Supporting Information

Kinetic Resolution *via* Supramolecular Iminium Catalysis: Multiactivation Enables the Asymmetric Synthesis of β-Aryl Substituted Aldehydes and Densely Functionalized Cyclohexanes

Zhi-Long Jia,[a] Yao Wang, *[b] Guo-Qiang Xu,[a] and Peng-Fei Xu*[a]

[a] *State Key Laboratory of Applied Organic Chemistry, College of Chemistry and Chemical Engineering, Lanzhou University, Lanzhou 730000 (P.R. China).*

[b] *School of Chemistry and Chemical Engineering, Shandong University, Jinan, 250100 (China)*

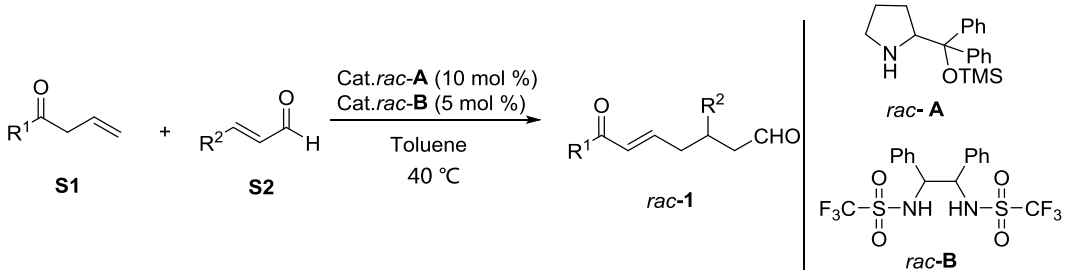
Table of Contents

1. General Information

Chemicals were either purchased from commercial suppliers or purified by standards techniques. Ultra dry 1,2-dichloroethane(DCE) was purchased from commercial suppliers. Toluene, dichloromethane (DCM), tetrahydrofuran (THF), and acetonitrile were dried through aluminia using a Pure-Solv PS-MD-5 Solvent Purification System (Innovative Technology). Analytical thin-layer chromatography (TLC) was performed on silica gel plates with F-254 indicator and compounds were visualized by irradiation with UV light. Flash chromatography was carried out utilizing silica gel 200-300 mesh. ^{1}H NMR, ^{13}C NMR spectra were recorded on a Bruker AM-400 spectrometer (400 MHz ^{1}H, 101 MHz ^{13}C). The spectra were recorded in $CDCl_3$ or DMSO-d_6 as solvents at room temperature, ^{1}H and ^{13}CNMR chemical shifts are reported in ppm relative to either the residual solvent peak (^{13}C) (δ = 77.00 ppm) or TMS (^{1}H) (δ = 0 ppm) as an internal standard. Data for ^{1}H NMR are reported as follows: chemical shift (δ ppm), multiplicity (s = singlet, d = doublet, t = triplet, m = multiplet, dd = double doublet), coupling constant (Hz) and integration. Data for ^{13}C NMR are reported as chemical shift. IR spectra were recorded using Nicolet NEXUS 670 FT-IR instrument and are reported in wavenumbers (cm^{-1}). HRMS were performed on Bruker Apex II mass instrument (ESI). Enantiomeric excess values were determined by HPLC with employing a Daicel Chirapak AD-H, AS-H, OD-H. on Agilent 1100 series and eluting with *i*-PrOH and *n*-hexane. Optical rotation was measured on the Perkin Elmer 341 polarimeter with $[\alpha]_D$ values reported in degrees; concentration (c) is in g/100 mL.

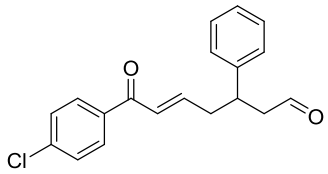
2. Preparation of Substrates

Substrates **1** were prepared following the published procedures.



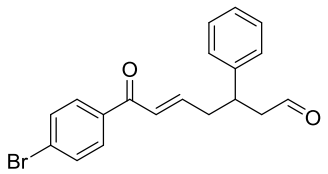
To a solution of catalysts *rac*-**A** (10 mol %) and *rac*-**B** (5 mol %) in dry toluene or DCE was added unsaturated aldehyde **S2** (1 equiv) at room temperature. Then the reaction mixture was heated to 40 ℃ and Allyl Ketones **S1** (1.2 equiv) was added subsequently. The reaction mixture was stirred at 50 ℃ and monitored by TLC. Upon complete consumption of aldehyde **S2**, the reaction mixture was then immediately purified by flash chromatography on silica gel to give the desired products **1a-m**.

(E)-7-(4-chlorophenyl)-7-oxo-3-phenylhept-5-enal (1b)



Faint yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.68 (s, 1H), 7.78 - 7.61 (m, 2H), 7.44 - 7.09 (m, 7H), 6.96 - 6.77 (m, 1H), 6.71 (d, *J* = 15.6 Hz, 1H), 3.54 - 3.29 (m, 1H), 2.89 - 2.74 (m, 2H), 2.74 - 2.50 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 200.6, 189.0, 146.2, 142.3, 139.0, 135.8, 129.8, 128.7, 128.6, 127.6, 127.3, 126.9, 49.4, 39.3, 39.0. HRMS (ESI): exact mass calculated for $[M+H]^+$ ($C_{19}H_{18}ClO_2$) requires m/z 313.0990, found m/z 313.0994.

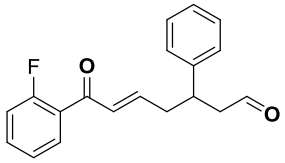
(E)-7-(4-bromophenyl)-7-oxo-3-phenylhept-5-enal (1d)



Faint yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.68 (t, *J* = 1.2 Hz, 1H), 7.62 (d, *J* = 8.4 Hz, 2H), 7.54 (d, *J* = 8.8 Hz, 2H), 7.32 (t, *J* = 7.2 Hz, 2H), 7.25 - 7.15 (m, 3H), 6.93 - 6.76 (m, 1H), 6.70 (d, *J* = 15.2 Hz, 1H), 3.51 - 3.38 (m, 1H), 2.88 - 2.75 (m, 2H), 2.74 - 2.54 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 200.6, 189.3, 146.3, 142.3, 136.2,

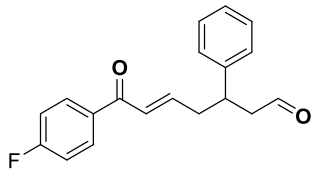
131.7, 129.9, 128.8, 127.7, 127.6, 127.3, 127.0, 49.5, 39.3, 39.0. HRMS (ESI): exact mass calculated for $[M+H]^+$ ($C_{19}H_{18}BrO_2$) requires m/z 357.0485, found m/z 357.0484.

(E)-7-(2-fluorophenyl)-7-oxo-3-phenylhept-5-enal (1f)



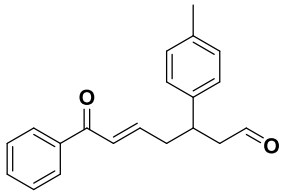
Faint yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.68 (s, 1H), 7.62 (t, *J* = 7.6 Hz, 1H), 7.47 (dd, *J* = 13.2, 6.4 Hz, 1H), 7.31 (t, *J* = 7.6 Hz, 2H), 7.25 - 7.15 (m, 4H), 7.14 - 7.04 (m, 1H), 6.86 - 6.72 (m, 1H), 6.66 (d, *J* = 15.6 Hz, 1H), 3.44 (p, *J* = 7.2 Hz, 1H), 2.81 (d, *J* = 7.2 Hz, 2H), 2.64 (t, *J* = 7.2 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 200.8, 189.1 (d, *J* = 2 Hz), 161.0 (d, *J* = 251 Hz), 146.3, 142.4, 133.8 (d, *J* = 8 Hz), 131.5 (d, *J* = 6 Hz), 130. (d, *J* = 2 Hz), 128.8, 127.3, 127.0, 126.6 (d, *J* = 14 Hz), 124.3 (d, *J* = 3 Hz), 116.4 (d, *J* = 22 Hz), 49.4, 39.4, 39.0. HRMS (ESI): exact mass calculated for $[M+H]^+$ ($C_{19}H_{18}FO_2$) requires m/z 297.1285, found m/z 297.1289.

(E)-7-(4-fluorophenyl)-7-oxo-3-phenylhept-5-enal (1i)



Faint yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.70 (t, *J* = 1.2 Hz, 1H), 7.86 - 7.75 (m, 2H), 7.33 (t, *J* = 7.6 Hz, 2H), 7.28 - 7.18 (m, 3H), 7.09 (t, *J* = 8.4 Hz, 2H), 6.91 - 6.78 (m, 1H), 6.73 (d, *J* = 15.2 Hz, 1H), 3.53 - 3.38 (m, 1H), 2.83 (d, *J* = 7.2 Hz, 2H), 2.75 - 2.58 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 200.7, 188.8, 165.5 (d, *J* = 253 Hz), 145.9, 142.3, 133 (d, *J* = 3 Hz), 131.1 (d, *J* = 9 Hz), 128.8, 127.8, 127.4, 127.0, 115.5 (d, *J* = 21 Hz), 49.6, 39.4, 39.1. HRMS (ESI): exact mass calculated for $[M+H]^+$ ($C_{19}H_{18}FO_2$) requires m/z 297.1285, found m/z 297.1289.

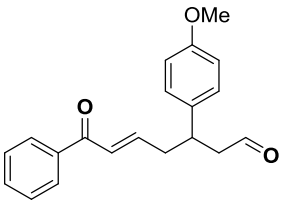
(E)-7-oxo-7-phenyl-3-(p-tolyl)hept-5-enal (1j)



Faint yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.69 (s, 1H), 7.79 (d, *J* = 7.2 Hz, 2H), 7.54 (t, *J* = 7.2 Hz, 1H), 7.43 (t, *J* = 7.6 Hz, 2H), 7.12 (m, 5 H), 6.82 (m, 2H), 3.47 – 3.36 (m, 1H), 2.82 – 2.77 (m, 1H), 2.65 (dd, *J* = 13.2, 6.6 Hz, 1H), 2.34 – 2.25 (m, 5H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 201.0, 190.5, 145.9, 139.3, 137.7, 136.7, 132.7, 129.5, 128.5, 128.5, 128.2, 127.3, 49.6, 39.6, 38.9,

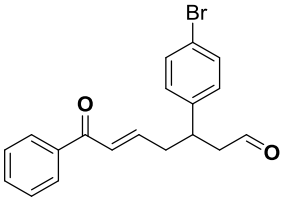
21.0. HRMS (ESI): exact mass calculated for $[M+H]^+$ ($C_{20}H_{21}O_2$) requires m/z 293.1536, found m/z 293.1532.

(E)-3-(4-methoxyphenyl)-7-oxo-7-phenylhept-5-enal (1k)



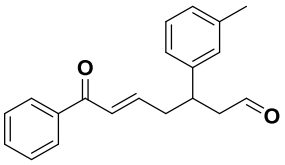
Faint yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.67 (s, 1H), 7.85 – 7.74 (m, 2H), 7.53 (t, *J* = 7.6 Hz, 1H), 7.42 (t, *J* = 7.6 Hz, 2H), 7.13 (d, *J* = 8.8 Hz, 2H), 6.91 – 6.69 (m, 4H), 3.77 (s, 3H), 3.48 – 3.33 (m, 1H), 2.78 (dd, *J* = 7.2, 1.6 Hz, 2H), 2.71 – 2.52 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 201.0, 190.4, 158.4, 145.9, 137.6, 134.3, 132.6, 128.4, 128.4, 128.3 128.0, 114.1, 55.1, 49.6, 39.6, 38.4. HRMS (ESI): exact mass calculated for $[M+H]^+$ ($C_{20}H_{21}O_3$) requires m/z 309.1485, found m/z 309.1490.

(E)-3-(4-bromophenyl)-7-oxo-7-phenylhept-5-enal (1l)



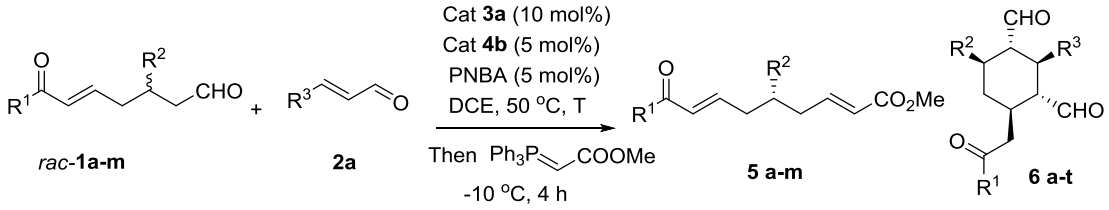
Faint yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.67 (s, 1H), 7.86 – 7.72 (m, 2H), 7.54 (t, *J* = 7.4 Hz, 1H), 7.43 (dd, *J* = 7.8, 5.8 Hz, 4H), 7.09 (d, *J* = 8.4 Hz, 2H), 6.88 – 6.71 (m, 2H), 3.46 – 3.39 (m, 1H), 2.81 – 2.79 (m, 2H), 2.72 – 2.55 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 200.1, 190.2, 145.0, 141.5, 137.4, 132.7, 131.8, 129.1, 128.5, 128.4, 128.2, 120.7, 49.3, 39.1, 38.4. HRMS (ESI): exact mass calculated for $[M+H]^+$ ($C_{19}H_{18}BrO_2$) requires m/z 357.0485, found m/z 357.0484.

(E)-7-oxo-7-phenyl-3-(m-tolyl)hept-5-enal (1m)



Faint yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.69 (s, 1H), 7.79 (d, *J* = 7.2 Hz, 2H), 7.53 (t, *J* = 7.2 Hz, 1H), 7.43 (t, *J* = 7.6 Hz, 2H), 7.21 (t, *J* = 7.2 Hz, 1H), 7.05 - 7.00 (m, 3H), 6.91 - 6.69 (m, 2H), 3.41 (p, *J* = 7.2 Hz, 1H), 2.80 (d, *J* = 7.2 Hz, 2H), 2.70 - 2.57 (m, 2H), 2.33 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 201.0, 190.6, 145.9, 142.3, 138.4, 137.6, 132.7, 128.7, 128.50, 128.4, 128.2, 127.8, 124.3, 49.5, 39.5, 39.1, 21.4. HRMS (ESI): exact mass calculated for $[M+H]^+$ ($C_{20}H_{21}O_2$) requires m/z 293.1536, found m/z 293.1541.

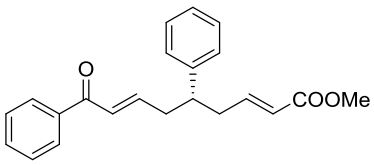
3. General procedure



Materials were purified by chromatography before use. To a flame dried reaction vial with a magnetic stirring bar was added catalyst **3a** (0.02 mmol, 10 mol%) and catalyst **4b** (0.01 mmol, 5 mol%) and 4-nitrobenzoic acid (0.01 mmol, 5 mol%). Under the protection of nitrogen, a solution of substrate **1** in ultra dry DCE (0.2 mol/L, 1.0 mL) and cinnamaldehyde (0.2 mmol) was added by syringe respectively. Then the reaction mixture was stirred at 50 ℃ for the specified time and monitored by TLC. Since the two products are difficult to separate, after the reaction was completed, the reaction mixture was cooled to -10 ℃, then $Ph_3PCHCOOMe$ (0.15 mmol) was added and the reaction was monitored by TLC. After reacting for 4 h, the mixture was warmed to room temperature for another hour and then purified by chromatography to give the desired products.

4. Analytical and spectra data

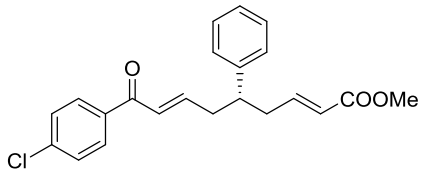
methyl (S,2E,7E)-9-oxo-5,9-diphenylnona-2,7-dienoate (5a)



Colorless oil; $[\alpha]_D^{20}$ = -3 (*c* 1.0, CH_2Cl_2, 95% ee); IR(KBr cm^{-1}): 3194, 3061, 3029, 2950, 2927, 1721, 1669, 1620, 1598, 1449, 1437, 1278, 1209, 982, 763; ^1H NMR (400 MHz, $CDCl_3$) δ 7.78 (d, *J* = 7.2 Hz, 2H), 7.53 (t, *J* = 7.6 Hz, 1H), 7.32 (t, *J* = 7.2 Hz, 2H), 7.23 (t, *J* = 6.4 Hz, 1H), 7.17 (d, *J* = 7.2 Hz, 2H), 6.90 – 6.71 (m, 3H), 5.80 (d, *J* = 15.6 Hz, 1H), 3.69 (s, 3H), 3.04 – 2.91 (m, 1H), 2.74 – 2.52 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 190.5, 166.6, 146.5, 146.4, 142.6, 137.6, 132.6, 128.7, 128.4, 128.4, 127.9, 127.4, 126.8, 122.8, 51.4, 44.3, 39.2, 38.7. The enantiomeric excess was determined by HPLC with AS-H column. (*n*-hexane:*i*-PrOH = 80:20), 1mL/min; major enantiomer t_R = 11.81 min, minor

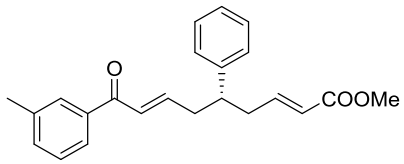
enantiomer t_R = 13.18 min. HRMS (ESI) : $[M+H]^+$calcd for $[C_{22}H_{23}O_3]$: 335.1642, found: 335.1643.

methyl (2E,7E)-9-(4-chlorophenyl)-9-oxo-5-phenylnona-2,7-dienoate (5b)



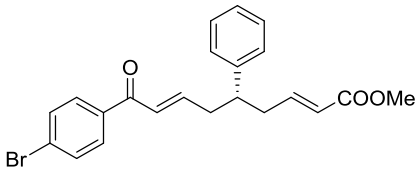
Colorless oil; $[\alpha]_D^{20}$ = +3 (*c* 1.0, CH_2Cl_2, 89% ee); IR(KBr cm^{-1}): 3058, 3028, 2950, 2926, 2850, 1721, 1670, 1621, 1597, 1492, 1448, 1436, 1277, 1211, 1092, 1014, 982; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.75 – 7.64 (m, 2H), 7.46 – 7.34 (m, 2H), 7.31 (t, *J* = 7.4 Hz, 2H), 7.23 (t, *J* = 7.6 Hz, 1H), 7.19 – 7.12 (m, 2H), 6.90 – 6.78 (m, 2H), 6.69 (d, *J* = 15.6 Hz, 1H), 5.80 (d, *J* = 15.6 Hz, 1H), 3.68 (s, 3H), 2.97 (p, *J* = 7.2 Hz, 1H), 2.76 – 2.50 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 189.2, 166.5, 146.8, 146.3, 142.5, 139.0, 135.9, 129.9, 128.7, 127.5, 127.4, 126.9, 122.8, 51.4, 44.3, 39.1, 38.7. The enantiomeric excess was determined by HPLC with AS-H column. (*n*-hexane:*i*-PrOH = 80:20), 1mL/min; major enantiomer t_R = 16.61 min, minor enantiomer t_R = 20.32 min. HRMS (ESI) : $[M+H]^+$calcd for $[C_{22}H_{22}ClO_3]$: 369.1252, found: 369.1248.

methyl (S,2E,7E)-9-oxo-5-phenyl-9-(m-tolyl)nona-2,7-dienoate (5c)



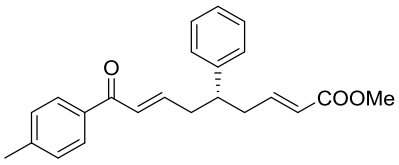
Colorless oil; $[\alpha]_D^{20}$ = +5 (*c* 1.0, CH_2Cl_2, 96% ee); IR(KBr cm^{-1}): 3060, 3028, 2951, 2926, 2854, 1721, 1671, 1620, 1585, 1453, 1436, 1398, 1267, 1212, 1070, 1009; ^{1}H NMR (400 MHz, $CDCl_3$) δ7.62 – 7.53 (m, 2H), 7.37 – 7.27 (m, 4H), 7.25 – 7.20 (m, 1H), 7.20 – 7.15 (m, 2H), 6.90 – 6.79 (m, 2H), 6.75 (d, *J* = 15.6 Hz, 1H), 5.80 (d, *J* = 15.6 Hz, 1H), 3.69 (s, 3H), 3.02 – 2.92 (m, 1H), 2.72 – 2.55 (m, 4H), 2.38 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 190.8, 166.6, 146.5, 146.1, 142.6, 138.2, 137.7, 133.4, 129.0, 128.7, 128.3, 128.1, 127.4, 126.8, 125.7, 122.8, 51.4, 44.3, 39.2, 38.7, 21.3. The enantiomeric excess was determined by HPLC with AS-H column. (*n*-hexane:*i*-PrOH = 80:20), 1mL/min; major enantiomer t_R = 12.81 min, minor enantiomer t_R = 14.79 min. HRMS (ESI) : $[M+H]^+$calcd for $[C_{23}H_{25}O_3]$: 349.1798, found: 349.1797.

methyl (S,2E,7E)-9-(4-bromophenyl)-9-oxo-5-phenylnona-2,7-dienoate (5d)



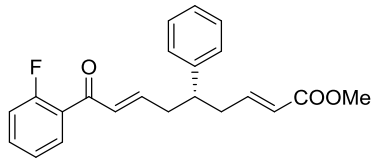
Colorless oil; $[\alpha]_D^{20}$ = +7 (*c* 1.0, CH_2Cl_2, 95% ee); IR(KBr cm^{-1}): 3028, 2951, 2924, 2857, 1722, 1670, 1621, 1452, 1436, 1278, 1204, 1165, 1032, 982; ^1H NMR (400 MHz, $CDCl_3$) δ 7.61 (d, *J* = 8.8 Hz, 2H), 7.53 (d, *J* = 8.4 Hz, 2H), 7.31 (t, *J* = 7.6 Hz, 2H), 7.22 (t, *J* = 7.6 Hz, 1H), 7.16 (d, *J* = 7.6 Hz, 2H), 6.90 - 6.78 (m, 2H), 6.68 (d, *J* = 15.6 Hz, 1H), 5.80 (d, *J* = 15.6 Hz, 1H), 3.67 (s, 3H), 3.04 - 2.86 (m, 1H), 2.79 - 2.49 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 189.3, 166.4, 146.8, 146.2, 142.4, 136.3, 131.6, 129.9, 128.6, 127.6, 127.4, 127.3, 126.8, 122.8, 51.3, 44.2, 39.0, 38.7. The enantiomeric excess was determined by HPLC with AS-H column. (*n*-hexane:*i*-PrOH = 80:20), 1mL/min; major enantiomer t_R = 15.45 min, minor enantiomer t_R = 17.24 min. HRMS (ESI) : $[M+H]^+$calcd for $[C_{22}H_{22}BrO_3]$:412.0747, found: 413.0744.

methyl (S,2E,7E)-9-oxo-5-phenyl-9-(p-tolyl)nona-2,7-dienoate (5e)



Colorless oil; $[\alpha]_D^{20}$ = +6 (*c* 1.0, CH_2Cl_2, 91% ee); IR(KBr cm^{-1}): 3061, 3027, 2950, 2926, 2851, 1722, 1654, 1620, 1453, 1436, 1272, 1210, 1155, 1038, 982; ^1H NMR (400 MHz, $CDCl_3$) δ 7.70 (d, *J* = 8.0 Hz, 2H), 7.30 (t, *J* = 7.2 Hz, 2H), 7.25 - 7.10 (m, 5H), 6.93 - 6.68 (m, 3H), 5.79 (d, *J* = 15.6 Hz, 1H), 3.67 (s, 3H), 3.05 - 2.85 (m, 1H), 2.73 - 2.50 (m, 4H), 2.38 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 189.9, 166.5, 146.4, 145.7, 143.4, 142.6, 135.0, 129.1, 128.6, 128.5, 127.8, 127.3, 126.7, 122.7, 51.3, 44.3, 39.1, 38.6, 21.5. The enantiomeric excess was determined by HPLC with AS-H column. (*n*-hexane:*i*-PrOH = 80:20), 1mL/min; major enantiomer t_R = 12.76 min, minor enantiomer t_R = 16.28 min. HRMS (ESI) : $[M+H]^+$calcd for $[C_{23}H_{25}O_3]$: 349.1798, found: 349.1797.

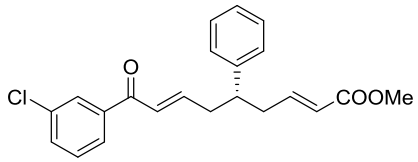
methyl (S,2E,7E)-9-(2-fluorophenyl)-9-oxo-5-phenylnona-2,7-dienoate (5f)



Colorless oil; $[\alpha]_D^{20}$ = +0 (*c* 1.0, CH_2Cl_2, 88% ee); IR(KBr cm^{-1}): 3029, 2950, 2926, 1721, 1657, 1618, 1481, 1452, 1275, 1210, 1155, 1103, 1028, 981; ^1H NMR (400

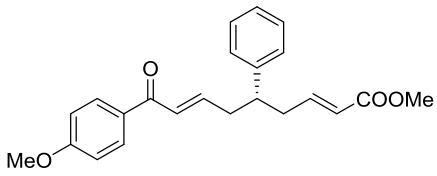
MHz, $CDCl_3$) δ 7.61 (td, *J* = 7.6, 1.6 Hz, 1H), 7.46 (ddd, *J* = 15.2, 5.2, 1.6 Hz, 1H), 7.30 (t, *J* = 7.6 Hz, 2H), 7.24 - 7.13 (m, 4H), 7.09 (dd, *J* = 10.0, 8.8 Hz, 1H), 6.90 - 6.71 (m, 2H), 6.70 - 6.60 (m, 1H), 5.79 (d, *J* = 15.6 Hz, 1H), 3.68 (s, 3H), 3.02 - 2.90 (m, 1H), 2.70 - 2.51 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 189.1 (d, *J* = 2 Hz), 166.6, 160.9 (d, *J* = 252 Hz), 147.0, 146.4, 142.5, 133.7 (d, *J* = 8 Hz), 131.2 (d, *J* = 5 Hz), 130.8 (d, *J* = 3 Hz), 128.6, 127.3, 126.8, 126.7 (d, *J* = 13 Hz), 124.3 (d, *J* = 6 Hz), 122.8, 116.3 (d, *J* = 23 Hz), 51.4, 44.2, 39.1, 38.5. The enantiomeric excess was determined by HPLC with AS-H column. (*n*-hexane:*i*-PrOH = 80:20), 1mL/min; major enantiomer t_R = 11.94 min, minor enantiomer t_R = 14.33 min. HRMS (ESI) : $[M+NH_4]^+$calcd for $[C_{22}H_{25}FNO_3]$: 370.1813, found: 370.1814.

methyl (S,2E,7E)-9-(3-chlorophenyl)-9-oxo-5-phenylnona-2,7-dienoate (5g)



Colorless oil; $[\alpha]_D^{20}$ = +1 (*c* 1.0, CH_2Cl_2, 89% ee); IR(KBr cm^{-1}): 3066, 2925, 2854, 1720, 1656, 1620, 1451, 1438, 1382, 1278, 1226, 1198, 1148, 1097, 1030, 982; ^1H NMR (400 MHz, $CDCl_3$) δ 7.72 (s, 1H), 7.62 (d, *J* = 7.6 Hz, 1H), 7.49 (dd, *J* = 8.0, 1.2 Hz, 1H), 7.39 - 7.29 (m, 3H), 7.23 (t, *J* = 7.6 Hz, 1H), 7.17 (d, *J* = 6.8 Hz, 2H), 6.91 -6.76 (m, 2H), 6.67 (d, *J* = 15.6 Hz, 1H), 5.81 (d, *J* = 15.6 Hz, 1H), 3.69 (s, 3H), 2.97 (p, *J* = 7.2 Hz 1H), 2.76 - 2.54 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 189.3, 166.6, 147.3, 146.3, 142.5, 139.3, 134.7, 132.6, 129.8, 128.8, 128.6, 127.6, 127.4, 127.0, 126.5, 122.9, 51.4, 44.3, 39.2, 38.8. The enantiomeric excess was determined by HPLC with AS-H column. (*n*-hexane:*i*-PrOH = 80:20), 1mL/min; major enantiomer t_R = 15.47 min, minor enantiomer t_R = 17.03 min. HRMS (ESI) : $[M+H]^+$calcd for $[C_{22}H_{22}ClO_3]$: 369.1252, found: 369.1248.

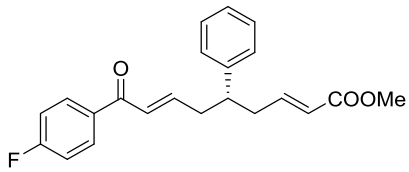
methyl (S,2E,7E)-9-(4-methoxyphenyl)-9-oxo-5-phenylnona-2,7-dienoate (5h)



Colorless oil; $[\alpha]_D^{20}$ = +4 (*c* 1.0, CH_2Cl_2, 95% ee); IR(KBr cm^{-1}): 3058, 2969, 2933, 1720, 1664, 1619, 1600, 1511, 1437, 1340, 1306, 1264, 1172, 1028, 982; ^1H NMR (400 MHz, $CDCl_3$) δ 7.80 (d, *J* = 8.8 Hz, 2H),

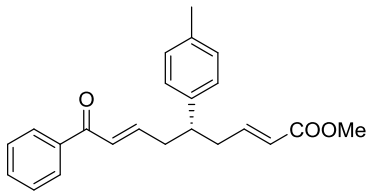
7.33 - 7.27 (m, 2H), 7.26 - 7.13 (m, 3H), 6.90 - 6.74 (m, 5H), 5.80 (d, *J* = 15.6 Hz, 1H), 3.85 (s, 3H), 3.68 (s, 3H), 3.03 - 2.90 (m, 1H), 2.72 - 2.50 (m, 4H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 188.7, 166.6, 163.3, 146.5, 145.2, 142.7, 130.7, 130.5, 128.6, 127.6, 127.4, 126.8, 122.7, 113.6, 55.4, 51.4, 44.3, 39.1, 38.6. The enantiomeric excess was determined by HPLC with AS-H column. (*n*-hexane:*i*-PrOH = 80:20), 1mL/min; major enantiomer t_R = 21.65 min, minor enantiomer t_R = 26.47 min. HRMS (ESI) : $[M+H]^+$calcd for $[C_{23}H_{25}O_4]$: 365.1747, found: 365.1750.

methyl (S,2E,7E)-9-(4-fluorophenyl)-9-oxo-5-phenylnona-2,7-dienoate (5i)



Colorless oil; $[\alpha]_D^{20}$ = +4 (*c* 1.0, CH_2Cl_2, 96% ee); IR(KBr cm^{-1}): 3062, 3028, 2950, 2928, 1721, 1671, 1657, 1621, 1598, 1507, 1436, 1338, 1277, 1229, 1156, 1031, 982; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.79 (dd, *J* = 8.0, 5.6 Hz, 2H), 7.32 (t, *J* = 7.2 Hz, 2H), 7.27 - 7.13 (m, 3H), 7.08 (t, *J* = 8.4 Hz, 2H), 6.95 -6.76 (m, 2H), 6.72 (d, *J* = 15.6 Hz, 1H), 5.80 (d, *J* = 15.6 Hz, 1H), 3.68 (s, 3H), 3.05 - 2.85 (m, 1H), 2.78 - 2.45 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 188.8, 166.7, 165.4 (d, *J* = 253 Hz), 146.4 (d, *J* = 14 Hz), 142.5, 133.9 (d, *J* = 3 Hz), 131.1, 131.0, 128.7, 127.5, 127.4, 126.8, 122.8, 115.5 (d, *J* = 21 Hz), 51.4, 44.3, 39.1, 38.7. The enantiomeric excess was determined by HPLC with AS-H column. (*n*-hexane:*i*-PrOH = 80:20), 1mL/min; major enantiomer t_R = 14.87 min, minor enantiomer t_R = 16.79 min. HRMS (ESI) : $[M+H]^+$calcd for $[C_{22}H_{22}FO_3]$: 353.1547, found: 353.1546.

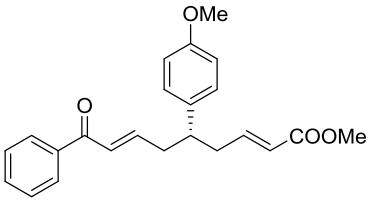
methyl (S,2E,7E)-9-oxo-9-phenyl-5-(p-tolyl)nona-2,7-dienoate (5j)



Colorless oil; $[\alpha]_D^{20}$ = -1 (*c* 1.0, CH_2Cl_2, 98% ee); IR(KBr cm^{-1}): 2950, 2924, 2856, 1722, 1670, 1621, 1598, 1447, 1437, 1276, 1209, 1178, 1157, 1037, 1020, 981; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.81 - 7.75 (m, 2H), 7.57 - 7.50 (m, 1H), 7.42 (t, *J* = 7.6 Hz, 2H), 7.15 - 7.09 (m, 2H), 7.09 - 7.01 (m, 1H), 6.90 - 6.70 (m, 3H), 5.80 (d, *J* = 15.6 Hz, 1H), 3.69 (s, 3H), 2.99 - 2.89 (m, 1H), 2.70 - 2.54 (m, 4H), 2.32 (s,

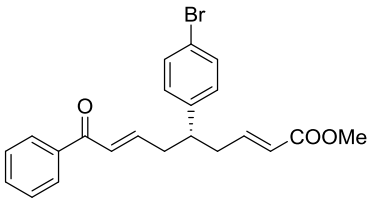
3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 190.7, 166.7, 146.7, 146.6, 139.6, 137.7, 136.4, 132.6, 129.4, 128.5, 128.4, 127.9, 127.3, 122.8, 51.4, 44.0, 39.3, 38.8, 21.0. The enantiomeric excess was determined by HPLC with AS-H column. (*n*-hexane:*i*-PrOH = 80:20), 1mL/min; major enantiomer t_R = 14.31 min, minor enantiomer t_R = 15.74 min. HRMS (ESI) : $[M+H]^+$calcd for $[C_{23}H_{25}O_3]$: 349.1798, found: 349.1799.

methyl (S,2E,7E)-5-(4-methoxyphenyl)-9-oxo-9-phenylnona-2,7-dienoate (5k)



Colorless oil; $[\alpha]_D^{20}$ = +8 (*c* 1.0, CH_2Cl_2, 96% ee); IR(KBr cm^{-1}): 3057, 3029, 3000, 2950, 2931, 1721, 1657, 1618, 1513, 1446, 1437, 1275, 1249, 1179, 1036, 981; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 - 7.72 (m, 2H), 7.56 - 7.49 (m, 1H), 7.41 (t, *J* = 7.6 Hz, 2H), 7.08 (d, *J* = 8.4 Hz, 2H), 6.92 - 6.70 (m, 5H), 5.79 (d, *J* = 15.6 Hz, 1H), 3.77 (s, 3H), 3.68 (s, 3H), 3.01 – 2.86 (m, 1H), 2.73 – 2.45 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 190.5, 166.6, 158.3, 146.6, 146.5, 137.6, 134.6, 132.6, 128.4, 128.4, 128.3, 127.8, 122.7, 114.0, 55.1, 51.3, 43.5, 39.4, 38.9. The enantiomeric excess was determined by HPLC with AS-H column. (*n*-hexane:*i*-PrOH = 80:20), 1mL/min; major enantiomer t_R = 20.05 min, minor enantiomer t_R = 22.09 min. HRMS (ESI) : $[M+H]^+$calcd for $[C_{23}H_{25}O_4]$: 365.1747, found: 365.1748.

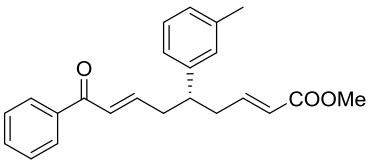
methyl (S,2E,7E)-5-(4-bromophenyl)-9-oxo-9-phenylnona-2,7-dienoate (5l)



Colorless oil; $[\alpha]_D^{20}$ = -6 (*c* 1.0, CH_2Cl_2, 89% ee); IR(KBr cm^{-1}): 3423, 2950, 2927, 1721, 1669, 1621, 1488, 1448, 1437, 1277, 1228, 1209, 1074, 1010, 981; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.78 (d, *J* = 7.2 Hz, 2H), 7.54 (t, *J* = 7.2 Hz, 1H), 7.46-7.42 (m, 4H), 7.05 (d, *J* = 8.4 Hz, 2H), 6.88 – 6.70 (m, 3H), 5.79 (d, *J* = 15.6 Hz, 1H), 3.69 (s, 3H), 3.01 – 2.89 (m, 1H), 2.71 – 2.49 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 190.4, 166.5, 145.8, 145.6, 141.6, 137.6, 132.8, 131.9, 129.2, 128.5, 128.5,128.1 123.2, 120.7, 51.5, 43.9, 39.1, 38.5. The enantiomeric excess was determined by HPLC with AS-H column. (*n*-hexane:*i*-PrOH = 80:20), 1mL/min; major enantiomer t_R = 28.91 min,

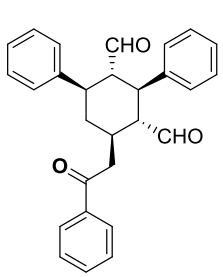
minor enantiomer t_R = 32.35 min. HRMS (ESI) : $[M+H]^+$calcd for $[C_{22}H_{22}BrO_3]$: 413.0747, found: 413.0745.

methyl (S,2E,7E)-9-oxo-9-phenyl-5-(m-tolyl)nona-2,7-dienoate (5m)



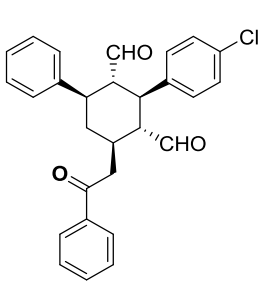
Colorless oil; $[\alpha]_D^{20}$ = -4 (*c* 1.0, CH_2Cl_2, 93% ee); IR(KBr cm^{-1}): 3425, 3056, 3024, 2949, 2924, 1721, 1670, 1620, 1447, 1436, 1277, 1210, 1178, 1037, 1020, 982; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 - 7.73 (m, 2H), 7.57 - 7.49 (m, 1H), 7.42 (t, *J* = 7.6 Hz, 2H), 7.20 (t, *J* = 8.0 Hz, 1H), 7.04 (d, *J* = 7.2 Hz, 1H), 6.98 - 6.96 (m, 2H), 6.88 -6.74 (m, 3H), 5.81 (d, *J* = 15.6 Hz, 1H), 3.69 (s, 3H), 3.02 – 2.85 (m, 1H), 2.76 – 2.52 (m, 4H), 2.33 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 190.7, 166.7, 146.6, 146.5, 142.6, 138.3, 137.7, 132.6, 128.6, 128.5, 128.4, 128.2, 127.9, 127.6, 124.4, 122.7, 51.4, 44.2, 39.3, 38.7, 21.5. The enantiomeric excess was determined by HPLC with AS-H column. (*n*-hexane:*i*-PrOH = 80:20), 1mL/min; major enantiomer t_R = 10.78 min, minor enantiomer t_R = 11.55 min. HRMS (ESI) : $[M+H]^+$calcd for $[C_{23}H_{25}O_3]$: 349.1798, found: 349.1799.

(1S,2S,3R,4R,6R)-4-(2-oxo-2-phenylethyl)-2,6-diphenylcyclohexane-1,3-dicarbaldehyde (6a)



White solid; $[\alpha]_D^{20}$ = +31 (*c* 1.0, CH_2Cl_2, 97% ee); IR(KBr cm^{-1}): 2955, 2924, 2870, 2850, 1719, 1684, 1596, 1494, 1456, 1446, 1394, 1286, 1276; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.42 (d, *J* = 4.0 Hz, 1H), 9.24 (d, *J* = 2.8 Hz, 1H), 7.89 (d, *J* = 7.6 Hz, 2H), 7.54 (t, *J* = 7.2 Hz, 1H), 7.43 (t, *J* = 7.6 Hz, 2H), 7.33 – 7.14 (m, 10H), 3.40 (t, *J* = 10.4 Hz, 1H), 3.20 – 3.03 (m, 3H), 2.88 (dd, *J* = 17.1, 7.6 Hz, 1H), 2.84 – 2.66 (m, 2H), 2.21 (d, *J* = 13.2 Hz, 1H), 1.62 (dd, *J* = 24.1, 11.7 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 203.3, 202.9, 198.2, 141.6, 138.7, 136.7, 133.3, 129.2, 128.8, 128.6, 128.0, 128.0, 127.8, 127.3, 127.2, 60.0, 59.9, 46.0, 45.0, 42.4, 39.6, 33.1. HPLC: The enantiomeric excess was determined by HPLC with an AD-H column after converted to corresponding ester **7a** with $Ph_3PCHCOOMe$ (hexane: *i*-PrOH = 70:30), 1.0 mL/min; minor enantiomer *t* = 9.64 min, major enantiomer *t* = 13.28 min. HRMS (ESI): $[M+H]^+$ calcd for $[C_{28}H_{27}O_3]$: 411.1955, found: 411.1952.

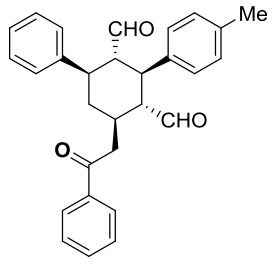
(1S,2S,3R,4R,6R)-2-(4-chlorophenyl)-4-(2-oxo-2-phenylethyl)-6-phenylcyclohexane-1,3-dicarbaldehyde (6b)



White solid; $[\alpha]_D^{20}$ = +21 (*c* 1.0, CH_2Cl_2, 96% ee); IR(KBr cm^{-1}): 3060, 2954, 2923, 2851, 2724, 1722, 1681, 1597, 1580, 1492, 1448, 1410, 1090, 1013; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.42 (d, *J* = 4.0 Hz, 1H), 9.23 (d, *J* = 2.4 Hz, 1H), 7.88 (d, *J* = 7.6 Hz, 2H), 7.55 (t, *J* = 7.2 Hz, 1H), 7.43 (t, *J* = 7.6 Hz, 2H), 7.33 – 7.13 (m, 9H), 3.41 (t, *J* = 10.6 Hz, 1H), 3.09 (m, 3H), 2.90 (dd, *J* = 17.2, 7.6 Hz, 1H), 2.77 (dd, *J* = 7.6, 3.6 Hz, 1H), 2.67 (td, *J* = 11.2, 4.0 Hz, 1H), 2.21 (d, *J* = 13.2 Hz, 1H), 1.63 (dd, *J* = 24.8, 12.0 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 202.9, 202.6, 198.1, 141.3, 137.4, 136.7, 133.6, 133.4, 129.4, 129.4, 128.9, 128.7, 128.0, 127.3, 127.3, 59.9, 59.8, 45.3, 45.1, 42.3, 39.5, 33.1.HPLC: The enantiomeric excess was determined by HPLC with an AD-H column after converted to corresponding ester **7b** with $Ph_3PCHCOOMe$ (hexane: *i*-PrOH = 70:30), 1.0

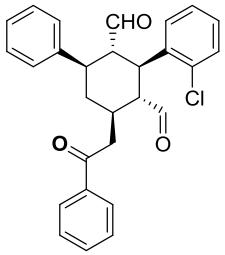
mL/min; minor enantiomer t = 11.70 min, major enantiomer t = 18.82 min. HRMS (ESI): $[M+H]^+$calcd for $[C_{28}H_{26}ClO_3]$: 445.1565, found: 445.1566.

(1S,2S,3R,4R,6R)-4-(2-oxo-2-phenylethyl)-6-phenyl-2-(p-tolyl)cyclohexane-1,3-dicarbaldehyde (6c)



White solid; $[\alpha]_D^{20}$ = +12 (*c* 0.5, CH_2Cl_2, 98% ee); IR(KBr cm^{-1}): 3060. 2955, 2923, 2869, 2851, 1719, 1678, 1457, 1378, 1023; ^1H NMR (400 MHz, $CDCl_3$) δ 9.42 (d, *J* = 4.4 Hz, 1H), 9.25 (d, *J* = 2.4 Hz, 1H), 7.89 (d, *J* = 7.6 Hz, 2H), 7.55 (t, *J* = 7.6 Hz, 1H), 7.44 (t, *J* = 7.6 Hz, 2H), 7.33 - 7.15 (m, 5H), 7.15 - 7.06 (m, 4H), 3.36 (t, *J* = 10.8 Hz, 1H), 3.16 - 3.03 (m, 3H), 2.88 (dd, *J* = 17.2, 7.6 Hz, 1H), 2.83 - 2.63 (m, 2H), 2.27 (s, 3H), 2.24 - 2.15 (m, 1H), 1.68 - 1.55 (m, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 203.5, 203.0, 198.2, 141.7, 137.5, 136.7, 135.6, 133.3, 129.9, 128.8, 128.6, 128.0, 127.8, 127.4, 127.2, 60.1, 60.0, 45.7, 45.0, 42.5, 39.6, 33.1, 21.0. HPLC: The enantiomeric excess was determined by HPLC with an AD-H column after converted to corresponding ester **7c** with $Ph_3PCHCOOMe$ (hexane: *i*-PrOH = 70:30), 1.0 mL/min; minor enantiomer t = 7.58 min, major enantiomer t = 10.30 min. HRMS (ESI): $[M+H]^+$ calcd for $[C_{29}H_{29}O_3]$: 425.2111, found: 425.2109.

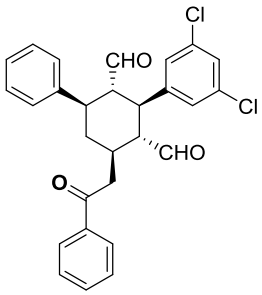
(1S,2S,3R,4R,6R)-2-(2-chlorophenyl)-4-(2-oxo-2-phenylethyl)-6-phenylcyclohexane-1,3-dicarbaldehyde (6d)



White solid; $[\alpha]_D^{20}$ = +10 (*c* 1.0, CH_2Cl_2, 99% ee); IR(KBr cm^{-1}): 2955, 2924, 2870, 2852, 1722, 1673, 1450, 1214, 1033, 1015; ^1H NMR (400 MHz, $CDCl_3$) δ 9.46 (d, *J* = 3.2 Hz, 1H), 9.28 (d, *J* = 4.0 Hz, 1H), 7.89 (d, *J* = 7.6 Hz, 2H), 7.55 (t, *J* = 7.6 Hz, 1H), 7.50 - 7.40 (m, 3H), 7.40 - 7.08 (m, 8H), 4.17 (t, *J* = 11.2 Hz, 1H), 3.30 - 2.80 (m, 5H), 2.70 - 2.50 (m, 1H), 2.26 (d, *J* = 10.4 Hz, 1H), 1.80 - 1.52 (m, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 202.5, 201.4, 198.0, 141.4, 136.7, 136.5, 133.6, 133.4, 130.0, 128.9, 128.8, 128.6, 128.5, 128.0, 127.8, 127.3, 61.0, 60.5, 44.7, 42.4, 40.2, 39.4, 32.9. HPLC: The enantiomeric excess was determined by HPLC with an AD-H column after converted to corresponding ester **7d** with $Ph_3PCHCOOMe$ (hexane:

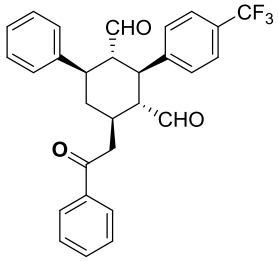
i-PrOH = 70:30), 1.0 mL/min; minor enantiomer *t* = 7.32 min, major enantiomer *t* = 12.17 min. HRMS (ESI): $[M+H]^+$ calcd for $[C_{28}H_{26}ClO_3]$: 445.1565, found: 445.1562.

