.4, 129.8 (×2), 129.6, 128.5, 125.5 (×2), 122.7, 118.1, 115.8, 84.1, 78.4, 73.3, 37.0, 21.3 ppm; HRMS (EI+) calcd for $[C_{17}H_{16}N_2O_5]^+$ m/z 328.1059, found 328.1062.



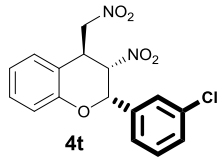
4r

(2S,3S,4S)-2-(4-fluorophenyl)-3-nitro-4-(nitromethyl)chromane, white solid, mp 135-137 ℃, 69% yield, 93% ee, 13:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak OD-H with hexane/*i*-PrOH (70:30) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22} = 114.513$ (c = 0.58 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.41-7.38 (m, 2H), 7.35-7.32 (m, 1H), 7.14-7.10 (m, 3H), 7.05 (dd, *J* = 16, 8.5 Hz, 2H), 5.68 (d, *J* = 7 Hz, 1H), 5.26 (dd, *J* = 7.5, 4.5 Hz, 1H), 5.03 (dd, *J* = 14.5, 7.5 Hz, 1H), 4.92 (dd, *J* = 14.5, 6 Hz, 1H), 4.32 (m, *J* = 12, 6 Hz, 1H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 162.1, 153.9, 130.3, 129.9, 128.5, 127.6, 127.5, 123.0, 118.1, 116.1, 116.0, 115.8, 84.0, 78.4, 72.8, 37.0 ppm; HRMS (EI+) calcd for $[C_{16}H_{13}FN_2O_6]^+$ m/z 332.0808, found 332.0804.



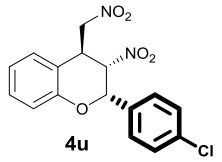
4s

(2S,3S,4S)-2-(2-chlorophenyl)-3-nitro-4-(nitromethyl)chromane, white solid, mp 157-159 ℃, 61% yield, 96% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak AS-H with hexane/*i*-PrOH (90:10) as the eluent, flow = 1.0 mL/min, UV = 212 nm $[\alpha]_D^{22} = 111.000$ (c = 1 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.65-7.63 (m, 1H), 7.49-7.47 (m, 1H), 7.43-7.39 (m, 2H), 7.35-7.31 (m, 2H), 7.16-7.13 (m, 1H), 7.08 (dd, *J* = 8, 1.5 Hz, 1H), 5.62 (d, *J* = 2 Hz, 1H), 5.45 (dd, *J* = 2, 1 Hz, 1H), 4.91 (dd, *J* = 14, 4 Hz, 1H), 4.82 (dd, *J* = 14, 11 Hz, 1H), 4.41 (dd, *J* = 11, 4 Hz, 1H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 154.1, 132.1, 130.8, 130.4, 129.6, 129.5, 128.9, 127.9, 127.6, 123.1, 118.0, 116.5, 81.5, 78.1, 70.8, 37.3 ppm; HRMS (EI+) calcd for $[C_{16}H_{13}ClN_2O_6]^+$ m/z 348.0513, found 348.0516.



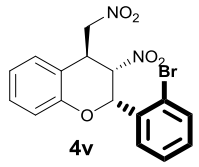
4t

(2S,3S,4S)-2-(3-chlorophenyl)-3-nitro-4-(nitromethyl)chromane, white solid, mp 143-145 ℃, 58% yield, >99% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak OD-H with hexane/*i*-PrOH (80:20) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22} = 73.333$ (c = 0.15 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.48-7.46 (m, 1H), 7.41-7.40 (m, 2H), 7.36-7.29 (m, 3H), 7.15-7.10 (m, 2H), 5.32 (d, *J* = 2.5 Hz, 1H), 5.23 (dd, *J* = 4.5, 1.5 Hz, 1H), 4.92 (dd, *J* = 13.5, 4 Hz, 1H), 4.78 (dd, *J* = 13.5, 9.5 Hz, 1H), 4.31-4.28 (m, 1H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 153.7, 136.2, 135.0, 130.2, 129.9, 129.4, 128.6, 125.9, 123.7, 123.1, 118.8, 115.7, 83.8, 78.4, 72.5, 37.0 ppm; HRMS (EI+) calcd for $[C_{16}H_{13}ClN_2O_6]^+$ m/z 348.0513, found m/z 348.0528.



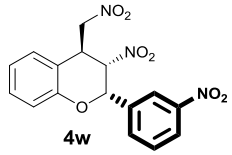
4u

(2S,3S,4S)-2-(4-chlorophenyl)-3-nitro-4-(nitromethyl)chromane, white solid, mp 139-141 ℃, 57% yield, 92% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak OD-H with hexane/*i*-PrOH (70:30) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22} = 98.215$ (c = 1 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.44-7.39 (m, 4H), 7.32-7.3 (m, 1H), 7.27-7.25 (m, 1H), 7.12-7.09 (m, 1H), 7.03 (dd, *J* = 8.5, 1.5 Hz, 1H), 5.42 (t, *J* = 9 Hz, 1H), 5.31 (d, *J* = 9 Hz, 1H), 4.84 (dd, *J* = 14.5, 8.5 Hz, 1H), 4.69 (dd, *J* = 14.5, 11 Hz, 1H), 4.49-4.45 (m, 1H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 153.8, 136.0, 133.0, 129.8, 129.4 (×2), 128.5 (×2), 126.6, 123.2, 118.1, 117.4, 86.8, 77.9, 74.7, 39.1 ppm; HRMS (EI+) calcd for $[C_{16}H_{13}ClN_2O_6]^+$ m/z 348.0513, found 348.0524.



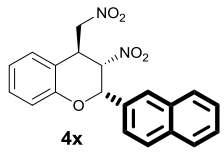
4v

(2S,3S,4S)-2-(2-bromophenyl)-3-nitro-4-(nitromethyl)chromane, white solid, mp 175-177 ℃, 65% yield, 87% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak OD-H with hexane/*i*-PrOH (80:20) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22} = 127.434$ (c = 0.83 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.67 (dd, *J* = 8, 1.5 Hz, 1H), 7.62 (dd, *J* = 7.5, 1.5 Hz, 1H), 7.47-7.43 (m, 1H), 7.35-7.32 (m, 3H), 7.16-7.13 (m, 1H), 7.08 (dd, *J* = 8, 1 Hz, 1H), 5.58 (d, *J* = 1.5 Hz, 1H), 5.49 (dd, *J* = 2, 1 Hz, 1H), 4.93-4.85 (m, 2H), 4.42 (dd, *J* = 10, 5 Hz, 1H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 154.2, 133.5, 132.8, 130.8, 129.6, 128.9, 128.4, 128.2, 123.1, 120.8, 118.0, 116.6, 81.5, 78.0, 73.0, 37.4 ppm; HRMS (EI+) calcd for $[C_{16}H_{13}BrN_2O_5]^+$ m/z 392.0008, found m/z 392.0017.



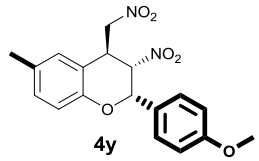
4w

(2S,3S,4S)-3-nitro-4-(nitromethyl)-2-(3-nitrophenyl)chromane, white solid, mp 131-134 ℃, 67% yield, 94% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak OD-H with hexane/*i*-PrOH (80:20) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22} = 136.000$ (c = 1 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 8.38 (t, *J* = 2 Hz, 1H), 8.32-8.29 (m, 1H), 7.83-7.81 (m, 1H), 7.68 (t, *J* = 3 Hz, 1H), 7.39-7.32 (m, 2H), 7.19-7.13 (m, 2H), 5.46 (d, *J* = 2 Hz, 1H), 5.32 (dd, *J* = 2.5, 1.5 Hz, 1H), 4.97 (dd, *J* = 14, 4 Hz, 1H), 4.84 (dd, *J* = 13.5, 10.5 Hz, 1H), 4.37 (dd, *J* = 10, 4 Hz, 1H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 153.4, 148.6, 136.9, 131.6, 130.0 (×2), 128.7, 124.1, 123.4, 121.0, 118.2, 115.7, 83.7, 78.4, 72.3, 36.9 ppm.



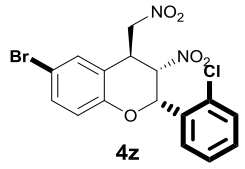
4x

(2S,3S,4S)-2-(naphthalen-2-yl)-3-nitro-4-(nitromethyl)chromane, white solid, mp 172-175 ℃, 57% yield, >99% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak OD-H with hexane/*i*-PrOH (80:20) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22} = 125.000$ (c = 0.08 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.97 (s, 1H), 7.94 (d, *J* = 8.5 Hz, 1H), 7.1-7.88 (m, 2H), 7.56-7.54 (m, 2H), 7.47 (dd, *J* = 8.5, 2 Hz, 1H), 7.39-7.35 (m, 1H), 7.33-7.31 (m, 1H), 7.18-7.13 (m, 2H), 5.52 (d, *J* = 2.5 Hz, 1H), 5.35 (t, *J* = 2 Hz, 1H), 4.95 (dd, *J* = 13.5, 4.5 Hz, 1H), 4.84 (dd, *J* = 14, 10 Hz, 1H), 4.34-4.31 (m, 1H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 153.1, 133.5, 133.2, 131.8, 129.8, 128.9, 128.6, 128.3, 127.9, 126.8, 126.7, 125.3, 122.9, 122.9, 118.1, 116.0, 84.0, 78.5, 73.4, 37.1 ppm. HRMS (EI+) calcd for $[C_{20}H_{16}N_2O_5]^+$ m/z 364.1059, found 364.1056.



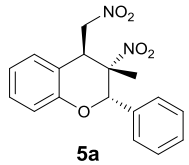
4y

(2S,3S,4S)-2-(4-methoxyphenyl)-6-methyl-3-nitro-4-(nitromethyl)chromane, white solid, mp 177-179 ℃, 64% yield, 96% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak OD-H with hexane/*i*-PrOH (80:20) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22} = 134.513$ (c = 0.5 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.33 (d, *J* = 8.5 Hz, 2H), 7.12 (dd, *J* = 8, 2 Hz, 1H), 7.07 (d, *J* = 2 Hz, 1H), 6.98-6.95 (m, 3H), 5.28 (d, *J* = 2.5 Hz, 1H), 5.16 (t, *J* = 2 Hz, 1H), 4.90 (dd, *J* = 13.5, 4 Hz, 1H), 4.76 (dd, *J* = 13.5, 10.5 Hz, 1H), 4.22-4.19 (m, 1H), 3.84 (s, 3H), 2.35 (s, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 160.2, 152.0, 132.2, 130.6, 128.6, 127.0 (×2), 126.6, 117.8, 115.4, 114.3 (×2), 84.2, 78.5, 73.2, 55.3, 37.0, 20.7 ppm.



4z

(2S,3S,4S)-6-bromo-2-(2-chlorophenyl)-3-nitro-4-(nitromethyl)chromane, white solid, mp 168-170 ℃, 57% yield, 86% ee, >20:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak AS-H with hexane/*i*-PrOH (90:10) as the eluent, flow = 1.0 mL/min, UV = 212 nm, $[\alpha]_D^{22} = 133.125$ (c = 0.5 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.60-7.58 (m, 1H), 7.49-7.47 (m, 2H), 7.45-7.40 (m, 3H), 6.98 (d, *J* = 8.5 Hz, 1H), 5.60 (d, *J* = 0.5 Hz, 1H), 5.43 (dd, *J* = 2, 1 Hz, 1H), 4.91 (dd, *J* = 14.5, 4 Hz, 1H), 4.81 (dd, *J* = 14, 6 Hz, 1H), 4.39 (dd, *J* = 11, 4 Hz, 1H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 153.3, 132.8, 131.6, 131.5, 130.8, 130.6, 129.6, 127.8, 127.7, 119.8, 118.6, 115.2, 81.0, 77.8, 71.0, 37.1 ppm.

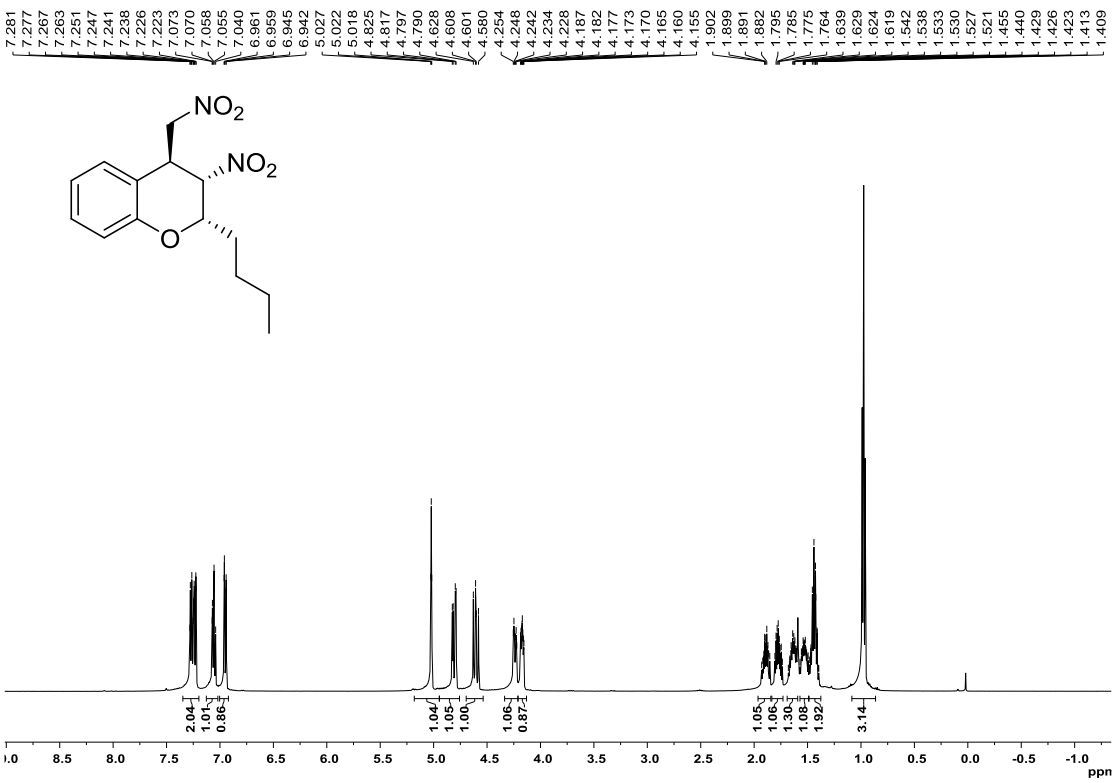


5a

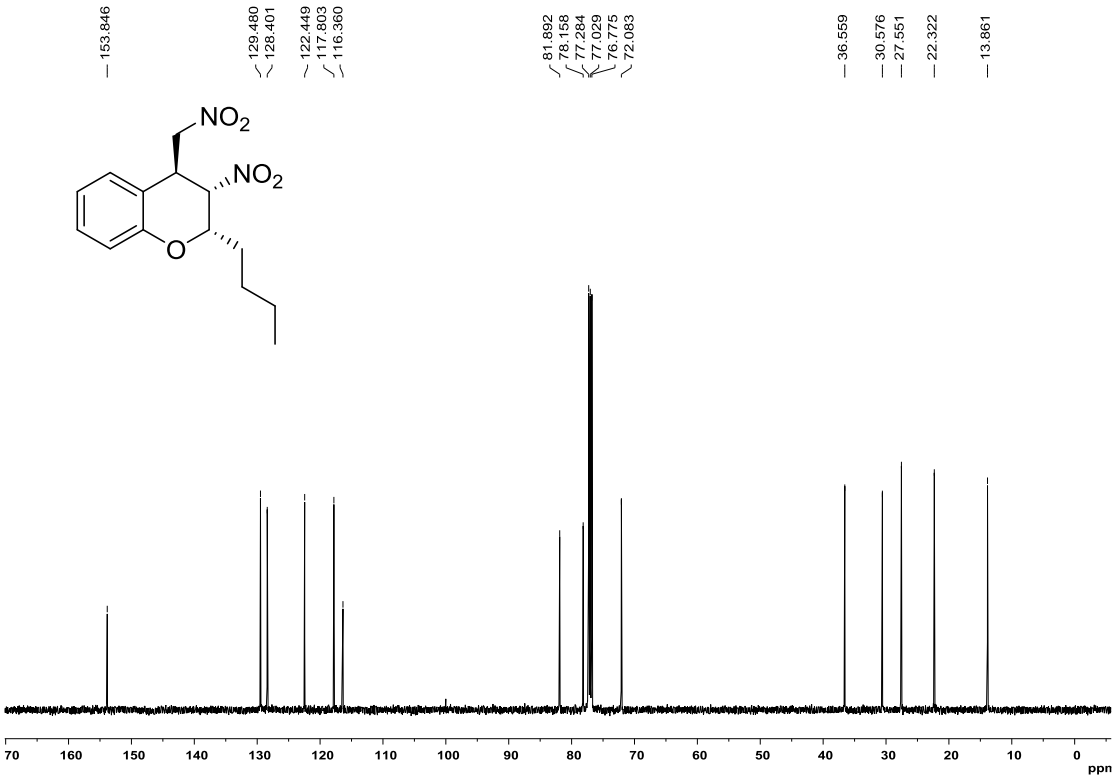
(2S,3S,4S)-3-methyl-3-nitro-4-(nitromethyl)-2-phenylchromane, white solid, mp 166-168 ℃, 59% yield, 91% ee, 8:1 dr. The enantiomeric excess was determined by HPLC on Daicel Chiralpak AS-H with hexane/*i*-PrOH (90:10) as the eluent, flow = 1.0 mL/min, UV = 212 nm $[\alpha]_D^{22} = 116.620$ (c = 0.66 in CH_2Cl_2). **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.41-7.29 (m, 6H), 7.21-7.18 (m, 1H), 7.10-7.00 (m, 2H), 5.77 (d, *J* = 9 Hz, 1H), 5.18-5.12 (m, 1H), 4.93-4.88 (m, 1H), 4.17 (d, *J* = 6.5 Hz, 1H), 1.66 (d, *J* = 7.5 Hz, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$): δ 152.3, 134.2, 130.0, 129.6, 128.7 (×2), 128.3, 128.1 (×2), 122.5, 118.4, 117.4, 88.4, 78.0, 77.4, 42.4, 19.4 ppm. HRMS (EI+) calcd for $[C_{17}H_{16}N_2O_5]^+$ m/z 328.1059, found 328.1055.

3. ^{1}H, ^{13}C NMR spectra and HPLC chromatograms of compounds 4a-5a

^{1}H NMR spectrum of 4a

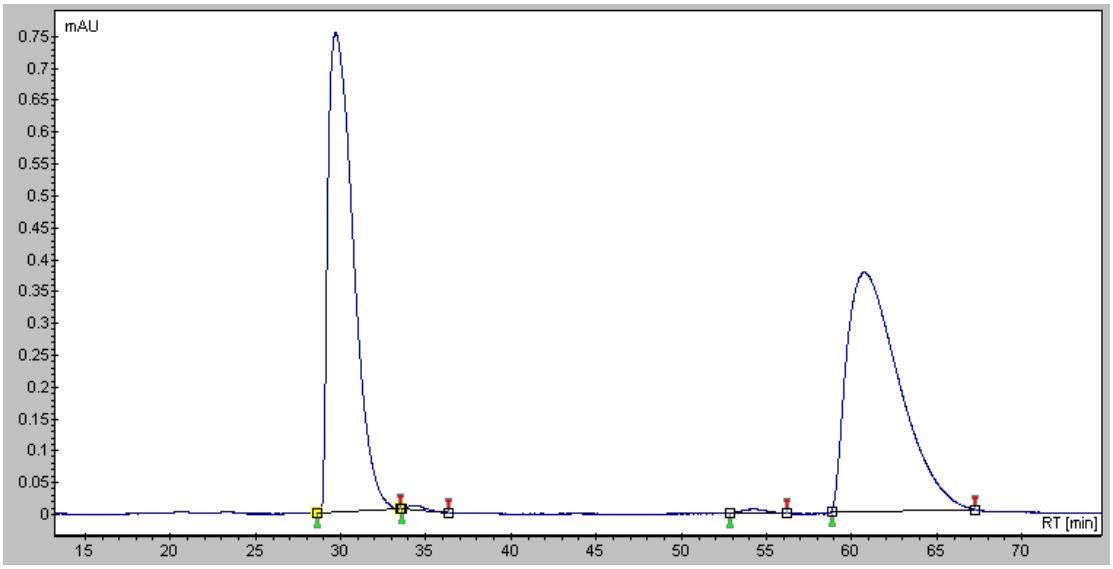


^{13}C NMR spectrum of 4a



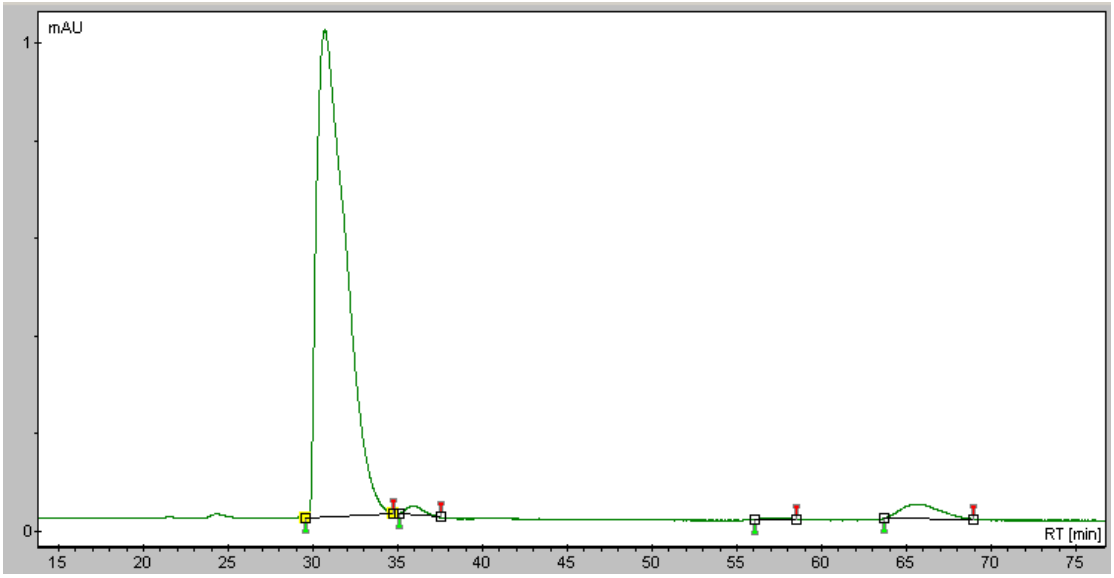
HPLC chromatograms of 4a

4a-rac



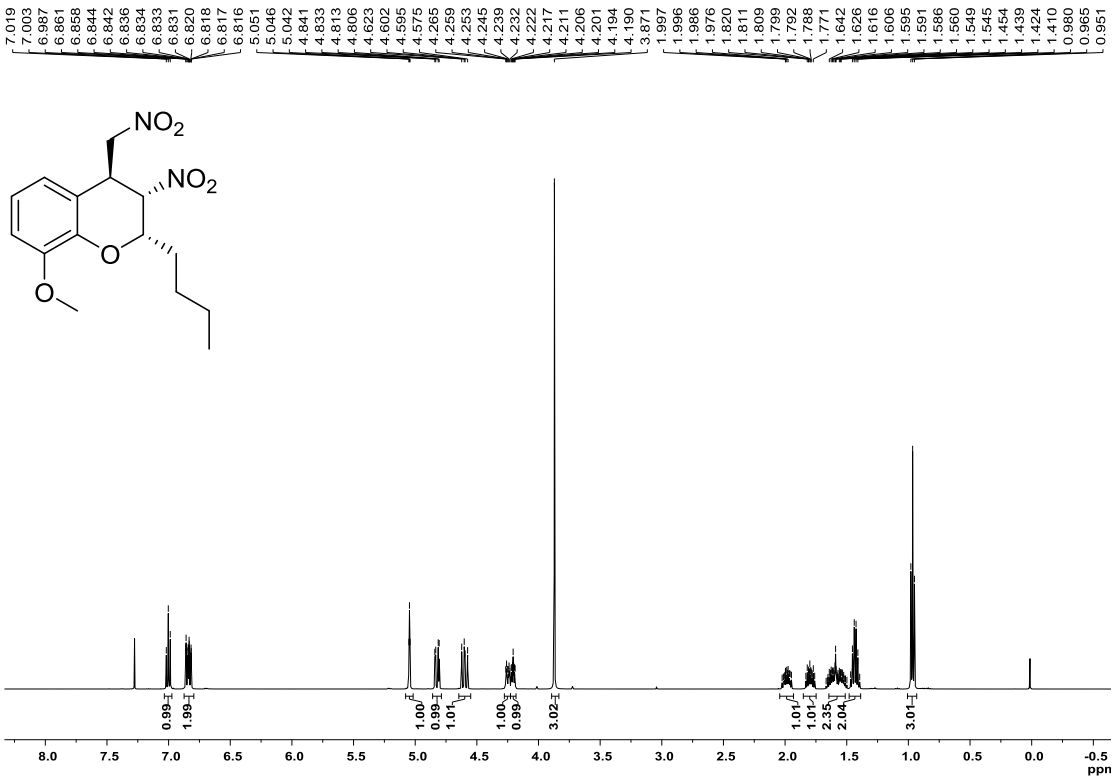
#	Start time[min]	Time[min]	End time[min]	Area%
1	28.67	29.709	33.537	48.9
2	33.56	34.388	36.326	0.31
3	52.892	54.221	56.16	0.396
4	58.821	60.818	67.285	50.394

4a-chr

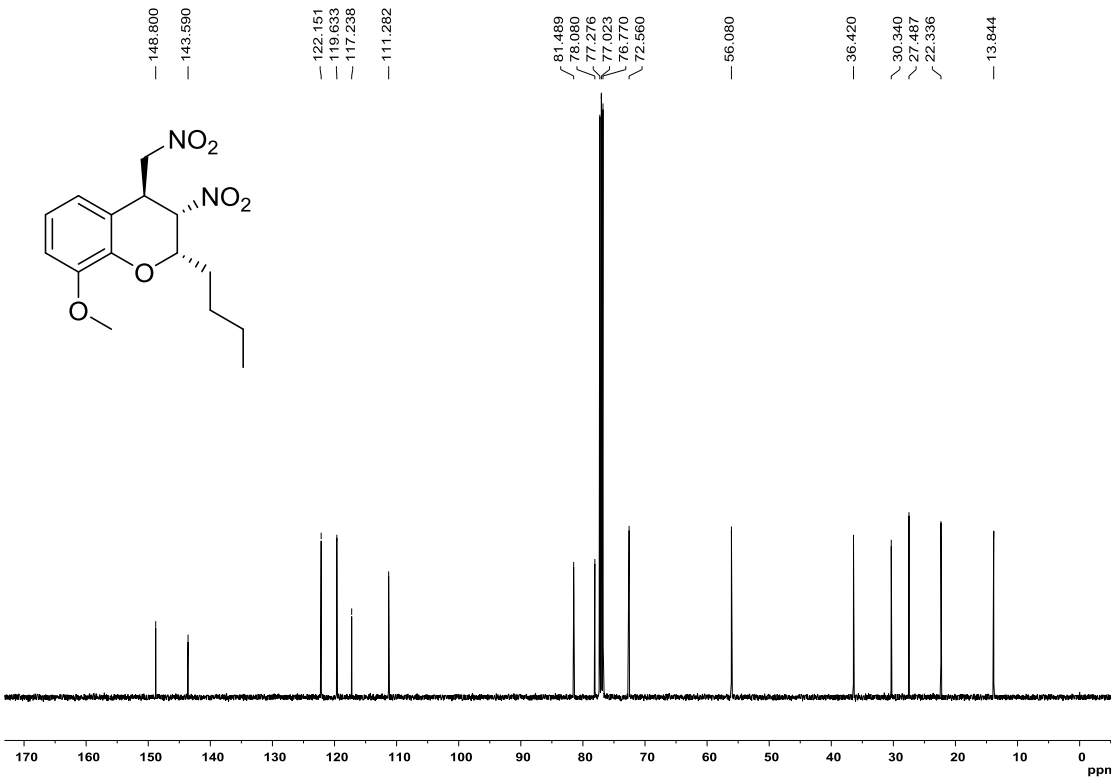


#	Start time[min]	Time[min]	End time[min]	Area%
1	29.587	30.682	34.776	94.868
2	35.107	35.894	37.536	1.061
3	56.083	57.14	58.512	0.253
4	63.7	65.603	68.889	3.818

^{1}H NMR spectrum of 4b

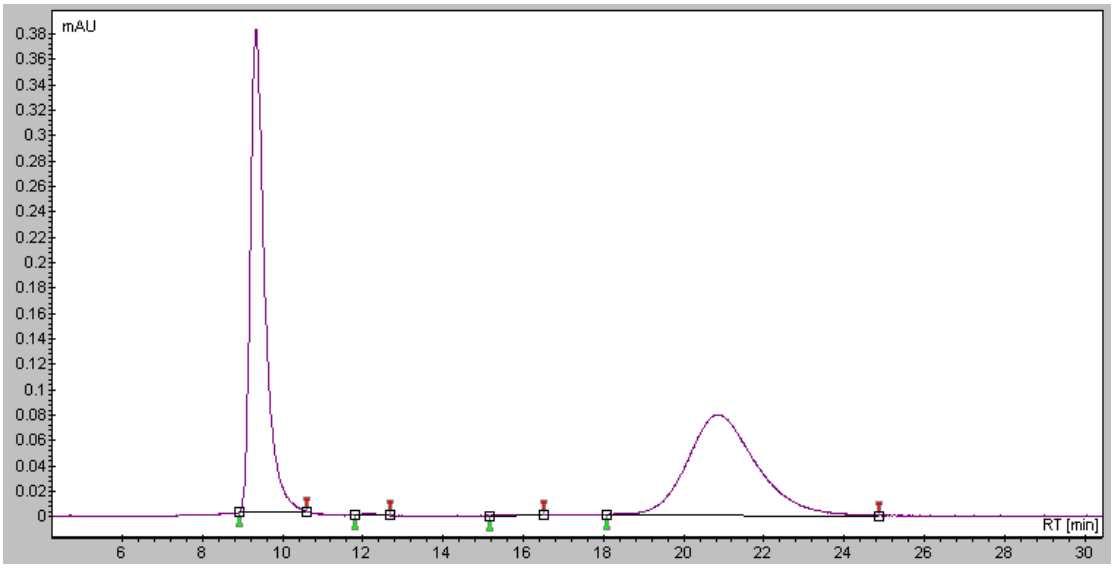


^{13}C NMR spectrum of 4b



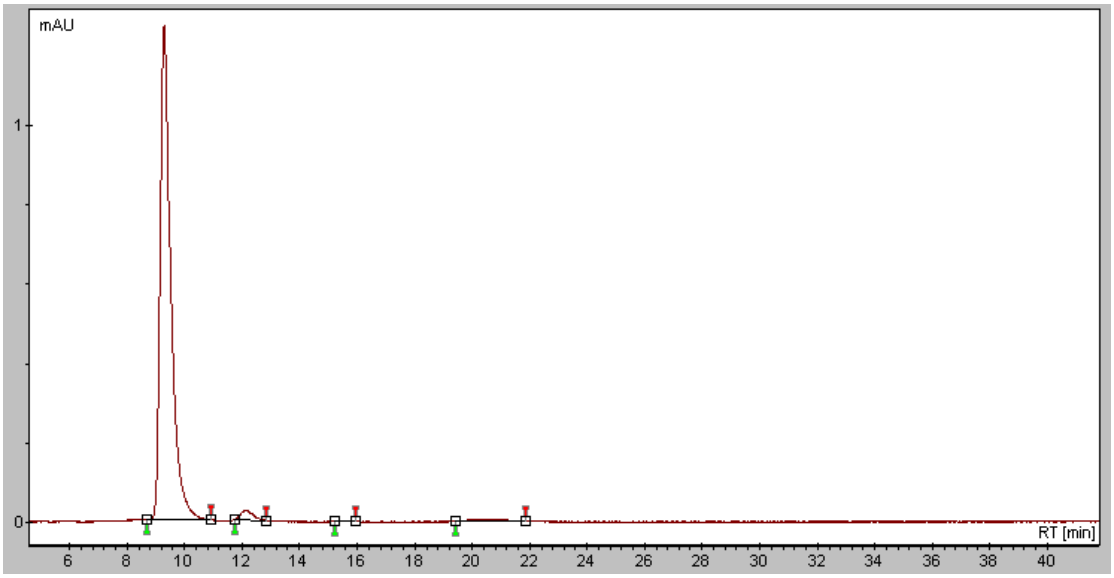
HPLC chromatograms of 4b

4b-rac



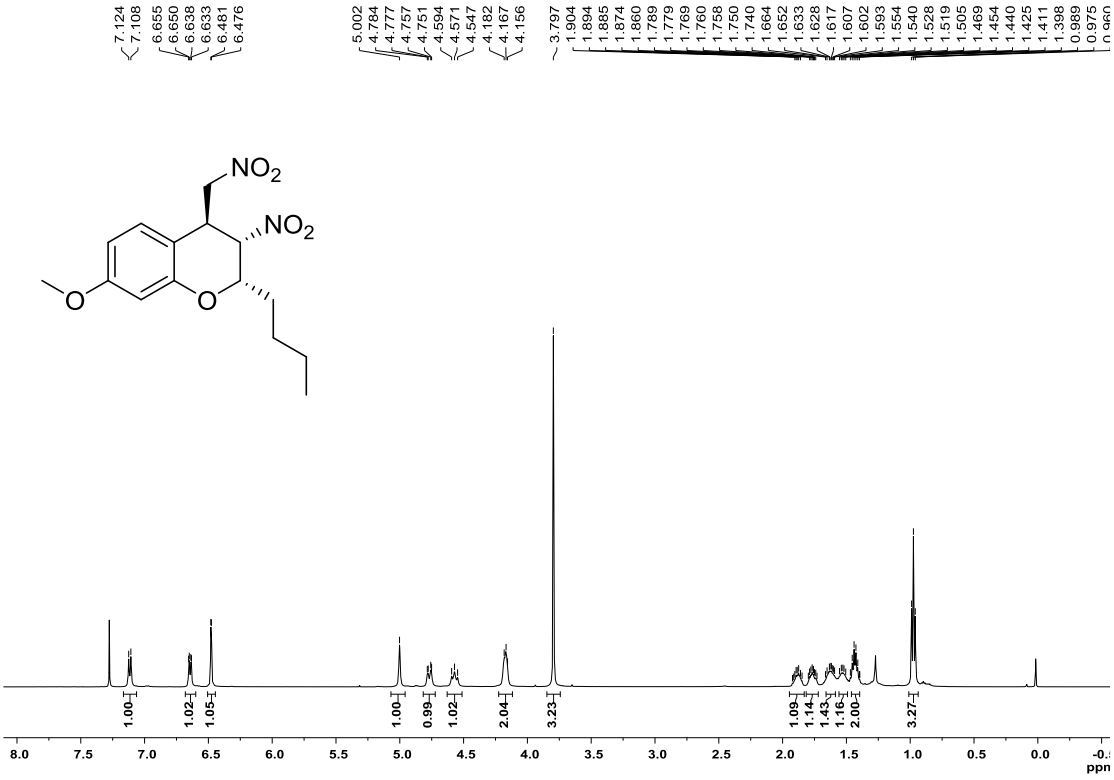
#	Start time[min]	Time[min]	End time[min]	Area%
1	8.93	9.333	10.589	50.443
2	11.807	12.172	12.691	0.181
3	15.148	15.679	16.524	0.143
4	18.096	20.852	24.876	49.233

