Angewandte Chemie
Eine Zeitschrift der Gesellschaft Deutscher Chemiker

Supporting Information

69451 Weinheim, Germany

Enantioselective Rhodium-catalyzed Addition of Arylboronic Acids to α-Ketoesters

Hai-Feng Duan, Jian-Hua Xie, Xiang-Chen Qiao, Li-Xin Wang, and Qi-Lin Zhou*

State Key Laboratory and Institute of Elemento-organic Chemistry, Nankai University, Tianjin 300071, China.

CONTENTS:

General:

All reactions and manipulations were performed using standard Schlenk techniques. H_2O, Toluene, DME, EtOH, DCE were simply distilled before use. $[RhCl(C_2H_4)_2]_2$ [1] was prepared according to the reported procedures. Arylboronic acids were purchased from Aldrich or Shijiazhuang Tianyue Fine Chemicals Co., Ltd and used as received.

NMR spectra were recorded with a Bruker-400 spectrometer, operating at 400 MHz for ^1H NMR, 100 MHz for ^{13}C NMR. Chemical shifts in $CDCl_3$ were reported in ppm down field from internal Me_4Si and external 85% H_3PO_4, respectively. Melting points were measured on a RY-I apparatus and uncorrected. Optical rotations were determined using a Perkin Elmer 341 MC polarimeter. Elemental analyses were performed on the Yanaca CDRDER MT-3 instrument. Mass spectra were recorded on the VG-7070E spectrometer. HRMS were recorded on APEXII and ZAB-HS spectrometer. HPLC analyses were performed using a Hewlett Packard Model HP 1100 Series or Waters 2996 instruments and SFC analyses were performed on a Berger Analytix SFC instrument.

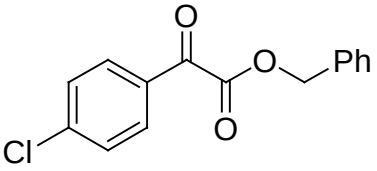
---

[1] R. Cramer, *J. Am. Chem. Soc.* **1964**, *86*, 217-222.

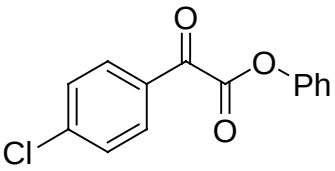
(A) Preparation of New α-Ketoesters [2]

Benzyl 2-(4-chlorophenyl)-2-oxoacetate

Benzyl alcohol (5.2 mL, 50 mmol) was added slowly to freshly distilled oxalyl chloride (8.5 mL, 100 mmol) at 0 °C within 15 min and wormed up to room temperature. After 4 h, the reaction mixture was distilled under reduced pressure to give the Benzyl chloro(oxo)acetate at 95 °C /1 mmHg, yield 60%. Benzyl chloro(oxo)acetate (5.9 g, 30 mmol) in THF (10 mL) was added dropwise to stirred solution of imidazole (4.1 g, 60 mmol) in THF (30 mL) at 0 °C under N_2. After an additional 2 h of being stirred at room temperature, the mixture was filtered and the precipitate was washed with anhydrous THF (10 mL). The filtrate was cooled to –50 °C under nitrogen. The solution of 4-chlorophenyl magnesium bromide (30 mmol in 30 mL THF) was added dropwise over 30 min with stirring. The solution was allowed to come to room temperature over 3 h and poured into ice-water. The solution was extracted with ether, washed with brine and dried over $MgSO_4$. Removal of solvents with reduced pressure and purified by chromatography on silica gel with petrol ether/ethyl acetate (8/1) to give benzyl 2-(4-chlorophenyl)-2-oxoacetate as White solid, 67% yield, mp 52–53 °C; ^{1}H NMR ($CDCl_3$): δ 7.92 (d, *J* = 11.2 Hz, 2H), 7.47–7.37 (m, 7H), 5.40 (s, 2H). ^{13}C NMR ($CDCl_3$): δ 184.5, 163.0, 141.6, 134.4, 131.4, 130.9, 129.3, 128.8, 128.7, 128.6, 67.9. FAB-MS m/z 275 $[M+H]^+$. Anal. Calcd. for $C_{15}H_{11}ClO_3$: C, 65.58; H, 4.04. Found: C, 65.28; H, 4.38.

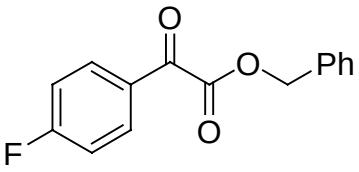


Phenyl 2-(4-chlorophenyl)-2-oxoacetate



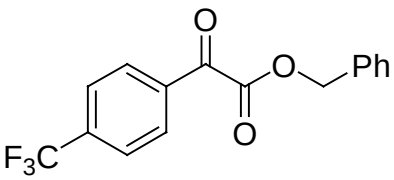
White solid, 55% yield, mp 50–52 °C; ^{1}H NMR ($CDCl_3$): δ 8.07 (d, *J* = 11.2 Hz, 2H), 7.52–7.42 (m, 4H), 7.33–7.24 (m, 3H). ^{13}C NMR ($CDCl_3$): δ 183.7, 161.1, 149.9, 131.5, 130.7, 129.4, 126.8, 121.1. FAB-MS m/z 261 $[M+H]^+$. Anal. Calcd. for $C_{14}H_9ClO_3$: C, 64.51; H, 3.48. Found: C, 64.66; H, 3.18.

Benzyl 2-(4-fluorophenyl)-2-oxoacetate



White solid, 62% yield, mp 40–42 °C; ^{1}H NMR ($CDCl_3$): δ 8.04–8.01 (m, 2H), 7.45–7.36 (m, 5H), 7.16-7.12 (m, 2H), 5.40 (s, 2H). ^{13}C NMR ($CDCl_3$): δ 184.7, 168.3, 165.7, 165.4, 163.4, 134.6, 133.2, 133.1, 129.2, 129.0, 128.9, 128.8, 116.6, 116.3, 68.1. FAB-MS m/z 259 $[M+H]^+$. Anal. Calcd. for $C_{15}H_{11}FO_3$: C, 69.76; H, 4.29. Found: C, 69.64; H, 4.45.

Benzyl 2-(4-(trifluoromethyl))-2-oxoacetate

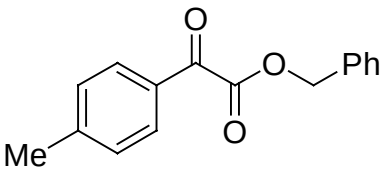


White solid, 45% yield, mp 61–62 °C; ^{1}H NMR ($CDCl_3$): δ 8.10 (d, *J* = 8.0 Hz, 2H), 7.73 (d, *J* = 8.0 Hz, 2H), 7.46–7.36 (m, 5H), 5.43 (s, 2H). ^{13}C NMR ($CDCl_3$): δ 184.8, 162.8, 135.4, 134.5, 130.8, 129.1, 129.0, 128.9, 126.1, 122.1, 68.3. FAB-MS m/z 309 $[M+H]^+$. Anal. Calcd. for $C_{16}H_{11}F_3O_3$: C, 62.34; H, 3.60. Found: C, 62.13; H, 3.34.

Benzyl 2-(4-methylphenyl)-2-oxoacetate

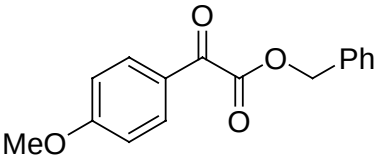
---

[2] J. S. Nimitz, H. S. Mosher, *J. Org. Chem.* **1981**, *46*, 211-213.



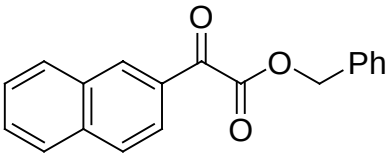
White solid, 80% yield, mp 58–60 °C; ^{1}H NMR ($CDCl_3$): δ 7.85 (d, *J* = 8.0 Hz, 2H), 7.45–7.36 (m, 5H), 7.27 (d, *J* = 8.0 Hz, 2H), 5.40 (s, 2H), 2.42 (s, 3H). ^{13}C NMR ($CDCl_3$): δ 186.0, 164.1, 146.5, 134.9, 130.3, 130.2, 129.8, 128.9, 128.8, 67.8, 22.1. EI-MS m/z 254 (M^+). Anal. Calcd. for $C_{16}H_{14}O_3$: C, 75.57; H, 5.55. Found: C, 75.91; H, 5.75.

Benzyl 2-(4-methoxyphenyl) -2-oxoacetate



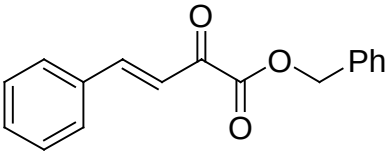
Colorless oil, 76% yield. ^{1}H NMR ($CDCl_3$): δ 7.95 (d, *J* = 8.8 Hz, 2H), 7.45–7.31 (m, 5H), 6.94 (d, *J* = 8.8 Hz, 2H), 5.39 (s, 2H), 3.87 (s, 3H). ^{13}C NMR ($CDCl_3$): δ 184.7, 165.3, 164.2, 134.9, 132.7, 128.9, 128.7, 114.5, 113.5, 67.7, 55.8. EI-HRMS Calcd for $C_{16}H_{14}O_4$: 270.0892. Found: 270.0890.

Benzyl 2-(2-naphthyl) -2-oxoacetate



Pale orange solid, 60% yield, mp 47–49 °C; ^{1}H NMR ($CDCl_3$): δ 8.43 (s. 1H), 8.03–8.01 (m, 1H), 7.85–7.84 (m, 3H), 7.60–7.40 (m, 7H), 5.49 (s, 2H). ^{13}C NMR ($CDCl_3$): δ 186.2, 164.1, 136.5, 134.9, 133.8, 132.4, 130.1, 130.0, 129.8, 129.4, 129.2, 129.1, 129.0, 128.7, 128.1, 127.4, 124.0, 68.0. EI-HRMS Calcd for $C_{19}H_{14}O_3$: 290.0943. Found: 290.0942.

(*E*)-benzyl 2-oxo-4-phenylbut-3-enoate



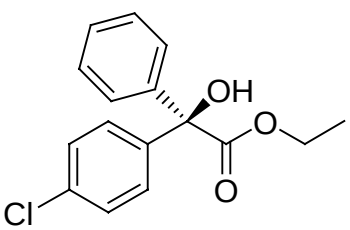
Yellow solid, 45% yield, mp 77–79 °C. ^{1}H NMR ($CDCl_3$): δ 7.82 (d. *J* = 16 Hz, 1H), 7.59–7.57 (m, 2H), 7.46–7.31 (m, 9H), 5.35 (s, 2H). ^{13}C NMR ($CDCl_3$): δ 182.6, 162.1, 148.5, 134.7, 134.0, 131.6, 129.1, 129.0, 128.8, 128.7, 120.7, 67.9. EI-HRMS Calcd for $C_{17}H_{14}O_3$: 266.0943. Found: 266.0949.

(B) General Procedure for Asymmetric Addition of Arylboronic Acids to α-Ketoesters

A Schlenk tube was charged with $[RhCl(CH_2CH_2)_2]_2$ (1.2 mg, 0.006 mmol Rh) and (*S*)-**1c** (4.8 mg, 0.012 mmol) in nitrogen atmosphere. DCE (0.4 mL) and water (1.6 mL) were then added and the mixture was stirred at room temperature for 10 min. $ArB(OH)_2$ (0.4 mmol), LiF (13 mg, 0.4 mmol) and α-ketoester (0.2 mmol) were added sequentially and the mixture was stirred for appropriate time at given temperature. The mixture was extracted with CH_2Cl_2, and the extract was dried over $MgSO_4$, concentrated. The crude product was purified by chromatography on silica gel with petrol ether/ethyl acetate. Enantiomeric excesses (ee) were determined by chiral HPLC analyses or SFC analyses.

(C) Analytical Data for the Addition Products

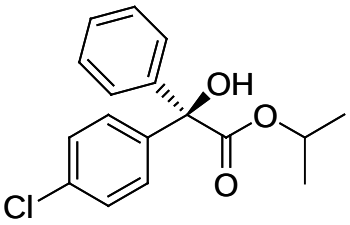
Ethyl 2-(4-chlorophenyl)-2-hydroxy-phenylacetate (4a)



Colorless oil, 96 % yield, 77 % ee. $[\alpha]_D^{20}$ = –16.7 (*c* 2.4, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.40–7.29 (m, 9H), 4.35–4.28 (m, 2H), 1.27 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR ($CDCl_3$): δ 174.2, 141.9, 140.4, 133.9, 128.9, 128.2, 128.1, 127.1, 80.4, 63.1, 13.9. EI-MS m/z 290 (M^+). Anal. Calcd. for $C_{16}H_{15}ClO_3$: C, 66.10; H, 5.20. Found: C, 66.35; H, 5.01. HPLC conditions: Daicel Chiralpak AD-H column (25 cm × 0.46 cm ID), *n*-hexane/*i*-

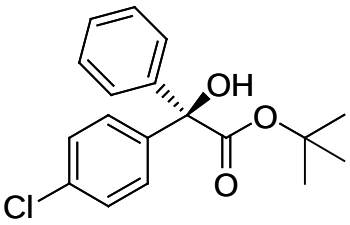
PrOH = 90:10, 1.0 mL/min, 230 nm; t_R = 13.31 min (minor) and 15.33 min (major).

Isopropyl 2-(4-chlorophenyl)-2-hydroxy-phenylacetate (4b)



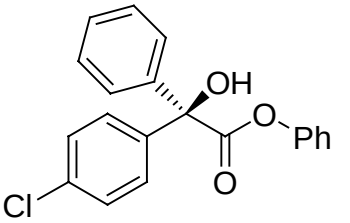
Colorless oil, 93 % yield, 80 % ee. $[\alpha]_D^{22}$ = –15.8 (*c* 2.4, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.41–7.29 (m, 9H), 5.19–5.11 (m, 1H), 4.38 (s, 1H), 1.27–1.23 (m, 6H). ^{13}C NMR ($CDCl_3$): δ 173.7, 142.1, 140.7, 134.0, 129.1, 128.4, 128.3, 128.2, 127.4, 80.5, 71.6, 21.7. EI-HRMS Calcd for $C_{17}H_{17}ClO_3$: 304.0866. Found: 304.0872. HPLC conditions: Daicel Chiralpak AD-H column (25 cm × 0.46 cm ID), *n*-hexane/*i*-PrOH = 90:10, 1.0 mL/min, 230 nm; t_R = 14.46 min (minor) and 15.99 min (major).

***tert*-Butyl 2-(4-chlorophenyl)-2-hydroxy-phenylacetate (4c)**



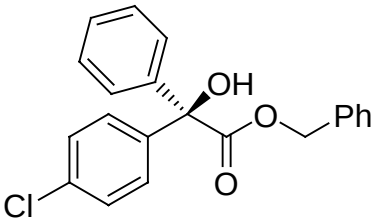
Colorless oil, 51 % yield, 70 % ee. $[\alpha]_D^{20}$ = –12.4 (*c* 0.7, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.41–7.25 (m, 9H), 4.35 (s, 1H), 1.45 (s, 9H). ^{13}C NMR ($CDCl_3$): δ 173.0, 142.2, 140.8, 133.9, 128.9, 128.7, 128.2, 128.1, 128.0, 127.2, 84.3, 80.4, 27.8. EI-HRMS Calcd for $C_{18}H_{19}ClO_3$: 318.1023. Found: 318.1027. SFC conditions: Daicel Chiralpak AD-H column (25 cm × 0.46 cm ID), sc CO_2/*i*-PrOH = 90:10, P_{CO2} = 100 bar, 2.0 mL/min, oven 40 °C, UV detector (210 nm) t_R = 8.9min (minor) and 9.5 min (major).

Phenyl 2-(4-chlorophenyl)-2-hydroxy-phenylacetate (4d)



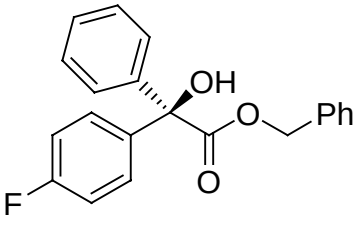
Colorless oil, 90 % yield, 72 % ee. $[\alpha]_D^{22}$ = –16.5 (*c* 2.4, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.54–7.53 (m, 4H), 7.44–7.37 (m, 7H), 7.29–7.25 (m, 1H), 7.06 (d, *J* = 8.0 Hz, 2H), 4.24 (s, 1H). ^{13}C NMR ($CDCl_3$): δ 173.0, 150.6, 141.5, 140.0, 134.5, 129.8, 129.2, 128.8, 128.7, 128.6, 127.5, 126.8, 121.0, 81.1. EI-HRMS Calcd for $C_{20}H_{15}ClO_3$: 338.0710. Found: 338.0713. HPLC conditions: Daicel Chiralpak AD-H column (25 cm × 0.46 cm ID), *n*-hexane/*i*-PrOH = 98:2, 1.0 mL/min, 230 nm; t_R = 22.99 min (minor) and 25.94 min (major).

Benzyl 2-(4-chlorophenyl)-2-hydroxy-phenylacetate (4e)



White solid, mp 61–62 °C, 81 % yield, 90 % ee. $[\alpha]_D^{20}$ = –6.9 (*c* 1.0, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.37–7.21 (m, 14H), 5.29 (s, 2H), 4.25 (s, 1H). ^{13}C NMR ($CDCl_3$): δ 174.0, 141.8, 140.4, 134.8, 134.2, 129.2, 128.8, 128.8, 128.4, 128.3, 127.4, 80.8, 68.8. FAB-MS m/z 335 $[M–OH]^+$. Anal. Calcd. for $C_{21}H_{17}ClO_3$: C, 71.49; H, 4.68. Found: C, 71.37; H, 4.97. HPLC conditions: Daicel Chiralcel AS column (25 cm × 0.46 cm ID), *n*-hexane/*i*-PrOH = 97:3, 1.0 mL/min, 230 nm; t_R = 8.63 min (major) and 9.90 min (minor).

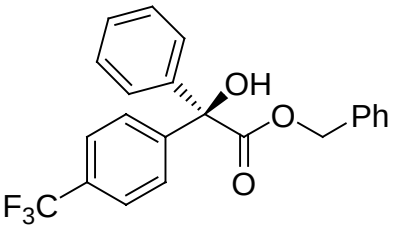
Benzyl 2-(4-fluorophenyl)-2-hydroxy-phenylacetate (4f)



Colorless oil, 84 % yield, 88 % ee. $[\alpha]_D^{22}$ = –10.3 (*c* 1.8, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.39–7.30 (m, 10H), 7.22–7.20 (m, 2H), 7.00–6.96 (m, 2H), 5.28 (s, 2H), 4.22 (s, 1H). ^{13}C NMR ($CDCl_3$): δ 174.0, 164.0, 160.8, 141.8, 137.8, 134.6, 129.4, 129.3, 128.5, 128.1, 127.2, 114.9, 114.7, 80.6, 68.4. EI-

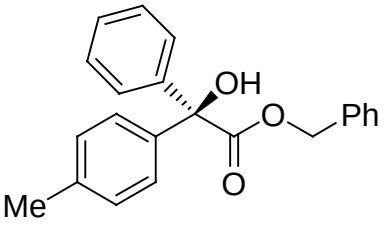
HRMS Calcd for $C_{21}H_{17}FO_3$: 336.1162. Found: 336.1158. HPLC conditions: Daicel Chiralcel AS column (25 cm × 0.46 cm ID), *n*-hexane/*i*-PrOH = 95:5, 1.0 mL/min, 230 nm; t_R = 10.63 min (major) and 13.68 min (minor).

Benzyl 2-(4-trifluoromethylphenyl)-2-hydroxy-phenylacetate (4g)



White solid, mp 79-81 °C, 93 % yield, 91 % ee. $[\alpha]_D^{22}$ = –12.1 (*c* 2.3, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.62–7.57 (m, 4H), 7.34–7.22 (m, 10H), 5.31 (s, 2H), 4.32 (s, 1H). ^{13}C NMR ($CDCl_3$): δ 173.7, 146.7, 141.6, 134.7, 128.9, 128.8 128.6, 128.5, 128.4, 128.2, 127.4, 125.2, 125.2, 81.0, 68.9. EI-MS m/z 386 (M^+). Anal. Calcd. for $C_{22}H_{17}F_3O_3$: C, 68.39; H, 4.43. Found: C, 68.33; H, 4.21. HPLC conditions: Daicel Chiralcel AS column (25 cm × 0.46 cm ID), *n*-hexane/*i*-PrOH = 98:2, 1.0 mL/min, 230 nm; t_R = 9.57 min (major) and 11.89 min (minor).

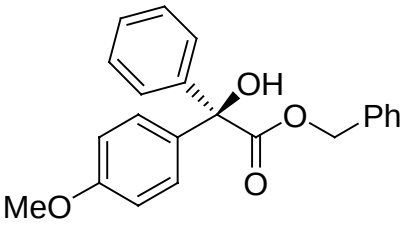
Benzyl 2-hydroxy-2-(4-methylphenyl)-phenylacetate (4h)



Colorless oil, 96 % yield, 84 % ee. $[\alpha]_D^{24}$ = +5.7 (*c* 1.2, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.32–6.99 (m, 14H), 5.16 (s, 2H), 4.06 (s, 1H), 2.23(s, 3H). ^{13}C NMR ($CDCl_3$): δ 174.4, 142.0, 139.1, 137.8, 134.9, 128.8, 128.5, 128.4, 128.1, 128.0, 127.5, 127.4, 81.0, 68.2, 21.1. FAB-MS m/z 315 $[M–OH]^+$. Anal. Calcd. for $C_{22}H_{20}O_3$: C, 79.50; H, 6.06. Found: C, 79.56; H, 6.15. HPLC conditions: Daicel Chiralcel AS column (25 cm × 0.46 cm ID), conditions: *n*-hexane/*i*-PrOH = 90:10, 1.0 mL/min, 230 nm; t_R = 11.53 min (minor) and 12.82 min (major).

The addition of 4-methylphenylboronic acid to benzyl 2-phenyl-2-oxoacetate gave product **4h** in 85% yield, 80% ee with a reverse configuration, $[\alpha]_D^{24}$ = –6.3 (*c* 1.4, $CHCl_3$).

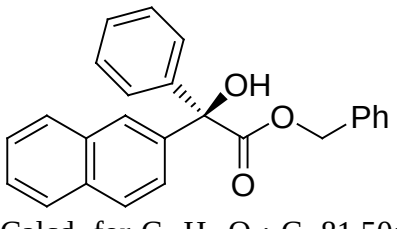
Benzyl 2-hydroxy-2-(4-methoxyphenyl)-phenylacetate (4i)



Colorless oil, 93 % yield, 86 % ee. $[\alpha]_D^{22}$ = +0.48 (*c* 3.5, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.38–7.21 (m, 12H), 6.82 (d, *J* = 11.6 Hz, 2H), 5.27 (s, 2H), 4.14 (s, 1H), 3.79 (s, 3H). ^{13}C NMR ($CDCl_3$): δ 174.4, 159.3, 142.1, 134.9, 134.1, 128.7, 128.5, 128.4, 128.1, 128.0, 127.4, 113.4, 80.8, 68.2, 55.2. EI-MS m/z 348 (M^+). Anal. Calcd. for $C_{22}H_{20}O_4$: C, 75.84; H, 5.79. Found: C, 75.62; H, 5.95. HPLC conditions: Daicel Chiralcel AS column (25 cm × 0.46 cm ID), *n*-hexane/*i*-PrOH = 95:5, 1.0 mL/min, 230 nm; t_R = 20.72 min (minor) and 23.01 min (major).

The addition of 4-methoxyphenylboronic acid to benzyl 2-(phenyl)-2-oxoacetate gave product **4i** 80% yield, 83% ee with a reverse configuration, $[\alpha]_D^{24}$ = –0.44 (*c* 3.4, $CHCl_3$).

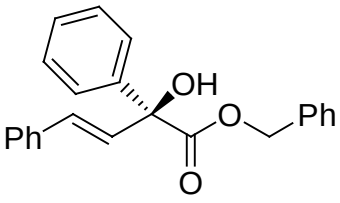
Benzyl 2-hydroxy-2-(naphthalen-2-yl)-phenylacetate (4j)



Colorless oil, 78 % yield, 80 % ee. $[\alpha]_D^{25}$ = +23.6 (*c* 1.5, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.87–7.71 (m, 4H), 7.51–7.44 (m, 5H), 7.35–7.25 (m, 8H), 5.36 (d, *J* = 13.6 Hz, 2H), 4.35 (s, 1H). ^{13}C NMR ($CDCl_3$): δ 174.2, 141.8, 139.2, 134.8, 132.9, 132.7, 128.6, 128.4, 128.3, 128.1, 127.8, 127.6, 127.5, 126.4, 126.2, 125.7, 81.2, 68.4. EI-MS m/z 368 (M^+). Anal. Calcd. for $C_{25}H_{30}O_3$: C, 81.50; H, 5.47. Found: C, 81.89; H, 5.25. HPLC conditions: Daicel

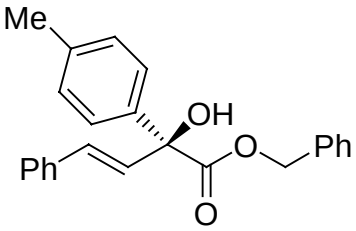
Chiralcel AS column (25 cm × 0.46 cm ID), *n*-hexane/*i*-PrOH = 95:5, 1.0 mL/min, 230 nm; t_R = 12.78 min (minor) and 14.59 min (major).

Benzyl 2-hydroxy-2-phenyl-4-phenylbut-3-enoate (6a)



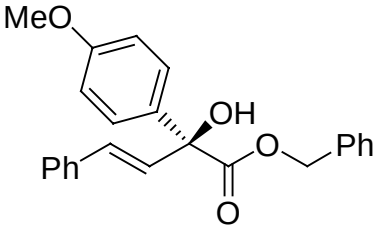
White solid, mp 87–89 °C, 70 % yield, 93 % ee. $[\alpha]_D^{25}$ = +40.9 (*c* 1.0, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.55 (d, *J* = 7.6 Hz, 2H), 7.42–7.25 (m, 13H), 6.96 (d, *J* = 16.0 Hz, 1H), 6.75 (d, *J* = 16.0 Hz, 1H), 5.27 (s, 2H), 4.03 (s, 1H). ^{13}C NMR ($CDCl_3$): δ 174.2, 141.5, 136.5, 135.1, 130.9, 129.2, 128.9, 128.7, 128.6, 128.4, 128.3, 128.1, 127.0, 126.4, 78.7, 68.5. EI-MS m/z 344 (M^+). Anal. Calcd. for $C_{23}H_{20}O_3$: C, 80.21; H, 5.85. Found: C, 79.97; H, 6.12. HPLC conditions: Daicel Chiralcel AS column (25 cm × 0.46 cm ID), *n*-hexane/*i*-PrOH = 95:5, 1.0 mL/min, 254 nm; t_R = 14.57 min (major) and 19.19 min (minor).

Benzyl 2-hydroxy-2-(4-methylphenyl)-4-phenylbut-3-enoate (6b)



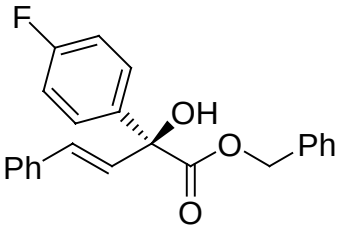
White solid, mp 74–76 °C, 77 % yield, 93 % ee. $[\alpha]_D^{25}$ = +27.2 (*c* 1.8, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.45–7.27 (m, 12H), 7.17 (d, *J* = 8.0 Hz, 2H), 6.96 (d, *J* = 15.6 Hz, 1H), 6.75 (d, *J* = 15.6 Hz, 1H), 5.28 (d, *J* = 6.4 Hz, 2H), 4.00 (s, 1H), 2.36 (s. 3H). ^{13}C NMR ($CDCl_3$): δ 174.1, 138.5, 137.9, 136.4, 135.0, 130.5, 129.2, 129.1, 128.5, 128.1, 127.9, 126.8, 126.1, 78.4, 68.2, 21.0. EI-MS m/z 358 (M^+). Anal. Calcd. for $C_{24}H_{22}O_3$: C, 80.42; H, 6.19. Found: C, 80.63; H, 5.98. HPLC conditions: Daicel Chiralpak AD-H column (25 cm × 0.46 cm ID), *n*-hexane/*i*-PrOH = 95:5, 1.0 mL/min, 254 nm; t_R = 17.43 min (major) and 24.81 min (minor).

Benzyl 2-hydroxy-2-(4-methoxyphenyl)-4-phenylbut-3-enoate (6c)



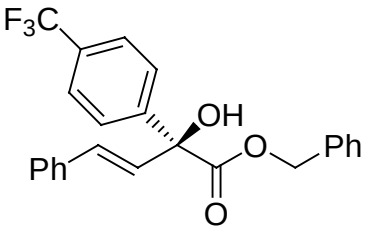
Colorless oil, 75 % yield, 90 % ee. $[\alpha]_D^{25}$ = +23.1 (*c* 1.7, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.50 (d, *J* = 8.8 Hz, 2H), 7.44 (d, *J* = 7.6 Hz, 2H), 7.37–7.29 (m, 8H), 6.98 (d, *J* = 16.0 Hz, 1H), 6.91 (d, *J* = 7.6 Hz, 2H), 6.78 (d, *J* = 16.0 Hz, 1H), 5.29 (s, 2H), 4.09 (s, 1H), 3.81 (s. 3H). ^{13}C NMR ($CDCl_3$): δ 174.2, 159.4, 136.4, 135.0, 133.6, 130.6, 129.3, 128.6, 128.5, 128.1, 127.9, 127.6, 126.9, 113.8, 78.2, 68.2, 55.3. EI-MS m/z 374 (M^+). Anal. Calcd. for $C_{24}H_{22}O_4$: C, 76.99; H, 5.92. Found: C, 76.78; H, 6.09. HPLC conditions: Daicel Chiralcel AS column (25 cm × 0.46 cm ID), *n*-hexane/*i*-PrOH = 90:10, 1.0 mL/min, 254 nm; t_R = 11.68 min (major) and 16.63 min (minor).

Benzyl 2-(4-fluorophenyl)-2-hydroxy -4-phenylbut-3-enoate (6d)



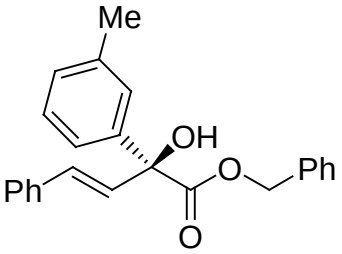
Colorless oil, 93 % yield, 92 % ee. $[\alpha]_D^{25}$ = +29.2 (*c* 1.5, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.54–7.50 (m, 2H), 7.41–7.25 (m,10H), 7.04–7.00 (m, 2H), 6.92 (d, *J* = 15.6 Hz, 1H), 6.70 (d, *J* = 15.6 Hz, 1H), 5.27 (s, 2H), 4.04 (s, 1H). ^{13}C NMR ($CDCl_3$): δ 174.0, 163.9, 161.5, 137.3, 136.3, 134.9, 131.1, 129.0, 128.9, 128.8, 128.5, 128.4, 128.3, 127.0, 115.5, 115.3, 78.2, 68.7. EI-MS m/z 362 (M^+). Anal. Calcd. for $C_{23}H_{19}FO_3$: C, 76.23; H, 5.28. Found: C, 76.55; H, 4.84. HPLC conditions: Daicel Chiralcel AS column (25 cm × 0.46 cm ID), *n*-hexane/*i*-PrOH = 90:10, 1.0 mL/min, 254 nm; t_R = 7.93 min (major) and 9.67 min (minor).

Benzyl 2-(4-trifluoromethylphenyl)-2-hydroxy-4-phenylbut-3-enoate (6e)



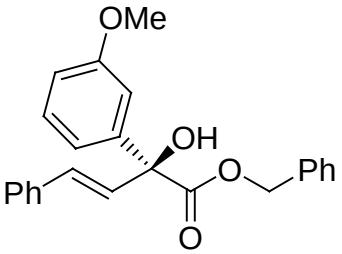
Colorless oil, 61 % yield, 90 % ee. $[\alpha]_D^{25}$ = +13.0 (*c* 1.3, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.67 (d, *J* = 8.0 Hz, 2H), 7.58 (d, *J* = 8.0 Hz, 2H), 7.38–7.27 (m, 10H), 6.92 (d, *J* = 16.0 Hz, 1H), 6.66 (d, *J* = 16.0 Hz, 1H), 5.25 (s, 2H), 4.06 (s, 1H). ^{13}C NMR ($CDCl_3$): δ 173.3, 145.0, 135.9, 134.5, 131.3, 128.9, 128.8, 128.7, 128.6, 128.3, 128.2, 126.8, 126.7, 125.3, 125.2, 78.1, 68.7. EI-MS m/z 412 (M^+). Anal. Calcd. for $C_{24}H_{19}F_3O_3$: C, 69.90; H, 4.64. Found: C, 70.25; H, 4.31. HPLC conditions: Daicel Chiralpak AD-H column (25 cm × 0.46 cm ID), *n*-hexane/*i*-PrOH = 95:15, 1.0 mL/min, 254 nm; t_R = 15.67 min (major) and 20.02 min (minor).