(1S,2S,3R,4R,6R)-2-(3,5-dichlorophenyl)-4-(2-oxo-2-phenylethyl)-6-phenylcyclohexane-1,3-dicarbaldehyde (6e)



White solid; $[\alpha]_D^{20}$ = +25 (*c* 1.0, CH_2Cl_2, 94% ee); IR(KBr cm^{-1}): 2955, 2924, 2852, 2725, 1723, 1682, 1587, 1566, 1449, 1433, 1215; ^1H NMR (400 MHz, $CDCl_3$) δ 9.45 (d, *J* = 4.4 Hz, 1H), 9.24 (d, *J* = 2.4 Hz, 1H), 7.88 (d, *J* = 7.2 Hz, 2H), 7.55 (t, *J* = 7.2 Hz, 1H), 7.44 (t, *J* = 7.6 Hz, 2H), 7.35 – 7.15 (m, 6H), 7.13 (d, *J* = 1.6 Hz, 2H), 3.40 (t, *J* = 11.2 Hz, 1H), 3.16 – 2.92 (m, 3H), 2.92 – 2.82 (m, 1H), 2.82 – 2.60 (m, 2H), 2.20 (d, *J* = 13.6 Hz, 1H), 1.65 (dd, *J* = 24.8, 12.8 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 202.5, 202.3, 197.9, 142.7, 141.0, 136.6, 135.6, 133.4, 129.0, 128.7, 128.1, 127.9, 127.5, 127.3, 126.6, 59.6, 59.3, 45.4, 44.9, 42.2, 39.5, 33.0. HPLC: The enantiomeric excess was determined by HPLC with an AD-H column after converted to corresponding ester **7e** with $Ph_3PCHCOOMe$ (hexane: *i*-PrOH = 70:30), 1.0 mL/min; minor enantiomer *t* = 9.91 min, major enantiomer *t* = 11.99 min. HRMS (ESI): $[M+H]^+$ calcd for $[C_{28}H_{25}Cl_2O_3]$: 479.1175, found: 479.1171.

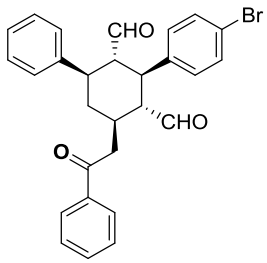
(1S,2S,3R,4R,6R)-4-(2-oxo-2-phenylethyl)-6-phenyl-2-(4-(trifluoromethyl)phenyl)cyclohexane-1,3-dicarbaldehyde (6f)



White solid; $[\alpha]_D^{20}$ = +22 (*c* 1.0, CH_2Cl_2, 95% ee); IR(KBr cm^{-1}): 2952, 2924, 2851, 1719, 1674, 1620, 1450, 1330, 1287, 1165, 1118, 1069; ^1H NMR (400 MHz, $CDCl_3$) δ 9.43 (d, *J* = 4.0 Hz, 1H), 9.23 (d, *J* = 2.8 Hz, 1H), 7.88 (d, *J* = 7.2 Hz, 2H), 7.63 - 7.48 (m, 3H), 7.44 (t, *J* = 7.6 Hz, 2H), 7.36 (d, *J* = 8.0 Hz, 2H), 7.33 - 7.14 (m, 5H), 3.51 (t, *J* = 10.8 Hz, 1H), 3.21 - 3.00 (m, 3H), 2.92 (dd, *J* = 17.2, 7.2 Hz, 1H), 2.86 - 2.67 (m, 2H), 2.29 - 2.16 (m, 1H), 1.67 (dd, *J* = 24.8, 11.2 Hz, 1H). ^{13}C NMR (101

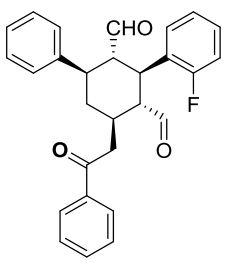
MHz, $CDCl_3$) δ 202.7, 202.50, 198.0, 143.2, 141.1, 136.6, 133.4, 129.9 (q, *J* = 33 Hz), 128.9, 128.7, 128.6, 127.9, 127.4, 127.3, 126.1 (q, *J* = 4 Hz), 123.8 (q, *J* = 271 Hz), 59.8, 59.6, 45.4, 45.3, 42.2, 39.6, 33.1. HPLC: The enantiomeric excess was determined by HPLC with an AD-H column after converted to corresponding ester **7f** with $Ph_3PCHCOOMe$ (hexane: *i*-PrOH = 70:30), 1.0 mL/min; minor enantiomer *t* = 11.47 min, major enantiomer *t* = 19.47 min. HRMS (ESI): $[M+H]^+$ calcd for $[C_{29}H_{26}F_3O_3]$: 479.1829, found: 479.1826.

(1S,2S,3R,4R,6R)-2-(4-bromophenyl)-4-(2-oxo-2-phenylethyl)-6-phenylcyclohexane-1,3-dicarbaldehyde (6g)



White solid; $[\alpha]_D^{20}$ = +22 (*c* 1.0, CH_2Cl_2, 97% ee); IR(KBr cm^{-1}): 2956, 2923, 2851, 1718, 1683, 1489, 1458, 1378, 1013; ^1H NMR (400 MHz, $CDCl_3$) δ 9.41 (d, *J* = 4.4 Hz, 1H), 9.21 (d, *J* = 2.4 Hz, 1H), 7.88 (d, *J* = 7.2 Hz, 2H), 7.53 (t, *J* = 7.6 Hz, 1H), 7.48 - 7.35 (m, 4H), 7.33 - 7.15 (m, 6H), 7.10 (d, *J* = 8.4 Hz, 2H), 3.39 (t, *J* = 10.8 Hz, 1H), 3.16 - 2.99 (m, 3H), 2.89 (dd, *J* = 17.2, 7.6 Hz, 1H), 2.84 - 2.62 (m, 2H), 2.20 (d, *J* = 13.2 1H), 1.62 (dd, *J* = 24.8, 12.8 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 202.9, 202.6, 198.0, 141.3, 137.9, 136.6, 133.3, 132.2, 129.7, 128.8, 128.6, 127.9, 127.2, 121.5, 59.8, 59.6, 45.1, 45.0, 42.2, 39.4, 33.0. HPLC: The enantiomeric excess was determined by HPLC with an AD-H column after converted to corresponding ester **7g** with $Ph_3PCHCOOMe$ (hexane: *i*-PrOH = 70:30), 1.0 mL/min; minor enantiomer *t* = 14.20 min, major enantiomer *t* = 22.37 min. HRMS (ESI): $[M+H]^+$ calcd for $[C_{28}H_{26}BrO_3]$: 489.1060, found: 489.1059.

(1S,2S,3R,4R,6R)-2-(2-fluorophenyl)-4-(2-oxo-2-phenylethyl)-6-phenylcyclohexane-1,3-dicarbaldehyde (6h)

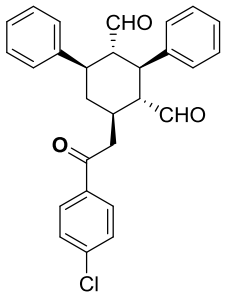


White solid; $[\alpha]_D^{20}$ = +21 (*c* 1.0, CH_2Cl_2, 97% ee); IR(KBr cm^{-1}): 2952, 2921, 2850, 1718, 1685, 1598, 1579, 1511, 1447, 1285, 1231, 1162, 1100, 838; ^1H NMR (400 MHz, $CDCl_3$) δ 9.42 (d, *J* = 4.4 Hz, 1H), 9.24 (d, *J* = 2.0 Hz, 1H), 7.88 (d, *J* = 7.6 Hz, 2H), 7.55 (t, *J* = 7.2 Hz, 1H), 7.44 (t, *J* = 7.6 Hz, 2H), 7.36 - 7.11 (m, 7H), 6.98 (t, *J* = 8.4 Hz, 2H),

3.42 (t, *J* = 10.8 Hz, 1H), 3.18 - 2.99 (m, 3H), 2.90 (dd, *J* = 17.2, 7.6 Hz, 1H), 2.85 - 2.70 (m, 1H), 2.67 (td, *J* = 11.2, 4.4 Hz, 1H), 2.21 (d, *J* = 13.2 Hz, 1H), 1.75 - 1.52 (m, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 203.1, 202.8, 198.1, 162.0 (d, *J* = 245 Hz), 141.4, 136.7, 134.6, 134.6, 133.4, 129.6, 129.6, 128.9, 128.6, 128.0, 127.3, 116.2, 116.0, 60.1, 60.0, 45.2, 45.0, 42.3, 39.5, 33.1. HPLC: The enantiomeric excess was determined by HPLC with an AD-H column after converted to corresponding ester **7h** with $Ph_3PCHCOOMe$ (hexane: *i*-PrOH = 70:30), 1.0 mL/min; minor enantiomer *t* = 11.70 min, major enantiomer *t* = 15.81 min. HRMS (ESI) : $[M+H]^+$calcd for $[C_{28}H_{26}FO_3]$: 419.1860, found: 419.1858.

(1S,2S,3R,4R,6R)-4-(2-(4-chlorophenyl)-2-oxoethyl)-2,6-diphenylcyclohexane-1,3-dicarb

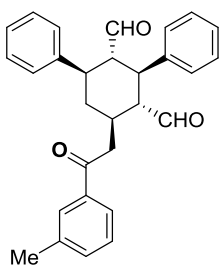
aldehyde (6i)



White solid; $[\alpha]_D^{20}$ = +31 (*c* 1.0, CH_2Cl_2, 94% ee); IR(KBr cm^{-1}): 3418, 2956, 2924, 2869, 2851, 1716, 1673, 1587, 1493, 1456, 1285, 1090, 1009; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.41 (d, *J* = 4.0 Hz, 1H), 9.24 (d, *J* = 2.8 Hz, 1H), 7.83 (d, *J* = 8.4 Hz, 2H), 7.41 (d, *J* = 8.4 Hz, 2H), 7.34 - 7.09 (m, 10H), 3.38 (t, *J* = 10.4 Hz, 1H), 3.23 - 2.98 (m, 3H), 2.88 - 2.63 (m, 3H), 2.29 - 2.13 (m, 1H), 1.61 (dd, *J* = 24.0, 11.6 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 203.4, 202.8, 197.0, 141.6, 139.8, 138.6, 135.0, 129.4, 129.2, 129.0, 128.9, 128.0, 127.9, 127.3, 127.3, 59.9, 46.1, 45.1, 42.4, 39.6, 33.0. HPLC: The enantiomeric excess was determined by HPLC with an AD-H column after converted to corresponding **7i** ester with $Ph_3PCHCOOMe$ (hexane: *i*-PrOH = 70:30), 1.0 mL/min; minor enantiomer *t* = 16.78 min, major enantiomer *t* = 18.62 min. HRMS (ESI) : $[M+H]^+$calcd for $[C_{28}H_{26}ClO_3]$: 445.1565, found: 445.1561.

(1S,2S,3R,4R,6R)-4-(2-oxo-2-(m-tolyl)ethyl)-2,6-diphenylcyclohexane-1,3-dicarbaldehyd

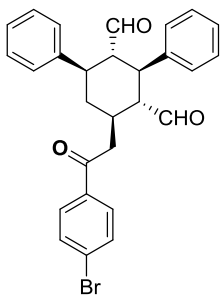
e (6j)



White solid; $[\alpha]_D^{20}$ = +48 (*c* 0.5, CH_2Cl_2, 95% ee); IR(KBr cm^{-1}): 3425, 2955, 2922, 2869, 2851, 1721, 1679, 1602, 1585, 1494, 1455, 1377, 1157, 1030; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.43 (d, *J* = 4.4 Hz, 1H), 9.24

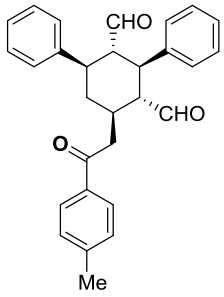
(d, *J* = 2.8 Hz, 1H), 7.68 (d, *J* = 9.2 Hz, 2H), 7.40 - 7.13 (m, 12H), 3.40 (t, *J* = 10.8 Hz, 1H), 3.18 - 3.04 (m, 3H), 2.95 - 2.65 (m, 3H), 2.39 (s, 3H), 2.22 (d, *J* = 10.0 Hz, 1H), 1.61 (dd, *J* = 24.4, 11.6 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 203.4, 202.9, 198.4, 141.7, 138.7, 138.5, 136.8, 134.1, 129.2, 128.8, 128.5, 128.5, 128.0, 127.8, 127.4, 127.2, 125.2, 60.1, 59.9, 46.0, 45.1, 42.5, 39.6, 33.1, 21.3. HPLC: The enantiomeric excess was determined by HPLC with an AD-H column after converted to corresponding ester **7j** with $Ph_3PCHCOOMe$ (hexane: *i*-PrOH = 70:30), 1.0 mL/min; minor enantiomer *t* = 7.82 min, major enantiomer *t* = 11.05 min. HRMS (ESI) : $[M+H]^+$calcd for $[C_{29}H_{29}O_3]$: 425.2111, found: 425.2110.

(1S,2S,3R,4R,6R)-4-(2-(4-bromophenyl)-2-oxoethyl)-2,6-diphenylcyclohexane-1,3-dicarbaldehyde (6k)



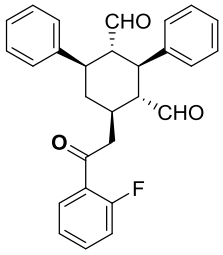
White solid; $[\alpha]_D^{20}$ = +27 (*c* 1.0, CH_2Cl_2, 92% ee); IR(KBr cm^{-1}): 3028, 2955, 2913, 2839, 2736, 1716, 1673, 1600, 1585, 1567, 1494, 1455, 1433, 1397, 1314, 1293, 1164, 1069, 1006. ^{1}H NMR (400 MHz, DMSO) δ 9.38 (d, *J* = 3.6 Hz, 1H), 9.23 (d, *J* = 3.2 Hz, 1H), 7.82 (d, *J* = 8.4 Hz, 2H), 7.71 (d, *J* = 8.0 Hz, 2H), 7.40 - 7.10 (m, 10H), 3.56 (t, *J* = 10.0 Hz, 1H), 3.26 - 2.88 (m, 4H), 2.80 - 2.60 (m, 2H), 1.94 (d, *J* = 12.8 Hz, 1H), 1.72 (dd, *J* = 22.0, 10.8 Hz, 1H). ^{13}C NMR (101 MHz, DMSO) δ 204.5, 203.7, 197.9, 142.7, 139.9, 135.6, 131.8, 129.9, 128.6, 128.5, 128.2, 127.5, 127.4, 127.1, 126.7, 59.2, 59.0, 44.2, 43.6, 42.3, 38.2, 32.6. HPLC: The enantiomeric excess was determined by HPLC with an AD-H column after converted to corresponding ester **7k** with $Ph_3PCHCOOMe$ (hexane: *i*-PrOH = 70:30), 1.0 mL/min; minor enantiomer *t* = 13.84 min, major enantiomer *t* = 17.80 min. HRMS (ESI) : $[M+H]^+$calcd for $[C_{29}H_{26}BrO_3]$: 489.1060, found: 489.1058.

(1S,2S,3R,4R,6R)-4-(2-oxo-2-(p-tolyl)ethyl)-2,6-diphenylcyclohexane-1,3-dicarbaldehyde (6l)



White solid; $[\alpha]_D^{20}$ = +20 (*c* 1.0, CH_2Cl_2, 98% ee); IR(KBr cm^{-1}): 3029, 2954, 2922, 2851, 2727, 1722, 1677, 1605, 1572, 1494, 1454, 1377, 1233, 1182, 1030; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.42 (d, *J* = 4.0 Hz, 1H), 9.24 (d, *J* = 2.8 Hz, 1H), 7.79 (d, *J* = 8.4 Hz, 2H), 7.37 - 7.07 (m, 12H), 3.39 (t, *J* = 10.4 Hz, 1H), 3.21 - 2.99 (m, 3H), 2.90 - 2.65 (m, 3H), 2.38 (s, 3H), 2.27 - 2.15 (m, 1H), 1.60 (dd, *J* = 24.0, 11.6 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 203.4, 202.9, 197.9, 144.2, 141.6, 138.7, 134.2, 129.3, 129.2, 128.8, 128.7, 128.1, 128.0, 127.8, 127.3, 127.2, 60.0, 59.9, 45.9, 45.0, 42.3, 39.5, 33.1, 21.6. HPLC: The enantiomeric excess was determined by HPLC with an OD-H column after converted to corresponding ester 7**l** with $Ph_3PCHCOOMe$ (hexane: *i*-PrOH = 70:30), 1.0 mL/min; major enantiomer *t* = 16.51 min, minor enantiomer *t* = 36.10 min. HRMS (ESI) : $[M+H]^+$ calcd for $[C_{29}H_{29}O_3]$: 425.2111, found: 425.2108.

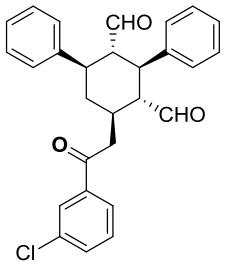
(1S,2S,3R,4R,6R)-4-(2-(2-fluorophenyl)-2-oxoethyl)-2,6-diphenylcyclohexane-1,3-dicarbaldehyde (6m)



White solid; $[\alpha]_D^{20}$ = +42 (*c* 0.5, CH_2Cl_2, 95% ee); IR(KBr cm^{-1}): 2955, 2922, 2869, 2851, 2724, 1722, 1683, 1608, 1479, 1455, 1377, 1271, 1210, 1016; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.42 (d, *J* = 4.4 Hz, 1H), 9.25 (d, *J* = 2.8 Hz, 1H), 7.78 (td, *J* = 7.6, 2.0 Hz, 1H), 7.54 - 7.45 (m, 1H), 7.34 - 7.26 (m, 4H), 7.21 (dd, *J* = 13.6, 6.8 Hz, 7H), 7.15 - 7.05 (m, 1H), 3.40 (t, *J* = 11.2 Hz, 1H), 3.17 - 3.06 (m, 3H), 2.93 (ddd, *J* = 18.4, 7.6, 3.2 Hz, 1H), 2.85 -2.72 (m, 1H), 2.67 (td, *J* = 11.2, 6.8 Hz, 1H), 2.26 - 2.17 (m, 1H), 1.64 (dd, *J* = 24.8, 12.0 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 203.1, 203.1, 196.5 (d, *J* = 4 Hz), 161.8 (d, *J* = 253 Hz), 141.7, 138.7, 134.8, (d, *J* = 9 Hz), 130.6 (d, *J* = 2 Hz), 129.2, 128.9, 128.1, 127.8, 127.4, 127.2, 125.5 (d, *J* = 13 Hz), 124.5 (d, *J* = 4 Hz), 116.7 (d, *J* = 24 Hz), 60.0, 59.9, 47.5, 47.4, 45.9, 45.1, 39.7, 32.9. HPLC: The enantiomeric excess was determined by HPLC with an OD-H column after converted to corresponding ester **7m** with $Ph_3PCHCOOMe$ (hexane:

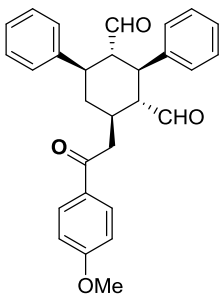
i-PrOH = 70:30), 1.0 mL/min; major enantiomer *t* = 9.15 min, minor enantiomer *t* = 22.89 min. HRMS (ESI) : $[M+H]^+$ calcd for $[C_{28}H_{26}FO_3]$: 429.1860, found: 429.1859.

(1S,2S,3R,4R,6R)-4-(2-(3-chlorophenyl)-2-oxoethyl)-2,6-diphenylcyclohexane-1,3-dicarbaldehyde (6n)



White solid; $[\alpha]_D^{20}$ = +42 (*c* 0.5, CH_2Cl_2, 97% ee); IR(KBr cm^{-1}): 3424, 2955, 2924, 2869, 2851, 1721, 1686, 1599, 1571, 1494, 1456, 1377, 1211, 1022, 908; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.41 (d, *J* = 4.0 Hz, 1H), 9.24 (d, *J* = 2.8 Hz, 1H), 7.86 (s, 1H), 7.76 (d, *J* = 7.6 Hz, 1H), 7.52 (d, *J* = 8.0 Hz, 1H), 7.40 - 7.15 (m, 11H), 3.39 (t, *J* = 10.4 Hz, 1H), 3.20 - 3.02 (m, 3H), 2.92 - 2.62 (m, 3H), 2.20 (d, *J* = 13.2 Hz, 1H), 1.62 (dd, *J* = 24.0, 11.2 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 203.4, 202.9, 196.9, 141.5, 138.6, 138.2, 135.0, 133.2, 130.0, 129.2, 128.9, 128.1, 128.0, 127.9, 127.3, 127.2, 126.1, 59.9, 59.8, 46.0, 45.0, 42.6, 39.5, 32.9. HPLC: The enantiomeric excess was determined by HPLC with an AD-H column after converted to corresponding ester **7n** with $Ph_3PCHCOOMe$ (hexane: *i*-PrOH = 70:30), 1.0 mL/min; minor enantiomer *t* = 9.7 min, major enantiomer *t* = 14.6 min. HRMS (ESI) : $[M+H]^+$ calcd for $[C_{28}H_{26}ClO_3]$: 445.1565, found: 445.1564.

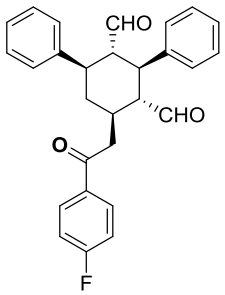
(1S,2S,3R,4R,6R)-4-(2-(4-methoxyphenyl)-2-oxoethyl)-2,6-diphenylcyclohexane-1,3-dicarbaldehyde (6o)



White solid; $[\alpha]_D^{20}$ = +42 (*c* 0.5, CH_2Cl_2, 98% ee); IR(KBr cm^{-1}): 3417, 3028, 2955, 2922, 2850, 1719, 1668, 1599, 1574, 1510, 1456, 1419, 1377, 1317, 1253, 1168, 1030; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.42 (d, *J* = 4.4 Hz, 1H), 9.24 (d, *J* = 3.2 Hz, 1H), 7.88 (d, *J* = 8.8 Hz, 2H), 7.34 - 7.14 (m, 10H), 6.94 - 6.86 (m, 2H), 3.84 (s, 3H), 3.39 (t, *J* = 10.4 Hz, 1H), 3.19 - 3.00 (m, 3H), 2.86 - 2.65 (m, 3H), 2.21 (d, *J* = 10.4 Hz, 1H), 1.60 (dd, *J* = 24.0, 12.8 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 203.4, 202.9, 196.7, 163.7, 141.7, 138.8, 130.3, 129.8, 129.2, 128.8, 128.0, 127.8, 127.3, 127.2, 113.8, 60.1, 59.9, 55.4, 46.0, 45.1, 42.1, 39.6, 33.3. HPLC: The product was converted to corresponding ester **7o** with $Ph_3PCHCOOMe$ and enantiomeric

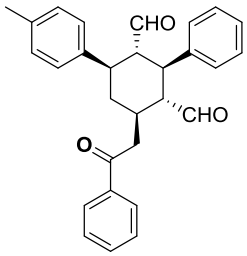
excess was determined by HPLC with an AD-H column (hexane: *i*-PrOH = 80:20), 1.0 mL/min; minor enantiomer *t* = 23.44 min, major enantiomer *t* = 26.94 min. HRMS (ESI) : $[M+H]^+$ calcd for $[C_{29}H_{29}O_4]$: 441.2060, found: 441.2058.

(1S,2S,3R,4R,6R)-4-(2-(4-fluorophenyl)-2-oxoethyl)-2,6-diphenylcyclohexane-1,3-dicarbaldehyde (6p)



White solid; $[\alpha]_D^{20}$ = +25 (*c* 1.0, CH_2Cl_2, 97% ee); IR(KBr cm^{-1}): 2955, 2920, 2850, 2729, 1715, 1683, 1672, 1595, 1506, 1495, 1455, 1435, 1410, 1231, 1175, 1101; ^1H NMR (400 MHz, $CDCl_3$) δ 9.41 (d, *J* = 3.6 Hz, 1H), 9.24 (d, *J* = 2.4 Hz, 1H), 7.92 (dd, *J* = 8.4, 5.6 Hz, 2H), 7.34 - 7.14 (m, 10H), 7.10 (t, *J* = 8.4 Hz, 2H), 3.39 (t, *J* = 10.4 Hz, 1H), 3.20 - 3.03 (m, 3H), 2.88 - 2.65 (m, 3H), 2.20 (d, *J* = 13.2 Hz, 1H), 1.61 (dd, *J* = 23.6, 12.0 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 203.4, 202.8, 196.6, 165.9 (d, *J* = 250 Hz), 141.6, 138.6, 133.1 (d, *J* = 3 Hz), 130.7 (d, *J* = 9 Hz), 129.2, 128.8, 128.0, 127.8, 127.3, 127.2, 115.8 (d, *J* = 22 Hz), 59.9, 59.8, 46.0, 45.0, 42.4, 39.6, 33.0. HPLC: The enantiomeric excess was determined by HPLC with an AD-H column after converted to corresponding ester **7p** with $Ph_3PCHCOOMe$ (hexane: *i*-PrOH = 80:20), 1.0 mL/min; minor enantiomer *t* = 19.28 min, major enantiomer *t* = 25.31 min. HRMS (ESI) : $[M+H]^+$ calcd for $[C_{28}H_{26}FO_3]$: 429.1860, found: 429.1858.

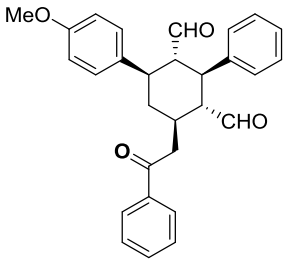
(1S,2S,3R,4R,6R)-4-(2-oxo-2-phenylethyl)-2-phenyl-6-(p-tolyl)cyclohexane-1,3-dicarbaldehyde (6q)



White solid; $[\alpha]_D^{20}$ = +16 (*c* 1.0, CH_2Cl_2, 95% ee); IR(KBr cm^{-1}): 2955, 2923, 2851, 1723, 1682, 1597, 1580, 1514, 1449, 1377, 1218, 1182, 1021; ^1H NMR (400 MHz, $CDCl_3$) δ 9.42 (d, *J* = 4.4 Hz, 1H), 9.24 (d, *J* = 3.2 Hz, 1H), 7.96 - 7.85 (m, 2H), 7.59 - 7.51 (m, 1H), 7.43 (t, *J* = 7.6 Hz, 2H), 7.34 - 7.16 (m, 5H), 7.12 - 7.06 (m, 4H), 3.39 (t, *J* = 10.8 Hz, 1H), 3.17 - 3.00 (m, 3H), 2.88 (dd, *J* = 17.2, 7.6 Hz, 1H), 2.83 - 2.65 (m, 1H), 2.27 (s, 3H), 2.19 (dt, *J* = 13.2, 3.2 Hz, 1H), 1.59 (dd, *J* = 24.8, 11.6 Hz, 1H). ^{13}C NMR (101 MHz,

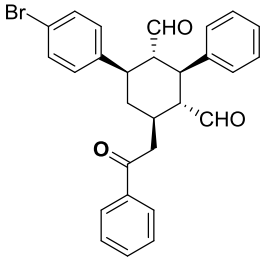
$CDCl_3$) δ 203.4, 203.0, 198.2, 138.8, 138.6, 136.8, 136.7, 133.3, 129.5, 129.2, 128.6, 128.0, 128.0, 127.8, 127.2, 60.0, 60.0, 46.0, 44.7, 42.4, 39.7, 33.1, 21.0. HPLC: The enantiomeric excess was determined by HPLC with an AD-H column after converted to corresponding ester **7q** with $Ph_3PCHCOOMe$ (hexane: *i*-PrOH = 80:20), 1.0 mL/min; minor enantiomer *t* = 10.10 min, major enantiomer *t* = 16.57 min. HRMS (ESI) : $[M+H]^+$ calcd for $[C_{29}H_{29}O_3]$: 425.2111, found: 425.2108.

(1R,2S,3S,4R,6R)-4-(4-methoxyphenyl)-6-(2-oxo-2-phenylethyl)-2-phenylcyclohexane-1, 3-dicarbaldehyde (6r)



White solid; $[\alpha]_D^{20}$ = +26 (*c* 1.0, CH_2Cl_2, 97% ee); IR(KBr cm^{-1}): 2954, 2923, 2850, 2740, 1718, 1682, 1612, 1597, 1580, 1515, 1457, 1446, 1246, 1178, 1030, 1002; ^1H NMR (400 MHz, $CDCl_3$) δ 9.42 (d, *J* = 4.0 Hz, 1H), 9.24 (d, *J* = 2.8 Hz, 1H), 7.93 - 7.83 (m, 2H), 7.61 - 7.50 (m, 1H), 7.43 (t, *J* = 7.6 Hz, 2H), 7.33 - 7.26 (m, 2H), 7.25 - 7.16 (m, 3H), 7.15 - 7.08 (m, 2H), 6.81 (d, *J* = 8.8 Hz, 2H), 3.74 (s, 3H), 3.39 (t, *J* = 11.2 Hz, 1H), 3.17 - 2.97 (m, 3H), 2.88 (dd, *J* = 17.2, 7.6 Hz, 1H), 2.81 - 2.63 (m, 2H), 2.25 - 2.12 (m, 1H), 1.66 - 1.51 (m, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 203.4, 203.0, 198.2, 158.6, 138.8, 136.7, 133.7, 133.3, 129.2, 128.6, 128.3, 128.0, 128.0, 127.8, 114.2, 60.2, 60.0, 55.2, 46.0, 44.2, 42.4, 39.8, 33.1. HPLC: The enantiomeric excess was determined by HPLC with an AS-H column after converted to corresponding ester **7r** with $Ph_3PCHCOOMe$ (hexane: *i*-PrOH = 80:20), 1.0 mL/min; minor enantiomer *t* = 11.04 min, major enantiomer *t* = 16.41 min. HRMS (ESI) : $[M+H]^+$ calcd for $[C_{29}H_{29}O_4]$: 441.2060, found: 441.2059.

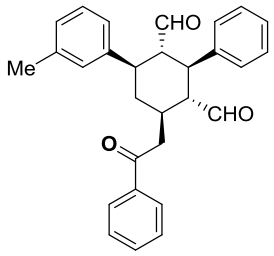
(1R,2S,3S,4R,6R)-4-(4-bromophenyl)-6-(2-oxo-2-phenylethyl)-2-phenylcyclohexane-1,3-dicarbaldehyde (6s)



White solid; $[\alpha]_D^{20}$ = +21 (*c* 1.0, CH_2Cl_2, 99% ee); IR(KBr cm^{-1}): 2955, 2922, 2850, 2731, 1714, 1688, 1678, 1596, 1488, 1448, 1160, 1073, 1010, 978; ^1H NMR (400 MHz, $CDCl_3$) δ 9.41 (d, *J* = 3.8 Hz, 1H), 9.23 (d, *J* = 2.4 Hz, 1H), 7.93 – 7.82 (m, 2H), 7.55 (t, *J* = 7.4

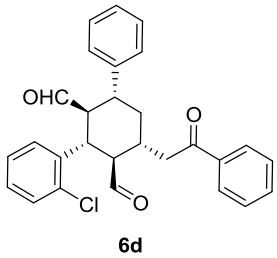
Hz, 1H), 7.48 – 7.36 (m, 4H), 7.34 – 7.26 (m, 2H), 7.24 – 7.18 (m, 3H), 7.09 (d, *J* = 8.4 Hz, 2H), 3.36 (t, *J* = 10.7 Hz, 1H), 3.16 – 3.03 (m, 3H), 2.88 (dd, *J* = 17.2, 7.5 Hz, 1H), 2.81 – 2.67 (m, 2H), 2.18 (d, *J* = 13.3 Hz, 1H), 1.66 – 1.54 (m, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 203.1, 202.6, 198.1, 140.7, 138.4, 136.6, 133.4, 131.9, 129.3, 129.1, 128.7, 128.0, 120.9, 59.8, 59.8, 46.2, 44.3, 42.3, 39.3, 33.0. HPLC: The enantiomeric excess was determined by HPLC with an AD-H column after converted to corresponding ester **7s** with $Ph_3PCHCOOMe$ (hexane: *i*-PrOH = 70:30), 1.0 mL/min; minor enantiomer *t* = 10.16 min, major enantiomer *t* = 17.32 min. HRMS (ESI) : $[M+H]^+$ calcd for $[C_{28}H_{26}BrO_3]$: 489.1060, found: 489.1059.

(1S,2S,3R,4R,6R)-4-(2-oxo-2-phenylethyl)-2-phenyl-6-(m-tolyl)cyclohexane-1,3-dicarbal dehyde (6t)

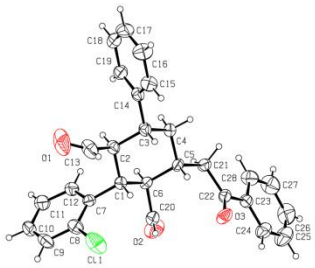


White solid; $[\alpha]_D^{20}$ = +23 (*c* 1.0, CH_2Cl_2, 95% ee); IR(KBr cm^{-1}): 2954, 2922, 2850, 2735, 1715, 1680, 1598, 1581, 1493, 1454, 1447, 1279, 1162, 1007 . ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.42 (d, *J* = 4.0 Hz, 1H), 9.25 (d, *J* = 3.2 Hz, 1H), 7.88 (d, *J* = 7.2 Hz, 2H), 7.54 (t, *J* = 7.2 Hz, 1H), 7.43 (t, *J* = 7.6 Hz, 2H), 7.34 - 6.95 (m, 9H), 3.39 (t, *J* = 11.2 Hz, 1H), 3.21 – 2.97 (m, 3H), 2.88 (dd, *J* = 17.2, 7.6 Hz, 1H), 2.81 – 2.62 (m, 2H), 2.30 (s, 3H), 2.19 (dt, *J* = 13.2, 3.2 Hz, 1H), 1.60 (dd, *J* = 24.8, 12.0 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 203.4, 202.9, 198.2, 141.6, 138.8, 138.4, 136.7, 133.3, 129.2, 128.7, 128.6, 128.1, 128.0, 127.9, 127.9, 127.8, 124.3, 60.0, 59.8, 45.9, 45.0, 42.4, 39.6, 33.1, 21.4. The enantiomeric excess was determined by HPLC with an AD-H column after converted to corresponding ester **7t** with $Ph_3PCHCOOMe$ (hexane: *i*-PrOH = 80:20), 1.0 mL/min; minor enantiomer *t* = 11.40 min, major enantiomer *t* = 16.62 min. HRMS (ESI) : $[M+H]^+$ calcd for $[C_{29}H_{29}O_3]$: 425.2111 found: 425.2109.

5. X-ray crystallography of product **6d**



6d



CCDC 1526972

Bond precision: C-C = 0.0059 A Wavelength=0.71073

Cell: a=6.5747(5) b=16.8602(9) c=10.7211(7)

alpha=90 beta=93.733(7) gamma=90

Temperature: 293 K

	Calculated	Reported
Volume	1185.92(14)	1185.93(14)
Space group	P 21	P 1 21 1
Hall group	P 2yb	P 2yb
Moiety formula	C28 H25 Cl O3	C28 H25 Cl O3
Sum formula	C28 H25 Cl O3	C28 H25 Cl O3
Mr	444.93	444.93
Dx,g cm-3	1.246	1.246
Z	2	2
Mu (mm-1)	0.188	0.188
F000	468.0	468.0
F000'	468.50	
h,k,lmax	8,20,13	8,20,13
Nref	4650[2409]	4371
Tmin,Tmax		0.616,1.000
Tmin'		

Correction method= # Reported T Limits: Tmin=0.616 Tmax=1.000 AbsCorr = MULTI-SCAN

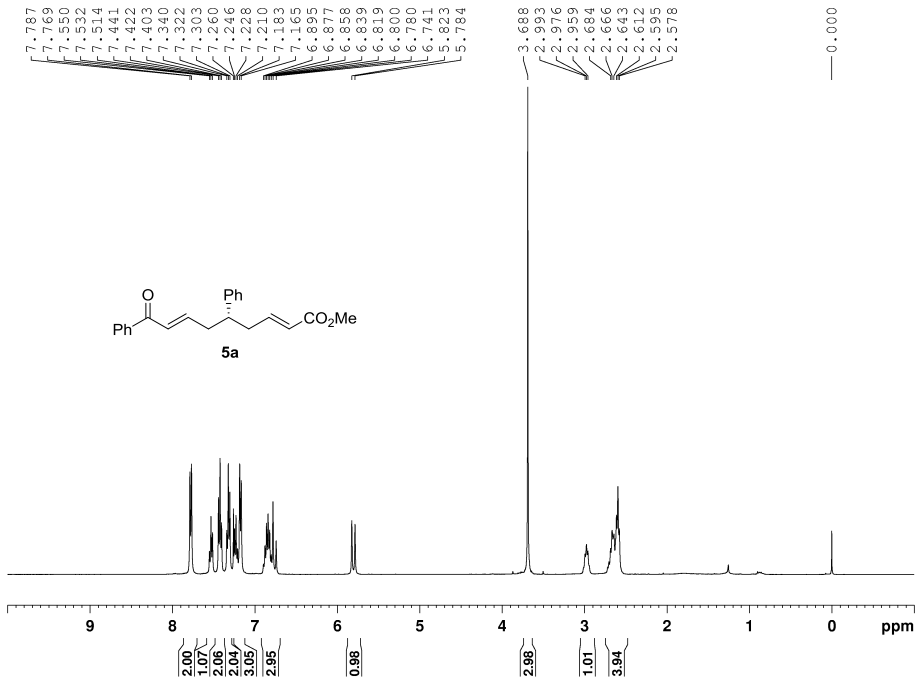
Data completeness= 1.81/0.94 Theta(max)= 26.020

R(reflections)= 0.0558(2772) wR2(reflections)= 0.1261(4371)

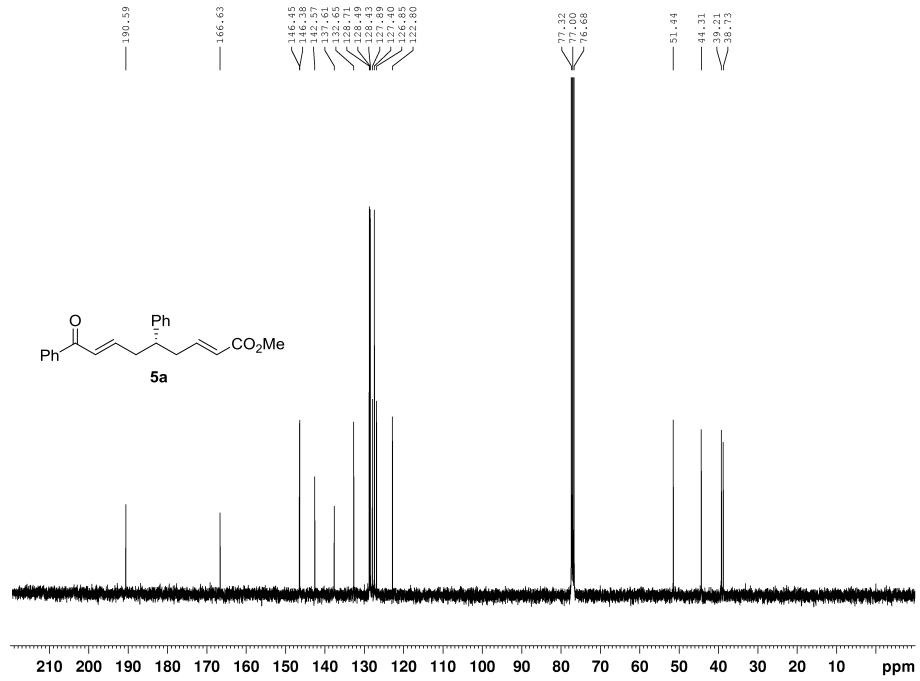
S = 1.034 Npar= 289

Displacement ellipsoids are drawn at 30% probability level

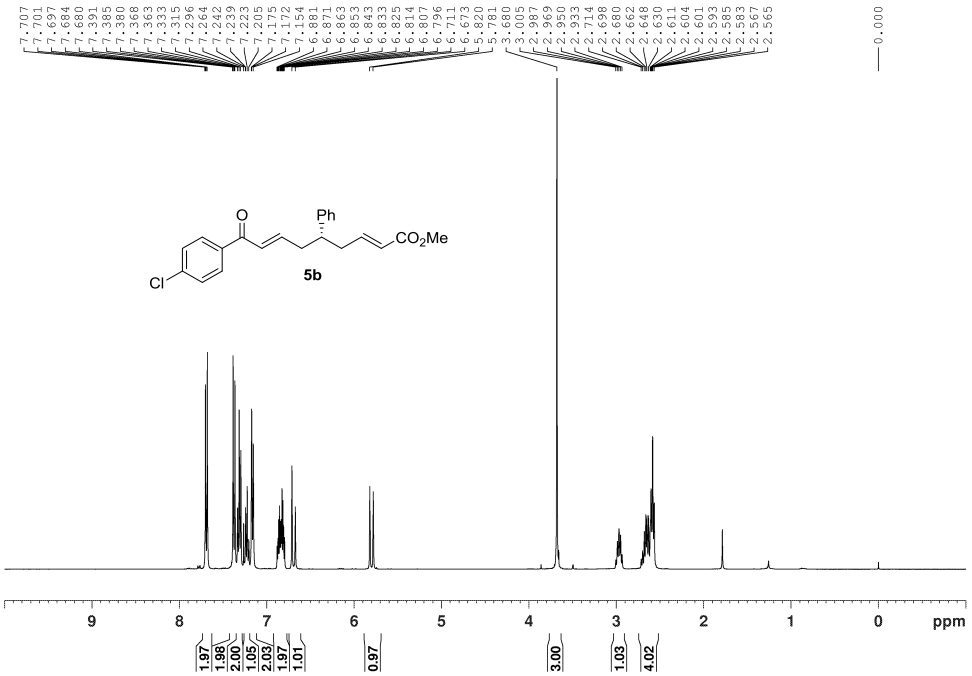
^{1}H NMR of **5a** (400M, $CDCl_3$)



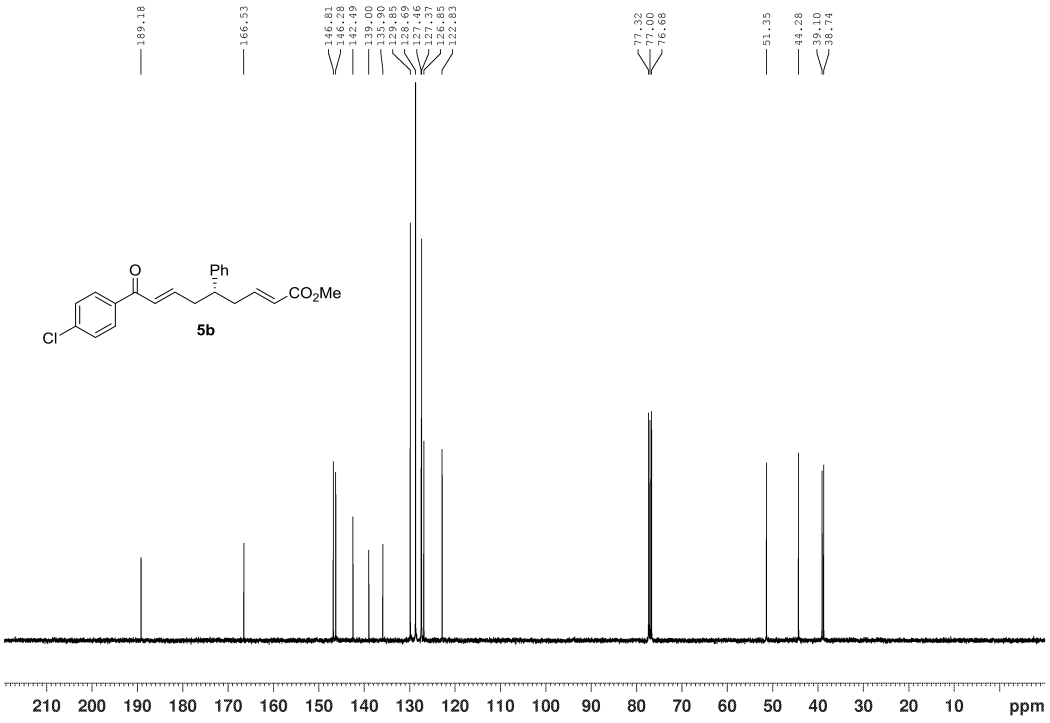
^{13}C NMR of **5a** (101M, $CDCl_3$)



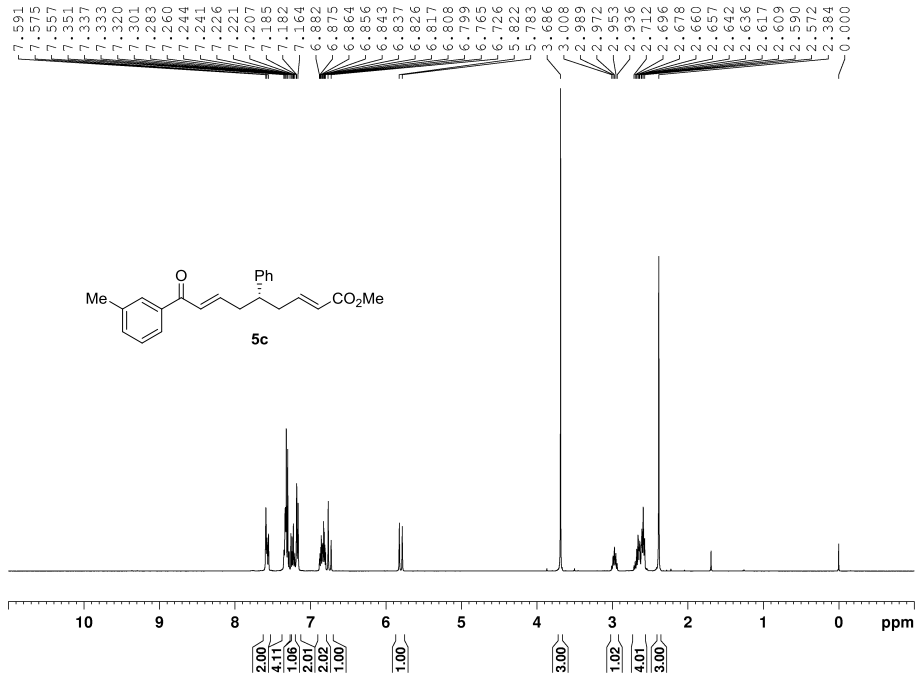
^{1}H NMR of **5b** (400M, $CDCl_3$)



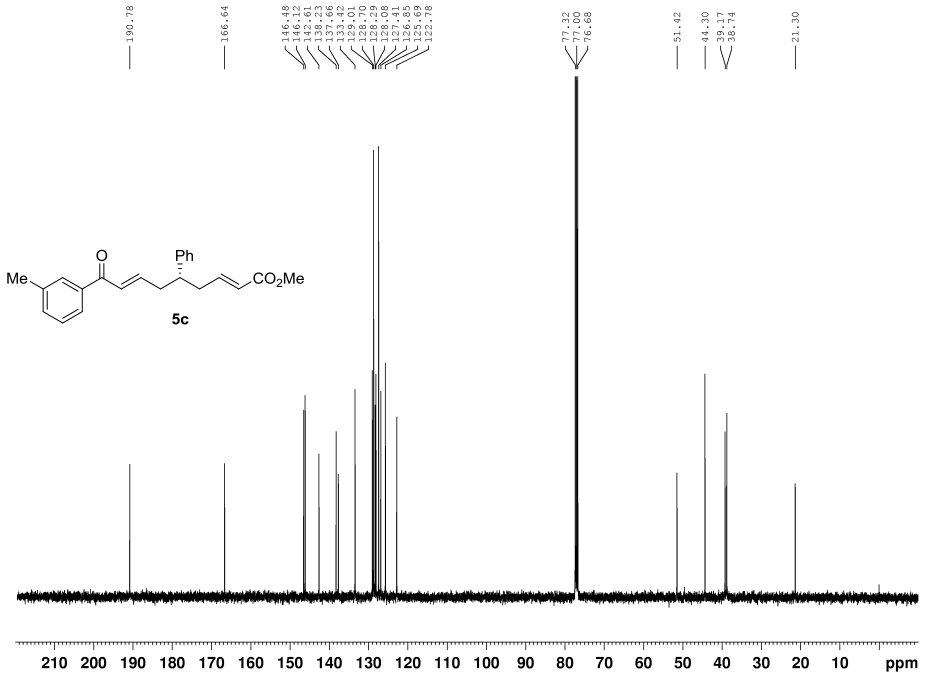
^{13}C NMR of **5b** (101M, $CDCl_3$)