4b-chr

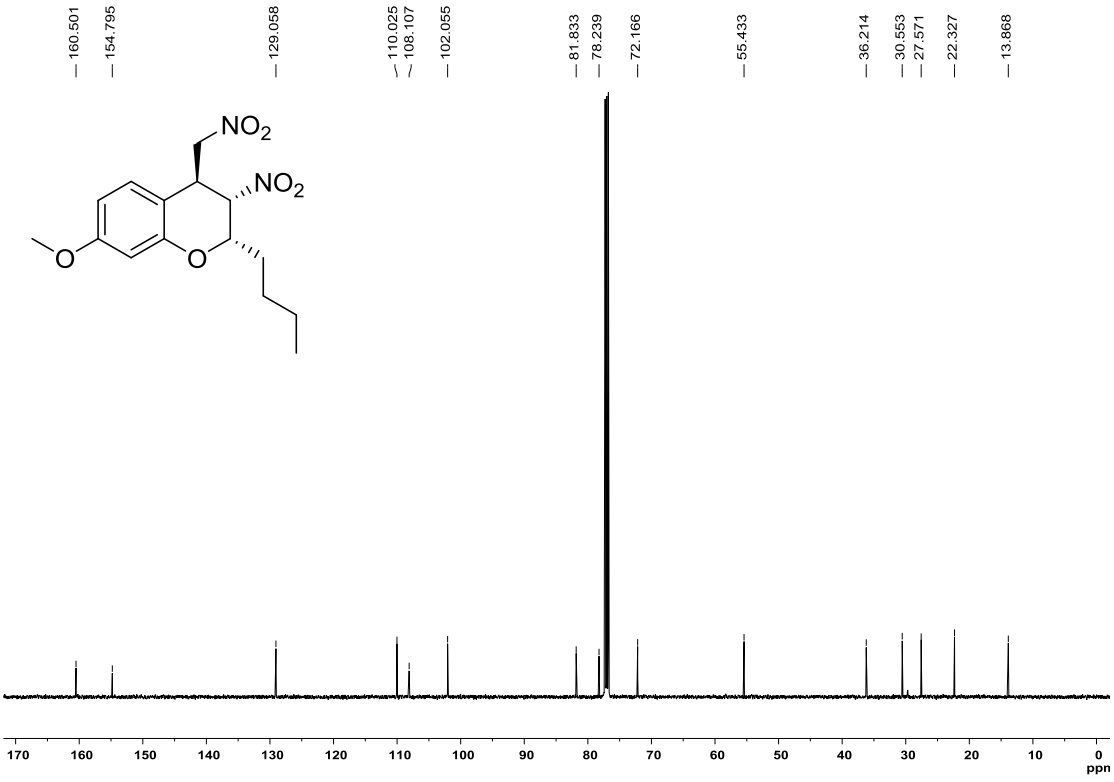


#	Start time[min]	Time[min]	End time[min]	Area%
1	8.668	9.293	10.924	96.805
2	11.755	12.132	12.824	2.085
3	15.198	15.532	15.97	0.084
4	19.414	20.425	21.848	1.026

^{1}H NMR spectrum of 4c

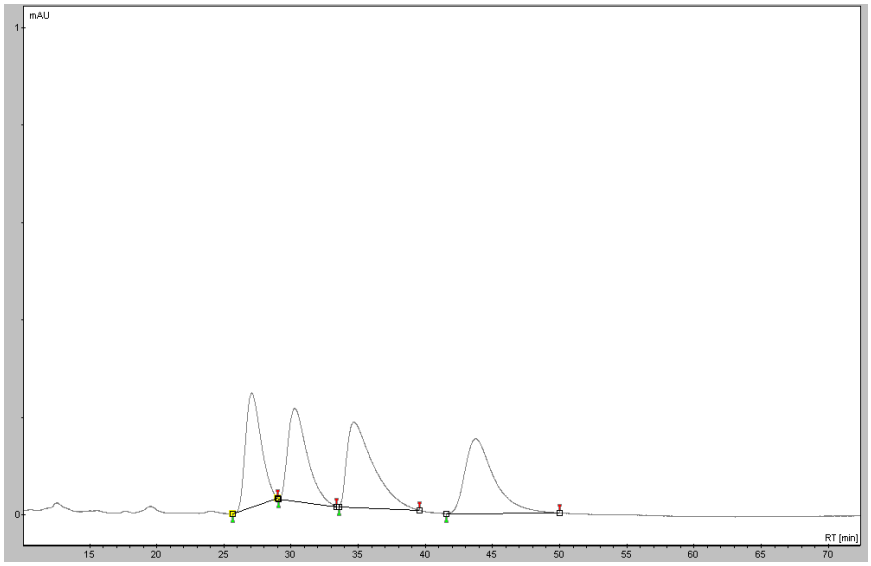


^{13}C NMR spectrum of 4c



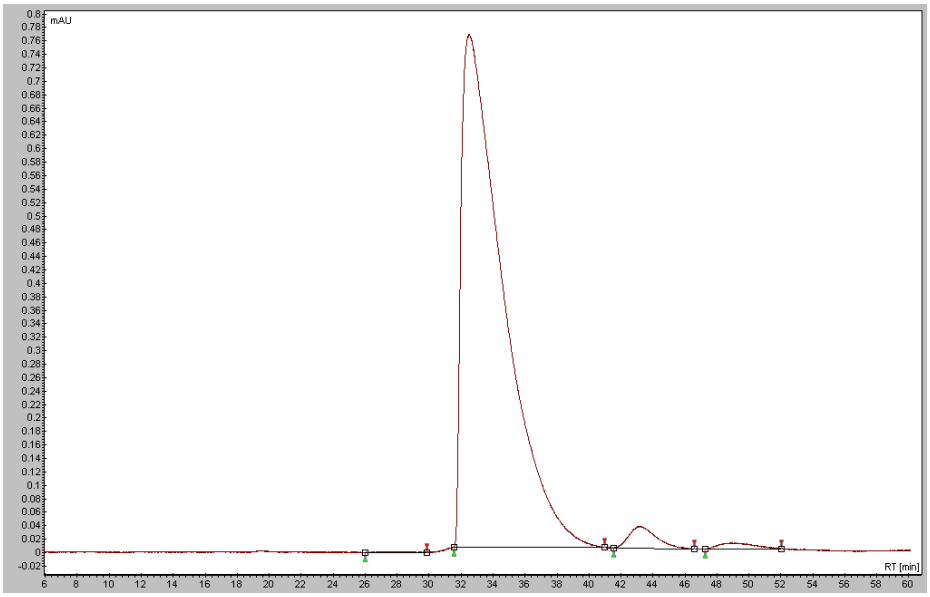
HPLC chromatograms of 4c

4c-rac



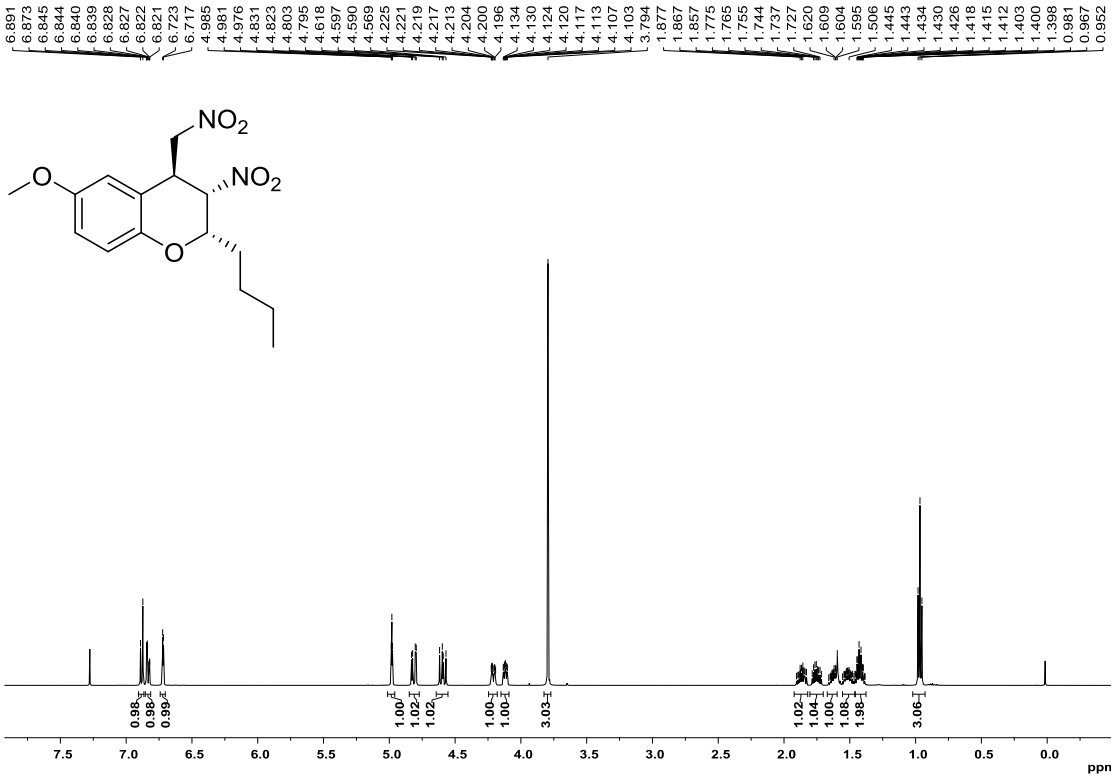
#	Start time[min]	Time[min]	End time[min]	Area%
1	25.635	27.057	29.000	22.415
2	29.080	30.269	33.406	22.291
3	33.545	34.681	39.586	28.247
4	41.585	43.758	49.965	27.047

4c-chr

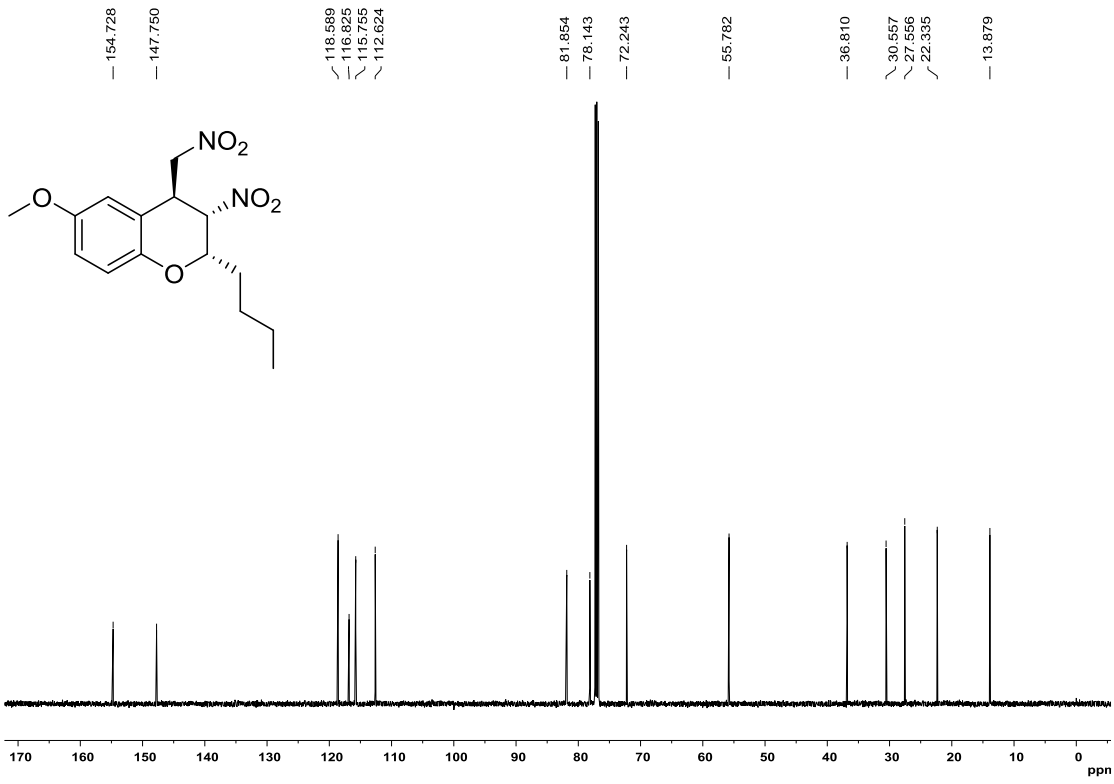


#	Start time[min]	Time[min]	End time[min]	Area%
1	25.985	28.411	29.866	0.049
2	31.544	32.518	40.982	96.301
3	41.541	43.197	46.570	2.694
4	47.253	48.890	52.034	0.957

^{1}H NMR spectrum of 4d

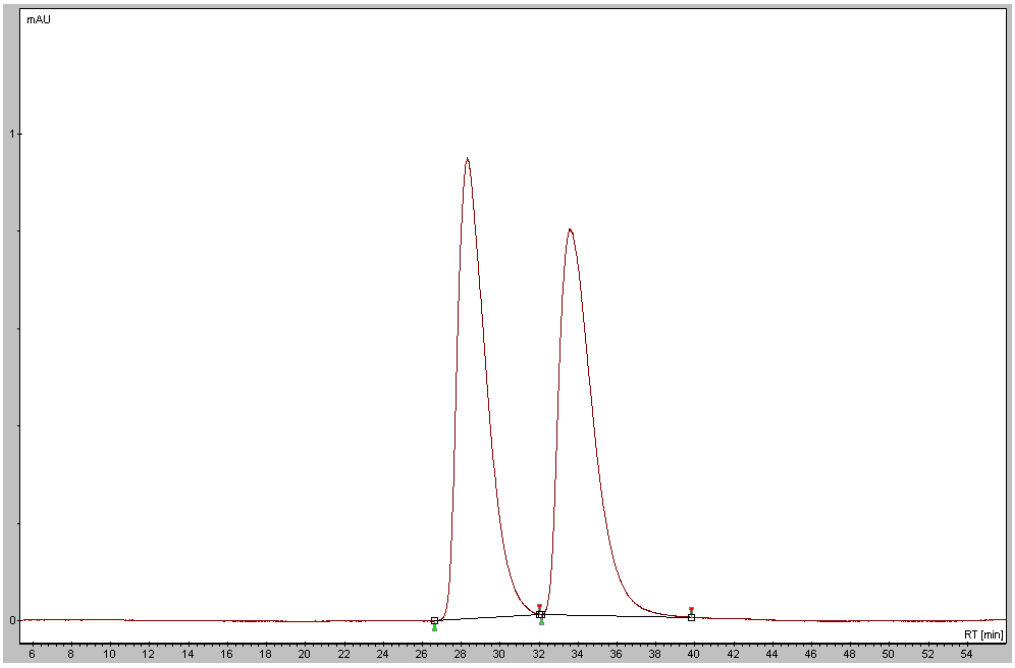


^{13}C NMR spectrum of 4d



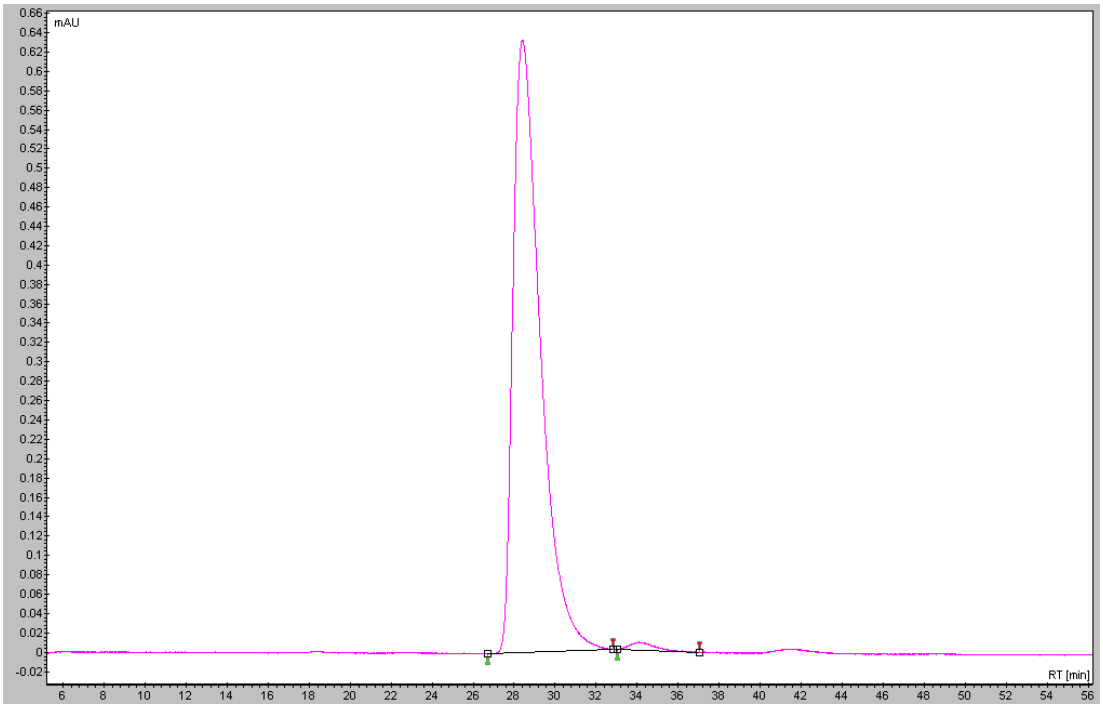
HPLC chromatograms of 4d

4d-rac



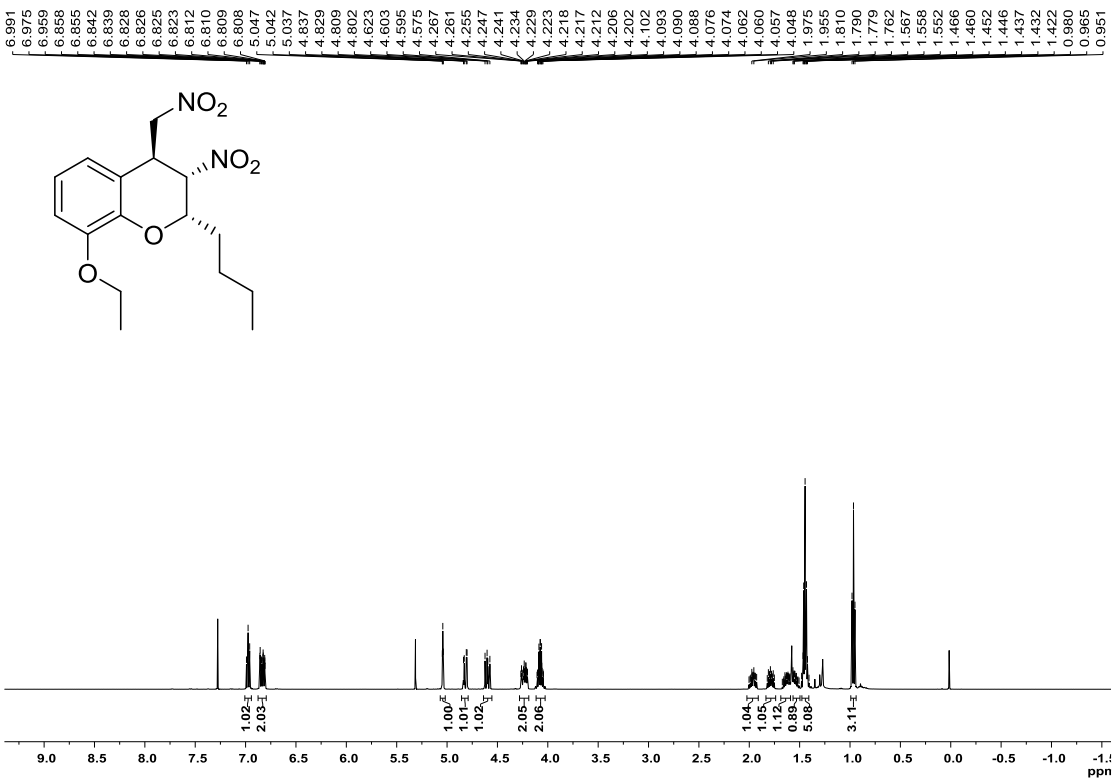
#	Start time[min]	Time[min]	End time[min]	Area%
1	26.637	28.291	32.022	50.331
2	32.138	33.598	39.840	49.669

4d-chr

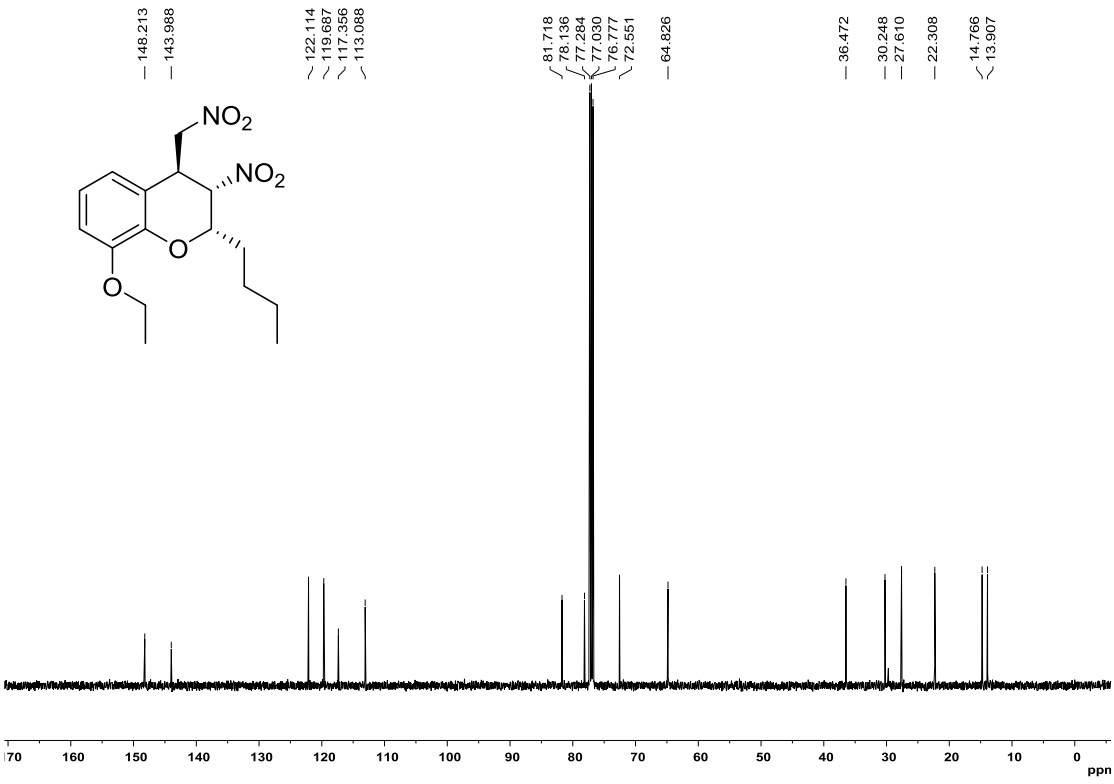


#	Start time[min]	Time[min]	End time[min]	Area%
1	26.735	28.390	32.830	98.822
2	33.026	34.214	37.056	1.178

^{1}H NMR spectrum of 4e

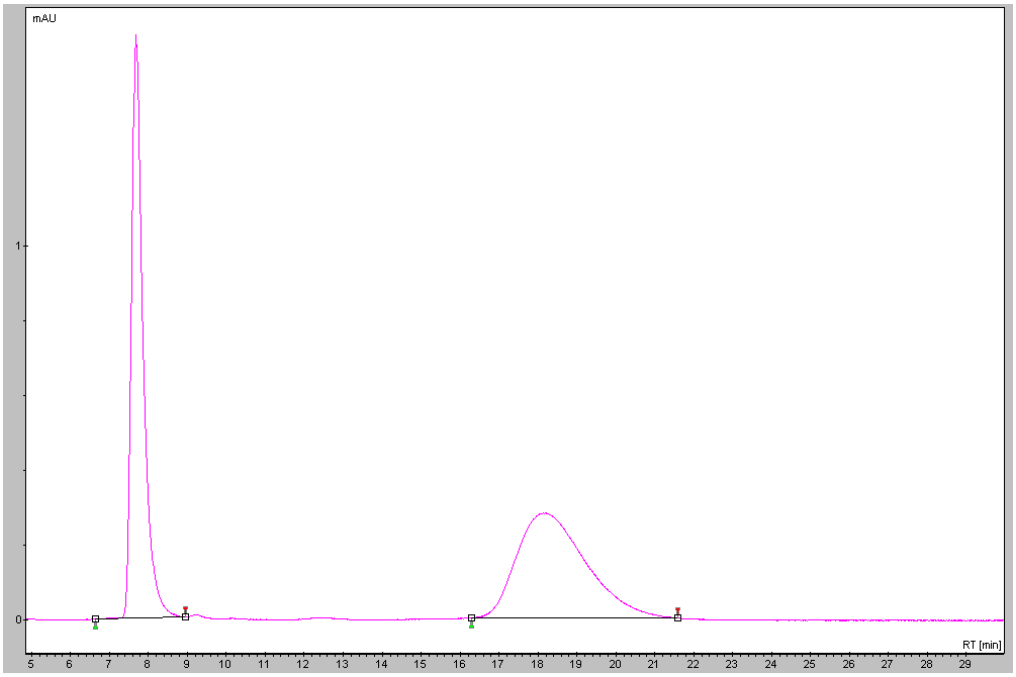


^{13}C NMR spectrum of 4e



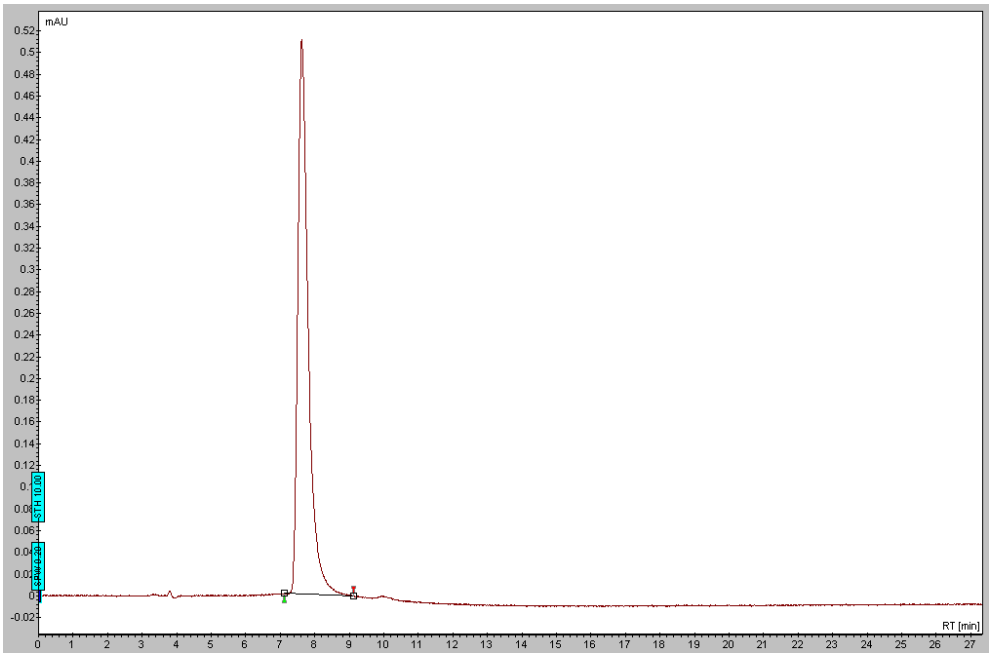
HPLC chromatograms of 4e

4e-rac



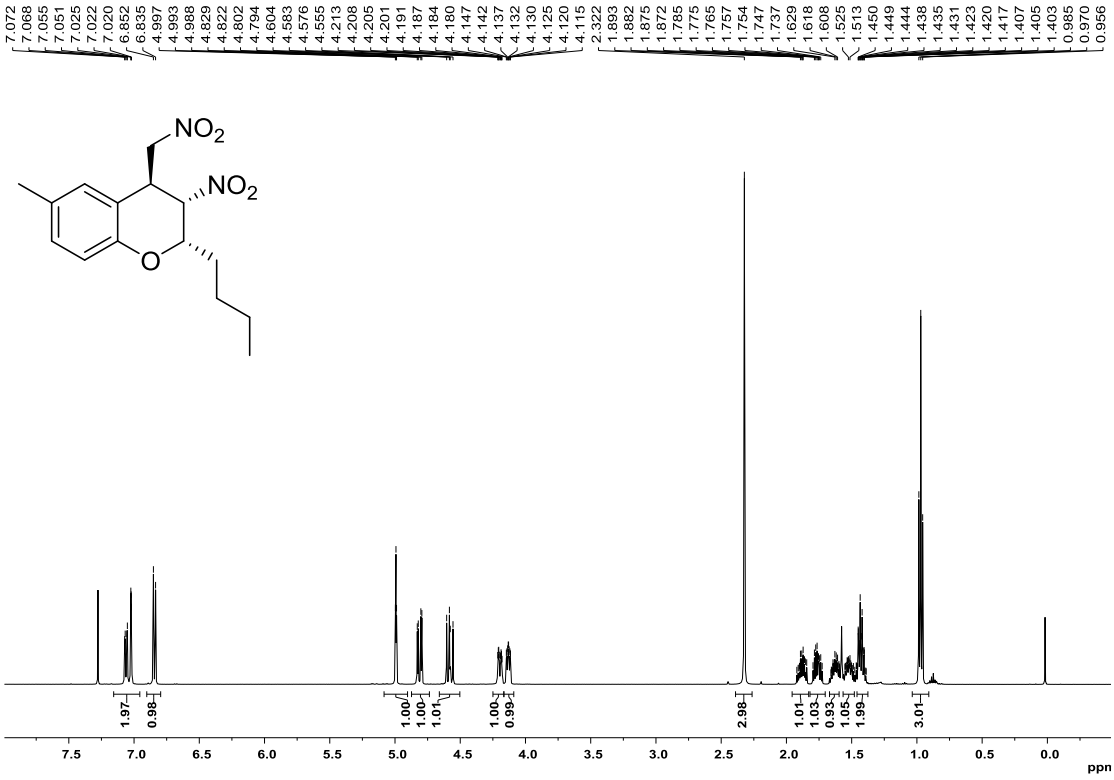
#	Start time[min]	Time[min]	End time[min]	Area%
1	6.628	7.666	8.945	48.366
2	16.305	18.185	21.591	51.634