Benzyl 2-hydroxy-2-(3-methylphenyl)-4-phenylbut-3-enoate (6f)



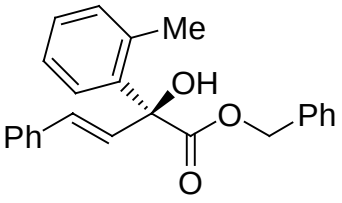
Colorless oil, 75 % yield, 91 % ee. $[\alpha]_D^{25}$ = +22.1 (*c* 1.0, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.41–7.09 (m, 14H), 6.93 (d, *J* = 21.2 Hz, 1H), 6.71 (d, *J* = 21.2 Hz, 1H), 5.26 (s, 2H), 3.94 (s, 1H), 2.30 (s. 3H). ^{13}C NMR ($CDCl_3$): δ 174.2, 141.4, 138.3, 136.5, 135.1, 130.7, 129.2, 129.1, 128.9, 128.8, 128.7, 128.5, 128.3, 128.1, 127.1, 127.0, 123.5, 78.7, 68.4, 21.7. EI-MS m/z 358 (M^+). Anal. Calcd. for $C_{24}H_{22}O_3$: C, 80.42; H, 6.19. Found: C, 80.30; H, 6.13. HPLC conditions: Daicel Chiralpak AD-H column (25 cm × 0.46 cm ID), *n*-hexane/*i*-PrOH = 90:10, 1.0 mL/min, 254 nm; t_R = 14.49 min (major) and 16.88 min (minor).

Benzyl 2-hydroxy-2-(3-methoxyphenyl)-4-phenylbut-3-enoate (6g)



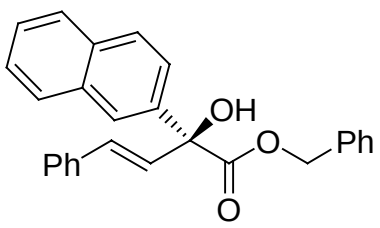
Colorless oil, 70 % yield, 93 % ee. $[\alpha]_D^{25}$ = +7.0 (*c* 1.0, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.40 (d, *J* = 7.2 Hz, 2H), 7.34–7.10 (m, 12H), 6.94 (d, *J* = 16.0 Hz, 1H), 6.72 (d, *J* = 16.0 Hz, 1H), 5.27 (s, 2H), 4.03 (s, 1H), 3.75 (s. 3H). ^{13}C NMR ($CDCl_3$): δ 174.1, 159.9, 136.5, 130.9, 129.6, 129.5, 129.3, 129.1, 128.7, 128.5, 128.3, 128.1, 127.8, 127.0, 118.8, 114.0, 112.0, 78.6, 68.5, 55.4. EI-HRMS Calcd for $C_{24}H_{22}O_4$: 374.1518. Found: 374.1516. HPLC conditions: Daicel Chiralcel AS column (25 cm × 0.46 cm ID), *n*-hexane/*i*-PrOH = 90:10, 1.0 mL/min, 254 nm; t_R = 12.38 min (major) and 16.30 min (minor).

Benzyl 2-hydroxy-2-(2-methylphenyl)-4-phenylbut-3-enoate (6h)



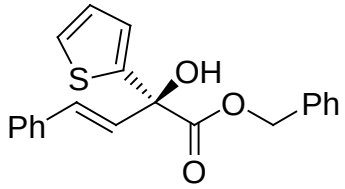
White solid, mp 101-103 °C, 92 % yield, 75 % ee. $[\alpha]_D^{25}$ = +57.8 (*c* 1.8, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.42–7.12 (m, 14H), 6.99 (d, *J* = 16.0 Hz, 1H), 6.69 (d, *J* = 16.0 Hz, 1H), 5.34–5.20 (m, 2H), 3.79 (br s, 1H), 2.27 (s, 3H). ^{13}C NMR ($CDCl_3$): δ 175.0, 138.9, 137.6, 136.4, 135.1, 132.2, 131.7, 129.9, 129.1, 128.8, 128.7, 128.5, 128.3, 127.1, 125.8, 79.7, 68.4, 20.2. EI-MS m/z 358 (M^+). Anal. Calcd. for $C_{24}H_{22}O_3$: C, 80.42; H, 6.19. Found: C, 80.34; H, 6.32. HPLC conditions: Daicel Chiralpak AD-H column (25 cm × 0.46 cm ID), *n*-hexane/*i*-PrOH = 90:10, 1.0 mL/min, 254 nm; t_R = 14.86 min (major) and 23.62 min (minor).

Benzyl 2-hydroxy-2-(naphthalen-2-yl)-4-phenylbut-3-enoate (6i)



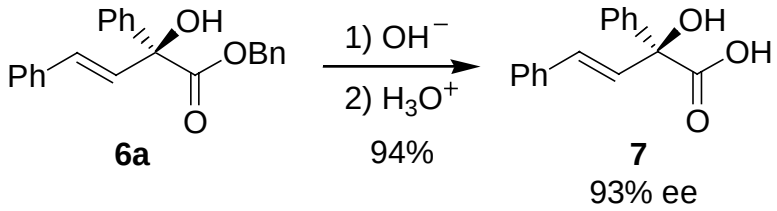
Colorless oil, 89 % yield, 90 % ee. $[\alpha]_D^{25}$ = +19.2 (*c* 1.2, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.98 (s, 1H), 7.84–7.78 (m, 3H), 7.64 (d, *J* = 8.8 Hz, 1H), 7.50-7.28 (m, 12H), 7.01 (d, *J* = 16.0 Hz, 1H), 6.84 (d, *J* = 16.0 Hz, 1H), 5.30 (s, 2H), 4.13 (s, 1H). ^{13}C NMR ($CDCl_3$): δ 174.2, 138.8, 136.5, 135.1, 133.3, 132.2, 131.2, 129.1, 128.8, 128.6, 128.4, 128.2, 127.7, 126.6, 126.4, 125.5, 124.4, 78.9, 68.6. EI-HRMS Calcd for $C_{27}H_{22}O_3$: 394.1569. Found: 394.1567. The ee was determined by HPLC analysis using Daicel Chiralcel AS column (25 cm × 0.46 cm ID), conditions: *n*-hexane/*i*-PrOH = 90:10, 1.0 mL/min, 254 nm; t_R = 13.14 min (major) and 20.03 min (minor).

Benzyl 2-hydroxy-4-phenyl 2-(thiophen-2-yl)-but-3-enoate (6j)



Colorless oil, 91 % yield, 88 % ee. $[\alpha]_D^{25}$ = +33.0 (*c* 1.1, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.39–7.25 (m, 12H), 7.17 (d, *J* = 3.6 Hz, 1H), 6.94 (d, *J* = 16.0 Hz, 1H), 6.65 (d, *J* = 16.0 Hz, 1H), 5.27 (s, 2H), 4.23 (s, 1H). ^{13}C NMR ($CDCl_3$): δ 173.0, 145.7, 136.0, 134.7, 130.5, 128.6, 128.1, 127.0, 126.9, 125.5, 125.0, 76.6, 68.7. EI-MS m/z 350 (M^+). Anal. Calcd. for $C_{21}H_{18}O_3S$: C, 71.98; H, 5.18. Found: C, 71.53; H, 5.32. HPLC conditions: Daicel Chiralcel AS column (25 cm × 0.46 cm ID), *n*-hexane/*i*-PrOH = 90:10, 1.0 mL/min, 254 nm; t_R = 9.39 min (major) and 13.88 min (minor).

(D) Hydrolysis of 6a



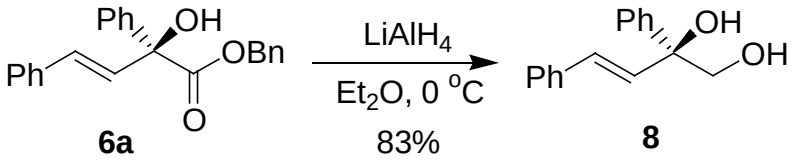
6a **7**

93% ee

Compound **6a** (0.12 g, 0.34 mmol) was hydrolyzed by refluxing in a NaOH solution (0.14 g NaOH, 2 mL H_2O, 6 mL MeOH) for 4 h. The reaction mixture was cooled to room temperature and acidified with diluted HCl acid, extracted with CH_2Cl_2. After removal of solvent the acid product **7** was obtained in 94% yield as a yellowish solid, mp 120–122 °C. $[\alpha]_D^{20}$ = +41.5 (*c* 1.7, acetone). ^{1}H NMR ($CDCl_3$): δ 7.61–7.59 (m, 2H), 7.44–7.25 (m, 8H), 6.97 (d, *J* = 16.0 Hz, 1H) 6.74 (d, *J* = 16.0 Hz, 1H). ^{13}C NMR ($CDCl_3$): δ 177.9, 162.3, 140.6, 136.0, 131.2, 128.6, 128.5, 128.1, 126.9, 126.1, 78.4. ESI-MS m/z 253 $[M–1]^-$. Anal. Calcd. for $C_{16}H_{14}O_3$: C, 75.57; H, 5.55. Found: C, 75.29; H, 5.85. The ee value of acid **7** (93% ee) was determined as **6a** after esterification with benzyl bromide and Cs_2CO_3 in DMF according to reported procedure.[3]

(E) Reduction of 6a

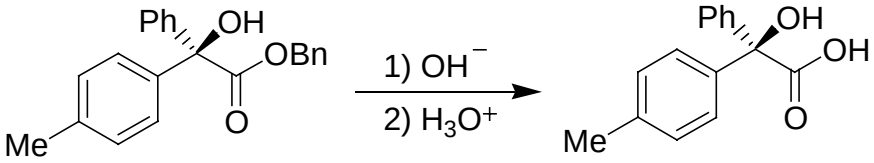
[3] J. P. Parrish, E. E. Dueno, S.-I. Kim, K. W. Jung, *Synth. Commun.*, **2000**, *30*, 2687.



6a

To a suspension of $LiAlH_4$ (55 mg, 1.44 mmol) in Et_2O (10 mL) was added compound **6a** (0.25 g, 0.72 mmol) in 5 mL Et_2O at 0 °C. The reaction mixture was stirred for 30 min, quenched carefully with water (5 mL), and extracted with ether. The extract was washed with brine, dried over $MgSO_4$ and concentrated under reduced pressure. Chromatography of crud product on silica gel with petrol ether/ethyl acetate (2/1) gave **8** in 83% yield as a white solid, mp 99–101 °C. $[\alpha]_D^{20}$ = +24.5 (*c* 1.7, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ 7.53–7.51 (m. 2H), 7.42–7.23 (m, 8H), 6.73 (d, *J* = 16.0 Hz, 1H) 6.49 (d, *J* = 16.0 Hz, 1H), 3.91–3.89 (m, 2H), 2.93 (s, 1H), 1.89 (br s, 1H). The ee value (93% ee) was determined by HPLC analysis using Daicel Chiralpak OD-H column (25 cm × 0.46 cm ID), conditions: *n*-hexane/*i*-PrOH = 80:20, 1.0 mL/min, 254 nm; t_R = 11.16 min (major) and 13.63 min (minor).

(F) Determination of the Absolute Configuration of 4h

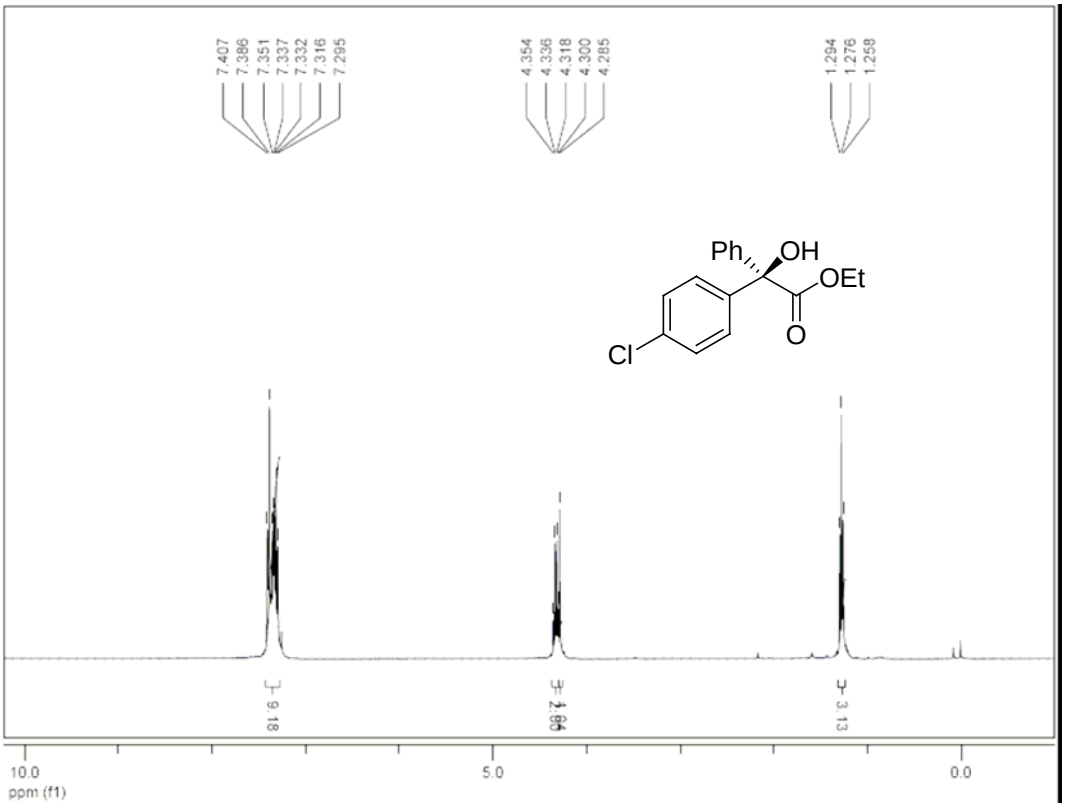


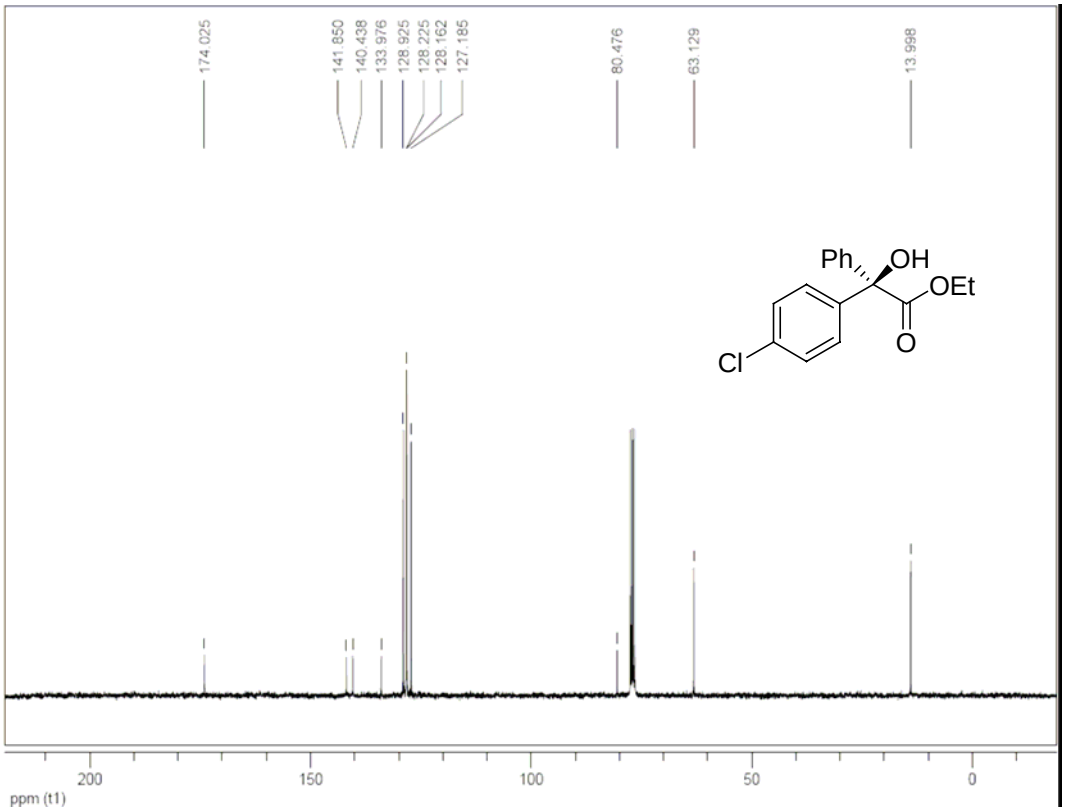
4h

Compound **4h** was hydrolyzed by the procedure described in D to give 2-hydroxy-2-phenyl-2-*p*-tolylacetic acid, mp 120–122 °C, $[\alpha]_D^{19}$ = +1.9 (*c* 5.0, 546 nm, EtOH). The absolute configuration was determined to be *R* by comparing with reported date ($[\alpha]_D^{19}$ = –2.4 (*c* 5.0, 546 nm, EtOH for *S* configuration). ref: A. I. Meyers, J. Slade, *J. Org. Chem.* **1980**, *45*, 2912–2914.

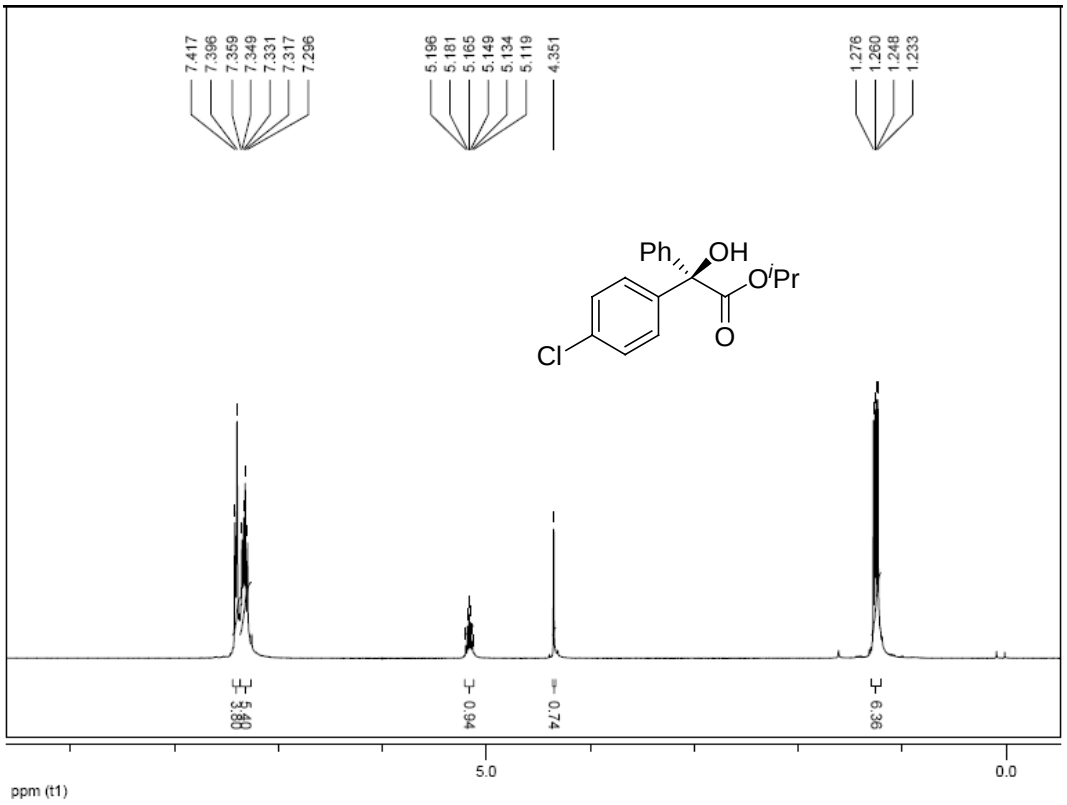
(G) NMR Spectra of Products

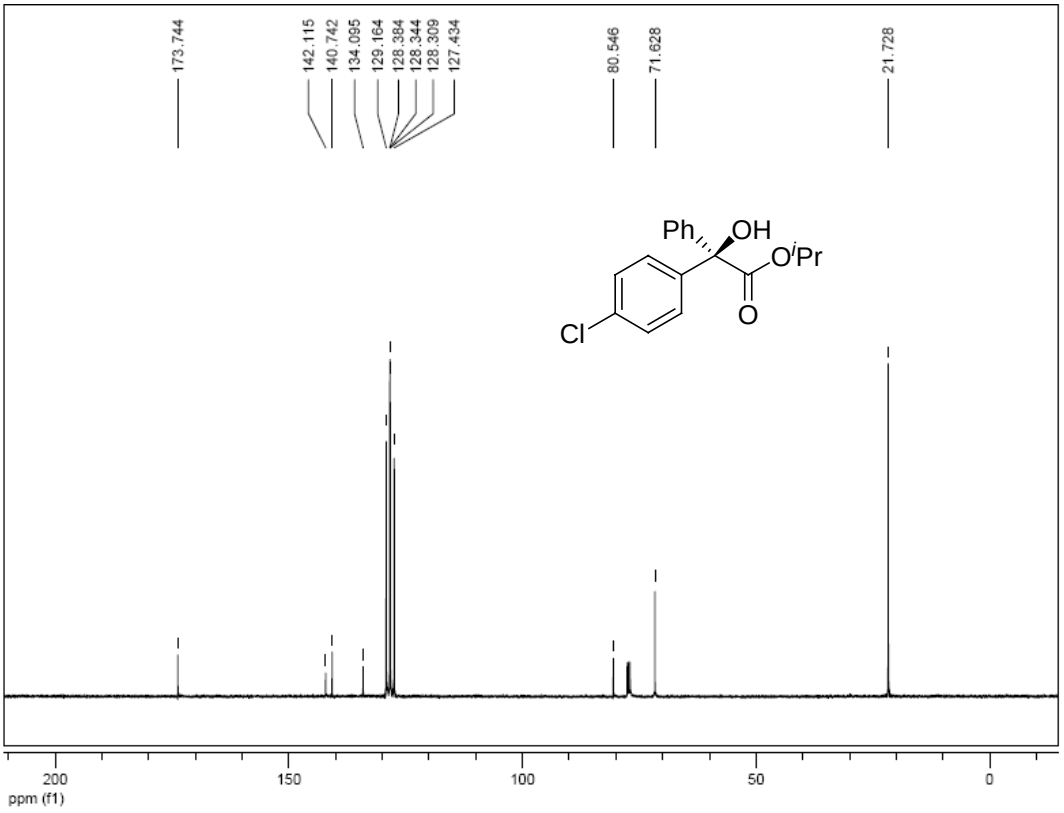
4a



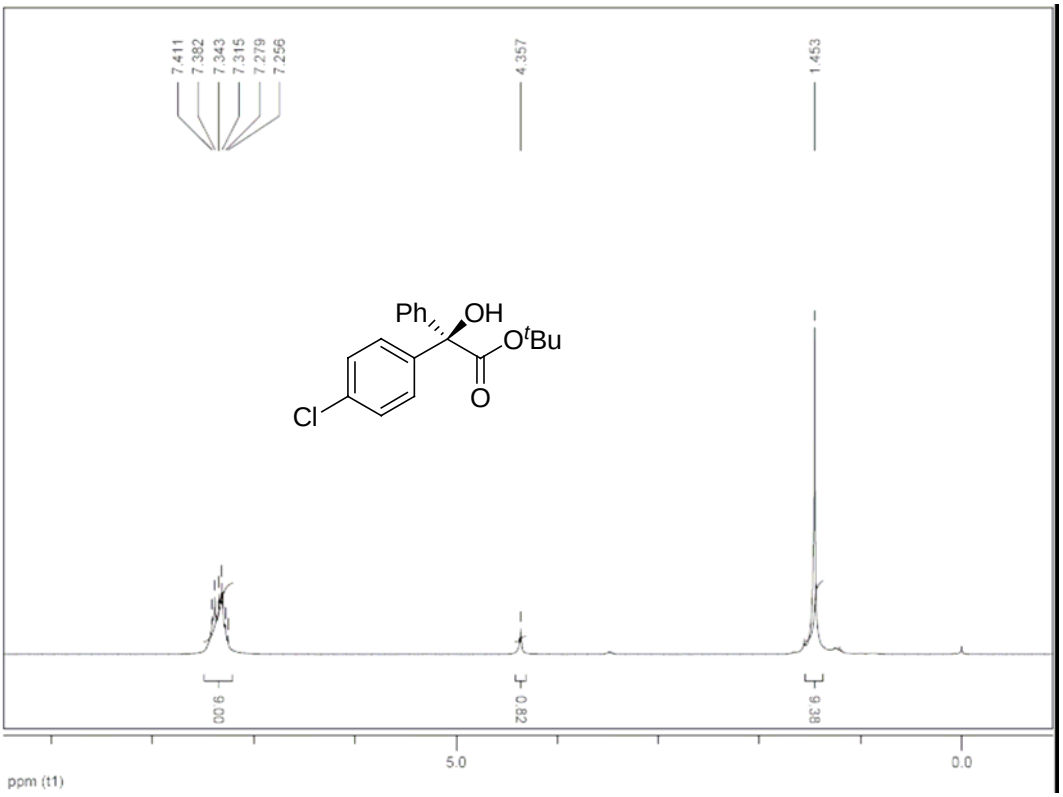


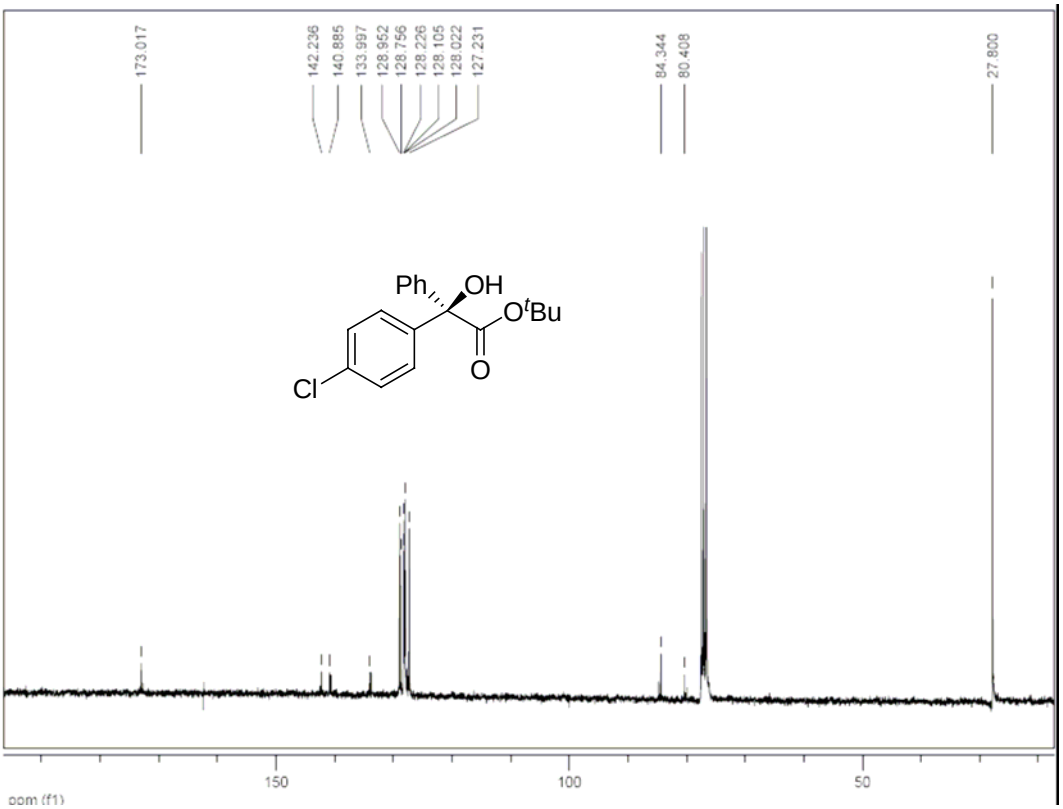
4b


7.417
7.396
7.359
7.349
7.331
7.317
7.296
5.196
5.181
5.165
5.149
5.134
5.119
4.351
1.276
1.260
1.248
1.233
Ph
OH
O^{i}Pr
O
Cl
5.40
0.94
0.74
6.36
5.0
0.0
ppm (t1)

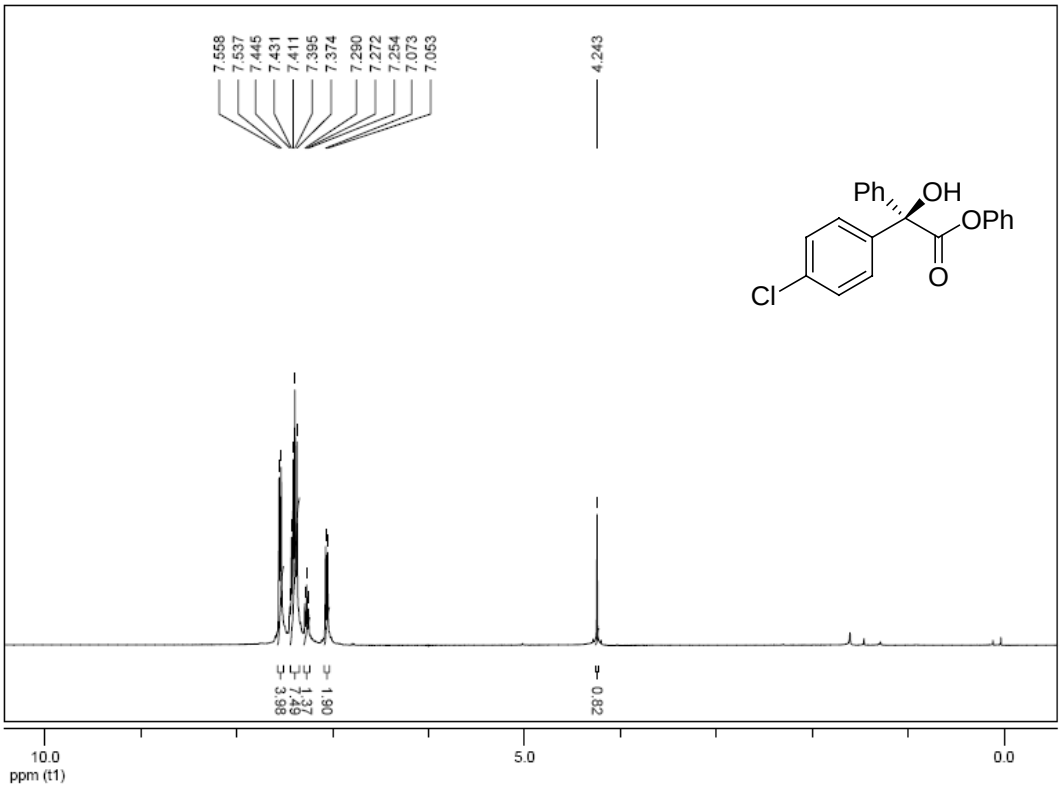

173.744
142.115
140.742
134.095
129.164
128.384
128.344
128.309
127.434
80.546
71.628
21.728
Ph
OH
O^{i}Pr
O
Cl
200
150
100
50
0
ppm (f1)

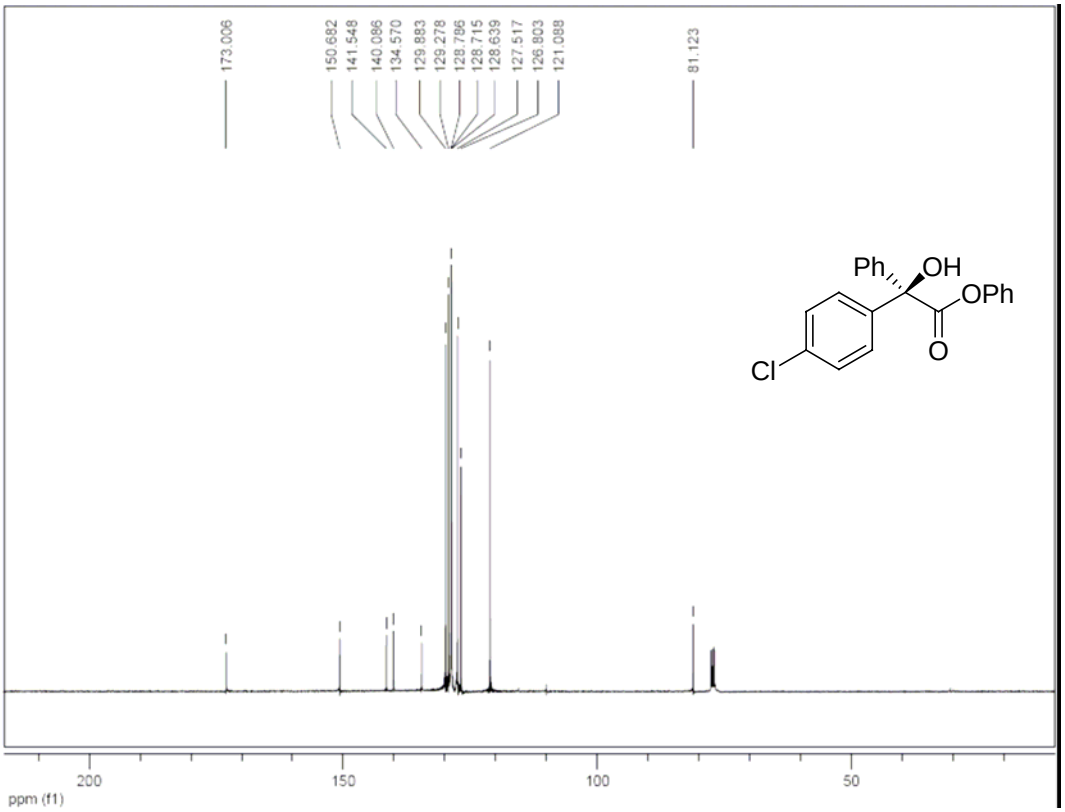
4c


7.411
7.382
7.343
7.315
7.279
7.256
4.357
1.453
Ph
OH
O^{t}Bu
O
Cl
9.00
0.82
9.38
5.0
0.0
ppm (t1)