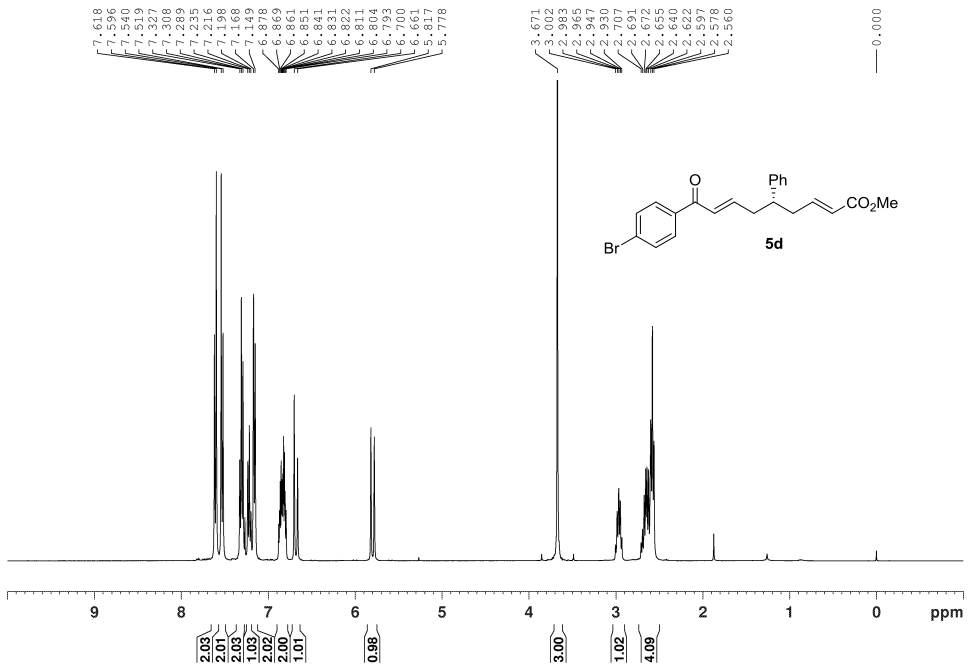
^{1}H NMR of **5c** (400M, $CDCl_3$)



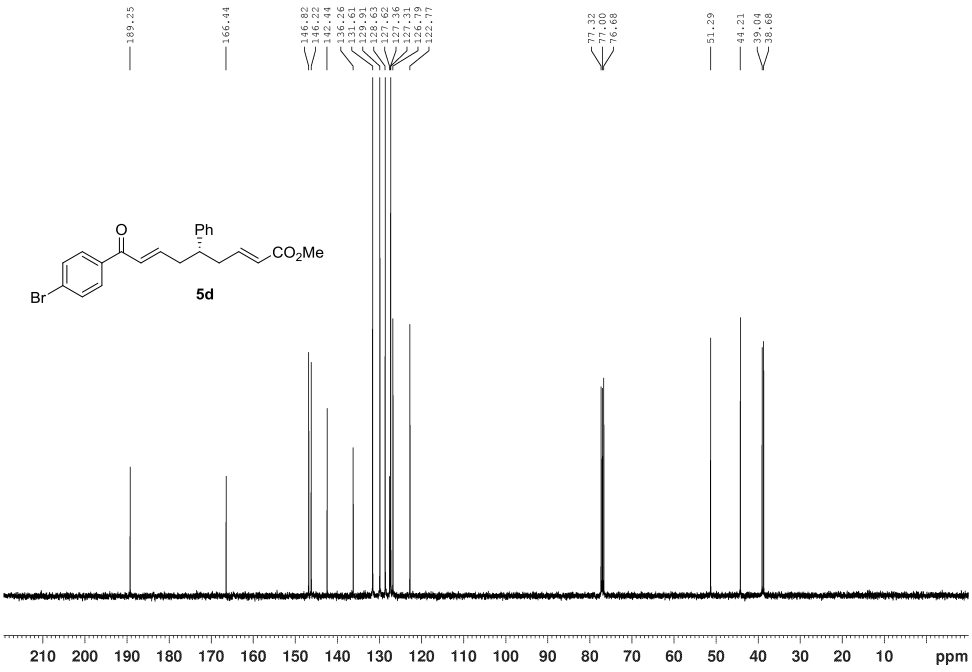
^{13}C NMR of **5c** (101M, $CDCl_3$)



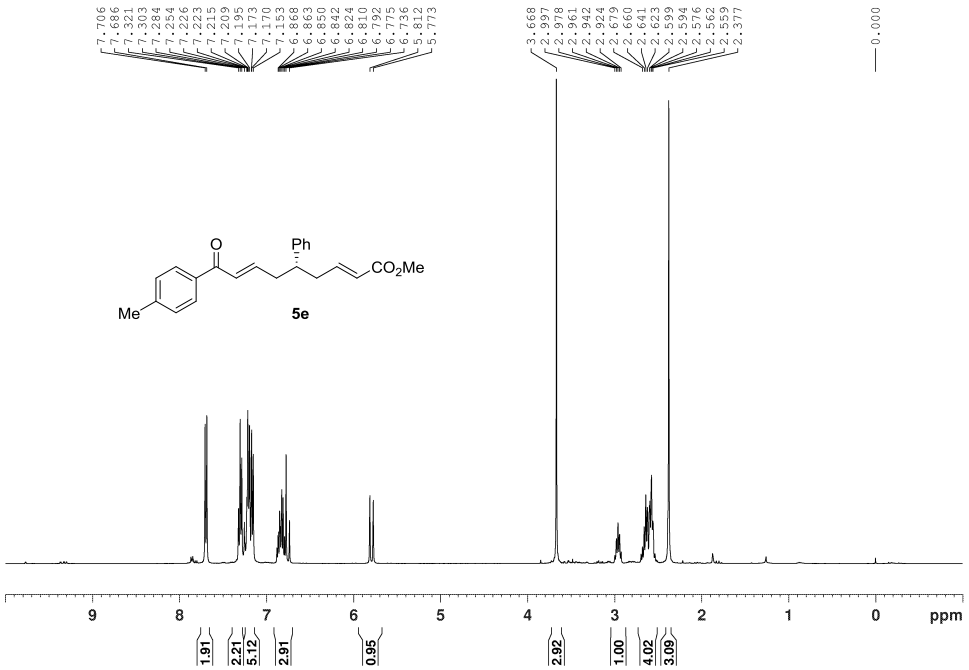
^{1}H NMR of **5d** (400M, $CDCl_3$)



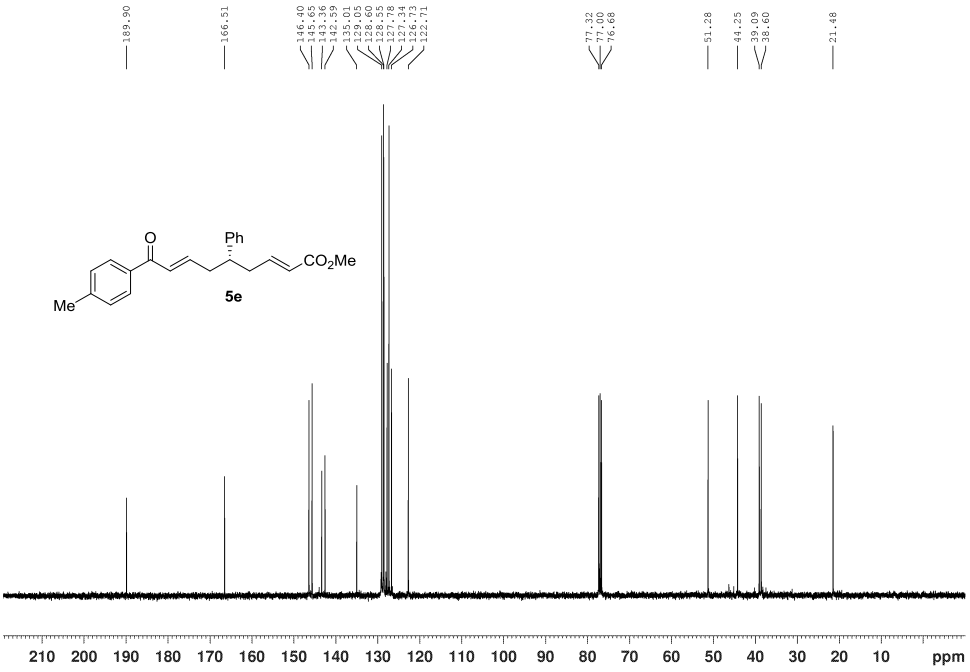
^{13}C NMR of **5d** (101M, $CDCl_3$)



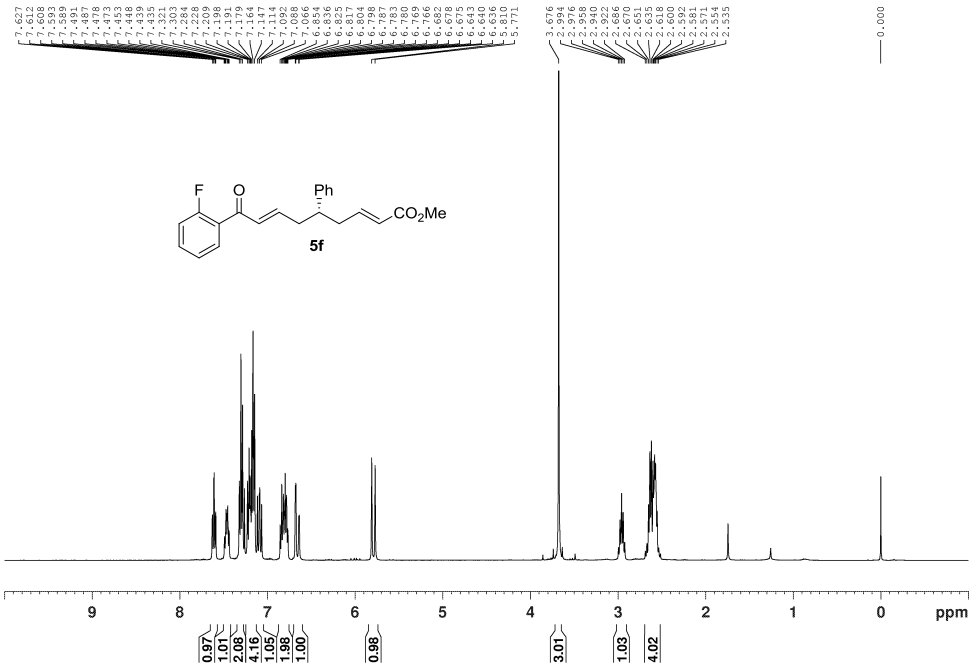
^{1}H NMR of **5e** (400M, $CDCl_3$)



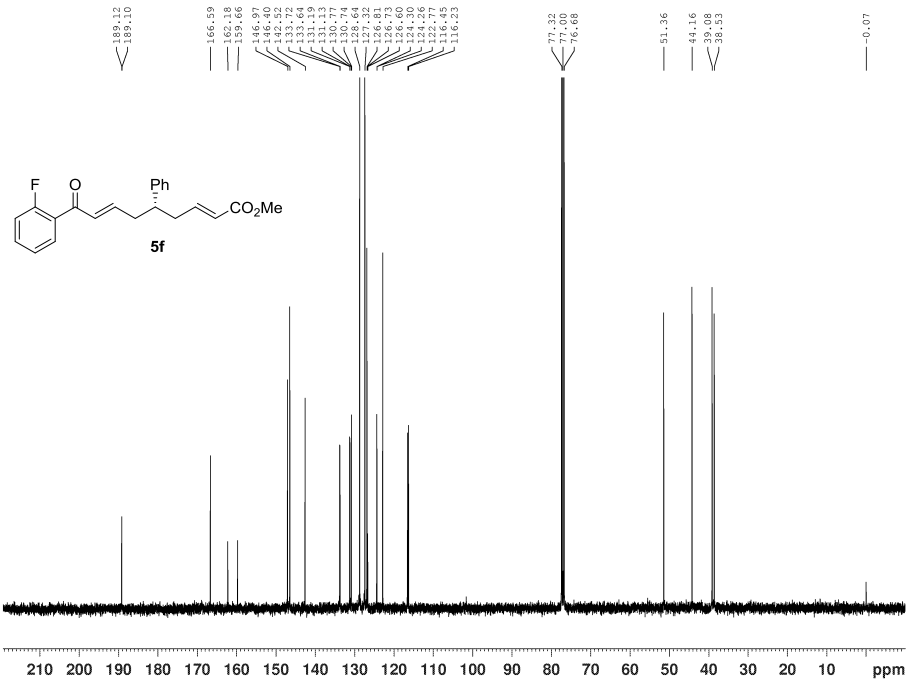
^{13}C NMR of **5e** (101M, $CDCl_3$)



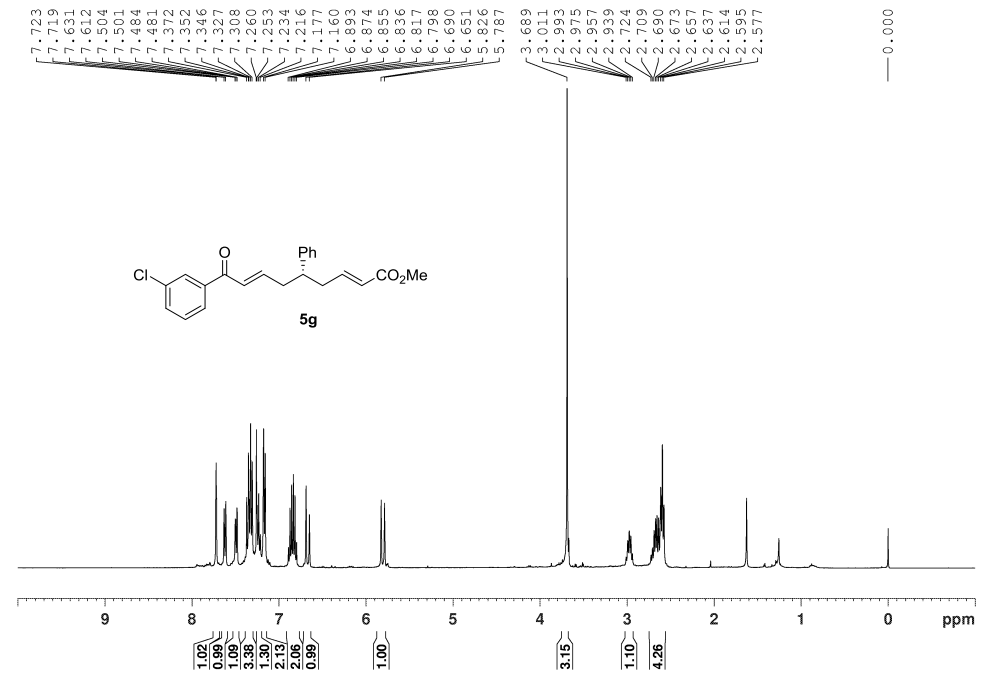
^{1}H NMR of **5f** (400M, $CDCl_3$)



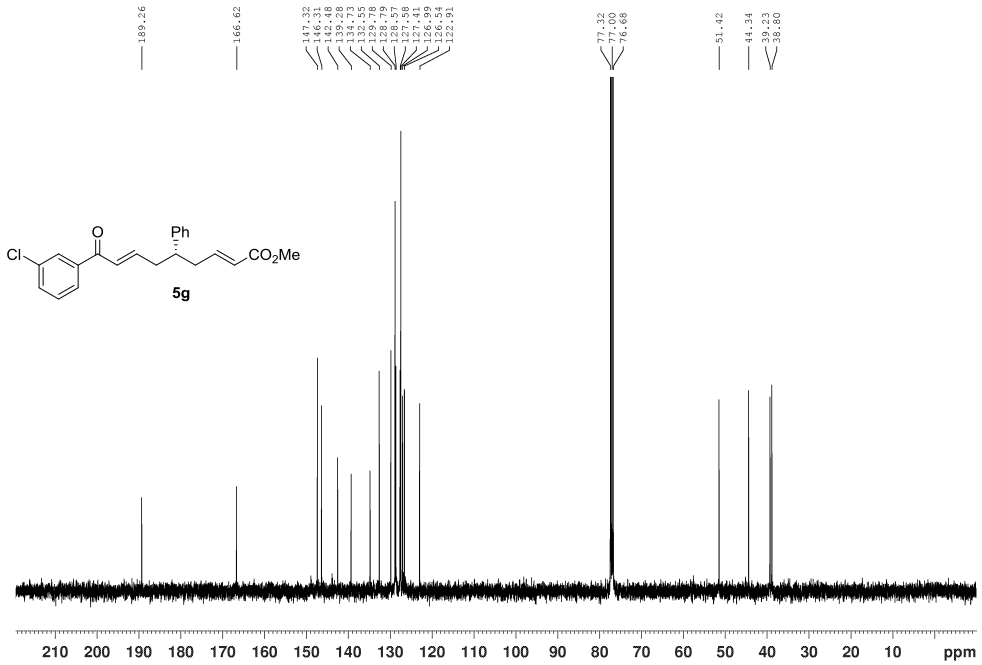
^{13}C NMR of **5f** (101M, $CDCl_3$)



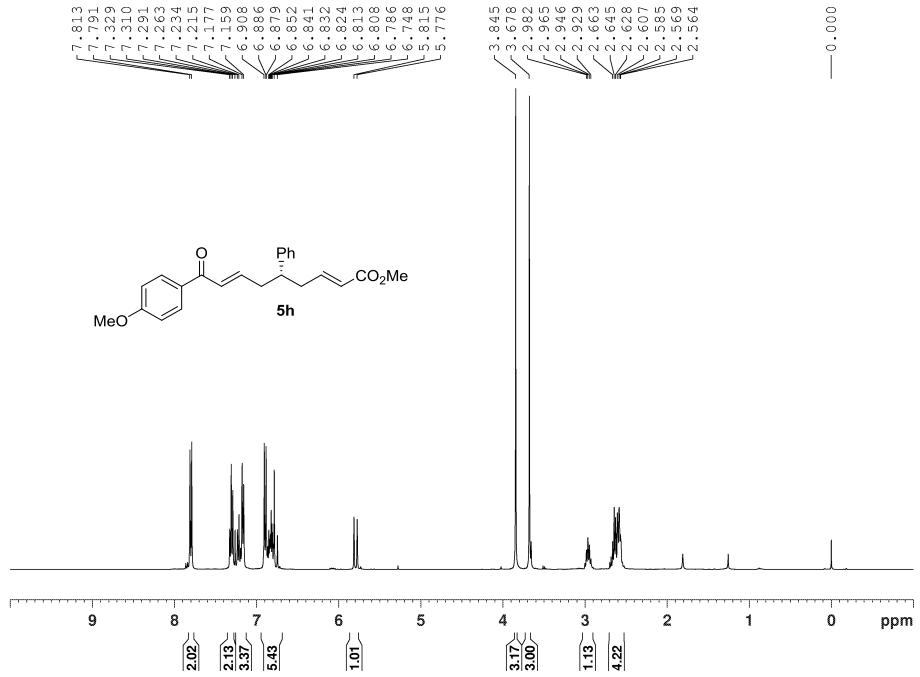
^{1}H NMR of **5g** (400M, $CDCl_3$)



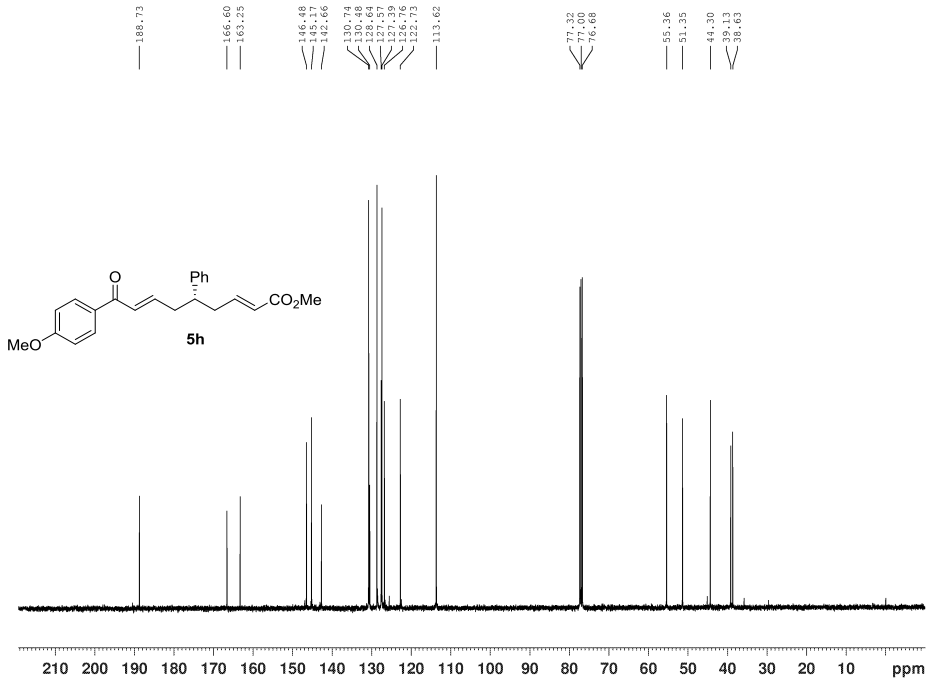
^{13}C NMR of **5g** (101M, $CDCl_3$)



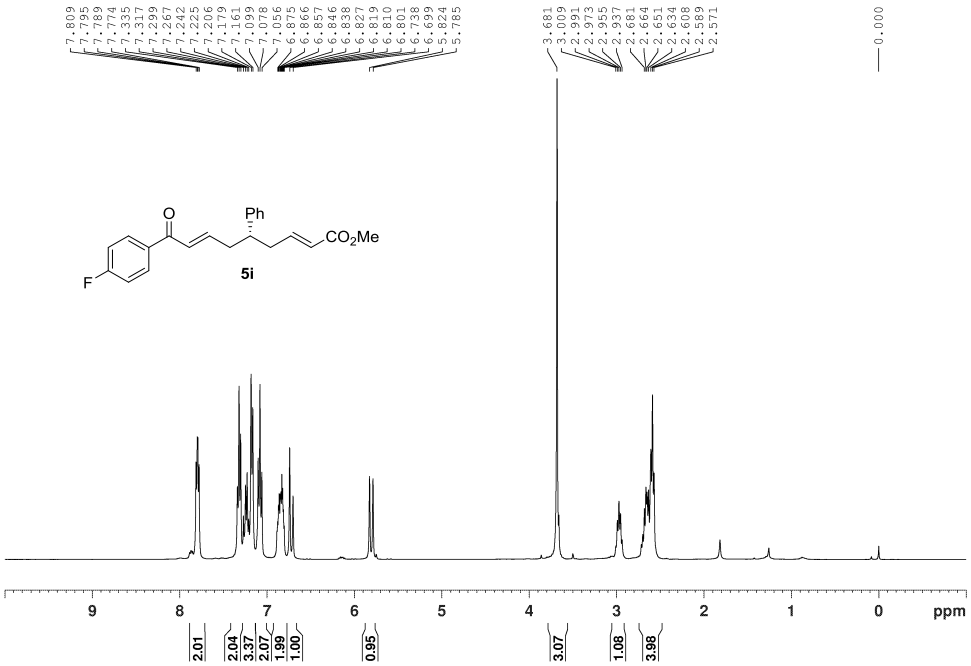
^{1}H NMR of **5h** (400M, $CDCl_3$)



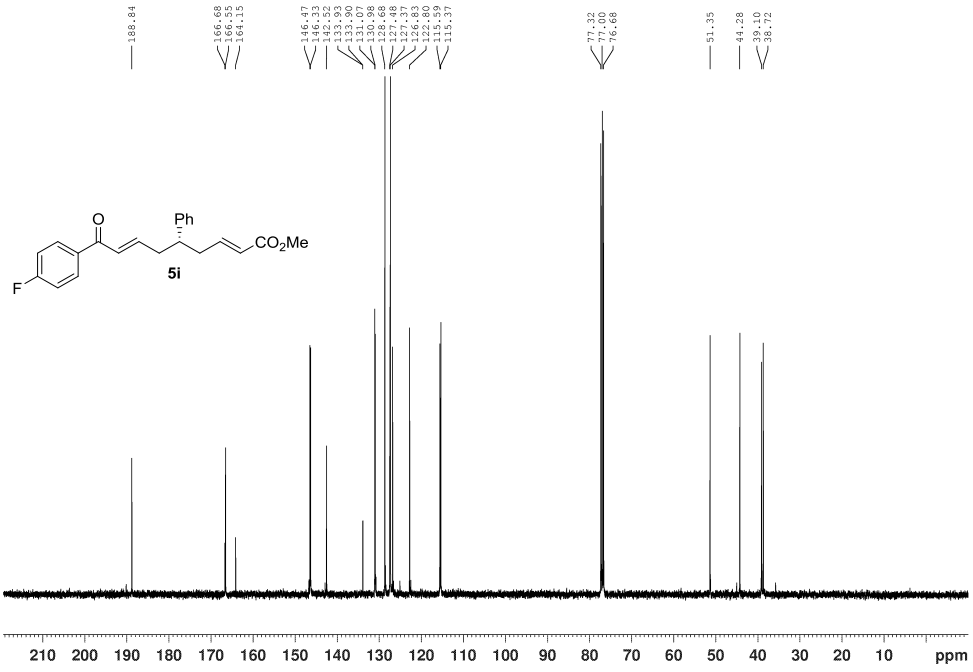
^{13}C NMR of **5h** (101M, $CDCl_3$)



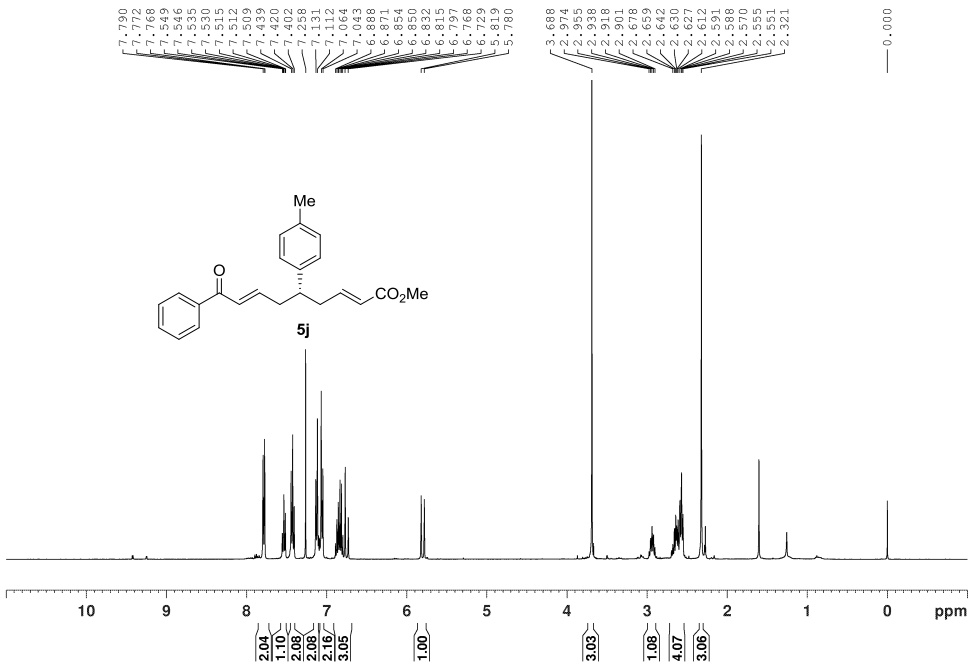
^{1}H NMR of **5i** (400M, $CDCl_3$)



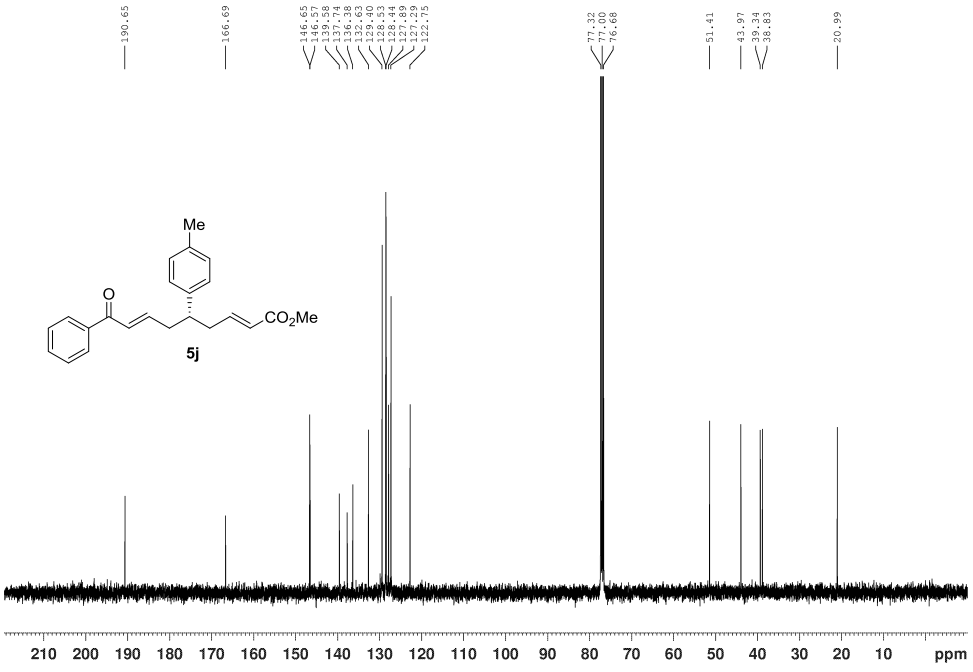
^{13}C NMR of **5i** (101M, $CDCl_3$)



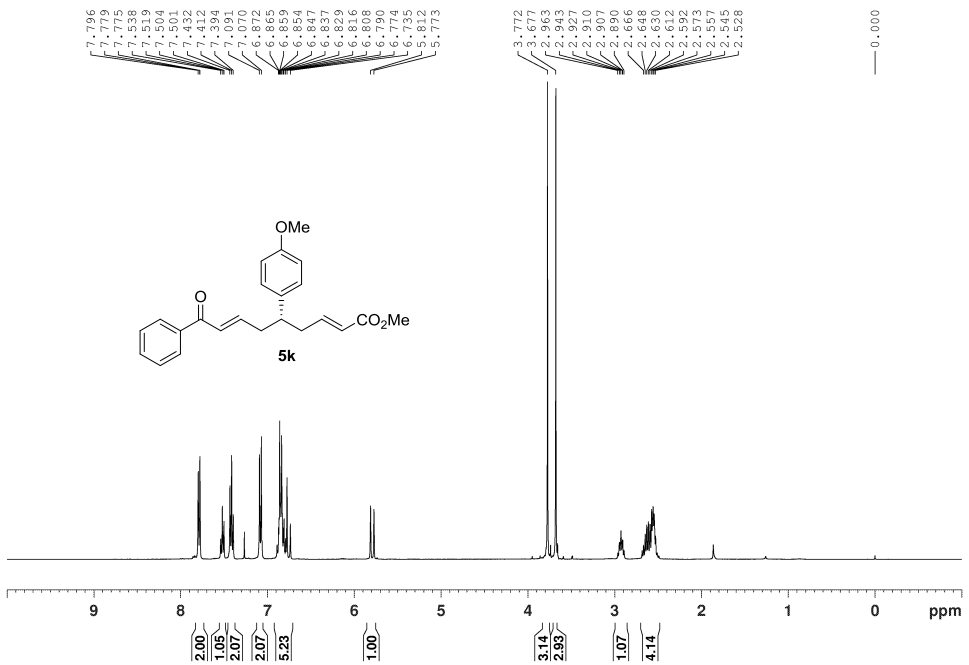
^{1}H NMR of **5j** (400M, $CDCl_3$)



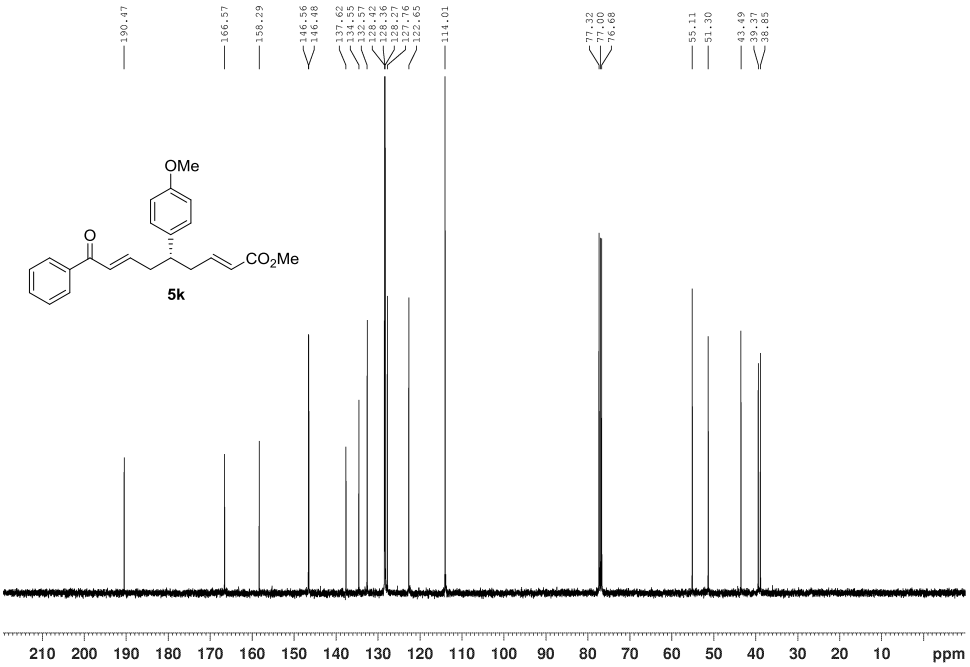
^{13}C NMR of **5j** (101M, $CDCl_3$)



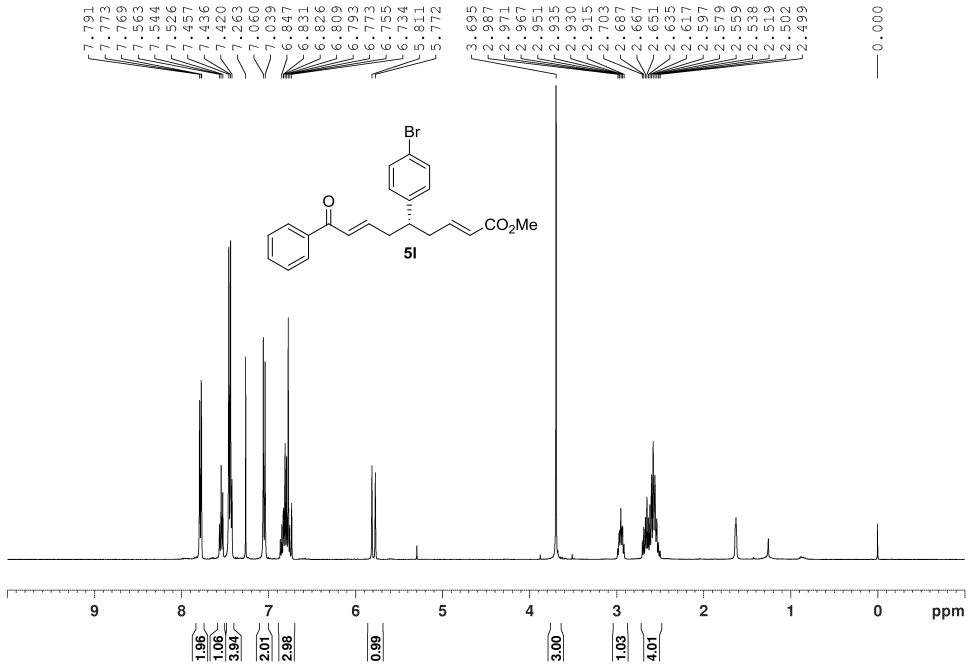
^{1}H NMR of **5k** (400M, $CDCl_3$)



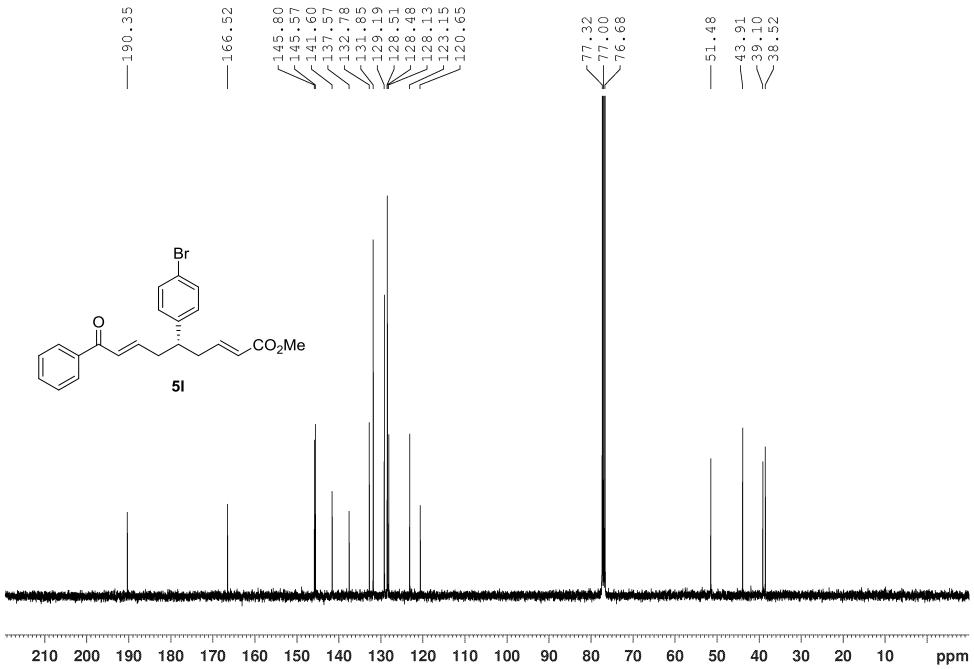
^{13}C NMR of **5k** (101M, $CDCl_3$)



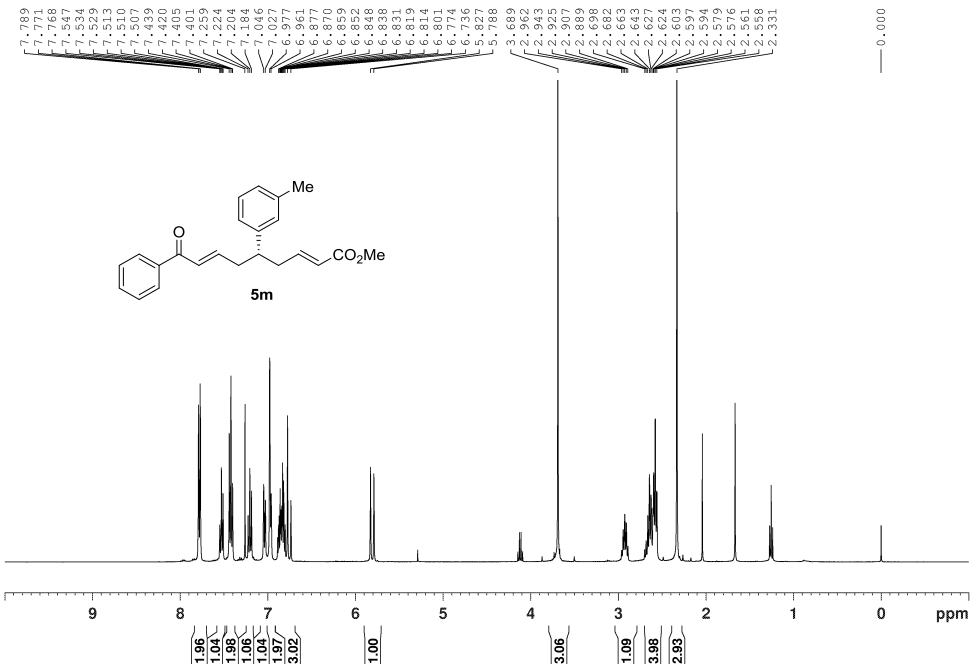
^{1}H NMR of **5l** (400M, $CDCl_3$)



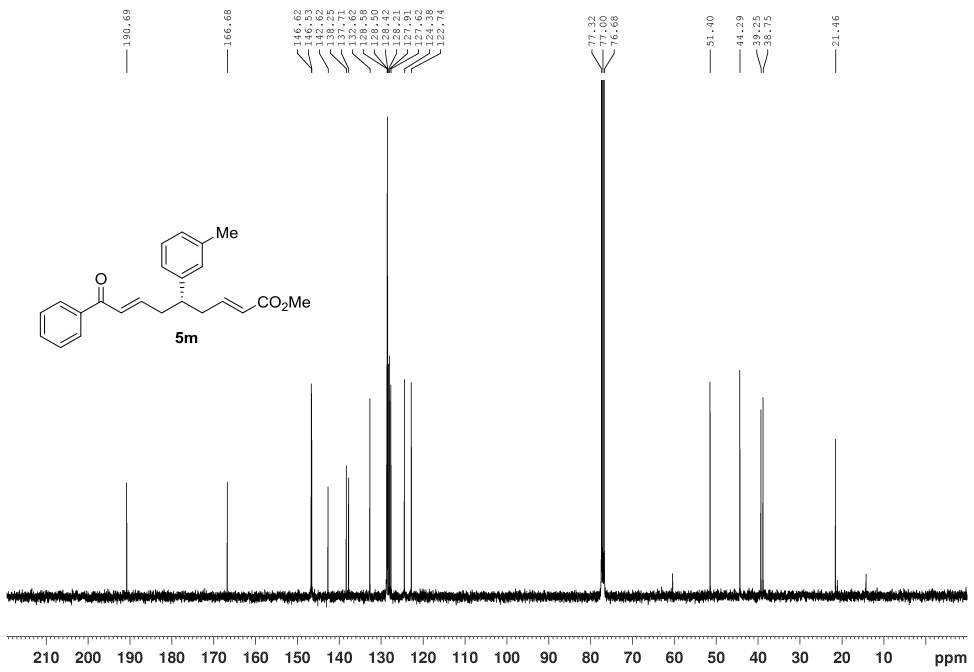
^{13}C NMR of **5l** (101M, $CDCl_3$)



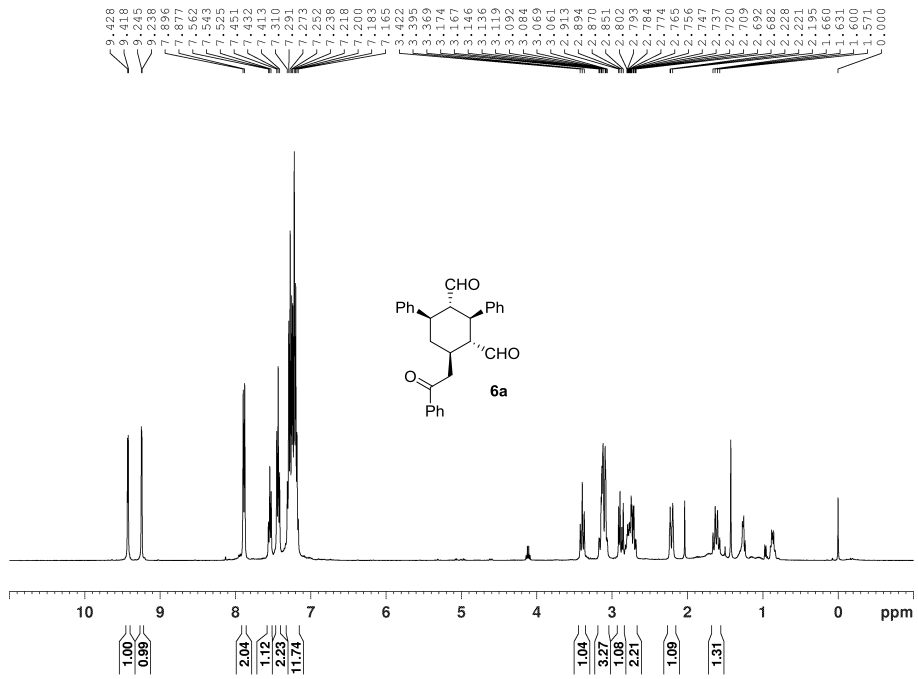
^{1}H NMR of **5m** (400M, $CDCl_3$)



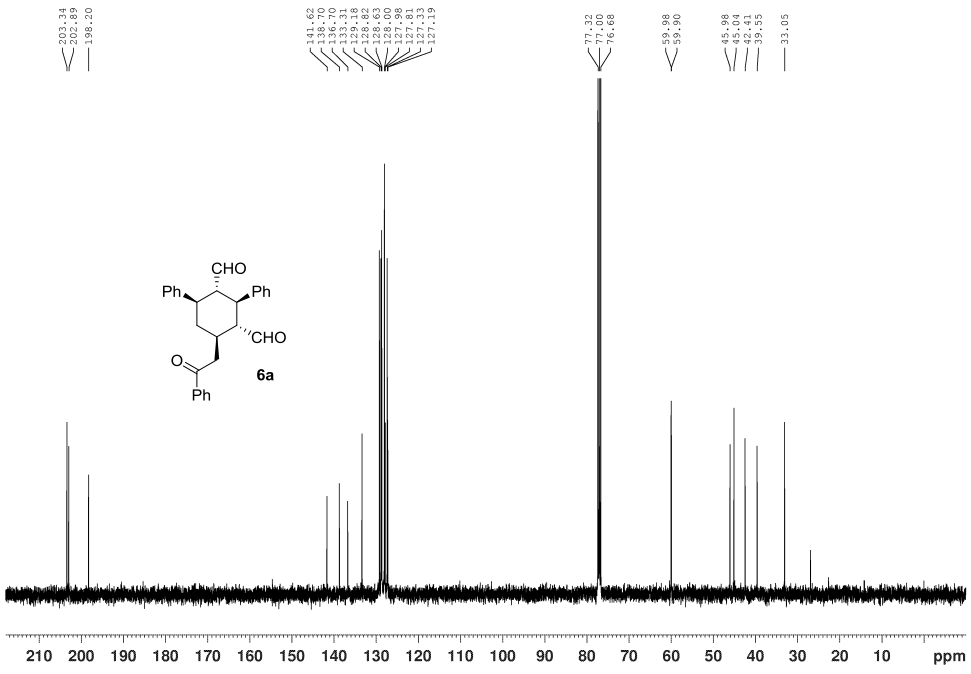
^{13}C NMR of **5m** (101M, $CDCl_3$)