4e-chr

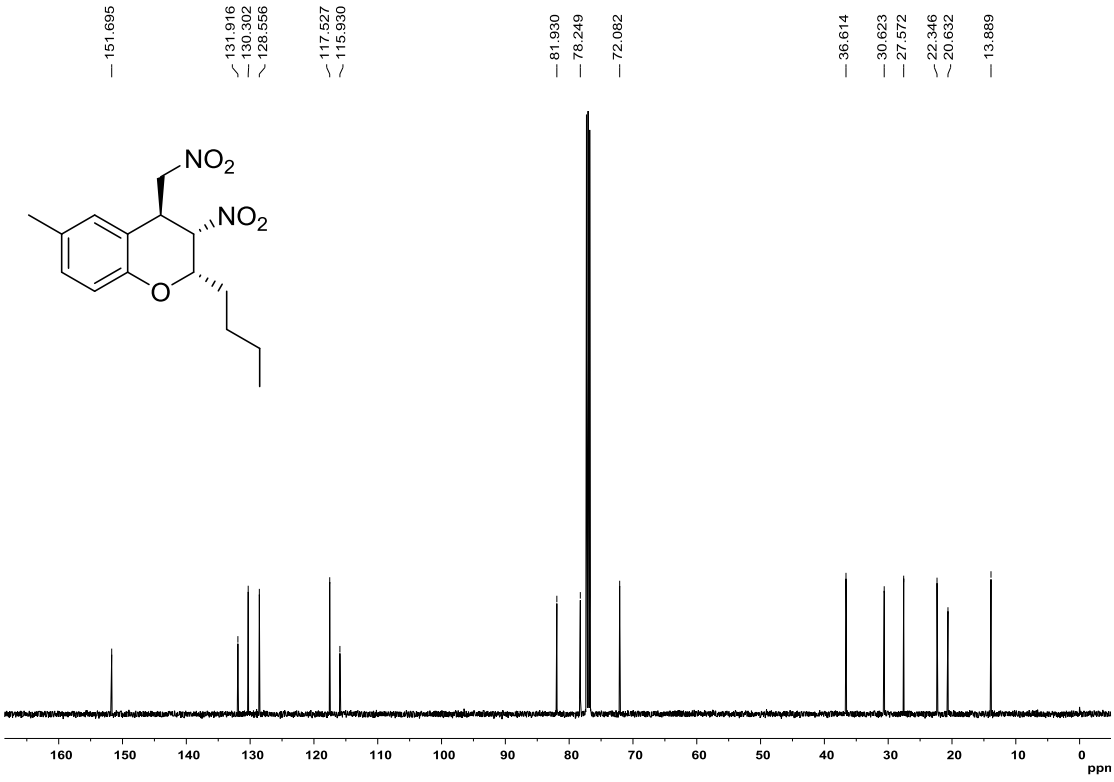


#	Start time[min]	Time[min]	End time[min]	Area%
1	7.119	7.626	9.125	100
2				

^{1}H NMR spectrum of 4f

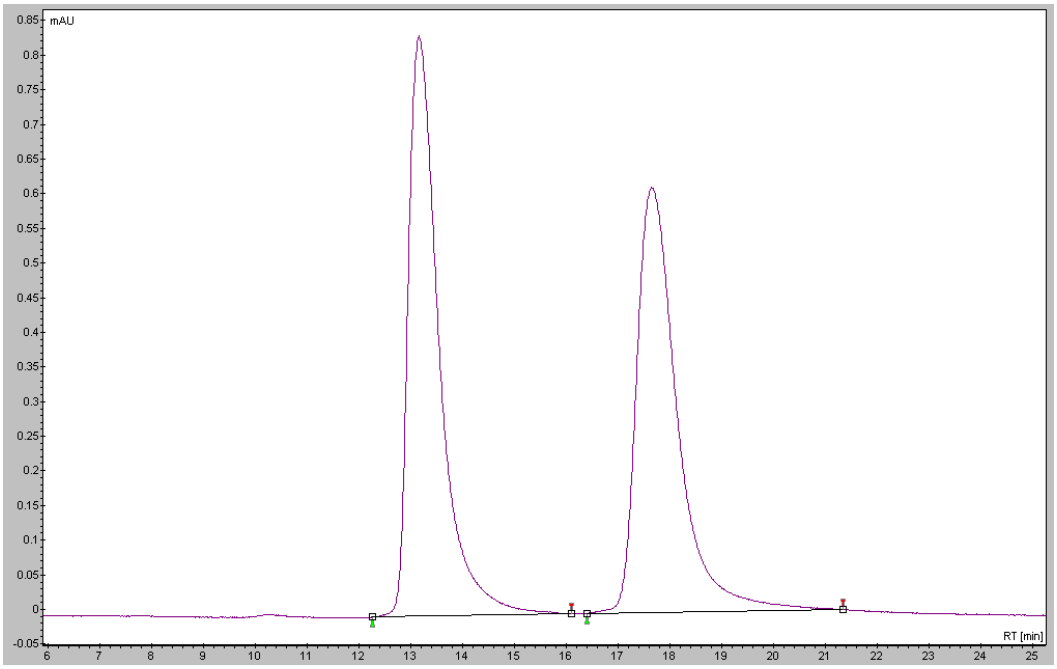


^{13}C NMR spectrum of 4f



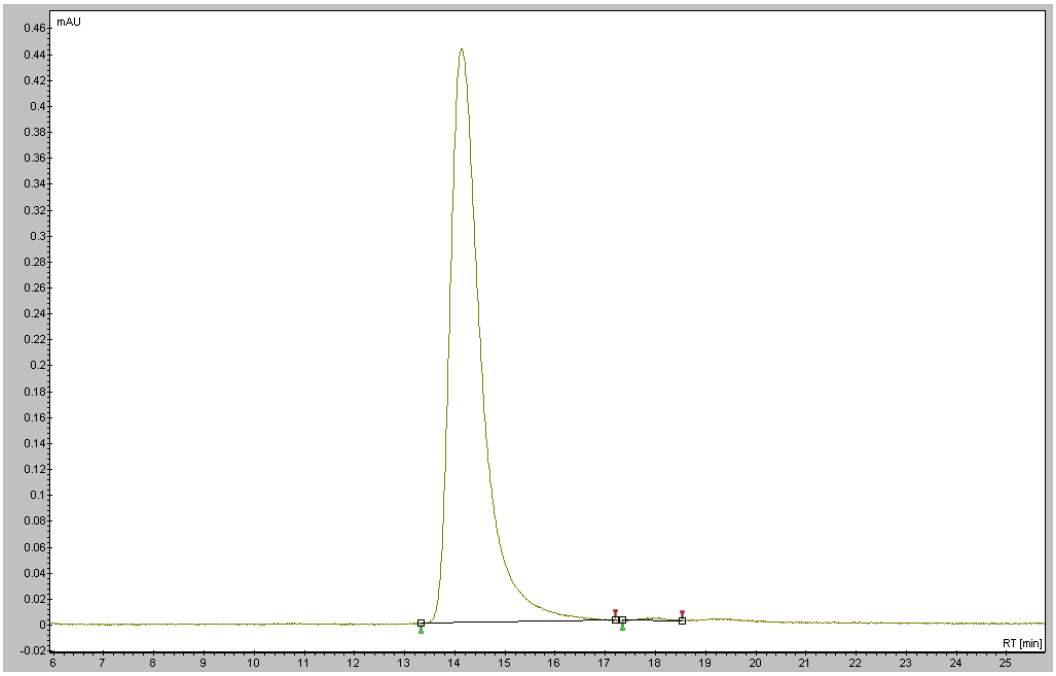
HPLC chromatograms of 4f

4f-rac



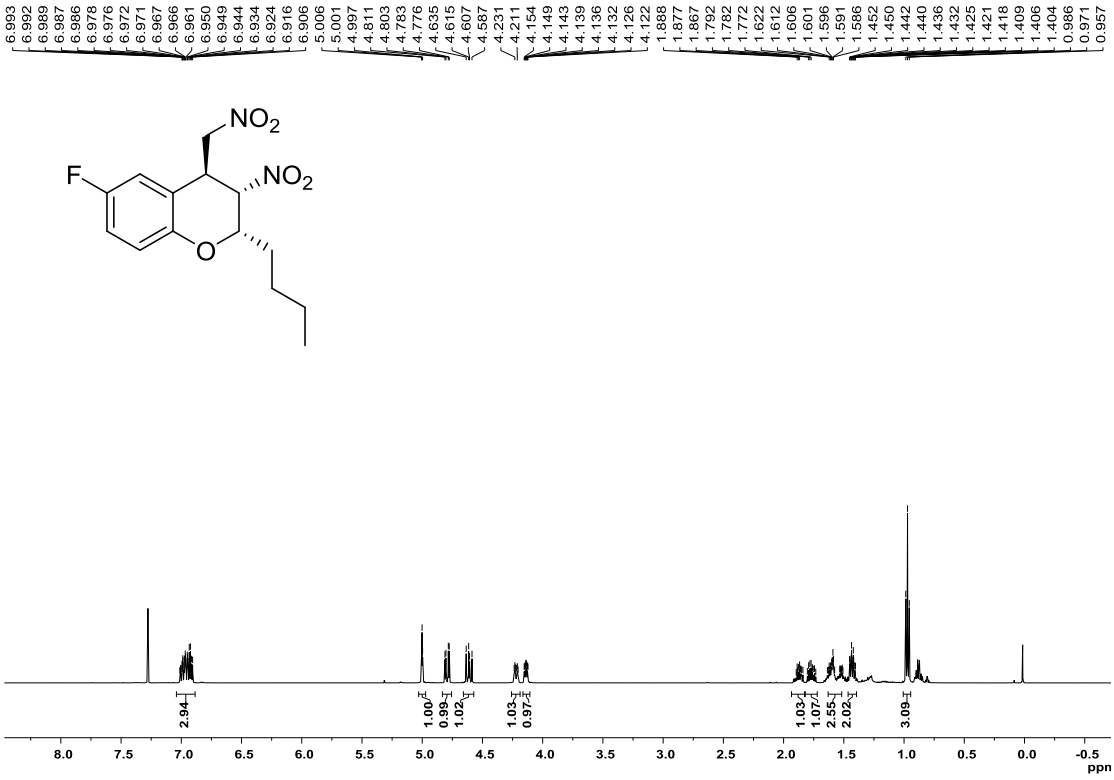
#	Start time[min]	Time[min]	End time[min]	Area%
1	12.243	13.146	16.086	51.031
2	26.339	17.652	21.325	48.969

4f-chr

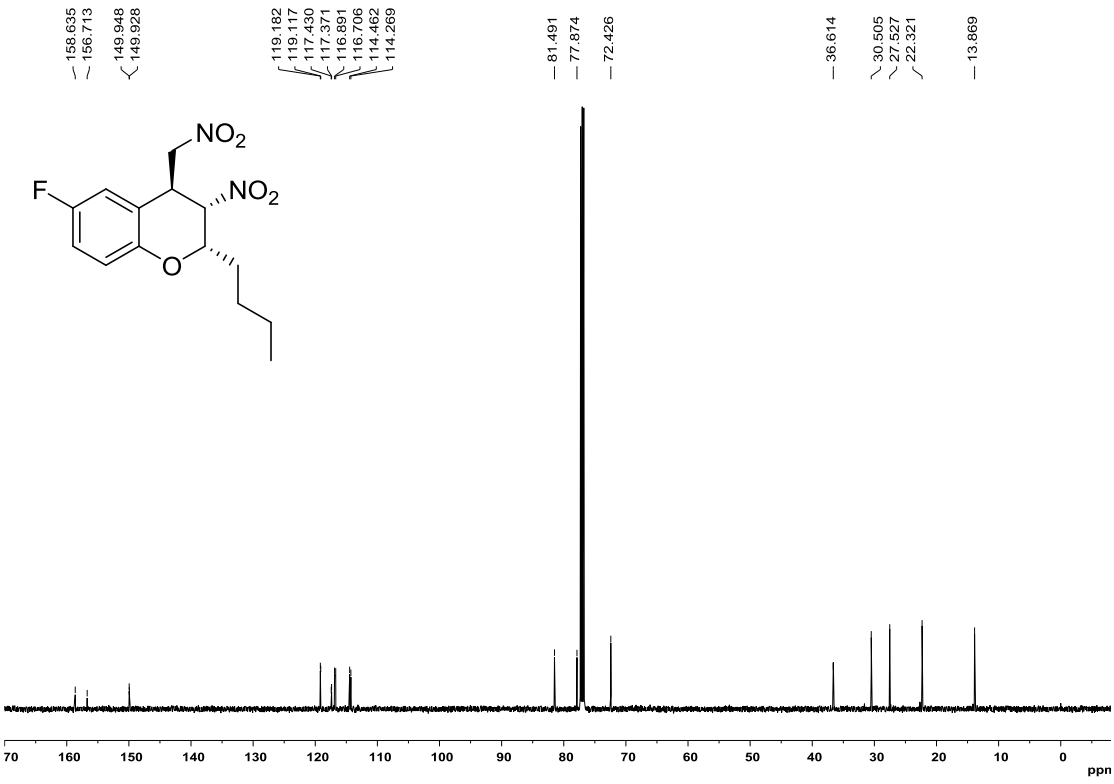


#	Start time[min]	Time[min]	End time[min]	Area%
1	13.320	14.132	17.202	99.679
2	17.344	17.945	18.533	0.321

^{1}H NMR spectrum of 4g

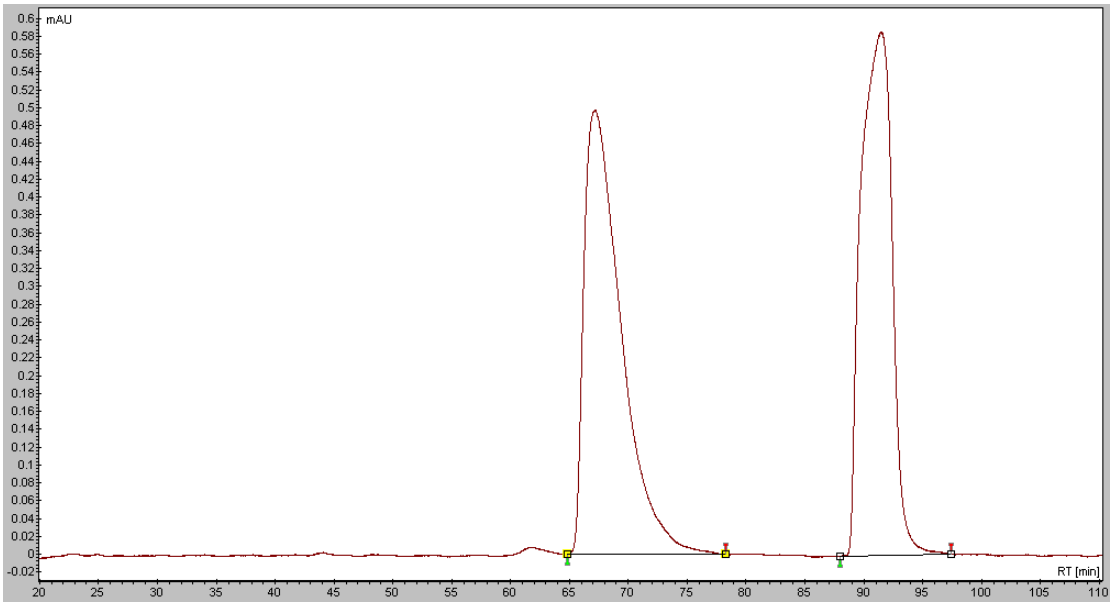


^{13}C NMR spectrum of 4g



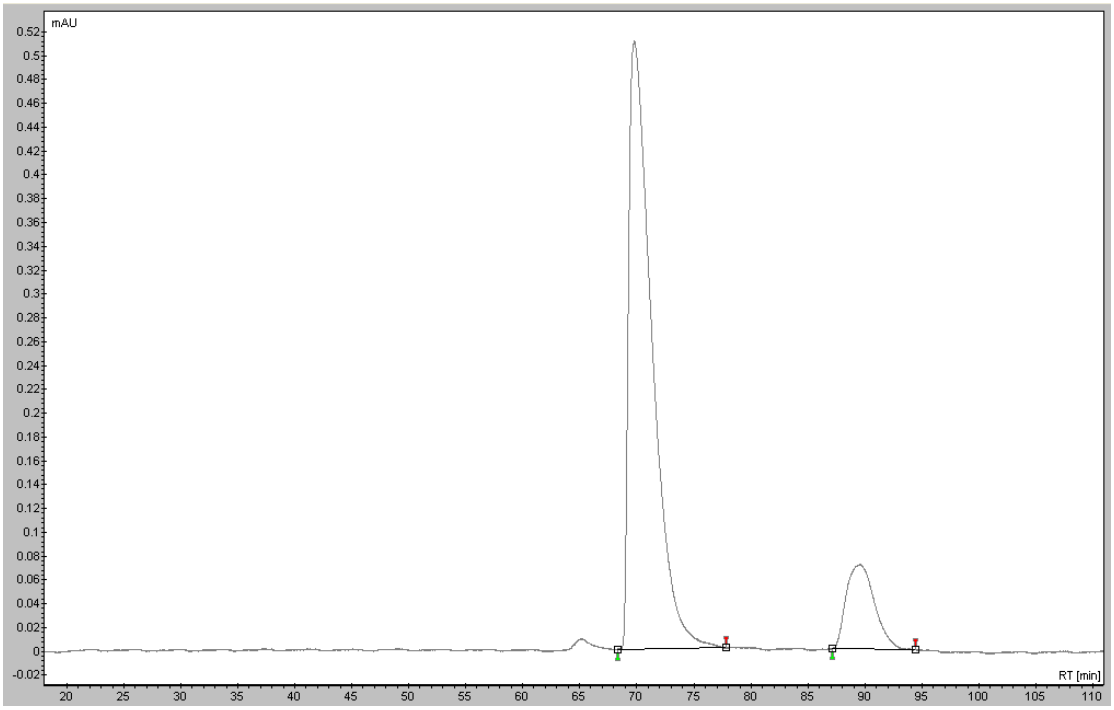
HPLC chromatograms of 4g

4g-rac



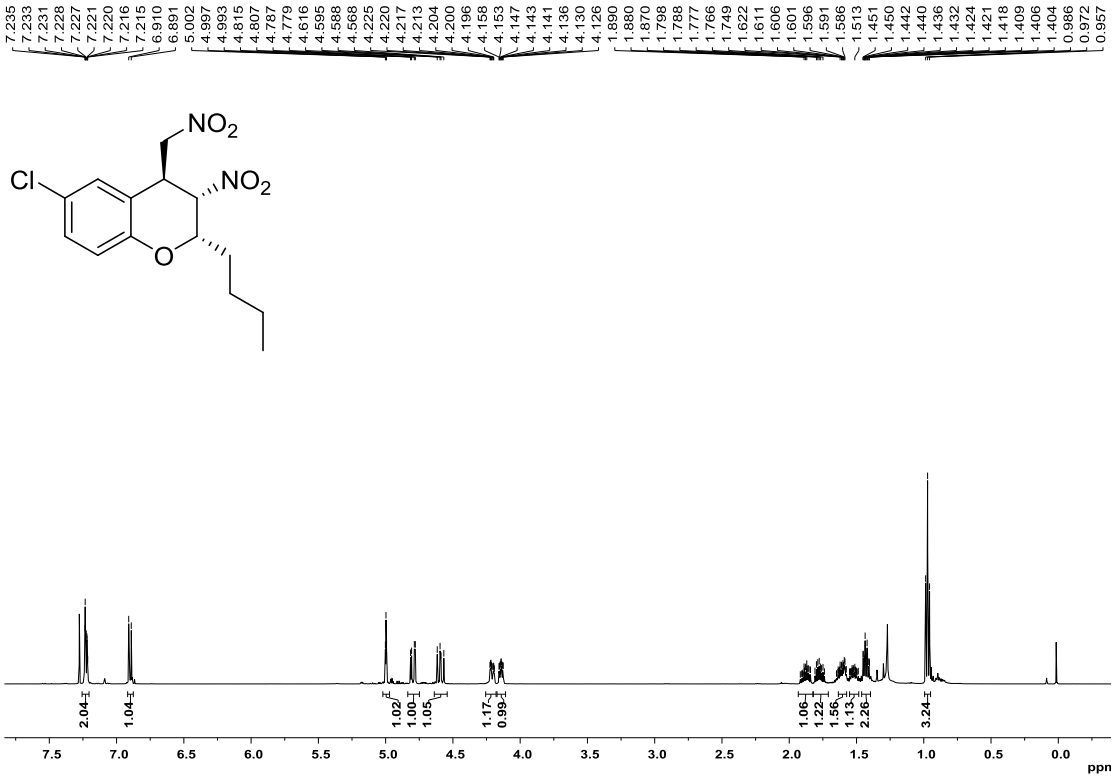
#	Start time[min]	Time[min]	End time[min]	Area%
1	64.795	67.216	78.284	50.360
2	87.990	91.487	97.445	49.640

4g-chr

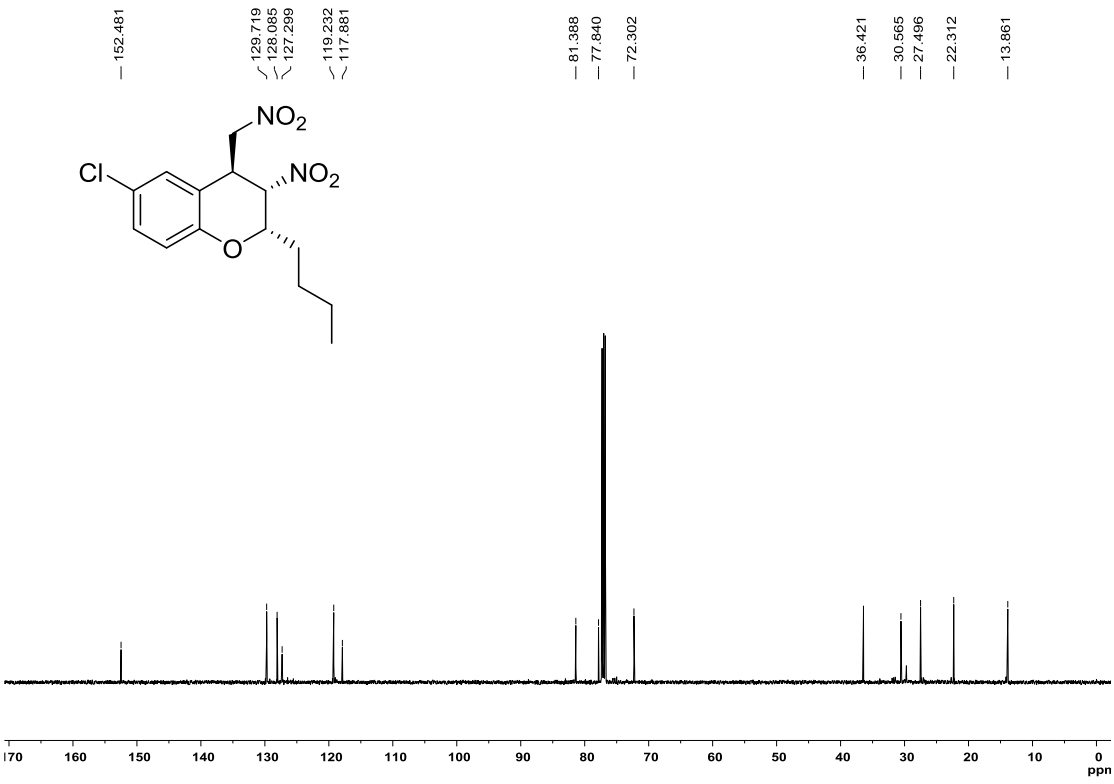


#	Start time[min]	Time[min]	End time[min]	Area%
1	68.329	69.788	77.848	85.543
2	87.107	89.555	94.409	14.457

^{1}H NMR spectrum of 4h

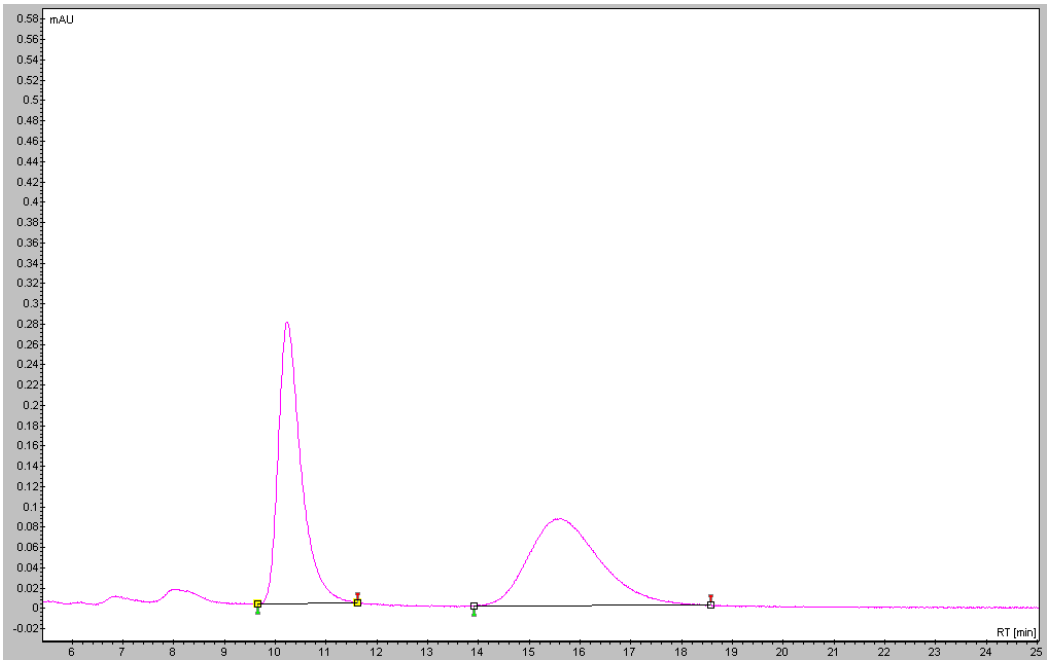


^{13}C NMR spectrum of 4h



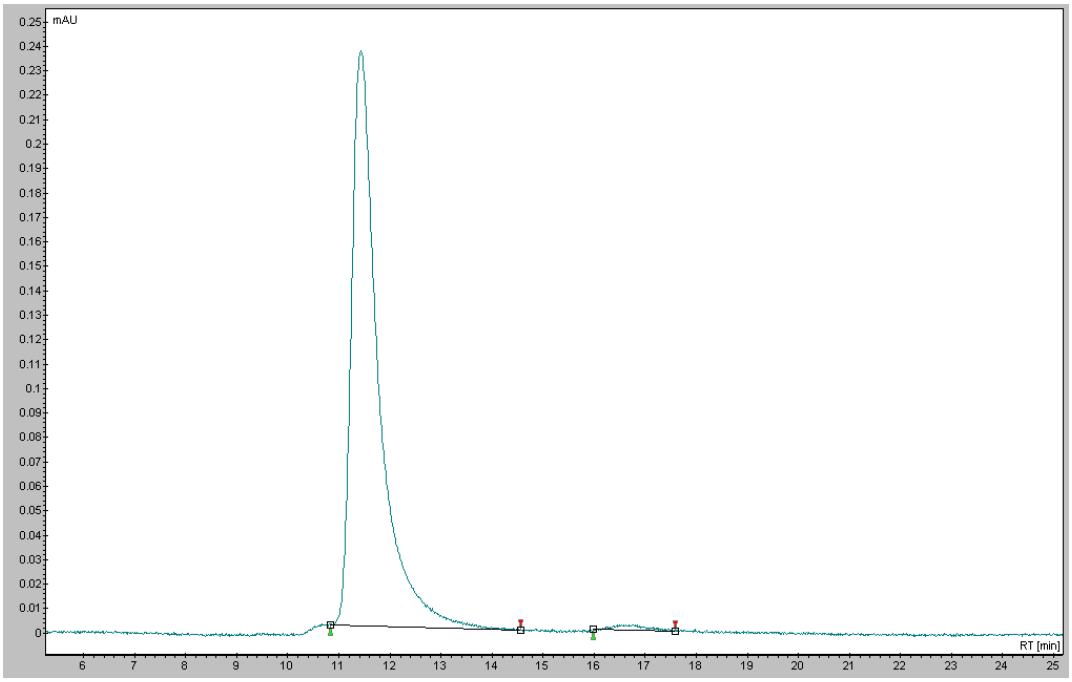
HPLC chromatograms of 4h

4h-rac



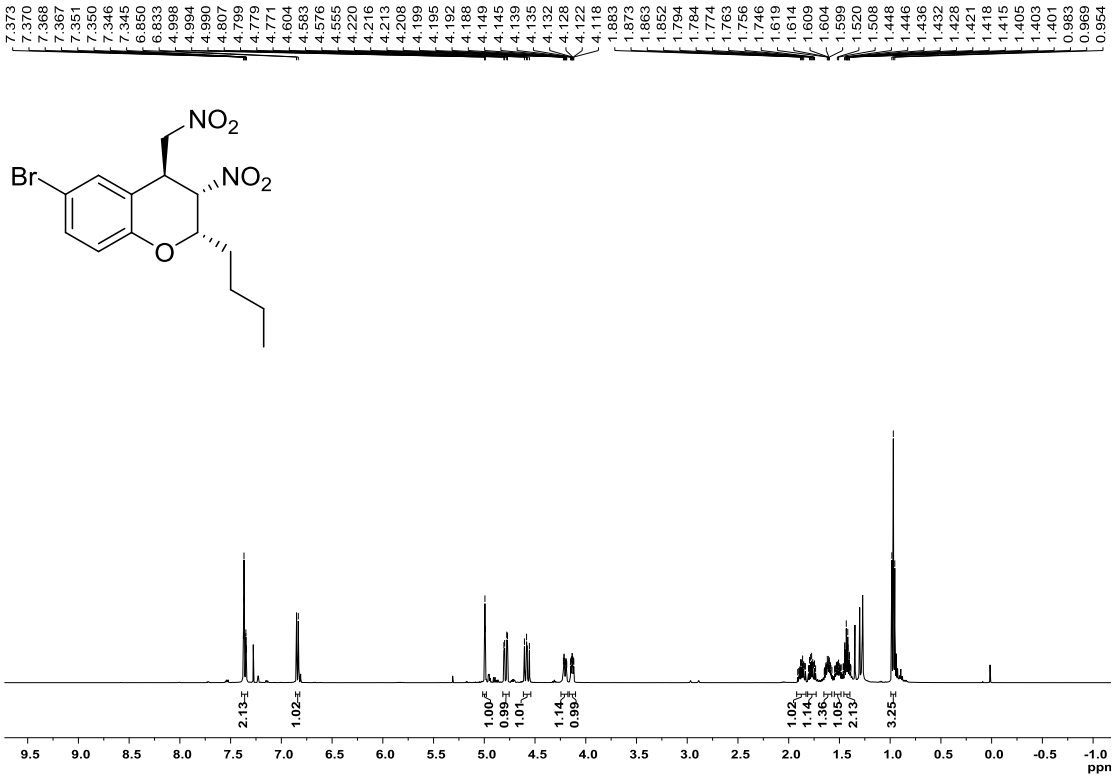
#	Start time[min]	Time[min]	End time[min]	Area%
1	9.648	10.239	11.621	50.908
2	13.913	15.586	18.577	49.092

4h-chr

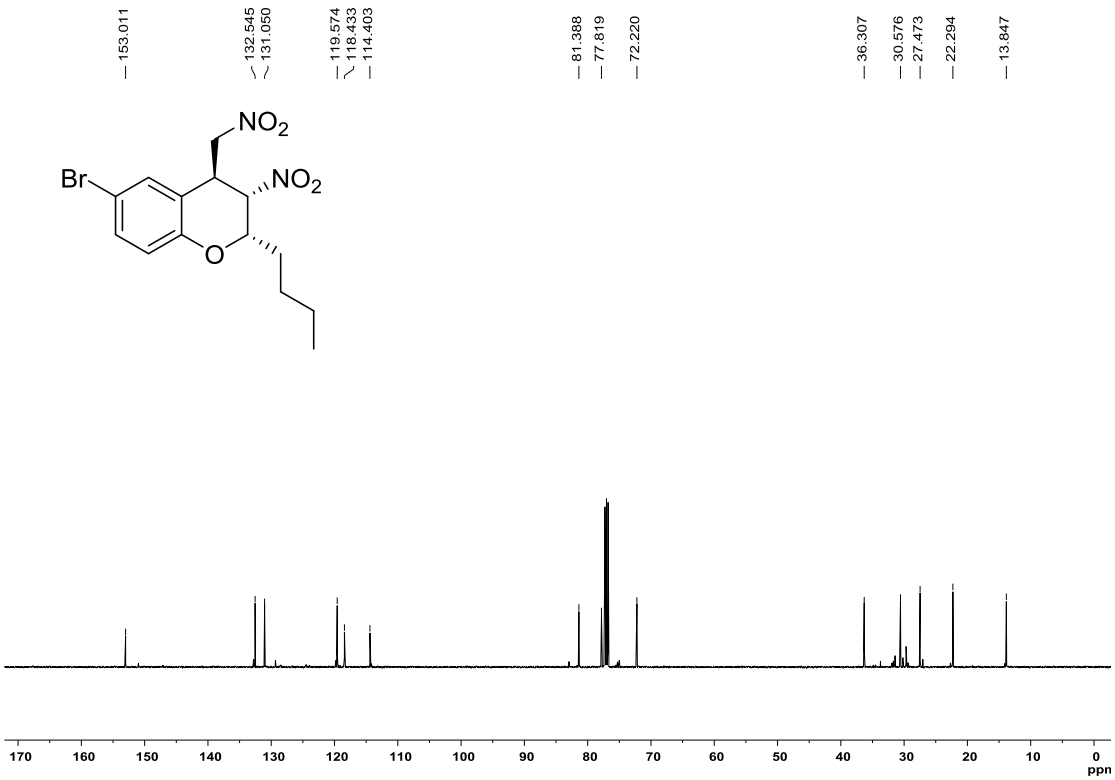


#	Start time[min]	Time[min]	End time[min]	Area%
1	10.835	11.439	14.565	98.894
2	15.986	16.692	17.584	1.106

^{1}H NMR spectrum of 4i

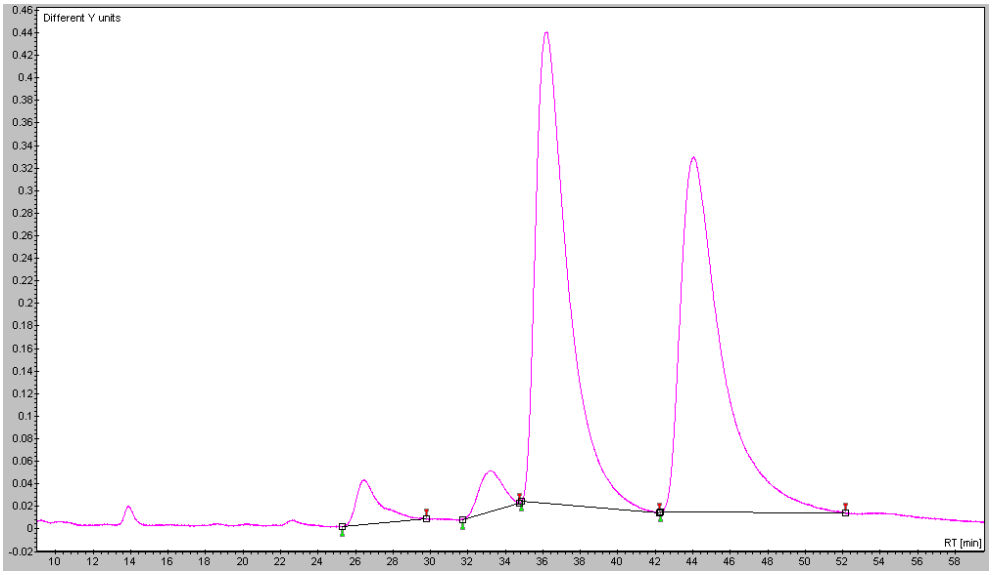


^{13}C NMR spectrum of 4i



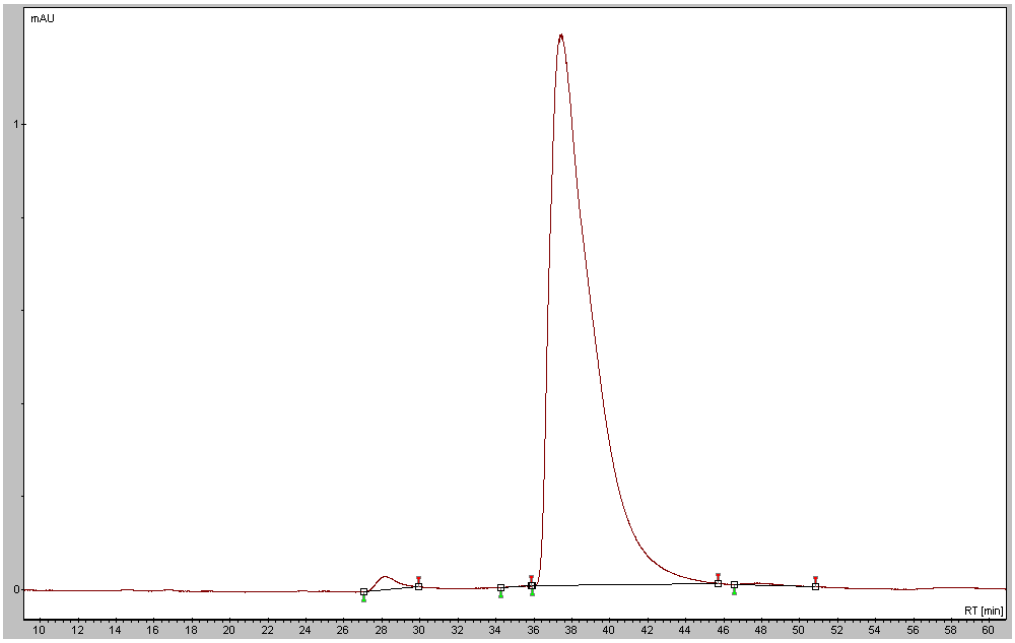
HPLC chromatograms of 4i

4i-rac



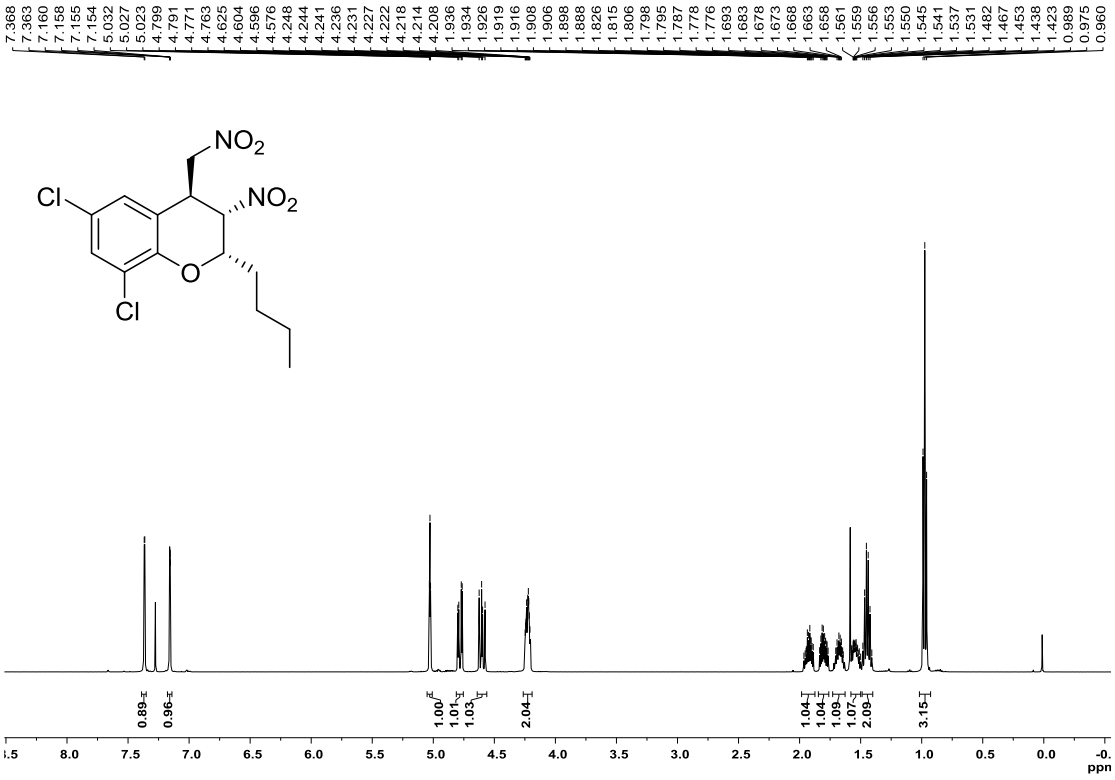
#	Start time[min]	Time[min]	End time[min]	Area%
1	25.289	26.438	29.803	3.283
2	31.720	33.171	34.750	3.004
3	34.873	36.197	42.231	47.990
4	42.293	44.050	52.124	45.723