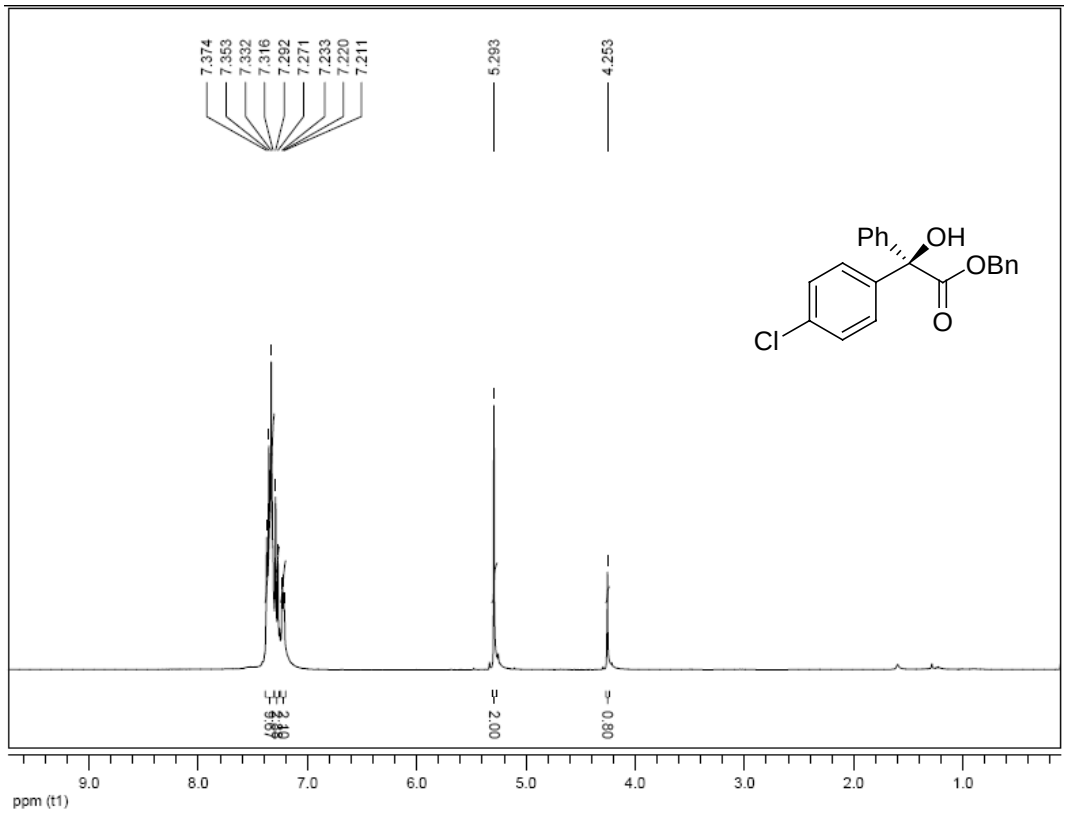

173.017
142.236
140.885
133.997
129.952
128.756
128.226
128.105
128.022
127.231
84.344
80.408
27.800
Ph
OH
O^{t}Bu
O
Cl
150
100
50
ppm (f1)

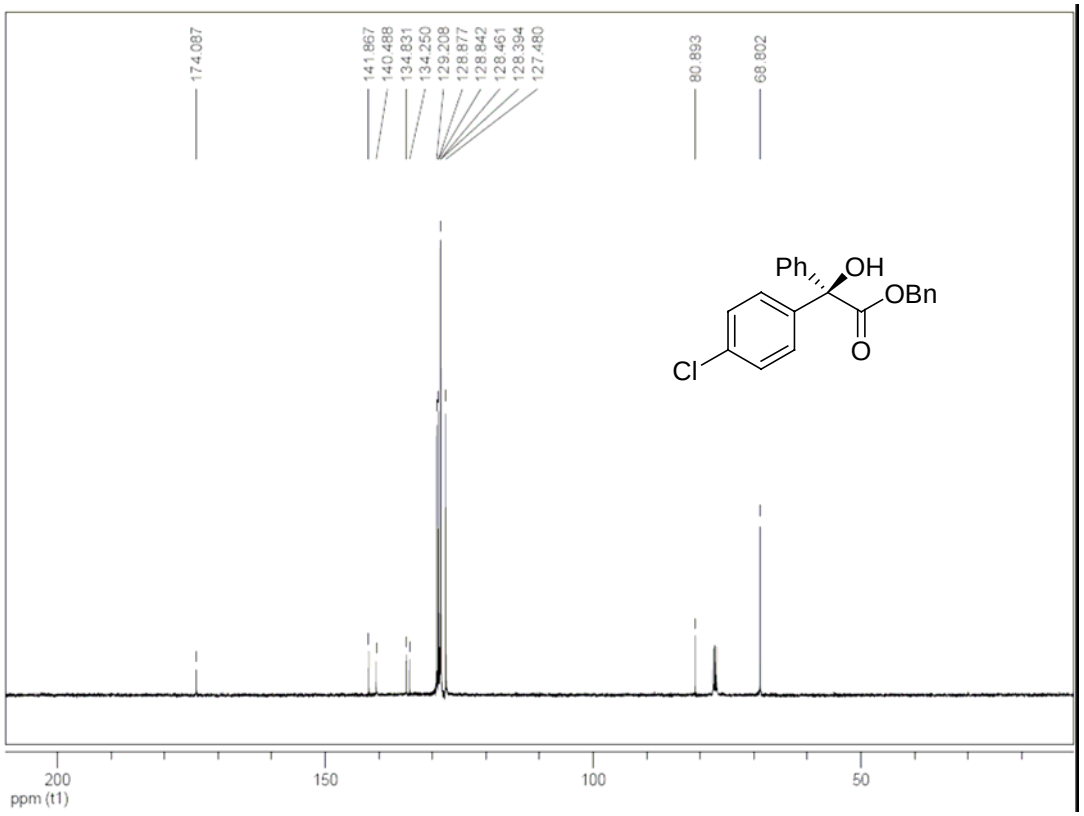
4d


7.558
7.537
7.445
7.431
7.411
7.396
7.374
7.290
7.272
7.254
7.073
7.053
4.243
Ph
OH
OPh
O
Cl
3.98
7.49
7.37
1.90
0.82
10.0
5.0
0.0
ppm (t1)

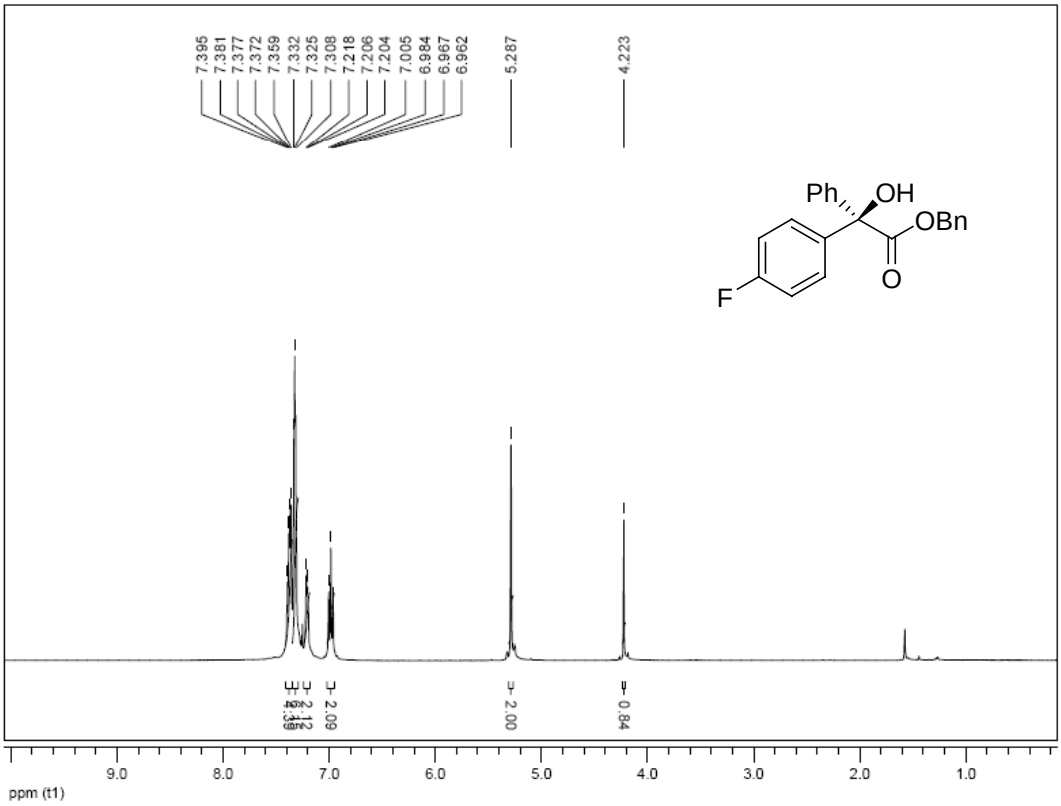

173.006
150.682
141.548
140.086
134.570
129.883
129.278
128.786
128.715
128.639
127.517
126.803
121.088
81.123
Ph
OH
OPh
O
Cl
200
150
100
50
ppm (f1)

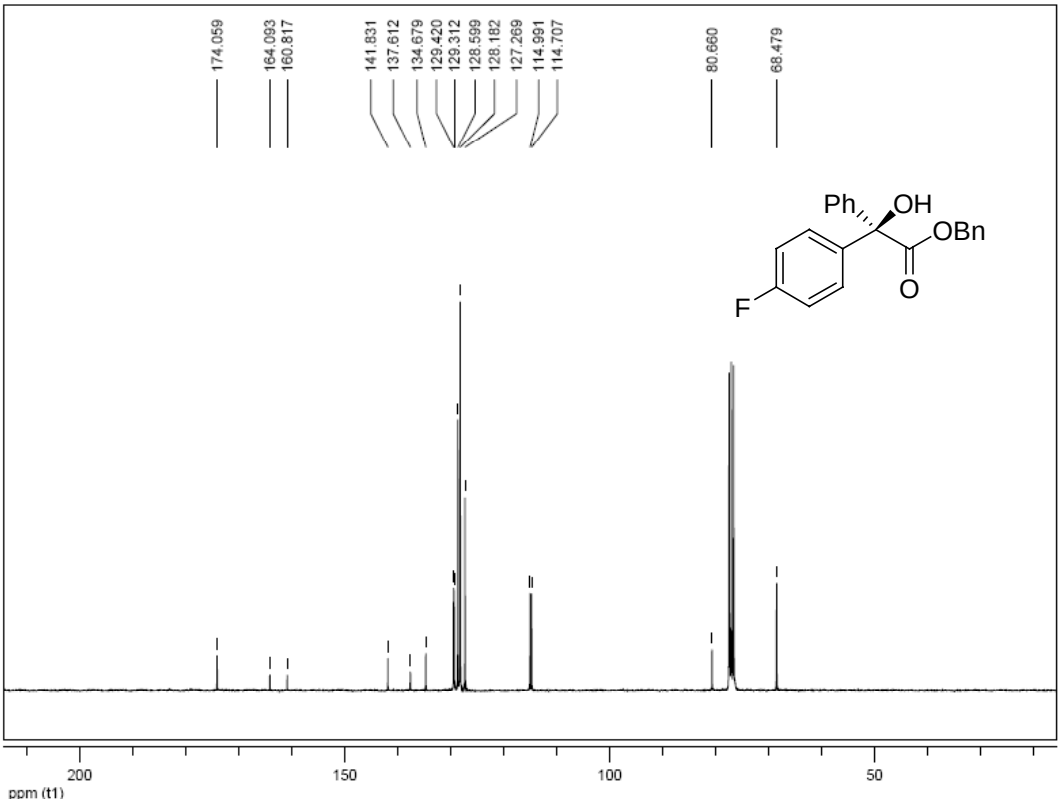
4e


7.374
7.353
7.332
7.316
7.292
7.271
7.233
7.220
7.211
5.293
4.253
Ph
OH
OBn
O
Cl
2.00
0.80
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
ppm (t1)

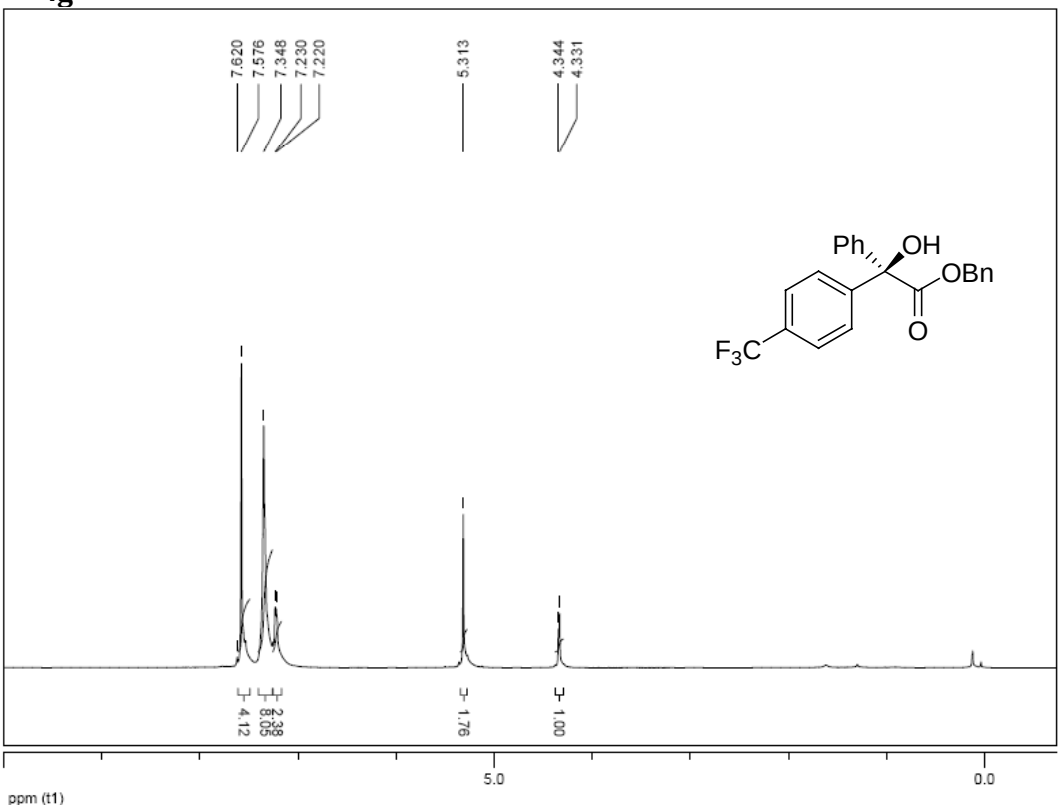

174.087
141.867
140.488
134.831
134.250
129.208
128.877
128.842
128.461
128.394
127.480
80.893
68.802
Ph
OH
OBn
O
Cl
200
150
100
50
ppm (t1)

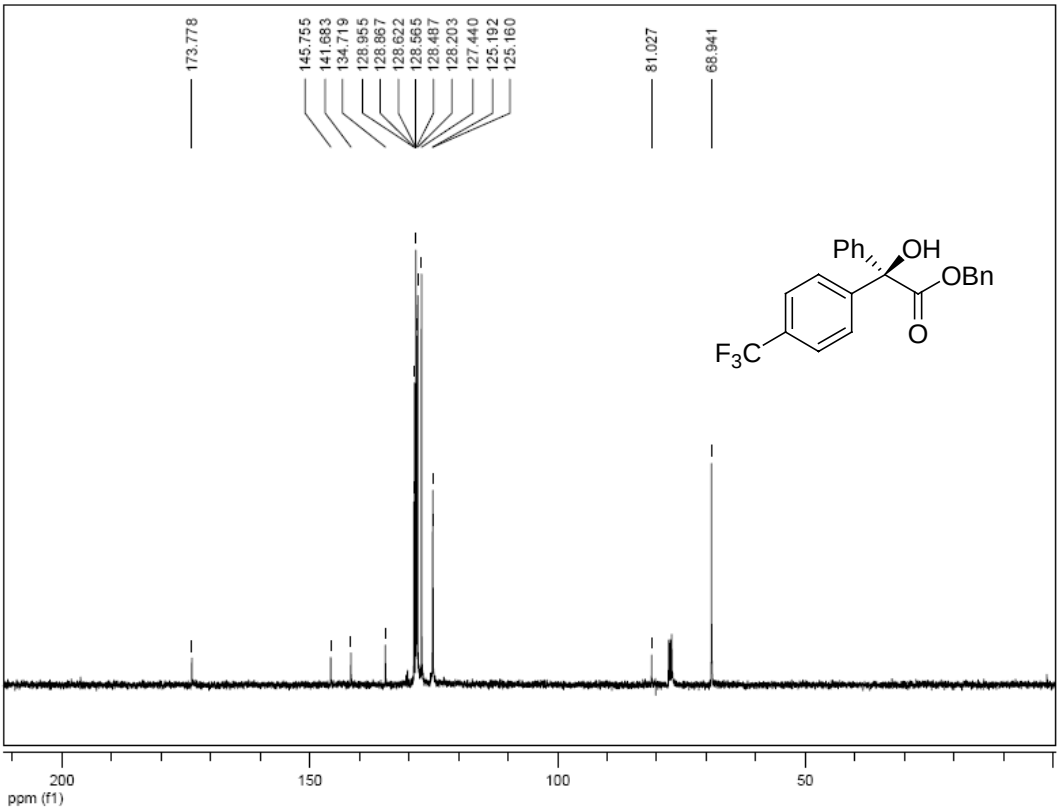
4f


7.396
7.381
7.377
7.372
7.359
7.332
7.325
7.308
7.218
7.206
7.204
7.005
6.984
6.967
6.962
5.287
4.223
Ph
OH
OBn
O
F
2.09
2.00
0.84
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
ppm (t1)

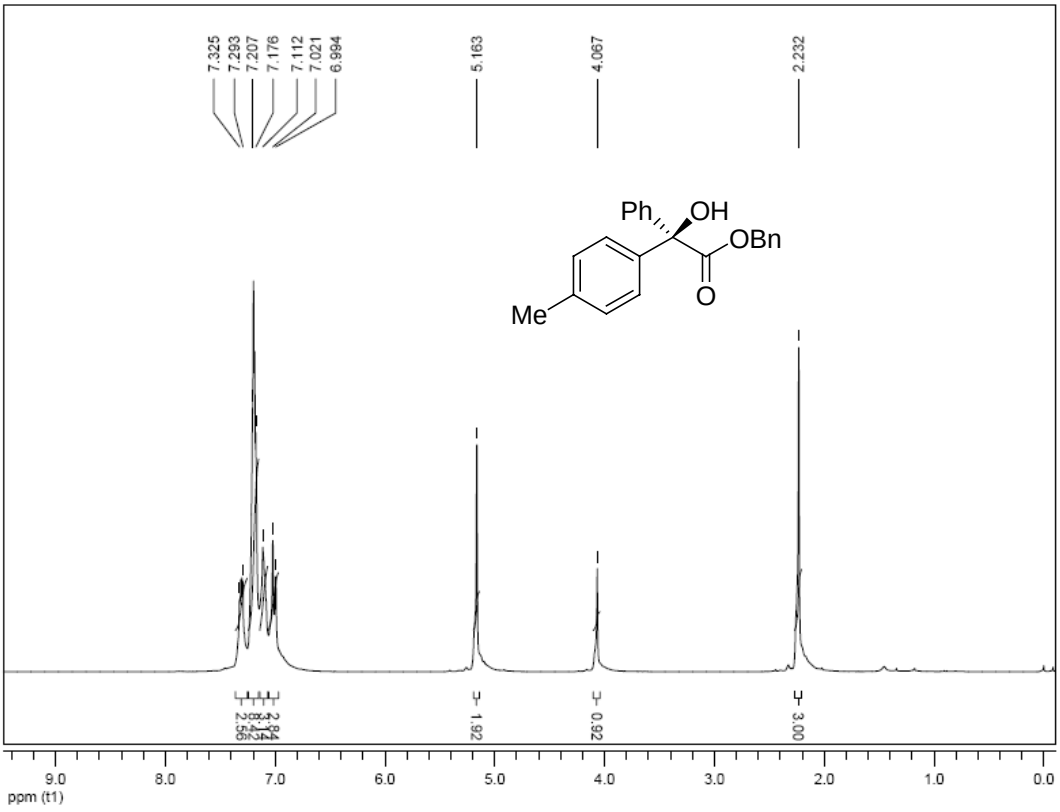

174.059
164.093
160.817
141.831
137.612
134.679
129.420
129.312
128.599
128.182
127.269
114.991
114.707
80.660
68.479
Ph
OH
OBn
O
F
200
150
100
50
ppm (t1)

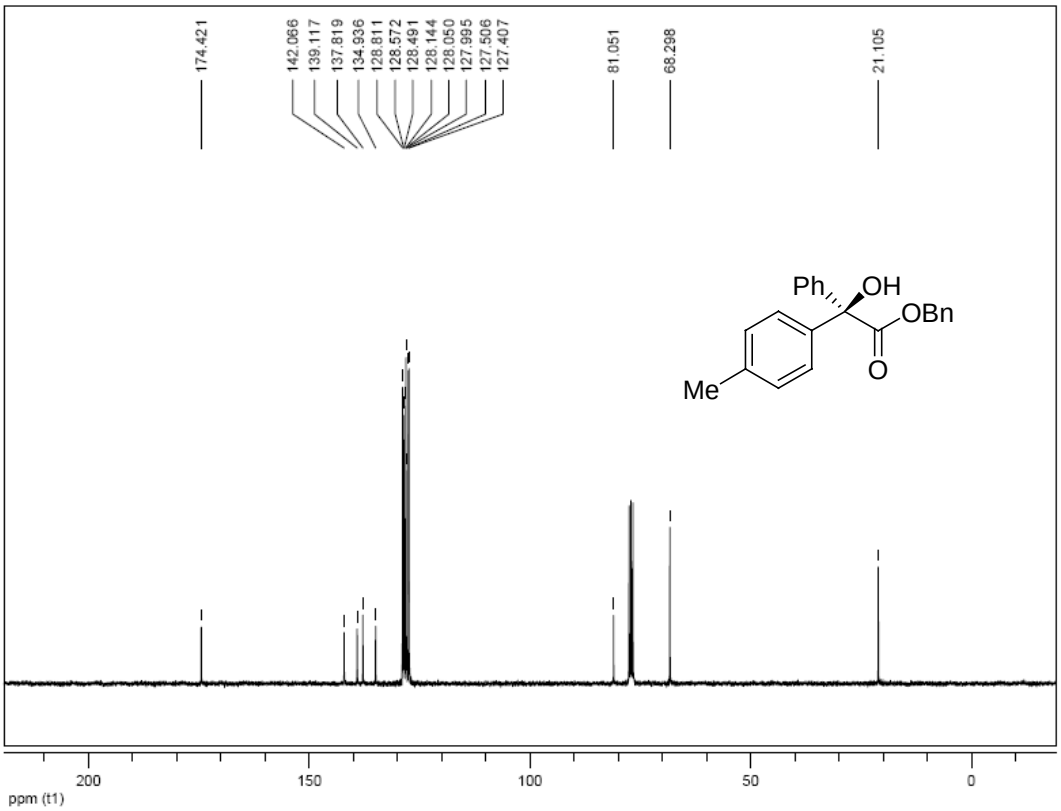
4g


7.620
7.576
7.348
7.230
7.220
5.313
4.344
4.331
Ph
OH
OBn
O
F3C
4.12
8.05
2.38
1.76
1.00
5.0
0.0
ppm (t1)

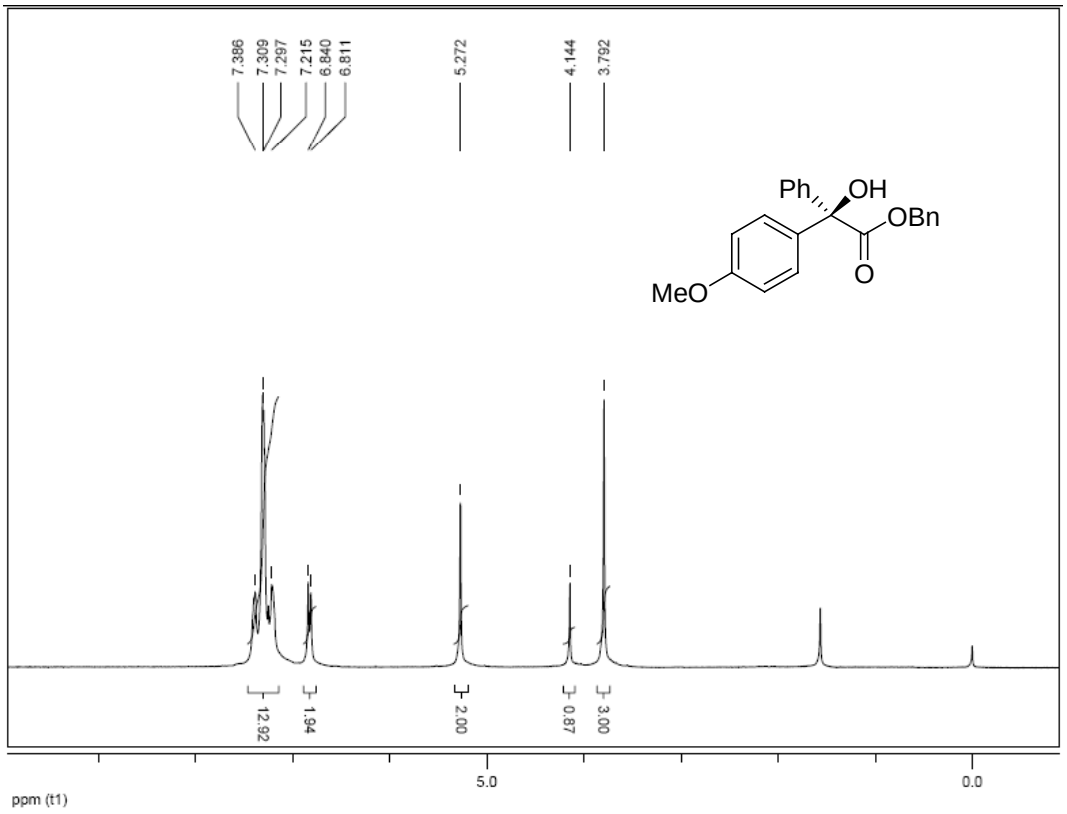

173.778
145.755
141.683
134.719
128.955
128.867
128.622
128.565
128.487
128.203
127.440
125.192
125.160
81.027
68.941
Ph
OH
OBn
O
F3C
200
150
100
50
ppm (f1)

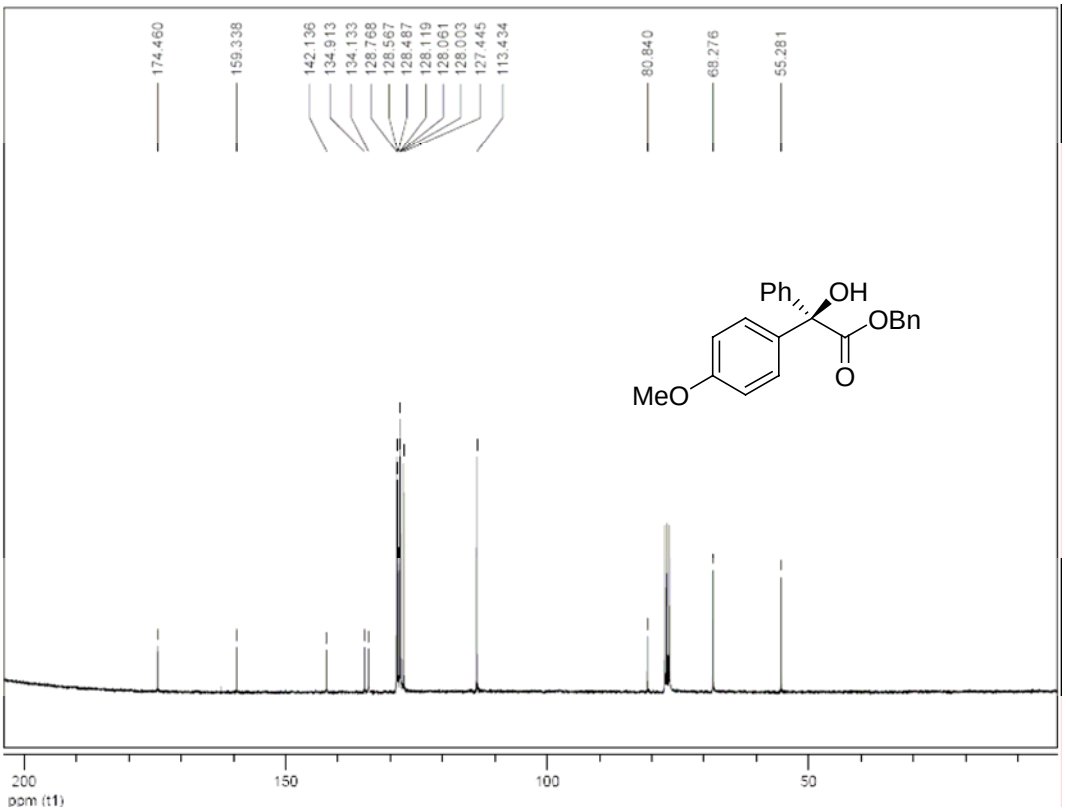
4h


7.325
7.293
7.207
7.176
7.112
7.021
6.994
5.163
4.067
2.232
Ph
OH
OBn
O
Me
1.92
0.92
3.00
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (t1)

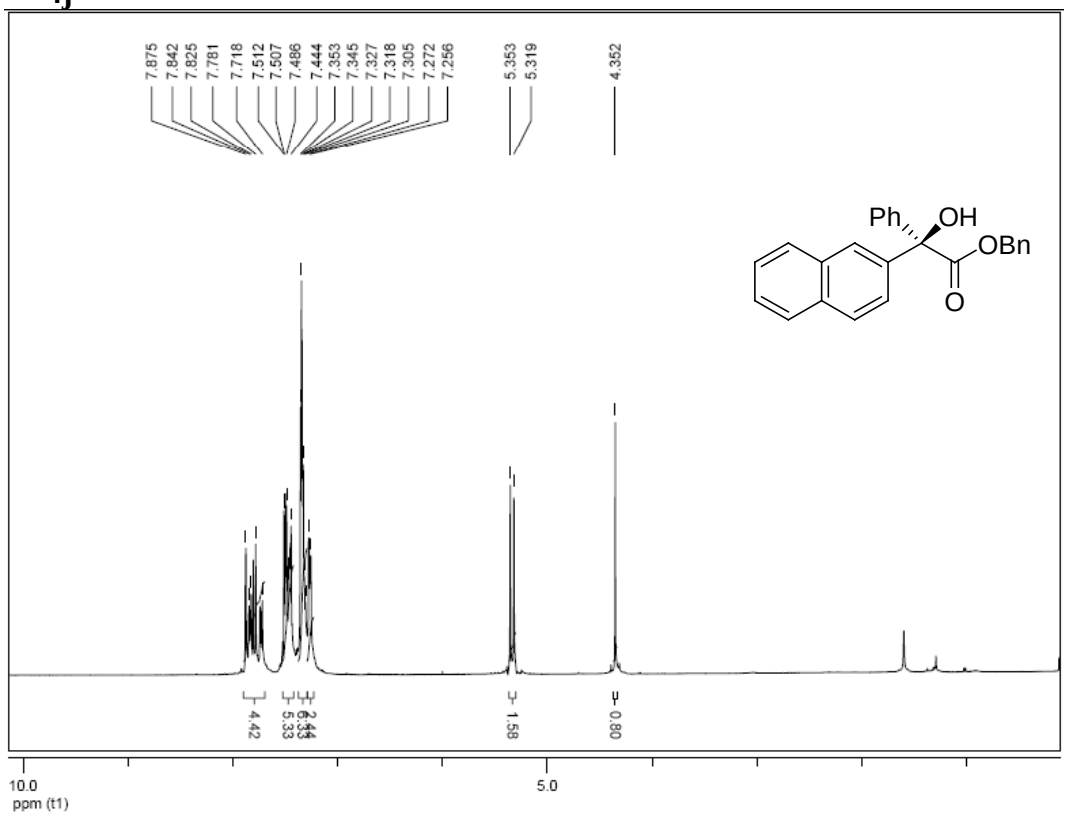

174.421
142.066
139.117
137.819
134.936
128.811
128.572
128.491
128.144
128.050
127.995
127.506
127.407
81.051
68.298
21.105
Ph
OH
OBn
O
Me
200
150
100
50
0
ppm (t1)