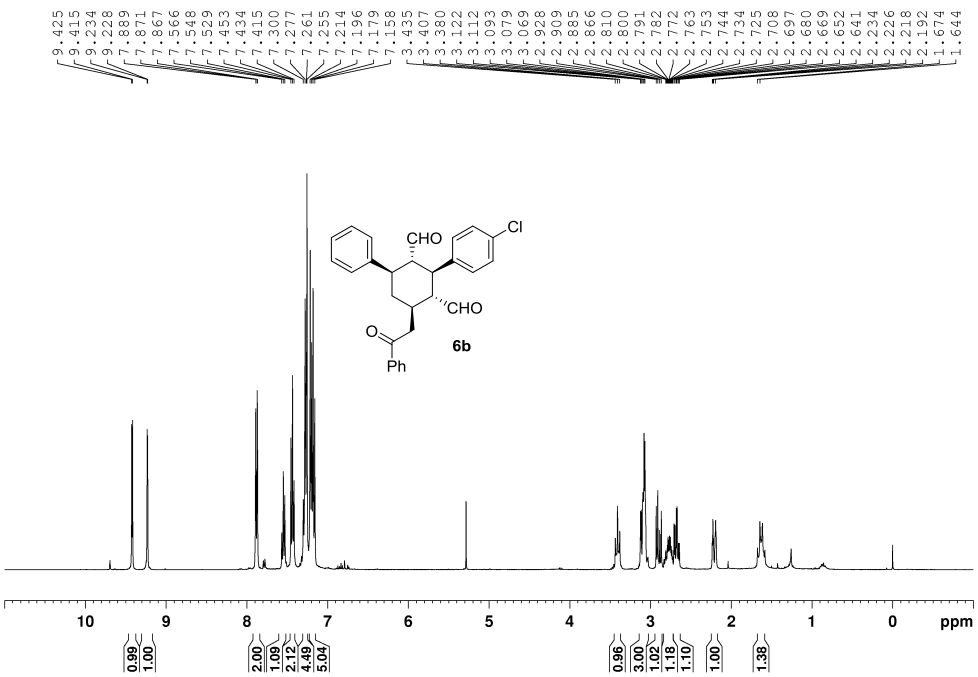
^{1}H NMR of **6a** (400M, $CDCl_3$)



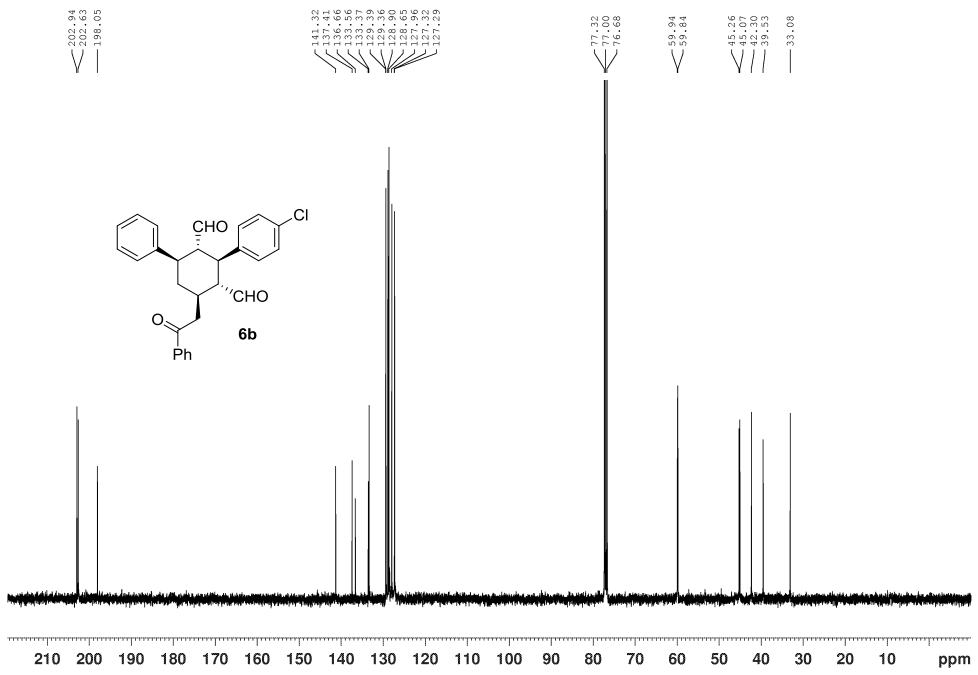
^{13}C NMR of **6a** (101M, $CDCl_3$)



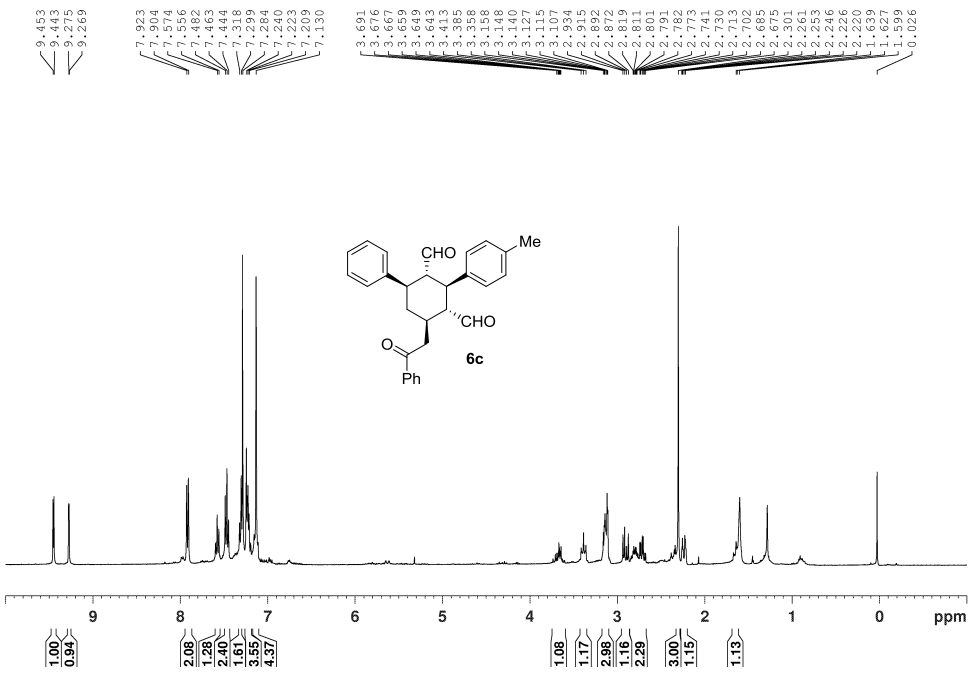
^{1}H NMR of **6b** (400M, $CDCl_3$)



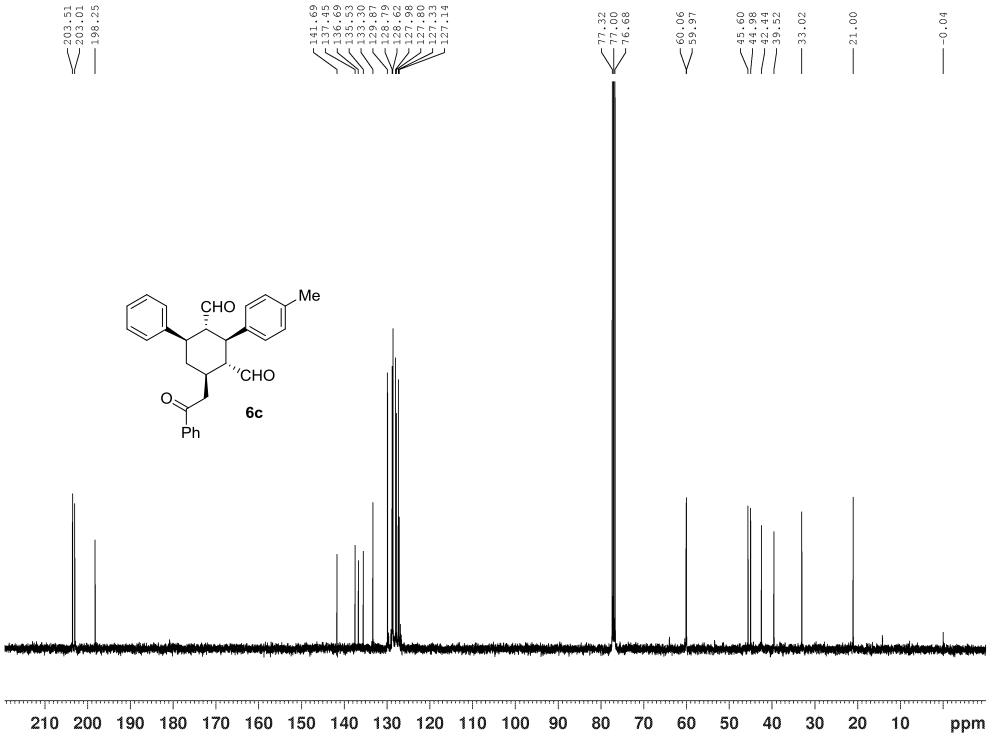
^{13}C NMR of **6b** (101M, $CDCl_3$)



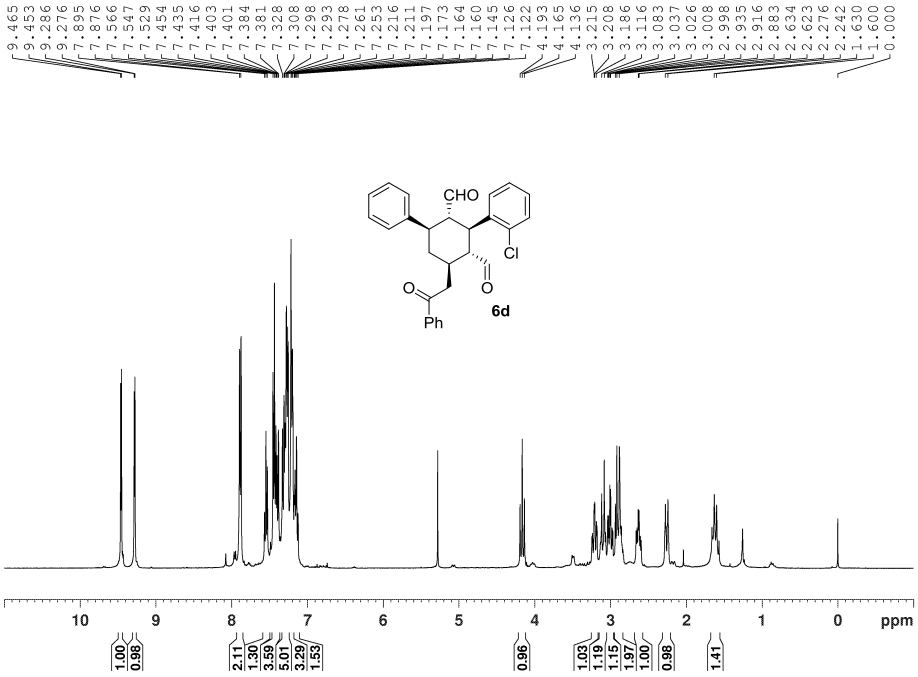
^{1}H NMR of **6c** (400M, $CDCl_3$)



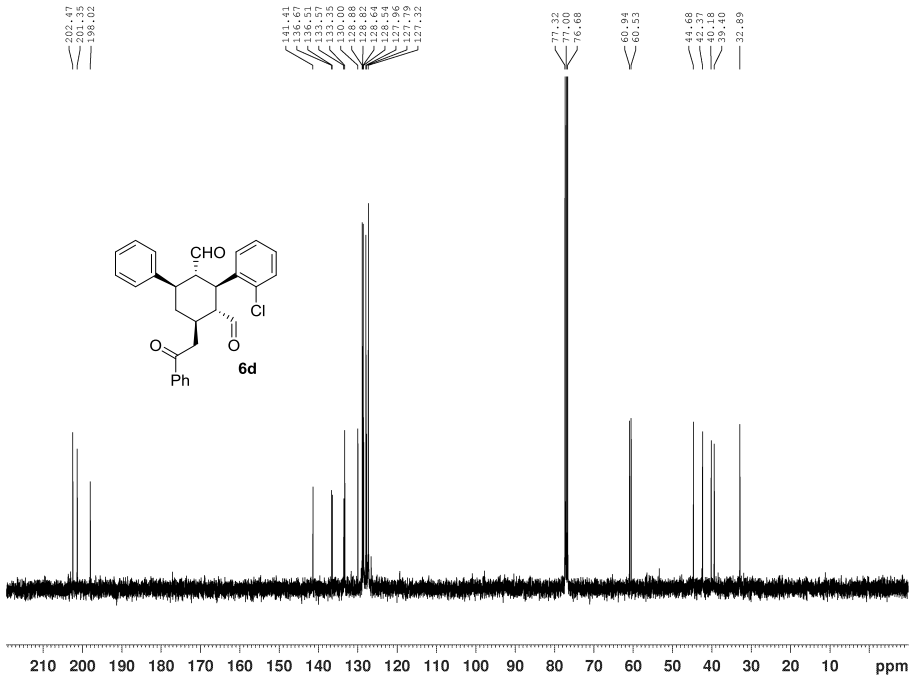
^{13}C NMR of **6c** (101M, $CDCl_3$)



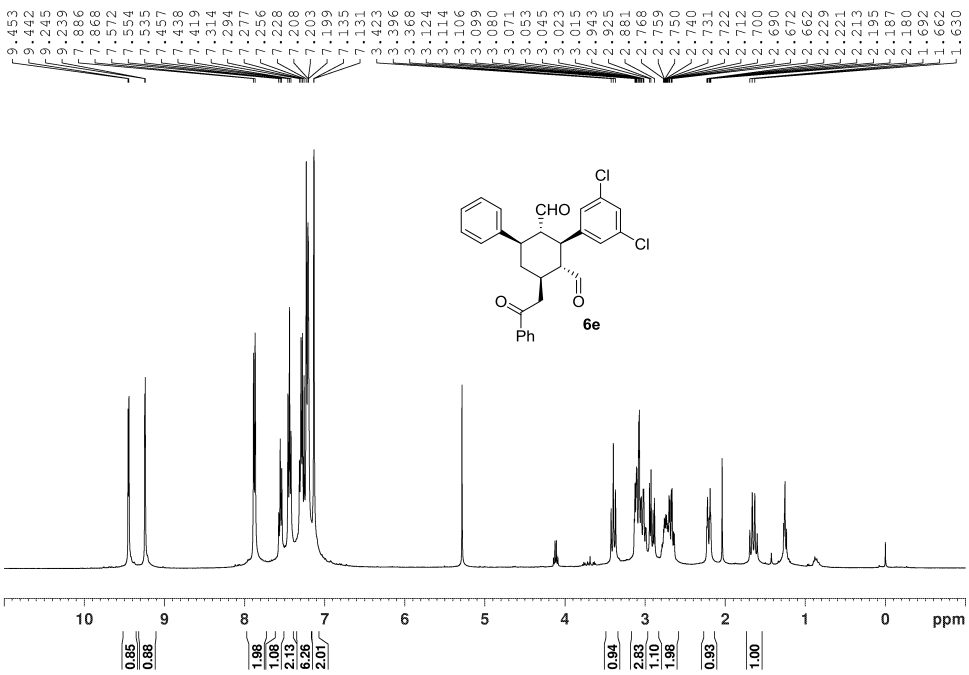
^{1}H NMR of **6d** (400M, $CDCl_3$)



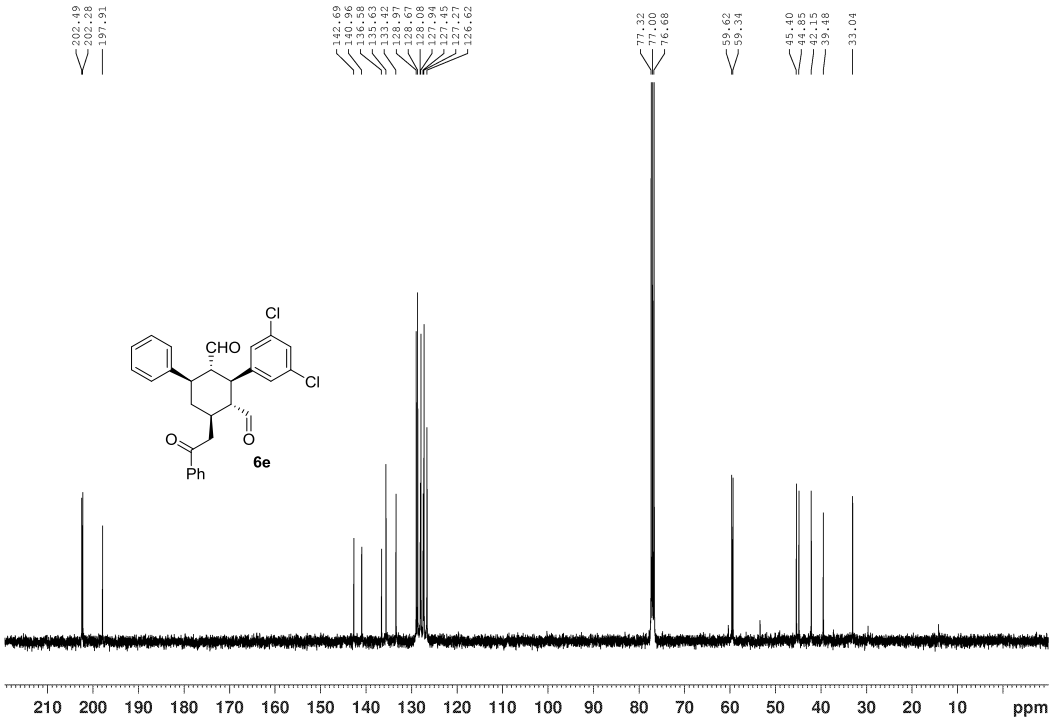
^{13}C NMR of **6d** (101M, $CDCl_3$)



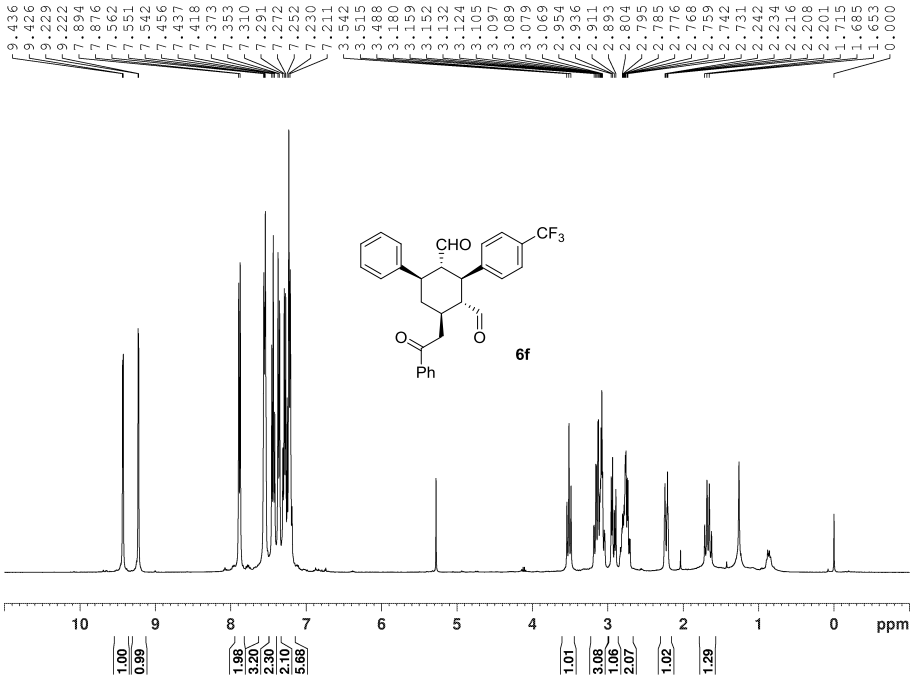
^{1}H NMR of **6e** (400M, $CDCl_3$)



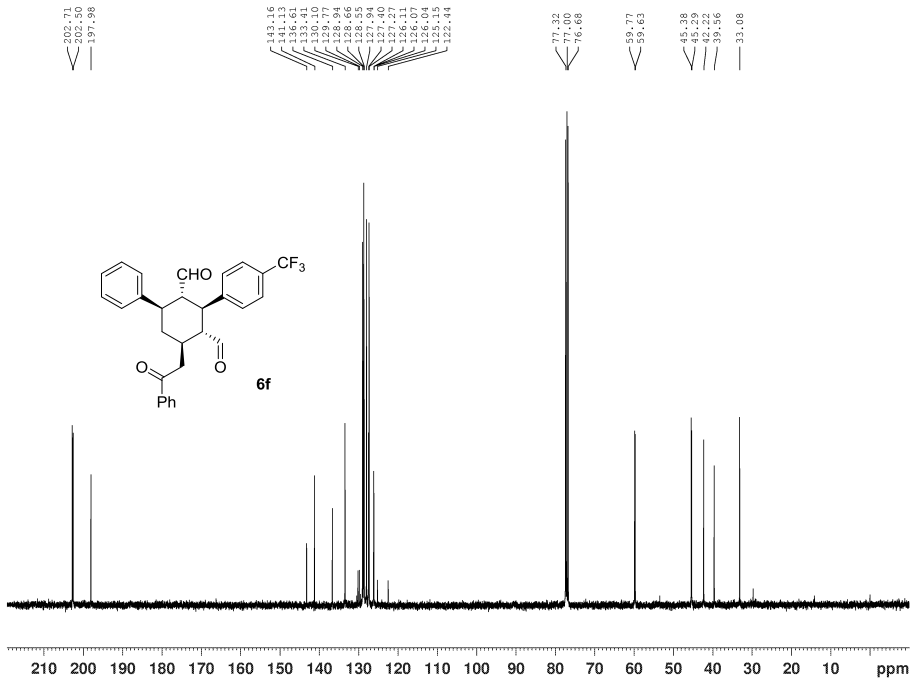
^{13}C NMR of **6e** (101M, $CDCl_3$)



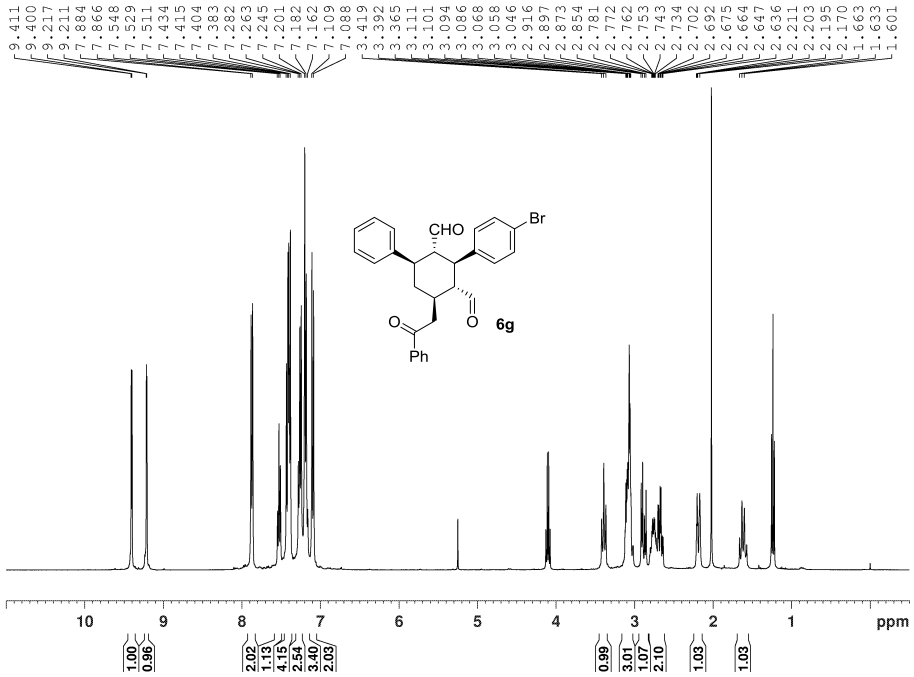
^{1}H NMR of **6f** (400M, $CDCl_3$)



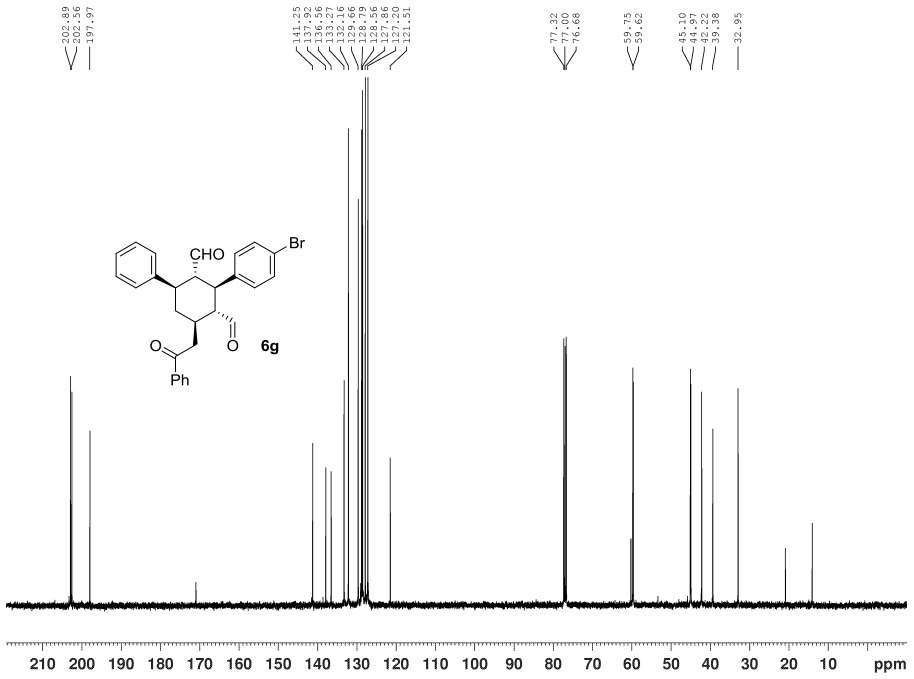
^{13}C NMR of **6f** (101M, $CDCl_3$)



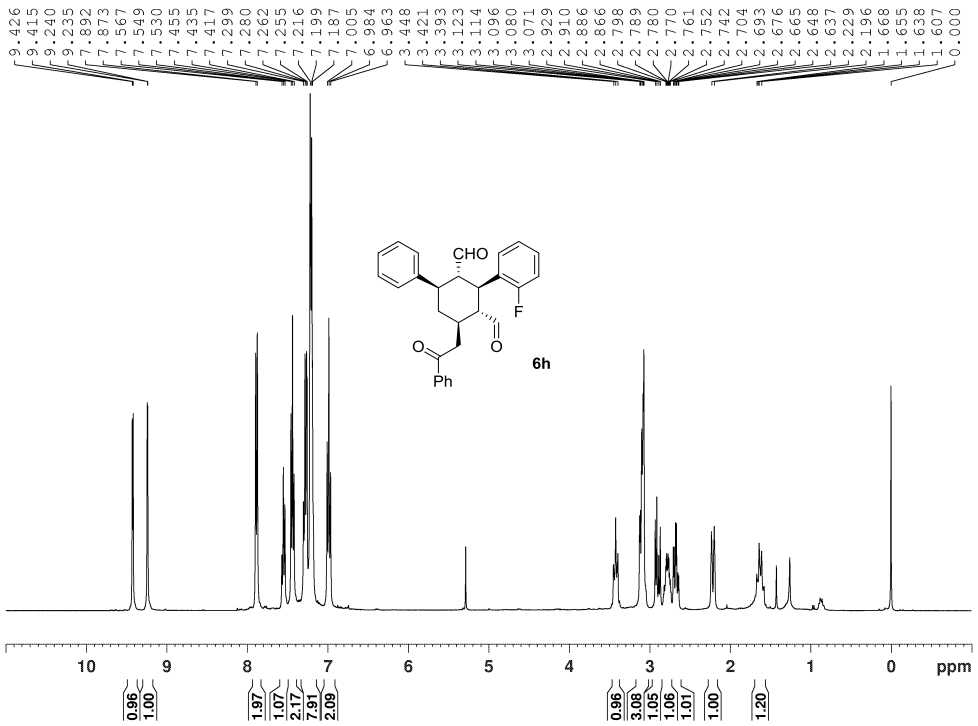
^{1}H NMR of **6g** (400M, $CDCl_3$)



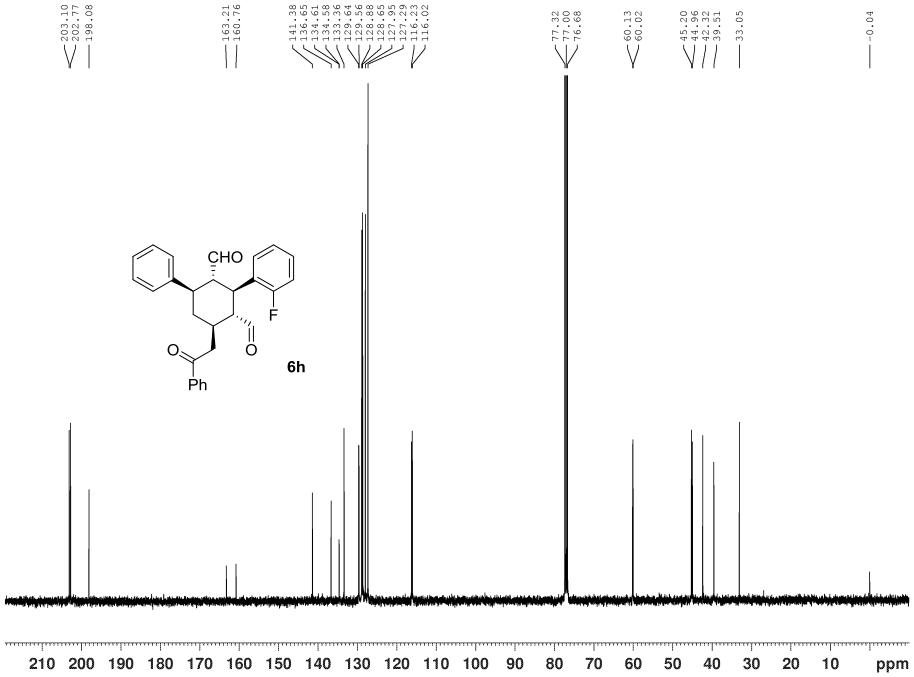
^{13}C NMR of **6g** (101M, $CDCl_3$)



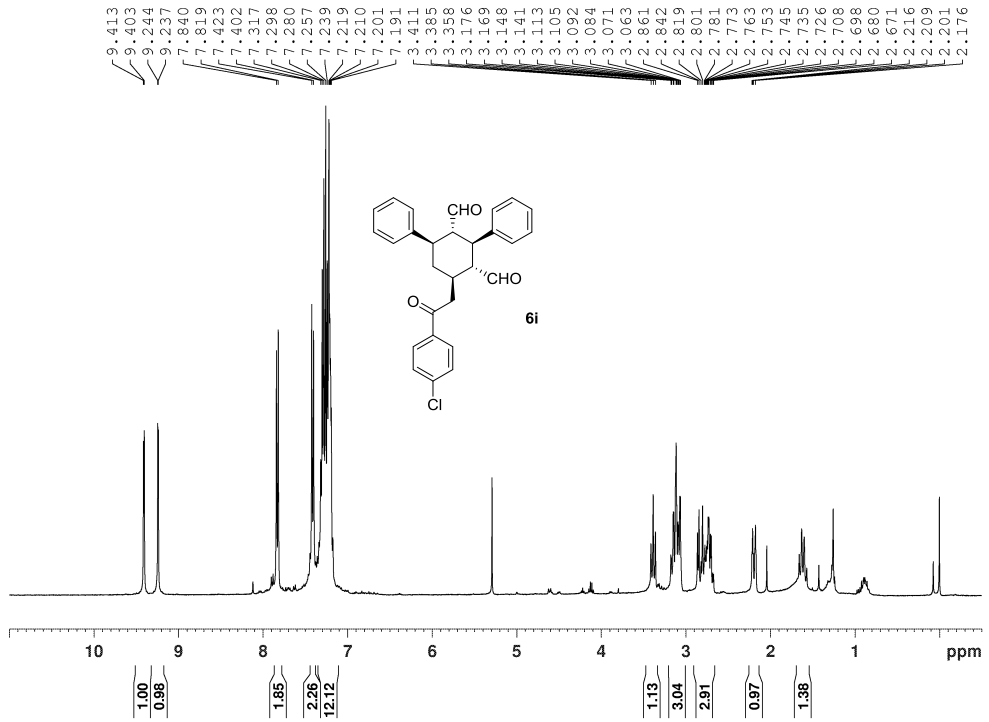
^{1}H NMR of **6h** (400M, $CDCl_3$)



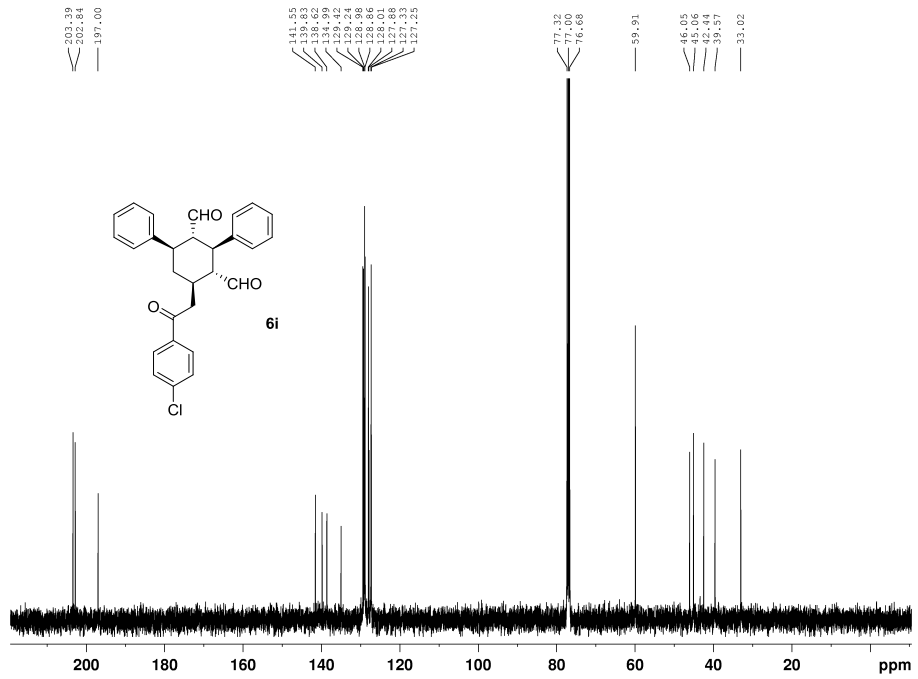
^{13}C NMR of **6h** (101M, $CDCl_3$)



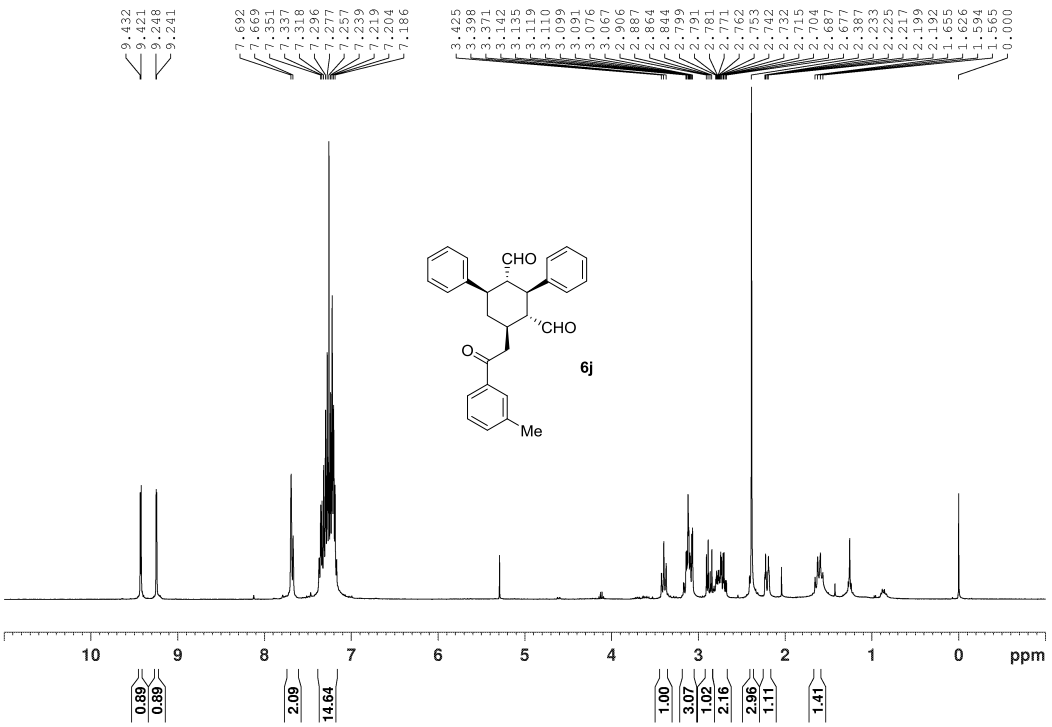
^{1}H NMR of **6i** (400M, $CDCl_3$)



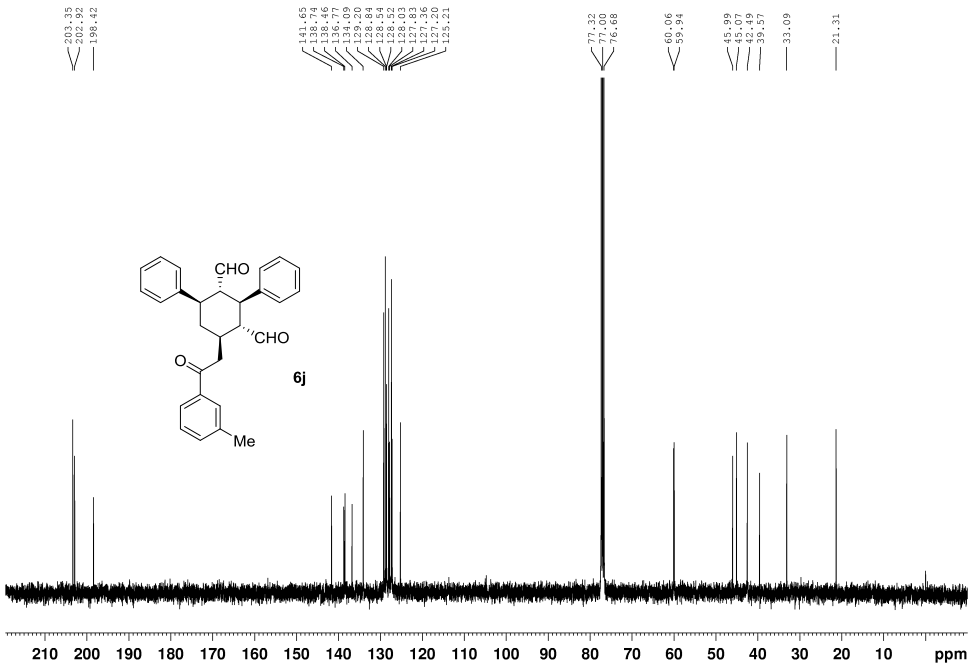
^{13}C NMR of **6i** (101M, $CDCl_3$)



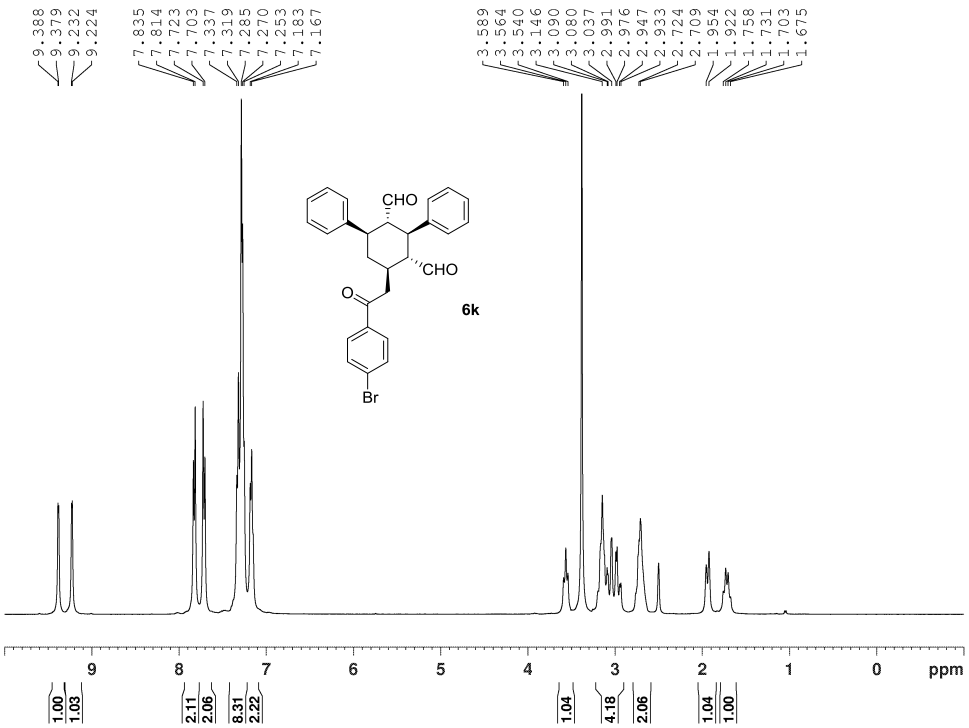
^{1}H NMR of **6j** (400M, $CDCl_3$)



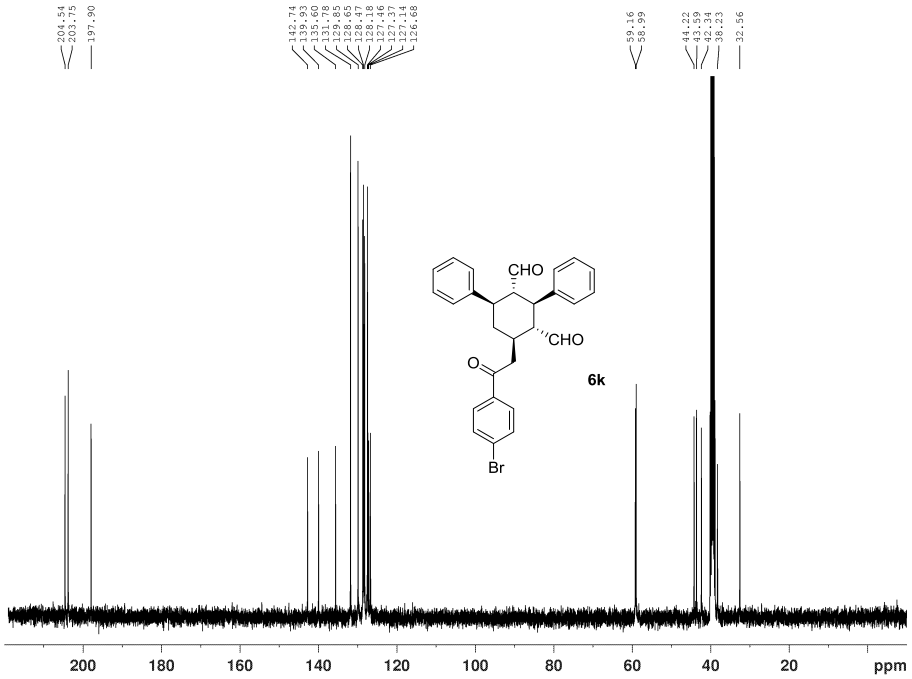
^{13}C NMR of **6j** (101M, $CDCl_3$)



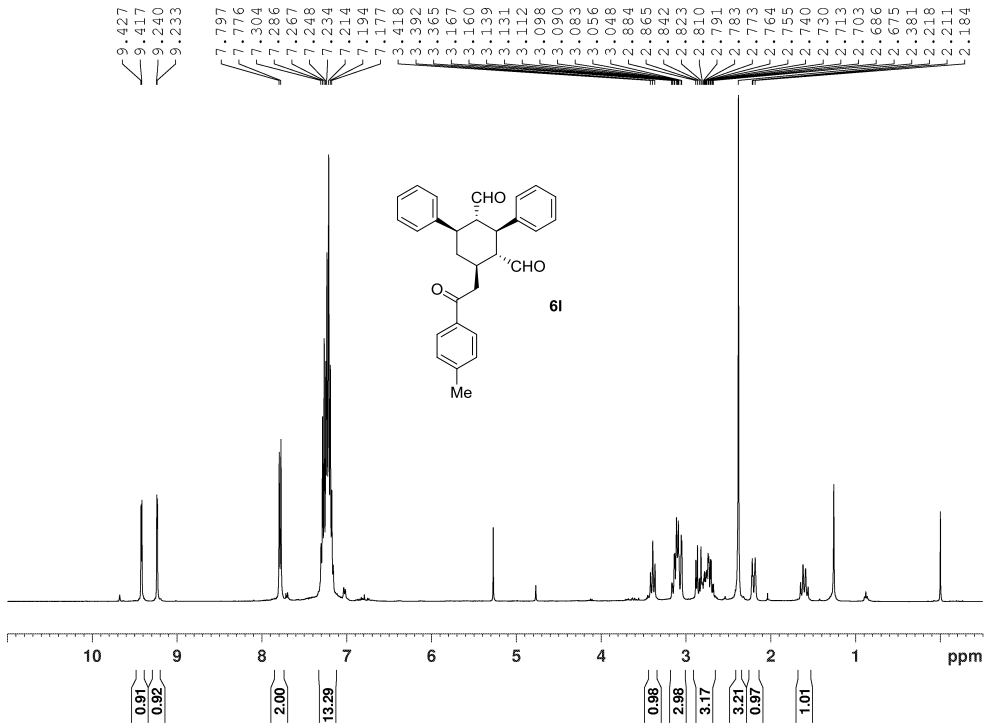
^{1}H NMR of **6k** (400M, DMSO-d_6)



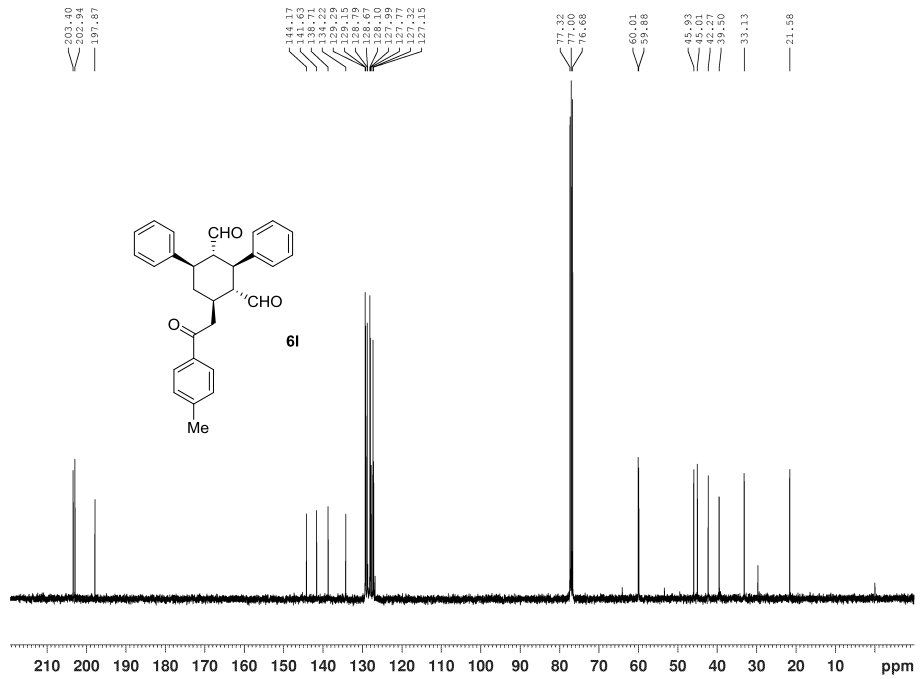
^{13}C NMR of **6k** (101M, DMSO-d_6)