4i-chr

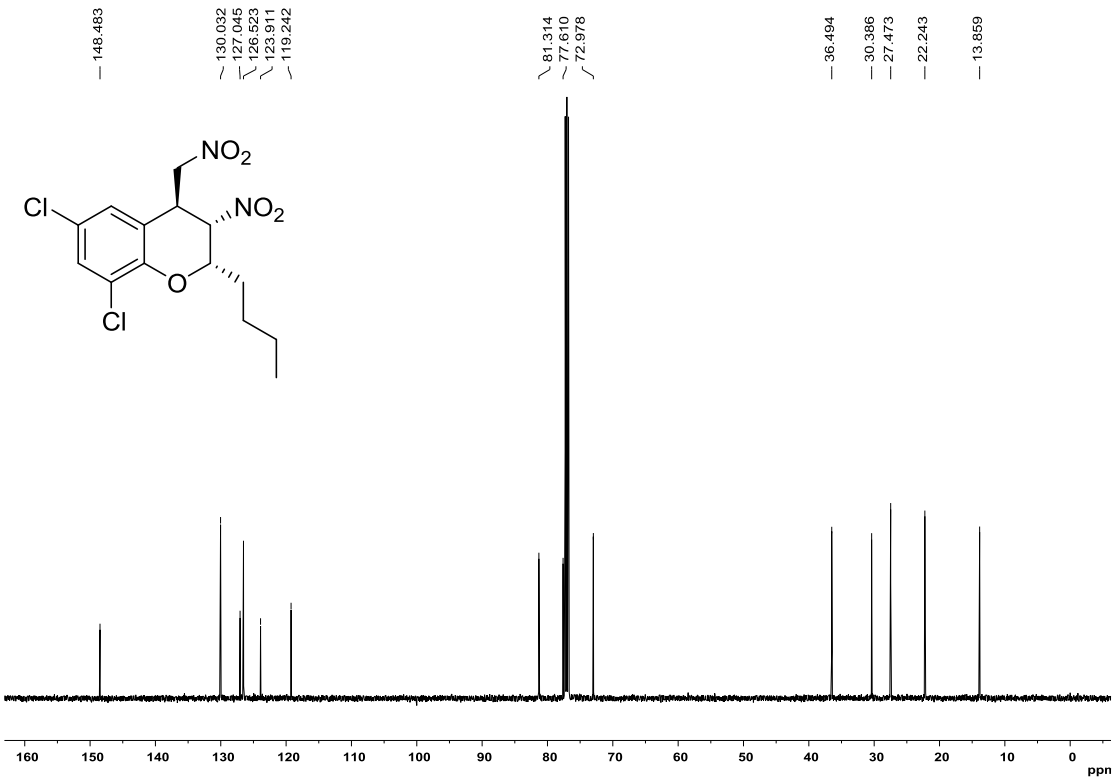


#	Start time[min]	Time[min]	End time[min]	Area%
1	27.067	28.137	29.949	1.160
2	34.238	35.041	35.855	0.028
3	35.925	37.453	45.697	98.526
4	46.541	47.810	50.829	0.285

^{1}H NMR spectrum of 4j

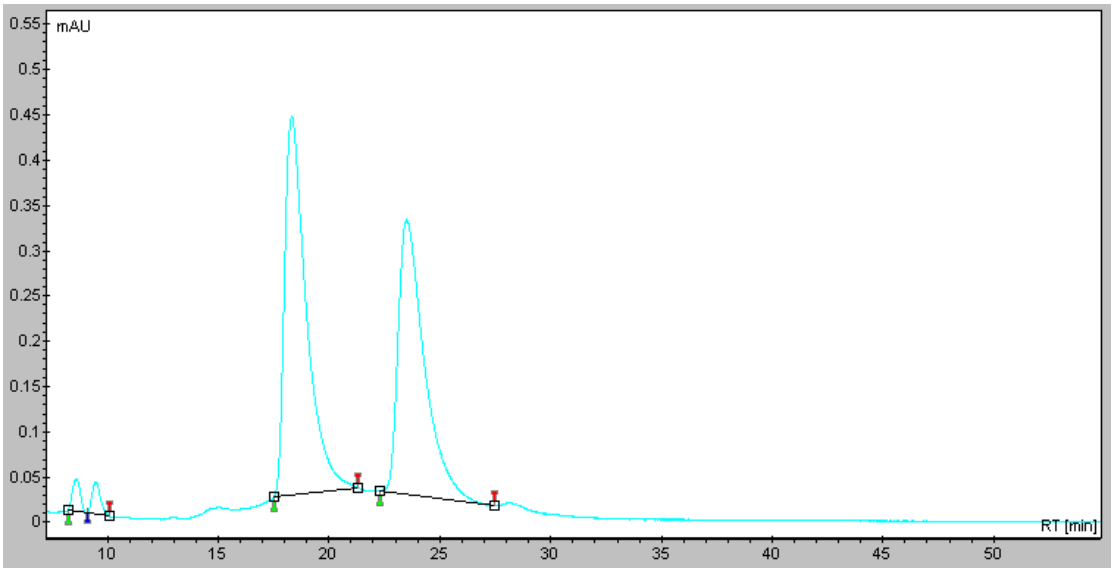


^{13}C NMR spectrum of 4j



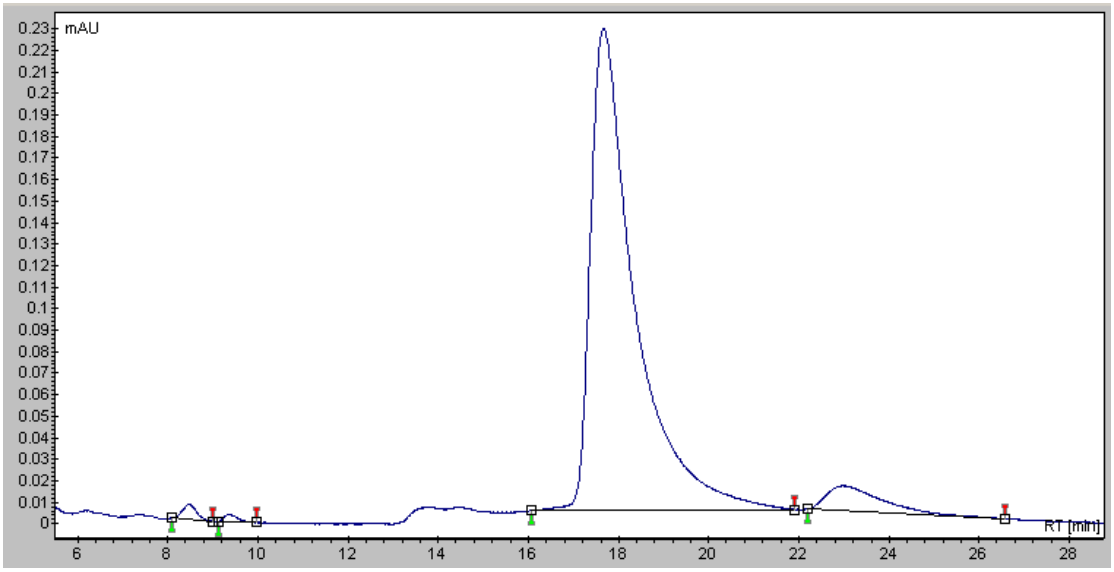
HPLC chromatograms of 4j

4j-rac



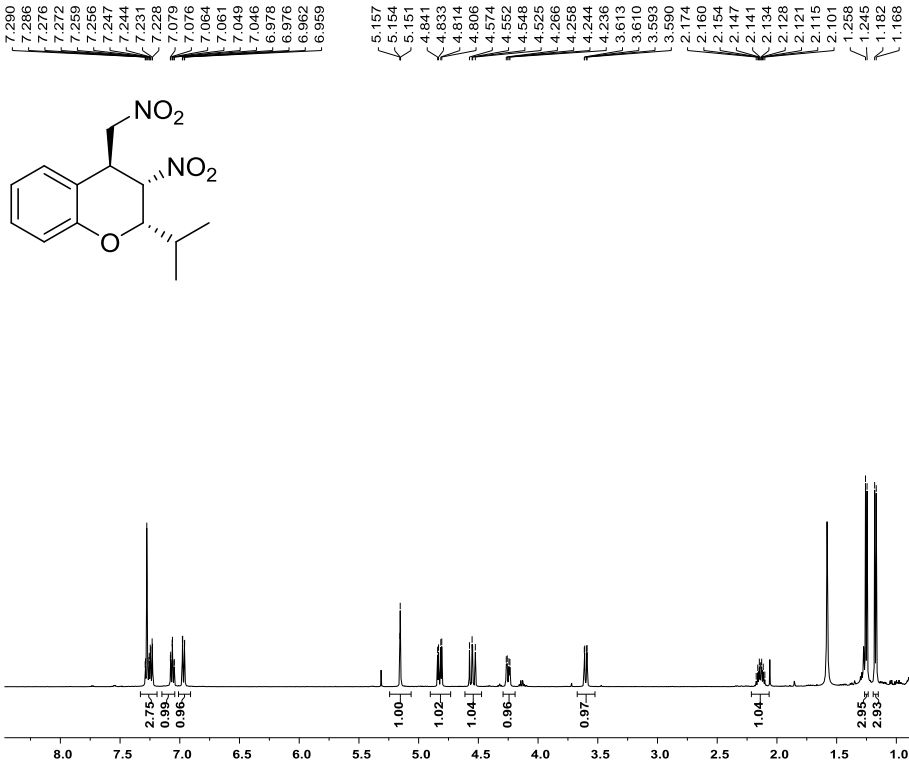
#	Start time[min]	Time[min]	End time[min]	Area%
1	8.232	8.599	9.12	1.55
2	9.12	9.479	10.088	1.723
3	17.52	18.319	21.3	48.964
4	22.295	23.505	27.467	47.763

4j-chr

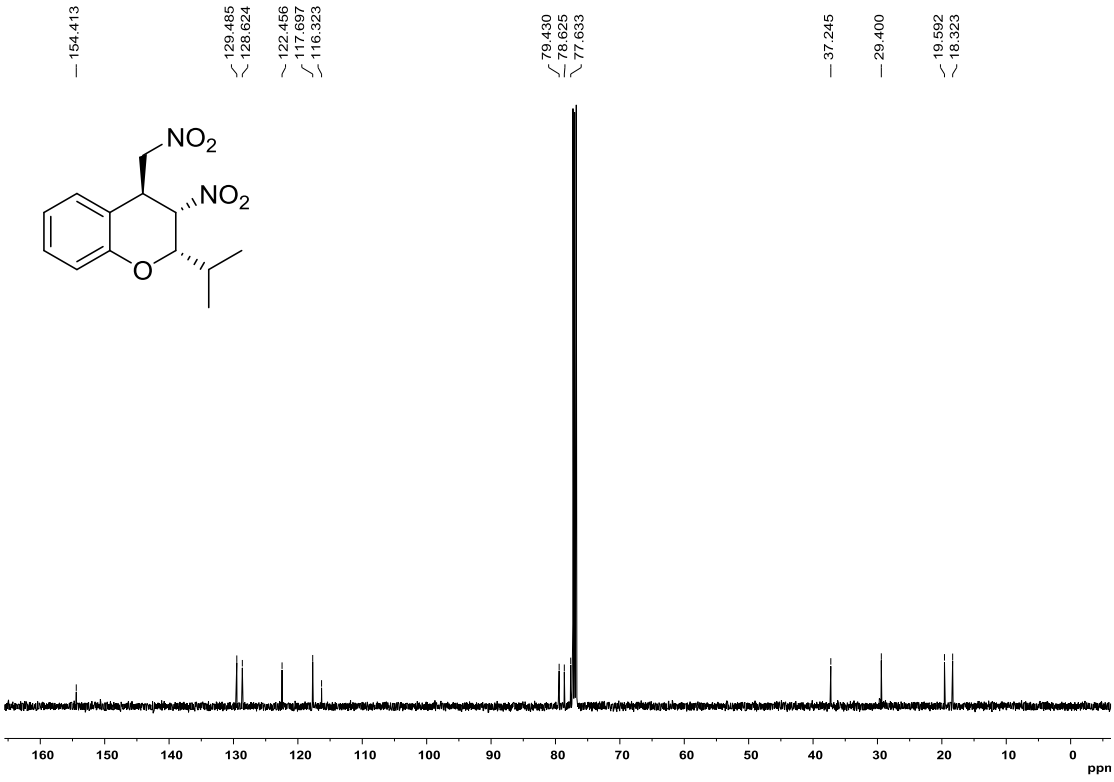


#	Start time[min]	Time[min]	End time[min]	Area%
1	8.074	8.466	8.997	0.951
2	9.118	9.359	9.961	0.416
3	16.067	17.665	21.891	92.623
4	22.212	23.012	26.591	6.01

^{1}H NMR spectrum of 4k

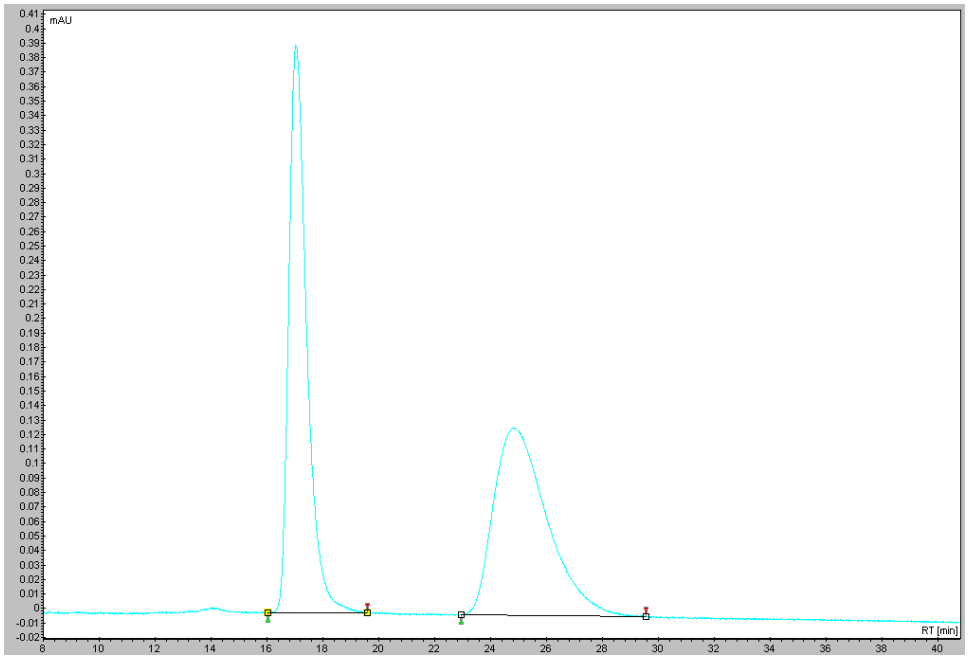


^{13}C NMR spectrum of 4k



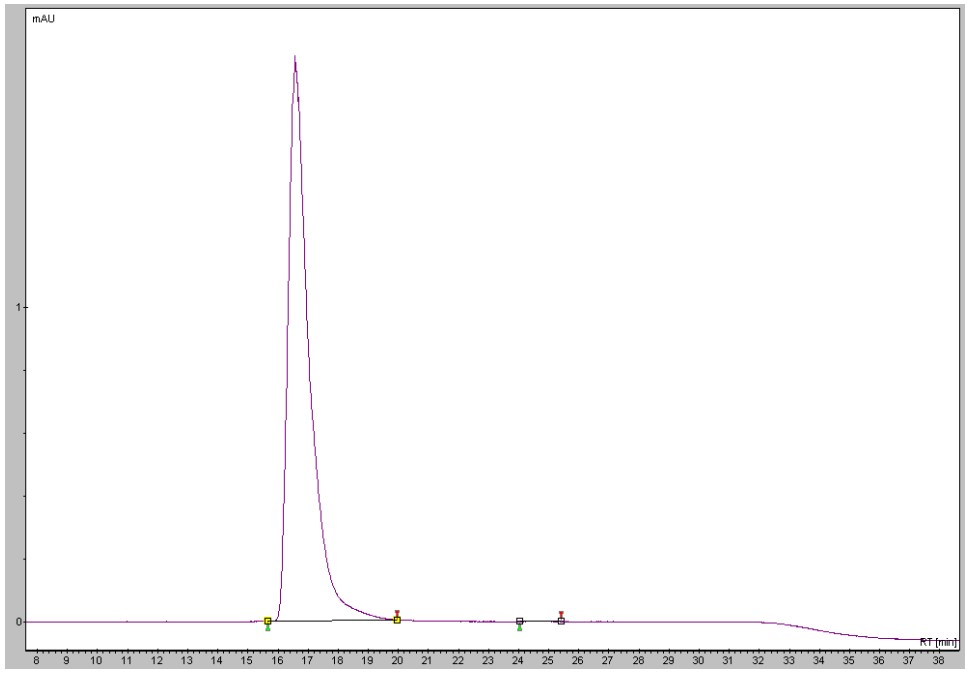
HPLC chromatograms of 4k

4k-rac



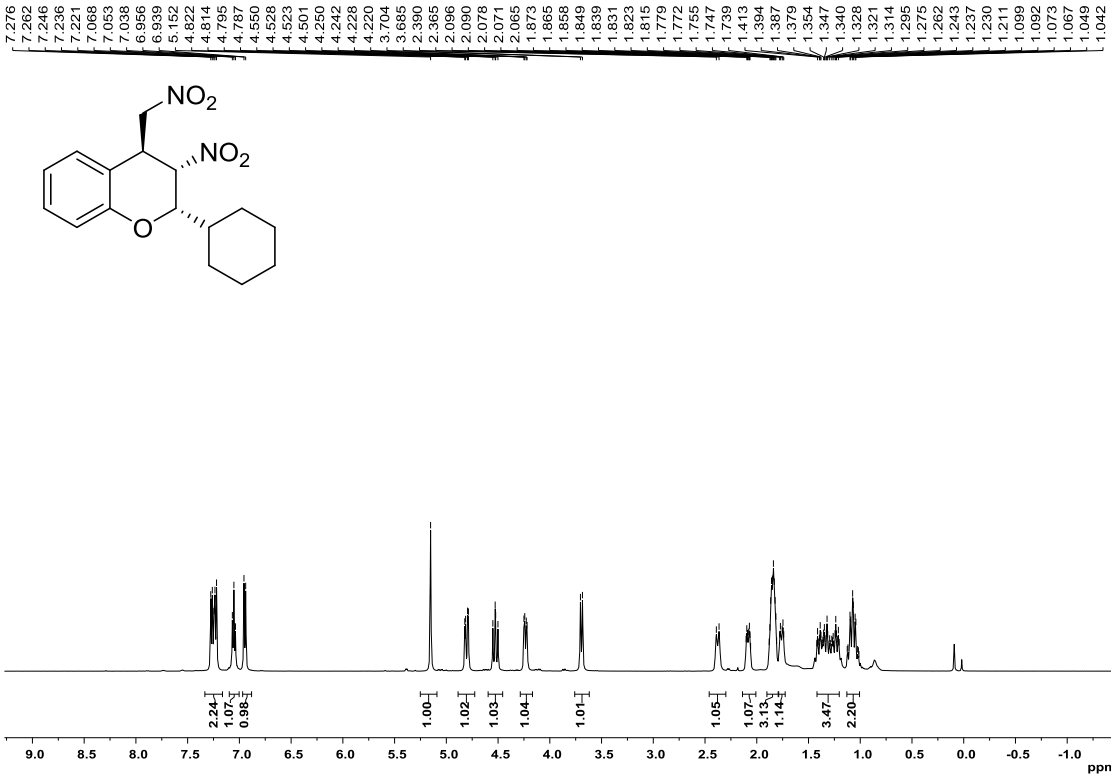
#	Start time[min]	Time[min]	End time[min]	Area%
1	16.012	17.025	19.588	50.477
2	22.951	24.838	29.570	49.523

4k-chr

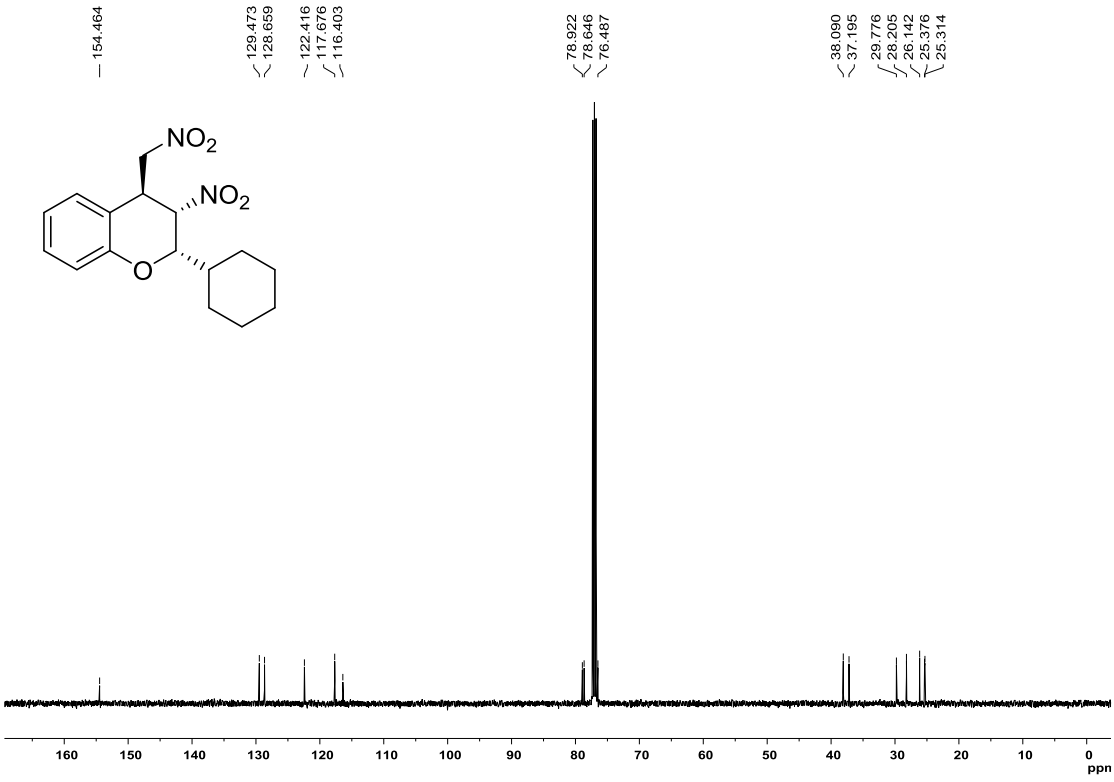


#	Start time[min]	Time[min]	End time[min]	Area%
1	15.653	16.572	19.955	99.963
2	24.050	24.612	25.398	0.037

^{1}H NMR spectrum of 4l

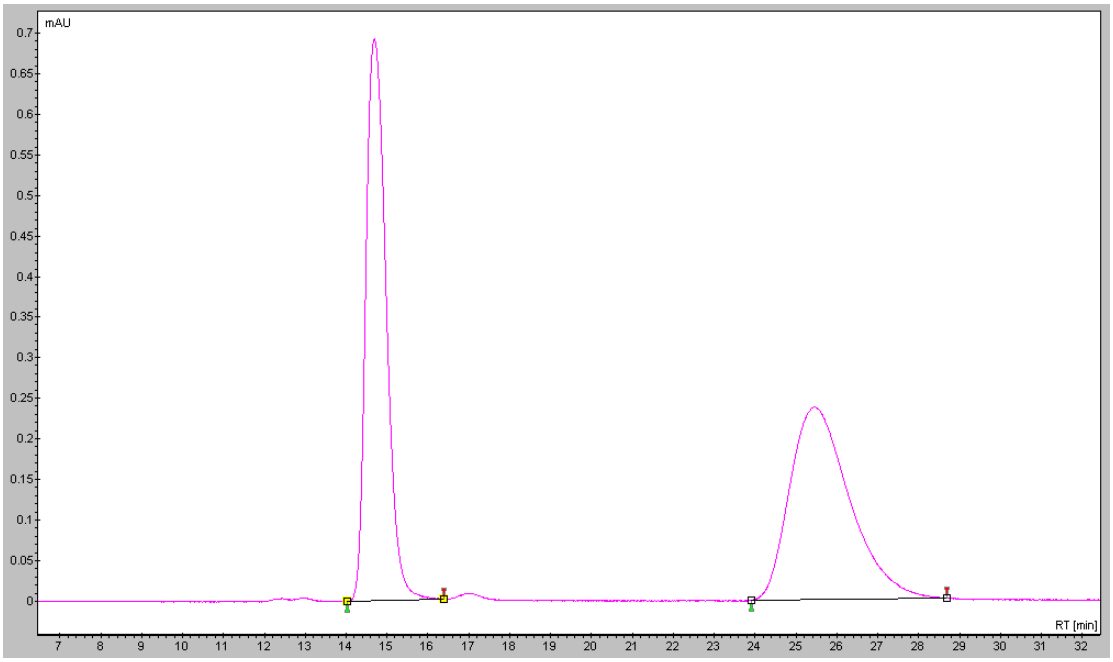


^{13}C NMR spectrum of 4l



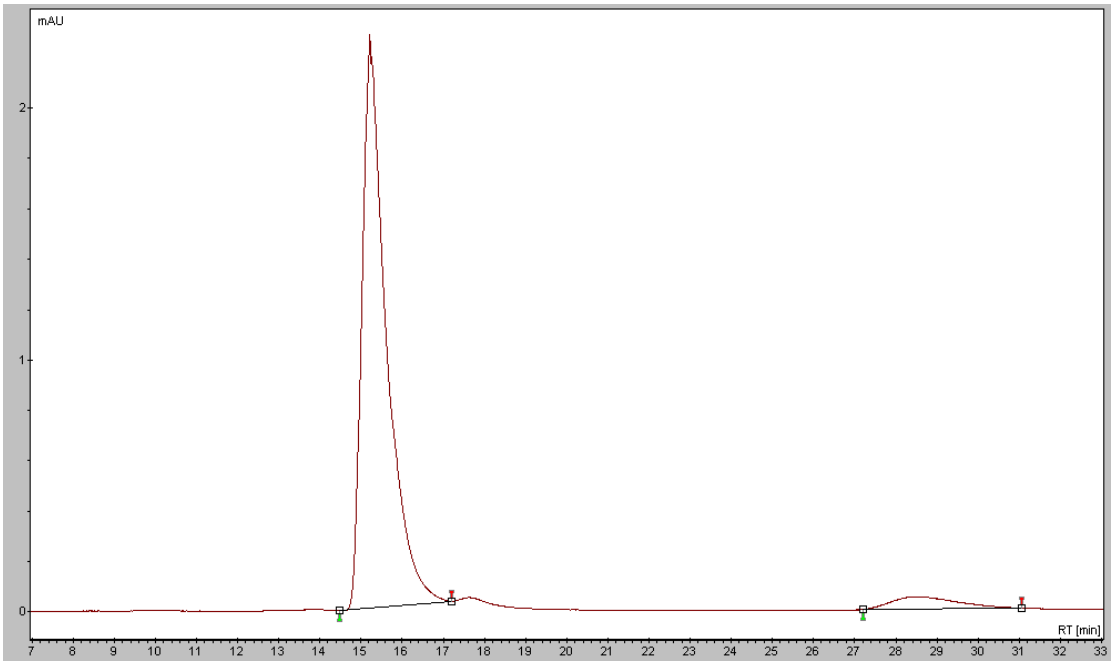
HPLC chromatograms of 4l

4l-rac



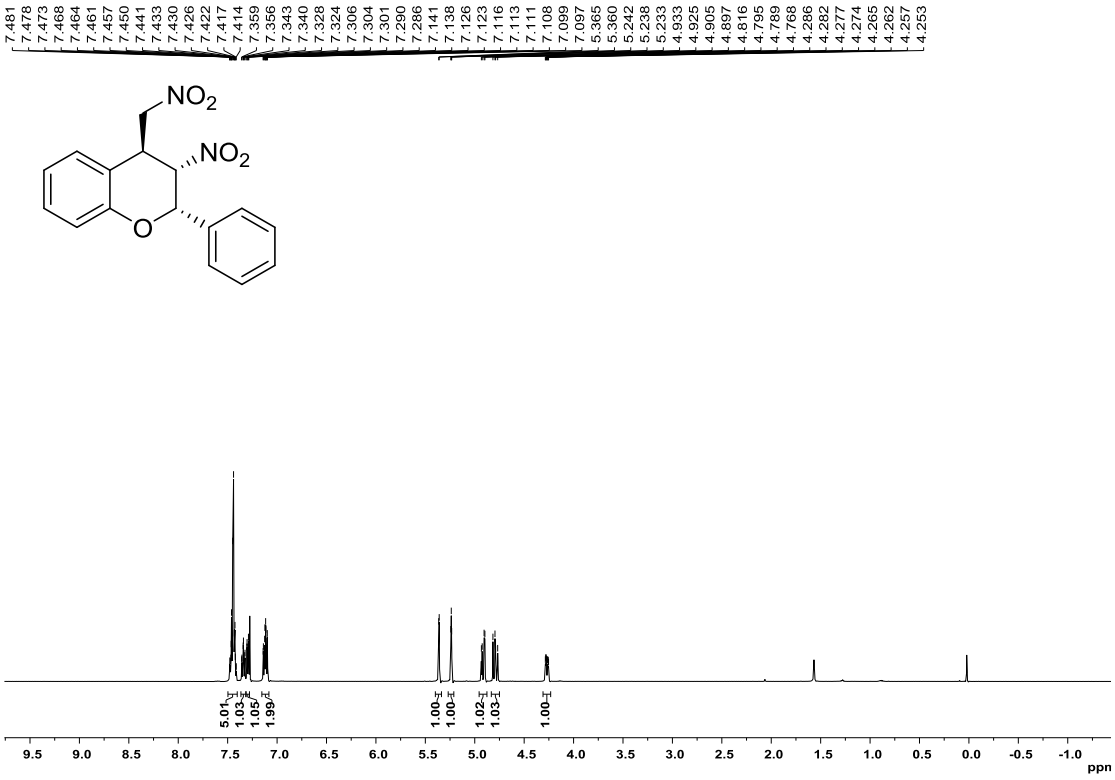
#	Start time[min]	Time[min]	End time[min]	Area%
1	14.026	14.692	16.294	49.938
2	24.004	25.451	28.400	50.062