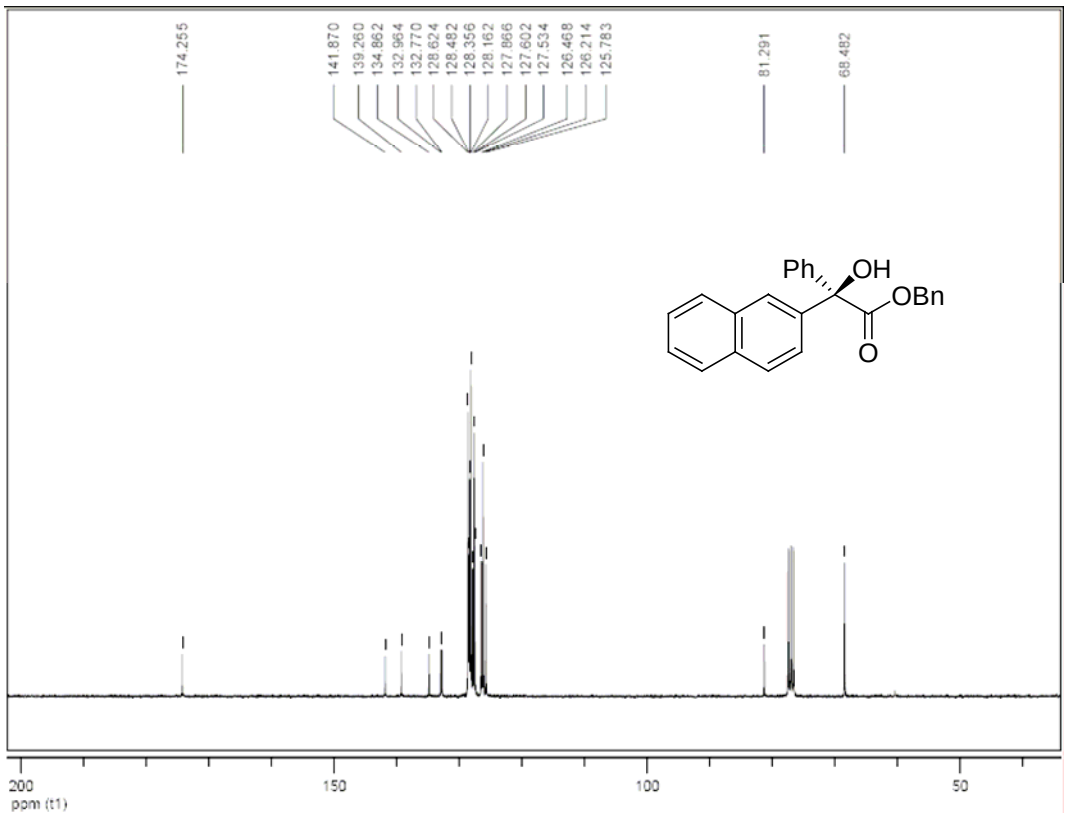
4i


7.386
7.309
7.297
7.215
6.840
6.811
5.272
4.144
3.792
Ph
OH
OBn
O
MeO
12.92
1.94
2.00
0.87
3.00
5.0
0.0
ppm (t1)

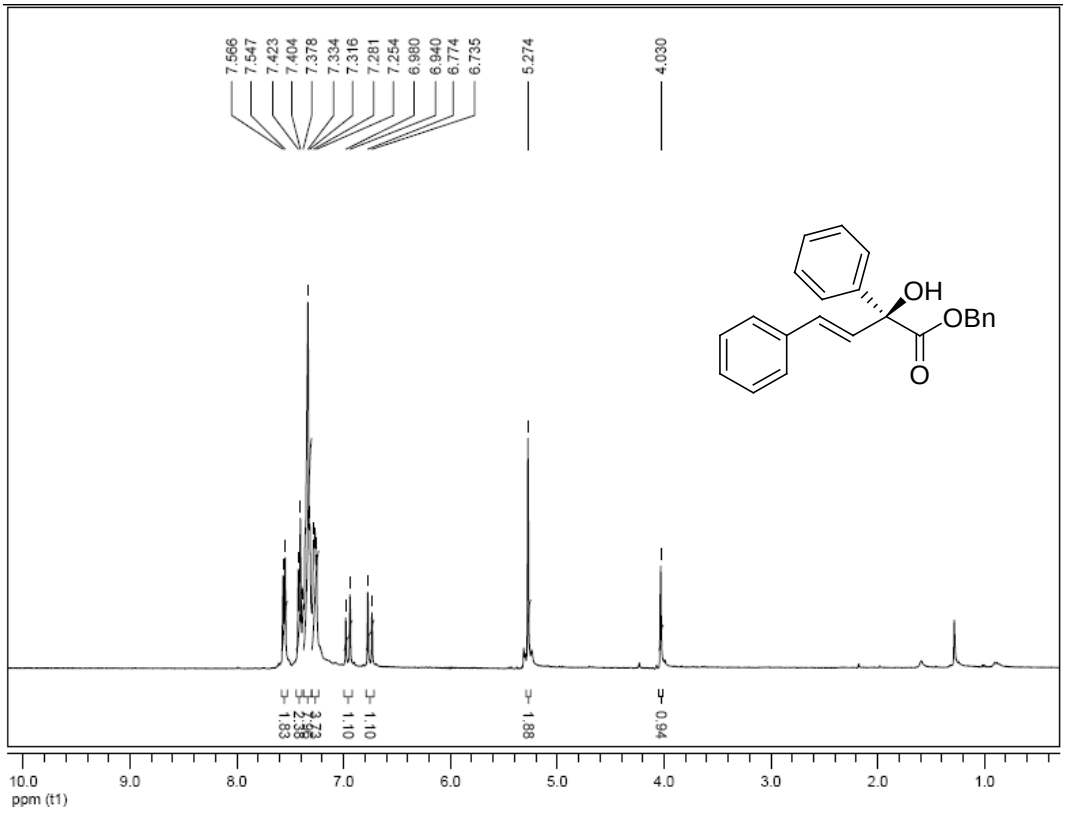

174.460
159.338
142.136
134.913
134.133
128.768
128.567
128.487
128.119
128.061
128.003
127.445
113.434
80.840
68.276
55.281
Ph
OH
OBn
O
MeO
200
150
100
50
ppm (t1)

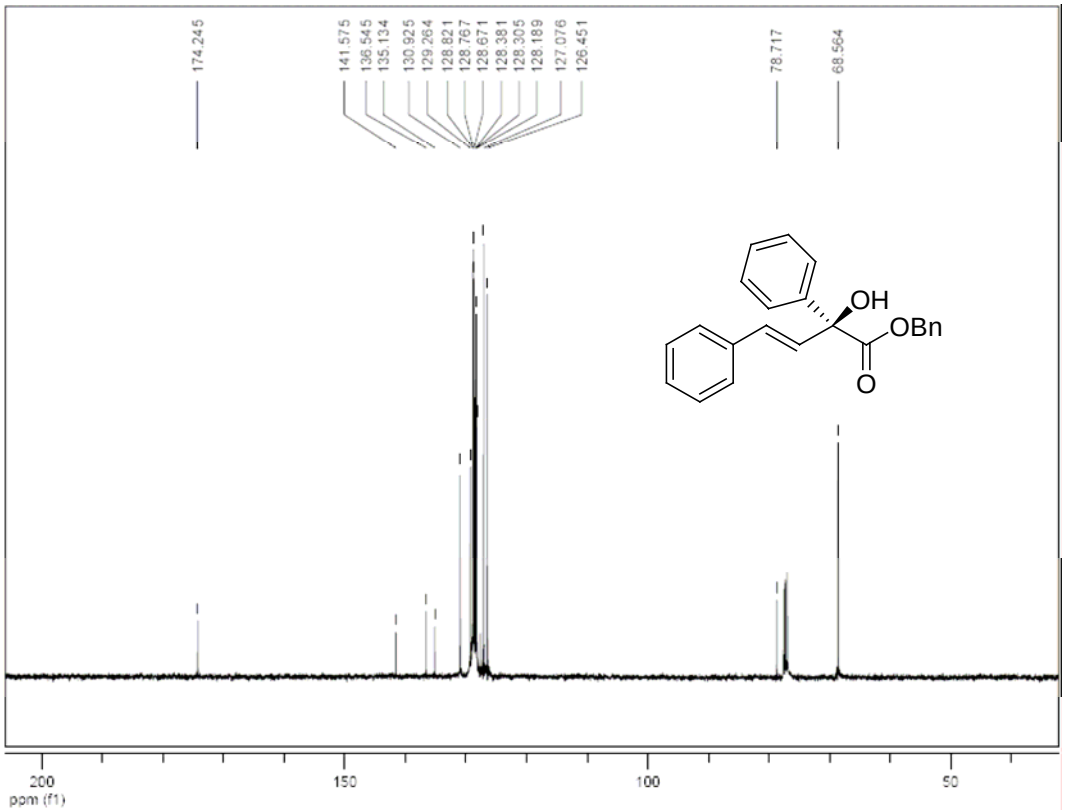
4j


7.875
7.842
7.825
7.781
7.718
7.512
7.507
7.486
7.444
7.353
7.345
7.327
7.318
7.305
7.272
7.256
5.353
5.319
4.352
Ph
OH
OBn
O
4.42
5.33
1.58
0.80
10.0
ppm (t1)
5.0

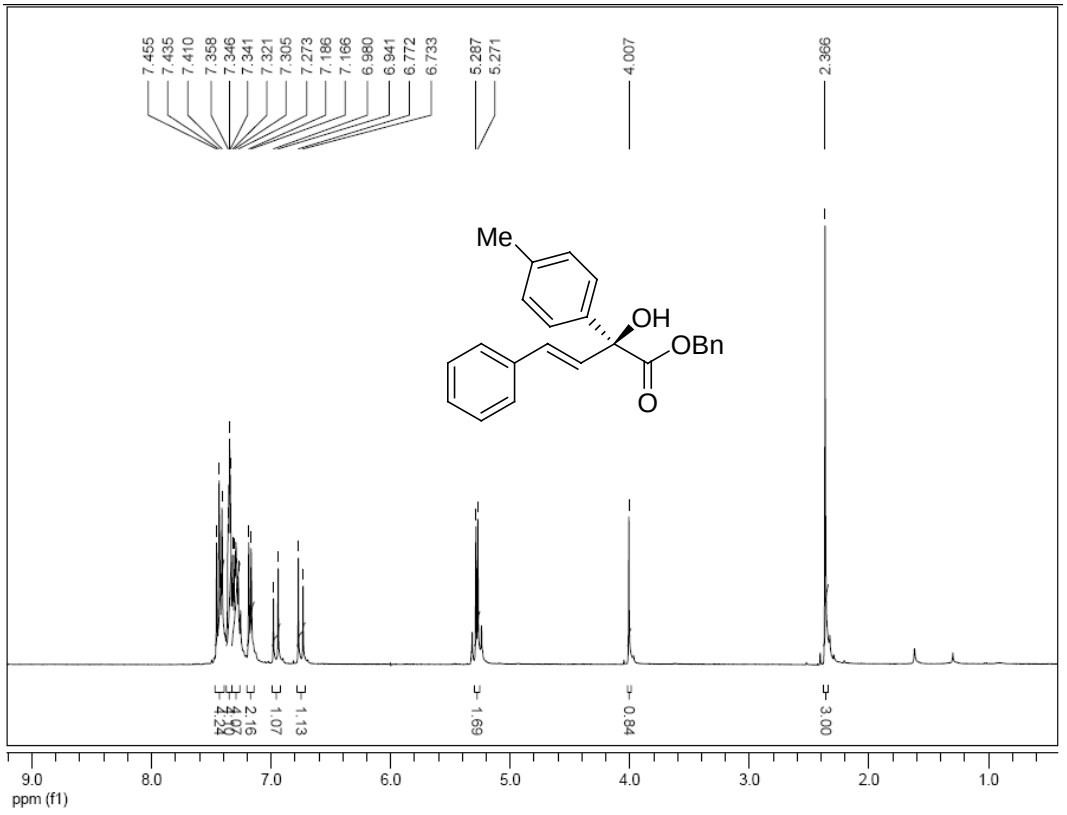

174.255
141.870
139.260
134.862
132.964
132.770
128.624
128.482
128.356
128.162
127.866
127.602
127.534
126.468
126.214
125.783
81.291
68.482
Ph
OH
OBn
O
200
ppm (t1)
150
100
50

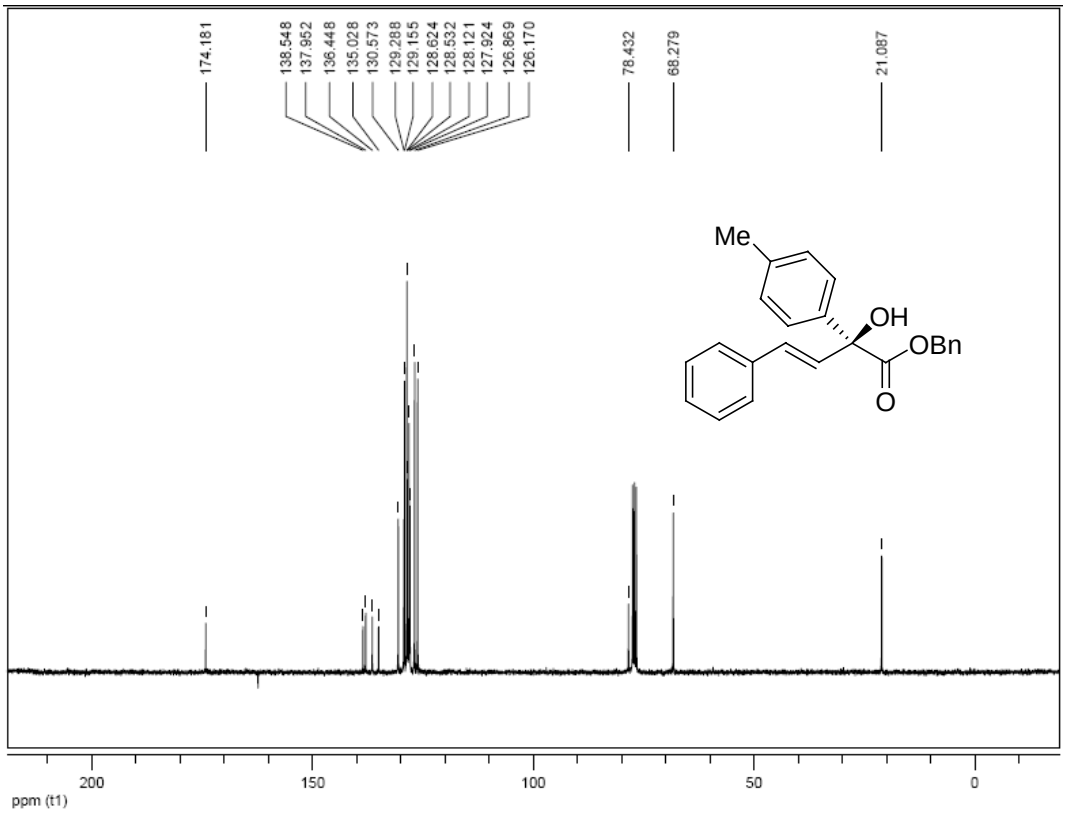
6a


7.566
7.547
7.423
7.404
7.378
7.334
7.316
7.281
7.254
6.980
6.940
6.774
6.735
5.274
4.030
1.83
2.78
3.28
1.10
1.10
1.88
0.94
OH
OBn
O
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
ppm (t1)

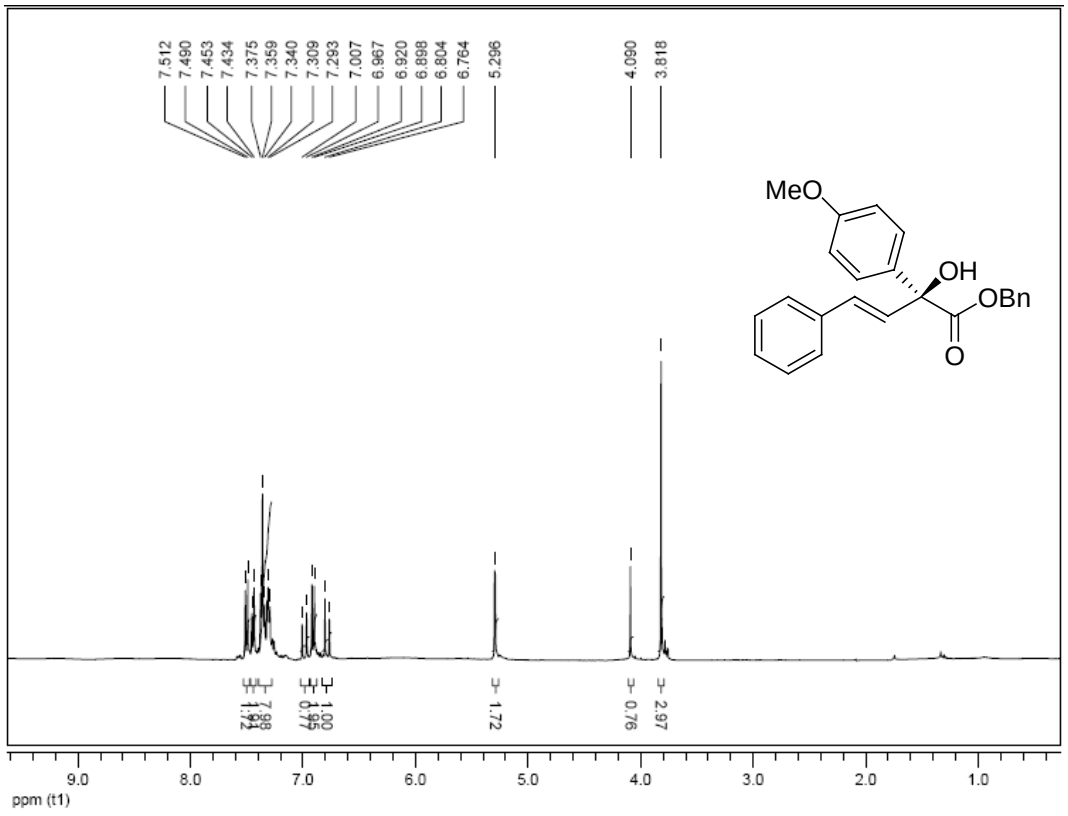

174.245
141.575
136.545
135.134
130.925
129.264
128.821
128.767
128.671
128.381
128.305
128.189
127.076
126.451
78.717
68.564
OH
OBn
O
200
150
100
50
ppm (f1)

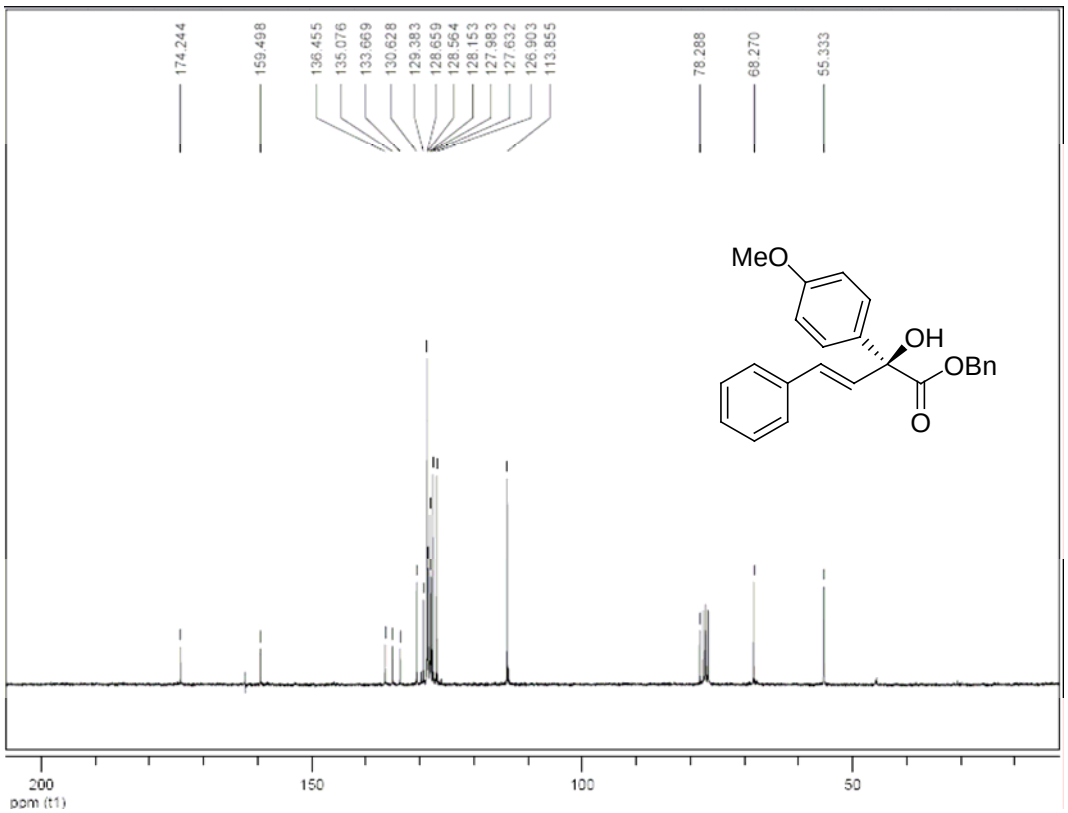
6b


7.455
7.435
7.410
7.358
7.346
7.341
7.321
7.305
7.273
7.186
7.166
6.980
6.941
6.772
6.733
5.287
5.271
4.007
2.366
Me
OH
OBn
O
4.24
4.07
2.16
1.07
1.13
1.69
0.84
3.00
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
ppm (f1)

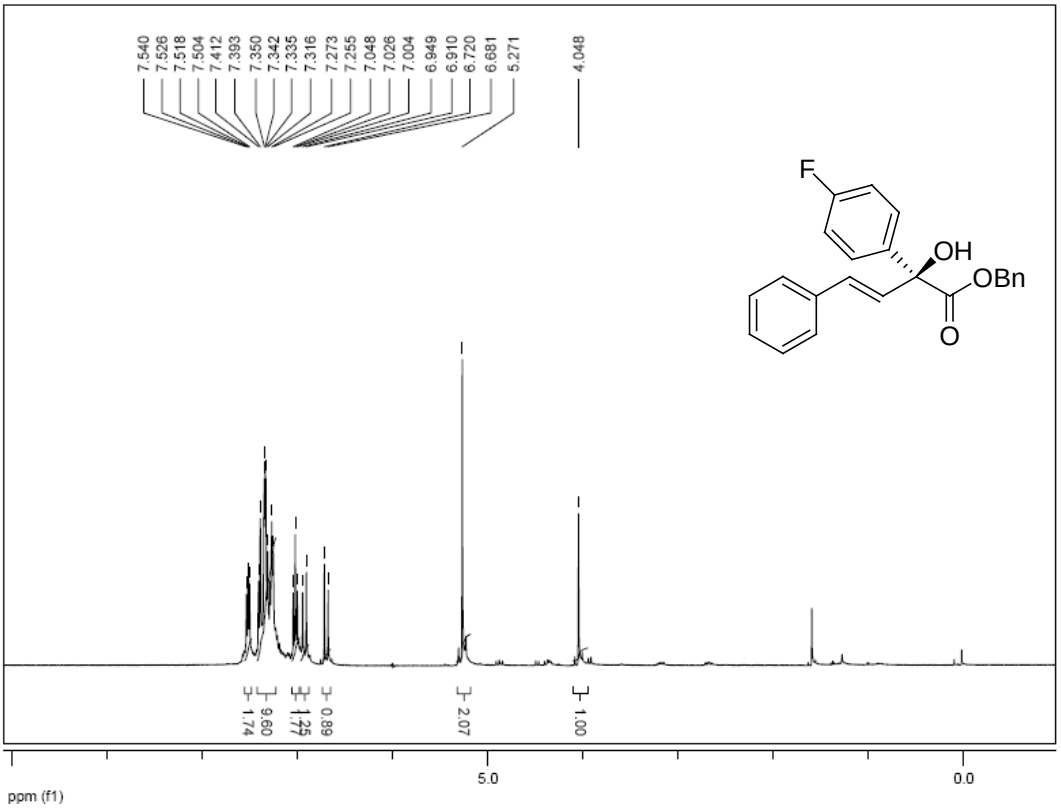

174.181
138.548
137.952
136.448
135.028
130.573
129.288
129.155
128.624
128.532
128.121
127.924
126.869
126.170
78.432
68.279
21.087
Me
OH
OBn
O
200
150
100
50
0
ppm (t1)

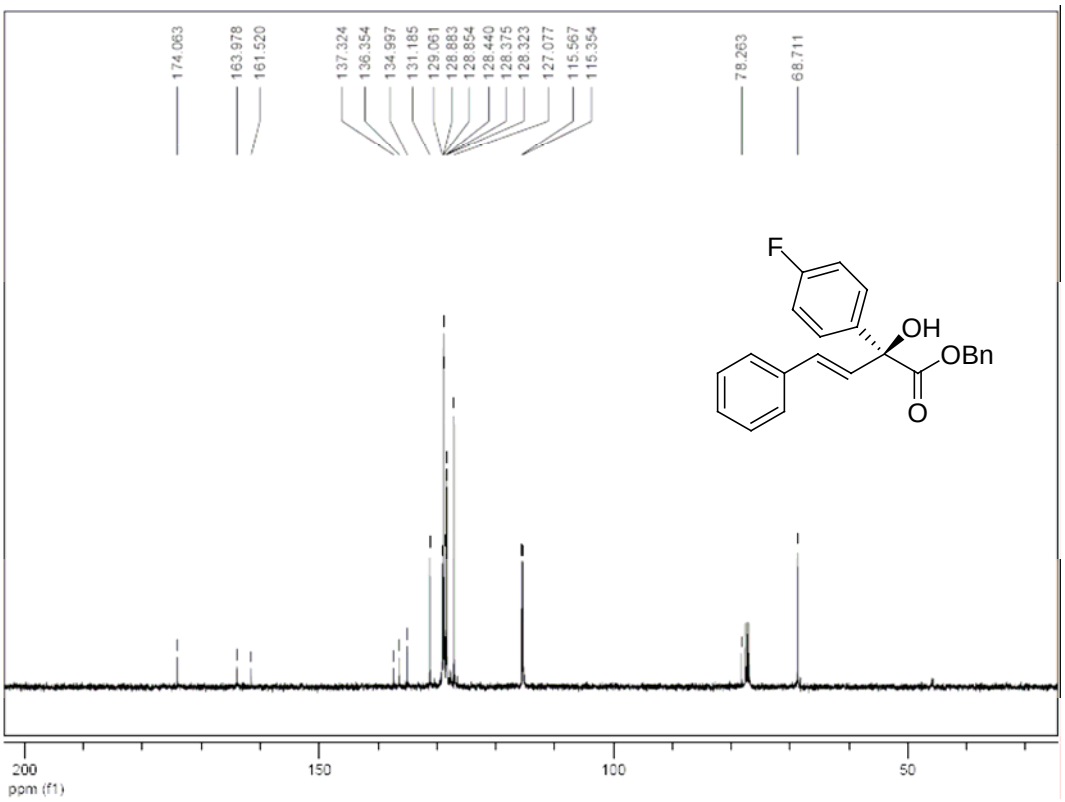
6c


7.512
7.490
7.453
7.434
7.375
7.359
7.340
7.309
7.293
7.007
6.967
6.920
6.898
6.804
6.764
5.296
4.090
3.818
MeO
OH
OBn
O
1.72
0.76
2.97
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
ppm (t1)

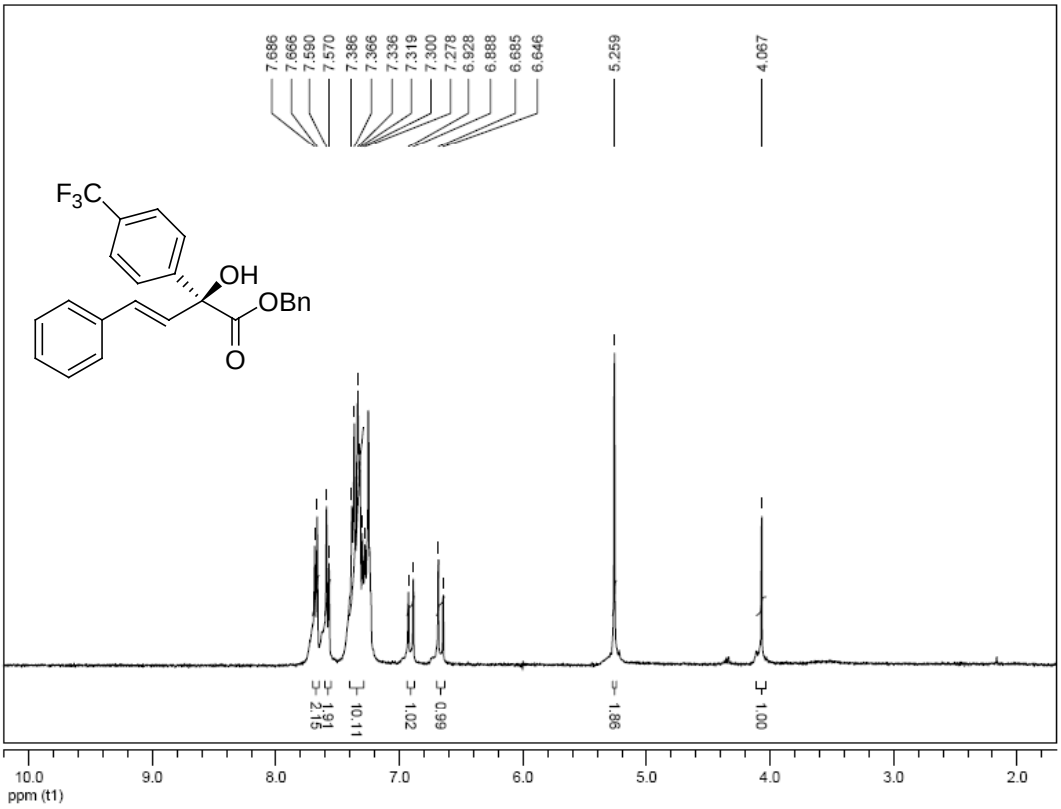

174.244
159.498
136.455
135.076
133.669
130.628
129.383
128.659
128.564
128.153
127.983
127.632
126.903
113.855
78.288
68.270
55.333
MeO
OH
OBn
O
200
150
100
50
ppm (t1)

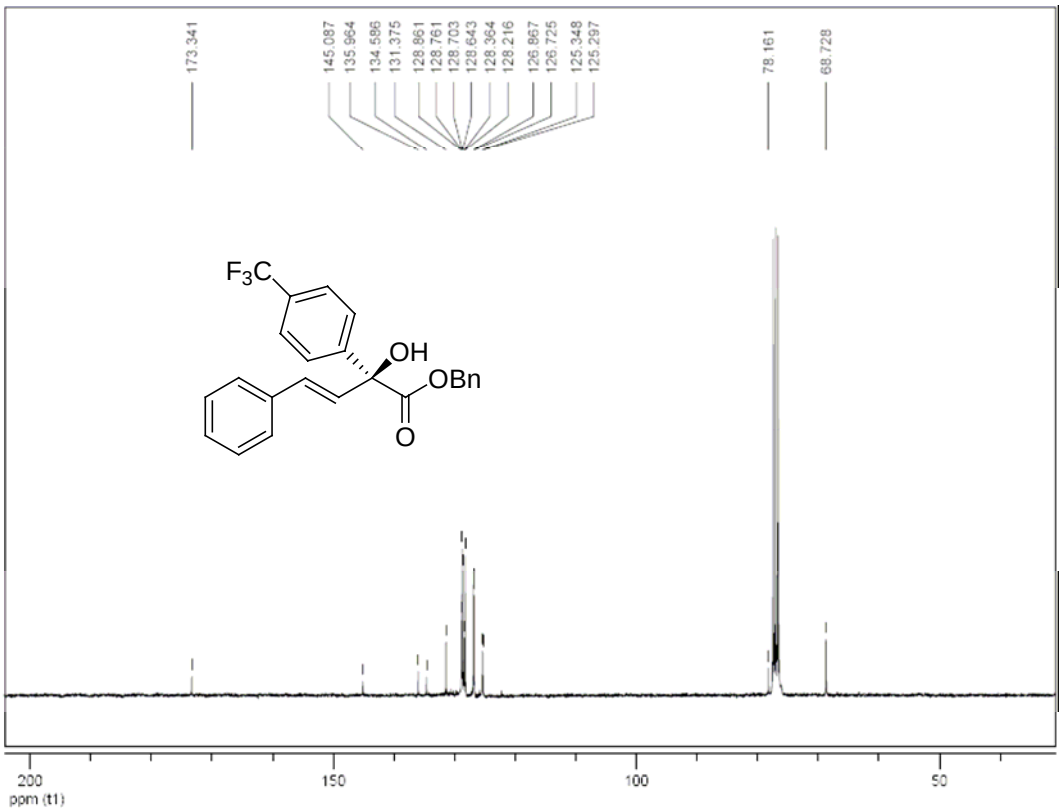
6d


7.540
7.526
7.518
7.504
7.412
7.393
7.350
7.342
7.335
7.316
7.273
7.255
7.048
7.026
7.004
6.949
6.910
6.720
6.681
5.271
4.048
F
OH
OBn
O
1.74
9.60
1.77
1.75
0.89
2.07
1.00
5.0
0.0
ppm (f1)