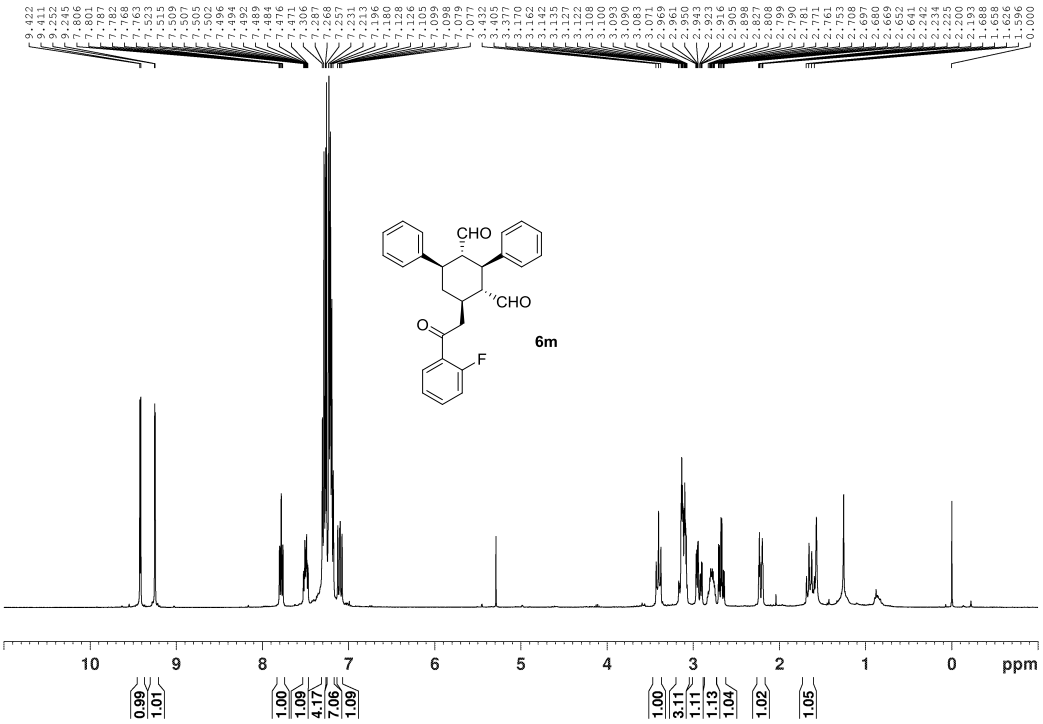
^{1}H NMR of **6l** (400M, $CDCl_3$)



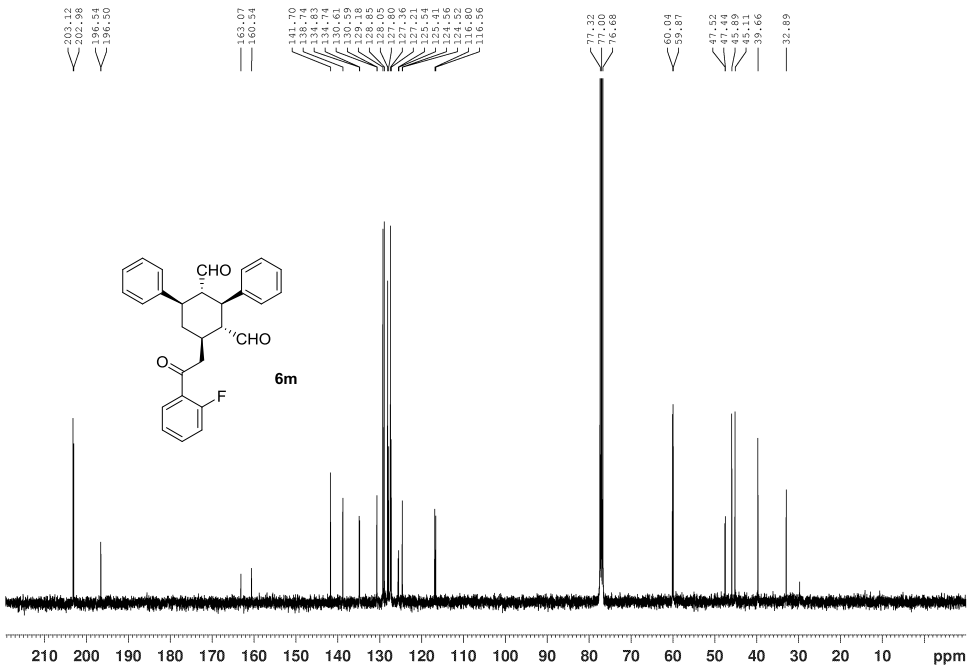
^{13}C NMR of **6l** (101M, $CDCl_3$)



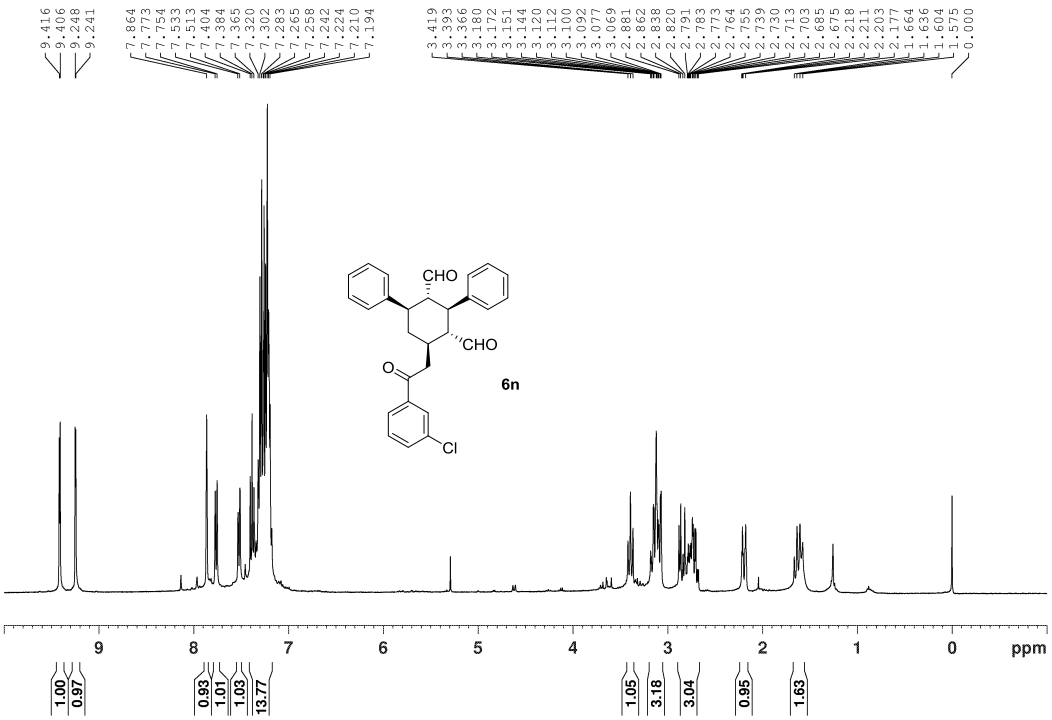
^{1}H NMR of **6m** (400M, $CDCl_3$)



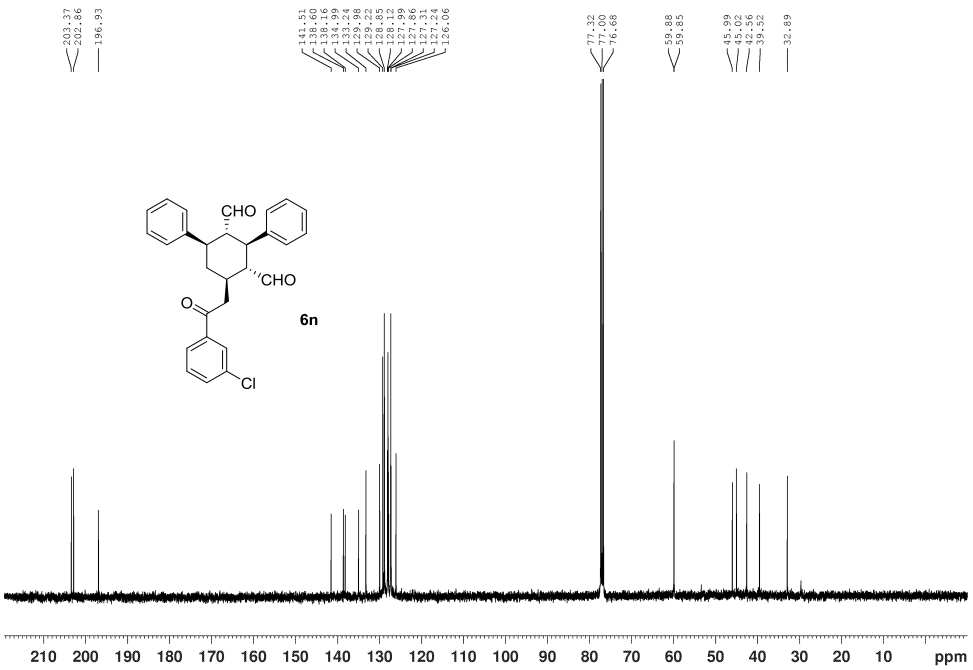
^{13}C NMR of **6m** (101M, $CDCl_3$)



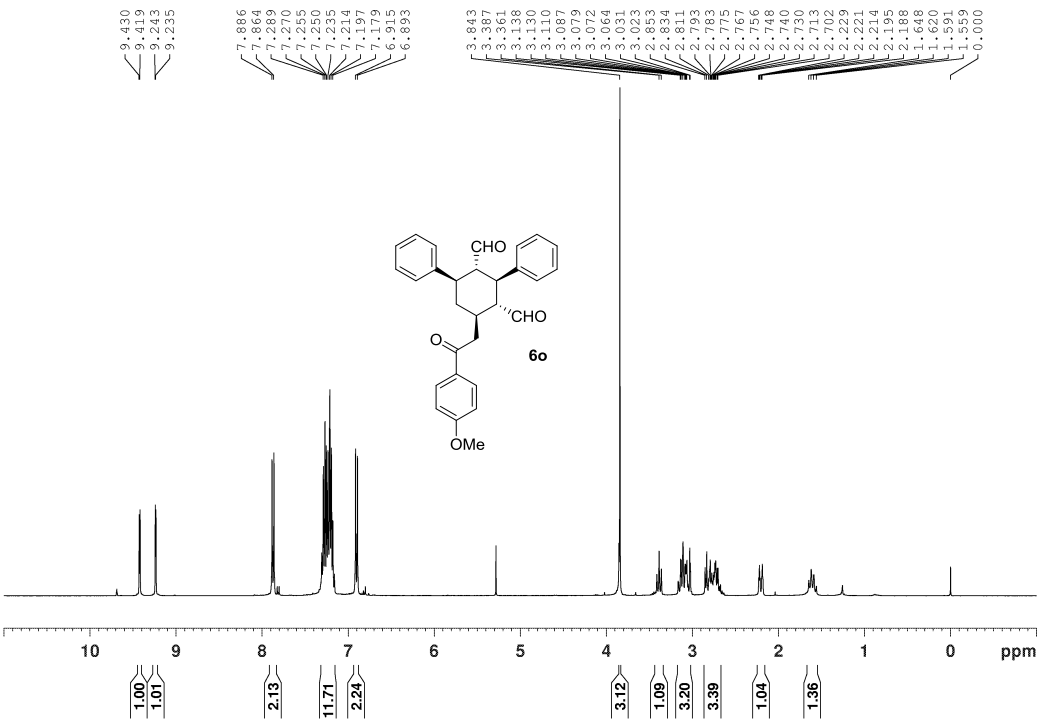
^{1}H NMR of **6n** (400M, $CDCl_3$)



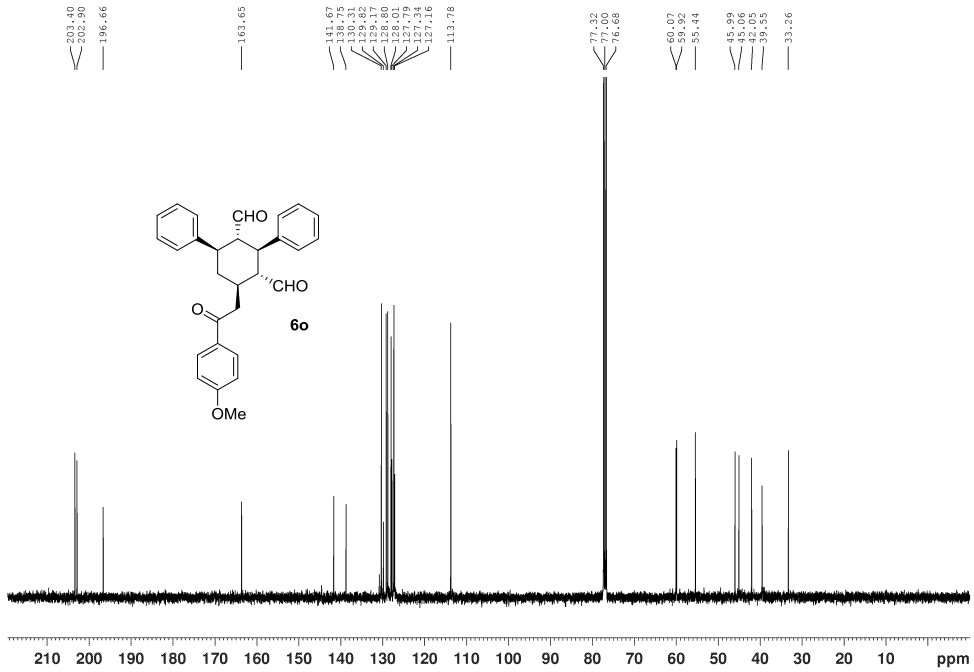
^{13}C NMR of **6n** (101M, $CDCl_3$)



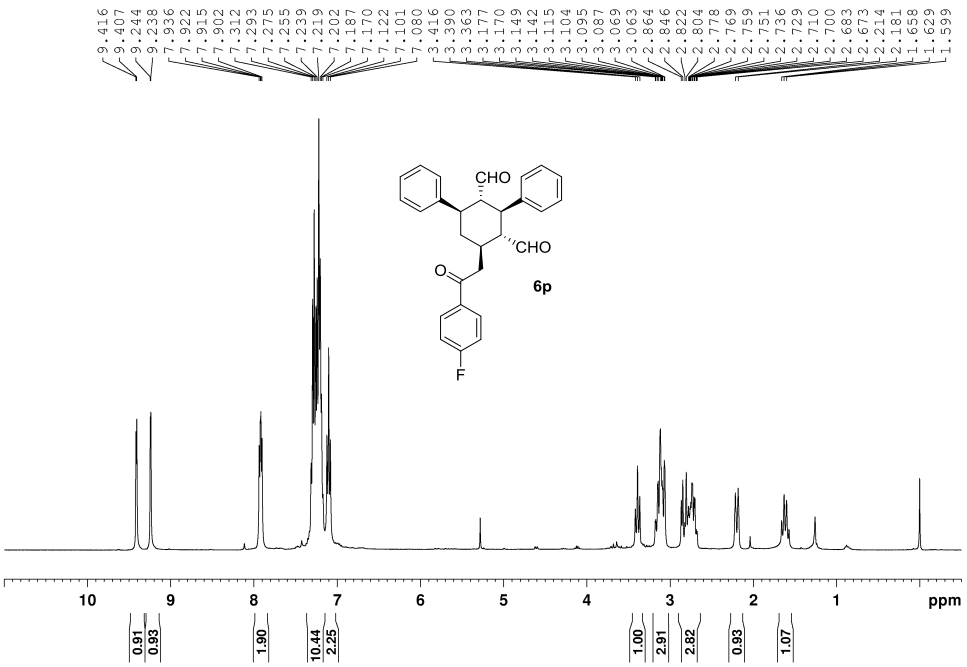
^{1}H NMR of **6o** (400M, $CDCl_3$)



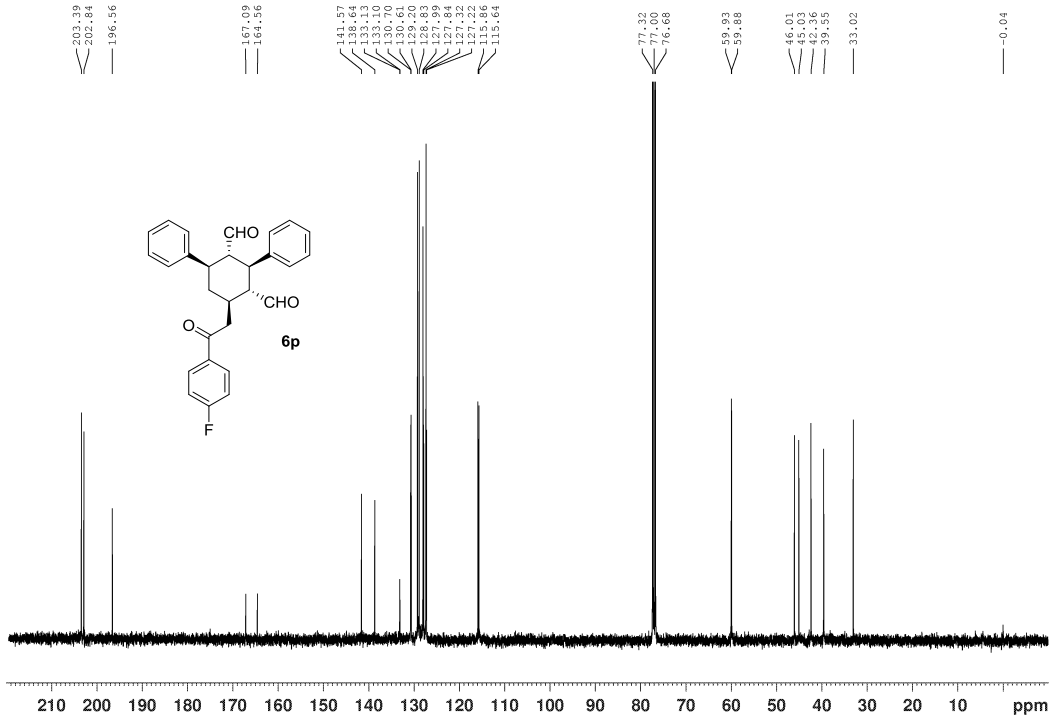
^{13}C NMR of **6o** (101M, $CDCl_3$)



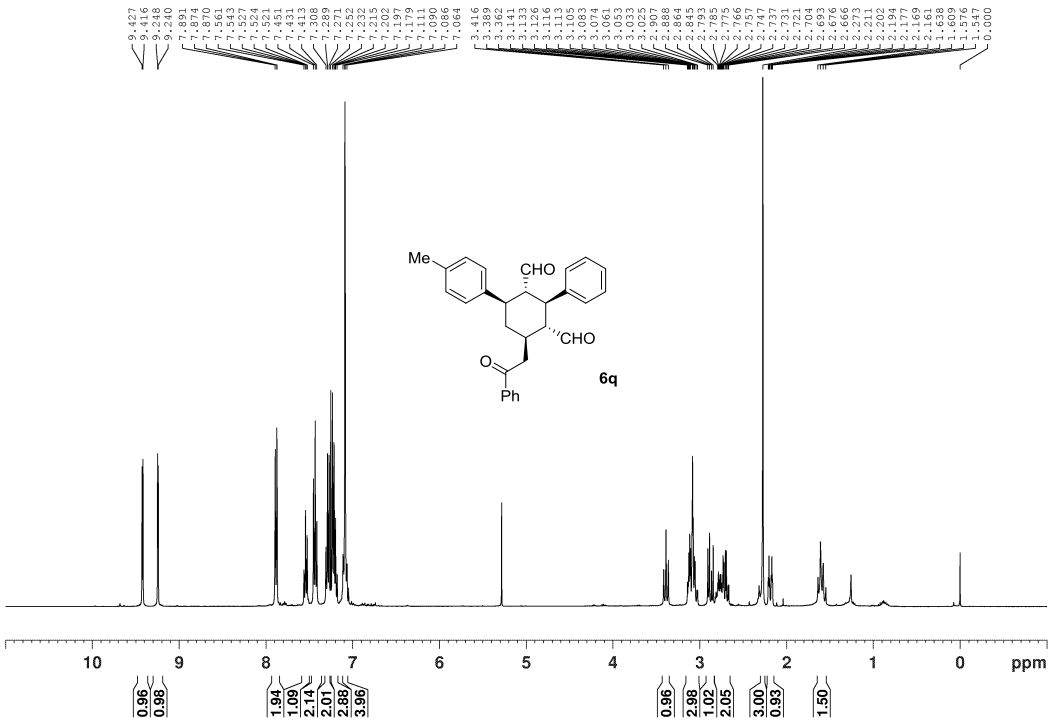
^{1}H NMR of **6p** (400M, $CDCl_3$)



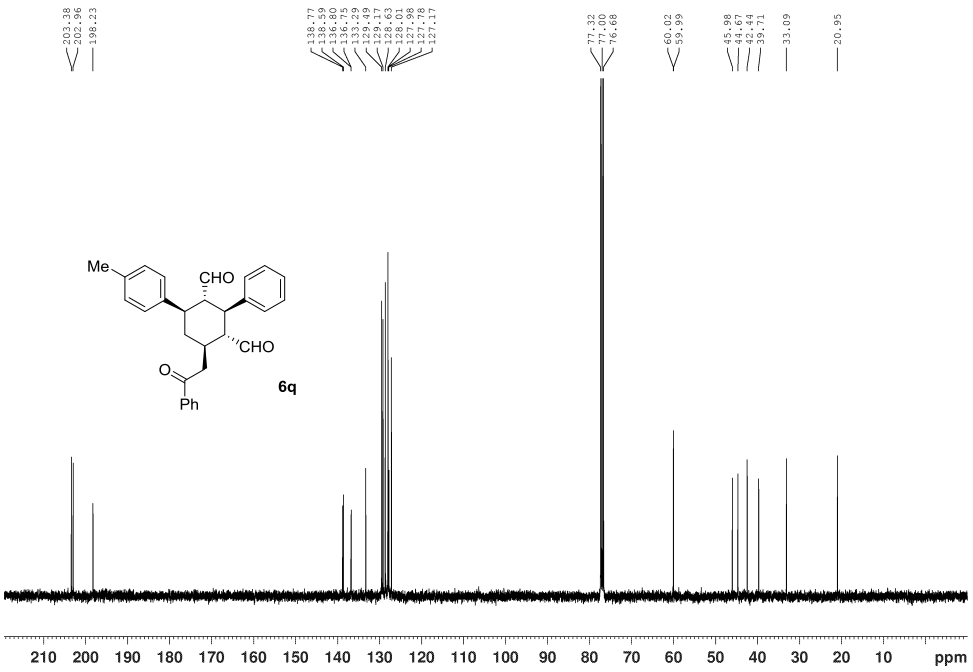
^{13}C NMR of **6p** (101M, $CDCl_3$)



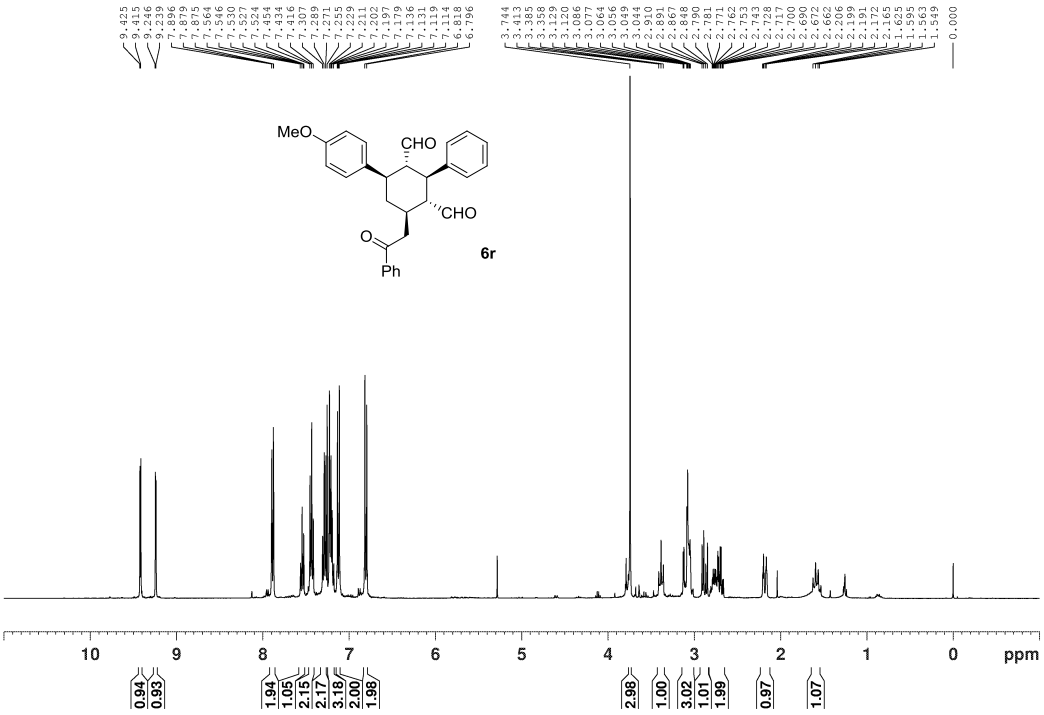
^{1}H NMR of **6q** (400M, $CDCl_3$)



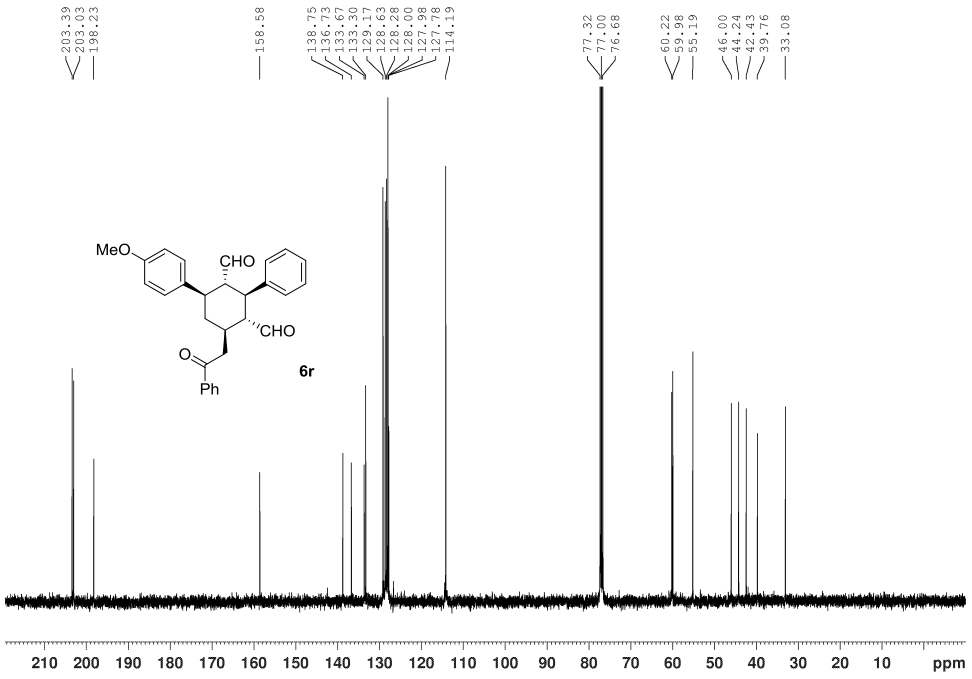
^{13}C NMR of **6q** (101M, $CDCl_3$)



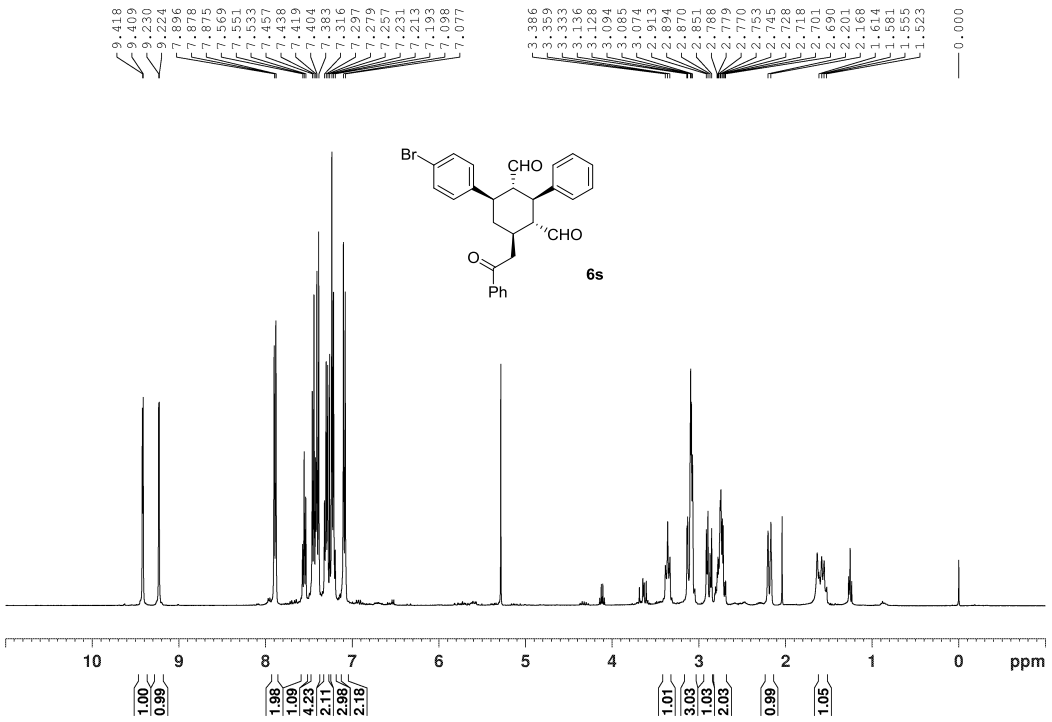
^{1}H NMR of **6r** (400M, $CDCl_3$)



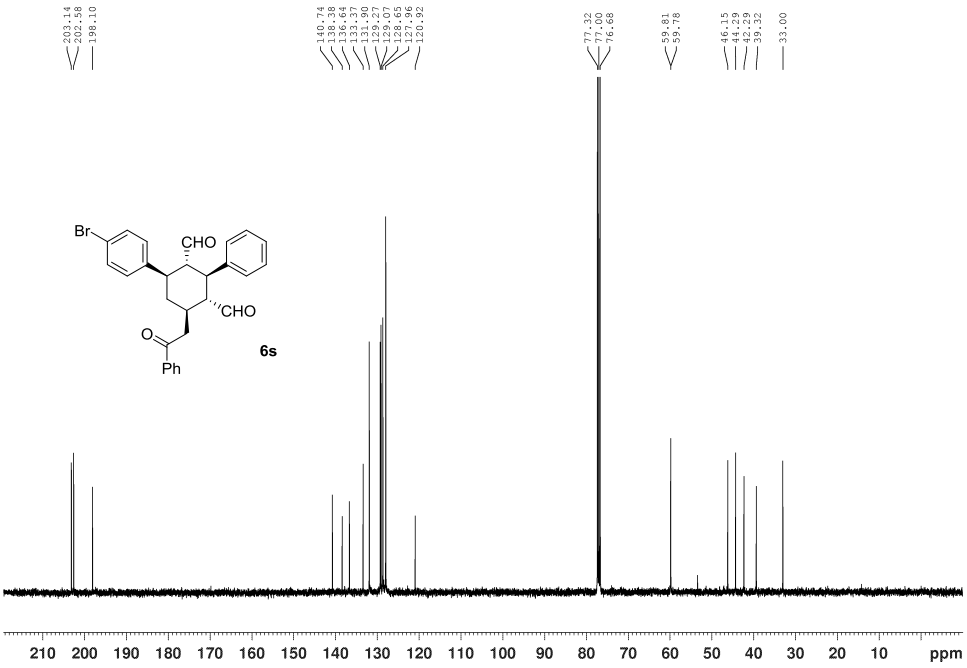
^{13}C NMR of **6r** (101M, $CDCl_3$)



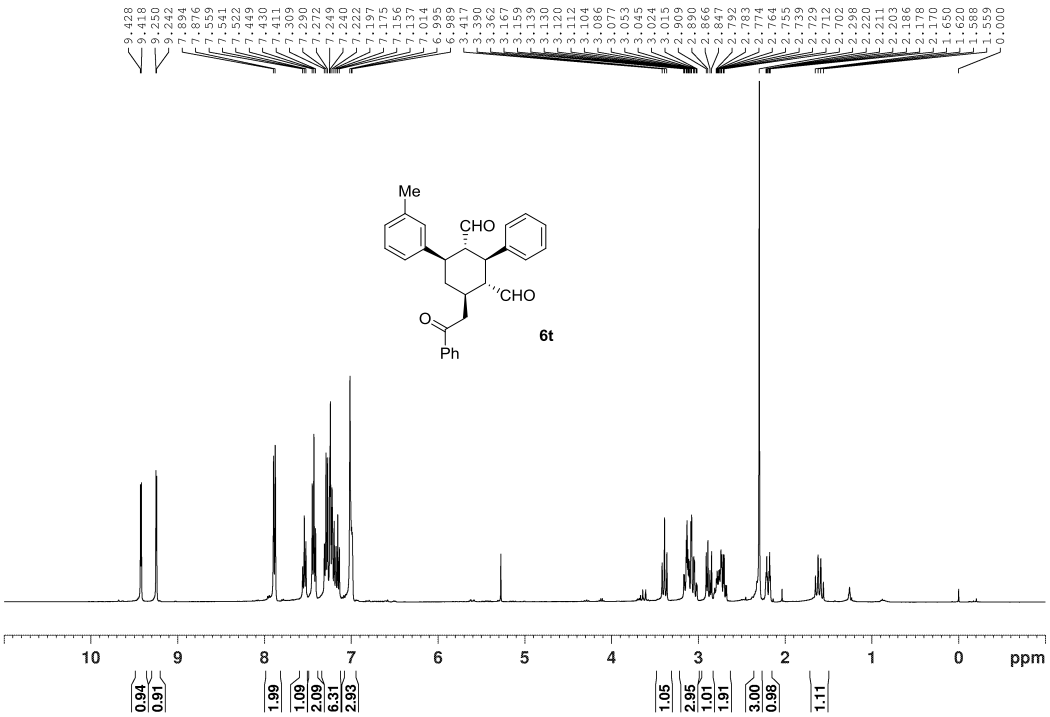
^{1}H NMR of **6s** (400M, $CDCl_3$)



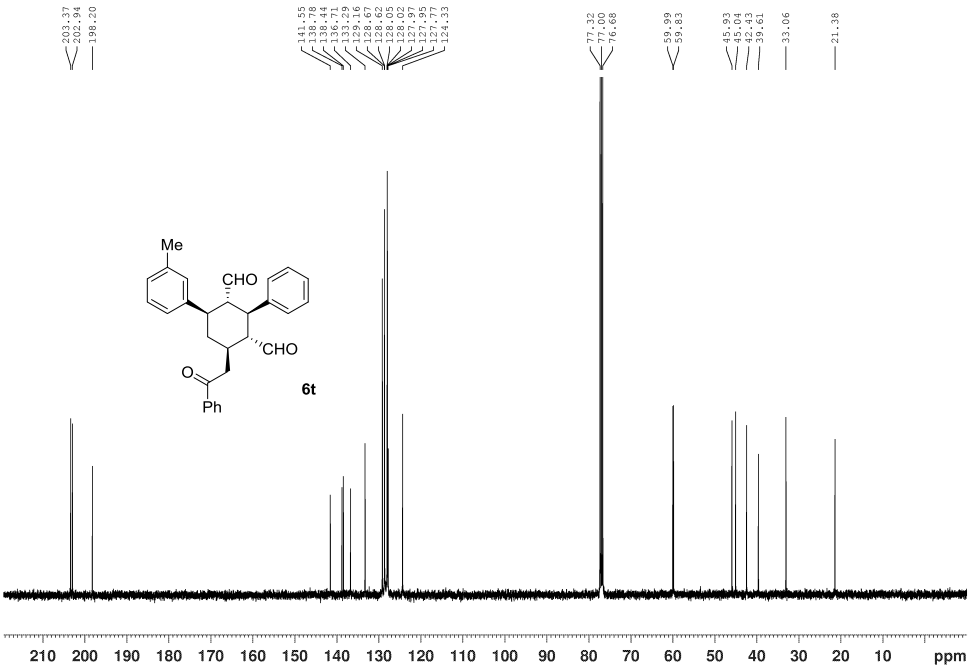
^{13}C NMR of **6s** (101M, $CDCl_3$)



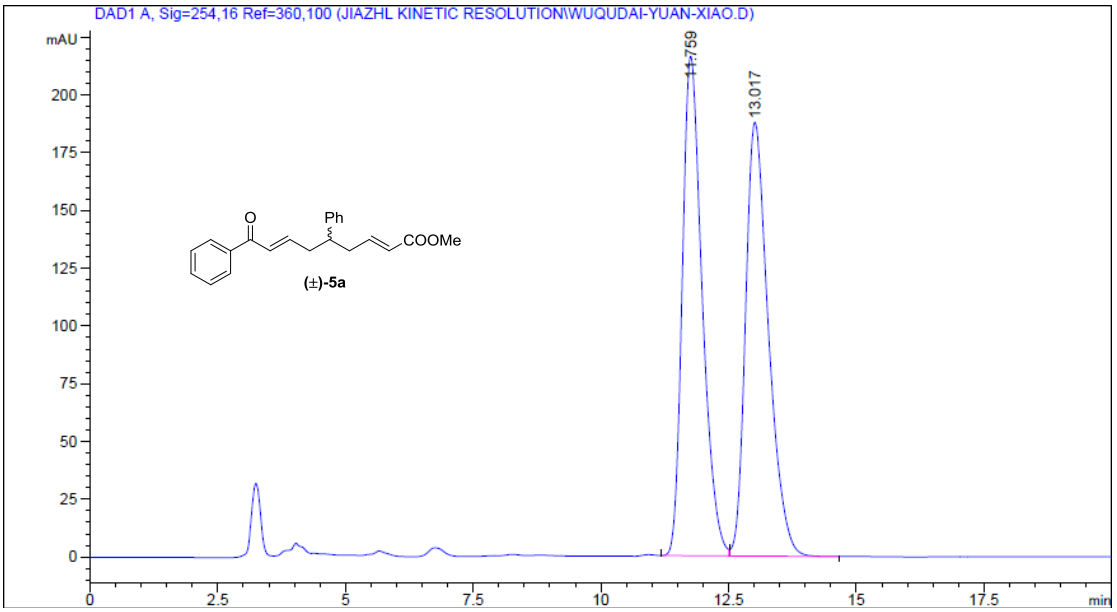
^{1}H NMR of **6t** (400M, $CDCl_3$)



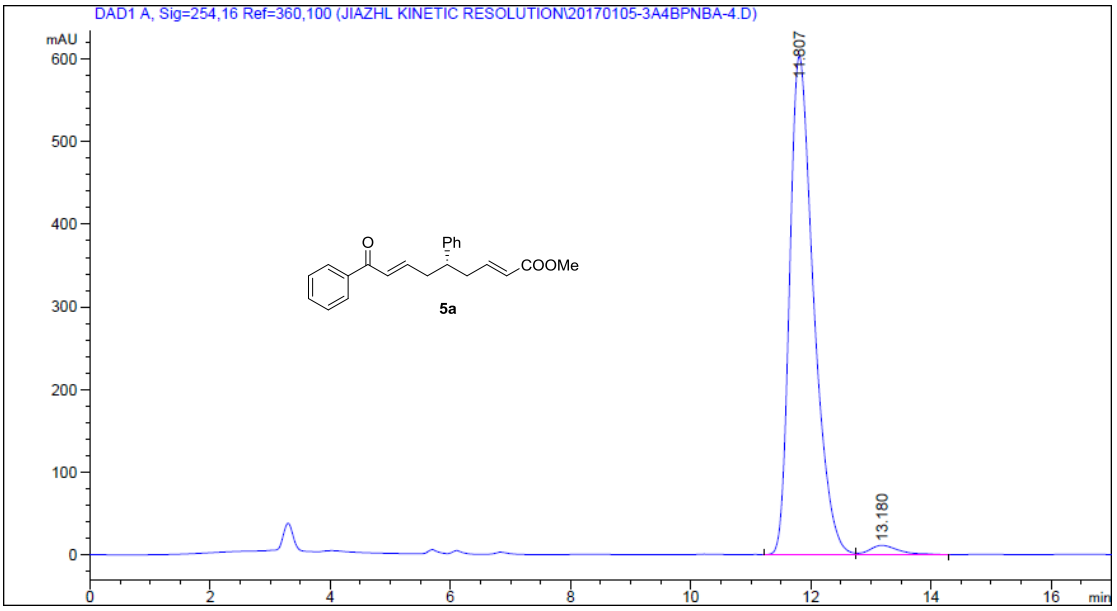
^{13}C NMR of **6t** (101M, $CDCl_3$)



HPLC using an AS column (hexane: *i*-PrOH = 80:20, 1.0 mL/min)

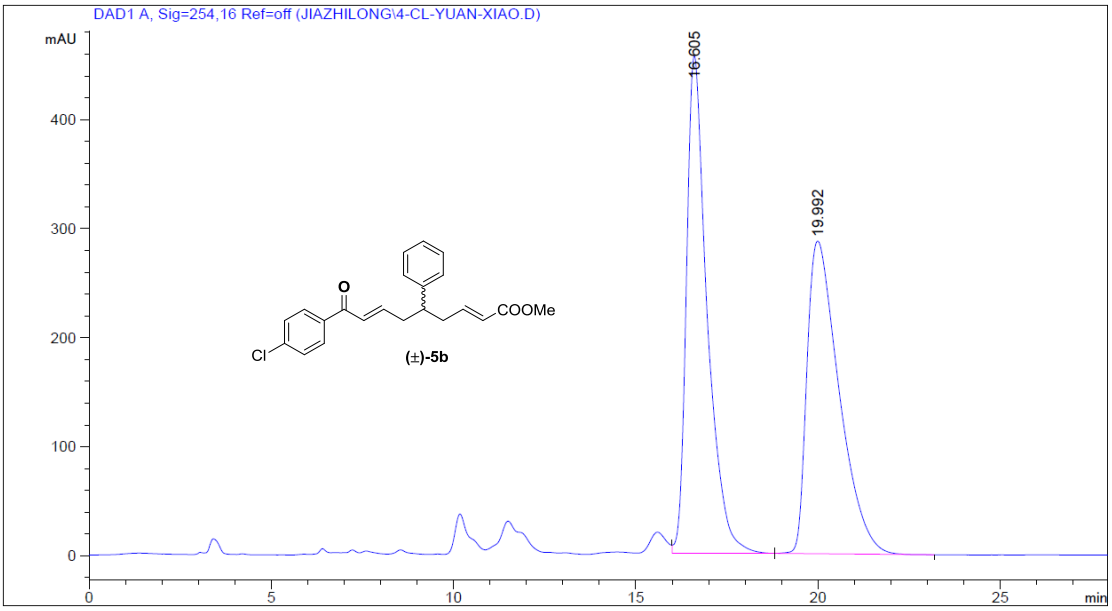


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254,16 nm	11.759	5851.89551	216.26814	49.9915
2	DAD 254,16 nm	13.017	5853.89648	187.79453	50.0085

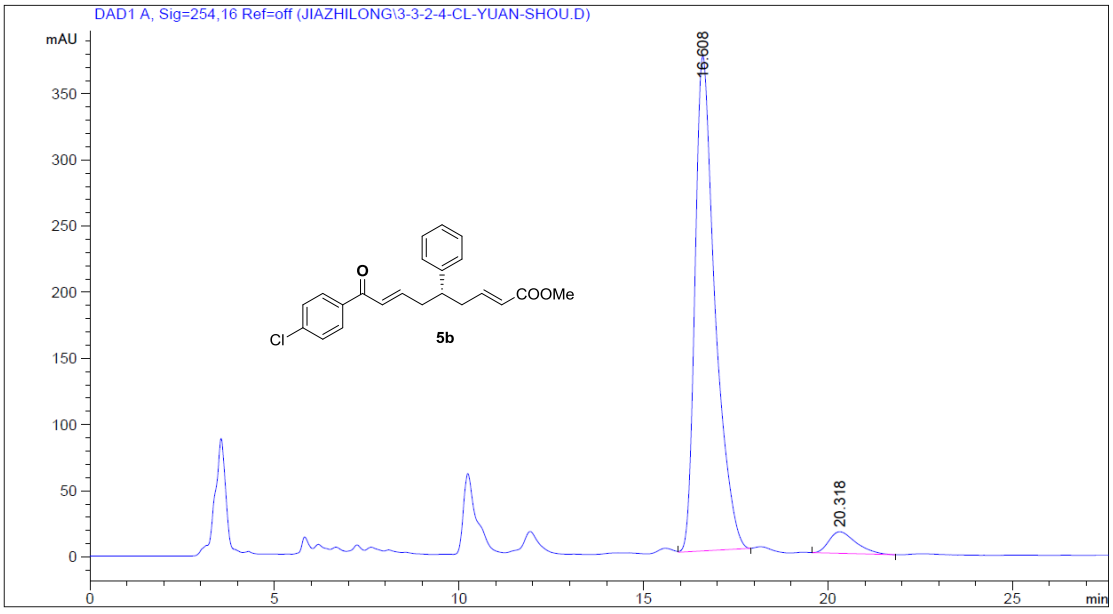


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254,16 nm	11.807	1.66291e4	603.08282	97.7341
2	DAD 254,16 nm	13.180	385.53983	11.35658	2.2659

HPLC using an AS column (hexane: *i*-PrOH = 80:20, 1.0 mL/min)

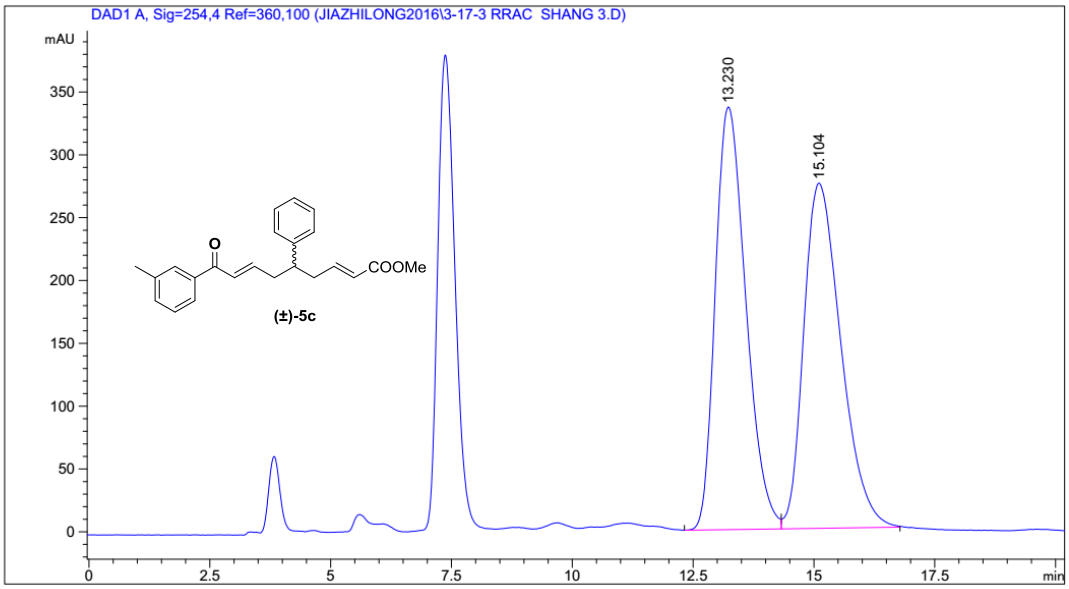


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 16 nm	16.605	1.80234e4	456.15805	50.6735
2	DAD 254, 16 nm	19.992	1.75442e4	286.77222	49.3265