4l-chr

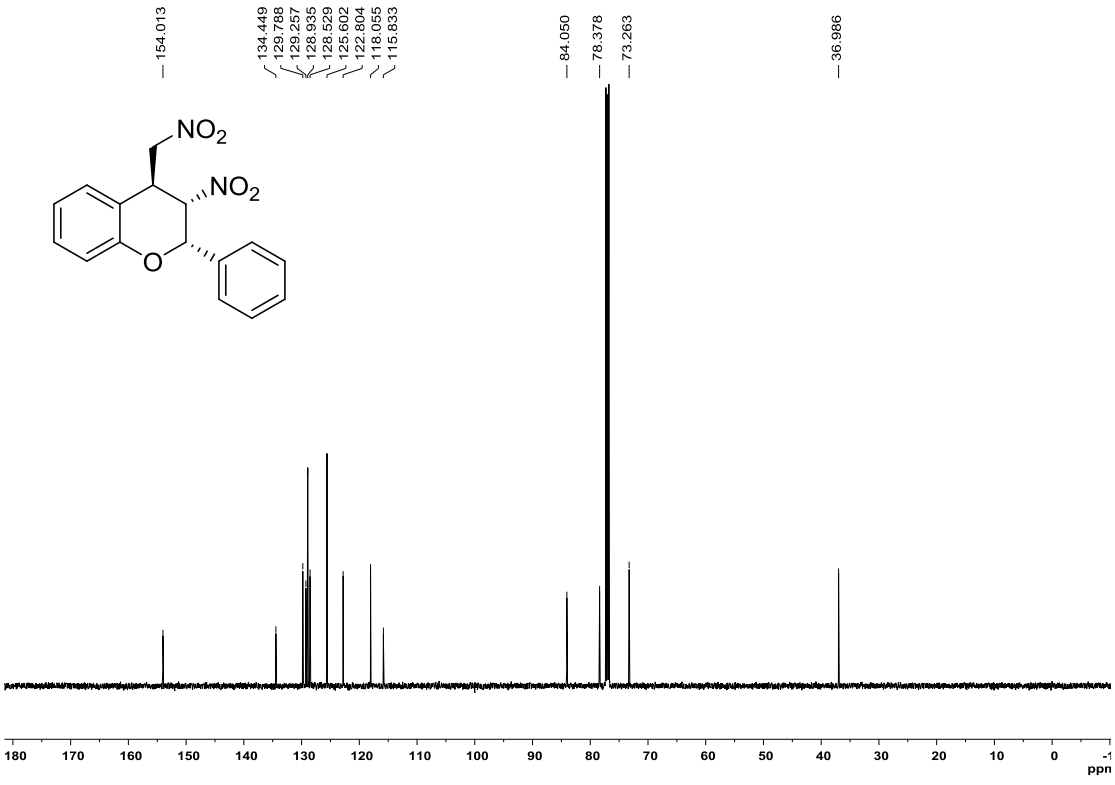


#	Start time[min]	Time[min]	End time[min]	Area%
1	14.487	15.212	17.207	94.653
2	27.248	28.478	30.962	5.347

^{1}H NMR spectrum of 4m

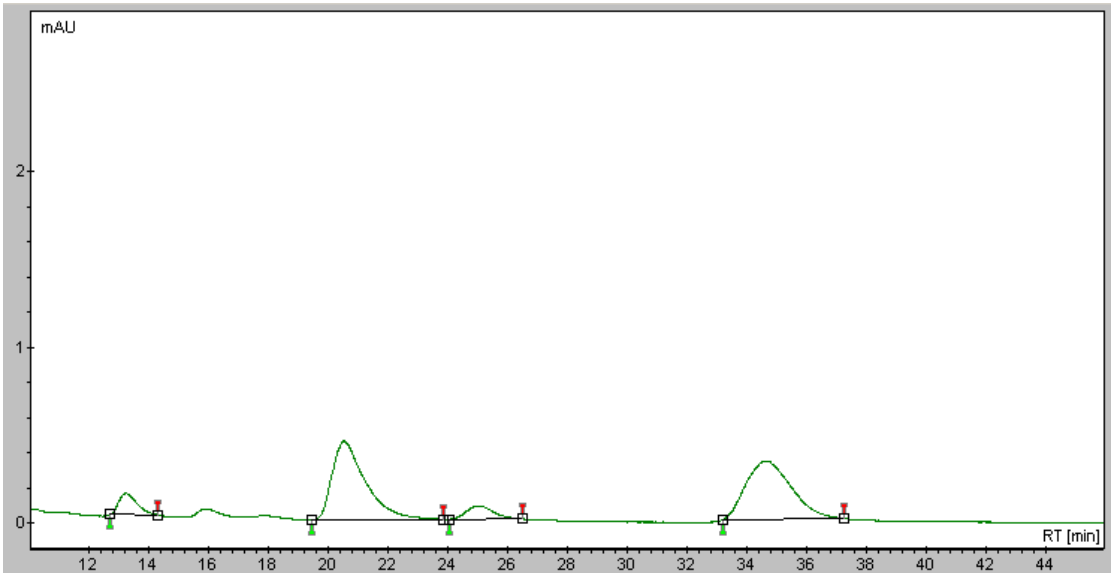


^{13}C NMR spectrum of 4m



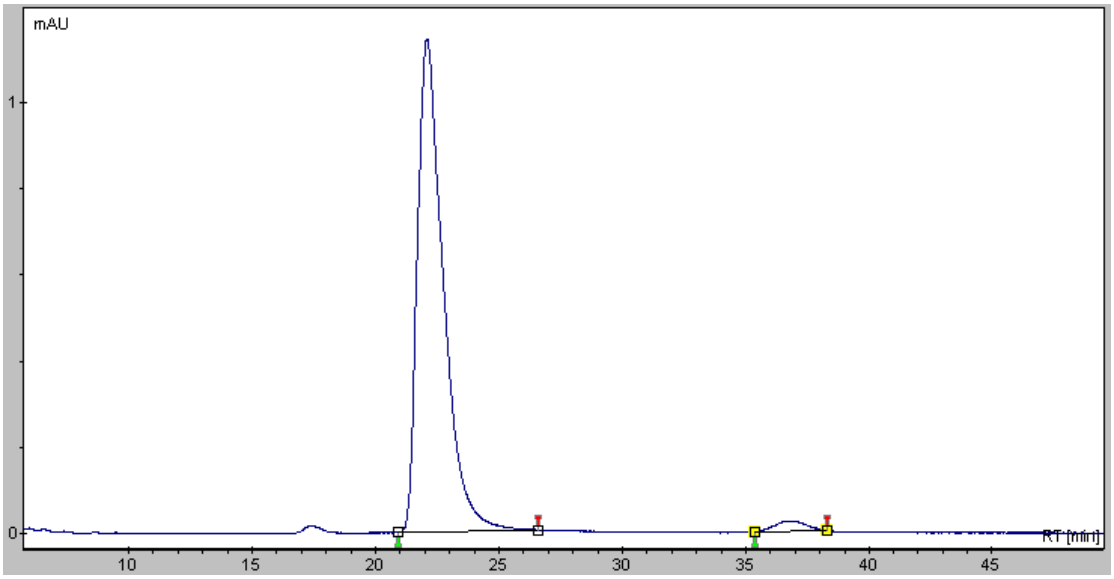
HPLC chromatograms of 4m

4m-rac



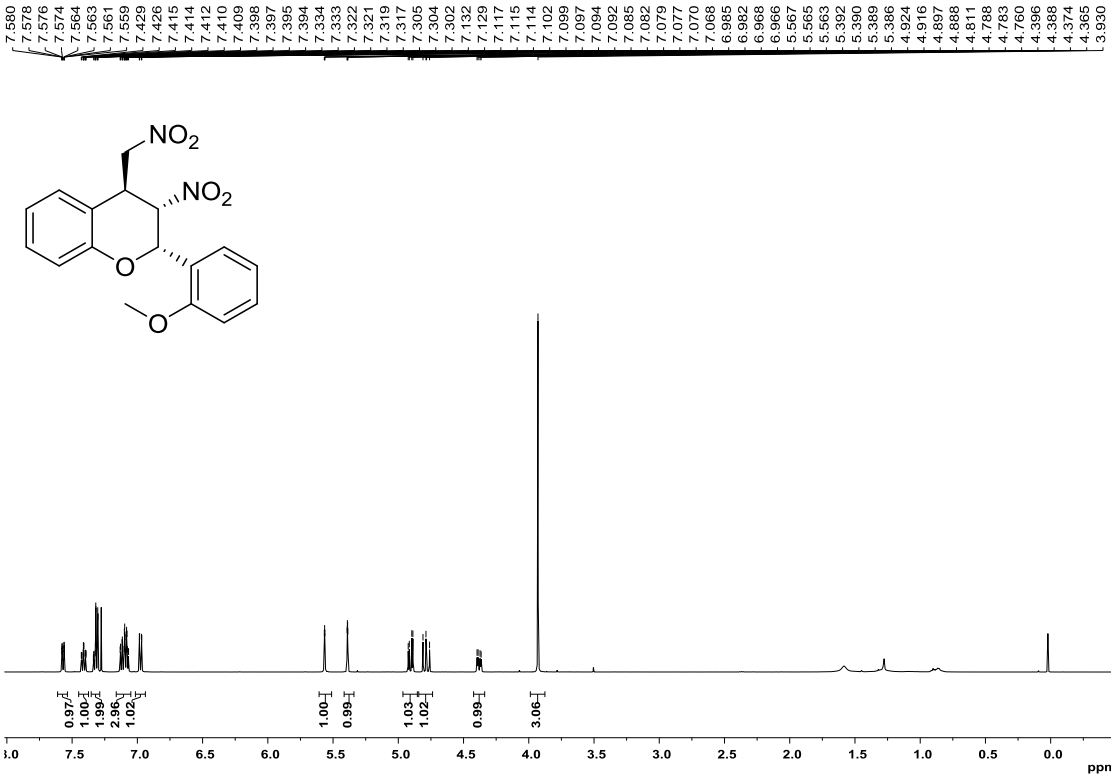
#	Start time[min]	Time[min]	End time[min]	Area%
1	12.731	13.252	14.33	6.434
2	19.448	20.532	23.862	43.407
3	24.054	25.038	26.485	6.012
4	33.203	34.637	37.233	44.148

4m-chr

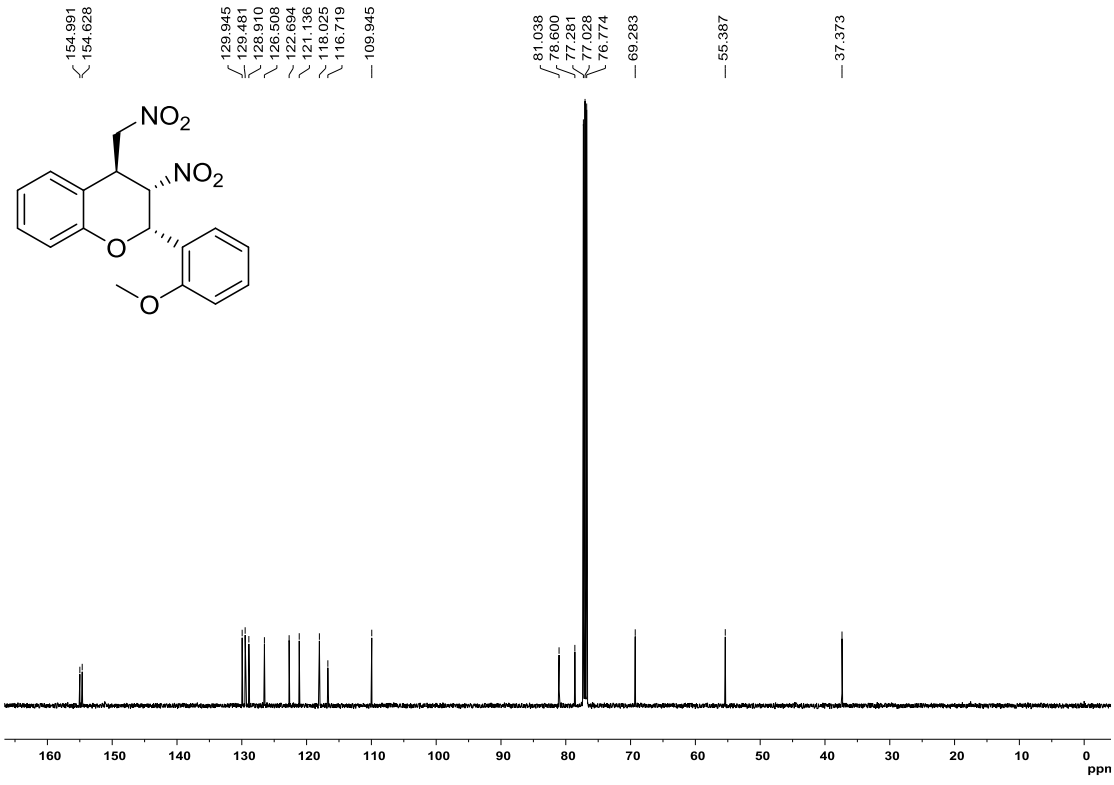


#	Start time[min]	Time[min]	End time[min]	Area%
1	20.892	22.052	25.478	96.775
2	34.929	36.797	39.648	3.225

^{1}H NMR spectrum of 4n

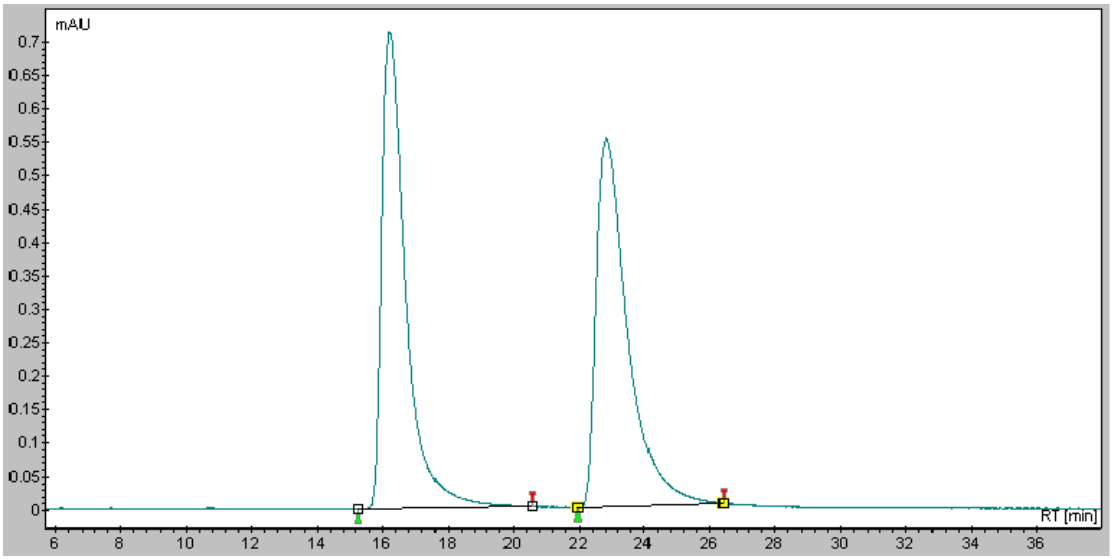


^{13}C NMR spectrum of 4n



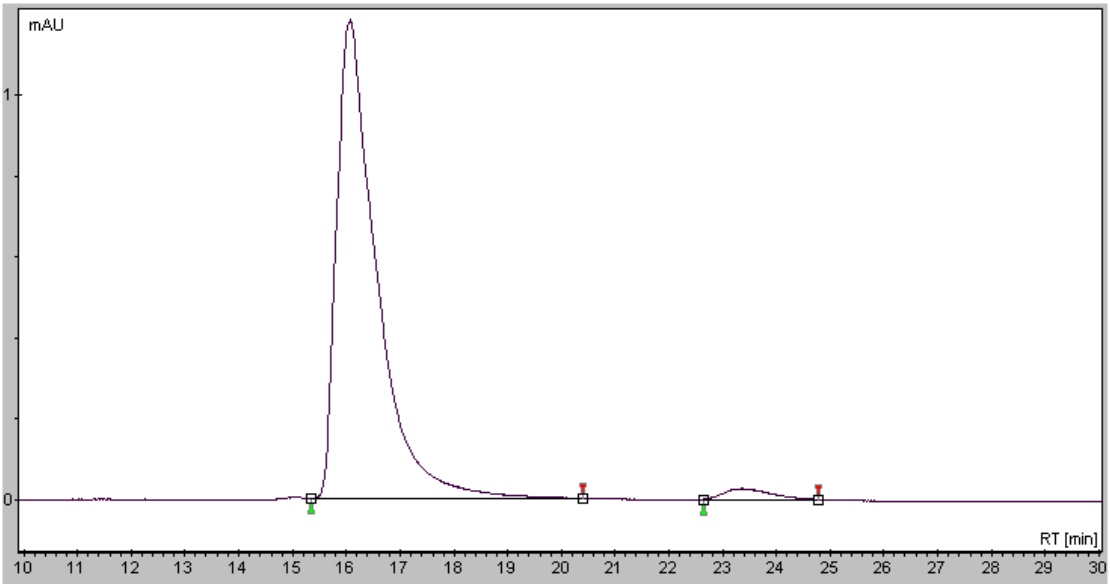
HPLC chromatograms of 4n

4n-rac



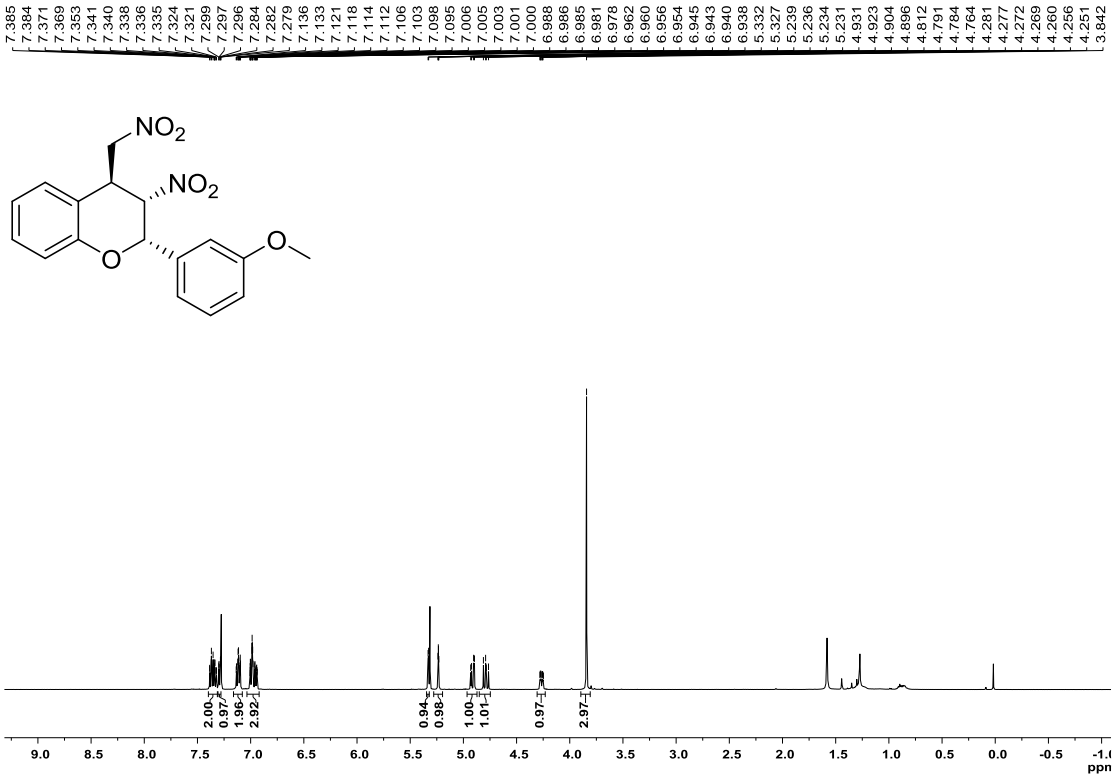
#	Start time[min]	Time[min]	End time[min]	Area%
1	15.280	16.225	20.578	49.807
2	21.945	22.825	26.425	50.193

4n-chr

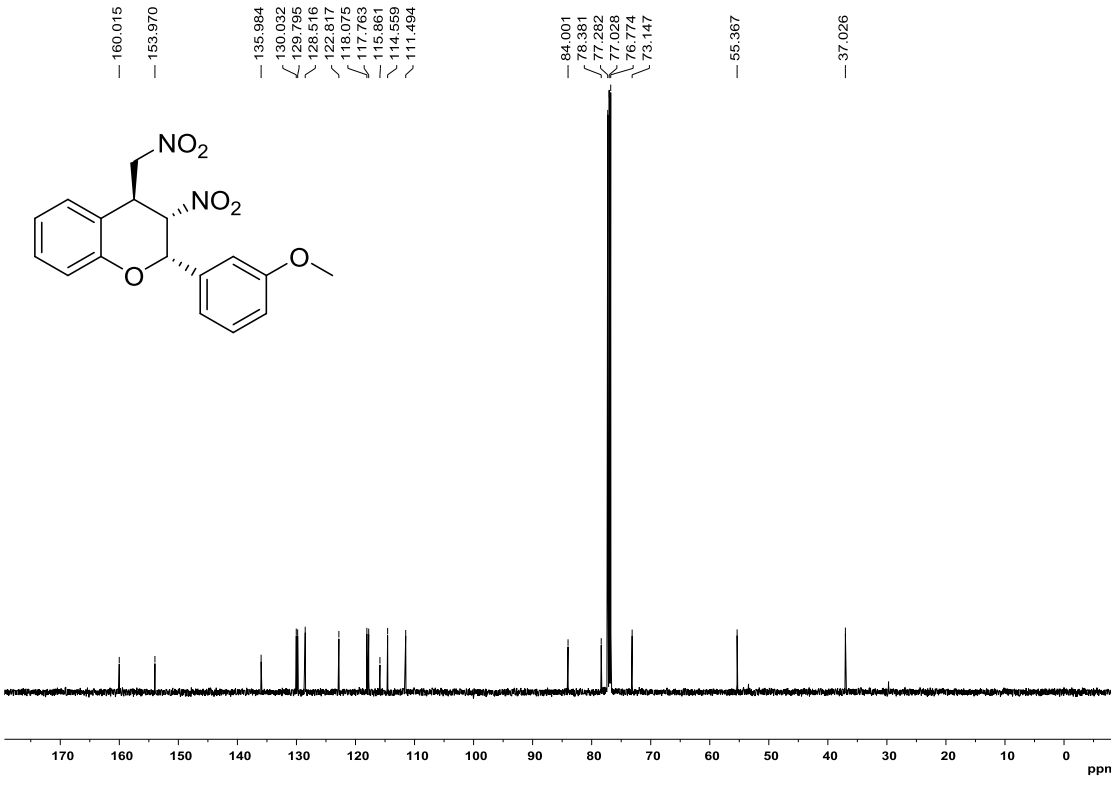


#	Start time[min]	Time[min]	End time[min]	Area%
1	15.345	16.079	20.339	97.470
2	22.646	23.358	24.780	2.530

^{1}H NMR spectrum of 4o

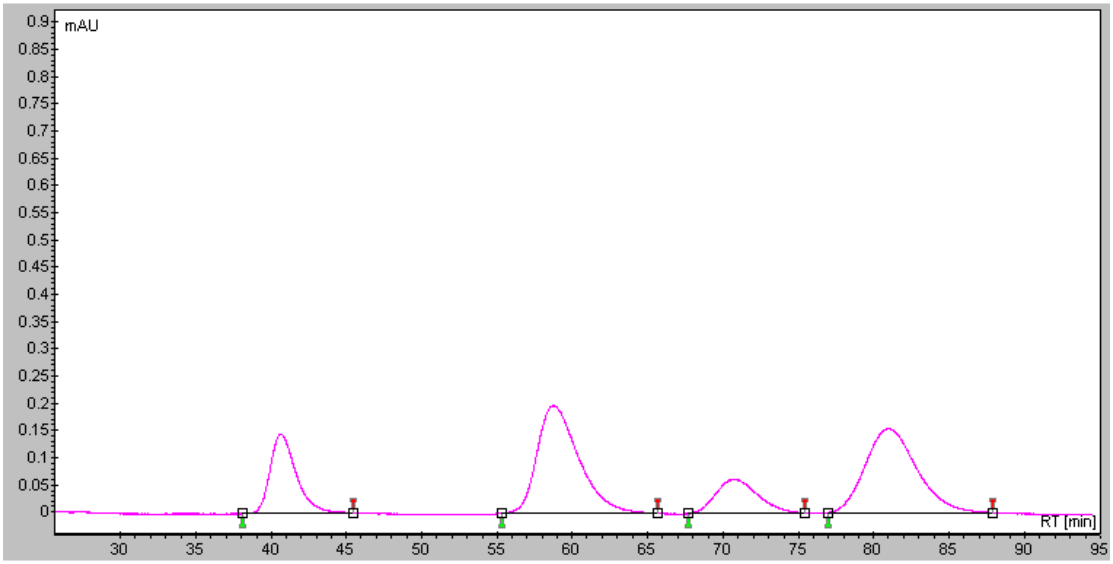


^{13}C NMR spectrum of 4o



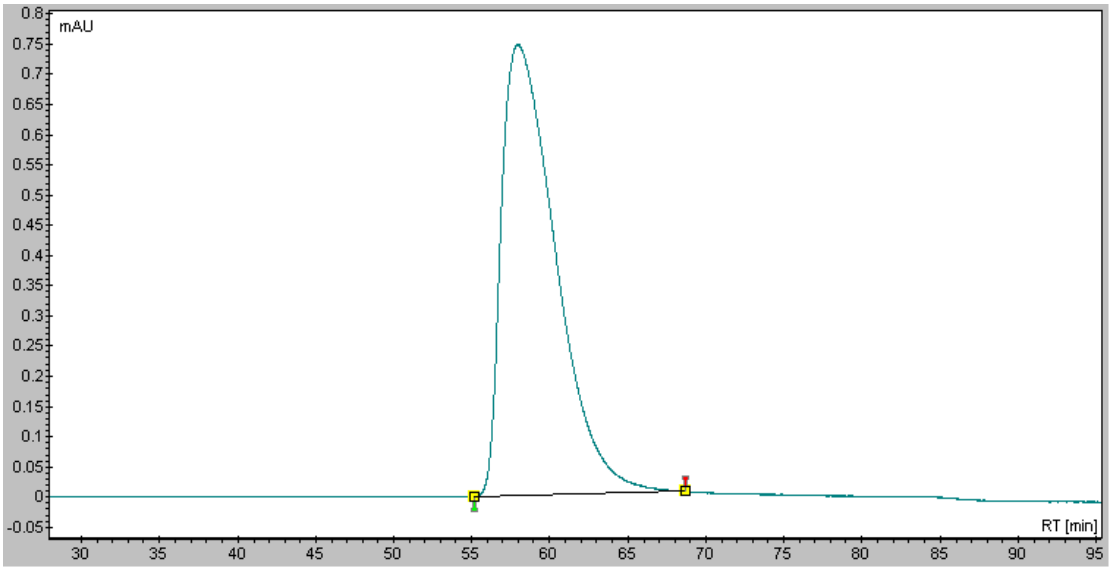
HPLC chromatograms of 4o

4o-rac



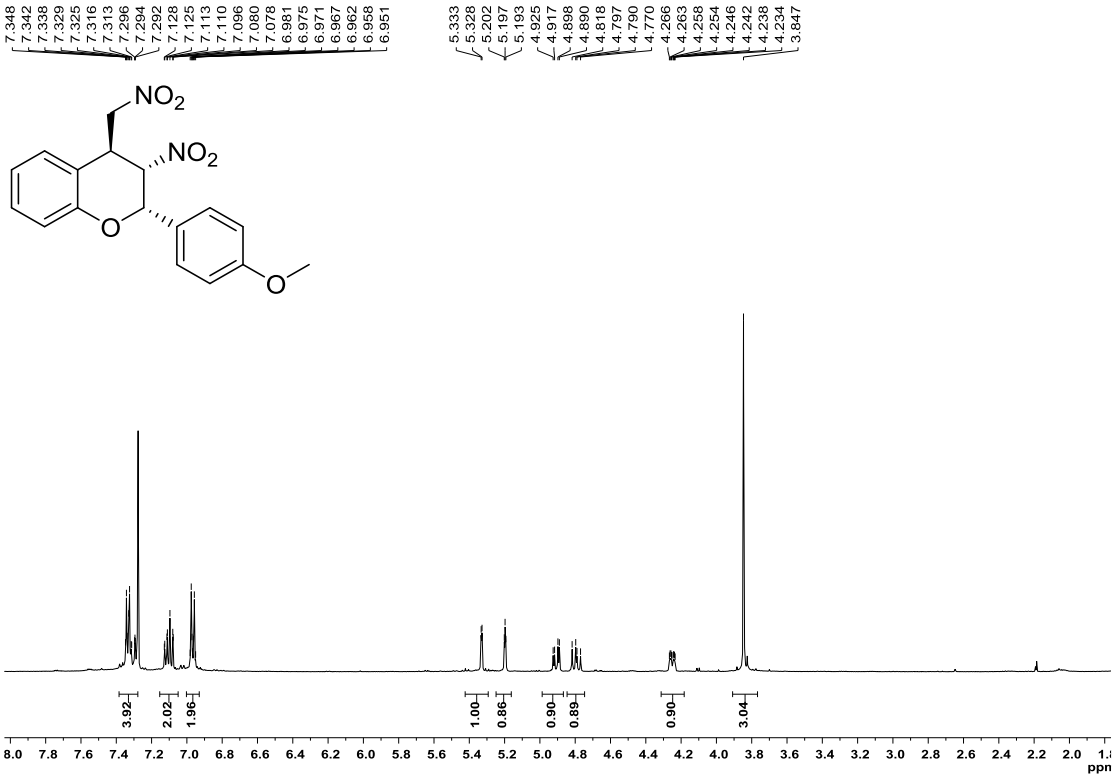
#	Start time[min]	Time[min]	End time[min]	Area%
1	38.103	40.625	45.451	14.838
2	55.312	58.739	65.657	36.447
3	67.687	70.735	75.421	13.611
4	76.968	80.984	87.893	35.104

4o-chr

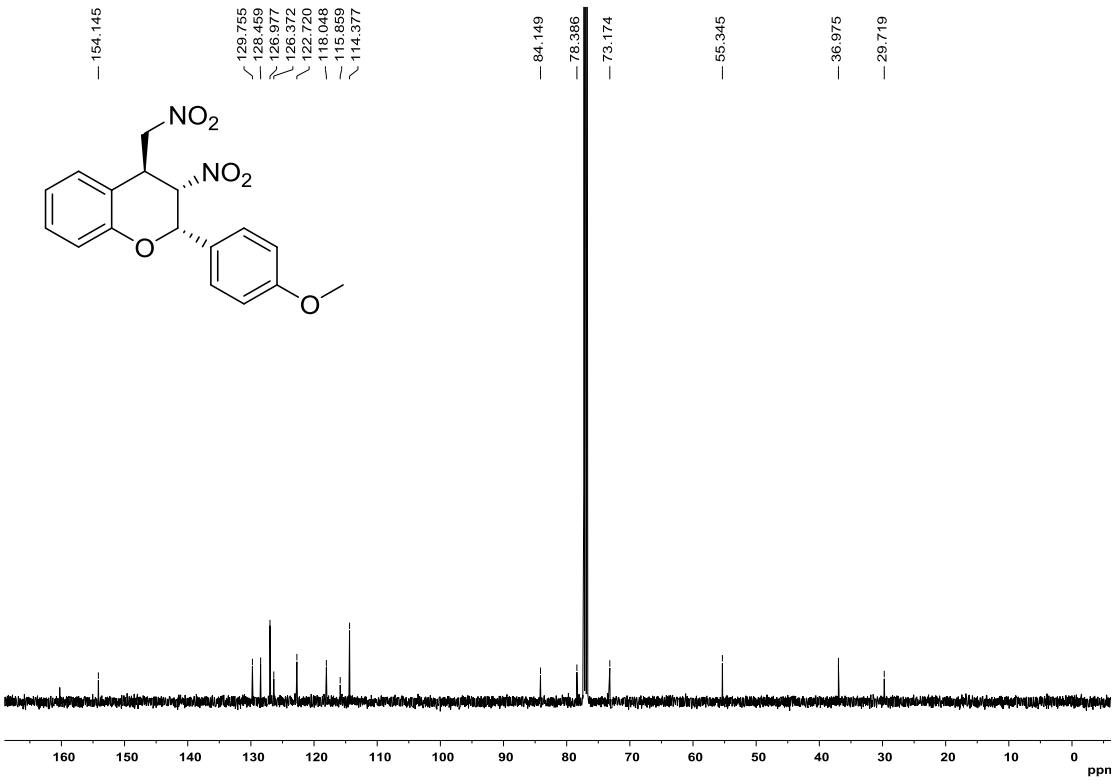


#	Start time[min]	Time[min]	End time[min]	Area%
1	55.164	57.966	68.693	100
2				

^{1}H NMR spectrum of 4p

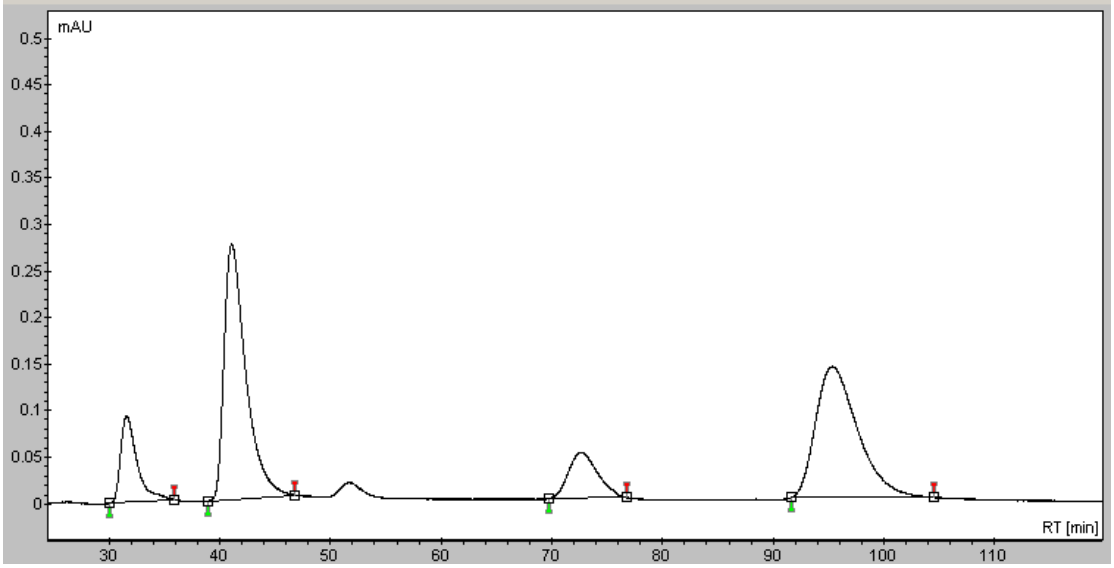


^{13}C NMR spectrum of 4p



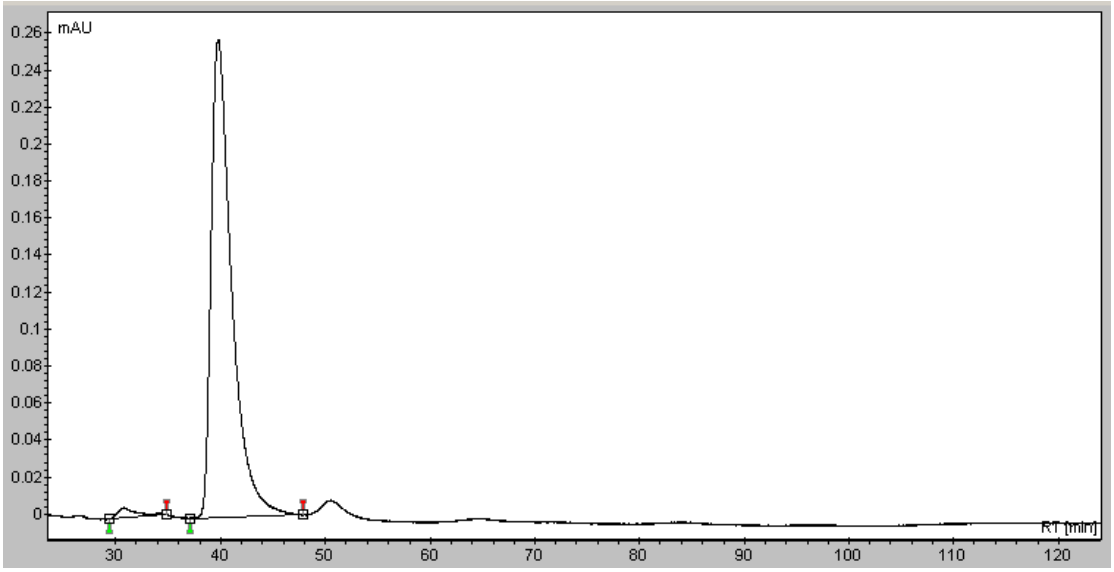
HPLC chromatograms of 4p

4p-rac



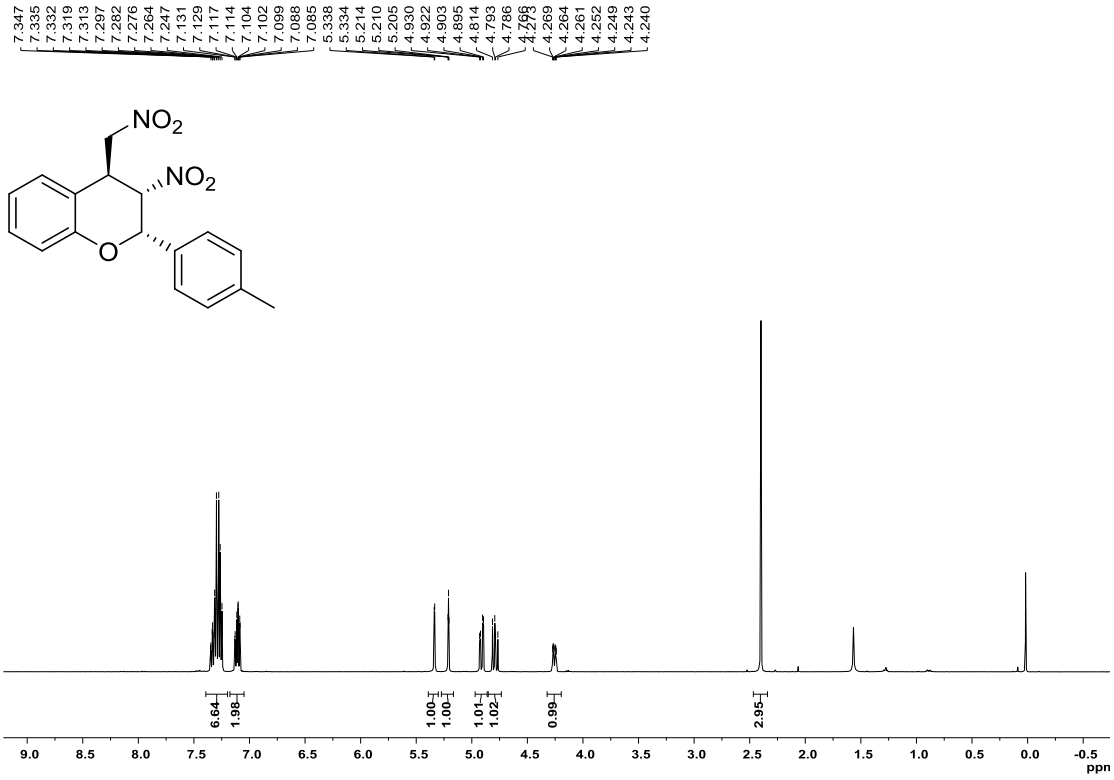
#	Start time[min]	Time[min]	End time[min]	Area%
1	29.907	31.562	35.813	10.000
2	39.081	41.092	46.997	38.227
3	69.868	72.641	77.407	9.679
4	91.356	95.339	104.173	37.983