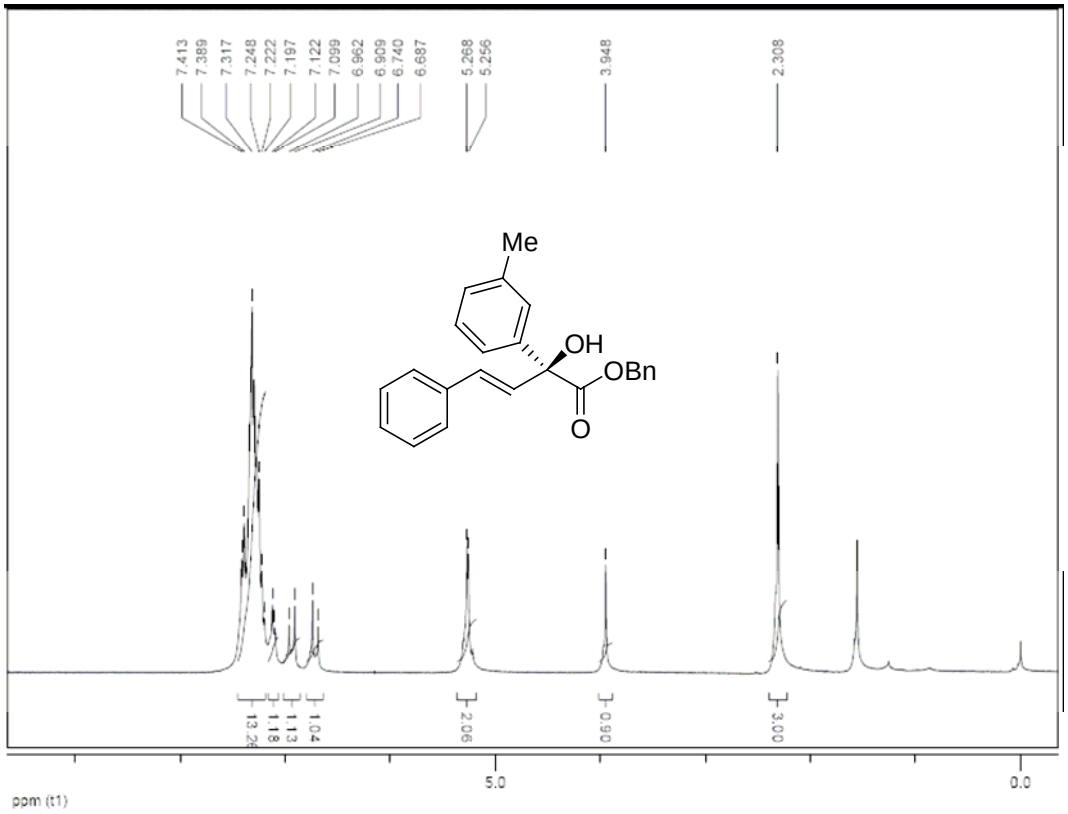

174.063
163.978
161.520
137.324
136.354
134.997
131.185
129.061
128.883
128.854
128.440
128.375
128.323
127.077
115.567
115.354
78.263
68.711
F
OH
OBn
O
200
150
100
50
ppm (f1)

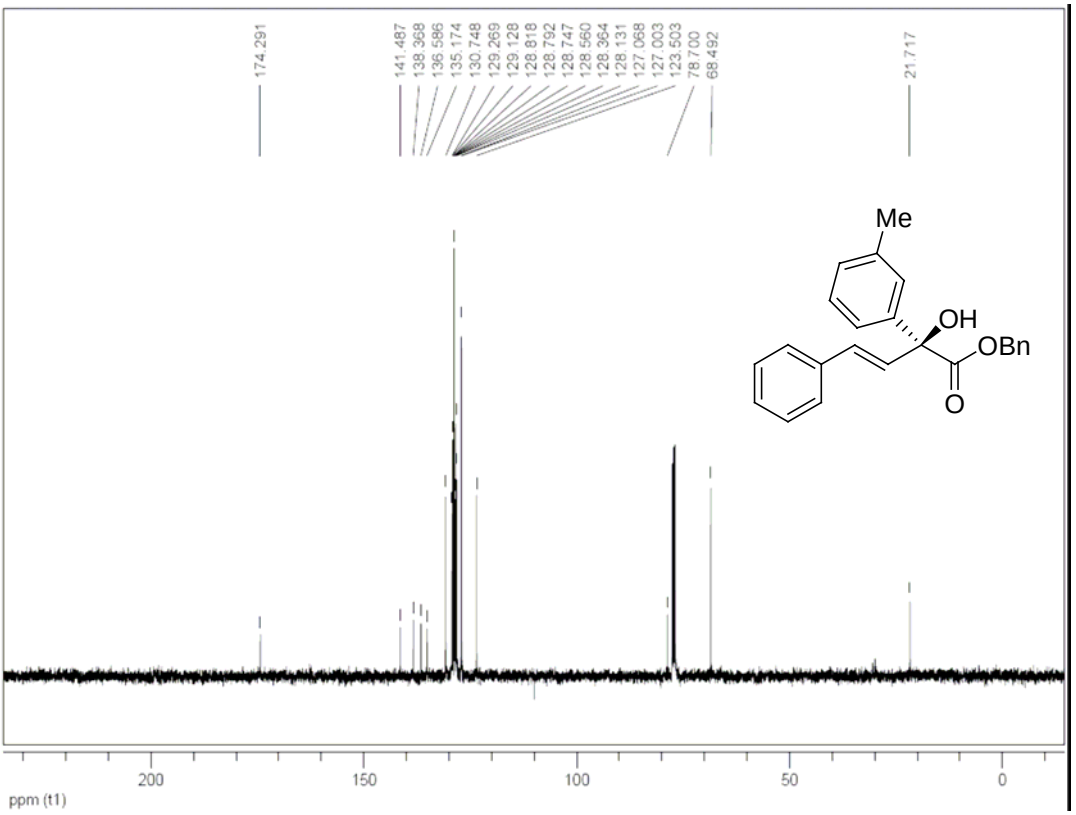
6e


7.686
7.666
7.590
7.570
7.386
7.366
7.336
7.319
7.300
7.278
6.928
6.888
6.685
6.646
5.259
4.067
F3C
OH
OBn
O
2.15
2.61
10.11
1.02
0.99
1.86
1.00
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
ppm (t1)

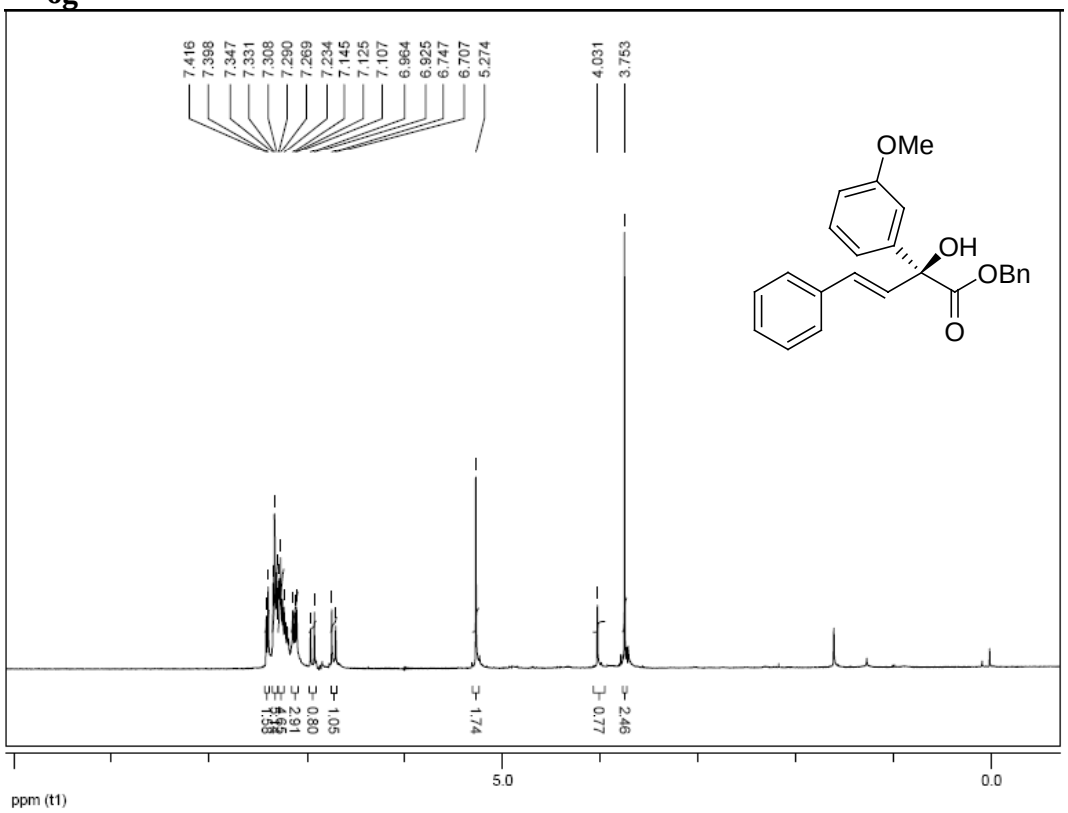

173.341
145.087
135.964
134.586
131.375
128.861
128.761
128.703
128.643
128.364
128.216
126.867
126.725
125.348
125.297
78.161
68.728
F3C
OH
OBn
O
200
150
100
50
ppm (t1)

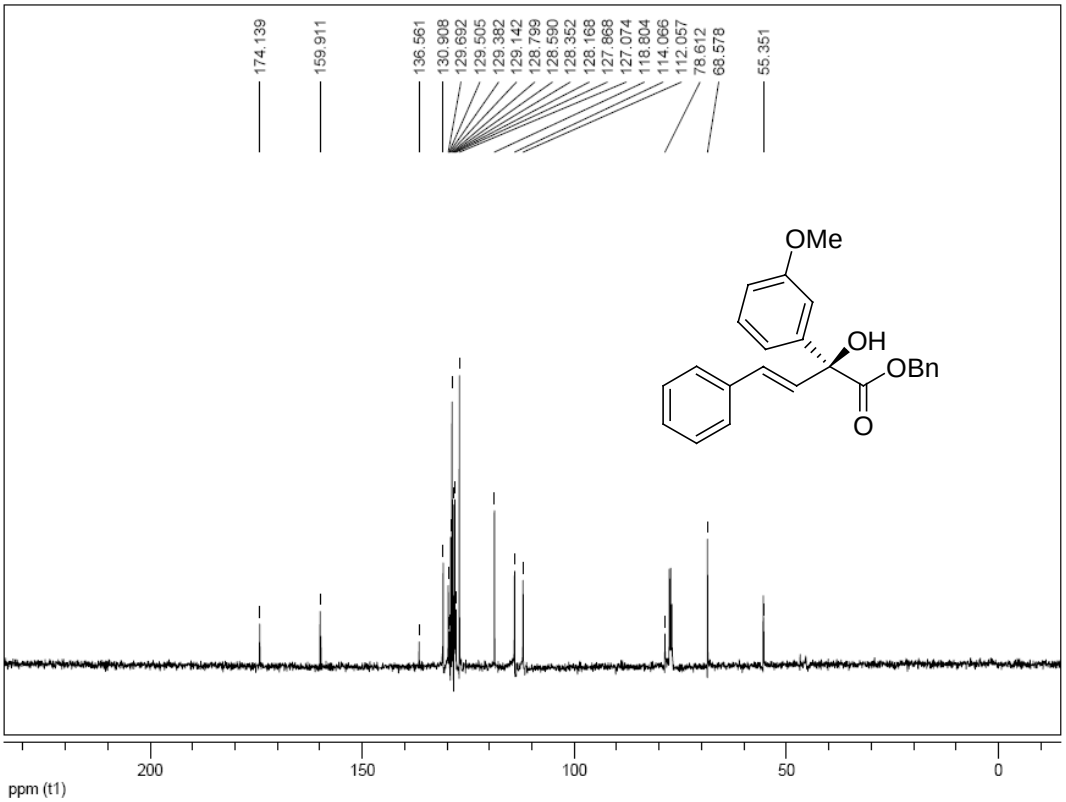
6f


7.413
7.389
7.317
7.248
7.222
7.197
7.122
7.099
6.962
6.909
6.740
6.687
5.268
5.256
3.948
2.308
Me
OH
OBn
O
1.32
1.18
1.13
1.04
2.06
0.90
3.00
5.0
0.0
ppm (t1)

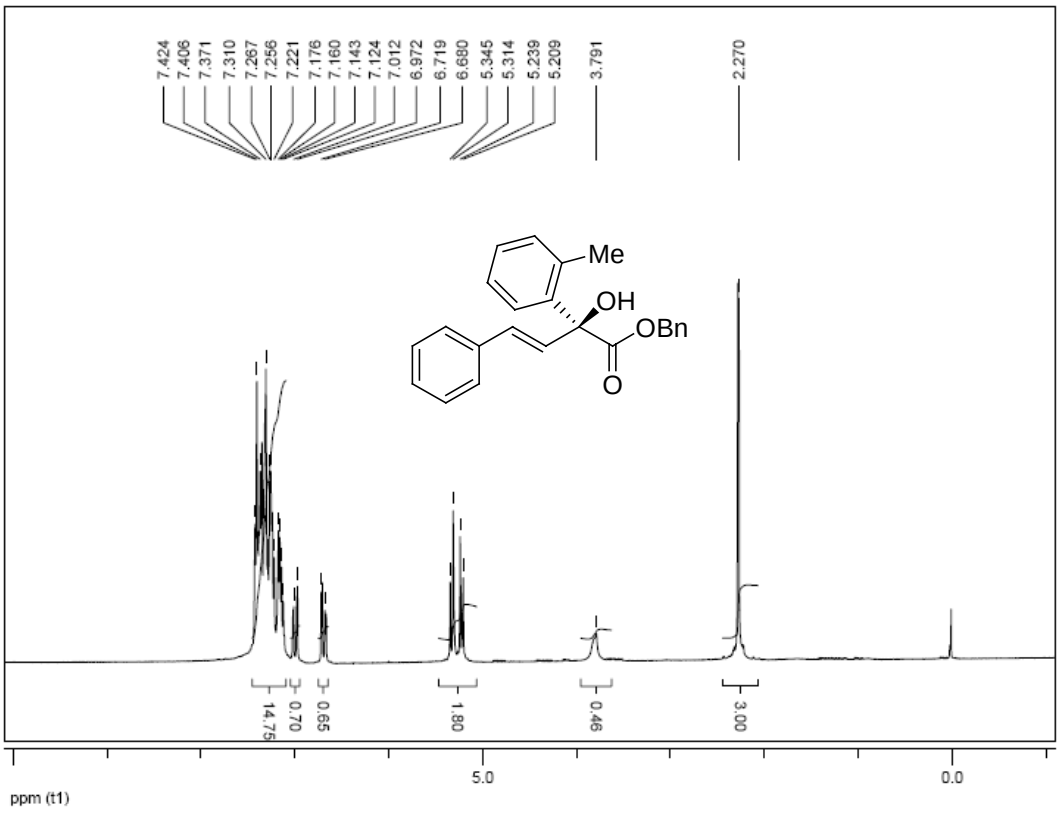

174.291
141.487
138.368
136.586
135.174
130.748
129.269
129.128
128.818
128.792
128.747
128.560
128.364
128.131
127.088
127.003
123.503
78.700
68.492
21.717
Me
OH
OBn
O
200
150
100
50
0
ppm (t1)

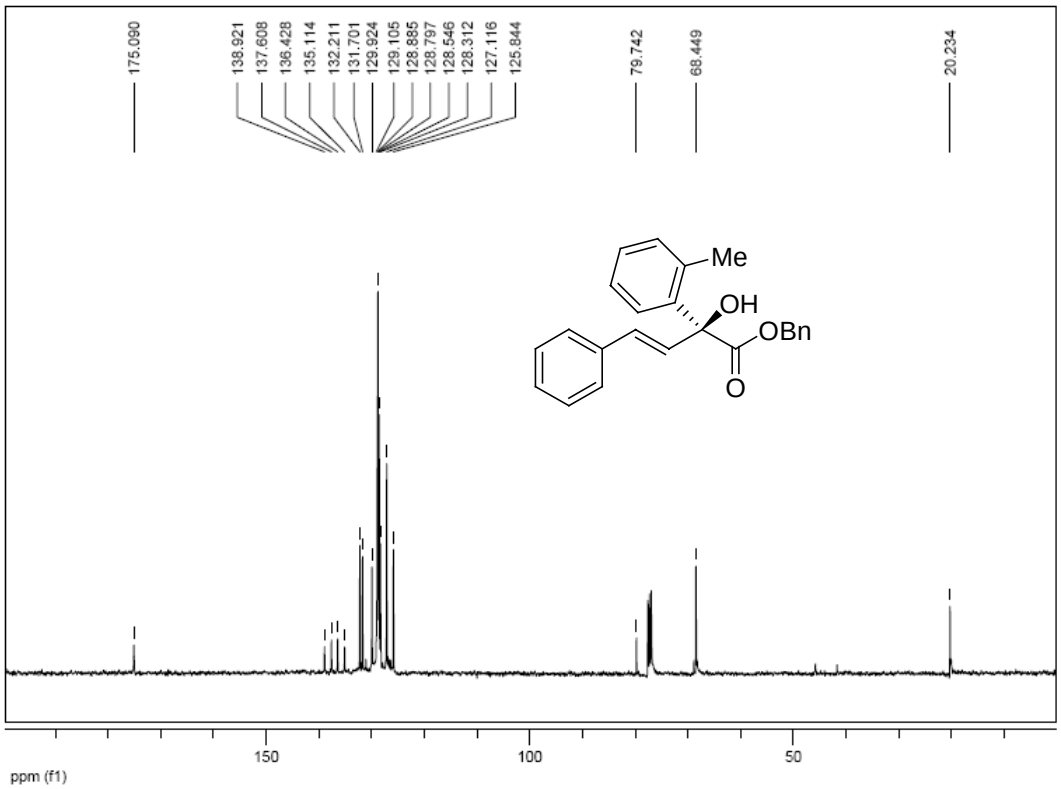
6g


7.416
7.398
7.347
7.331
7.308
7.290
7.269
7.234
7.145
7.125
7.107
6.964
6.925
6.747
6.707
5.274
4.031
3.753
OMe
OH
OBn
O
2.91
0.80
1.05
1.74
0.77
2.46
5.0
0.0
ppm (t1)

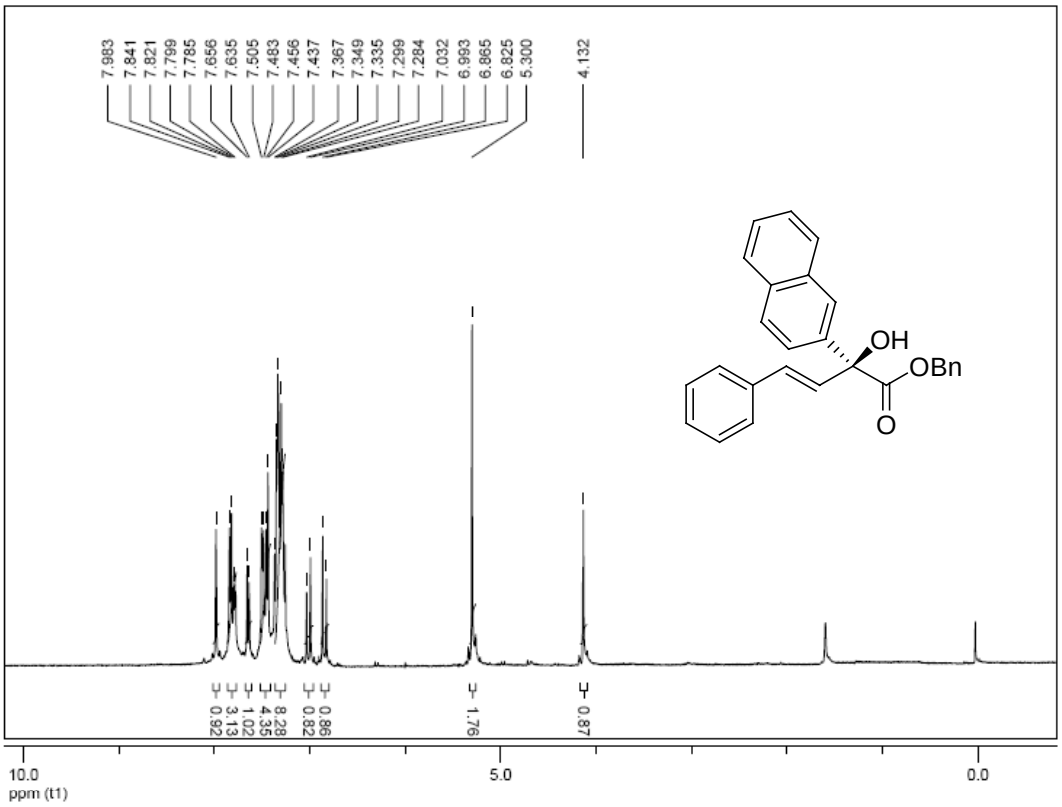

174.139
159.911
136.561
130.908
129.692
129.505
129.382
129.142
128.799
128.590
128.352
128.168
127.868
127.074
118.804
114.066
112.057
78.612
68.578
55.351
OMe
OH
OBn
O
200
150
100
50
0
ppm (t1)

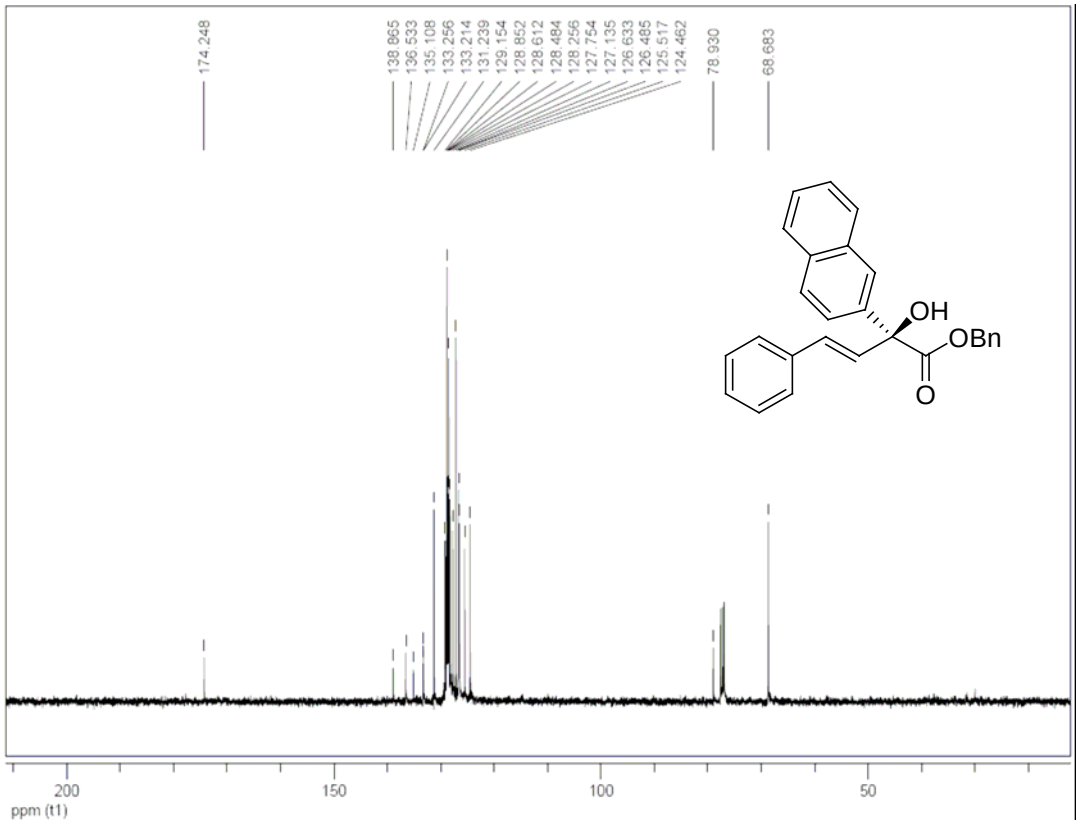
6h


7.424
7.406
7.371
7.310
7.267
7.256
7.221
7.176
7.160
7.143
7.124
7.012
6.972
6.719
6.680
5.345
5.314
5.239
5.209
3.791
2.270
Me
OH
OBn
O
14.75
0.70
0.65
1.80
0.46
3.00
5.0
0.0
ppm (t1)

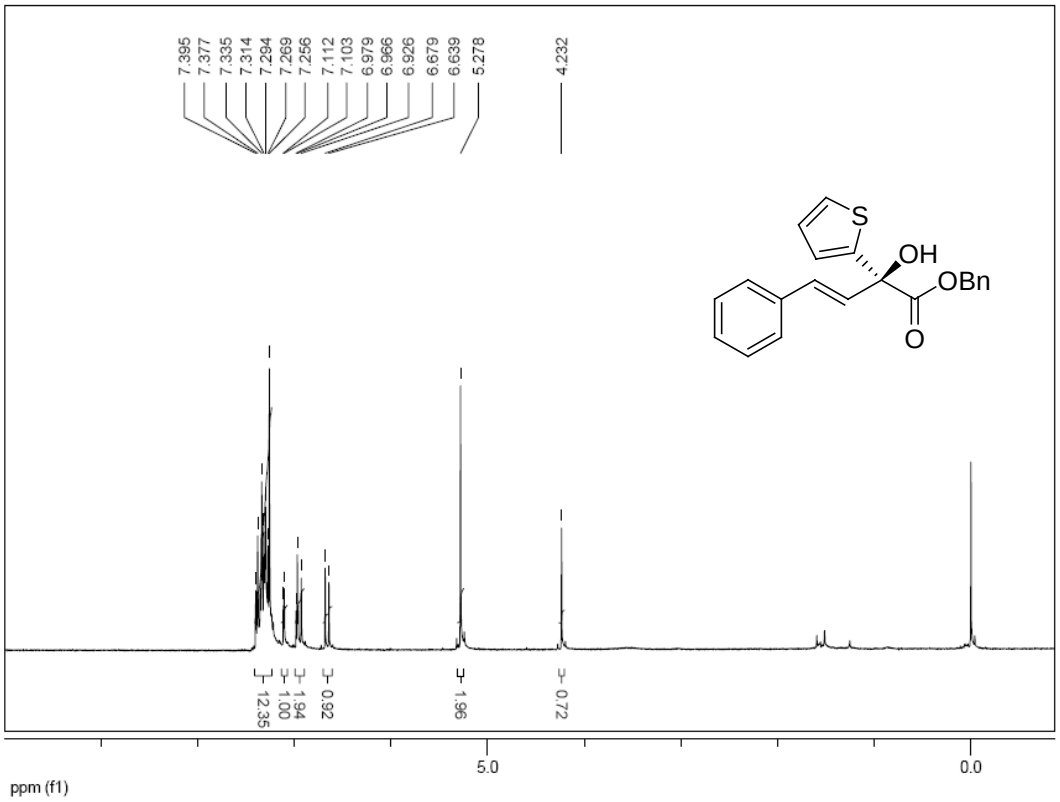

175.090
138.921
137.608
136.428
135.114
132.211
131.701
129.924
129.105
128.885
128.797
128.546
128.312
127.116
125.844
79.742
68.449
20.234
Me
OH
OBn
O
150
100
50
ppm (f1)

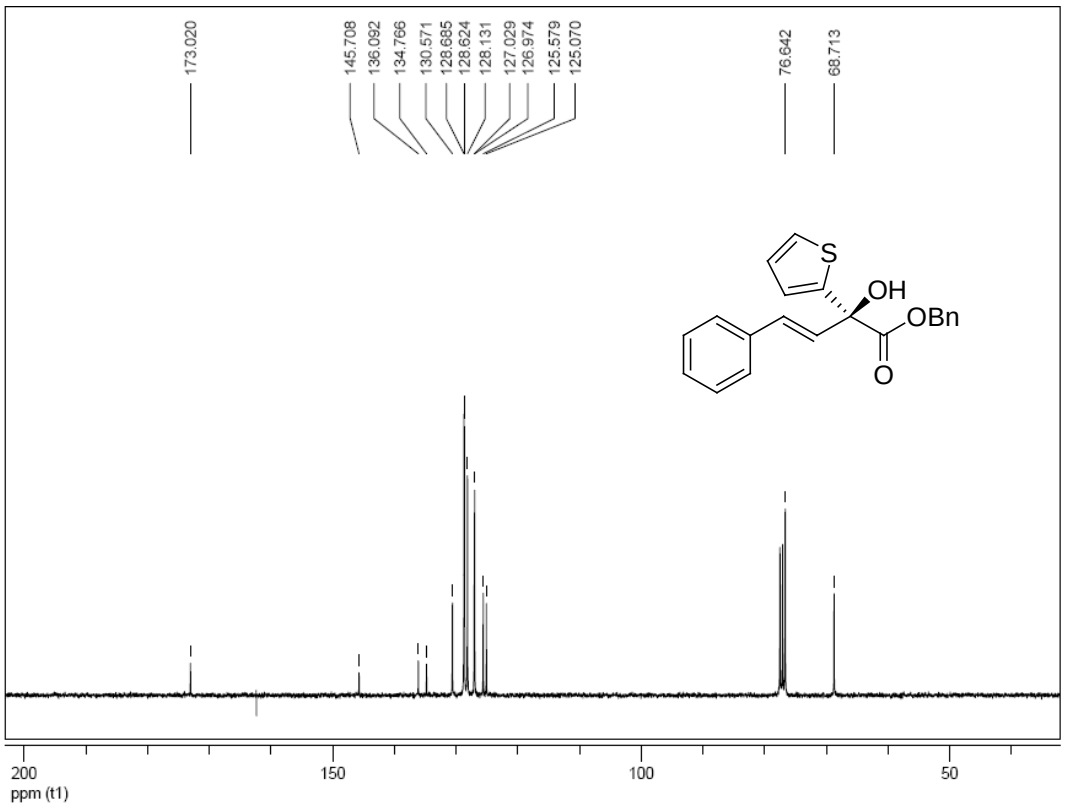
6i


7.983
7.841
7.821
7.799
7.785
7.656
7.635
7.505
7.483
7.456
7.437
7.367
7.349
7.335
7.299
7.284
7.032
6.993
6.865
6.825
5.300
4.132
OH
OBn
O
0.92
3.13
1.02
3.35
8.28
0.82
0.86
1.76
0.87
10.0
5.0
0.0
ppm (t1)

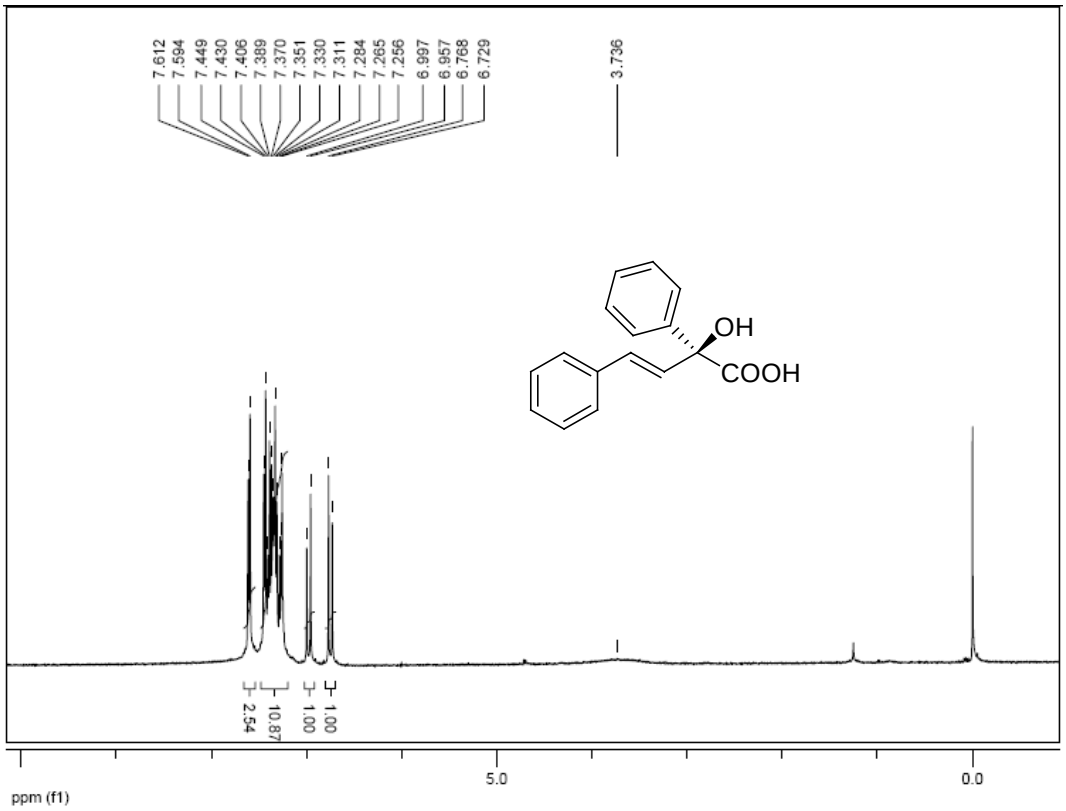

174.248
138.865
136.533
135.108
133.256
133.214
131.239
129.154
128.852
128.612
128.484
128.256
127.754
127.135
126.633
126.485
125.517
124.462
78.930
68.683
OH
OBn
O
200
150
100
50
ppm (t1)