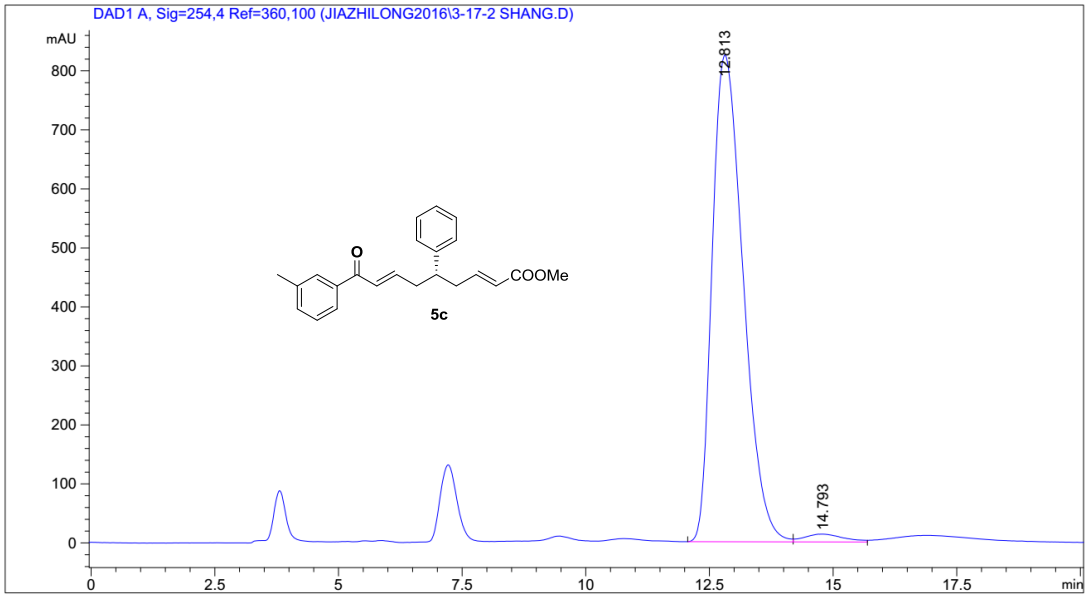


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 16 nm	16.608	1.41172e4	374.07816	94.4590
2	DAD 254, 16 nm	20.318	828.12292	16.25900	5.5410

HPLC using an AS column (hexane: *i*-PrOH = 80:20, 1.0 mL/min)

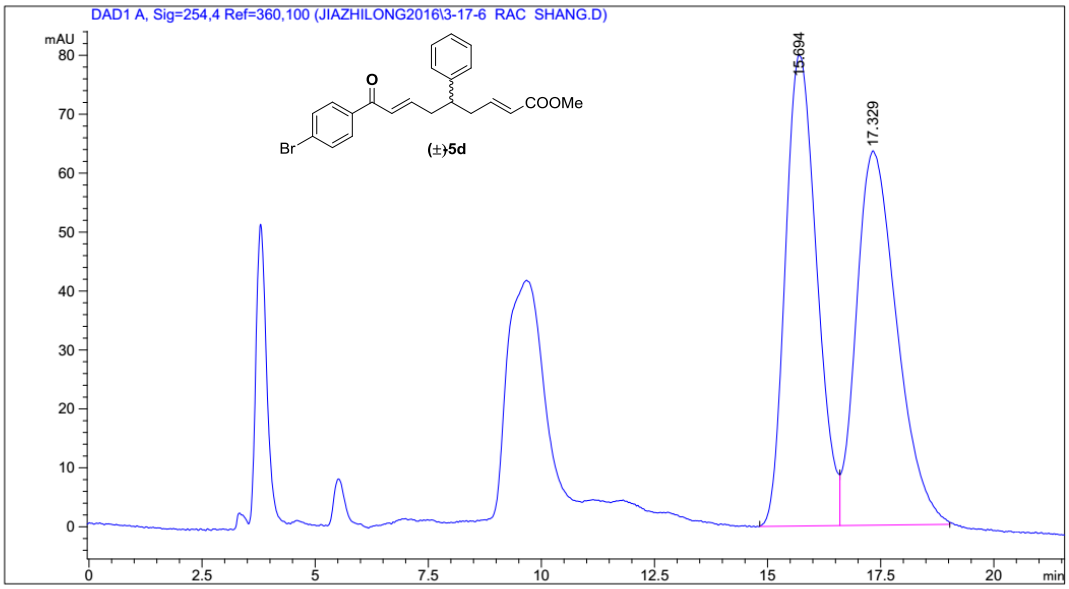


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 4 nm	13.230	1.47805e4	336.27496	50.1471
2	DAD 254, 4 nm	15.104	1.46938e4	274.74304	49.8529

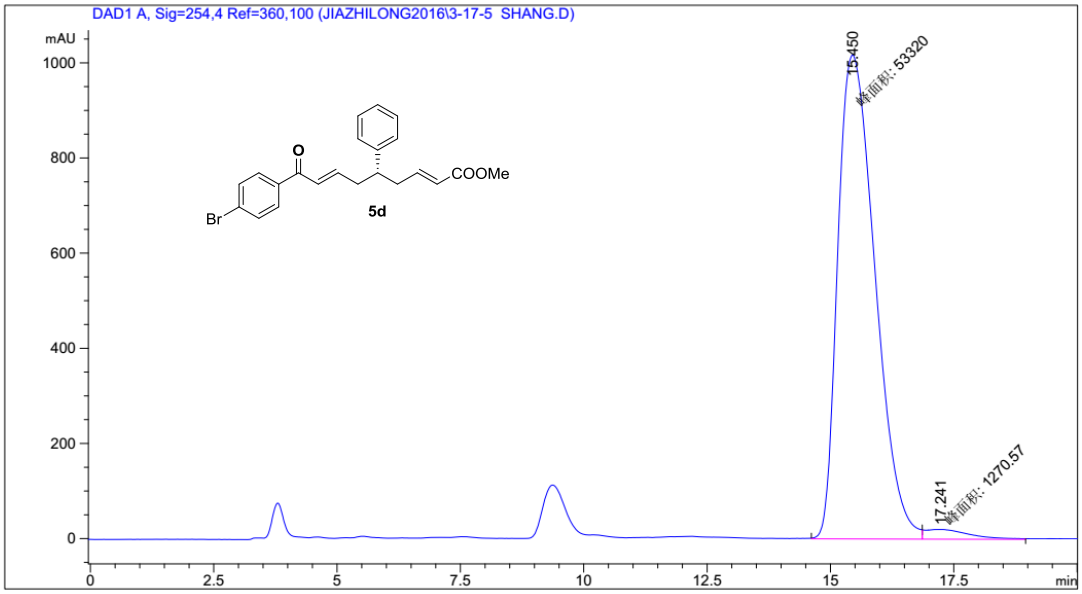


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 4 nm	12.813	3.58698e4	825.17041	98.0333
2	DAD 254, 4 nm	14.793	719.58789	13.14374	1.9667

HPLC using an AS column (hexane: *i*-PrOH = 80:20, 1.0 mL/min)

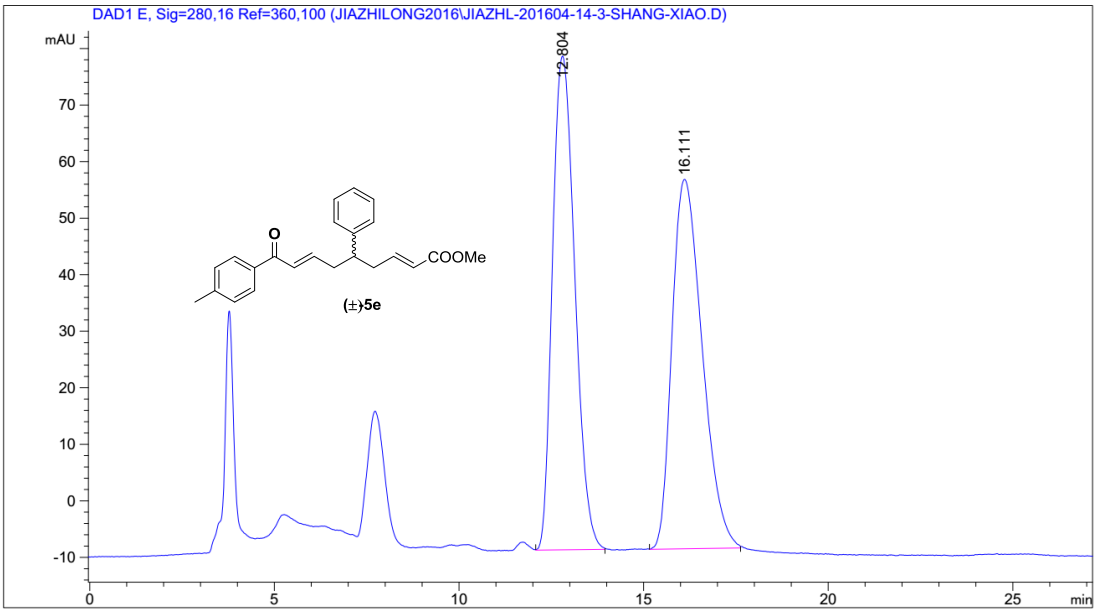


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 4 nm	15.694	3850.37939	79.90881	49.2731
2	DAD 254, 4 nm	17.329	3963.98071	63.54708	50.7269

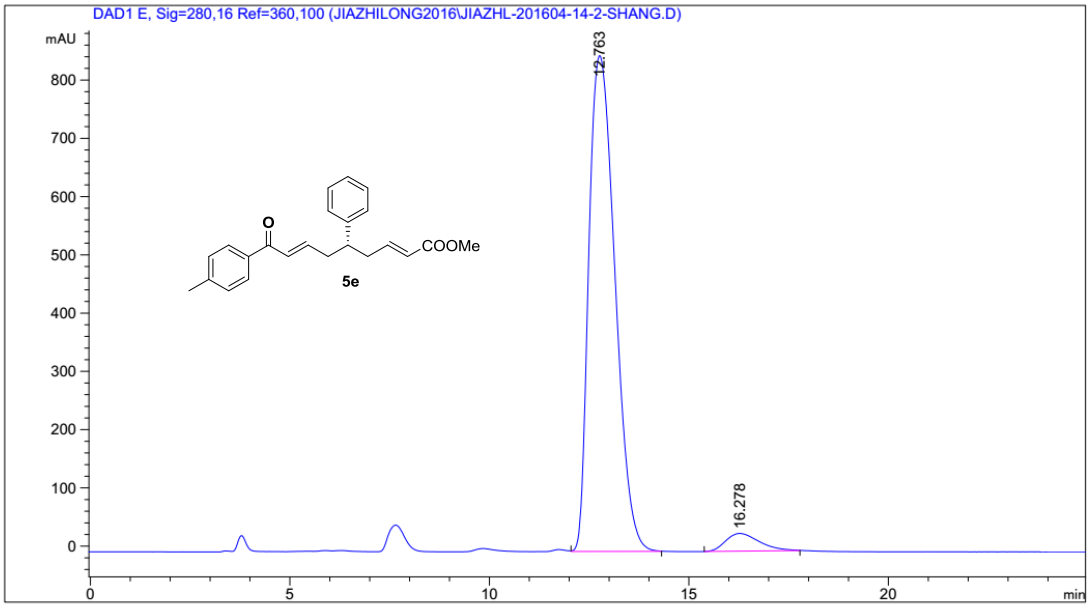


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 4 nm	15.450	5.33200e4	1017.90649	97.6725
2	DAD 254, 4 nm	17.241	1270.57446	20.32446	2.3275

HPLC using an AS column (hexane: *i*-PrOH = 80:20, 1.0 mL/min)

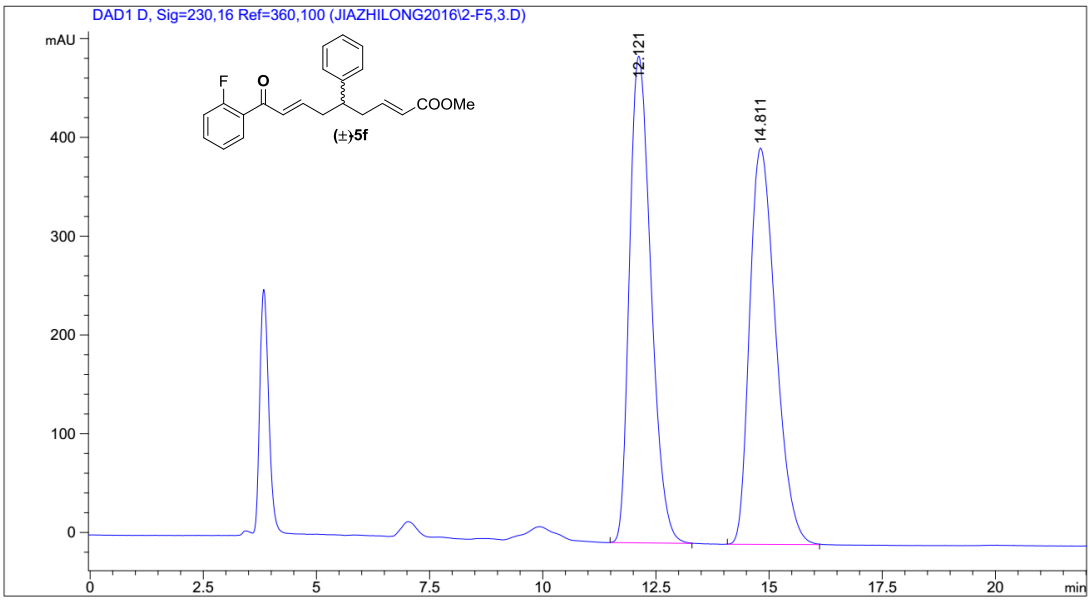


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 280, 16 nm	12.804	3675.54028	87.33235	49.8103
2	DAD 280, 16 nm	16.111	3703.53125	65.34211	50.1897

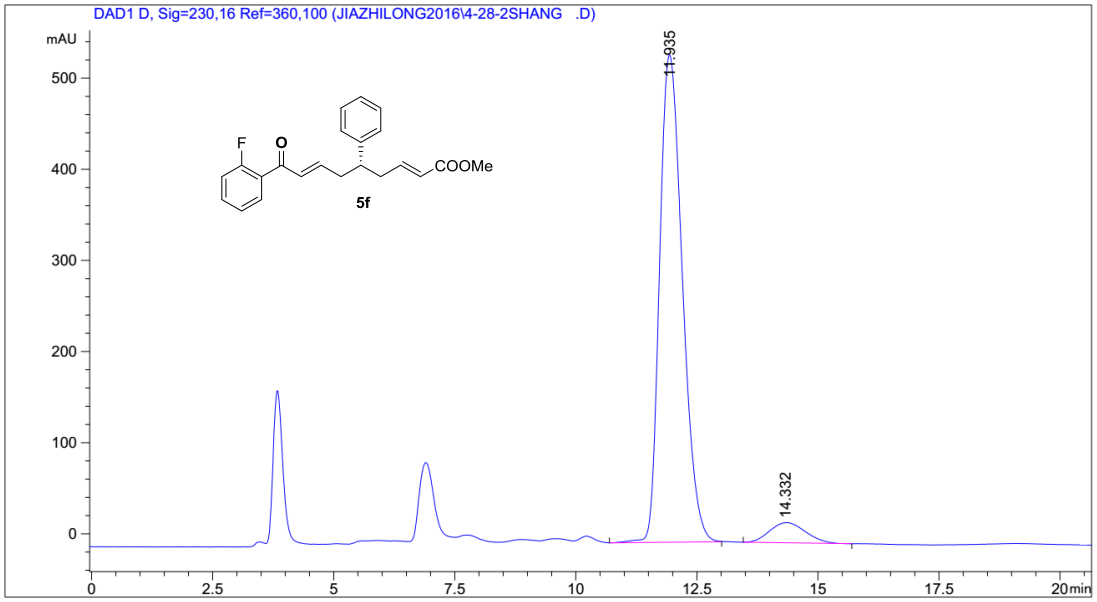


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 280, 16 nm	12.763	3.85833e4	851.10498	95.5695
2	DAD 280, 16 nm	16.278	1788.66980	30.48558	4.4305

HPLC using an AS column (hexane: *i*-PrOH = 80:20, 1.0 mL/min)

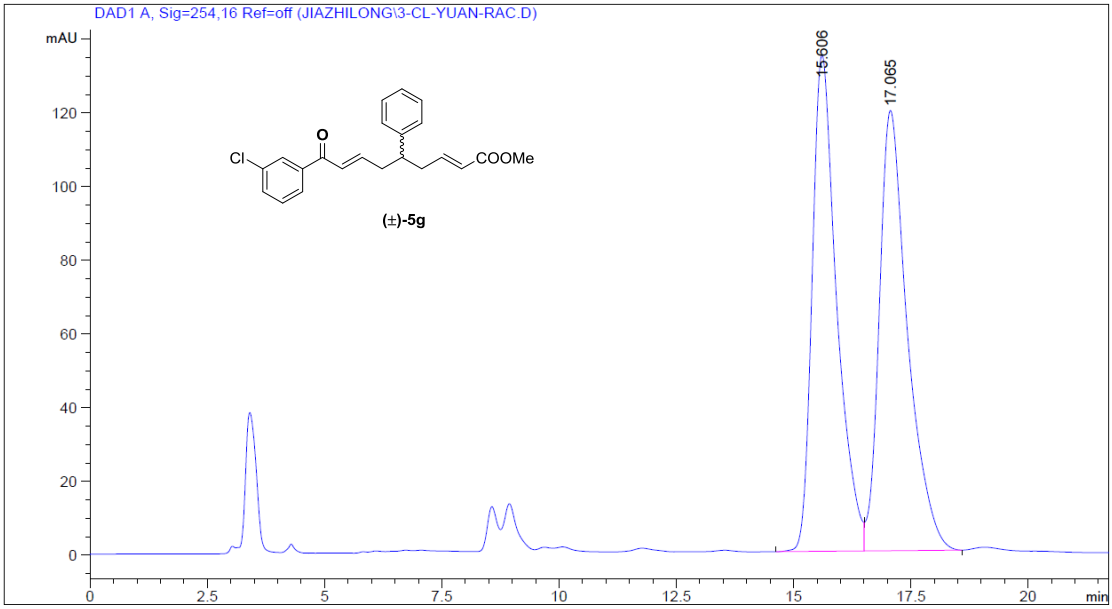


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	12.121	1.62845e4	492.78973	50.3320
2	DAD 230, 16 nm	14.811	1.60697e4	401.10657	49.6680

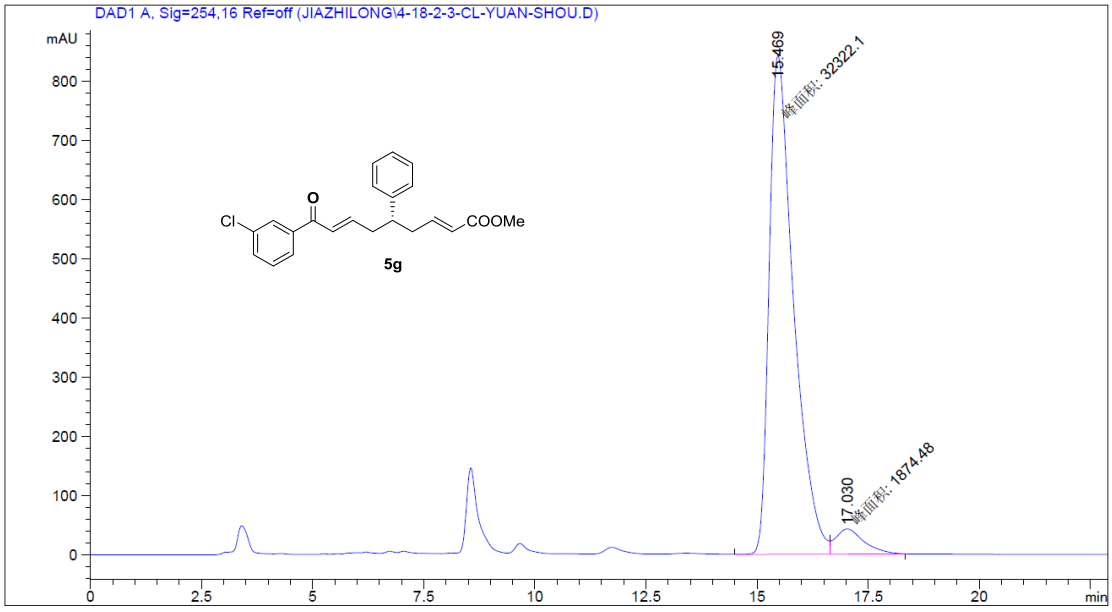


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	11.935	1.74840e4	534.64960	93.9158
2	DAD 230, 16 nm	14.332	1132.67139	22.10943	6.0842

HPLC using an AS column (hexane: *i*-PrOH = 80:20, 1.0 mL/min)

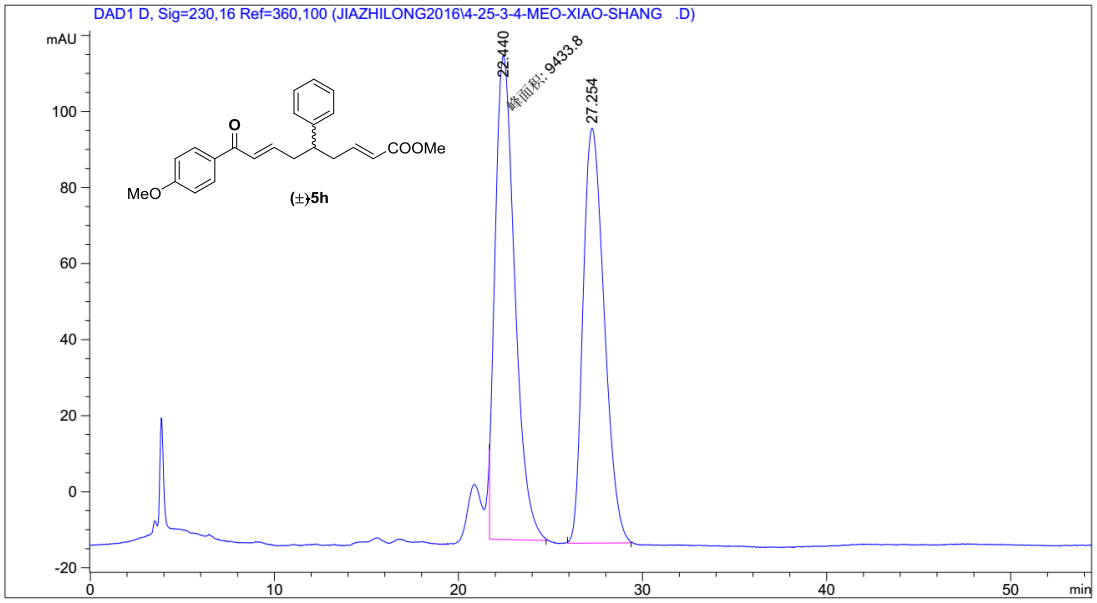


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 16 nm	15.606	4898.58252	134.65163	49.4811
2	DAD 254, 16 nm	17.065	5001.32764	119.42539	50.5189

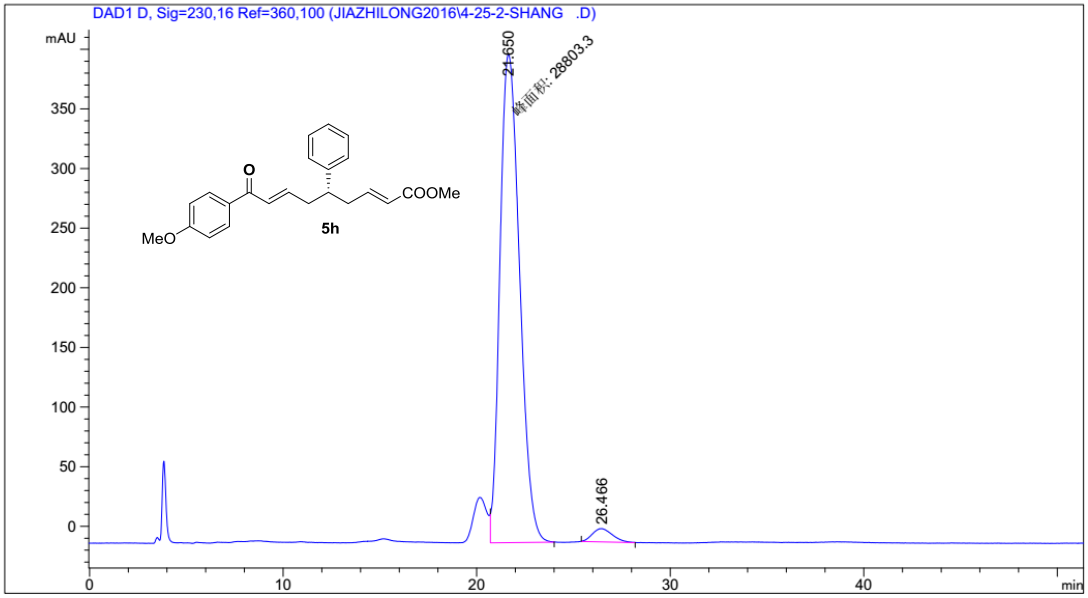


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 16 nm	15.469	3.23221e4	842.05261	94.5185
2	DAD 254, 16 nm	17.030	1874.48193	42.53213	5.4815

HPLC using an AS column (hexane: *i*-PrOH = 80:20, 1.0 mL/min)

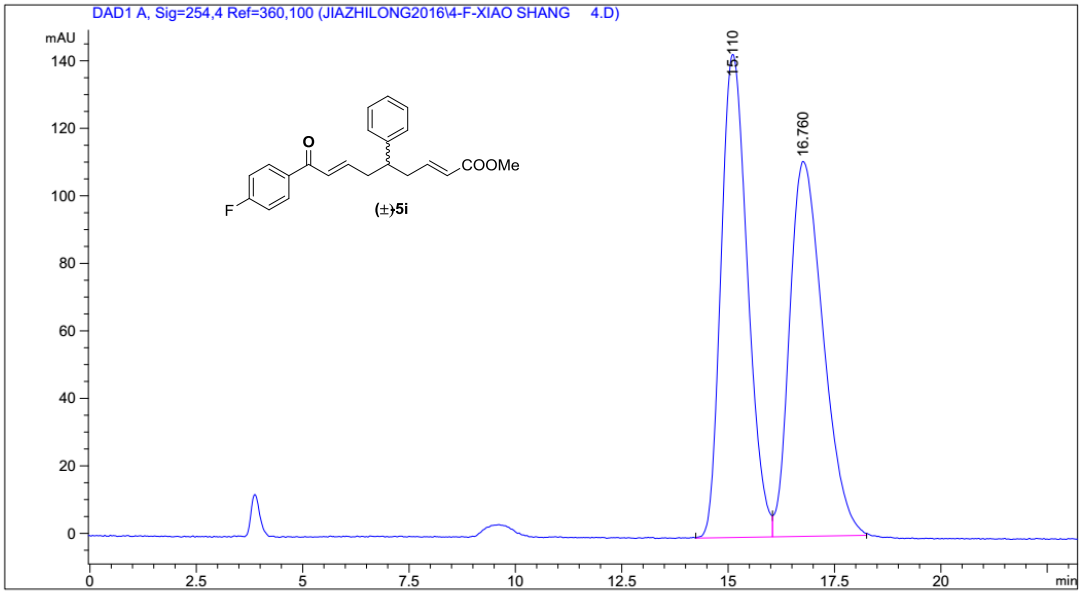


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	22.440	9433.79688	127.34587	51.8876
2	DAD 230, 16 nm	27.254	8747.41797	109.12292	48.1124

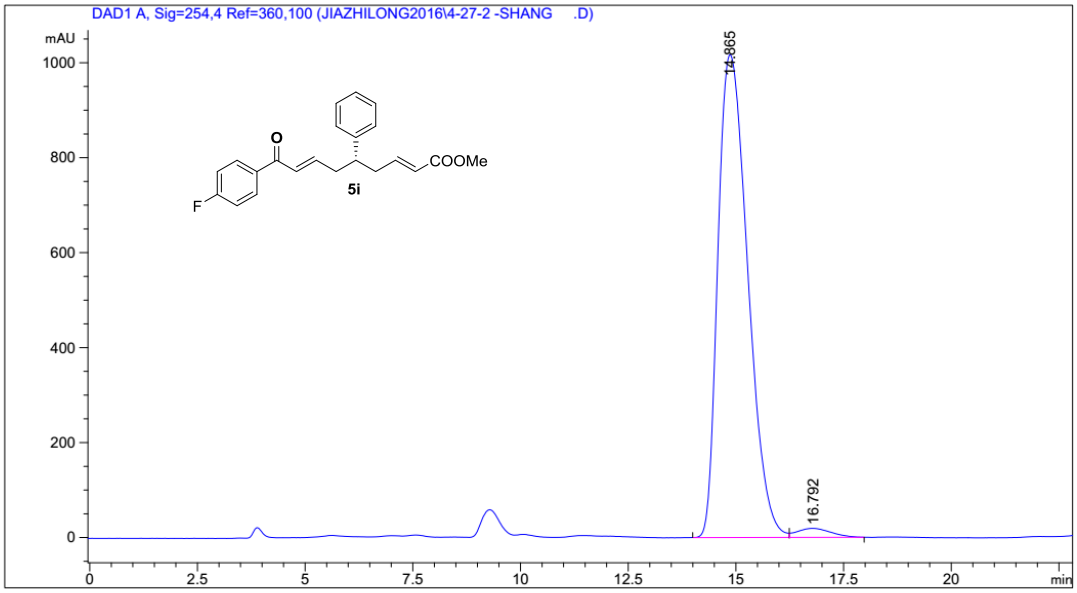


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	21.650	2.88033e4	409.35922	97.3151
2	DAD 230, 16 nm	26.466	794.68066	11.14236	2.6849

HPLC using an AS column (hexane: *i*-PrOH = 80:20, 1.0 mL/min)

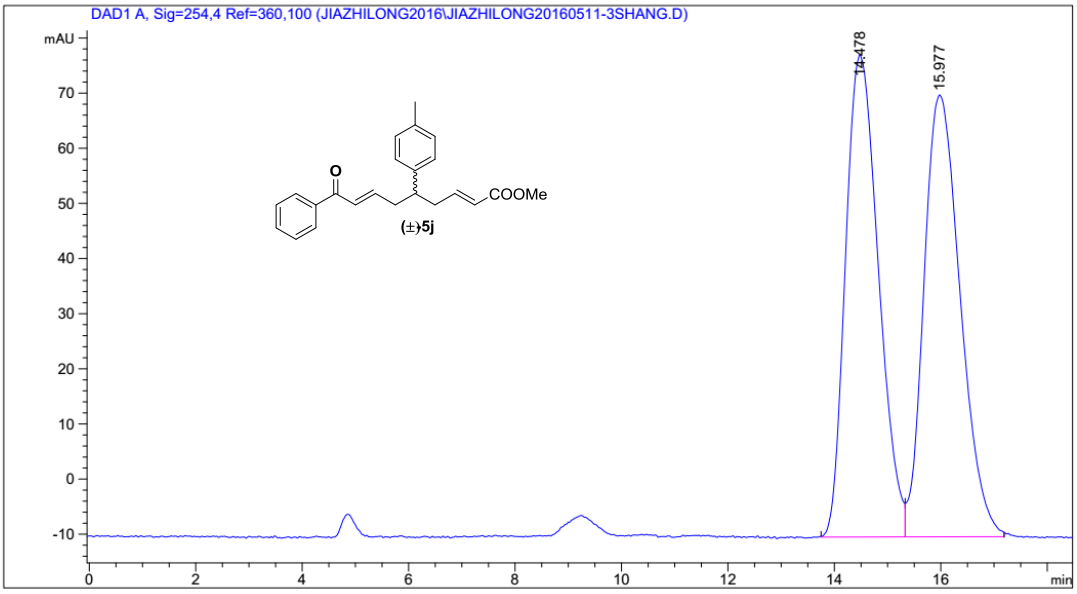


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 4 nm	15.110	6185.77832	143.14149	50.4013
2	DAD 254, 4 nm	16.760	6087.28467	111.09929	49.5987

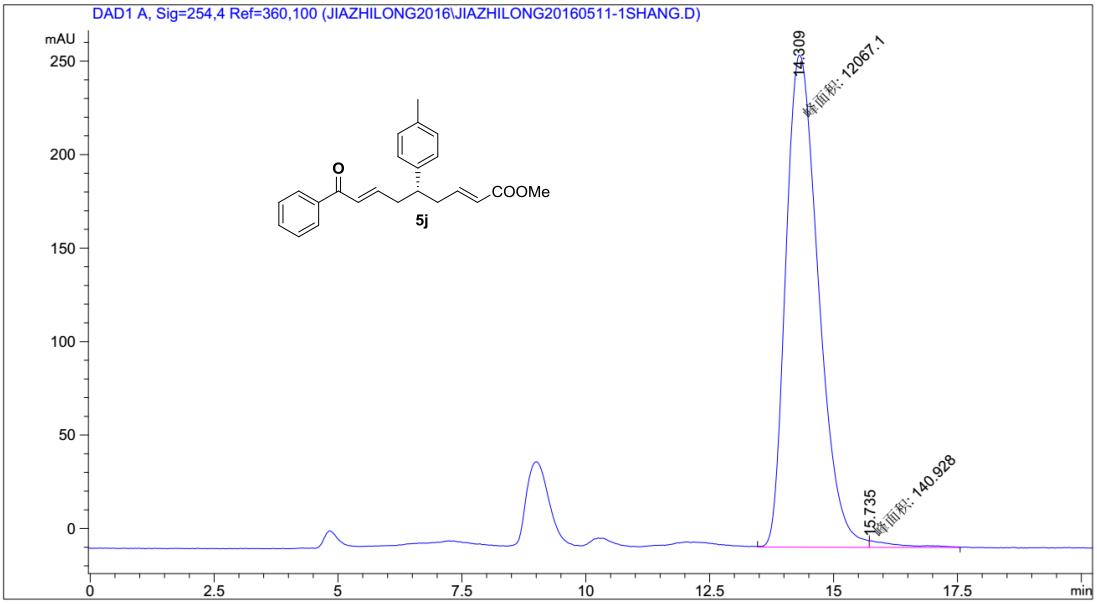


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 4 nm	14.865	4.88781e4	1017.24554	97.9102
2	DAD 254, 4 nm	16.792	1043.27332	19.13320	2.0898

HPLC using an AS column (hexane: *i*-PrOH = 80:20, 1.0 mL/min)

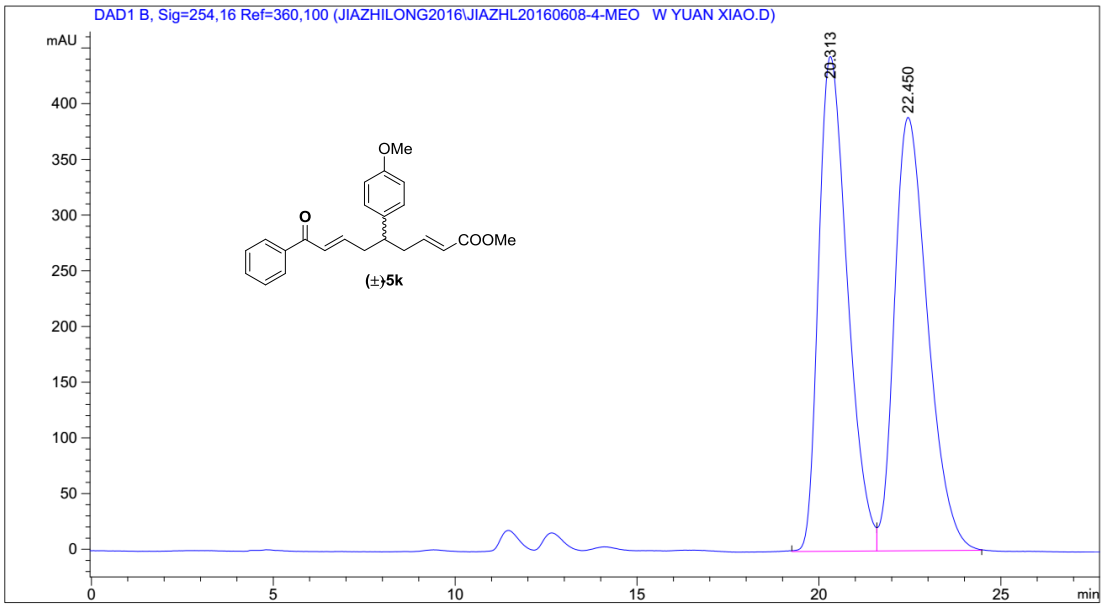


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 4 nm	14.478	3758.25244	87.45330	49.7217
2	DAD 254, 4 nm	15.977	3800.32617	80.14983	50.2783

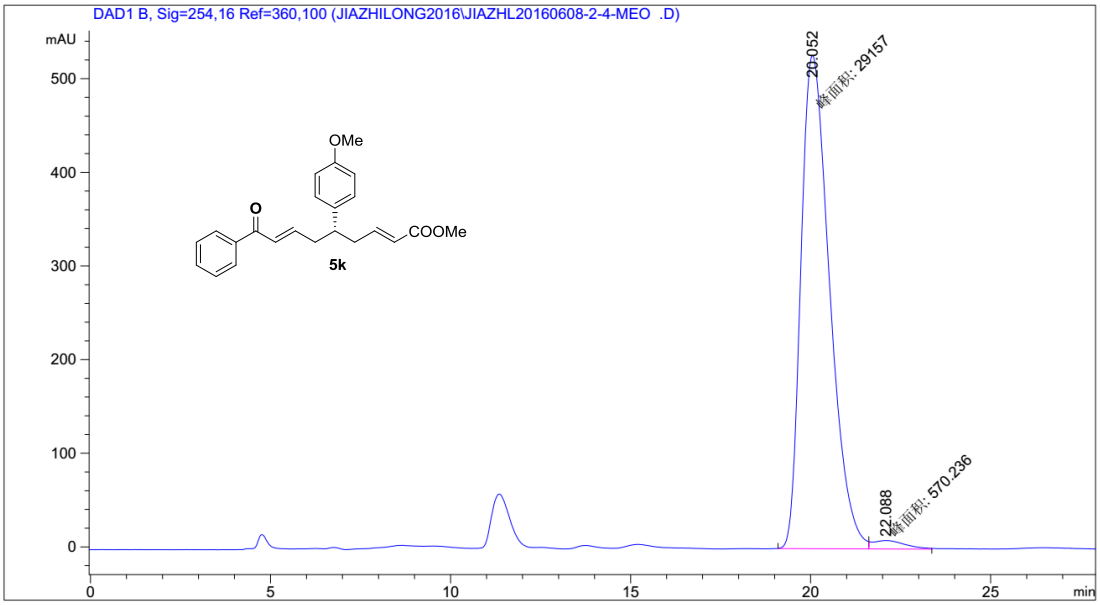


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 4 nm	14.309	1.20671e4	263.18414	98.8456
2	DAD 254, 4 nm	15.735	140.92809	3.52518	1.1544

HPLC using an AS column (hexane: *i*-PrOH = 80:20, 1.0 mL/min)

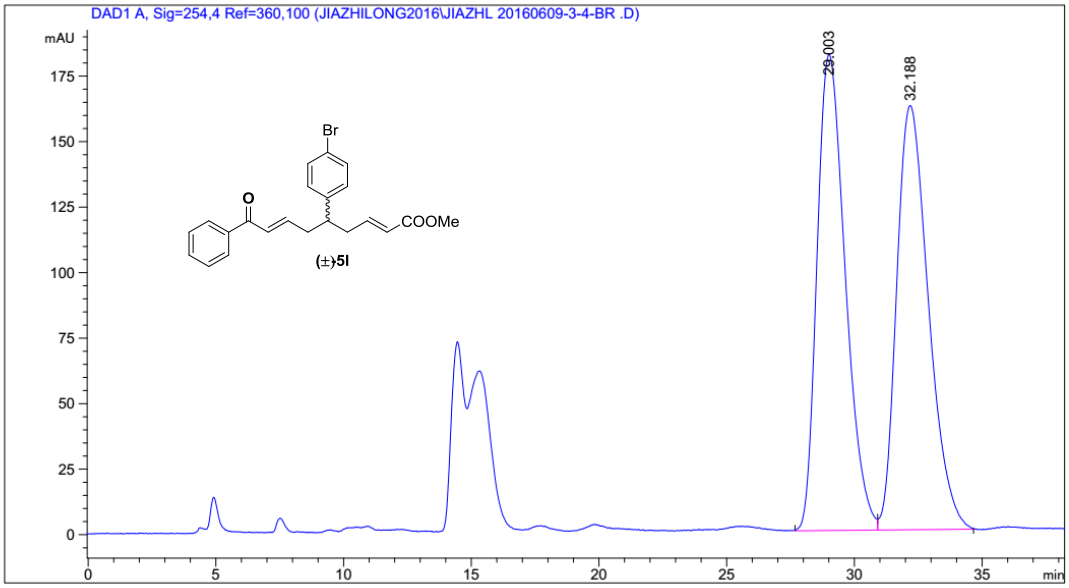


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 16 nm	20.313	2.45412e4	444.10345	49.8146
2	DAD 254, 16 nm	22.450	2.47239e4	389.03632	50.1854

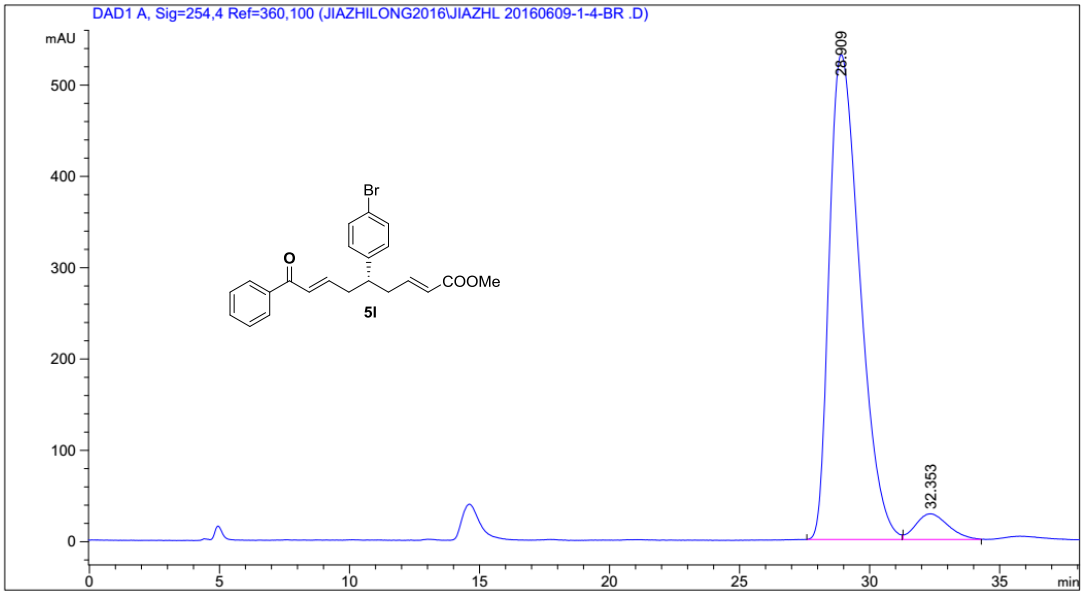


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 16 nm	20.052	2.91570e4	526.70801	98.0818
2	DAD 254, 16 nm	22.088	570.23621	9.06597	1.9182

HPLC using an AS column (hexane: *i*-PrOH = 80:20, 1.0 mL/min)

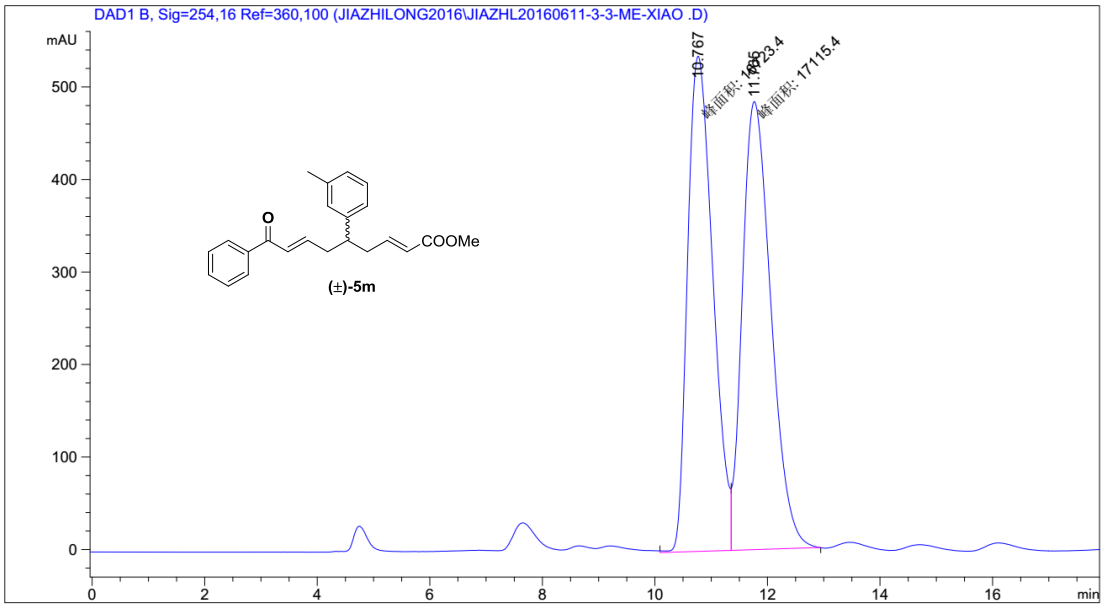


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 4 nm	29.003	1.39707e4	181.81752	49.9643
2	DAD 254, 4 nm	32.188	1.39906e4	161.89824	50.0357

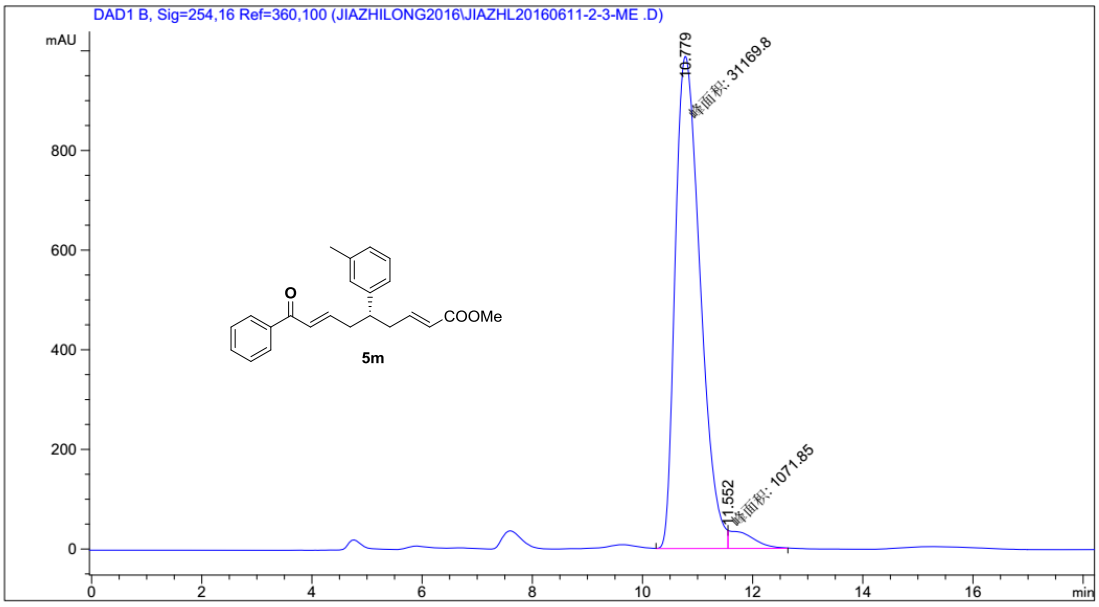


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 4 nm	28.909	4.33440e4	531.00928	94.6963
2	DAD 254, 4 nm	32.353	2427.56738	28.10785	5.3037