4p-chr

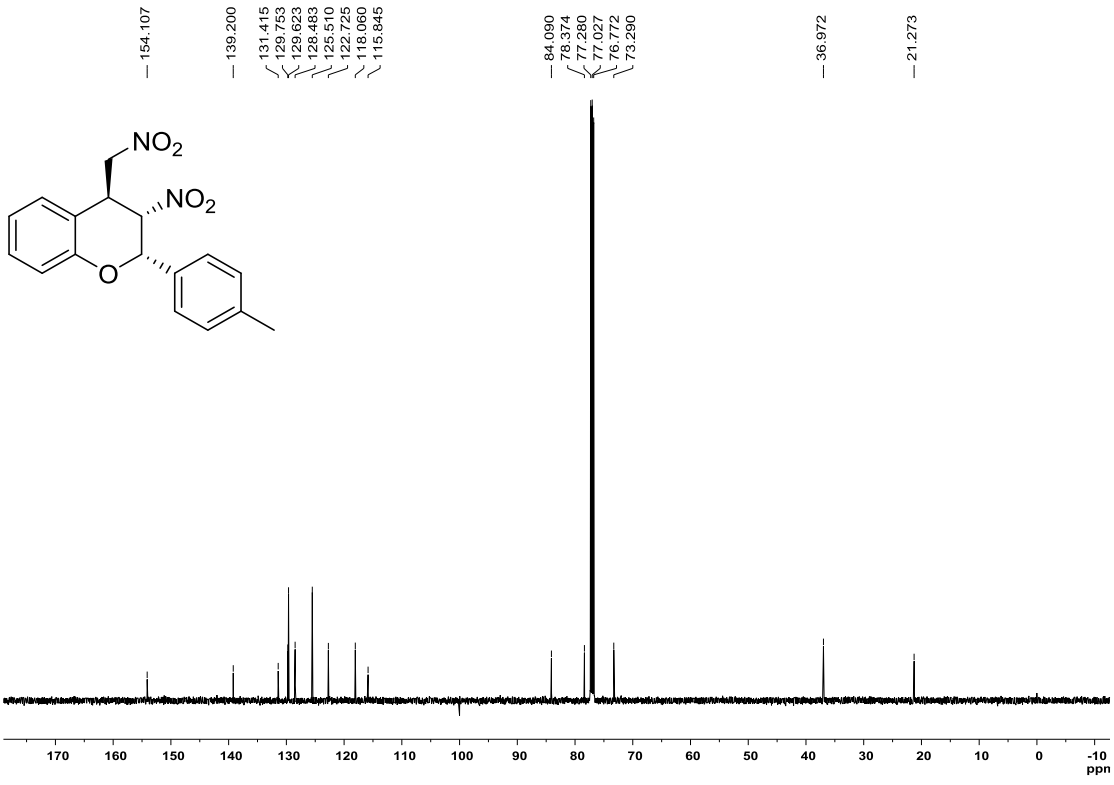


#	Start time[min]	Time[min]	End time[min]	Area%
1	29.308	30.696	32.956	1.357
2	37.046	39.772	47.659	98.643

^{1}H NMR spectrum of 4q

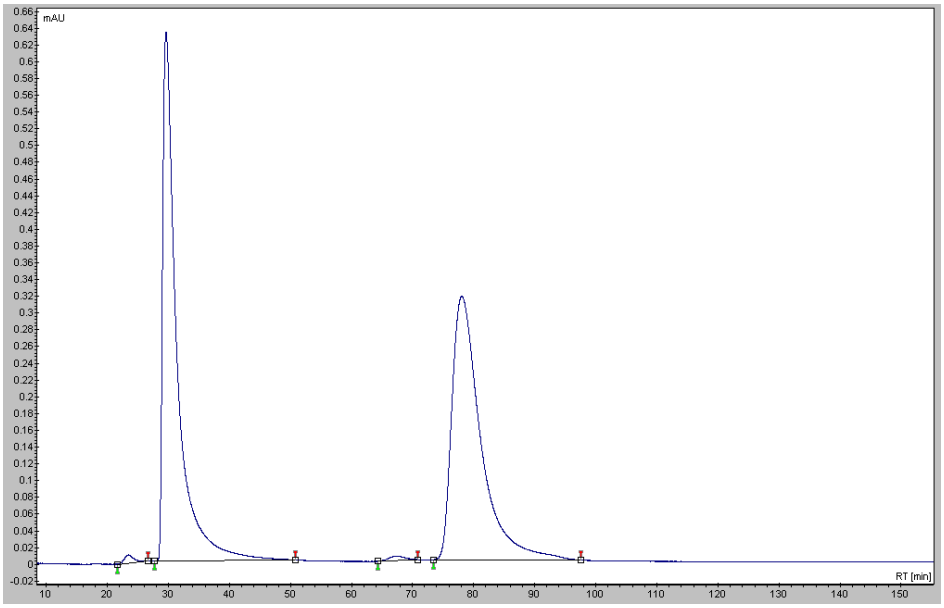


^{13}C NMR spectrum of 4q



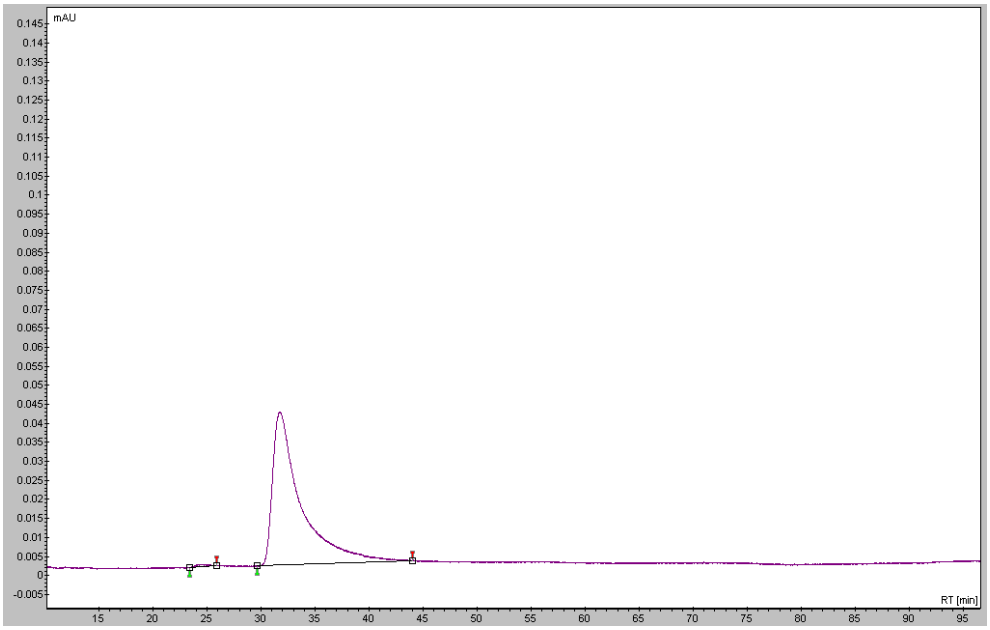
HPLC chromatograms of 4q

4q-rac



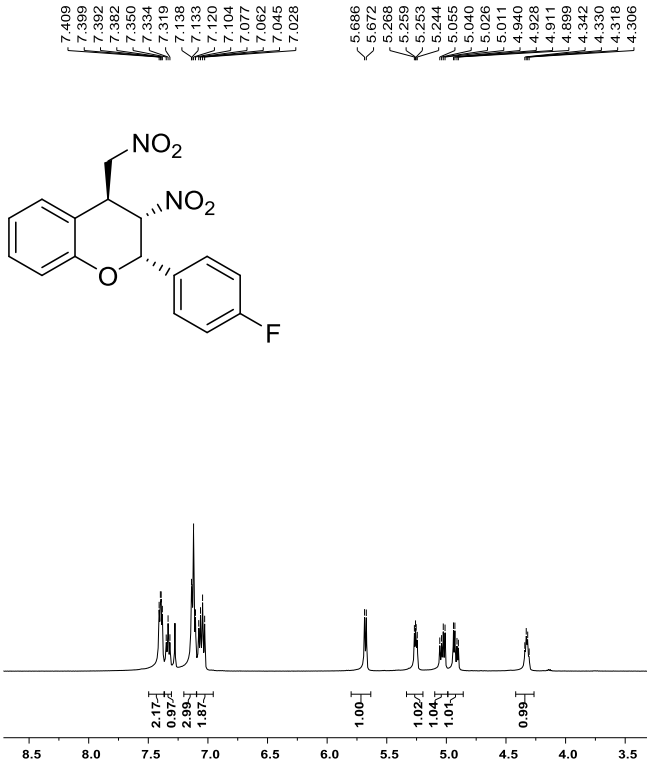
#	Start time[min]	Time[min]	End time[min]	Area%
1	21.675	23.418	26.663	0.508
2	27.814	29.639	50.832	49.165
3	64.289	67.271	70.900	0.478
4	73.466	78.101	97.635	49.849

4q-chr

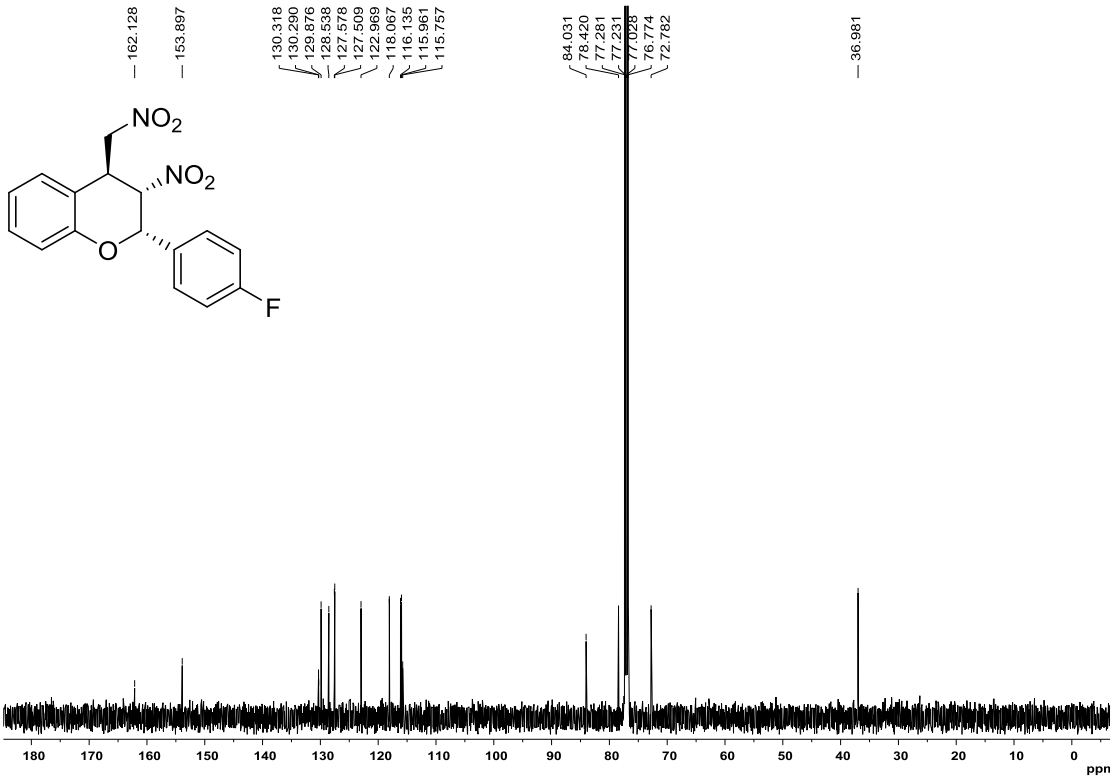


#	Start time[min]	Time[min]	End time[min]	Area%
1	23.421	24.325	25.881	0.736
2	29.628	31.749	44.032	99.264

^{1}H NMR spectrum of 4r

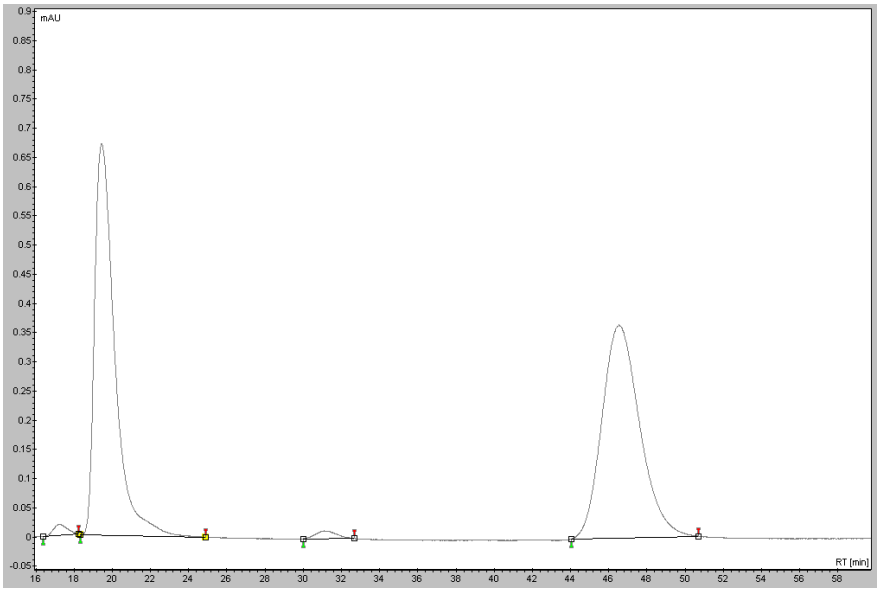


^{13}C NMR Spectra of 4r



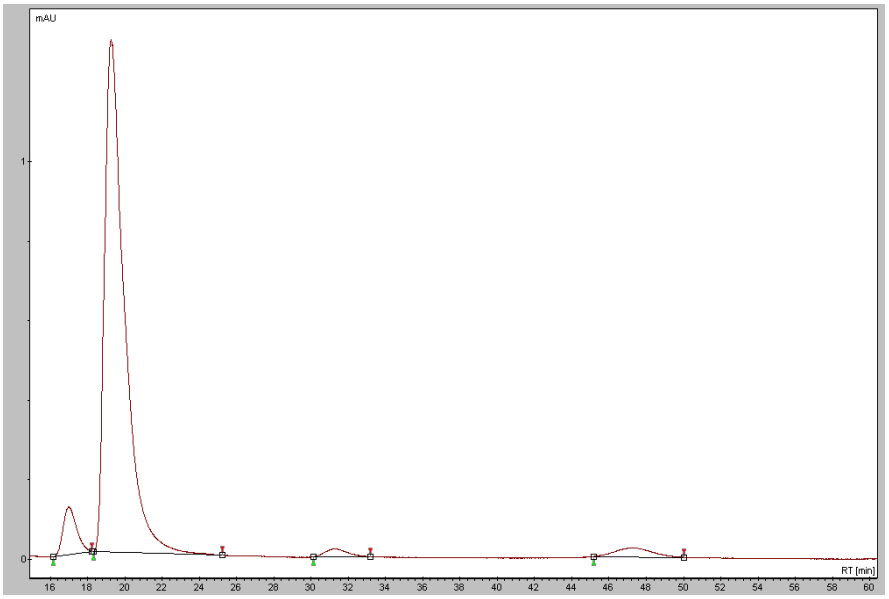
HPLC chromatograms of 4r

4r-rac



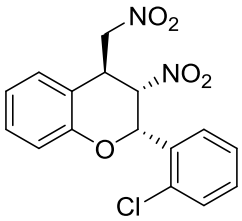
#	Start time[min]	Time[min]	End time[min]	Area%
1	16.377	17.247	18.246	0.955
2	18.321	19.446	24.902	48.391
3	29.987	31.149	32.679	1.029
4	44.045	46.543	50.701	49.626

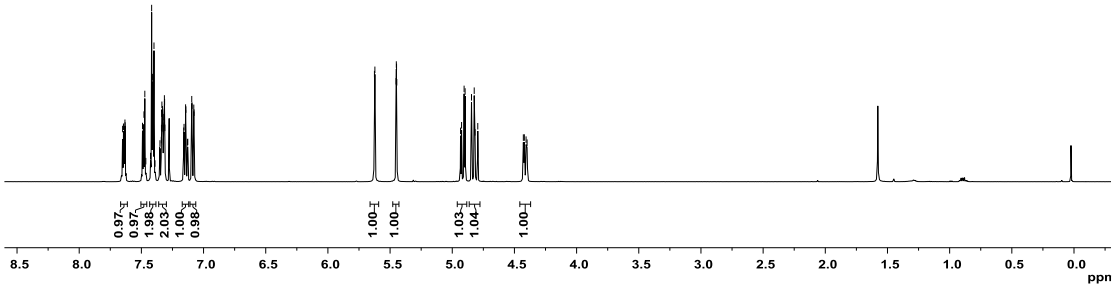
4r-chr



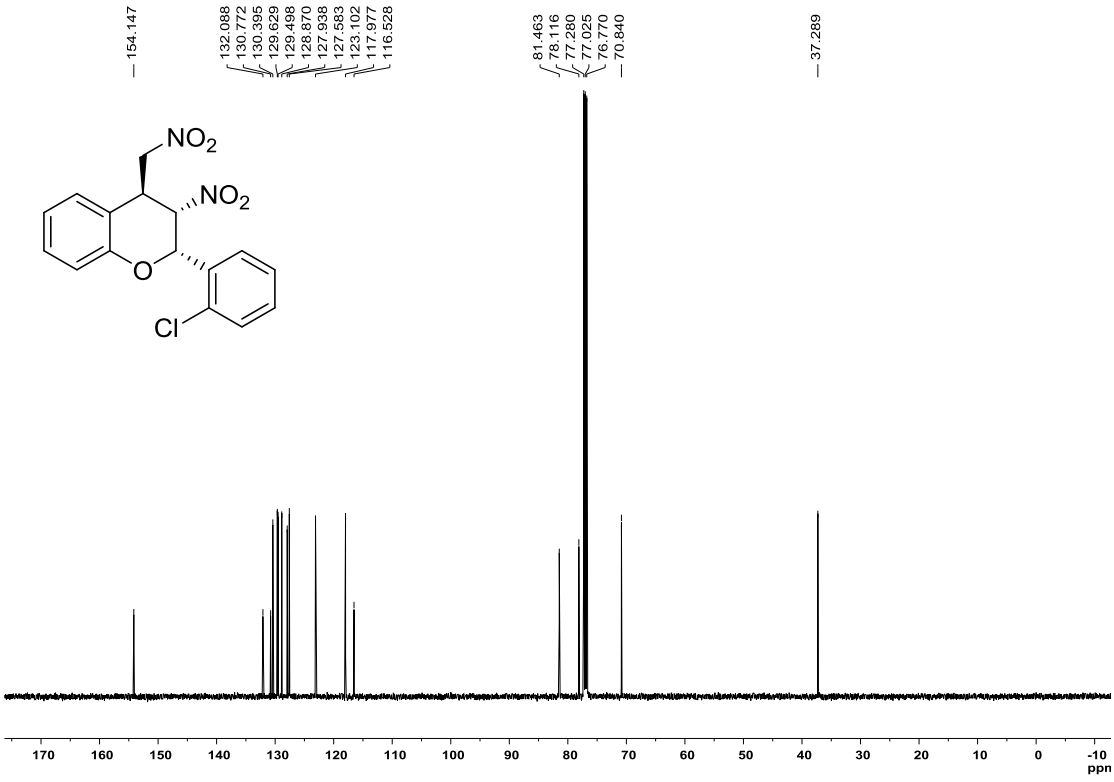
#	Start time[min]	Time[min]	End time[min]	Area%
1	16.171	16.981	18.237	5.715
2	18.309	19.273	25.219	89.772
3	30.134	31.255	33.198	1.580
4	45.166	47.156	50.010	2.932

^{1}H NMR spectrum of 4s



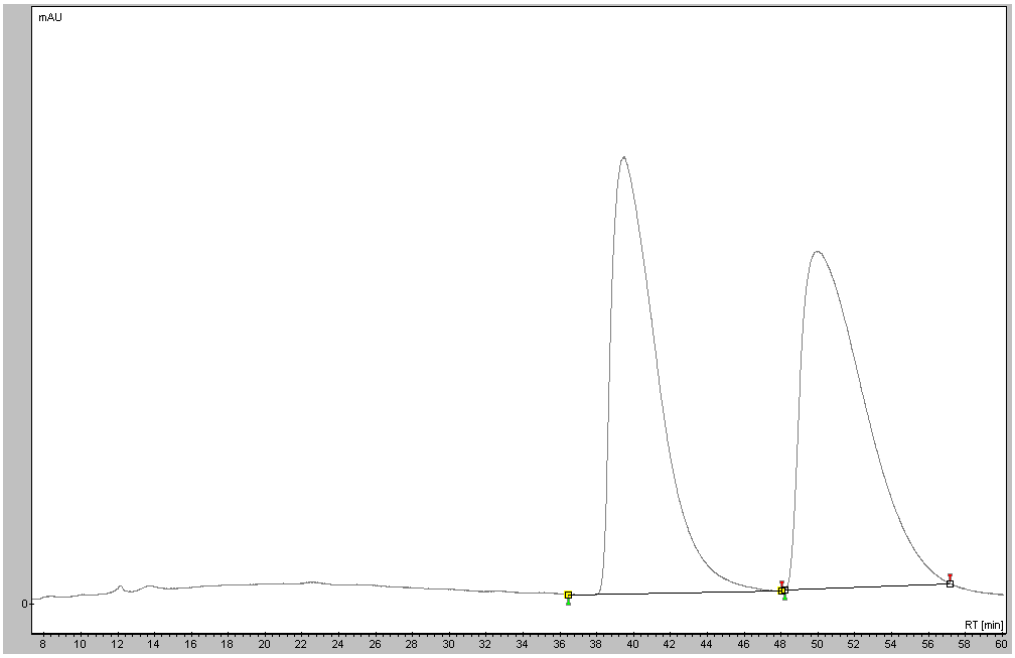


^{13}C NMR spectrum of 4s



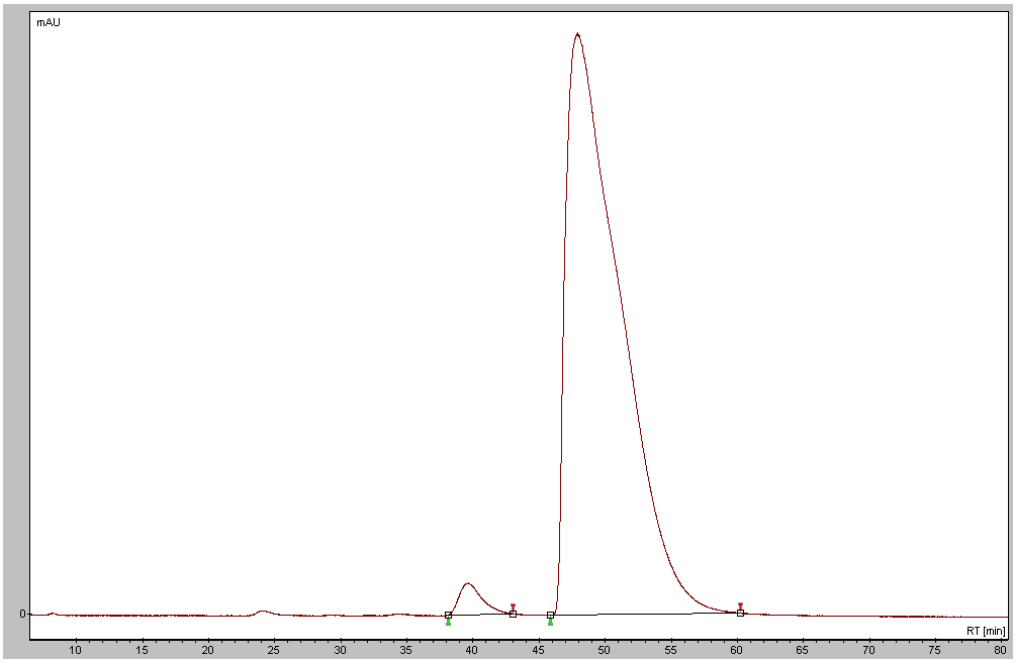
HPLC chromatograms of 4s

4s-rac



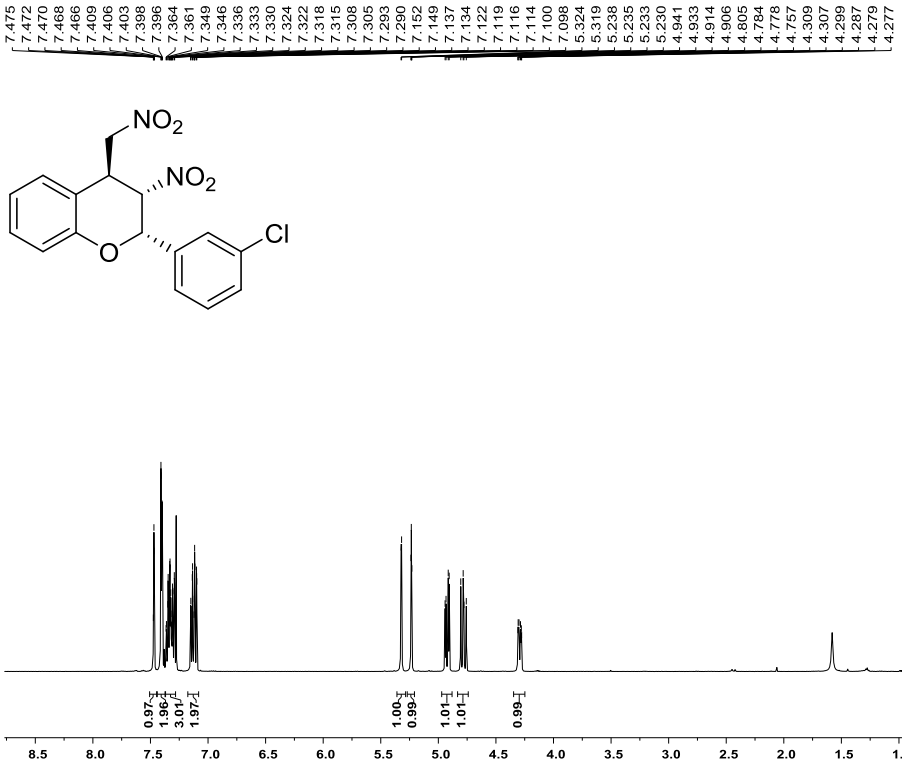
#	Start time[min]	Time[min]	End time[min]	Area%
1	36.449	39.477	48.060	48.363
2	48.185	49.983	57.188	51.637

4s-chr

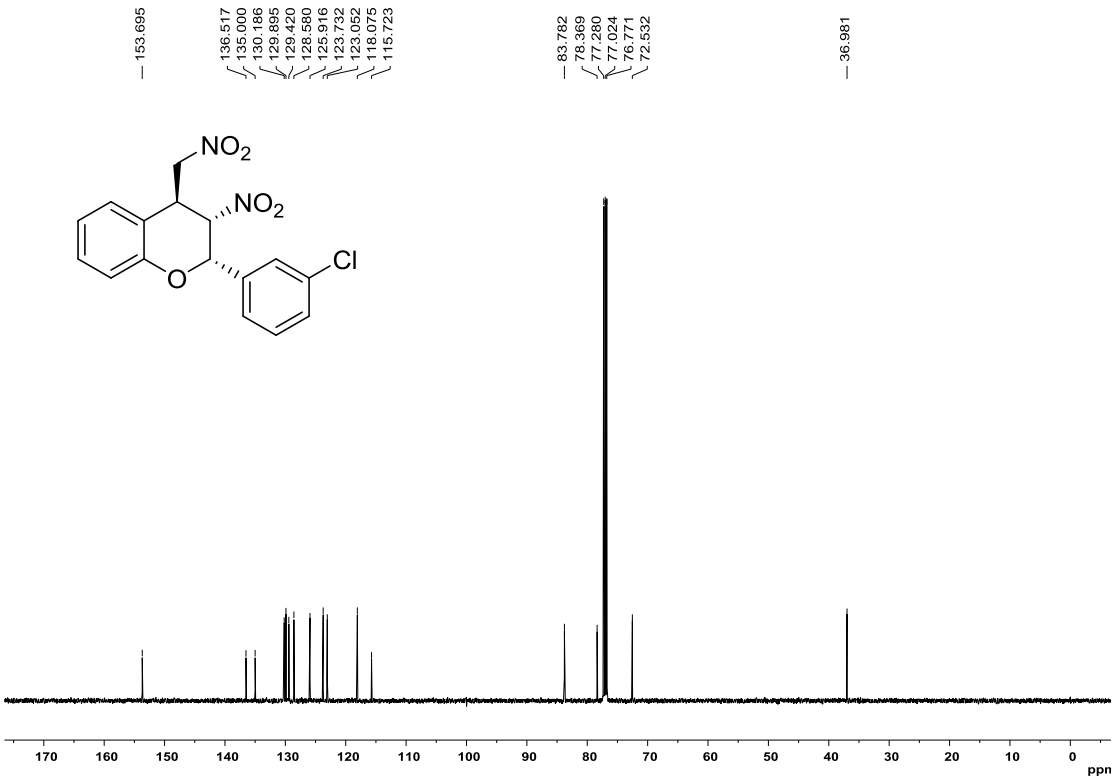


#	Start time[min]	Time[min]	End time[min]	Area%
1	38.094	39.612	43.006	2.218
2	45.850	47.916	60.243	97.782

^{1}H NMR spectrum of 4t

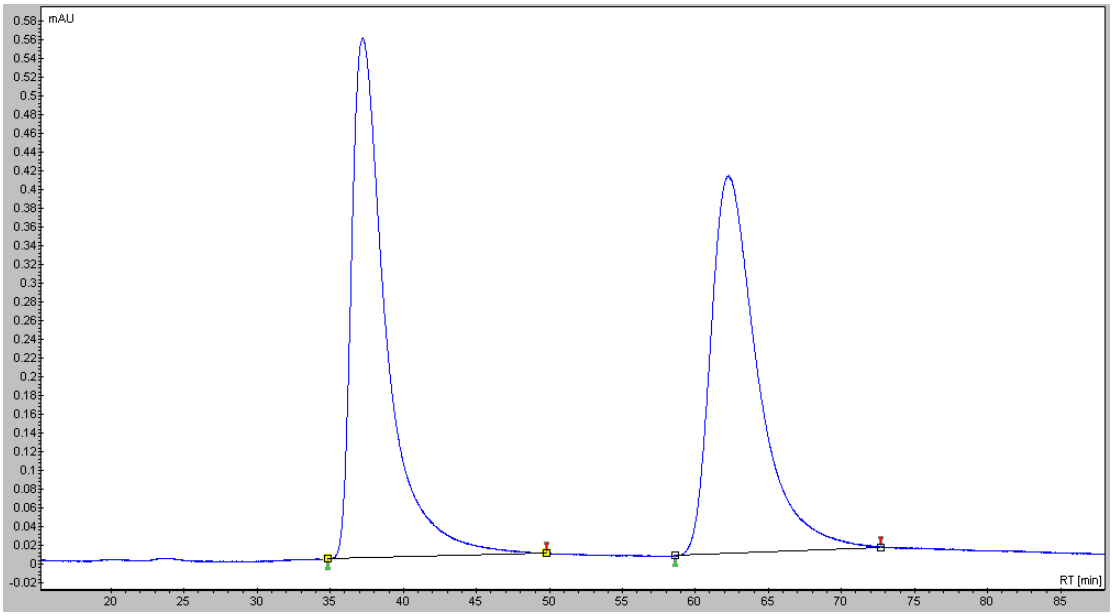


^{13}C NMR spectrum of 4t



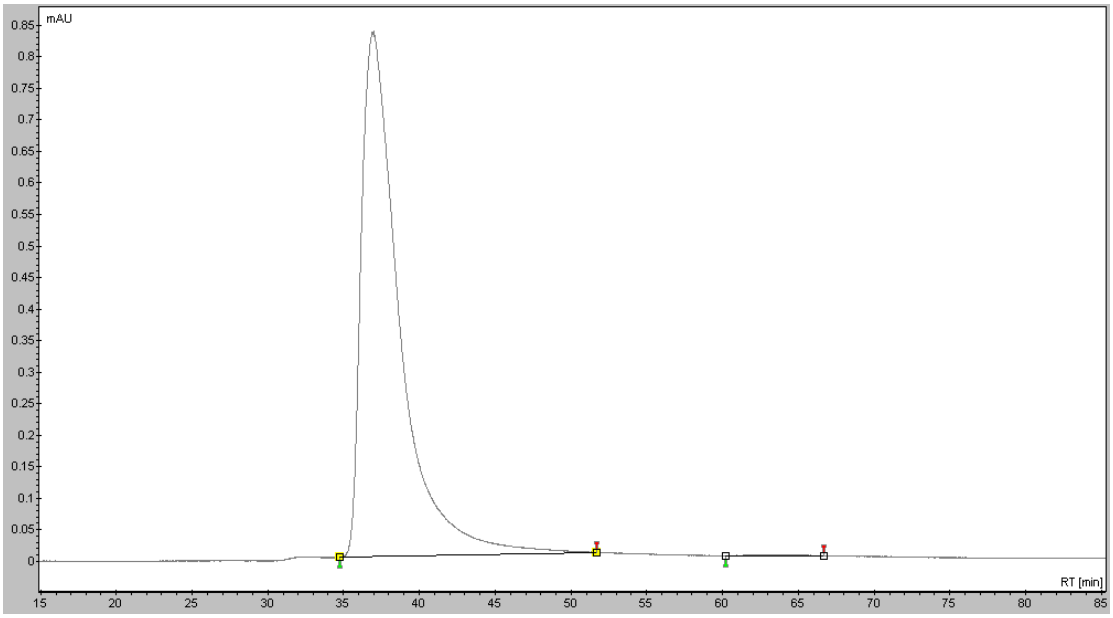
HPLC chromatograms of 4t

4t-rac



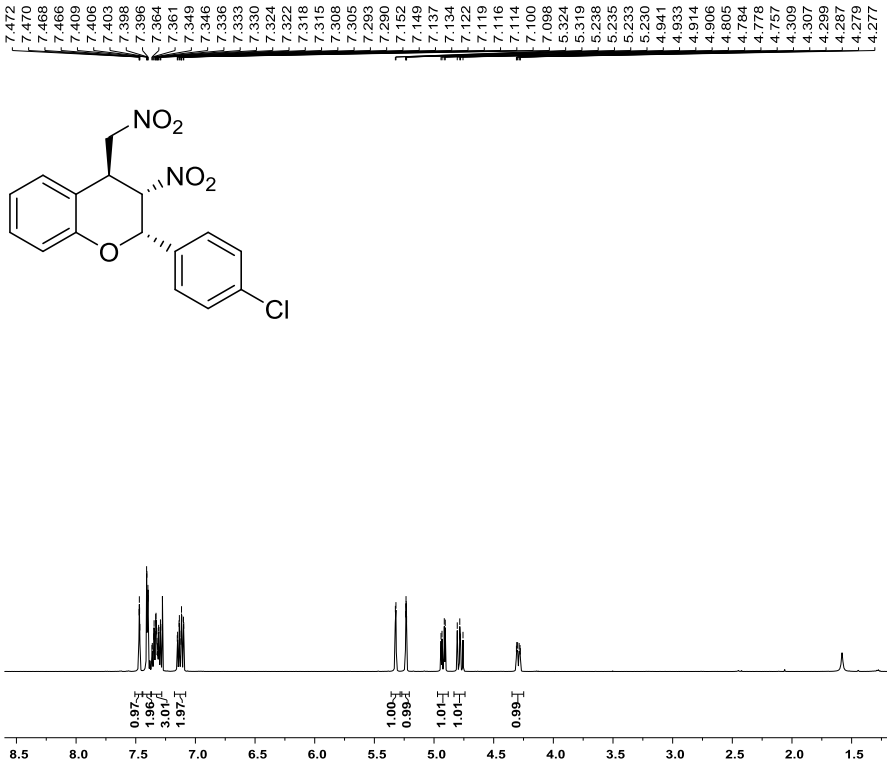
#	Start time[min]	Time[min]	End time[min]	Area%
1	34.833	37.213	49.804	50.496
2	58.587	62.218	72.660	49.504