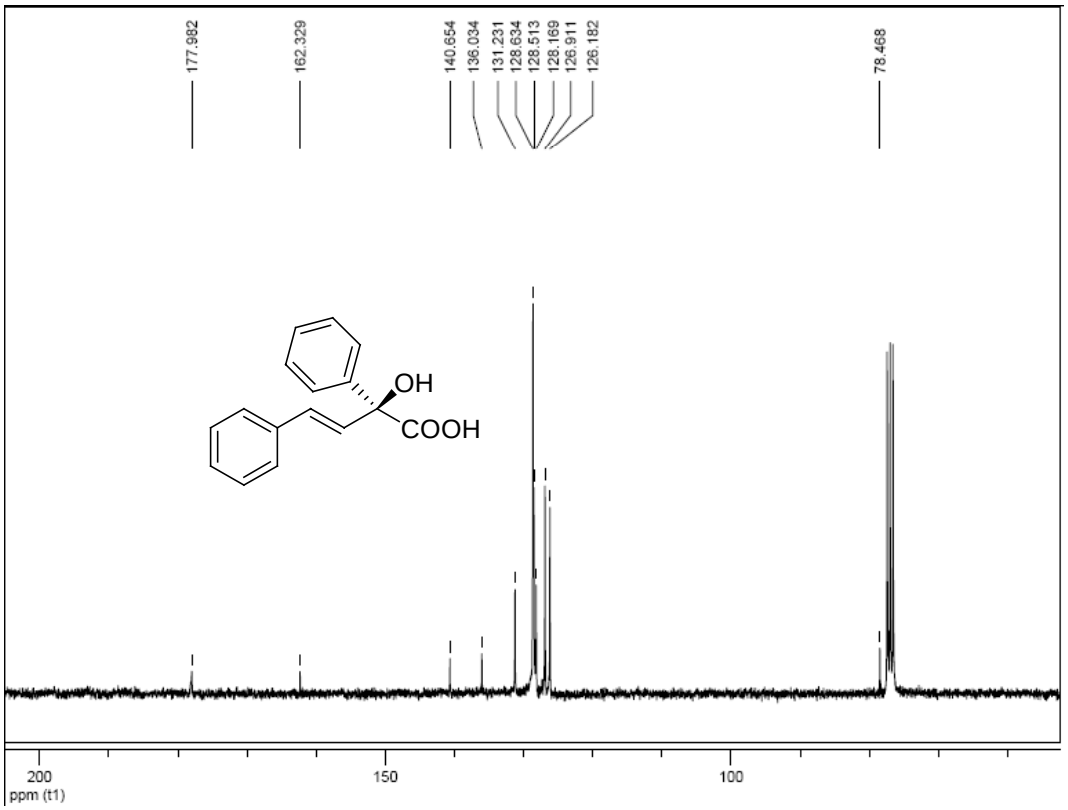
6j


7.395
7.377
7.335
7.314
7.294
7.269
7.256
7.112
7.103
6.979
6.966
6.926
6.679
6.639
5.278
4.232
S
OH
OBn
O
12.35
1.00
1.94
0.92
1.96
0.72
5.0
0.0
ppm (f1)


173.020
145.708
136.092
134.766
130.571
128.885
128.624
128.131
127.029
126.974
125.579
125.070
76.642
68.713
S
OH
OBn
O
200
150
100
50
ppm (t1)

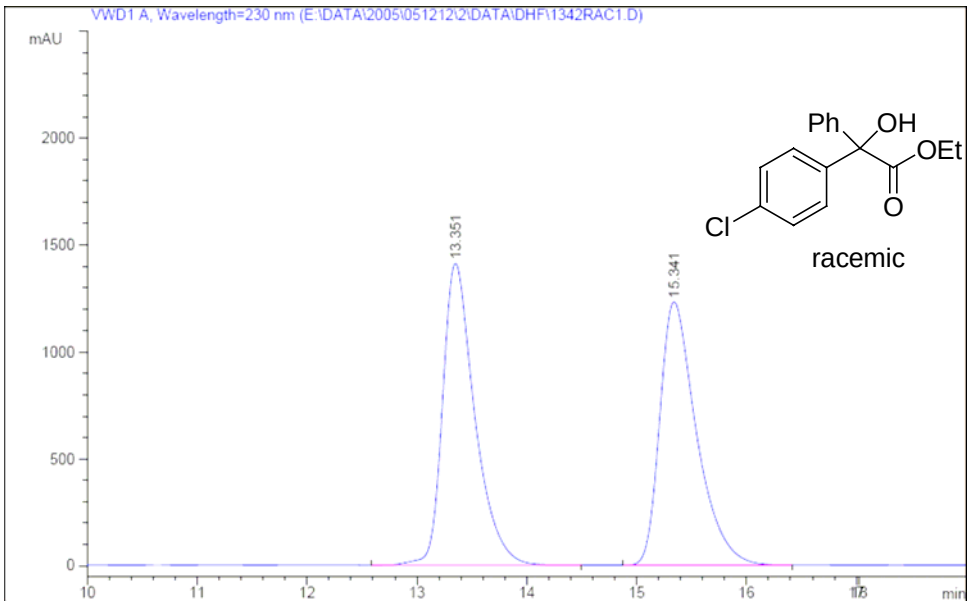
7

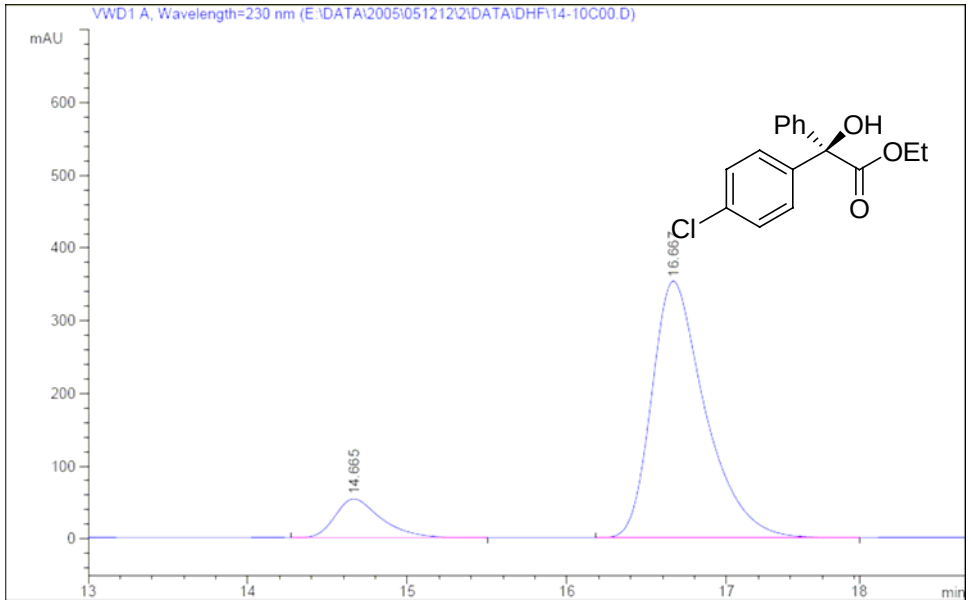

7.612
7.594
7.449
7.430
7.406
7.389
7.370
7.351
7.330
7.311
7.284
7.265
7.256
6.997
6.957
6.768
6.729
3.736
OH
COOH
2.54
10.87
1.00
1.00
5.0
0.0
ppm (f1)


177.982
162.329
140.654
136.034
131.231
128.634
128.513
128.169
126.911
126.182
78.468
OH
COOH
200
150
100
ppm (t1)

(H) HPLC Charts of Products

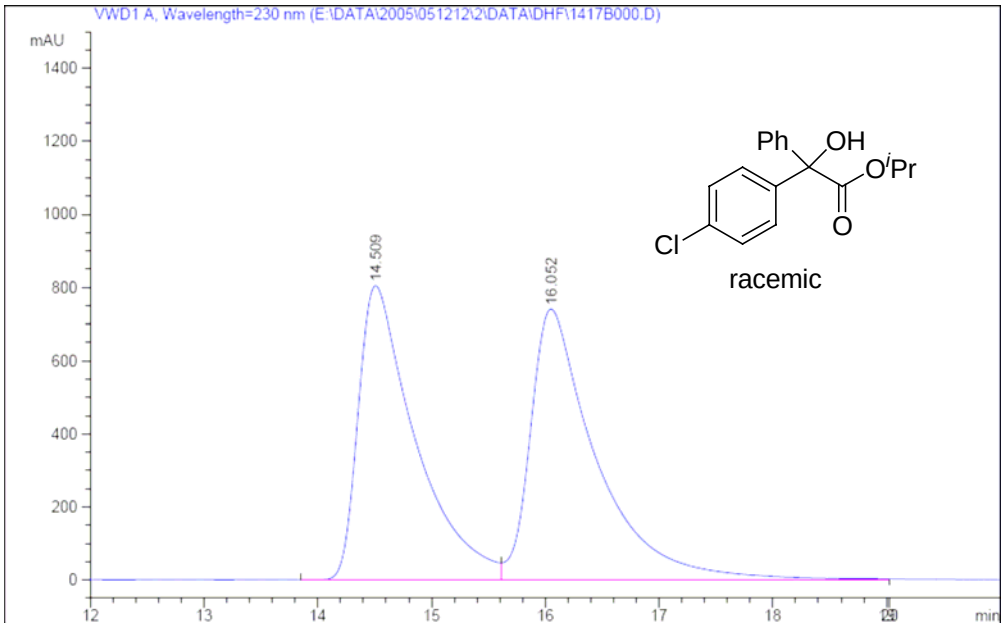
4a

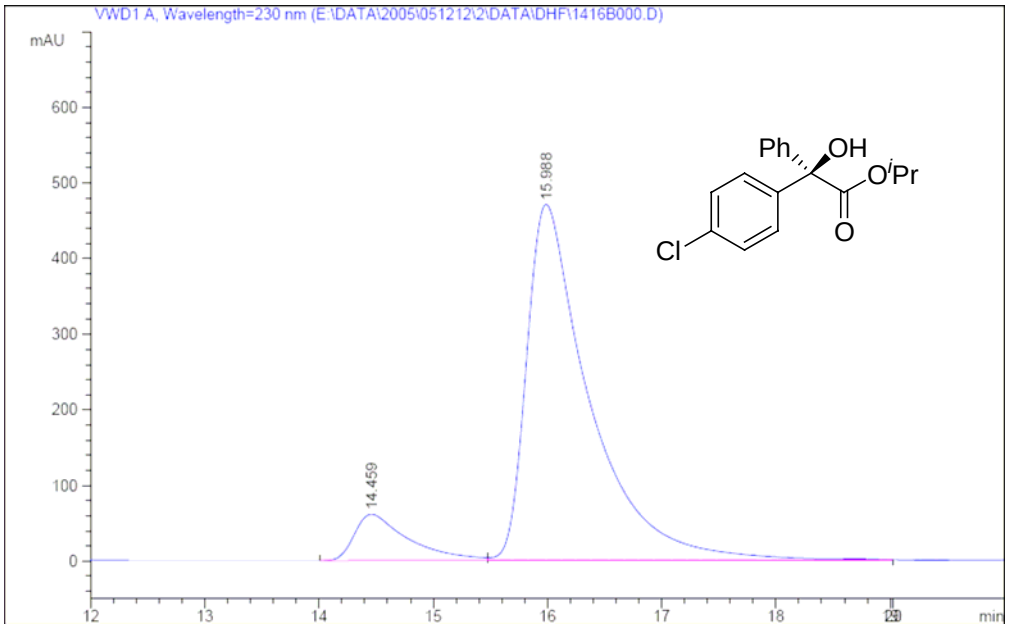




Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	14.665	VP	0.3006	1085.81836	53.56576	11.6297
2	16.667	BB	0.3483	8250.76465	353.13992	88.3703

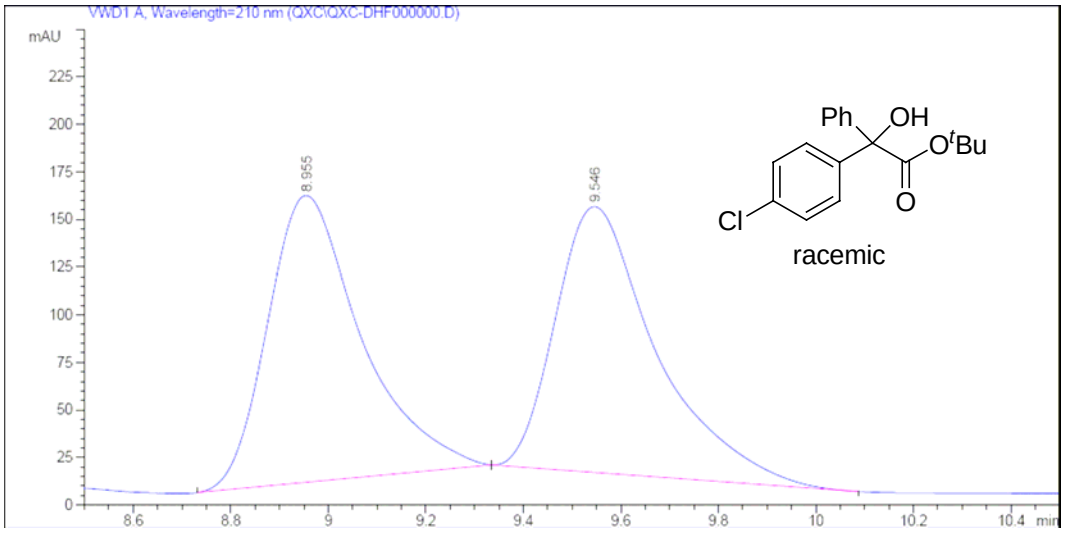
4b

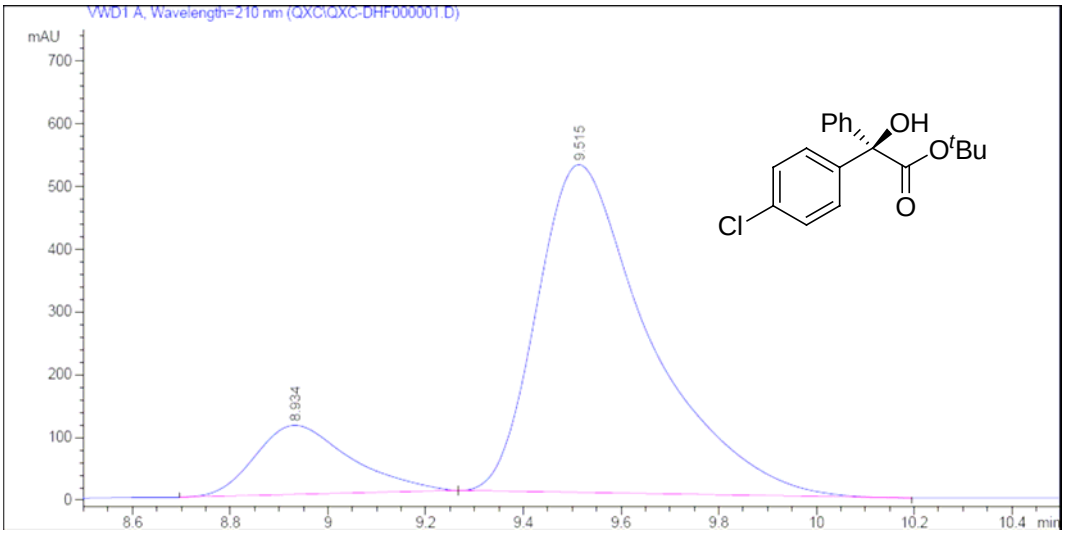




Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	14.459	PV	0.4659	2009.80017	61.47454	9.9234
2	15.988	VB	0.5509	1.82433e4	470.98737	90.0766

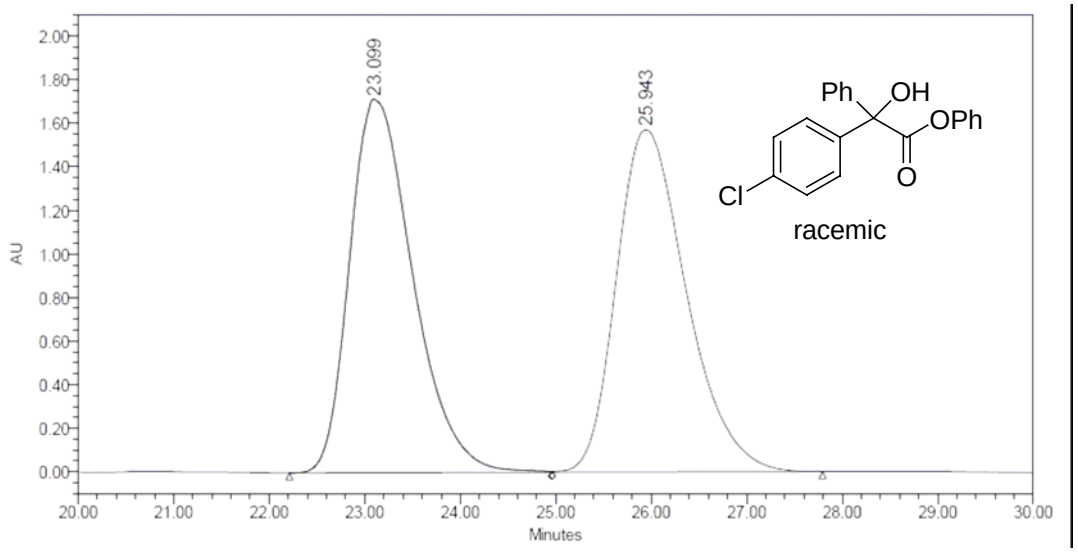
4c

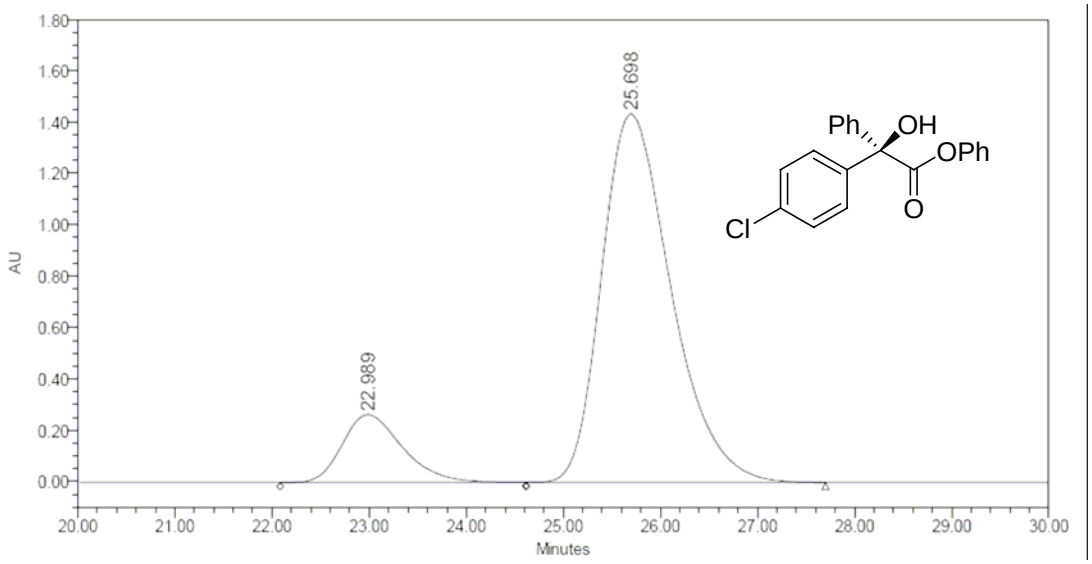




Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Area %	Name
1	8.934	BB	0.2044	1486.10938	15.1032	?
2	9.515	BB	0.2392	8353.61035	84.8968	?

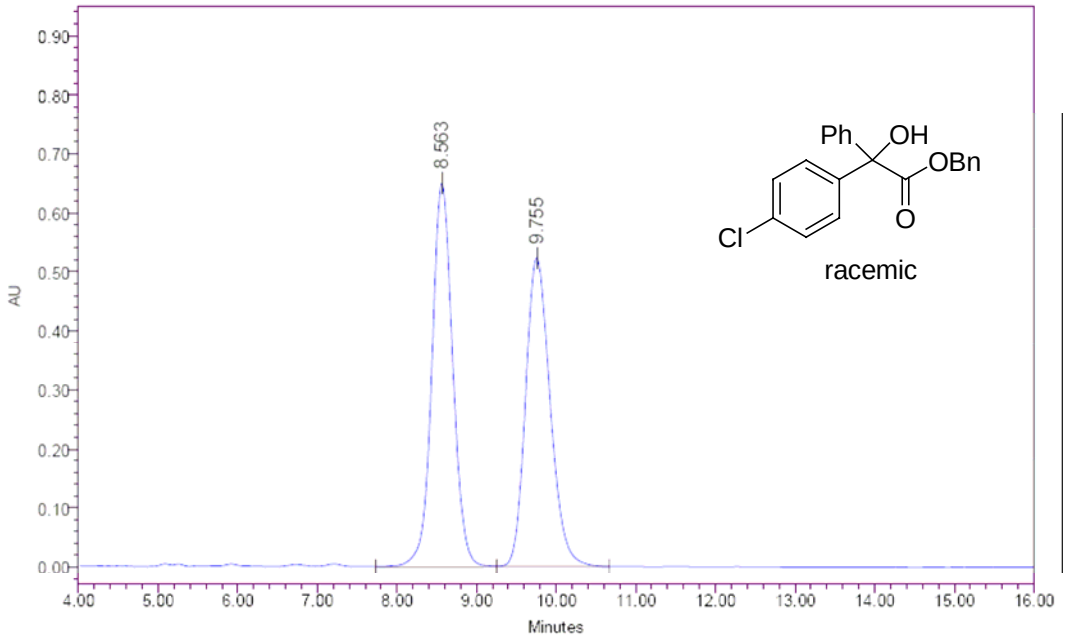
4d

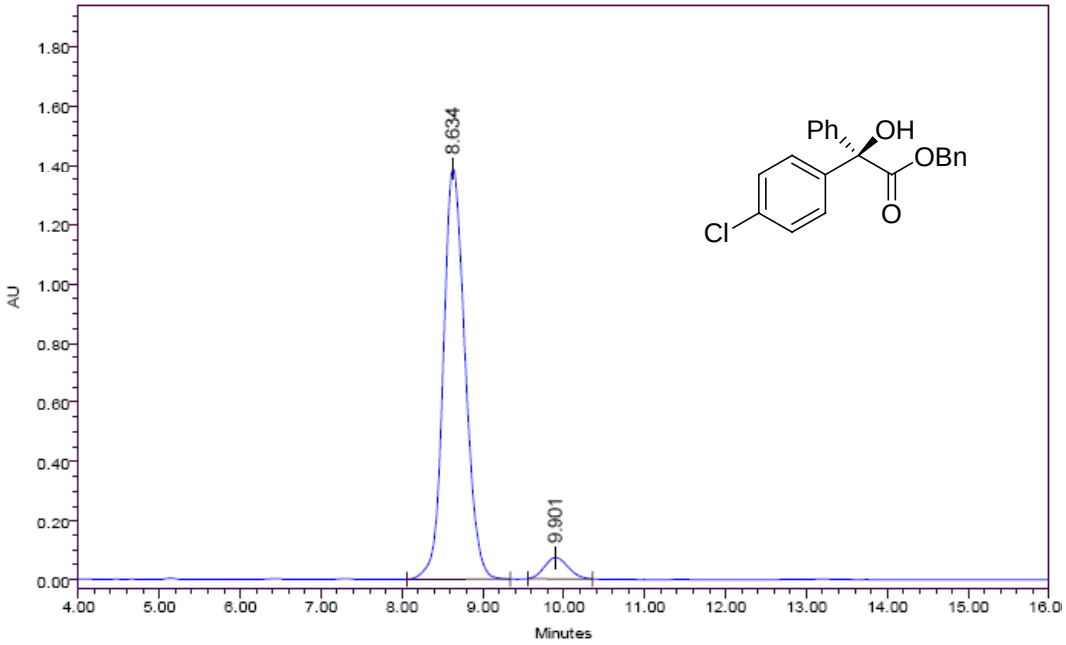




	RT	Area	% Area	Height
1	22.989	11545024	13.88	265467
2	25.698	71613850	86.12	1436630