HPLC using an AS column (hexane: *i*-PrOH = 80:20, 1.0 mL/min)

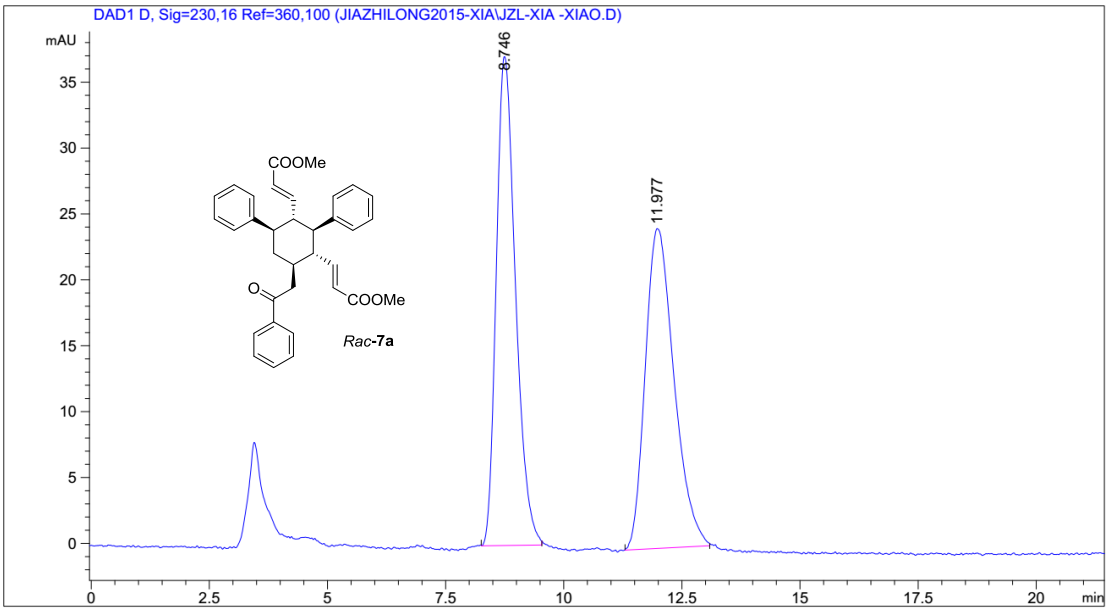


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 16 nm	10.767	1.67234e4	535.32800	49.4207
2	DAD 254, 16 nm	11.765	1.71154e4	484.28903	50.5793

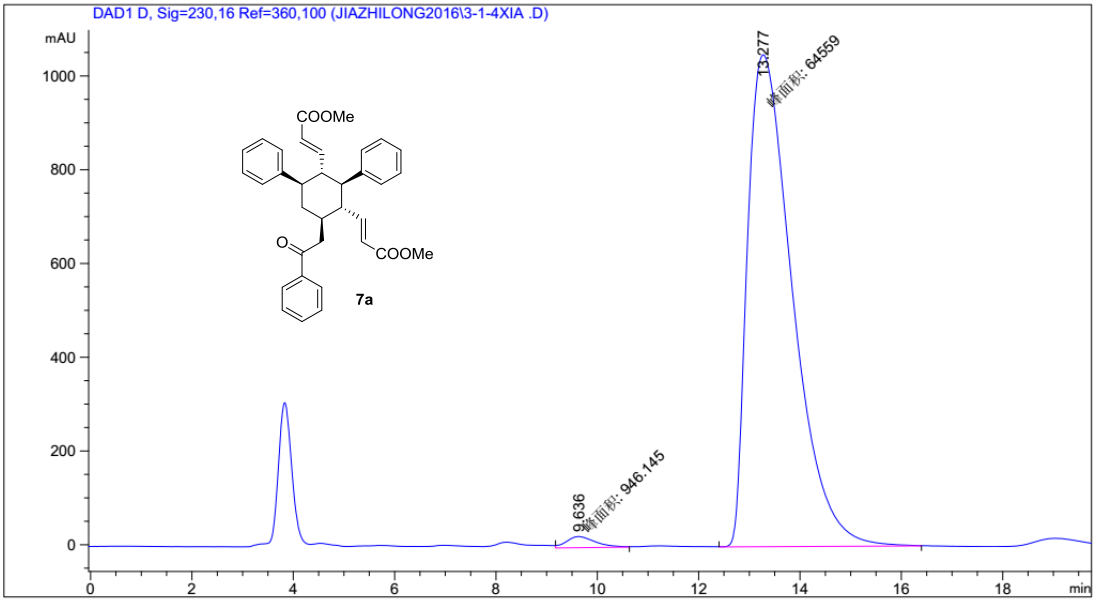


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 16 nm	10.779	3.11698e4	987.84576	96.6756
2	DAD 254, 16 nm	11.552	1071.84900	36.24280	3.3244

HPLC using an AD column (hexane: *i*-PrOH = 70:30, 1.0 mL/min)

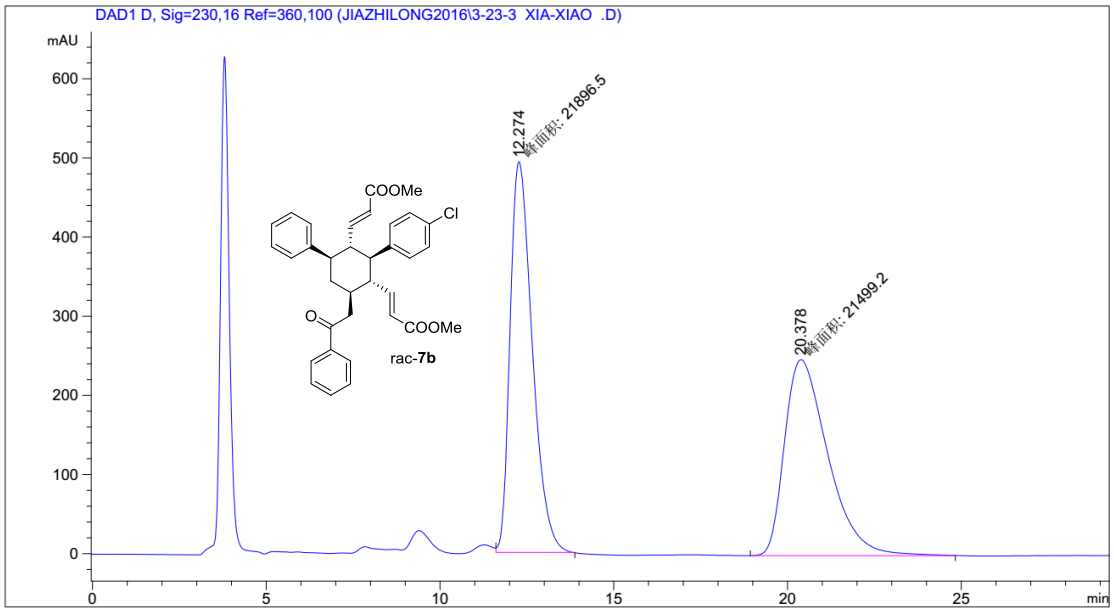


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	8.746	1048.69092	37.09874	50.5125
2	DAD 230, 16 nm	11.977	1027.40991	24.26802	49.4875

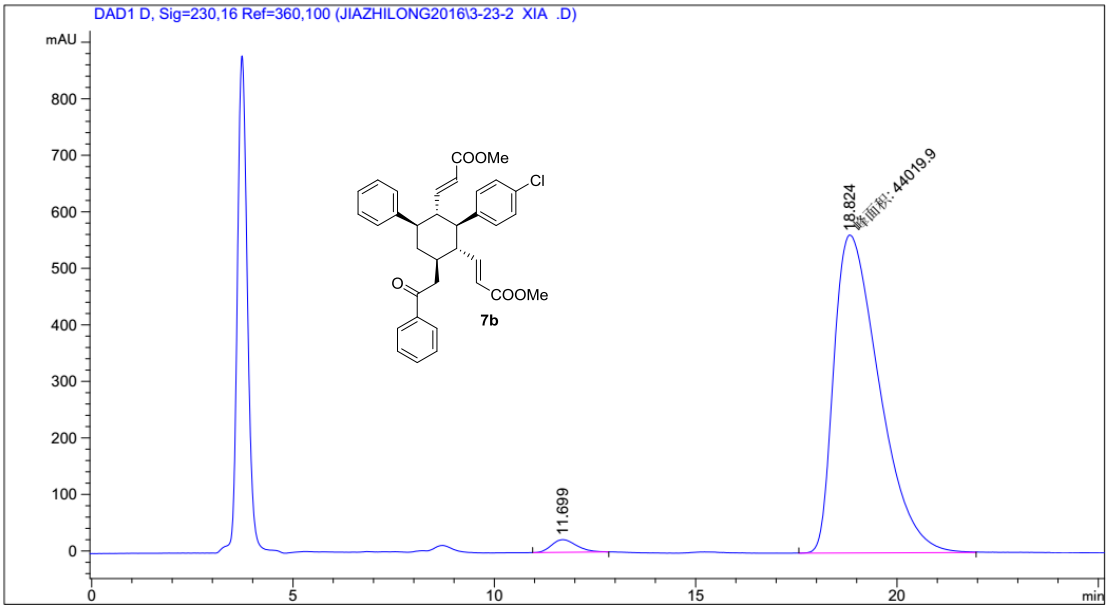


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	9.636	946.14496	23.83072	1.4444
2	DAD 230, 16 nm	13.277	6.45590e4	1049.38318	98.5556

HPLC using an AD column (hexane: *i*-PrOH = 70:30, 1.0 mL/min)

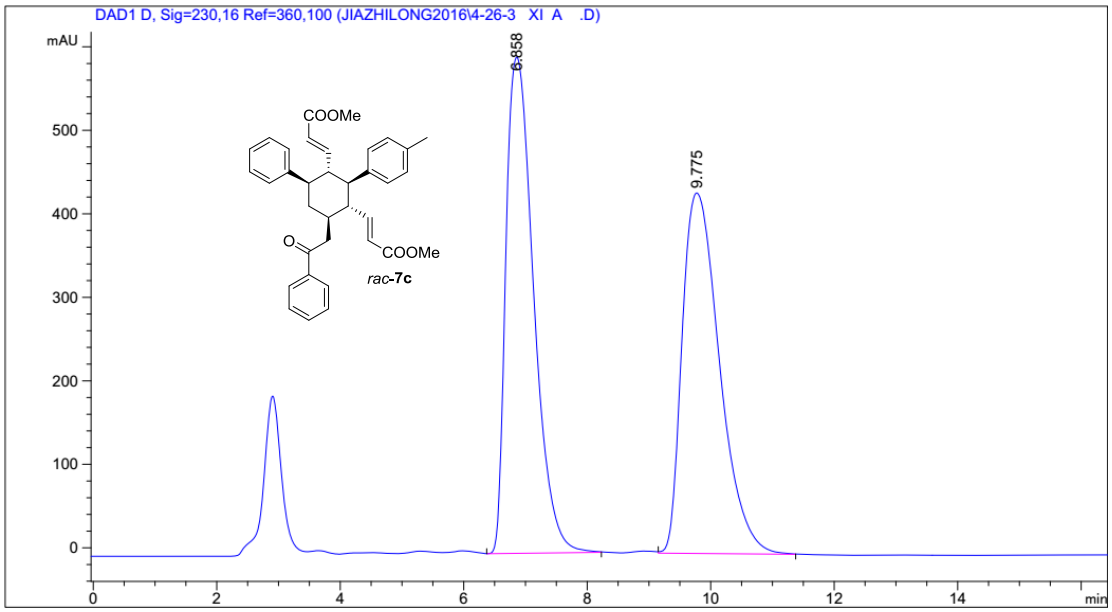


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	12.274	2.18965e4	493.51340	50.4578
2	DAD 230, 16 nm	20.378	2.14992e4	247.50015	49.5422

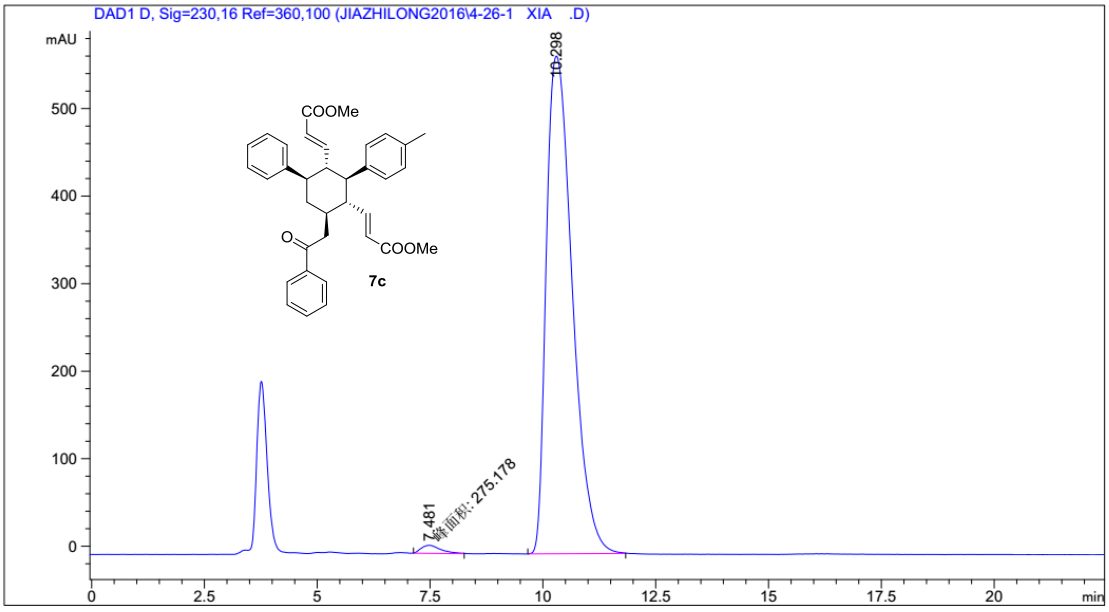


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	11.699	970.12482	22.45220	2.1563
2	DAD 230, 16 nm	18.824	4.40199e4	562.49994	97.8437

HPLC using an AD column (hexane: *i*-PrOH = 70:30, 1.0 mL/min)

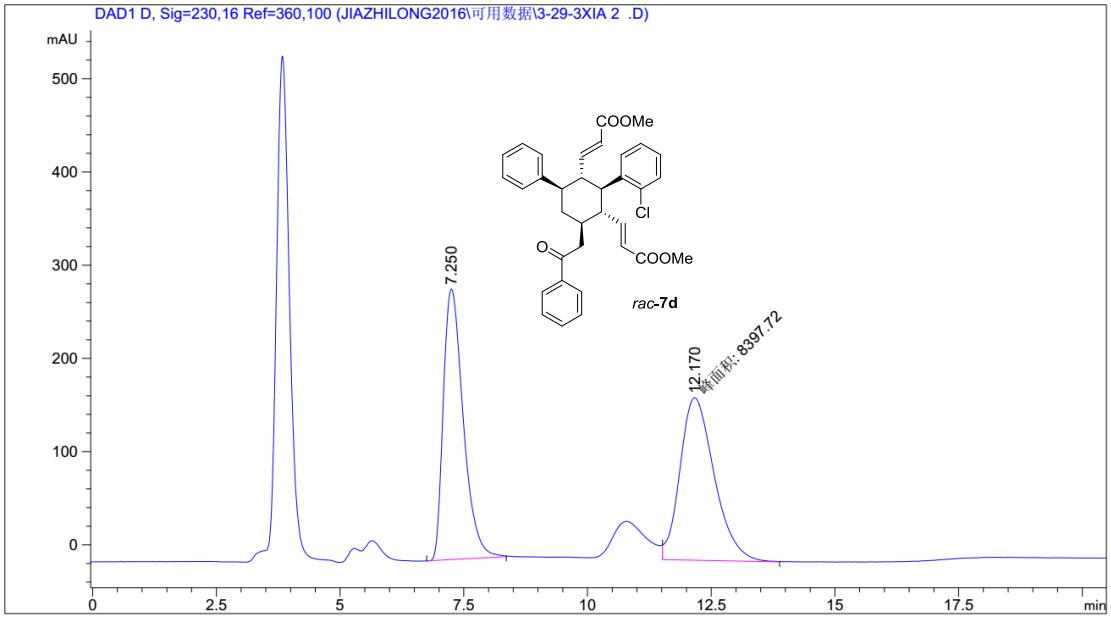


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	6.858	1.84747e4	594.32758	50.4768
2	DAD 230, 16 nm	9.775	1.81257e4	431.72662	49.5232

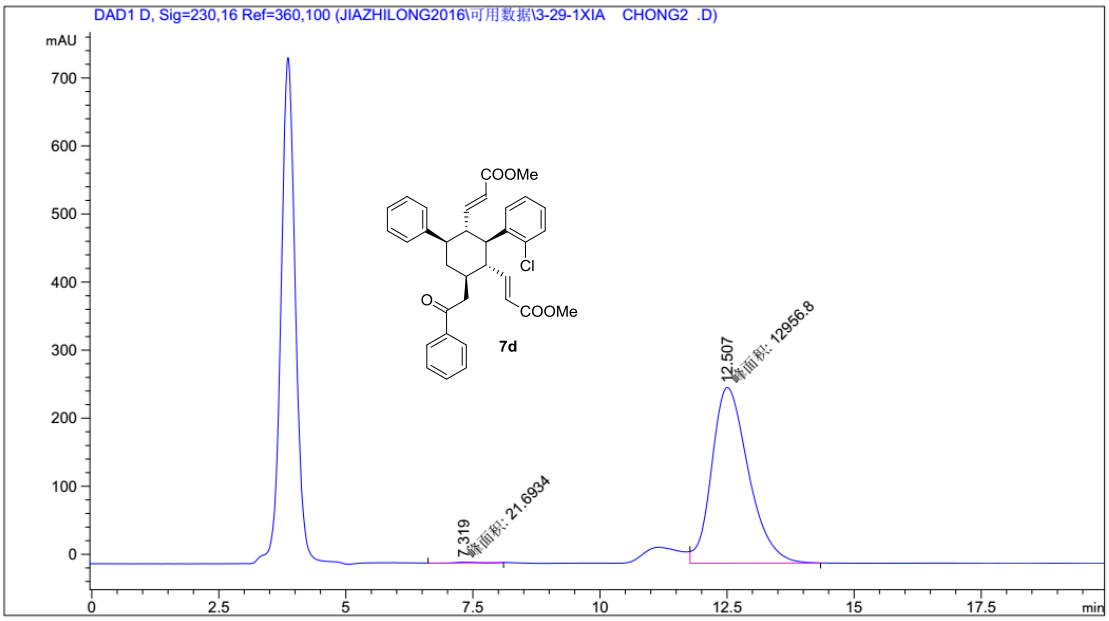


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	7.481	275.17828	9.15802	1.1946
2	DAD 230, 16 nm	10.298	2.27591e4	568.62335	98.8054

HPLC using an AD column (hexane: *i*-PrOH = 70:30, 1.0 mL/min)

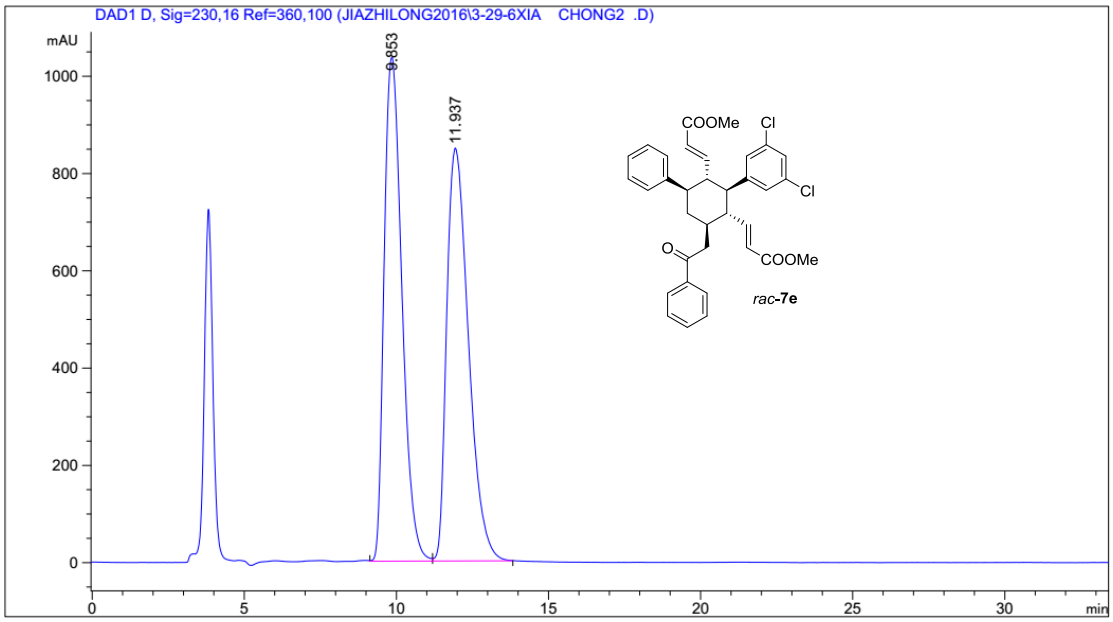


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	7.250	8129.36377	290.16644	49.1881
2	DAD 230, 16 nm	12.170	8397.72363	174.19775	50.8119

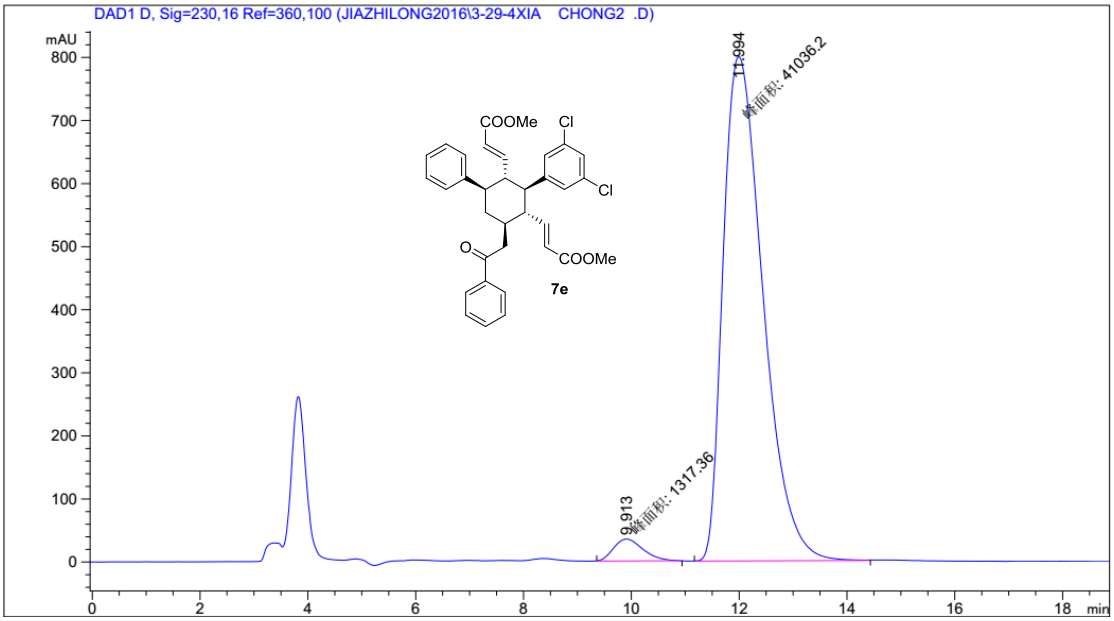


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	7.319	21.69337	1.08856	0.1672
2	DAD 230, 16 nm	12.507	1.29568e4	258.33707	99.8328

HPLC using an AD column (hexane: *i*-PrOH = 70:30, 1.0 mL/min)

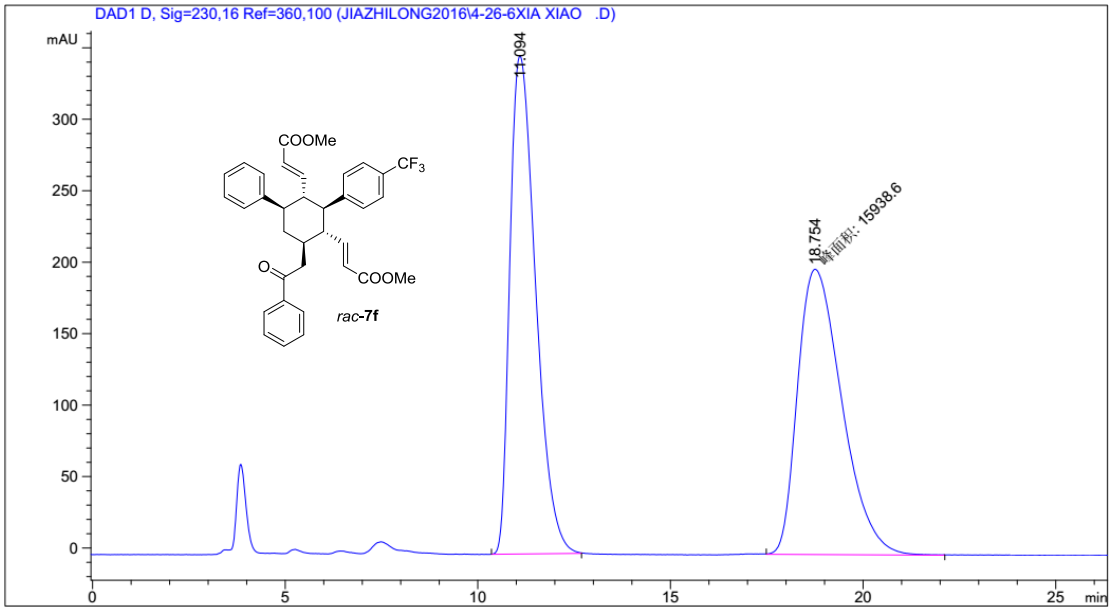


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	9.853	4.20913e4	1035.35217	49.9621
2	DAD 230, 16 nm	11.937	4.21552e4	848.90930	50.0379

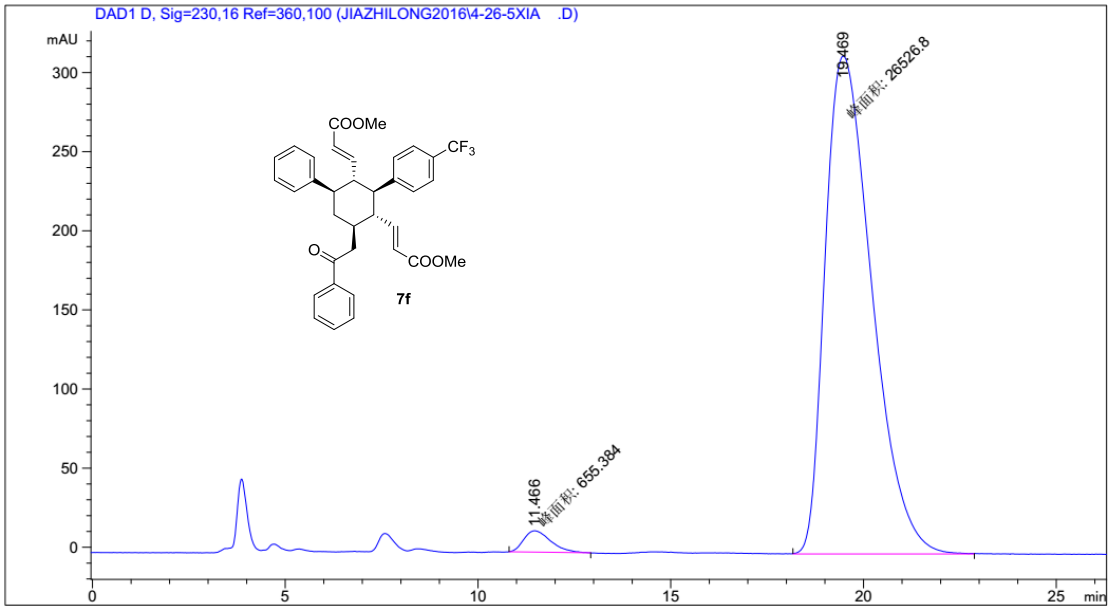


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	9.913	1317.35828	34.80242	3.1104
2	DAD 230, 16 nm	11.994	4.10362e4	799.49957	96.8896

HPLC using an AD column (hexane: *i*-PrOH = 70:30, 1.0 mL/min)

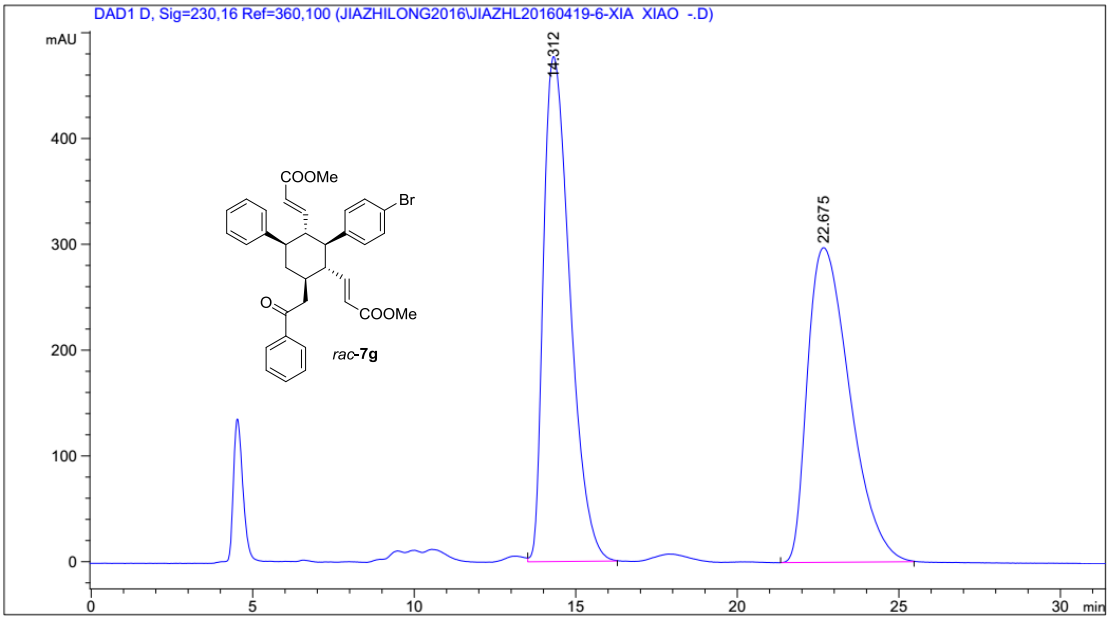


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	11.094	1.61838e4	348.39716	50.3817
2	DAD 230, 16 nm	18.754	1.59386e4	199.63060	49.6183

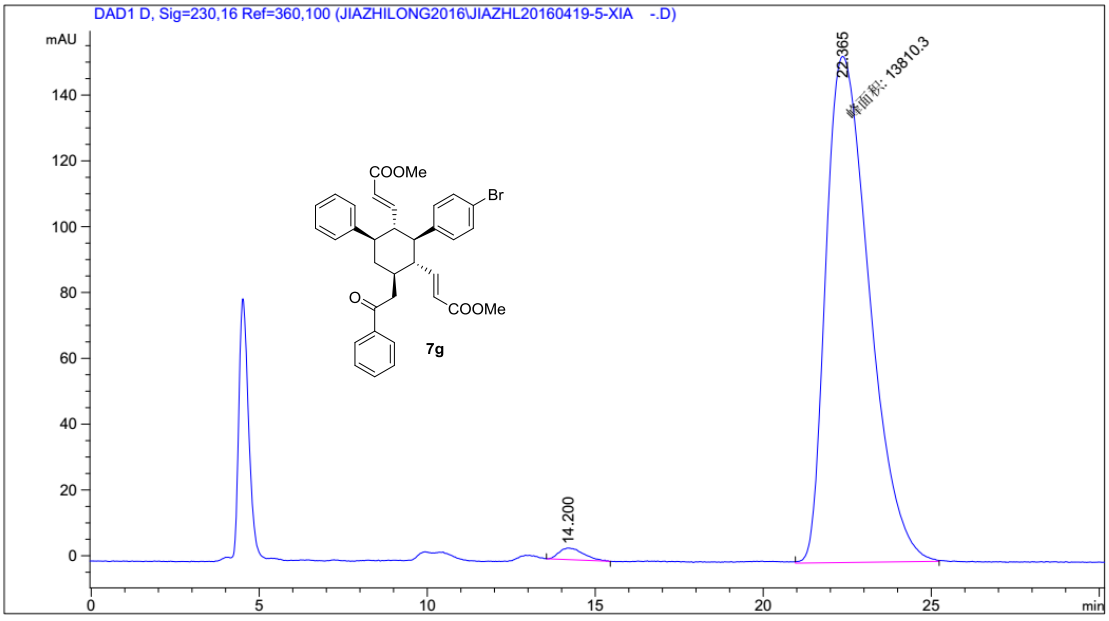


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	11.466	655.38385	13.49150	2.4111
2	DAD 230, 16 nm	19.469	2.65268e4	314.56116	97.5889

HPLC using an AD column (hexane: *i*-PrOH = 70:30, 1.0 mL/min)

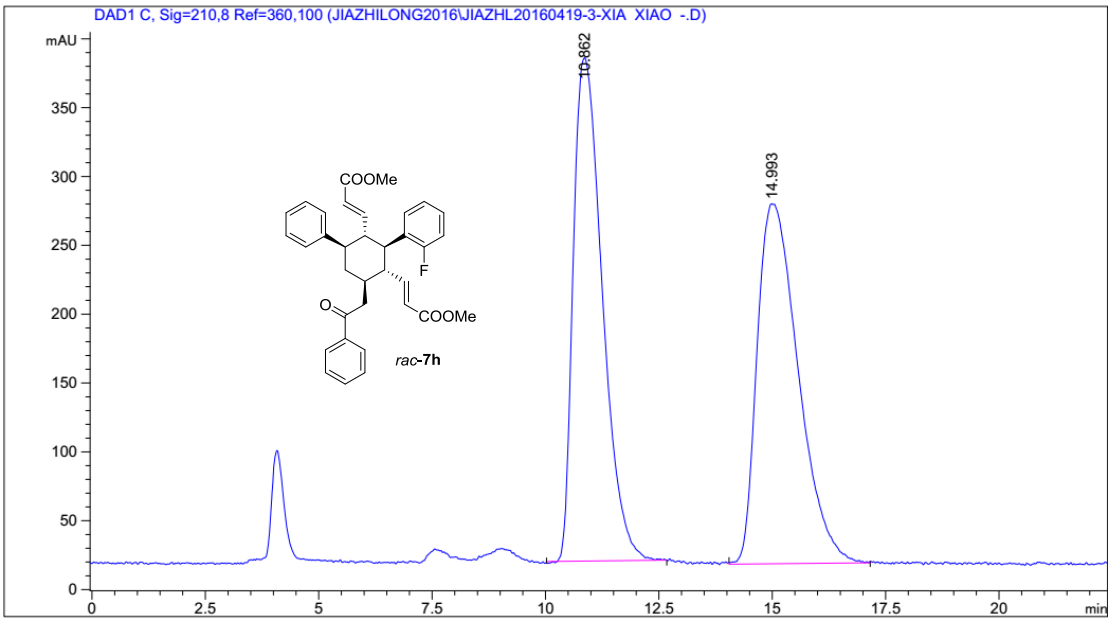


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	14.312	2.72915e4	477.50385	50.2361
2	DAD 230, 16 nm	22.675	2.70350e4	297.45288	49.7639

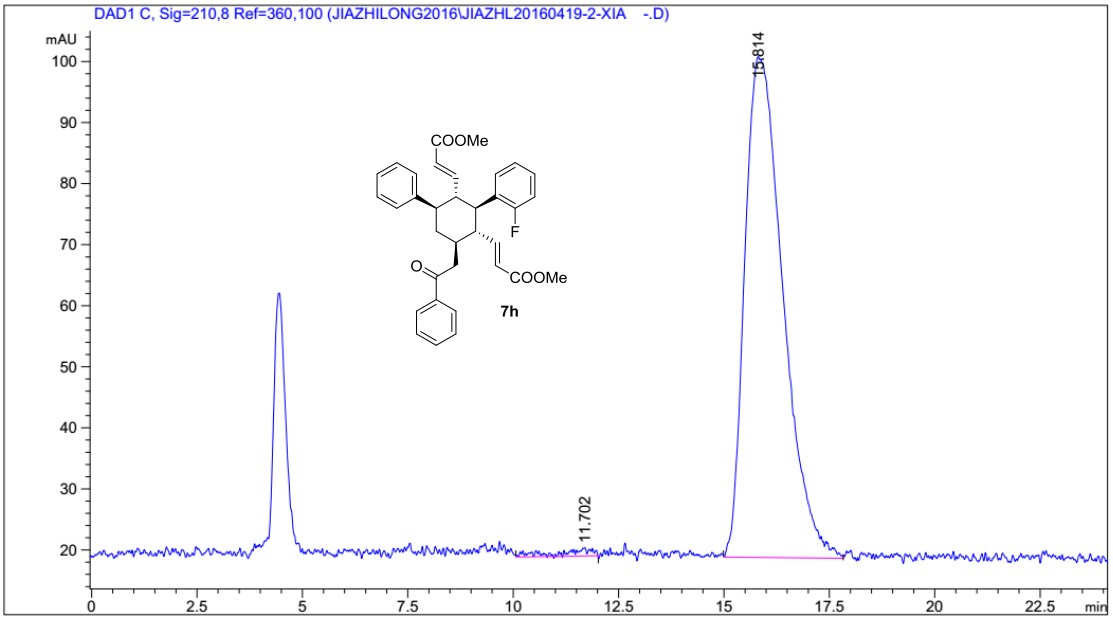


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	14.200	178.43895	3.52076	1.2756
2	DAD 230, 16 nm	22.365	1.38103e4	153.80035	98.7244

HPLC using an AD column (hexane: *i*-PrOH = 70:30, 1.0 mL/min)

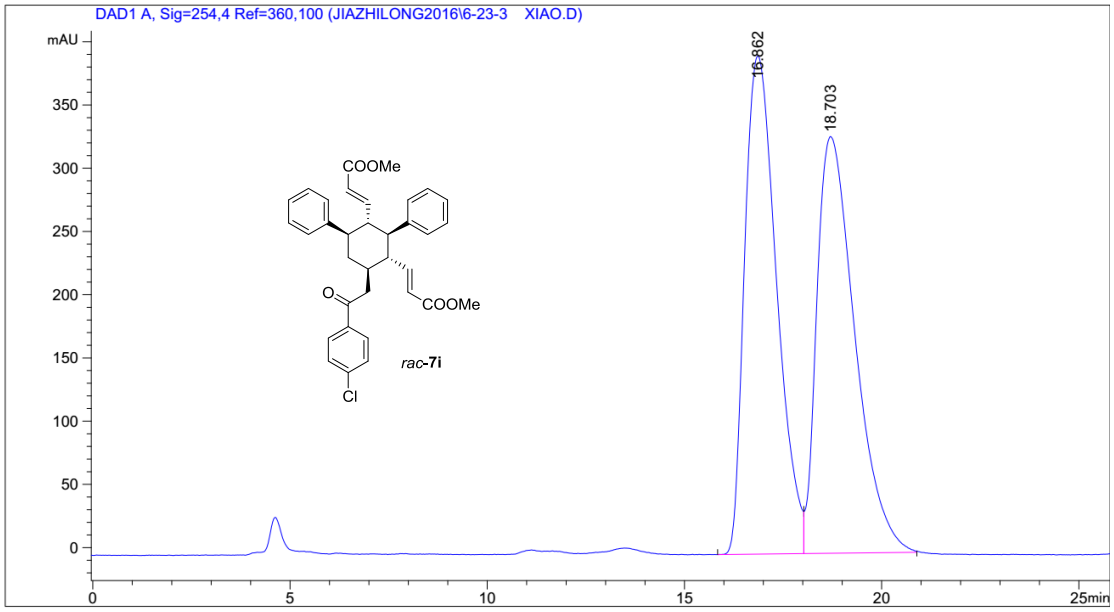


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 210, 8 nm	10.862	1.62601e4	365.66080	49.7116
2	DAD 210, 8 nm	14.993	1.64488e4	261.53769	50.2884

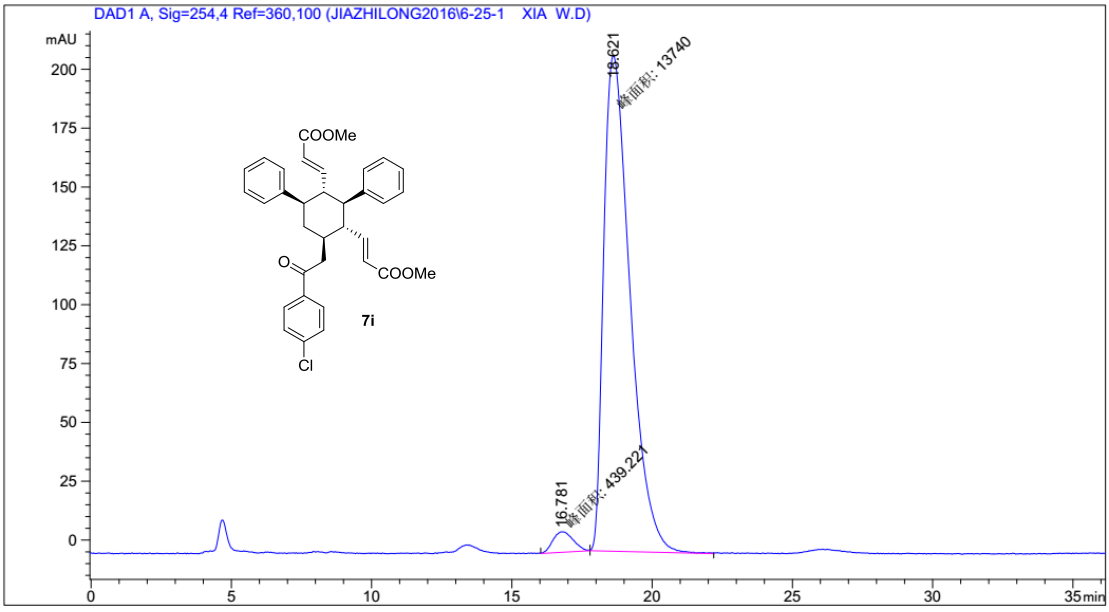


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 210, 8 nm	11.702	66.57973	1.35086	1.2734
2	DAD 210, 8 nm	15.814	5161.90137	82.04559	98.7266

HPLC using an AD column (hexane: *i*-PrOH = 70:30, 1.0 mL/min)

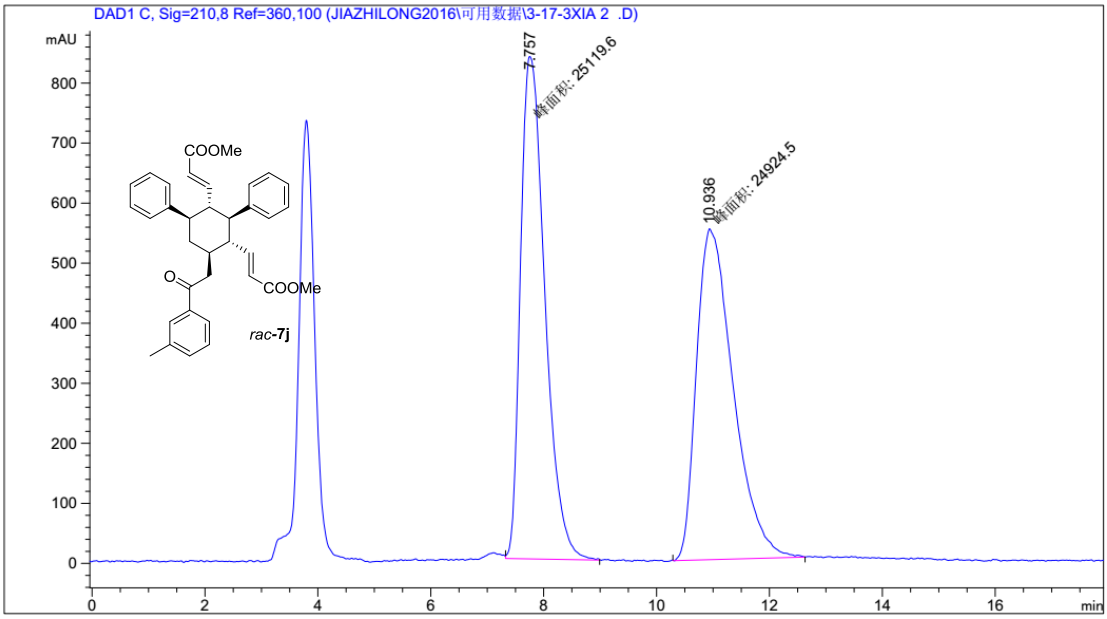


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 4 nm	16.862	2.22083e4	393.87048	50.1479
2	DAD 254, 4 nm	18.703	2.20773e4	329.58698	49.8521

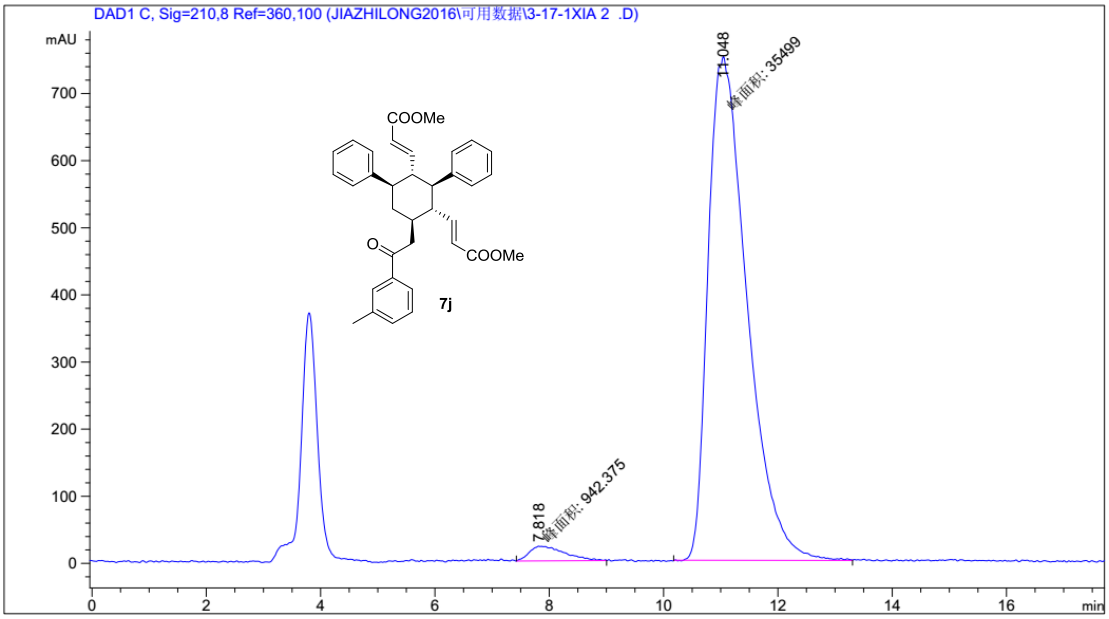


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 4 nm	16.781	439.22089	8.70777	3.0976
2	DAD 254, 4 nm	18.621	1.37400e4	210.42262	96.9024

HPLC using an AD column (hexane: *i*-PrOH = 70:30, 1.0 mL/min)