4t-chr

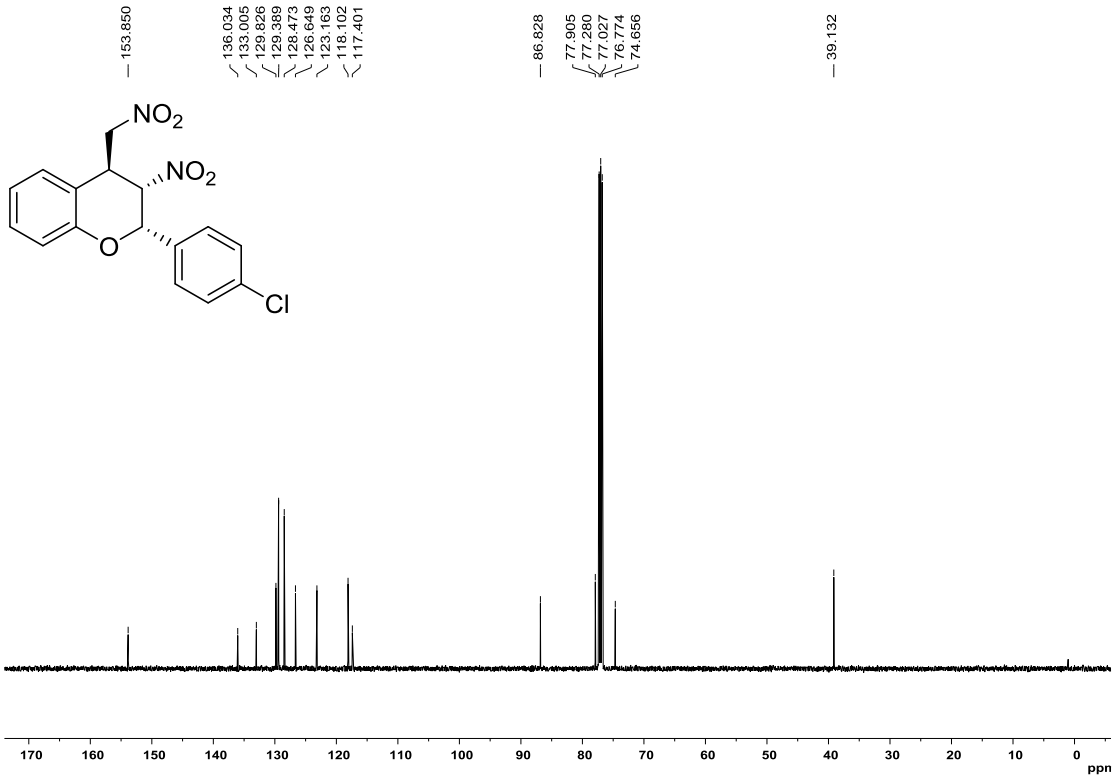


#	Start time[min]	Time[min]	End time[min]	Area%
1	34.770	36.973	51.714	99.799
2	60.213	63.151	66.707	0.201

^{1}H NMR spectrum of 4u

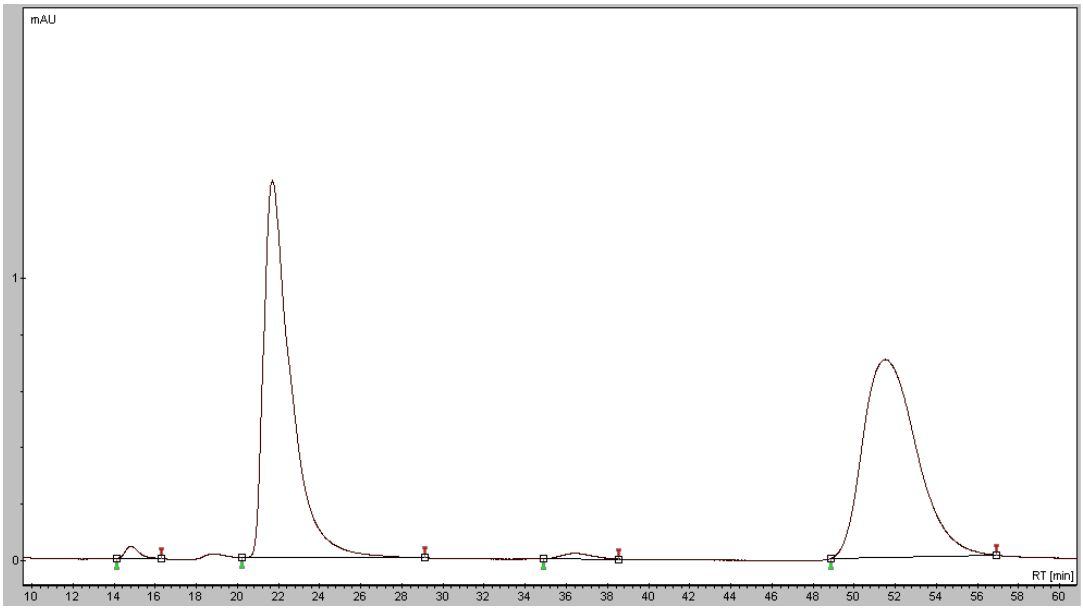


^{13}C NMR spectrum of 4u



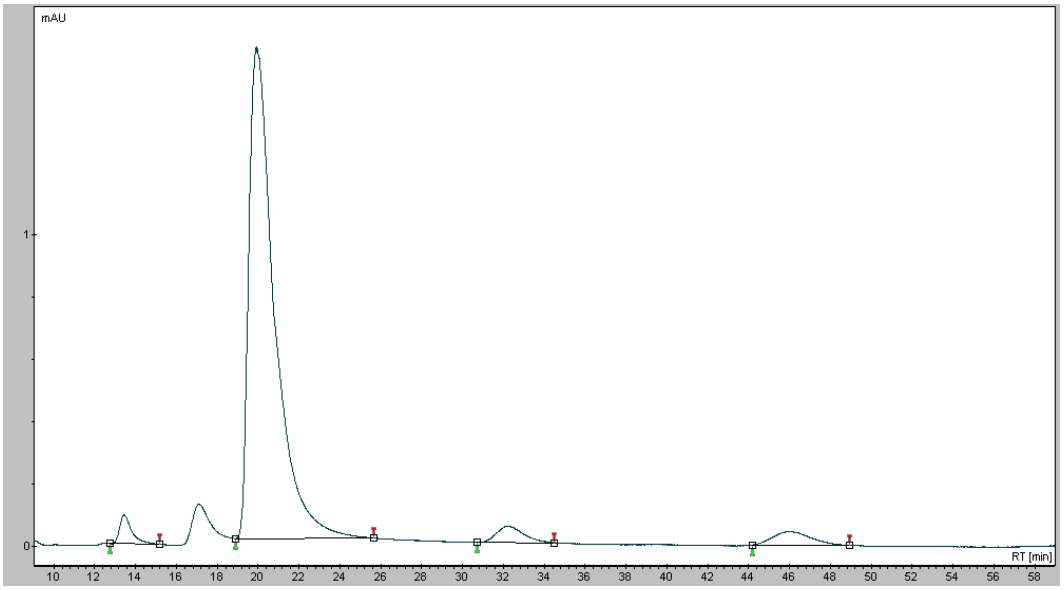
HPLC chromatograms of 4u

4u-rac



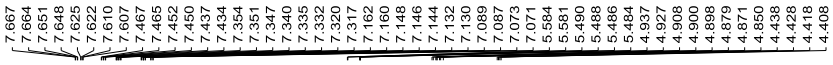
#	Start time[min]	Time[min]	End time[min]	Area%
1	14.128	14.835	16.290	0.829
2	20.227	21.712	29.106	48.009
3	34.896	36.440	38.525	0.798
4	48.870	51.515	56.899	50.364

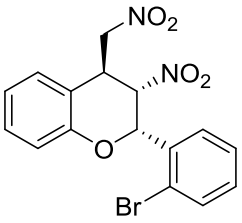
4u-chr

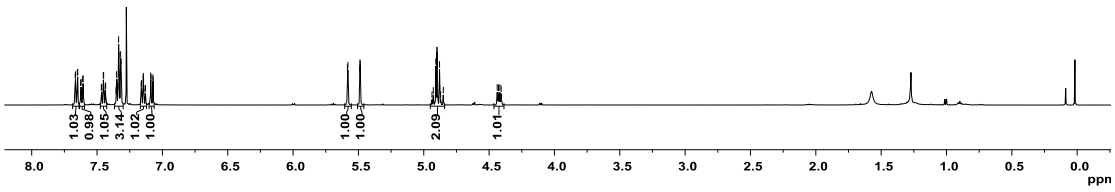


#	Start time[min]	Time[min]	End time[min]	Area%
1	12.752	13.449	15.191	2.012
2	18.884	19.926	25.643	91.363
3	30.730	32.228	34.493	2.640
4	44.179	45.984	48.918	3.985

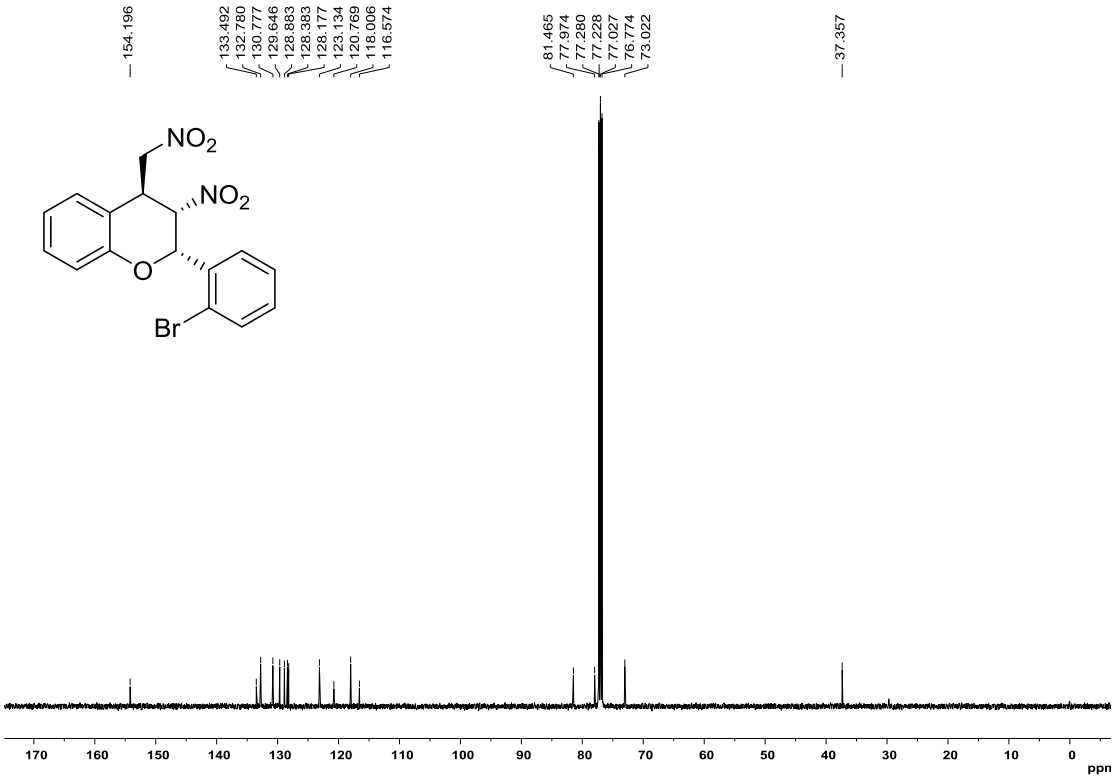
^{1}H NMR spectrum of 4v





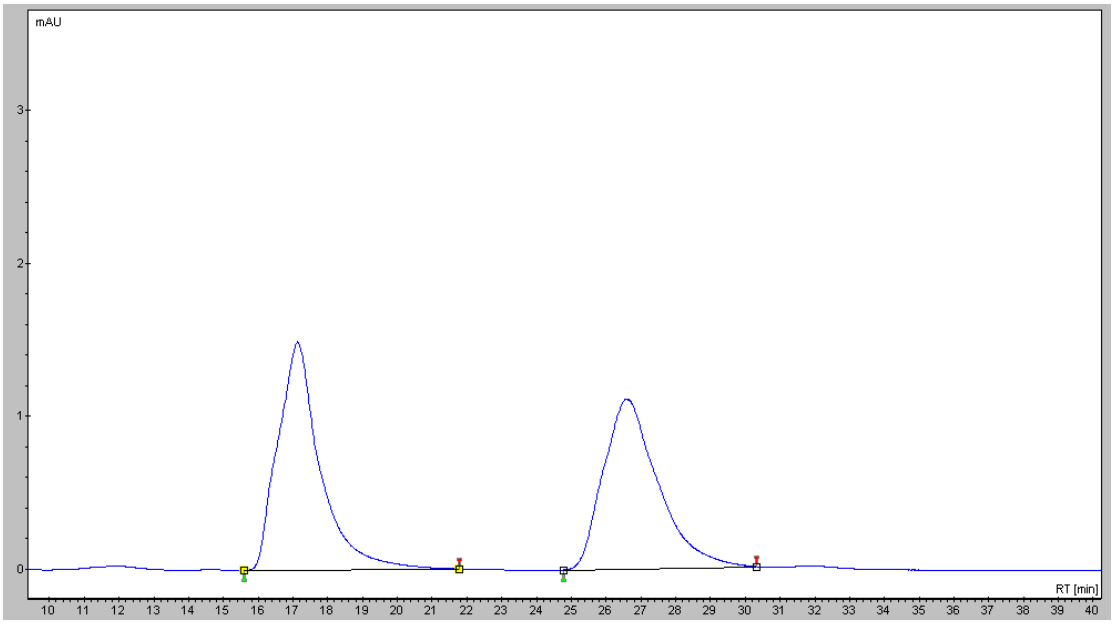


^{13}C NMR spectrum of 4v



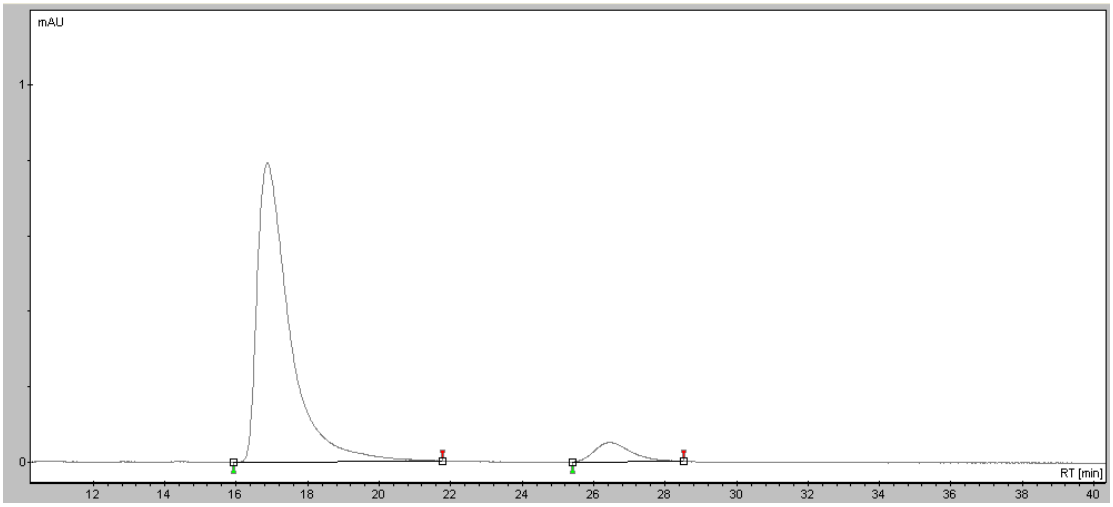
HPLC chromatograms of 4v

4v-rac



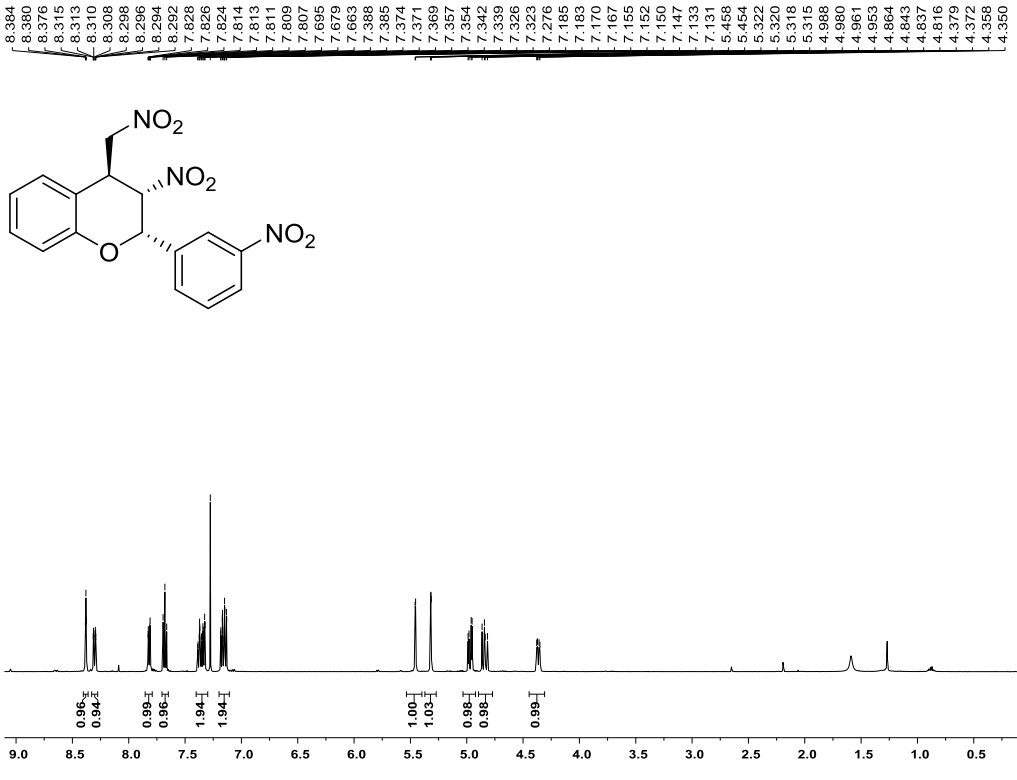
#	Start time[min]	Time[min]	End time[min]	Area%
1	15.584	17.127	21.787	50.964
2	24.656	26.577	30.238	49.036

4v-chr

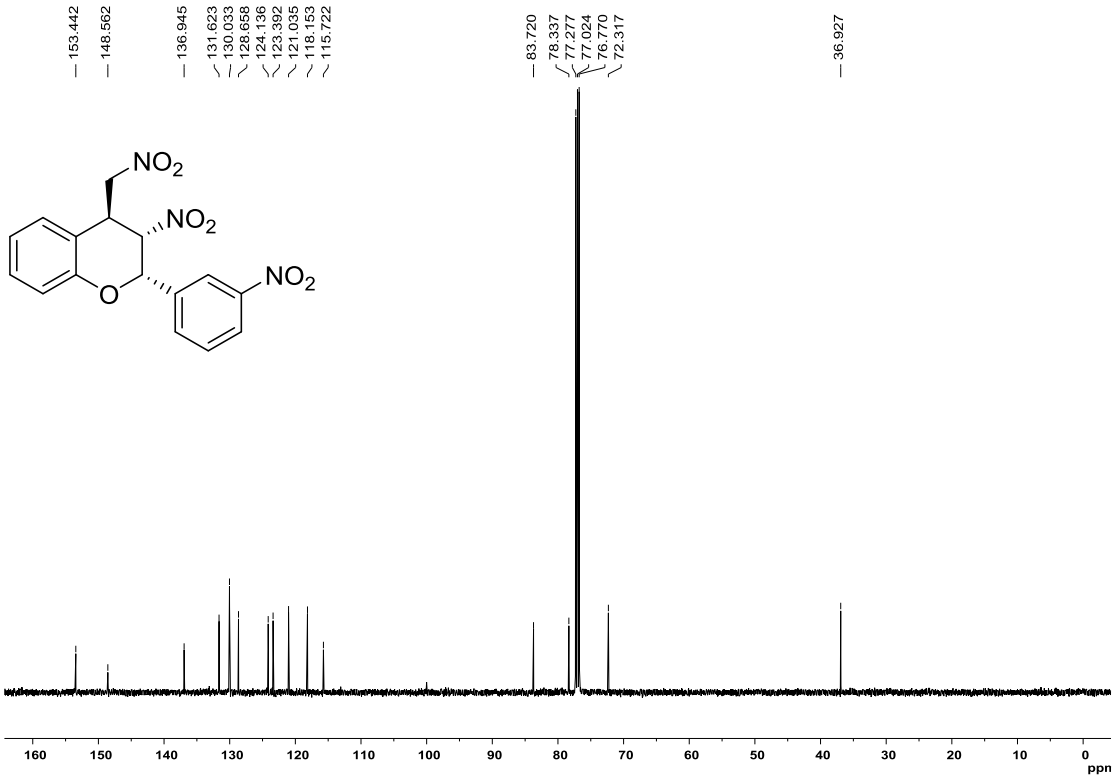


#	Start time[min]	Time[min]	End time[min]	Area%
1	15.943	16.874	21.784	93.253
2	25.426	26.457	28.518	6.747

^{1}H NMR spectrum of 4w

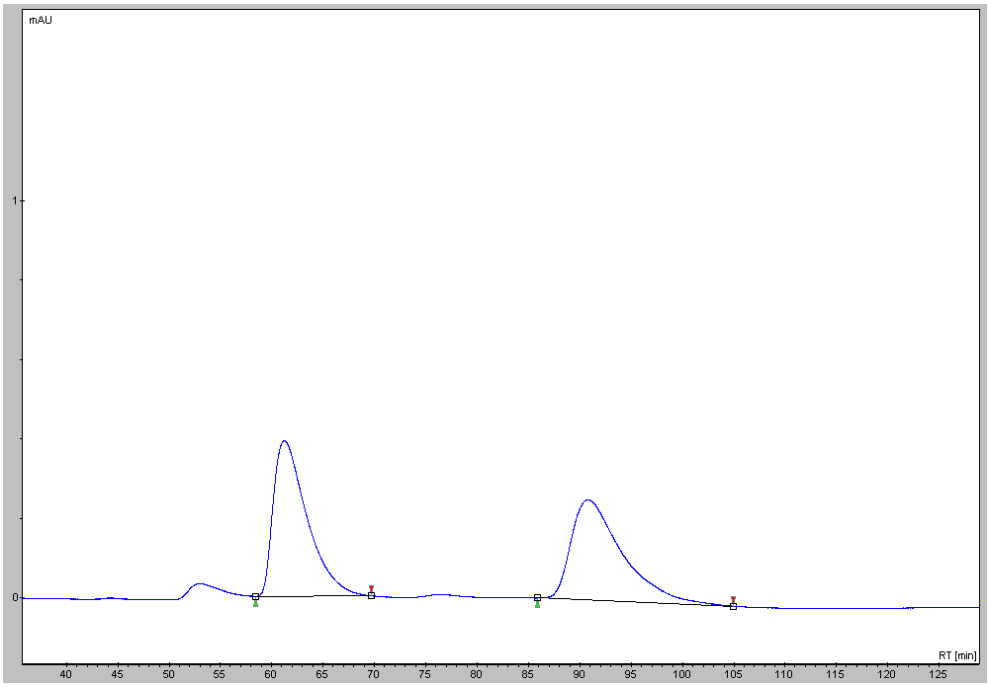


^{13}C NMR spectrum of 4w



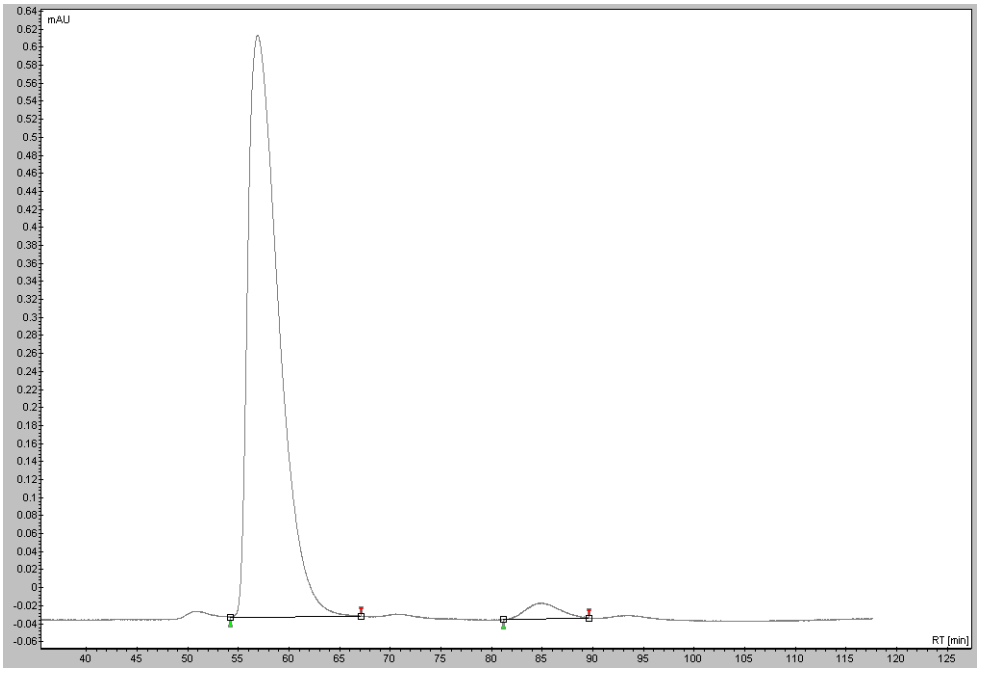
HPLC chromatograms of 4w

4w-rac



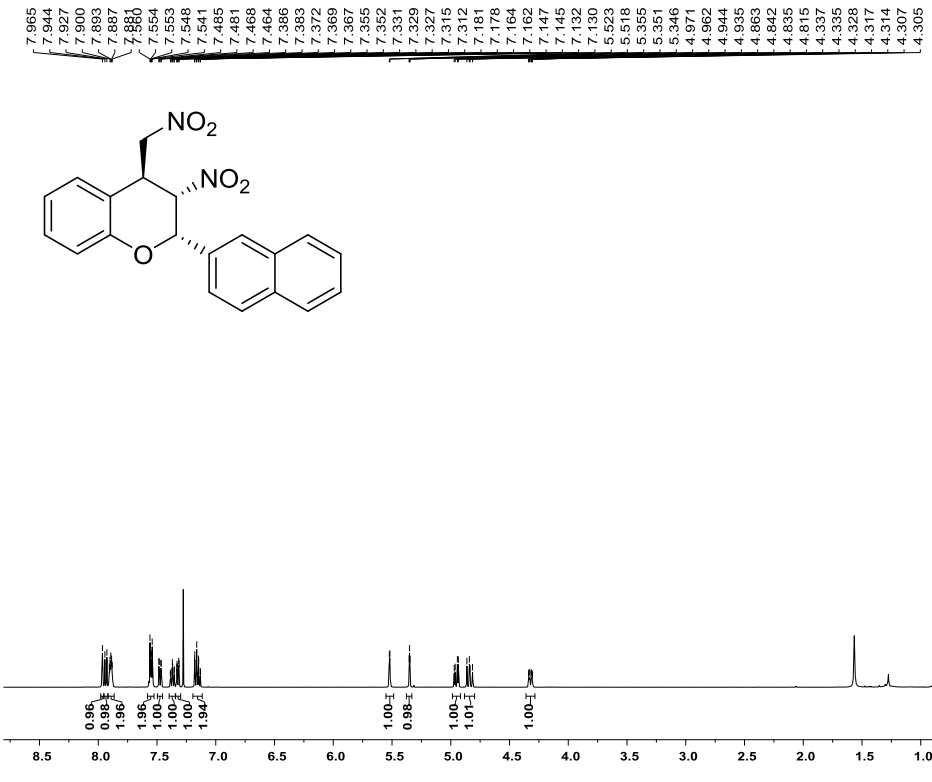
#	Start time[min]	Time[min]	End time[min]	Area%
1	58.452	61.236	69.709	50.700
2	85.873	90.882	104.924	49.300