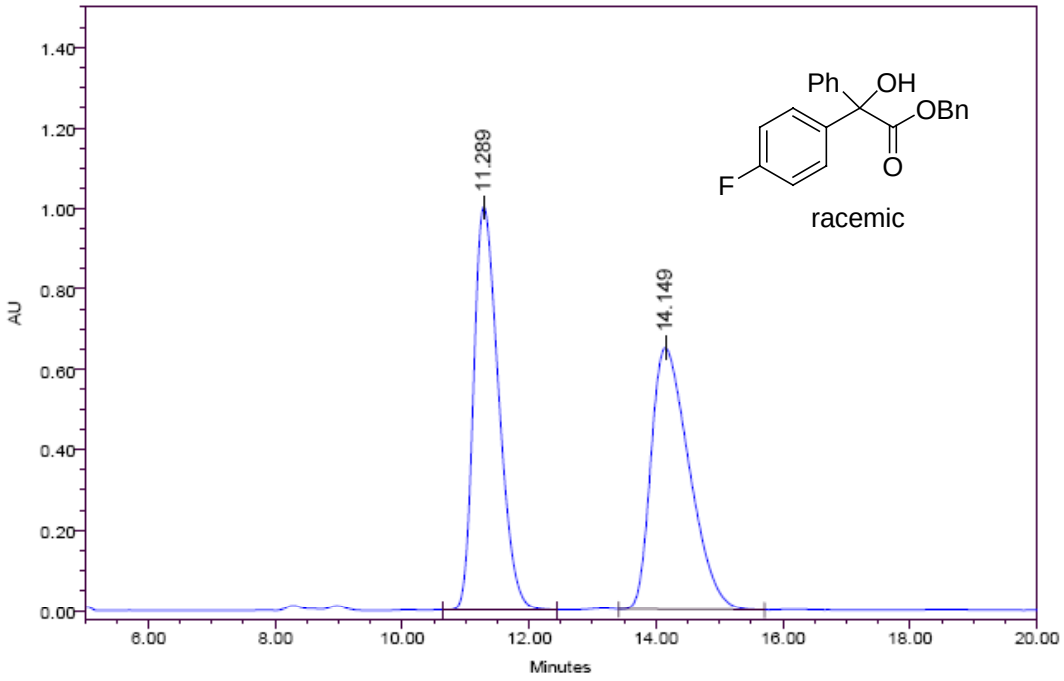
4e

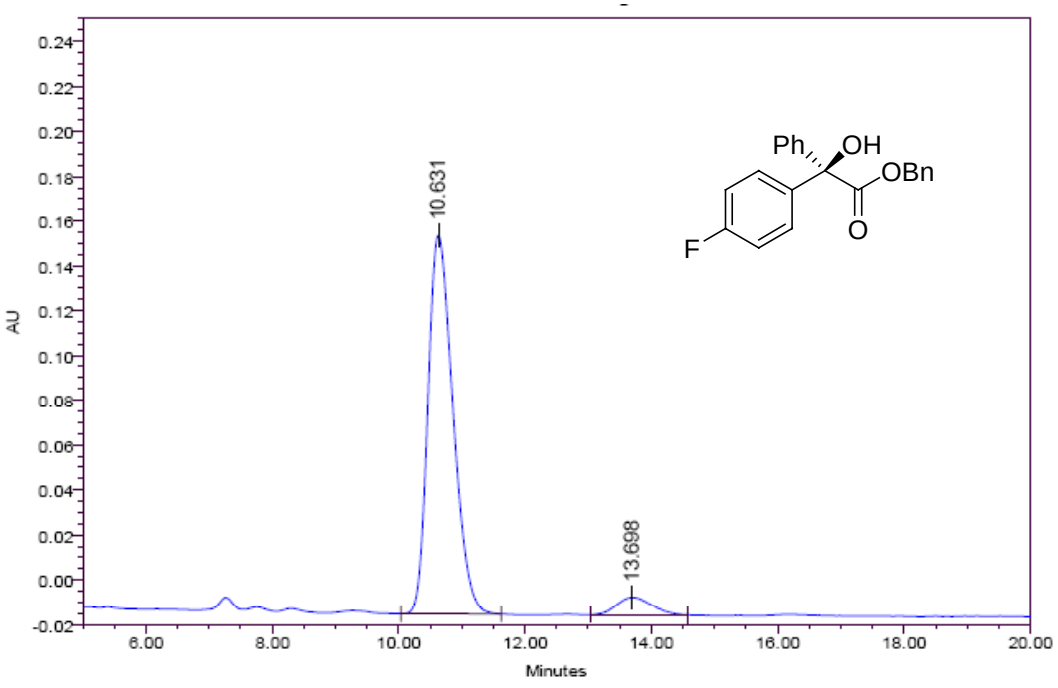




	RT	Area	% Area	Height
1	8.634	25908344	94.74	1389907
2	9.901	1437584	5.26	70947

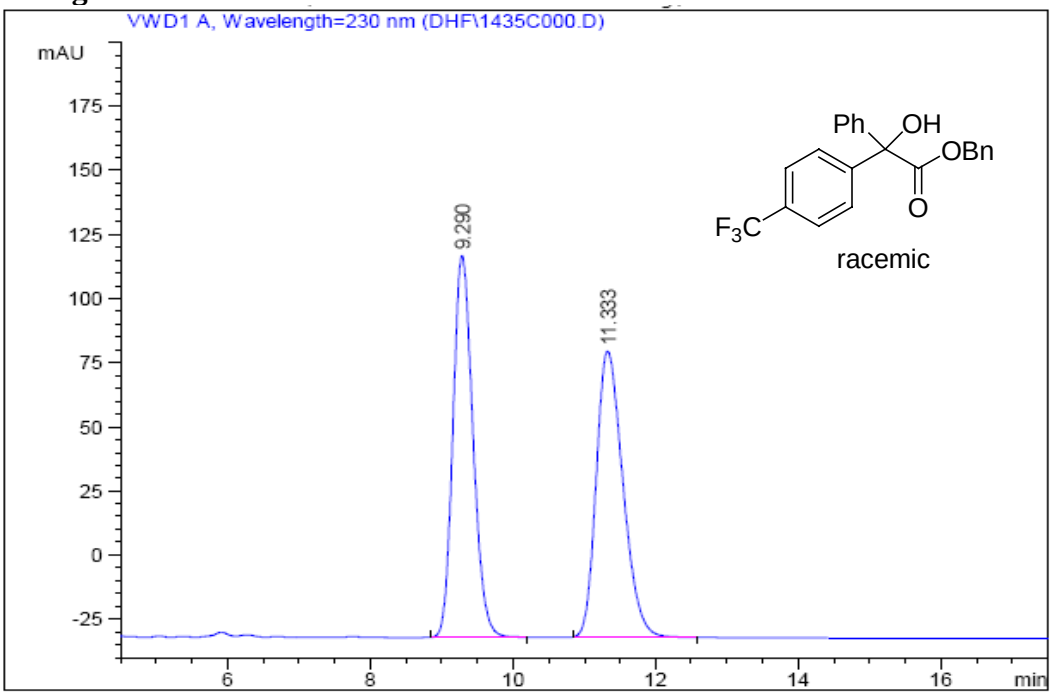
4f

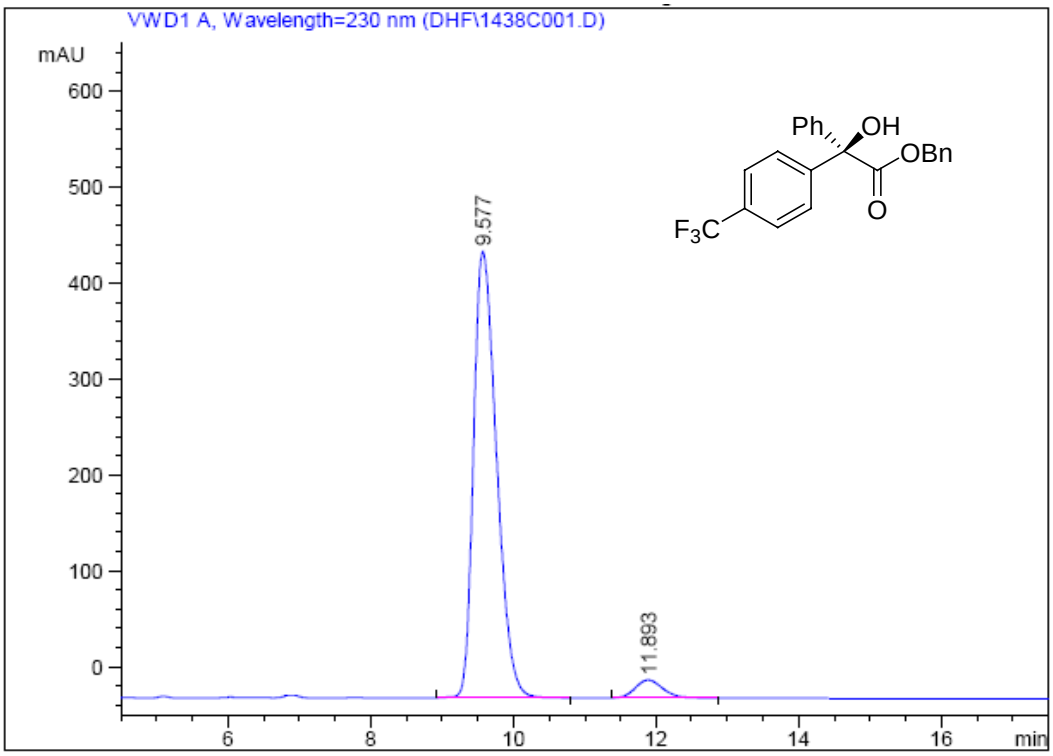




	RT	Area	% Area	Height
1	10.631	4631552	93.77	168886
2	13.698	307641	6.23	7898

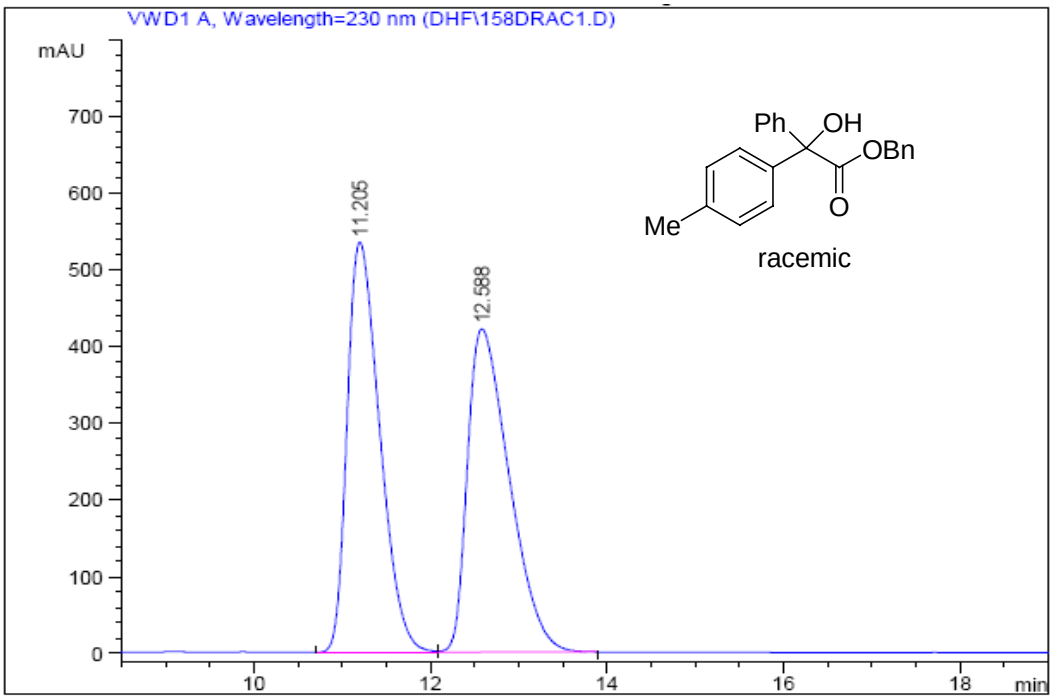
4g

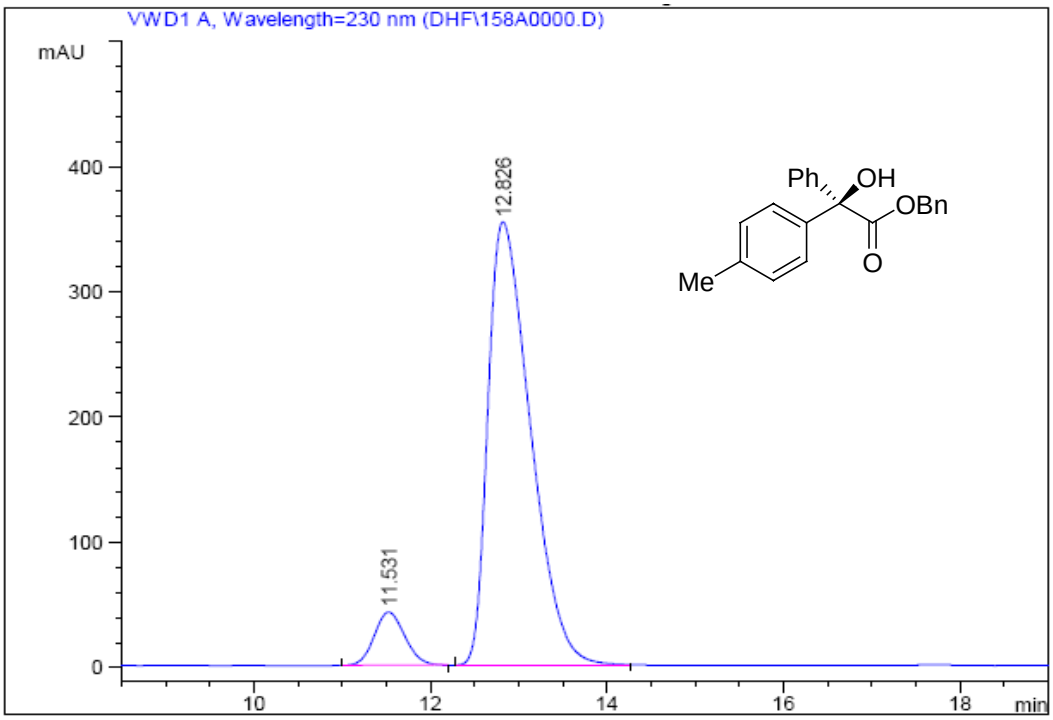




Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	9.577	BB	0.3485	1.04086e4	464.96619	95.3298
2	11.893	BB	0.4197	509.92255	18.72203	4.6702

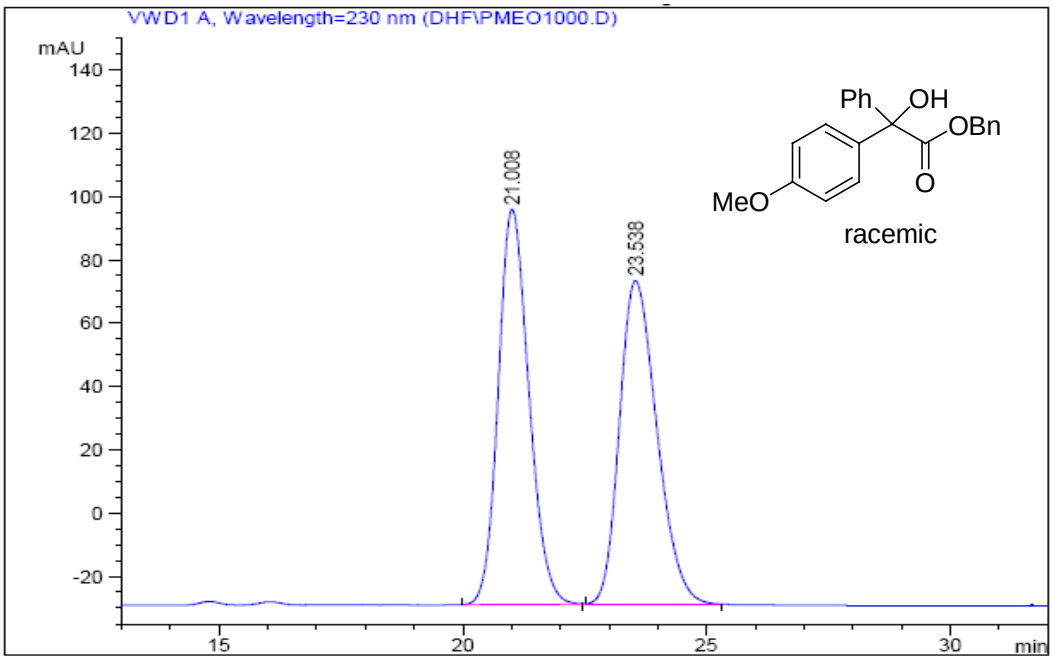
4h

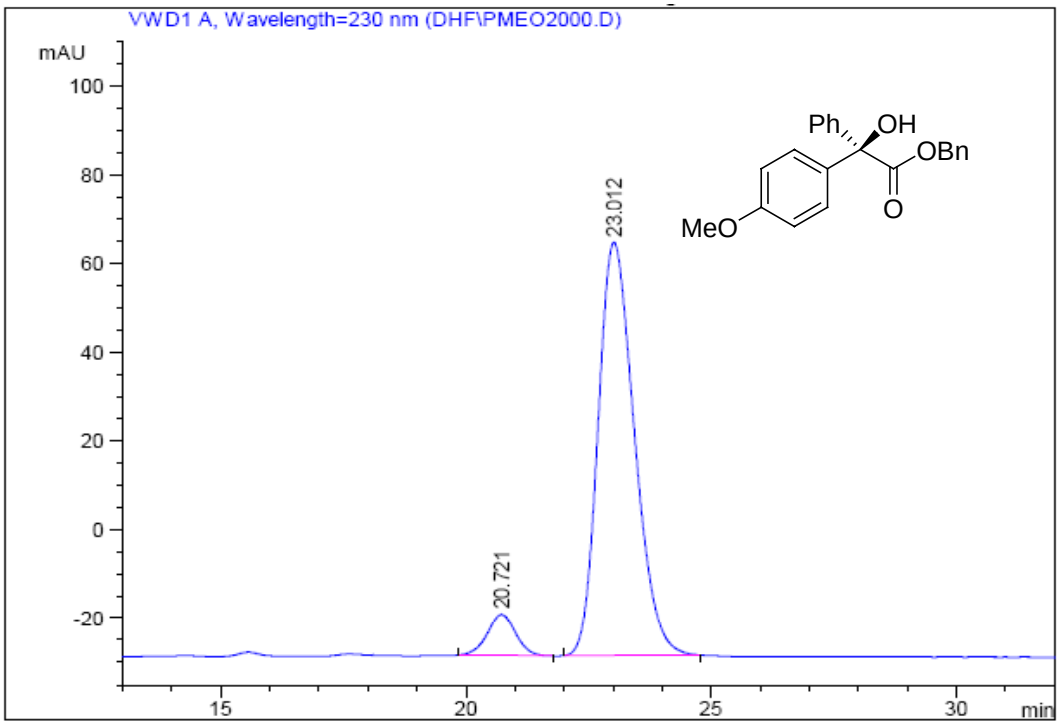




Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	11.531	BB	0.3757	1029.21069	42.50277	8.0291
2	12.826	BB	0.5157	1.17893e4	353.57678	91.9709

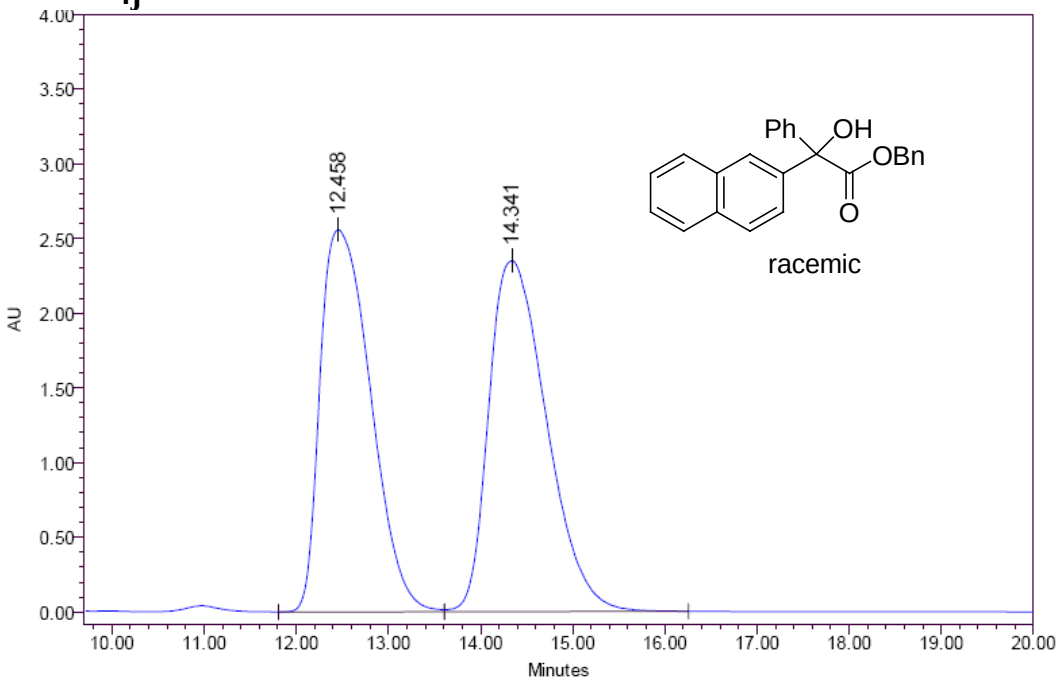
4i

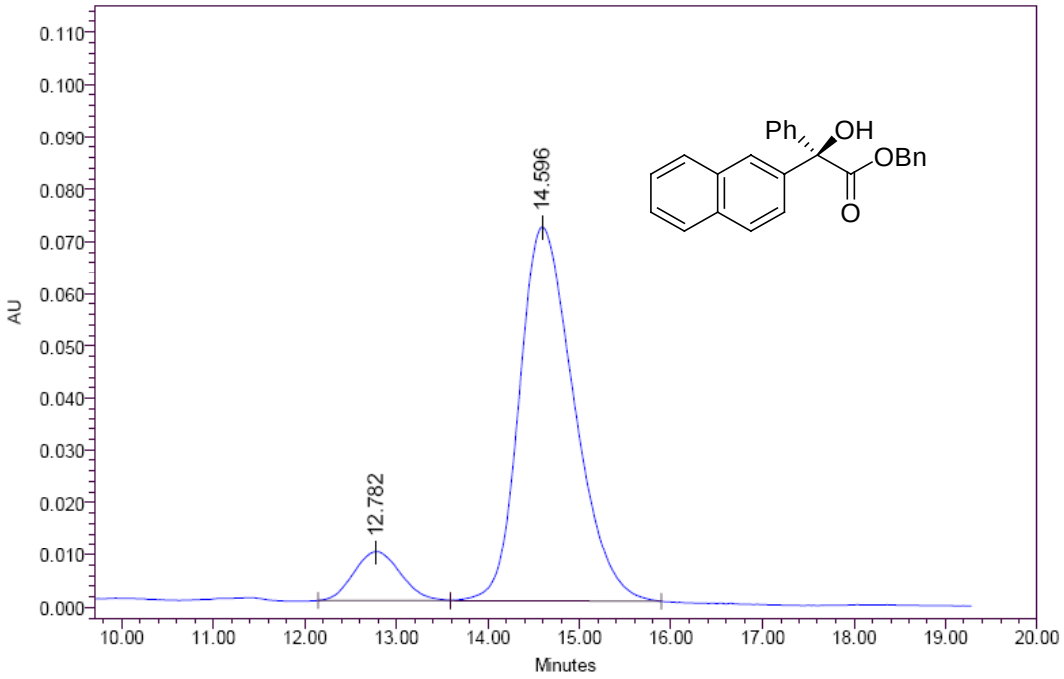




Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	20.721	BP	0.6112	373.80383	9.27995	7.2445
2	23.012	BB	0.7786	4786.02393	93.13619	92.7555

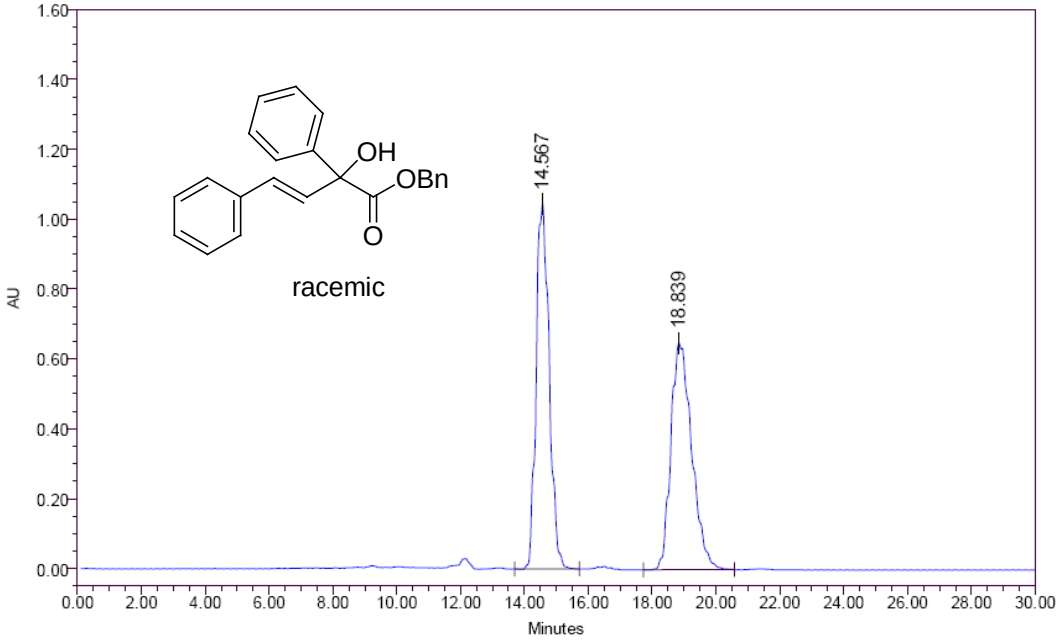
4j

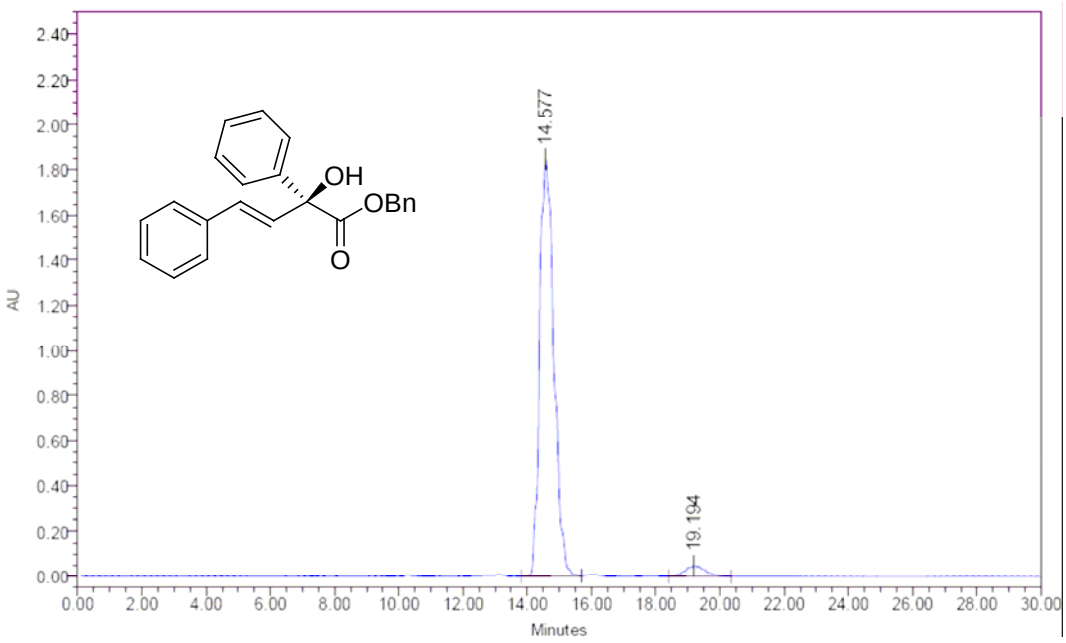




	RT	Area	% Area	Height
1	12.782	326890	9.92	9228
2	14.596	2967044	90.08	71587

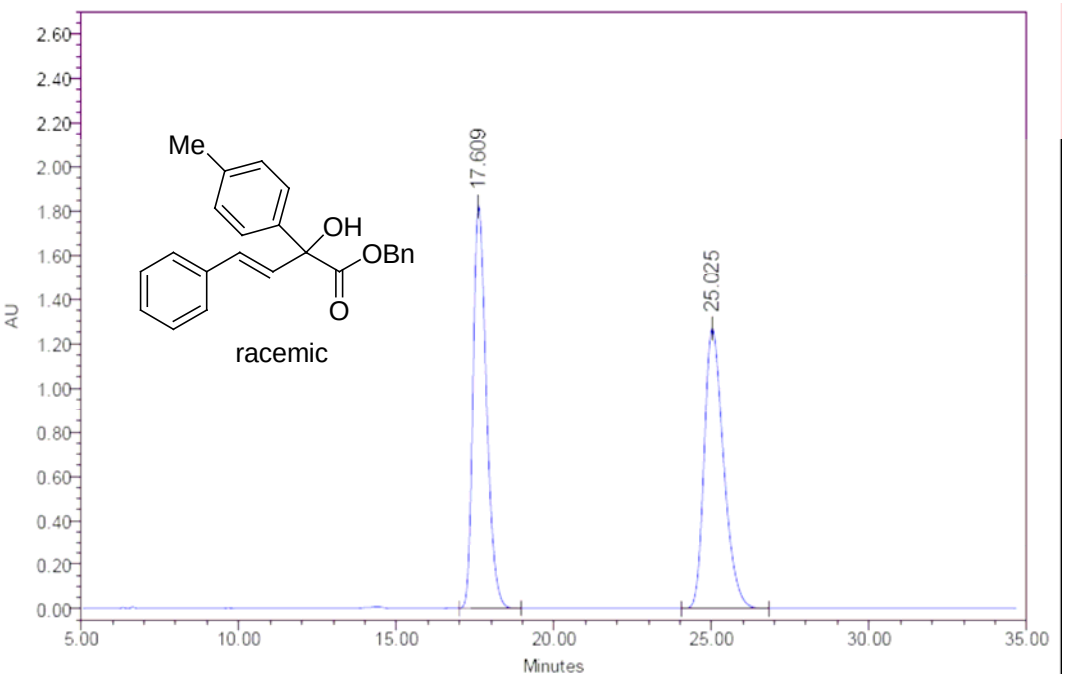
6a

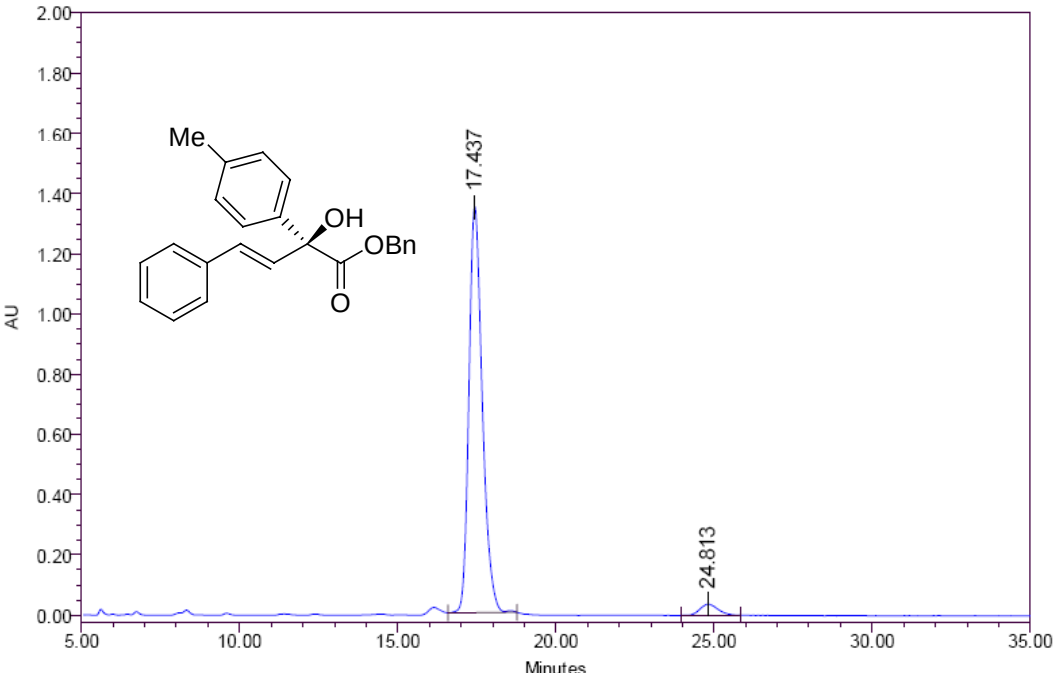




	RT	Area	% Area	Height
1	14.577	56617869	96.47	1845985
2	19.194	2070938	3.53	47937

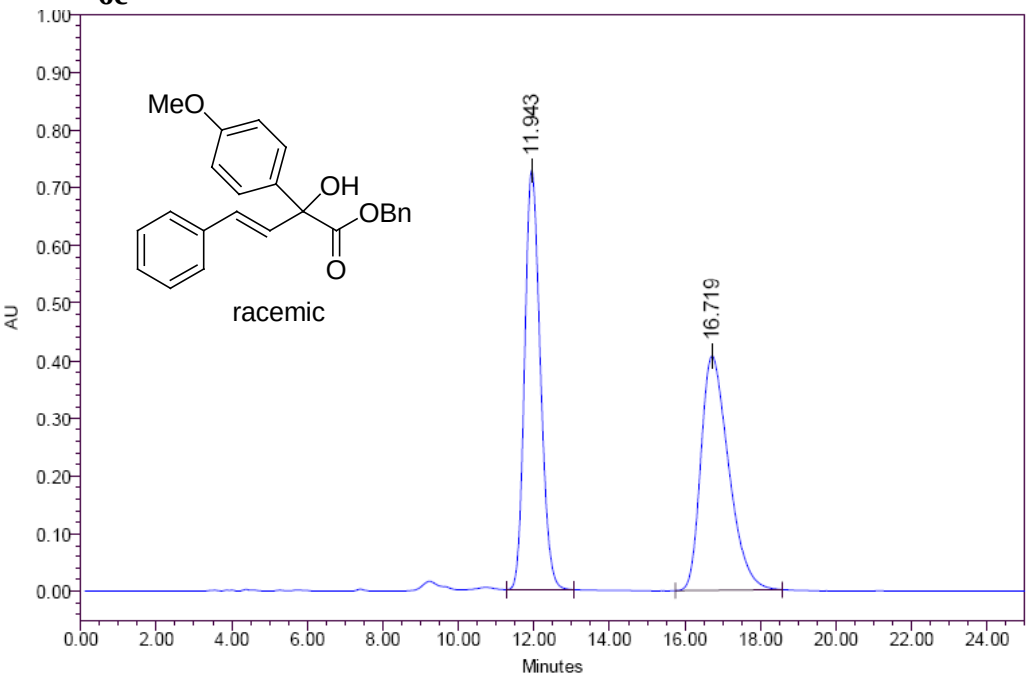
6b

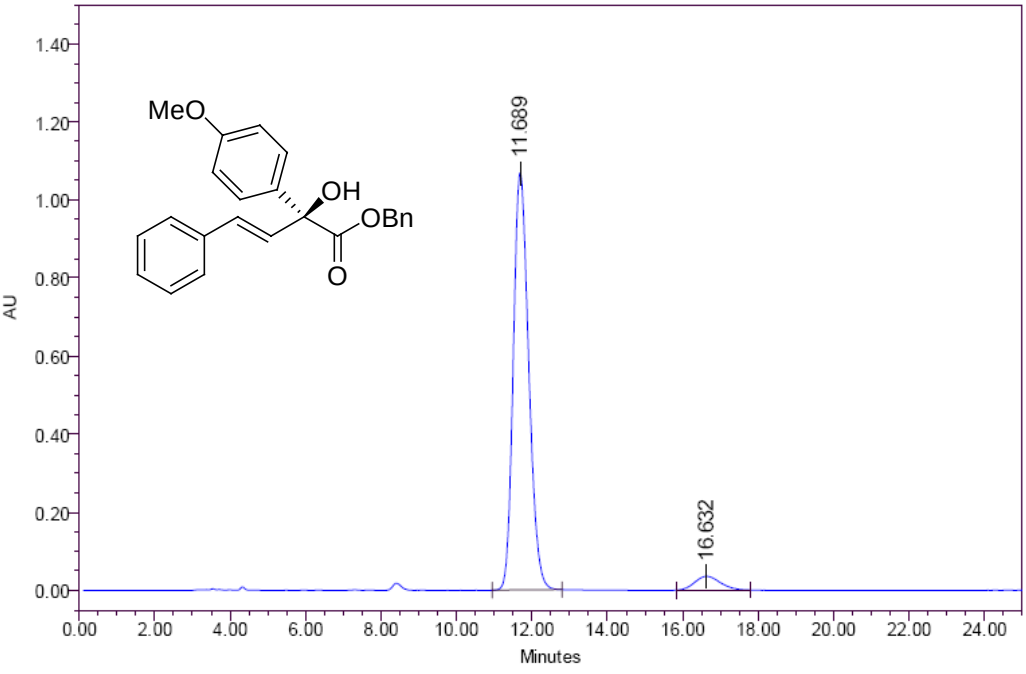




	RT	Area	% Area	Height
1	17.437	39472822	96.32	1346732
2	24.813	1506353	3.68	36732

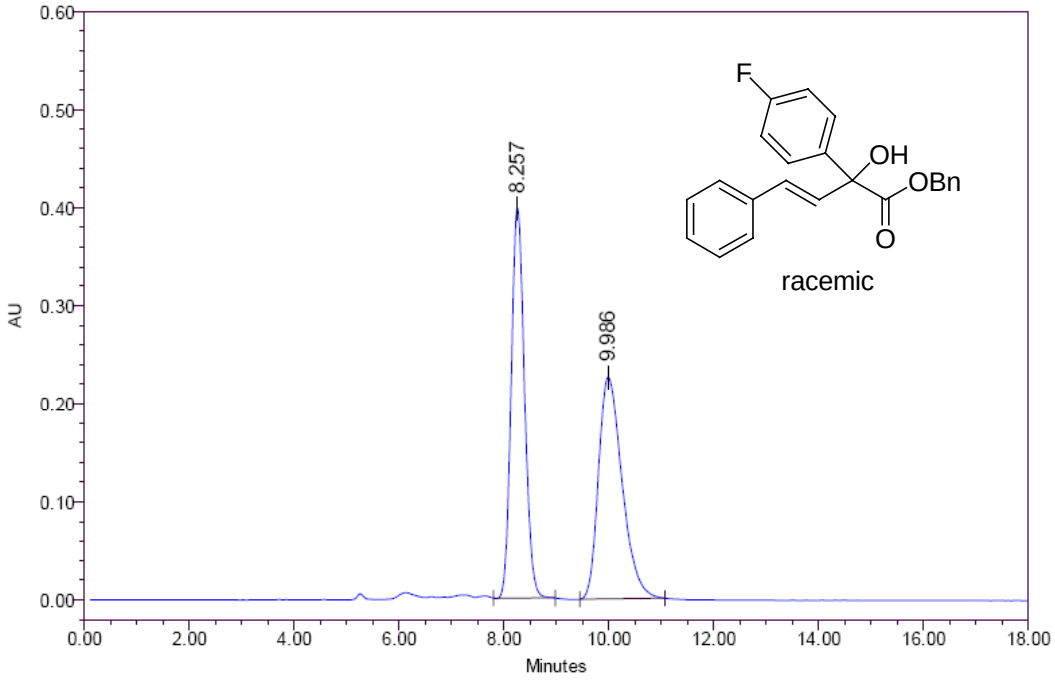
6c

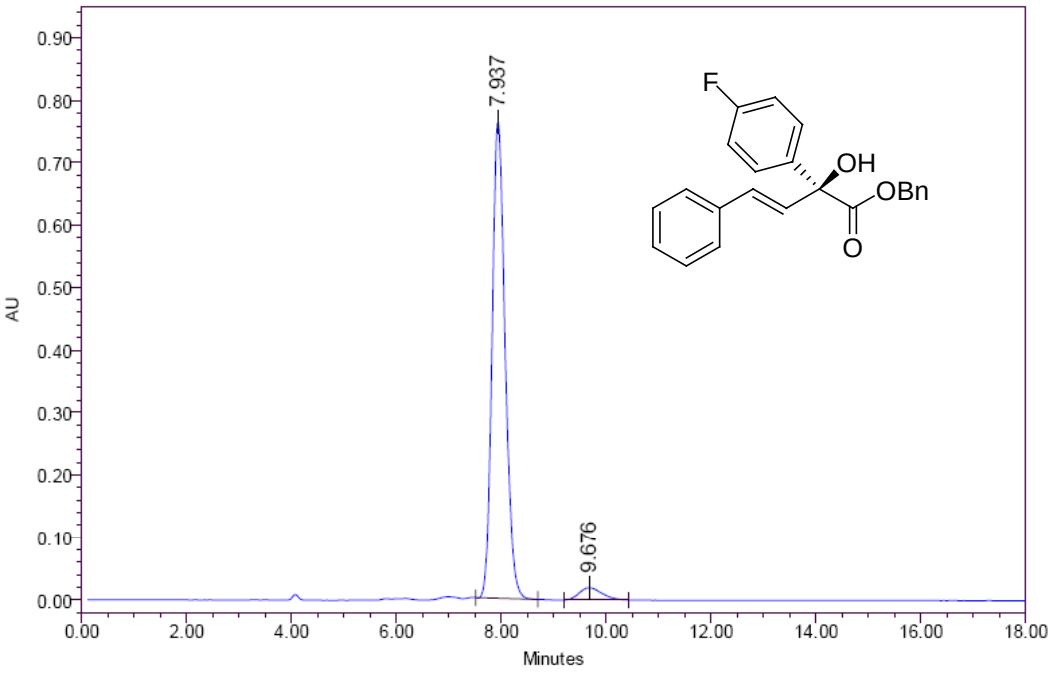




	RT	Area	% Area	Height
1	11.689	30282408	94.87	1067338
2	16.632	1638589	5.13	34757