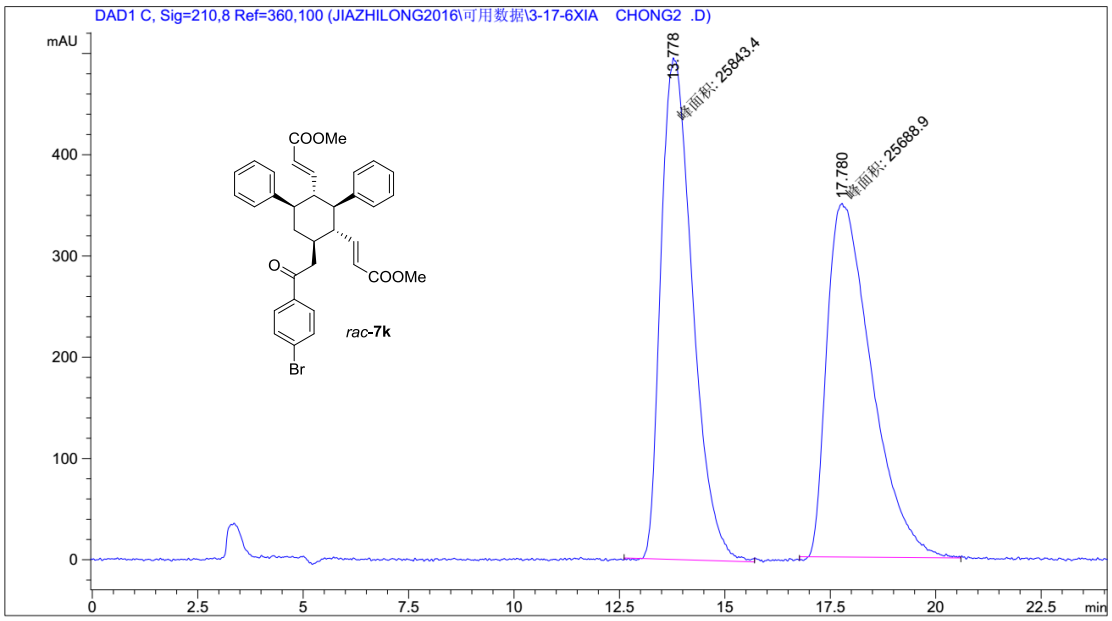


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 210, 8 nm	7.757	2.51196e4	836.81396	50.1949
2	DAD 210, 8 nm	10.936	2.49245e4	551.32385	49.8051

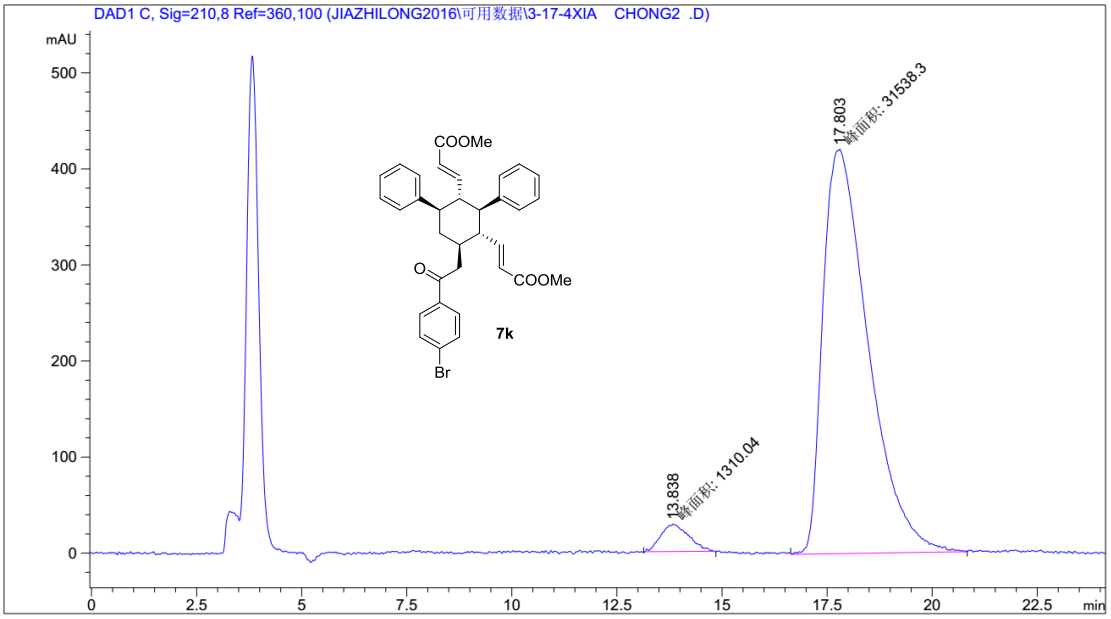


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 210, 8 nm	7.818	942.37524	21.96951	2.5860
2	DAD 210, 8 nm	11.048	3.54990e4	750.54181	97.4140

HPLC using an AD column (hexane: *i*-PrOH = 70:30, 1.0 mL/min)

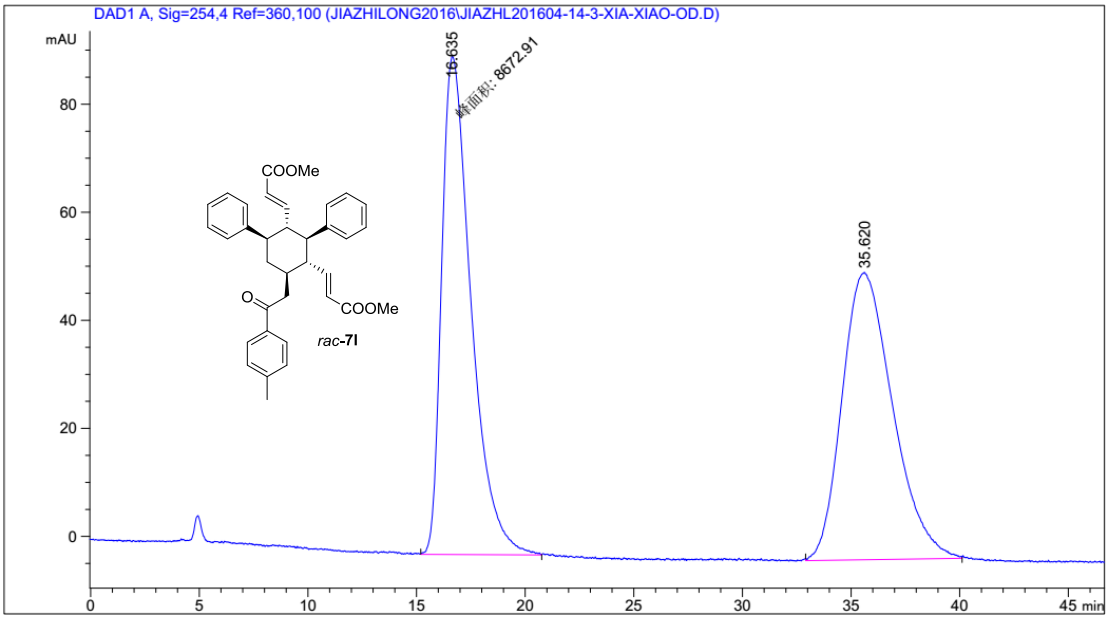


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 210, 8 nm	13.778	2.58434e4	495.59573	50.1499
2	DAD 210, 8 nm	17.780	2.56889e4	349.41125	49.8501

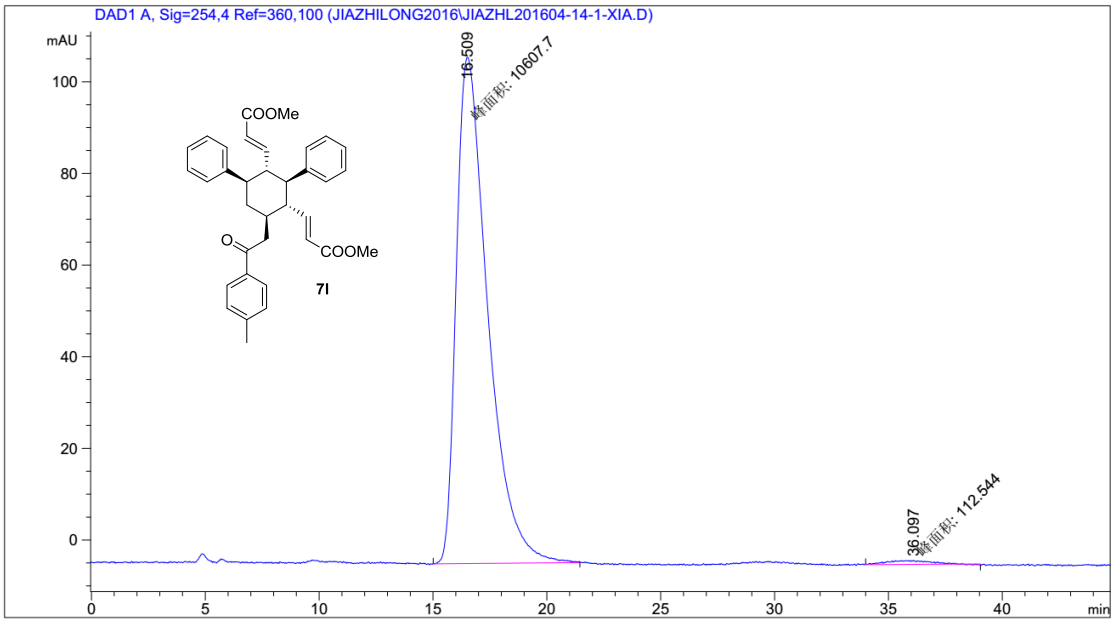


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 210, 8 nm	13.838	1310.04456	28.50111	3.9882
2	DAD 210, 8 nm	17.803	3.15383e4	421.07962	96.0118

HPLC using an OD column (hexane: *i*-PrOH = 70:30, 1.0 mL/min)

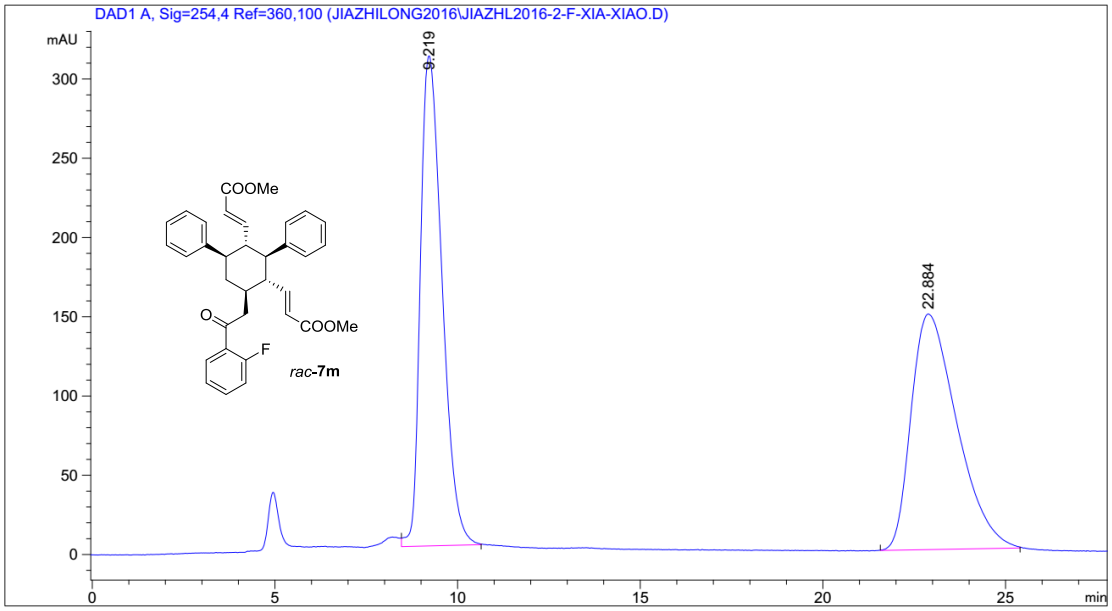


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 4 nm	16.635	8672.90527	92.16481	50.1836
2	DAD 254, 4 nm	35.620	8609.45410	53.17858	49.8164

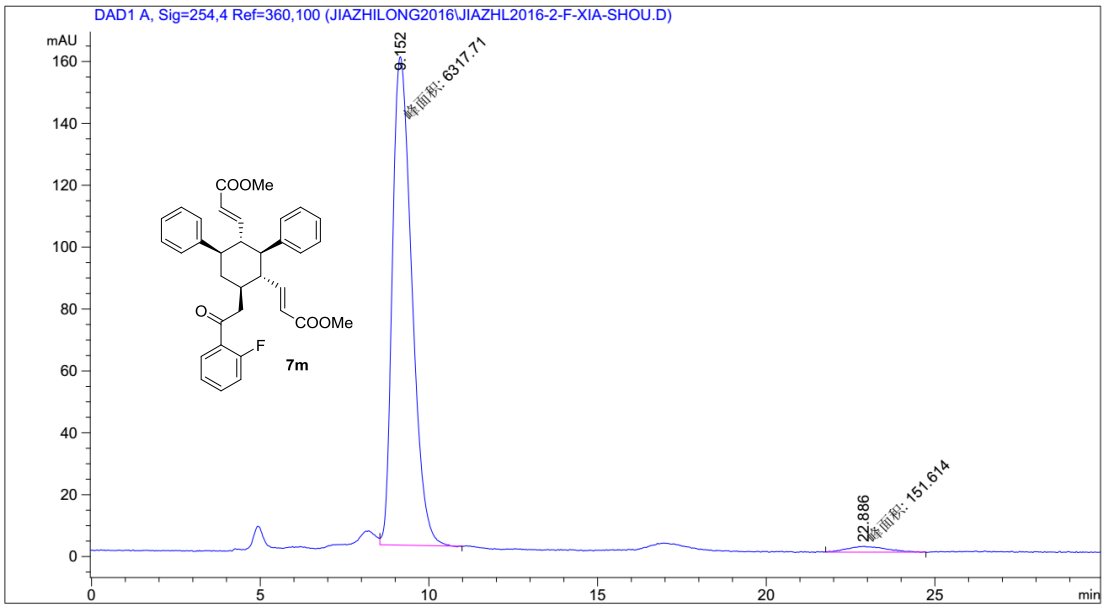


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 4 nm	16.509	1.06077e4	110.49479	98.9502
2	DAD 254, 4 nm	36.097	112.54442	8.74923e-1	1.0498

HPLC using an OD column (hexane: *i*-PrOH = 70:30, 1.0 mL/min)

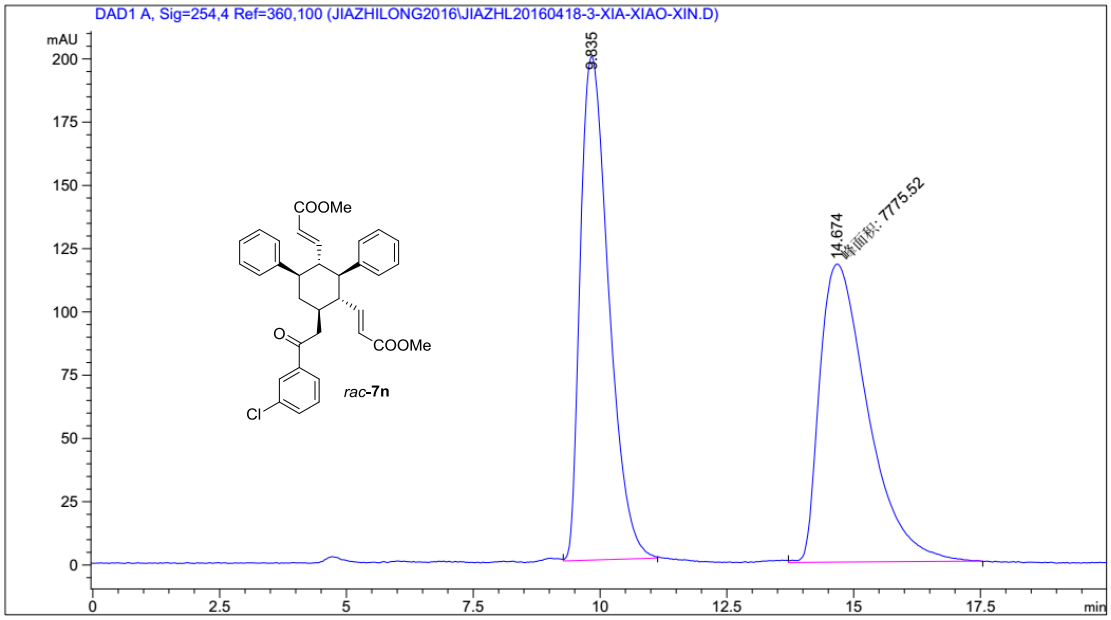


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 4 nm	9.219	1.27589e4	309.13327	49.6295
2	DAD 254, 4 nm	22.884	1.29494e4	148.70950	50.3705

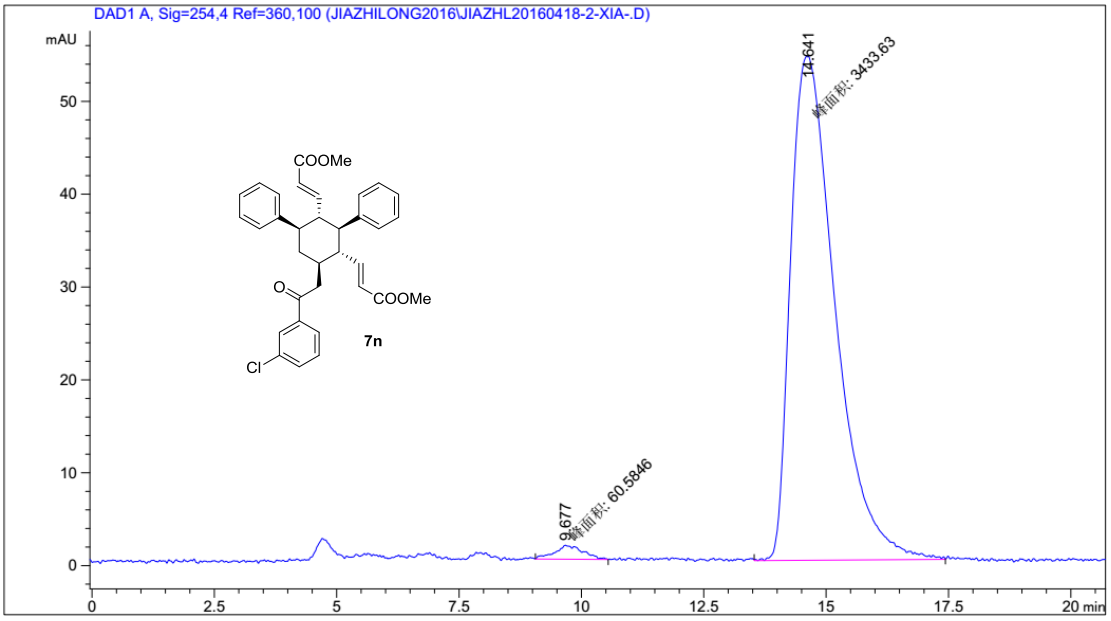


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 4 nm	9.152	6317.70605	157.86595	97.6564
2	DAD 254, 4 nm	22.886	151.61403	1.91411	2.3436

HPLC using an AD column (hexane: *i*-PrOH = 70:30, 1.0 mL/min)

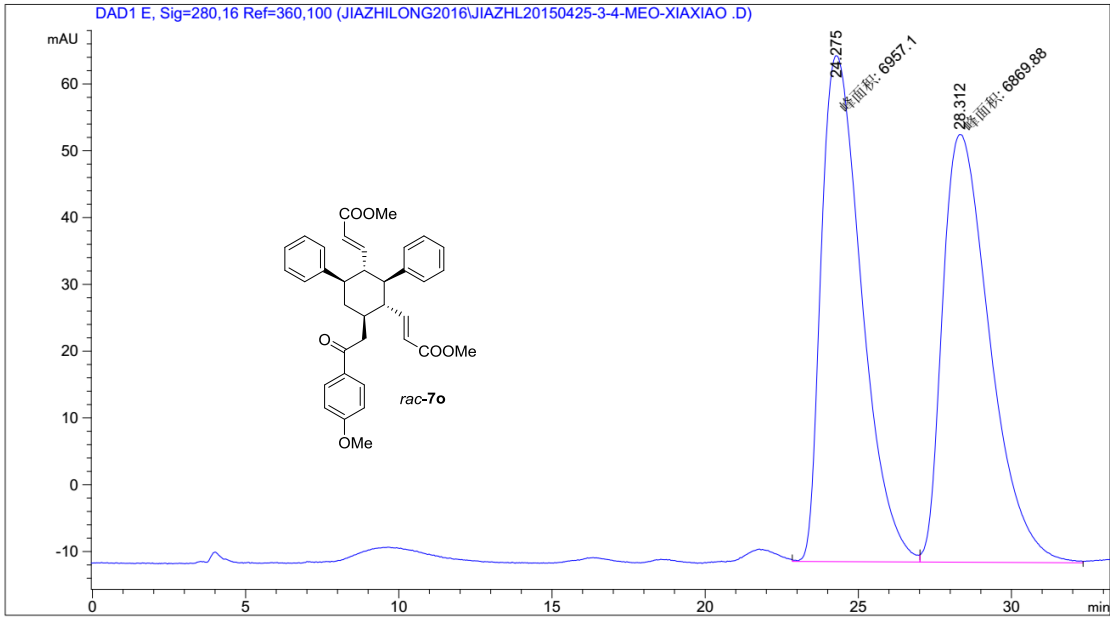


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 4 nm	9.835	7782.63037	198.95479	50.0229
2	DAD 254, 4 nm	14.674	7775.52002	117.77306	49.9771

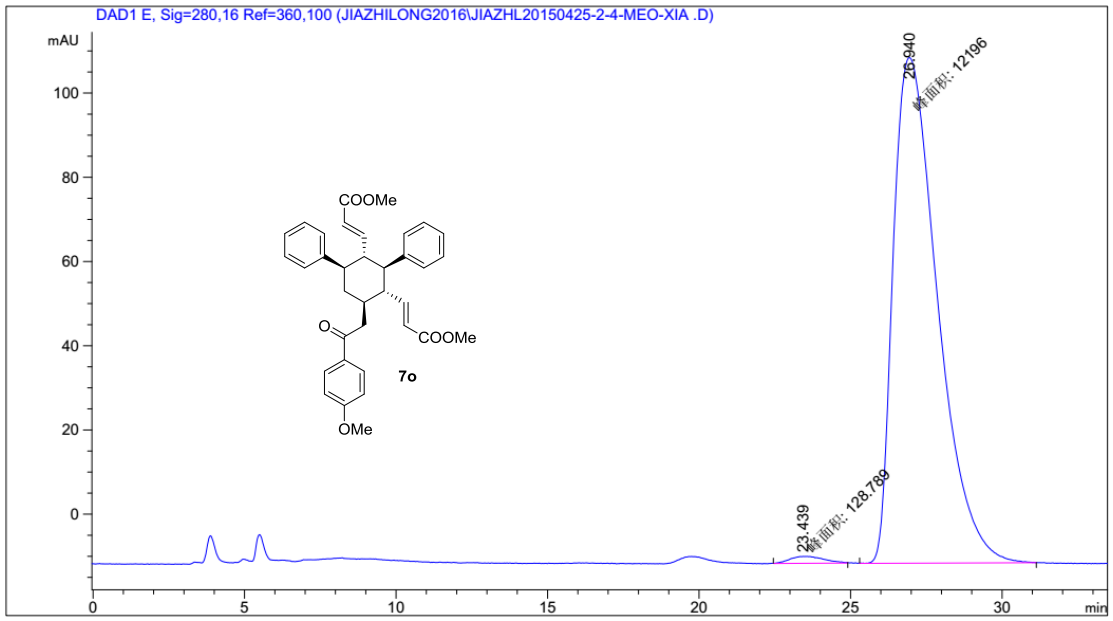


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 4 nm	9.677	60.58463	1.50757	1.7339
2	DAD 254, 4 nm	14.641	3433.63013	54.26755	98.2661

HPLC using an AD column (hexane: *i*-PrOH = 80:20, 1.0 mL/min)

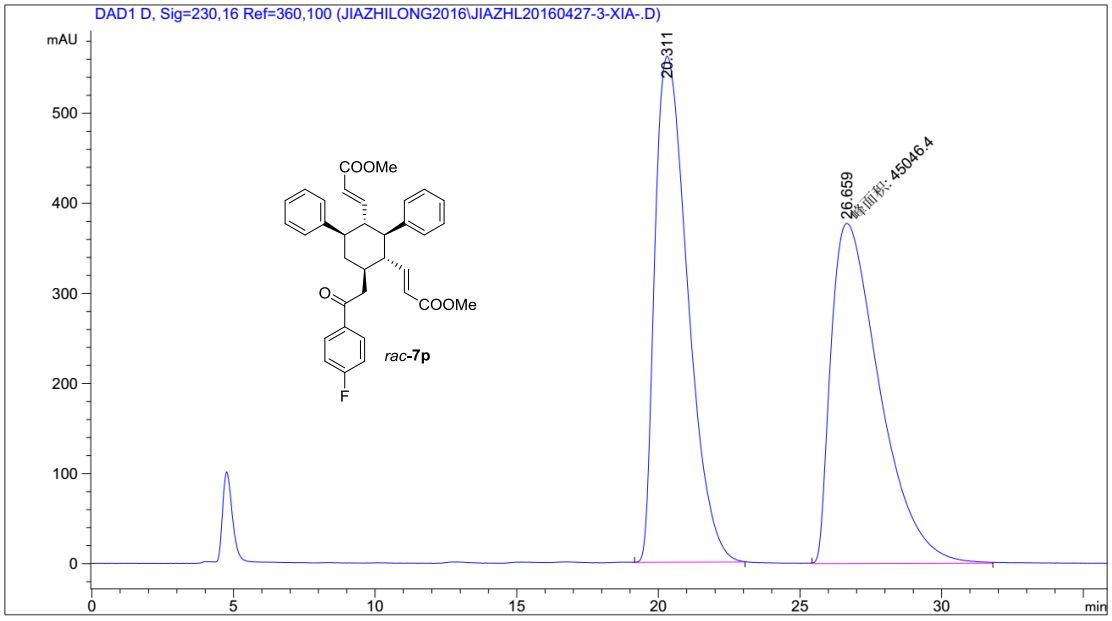


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 280, 16 nm	24.275	6957.09570	75.75133	50.3154
2	DAD 280, 16 nm	28.312	6869.87598	64.03755	49.6846

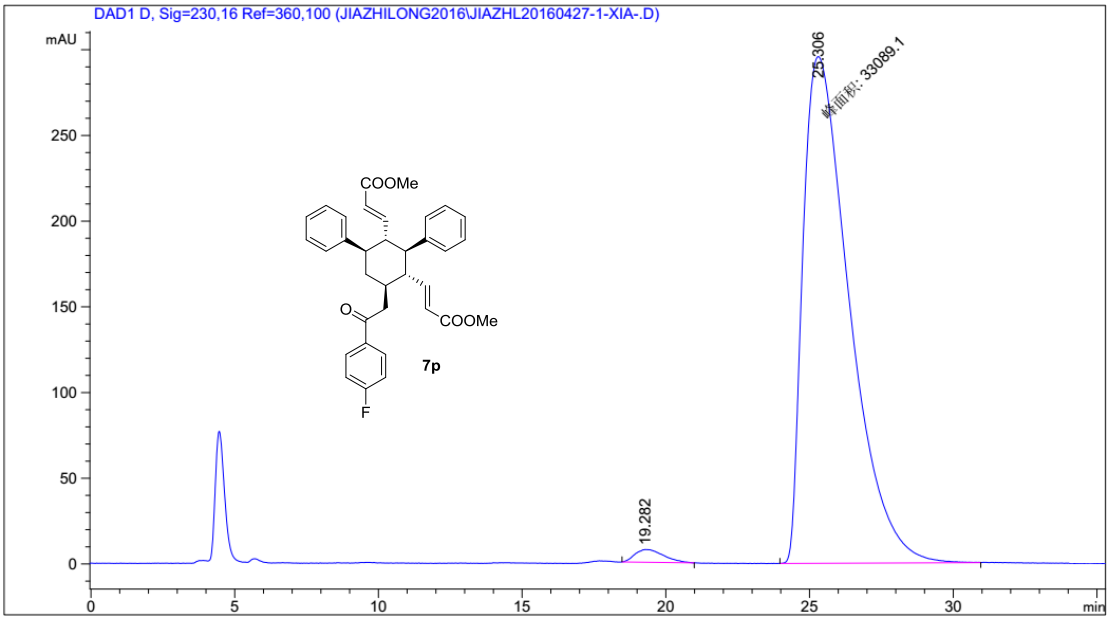


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 280, 16 nm	23.439	128.78914	1.65331	1.0450
2	DAD 280, 16 nm	26.940	1.21960e4	120.09196	98.9550

HPLC using an AD column (hexane: *i*-PrOH = 80:20, 1.0 mL/min)

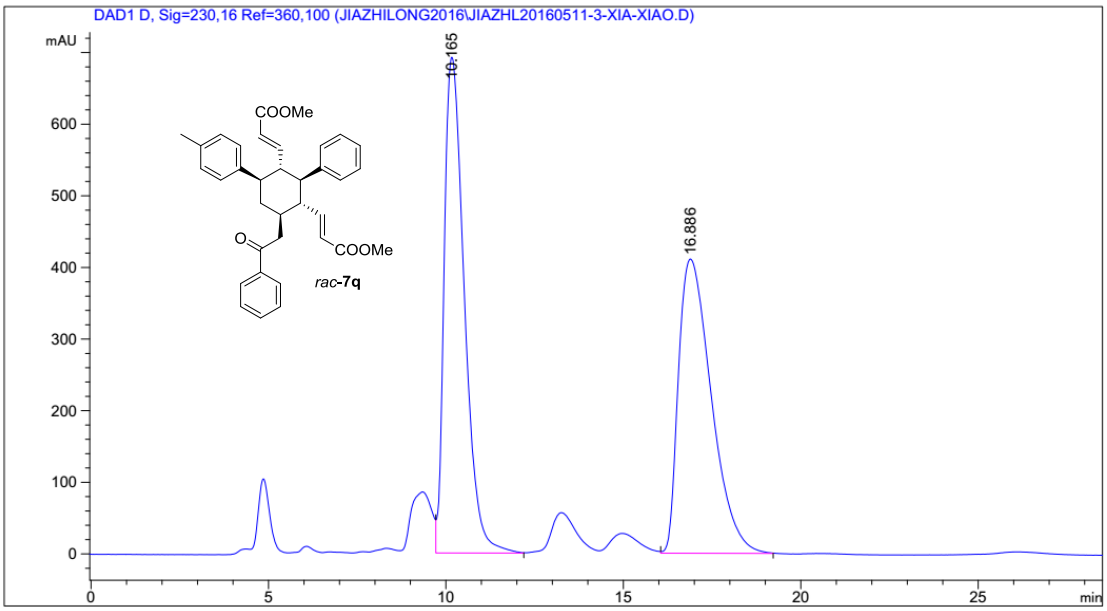


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	20.311	4.54122e4	561.84076	50.2022
2	DAD 230, 16 nm	26.659	4.50464e4	377.79135	49.7978

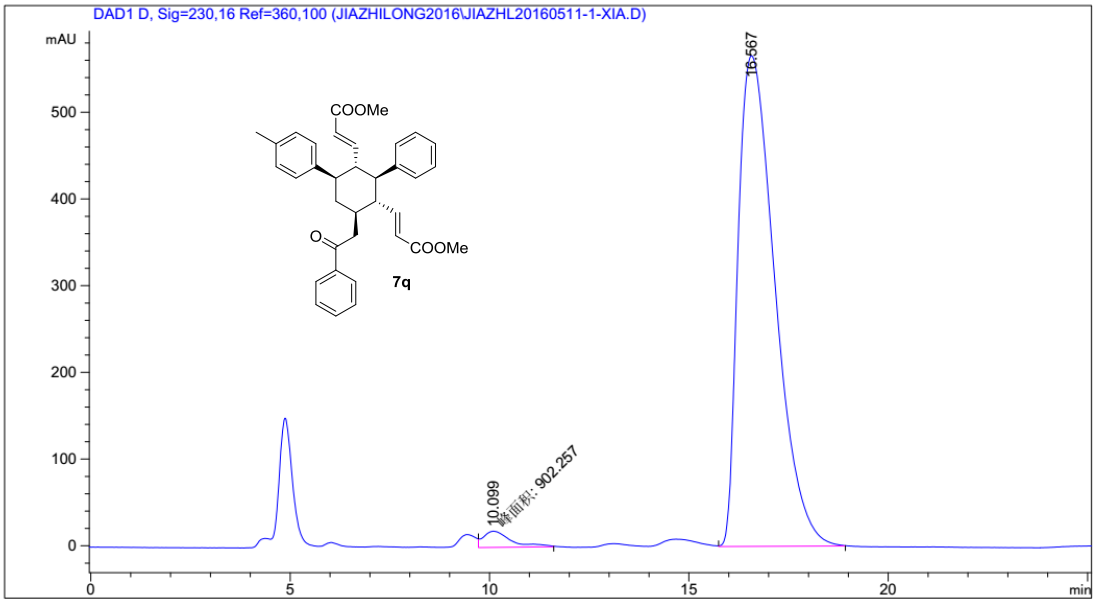


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	19.282	514.77063	7.44656	1.5319
2	DAD 230, 16 nm	25.306	3.30891e4	295.56290	98.4681

HPLC using an AD column (hexane: *i*-PrOH = 70:30, 1.0 mL/min)

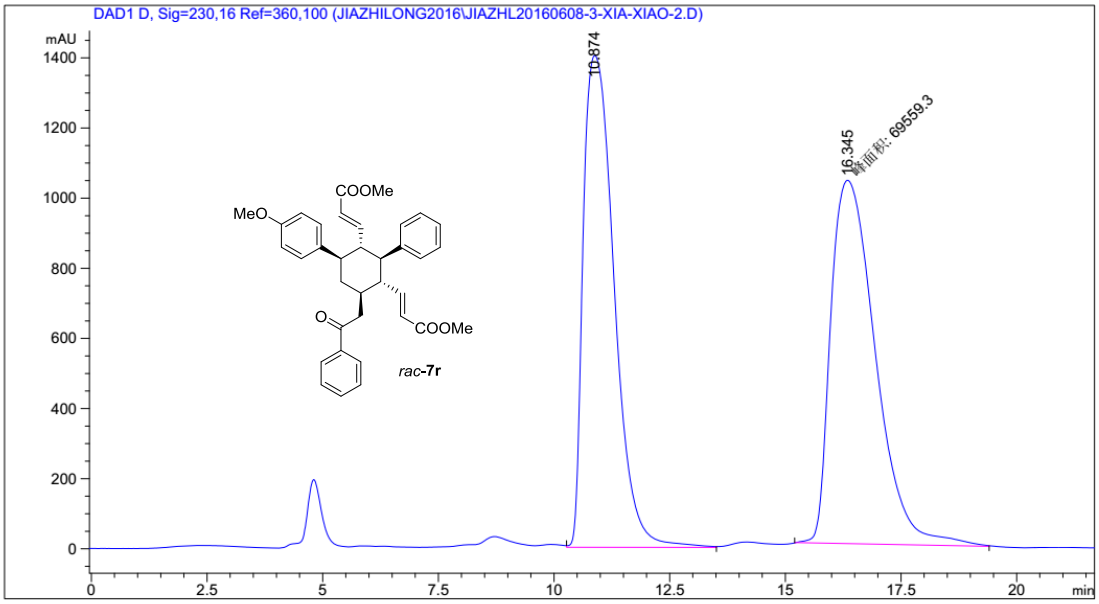


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	10.165	2.72442e4	692.17053	50.7811
2	DAD 230, 16 nm	16.886	2.64061e4	410.92798	49.2189

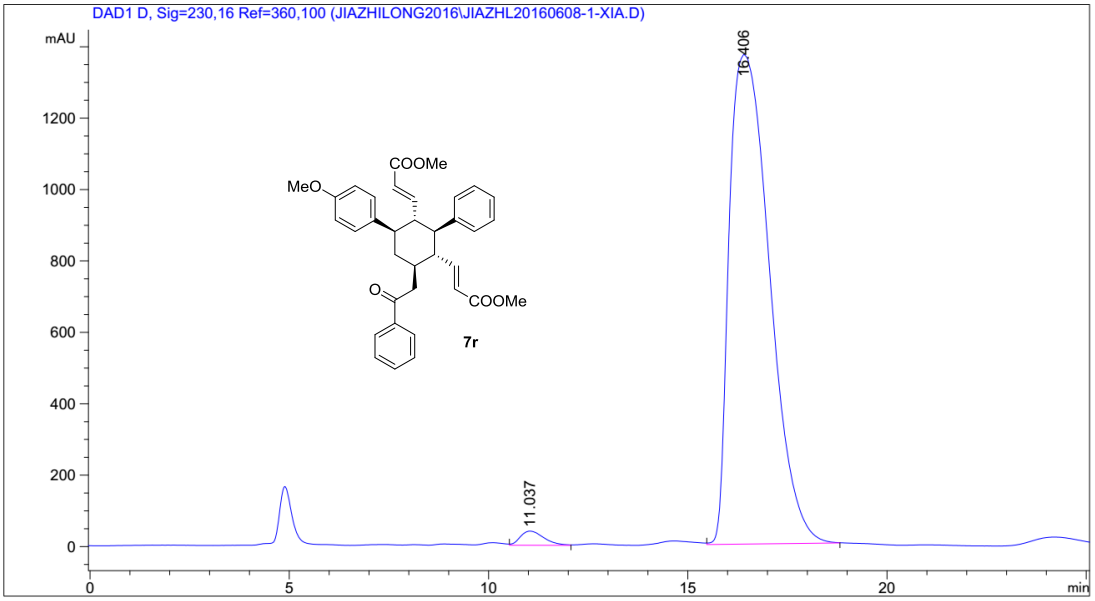


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	10.099	902.25653	18.68415	2.4243
2	DAD 230, 16 nm	16.567	3.63142e4	566.01001	97.5757

HPLC using an AS column (hexane: *i*-PrOH = 80:20, 1.0 mL/min)

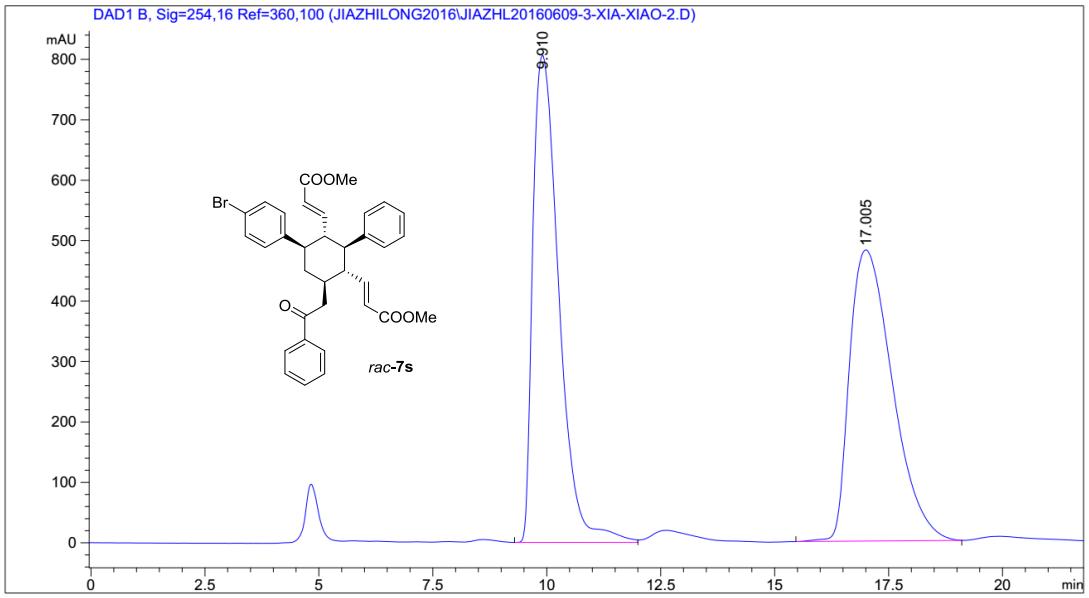


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	10.874	6.52911e4	1402.50452	48.4175
2	DAD 230, 16 nm	16.345	6.95593e4	1036.28333	51.5825

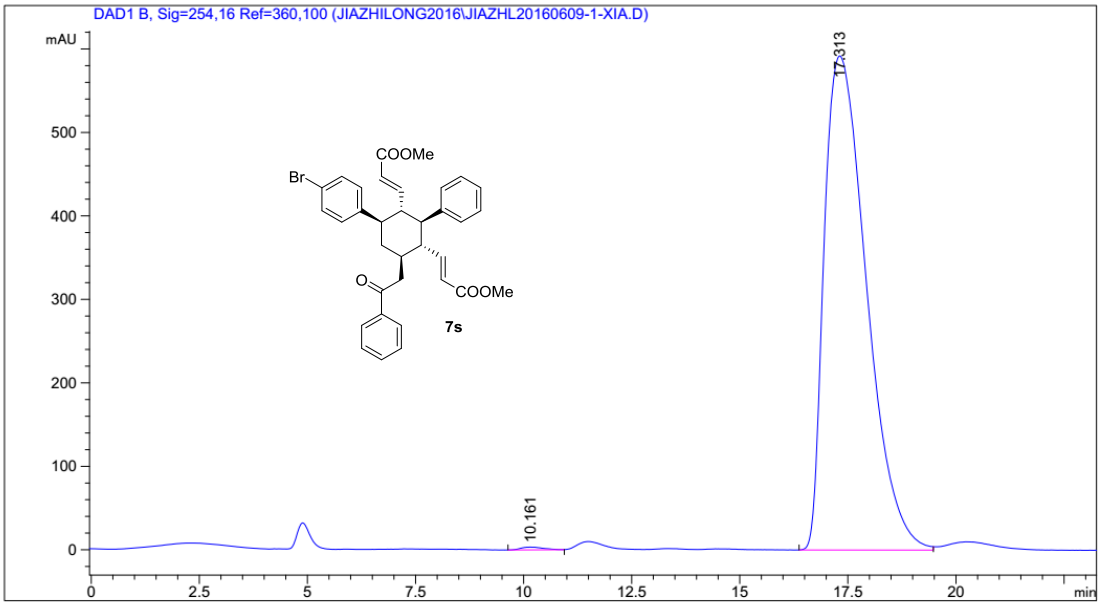


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 230, 16 nm	11.037	1634.63721	39.68741	1.6658
2	DAD 230, 16 nm	16.406	9.64933e4	1371.35571	98.3342

HPLC using an AD column (hexane: *i*-PrOH = 70:30, 1.0 mL/min)

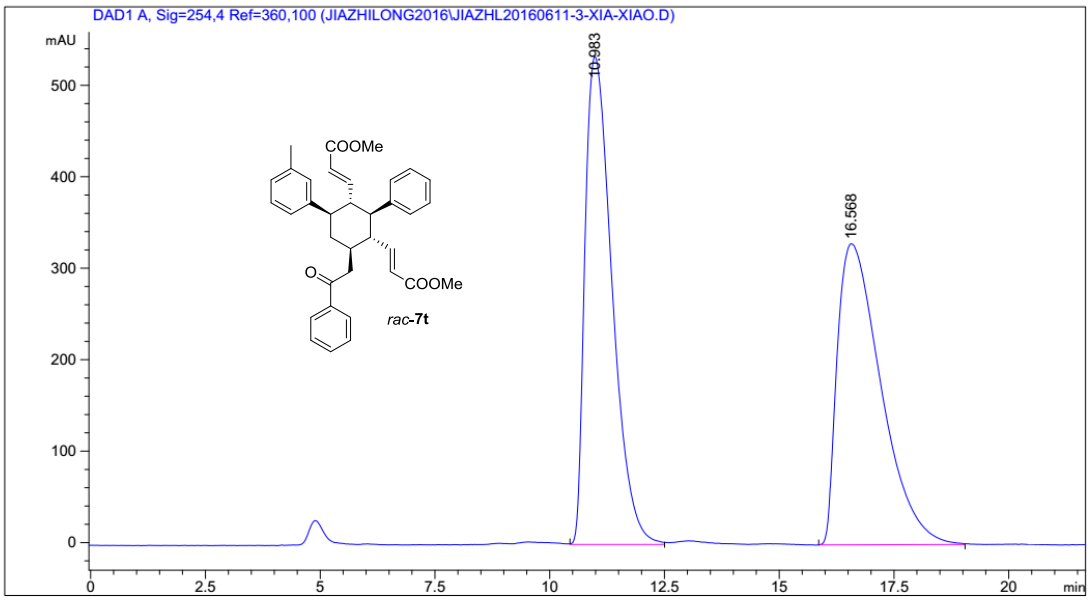


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 16 nm	9.910	3.20494e4	805.71521	50.4087
2	DAD 254, 16 nm	17.005	3.15297e4	481.81137	49.5913

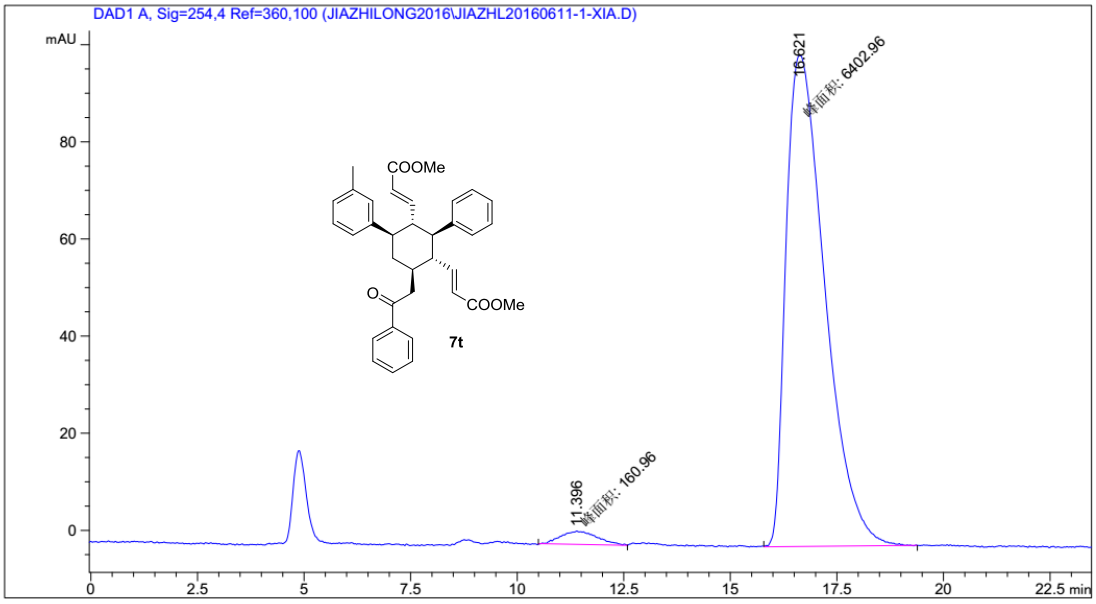


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 16 nm	10.161	119.51803	3.27890	0.2969
2	DAD 254, 16 nm	17.313	4.01373e4	591.93286	99.7031

HPLC using an AD column (hexane: *i*-PrOH = 80:20, 1.0 mL/min)



Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 4 nm	10.983	2.19026e4	533.39642	50.1786
2	DAD 254, 4 nm	16.568	2.17468e4	329.08218	49.8214



Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Height (mAU)	Peak Area (%)
1	DAD 254, 4 nm	11.396	160.96036	2.74149	2.4522
2	DAD 254, 4 nm	16.621	6402.95947	101.07990	97.5478