4w-chr

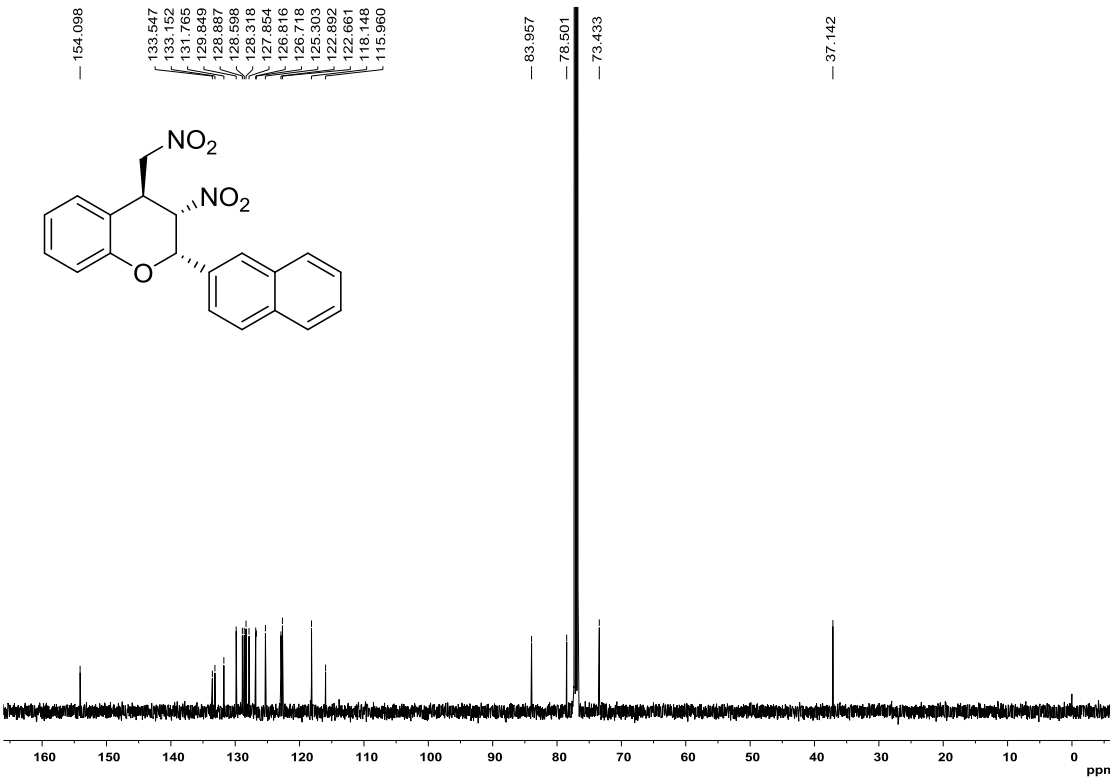


#	Start time[min]	Time[min]	End time[min]	Area%
1	54.214	56.900	69.099	97.121
2	81.200	84.903	89.587	2.879

^{1}H NMR spectrum of 4x

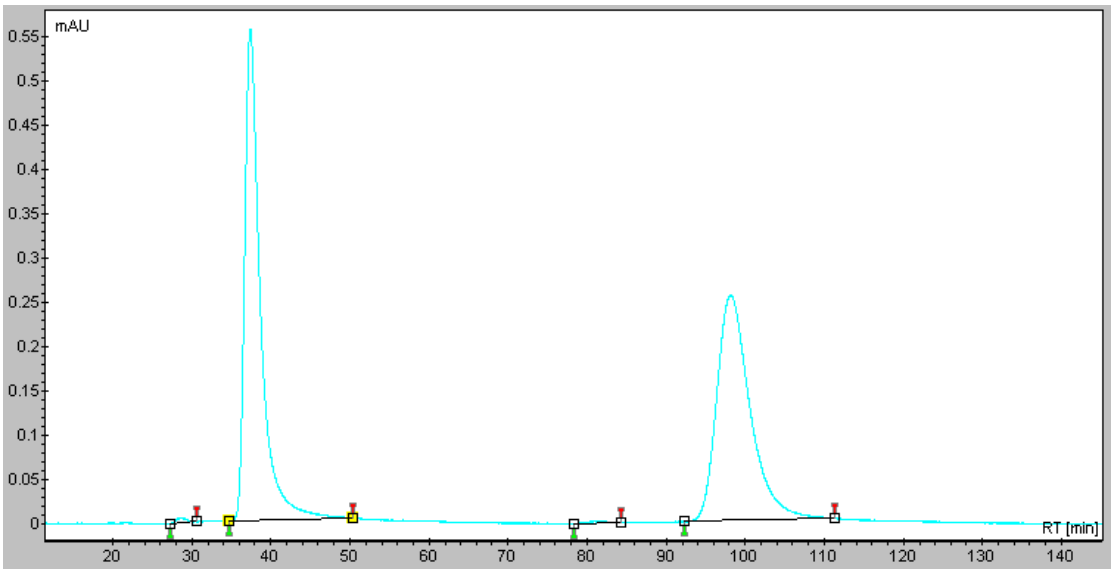


^{13}C NMR spectrum of 4x



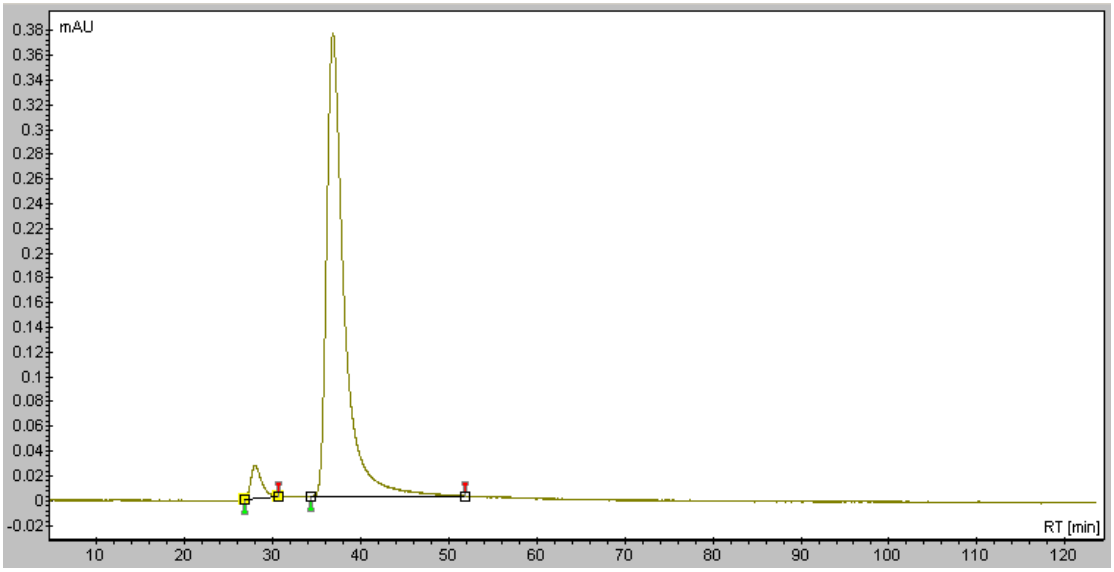
HPLC chromatograms of 4x

4x-rac



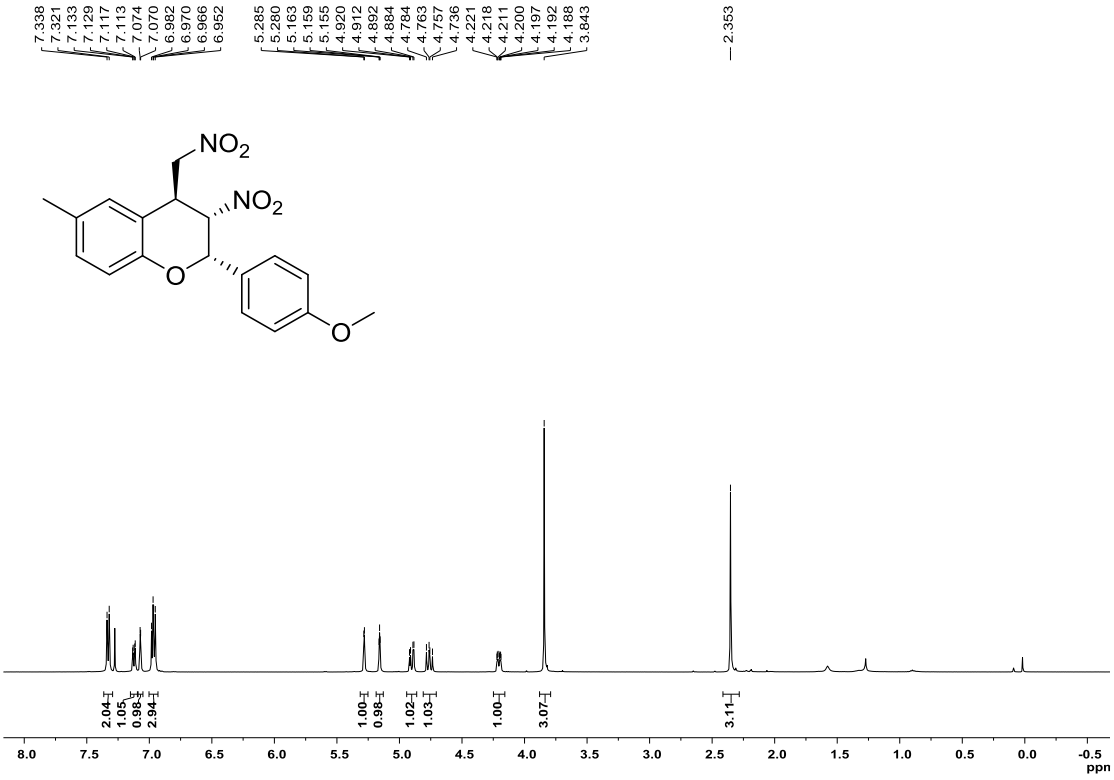
#	Start time[min]	Time[min]	End time[min]	Area%
1	27.386	28.627	30.57	0.326
2	34.816	37.405	50.314	50.428
3	78.372	81.058	84.389	0.241
4	92.348	98.175	111.242	49.005

4x-chr

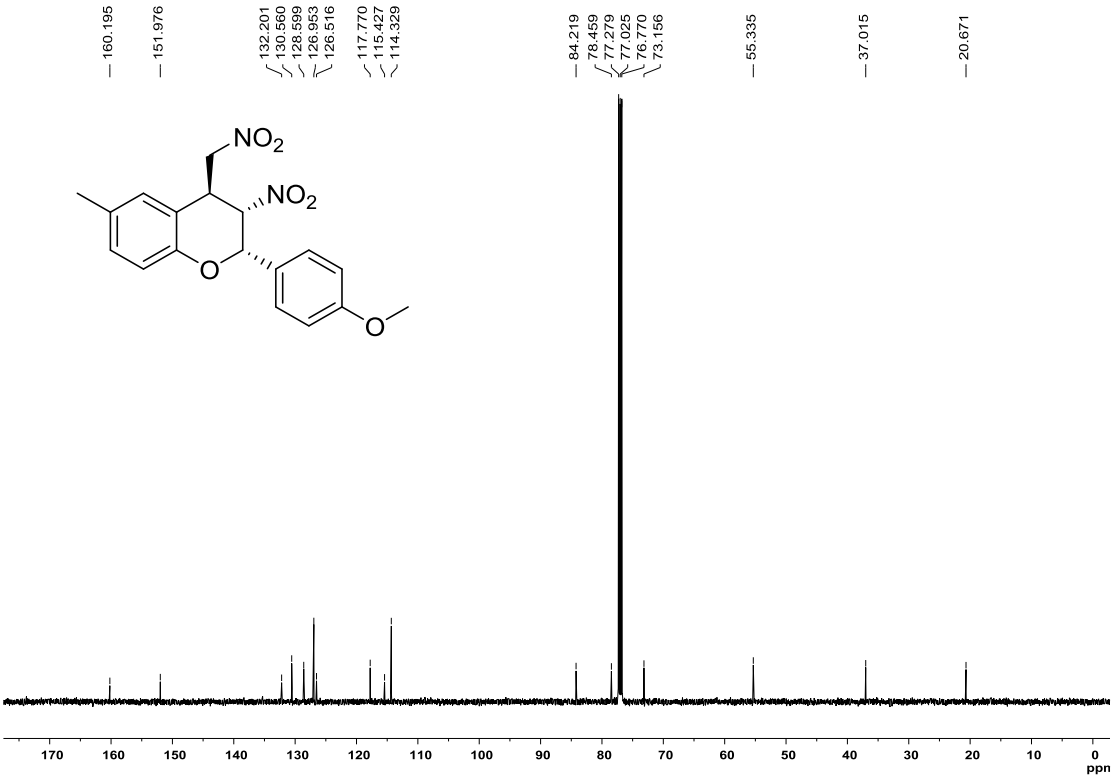


#	Start time[min]	Time[min]	End time[min]	Area%
1	26.852	28.03	30.638	4.291
2	34.425	36.84	51.81	95.709

^{1}H NMR spectrum of 4y

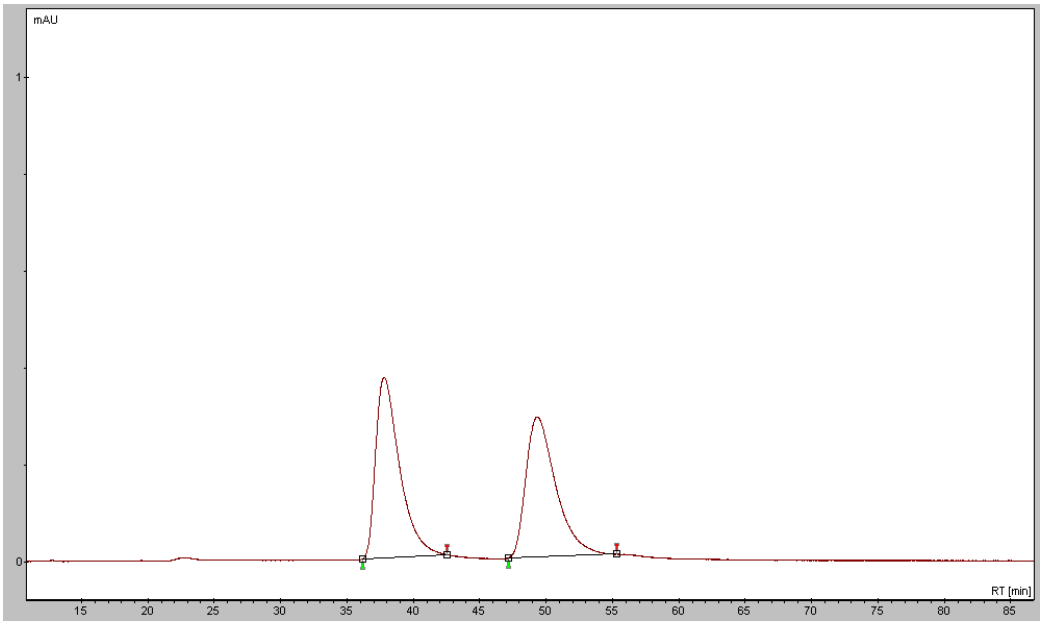


^{13}C NMR spectrum of 4y



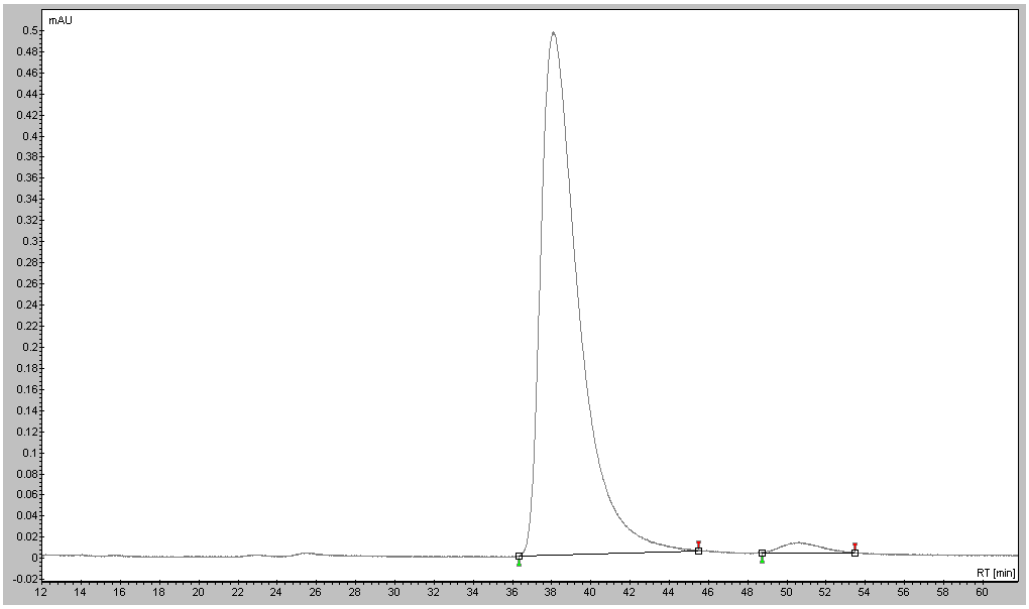
HPLC chromatograms of 4y

4y-rac



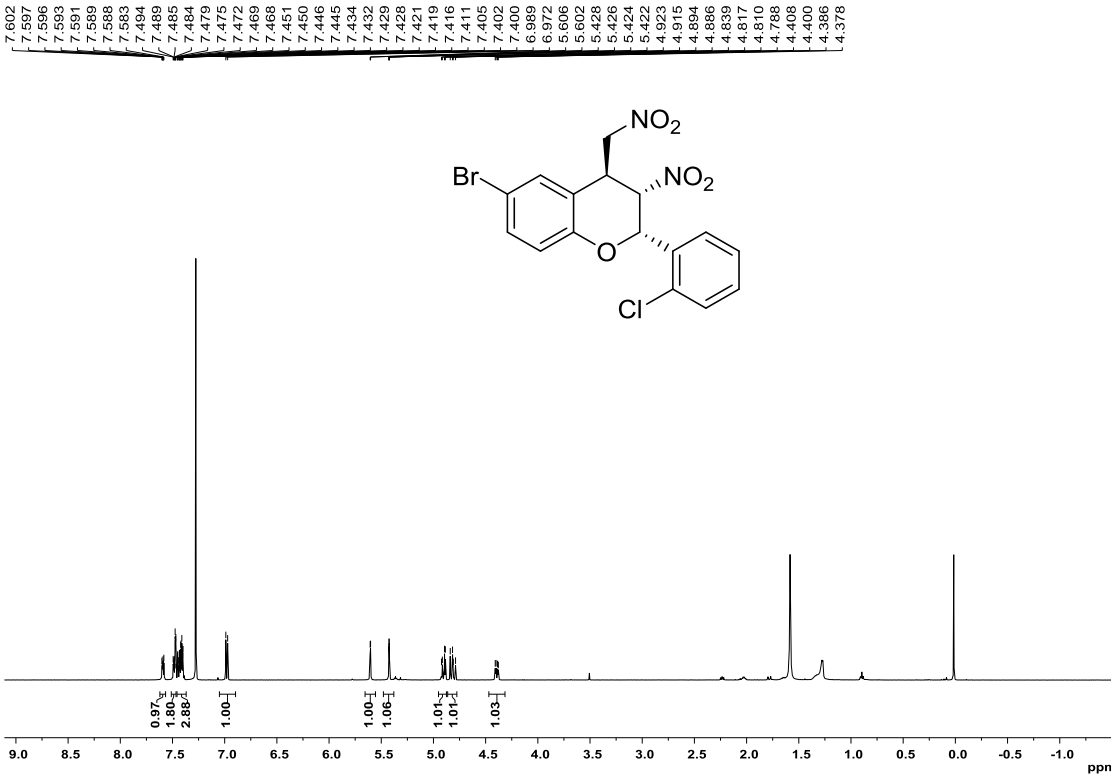
#	Start time[min]	Time[min]	End time[min]	Area%
1	36.181	37.786	42.535	50.787
2	47.163	49.316	55.321	49.213

4y-chr

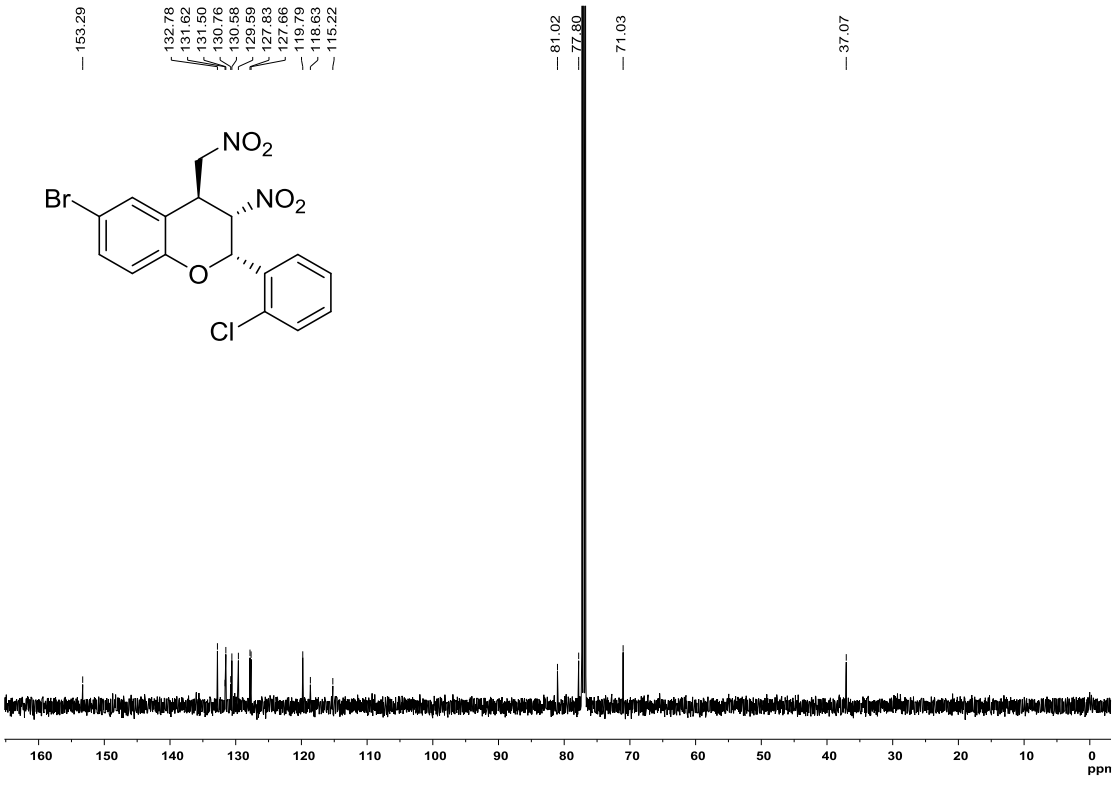


#	Start time[min]	Time[min]	End time[min]	Area%
1	36.349	38.077	45.501	98.119
2	48.723	50.556	53.493	1.881

^{1}H NMR spectrum of 4z

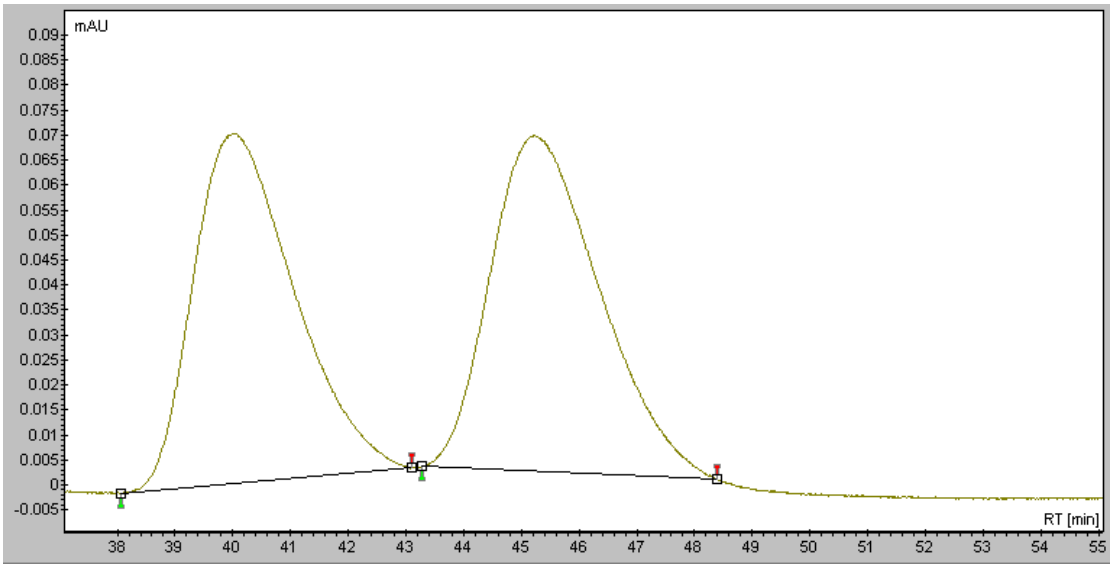


^{13}C NMR spectrum of 4z



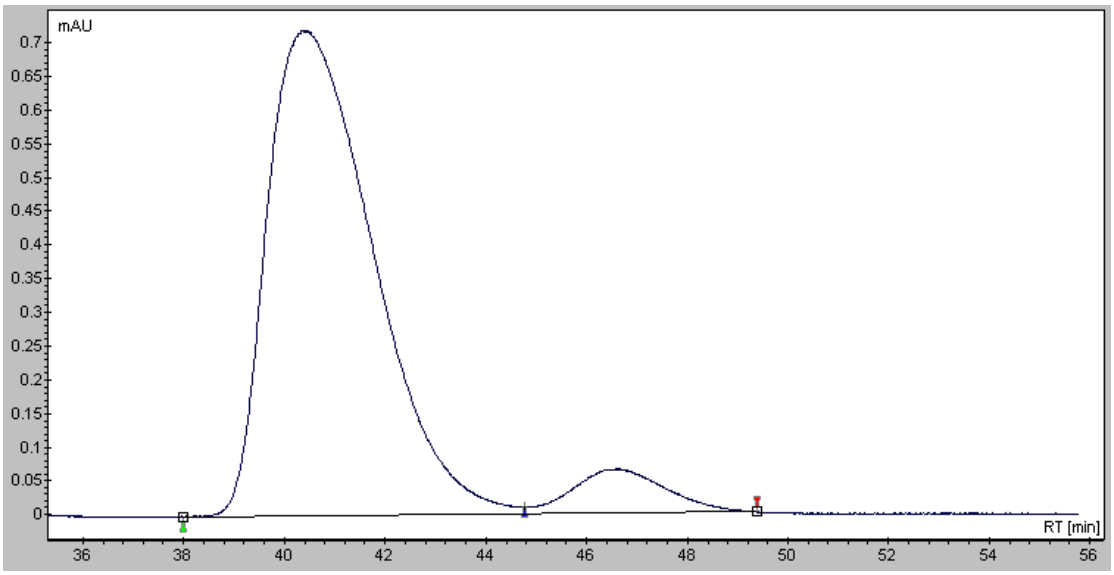
HPLC chromatograms of 4z

4z-rac



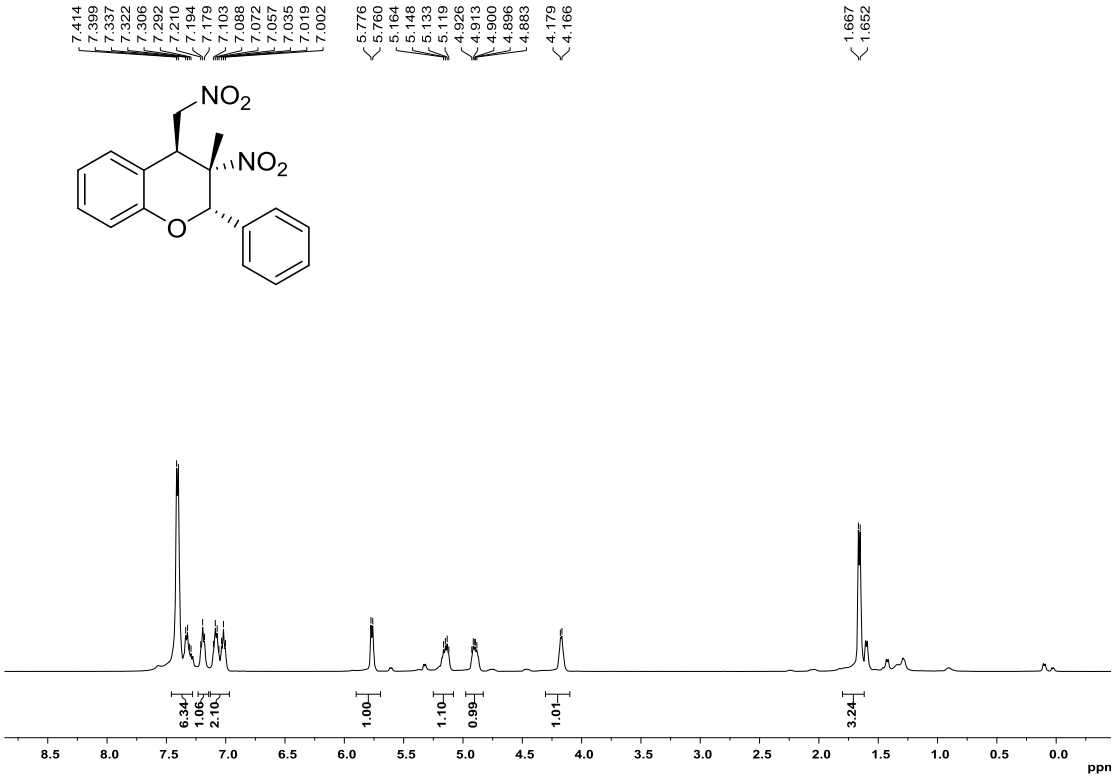
#	Start time[min]	Time[min]	End time[min]	Area%
1	38.066	39.997	43.111	48.915
2	43.267	45.223	48.39	51.085

4z-chr

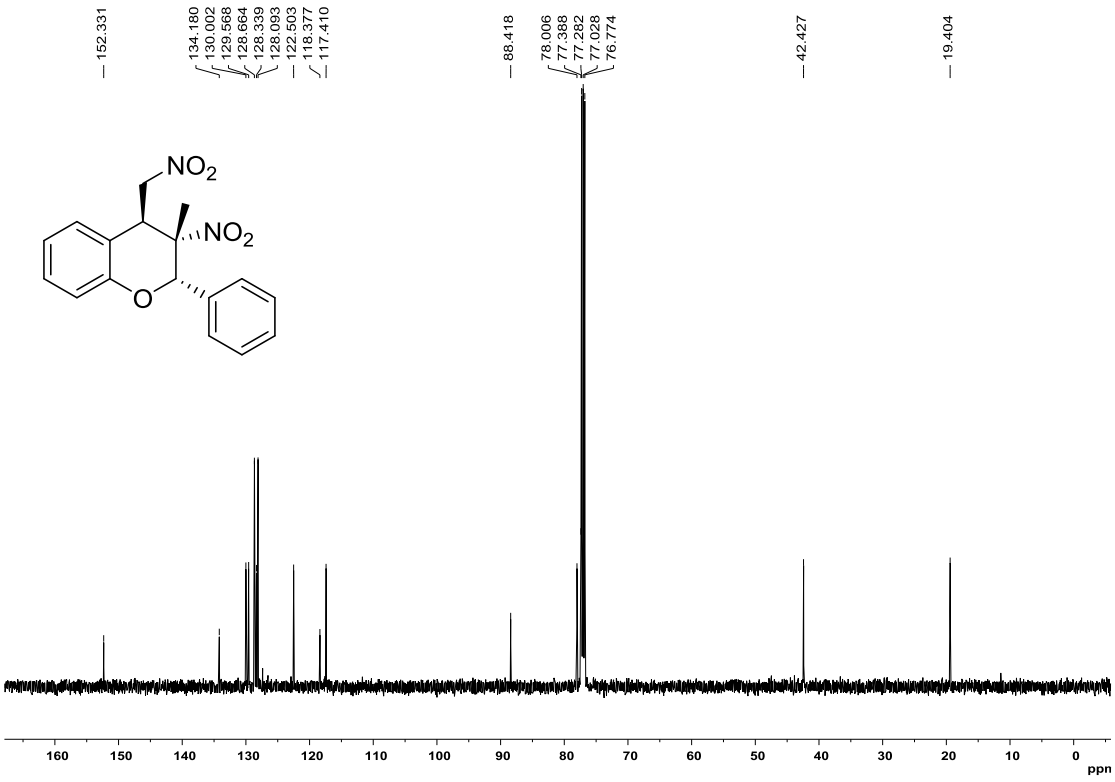


#	Start time[min]	Time[min]	End time[min]	Area%
1	38.249	40.397	44.759	92.965
2	44.759	46.57	49.42	7.035

^{1}H NMR spectrum of 5a

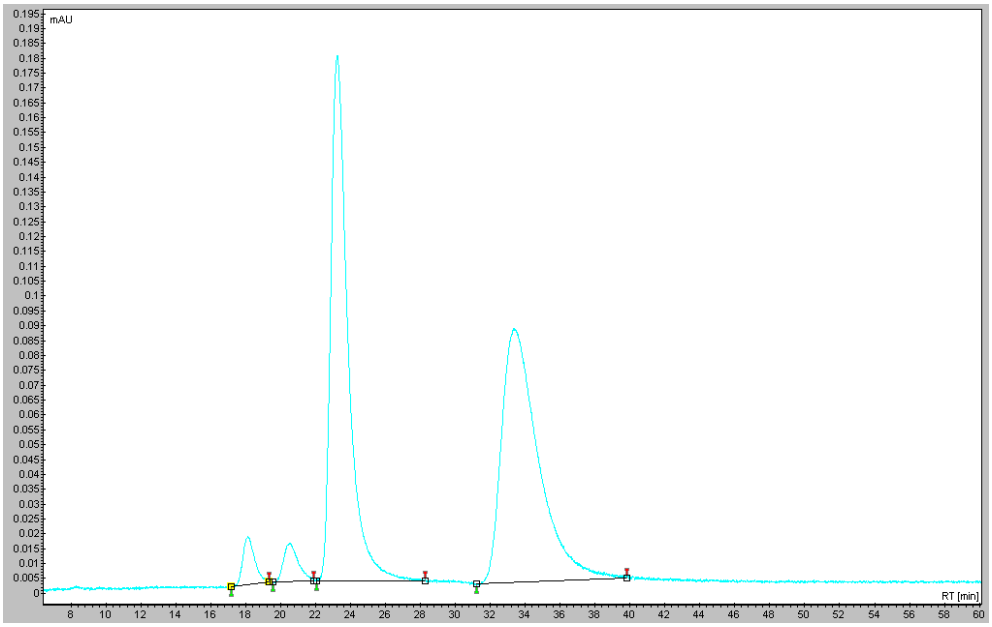


^{13}C NMR spectrum of 5a



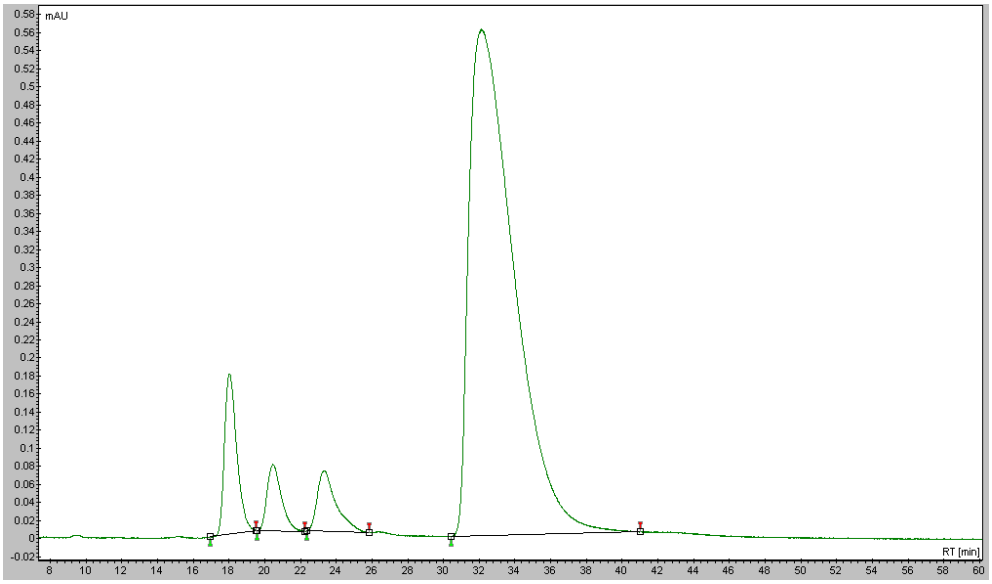
HPLC chromatograms of 5a

5a-rac



#	Start time[min]	Time[min]	End time[min]	Area%
1	17.171	18.114	19.326	2.838
2	19.535	20.499	21.898	2.804
3	22.037	23.232	28.294	46.508
4	31.214	33.375	39.834	47.851

5a-chr



#	Start time[min]	Time[min]	End time[min]	Area%
1	16.924	18.034	19.528	7.338
2	19.587	20.459	22.250	3.537
3	22.377	23.325	25.842	4.237
4	30.407	32.095	41.009	84.888

4. X-ray crystal structure of the compound 4s

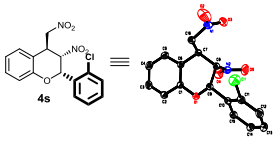


Figure 1 X-ray crystal structure of the compound **4s**

Table 1. Crystal data and structure refinement parameters of the compound **4s**

Parameter	Value
CCDC deposition number	1437002
Empirical formula	$C_{16}H_{13}ClN_2O_5$
Formula weight	348.73
Temperature	293(2)K
Wavelength	0.71073 Å
Crystal system	Monoclinic
Space group	P 21/c
Cell dimensions	a = 9.4352(14) Å α= 90 ° b = 10.2572(16) Å β= 105.653(3) ° c = 16.421(2) Å γ = 90 °
Volume	1530.3(4) $Å^3$
Z	4
Density (calculated)	1.514 Mg/m^3
Absorption coefficient	0.280 mm^{-1}
F_{000}	720
Crystal size	0.2110 ×0.170 ×0.110 mm^3
Theta range for data collection	2.242 °to 25.998 °
Index ranges	$-10 \le h \le 11$ $-12 \le k \le 12$ $-20 \le l \le 18$
Reflections collected	8914
Independent reflections	3013 [R_{int} = 0.0333]
Absorption correction	T_{min} = 0.6682, T_{max} = 0.7456
Refinement method	Full-matrix least-squares on F^2
Data /restraints /parameters	3013/0/217
Goodness of fit on F^2	1.048
Final R indices [$I > 2\sigma(I)$]	R_1 = 0.0449, ωR_2 = 0.1131
R indices (all data)	R_1 = 0.0573, ωR_2 = 0.1199
Extinction correction	None
Largest diff. peak and hole	0.270 and -0.216 e.$Å^{-3}$