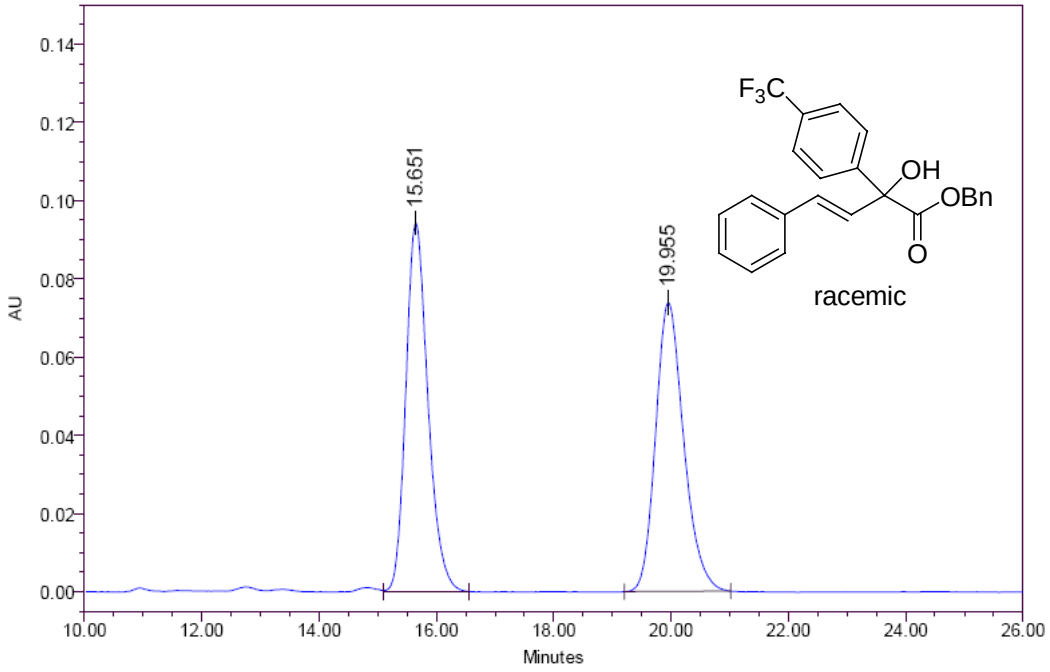
6d

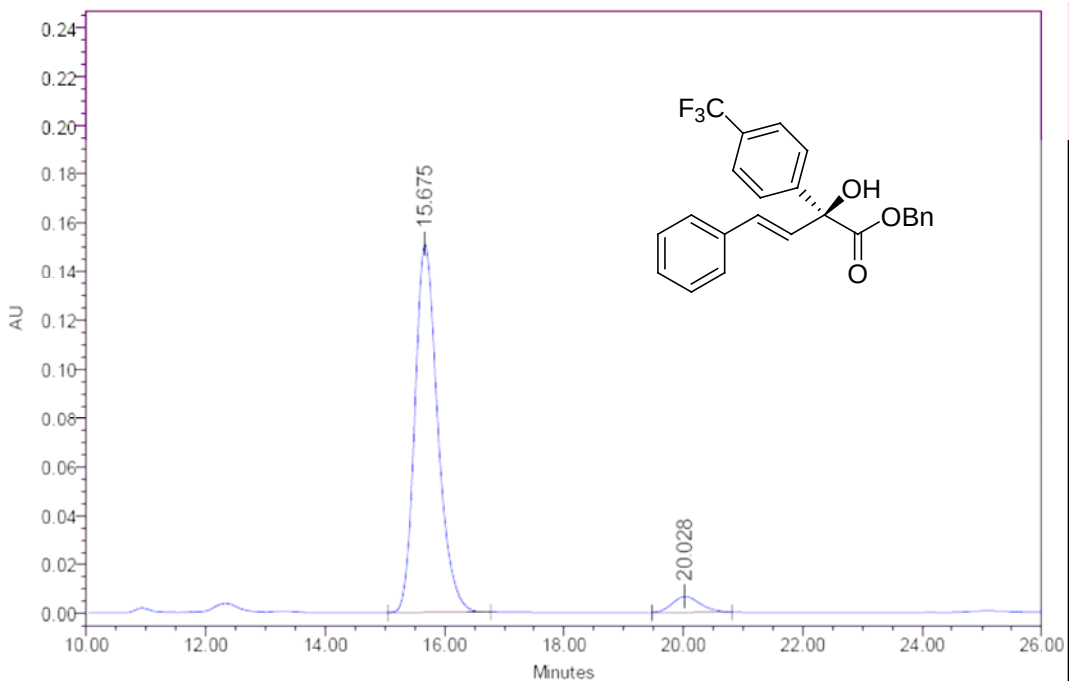




	RT	Area	% Area	Height
1	7.937	13151779	95.75	764655
2	9.676	584095	4.25	19523

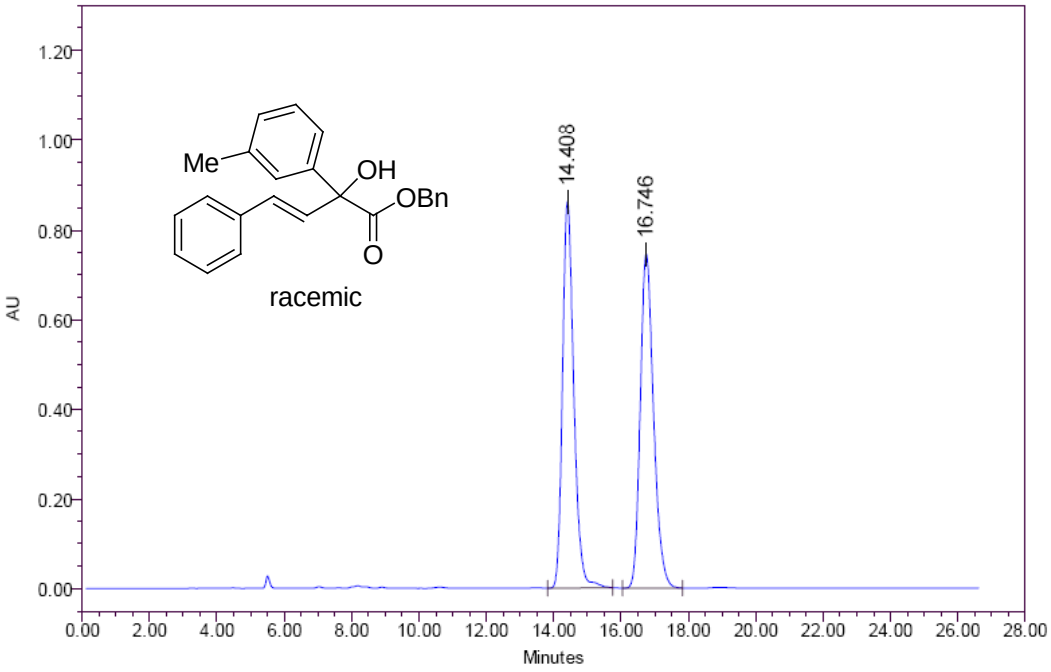
6e

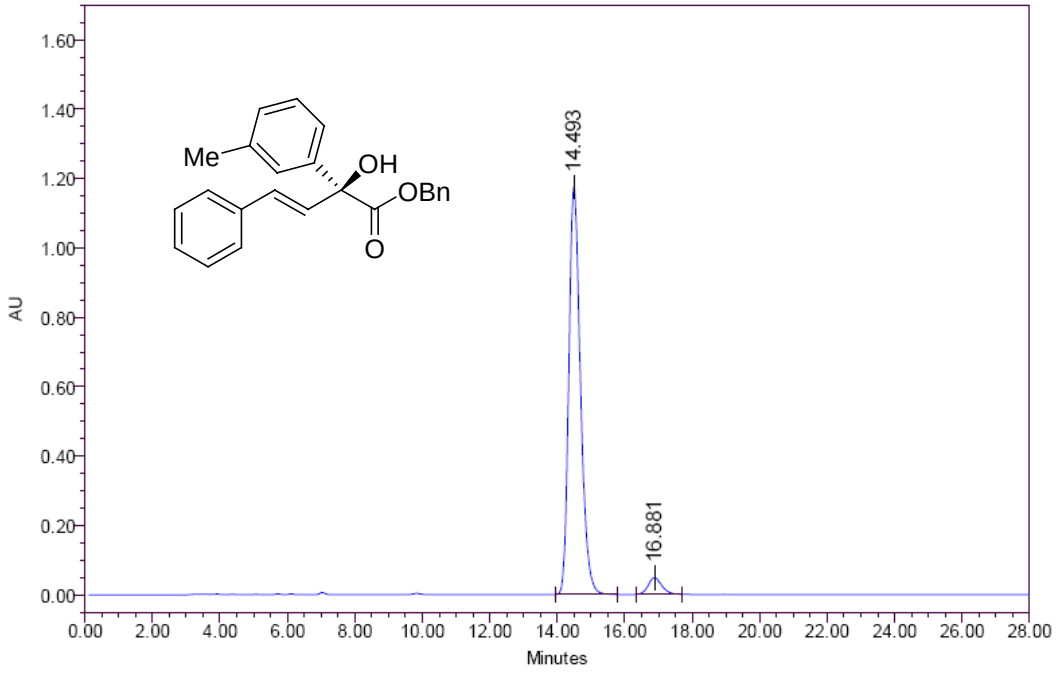




	RT	Area	% Area	Height
1	15.675	4008664	94.99	151205
2	20.028	211564	5.01	6482

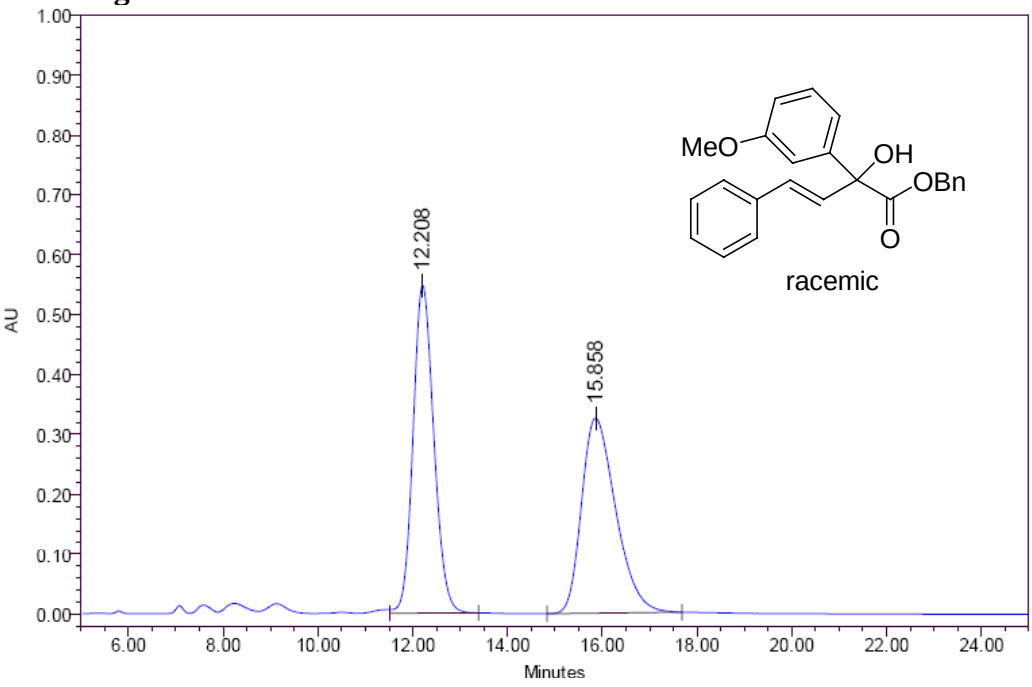
6f

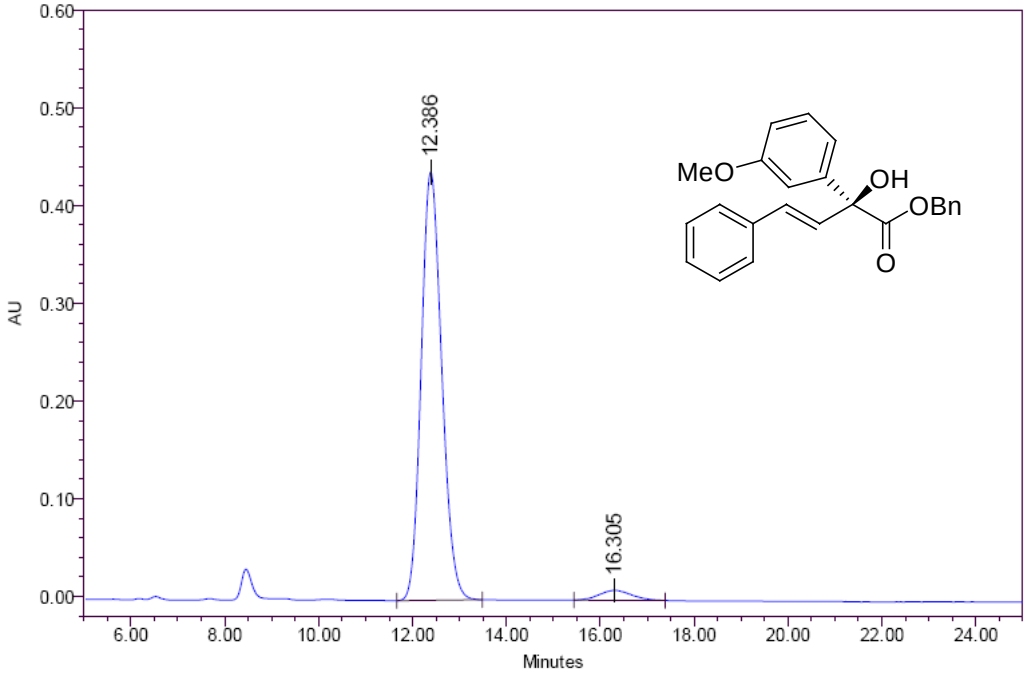




	RT	Area	% Area	Height
1	14.493	28140146	95.48	1175357
2	16.881	1331139	4.52	47887

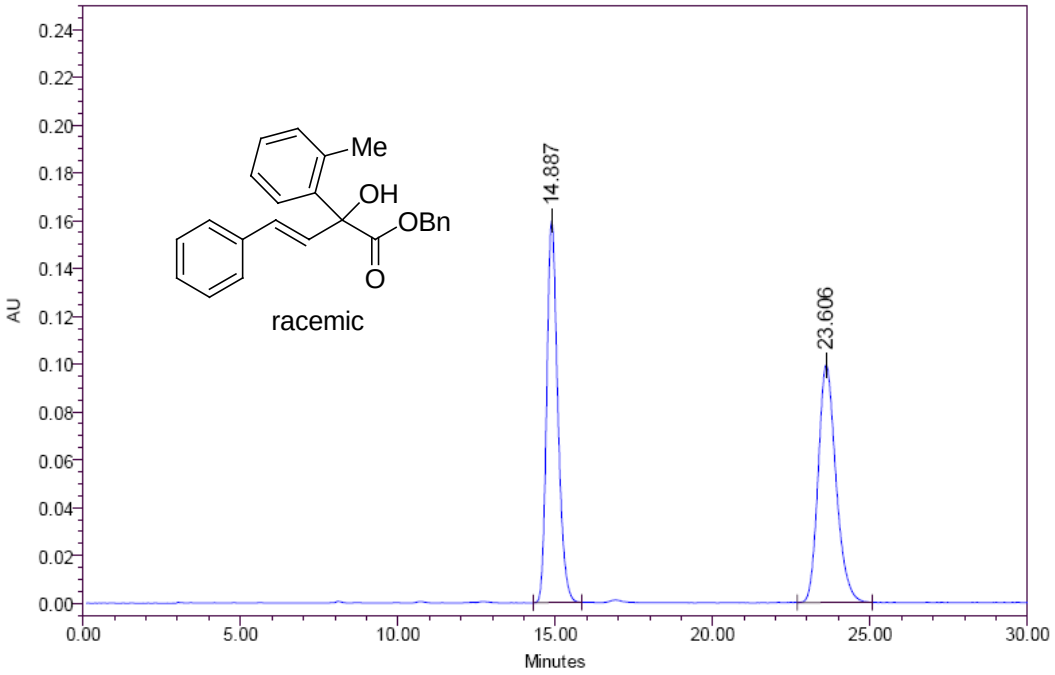
6g

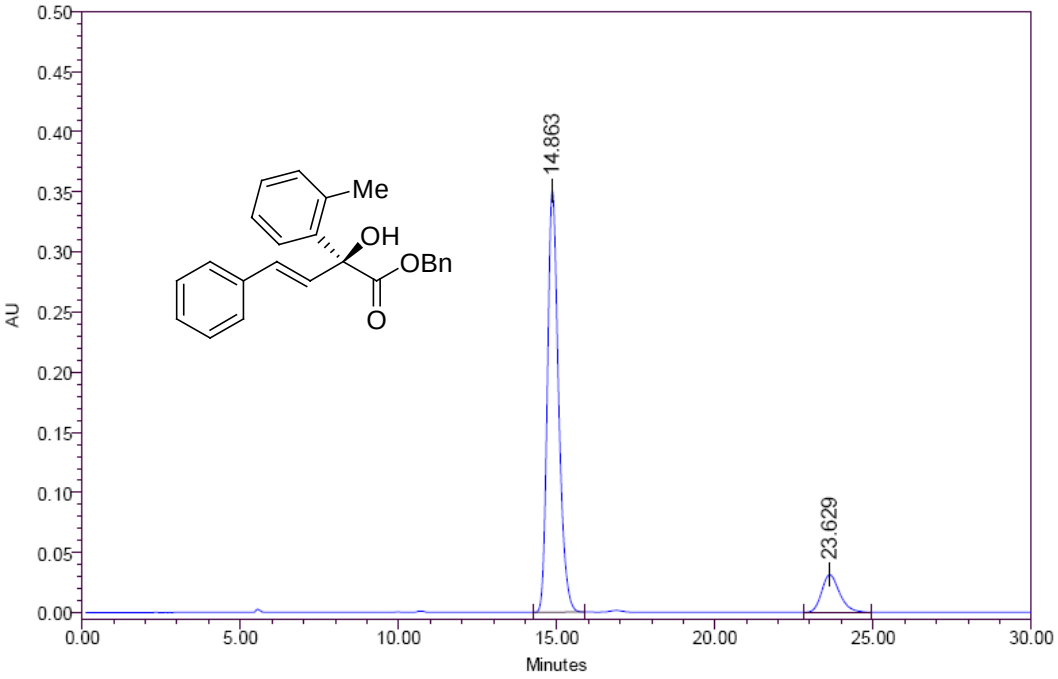




	RT	Area	% Area	Height
1	12.386	13306961	96.47	438279
2	16.305	487047	3.53	10105

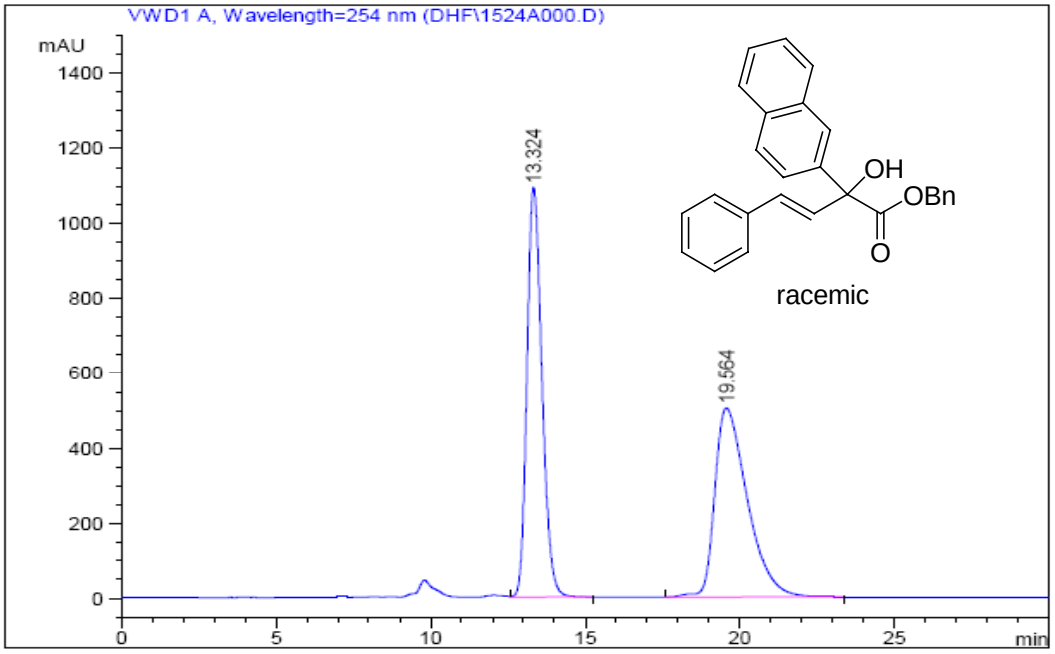
6h

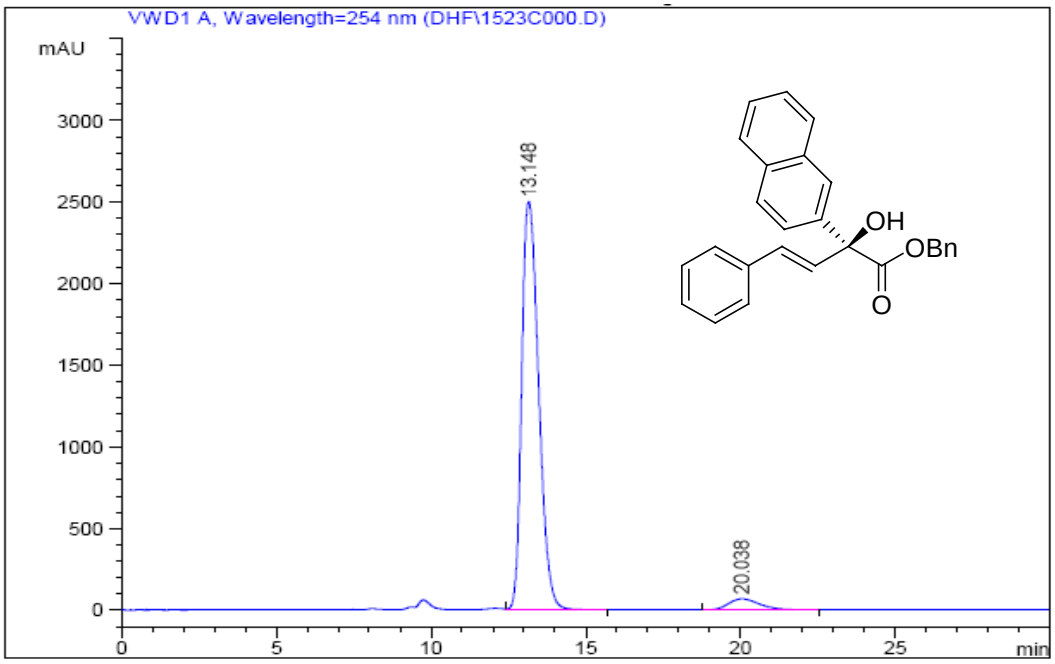




	RT	Area	% Area	Height
1	14.863	8562278	87.54	350612
2	23.629	1218717	12.46	31181

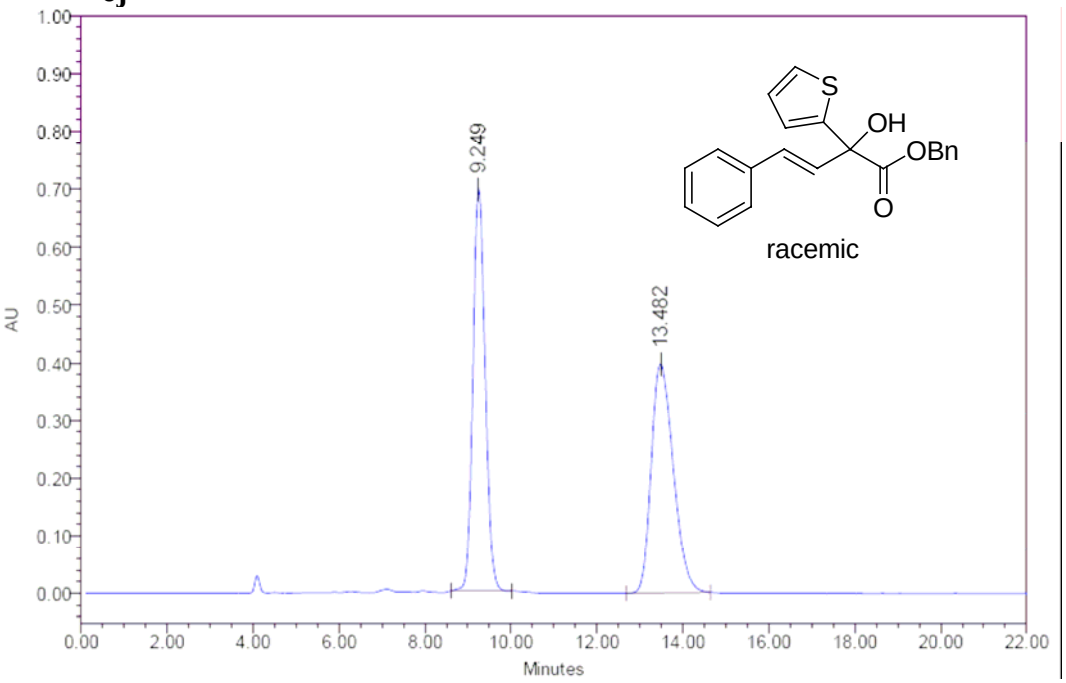
6i

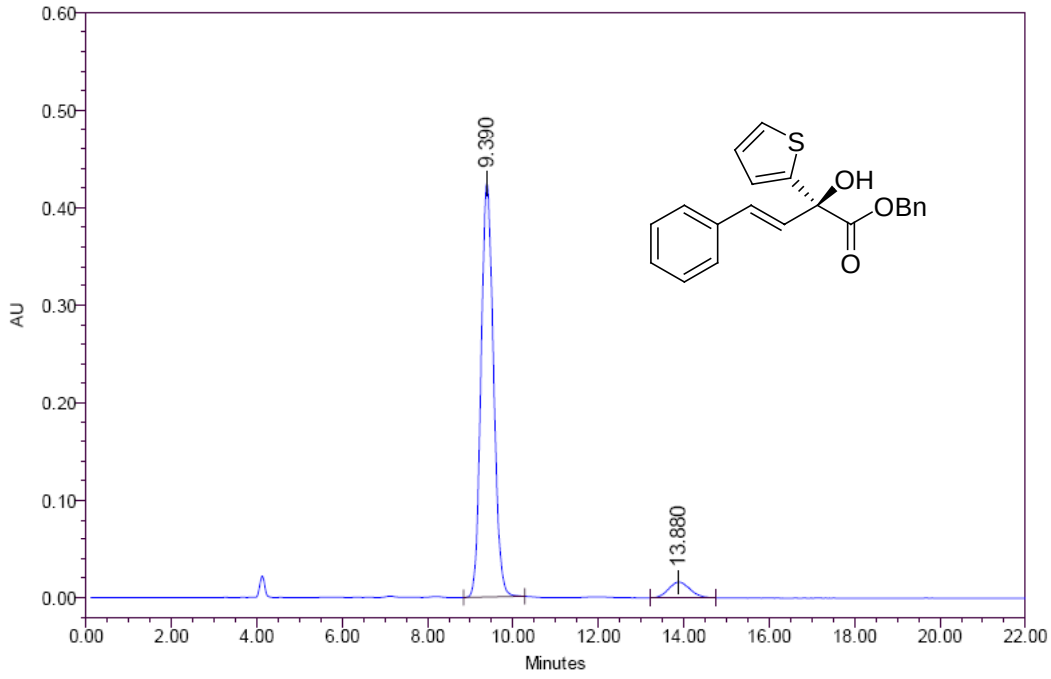




Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	13.148	VB	0.6001	9.53997e4	2496.90869	95.2660
2	20.038	BB	1.0770	4740.66064	67.26950	4.7340

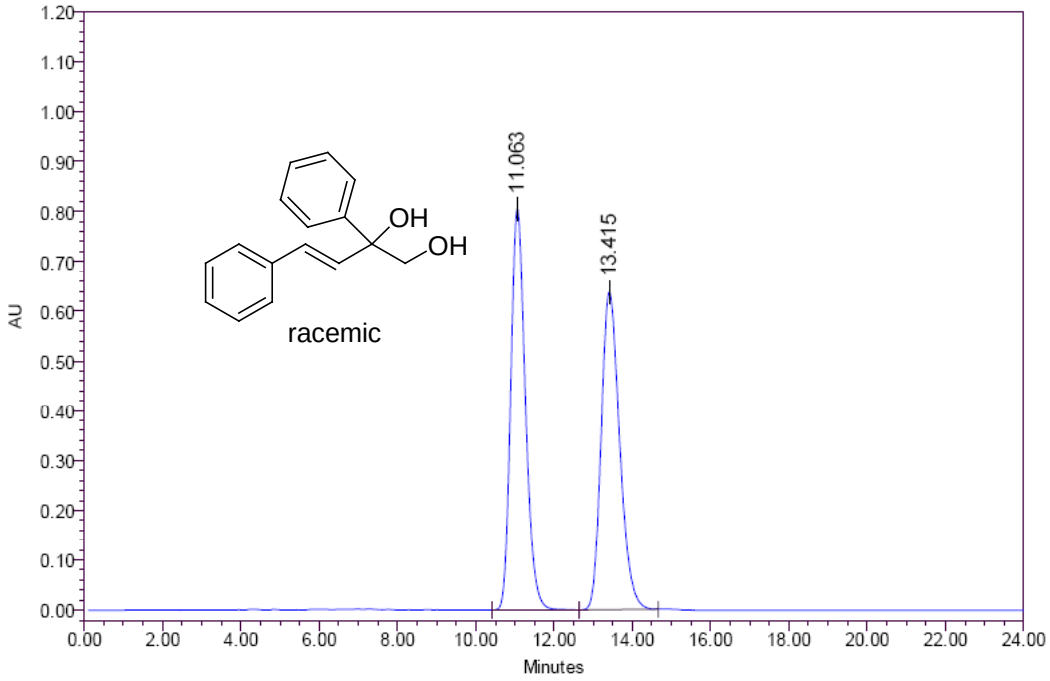
6j

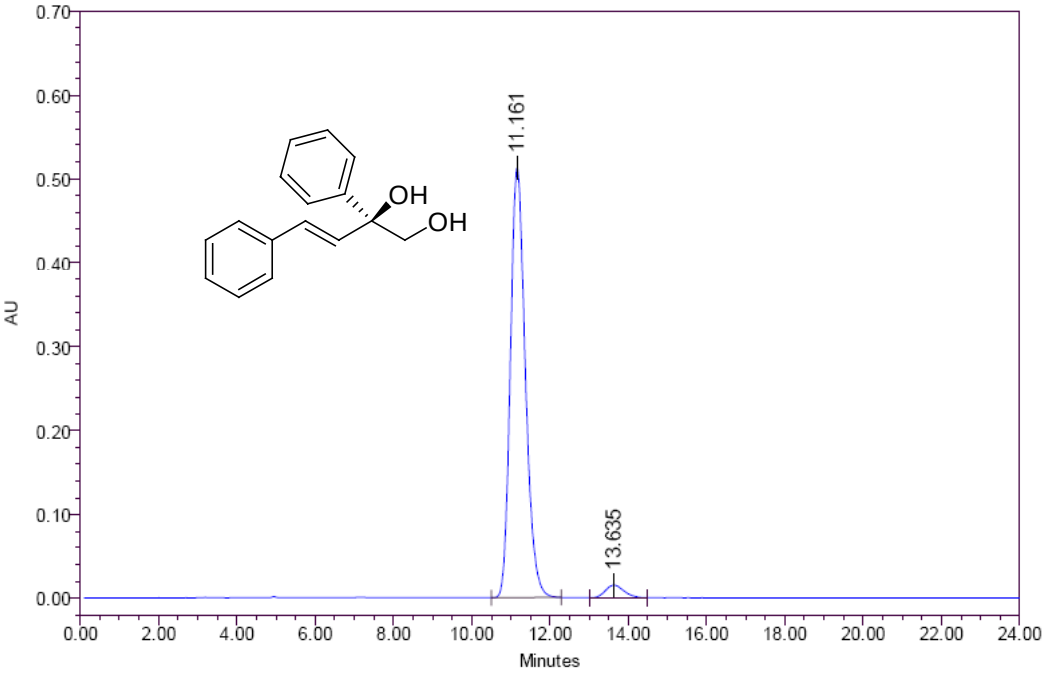




	RT	Area	% Area	Height
1	9.390	8626002	93.89	424186
2	13.880	561473	6.11	16065

8





	RT	Area	% Area	Height
1	11.161	13634518	96.49	512373
2	13.635	495749	3.51	15002